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Encyclopedia of Textile Finishing

Springer

Foreword

The international economy, accompanied by a marked shift in the political landscape in many areas of the world, is currently undergoing profound change. Not only are a great number of industrialised, recently-industrialised and developing countries affected by these developments but also many manufacturing companies and public utilities. Changes are likewise taking place from the sociological standpoint: due to a constantly increasing world population, resources and jobs are becoming scarcer, the threat to the environment is increasing, more and more people are being excluded from active employment and the number of old people is on the rise.

The consequences – especially in the political sphere – are far-reaching. Within the realms of corporate strategy the process of industrial concentration continues; associations and institutions also follow this trend by combining to form more efficient units. The struggle for market shares, skilled labour and young talent, for greater competitiveness and business survival is becoming harder and harder. The textile industry, in particular, is seriously affected by these developments. Despite increasing productivity in certain sectors, factories and jobs are both victims to these events. The market for textiles now demands an ever quicker supply of merchandise and the more development a company pursues, the greater its need for information on research in the industrial field. As a common objective of theory and practice, the translation of scientific knowledge into new products and production techniques is a necessary prerequisite for the promotion of structural change in small textile companies. Various avenues present themselves for an effective transfer of knowledge, e. g.:

- technology centres,
- trade conferences,
- specialised seminars,
- expert consultancy,
- trade exhibitions with accompanying symposia and, of course,
- publications in technical journals and books.

The rapid progress of technology has meant that complete works on the subject of textile finishing, including its peripheral fields, are either no longer available or out of date, and have become less comprehensible due to continual amendments. Communication problems between theorists and practitioners are an additional factor. Process technology, as the link between theory and practice, represents the optimum means for bringing together theoretical knowledge and practical procedure in order that reproducible and profitable products can be manufactured.

Against this background an encyclopedia has been compiled which provides a comprehensive treatment of textile finishing technology and all its peripheral fields. The underlying concept has been to structure the data and consider different user perspectives, since the **Encyclopedia of Textile Finishing** is intended to serve the needs of several user groups. Thus, responsibility for locating desired information should not lie with the reader – rather he/she should be guided by the system itself. An information system of this nature offers the textile finisher a wide range of directly usable information on textile technology which, with regard to the amount of dedicated effort and extent of compilation involved, has simply not been available hitherto. The **Encyclopedia of Textile Finishing** describes common and new terms methodically by means of concise definitions. Keywords of special significance are dealt with in their entirety and treated more extensively in their ecological, process technological and application-oriented contexts, e. g.:

- manufacturing technology,
- products,
- by-product areas,
- energy, mass and information flows,
- human environments,
- complete production lines for textile and clothing manufacture up to waste disposal,
- eco-balances.

The **Encyclopedia of Textile Finishing** thereby serves to describe the wealth of information involved in the dyeing, printing, finishing and coating of textiles such as clothing, home textiles, industrial textiles, medical textiles and geotextiles. At the same time, particular attention has been paid to the environmental problems peculiar to textile finishing. The German laws and regulations mentioned in this work are exemplary for the worldwide environmental protection. Chemical concepts are explained with the aid of formulae. Knowledge of textile chemistry is regarded as fundamental for a clear understanding of textile finishing and, for this reason, knowledge relating to:

- macromolecular chemistry,
- dye chemistry,
- water and tenside chemistry,
- colloid chemistry,
- and physical chemistry

has received prominent coverage.

Polymer physics is responsible for shaping the morphological structure of natural and synthetic fibres, and the properties of the fibres themselves are related to their structure. These interrelationships are important to the textile finisher and have received comprehensive treatment.

The processes of diffusion, adsorption and immobilisation are kinetic aspects of all chemical and coloristic modifications to fibres which only seldom proceed to thermodynamic equilibrium. From such considerations, a modern concept of the processing technology involved in textile finishing results which aims to satisfy the quality standards demanded in the application of fibres. Extensive information on the machinery, equipment and installations used in these applications, with typical modern examples, forms the basis of detailed descriptions. Problems of such vital importance as environmental pollution are treated in encyclopedic scope by the **Encyclopedia of Textile Finishing.**

Since the range of knowledge covered by the encyclopedia extends far beyond the realm of textile finishing per se, and necessarily includes the preceding and succeeding production stages of textile technology, an integral view predominates in many of the definitions. The **Encyclopedia of Textile Finishing** has been so named because comprehensive knowledge from every specialised area having a bearing on textile finishing has been amassed for the benefit of the textile finisher. The **Encyclopedia of Textile Finishing** has its origin in the Department of Textile and Clothing Technology of the University of Applied Science, Fachhochschule Niederrhein where teaching is practised by "specialists in the field". This English version is a translation and update of the German edition published in 1995 by Laumann-Verlag. It is nevertheless not surprising that the **Encyclopedia of Textile Finishing** represents the culmination of seven years painstaking effort and that it draws on numerous outside publications. Because of the great number of publications involved, it has not been possible to quote this borrowed intellectual property which forms such a substantial part of the encyclopedia. Literature references have been dispensed with entirely, for which we kindly request the understanding of the various authors concerned. Their published work is considered to reflect the latest state of knowledge and, in a few cases, has been acknowledged at the end of a keyword with the postscript "according to XY". Manufacturer's and trade names have also been omitted from the text as far as possible. Where, occasionally, it has been necessary to describe individual products (e. g., machines, dyes, etc.), details of the respective manufacturers have been given. Diagrams borrowed from outside publications have likewise been acknowledged according to manufacturer or source.

It is anticipated that the **Encyclopedia of Textile Finishing** will appeal particularly to:

- plant owners, directors, management,
- factory managers, qualified engineers, technologists, practitioners, foremen, environmental officers,
- chemist-colourists, clothing manufacturers, textile designers, fashion designers, quality inspectors, dry-cleaners,
- students, professors, teachers, lecturers, trainees, research workers,
- buyers, sales personnel, wholesalers,
- personnel in various authorities and ministries,
- machine makers, personnel in supply industries catering to the needs of textile manufacture, representatives of the chemical industry,
- organizers of trade fairs, journalists,
- lawyers, judges and experts in the judiciary,
- consumers, who either enjoy close contact with the end-products of textile finishing, ore use them in a variety of ways as technical or medical textiles.

…

To facilitate searching for specific terms and to make cross-references easier to find, an electronic version of the **Encyclopedia of Textile Finishing** is available on a CD-ROM.

Aachen, autumn 2000

Prof. Dr. Hans-Karl Rouette

Instructions for Use

1. Keywords are printed in bold.

2. Keywords are listed in alphabetical order.
   Terms beginning with capital letters are listed before those beginning with small initial letters, e.g.:

   D, symbol for:
   I. → Debye.
   II. → Dielectric constant.
   III. → Diffusion coefficient.
   IV. deuterium.

   d,
   I. unit prefix for: …
   II. abbrev. for: …

   DA, abbrev. for: …

   da, symbol for: …

3. All keywords are written with a capital letter. Exceptions are terms or abbreviations which are always written with a small initial letter, e.g. pH.

4. Cross-references are indicated with an arrow:
   → see
   →: see following terms

   No cross-references are given for keywords which are recognised as generic terms such as dyestuff categories (reactive dyes, acid dyes etc.) or fibres (cotton, wool etc.). Cross-references should serve as a source of secondary information.

5. Textile fibre symbols are not used within the body of the text, as the various co-existing systems contradict one another to a certain extent. The textile fibre symbols are listed as keywords. The current standard DIN 60 001 is taken into consideration (valid as of 1991).

6. All units used in the text are based on those stipulated in the SI system of units. Reference should be made to the entry under → SI system of units for any necessary conversions.

7. The current chemical nomenclature is used for keywords and in the definitions of the terms, e.g. sodium hydrogen carbonate (as opposed to sodium bicarbonate), ethene (as opposed to ethylene).
   The correct chemical terms are used in place of trivial names, e.g. sodium carbonate (not soda).

Abbreviations

abbrev.	abbreviation(s)
Am.	American
approx.	approximately
at. wt.	atomic weight
atm.	atmosphere
b.p.	boiling point
°Bé	degree(s) Baumé
Br.	British
°C	degree(s) Celsius
c.	century
ca.	circa
chem.	chemistry, chemical
cm	centimetre(s)
comp.	computers, computing
conc.	concentrate, concentrated
dil.	dilute, diluted
dist.	distilled
e.g.	for example
etc.	et cetera
Fig.	figure
Fl.p.	flash point
f.p.	freezing point
Fr.	French
g	gram(s)
gen.	general
Ger.	German
Gk.	Greek
h	hour(s)
HT	high temperature
i.e.	that is
kg	kilogram(s)
kJ	kilojoule
l	litre(s)
Lat.	Latin
m	metre(s)
manuf.	manufacturer
max.	maximum
mg	milligram(s)
mill.	million(s)
min	minute(s)
ml	millilitre(s)
mm	millimetre(s)
µm	micrometre(s)
mol. wt.	molecular weight
m.p.	melting point
MW	molecular weight
nm	nanometre(s)
Port.	Portuguese
poss.	possibly
ppb	parts per billion
ppm	parts per million
resp.	respectively
rpm	revolutions per minute
s	second(s)
sec.	second, secondary
SI(unit)	Système International (d‘Unités)
Sp.	Spanish
Tab.	table(s)
TLV	threshold limit value
TN	trade (proprietary) name
vol.%	percentage by volume
wt.%	percentage by weight

A

A, abbrev. for:

I. → Ampere.

II. (Ger.) Arbeitsausschuß (independent working committee within the → DNA = Deutscher Normenausschuß).

III. (Ger.) absetzbare (Schad-)Stoffe im Abwasser → Settlable solid pollutants in waste water.

a, abbrev. for:

I. amplitude.

II. acceleration.

III. → Anionic.

°**a** symbol for American degree of water hardness (→ Water hardness units).

Å symbol for → Ångström.

AA (Ger.) abbrev. for: Arbeitsausschuß (working committee within the standards committees of the → DNA = Deutscher Normenausschuß).

Aachen felting test is used to measure the felting propensity of wool. A ball of loose wool fibres, formed by hand, is introduced into a shaker flask filled with milling liquor. The flask is shaken for a specific period of time to allow the wool fibres to begin felting. On completion of the test, the ball of fibres shrinks in size to a particular radius which corresponds to the felting characteristics of the wool. After drying, this represents a measure of the felting propensity of the fibres tested.

Aachen fine cloth Descriptive term of origin generally applied to high quality cloth and fabrics of pure wool. The worldwide reputation of Aachen quality lies behind these original fabrics, produced in plain weave constructions from fine carded yarns based on very fine merino wools and finished with a fine closely napped surface. Such high quality fabrics were founded, above all, on Aachen's thousand year old tradition as a cloth city. Since the turn of the century, however, Aachen has concentrated less on the production of carded wool fabrics and more on the manufacture of high quality worsted cloths, both piece-dyed and as fine worsted novelties.

AAE abbrev. for: American Association of Engineers; → Technical and professional organizations.

AAQTC (Sp.) abbrev. for: Asociación Argentina de Químicos Textiles y Coloristas, Buenos Aires (Argentine Association of Textile Chemists and Colorists); → Technical and professional organizations.

AAS abbrev. for:

I. → Alkyl aryl sulphonates.

II. → Atomic absorption spectroscopy.

AATCC abbrev. for: American Association of Textile Chemists and Colorists → Technical and professional organizations.

AATCC Fading Unit (AFU) Unit for the evaluation of → Colour fastness to light. 20 AFU corresponds to the amount of light exposure necessary to bring about a just perceptible change of shade in a specified blue standard (AATCC blue scale).

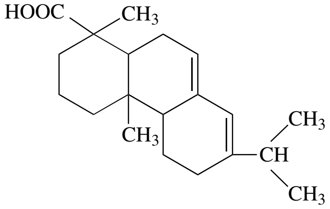
AB → Manila fibre, → Standard abbrev. for textile fibres, according to DIN 60 001 T4/08.91.

Abaca → Manila fibre.

Abietene Oily resinous hydrocarbon. Formed by the chemical decomposition of → Abietic acid. Contains less than 1% of abietic acid. Used in the manufacture of → Resin sulphonation products.

Abietic acid (abietinic acid, sylvic acid), is the most important of the → Resin acids, and is the main component of → Colophony. It consists of a yellowish mass, melting at 173°C. Insoluble in water, soluble in alcohol and ether. Alkali salts form water-soluble, capillary-active rosin soaps.

Heavy metal salts are insoluble. Uses: in the form of colophony (modifications) with synthetic resins, etc. or rosin soaps, e.g. as the basis for anti-slip/snag and ladderproof finishing agents (→ Resin sulphonation products).



Abietinic acid → Abietic acid.

Abietinols, abietyl alcohol → Resin alcohols.

Abnormal fibre (wool) Originating from sick animals, displays anomalous thickening and necking. → Evenness.

ABNT (Port.) abbrev. for: Associacão Brasileira de Normas Técnicas, Rio de Janeiro (Brazilian Technical Standards Association); → Technical and professional organizations.

Above floor level → Underfloor.

Abrasion ghosting → Ghosting, Ghosting effects.

Abrasion resistance The ability of textile fabric surfaces to withstand abrasive stresses. It is used as a measure of their wear resistance.

In DIN 53 863 the standard requirements for abrasion tests are given:

- Abrasion: the relative movement, combined with friction, between a textile test specimen and an abrading body or abradant.
- Abrading action: test carried out within a prescribed time of abrasion without causing any visible damage to the test specimen.
- Destructive abrasion: test carried out to the point of destruction (i.e. the formation of holes).
- Abrasive wear: change occurring in the surface or structure of a textile test specimen as a result of abrasive action.
- Abrasion loss: weight loss of a textile test specimen as a result of abrasion.

In testing for abrading action the abrasion resistance is evaluated according to the extent of abrasion, changes in material properties (tensile strength, extensibility, etc.) or changes in appearance (formation of pills, surface roughening, exposure of the weave structure, etc.).

In testing for destructive abrasion either the time required, or the number of strokes required for holes to appear in the test specimen are given. For abrasion testing, a number of different (non-standard) methods and test instruments are used which are intended to simulate the various kinds of abrasion stresses encountered in practice. Methods differ in the type of contact between the textile test specimen and the abradant, the type of abradant (textile material, emery paper), the direction of abrasive stress, the tension applied to the test specimen as well as technical parameters of the various test instruments such as the pressure, speed and duration of abrasive action, removal of fibre dust, etc.

ABS, abbrev. for:

I. acrylonitrile-butadiene-styrene copolymer.

II. → Alkyl benzene sulphonates.

Abscissa Horizontal axis of coordinate systems. Vertical axis → Ordinate.

Absolute alcohol, water-free ethanol; → Alcohols.

Absolute humidity → Air humidity.

Absolute system of measure, physical system of measure.

Absolute temperature → Temperature.

Absorbency →: Wettability, Hydrophilic treatments.

Absorbent The capacity of a substrate to take up liquid. In the case of textile fabrics, absorption takes place within the fibre, adsorption or adhesion on the fibre surface, intercapillary absorption between fibres in a yarn structure and absorption between the loops of knitted fabrics. Since, in the case of knitted fabrics, the pore volume (excluding intermolecular pores) occupies at least 70–95% of the entire material and is much greater, expressed in cm^3/m^2, compared with flat fabrics, the absorbable quantity of liquid is high. Absorbency is proportional to the pore volume (→: Moisture behaviour of fibres and yarns; Wetting process). The pretreatment of cotton fabrics is carried out, among other things, to increase the absorbency to such an extent that sufficient liquor is absorbed in continuous dyeing processes even during the shortest possible contact times in the padder.

Absorbent compounds These are substances which swell and are capable of absorbing several times their own weight of liquid, especially water. Starting products are polymers containing OH or NH_3 groups, e.g. cellulose, starch and polyacrylamides which, by suitable modification, are converted into absorbent compounds.Uses: particularly for the hygiene sector. → Superabsorbers.

Absorptiometer An instrument for measuring the absorption of light, based on a similar principle to the → Photometer.

Absorption The ability of one material to take up another. In this way, for example, gases are absorbed by liquids (ammonia, hydrochloric acid), or liquids, gases and radiation by solid materials. Selective absorption is based on different strengths of absorption of monochromatic radiation. In the visible spectrum, this is the reason for colour vision, where a balance is reached between absorption colours and complementary colours. Radiant absorption is that portion of incident light which is not reflected. The radiated body gains energy through absorption, e.g. by conversion into heat. In this way, the radiation absorbed by atoms causes an increase in the kinetic energy. Opposite term → Reflection.

Absorption colour Absorbed spectral colour; → Complementary colour.

Absorption of dye in dyeing Absorption of dye from the liquor during dyeing. Many dyes are very slowly absorbed by the substrate, and treatment must therefore continue for a fairly lengthy time in order to exhaust the dye liquor. For testing the exhaustion capacity of a dye, undyed fabric of the same type is used at the end of the dyeing process for the dye liquor used, in order to test bath exhaustion by subjective assessment of the subsequent absorption by the sample then taken.

Absorption of liquids → Wetting properties, hydrophilic treatment process.

ABTN, abbrev. for: Brazilian Standards Association → Technical and professional organizations.

ABwAG, (Ger.) abbrev. for: → Abwasserabgabengesetz (German Waste Water Disposal Law).

Abwassertechnische Vereinigung (ATV) → Technical and professional organizations.

AC → Acetate fibres, → Standard abbrev. for textile fibres, according to the → EDP Code; DIN standard abbrev.: → CA.

Ac,

I. chemical symbol for the element actinium (89).

II. abbrev. for acetate, acetyl.

III. abbrev. in chemical formulae for → Acyl. For example, as frequently encountered in scientific and patent literature, any monobasic acid (hydrochloric acid, for instance) can be represented in the following form:

$H^+ + Ac^-$

The corresponding salts (sodium chloride) are thus represented as follows:

$Me^+ + Ac^-$ (→ Me = symbol for cation, usually an alkali metal)

From the same standpoint, a cationic compound of a quaternary ammonium base with an acid group (Ac) is represented as follows:

$[R\text{-}NH_3]^+ + Ac^-$.

ACANOR, (Fr.) Association des Cadres de Normalisation d'Enterprise, Paris (Association of Industrial Standardization Offices); → Technical and professional organizations.

Accelerator →: Carriers, vulcanization accelerators.

Accelerotor The Accelerotor is an instrument for making rapid laboratory determinations of the abrasion resistance and wear characteristics (including pilling propensity) of textiles and other flexible materials. The instrument was developed and patented by the → AATCC. The Accelerotor simulates all of the various types of dry, moist, and wet abrasion encountered in normal end use situations. The random motion of an unfettered test specimen employed in the Accelerotor frees it from the limitations of rigidly mounted test specimens. This principle produces samples with a close and completely realistic relationship to end-wear use. The Accelerotor is routinely used for testing woven, nonwoven, knitted, felted pile, tufted and coated fabrics. It is also applicable to combinations of fibres including glass as well as flexible samples of paper, leather, plastic films, etc. Manuf.: Atlas Electric (USA).

Acceptable quality level AQL (acceptable quality level), standard value, under which acceptance sampling specifications are compiled into an acceptance sampling plan. Batches with a fault content equal to or less than AQL are very probably accepted in acceptance sample testing.

Acceptance sampling Used for acceptance testing in the supply of finished products, mainly by taking a random sample and testing its quality (e.g. good/bad characteristics, defect criticality) or measurement testing (e.g. calculating the characteristic rejection rate from mean value and standard deviation).

Acceptance testing → Quality control of finished products. Final inspection.

Acceptor An atom, molecule, or ion that is electron deficient and which can form a coordinate link with an electron donor, e.g. proton acceptors (bases) are substances which take up OH^- ions in aqueous solution. Opposite term → Donor.

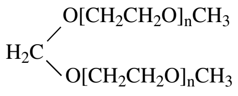
Accomodation Adaptation, e.g. the term, accomodation point, is used in relation to thermoplastic fibres, i.e. → Melting point.

Accumulation, build up, superimposition, e.g. tone shifts in dyed goods resulting from, e.g. improper treatments. The problem is particularly important in the case of domestic detergents containing fluorescent brightening agent additives. After a certain number of washes with such products, an equilibrium establishes itself between the fluorescent brightening agent dissolved out of the textile and that which exhausts on to it again.

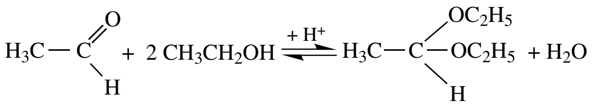
Accumulators → Fabric accumulators which are used as compensating stations in continuous fabric throughput on an extremely wide variety of finishing lines.

ACESA, abbrev. for: Australian Commonwealth Engineering Standards Association → Technical and professional organizations.

Acetal reactants Reactant type crosslinking agents for cellulose which are not subject to chlorine retention.



Acetals Compounds derived from the reaction of an aldehyde or ketone with an alcohol using an acid catalyst, as a result of which water is split off and 2 oxygen atoms are linked to 1 carbon atom, e.g.:

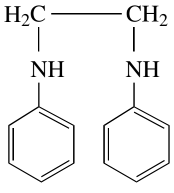


Acetaldehyde *Ethanol*

Constitutionally, acetals are comparable with ethers but possess different properties due to the double C-O-C bond. Acetals are completely stable to alkalies, but on boiling with dilute acids, they split up again into the respective aldehyde and alcohol. Polymer chains with cyclic acetals are present in, e.g. → Polyvinylacetals. The cyclic hemiacetal (a C-O-C bond) of glucose participates decisively in the molecular structure of cellulose.

Acetate cellulose → Cellulose acetate.

Acetate dyeings, colour fastness The colour fastness of disperse dyes to chlorine and gas-fume fading is variable. The latter is improved by gas-fume fading inhibitors which can be applied either during or after dyeing. A product with a very effective inhibiting action is, e.g. N,N'-diphenylethylenediamine. On acetate, cationic dyes have adequate wet fastness properties but poor light fastness.



N,N´-diphenylethylenediamine

Acetate dyeings, identification tests Separation of water-soluble from water-insoluble dyes (see Table 1). Confirmatory test: treat the dyed specimen at room temperature for approx. 15 min in a mixture of alcohol and ethyl acetate (1 :1). After evaporating off the solvent, dissolve the residue in water. Substantive dyes can be distinguished from cationic and acid dyes by carrying out dye staining tests on cotton, wool, etc.

Acetate dyes, identification of dye class The dye classes listed in the table (Table 2) can be identified by applying the test methods given.

test method	disperse dyes	disperse developing dyes	cationic dyes
boiling water test (boil for 5 mins in distilled water)	B: + o W: o	B: o or + o W: o	B: + W: s +
wash test (5 g/l of soap, 5 mins, 80 oC)	B: + + W: st + + +	B: + W: st at the most +	B: + + + W: st + + +
activated charcoal-boiling water test	S: mostly + + +	S: o	S: mostly + + +
benzene test	positive: benzene dyed	negative	positive: aqueous phase dye
paraffin test	negative	slightly positive	negative

Tab. 2

Key to abbrev. given in the table 2:
S = stripped
B = bleeds
W = white acetate sample
W:s = W soiled
W:st = W stained
+++ = very heavily or completely
++ = heavily
+ = lightly
+o = very lightly
o = no change

test method	cationic dyes	disperse dyes	diazotising dyes	naphthols (acetobenzoic dyes)
water test (boil for 5 mins)	slight bleeding, interconnected acetate fibres are slightly soiled	very slight bleeding, acetate white test specimen not stained	only very slight or no bleeding, no white test specimen staining	
wash test (5 g/l of soap, 80° C, treat for 15 mins)	very severe bleeding, interconnected acetate fibres stained	substantial bleeding, white test specimen stained	slight bleeding, white test specimen slightly soiled at the most	dye mostly completely exhausted
Boiling test with water + activated carbon	dye mostly completely exhausted		dye not exhausted	
benzene test	positive	positive	negative	
	(see above for difference)			
paraffin test (?)	negative	negative	slightly positive	very positive.

Tab. 1: Acetate dyestuffs verification.

Acetate fibres belong to the class of man-made cellulosic fibres, sub-group: cellulose ester fibres. Acetate fibres are manufactured by treating cellulose in the form of pure wood pulp or, less frequently, cotton linters, with a mixture of glacial acetic acid and acetic anhydride at low temperature (under cooling) in the presence of an activation catalyst such as sulphuric acid, perchloric acid, zinc chloride or similar salts. The strongly exothermic reaction results in the formation of cellulose triacetate (primary acetate, $C_6H_7O_5$ $(OC–CH_3)$). On the assumption that all 3 OH groups of the glucose units forming the cellulose molecule are acetylated, cellulose acetate contains 44,8% acetyl or 62,5% acetic acid content. For many purposes, the complete acetylation of cellulose is neither necessary nor desired and, during a subsequent stage of hydrolysis, some of the original cellulosic OH groups necessary for solubility are regenerated. This saponification process with dilute sulphuric acid may be terminated at any desired point with sodium acetate. A partial esterification to produce partially-acetylated cellulose is not possible, and a mixture of free and triacetylated cellulose is obtained instead. The cellulose acetate produced in the above manner is described as secondary acetate, and corresponds to the ester group content of “2,5 acetate” (37,5% acetyl or 57% acetic acid content).

Fibre manufacture: the cellulose acetate flake is precipitated in water, washed, purified and dried. In the case of triacetate, it is then dissolved in dichloromethane and, in the case of 2,5 acetate, acetone and alcohol are used. The resultant highly viscous solution is filtered, freed from air, and extruded through spinnerets in the dry spinning process. Filament yarns composed of several filaments (depending on the number of holes in the spinning jets) are produced by this means. In the manufacture of staple fibre, the filaments from numerous spinnerets are combined into tow form, crimped, and cut to the required length. Fibre properties: moisture regain 6–6,5%, water retention 25–28% (lower in comparison to cotton, cupro and viscose), High affinity towards organic solvents (alcohol, acetone, chloroform, glacial acetic acid, ethyl ether, etc.) in which the fibres either dissolve or swell. On the other hand, cellulose acetate, being an ester, is itself a good solvent for numerous organic substances (dyes, etc.); → Acetate/triacetate fibres – solubility in organic solvents. As a result of the properties conferred by acetylation, acetate fibre exhibits a different affinity towards dyes compared to other cellulosic man-made fibres, and is extremely sensitive to alkalies (action of alkalies causes deacetylation or saponification = loss of characteristic properties) and also acids. Melting point 225°C, max. ironing temperature 180°C. Drycleaning is carried out exclusively with tetrachloroethane (perchlorethylene), fluorocarbons or special boiling point spirits.

Acetate fibres, determination of acetic acid content Approx. 2 g of prewashed and dried fibres are weighed and saponified for 48 h in 50 ml 0,9 n alcoholic potassium hydroxide solution at 20°C. After the addition of hydrochloric acid, the fibres are treated for a further 45 min. at 50°C and then titrated with sodium hydroxide solution using phenolphthalein as indicator. A blank control test (blank test on alcoholic potassium hydroxide solution) must also be carried out.

$$Q = \frac{(a - b) \cdot 0{,}06 \cdot 100}{E}$$

Q = acetic acid content in% based on dry material,
a = consumption of potassium hydroxide solution in ml required to bind the acetic acid liberated,
b = consumption of blank test in ml,
E = weight of dried material in g.

Acetate fibres, dyeing of Although acetate is a regenerated cellulosic fibre it bears a greater resemblance to synthetic fibres because of its hydrophobic character, i.e. neither direct nor vat dyes can dye the fibre satisfactorily. For this reason, the following dye classes are used to dye acetate:

1. Cationic dyes: brilliant shades with relatively poor colour fastness are obtainable with selected dyes of this type.
2. Acid dyes: pale to medium depth dyeings are obtained with selected dyes.
3. Disperse dyes: universally applicable.
4. Disperse dyes capable of diazotization and development: applied by special dyeing methods; used for the production of deep shades with high wet fastness properties.
5. Pigment colorants: applied with a pigment binder. Seldom used on acetate and then only for pale (pastel) shades.

Disperse dyes are by far the most important class of dyes for the dyeing of acetate.

Acetate fibres in direct printing Nowadays, woven and knitted acetate fabrics are printed almost exclusively with selected disperse dyes. Liquid dyes are preferred because of the simplified print paste preparation, i.e. without the need to predisperse the dye. Disperse dyes are selected on the basis of shade, light fastness, wet fastness, sublimation fastness and processing fastness. The importance of the individual criteria depends on the type of article and fibre. Typical print paste recipe (1000 g): 1–150 g disperse dye, x g water, 500 g thickener (guar or locust bean derivative 9–12% solution), 0–50 g fixation auxiliary. Urea, thiodiethylene glycol, glycerol esters and glycol derivatives are used in limited quantities as fixation auxiliaries.Whilst these additions assist dye fixation, excessive amounts can cause fibre damage. Very occasionally, cationic dyes are used to achieve particularly brilliant shades. The colour yield is likewise improved by the addition of urea. When printing cationic and disperse dyes alongside each other in the same design, it is helpful to precipitate the cationic dyes in a finely dispersed form by the addition of an anionic auxiliary. Fixation of prints on acetate with disperse and cationic dyes is carried out by steaming the goods in the star or universal loop steamer with saturated steam at 102°C for 20–40 min. Acid and metal-complex dyes are also still used occasionally, in which case dye fixation can be achieved without steaming.

Acetate fibres in discharge printing Dyeings with selected disperse and cationic dyes are used as dischargeable grounds. The best white discharges are obtained with zinc formaldehyde sulphoxylate. For coloured discharges, tin (II) chloride is used as the discharging agent, which permits a wider range of discharge-resistant dyes to be used. Discharge printing methods based on thiourea dioxide have also been employed on acetate.

Acetate fibre solvents Spotting agents which can dissolve or swell acetate fibres include: formic acid, ethyl ether, ethyl acetate, ethylenediamine, acetone, benzaldehyde, chloroform, glacial acetic acid, (acetic ether = ethyl acetate), nitrobenzene, phenol liquid, pyridine, (sulphuric ether = ethyl ether) and tetrachloroethane. Particularly dangerous are warm solvents besides solvent mixtures, e.g. benzene/alcohol and chloroform/trichloroethylene.

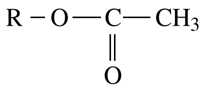
Acetate fibres, test for chemical damage Determination of the → Viscosity index of a very dilute solution of acetate in m-cresol.

Acetate of alumina → Aluminium acetate.

Acetates contain the typical CH_3COO– acetate group.

I. Salts of acetic acid (CH_3COOH) of the type CH_3COONa (sodium acetate). All neutral acetates are water-soluble, basic acetates sparingly soluble. Properties: →: Aluminium, Ammonium, Calcium, Chromium, Iron, Sodium and Tin acetates.

II. Acetic acid esters, e.g. of the cellulose acetate type which have the following configuration:



$$R-O-\underset{\underset{O}{\|}}{C}-CH_3$$

Acetate/triacetate fibres – solubility in organic solvents Differences in solubility can be used for the identification of both these textile fibres. In principle, acetate fibre dissolves in polar solvents such as acetone whereas, by contrast, triacetate fibre, which no longer has any free -OH groups, dissolves very well in certain non-polar solvents such as dichloromethane (see Table).

solvent	acetate	triacetate
formic acid	soluble	soluble
amylacetate	soluble	swells
acetone	soluble	swells/soluble
benzine (doubled)	resistant	resistant
benzine, petroleum ether	resistant	resistant
benzene, toluene, xylene	resistant	resistant
benzyl alcohol	soluble hot	insoluble/agglomerates
chlorinated benzenes	swells	swells
chloroform	swells	swells/soluble
cyclohexanone	soluble hot	soluble hot
dichloromethane	swells	soluble
dimethyl formamide	soluble	soluble
dioxane	soluble	slowly soluble
glacial acetic acid	soluble	soluble warm
acetic ether	soluble	swells
ethanol	insoluble	swells
ethylene chloride	soluble	soluble
ethylene diamine hydrate	soluble	insoluble cold
m-cresol	soluble hot	slowly soluble
methanol	resistant	resistant
phenol	soluble	soluble
tetrachlorethene	resistant	resistant
carbon tetrachloride	resistant	resistant
trichlorethene	resistant	swells

Tab.: Acetate and triacetate solvents.

Acetic acid (glacial acetic acid, ethanoic acid), CH_3COOH. Most important member of the → Fatty acids. MW 60,42. Salts are known as acetates. The water-free acid is a clear, colourless liquid with a pungent odour irritating to the eyes. The 100% acid is known as glacial acetic acid. Acetic acid is miscible in all proportions with water, alcohol, ethers, carbon tetrachloride, chloroform, glycerol and ethereal oils. Synthetic acetiñ`acid is pure. Typical impurities can be: hydrochloric, sulphuric and sulphurous acids as well as catalysts (mercury, manganese, iron). Properties: pure acetic acid is flammable, turns litmus paper red only after moistening; medium strength acids burn the skin; dilution with water causes evolution of heat and diminution in volume; volatile. Uses: dyebath additive (for dyes exhausting under weakly acidic conditions, especially acid and chrome dyes); in printing it has a slower dye-exhausting action than sulphuric acid (reduces lake formation); souring and neutralizing; pH adjustment of water; solvent for cationic dyes; spotting agent (for dyes, as well as resin, oil and blood stains).

Acetic ester → Ethyl acetate.

Acetoacetanilide (acetylacetanilide) → Acetyl compounds.

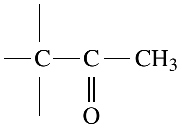
Acetoacetic ester $CH_3CO–CH_2–COO–C_2H_5$; used in the printing of acetate fibres with water-soluble acetate dyes.

Acetone (propanone, dimethyl ketone), CH_3COCH_3, MW 58, density 0,79, b.p. 56°C, flashpoint 17°C. Acetone is a clear, colourless, volatile liquid with a sweetish odour. Hazard: flammable, dangerous fire risk. Properties: neutral reaction; miscible with water, alcohol and ether in any proportions. Uses: spotting agent (for grease, rubber, varnish, oil and pitch stains, etc.); fibre reagent (→ Acetone solubility test); swelling agent in printing, etc.

Acetone solubility test For the identification of acetate and polyvinyl chloride fibres. Acetate is either partially or completely dissolved in acetone. In doubtful cases, add water – a precipitate confirms the presence of acetate. More reliable is the → Glacial acetic acid solubility test. Polyvinyl chloride dissolves slowly in acetone.

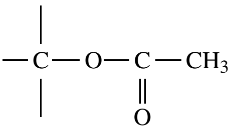
Acetosole → Tetrachloroethane.

Acetyl cellulose An inappropriate term widely encountered in the literature for → Cellulose acetate. A true “acetyl cellulose”, stable to hydrogen and hydroxyl ions, must, as an → Acetyl compound, possess the following molecular grouping:



$$-\overset{|}{\underset{|}{C}}-\underset{\|\atop O}{C}-CH_3$$

This is not the case, however, for actual cellulose acetate which, as an acetate, contains the typical ester group:



$$-\overset{|}{\underset{|}{C}}-O-\underset{\|\atop O}{C}-CH_3$$

As is well-known, this is the reason why cellulose acetate, as a cellulose ester, is very sensitive towards H and OH ions, which makes it necessary to dye the fibre under conditions that are as close to neutral as possible.

Acetylacetone method A test method based on acetylacetone (pentanedione-2,4) for the quantitative colorimetric determination of free formaldehyde on textiles in accordance with Japanese Law 112–1973. It involves aqueous extraction of the test specimen, the addition of acetylacetone reagent solution and colorimetric measurement.

Acetylated cotton Modification of cotton by esterification with glacial acetic acid. The treatment results in chemically modified cotton which is especially characterized by improved resistance against microbial attack, rotting, heat and acids. Depending on the degree of acetylation, partial, high and fully acetylated cottons are obtained. The acetylation takes place mainly in the readily accessible amorphous regions of the fibre. Continuous and discontinuous acetylation processes are subdivided into the following sub-stages: cleaning, activation, acetylation and rinsing.

Acetylation Introduction of the acetyl group, CH_3CO (→ Acyl group) into an organic compound containing either an OH-group or NH-groups. Not to be confused with the introduction of the acetate group, CH_3COO (→ Acetates) since acetylation does not involve esterification. → Acetyl compounds.

Acetyl compounds, are formed by → Acetylation and thus contain the typical acetyl group CH_3CO (→ Acyl group), e.g. acetamide CH_3CONH_2, acetyl chloride CH_3COCl. Other acetyl compounds are e.g. acetoacetic anilides of the type $CH_3COCH_2CO–NHC_6H_5$ which are important in dye chemistry, e.g. as developers and Naphthol AS dyes (Naphthol AS-G = diacetoacetic tolidide). Cellulose acetate, on the other hand, is not an acetyl compound.

Acetylene (ethyne), C_2H_2; colourless and virtually odourless toxic gas, lighter than air, ignites above 335°C, burns with a bright and smoky flame, combined with oxygen it develops temperatures of approx. 3000°C (1 m^3 = 60 060 joules), commercially available in pressure-tight steel bottles (22,5% acetylene and 40% acetone in 25% kieselguhr, to reduce the risk of explosion). Produced by the action of water on calcium carbide. Acetylene is the most important gas in chemical synthesis (dyestuffs, chemical auxiliaries, solvents, etc.)

Acetylene dichloride → Dichloroethylene.

Acetylene diurea, glyoxal diureide. The methylol compound of acetylene diurea is used, among other applications, as a resin finishing agent. → Tetramethylol acetylene diurea.

Acetylene tetrachloride → Tetrachloroethane.

Acetylides → Carbides.

Achema, exhibition of chemical instrumentation within → Dechema.

Achromatic, colourless. A property of optical instruments (mostly compound lenses) to avoid chromatic aberration, i.e. prevention of coloured fringes surrounding the image.

Achromatic colours According to Ostwald the colours “white, grey, black and all those that lie between”. →: Grey series; Pure spectral colour; Chromatic colours.

Achromatic objectives Optical objectives with compound lens systems having the highest degree of correction for chromatic aberration.

Achromatic point (white point) The achromatic point is effective as the colour point of the lighting-dependent physical → Ideal white.

Achromatism → Colour blindness.

Achromatopsia, total → Colour blindness.

Acid ager This type of steamer is used for dye fixation (development) on printed fabrics by acid steam development. →: Flash ageing process; Rapid ager.

Acid amides are organic compounds containing the functional group -NH-CO-. They are formed from → Oxo acids, through substitution of hydroxyl groups

(OH) by monovalent amide groups (NH_2). Oxo acids are of great significance in the manufacture of dyestuffs and textile auxiliaries. Amongst the latter, detergents and wetting agents derived from paraffin hydrocarbons as sulphamides or → Sulphimides are of particular importance. These are formed by the action of ammonia on the sulphochlorides of paraffin hydrocarbons. An example of a polymer acid amide is → Polyamide.

Acid anhydrides, are formed by the removal of water from → Acids, e.g.

$$2\,HOCl \rightleftharpoons Cl_2O + H_2O$$

Some acid anhydrides can form several acids with different numbers of water molecules, e.g. phosphorus pentoxide, P_2O_5

$+ 1\ H_2O \rightarrow (HPO_3)_2$ metaphosphoric acid
$+ 2\ H_2O \rightarrow H_4P_2O_7$ pyrophosphoric acid
$+ 3\ H_2O \rightarrow (H_3PO_4)_2$ orthophosphoric acid

As an example of the tribasic → Phosphoric acids,

- ortho acid is an acid without elimination of H_2O which, in this case, is referred to as phosphoric or orthophosphoric acid H_3PO_4.
- meta acid is formed from one molecule of a tribasic acid with elimination of one molecule of H_2O, in this case metaphosphoric acid HPO_3.
- pyro acid (from Gr. pyro = fire, since heat energy must be supplied) is formed from two molecules of a polybasic acid with the elimination of one molecule of H_2O, in this case pyrophosphoric acid $H_4P_2O_7$.

Substitution of the remaining acidic hydrogens, e.g. by alkali metals, yields the corresponding salts; i.e. orthophosphates, metaphosphates and pyrophosphates.

Acid chlorides are formed from → Oxo acids through the substitution of hydroxyl groups by chlorine. Acidic chlorides of wide importance in the chemical industry are products such as e.g. sulphuryl chloride: sulphuric acid $H_2SO_4 = SO_2(OH)_2 \rightarrow SO_2OHCl$ (chlorosulphonic acid) → SO_2Cl_2 (sulphuryl chloride) etc.

Acid chlorination, colour fastness to → Colour fastness to acid chlorination.

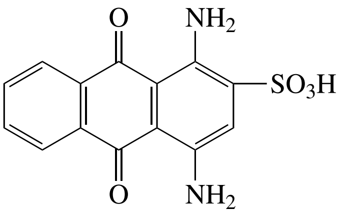
Acid damage to cellulose → Hydrocellulose.

Acid discharges (discharge resists), → Discharges based mainly on citric or tartaric acids or their salts. Used e.g. for mordant and cationic dyes.

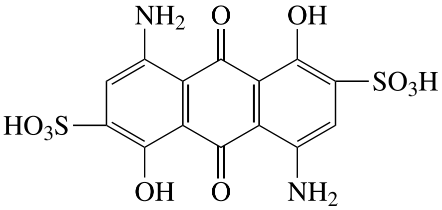
Acid donor A term used in resin finishing for inorganic and organic compounds which break down under certain conditions, mainly at elevated temperatures (e.g. 150°C), liberating acids. They are used as reaction accelerators for the crosslinking of resin finishes. → Resin finishing catalysts.

Acid dyes, are mainly alkali salts of sulphonic and/or carboxylic acids (containing SO_3H, COOH or OH groups):

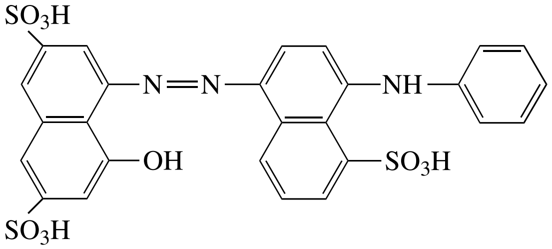
- type monosulphonated dye



- type disulphonated dye



- type trisulphonated dye



Acid dyes have good water solubility and excellent affinity for wool, silk and polyamide fibres. The acid dyes represent an important dye class for these fibres: they are easily dyed, have generally good levelling properties, and produce uniformly exhausted, well penetrated dyeings. Fabric handle and lustre are unaffected. An extensive range of acid dyes is available.

Acid dyes exhaust directly from neutral to strongly acidic dyebaths. Additions of acid accelerate, whilst additions of salt retard the rate of exhaustion (regulator for levelling). When dyeing is correctly carried out, the dyebath exhaustion is generally complete (clear liquor). Attention must be paid to dye selection, e.g. for wool/polyamide blends, monosulphonated acid dyes are the most suitable (higher rate of saturation, deeper dyeings, good parity between both fibres), whilst disulphonated acid dyes exhaust preferentially on to wool depending on the acidity of the dyebath (wool has a higher acid-binding capacity than polyamide). For this reason, combinations of mono and disulphonated acid dyes (with few exceptions) should not be used to produce plain-dyed shades on wool/polyamide blends since the monosulphonated dye will be absorbed preferentially and the disulphonated dye displaced by the polyamide component (blocking effect), thereby increasing exhaustion of the latter on to the wool component.

The examples of di- and trisulphonated acid dye types illustrated by the formulae given at the beginning of this section are representative of polysulphonated acid dyes. In practical applications, no technical distinction is made between di-, tri- or multifunctional dyes. The application of disulphonated acid dyes in wool dyeing can also be extended by the use of trisulphonated dyes according to their affinity. The quantities of auxiliary additions, which may be necessary to prevent tippy dyeings, are frequently different for di- and trifunctional dyes. The dyeing of homogeneously dyeable polyamide materials with polysulphonated acid dyes is not based on considerations of technical application but rather on lower cost. In order to achieve high contrasts in the dyeing of differential-dyeing polyamide, di- and trifunctional acid dyes are recommended, with preference being given to the former type.

Acid dyes are important dyes for natural protein fibres (wool, silk) as well as various synthetic fibres (e.g. polyamide) and even, to some extent, for cellulosic fibres.

I. Wool dyeing in particular (yarn, piece and fully-fashioned articles); e.g. cheaper qualities of carpet yarns; braids; tapes; cheaper menswear and lightweight women's (dress) fabrics; flannel; blankets; furnishing and upholstery fabrics; flags, etc.; plush; felts; knitwear and hat dyeing.

II. Silk dyeing (hanks, piece and fully-fashioned articles); also for weighted silk (exception: black).

III. Fibre blends, e.g. with cellulosics (and fully-fashioned articles). Acid dyes are particularly versatile in these applications:

a) two-bath method for plain-dyed shades (= better handle, avoidance of heat creases), involves pre-dyeing with acid dyes and topping with substantive dyes.
b) single or two-bath methods for two-tone or resist effects with selected dyes.

IV. Acid dyes are used for bright and cheap dyeings on jute; for bright shades etc. on hemp (sisal); coconut fibres and yarn; bast fibre braids (with substantive dyes); raffia bast; fibres (for upholstery purposes, brushes); hog's bristles; horsehair for linings, fillings, brushes, etc.; paper (yarns and fabrics).

The dyeing behaviour of acid dyes on wool can be characterized as follows:

1. Migration: a dye property which is dependent on the rates of desorption, diffusion and sorption.
2. Build-up: a factor which is determined by affinity of the dye for the fibre under specific conditions of pH. Further dye properties of decisive importance in practical application may be derived from the above two factors, e.g. dye combinability and wet fastness.
3. Combinabilty: Good combinability exists when the particular dyes selected exhaust and migrate tone-in-tone. This behaviour is dependent on dye affinity as well as the rates of diffusion/desorption, and can therefore be characterized equally effectively by the much more familiar dyer's terms of migration and build-up.

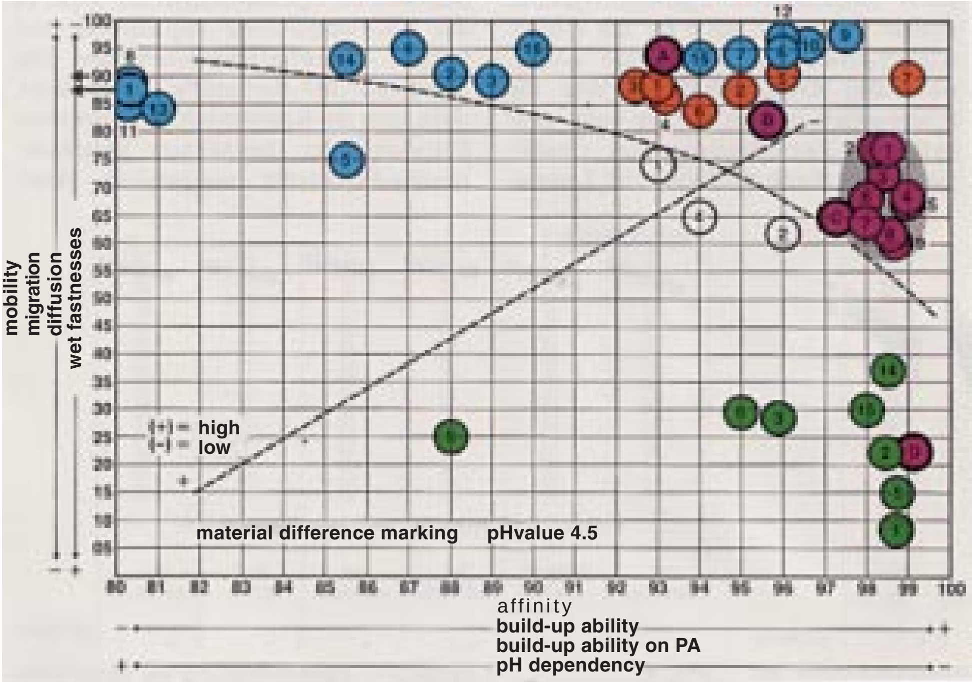


Fig.: Dyeing behaviour of acid dyes on wool. A (blue) = levelling dyes; B (red) = levelling dyes with good perspiration fastness; C (violet) = Sandolan MF dyes (Clariant); D (green) = milling dyes.

4. Wet fastness properties: Since the processes of desorption, diffusion and adsorption are likewise responsible for wet fastness, a close relationship between migration and wet fastness properties has to be assumed. For this reason, therefore, it cannot simply be expected that dyes with high wet fastness will also migrate readily. In order to achieve this objective as closely as possible in practice, special dyeing systems have been developed. If acid dyes are schematically represented on a graph according to their migration/mobility and exhaustion/affinity behaviour then each dye will take up a position on the graph corresponding to its properties (see Fig.). These positions are characterized by the dye chemistry, e.g.:

- degree of sulphonation,
- molar dye strength,
- chemical constitution,
- molecular weight.

As a prerequisite for the reliabilty of this classification, test conditions such as those listed below must be maintained exactly:

- depth of dyeing,
- pH of dye liquor,
- dyeing time and temperature,
- dyeing substrate and its pretreatment.

The Figure illustrates the positions of a series of well-known types of acid dye. Dye mobility (which is expressed as levelling behaviour), is indicated by strength differences between dyed material and adjacent material after a migration test: 100% = complete levelling, 0% = no levelling) and is represented along the vertical axis of the figure. Dyebath exhaustion, under specified conditions, is represented along the horizontal axis (100% = complete bath exhaustion; 80% exhaustion = 20% of the dye used remains in the dyebath). The curved line running from upper left to lower right of the figure separates the monosulphonated from the disulphonated dyes. Those dyes positioned in the upper right-hand sector exhibit high affinity resp. a high exhaustion capacity, good migration properties and good levelling of root/tip differences in wool dyeing. With decreasing affinity and migration capacity (towards lower left), this levelling ability falls off (increased selective exhaustion). In this last sector, special dyeing methods are usually necessary to achieve good equalizing resp. good levelling of root/tip differences, as is the case, e.g. with turquoise dyes of high wet fastness.

Good combinability exists therefore when dyes which are applied in combination exhibit uniform dyeing behaviour irrespective of their application quantities in the recipe, and when they have no influence on each other. Thus the closer dyes are positioned to one another in the schematic diagram, the more ideal, i.e. concentration-independent, their suitability in combination, and the greater is the likelihood that their wet fastness properties will be similar. (Frauenknecht, Hextall and Welham).

Acid dyes in dyeing

I. Wool: Acid dyes exhibit wide differences in affinity for wool fibres. However, a strict subdivision is not possible since fluid transitions exist. The starting pH of the dyebath ranges from pH 1,8–6 depending on the affinity of the dyes used. Initial acidity, however, depends not only on dye affinity characteristics but may also be determined by other factors from time to time. With high acidity, the dyeing process does indeed proceed more quickly since more ammonium cations are present. However, the electrostatic bond of dyes exhausting from strongly acid baths is not particularly stable, i.e. the dye salt may be broken down hydrolytically during the course of dyeing, which means that non-uniform dye uptake is levelled out again through dye migration. For this reason, dyes which exhaust from strongly acid baths are also known as levelling or equalizing acid dyes. Acid dyes which exhaust from weakly acidic baths are less easy to level because of their stronger bonding to the wool fibre, so that greater care is necessary in dyeing. Such dyes are generally known as milling acid dyes. They find application for knitted and warp-knit fabrics in deep shades, swimwear, women's wear, milled fabrics, etc. Acid dyes exhausting under strongly acidic conditions are employed when, in the interests of gentle treatment of the wool fibre, the dyeing process should be as short as possible, and their use appears advisable because of problems with levelling or penetration. They may only be used, however, provided that the wet fastness properties are sufficient to meet the particular end-use requirements. Applications include the dyeing of knitted and warp-knit fabrics in pale to medium shades as well as upholstery fabrics, etc. Their main use is for the dyeing of wool qualities that are prone to felting. They are also important in yarn dyeing, being especially suitable for the dyeing of yarn packages where their use ensures perfectly penetrated dyeings. Sodium sulphate promotes levelling by reducing the effective forces which exist between the wool fibre and the dye anion, thus keeping the dye in solution longer without exhausting on to the fibre.

II. Silk: In general, the same methods can be used for dyeing silk as for wool. Peculiar to silk dyeing, however, is the use of bast soap in the dyebath, which functions as a levelling agent and is beneficial for fibre quality. In many cases, the bast soap is broken by the addition of acids, and dyeing is carried out in a broken bast soap bath, in which the fatty acids separated from the soap are maintained in a finely dispersed state by the sericin. Many acid dyes may also be dyed on silk from a neutral bath containing soap and, possibly, sodium sulphate.

III. Polyamide: Because of their cationic character, polyamide fibres may be dyed with acid dyes, including those which exhaust under strongly acid as well as weakly acid or neutral conditions. It is recommended that dyeing be carried out only in the presence of ammonium acetate, ammonium sulphate or acetic acid. Due to the stable bonding of acid dyes on polyamide, dyeings on this fibre possess wet fastness properties which are to some extent superior to the corresponding dyeings on wool. The light fastness of many acid dyes on polyamide is also good. It is, however, important in the dyeing of polyamide to select only those acid dyes which are particularly suitable for dyeing this fibre having regard to levelling properties, combinability (blocking effect), ability to cover material-inherent streakiness, and achievement of desired fastness properties. (→: Dyeing of polyamide fibres; Acid dyes in printing)

Acid dyes in printing

I. Wool: Printing is mainly carried out on wool which has been given an oxidative pretreatment. The most commonly used thickeners are locust bean and guar derivatives, crystal gum and British gum. As acid components, acetic or formic acids are used (20–30 g/kg) or, less frequently, tartaric, oxalic or glycolic acids. For dark shades and dyes which are sensitive to reduction in the steamer, an addition of sodium chlorate (10–15 g/kg) is often made to the print pastes. Urea, *inter alia*, is used as a dye solvent. For areas of heavy coverage in hand printing, an addition of sodium tungstate is also useful (promotes levelling). Coacervate-forming chemicals also have a favourable effect on levelness. As hygroscopic agent, an addition of glycerol (20–30 g/kg) is used. After printing, the goods are dried (not too intensely) and finally steamed for 40–60 min. at 101–103°C. Good fixation of the prints can only be achieved with saturated and moist steam. After fixation, the goods are well rinsed, lightly soaped if necessary, then hydro-extracted and dried.

II. Silk: The most commonly used thickeners are locust bean and guar derivatives, crystal gum and British gum. In roller printing, gum arabic is still frequently used. Formic acid is mainly employed as an acid component (10–20 g/kg). For dark shades and dyes which are sensitive to reduction in the steamer, an addition of sodium chlorate (10–15 g/kg) is often made to the print pastes. Urea, *inter alia,* and occasionally benzyl alcohol are used as dye solvents. Where levelling problems are encountered, particularly in the printing of large areas in pale to medium shades, it is advantageous to work without formic acid or neutralize the print pastes with ammonia. Alternatively, the formic acid may be substituted by ammonium tartrate 20°Bé (10–40 g/kg). After printing, the dyes are fixed in saturated steam for 30–50 min., rinsed well with a plentiful supply of cold water and, if a scroopy handle is desired, finished (1–2 ml/l acetic acid 80% or formic acid 85%; 5–10 min. cold). To improve wet fastness, 1–2 g/l of a cationic surfactant can be added to the finishing bath or applied from a fresh bath. Finally, the goods are hydro-extracted and dried.

III. Polyamide: As thickeners, preference is given to low-viscosity locust bean or guar derivatives as well as crystal gum. Instead of free acids, additions of acid donors such as ammonium sulphate and ammonium tartrate are employed. Urea, *inter alia,* is used as a dye solvent. In order to prevent frosting effects, 3–5 g/kg of special surfactants can be made to the print pastes. For reasons of improved levelling when printing pale shades, it is recommended to add 5–10 g of a levelling agent to the print pastes. After printing, the dyes are fixed by steaming for 20–30 min. at 0,2 bar, rinsed cold (at pH4 to prevent staining of white grounds), soaped at 50°C, rinsed again cold and, to improve fastness if desired, given an aftertreatment (pH4) with 2 g/l of a cationic surfactant.

IV. Acetate: With selected acid dyes, excellent wet fastness ratings are obtained on acetate which are far superior to those achieved in printing with disperse dyes. Moreover, bleeding and staining in the washing process is largely avoided. As thickeners, locust bean and guar derivatives, as well as crystal gum, possibly in admixture with carboxymethylcellulose, are used. Urea, *inter alia,* is used as a dye solvent. After printing and drying, the dyes are fixed by steaming for 20–30 min. in saturated steam, rinsed well cold and, to achieve optimum wet fastness, soaped at approx. 60°C, rinsed again cold, then dried.

V. Triacetate: Brilliant shades with excellent wet fastness are obtained on triacetate with selected acid and metal-complex dyes. Moreover, bleeding and staining in the washing process is largely avoided. As thickeners, locust bean and guar derivatives, crystal gum, carboxymethylcellulose and starch-ethers are used. Benzoic acid, thiourea and resorcinol are employed as fibre swelling agents. Products such as e.g. benzyl alcohol and ethanol are used as solvents. After printing and drying, the dyes are fixed by steaming for 10–15 min. in saturated steam, rinsed well cold, soaped at 80–90°C to achieve optimum wet fastness, rinsed again cold, then dried.

VI. Viscose: Prints of outstanding brilliance and adequate wet fastness, e.g. as occasionally demanded by the fashion apparel market, are obtained with selected acid and metal-complex dyes on this fibre. Locust bean and guar derivatives, as well as crystal gum are used as thickeners.

After printing and drying, the dyes are fixed by steaming for 20–30 min. in saturated steam, rinsed well cold, then aftertreated with 2 g/l of a cationic surfactant in the final rinse bath for 5–10 min. Finally, the prints are hydro-extracted and dried.

Acid dyes on textiles, identification tests

1. A sample of the dyed material is boiled with 3 ml dilute sodium hydroxide solution in a test tube, cooled, approx. 3 ml ether added, then shaken. The ether is poured off into a second test tube and dilute acetic acid added. If an acid dye is present, the lower layer (dilute acetic acid) must remain uncoloured.

2. Finally, a wash test is carried out: the sample is boiled for exactly 2 min. in 1% ammonia solution. The dye is lightly to heavily stripped. Remove the sample from the liquor. Carry out a dyeing test in the liquor by adding both white wool and white cotton material together with sodium sulphate, then boil for 5–10 min. Heavily stained wool indicates the presence of an acid dye (control reaction: borax beads must remain uncoloured). If the cotton is likewise heavily stained, a direct dye is indicated.

Acid equivalent of protein and polyamide fibres (Acid binding equivalent), (acid saturation value), the binding equivalent of acid dyes per unit of weight of protein fibres (wool, silk) as well as polyamide fibres is normally dependant on the respective numbers of free amine groups in the fibre molecule available to form salts. This number is comparatively low in polyamides where only amino end groups exist, whereas protein fibres have additional amine side groups. Consequently, the acid dye equivalent and, with it, the saturation value for anionic dyes (acid dye type) is significantly lower for polyamide fibres than for protein fibres. This also explains the higher acid dye affinity of Polyamide 6 as opposed to Polyamide 6.6 as well as the general differences in acid equivalents of the various polyamide fibre types. In protein fibres, the acid binding power increases with falling pH (optimum condition between pH 1–2) until between pH 1.3–0.8 a saturation value is reached. Then under pH 0.8, the acid take up climbs quickly again due to the charge on the imino group in the peptide linkage and the acid links thus freed. In Polyamide fibres, the acid binding power increases with reducing pH and reaches saturation at between pH 3.0–2.4. Beneath pH 2.4 there is once again a sharp rise caused by the charged amino groups contributing to the acid binding. At this stage, the acid binding power approaches that of wool.

fibre type	acid gramme equivalent per kg of fibre (millequivalent)	equivalent weight as base
wool	0,8 –1,0	approx. 1 200
silk	0,2 –0,3	approx. 4 000
polyamides	0,04 –0,08	approx. 17 000
polyamide 6	0,06 –0,08	approx. 14 000
polyamide 6.6	0,04 –0,06	approx. 20 000

Tab.: Acid bonding capacity of protein and polyamide fibres.

Acid fading, is caused by the breakdown of dye-fibre bonds under acidic atmospheric conditions, resulting in a deterioration of wet fastness properties. The problem occurs chiefly with reactive dyes. → Gas fume fading.

Acidic boiler feed water is the cause of boiler corrosion and breakdown, risk of explosion, costly repairs, etc.

Acidic chlorination (also known as wool chlorination) Fastness to acid hypochlorite solution: the test sample is soaked in 6ml/l of hydrochloric acid solution (d = 1.16 g/cm^3) at 20°C for 10 min. (liquor ratio 25:1), an equal volume of hypochlorite solution containing 1 g/l active chlorine is added, and the sample is left for another 10 min., rinsed in fresh water and dechlorinated with 3 g/l sodium sulphite (crystals) for 10 min. at 35–40°C, rinsed again in running water and dried at a maximum of 60°C. The assessment is with the grey scale.

Acidic washing prevents bleeding of cheap dyeings produced from dyes having poor wash fastness. The process is used especially for white effects, white discharges, or white goods washed together with dyed materials of poor wet fastness.

Wool, in particular, benefits from the mildest treatment conditions when washing is carried out at its → Isoelectric point of pH 4,9 which corresponds to the minimum solubility of free amino acids. At the isoelectric point, wool exhibits the lowest degree of swelling, the least reactivity and the greatest stability, so that the risk of felting is minimal. In order to improve the fibre's processability, and thereby achieve troublefree spinning, the fibres must be treated at the isoelectric point during raw wool scouring with an antistatic agent in the last rinsing bath. For the best effects, only nonionic surfactants which maintain their washing activity in strongly acidic liquors even at the boil are employed (possibly combined with dyeing at the same time). Corrosion-resistant processing equipment is necessary.

Acidimetry → Titration.

Acidity is a property of acids and acidic salts whereby hydrogen ions are split off in aqueous solution. → Dissociation. Opposite term → Basicity.

Acidity, degree of → Acidity; pH.

Acid metal-complex dyes → Metal-complex dyes.

Acid milling → Milling in liquor acidified with sulphuric, acetic or formic acid plus the addition of acid-stable oils (highly-sulphonated Turkey red oils), either (after a good prescour) for 30–60 min. acid treatment followed by hydroextraction and milling with the residual acid, or (without prescour) as an "acidic soil-milling." In the latter case, the process is only carried out in the presence of suitable fibre lubricants. A final neutralization must be given in all cases (especially with wool materials containing cellulosic fibres). Alternative process: after prescouring, the goods are treated with 100% water and 25–50 g/l alkylnaphthalene sulphonic acid with/without acetic acid. This method is used for milling high quality cloths, sports fabrics, blankets, scarves, etc., since it offers advantages of higher tensile strength, better preservation of the material and more favourable milling time compared to the usual acid and alkaline milling treatments. It is more advantageous to carry out milling in the pH range which extends downwards by 1–2 pH units from the (isoelectric) neutral point of wool of pH 4,9 into the more strongly acidic region, than upwards by 5–6 units into the alkaline region around pH 10, for the following reasons: more gentle fibre treatment, reduction in the milling time by approx. one half, better tensile strength and extensibility values, less risk of bleeding with dyeings of poor fastness, firmer handle etc. The process is also used for technical felts. Corrosion-resistant machines and equipment are, of course, a prerequisite for acid milling.

Acid peroxide bleaching of wool (acidic wool bleach) In contrast to alkaline peroxide bleaching (→ Bleaching of wool), acid peroxide bleaching proceeds in the isoelectric range of wool which, in addition to savings in time, represents a far gentler treatment of the material. The action involves the oxidation of natural fibre impurities (conversion to the colourless form). As stabilizer, water glass, which is commonly used in cotton bleaching, is also suitable for wool although it may also be substituted by sodium pyrophosphate or proprietary stabilizers. The pH is adjusted with ammonia provided silicate is not used. The optimum temperature is 50°C for a treatment time of 3–4 h. Peroxide bleaching is carried out under acidic conditions because of the alkali-sensitivity of wool. Opinions on the results of acid peroxide bleaching in comparison to alkaline bleaching are varied. In the final analysis, however, better and more stable whites, without any appreciable fibre damage, should be achieved by this process.

Acid radical The negatively charged residue of an → Acid minus its electropositively charged hydrogen (H^+) ions, e.g.:

Hydrochloric acid:	HCl	→	$H^+ + Cl^-$
Sulphuric acid:	H_2SO_4	→	$2\,H^+ + SO_4^{2-}$
Acetic acid:	CH_3COOH	→	$H^+ + CH_3COO^-$

Due to their negative charge, acid radicals are always anions and are also present in salts in this form. Thus, e.g. sodium sulphate dissolved in water breaks down (dissociates) again into the basic radical cation and the sulphuric acid radical anion: $Na_2SO_4 \rightarrow 2\,Na^+ + SO_4^{2-}$.

Acid-resistant linings for processing machinery and vessels Materials such as rubber, ceramics, or acid-resistant plastics (including fibreglass) are normally used for this purpose.

Acids, are compounds containing hydrogen which dissociate in water to give positive hydrogen H^+ ions (protons) and function, therefore, as proton donors. The general formula is H_nA where A = acid radical or conjugate base, n = basicity of A. The dissociation of acids (protonic reaction) proceeds thus:

$$H_nA + H_2O \rightleftharpoons n\,H_3O^+ + A^{n-}$$

or shortened

$$H_nA \rightleftharpoons n\,H^+ + A^{n-}$$

Acids have a an acidic reaction ($pH < 7$) and a sharp taste. They turn blue litmus red and cause colour changes with other indicators. Inorganic acids include → Hydrogen halides (e.g. hydrochloric acid HCl) and → Oxo acids (e.g. sulphuric acid H_2SO_4) whilst organic acids include e.g.: dye acids, fatty acids, carboxylic acids, oxy-acids, amino acids, phenols. Strong acids are almost completely dissociated in water (more than 50%) whilst weak acids are only partly dissociated (below 1%). See also → Dissociation, degree of.

Acid salts These are → Salts of polybasic acids (i.e. acids having two or more acidic hydrogens) in which not all the hydrogen atoms have been replaced by positive ions. For example, the dibasic acid carbonic acid (H_2CO_3) forms acid salts (hydrogen carbonates) containing the ion HCO_3^-.

Acids, colour fastness to → Colour fastness to acid spotting.

Acid shock dyeing A process for the continuous dyeing of polyamide wovens and knits with acid and metal-complex dyes. Principle: the dye is applied by padding followed by heat setting on the stenter. Fixation of dye on the fibre is achieved by a shock treatment on the jigger or open-width washing range in a boiling bath containing 3 ml/l formic acid 85%.

Acid soaps These are sulphonated oil products which have not been fully neutralized (→ Sulphonated surfactants) based on castor oil, e.g. monopol soaps (fairly resistant to hard water and acids, with good wetting, levelling and softening properties). Designation for free fatty sulphuric esters or fatty alcohol sulphuric acid esters, sulphonic acids etc. that are present in acid baths and that bind chemically to wool protein and hence effectively protect the fibre. Remain surface active in → Acid washing.

Acid traces, tests for Extract the sample by boiling with distilled water and test the filtrate. Alternatively, moisten the sample with distilled water and place in contact with an appropriate test paper between glass plates. For qualitative determinations, colour changes with indicators such as litmus, potassium iodide-starch solution or paper, Congo red, methyl red or violet are suitable. Quantitative determinations are carried out by titration of the aqueous or alcoholic extracts using phenolphthalein as indicator.

Acid value A measure of the free acid content of natural oils, resins, waxes etc., indicated by the number of mg of pure potassium hydroxide (KOH) required to neutralize 1 g of the substance. In practice, this is carried out by shaking with a few drops of phenolphthalein solution and titrating with standard KOH solution until a pink colour develops. 1 ml of 0,1 n potassium hydroxide solution = 0,00561 g pure KOH. Although fresh fats and oils contain glycerides of fatty acids and very little free acid, the glycerides decompose slowly with time due to hydrolysis through the action of light and air which causes an increase in the acid value. Examples:

1. Widely scattered acid values between 0–50: coconut oil 5–50; olive oil 2–50; castor oil 0,1–15; rapeseed oil 1,4–13,2; sesame oil 0,25–20.
2. High acid values: beeswax 19–21; Japan wax 18–25; palm oil 24–200; wool fat 13–25.
3. Low acid values: peanut oil 1–8 (technical oils up to 40); cottonseed oil 0–2; linseed oil 1–8; palm kernel oil 8,5; beef tallow 2–7 (when old up to 50); sunflower oil 0–1; sperm oil = traces.

ACIMIT, abbrev. for: Associazione Costruttori Italiani di Macchinario per l'Industria Tessile, Milano (Italian Association of Textile Machinery Manufacturers); → Technical and professional organizations.

ACIT, abbrev. for: Association des Chimistes de l'Industrie Textile (French Association of Chemists of the Textile Industry); → Technical and professional organizations.

Acoustic pressure (sound pressure) Symbol: p. It describes the periodic pressure variations which occur in a sound wave and is measured in pascals.

Acraldehyde → Acrolein.

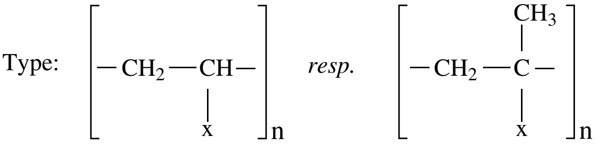
Acramin dyeing process Pigment pad process. Pigment colorants, together with a binder and a catalyst, are fixed on textile fabrics by a heat treatment. Good fastness properties. Suitable for the production of pale to medium shades on cotton and viscose fabrics; pale shades only on blend fabrics. The process may be combined with resin finishing as a single-bath application, or with other finishes and softeners in the pad liquor (Bayer). Other pigment systems are also suitable for application by this process, e.g. Helizarin pigments and binders (BASF); Imperon pigments and binders (Hoechst), etc.

Acrolein (acraldehyde, acrylaldehyde, allyl aldehyde, vinyl aldehyde, propenal), $CH_2{=}CH{-}CHO$, is the simplest unsaturated aldehyde; mobile, colourless, toxic liquid with an intensely pungent disagreeable odour. TLV: 0,1 ppm in air. Acrolein is very reactive. Soluble in organic solvents, e.g. alcohol, ether, etc.

Acrylaldehyde → Acrolein.

Acrylamide group, $-NH{-}CO{-}CH{=}CH_2$ Reactive group, reacts *inter alia* in the presence of alkali with the OH-groups of cellulose ($-NH{-}CO{-}CH_2{-}CH_2{-}O{-}Cell$). Contained in → Methylolacrylamide as an ambivalent crosslink.

Acrylate polymers (acrylic polymers), are polymers and copolymers of → Acrylic acid (→ Polyacrylic acid) and methacrylic acid (polymethacrylic acid).



$$\text{Type: } \left[-CH_2-\underset{\substack{|\\ x}}{CH}-\right]_n \quad \textit{resp.} \quad \left[-CH_2-\overset{\substack{CH_3\\ |}}{\underset{\substack{|\\ x}}{C}}-\right]_n$$

As acids [$x = COO^-H^+$], salts [$x = COO^-Me^+$ (Na^+, NH_4^+, Mg^{2+}, Ca^{2+})], esters [$x = COOCH_3$ (C_2H_5, C_4H_9, etc.)], nitriles [$x = CN$], polyesters [$x = OOC{-}CH_3$].

An extensive group of polymers which also includes methacrylate resins (acrylic glass) and many acrylonitrile copolymers. Produced by polymerization in solution, emulsion, suspension or solid form. Crosslinking occurs on thermosetting (the thermoset products have the properties of duroplasts). As a rule, acrylate polymers are transparent and, depending on the monomer building blocks, degree of polymerization, functional groups, cations, degree of neutralization etc., are capable of yielding products with a wide range of properties between liquid and solid in any desired transitions (water-insoluble – dispersible – water-soluble), hydrophobic, hydrophilic and so on, e.g. for sizing agents, dispersing agents, migration inhibitors, and thickeners for printing and finishing (→ Polyacrylate …).

The structure and properties of synthetic water soluble acrylate polymers are as follows:

a) unidimensional (chain structure):

MW	100 000	readily soluble, easy flowing
MW	1 000 000	somewhat less soluble, ropy
MW	2 000 000	poor solubility, very ropy, slightly thickening

b) two-dimensional (polymers):

Polymers with many branches	readily soluble, easy flowing, slightly thickening

c) three-dimensional (crosslinked polymers):

low crosslinking	good increase in viscosity, fairly poor solubility, tendency towards gel formation
high crosslinking	low solubilty, high swelling, give thixotropic pastes.

Water soluble acrylate polymers mostly contain carboxyl groups [–COOH, –COOMe] in the macromolecule. In aqueous solutions the free acids behave like poly acids and the salts like anionic polyelectrolytes. They consist of thread-like macromolecular structures which are, to a greater or lesser degree, extensively tangled in aqueous solution. The extent of tangling can vary considerably depending on the composition of the aqueous solution (influenced by pH and electrolyte content); this has a great effect on viscosity. This latter property is increased by longer chain length and rising concentration; it is reduced, however, by increase in temperature and water soluble salts. Tangling of the macromolecule, as well as reduction in viscosity, are further determined by the counter ion (cation). In polyacrylate sizes for example, the polymerized acrylic acid is present mostly in the form of sodium or ammonium salts; and in the newer, increasingly important alkaline earth polyacrylates (higher content of alkaline earths causes a greater reduction in viscosity) preferably in the form of calcium or magnesium.

Acrylate sizes and finishes → Polyacrylate sizes.

Acrylic Generic description (U.S. Federal Trade Commission) for a manufactured fibre in which the fibre-forming substance is any long chain synthetic polymer composed of at least 85% by weight of acrylonitrile units → Polyacrylonitrile fibres.

Acrylic acid (acroleic acid, propenoic acid), $CH_2=CH-COOH$. Important, organic, unsaturated carboxylic acid used as a polymerizable starting product for polyacrylic acid derivatives.

Acrylic dyeings, identification of dye class

1. Identification scheme: The dyed or printed fibre material is subjected to a series of different tests with the first five tests being carried out one after the other on the same fibre specimen (6–8 min. boiling in each case, with intermediate rinsing only after the glacial acetic acid test). → Dye class identification tests on the fibre.

2. Staining tests: strip the dye by boiling with glacial acetic acid, concentrate by evaporation, add water, and carry out dyeing tests. Vat dyes remain insoluble (but will dissolve in caustic soda solution + sodium dithionite).

Acrylic dyes Commonly used term in practice for dyes suitable for dyeing polyacrylonitrile fibres. The following dye classes are suitable:

I. Cationic dyes are the most widely used.

II. Disperse dyes are suitable for pale shades only.

III. Acid dyes are suitable only for acid-dyeable fibre types, i.e. the incorporation of special comonomers in the fibre is essential here.

Acrylic fibres Expression for → Polyacrylonitrile fibres with a min. 85 wt% → Acrylonitrile.

Acrylic monomers are used as finishing agents for crosslinking on the fibre.

Acrylic resins, polyacrylate resins (→ Synthetic resins) including the corresponding copolymers.

Acrylonitrile (propenenitrile; vinyl cyanide), $CH_2=CH-CN$. Raw material for the manufacture of → Polyacrylonitrile fibres, derived mainly by the Sohio process from propene, ammonia and oxygen, b.p. 77°C.

ACS, abbrev. for: American Chemical Society.

Acticarbone → Activated carbon as a clarifying agent.

Actinic, chemically active. The term relates to actinic rays and radiation (sunlight, ultraviolet light, etc.) and their effect on substances which undergo chemical change on exposure to such rays. It is the basis of photochemistry (→ Photochemical reactions), e.g. cellulose, certain vat dyes (→ Fibre damage by vat dyes) and printing effects on vat-dyed grounds etc., e.g. with ferric salts (reduction by exposure to a strong arc lamp).

Action plan Strategically developed procedure for the achievement of a specific objective, e.g. the quality assurance of finished fabrics (see Fig.).

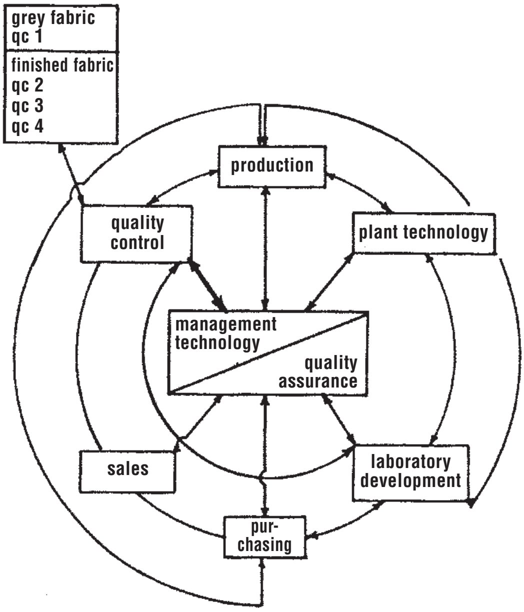


Fig.: Action diagram of quality assurance according to Windel.

Activated carbon (active carbon, decolorizing charcoal) Amorphous form of → Carbon (carbon content above 90%) with a honeycomb-like, porous, internal structure, characterized by high adsorptivity for many gases, vapours and colloidal solids. The carbon is obtained as a residue from the destructive distillation of organic matter (wood, coconut shells, peat, brown or hard coal, oil or gas coke, etc.) in the absence of air. It is "activated" by heating to 800–900°C with steam or carbon dioxide, or by treatment with zinc chloride or acids. This activation removes impurities and results in an open structure containing innumerable ultramicroscopic fine capillaries, pores, fissures and cracks. Disordered and unsaturated carbon atoms which are accessible on the crystal faces represent the focus of attraction for adsorption and are responsible for the active properties. The structure of the carbon particles can be made more or less open depending on the degree of activation thus providing a correspondingly high adsorption energy. Activated carbon is an extremely absorbent medium for gases and solvent vapours which are adsorptively bound almost immediately in the capillaries (the adsorptive capacity can amount to 100% of its own weight). Regeneration is achieved by stripping out in steam.

The properties of the material to be adsorbed are also decisive for the adsorptive capacity of activated carbon. In a homologous series the adsorptive capacity rises with increasing molecular weight until a maximum is reached whereafter it decreases again. Activated carbon has a lower affinity for aliphatic compounds in comparison with aromatics. Hydrophilic substituents such as OH, COOH or SO_3H built into the molecule result in a reduced adsorptive capacity. From this it follows that low molecular weight alcohols and carboxylic acids as well as highly sulphonated aromatics are much less readily adsorbed than aromatic nitro compounds, aromatic amines and phenols. The adsorptive capacity of activated carbon is also influenced by the pH of aqueous phases. Whilst e.g. aniline is better adsorbed from an alkaline medium, phenol may be separated more readily in the acidic range.

For the solution of practical applications where the separation of several substances is frequently required, knowledge relating to the behaviour of individual components is of only limited value since the adsorptive behaviour of mixtures is considerably impaired e.g. by coadsorption with displacement effects, different adsorption kinetics or hydrophilic characteristics. Influences of this kind make the selection of a suitable grade of activated carbon by the evaluation of adsorption isotherms for individual products more difficult, so that reliable operational data is often only obtainable after laborious on-site semi-industrial trials with the actual mixtures involved.

Uses: solvent recycling (drycleaning machines), decolorizing and deodorizing of aqueous liquids, organic solvents, etc. (filters in drycleaning systems), water dechlorination, removal of oil from water, etc.

Activated carbon as filler for coatings Fillers like chalk or carbon are used in coating masses. For this purpose, activated carbon has an especially pronounced fine structure which provides typical consistency in the mixing of the coating paste.

Activated carbon/boiling water test Used for the detection of cationic and disperse dyes on acetate (→ Acetate fibre dyeings, identification tests). The dyeing (or print) is boiled for 20 min. in water with the addition of some activated carbon. Positive test: the dyes are, for the most part, completely stripped and adsorptively bound by the carbon from which they are readily removed by rinsing in hot water containing a little soap.

Activated carbon filter → Sewerage filter.

Activated carbon in dyeing and printing Used as an addition to wash baths when washing off dyeings and prints to prevent staining of grounds by redeposition.

Activated carbon in waste water treatment Both communal and industrial waste waters can contain a variety of different pollutants which may be classified according to their treatment characteristics. Whilst aspects such as density, solubility, sedimentation properties and biodegradability are decisive for the efficacy of individual treatment stages in standard mechanical-biological waste water treatment processes, for activated carbon useage it is the adsorptivity and carrier function for microorganisms that are of primary importance. The most important target groups for adsorptive or adsorptive-biological waste water treatment are organic substances which

- are not biodegradable and can therefore only be removed by adsorption,
- have a toxic action on bacteria and would therefore damage the biological treatment,
- are only slowly biodegradable and, for this reason, must first be bound adsorptively where advantages of accumulation are observed,
- can only be broken down by microorganisms with a low rate of growth for which purpose their immobilization on a carrier material such as activated carbon is necessary.

Depending on which category the pollutants are to be classified under, the activated carbon is used for another function and in a different area of the entire cleaning concept as

- an adsorbent in the mixing process,
- an adsorbent in filtration plants,
- a carrier material in anaerobic bioreactors,
- a carrier material in aerobic bioreactors,
- an adsorbent and carrier material in activated sludge processes.

Activated carbon treatment, chemical → Waste water treatment.

Activated sludge process Micro-organisms, bacteria in particular, can degrade organic materials, using them as nutrients. The simplest equation for aerobic respiration is $\langle CH_2O \rangle + O_2 \rightarrow CO_2 + H_2O$. The dynamics of a simple activated sludge unit can be described mathematically: the yield, y, of the mass of bacteria created (or the concentration of bacteria, B) is related to the decrease in the mass of the substrate, S:

$$\text{Yield } y = \frac{dB}{dS} = \frac{\text{bacteria mass increase}}{\text{substrate mass decrease}}$$

The exponential growth of the bacteria can be expressed by

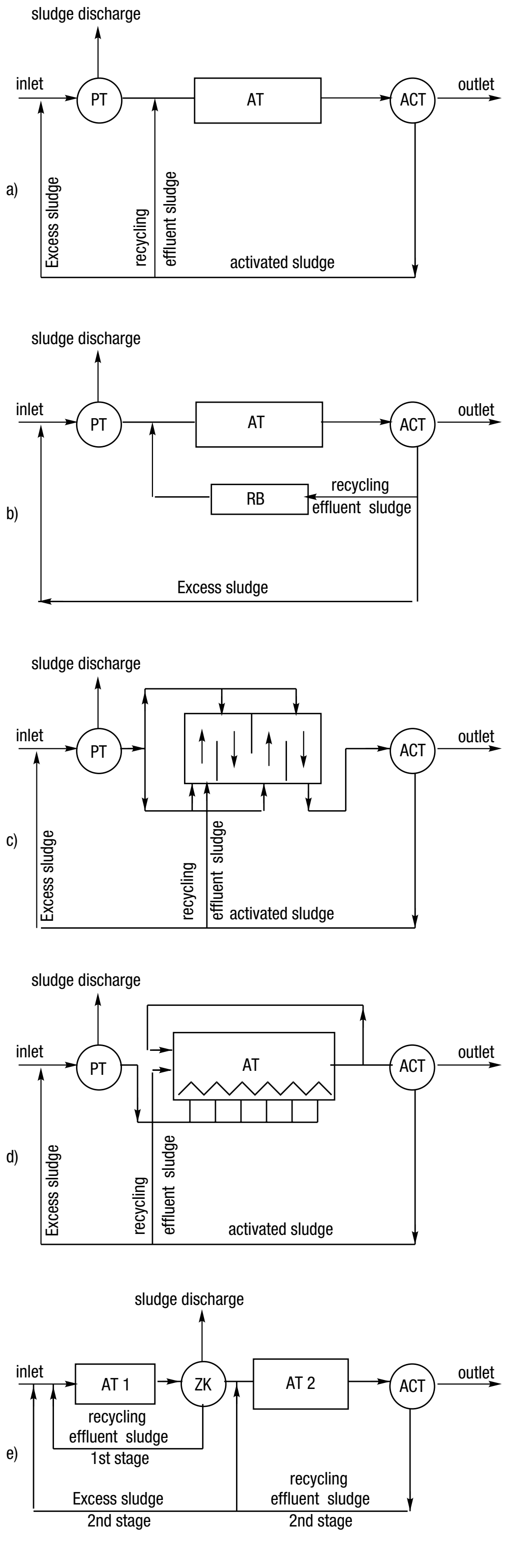


Fig. 1: Development stages of the conventional activation process; PT = pre-clarification tank; AT = activation tank; ACT = after-clarification tank.
a) conventional activation process (with sludge discharge from the pre-clarification vessel); b) activated sludge process with sludge regeneration; c) stepwise addition according to Gould; d) Schmitz-Lenders distributed effluent input; e) two-stage activation process (after Mangold et al.).

$$\frac{dB}{dt} = \mu B \,;\; B = B_0 \cdot e^{\mu t}$$

where μ is the rate of growth and B_0 is the mass bacteria (per unit volume) at time $t = 0$. The rate of growth of the bacterial biomass is determined only by the hydrodynamics of the activated sludge plant.

In an activated effluent treatment plant, activated sludge is used for → Biological waste water treatment. Such plants consist of aeration tanks, after-clarification tanks and aerating equipment (Fig. 1). The activated sludge consists largely of micro-organisms that form flocks and it is mixed with the effluent and dissolved oxygen. The organic content is absorbed by the micro-organisms and a biomass sludge is formed. The biological processes take place on the flocks of sludge. Mangold et al. have outlined the development stages of the conventional activation process:

a) in the original form, the effluent flowed through a pre-clarification tank, was aerated with the activated sludge for 6–10 hours and then separated from the sludge in an after-clarification tank. The sludge was returned to the activation tank. Excess sludge with a water content of 98–99% is known to be difficult to dewater. In the process developed by Imhoff, excess sludge was returned to the pre-clarification tank where its concentration was increased by mixing it with fresh sludge from the crude water to give a water content of about 95%.
b) Shortening the aeration time allows the sludge that has been separated from the aeration tank to be regenerated.
c) Gould introduced stepwise addition to improve the process. The recycling effluent sludge is fed into the aeration tank slowly and in stages at several points until the whole charge has been added.
d) In the Schmitz-Lenders system, the effluent is fed in along the whole length of the tank. In this way the activated sludge is charged evenly.
e) The high-capacity, economical two stage activation process was a further advance.

The Magdeburg P process activated sludge plant is a well-known purification unit (Fig. 2) (contributed by Peschel and Belouschek).

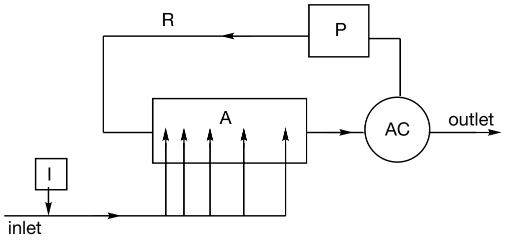


Fig. 2: Diagram of a Magdeburg P activated sludge process. I = input of nutrient salts; A = aeration tank; AC = after-clarification tank; P = recycling pump (after Meinck et al.).

Activation

Activation (Lat.: *activus* = work)

I. In general: put to work.

II. Chemically: the process of treating a substance or a molecule or atom by heat or radiation or the presence of another substance so that the first mentioned substance, atom or molecule will undergo chemical or physical change more rapidly or completely.

Activation energy Generally the heat that is required to make a chemical reaction go. An “energy barrier” has to be overcome before a starting material can be converted into a product. The height of the barrier is directly proportional to the rate of the reaction.

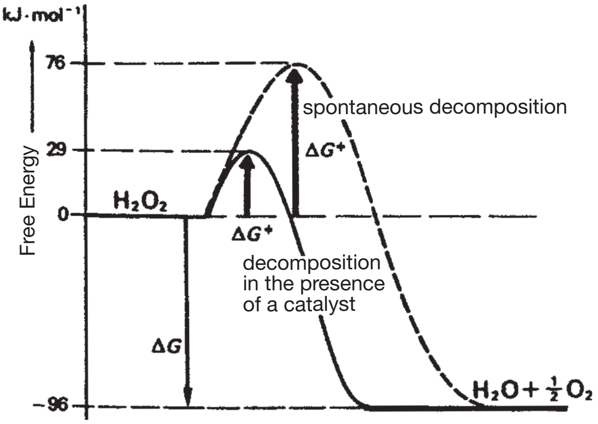


Fig. 1: Activation energy G for spontaneous and catalysed decomposition of hydrogen peroxide.

Apart from water, hydrogen and oxygen can also form hydrogen peroxide (H_2O_2). When this is dry, it is a blue liquid with properties that are very similar to those of water (boiling point 150.2°C, freezing point –0.43°C). The molecule is diamagnetic. In the diagram (Fig. 1), the metastable initial state is separated from the final product (water) by an energy barrier, the “activation energy”. This means that the decomposition of hydrogen peroxide is thermodynamically possible:

$$H_2O_2 \rightarrow H_2O + {}^1/_2\, O_2 ; \quad \Delta G = -96 \text{ kJ/mol}$$

However at room temperature, very few molecules have sufficient energy to reach the free energy of activation (ΔG) of 76 kJ/mol. Decomposition can be accelerated greatly by heating; it can also be accelerated by catalysts (catalytic effect of simple metal ions).

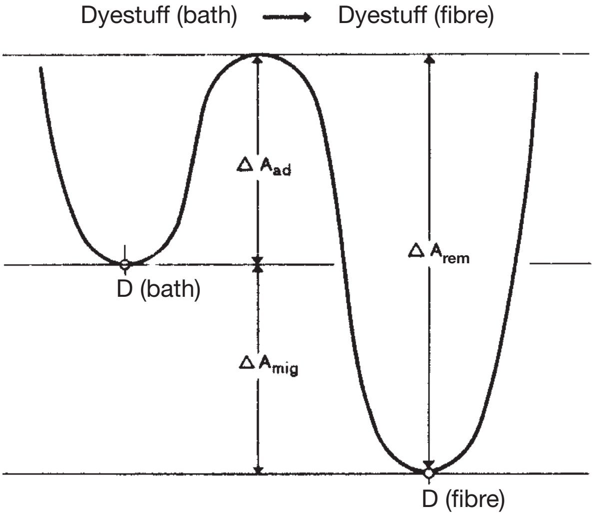


Fig. 2: Diagram of energy relationships in dyeing.
ΔA_{ad} = Activation energy for adsorption of dyestuff;
ΔA_{mig} = Activation energy for migration of the adsorbed dyestuff;
ΔA_{rem} = Activation energy for removal of the adsorbed dyestuff.

As a rough approximation, dyeing can be considered to be a solution process in which the dyestuff is more soluble in the substrate (D_{fibre}) than in the dyebath (D_{bath}). From a kinetic point of view, D_{bath} and D_{fibre} correspond to the initial and final states. As the starting and finishing states of a reaction are always thermodynamically stable, both states lie in an “energy valley”. It can be seen from the shape of the energy curve (Fig. 2) that a direct transition from D_{bath} to D_{fibre} is not possible because the energy barrier has to be overcome. Only dyestuff molecules that have acquired enough energy (ΔA_{ad}) by heating are capable of escaping from the water and dissolving in the substrate. This energy corresponds to the energy of activation well-known in chemical reactions. It is determined from the increase in the rate of a reaction as the temperature is increased; the smaller the temperature increase, the greater the activation energy needed. In dyeing, the ac-

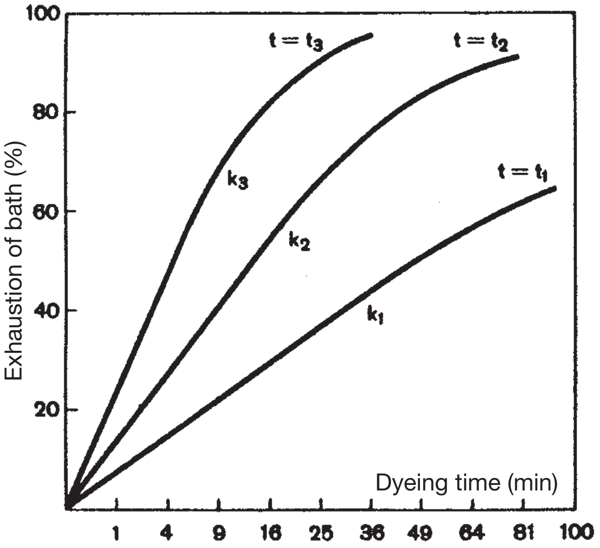


Fig. 3: Dependence of rate of dyeing on temperature.
k = rate coefficient; t = temperature.
$t_1 < t_2 < t_3$ and $k_1 < k_2 < k_3$.

celeration is determined from the quotients of the exhaustion rate coefficients k with increasing temperature T (Fig. 3).

It can also be seen from the energy relationship diagram that the end state D_{fibre} is at a much lower energy level than the initial state D_{bath}. The significance of this is that the dyestuff is much more soluble in the substrate than in the dyebath (the reversal of the dyeing process is greatly hindered because of ΔA_{rem}). The difference in the levels is a measure of the affinity.

Whether the dyeing proceeds quickly or slowly is determined essentially by the activation energy needed to form the activated complex. When the activation energy is high, only few molecules have enough kinetic energy; dyeing proceeds slowly. If ΔA_{ad} is too high no dyeing takes place at all. This is expressed by the Arrhenius equation:

$$k = P \cdot Z \cdot e^{-\Delta A_{ad}/RT}$$

Z = the collision number,
P = the steric factor.

If $\Delta A_{ad} >> RT$, the Boltzmann factor $e^{-\Delta A_{ad}/RT}$ is very small and consequently the rate constant k is also small. A lot of reactions are thermodynamically allowed but proceed very slowly because of the high activation energy and are therefore kinetically inhibited. In principle, the inhibition can be eliminated by increasing the temperature. If T is increased, the negative exponent in the Boltzmann factor becomes smaller, i.e. the rate constant increases (Fig. 4). On the atomic scale, the energy distribution changes with the increase in temperature so that the number of dyestuff molecules with high kinetic energy increases.

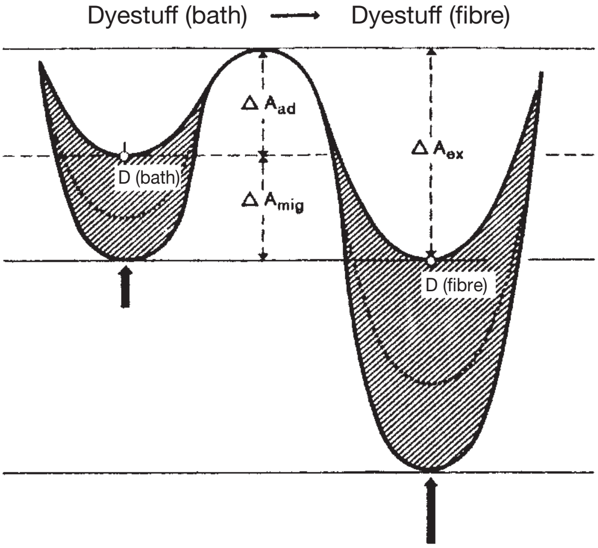


Fig. 4: Energy diagram showing the effect of the dyeing temperature on the rate of dyeing.

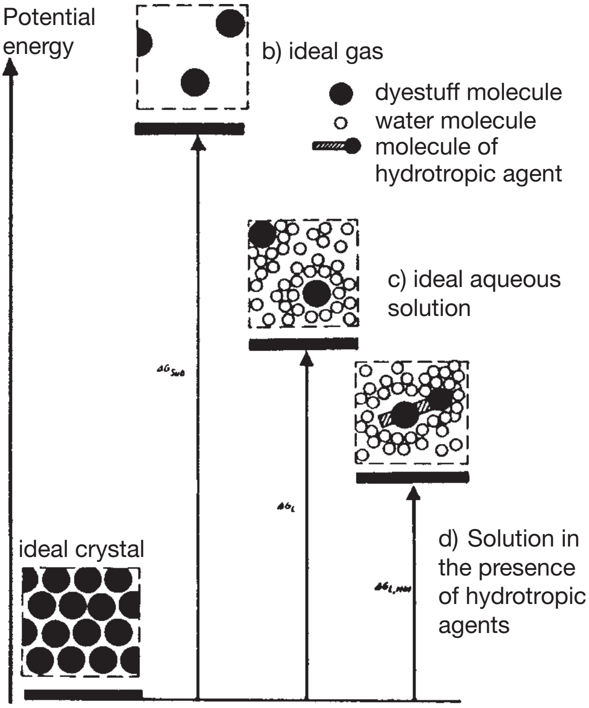


Fig. 5: Energy diagram for disperse dyes in various states.

The activation energy depends essentially on the dyeing mechanism. For disperse dyes in transfer printing, a lot of energy has to be put in to convert the dye molecules from their (assumed) form of ideal crystals into the gas phase (Fig. 5). This is expressed in the fundamental thermodynamic equation:

$$\Delta G = \Delta H - T \cdot \Delta S$$

G = free energy,
H = enthalpy,
S = entropy.

For example, about 120 kJ – calculated from 0°C – (the so-called sublimation enthalpy ΔH_{sub}) is required to vaporize completely 1 mole of crystalline C.I. Disperse Red 73 in a vacuum. This value is obtained from the Clausius-Clapeyron equation and the change in the vapour pressure of the dye with temperature. ΔH_{sub} is a measure of the strength of intermolecular forces in the crystal. At room temperature almost 15% of the lattice forces are accounted for by the heat $T\Delta S_{sub}$ that comes from the surroundings, so that only a free sublimation energy ΔG_{sub} of about 105 kJ/mol is required to destroy the crystal completely.

The molecules that leave the surface of a crystal and pass into a vacuum cannot interact with other molecules to lower their high potential energy. The situation is much more favourable for dissolving a crystal in water. The dispersion forces that act universally (including those between water and dyestuff molecules) have a considerable stabilizing effect on the individual

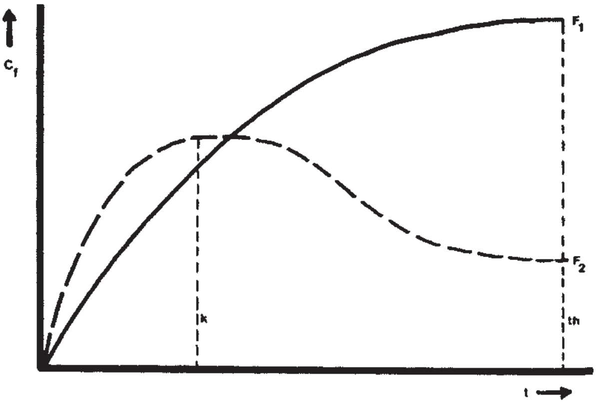


Fig. 6: Source of kinetically or thermodynamically controlled dyeing in competitive adsorption of two dyestuff molecules (1 & 2).
k = kinetically, th = thermodynamically controlled.

molecules that are removed from the crystal lattice. The free energy of solution ΔG_L required to destroy the lattice can be calculated from the molar solubility c_L:

$$\Delta G_L = - R \cdot T \cdot \ln c_L$$

R = gas constant = 8.3 kJ/mol · K

At 22°C pure (unstandardized) C.I. Disperse Red 73 has a molar solubility of $8.6 \cdot 10^{-6}$ mol/l. The free energy of solution ΔG_L at 22°C (= 295 K) is calculated from this to be 28.6 kJ/mol. To dissolve 1 mole of this dyestuff completely in water requires only 27% of the heat needed to vaporize it in a vacuum. This shows very clearly the extent to which the dyeing medium stabilizes the state of monomolecular solution.

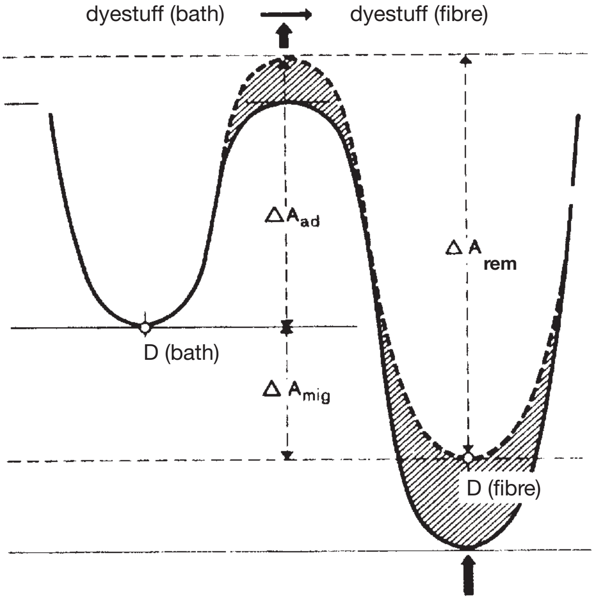


Fig. 7: The effect of higher (arrowed) pH of the dyebath on the activation energy in dyeing wool with acid dyes.

There is a further increase in the strength of interactions between the dissolved dyestuff and its molecular surroundings when hydrotropic compounds are added to the dyebath, and this reduces the potential energy by another "step". Solvent complexes are formed where a dyestuff molecule is held by relatively strong bonds to one or more molecules of the hydrotropic agent. An especially low relative energy level is subsequently reached if the dyestuff can interact with the polyester fibre "solvent" (giving the thermodynamically favoured product). When there is competition between two types of dye molecules for adsorption into a substrate, the dyeing may be controlled kinetically (Fig. 6), with the smaller dyestuff molecules being distributed quickly and more evenly in the fibre at the beginning of dyeing. If dyeing is continued until the dye equilibrium is effectively reached, the larger (slower diffusing) dyestuff molecules with the higher affinity will displace the smaller ones, which may then be partly desorbed.

In dyeing wool, increasing the pH of the dyebath raises the activation energy (Fig. 7).

Active bleach → Available chlorine.

Active chlorine losses, due to the consumption of active chlorine by organic components in soiled goods during a thermochemical disinfection wash. The extent of active chlorine loss is dependent on the nature and quantity of the soil: the active chlorine released by organic chlorine compounds (hypochlorite) is more or less bound (consumed) by the soil, and impairs the efficiency of disinfection. For this reason (according to the regulations of the Federal Board of Health in Germany) disinfection wash processes susceptible to active chlorine losses are not suitable for heavily soiled goods. The alternative, i.e. to overdose with products capable of liberating active chlorine can result in loss of textile strength and the fading of coloured goods (with dyeings having poor chlorine fastness).

Active content A term used to describe the active content of a pure substance or auxiliary which is supplied as a diluted product in water, solvent, etc.

Active earths → Bleaching earths.

Active oxygen is oxygen in the formative state, i.e. at the moment of decomposition (from bleaching agents). Formerly regarded as being responsible for the bleaching resp. decolorizing action in bleaching processes.

Active substances A group of highly active chemical compounds which are essential to life through their control functions in organisms, e.g. →: Ferments, Enzymes and Vitamins.

Active wear A term used to describe → Functional clothing, for active leisure and sports activities, e.g. fashionable jogging coordinates. In contrast to → Casual wear.

Activity sampling Fixed component of work study as a “quick method” of determining work quotas in order to clarify in relatively simple ways the question of multiple machine minding. It enables the actual state of the locational-spatial and organisational data of studied work stations to be represented for time recording, i.e. it offers time content percentages, but no handling times and no mandatory data on causes or causal connections of the cycle types or processes studied. It helps however to isolate causes. The main advantages of this activity analysis are in simple recording processes without time measurement. It cannot however replace time study with timing equipment.

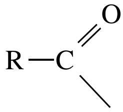
Actual blend ratio (DIN 60 003) In a textile product, the ratio of different fibres determined by analysis.

Actuator → Servo component.

Actuator drive Servomotor and transmission, main component of the actuating unit for producing actuating power for operating the → Actuator, the actuating power being obtained from secondary energy.

Acyclic compounds Compounds containing chains, possibly branched, but without rings. See also → Cyclic compounds.

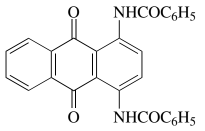
Acyl General name for organic acid groups which are the residues of carboxylic acids after removal of the –OH group:



The names of the individual acyl groups are formed by replacing the *-ic* of the corresponding acid by *-yl*. Examples:

formic acid	H–COOH	formyl
acetic acid	H_3C–COOH	acetyl
propionic acid	H_3C–CH_2–COOH	propionyl

Acylaminoanthraquinones Structurally, these are representative of the simplest vat dyes and give mainly yellow, orange, red or violet shades. Example: Indanthren Red 5GK:



Due to the sensitivity of the acyl group to hydrolysis, these dyes are applied by cold dyeing methods for preference.

Acylation The introduction of an organic or inorganic acid grouping into a molecule during chemical processses. An example of its practical application in textile processing is acylation of the cotton component in polyester/cotton blend fabrics for heat transfer printing. As a result of this modification to the cotton, only a thirtieth of all the cellulosic OH groups are acetylated, which corresponds to an average degree of substitution of 0,12. This is nevertheless sufficient to provide the cotton with an affinity for disperse dyes.

Acylcellulose Acyl substituted cellulose, e.g., cellulose esters → Cellulose derivatives.

Acyl polyglycolethers → Polyglycolethers.

Adamkiewics Reaction

1. Test for protein in starch analysis (1 part conc. Sulphuric acid + 2 parts Acetic acid, warmed = red violet colour).
2. Test for damaged (degraded) wool: sample + Acetic acid (= solution of protein) + conc. Sulphuric acid = violet colour; fluorescent solution.

Adaptation Adjustment of eyes to light levels. With a so called normal sighted eye, one refers to the ability of the eye to adjust to light i.e. the automatic change in sensitivity of the human retina (→ Colour vision) which makes it possible to see well in wide variations in light levels provided that the eye has sufficient time to adapt itself to the light variations (→ Chromatic adaptation).

Adaptive system, also called adaptive digital process control, is a self-regulating or self-adjusting system that is not controlled by a rigid programme but that has a mode of action that adapts to changing conditions by target-oriented responses so that a defined state can be reached or a particular function can be maintained.

ADC, abbrev. for → Analogue to digital converter.

Addition complexes → Complex compounds.

Addition high-wet pick-up In this process the damp cloth (from a preliminary washing stage e.g. for the removal of water-soluble sizing agents) is squeezed out and run through a special high-wet pick-up plant without liquor exchange; this is obtained with extremely low liquor contents and rapid continuous liquor renewal. This means that up to 80% by weight additional liquor is taken up by the interstitial volume of the cloth (e.g. Flexnip by Küsters, Fig. 1).

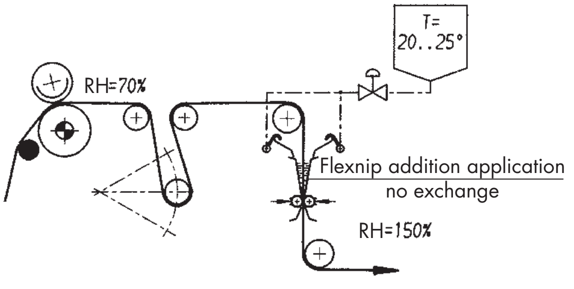


Fig. 1: Addition pick-up in the Flexnip system by Küsters (used in bleaching since approx. 1989; first used for dyeing in 1987).

Addition high-wet pick-up

If the liquor quantity is increased (to 100–150% pick-up) in cotton fabrics during preliminary finishing (desizing, boiling off, peroxide bleaching), the following improvements can be achieved:

1. Lower tendency of the cloth to crease during the steaming pass with tension-free cloth travel, as the greater availability of swelling agent leads to reduced swelling differences and no migration from higher to lower alkali concentrations.
2. More effective alkali activity on the primary wall and seed coat because more alkali is available in longer liquors consumed by neutralisation during boiling off.
3. Less fibre damage, as at sites well wetted-out with liquor there is less possibility of attack by atmospheric oxygen.
4. One-stage bleaching only with peroxide (i.e. without ecologically suspect hypochlorite), as greater amounts of oxidizing agent are available; in addition the optimised boiling off process means the fibre is better prepared for the bleach process (even more efficient if mercerizing is carried out as part of the addition process between boiling off and bleaching).

For the addition process a liquor strengthened at most up to 1.5 times is all that is needed. The liquor addition also means that the requirement for alkali stability of the auxiliary is substantially reduced, thus offering a greater choice of tensides with optimum qualities. The selection of a good stabilizer system makes it possible to supply the ready-for-use alkali/bleach liquor including all components from one formulating tank. The liquor formulation can be carried out manually, or semi- or fully automatically. Differences in concentration on the fabric are eliminated, as no liquor exchange takes place at this point in time. Titration of the alkali/bleach liquor is not necessary. The cloth finally progresses to the catalytic steamer with a total liquor volume of up to 60–70% + 80% = 150%. In the case of the Küsters Contidos System (Fig. 2), for example, the chemicals are continuously supplied to the Flexnip (Fig. 3).

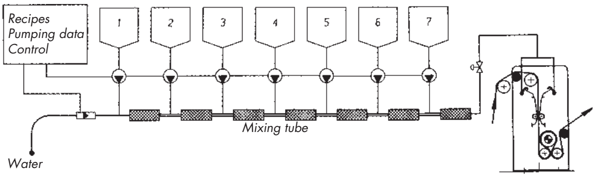


Fig. 2: Computer-controlled continuous chemical metering by the Contidos from Küsters.

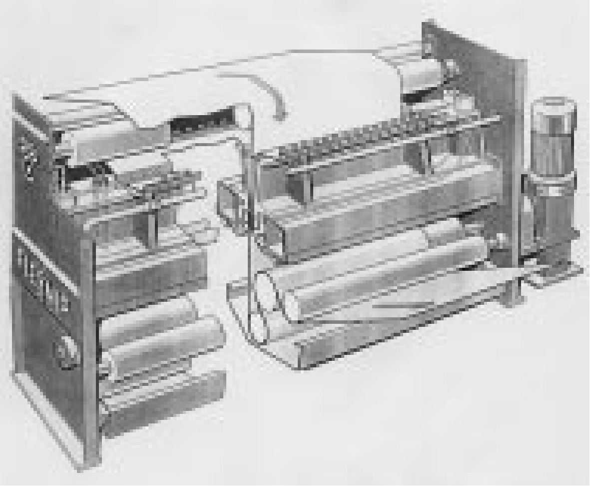


Fig. 3: The Flexnip, introduced in 1987 by Küsters as the first high-wet addition pick-up system.

Since 1991 other machine manufacturers have also offered high-wet pick-up systems:

a) Optimax by Menzel: 2 horizontal squeeze rollers, part of a high-performance squeezing system, express the cloth at high pressure so that it draws in large quantities of liquor due to the sponge effect when "opening up" as it enters the liquor in the trough. The nip of a superposed squeeze unit strips off the excess liquor (Fig. 4).

b) In the Super-Sat 2 by Babcock, several rollers are traversed, so that each time as much liquor as possible from the trough is squeezed through the cloth (Fig. 5).

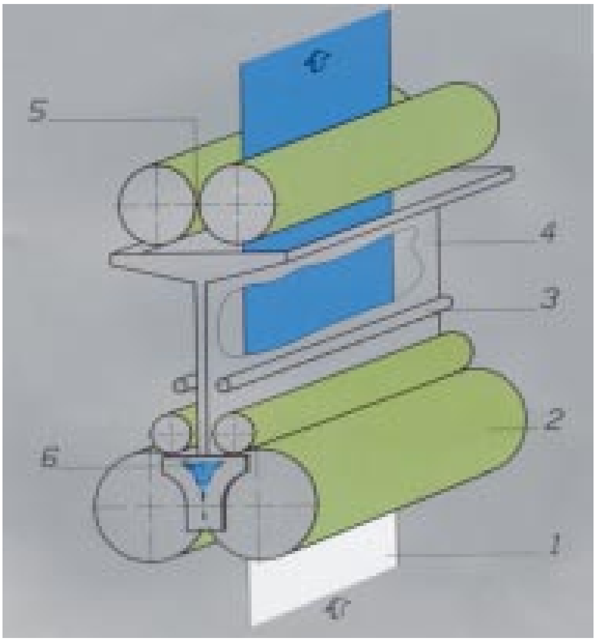


Fig. 4: The Optimax System by Menzel.
1 = cloth path; 2 = high-performance squeeze rollers with Rowatex roller; 3 = liquor feed with level control; 4 = liquor return plates; 5 = application squeeze unit; 6 = liquor trough.

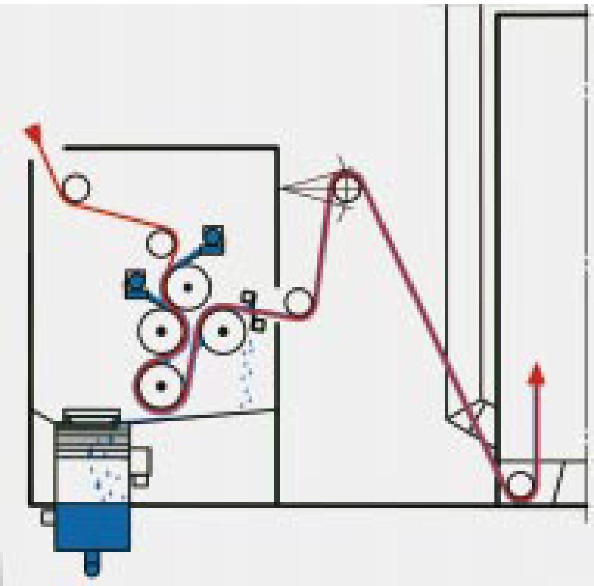


Fig. 5: Super-Sat 2 by Babcock.

c) By the Preyet-technology from Kleinwefers KTM a binary mixing nozzle combines steam and treatment liquor. The cloth runs past a series of jets and is thoroughly saturated with excess liquor. As with all such plant the Preyet-technology also requires an elaborate chemical metering system (Fig. 6).

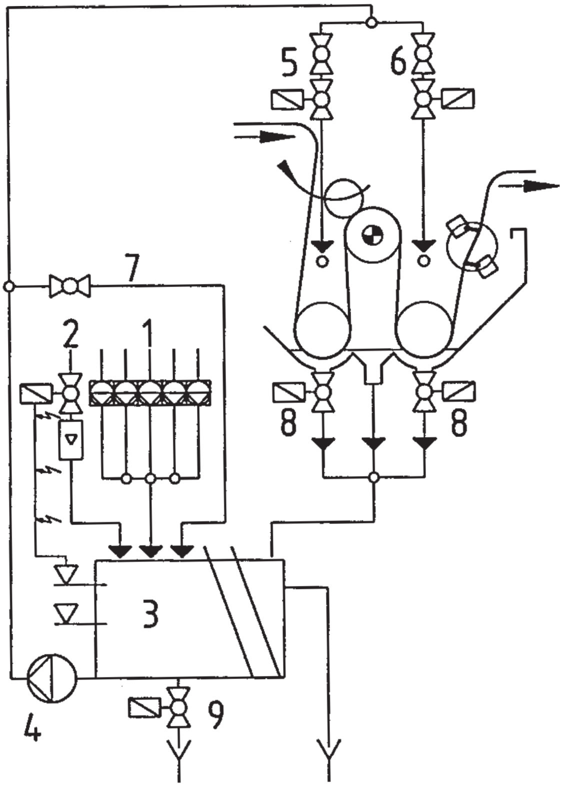


Fig. 7: Goller Dip-Sat System.
1 = dosing pumps; 2 = water feeding via transmitter; 3 = mixing tank; 4 = feeding pump; 5 = front distribution channel; 6 = rear distribution channel; 7 = mixing pipe; 8 = liquid return pipe; 9 = discharge valve.

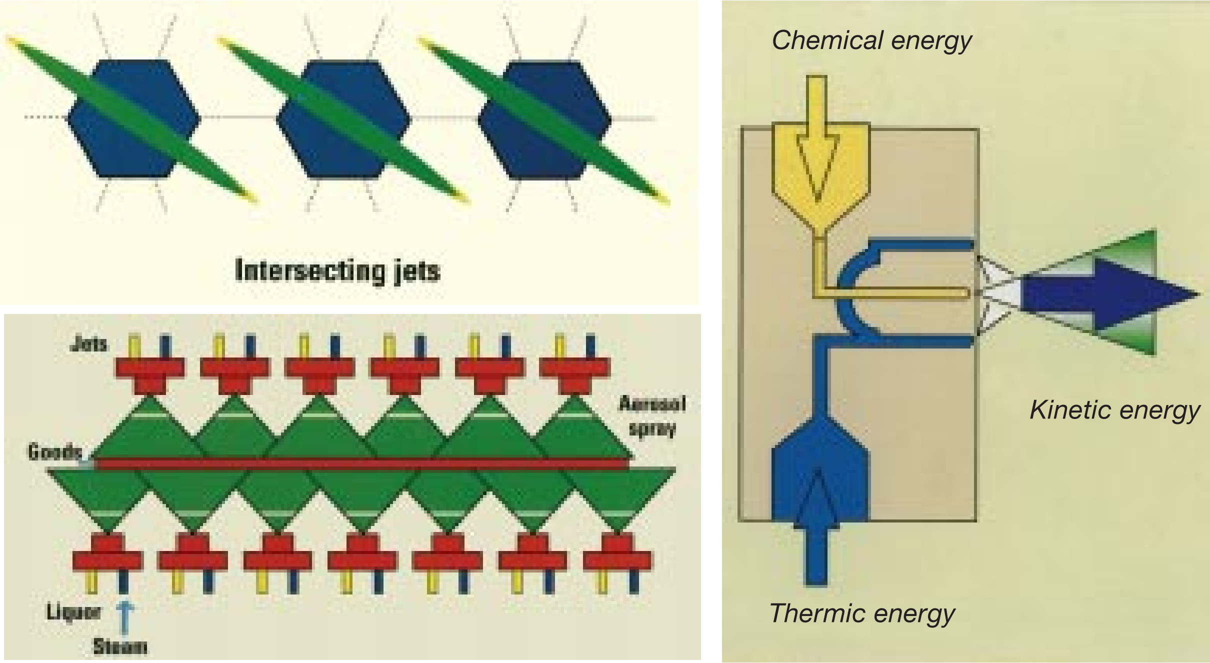


Fig. 6: Preyet-technology from Kleinewefers KTM.

d) The Dip-Sat System by Goller, like the Babcock plant, uses a system of impregnation from a trough (Fig. 7).

e) The Benninger system brings about high-wet pick-up by means of a combination of saturator and booster.

Addition (in dyeing) A term used to describe each corrective addition of dye made during the course of dyeing which is needed to achieve the closest possible colour match to a given colour standard or pattern.

Addition mercerisation The most feasible processing sequence incorporating the mercerising process would be obtained if mercerisation were to be effected between scouring and bleaching, or in subsequent single-stage processes. This gives the advantage of a clean and absorbent fabric, and reduces any lye contamination problems in concentrating lye by evaporation. In the case of cotton products, the most highly pre-quetched fabric possible, with a residual moisture content of 50–70%, is fed into the mercerising machine in order to save energy for an intermediate drying process. In the mercerising section of the line, the fabric is brought into contact as constantly as possible with a mercerising liquor concentration (300 g of NaOH/l or 30°Bé). Many squeeze points on roller mercerising machines, the liquor temperature, any necessary addition of wetting agents, and fabric absorbency, have a decisive effect on the dwell time required for obtaining approximately identical fabric NaOH and surrounding liquor concentrations. Substance interchange and diffusion processes are dependent on concentration gradient and liquor viscosity (and temperature).

Fig. 1 shows the considerable effect temperature has on the viscosity of highly concentrated NaOH in particular. This circumstance and the relationships between the relative swelling of cotton and time illustrated in Fig. 2 are used in applying hot mercerising technology. In this way, adequate cotton swelling for the mercerising process can be achieved after only 20 seconds dwell time.

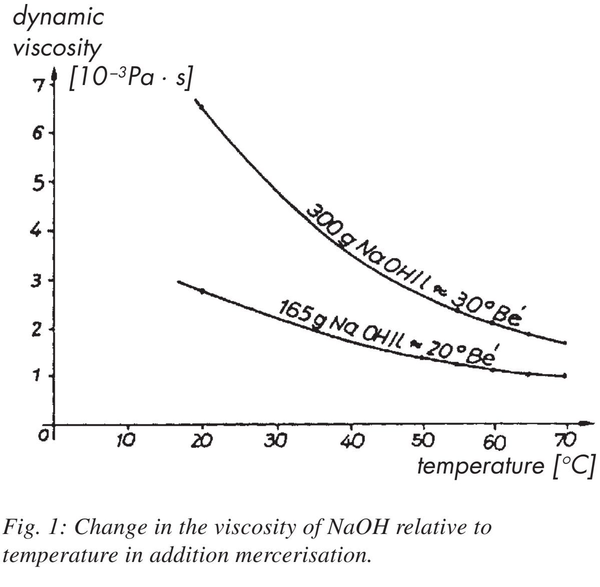


Fig. 1: Change in the viscosity of NaOH relative to temperature in addition mercerisation.

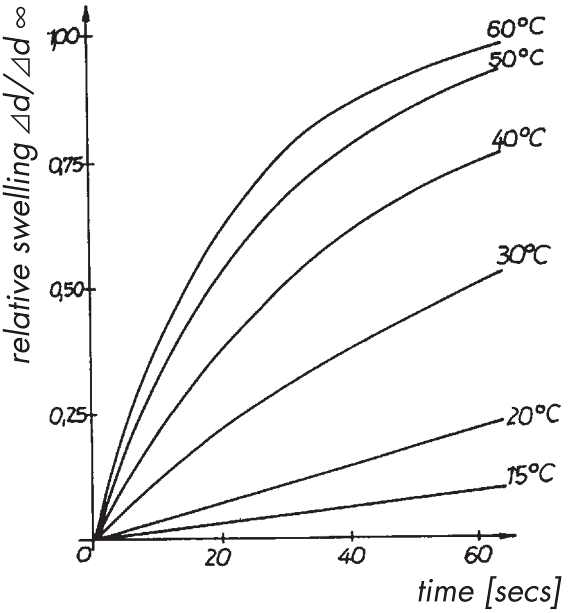


Fig. 2: Relative swelling of cotton (raw, desized) in relation to time (according to Bechter).

Comprehensive trials with various machine variants and relevant evaluation of the particularly interesting textile technical parameters during the mercerising process led to the addition mercerising process (Fig. 3). After a pre-scouring process, carried out with one or more scouring sections depending on the specific conditions, the fabric passes through a high-performance squeezing unit. Relative to the quetch effect, NaOH in the required concentration and quantity is applied uniformly to both sides of the fabric with the Flexnip (Küsters) addition unit already familiar from dyeing and pretreatment equipment, setting up the required mercerising lye concentration in the fabric after a short diffusion passage.

According to the large-scale trials available to date, the high degree of concentration of the added lye has the following main advantages over the processing technology employed up to the present:

1. A high concentration gradient between the water carried along with the fabric after the high performance squeeze unit and the strong lye added in the Flexnip result in significantly accelerated diffusion, the necessary dwell and mercerising times being reduced to about 10 seconds.
2. The entire lye circulation system in the earlier mercerising – now the diffusion – section with lye vats, containers, pumps, spray tubes etc is eliminated. This section can be significantly shortened on account of the short dwell times required.

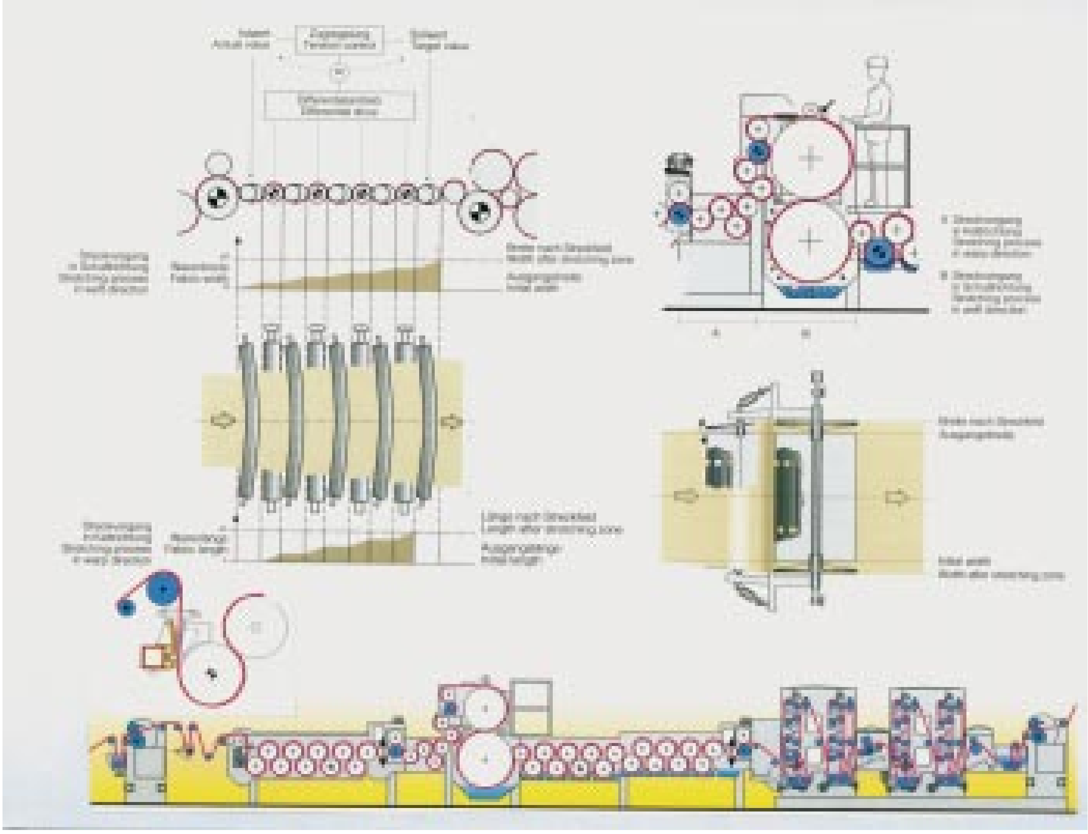
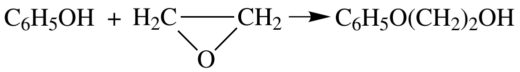


Fig. 3: Küsters addition mercerising line.

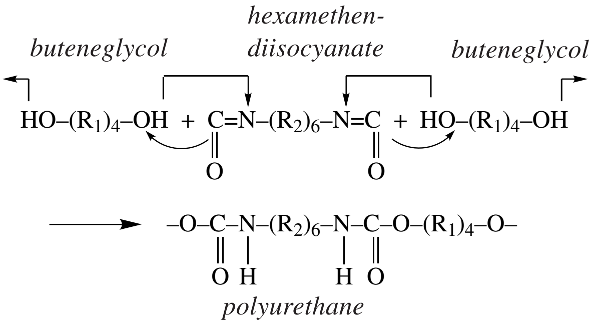
3. The addition of lye in a considerably higher concentration than before gives rise to immediate, practically spontaneous fibre swelling, resulting in the same mercerising effect with up to 25% less caustic soda usage/kg of fabric than with the processing method hitherto employed, resulting in significant savings in water, steam and chemicals, plus a considerable reduction in the ecological problems posed by the mercerising process (according to Greif).

Addition polymerization involves the production of high molecular weight synthetic compounds (→ Addition polymers) in which the participating components are joined together due to transmolecular rearrangements caused by the shifting of hydrogen atoms. Addition polymerization takes place without low molecular weight substances (e.g. water) being split off. Addition polymerization is employed *inter alia* in the manufacture of non-ionic detergents of the type:



$$C_6H_5OH + H_2C\!-\!CH_2\,(O) \rightarrow C_6H_5O(CH_2)_2OH$$

Other well-known examples are →: Polyurethanes, Polyureas. Thus, polyurethane fibres are formed by molecular linkage involving the shifting of hydrogen atoms as shown in the formular:



$$HO{-}(R_1)_4{-}OH + \underset{\displaystyle O}{\overset{}{C}}{=}N{-}(R_2)_6{-}N{=}\underset{\displaystyle O}{C} + HO{-}(R_1)_4{-}OH \longrightarrow {-}O{-}\underset{\displaystyle O}{C}{-}\underset{\displaystyle H}{N}{-}(R_2)_6{-}\underset{\displaystyle H}{N}{-}\underset{\displaystyle O}{C}{-}O{-}(R_1)_4{-}O{-}$$

→ Polymerization reactions for fibre-forming macromolecules.

Addition polymers, are synthetic products obtained by → Addition polymerization. Typical examples are the polyurethanes as a) linear macromolecules and b) crosslinked spherocolloids.

Additions in dyeing, coloristic justification for One of the main tasks of the colourist is to decide whether a dyeing represents a satisfactory colour match to a given standard or pattern or whether a further shading addition must be made to a dyeing as a correction. An absolute colour match between a dyeing and a standard is an exception; as a rule, there is always a slight difference in shade between both samples. In the evaluation of a dyeing, the colourist makes a visual assessment of these unavoidable differences and then makes his decision. It is well-known that the quantitative visual evaluation of colour differences with the human eye is difficult, even for the trained eye of an experienced colourist. Moreover, these limitations of colour matching, and consequently, the quality of evaluation, are not only dependent on subjective factors of the human eye but may also involve psychological considerations. These can include, e.g.: knowledge of the customer's tolerances, knowledge of the technical possibilities of the production process and, all too frequently, the time pressure under which the dyer has to work.

In the figure, the colour matching limit is represented in the form of a vertical line based on the ΔA_T value of 1,9 AN units. It divides the 100% field of significance for dyeings requiring correction in the opinion of the colourist into two frequency fields of different size. The shaded area of the curve to the left of the colour matching limit indicates the frequency of dyeings which were already within the colour matching tolerance limit but were falsely subjected to further corrections by the colourist. The area enclosed by the right hand curve of the colour matching field corresponds to the frequency of dyeings which were judged by the colourist as well as an instrumental colour matching system as unacceptable. As illustrated by the area of both curve fields in the example, 70% of the corrected dyeings already lay within the colour matching limit and therefore did not require any further correction. Only 30% of all the corrections made were really necessary. In this case, therefore, the dyer could have saved 70% of the corrections without any deterioration in the quality of colour matching.

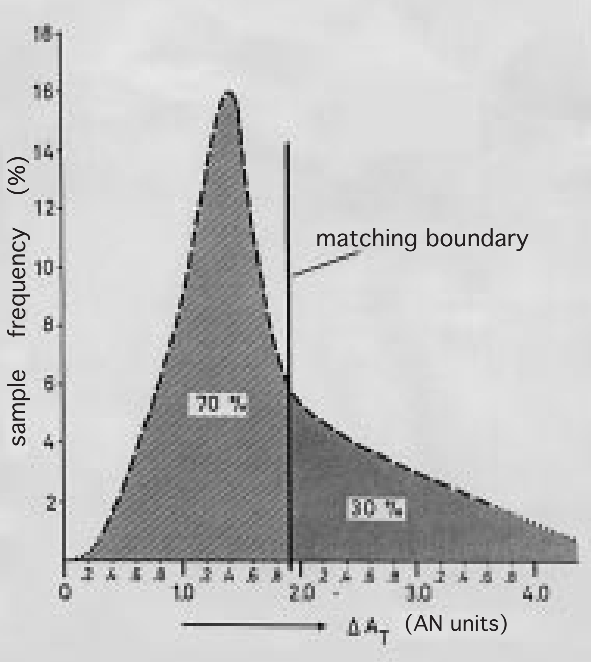


Fig.: Proportions of superfluous and necessary colour corrections, determined by statistical evaluation of the colorimetry data (specific to firm and product) (according to Rieker).

Addition test The quality of a dyeing is determined largely by three factors, i.e. sample conformity, levelness and fastness, dyeing levelness playing a central role. For this reason, the dyer tries to ensure and optimise levelness during processing. To this end, he has available the following instruments:

- the choice of dyestuff in terms of levelling behaviour,
- the concurrent use of suitable levelling agents,
- the choice and optimisation of the dyeing process.

The levelling behaviour of dyestuffs, auxiliary products and processes can be assessed by various means. The most well known is the method of measuring exhaustion and migration curves under defined dyeing conditions described as "classic". The resultant values of this operation (frequently in graph form) form the basis of the relevant dyestuff and auxiliary product manufacturers' documentation. All these test methods have their disadvantages of course. One important disadvantage in the "classic" combination of exhaustion and migration curves is that both aspects, regarded in fact in combination, have to be added to some extent in evaluation; a process which, from experience, gives rise to problems, due to a lack of integration potential. To this is added the fact that determining exhaustion and migration curves is time-consuming, requires a relatively high degree of accuracy, and depends on the substrate. Assessed overall, this "classic" process is therefore too expensive for practical application, too inaccurate in the overall aspect, and, moreover, too unadaptable (operation-specific factors like the nature of the substrate, the packing density of packages, water conditions etc. can be adopted only to a limited extent here).

The "addition test" process is derived from yarn package or beam dyeing, i.e. a dyeing technique which is, on principle, especially problematic in levelling terms (the package acts first of all as a filter, where the individual layers do not come into contact with the liquor simultaneously, but one after the other).

The processing principle is derived from the term "addition test".

Circulation dyeing is effected (on yarn package or beam), the total dye quantity being added only at final temperature (e.g. 98°C in wool or polyester dyeing), as an "addition", as it were, as is usual in shading addition in dyeing. The liquor circulates from inside to outside throughout the test, the dye naturally exhausting itself preferentially on the inner layers of the package; colouration intensity decreases from inside to outside. The degree of distribution depends first of all on the dye exhaustion rate and the retardant action of the levelling agent employed. As the test proceeds (dyeing is effected for 20–30 mins at the final temperature specified for the relevant process), the effect of the migration phase is added, dye distribution being improved in the inside to outside direction. After the specified test duration, a degree of distribution is reached which characterises the levelling behaviour of the dye employed and the dyestuff combination or the levelling agent.

The result comprises both rate of exhaustion and migration, and is, in this sense, to be evaluated as an overall statement of the levelling behaviour of the dye or the dye/auxiliary agent combination. The process is particularly suitable for comparative tests, i.e. evaluating and comparing different dyestuffs, dyestuff combinations and auxiliary agents (according to Bihn).

Additive An additive is generally a substance which, when added to a product, brings about a significant improvement in its desired properties and/or extends the range of properties still further. Additives are now particularly relevant in the case of surfactants and detergents, e.g. as antistatic agents, bactericides, colouring matters, corrosion inhibitors, fluorescent brightening agents, fragrances, etc.

Additive antifelt finishing → Antifelting finish.

Additive colour mixing → Colour mixtures.

Additive finishing Finishing process in which substance is supplied to the textile material (e.g. polymers for felt-free finishing). Conversely: processes in which the textile material loses weight and substance = subtractive finishing (e.g. scouring).

Additive pick-up Impregnation of moist fabric (max. 40–45% water) on a pad mangle with a small trough content. Here, the fabric takes up an additional 30–35% of liquid, there being no interchange between adhering water and impregnating liquid. Conversely: → Interchange impregnation.

Additives in resin finishing have a favourable effect on the technological properties, especially the abrasion resistance and to some extent, also the fabric handle. Dispersions based on polyesters, polyacrylonitrile esters and copolymers are of particular importance here. In the case of fabrics containing cellulosic fibres, finishing is frequently understood to mean resin finishing. The objective of resin finishing with formaldehyde crosslinking agents is to improve the crease resistance and shrinkage behaviour. Undesired side effects of resin finishing are strength losses in the form of tear strength, resistance to further tearing, and abrasion resistance, as well as a distinct firmness of handle. In order to overcome these side effects, softeners of various chemical types are employed, particularly fatty acid/alcohol derivatives, as well as products based on polyethylenes and silicones. They are not used here as processing aids but to improve the serviceability properties of the textile material. They can therefore be described as functional softeners. Technological properties are, to a large extent, important for woven fabrics. On the other hand, sewability is important for knitgoods, i.e. the avoidance of damage to the knitted loops during garment making with industrial high speed sewing machines. Consequently, softeners used to improve sewability in garment making often have the character of process aids.

Adduct (Lat.: *adducere* = to bring to)

I. Addition product, e.g. an ethylene oxide from which substituted polyglycolethers are formed.

II. An unstable compound formed between dyes and levelling agents which, after a long time of dyeing, gradually break down either partially or completely, thereby achieving a slower exhaustion of the dye = improved dye levelling.

Adhered water Water collects at the intersection of the warp and weft and is so tightly bound that it cannot be removed as easily as other surface water. When fabric is passed through a washing range, a layer of adhered water is formed directly on the surface of the fabric (Fig. 1) which forms an obstruction to the diffu-

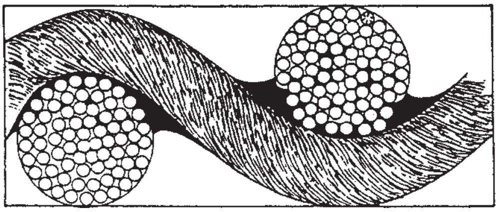


Fig. 1: Adherent water in nips (warp and weft in a woven fabric cross-section).

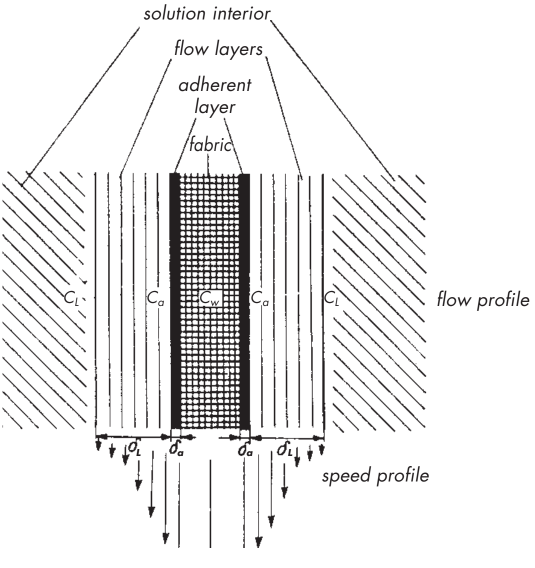


Fig. 2: Schematic diagram of the flow and concentration relationships in an open-width scouring machine.
c_w = chemical concentration on the fabric; d_a = adherent diffusion layer; c_L = chemical concentration in the liquor; d_L = laminar flow layer with concentration c_a at the limit d_a/d_L.

sion of dissolved soil. Only a vigorous flushing will disturb the lamellar film boundaries (Fig. 2).

Adhering water (wetting water, surface water, adhesion water), superficially loosely adhering water, chiefly in yarn and fabric interstices etc. Removal by pre-drying.

Adhesion Adhesion between solid materials arises principally through the following types of interaction: covalent chemical bonding, dispersion forces and polar forces. Covalent bonding is ruled out for most fibre and soil components. Chelate bonds can form only between cellulose and iron (III) compounds. On the other hand dispersion forces act between all fibres and every kind of soil. This is a non-specific type of attraction that results from the movement of electrons in molecules. It is related to the tendency of particular fibres to soiling. Surface roughness affects the attraction by changing the supporting surface and the distances from the fibres. The generic term polar forces covers all interactions caused by permanent dipoles or ions that are adsorbed or formed by dissociation at the surface. The specific adhesion is proportional to the dipole moment of the molecular or ionic groups at the surface. No precise methods for determining this quantity are known. → Soil adhesion; cohesion.

Adhesion energy, free Potential energy, at a steady temperature, released when a free liquid surface is formed from the separation of 2 phases (liquid/solid). To cause an increase in free energy (Adhesion energy expressed in Ergs or Joules).

Adhesion water → Adhered water.

Adhesive-bonded cloqué Two woven fabrics (e.g. wool) are stuck together by applying adhesive and then laminating, one fabric being shrunk and the second remaining untreated. By subsequent crêping in hot water or alkaline crêping baths, the untreated fabric shrinks, producing a crêpe effect. The adhesive is applied in strips or dots. Two-component adhesives are mainly used.

Adhesive bonded knop textiles Fabrics in accordance with DIN 60 000 which are produced by sticking a knop yarn or fibre web on to a textile or plastic substrate.

Adhesive bonded, nonwoven → Nonwovens.

Adhesive-bonded pile coverings In the style of → Adhesive-bonded pile textiles for adhesive-bonded carpeting. The running layer frequently consists of a fibre web. The material is first of all laid by machine in small folds, and then stuck on to a prefabricated woven ground fabric, resulting in a continuous rib structure. When the ribs are shorn, the covering has a typical velours look.

Adhesive-bonded repair Tears, cuts, small holes, worn corners/edges of linen and industrial clothing, for which → Adhesive-bonded textiles are used.

Adhesive-bonded textile Textile fabric for permanent adhesion as a thermal adhesive for adhesive repairs etc. A fabric layer is sintered by the dry or wet process, preferably with powdered thermoplasts by air doctor application, electrostatic sprinkler (→ Powder dot coating) or combined roller/brush units. Subsequently sintered or gelled (mainly in a heating flue with infra-red heaters) on to the textile material under the effect of heat. The sintered fabric layer is applied to the textile material to be glued (partner textile) under the influence of pressure and temperature. Optimum adhesive effects are dependent on sintering quantity, pressing time, pressing temperature and pressure. Automatic setting presses are preferable to irons for producing an adhesive bond. → Adhesive-bonded fabrics.

Adhesive bonding nets Strong polymeric textile fabrics as a net structured adhesive system based on a whole range of polymers. Supplied in roll form. Adhesive processing, e.g. with the aid of an ironing press or, following prior thermal activation with infra-red radiators for example, lamination on to the substrate. Adhesive bonding nets offer various advantages: practically no impairment of the air permeability of the united system, elimination of the danger of bleeding through, no unpleasant fabric stiffening. If necessary, adhesives can be placed in the form of a discrete layer.

Adhesive, contact For the production of self-adhesive floor and wall coverings. Contact adhesives are two-phase systems comprising a polymer phase and an adhesive resin which comes on to the surface under pressure.

Adhesive lamination Laminating process for applying a foamed material film to textile material. Advantages: no loss of thickness as in → Fusion lamination.

Adhesive strike-through This problem occurs in screen printing if excessive quantities of adhesive film are applied to the printing blanket causing it to penetrate through the fabric being printed.

Adipic acid (1,4-butanedicarboxylic acid; hexanedioic acid), $HOOC–(CH_2)_4–COOH$. It is the acid component used in the synthesis of polyamide 6,6 (→ Adipic hexamethylene diamine salts) and also for the manufacture of 1,6-diaminohexane (hexamethylene diamine), alkyd resins, and esters used as plasticizers. Its former derivation by the oxidation of fat (Lat.: *adeps)* was the origin of the name adipic acid. Manufactured e.g., from cyclohexanone.

Adipic acid fibres Polyamide fibres of the polyamide 6,6 type, produced from adipic acid and 1,6-diaminohexane (hexamethylene diamine).

Adipic hexamethylene diamine salts (Polyamide 6.6 salts), Hexamethylene diamine adipate; monomeric exchange product of adipic acid and 1,6-diamino hexane (hexamethylene diamine) which, once purified by crystallisation, forms Polyamide 6.6 by polycondensation.

Adire Name given by the Yoruba tribe in Nigeria to the patterns created by reserve Africa print techniques on cotton using indigo.

“Adire oniko” is a tie-and-die technique (Fig. 1). In “Adire eleso” small plant seeds, fruit capsules, shells or stones are incorporated in the damp cloth as a means for producing circular and star-shaped patterns. The “Adire alabere” technique employs basting and whip stitches to produce reserve patterning. Two superposed fabrics arranged in a particular way are thus basted with offset rows of stitches passing through the two plies of cloth. By means of an additional rolled-in pleat a feather-type design is produced called “Agosofin” by the Yoruba (Fig. 2).

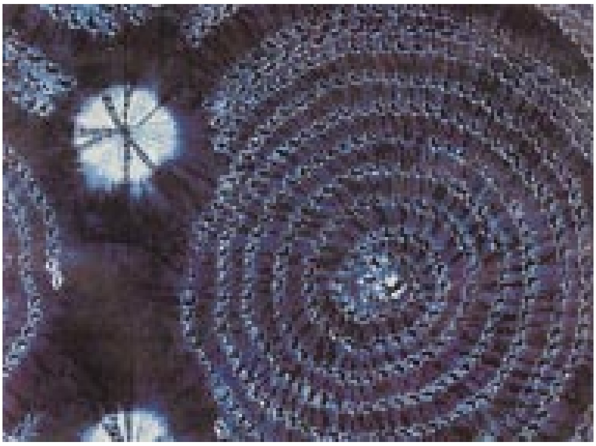


Fig. 1: “Adire oniko”.

One of the most popular traditional designs created with reserve paste is called “Olokun” by the Yoruba. As distinct from the tie-dye and stitched reserve techniques, “adire eleko” is an African variant of the Indonesian batik technique. The reserve agent used is “eko”, a vegetable starch prepared in the form of a paste from rice or cassava root (manioc). The starch is thickly applied to coat one face and no cracks must appear in the paste during drying as these would cause indistinct outlines in subsequent dip-dyeing.

Fig. 2: “Agosofin”.

Adjacent fabric (colour fastness testing) Undyed white fabric composed of one or several types of fibre used in → Colour fastness tests to determine the degree of staining from an accompanying dyed or printed test specimen. Such test fabrics must be completely free of finishes or other impurities. (1) Single fibre adjacent fabrics are standard fabrics of average weight composed of a single fibre type in a plain weave construction. For a particular colour fastness test, one piece made of the same fibre as the test specimen as well as one piece made of a different fibre type (specified) are required. (2) Multifibre adjacent fabric is supplied in strips woven from yarns of 6 different fibre types. Type DW = acetate, bleached cotton, polyamide, polyester, polyacrylonitrile, wool; Type TV = triacetate, bleached cotton, polyamide, polyester, polyacrylonitrile, viscose. Only one multifibre adjacent fabric is required for a particular colour fastness test.

ADR, abbrev. for: American Dyestuff Reporter (An American technical journal published monthly).

Adrianopolis red Identical with → Turkey red. Named after the Turkish city of Adrianopolis (Edirne).

Adsorbate → Adsorption.

Adsorbent → Adsorption.

Adsorbents for clarification purposes →: Bleach earth; Kieselguhr; Active carbon.

Adsorbing substances → Adsorption.

Adsorption (Latin: ad = to + sorbere = to suck in) is taking up, normally of soluble substances (adsorbate) onto the surface of a solid body (adsorbant) (see Table), e.g. dissolved substances onto fibres, moisture onto machine parts, gases onto solid bodies. It is extremely important in almost all dyeing and finishing processes. Adsorption is understood to involve various phenomena including chemical forces and the forces that act between solid/solid and solid/liquid phases where the phases adhere through another substance. The dissolved adsorbant (textile auxiliaries, dyestuffs etc.) or their ions (e.g. the fatty anions of auxiliaries) are forced out of solution by the water molecules onto the interfaces (fibre-water, soil-water) (see Fig.) and tend to diffuse into the surface. The concentrating effect produced at the surface can be 100–1000 times the concentration in the bath. When the dissolved substances are ionic they transfer their electrical charge to the boundary or surface (fibre, soil) (when there is ion exchange = exchange adsorption; when ions of one type accumulate at an interface = polar or hydrolytic adsorption; when the ion types are concentrated in the

adsorbent	form	examples of use
activated charcoal	granulate, powder, ball, fibre (untreated, doped)	exhaust air/exhaust gas decontamination,gas purification, water purification, dye stripping, catalyst or carrier medium
activated coke	granulate	exhaust gas decontamination, special flue gas desulphuration/ denitrification, preliminary filter (exhaust gas/water)
carbon-molecular sieve	granulate	separation of gases and hydrocarbons
scavengers	granulate	water purification, dye stripping, gas purification
silica gel	granulate	drying, catalyst or carrier medium
aluminium oxide	granulate	drying, catalyst or carrier medium, adsorption of polar substances
molecular sieve	granulate, powder	drying, gas separation, exhaust gas decontamination (polar substances)

Tab.: Technical absorbents: products, form, examples of application.

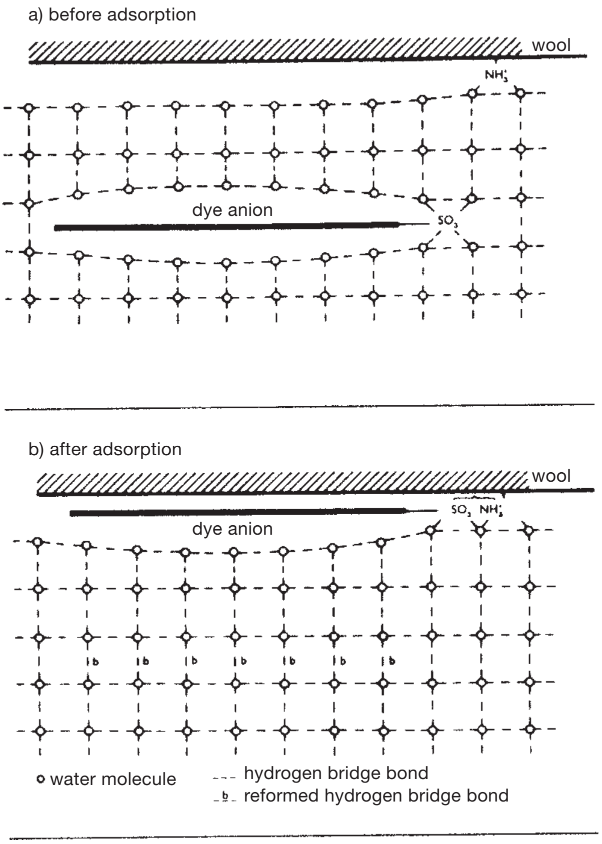


Fig.: Illustration of the adsorption of a dyestuff anion onto wool from a water matrix: after the adsorption seven hydrogen bonds have been formed between previously separate water molecules.

same proportions as they are present in the solution = normal or apolar adsorption). When e.g. soil becomes electrically charged with ions of the same sign, its mobility is increased and the soil particles separate from the surface.

Adsorption carbon → Activated carbon.

Adsorption chromatography → Chromatography.

Adsorption displacing activities For example, polyphosphates have the ability to reverse the adsorption of surface active agents to fibres etc.

Adsorption isotherms From the application point of view (exhaust processes, mechanical application), dyeing processes can essentially be divided into the following groups:

1. Mechanical anchoring of dyestuff on the substrate (pigment dyeing).
2. Sorption processes in which transport (diffusion) phenomena occur first and which are often accompanied by chemical reactions. In each case migration of the dyestuff is followed by its fixation in the substrate; when water-soluble dyes are being used, dyeing is a case of equilibrium distribution of the dyestuff between the liquid phase of the dyebath and the solid phase of the fibre.
3. In dyeing with (sparingly water-soluble) disperse dyes, the particles of the dispersion act as a 3rd phase; dye is transferred from these solid particles into the solid substrate via solution in water.
4. Thermosol dyeing and transfer printing are high temperature processes (180–200°C) in which the disperse dyestuff is transferred by sublimation from

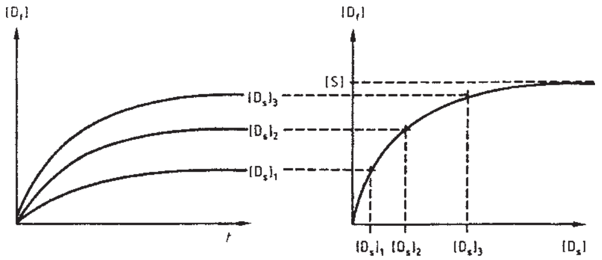


Fig. 1: Kinetics and thermodynamics of a dyeing process (from Zollinger).
D_s = concentration of dyestuff in solution (mmol/l);
D_f = concentration of dyestuff in the fibre (mmol/l);
t = dyeing time (s); S = saturation value.

the solid phase through the gas phase into the polyester substrate.

The distribution of a dyestuff between two phases in sorption dyeing can be described by the kinetic (transport and reaction phenomena) and equilibrium characteristics (thermodynamics of adsorption and desorption in dyeing equilibria) (Fig. 1). The results of static and kinetic dyeing experiments shown as graphs of the dyestuff concentration in the dyebath against the dyestuff concentration in the fibre are called dyeing isotherms. They are obtained from exhaustion curves. → Sorption isotherms

Ionic dyes are taken up according to a Langmuir adsorption isotherm, whereas disperse dyes exhaust by a Nernst (linear) or a Freundlich adsorption isotherm (Figs. 2 and 3).

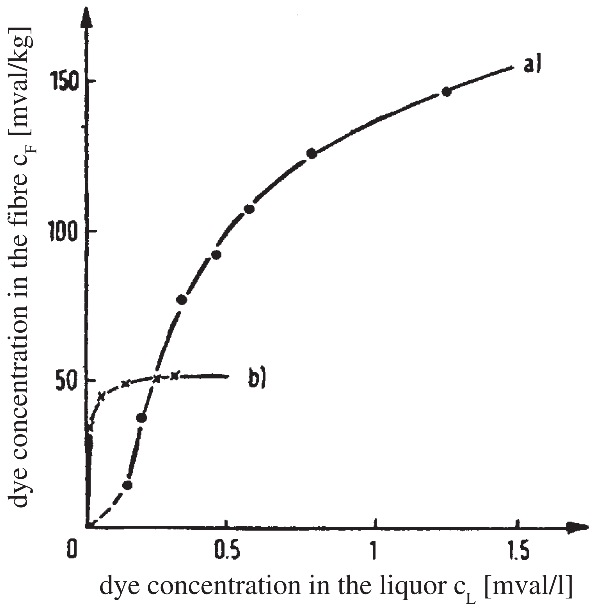


Fig. 2: Uptake of an acid dyestuff (C.I. Acid Blue 25) by a) an Elasthane fibre and b) a nylon-6 fibre (100°C, pH 4.7, 4 h); b) corresponds to the Langmuir and a) to the Freundlich or Nernst isotherm.

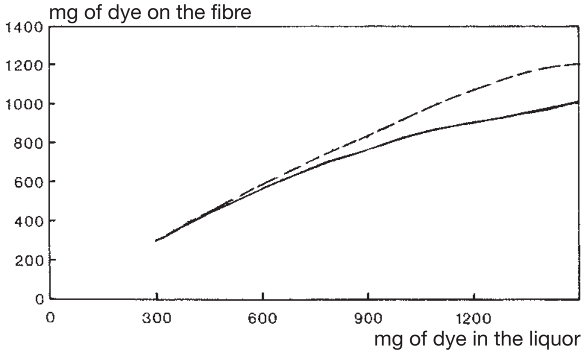


Fig. 3: Adsorption isotherms of cashmere (– –) and cashgora fibres (—) dyed with the same wool dyestuff to compare the dyeability of the two types of fibre.

Adsorption liquid Liquid retained as a deposit of liquid molecules in amorphous areas and on the surface of crystalline areas of fibres. The binding takes place through valency forces provided that the liquid has polar properties.

AECC, (Sp.) abbrev. for: Asociación Española para el Control de la Calidad, Madrid (Spanish Quality Control Association); member of the → EOQC; → Technical and professional organizations.

AEK, abbrev. for “Amerikanische Echtheitskommission”, Fastness Committee of AATCC → Technical organizations.

AEQCT, (Sp.) abbrev. for: Asociación Española de Químicos y Coloristas Textiles (Spanish Association of Textile Chemists and Colourists); → Technical and professional organizations.

Aeré Woollen yarn fabric with a tweed-like character, and a marked crocheted openwork pattern effect.

Aerobic bacteria (Gr. *aer* = air), are microorganisms which thrive especially in the presence of atmospheric oxygen, so-called aerobes. Opposite term → Anaerobic bacteria.

Aerobic degradation Biological degradation or biodegradation occurs as a result of any conversion of dissolved or solid matter into other compounds through the action of organisms. Besides assimilation by photosynthesis in which dissolved substances are taken up by biological systems, the biodegradation of organic compounds by microorganisms such as bacteria and moulds represents the most important process. In this process, organic substrates are oxidized and part of the energy released is used by the microorganisms for reproduction (see Fig.). This type of respiration (also often referred to as mineralization) consumes oxygen or, if this is not available, other oxidizing agents such as nitrates, sulphates or organic compounds that are already partially oxidized.

Aerobic respiration: In this process, organic substances are oxidized and oxygen is reduced. Under ide-

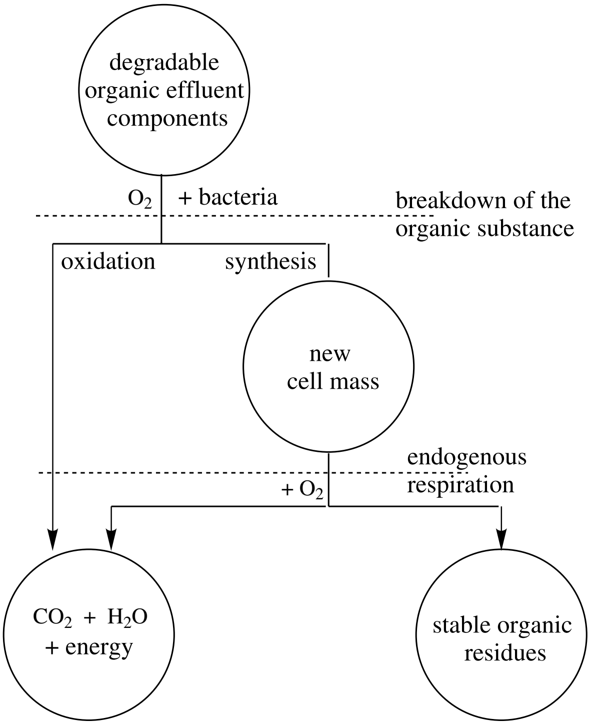


Fig.: Diagram of the aerobic breakdown of the organic effluent components in activated sludge.

al circumstances, this oxidation proceeds to carbon dioxide and water:

$$CH_2O + O_2 \rightarrow CO_2 + H_2O$$

These various stages of reaction have been thoroughly investigated and, together with anaerobic processes, are employed in the biological purification of waste water. By this means, about 50% of the organic substrates are oxidized through the release of energy in aerobic respiration and the remainder is converted into bacterial mass (sewage sludge). In anaerobic methane fermentation, on the other hand, only about 10% of the substrate is converted into bacterial mass (Kummert and Stamm).

Aerobic fermentation During biodegradation of the organic constituents in waste water, an oxidative degradation of substances catalyzed by bacteria takes place. However, new cell mass is built up at the same time since the nutrient supply promotes bacterial growth. This cell mass also breaks down itself by endogenous respiration through oxygen consumption, as a result of which organic residues no longer capable of further degradation are formed. In total, the products of aerobic degradation are CO_2, H_2O, besides energy and waste substances.

Aerodynamic dyeing systems In a rope dyeing machine, a distinction is drawn between the dwell zone (diffusion in the fibre) and the liquor exchange system (reduction of the laminar boundary layer through intensive fibre flushing in order to improve uniform dye absorption on the fibre surface). The liquor to fabric substance interchange is effected in various systems (Fig. 1):

1. Mechanically in the winch with a 20 : 1 liquor ratio.
2. Hydraulically in overflow or jet dyeing machines (depending on the fabric propulsion system principle in the fabric to liquor interchange zone) with a straight (12 : 1 liquor ratio) or circular (10 : 1 to 5 : 1 liquor ratio) fabric store.
3. Aerodynamically: the fabric is propelled by a gas flow; the treatment liquor is injected into the gas flow. Liquor ratio: 4 : 1 to 2 : 1 (Fig. 2).

As the liquor supply is greatly reduced in consequence, the textile fabric liquor charge is reduced, i.e. in the case of fabric movement in a gas flow, the free space between fibres is not completely filled with liquor. Depending on the physical parameters of the gas, as air with a differing water vapour content, a state of equilibrium occurs in which the injected liquor quantity is interchanged with the textile fabric moisture charge. This flows out of the treatment vessel (Fig. 3) back into the injection circuit in the same quantity as the injected liquor. The suction conditions of the injection pump are better than those of a liquor pump, and only a small liquor supply is therefore necessary.

The aerodynamic system developed with the Then Airflow moves and controls the fabric by means of the

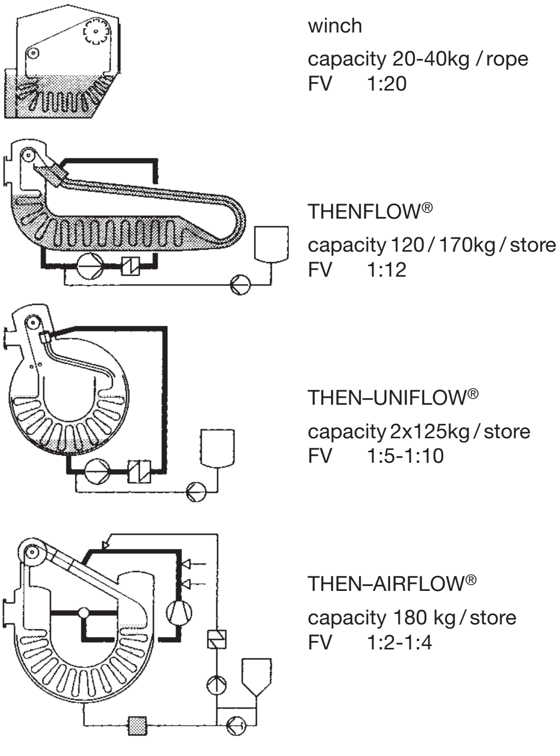


Fig. 1: Then piece dyeing machines in development from the winch to the Airflow aerodynamic dyeing system.

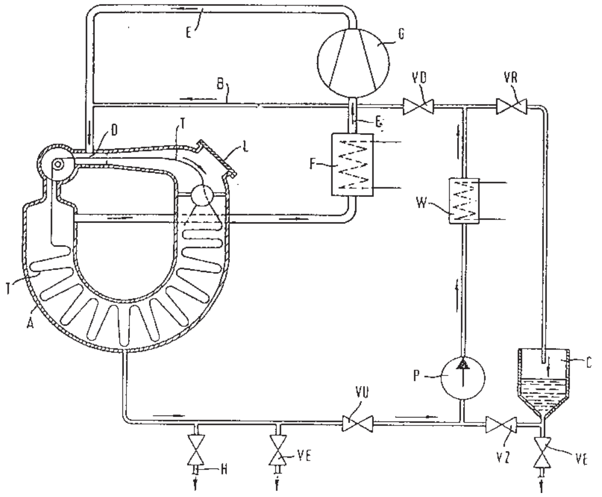


Fig. 2: Diagram of a jet dyeing machine with aerodynamic-fabric drive (Then).
A = dye jet; B = liquor circulation system; C = preparation vessel; D = nozzle section; E = gas circulation; F = air heater; G = fan; H = HT drain; L = sampling window; P = circulation pump; T = textile fabric; VD = throttle valve; VE = emptying valve; VR = return flow valve; VU = circulation valve; W = heat exchanger.

circulating gas. Higher fabric speeds can be used in the gas flow than is possible in a hydraulic system, since the fabric rope is carried neither in the liquor nor with the liquor, and is consequently subject to lower tension during acceleration. There are therefore different prerequisites in bath exhaustion, produced not by the liquor encompassing the textile fabric but from the dye and product preparations distributed through the textile fabric. In this respect, the liquor ratio is largely dependent on textile fabric liquor absorption. In finishing operations, there is a thermodynamic equilibrium, e.g. at the dye fixation temperature, between the distributed dye preparation and the gas flow the gases largely employed being air and water vapour, which are in direct contact with the dye and product preparation distributed over the textile surface and with the liquid phase of the preparation distributed in the gas flow. With a change in temperature and pressure, a coupled heat and substance interchange takes place between these media with the aggregation states of the liquid and gaseous phase.

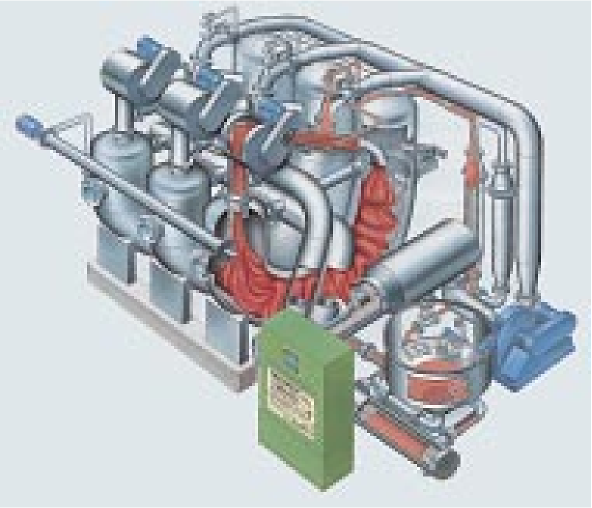


Fig. 3: Then Airflow AF 540.

Atmospheric air is a mixture of air and water vapour, i.e. the available water content is in a gaseous state until the air reaches saturation point. Water vapour is a gaseous water phase, for the formation of which water has to be heated to boiling point, passing into a proportional gaseous state due to further heating. This heat content is described as heat of vaporisation, which is approximately equivalent to five times the heat quantity of water heated to boiling point. The H,s diagram of moist air applies to the constitutional values in the case of treatment processes up to approx. 100°C and with the use of air as the gaseous medium. The heat content of the air is plotted on the ordinate axis in right-angled coordinates. The heat content of the moisture proportion of the air is related to steam with 0°C. The temperature curves (straight lines) rise to the right in the diagram, so that the heat contents of the dry air and of the moisture content can be read off. In addition, curves are drawn in for the saturation state of the air at various total pressures. Since the total pressure in the machine is measured, the moisture or water vapour content of the air in the saturated state can be read off with the temperature. The textile fabric has the property of absorbing moisture from the air. A constant moisture content forms in the textile fabric for a constant air condition.

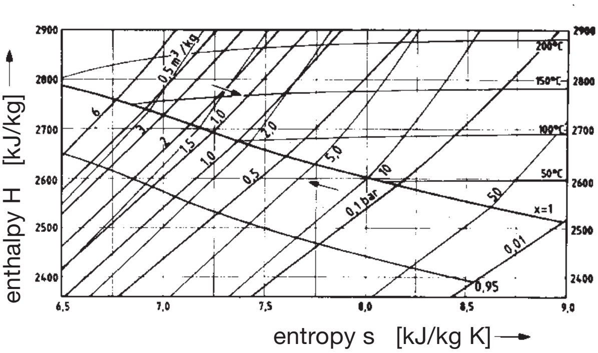


Fig. 4: Mollier H,s diagram for water vapour.
H = enthalpy; s = entropy.

The H,s water vapour diagram (Fig. 4) provides information about the gas condition in the machine for condition changes, e.g. in heating, for the state of equilibrium at fixation temperature, for heat outflow and for the cooling process. Entropy is a variable quantity; its difference is the quantity of heat transferred at a specific temperature. The H,s graph shows the curves for constant pressure, temperature and volume, and with x = 1, the saturation line. Owing to the large textile fabric surface, it is heated rapidly together with the liquor adhering to it. Heating is effected by condensing the water vapour, i.e. the steam transfers the condensation enthalpy to the textile fabric and additionally the heat content of this moisture. The advantage of this system (Fig. 5) lies in the very small temperature differences, since there is thermodynamic equilibrium in almost every stage.

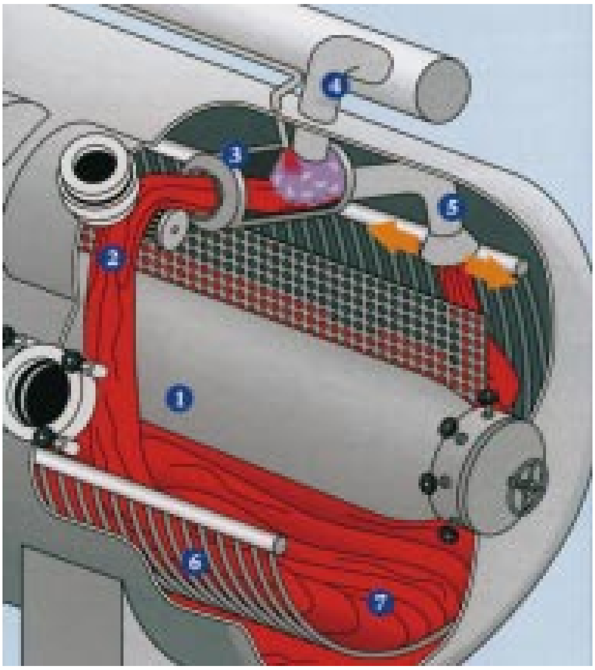


Fig. 5: Advantages of the latest version AFT from Then. 1. Safe fabric transport, optimum displacement and little crease formation are ensured by the aerodynamic drive. 2. By means of the active fabric run control a slip regulation is possible, facilitating the exact monitoring of fabric speed and the best possible fabric handling. 3. The unique rinsing method by spraying fresh water allows short processing times with best rinsing effect. 4. Utmost shade fastness by aerodynamic fabric transport without hydraulic and dye in saturated steam atmosphere. 5. Optimized fabric smooth plaiter ensures an excellent displacement of the fabric. 6. Combined Teflon slide bottom consists of foil and sliding rods for the best, careful treatment of fabric surface and a smooth transport in the storage chamber. 7. By enlarged liquor sump, also in case of difficult dyeing procedures, fabric displacement is always above the dye liquor.

During heat outflow, e.g. from 135°C, a very rapid temperature drop occurs due to steam pressure reduction from 2.13 bar to pressureless operation. The moisture evaporation within the fabric occurring during this process prevents crease marking. Only a few minutes are required for heat outflow, whereas lengthy cooling times are required in the case of jet dyeing machines, as cooling can often be effected only at a rate of 1°C/min.

Aerogel → Gel.

Aerosol (Lat.: *aer* = air, atmosphere; sol = colloidal solution) A dispersion in which finely divided solid or liquid matter is suspended in a gas and the particles are of colloidal dimensions, e.g. smoke or fog. The table shows the number of particles which can be produced from 1 ml of water in the size range from 1–20 µm, together with details of their effective surface area.

particle size in µm	number of particles in billions	surface in cm²
20	0,24	3 140
10	2	6 280
5	15	12 000
2	240	30 000
1	2 000	63 000

Tab.: Aerosol particles in 1 ml of water.

The table clearly shows the enormous increase in surface area compared with the volume of the water particles, and the extreme fineness of the aerosols is inevitably accompanied by rapid vaporization. For this reason, aerosols are the preferred means of air conditioning using jets for atomization (air conditioning plants) or aerosol generators for still greater efficiency.

Aerosol dyeing Principle: dye is applied to a textile material in the form of an → Aerosol composed of air, dye and water vapour.

AFA, Afa, (Ger.) abbrev. for: steuerliche Absetzung für Abnutzung (depreciation/depreciation for wear and tear). → Service life of textile plant and equipment.

AFCT, (Fr.) abbrev. for: Association Française de Contrôle Textile (French Association for Textile Control). Founded by all French manufacturers of cellulosic man-made fibres with the objective of promoting the quality of these materials. → Technical and professional organizations.

Afei French consumer carpet label (Institut National du Tapis) for French and imported goods. Provides information on the name of the manufacturer, the manufacturing process, as well as details concerning backcoating, colour fastness, flammability resistance, flame propagation, sound insulation and a 5 year warranty.

Affinity is a measure of the force which binds e.g. a dye or even a textile auxiliary to a substrate (fibre, etc.). It is generally accepted that, besides dye/fibre interactions in dyeing, interactions between substances present in the dye liquor (dyes, chemicals, water) also take place simultaneously during the dyeing process. For this reason, particular attention is given to the dye/fibre equilibrium state. This equilibri-

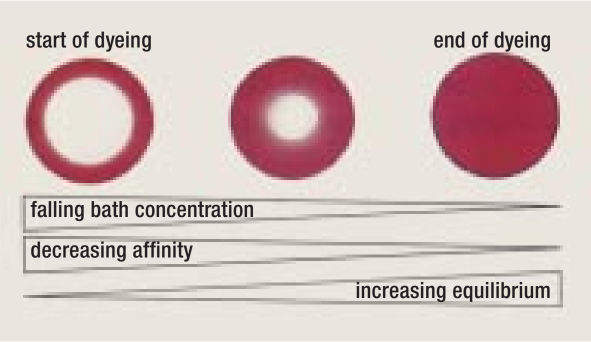


Fig. 1: Dyestuff/fibre equilibrium (thermodynamic affinity).

um can be described physically and chemically by the thermodynamic affinity (Fig.1).

High affinity prevails then, if a max. number of interactions between fibre and dye can be achieved on reaching dyeing equilibrium. For direct dyes on cotton, the planarity of the dye molecule also play a role here, e.g. with regard to the degree of affinity (Fig. 2).

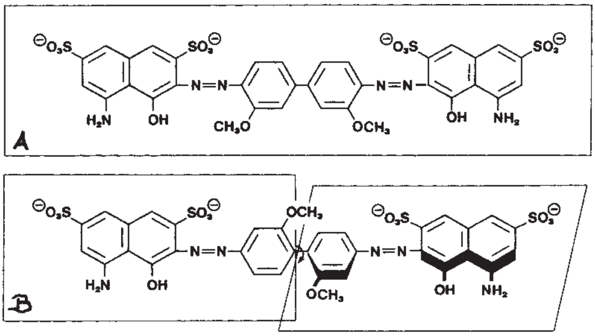
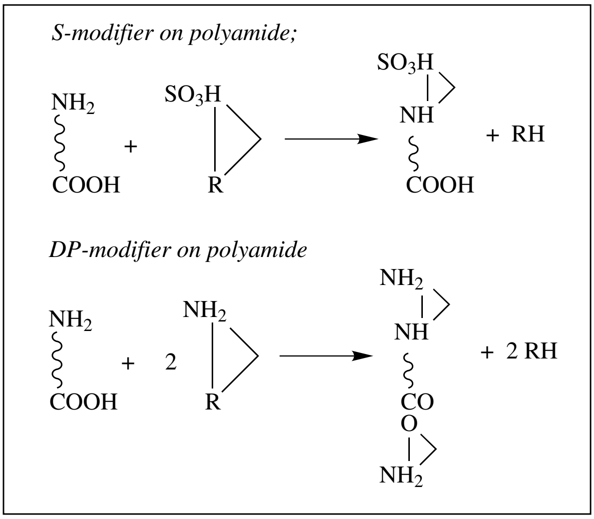


Fig. 2: Importance of the planarity of the dye molecule for affinity for cellulose.
A = high affinity for cellulose (direct dyes);
B = low affinity for cellulose (acid dyes).

Vat dyes (in the vatted form) and direct dyes have affinity for cellulose (cotton or viscose) if their molecules are capable of forming conjugate structures. Delocalizable π-electrons in the conjugated system must polarize the molecule in such a way that the excited phase of the resonance system induced by increased temperature forms a (negatively or positively charged) “charge transfer” complex with the cellulose.(In the case of vat dyes, this corresponds to a quinone-imide structure whereby a proton transfers from the dye to the cyclically-bound acetal-oxygen atom of the cellulose. With direct dyes, a proton from a cellulose OH group can also transfer to a central function of the direct dye which becomes positively charged as a result). Conjugation is therefore a prerequisite for affinity.

Affinity factor Serves to characterise the affinity effect in the pad dyeing process. Also described as x-value: $x = C_f/C_\infty$.

Affinity modification Modification of the dyeing


S-modifier on polyamide;

DP-modifier on polyamide

Fig.: S-modified and DP-modified polyamide fibres.
R = reactive group; |> = undefined bond.

behaviour of (polyamide for example) substrates as against standard dyestuff classes, functional end groups, which are responsible for dye to fibre bonding, being either blocked or multiplies, e.g. shown schematically in the Figure.

Most fibre-reactive affinity modifiers covalently bonded to substrates are produced by the 2-stage application of fast to cross dyeing reserve or mordant effects (shade deepening):

1st stage: treatment of the substrate with affinity modifiers by all possible methods, such as exhaust, printing and spray processes etc. This is followed possibly by intermediate drying and then setting by means of superheated steam, saturated steam or dry heat (storage if necessary).

2nd stage: rinsing (removal of thickener residues and marking colours) and dyeing by the exhaust or continuous process, i.e. subsequent colouration of the treated proportions in competitive reaction with the untreated proportions of the substrate for required differential, reserve and/or two-colour effects.

Affinity modifier Defined chemical group, which, for example in → Acylation or → Affinity modification, is introduced into a fibre molecule, changing the affinity of the fibre for specific dyes, i.e. reducing or increasing.

Afgalaine, afghalaine Soft worsted fabric for ladies’ dress material (similar to → Duvetine), with faint, striped pattern on the back. Originally, the fabrics were produced from Afghan wool (laine = wool). Today, however, the term is no longer a registered name. These days, afghalaine fabrics are mainly produced from single, medium-fine, spun woollen yarns in warp and weft, frequently “1S” and “1Z” twist yarn. Thus, the weave has a somewhat grainy texture with an essentially well-defined finish. Piece-dyed, ladies’ dress materials with soft to full handle in practically all shades, including black for mourning dress, e.g. in pure wool, in blends with max. 50% viscose and also in blends with about 10–15% polyamide.

Afghan carpet Long-pile tied carpet from Afghanistan. Octagonal, clover leaf and camel's foot patterning in bright red, dark blue and ivory colours on a brownish red ground. Goats' hair warp ends, 80 000–150 000 knots/m^2.

AFNOR, (Fr.) abbrev. for: Association Française de Normalisation, Paris (French Standards Association); → Technical and professional organizations.

AFNOR Method → Au portique.

Afric, African Fibre → Crin d'Afrique.

African silk → Anaphe silk.

Africa prints Printing technique on cotton fabrics used mainly in the countries of West and Central Africa (e.g. Congo, Nigeria, Ivory Coast, Senegal, etc.). The prints are characterized by typical naturalistic designs coloured with a few frequently repeated colour combinations. For Africa print styles, fully-penetrated prints are generally demanded. Printing is mostly carried out on naphtholated grounds with diazo fast colour salts in combination with reactive dyes. Indigo, mordant and phthalocyanine dyes are also used. Printing styles: →: Real Wax, Imi Wax, Java Print, Green Ground, Fancy Print (see Fig.)

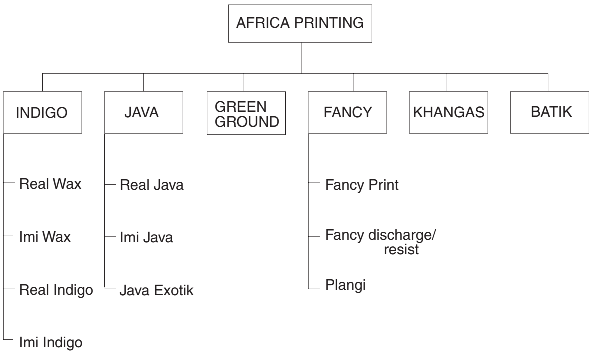


Fig.: Product breakdown in Africa printing.

Textile printing has a long tradition in the countries of West and Central Africa. For several centuries primitive people have added design and colour to textiles. The designs were mainly produced by methods involving the application of resists followed by subsequent dyeing. Original handcraft techniques are still in use today although, as a result of the industrialization of African countries which began in the 1930's, various imitations have since been developed. Despite these changes, the strong traditional attachment in these countries even continues to place extremely high demands on the quality of these technical imitations. Historically, as in Africa, a comparable tradition also developed in Indonesia. The well-known (Java) batik fabrics differ from Africa prints chiefly in design and colour combinations although the technique (processes and dyes used) is nevertheless very similar. → Indigo styles in Africa prints.

After-burn time Time taken between the moment the ignition flame is removed and extinction of the flame on the test specimen. → Burning behaviour of textiles.

Afterchrome dyes Dyes for wool. The chrome dye is applied in a similar manner to an acid dye and then treated in a chrome bath to produce the final shade. Dyeings with good light and wet fastness properties are obtained. → Chrome dyes.

Afterchroming → Chroming of dyes.

Aftercoppering dyes Direct dyes containing mordant-attracting groups in their molecules which are capable of forming stable metal-complexes with metal ions (e.g. o,o'-dioxyazo groups). Aftercoppering dyes are dyed in a similar manner to normal direct dyes then finally aftertreated with metal salts (mainly copper salts) plus an additional cationic treatment if desired.

Dyes possessing a hydroxy group in an ortho position to the azo nitrogen atom are suitable for aftertreatment with copper salts to give dyeings of improved light fastness. The treatment causes a distinct change of shade. Dyes of the benzidine type with two OH groups in the para position to the azo group exhibit improved fastness to light as well as washing after an aftercoppering treatment. Dyes which possess a glycollic acid group –CH–OH–COOH instead of an OH group (some Benzo Fast copper dyes) may also be given an aftercoppering treatment. Benzidine dyes such as e.g. Congo red, have been found to be carcinogenic and are no longer manufactured.

After-coppering of direct dyeings → Copper sulphate aftertreatment.

Aftercoppering test A useful test in doubtful cases to distinguish aftercoppered dyeings from the more usual direct and sulphur dyeings. Test procedure: Place 10 ml hydrogen peroxide 30% in a test tube with 2–3 drops sodium silicate solution. Shake briefly and add 1 ml conc. ammonia. After careful shaking, add the dyed test specimen as soon as the evolution of gas ceases. An effervescent evolution of oxygen occurs in the presence of an aftercoppered dyeing after a few minutes. No other type of aftertreatment gives this reaction.

After-glow Textiles are much more dangerous if they burn without flames, or if they re-ignite, than if they burn with a visible flame. The reason for this is the glow, which occurs after the flame is extinguished. The results depend on fabric weight and after-treatment. If burning with an open flame is controlled by oxidative processes, pyrolysis – polymer destruction in the absence of oxygen, i.e. reductive processes – is the main factor in after-glow.

After-glow time The time during which the test specimen continues to glow after flame extinction.

After-print washing This term is not clear, for

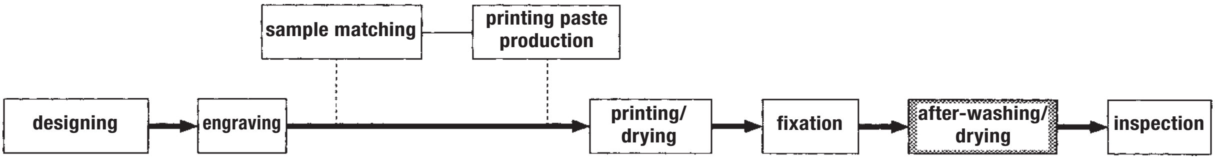


Fig. 1: Textile printing - processing cycle diagram.

after-print washing primarily means “washing off printed fabrics”, which should accordingly be called printed fabric washing. The term after-print washing has of course largely prevailed, although it can also certainly be implemented without printing (e.g. with horizontal or rope scouring machines), i.e. in contrast to spray washing machines operating with low or high pressure jet systems, from which the usual trade term also stems to some extent (e.g. Küsters high pressure jet washing machine).

The washing off process is of quite special importance in the production of high quality printed fabrics e.g. with reactive dyestuffs. Whether the quality requirements imposed as regards colour brilliance, colour fastness, shade consistency, white ground have been met is revealed at the latest by the washing process. The first and most important purpose of after-print washing is to ensure that the required quality in terms of fastness and print appearance is achieved. It happens again and again however that after-print washing must also bear the brunt of ironing out the faults from preceding operations (Fig. 1).

This involves for example

- print fabric pre-treatment,
- printing paste additions,
- printing paste application quantity,
- drying and fixating.

An after-washing process, which is used predominantly for eliminating these faults and irregularities, can scarcely produce optimum results. After-print washing is extremely costly and labour intensive, and is also an operation in which ecological standpoints should be taken into account. A great deal of care must therefore be taken in order to achieve the best possible effect with low water consumption and low effluent contamination.

After-print washing breaks down into four stages:

1. Wetting out: impregnating the print with washing liquor.
2. Swelling: thickener and fibre swelling.
3. Spraying: removing the swollen thickener and associated chemicals.
4. Washing: removing the unfixated dyestuff (fastness wash).

The effect of reaction time, temperature and mechanical action can be seen during the various process stages. Decisive factors are

a) Electrolytes: they increase dyestuff hydrolysate substantivity, for which reason washing in a liquor with as low as possible an electrolyte content should be aimed for.
b) Temperature increase: as the temperature rises, dyestuff hydrolysate decreases, and diffusion from the interior of the fibre consequently increases. Dye disaggregation by way of the highest possible washing temperature is the aim.
c) Sodium alginate: together with calcium ions, this forms a salt which is insoluble in water. The resultant film has a negative effect on washing speed, wet fastness, brilliance, shade and fabric handle. The addition of a sequestering agent is therefore necessary with the use of hard water. Excesses should be avoided on account of electrolyte formation.

After-print washing can be effected with the fabric in open width (Fig. 2), in rope form, or in a combination of rope form and open width (Fig. 3). The 4 stages of the washing process (Fig. 4) are as follows:

Stage 1: attention should be drawn here first of all to a specific peculiarity of the two-stage technique. Whilst, with all single stage fixating processes, the fabric leaves the steamer in a relatively dry state (wet-

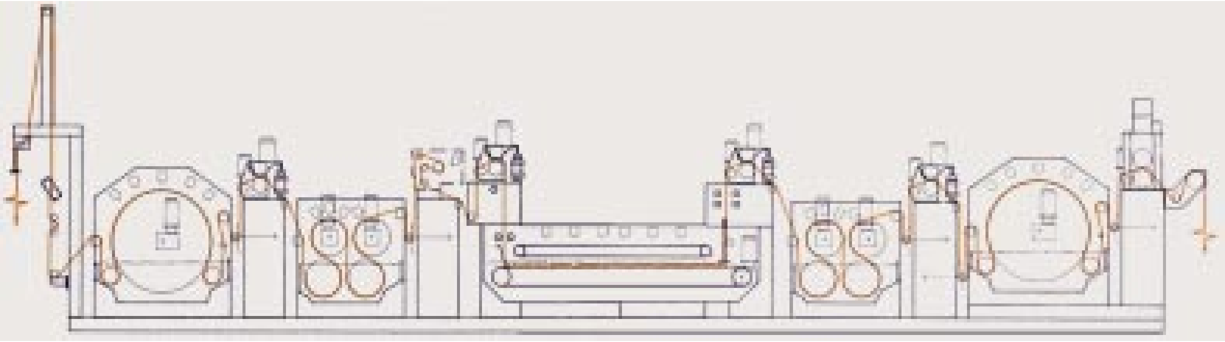


Fig. 2: Arioli open-width after-print washing line.

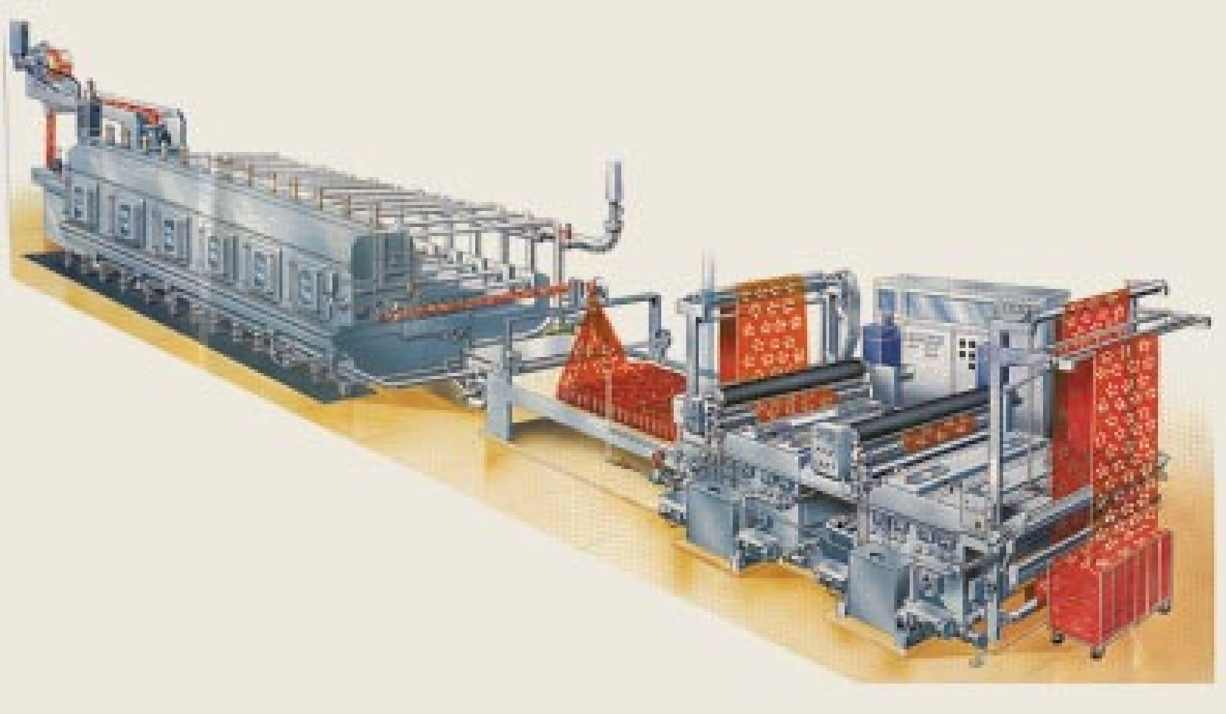


Fig. 3: MCS after-print washing line with open-width section for repelling thickener, and also with a rope washing section for the fastness wash.

ting, swelling and partial thickener film dissolution are time-dependent), the fabric stays damp in the two-stage process. The thickener film and the fibres remain swollen, providing easy access for water. Rapid alkali removal by spraying is therefore first of all important before entry into the liquor baths and a rise in temperature. The operation should be performed with soft water or with the aid of softening agents in order to prevent the formation of calcium alginate, which is difficult to dissolve.

Stage 2: this stage concludes the transfer of the dyestuff hydrolysate still loosely anchored in the fibre structure together with dissolved auxiliary agents. Temperature should be between 40 and 60°C.

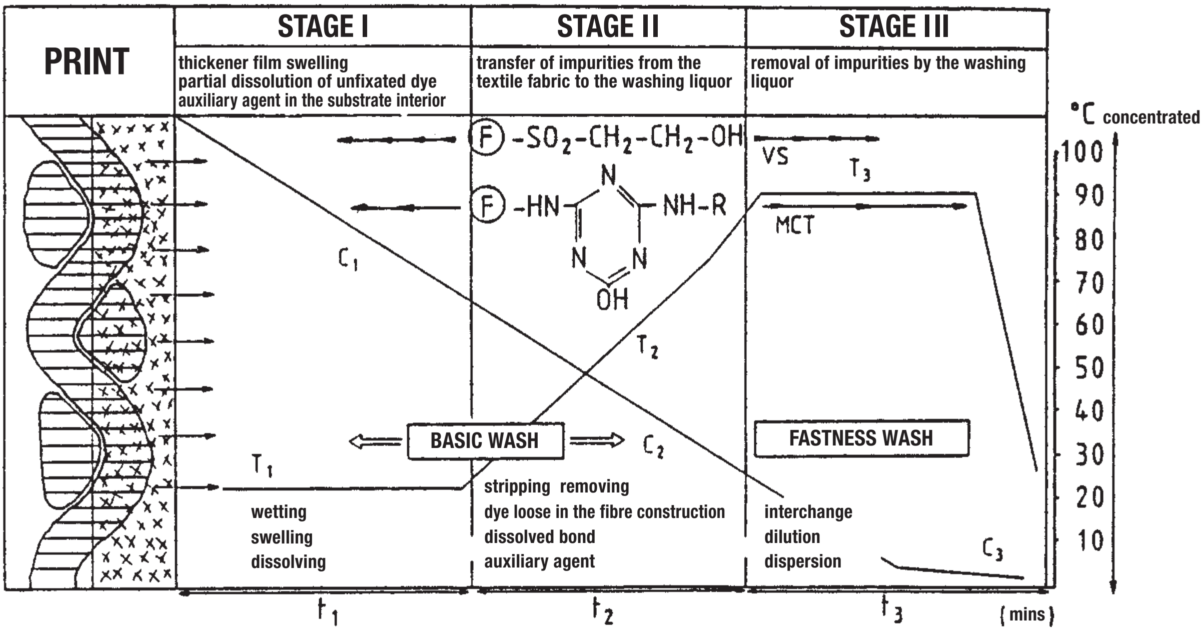


Fig. 4: Reactive print after-treatment (washing process stages) before the final rinse (according to Hoechst).

Stage 3: this stage, also termed fastness washing, requires time and increased temperature, since it largely involves a diffusion process, in which the hydrolysed reactive dye still on and in the fabric can diffuse from the fibre into the baths. As regards the use of a washing agent, no exaggerated expectations should be placed on the effect of a washing agent when washing out water-soluble dyes. It is much more important to ensure that the substantivity of the hydrolysed dyestuff decreases as the temperature rises, while the rate of diffusion increases (Fig. 5), which has a beneficial effect in removing the hydrolysed dye.

Stage 4: rinsing.

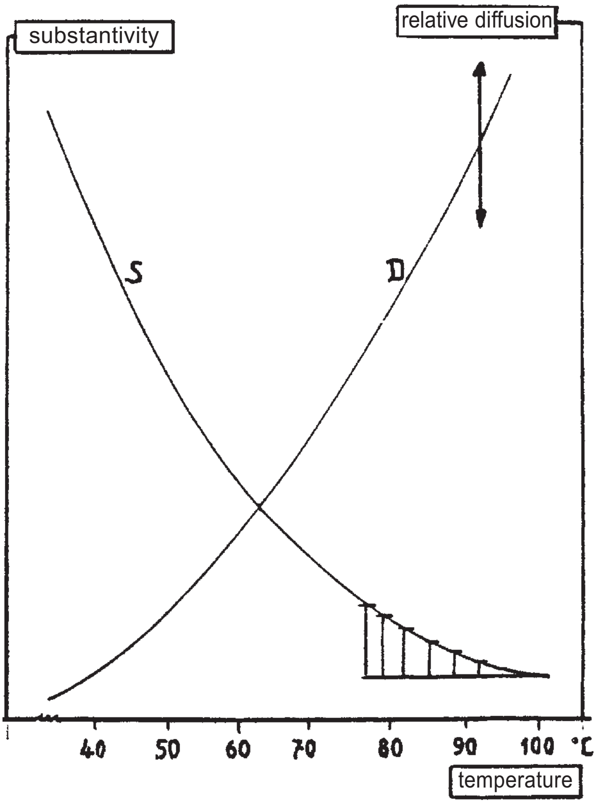
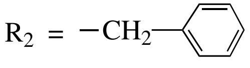


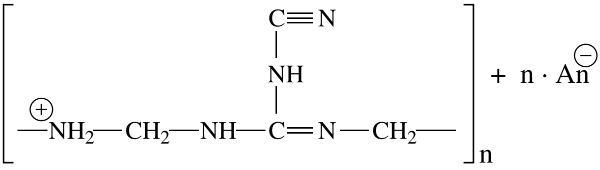
Fig. 5: Effect of diffusion/substantivity relative to temperature (fastness after-wash-reactive printing).

After-treatment of dyeings For improving fastness. Most conventional after-treatment agents are constructed on the basis of formaldehyde condensation products or are polyammonium compounds (Figs. 1 + 2).

It is possible to modify the polyammonium compounds in such a way that a softening effect takes place in addition to the fastness-improving action. Modification is effected by changes in R_1 and R_2. Typical:

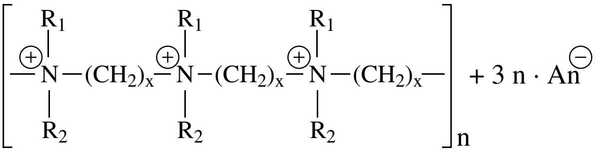
$R_1 = -C_2H_4OH$





$$\left[\overset{\oplus}{-NH_2}-CH_2-NH-\overset{\substack{C\equiv N\\ |\\ NH\\ |}}{C}=N-CH_2-\right]_n + n\cdot An^{\ominus}$$

Fig. 1: Structure in principle of a formaldehyde condensation product.



$$\left[-\overset{\substack{R_1\\ |}}{\underset{\substack{|\\ R_2}}{\overset{\oplus}{N}}}-(CH_2)_x-\overset{\substack{R_1\\ |}}{\underset{\substack{|\\ R_2}}{\overset{\oplus}{N}}}-(CH_2)_x-\overset{\substack{R_1\\ |}}{\underset{\substack{|\\ R_2}}{\overset{\oplus}{N}}}-(CH_2)_x-\right]_n + 3\,n\cdot An^{\ominus}$$

Fig. 2: Structure in principle of a polyammonium compound.

Cationic after-treatment agents can bond with anionic dyestuffs. Bonding can take place in different places. Reactive dyes and direct dyes are bonded on the same principle. A molecule of the cationic after-treatment agent can make a number of different bonds. The easiest bonding to understand is achieved with the anionic dyestuff. The water solubility of the dye is reduced by this bonding. Agglomeration can also take place via any metal contained in the dye. Furthermore, the after-treatment agent can bond not only with the dye but also with the cellulose itself. This is observed when undyed cellulose was treated with a cationic agent; the cellulose takes on a high degree of dye affinity via the mordanting effect.

Printing and dyeing wet fastness improvement is the primary aim in after-treatment. Dye migration, whether it be substantive dye or reactive dye hydrolysate, is prevented. Dyes not after-treated can migrate in the material to be dyed. This process is observed in uneven water extraction or drying, higher temperatures accelerating migration. The migrating dye moves with the escaping water. In package dyeing for example, this phenomenon results in visible outside-to-inside unlevelness. In tricot dyeing, cloudy unlevelness is observed if the moist fabric is allowed to stand for some time. This is caused by migrating dye in places starting to dry, or in places retaining water as the water level falls. Much greater damage occurs due to migration in made-up goods. In a hot, humid medium, e.g. in steaming garment components, edging and spotting may occur. Reactive dyes tend less to this type of phenomenon of course. They are securely bonded to the cellulose, and the chemically fixated dye cannot migrate. Reactive dyeing not only contains fixated dye; dye hydrolysates are also present. These form during dyeing if the reactive dye reacts with the water instead of the hydroxyl group of the cellulose. The fast-soaping process following dyeing should remove these dye hydrolysates from the cellulose. In addition to the dye hydrolysates which remain in the fibre, others can occur through subsequent dye hydrolysis. With dye hydrolysis, the dye fixated on the cellulose is split on account of various conditions. Under certain circumstances, high temperatures, such as occur during drying, for example, split the reactive bond between dye and fibre to some extent. This process is termed thermohydrolysis. Dye/fibre splitting in an acid medium is termed acid hydrolysis. This frequently occurs following softener application, since softeners have to be applied in an acetic acid medium in order to improve exhaustion. Softening is not followed by rinsing; the acid remains in the fabric, and can in time damage dye to fibre bonding to a greater or lesser extent until it is removed by drying. In the same way, acid exhaust gases or hot and humid climatic conditions have an effect during storage. With reactive dyes, after-treatment has frequently won favour due to this phenomenon, reactive dye hydrolysates being bonded to the cellulose via the after-treatment agent (according to Kahle).

AFU → AATCC Fading Unit.

AG, abbrev. for:

I. (Ger.) Aktiengesellschaft (joint stock company, corporation).

II. (Ger.) Arbeitsgemeinschaft (study group, joint venture).

III. → Alginate fibre → Standard abbrev. for textile fibres, according to the → EDP Code; DIN standard abbrev. → ALG.

Ag,

I. → Alfa grass → Standard abbrev. for textile fibres, according to DIN 60 001 until 1988, from 1991 → AL.

II. chemical symbol for → Silver (47).

AgA, (Ger.) abbrev. for: Ausschuß für gefährliche Arbeitsstoffe (Committee for dangerous working materials) of the Federal German Ministry for Work and Social Order. The AgA is responsible, *inter alia,* for establishing technical guide concentrations (TRK values).

Agar agar is extracted from marine algae (China, India) and is a mixture of two polysaccharides, agarose and agaropectin. It swells greatly in water, dissolves in hot water and sets on cooling to a jelly at a concentration as low as 0,5%. Its gel-forming power is 6 times greater than gelatine. Agar agar is extracted from various red and brown algae which grow on the sea bed in warm temperate seas. It is marketed as a dry powder, flakes or strips which may be yellow or bleached (greyish to yellowish-white). It has found application as a textile finishing agent (“natural finish” for cotton = soft voluminous soapy handle without natural firmness; also for wool). Apart from this it is used as a clarifying agent, thickener or gelling agent, and as a biological culture medium.

Agave fibres belonging to the group of → Hard fibres, a sub group of plant fibres. All Agave fibres are recovered from leaves. Through their common origin from leaves, different Agave types (elongated, fleshy spear shaped leaves upto 1.5 m long) from subtropical areas are similar to one another in many respects. Among Agave fibres can be found → Henequen, Pita, Cantala and Sisal fibres.

Ageing The change in the colloidal state over time, normally a change from the labile to the stabile form, where the particles increase in size and the degree of dispersion falls accordingly. Ageing processes are known e.g. in soap solutions, in certain dye baths and finishing baths. Thus, fresh artificial resin solutions give much better crease resistance than those stored for any length of time. Ageing can progress to such an extent that water solubility can be partially or completely lost; an important reason why auxiliary firms only offer limited guarantees on storage life on some artificial resins.

Ageing fastness → Light-induced ageing, resistance to.

Ageing of carpets (artifical) → Carpet ageing.

Ageing of textile materials at room temperature is a slow deterioration or improvement in the mechanical properties of materials, caused by intrinsic instability or by normal atmospheric action.

Some of the causes are crystallization, separation, crosslinking and oxidation. Ageing of materials can be accelerated by heating or by combined heat and oxygen.

I. Air ageing (heat ageing): the textile sample is exposed for a set time in an oven at a temperature of 70°C.

II. Oxygen-pressure ageing: the textile sample is exposed for a set time in a chamber at a pressure of 200 N/cm^2 and a temperature of 70°C.

The ageing time will be chosen according to the purpose of the test. The recommended times are 1, 2, 4, 8, 14 days etc. (DIN 53 896).

Age-related erythropsia A normal phenomenon in persons over approx. 40 years of age who tend to see all shades redder than younger persons. Age-related erythropsia is not to be regarded as a form of → Defective colour vision, although it can lead to problems in colour matching.

Agglomerate (Lat. *agglomerare* = to form into a ball) A combination or → Aggregation of colloidal particles, molecules, ions, dyes, particulate dirt, etc., in the form of clusters of approximately spherical shape.

Agglomeration The tendency to form → Agglomerates, resp. → Associates, e.g. the agglomeration of dye molecules which results in unsatisfactory dye levelling, especially with vat and disperse dyes. The problem is minimized by special dyeing methods or the use of levelling agents.

Aggregate,
I. material state (solid, liquid, gaseous).
II. assemblage of several separate units.
III. → Aggregation.

Aggregate Dyestuff occurs in, amongst other things, flat bed screen printing due to surplus dye paste passing through the screen. The dye paste is not adsorbed by the substrate during the squeegee process, but nevertheless ends up on the printed goods when the screen is lifted and causes dyestuff aggregation there.

Aggregation (Lat. *aggregare* = to attach to), chemical association of dissimilar molecules to form molecular associates, e.g. as occurs typically between dyes and levelling agents which possess dye-affinity.

Aggregation number Number of molecules in an → Aggregate. → Association value.

Aglycone Non sugar component of → Glycoside, mostly containing hydroxy (alcohols/phenols) or containing nitrogen (amines).

AGV, (Ger.) abbrev. for: Arbeitsgemeinschaft der Verbraucherverbände (Study Group of the German Consumers' Association); → Technical and professional organizations.

AI, abbrev. for: → Artificial intelligence.

AIC, abbrev. for: American Institute of Chemists → Technical and professional organizations.

AIChE, abbrev. for: American Institute of Chemical Engineers.

AICQ, (It.) abbrev. for: Associazione Italiana per il Controllo della Qualità, Milano (Italian Society for Quality Control), member of the → EODQ; → Technical and professional organizations.

AICTC, (It.) abbrev. for: Associazione Italiana di Chimica Tessile e Coloristica, Milano (Italian Association of Textile Chemists and Colorists); → Technical and professional organizations.

Aida canvas Coarse yarn, openwork, highly chemically finished woven fabric (cotton, viscose filament), also double weave consisting of 2–3 layers (and often patterned on both sides), in so-called mock leno or shoe canvas weave. Used as ground fabric for embroidery, runners, table cloths etc. A small gap occurs after every 4th longitudinal or transverse end due to counter-construction and relevant denting. The fabric is already considerably strengthened in finishing so that Aida can be more easily embroidered. Natte is the collective term under which the Aida weave is to be found; they reveal the chequered Panama surface all the more clearly.

Aids International, abbrev. for: Association of Interior Decor Specialists. Formed in 1972 out of the NIRC as an international association of "interior cleaning specialists" for home textiles with departments for the cleaning of carpets, fitted carpets, upholstery, drapes and fire damage limitation. Centres: Aids International (USA), Arlington (technical journal "Voice"), and Aids International (Deutschland), Hamburg (technical journal "Stimme"); → Technical and professional organizations.

AIF, (Ger.) abbrev. for: Arbeitsgemeinschaft Industrieller Forschungsvereinigung e.V. (German Study Group of Industrial Research Associations); → Technical and professional organizations.

AIIE, abbrev. for: American Institute of Industrial Engineers → Technical and professional organizations.

AIM, (Ger.) abbrev. for: Arbeits-Ist-Minute bei Zeittesten (work clock minute in time testing).

AIME, abbrev. for: American Institute of Mechanical Engineers → Technical and professional organizations.

AIP, abbrev. for: American Institute of Physics → Technical and professional organizations.

Air → Atmospheric air.

Air as a textile finishing medium Air is used in textile finishing applications as a substitute for water or in combination with water (air/water mixture):

1. Foam application in finishing and carpet backcoating as well as textile printing (e.g. pigment printing in areas of high coverage).
2. In the drying of textiles as a medium for absorbing water vapour and conducting it away from the surface of the textile material.
3. As a means of maintaining textile fabrics in the open state during open-width washing, e.g. Flainox and MAT machines (Fig. 1).

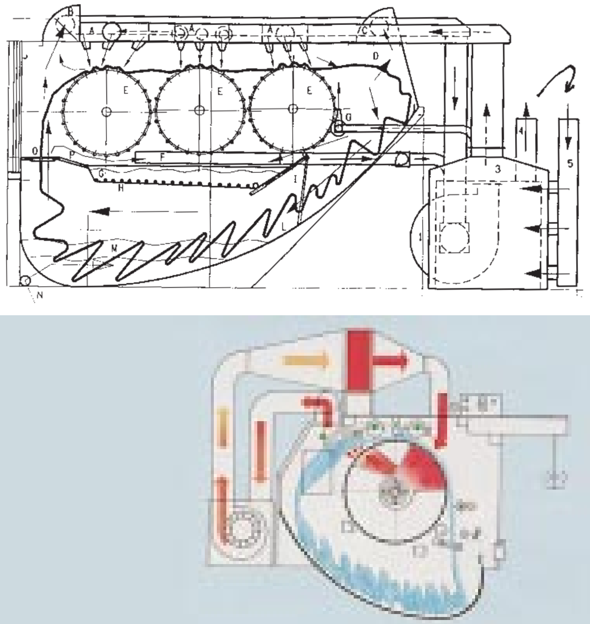


Fig. 1: Open-width scouring machines for woven fabrics width controlled by airflow (Flainox and MAT).

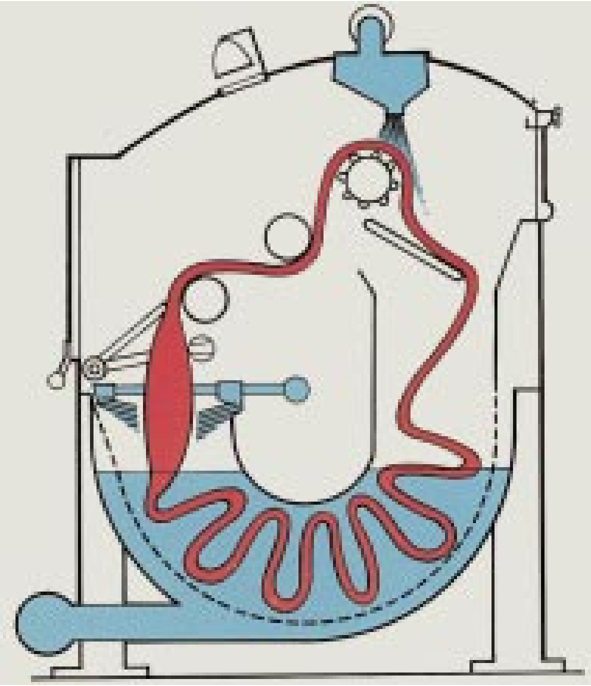


Fig. 2: Béné-Flow with fabric ballooning by air inclusion (similar to Krantz Blow-Dye).

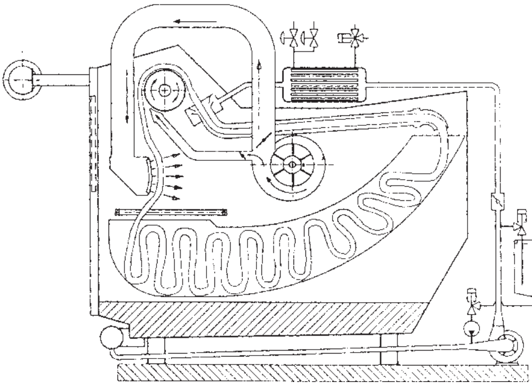


Fig. 3: Blowing unit in the dyeing machine for fabric laying (Flainox).

4. In dyeing to promote the shifting of fabric creases by “ballooning” (Figs. 2 + 3), or as a fabric transport medium in the “Aero-Dye” system (Krantz) (Fig. 4) and the “Airflow” system (Then) as well as the Raco-Yet principle (Ramisch-Kleinewefers) for the production of aerosols besides, e.g. the SuperSoft-Air-Tech process of Longclose (Fig. 5) for the uptake of aerosols containing dyes and levelling agents by the material.

A unique machine for the application of air as a transport medium is the “Airo 1000” machine from Biancalani (Fig. 6). The endless ropes of fabric which have been sewn together are propelled in an upwards direction by (hot or cold) air (up to 1000 m/min.) in 2 diago-

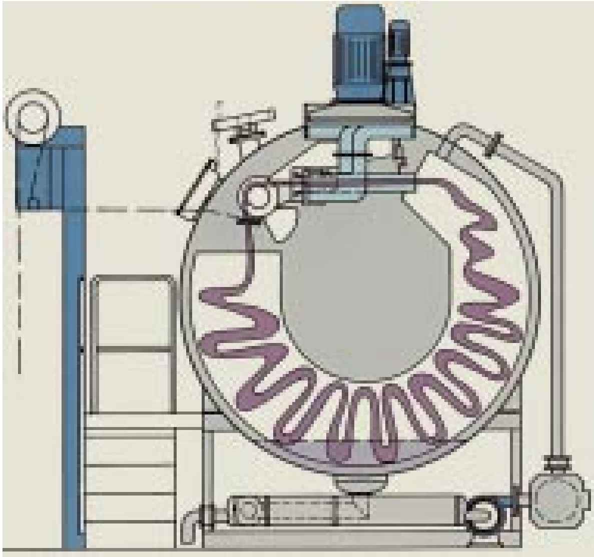


Fig. 4: “Aero-Dye” with fabric transport by air (Krantz).

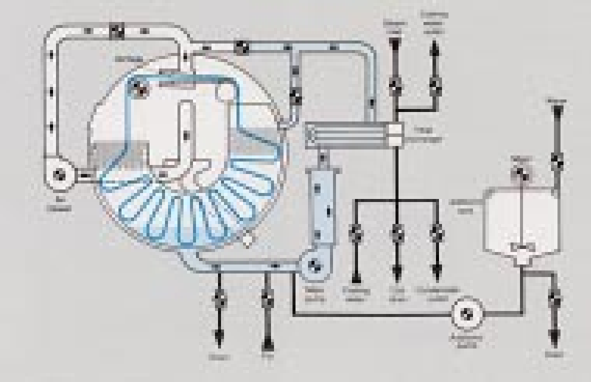


Fig. 5: SuperSoft-Air-Tech with fabric transport by air (Longclose).

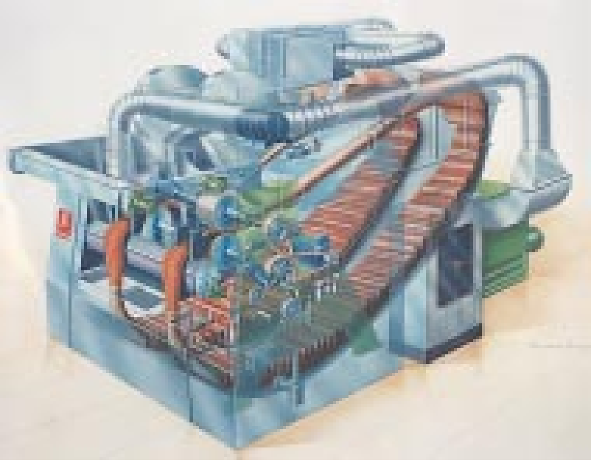


Fig. 6: “Airo 1000” rope treatment machine (Biancalani) with the use of air as a finishing medium.

nally arranged channels. Behind these channels is a baffle plate from which the fabric is again transported via a rope scray into the front section of the machine. The fabric is relaxed by the intensive mechanical action which gives the material a soft handle. The machine may also be used for carrying out chemical treatments such as wool carbonizing or enzyme treatments.

Air-balloon system English term by Calator for air injection for the untwisting and crease-free ballooning of tubular knitted fabrics.

Air blade →: Air knife; Squeegee.

Air blanket in dyeing machines An air pressure blanket created by compressed air and positioned above the dyebath is employed in some yarn and piece dyeing machines to reduce the liquor-to-goods ratio and prevent boiling of the liquor (see Fig.). Pump cavitation is also avoided by this means.

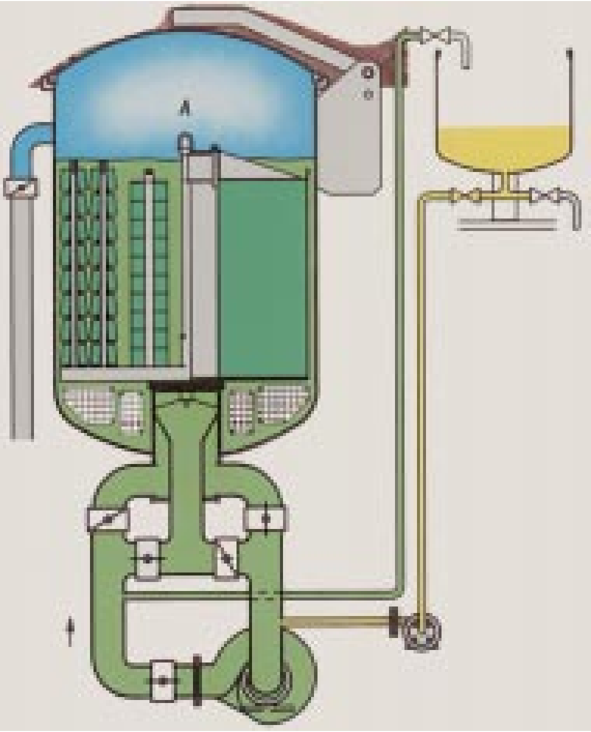


Fig.: Pressure cushion (A) by means of compressed air above the dye liquor in a yarn dyeing machine.

Air bottle A vessel used to determine the → Air content in steamers.

Air bubbling Blowing air into HT beam dyeing machines in order to accelerate the dyeing process (L. Svenson, Kinna/Sweden patent).

Air conditioning,

I. Setting defined temperature and humidity conditions in rooms by means of air conditioning equipment. This is particularly important in the textile sector, as almost all textile raw materials react sensitively to variations in temperature and humidity. The so-called standard climate for laboratory premises has therefore been laid down in DIN 53 802 at 65 ± 2% relative humidity and 20 ± 2°C room temperature.

II. By the air conditioning of textile (fibre) material is meant its adjustment to specific climatic conditions. This takes place by absorption (from a lower to a higher moisture content) or desorption (from a higher to a lower moisture content), the textile moisture content being dependent on which of the two routes is selected (hysteresis). Test specimens for textile testing should basically be brought to the standard condition by absorption.

Air conditioning plants are used to produce desired conditions of air humidity and temperature in closed rooms automatically, e.g. spinning plants, weaving sheds and storage facilities. Air conditioning plants must be equipped with systems for cleaning, warming, cooling, humidifying and possibly dehumidifying the incoming air which comply with VDI ventilation regulations so that any desired climatic conditions can be produced and maintained irrespective of the outside temperature and moisture (see Fig.).

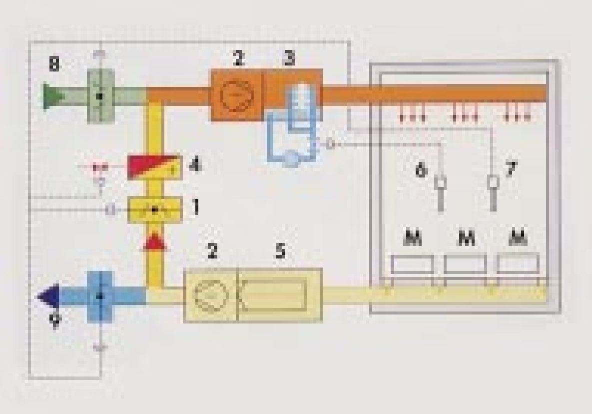


Fig.: Air conditioning plant diagram.
M = textile machine; 1 = control flap; 2 = fan;
3 = air washer; 4 = air heater; 5 = exhaust air filter;
6 = moisture sensor; 7 = temperature sensor; 8 = supply air;
9 = exhaust air.

Air conduction in textile driers The ducting of air flows in drying machines is an important factor in energy consumption. The total air circulation in a drier consists of that portion which, as moist air, is discharged as exhaust air and that portion which is reheated after passing through a heat exchanger (see Fig.). The latter should be as large as possible in the conception of a drying machine.

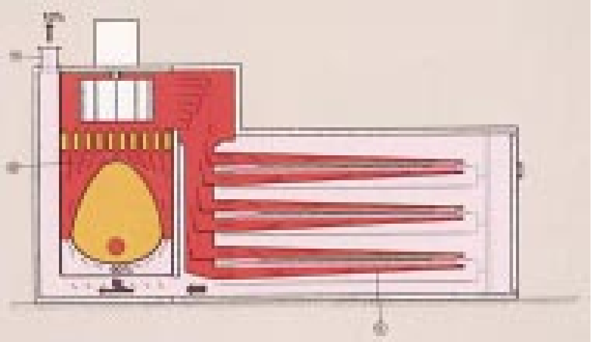


Fig.: Air control in the Monti shrink dryer.
8 = hot airflow on the fabric; 11 = moist, cooled air exhaust (pink); 12 = heat exchanger with freshly heated air (red).

Air content in steamers The generation of air-free steam is of general importance with regard to the production of highly saturated steam, as generally preferred for optimum dye fixation, but which is disrupted by the presence of other gases. It is, however, especially important in the fixation of vat dye prints due to the oxidative effect of atmospheric oxygen. It is for this reason that the determination of air content in a steamer is an important means of preventing inadequate dye fixation. A simple method employs a so-called air bottle (Fig. 1) filled with water and connected to a side opening of the steamer by means of a flexible tube. When the steamer is heated up to operating temperature, water drains off slowly through a tube (7) and forms a slight underpressure in the bottle (6). A portion of the steam atmosphere is drawn into the bottle (6) via the flexible tube connection (3, 4, 5). The water vapour component condenses in the cold water contained in the bottle (6) whilst the air component escapes at point "X" from the tube (5) clearly visible in the form of bubbles and collects in the upper part of the bottle (6).

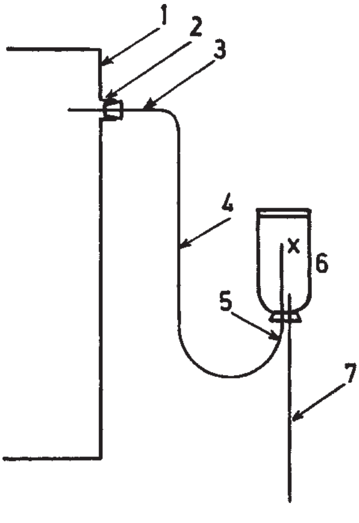


Fig. 1: Qualitative air indication.

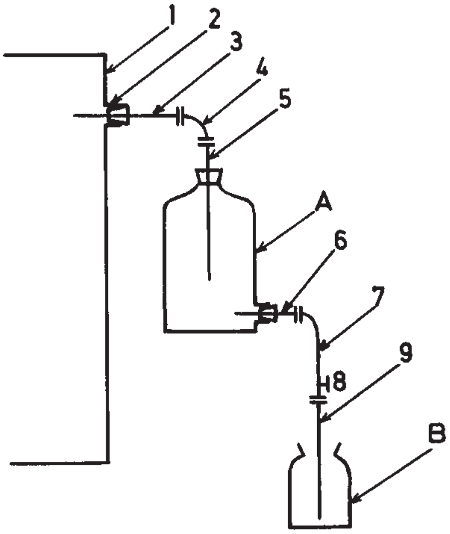


Fig. 2: Quantitative air indication.

The tube (7) is at least 350 mm long and of small diameter so that no air bubbles can flow back through the tube. Quantitative determinations are also possible by this means (Fig. 2).

Air detection → Air content in steamers.

Air dryer → Conveyor drier.

Air drying of textiles is carried out in the open (so-called drying rooms), with the goods suspended by hanging over rods or wooden slats, or on frames. It is the simplest and most gentle method of drying and involves no energy consumption.

Air-entangled yarns A process of Akzo Faser AG may be taken as an example of an environmentally-friendly concept in which draw-winding machines deliver filament yarns without protective twist on cross-wound packages (Fig. 1). The required yarn cohesion is achieved by air-entanglement. This process produces yarn with a high degree of stability due to the

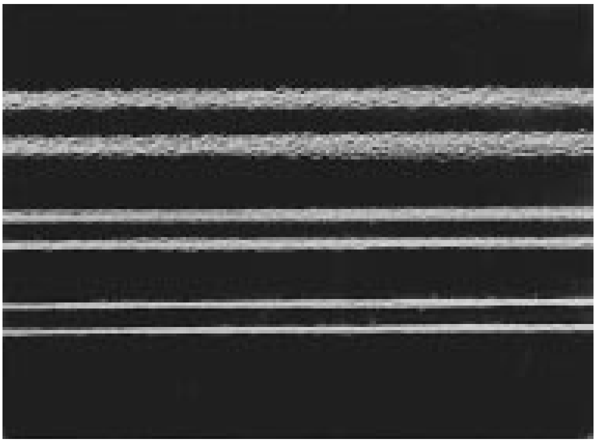


Fig. 1: Textured polyester yarn (76 dtex f 36 mt) not tangled (Akzo).

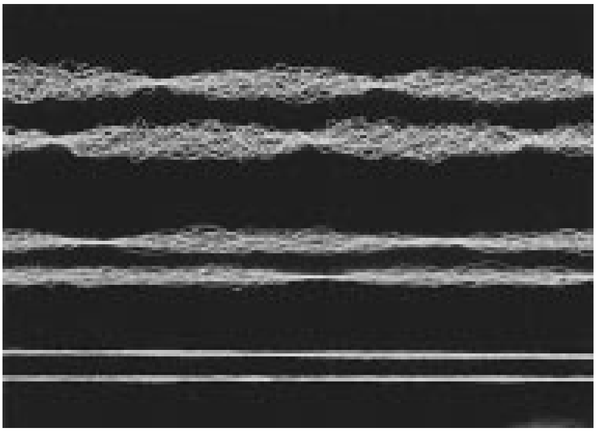


Fig. 2: Textured polyester yarn (76 dtex f 36 mt) tangled (Akzo).

introduction of intermingling points or knots which occur at intervals of 8–10 mm (Fig. 2). Depending on the yarn density in weaving, air-entangled flat yarns as well as textured yarns do not require sizing. The intermingling points should not, of course, remain visible in the final fabric. For this reason, in finishing, where no desizing is necessary, the fabric is heat set (30 s at 190–210°C) so that the fibres shrink and the intermingling points are smoothed out (disentangled). On no account must the intermingling points or knots come undone before finishing especially as a result of the tensile strains to which the yarn is subjected during fabric formation.This method of production, considered through all its production stages, offers clear environmental advantages since fabrics produced with air-entangled yarns require neither sizing nor desizing.

Air filter Generally a component of → Air conditioning plants to facilitate the wet or dry precipitation of airborne impurities (air scrubber).

Airflow Then piece dyeing machine on the → Aerodynamic principle, with 1–6 storage compartments, each of 180 kg nominal capacity, large savings in water and steam consumption, a high degree of reproducibility, no foaming, simple recipe transfer. Then started development of the “Then Airflow” in 1979. This machine is based on the first time use of the principle of propelling the fabric by means of an airstream, to which finely dispersed dyes and auxiliary products are fed via jet systems. This new and now patented development was pushed ahead in conjunction with Hoechst AG; it also precedes the patented process comprising fabric propulsion by means of a vapour flow.

The fabric rests above the liquor level in a store furnished with Teflon bars. It is fed to the air jet via a feed winch, and then distributed in the store with or without a plaiter. Fabric speeds well beyond 600 m/min, with a peak of even 1000 m/min, can be attained, and even in liquor dropping operations the fabric can be kept in motion with no liquor flow. The injection system constantly sucks the liquor from the store, distributing it under controlled temperature on to the fabric through suitable nozzles. Dyes and auxiliary agents, dosed in quantity as required, are also sprayed.

The Airflow-System provides the following advantages:
- shortened dyeing time,
- shorter liquor ratio with consequent water and heat energy savings,
- salt, chemical and auxiliary product savings,
- a bulkier fabric due to the airflow,
- high circulation speed,
- problem-free fabric run.

Typical of the Airflow principle is the simultaneous use of a gas stream with treatment medium injection, and, after contact with the textile fabric, the separate return of the gas flow and part of the treatment bath depending on the quantity injected as the case may be (Fig. 1).

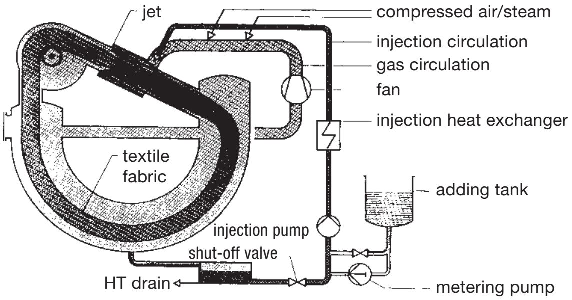


Fig. 1: Then Airflow aerodynamic system connection diagram.

The gas circulation maintains the circulatory fabric motion, the feed action being created by the fan. The gas flow is fed and contact made with the textile fabric in the jet zone, fabric movement being independent of the textile fabric moisture charge. The injection system is connected to the gas circulation. Due to the direct introduction and atomisation of the liquid treatment media in the gas flow, these are distributed in the textile fabric by contact with the gases in the jet zone, i.e. the atomised liquid condenses on the fabric, and is distributed in it. This function breaks down into:
- feeding the treatment bath from the adding tank with closed cut-off unit,
- feeding a treatment medium from the adding tank into the injection circuit via a metering pump,
- the injection circuit with no adding tank connection.

With the 3 basic connections of the injection system to the gas circulation, the main treatment stages of a finishing process can be implemented together with rins-

Air-flow doctor blade system

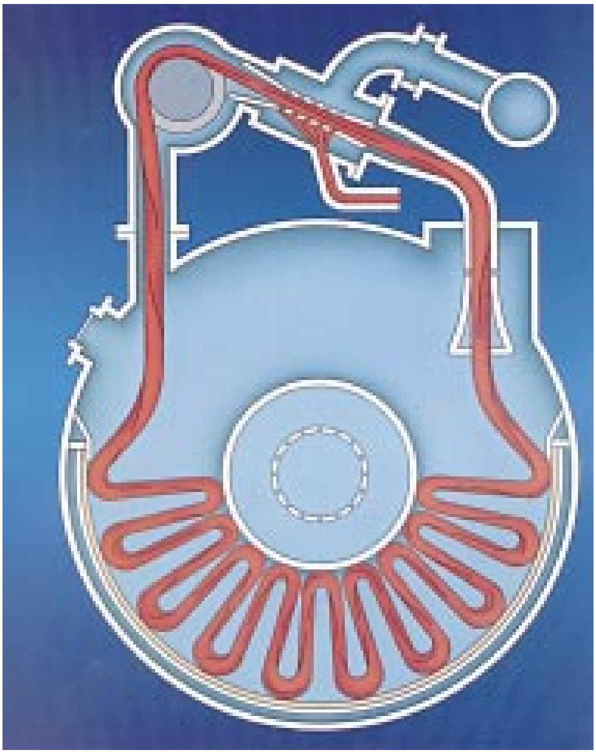


Fig. 2: Then Airflow AFS.

ing processes. The constant loading of the textile fabric in the jet zone is denoted by the density of hatching in Fig. 1. The moisture uptake of the textile fabric is determined by contact and the distribution of a specified treatment bath quantity over the circulating gas flow. The max. liquor uptake of the textile fabric, i.e. the fabric retention capacity, is therefore dependent on the fibre material, the nature of the product – such as yarn, type of construction and density – and the viscosity of the treatment liquor for example. A state of equilibrium of this type occurs in a very short time with the fabric circulating in the treatment vessel with the injection system in operation. The liquor charge due to the injection flow is therefore interchanged with the liquor proportion in the textile fabric, volume interchange being aided by the force effect of the fabric drive in the jet zone. This produces a faster concentration interchange.

Since 1991, Then has built with the Airflow AFS a simplified handling system (Fig. 2) as compared with the AF (Fig. 4) and AFT as the latest version (Fig. 3).

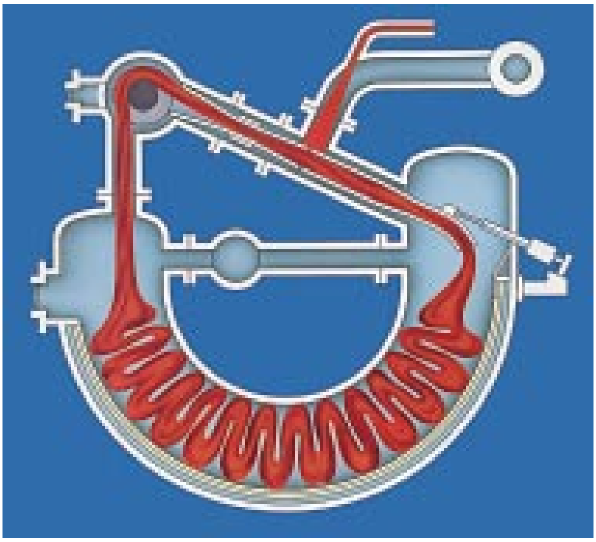


Fig. 4: Then Airflow AF.

Air-flow doctor blade system Steel doctor blade system with a plastic profile making possible precise control of colour paste application and penetration during printing by independent adjustment of doctor blade angle and contact pressure (Fig.).

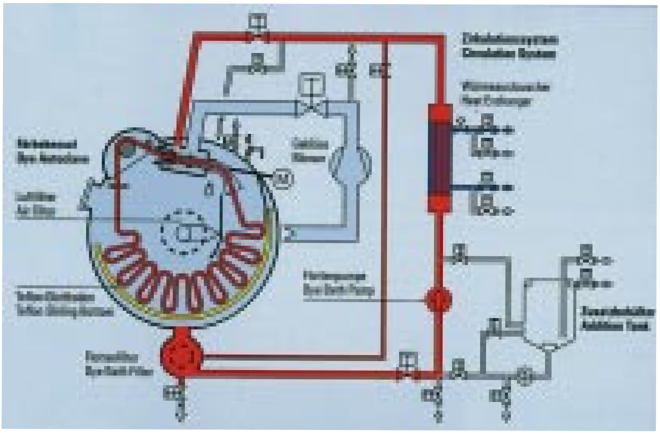


Fig. 3: Then Airflow AFT.

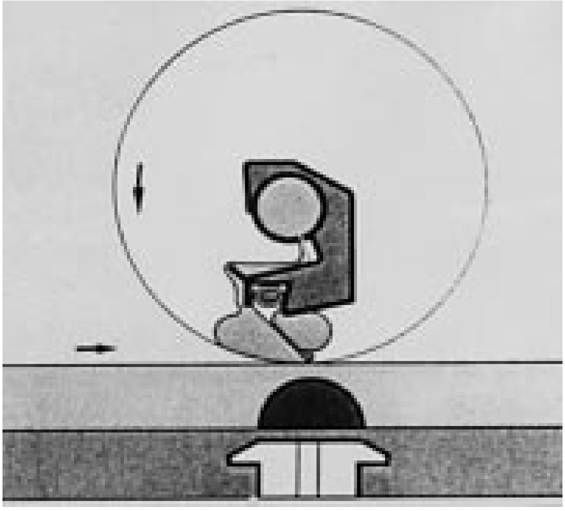


Fig.: Stork Airflow doctor blade.

This results in greater printing precision. The plastic profile ensures uniform printing across the entire fabric width, while computer controlled automatic pre-registration simplifies machine operation. – H. Stork.

Air humidification Achieved by using a water spray or atomizer (→ Air conditioning plants). A centrifugal atomizer installed within an air duct of up to 2 m diameter can, for example, humidify the air passing though it with a very finely dispersed spray of water droplets (see Fig.).

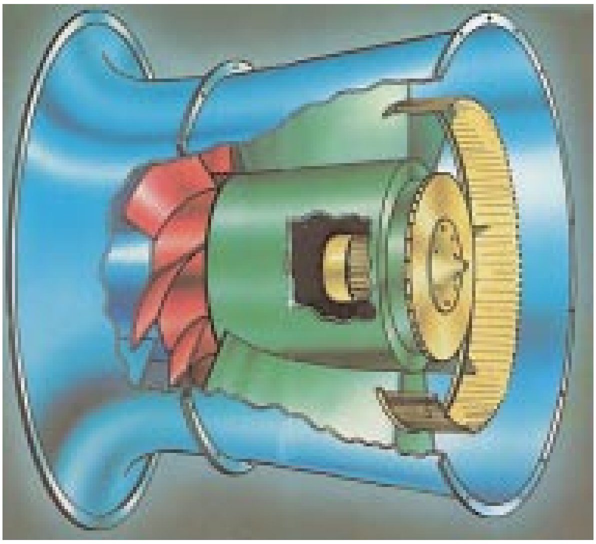


Fig.: Centrifugal atomiser for air humidification (Prött).

Air humidity A distinction is made between:

I. Absolute humidity: i.e. the complete temperature-dependent saturation of air with water with the water content expressed in g/m^3 of air (Table 1).

°C	g/m^3	°C	g/m^3
0	4,85	40	51,12
5	6,80	50	82,98
10	9,41	60	129,81
20	17,32	80	290,80
30	30,39	100	580,00

Tab. 1: Absolute air humidity.

II. Relative humidity: the ratio of the actual vapour pressure of moisture in air to the saturation vapour pressure at ambient temperature. Air saturated with water vapour at a specific temperature is therefore always of 100% relative humidity and corresponds to the values given in Table 1, e.g. as occurs in predominantly foggy weather. In dry weather conditions or in heated rooms, however, this degree of saturation is never reached and such unsaturated air then has a humidity below 100%. If, for example, the relative humidity at 20°C amounts to 60% then this will correspond (see Table 1) to only 10,39 g/m^3 instead of 17,32 g/m^3 (absolute humidity), i.e. a saturation "deficit" of 40% humidity or 17,32 – 10,39 = 6,93 g/m^3 of water. The relative humidity must always be considered in relation to the specific temperature at which it is measured since the same relative humidities correspond to different absolute water content values at different temperatures (Table 2).

% r. H.	20 °C	25 °C	30 °C	40 °C
40	0,007	0,009	0,012	0,020
50	0,009	0,012	0,015	0,025
60	0,010	0,014	0,018	0,031
70	0,012	0,016	0,021	0,036
80	0,014	0,019	0,024	0,041
90	0,016	0,021	0,027	0,046
100	0,017	0,023	0,030	0,051

Tab. 2: Relative air humidity in g/m^3 at different temperatures.

III. Specific humidity: expressed as the water vapour content in g/kg of air.

IV. Normal humidity: in Central Europe this corresponds to the daily mean of approx. 65% relative humidity at mid-year.

V. Standard atmospheric conditions: In DIN 53 802 the standard atmospheric conditions for textile testing are specified as 65 ± 2% relative humidity at a room temperature of 20 ± 2°C.

Air injection dyeing A dyeing procedure employed in beam dyeing machines which involves the injection of fine bubbles of air in order to reach dead zones in the yarn package and disperse the air contained therein.

Air jet spinning was developed by the Japanese firm of Murata. The roving is fed directly to the spinning machine through a drawing frame into the spinning zone in which two air jets are arranged one behind the other (Fig.). In the first jet the yarn is given a false twist effect that is untwisted by the second jet. Hence the conditions are similar to those of an OE spinning process. With this process fine yarns can be spun at high velocity. The yarn is wound directly onto bobbins. In this system pre-spinning as well as subsequent winding operations are eliminated. The yarn produced has better breaking strength than rotor spun yarn (80–90% of ring spun), is more even that ring spun yarn and less hairy, but is somewhat harder in handle. The process is not suitable for all spun fibres as a minimum fibre length is necessary.

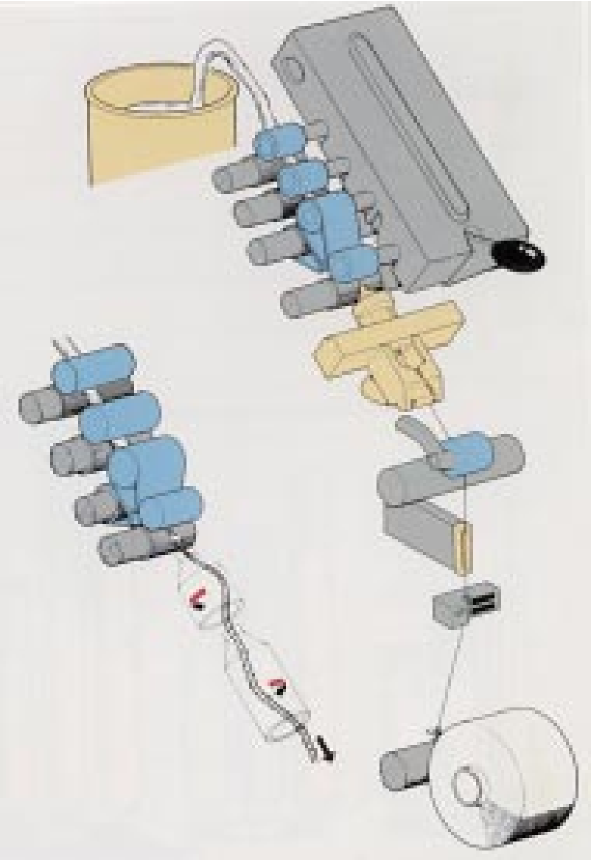


Fig.: Air jet spinning.
Left: arrangement of drawing frame and jets; right: flow of material from roving to the bobbin.

Air-jet texturing → Texturizing.

Air jet weaving machines An intermittently directed stream of compressed air, with or without additional air jets (via relay nozzles), serves as the weft insertion medium by conveying tweft yarn through the shed (see Fig.).

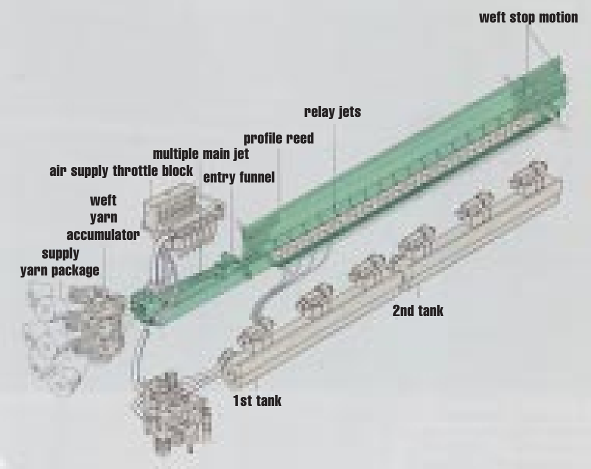


Fig.: 6-colour weft insertion system on the Dornier air jet weaving machine.

Weft yarn reaches the multiple main jet via a self-threading weft accumulator. The main air jet is electronically controlled so as to give maximum energy transmission with minimum air consumption for the correct acceleration of each pick. For optimum economy, the start and end of the air blast is controlled in accordance with the yarn flight time. Yarn quality differences are consequently balanced out during weft insertion. Since air pressure is monitored at the point of compressed air supply, the machine can be automatically stopped if the air pressure falls below an adjustable level. Centering of up to 6 different weft packages is achieved by means of a fixed feed system and a conical comb. Relay jets insert the weft yarn across the entire fabric width. These are electronically controlled and, in conjunction with an integrated database, the reliable and simultaneous weft insertion of different as well as multiple yarns is assured. The compressed air supply to the relay jets is taken from 2 tanks so that different air pressures can be selected for savings in air consumption. Horizontal or vertical tensioning jets for staple and filament yarns guarantee low weft wastage and clean selvedges. The sensitivity of both weft detectors is controlled pick and pick according to the thickness and lightness of the weft yarns. The weft insertion systems, as well as all other functions, are controlled by multiprocessor technology.

Air knife A paste application system used in coating. The blade (see Fig.) applies a coating paste to the free-running fabric web, i.e. without support from underneath (the fabric web is maintained under tension by passing over one roller located in front of, and one roller behind, the knife contact area).

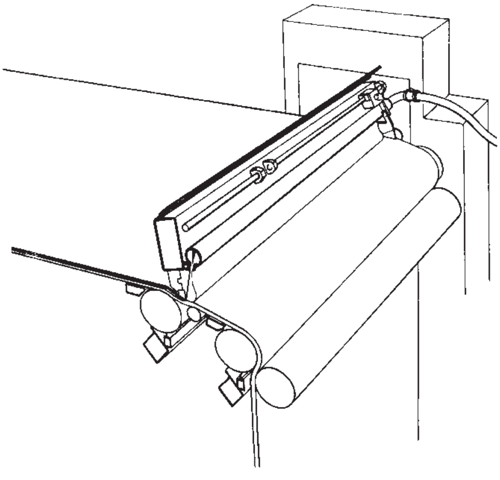


Fig.: Air knife coating technology, suitable for paste application.

Air laces These are etched-out products (burnt-out products) produced without printing. Yarns are embroidered on to a ground fabric which is then burnt out in subsequent after-treatment. Cotton, silk or synthetic fibres for example can be embroidered on to acetate ground fabrics, and the woven acetate fabric then dissolved out with acetone. The process is expensive and intricate, for which reason only simple etched-out products are produced as a rule.

Airo-1000 washing machine A rope washing machine developed by Biancalani in which the rope of fabric is transported by hot air through an upwards directed tube against a baffle plate. Very high circulation speeds are achieved by this means with optimum transport of the fabric rope.

Air pad batch This is a cold pad batch process for dyeing tubular knitgoods of cotton or other cellulosic fibres with reactive dyes. The principle is based on air injection using jets of compressed air → Air balloon system (Air-Tex technology) to prevent fold creases in the tubular fabric. Balloon formation occurs between the pad trough and the padder nip. After squeezing, the padded goods are batched on a roll and allowed to rotate for the required time of dyeing.

Air permeability An important performance requirement for impregnated, coated and metallized water-repellent apparel fabrics. The opposite requirement is placed on e.g. tent, balloon and parachute fabrics. Quantitative relationships exist between air permeability and → Porosity. The same applies between both terms and the skin breathability of a particular apparel fabric. The term “breathable fabrics” is used for, e.g. impregnated rainproof clothing which still possesses a certain permeability to air and water vapour (both directly proportional) even in the wet state, thereby avoiding the retention of heat, moisture and perspiration which promotes a degree of moisture and temperature regulation in the air environment next to the body thus favouring the natural transport of air. A certain relationship also exists, of course, in the case of non-impregnated, but preferably hydrophobic, low or non-swelling textiles composed of synthetic fibres between air permeability and the drying properties. The same applies to textiles with a swelling-resistant finish in the wet state. →: Breathability; Air permeability of textile fabrics; Air permeability tester.

Air permeability of textile fabrics The air permeability of textile fabrics (DIN 53 887) ranges between 1000 and 7000 l/h for wool articles depending on their construction. With increasing yarn fineness (20–100 tex) the air permeability decreases by twisting different numbers of yarns together. The degree of twist (measured by the coefficient of twist α_z = 90–140) has less influence on air permeability than the twist direction of ply yarns: fabrics produced with Z-twist yarns have higher air permeability values than those with S-twist. Yarn density (number of threads per cm of warp resp. weft), i.e. fabric density, likewise has a great influence on the permeability. The air permeability of fabrics increases sharply with the reciprocal of the square of the yarn density (1000–4000 l/h). With the same yarn density, the air permeability for plain weave fabric is relatively low (loomstate: 2500 l/h; finished: 1000 l/h) and higher for twill weave fabric (finished: 2000–3500 l/h). However, the influence of weave type is only slight with similar fabric densities. The air permeability of twill fabrics decreases considerably after finishing (2/2 twill by a half; 1/7 twill from 6000 to 4000 l/h) (Vesper).

Air permeability tester Apparatus for testing the → Air permeability (Schopper or Pohl-Schmidt method) of textile fabrics by suction of air through a restrained textile test specimen.

Evaluation by measurement of the air pressure as indicated by a manometer.

Another instrument is the Shirley Air Permeability Tester which uses a compressed air source and is suitable for carrying out tests in accordance with BS 5636: 1990.

Air pollution, is caused by changes in the natural composition of atmospheric air due, in particular, to the presence of smoke, soot, dust, gases, aerosols, vapours or foul-smelling substances. → Exhaust air problems in textile finishing.

Air pressure (gas pressure) A distinction is made between:

I. low pressure: → Vacuum.

II. standard pressure: 1,0133 bar.

III. overpressure: → Pressure above atmospheric pressure (standard pressure).

Air pumps (compressed air pumps) → Compressors.

Air recirculation in drying machines involves the recirculation of dry air within the drying machine (see Fig.) as a result of which optimum utilization of drying energy is assured. This performance-enhancing

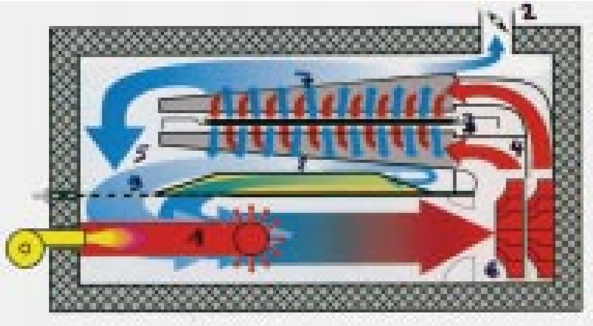


Fig.: Process control in the drying process in a circulating air stenter (Monforts) with twin-air-system.
1 = bare tube heat exchanger air/air; 2 = exhaust stubs with control flaps; 3 = woven fabric selvedge guiding; 4 = circulating air heated by gas burner; 5 = circulating air; 6 = fan; 7 = upper nozzle system; 8 = lower nozzle system; 9 = air filter screens.

and energy-saving process can be applied, quite independently of the ventilating system, to all driers based on the air circulation principle which contain several drying zones with separate heating and control systems. The process offers the maximum advantage when the fresh air is applied by counter-current flow (e.g. in a sieve drum drier). If, on the other hand, the drier is sectioned off into several zones with one exhaust air duct each, the drier must be operated with reduced quantities of exhaust air in the zones where the second drying phase takes place to avoid damaging the textile material (= higher energy losses through exhaust air).

Air retentivity By this term is meant all the forces existing in a garment which participate in retaining the layer of air which is in close contact with the human body even under stormy weather conditions. This layer of air is an outstanding warmth retaining medium. Measurement of air retentivity involves the analysis of a gas (carbon dioxide) in contact with a textile material and its displacement by a an entirely uniform flowing second gas (oxygen or nitrogen). Both the time taken for the first gas to be displaced as well as the amounts of gas displaced at specific time intervals are determined. Packing density and fibre weight must also be taken into consideration.

Air technology Collective term which includes refrigeration, climate, drying, dust removal and associated energy savings.

AIS, (Fr.) abbrev. for:

I. Association Internationale de la Savonnerie (International Association of Detergent Manufacturers).

II. Association Internationale de la Soie (International Silk Association).

AISI, abbrev. for industrial standards of the American Iron and Steel Institute.

AITIT, (Fr.) abbrev. for: Association Internationale de la Teinture et de l'Impression Textiles (European Association of Textile Dyers, Printers and Finishers); → Technical and professional organizations.

À jour fabrics Open-work woven or knitted fabrics produced with fine yarns. The open-work effects (holes) are due to the fabric construction. In woven varieties the ground is of plain weave and the open areas of leno weave construction. Used for dress materials and curtaining.

Ak, → Angora, → Standard abbrev. for textile fibres, according to DIN 60 001 until 1988. From 1991 → WA.

Akund (Asclepias fibre, Calotropis floss) A natural cellulosic fibre belonging to the → Vegetable hairs group. Seed hairs of the Asclepias type (Africa, Asia, Central and South America). Similar to the → Kapok fibre, it grows up to 50 mm in length. Akund is yellowish in colour, smooth, silklike, and lustrous but coarser and stiffer than kapok, very lignified, of low extensibility and slightly brittle. Main uses are for stuffing upholstery or braids. Seldom spun or blended. The fibre may be distinguished from cotton by zinc chlor-iodide solution = yellow staining.

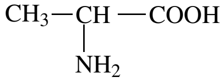
AL,

I. → Alfa grass, → Standard abbrev. for textile fibres according to DIN 60 001 T4/08.91.

II. → Alginate fibre, → Standard abbrev. for textile fibres according to DIN 60 001 until 1988. From 1991 → ALG.

Al, chemical symbol for → Aluminium (13).

Alanine, is an amino acid (monoaminomonocarboxylic acid) present e.g. in wool (4,4%) and silk (24,5%).



$$CH_3-\underset{NH_2}{\underset{|}{CH}}-COOH$$

Alarm and indicating equipment operating on a variety of principles, e.g. bimetal pulse generators or photocells. Used for safety and alarm purposes, triggering a visual display (e.g. red light) or emitting an acoustic warning when optimum operating conditions are exceeded or for automatic fire or intruder protection systems.

Albumen (albumin) Protein from animals (egg, blood, fish and milk albumens) or vegetable sources (soya). Albumens are water soluble, coagulated by heat, and can be salted out from their solutions by ammonium sulphate in the presence of alkali. Their former importance as printing thickeners and fixing agents in textile printing and finishing has greatly declined.

Alcantara Artificial leather consisting of 60% polyester and 40% polyurethane. It is manufactured from extremely fine polyester fibres (0,1 dtex, Ø 4 µm) which are bonded in polystyrene (matrix-fibril fibres), then processed into needle-punched felts and impregnated with polyurethane. Finally the polystyrene matrix is removed with dimethyl formamide so that the fibrils have relative freedom to move in the entire system. Properties: considerably lighter in comparison to natural leather (0,135 g/cm^3), crease-resistant and washable. Uses: clothing sector and the shoe industry.

Alcoholates Derived from → Alcohols in which the H atom of the –OH group is substituted by → Alkali metal. For example from ethanol (ethyl alcohol) C_2H_5-OH comes ethyl alcoholate (Sodium ethoxide) C_2H_5-ONa. Alcoholates react with water (humidity) to form the original alcohol and metal hydroxide, e.g.

$$R\text{-}ONa + H_2O \rightarrow R\text{-}OH + NaOH$$

A well known higher molecular alcoholate is → Soda cellulose. Alcoholates also play a role as alkylating agents in the preparation of acyclic compounds. → Metal alcoholates.

Alcohols (Arab.) contain the OH-group. They are the OH-substituted products of the corresponding hydrocarbons; alcohols may be divided into aliphatic and aromatic according to the type of hydrocarbon → Synthesis alcohols.

I. Aliphatic alcohols: formula C_nH_{2n+1}–OH. By far the largest and most important group of alcohols. They can be classified in various ways:

a) by the saturation of the hydrocarbon:

	Formula	Example	
Saturated alcohols (alkanols)	$C_nH_{(2n+1)}OH$	CH_3OH methyl alc.	$C_{18}H_{37}OH$ stearyl alc.
Unsaturated alcohols (alkenols)	$C_nH_{(2n-1)}OH$	$C_{18}H_{35}OH$ oleyl alc.	

b) by the number of OH-groups (functionality):

	Formula	nomenclature
monofunctional alcohols	$\underset{OH}{CH_3}$ methanol	C1-18 homologous series, see below
difunctional alcohols (diols)	$\underset{OH}{CH_2}–\underset{OH}{CH_2}$ glycol	after glycol (diol), the simplest member of the series
trifunctional alcohols (triols)	$\underset{OH}{CH_2}–\underset{OH}{CH}–\underset{OH}{CH_2}$ Glycerine	after glycerine or triol, the simplest member of the series
4-6 functional alcohols	$\underset{OH}{CH_2}–\underset{OH}{CH}–\underset{OH}{CH}–\underset{OH}{CH}–\underset{OH}{CH}–\underset{OH}{CH_2}$ sorbitol, mannitol	sugar alcohols, because of their relationship to sugars
polyfunctional alcohols	$CH_2–\underset{OH}{CH}–\left[CH_2–\underset{OH}{CH}\right]_x–CH_2$ polyvinyl alcohol	polyalcohols, polyglycols, polyglycerines, etc

c) by the type of end group:

	Formula	Example
primary alcohols	$R\text{-}CH_2OH$	CH_3CH_2OH ethanol
secondary alcohols	$R_{2\text{-}}CHOH$	$(CH_3)_2CHOH$ isopropanol
tertiary alcohols	$R_3\text{-}COH$	$(CH_3)_3COH$ tertiary butanol

The very low alcohols with $C_{1\text{-}3}$ are fluid liquids, $C_{4\text{-}12}$ are oily liquids, but the higher alcohols are solid waxes at normal temperatures and have no smell. The lower and middle alcohols, apart from their use as intermediate products, are important commercial solvents and components of a great many textile auxiliaries of various types, e.g. the saturated, monofunctional homologous series:

CH_3–OH	→	methanol (methyl alcohol)
C_2H_5–OH	→	ethanol (ethyl alcohol)
C_3H_7–OH	→	propanol (propyl alcohol)
C_4H_9–OH	→	butanol (butyl alcohol)
C_5H_{11}–OH	→	pentanol (pentyl alcohol)
C_6H_{13}–OH	→	hexanol (hexyl alcohol) etc.

Higher molecular weight alcohols are very important starting materials for textile auxiliaries, especially the high molecular weight alkyl sulphates (e.g. → Fatty alcohol sulphates), for many detergents, emulsifiers, finishes, hydrophobic agents etc. These alcohols, in the range of about $C_{10\text{-}18}$, are known as fatty alcohols because they are derived from fatty acids or waxy alcohols because they are derived from natural waxes. The most important high molecular weight monofunctional alcohols are e.g.:

a) saturated:

$C_{10}H_{21}$–OH	→	decyl alcohol
$C_{12}H_{25}$–OH	→	lauryl alcohol
$C_{14}H_{29}$–OH	→	myristyl alcohol
$C_{16}H_{33}$–OH	→	cetyl alcohol
C_6H_{13}–OH	→	stearyl alcohol

b) unsaturated:

$C_{18}H_{35}$–OH → oleyl alcohol.

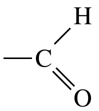
II. Aromatic alcohols: this group includes aromatic and cyclic molecules with OH-groups in side chains. Aromatic ring systems with OH-groups directly attached to the hydrocarbon ring are not considered to be alcohols but are called → Phenols and → Naphthols.

Alcohol tannin Tannin purified in alcohol. → Tannin.

Alcosol → Colloidal solution in alcohol.

Aldehyde green The first green synthetic mordant dye produced from rosaniline and formaldehyde by the manufacturing process of Eugen Lucius (1863).

Aldehydes, (alcohol dehydrogenatus) are obtained by the removal of 2 H atoms from alcohols. They are characterized by the presence of the aldehyde group:



Many aldehydes have a fruity or flowery odour and, for this reason, are used in perfumes and synthetic flavours. Boiling points rise with increasing molecular weight and lie below those of the corresponding alcohols. Lower aldehydes are water soluble, higher aldehydes water insoluble. Aldehydes have a neutral to weakly acidic reaction. They can be readily oxidized to the corresponding organic acids and behave as reducing agents towards Fehling's solution and ammoniacal silver nitrate solution.

Aldehydes, identification test (for formaldehyde) → Schiff's reagent.

Aldehyde-sodium bisulphite Resist agent used for the production of reactive dye resists under reactive dyes on cellulose. The thermally-unstable aldehyde-bisulphite compound releases sodium bisulphite on heating which reacts with the vinyl sulphone groups of the corresponding reactive dyes and thus prevents their reaction with the cellulose OH groups. Formaldehyde and glyoxal are the main aldehydes used.

Aldoses → Sugars.

Alfa grass (esparto grass), belongs to the group of → Hard fibres (natural cellulosic fibres) and is obtained from esparto grass stalks (North Africa, Spain, Sicily) by alkaline boiling and subsequent retting. Hemplike fibre without lustre, stiff, greenish yellow, 10–14 cm in length, 90–500 µm thick, with low tenacity. Uses: jute substitute, cellulose extraction, cheap rope products, mats, nets, hats, bags, etc.

Alfol alcohols and derivatives → Synthesis alcohols from the Ziegler Process, straight chained and even numbered homologous alcohols with chain lengths C_2-C_{22}. Also the alcohol sulphates and ethoxylates. Use: raw materials for detergents and hard surface cleaners including high and low foaming detergents for heavy duty and delicate laundry use.

ALG, → Alginate fibres → Standard abbrev. for textile fibres, according to DIN 60001 T4/08.91.

Algae, stemless unicellular or multicellular water-plants (phytoplankton, seaweed etc.) containing predominantly →: Alginates, Chlorophyll, Starch and sugar. Used as a finishing agent, e.g. →: Agar agar and Carrageen.

Alginate fibres These are cellulose-ester fibres and belong to the group of → Cellulosic man-made fibres. They are manufactured from calcium alginate which has a structure ($C_6H_8O_6$) resembling that of cellulose. Alginic acid is dissolved in sodium carbonate and wet spun into a coagulating bath containing calcium chloride dissolved in hydrochloric acid (wet spinning). Properties: high density (1,78), moisture uptake of 20,5%, soluble at room temperature in weakly alkaline solutions (e.g. soap solution). Applications: pattern effect yarns, support threads, base fabric for burn-out lace articles. Alginate fibres were first manufactured in Japan in 1939 and also in England after the Second World War. They are of no importance today.

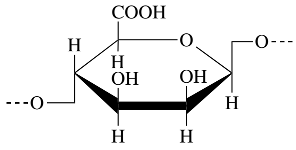
Alginate fibres, identification test The fibre specimen is boiled in a 10% solution of sodium carbonate which dissolves alginate fibres. On acidifying with dil. sulphuric acid, a gelatinous white precipitate is obtained which redissolves in conc. sulphuric acid. An addition of potassium (II) hexacyanoferrate solution produces a brownish black colour with alginate solution.

Alginate film consists of calcium alginate and is manufactured by precipitation from a soluble alkali alginate. Used as a paper substitute in heat transfer printing.

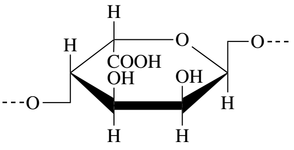
Alginates Salts of → Alginic acid. Sodium, potassium and magnesium alginates are water soluble whilst the calcium and chromium salts are insoluble. Alginates are used in the manufacture of alginate fibres and are employed as thickeners in finishing and sizing as well as textile printing. Derivation: moist or dried seaweed is broken down into coarse pieces and washed. The alginic acid is dissolved in alkali and the hemicelluloses and other insoluble components removed by subsequent flotation and filtration. Alginic acid is precipitated from the filtered solution with acid, filtered off, pulverized with sodium carbonate and dried.

Alginic acid is the main component of algae (→ Alginates) and belongs to the → Pectins. Insoluble in water and soluble in alkalies. Alginic acid is a polyuronic acid with long chain molecules composed of D-mannuronic acid and L-guluronic acid units. These polymer chains have 3 different structures:

a) a homopolymer chain of mannuronic acid,
b) a homopolymer chain of guluronic acid, and
c) a chain molecule containing alternate mannuronic and guluronic acid units:



β-*1,4-D mannuronic acid*



α-*1,4-L guluronic acid*

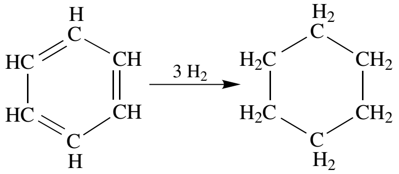
ALGOL English: algorithmic language = problem-oriented programming language.

Algorithm A set of mathematical rules which specify a sequence of actions to be taken to solve a problem. Each rule is precisely and unambiguously defined so that in principle it can be carried out by machine. Frequently based on a sequence of cyclic repeating rules.

Algorithm theory Theory of the definition, preparation, writing, evaluation and use of algorithms. It has its roots in mathematical logic and is the basis for algorithm or programming languages, such as Algol, Fortran, Pascal, Logo, Modula Pearl, PL1 etc.

Alicyclic (cyclo-aliphatic) → Alicyclic hydrocarbons.

Alicyclic hydrocarbons (cyclynes, cycloparaffins, naphthenes) A group of cyclic organic compounds characterized by arrangement of the carbon atoms in closed ring structures sometimes resembling boats, chairs, or even bird cages. These compounds have properties resembling those of aliphatics and should not be confused with aromatic compounds based on the hexagonal benzene ring. Many of their structures are formed from CH_2 groups (e.g. cyclohexanol, tetrahydronaphthalene) and such compounds may be regarded as hydrogen addition products of aromatic hydrocarbons in chemical properties but which are closer to the aliphatic hydrocarbons. Cyclohexane, which is present in some petroleum oils, but may also be produced from benzene by hydration, is the parent substance of this series:



Cyclohexane is, e.g. an important primary raw material (via adipic acid or caprolactam) of polyamide fibres and a range of important solvents which, as hydrated phenols, e.g. cyclohexanol, methylcyclohexanol and hydrated naphthalenes such as tetrahydronaphthalene and decahydronaphthalene, are well-known and are used as components in numerous textile auxiliaries because of their hydrotropic properties. They generally possess remarkable solvent properties for linseed oil sizes, fats, waxes, resins, mineral oils, etc., and, to some extent, for cellulose acetate, rubber and celluloid, etc., as well. The terpene hydrocarbons may also be mentioned under this group.

Aliphatic compounds (acyclic compounds) consist of open, straight or branched carbon chain organic compounds. Originally used to describe the fats (Gr. *aleiphar* = oil) and fatty acids which are typical of this structure. Derived from aliphatic → Hydrocarbons of the methane type CH_4. Typical examples of this group of compounds include, e.g. fats, oils, soaps, sugars, alcohols and fatty acids. See also → Aromatic compounds.

Aliphatic fats High molecular weight aliphatic compounds with a fatty character, e.g. →: Fatty acids; Fats.

Aliquot (Lat. Aliquantum = a small amount), in analytical chemistry, the term used for the analysed fraction of the total sample. From the composition of the aliquot, one can arrive at the composition of the whole analytical sample by simple multiplication.

Alizarin synthesis, first carried out by Graebe/Liebermann together with Caro (BASF) in 1868 and, independently by Riese (Hoechst) in 1869. Preparation: fusion of anthraquinone-2-sulphonic acid with alkali.

Alkali absorption Absorption of alkali hydroxides by fibres (mainly cellulose), sometimes involving reaction with the fibre.

Alkali binding agents (neutralizing agents), are employed in naphthol dyeing for the neutralization and pH adjustment of coupling baths. Typical alkali binding agents are acetic and formic acids; aluminium, zinc and magnesium sulphates; as well as mono and disodium phosphates. Also used for the buffering of coupling baths.

Alkali cellulose ($C_6H_9O_4$–O^-Na^+), primary intermediate product in the conversion of cellulose to viscose by treatment with caustic soda.

Alkali damage Caused by alkali retention on the fabric, e.g. after kier boiling, treatment in boiling water, caustic soda treatment and mercerising or alkaline dyeing processes. Alkali cannot be removed by rinsing alone, and acidification with after-rinsing is therefore advisable. Alkali damage gives rise to darker local shading with almost all dyestuffs. Wool may be dissolved by alkali.

Alkali donors are chemical compounds which release OH^- ions under the influence of heat during dyeing. The alkaline salts of volatile or easily decomposed organic acids are used for this purpose.

Alkalies Aqueous solutions of → Hydroxides and (basic) salts of → Alkali metals and alkaline earth metals, as well as ammonium hydroxide. They are characterized by “alkaline reactions” (→ Bases); e.g. caustic soda liquor, sodium carbonate.

Alkali fastness of dyeings and prints → Colour fastness to spotting: alkali.

Alkali metals Elements in the first main group of the periodic system: lithium, sodium, potassium, rubidium, caesium (cesium) and francium. Alkali metals are silver-white in colour, have low melting points and very low hardness. They possess a single, relatively weakly-bound electron in the outer shell which is a prerequisite for high reactivity. They are powerful reducing agents; their oxides and hydroxides form bases, hence the description caustic alkali. Qualitative identification by colour of the flame (potassium = vivid red-violet, lithium = deep red, sodium = intense yellow). Quantitative determination by spectrometric methods or specific chemical reactions.

Alkalimetry → Titration.

Alkaline discharge-resists Printing process for polyester. The prerequisite is that disperse dyes, which can be saponified by alkali, are used for the ground. Alkaline lyes, alkali carbonates, silicate of soda and alkali dispensers are used as alkalis. Advantages over alkaline discharge-resists containing reducing agents are a wider choice of illumination dyestuffs and their stability in light shades.

Alkaline discharges → Discharge printing using a discharge paste consisting of potassium carbonate (potash) or caustic soda.

Alkaline earth metals Collective term for the metallic elements calcium, strontium, and barium, which are classified under Group IIA of the periodic table. Magnesium is also often included as an alkaline earth metal, whilst the elements beryllium and radium, which are likewise classified under Group IIA, have properties that are closer to aluminium and may be considered as alkaline earths but not as actual alkaline earth metals. They are more stable in dry air than the → Alkali metals, and mostly (in the form of volatile compounds) give characteristic colours in a flame test (barium produces a yellow-green, calcium a reddish yellow, and strontium a red coloured flame). They are all divalent metals and, as cations, form colourless salts with colourless anions. They form hydroxides of a strongly basic character with water. On heating, they form oxides ("alkaline earths") which react alkaline in water. The alkaline earth metals may be distinguished from the alkali metals by their carbonates, phosphates and sulphates which are either insoluble or only sparingly soluble in water. The solubility of alkaline earth metal fluorides, hydroxides and oxalates increases in the order: calcium, barium, strontium, whilst that of the sulphates decreases in the same order.

Alkaline earths → Alkaline earth metals.

Alkaline earth soaps Identical with → Lime and magnesium soaps, which are formed as water-insoluble compounds from alkali soaps and water hardness salts.

Alkaline HT dyeing process for polyester In order to reduce the number of problems with oligomers, polyester lining fabric for example can be dyed at pH 9.5 in accordance with the HMK (Hoechst/Mitsubishi/Kaney) process with selected disperse dyes on a beam dyeing machine (but also suitable for jet and tops dyeing). As many azo dyes have a tendency, depending on pH, temperature and reduction conditions, to deteriorate in boiling, anthraquinone dyes in particular are used as more stable types for this purpose. In a Mitsubishi and Hoechst joint venture, a range of Dianix (anthraquinone) and Samaron (azo) dyes perform for the HMK process.

Alkaline milling → Milling.

Alkaline polysulphides Used for the stabilization of alkaline sulphur liquors in sulphur dyeing against the action of atmospheric oxygen when dyeing in jiggers or winch becks.

Alkaline reaction →: Dissociation; pH.

Alkaline scour combined → Alkaline scouring (alkaline boiling without pressure for the purpose of colour bleaching with Sodium Carbonate, and if necessary pressurising) and Chlorine bleach. A procedure for cotton (flock, thread, crosswound packages, warp beams) and cotton/viscose goods. Disadvantages: poor scale removal (cotton), lack of a hard white effect that does not post yellow. Advantage over → Kier boil-chlorine bleach: lower viscose loss.

Alkali phosphates Salts from → Alkali metals with phosphoric acids. Not to be confused with → Alkyl phosphates.

Alkali polyphosphates Alkali salts of so called polyphosphoric acid (condensed phosphates). As well as their known use in detergents and ion-exchange treatment of water, alkali polyphosphates are used as buffer agents.

Alkali resists → Aniline black and leuco vat esters in resist printing.

Alkali scour-chlorine-peroxide Combination bleach for cotton (flock, thread, crosswound packages, warp beams etc.) and viscose. On cotton, full scale removal occurs. In general, a good spin capability (flock) and a hard white that doesn't yellow results. In the case of → Viscose spun fibre one can count on a lower fibre loss when compared to a → Kier boil-chlorine-peroxide bleach treatment and this is an even more important consideration in comparison to → Kier boil-chlorine bleach.

Alkali scour peroxide bleach Bleach process for cotton and viscose spun fibres, especially for articles which cannot be pressurised. As a prebleach for printed goods etc. Process details → Bleaching of cotton.

Alkali shock process,

I. Scouring: short period process for the open-width scouring of woven cotton and cotton/polyester blend fabrics. Principle: impregnation with caustic soda, wetting agent and complex former followed by steaming and washing.

II. Printing: a two-stage process for reactive dyes, the printing paste containing no alkali, in contrast to the single-stage process. Normally, the fabric is treated with lye and electrolytes in an open-width scouring machine (1–2 boxes) in order to fixate the printed dyestuff. The treatment temperature is dependent on the reactivity of the reactive dyes employed. → Caustic shock process.

III. Alkali shock process (TT): when fixation is achieved by a sudden (shock-like) reaction due to external conditions (concentration, temperature), the pro-

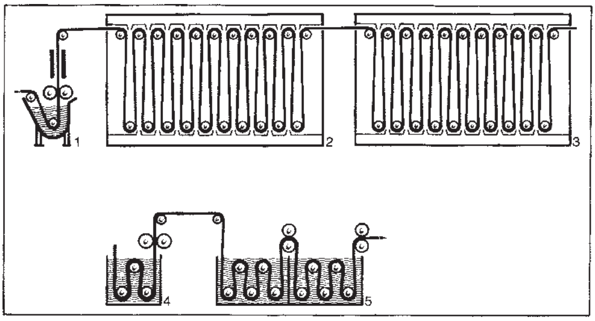


Fig.: Alkali shock process diagram (Bayer).
1 = pad/pre-dry; 2 = dry; 3 = thermosol; 4 = shock bath; 5 = after-treatments.

cedure is called a “shock process”. When, in the continuous dyeing of polyester/cotton fabric, the reactive dye is fixed by a pad mangle passage in concentrated caustic soda (Fig.), this fixation is called alkali shock.

Alkali solubility of wool is dependant on the wool treatment e.g. it can be increased by heat, light exposure, acids, oxidising or reducing agents and reduced by alkali treatment or crosslinking. Therefore alkali solubility can be used as a means of gauging any previous treatment of the wool. Procedure: a) determine the dry weight (m_1 in g); b) a second weighed sample is left 1 h in 0.1 n caustic soda at 65°C, filtered and the dry weight determined (m_2 in g). Calculation formulae (in %:)

for acid-free wool $$A = \frac{m_1 - m_2}{m_1} \cdot 100$$

for wool containing acid $$A_K = (A - S) \cdot \frac{100}{100 - S}$$

S = % dry weight

Alkali stains on textile fabrics Stains caused by alkalies are generally lighter in the centre, becoming gradually deeper towards the edges, then merging with no clear outline into the dyed background. Alkali test: a 10% solution of phenolphthalein produces a red colour which disappears again on acidification (e.g. with a fatty alcohol sulphate solution + 10% acetic, formic or citric acid). Alkaline residues on cellulose, mainly due to caustic soda, give rise to darker areas in subsequent dyeing. However, in the case of aniline black dyeings, such alkaline residues act as resists.

Alkali traces in textiles Detected with the aid of methyl green (0.01 g in 100 ml of distilled water): allow the fabric test specimen to exhaust with distilled water at 100°C, remove it and add 1–2 ml of methyl green solution. Alkali traces in the water cause the methyl green solution to lose colour.

Alkali treatment of polyester Alkaline pre-treatment for polyester. Under controlled conditions (pH, temperature and time), a staged, surface → Weight reduction of polyester fibres, also called “hole corrosion”, takes place (10–20% anticipated weight loss). In this process, the polyester molecules on the surface are hydrolytically split, and partially dissolved, producing a silk-like handle and drape together with reduced lustre and increased dye uptake.

Batch-type, semi-continuous and continuous processes are familiar in polyester alkaline treatment; batch processing on winches and jet and HT beam dyeing machines with 15–30 g/l of caustic soda; semi-continuous by impregnation and dwelling with up to 190 g/l of caustic soda; continuous by impregnation followed by steaming; with diluted NaOH: Apollotex machine; with highly concentrated NaOH: flash ager with downstream open-width scouring machine and Debaca process as a modified pad-steam process (Figs. 1 + 2). Reaction times of 120 secs. are possible for continuous processing when operating with superheated steam (Fig. 3).

Fig. 1: Surface of a polyester fibre after 22% degradation (alkali treatment) in the pad-steam process (125 g/l of NaOH); 165°C superheated steam).

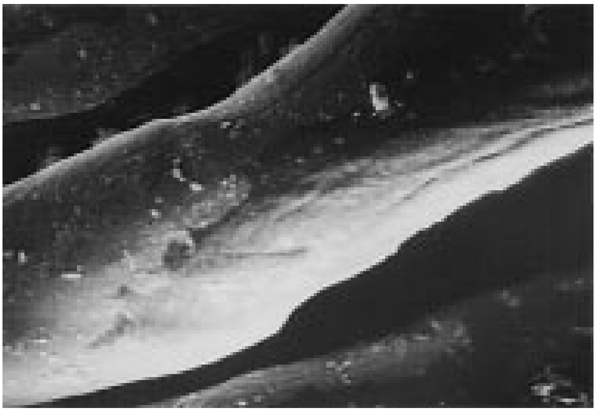


Fig. 2: Surface of a polyester fibre after 17% degradation (alkali treatment) in the application process (125 g/l of NaOH; 165°C hot air).

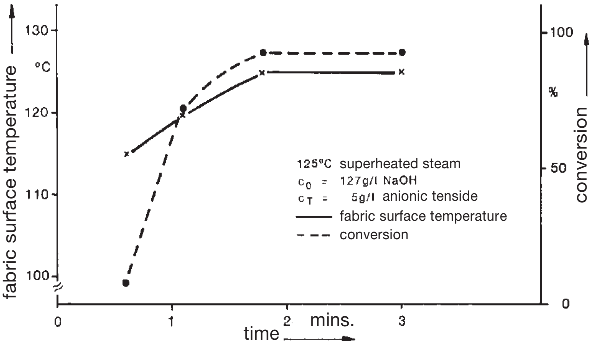


Fig. 3: Fabric surface temperature and polyester conversion relative to time.

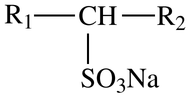
The following framework conditions must be met in order to obtain the required finishing result with the pad-steam or pad-dry process:

1. Liquor application must be uniform and reproducible. The same requirements as for continuous dyeing processes must therefore be placed on the application unit. Liquor uptake must be set as low as possible in order to keep the water charge in the textile fabric to be evaporated in the dryer as small as possible.
2. An anionic, alkali-stable wetting agent should be employed for wetting the textile fabric with the caustic soda and for adequate penetration into the yarn interstices. The tenside concentration in the padding liquor should be set relatively high, taking account of the best possible dissemination of the liquid film on the fibre surface, tenside concentrations of 3–4 g/l in the padding liquor having been found adequate. The quantity of tenside remaining on the fabric additionally facilitates washing out of the decomposition products.
3. Next to the initial charging of the textile fabric with caustic soda, the drying cycle in the machine represents the decisive criterion for the conversion achieved. Due to the fact that extremely different products, in terms of weave and the degree of weight reduction required, are alkali treated in practice, only general recommendations can be given here. Since little conversion is achieved in the first drying section, passage through it should be as fast as possible. Uniform temperature and moisture distribution must be guaranteed in the machine in order to prevent migration. The second drying section is decisive to the reaction, reaction times of approx. 10 secs only being necessary in this phase. In any case, the fabric must leave the dryer or steamer in the dry state in order to obtain optimum and reproducible conversion.

Alkaloids are base-like nitrogen-containing narcotics and poisons derived from the plant and animal kingdoms (quinine, morphine, strychnine, etc.)

Alkanes Saturated acyclic (aliphatic) → Hydrocarbons. The generic formula reads as C_nH_{2n+2}, where n = number of C atoms. Homologues in this series end in “ane” e.g. Methane.

Alkane sulphonates (Paraffin sulphonates, PS), Formula



$$R_1{-}\underset{\displaystyle SO_3Na}{\underset{|}{CH}}{-}R_2$$

Detergent raw materials from petrochemical origins. Starting products are unbranched paraffin cuts (certain fractions from mineral oil distillation) which are free from olefins and aromatic compounds. Further processing through chlorosulphonation or sulphoxidation and saponification (caustic soda) leads to alkane sulphonates. The surface active properties of paraffin monosulphonates are essentially dependant on the paraffin chain length and the position of the sulphonate group on the paraffin chain. So for example, with hexadecane sulphonate, the hexadecan-8-sulphonate has the best wetting power and the -2-sulphonate has the worst. On the other hand, the detergency is reduced by the movement of the sulphonate group towards the centre of the chain (“effective chain length”), which also agrees with research into other anionic detergents. In relation to → Alkylbenzene sulphonates (ABS), alkane sulphonates have better solubility, similar hard water tolerance and are especially suitable for use in liquid detergents and cleaning products. The biodegradability is good, slightly higher even than ABS. Alkane sulphonates have only limited suitability in powdered products due to their tendency to high hygroscopicity. Just as with the ABS, the foaming properties of alkane sulphonates are adjustable.

Alkanols Saturated acyclic (aliphatic) → Alcohols.

Alkanon Special silicate as a filter aid for chlorohydrocarbon processing and stabilisation: used for pH optimisation. Used acidic tetrachloroethylene baths are re-adjusted to the alkali range 7.4 – 7.8. Procedure (in addition to the use of Kieselguhr filter aid): reduce the Kieselguhr by 15–20% v/v and replace the balance by Alkanon. This allows longer running of dry-cleaning plants and gives an improvement in the product odour.

Alkenes Unsaturated acyclic (aliphatic) → Hydrocarbons with one or more double bonds. With I double bond, the formula reads C_nH_{2n} with n = number of C atoms. Homologues in this series end in “ene”. So a product derived from ethane = ethene. → Olefins.

Alkene sulphonates → Olefin sulphonates.

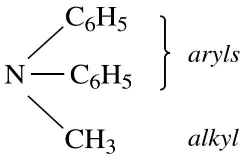
Alkenols, alkynols Unsaturated, acyclic (aliphatic) alcohols → Hydrocarbons.

Alkoxyalkylcarbamate → Dimethylol mono carbamate (DMC).

Alkyd resins represent an extensive group of synthetic resins formed by the condensation of polyhydric alcohols with aliphatic acids. The → Phthalate resins (glyptals), which are produced from glycerol and phthalic acid, also belong to this class. Typical applications of alkyd resins are: baking enamels, finishes, impregnations, coatings, print pastes, thickeners, etc. Further valuable products are the so-called modified alkyd resins (“oil-alkyds”), the principle of which is based on the fact that the OH groups of polyhydric alcohols (e.g. glycerol) are partially substituted by groups from monobasic resin or fatty acids. Such polycondensed alkyd resins are not only of interest in the varnish and paint sector, but also find use in sizing, crease-resist finishes, finishing and coating compounds, matt prints (in pigmented form) and washfast prints with coloured pigments, etc.

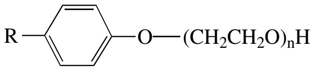
Alkylamines → Amines with substituted alkenes. The lower alkylamines are represented by, e.g. the methylamines: monomethylamine CH_3NH_2, dimethylamine $(CH_3)_2NH$ and trimethylamine $(CH_3)_3N$. Higher alkylamines correspond e.g. to the $R–CH_2–NH_2$ type.

Alkyl aryl compounds Substitution products which contain → Alkyl groups e.g. methyldiphenylamine:



Not to be confused with → Aralkyls which contain e.g. a benzyl group $–CH_2-C_6H_5$.

Alkyl aryl polyglycol ethers Originating from the ethoxylation of alkyl aryls. Alkyl aryl polyglycol ethers are frequently used in general detergent and cleaning products.

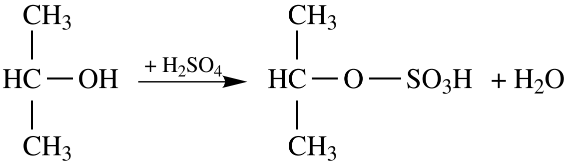


They are non-ionic and possess excellent detergency and emulsifying properties.

Alkyl aryl sulphonates (AAS), a term for aralkyl sulphonates. They are surface active substances with 1 or 2 aromatic rings which contain one or more alkyl chains and a sulpho group. Alkyl aryl sulphonates are classified into lower molecular weights (wetting agent types) and higher molecular weight (detergent types). The general rule is the more branched the chain, the better the wetting power and the better the detergency, the higher the molecular weight of the alkyl chain.

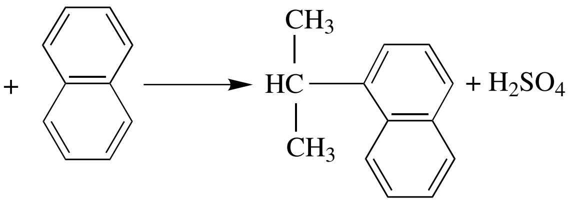
Alkylation involves the introduction of alkyl groups into organic compounds by substitution or addition. It is generally carried out by incorporating a succession of interlocking individual reactions into a single process:

1st. phase: esterification

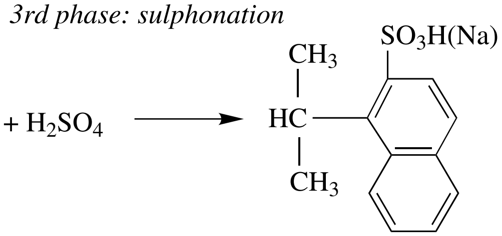


$$\underset{\mathrm{CH_3}}{\overset{\mathrm{CH_3}}{\mathrm{HC}}}-\mathrm{OH} \xrightarrow{+\mathrm{H_2SO_4}} \underset{\mathrm{CH_3}}{\overset{\mathrm{CH_3}}{\mathrm{HC}}}-\mathrm{O}-\mathrm{SO_3H} + \mathrm{H_2O}$$

2nd phase: alkylation



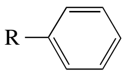
3rd phase: sulphonation



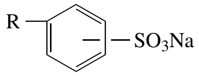
A wide range of application and utility properties for dyestuffs and textile auxiliaries can be achieved through alkylation, as well as the production of sizing and finishing agents, thickeners and man-made fibres from cellulose (alkyloses). An important factor in determining the utility properties is the → Alkylation, degree of.

Alkylation, degree of Descriptive term for the quantitative proportion of alkylated groups in a molecule. The respective degree of alkylation plays an important role, especially e.g. in so-called substituted celluloses with regard to their solubility and serviceability properties. Both these properties are influenced by the degree of alkylation so that it is possible to manufacture finishing agents, sizing agents and printing thickeners with the desired solubility properties, i.e. solubility in water, alkali or organic solvents; e.g. (cellulose derivatives): a) alkali-soluble = low degree of alkylation (compounds with low alkyl content); b) water-soluble = medium degree of alkylation; c) soluble in organic solvents = high degree of alkylation.

Alkyl benzenes Generic description for aromatic hydrocarbons in which the benzene ring is substituted with an alkyl chain. Because of the required biodegradability, straight chain alkyl benzenes have taken on a greater significance. The straight chain alkanes (n-alkanes) with C_{11-16} are based on mineral oil or α-olefins derived from the cracking of paraffins, polymerisation of ethene (Ziegler process), or chlorinated dehydration (Hüls).



Alkylbenzene sulphonates (ABS) Starting products are → Alkyl benzenes, which are then sulphonated. Alkylbenzene sulphonates, in the form of their sodium salts, are used in heavy-duty detergents and mild washing agents, generally in combination with other surfactants. They are also used as auxiliaries in the textile and paper industries. With alkyl chains of 8–15 C atoms they have good detergency and emulsifying properties, are high foaming and possess good stability to hard water. The potassium and triethanolamine salts of alkylbenzene sulphonates are employed in liquid washing agents and detergents because of their better solubility. Alkylbenzene sulphonates with alkyl chains with approx. 20 C atoms and above are soluble in hydrocarbons and organic solvents. Their share of the anionic surfactant market amounts to approx. 70%.



Alkylenes →: Alkenes, olefins.

Alkyl ether sulphates, are produced from alkyl sulphates by the inserion of an intermediate link consisting of one or several glycol ether groups linked to one chain between the hydrophobic alkyl chain and the hydrophilic sulphate group:

$C_nH_{2n+1}\ OSO_3Na$	alkyl sulphate
$C_nH_{2n+1}\ (OCH_2CH_2)_mOSO_3Na$	alkyl ether sulphate

Insertion of the glycol ether group brings about an extension of the hydrophobic chain.

Alkyl ether sulpho acids → Fatty sulpho acid esters.

Alkyl naphthalene sulphonates They are mainly based on short branched alkyl chains and lead to excellent (cold) wetting, dispersing and emulsifying agents, mostly with very good hard water and acid stability. They act especially as special wetting agents as well as dye penetration agents, levelling agents etc.

Alkyl naphthol polyglycol ethers → Polyglycol ethers.

Alkylphenol polyethylene oxide compounds (alkyl phenols) → Polyglycol ethers.

Alkyl phosphates In a similar manner to inorganic compounds → Alkali phosphates, organic compounds can also be made as esters of phosphoric acids in which one or more acid H atoms are replaced by → Alkyds (e.g. fatty acids, fatty alcohols). Most of the higher molecular organic phosphates originate in this way with many properties similar to soap, e.g. good dirt suspension and improved material handle.

Alkyl polyglycolether → Polyglycol ether.

Alkyls A term for saturated alkyl chains of general formula C_nH_{2n+1}; one obtains them if one removes an H atom from an alkane molecule. They are denoted by the ending "yl" e.g.

Methane	CH_4	→	Methyl	CH_3
Ethane	C_2H_6	→	Ethyl	C_2H_5
Propane	C_3H_8	→	Propyl	C_3H_7
Butane	C_4H_{10}	→	Butyl	C_4H_9
Pentane	C_5H_{12}	→	Pentyl	C_5H_{11}
Hexane	C_6H_{14}	→	Hexyl	C_6H_{13}

Alkyls can be bound to any of the following atoms: Carbon, Oxygen, Nitrogen, Sulphur, Silicon and various metal atoms.

Alkyl sulphates are important raw materials for detergents and textile auxiliaries. They have the general formula $RO\text{-}SO_3H(Na)$ and are fatty esters of sulphuric acid, better known as → Fatty alcohol sulphates.

Alkyl sulphides → Mercaptans.

Alkyl sulphonates Formula: $C_nH_{2n+1}SO_3Me$. Used in spin finishes.

Alkynes (Acetylene), unsaturated acyclic (aliphatic) → Hydrocarbons with one or more triple bonds. In the same molecule, a double bond may also be present. Only single bonds are available next to a triple bond so the general formula for a compound with 1 triple bond reads C_nH_{2n-2} where n = the number of C atoms. Homologues in this series end in "yne" from which follows that the derivative of ethane is ethyne.

Allergens are substances which give rise to allergic reactions in living organisms.

Allergy Abnormal hypersensitivity of the human body to foreign materials (allergens) in susceptible individuals. The development of an allergy is due to an inappropriate reaction of antigen-antibody responses (which form an important part of the body's normal immune defence system) to substances in the environment. Practically all substances outside the human body (haptens, e.g. even bacterial metabolites) can react with the serum albumin to form antigens. In simple terms, the immune system "learns" how to produce so-called specific antibodies on contact with antigens. On renewed contact with these same antigens, a reaction occurs in the organism releasing antibodies which then react with the corresponding antigens and, at the same time, further immune defence mechanisms are activated such as, e.g. the distribution of cell hormones. When an over-reaction occurs, as is the case with an allergy, inflammations and/or other health damaging manifestations are triggered.

For the purposes of industrial hygiene it is important that sensitization, i.e. provocation of the organism towards a state of over-reaction readiness, is avoided by ensuring that exposure is never so great that the immune system becomes overloaded. The following relationship thus applies:

Risk of sensitization = exposure x antigen.

Unfortunately, the equation is no longer valid once sensitization has occurred. Since an over-reaction is comparable to a chain reaction, even the smallest amount of a sensitizing substance is often sufficient to trigger an allergic reaction. Under such circumstances, the risk of allergic reaction can only be eliminated by the complete avoidance of any exposure whatsoever. The prerequisites for an allergic reaction are hereditary predisposition and contact with certain (sensitizing) substances. In view of the fact that more and more people have become susceptible to allergic reactions, it would appear to be a disease of civilization; the condition being properly described as medical atopy. A typical atopic subject will have parents who suffer from hay fever, asthma or other allergies, and who have passed on the genetic predisposition for over-reaction to natural substances such as plant pollens, animal hairs, etc. The specific sensitivity to skin allergens (→ Skin diseases) may also be explained on this basis. Atopic subjects should be particularly meticulous in the choice and care of their clothing.

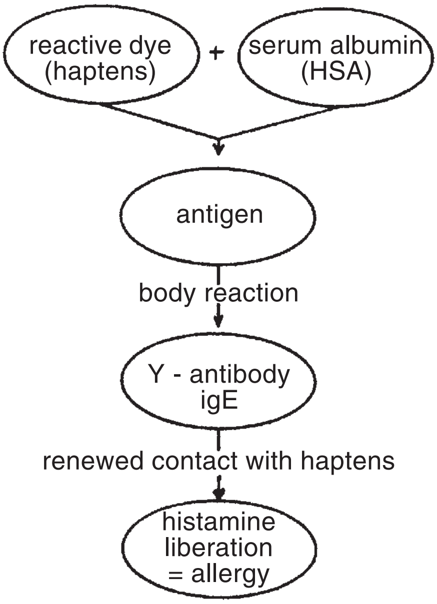


Fig. 1: Occurrence of allergies due to reactive dyestuffs as haptens.

The course of the reaction represented in Fig.1 can be postulated as follows: the reactive dye (hapten) reacts with human serum albumin (HSA) by forming a dye-HSA conjugate which functions as an antigen. As a response to this antigen, the body forms Y-shaped antibodies (immunoglobulin E, IgE) which take root on the surface of mast cells in the nasal mucous membranes. The mast cells release highly active substances such as, e.g. histamine, on renewed contact with the reactive dye and the condition becomes manifest as allergic rhinitis (which also includes allergic bronchial asthma).

The various factors responsible for the extent of antigen-antibody production, the initiation and intensity of sensitization, as well as the severity of the symptoms, are still not fully understood. It may well be that, e.g. physical properties such as the water-solubility of the reactive dye, steric factors (molecular forms of antigens and antibodies) and the degree of exposure have a role to play here. Determination of the cutaneous resorption rate of a substance is often of particular importance in this regard, i.e. determination of the quantity of a substance which can penetrate the skin barrier and thence become systemically distributed and active. In the interests of reducing or even eliminating the need for animal tests, whilst still maintaining the necessary safeguards to ensure freedom from health risks, the following possibilities exist:

1. Where a substance is not cutaneously resorbed, the test for subchronic toxicity may be waived in certain circumstances.
2. Where the cutaneous resorption rate of a substance is known. In this case, and under certain circumstances, a subcutaneous toxicity test may be carried out with only one dose.
3. Where the "no observed effect level" of a substance is known from a subcutaneous toxicity test, the determination of cutaneous resorption can be waived if this value is greater than the maximum quantity of substance which, having regard to the safety factor, can penetrate the skin according to pure calculation.

As far as textile finishing plants are concerned, the following precautions should be taken: a) careful handling of dyes and auxiliary chemicals, b) avoidance of any skin contact as far as possible, c) no inhalation of product dusts or vapours, d) the use of automated, dust-free product dispensing, weighing, and dosing systems, as well as e) the optimization of commercial forms of product (e.g. non-dusting brands).

Textile dyes known to be potential allergens include, e.g.:

- Anthraquinone dyes such as Disperse Red 11, 15 and Disperse Blue 1, 3, 7, 26, 35;
- Azo dyes such as Disperse Red 1, 17 and Disperse Blue 102, 124, as well as Disperse Orange 1, 3, 76;
- Nitro dyes such as Disperse Yellow 1, 9;
- Methine dyes such as Disperse Yellow 39, 49;
- Quinoline dyes such as Disperse Yellow 54, 64;
- Triphenylmethane dyes such as Acid Violet 17;
- Others, such as, e.g. chromates.

In this connection, two examples of practical relevance may be given here:

1. A range of textile dyes based on p-amino-azobenzene structures exists which, after extraction from dyed materials, e.g. through the action of perspiration alone, or after their transformation into p-phenylene diamine (derivatives) are able to function as haptens and can induce sensitization or trigger an allergic reaction (Fig. 2). In this case, the stability (wet fastness) of the dyeing is particularly important.

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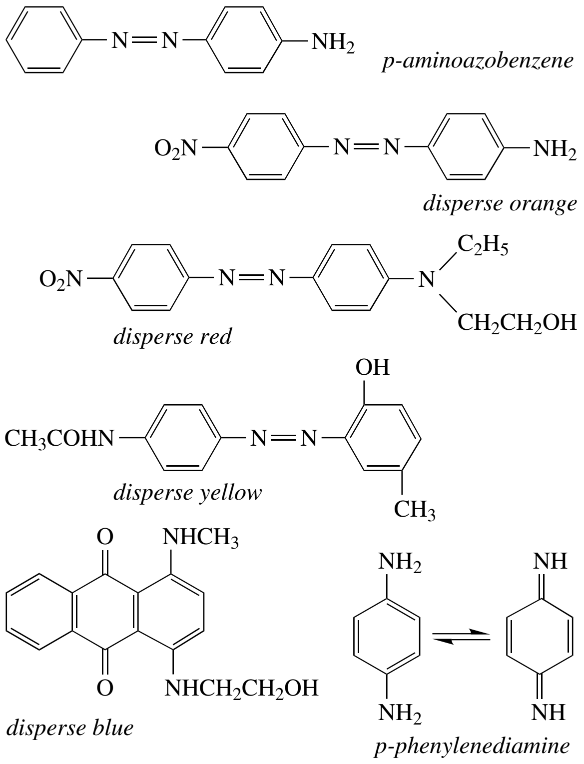

Fig. 2: p-aminoazobenzene dyestuff derivative which can function as haptens in the metabolism.

2. Formaldehyde is a toxicologically-relevant substance, especially as an allergen. From the results of toxicological tests, however, a distinct carcinogenic potential does not appear to have been clearly established in the case of formaldehyde. On the other hand, the potential allergenic activity of formaldehyde is indisputable, and for which a minimum concentration is necessary both to induce as well as to trigger an allergenic reaction. From the results of dermato-toxicological tests on cosmetic products, it is known that even those subjects allergic to formaldehyde only react to concentrations above 0,05% as a rule, provided the skin of the affected subject is not exceptionally easy to penetrate, e.g. as a result of abrasions (Lüpke, Moll, Rosenthal, Anliker and Steinle).

Allgaeu carpet (ribbon carpet, patchwork carpet), hand-made smooth carpet in a strong cotton yarn warp with a ribbon-like weft (fancy weft carpet) in strips of woven and knitted fabric remnants, stockings, selvege trimmings etc.

All-in method,

I. Dyeing: method for dyeing reactive dyes with dye/s, alkali and all the required auxiliaries from a single bath; e.g. as used for dyeing cotton fabrics with reactive dyes in a modern jet dyeing machine (Bayer method); see Fig.

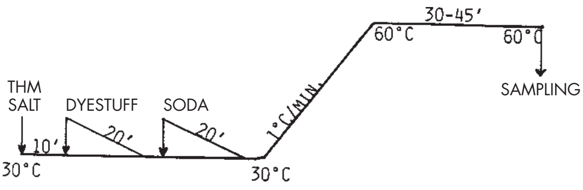

Fig.: Bayer all-in process for dyeing cotton with reactive dyes on jet dyeing machines.

II. Printing: A process in which the print paste contains, besides the dye/s, all the chemicals necessary for fixation, in contrast to the →: Two-phase printing process, Wet fixation process.

Allotrope (Gr.) One of several possible forms or modifications of a substance, e.g. the element carbon exists as soot, coal, graphite and diamond. Viscose fibres, as regenerated cellulose, represent an allotropic form of native cellulose.

All-over screens, flat or rotary printing screens which allow total flow of print paste across the entire squeegee width = 100% coverage.

Allowance In accordance with REFA, all irregularly occurring times in fabric processing, as (supplementary to → Basic time) those times which cannot properly be logged in every timing process or time calculation. Allowance is objectively and personally determined (independently of operation).

Alloys Solid or liquid mixtures of two or more metals, or of one or more metals with certain nonmetallic elements, as in carbon steels. Alloys are partly physical mixtures and partly chemical combinations. The physico-chemical properties of alloys are usually considerably different from their individual components (particularly with regard to melting point, strength, extensibility, hardness, processability, technical applications, and resistance to chemical corrosion).

All-skin fibres This means modified viscose fibres of the so-called Supercord and Superfest-S type, the cross-section of which no longer consists, as with normal viscose fibres, of core and skin, but exclusively of a highly oriented skin substance as a carrier of special quality features such as increased tear strength and higher wet modulus. According to electron microscope examination, HWM fibres reveal, apart from an also microscopically detectable skin zone, few small hollow spaces, whilst the polynosic fibre on the other hand has larger hollow spaces in the fibre interior (→ Modal fibres).

All-weather articles In order to qualify for the Indanthren quality label, such articles must be dyed with vat dyes. Certain types of apparel, bathing suits, knitgoods and, to some extent, home textiles composed of cellulosic fibres belong in this category.

Allwörden's reaction → Elasticum reaction.

Allyl aldehyde → Acrolein.

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Aloes fibre → Mauritius hemp.

Alpaca The alpaca is a close relative of the llama and is similar to the guanaco. It lives exclusively in Peru, Bolivia, Chile and the higher levels of the Andes. Its fleece belongs among the finer animal hair qualities. Shearing takes place every 2 years and, because of the prevailing raw climate, the alpacas are not shorn to the skin. The fleece is soft, lustrous and slightly curly.

Alpaca wool does not have a uniform colour; the colours extend from black, dark brown, chestnut, through to biscuit, camel, beige, etc., and from dark grey to silver grey. Up to 22 different shades are obtained by hand sorting. Alpaca is used, *inter alia,* for dress fabrics as well as jacket materials, e.g. with a warp of twisted cotton and a weft composed of alpaca or other llama-type fibre. Fabrics are mostly produced in plain or twill weave with a napless finish. Used for dresses, women's coats and lightweight summer jackets. → Animal fibres.

Alpha-naphthol (α-naphthol, 1-naphthol, 1-hydroxynaphthalene), see example under → Cyclic hydrocarbons.

Alpha rays → Radioactive emission.

Alum → Aluminium potassium sulphate.

Alumina → Aluminium oxide.

Alumina gel, $Al_4(SO_4)(OH)_{10} \cdot 2H_2O$. A strongly alkaline → Aluminium sulphate which is insoluble in water but soluble in acids. It is used to prepare aluminium mordants for dyeing and printing.

Aluminium, (aluminum**,** Al, atomic weight 26,98), is a silver-white highly-lustrous soft metal which is very ductile and extensible, capable of being rolled out into very thin foil (sheet aluminium). It has very good electrical conductivity (62% of the conductivity of copper). Aluminium is soluble in hydrochloric and sulphuric acids and forms aluminates (so-called acidic aluminium salts of the AlO_2Na type) on reaction with alkaline liquors which is accompanied by the evolution of hydrogen. When these are mixed with other metallic oxides, aluminium oxide Al_2O_3 and the corresponding metal are formed, often with explosive evolution of heat. Alloys with other metals generally give increased strength although corrosion-resistance is reduced, e.g. duralumin with 0,5% magnesium, 4,5% copper and 9,7% manganese. Aluminium is also used for aluminium bronze colours in textile printing.

Aluminium acetate (aluminium ethanoate, acetate of alumina, red liquor), $Al(CH_3COO)_3$, MW 204,19. Available as a relatively strongly acidic solution (approx. 8–10%) which should be sulphuric acid free, or as a white powder of high purity. Gives approx. 15% aluminium oxide on the fibre. Over time (and particularly on heating), the basic salt $Al(CH_3COO)_2OH$ separates out.

Aluminium acetate can also be made on a do-it-yourself basis from e.g. aluminium sulphate, acetic acid and calcium carbonate, or from the basic acetate on addition of sodium carbonate. Used for water-repellent finishing: e.g., treatment with 2–6°Bé (1,013–1,042 g/ml) aluminium acetate alone at 20–40°C for 1–2 h, followed by drying at 60–65°C, or in combination with paraffin wax and similar products. Aluminium acetate is also employed as a mordant in dyeing and printing.

Aluminium alcoholates are colourless liquid or solid compounds in the pure state, formed from metallic aluminium, aluminium amalgam and alcohols, which are then cleaned by filtration or vacuum distillation. Aluminium alcoholates are decomposed by water into their corresponding alcohols and aluminium hydrate. For this reason, they find application, when dissolved in organic solvents, as water-repellents, especially for the dry impregnation of cotton goods (e.g. poplin outerwear).

Aluminium ammonium sulphate (Ammonium alum), $NH_4Al(SO_4)_2 \cdot 12H_2O$, mol.wt. 453.54, colourless crystals, soluble in cold or extremely soluble in hot water. Uses: analogous to and replacement for potassium aluminium sulphate (alum).

Aluminium bronze powders for printing → Metal powders in textile printing.

Aluminium chlorate, $Al(ClO_3)_3$, MW 218. White crystalline deliquescent solid. Commercially available solutions have a variable aluminium chlorate content. Uses: substitute for sodium chlorate in discharges; oxidizing agent for aniline black; printing with vat leuco ester dyes; oxygen carrier (e.g. in aniline black dyeing).

Aluminium chloride, $AlCl_3$, MW 133,6. Available as colourless or (with traces of iron chloride) yellowish crystals, soluble in water and many organic solvents, or as a strongly acidic solution of 30°Bé (1,261 g/ml) (31–32% $AlCl_3$ as "chloraluminium"). Used for carbonizing dyed wool materials, especially reclaimed wool (gentle treatment) and, less frequently, as a mordant or in the production of burn-out prints on velvets.

Aluminium formate (formate of aluminium), $Al(HCOO)_3$, MW 162. Available mostly in solutions of 10°Bé (1,074 g/l). Can be prepared on a do-it-yourself basis as follows: 70 g aluminium hydroxide 100% is dissolved in 600 ml water and 150 ml formic acid 85%; this solution contains approx. 200 g/l of aluminium formate. Uses: water-repellent finishes, aftertreatment of dyeings, alizarin printing (does not attack the fibre; no lake formation during steaming under pressure).

Aluminium hydroxide (alumina trihydrate, hydrated alumina), $Al(OH)_3$, MW 78. White crystalline powder, balls, granules or in paste form (alternatively, it can be produced by hot precipitation from aluminium sulphate solution with ammonia, followed by thorough washing).

Used for the production of dye mordants and colour lakes.

Aluminium in dyeings, identification tests

1. Ash the dyed or printed specimen. Colour of ash = pure white (alizarin dyeing resp. aluminium mordant, wash test).
2. Transfer the ash to filter paper and make into a roll. Moisten well with dil. nitric acid and carefully pass the roll several times through a small flame (until the surface has dried); then place a few drops of dil. cobalt nitrate solution on the filter paper and heat until red hot in the flame: distinctive blue ash.
3. Place a little of the ashed specimen on to a molten bead of sodium or potassium carbonate fused on to a platinum wire, then refuse the bead for approx. 5 min. Dissolve the bead in dilute acetic acid and add a few drops of morin solution (1 pinch of morin in 50 ml ethanol).
   Greenish fluorescence which is very clearly visible if the solution is first heated slightly, cooled again with water, and held against a dark background. Daylight essential! The presence of iron or copper interferes with the test and, for this reason, these metals should be precipitated out with sodium hydroxide solution beforehand.

Aluminium oxide (alumina), Al_2O_3, exists in at least 5 known varieties. It forms an extremely thin corrosion-protective layer on aluminium surfaces exposed to air. Also obtained as an intermediate product in the extraction of aluminium. → Corundum.

Aluminium potassium sulphate (alum, potash alum), $Al_2(SO_4)_3 \cdot K_2SO_4 \cdot 24H_2O$. MW 949, density 1,94. Colourless crystals or white crystalline powder. Water soluble. The solution is weakly acidic and the free sulphuric acid content is mainly slight. Uses: aftertreatment of developed dyeings; mordant for alizarin dyes (dyeing and printing); weighting of silk; auxiliary mordant for resorcin dyes; neutralization of alkali blue (wool); water-repellent finishes; flame-retardant finishes; tanning (white) of rabbit pelts (alum tannage).

Aluminium silicates Collective term for compounds with varying proportions of Al_2O_3 and SiO_2 which occur in nature as andalusite, cyanite etc., or as components of other minerals (→: Kaolin, Bentonite, Fuller's earth, China clay).

Aluminium sulphate (sulphate of alumina), $Al_2(SO_4)_3 \cdot 18H_2O$, MW 666, density 1,62. White mass, broken pieces, grains or crystals with 15,33% Al_2O_3. Soluble in cold or hot water; the solution has a strongly acidic reaction and attacks metals such as iron, lead, copper and zinc. For use an alizarin mordant, the iron content must not exceed max. 0,001%. Uses: substitute for aluminium potassium sulphate (alum) (cheaper, more readily soluble, more effective); for water-repellent finishes (aluminium triformate is more effective for this purpose); dye mordant (iron-free); weighting of textiles; addition to print pastes (risk of metal corrosion); water purification; production of burn-out styles on velvets.

Aluminium thiocyanate (aluminium sulphocyanide), $Al(CNS)_3$, MW 402. Uses: as a mordant for printing alizarin pink on cotton, wool and silk (does not attack doctor blades, protects against the action of iron, no damage to the fibre on steaming) where the presence of iron is indicated by a red colour; also used for resists under aniline black.

Aluminium triformate, $Al(HCOO)_3 \cdot 3H_2O$. White crystalline chemically-pure aluminium formate (approx. 23% Al_2O_3 and 63% HCOOH). The aluminium content is 5 times higher than that of typical commercial grades of aluminium formate. Good solubility in hot water, slightly soluble in cold water. Stable to boiling without separation, resistant to hard water. Dissolve at 80–100°C and boil with direct steam. Uses: instead of liquid alumina products for water-repellent finishes (1–6°Bé = 1,006–1,042 g/ml); aftertreatment of dyeings; alizarin printing (no damage to the fibre on steaming); and for increasing the colour fastness of dyeings to water. Quantities: approx. 1/5 that of 13°Bé alumina solutions (1,098 g/ml) or 1/6 that of the 10°Bé solution (1,006 g/ml).

Aluminosilicates → Zeolite; Sodium aluminium silicate.

Am, chemical symbol for Americium (95).

Ambergris → Spermaceti.

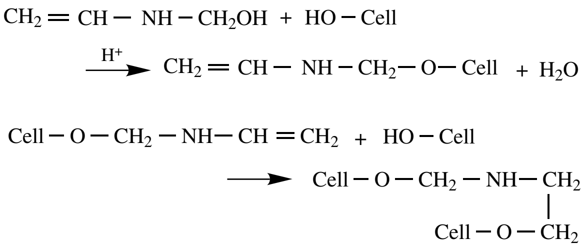
Ambient air Because of the hygroscopicity of textile fibres, the ambient air inside textile plants is of great importance for the entire processing operation. → Conditioning; air humidity.

Ambiente printing process, registered printing process of the Ambiente company, Helsinki, for the local coloration of open-width woven or knitted fabrics with thickened dye solutions in the nip of a two-bowl padder. A wide range of different lively variations in colour and design are obtained with stripes of variable widths and directions including circular, speckled and cloudlike motifs. Additional design variations are possible by employing different print paste viscosities. Both the face and back sides of the fabric have the same depth of colour, and each production batch represents a unique colour way since reproducibility of the prints is only possible to a certain extent from the basic design. In principle, wovens and knits of all kinds of fibres can be coloured by the Ambiente printing process. Print pastes are prepared according to customary recipes and their viscosity is adjusted as necessary to suit changes in conditions. Fixation and afterwashing are carried out under the same conditions as conventional textile prints.

Ambiphilic (Lat.: *ambo* = both, and Gr.: *phil* = loving). Ambiphilic substances have double solubility, i.e. in oil (→ Lipophilic) as well as in water (→ Hydrophilic). The term relates to the ambiphilic molecular structure of e.g. emulsifiers.

Ambivalent Term used in resin finishing to describe crosslinking agents with two different types of group capable of reacting with cellulose. → Ambivalent crosslinking.

Ambivalent crosslinking The crosslinking of cellulose with resin finishing agents containing different types of reactive groups. The term is mainly used to describe the two-stage resin finishing process based on methylolacrylamide as crosslinker (stage I: dry crosslinking; stage II: wet crosslinking):



$$CH_2{=}CH{-}NH{-}CH_2OH + HO{-}Cell \xrightarrow{H^+} CH_2{=}CH{-}NH{-}CH_2{-}O{-}Cell + H_2O$$

$$Cell{-}O{-}CH_2{-}NH{-}CH{=}CH_2 + HO{-}Cell \longrightarrow \begin{array}{l} Cell{-}O{-}CH_2{-}NH{-}CH_2 \\ \qquad\qquad\qquad\quad | \\ \qquad\qquad Cell{-}O{-}CH_2 \end{array}$$

AM cotton → Aminoethylated cotton. The introduction of amino groups confers an affinity for acid dyes.

Ames test A simple *in vitro* bacterial mutagenicity test devised by the American biochemist Bruce Ames for the relatively rapid screening of substances to detect those which are mutagenic (mutation-causing) and therefore potentially carcinogenic (cancer-producing). In the Ames test, mutant (His –) strains of the bacteria *Salmonella typhimurium,* lacking the ability to synthesize an essential nutrient, the amino acid → Histidine, and which can only grow in media where histidine is provided, are used. → Mutagenic agents which cause changes in their genetic material may induce reversion to the normal (His +) condition and thus facilitate growth in a histidine-deficient medium whereupon the change can be readily detected. Spontaneous reversion mutations occur but the extent of this is low and can be determined in experimental controls.

Some substances are not intrinsically mutagenic or carcinogenic but only become so when modified by metabolic processes. This may be simulated in the Ames test by adding mammalian liver homogenate (rat, S-9) to the preparation. Further refinements of the test include the use of bacterial strains in which the ability to repair the genetic material (DNA) is impaired, thereby increasing the probability that mutation will occur, and also by using strains with cell-wall defects which allow easier penetration by large molecules. Strains of histidine-deficient *Salmonella typhimurium* have been selected in which the actual genetic structural fault is known and thus the mode of action of the mutagen can be determined.

Amidases These are → Enzymes, belonging to the hydrolase group which can bring about the hydrolytic cleavage of C–N bonds. They include e.g. ureases (urea-splitting); arginases (which split the amino acid arginine into urea and ornithine and are also used for the analytical determination of arginine); and asparaginase (which splits asparagin into aspartic acid and ammonia).

Amide oils, identical with fatty acid amides; → Fatty acid condensation products.

Amide resins → Synthetic resins of the type which includes urea resins, melamine resins and dicyanodiamide resins.

Amides Organic compounds derived from ammonia by substitution of one or more of its hydrogen atoms by organic acid groups. Example: NH_3 → Oxamide $(CONH_2)_2$ → Urea $CO(NH_2)_2$.

Amido group $-CONH_2$ group, e.g. in formamide, urea and acetamide. In the past the → Amino group was often described as an amido group.

Amine odour on finished textiles See → Fish odour on finished textiles.

Amine oxides Amine oxides which are suitable as detergents originate from the condensation of a fatty alcohol with dimethylamine and subsequent oxidation. Their solubility is due to the hydrophilic amine oxide group. At higher temperatures, amine oxides decompose. They act as weak oxidising agents and possess good wetting and emulsification properties.

Amines Organic compounds derived from ammonia NH_3, by replacement of one or more of its hydrogen atoms by → Alkyl, or → Aryl groups, e.g. primary amines ($R{-}NH_2$): methylamine CH_3NH_2 and aniline $C_6H_5NH_2$; secondary amines (R2–NH): dimethylamine $(CH_3)_2NH$; tertiary amines ($R_3{-}N$): trimethylamine $(CH_3)_3N$. → Polyamines.

Amino acids (Amino carboxylic acids), $R{-}NH_2{-}COOH$, building blocks for → Proteins. Comprising of a carboxylic group (–COOH), an amino group ($-NH_2$) and a, mostly very complicated, chain (e.g. fatty acid chain) which can be aliphatic or aromatic. As a result of the simultaneous presence of amino and carboxylic groups, amino acids react as both acids and bases i.e. they are amphoteric and form Zwitterions with two opposite electrical charges which neutralise each other within the molecule (Isoelectric point). Through the joining of several amino acids, proteinaceous molecules are formed (see Table) (Peptide, Di-, Tri- and Polypeptide). Amino acids also arise from the decomposition of protein molecules. Test with Ninhydrin. In the composition of wool and silk, the knowledge of amino acid types with reactive or unreactive side groups is important. So one distinguishes:

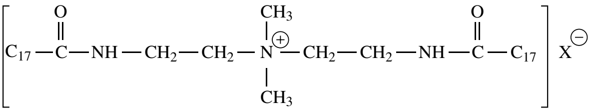
	Wool keratin	Silk fibroin	Groundnut protein	Paracasein	Gelatine
Alanine	4,40	24,50	4,1	1,5	8,7
Arginine	10,40	1,05	13,5	2,5	8,2
Asparagine	7,27	2,00	5,2	6,7	3,4
Cysteine	0,50	–	–	–	–
Cystine	12,20	–	1,5	0,2	–
Glutamic acid	15,27	2,03	16,7	15,5	5,8
Glycocoll	6,50	42,30	4,1	1,9	25,5
Histidine	0,70	0,47	1,9	5,9	0,9
Lanthionine	0,50	–	–	–	–
Leucine (isomers)	11,30	0,80	8,0	9,3	7,1
Lycine	3,30	0,44	5,0	1,5	5,9
Methionine	0,71	2,59	0,7	3,5	1,0
Oxyglutamic acid	–	–	–	3,8	–
Phenylalanine	3,75	1,50	2,6	3,2	1,4
Proline	6,75	1,50	5,3	10,5	19,4
Serine	9,41	16,24	5,2	0,5	0,4
Threonine	6,76	1,50	2,6	4,5	–
Tryptophane	0,70	1,00	0,7	0,7	–
Tyrosine	5,80	10,60	5,7	4,5	–
Valine	4,72	3,20	4,8	7,2	–

Tab.: Aminoacid composition of the most important proteins.

1. Amino acids with aliphatic side groups: Alanine, Glycine, Leucine, (Isoleucine), Valine (also Sarcosine and Betaine).
2. Cyclic amino acids: Phenylalanine, Proline, Tryptophan.
3. Amino acids with –OH groups: Serine, Threonine, Tyrosine.
4. Basic amino acids ("Hexon bases", diamino carboxylic acids): Arganine, Histidine, Lysine.
5. Amino acids with acid (carboxylic) groups: Asparagine, Glutamic acid.
6. Sulphur containing amino acids: Cysteine, Cystine, Methionine.

[3.-6. with reactive groups].

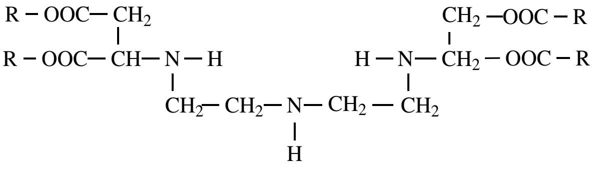
Aminoamides Are of increasing interest as cationic active finishing products e.g. dimethyl difatty acid ammonium salts as softeners:



$$\left[C_{17}-\overset{\overset{O}{\|}}{C}-NH-CH_2-CH_2-\underset{\underset{CH_3}{|}}{\overset{\overset{CH_3}{|}}{N^{\oplus}}}-CH_2-CH_2-NH-\overset{\overset{O}{\|}}{C}-C_{17}\right]X^{\ominus}$$

Aminocaproic lactam → Caprolactam.

Amino carboxylic acid ester (ACAE),



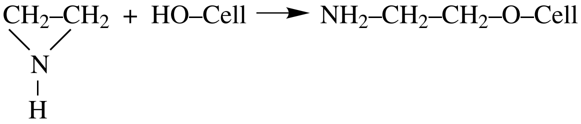
R = cetyl, stearyl and oleyl residues

They have cationic characteristics in the weakly acid pH range and after being taken up by the fibres, regain the properties and advantages of a non-ionic structure. As a rinse finish on cellulosics, the softening effect improves with falling pH and increasing concentration of active substance. Good results are achievable with 4g/kg material at pH 6. Amino carboxylic acid esters are especially effective as softeners on wool and synthetic fibres.

Aminocarboxylic acids → Amino acids.

Amino end-groups, so-called terminal → Amino groups (NH_3) which occur in the molecules of keratin (wool), fibroin (silk) and also polyamide fibres, with the difference that polyamide fibres only contain amino end-groups, i.e. no additional → Amino extra-groups, as is the case with wool and silk. For this reason, the acid equivalent and maximum dye-acid absorption of polyamide fibres is considerably lower: polyamide = 0,004–0,008 g/100 g; silk = 0,023 g/100 g and wool = 0,085 g/100 g.

Aminoethylated cotton is produced by the alkylation of cotton cellulose with aminoethylated compounds in acidic medium e.g. 2-aminoethylsulphuric acid in sodium hydroxide:



Aminoethylated cotton possesses increased swelling capacity, increased reactivity, somewhat lower strength, and increased elongation properties. It is dyeable with acid dyes and its wrinkle properties are scarcely influenced.

Amino extra-groups, originate from the diaminocarboxylic acids present as side-groups in the keratin and fibroin molecule, mainly from arginine, histidine and lysine. In addition to the → Amino end-groups, the number of amino extra-groups determines the fundamental behaviour of wool and silk towards acids, i.e. by reacting as bases. Since wool contains considerably more amino extra-groups than silk, it possesses an accordingly higher acid equivalent (0,085 : 0,023 g/100 g) and consequently a correspondingly higher dye-acid binding capacity. Polyamide, on the other hand, possesses no amino extra-groups.

Amino group $-NH_2$, is a monovalent radical that can occur in vastly different organic compounds which are then described as → Amine or amide. The amino group (as well as its derivatives) is classified as an auxochrome e.g. in cationic and diazo dyes. NH_2-compounds with carboxylic groups (–COOH) are known as → Amino acids (proteins).

Aminoplasts → Self-crosslinking resins. Application, *inter alia*, as resin finishing agents. Collective term still used very occasionally for urea-formaldehyde and melamine-formaldehyde compounds.

Aminopolycarboxylic acids A group of important organic complexing agents which are of particular value in water softening applications and which also find use in complexometry. Ethylenediaminetetraacetic acid (→ EDTA) and → Nitrilotriacetic acid (NTA), as well as their sodium salts are particularly important examples. The most notable property of these compounds is their ability to form very stable water-soluble complexes with metal ions in aqueous solution. The stability of these complexes is, however, influenced by external factors. Thus an increase in the stability of EDTA trisodium salts is achieved by raising the pH and raising the temperature. In the case of the EDTA tetrasodium salts (weak compounds) on the other hand, electrolyte additions, increasing valency of electrolyte anions and increasing temperatures reduce the stability. EDTA also functions as a stabilizer in peroxide bleaching.

Aminotrimethylcarboxylic acid, identical with → Nitrilotriacetic acid (NTA).

Ammonia → Ammonium hydroxide; the gas NH_3 dissolved in water.

Ammonia aftertreatment of reactive dyeings A mild (ammoniacal) aftersoaping treatment generally given to reactive dyeings on wool for the purpose of removing unbound dye and thus improving the colour fastness.

Ammoniacal silver nitrate solution, 100 ml of 0,1 n silver nitrate solution is dissolved in 15 ml ammonia and 40 ml of 38°Bé sodium hydroxide solution. Used for the detection of oxycellulose and hydrocellulose: Place the test specimen for a few minutes in the above solution heated to 80°C, then finally rinse off with dil. ammonia. Damaged cellulose exhibits a yellow to yellowish brown colour.

Ammonia cure process Ammonia condensation process. Application technology for certain flame-retardant finishes which crosslink with ammonia (mainly during a separate processing stage, often by gas treatment), e.g. Proban, Pyroset process, THPOH–NH_3 finishes.

Ammonia finishing → Liquid ammonia process.

Ammonia liquor → Ammonium hydroxide.

Ammonia process → Liquid ammonia process.

Ammonia soaps → Soaps. Used as lubricants for cotton or wool (with oleic acid and neutral fat = wool spinning oil) which can be readily washed out. Soaps for sensitive materials, finish additives, etc.

Ammonia test (for dyeings)

I. Specifically for the identification of wool/cotton unions resp. the differentiation of direct and acid dyes. Strip the dye/s from the test specimen by boiling several times with conc. ammonia. Combine the stained liquors and reduce the whole to 1–2 ml by evaporation. Dilute with 4–5 ml dist. water and take 2 ml of the resultant liquor in each case for the following dyeing tests: a) acidify with conc. formic acid, add one sample of wool and one of cotton, heat to the boil for 5–10 min. then rinse thoroughly with cold water; b): add 0,5 ml of 10% sodium sulphate solution and dye one sample each of wool and cotton for 5–10 min. at the boil, then rinse thoroughly in cold water; c): as for b) but with the addition of a little sodium carbonate solution followed likewise by dyeing of wool and cotton.

Evaluation: 1. Only the wool is stained in a) + b) and a) is more heavily stained than b) whilst in c) the wool is either unstained or only lightly stained = definitely acid dye. 2. Cotton is heavily stained in b) and possibly in c) as well = substantive dye. 3. Wool and cotton are more or less equally stained in a) + b) = wool/cotton union dye or a mixture of acid and direct dyes.

II. For the identification of fast dyes on synthetic fibres by separation (→ Dye class identification).

Ammonium (NH_4), monovalent radical of so-called ammonium compounds (type: ammonium hydroxide NH_4OH) which, in terms of structure and behaviour, possess many similarities to potassium and sodium compounds: e.g. especially their easy solubility and dissociation in solution into positively charged $[NH_4]^+$ cations and negatively charged acid anions.

Ammonium acetate (acetate of ammonia), CH_3COONH_4, MW 77, density 1,171. White, deliquescent solid, readily soluble in water and ethanol giving neutral solutions. Can be easily prepared on a do-it-yourself basis by mixing acetic acid and ammonia (720 ml acetic acid 30% + 280 ml ammonia liquor 25%; slight excess of ammonia is recommended, neither red nor blue litmus paper should change colour to any significant extent). On heating ammonium acetate liquors, acetic acid is slowly split off. This property is made use of in dyeing for the acidification and exhaustion of difficult levelling and too rapidly exhausting acid, developing and mordant dyes. Other uses, e.g. in wool dyeing, include the elimination of undesired shine in worn garments (brushing with ammonium acetate dissolved in ethanol).

Ammonium acetate bridges, salt bridges in wool keratin.

Ammonium alum → Aluminium ammonium sulphate.

Ammonium carbonate (crystal ammonia, ammonium sesquicarbonate, hartshorn), $(NH_4)_2CO_3$, MW 96. Hard white solid or fine powder (ammonium bicarbonate) with a strong smell of ammonia, slowly turns into a yellowish solid. Contains approx. 31% ammonia, and releases ammonia into the air (store dry in well-closed containers in a dark place). Slowly dissolves in 15 times its own weight of water. Decomposes with the formation of ammonia at 58°C. Uses: as the mildest alkali (wool scouring); neutralizing agent; spotting agent (for berry and red wine stains) etc.

Ammonium chloride (sal ammoniac), NH_4Cl, MW 53, density 1,52. White crystalline solid with a bitter salty taste, stable in air, soluble in cold water 1:3, in hot water 1:1,5, in alcohol 1:50 or in glycerol 1:8. Solutions are neutral but become weakly acidic on prolonged boiling (hydrolysis). Uses: various applications, especially in printing (aqueous solutions decompose into ammonia and hydrochloric acid).

Ammonium chromate $(NH_4)_2CrO_4$, MW 152. Lemon yellow crystalline needles or powder, readily soluble in water (approx. 40% solution at 30°C); decomposes readily on heating. Use: as a mordant for chrome dyes in printing (well-proven in printing alongside vat dyes).

Ammonium compounds, quaternary → Quaternary ammonium compounds.

Ammonium hydroxide (ammonia solution, ammonia liquor), NH_4OH. Colourless liquid: (volatile ammonia content) slippery, burns the skin, usually with 20–25% ammonia content (density 0,91, the density rises with falling concentration). Impurities: carbonate, tarry substances, alcohol, acetone; less frequently: sulphate, sulphide, chloride, copper. Properties: volatile (storage containers must be kept well-closed) and mild alkali; cellulosic and protein fibres are virtually unaffected; saponifying action on fats; attacks copper vessels (= blue stains); binds heat on evaporation. Uses: as a mild alkali in the scouring of wool, silk, etc.; degreasing agent (forms ammonia soaps which are easily rinsed out) and removal of soaps; for final neutralization in textile wet treatments; as a spotting agent (dissolves stains from metallic oxides, indelible markers, grass, etc.); volatile alkali, etc.

Ammonium linoleate Used as an emulsifier for fats, oils, waxes and solvents. Also used in the manufacture of spinning oils, washing agents, milling agents, etc.

Ammonium persulphate (ammonium peroxodisulphate), $(NH_4)_2S_2O_8$, MW 228,2. White crystals, soluble up to 559 g/l in water at 20°C, 98–99% purity, contains 6,8% active oxygen, good shelf-life in the dry state, decomposes under damp storage conditions, heating of aqueous solutions is accompanied by the evolution of oxygen. Uses: desizing; soap bleaching, oxidizing agent in dyeing and printing.

Ammonium phosphates,

I. Primary or monoammonium phosphate (ammonium phosphate, monobasic; ammonium diphosphate; ammonium dihydrogen phosphate), $NH_4H_2PO_4$, density 1,803. Colourless salt, readily soluble in water (368 g/l at 20°C), acid reaction. Uses: treatment of boiler feed water, specifically for sensitive high-pressure boilers as a corrective treatment (alkaline boiler steam); impregnation of candle wicks (prevention of afterglow and drops).

II. Secondary ammonium phosphate (ammonium phosphate, dibasic; diammonium hydrogen phosphate; diammonium phosphate (DAP); common ammonium phosphate), $(NH_4)_2HPO_4$, MW 132,07, density 1,619. Contains 53,75% P_2O_5 and 25,8% NH_3. Colourless, very soluble salt, 686 g/l at 20°C and 976 g/l at 60°C in water. Weakly alkaline reaction, 1% solution pH 7,62. On heating (fire) ammonia is split off and a phosphate melt is formed (flame-retardant). Uses: boiler feed water treatment, acid catalyst in pigment printing, flame retardant finishes.

Ammonium polyacrylate → Polyacrylate sizes.

Ammonium stearate, $C_{17}H_{35}COONH_4$, MW 301,50. Wax-like solid, soluble in alcohols. Use: foam generation in coating applications.

Ammonium sulphoricinoleate Yellow liquid, soluble in alcohol. → Turkey red oils.

Ammonium thiocyanate (ammonium sulphocyanide), NH_4CNS, MW 76, density 1,3. Colourless crystals, hygroscopic (deliquescent), readily soluble in water (up to 1620 g/l at 20°C), also soluble in alcohol. In aqueous (acidic) solution it forms the insoluble copper thiocyanate with copper salts, and the deep red iron (III) thiocyanate with trivalent iron salts. Uses: silk dyeing with vat leuco ester dyes; dyebath additive in copper vessels (as protection for copper-sensitive dyes); analytical detection of trivalent iron.

Ammonium thioglycolate, ammonium salt of → Thioglycolic acid.

Amorphous (Gr.: *amorphos* = shapeless), without structure or ordered arrangement. Noncrystalline in contrast to crystalline (→ Crystallite) as a highly ordered structure (see Fig.).

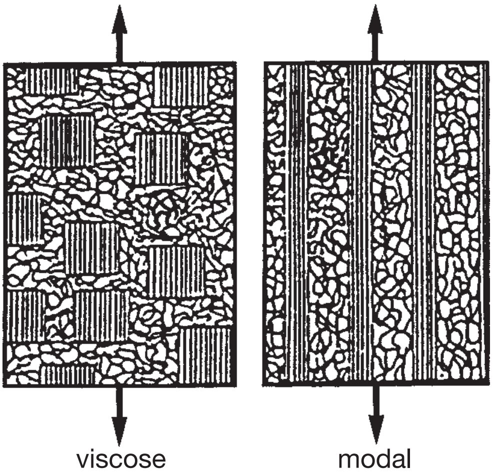
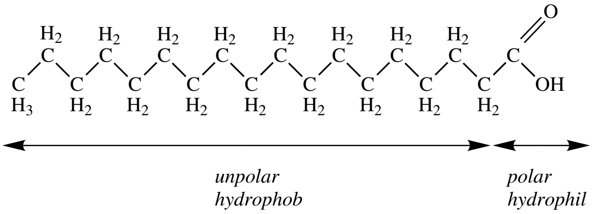


Fig.: Difference in submicroscopic structure of crystalline and amorphous areas in vicose and modal fibres.

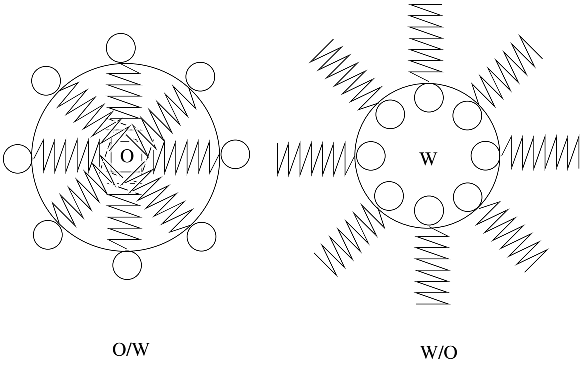
Amortisation Depreciation of value of buildings and fittings of all kinds. Amortisation rates set by taxation authorities are subject to varation → Service life of textile plant.

Amortisation of utility →: Amortisation, Service life of textile plant.

Amphiphilic Contains → Hydrophilic, (polar) and → Hydrophobic, (non-polar) molecular groups and therefore encompasses all → Surface active compounds.



In order to be able to achieve a large and stable surface of the inner phase of an oil/water emulsion system, surface active agents, so called emulsifiers, must be added. Such substances have an amphiphilic molecular construction and adsorb onto the oil/water interface. As a result, a water or oil stable emulsion film arises, which stops the droplets coalescing. It has been determined that effective emulsifiers have a small molecular volume. However the surface tension alone is not of decisive significance for the stability of the emulsion. The adsorption and orientation of emulsifiers in the oil/water interface depends on the solubility of the emulsifier in one of the two phases. In general, the emulsifier is more soluble in one phase than the other. With increasing solubility of the emulsifier, the interaction of the molecules of both phases with the emulsifier increases and there is a tendency for the two phases to separate. A surface film formed through the adsorption of the emulsifier is deformed in the direction of the phase with the higher surface tension. Therefore, the mechanical dispersion of two immiscible phases (water and oil) results in the phase with the higher surface tension being dispersed in the other phase in the form of droplets. According to Bancroft's Rule, the liquid in which the emulsifier is more soluble forms the outer phase. This means that a water soluble emulsifier is more likely to form O/W emulsions and an oil soluble emulsifier is more likely to form W/O emulsions. The adsorbed emulsifier molecule is so orientated at the interface that its hydrophobic (lipophilic) part dips into the oil and its hydrophilic (lyophilic) part dips into the water. This process can be seen in the diagram for W/O and O/W emulsions.



O/W W/O

Fig.: Orientation of the emulsifying agent molecule adsorbed at the water/oil emulsion.

Ampholyte Amphoteric electrolyte, a substance which can behave both as an acid and a base, i.e. it can donate as well as accept protons. → Zwitterions.

Ampholyte ion → Zwitterion.

Ampholytic surface-active compounds → Surface active compounds possessing two or more functional groups capable of ionization in aqueous solution which as a consequence, depending on the conditions of the medium, confer anionic or cationic properties on the product. In the broadest sense, this ionic behaviour is analogous to that of the → Amphoteric compounds.

Amphoteric The capacity to behave either as an acid or a base. A property typical of proteins and protein fibres which, due to the simultaneous presence of active amino groups ($–NH_2$) and carboxyl groups, possess the capacity to chemically bind acids and alkalies (by conversion to salts). → Ampholyte.

Amphoteric surfactants, ampholytic surfactants with several functional groups which become ionized in aqueous solution thereby giving the products an anionic or cationic character depending on the state of the medium. → Amphoteric.

AMSR Term for a solution of sodium methyl siliconate containing aluminium ions. Used for water repellent impregnation.

AMW, abbrev. for: → Average molecular weight.

Amyl alcohol (fusel oil, pentanol), $C_5H_{11}OH$, MW 88, density 0,82, boiling point 129–131°C, Fl.p. approx. 44°C. Mixture of two isomeric amyl alcohols. Oily liquid with highly flammable properties. Evaporation number 72. Uses: additive to process liquors of all kinds as a defoamer; spotting agent (for varnish, oil and tar stains, etc.); solvent for cationic dyes.

Amylases, (Gr.: *amylum* = starch) → Enzymes of the polyase family from plants, animals and bacteria (malt, pancreatic and bacterial diastases) which break down starch via dextrine into soluble maltose (starch degradation). Mixtures with lipases and proteases are also used in starch desizing agents. All amylases are only effective in the presence of monovalent anions

basis	optimum pH	optimum temperature
bacterial amylase	6,8	75 ˚C
pancreatic amylase	6,8	55 ˚C
malt amylase	4,5–5,5	60 ˚C

Tab.: Optimum effects of various amylases.

(e.g. chlorine ions). Not to be confused with → Amylose. Amylases achieve their optimum efficiency, like all enzymes, under specific conditions of temperature and pH (see Table).

Amylolytic Property of starch-decomposing → Enzymes

Amylopectin Constituent of the cell substance of starch grains (→ Starch).

Amylose The internal constituent of starch grains (→ Starch).

Anaerobic bacteria are bacteria which can live in the absence of oxygen (so-called anaerobes) such as typical saprogens which can also damage textiles. Sewage sludge can be reduced to hydrocarbons (especially methane, CH_4) in digestion towers with anaerobic bacteria under the exclusion of oxygen. Opposite term → Aerobic bacteria.

Anaerobic biodegradation Biological decomposition in the absence of oxygen. The question of the degree of biodegradation of a surface active agent in the environment points to the fact that a significant proportion of surfactants found in waste water is already eliminated by adsorption in the mechanical cleaning stage with so called "primary sludge". The slurry (primary and overflow sludge from the biodegradation stage) usually ends up in the settling tanks, where it is treated anaerobically and finally deposited, incinerated or used as a fertiliser. In many of the areas of the environment affected by surface active agents e.g. (sewage plant) settling plants, septic tanks for domestic sewage, soil and sometimes river sediments, anaerobic degradation plays an important role in the whereabouts of these substances in the environment. Doubtless, from an ecological standpoint, there exists the additional safeguard if surfactants are degraded not only aerobically but also anaerobically; thus it is assured that decomposition into natural end products can occur under all microbiological conditions.

Anaerobic respiration: organic substances are oxidised to form carbon dioxide, carbon dioxide is reduced to methane (methane fermentation):

$$CH_2O + {}^1/_2\,CO_2 \rightarrow CO_2 + {}^1/_2\,CH_4$$

or

$$CH_2O \rightarrow {}^1/_2\,CO_2 + {}^1/_2\,CH_4$$

With nitrate or sulphate:

$$2\,CH_2O + NO_3^- + 2\,H^+ \rightarrow 2\,CO_2 + NH_4^+ + H_2O$$

$$2\,CH_2O + SO_4^{2-} + 2\,H^+ \rightarrow 2\,CO_2 + H_2S + 2\,H_2O$$

Decomposition is also a multi-stage process in the anaerobic milieu in which many groups of bacteria partake consecutively. In particular in the settling towers, carbon dioxide and methane, along with a relatively small amount of biomass, form the main end products of anaerobic decomposition. The final decomposition of test substances can be followed from the generation of these gases. Admittedly, there exists at the present time no generally used standard test methodology, nevertheless the measurements for a series of surfactants are available on the basis of published test methods. Whilst the available simulation test, valid only for ^{14}C labelled compounds, represents a simple model of the sewage decomposition stage, the "ECOTOC-Screening

	ECETOC-Screeningtest		^{14}C digestive simulation test[a]			
surfactant	test duration [d]	fermentation gas formation [% CO_2 + CH_4]	^{14}C-mark position	gas formation $^{14}CO_2$	[% of Ao] $^{14}CH_4$	in total
anionic surfactants						
sodium palmitate (soap)	22	88	C chain	39,9	56,6	96,5
LAS	49	0	ring	0,2	0,1	0,3
C_{18}-FAS	56	>90	C chain	55,1	46,6	101,7
$C_{12/14}$-FA + 2 EO sulphate	41	74	–	–	–	–
α-methylester sulphonate (C_{16})	–	–	C chain	0,2	0,8	1,0
non-ionic surfactants						
$C_{16/18}$-FA + 9 EO	38	>90	EO chain[b]	36,8	47,0	83,8
$C_{12/14}$ alkyl glucoside	42	97	–	–	–	–
i-nonylphenol + 10 EO	84	20	–	–	–	–
cationic surfactants						
DTDMAC (C_{18})	–	–	C chain	6,7	8.2	<15[c]

a = test duration 4 weeks; b = C_{18}-FA + 7 EO was tested; c = gas formation due to test substance contamination

Tab.: Anaerobic decomposition behaviour of some surfactants under screening or simulation conditions.

Test on Anaerobic Degradability" allows for the testing of a wide range of substances. Just as with aerobic screening tests, a positive decomposition result can definitely be carried over into practice on account of the stringent requirements of this test (Table).

For a long time, the advantages (Biogas production, no energy consuming aeration and a small slurry yield) were unconvincing in comparison with the disadvantages (a supposedly small substrate spectrum, little slurry activity, an unstable process and small reactor capacity). The main drawback lies in the long generation times of anaerobic micro-organisms in comparison with aerobic bacteria. Through the fixation of the anaerobic biomass e.g. on sand, plastic beads or highly porous glass, it has become possible to uncouple the time spent in the decomposition reactor by the biomass from that spent by the substrate. Thus, high space/time yields are also achieved during anaerobic decomposition. Owing to the different optimum pH values of the micro-organisms involved in anaerobic decomposition, further optimisation was achieved by the use of 2 stage plants.

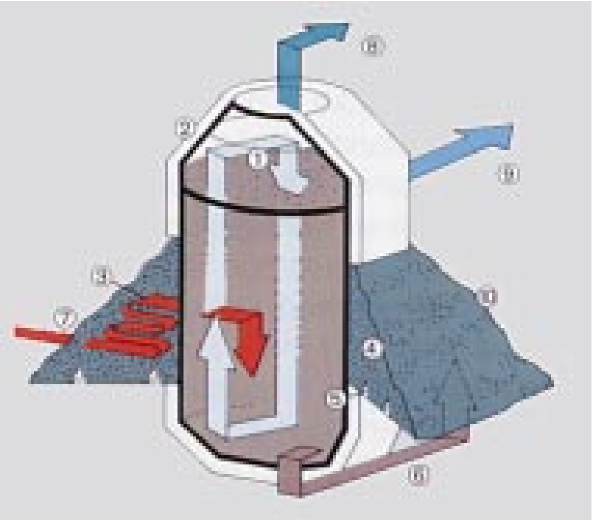


Fig.: Fermenter for anaerobic effluent purification (Hoechst).
1 = movement by pulsating circulation; 2 = insulation against hear radication; 3 = heat exchanger; 4 = heat supply by heat transfer from compost source; 5 = stack effect aeration; 6 = sludge discharge; 7 = effluent (liquid phase); 8 = biogas; 9 = purified effluent; 10 = compost.

Thus, today the anaerobic purification of industrial effluent is proving to be of interest. The fermenter, represented in the diagram, is particularly suitable for effluent which contains predominantly acetic and formic acids. The apparatus has a purification capacity of 16.4 tonne CSB/day (Chemical acid requirement/day) and produces up to 11000 Nm^3 Biogas with a methane content of 53%.

Various micro-organisms are involved in the anaerobic decomposition of organic substances. The first step in decomposition, which is mostly managed by fakultativen anaerobes, leads to the formation of fatty acids (Acidogenesis). With further decomposition acetic acid appears (Acetogenesis) along with carbon dioxide and hydrogen. The micro-organisms involved up to this stage of decomposition favour a slightly acidic environment. In the third stage of decomposition, Methanogenesis, acetic acid is broken down into methane and carbon dioxide on the one hand and on the other hand a portion of the carbon dioxide is reduced to methane by the hydrogen that has been formed. The methane forming bacteria function best in a neutral environment. Anaerobic decomposition is purposely carried out at 35°C and without light. →: Aerobic degradation; Methanation in the biogas process.

Anaerobic fermentation Anaerobic bacteria can reduce sewage sludge to hydrocarbons, particularly methane (CH_4), under exclusion of oxygen in digestion towers.

Analog digital control Hybrid control, or analog to digital control, is referred to when a → Digital controller operates as a master controller on an underlying analog cycle sequence. The dynamic behaviour is determined by an analog control circuit, to which a digital correction value is connected in order to achieve a high degree of long-term constancy.

Analogue computer A computer that performs computations (e.g. summation, multiplication and integration) by manipulating continuously varying physical quantities, commonly voltage and time. The variables are analogues of the quantities involved in the computation. Used in the design of computer models for dynamic systems.

Analogue displays Electrical equipment (direct reading instruments) which function according to the analogue principle. Physical systems are thus analagous to each other if they can be described by the same mathematical relationship.

Analogue output Functional part of the input and output system of a process control computer. Used to transmit signals to an output. The signals may be further modified by analogue processes and are suitable for use in set value transmitters, analogue recorders, regulating units etc.

Analogue to digital converter (ADC). Encoder, functional unit for the conversion of analogue signals into digital signals.

Analysis The breaking down of chemical compounds resp. the identification of individual components, either according to their type = qualitative (e.g. from hydrochloric acid HCl into hydrogen and chlorine) or their amount = quantitative (e.g. from 36,50 g HCl into 1,01 g H + 35,5 g Cl). Analysis involves the application of chemical procedures, frequently in the presence of an indicator (→ Titration) in which precipitates and colour reactions are obtained that are characteristic for each element. The various analytical procedures can be subdivided into e.g. →: Gravimetric analysis, Colorimetry, Complexometry, Volumetric analysis, etc.

Anaphe silk (African silk), → Wild silk, produced by a silkworm of the Anaphe family (Africa) which feeds on fig leaves. Groups of these caterpillars build large nests inside which they make their individual cocoons. The nests and cocoons are made entirely from silk. Anaphe silk is very fine and is processed into bourrette and schappe silk.

Anatase One of the three naturally occurring forms of → Titanium dioxide. Used as a white pigment in textile printing.

Anatolian carpets (Turk.: *Ana-doli* = eastern country). Oriental carpets originating from the interior of Asia Minor. They are mostly based on large geometric designs with highly stylized plant motifs in vivid, fresh colours. Figural motifs are absent. The principal regional varieties are: Bergama, Brussa, Dermirschi, Ghiordes, Hereke, Kayseri, Konya, Kula, Ladik, Mekri, Milas, Mudjur, Nigde, Panderma and Yuruk carpets.

Anchor-coating Used with woven cord fabrics for anchoring the pile on the underside in order to prevent the yarn loops from being pulled out when cut open, by means of stiffening agents which are applied on the back by brush.

Andanthron → Anthrone.

Anellation (Lat.: *anellus* = small ring). The term is used e.g. in dye chemistry, to describe anellated carbonyl compounds and anellated ring systems (synonym for condensed ring systems), when 2 carbon atoms lying next to each other together form part of 2 neighbouring rings, e.g. as in → Naphthalene and anthracene.

Anemometer (Gr. *anemos* = wind). Measuring instrument for air velocity, air quantity and gas flow.

Angle blade Used for applying the lacquer layer in → Screen production.

Angora Woven or knitted fabrics produced from angora wool. Fabrics composed solely of blends containing these animal hairs are also often falsely described as angora. Used for high quality outerwear, knitwear and hand-knitted articles.

Angora goat hair → Mohair.

Angora rabbit hair Hair of the angora rabbit, cultivated in Europe and East Asia, can be counted amongst the finest of the → Animal hairs. The annual yield amounts to 250 g of hair per rabbit from 3 to 4 shearings. The hair is mostly pure white, lustrous and silk-like (specific gravity 1,1–1,2). The coarse hair content, which is responsible for the fluff, amounts to approx. 2,2%. Hair thickness approx. 12,7 µm, tensile strength approx. 20 cN/tex., elongation at break approx. 38%, thermal retentivity approx. 50–70%. The fibres are obtained by shearing or combing. Angora hair has a high thermal retentivity due to the internal air-containing medulla (Fig.1) and is also very soft, light and free of pigment.

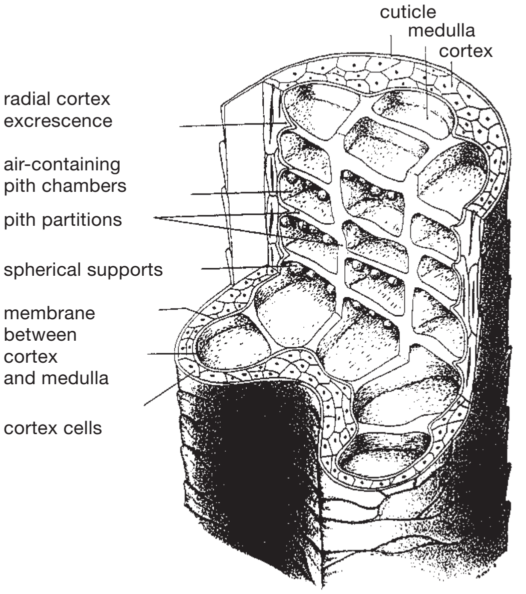
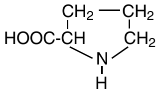
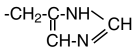


Fig. 1: Angora fibre morphology.

For technological reasons, these fibres are frequently spun with wool, a proportion of synthetic fibre or with cotton. Chemically, angora is a keratin fibre. The polypeptide chains of angora keratin are composed of approx. 20 different amino acids (see Table).

general formula of aminoacid	$HOO\text{–}\underset{NH_2}{CH}\text{–}R$	formula of the residue R	angora aminoacid content [%]
cystine	$-CH_2-S-S-CH_2-CH(NH_2)-COOH$		14,96
glutamic acid	$-CH_2-CH_2-COOH$		13,56
arginine	$-CH_2-CH_2-CH_2-NH-\underset{\overset{\|}{NH}}{C}-NH_2$		10,33
serine	$-CH_2OH$		7,62
leucine	$-CH_2-CH-(CH_3)_2$		7,46
proline			6,97
aspartic acid	$-CH_2-COOH$		5,89
threonine	$-CH(OH)-CH_3$		4,85
glycine	$-H$		4,79
lysine	$-CH_2-CH_2-CH_2-CH_2-NH_2$		4,59
tyrosine	$-CH_2-C_6H_4-OH$		3,78
valine	$-CH-(CH_3)_2$		3,50
phenylalanine	$-CH_2-C_6H_5$		3,08
alanine	$-CH_3$		3,01
isoleucine	$-CH(CH_3)-CH_2-CH_3$		2,71
histidine			2,65
citrulline	$-CH_2-CH_2-CH_2-NHCONH_{2-}$		0,27
methionine	$-CH_2-CH_2-S-CH_3$		0,00

Tab.: Aminoacid composition of angora hairs.

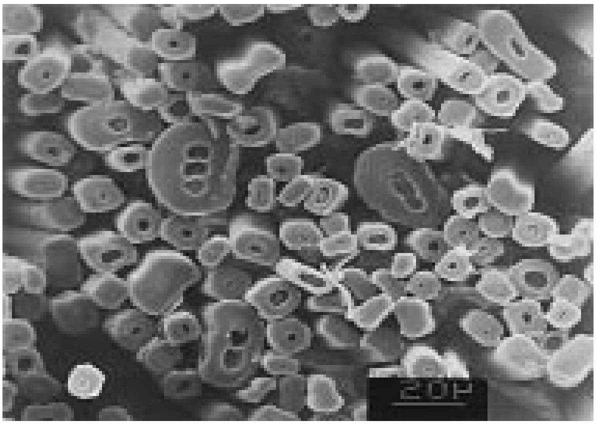


Fig. 2: Angora fibres in cross-section (magnified approx. 500 times).

Angora fibres consist of 3 main components (Fig. 1):

1. Cuticle: 0,3–0,4 μm thick, makes up 10% of the fibre weight. The typical arrangement of scales on the fibre surface can be described as chevron-structured (Fig. 3); they have a protective function, i.e. to prevent the penetration of foreign matter into the fibre interior.
2. Cortex: composed of microfibrils and matrix.
3. Medulla: depending on fibre type, the medulla is represented more or less frequently. It can be continuous or discontinuous and occurs only in fibres with a $\varnothing > 10\ \mu$m. In correlation with the diameter, the medullation increases in form so that the fibre can be marked with one or several rows.

In cross-section the fibres do not have a round, but an H, V or Y shape (Fig. 2). The longitudinal section (Fig. 3) reveals the scale structure of the angora hair.

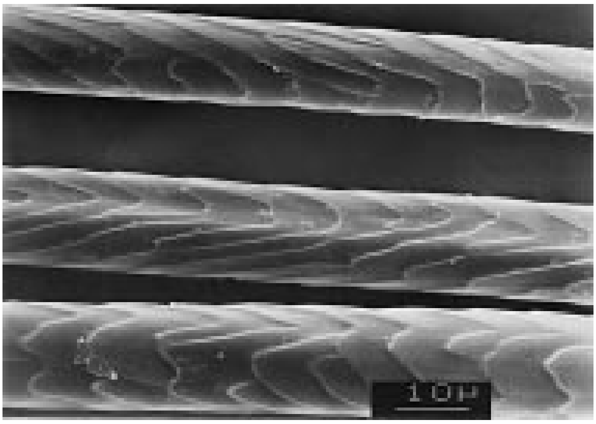


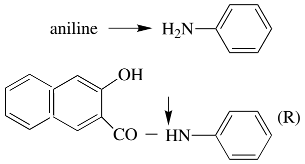
Fig. 3: Longitudinal view of angora fibres (magnified approx. 1000 times).

Ångström (Å), Ångström unit; 1 Å = 10^{-10} m. Named after the Swedish physicist A. J. Ångström (1814–1874). A unit formerly in common usage within the range from 1 Å to approx. 1000 Å principally for the measurement of molecular and fine internal fibre structures. Nowadays replaced in the metric system by the nm = 10^{-9} m, or the μm = 10^{-6} m.

Anhydride, water-free compound, e.g. from methanol CH_3OH = methyl ether $(CH_3)_2O$. The term is mainly used today for → acid anhydrides.

Anhydrous phosphates Identical with → Phosphate, condensed.

Anilides are derived from → Aniline, in which one hydrogen atom of the amide group is replaced by an organic acid group, e.g.:



(naphthol AS base type).

Aniline (aniline oil, phenylamine, aminobenzene), $C_6H_5NH_2$, MW 93, density 1,0265, b.p. 182°C. A constituent of coal-tar. In the pure state, a colourless, oily, highly hygroscopic liquid with a sweetish odour which turns brown on exposure to air. Hazardous blood and nerve poison which can be absorbed through the skin and via the lungs (MAK value = 8 mg/m^3, which corresponds to the odour threshold). Aniline is a weak base and forms salts with strong acids, readily soluble in aqueous solutions and miscible in all proportions with alcohol, ether and benzene. Aniline is the parent substance of the first synthetic dye (1856).

Aniline black (single-bath black, oxidation black, steam black, hanging black, Prud'homme black, prussiate black, Koechlin's black, diphenyl black). Insoluble oxidation dye from → Aniline, produced on the fibre (mostly cotton, less frequently wool/cotton unions) from individual soluble components. Chlorates and chromates are used as oxidizing agents and ferrocyanides, ammonium vanadate and copper salts as oxygen carriers. During development of the black, acid is liberated which, under inappropriate processing conditions, can cause damage to the fibre. Aniline black is one of the most beautiful blacks and is unsurpassed in depth and bloom. Shifts in tone towards green can occur on storage. Process variants:

I. Single-bath application (single-bath black) of a mixture of dissolved aniline salt, mineral acid and a chromium salt. Aniline black is gradually built-up on the fibre during the course of dyeing.

II. By subsequent oxidation (oxidation black, hanging black) of goods, impregnated with aniline salt, oxidizing agent, hygroscopic agent and oxygen carrier using dichromate/sulphuric acid.

III. By subsequent steam development (steam black) of goods, padded with aniline salt, yellow prussiate of soda and sodium chlorate. Only used for textile printing (in resist printing).

IV. Diphenyl black, produced by padding the black base followed by oxidation with sodium chlorate/oxygen carrier. Diphenyl black is free of the disadvantages associated with methods I–III above, namely, fibre damage and "greening" on storage of dyed goods.

With the exception of variant III, the other methods are no longer of any practical significance. A full handle accompanied by an increase in weight of up to approx. 10% is typical for goods dyed with aniline black. It is mainly used as the cheapest black with the highest fastness on cotton, dyed in hank form or in the piece. Its importance has now declined, however, in favour of sulphur black. Other applications on hank yarns, piece goods and knitgoods for stockings, linings and umbrella fabrics. Direct or sulphur dyeings are frequently overdyed with aniline black to achieve higher rub fastness.

Aniline black fastness properties Aniline black has excellent all-round fastness properties (including colour fastness to light, air, weathering, washing and alkaline perspiration). It is however sensitive to chlorine, which causes the shade to turn brownish. Aniline black produces blacks of the highest fastness on cotton. Single-bath black: has lower fastness properties, especially the colour fastness to rubbing and "greening" during wear (exception: diphenyl black).

Aniline black on the fibre, tests for →: Paraffin test for dyeings on cellulosic and protein fibres; Chlorine test for dyeings on cellulosic fibres; Chrome test for dyeings.

Aniline dyes Any of a large class of synthetic dyes made from intermediates based on or made from aniline. The term is still in use for individual brands.

Aniline salt (aniline hydrochloride), $C_6H_5NH_2$–HCl, MW 129,5. Colourless, large crystalline plates or lumps which turn dark green on prolonged storage, m.p. 192°C, readily soluble in water and alcohol. Often contains free hydrochloric acid. May be identified by the production of a green colour with methyl violet test paper.

Aniline sulphate test, for the identification of hemp resp. jute fibres: Place the fibres in a 1:20 solution of aniline sulphate (on a boiling water bath) for 20 min., rinse and dry. The fibres are stained a) pale yellow = hemp, or b) intense golden yellow = jute. Pure cellulosic fibres (including linen) remain unstained.

Animal colloids Stiffening agents such as →: Glue, Gelatine, Casein, used for sizes and finishes. → Colloids.

Animal fibres → Natural protein fibres.

Animal glue → Glue.

Animal hair fibres Angora, cashmere, mohair and other fine animal hair fibres (→ Natural protein fibres) occupy a significant place among textile fibres and play a considerable role in the fashion sector (Fig. 1).

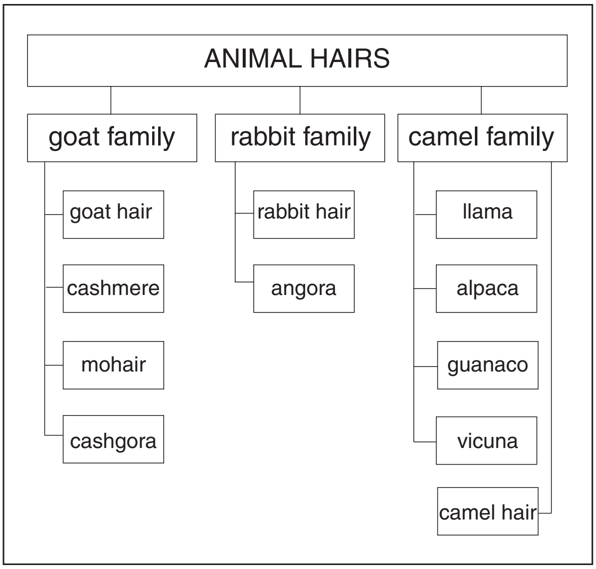


Fig. 1: Survey of the best known animal hairs which play a role in the textile sector.

In relation to world textile fibre production, however, the proportion of rarer animal hair fibres (excluding wool and silk) is very small (Table 1). The incentive to use these "luxury fibres" (rarer textile fibres) is due, on the one hand, to the commercial advantages of these materials such as, e.g. extreme softness, fineness and consequent low weight, as well as their rarity value and relative freedom from competition since fine animal hair fibres are of limited availability and they are able to justify a high price because of the general difficulties involved in their production. Moreover, a continuous trend towards the use of natural fibres in the apparel and home textiles sectors has been apparent for some years now. World production of the rarer animal hair fibres, as well as some specific data on these fibres, is given in Table 2.

	production x 1000 tonnes	percentage [%]
cotton	18 122	49,55
synthetic fibres	13 758	37,62
regenerated cellulose fibres	2 833	7,75
wool	1 753	4,79
silk	63	0,17
rare animal hairs	42	0,12
total	36 571	100

Tab. 1: World production of textile fibres (1987).

Tab. 2: World production of high-grade animal hairs (1987).
** varies with the situation on the international currency market.*

fibre	animal species	fibre diameter (µm)	fibre length [mm]	price class [£/kg]*	origin	world production [tonnes]	production trend
angora	angora rabbit	11–15	25–50	20–30	China South America France	8 500	increasing
vicuna guanaco	llama vicugna	10–20	30–50	150–200	Peru Chile	50	directly processed
cashmere	cashmere goat	15–19	25–90	35–70	China Mongolia Iran Afghanistan	5 000	ditto
					Russia	unknown	ditto
					Australia New Zealand	2 000	increasing
fine wool	sheep	17–22	50–60	6–10	Australia New Zealand South Africa	100 000	konstant
yak	cow	19–21	30–50	15	Tibet China Mongolia	unimport.	constant
cashgora	angora and cashmere goat	19–22	50–60	8–20	New Zealand Australia	200	increasing
camel hair	camel	18–26	29–120	10–12	China Mongolia	2 000	constant
alpaca llama	llama vicugna	22–25	75	12–15	Peru Chile	4 000	increasing
mohair	angora goat	24–40	75–100	6–18	South Africa Texas Turkey Australia Argentina	22 000	increasing

I. Rabbit hairs: → Angora rabbit hair is mainly used for high quality outerwear, knitwear, and hand-knitted articles. In the Federal German Republic the fibres are obtained by shearing and in France by plucking; the fibres are pigment-free, fine and supple, light and lofty. Because of their high warmth retention they may be beneficial to persons suffering from rheumatism.

II. Goat hairs: cashmere (cashmere goat) is used for scarves, blankets and fine outerwear fabrics. Depending on the provenance, a distinction is made between natural white, grey-beige, and brown cashmere, of which natural white cashmere is the rarest and most expensive quality. After combing, sorting, blending and washing, the long coarse hairs are separated from the fine downy hairs by means of a laborious depilatory procedure and the latter are further processed. The depilation of cashmere is based on a modified carding and combing process which often reduces the weight of the fibre by more than half. → Mohair (angora goat), which is obtained by shearing, is used in high quality wovens and knits and, in the form of worsted materials, for travel rugs, ladies' outerwear, and hand-knitting yarns in blends with wool. Mohair is a cool fibre which is comfortable in wear, crease-resistant, and possesses a silk-like lustre. Kid mohair, which is the fine wool of the young angora goat, is highly favoured in lightweight tropical clothing. → Cashgora is hair from the downy undercoat of the cashgora goat which was originally produced by crossbreeding female cashmere and male angora goats in New Zealand.

III. Llama-type fibres: →: Alpaca and llama are likewise obtained by shearing and are mainly used in their natural colours of white, cream, beige-brown and grey-black, for the production of cloths, apparel fabrics, high quality lightweight blankets and knitgoods. Vicuna and guanaco are the rarest animal hair fibres of this group and are supremely fine and soft. They are used on a limited scale in the production of high quality textiles.

IV. → Camel hair: the camel has an outer coat of dark, coarse hairs that may reach 30 cm or more in length, which are difficult to spin.These fibres are used in felts and blankets. Beneath the outer coat is a downy undercoat of fine soft hair 2.5–15 cm long. This camel hair undercoat is the really valuable part of the fleece and is as soft and fine as merino wool. These fibres are used for blankets, ladies' outerwear, loden and coat fabrics either alone or in blends with wool.

Fine animal hair fibres are frequently used in blends with wool, silk, and/or synthetic fibres to achieve particular effects with regard to shade, softness, lustre and handle, as well as improved technological properties and strength.

The growing interest of the consumer in high quality textiles produced from fine animal hair fibres and their blends, as well as the desire for labelling such

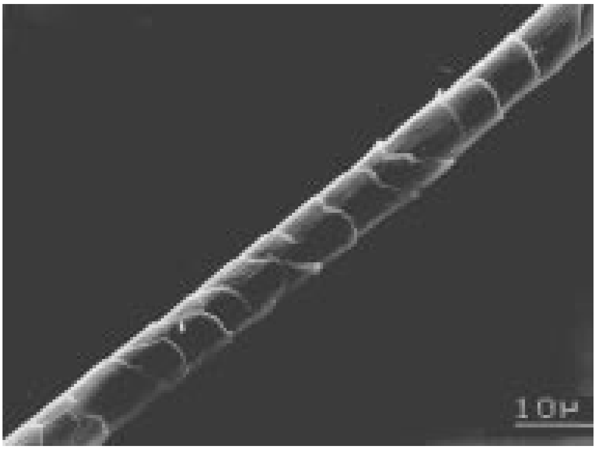


Fig. 2: REM photograph of a vicuna hair.

textiles to distinguish between wool and the higher quality animal hair fibres, was decisive in encouraging research aimed at the development of unambiguous analytical methods capable of characterizing these fibres. Fabrics containing blends of fine animal hair fibres are associated with higher quality textiles by the consumer. Blending of pure virgin wool with up to 20% of fine animal hair fibres is permitted by the International Wool Secretariate for the purposes of the Woolmark having regard to country-specific circumstances.

The application of electron microscopy (Figs. 2–4), chemical protein methods, as well as DNA analysis have provided the means for reliable identification of rare fibres as well their finishing treatments, and made the precise characterization of such textiles possible. Increasing efforts to breed finer and finer lambswool and merino qualities could pose a competitive threat to highly expensive, fine animal hair fibre varieties in future.

Animal hair fibres are mainly composed of keratin, a mixture of closely related structurally-bound proteins with a high cystine content. The keratins are localized in the exocuticle and macrofibrils of the cortex. From its morphological structure, the merino wool fibre is representative of a typically fine wool quality; it has a thin cuticle, contains the cortex as its main component, and the fibres are not medullated. By contrast, the fine animal hair fibres have a different morphology; they are often highly medullated to a greater or lesser degree, and the cuticle can consist of several layers.

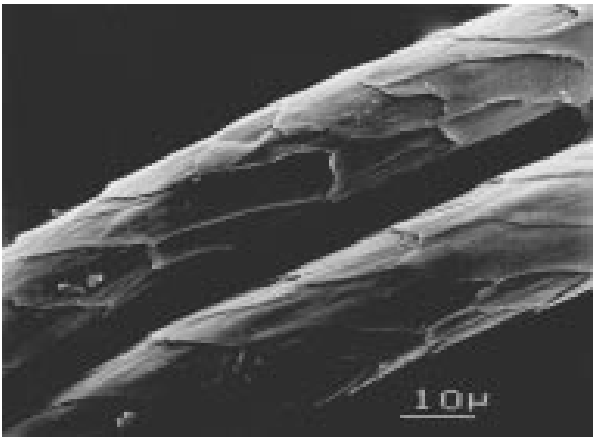


Fig. 3: REM photograph of camel hairs.

The proportion of medullae influences the cortex structure and, as a consequence, also the hair properties. Medullated hairs are stiffer than unmedullated ones, and exhibit variable dyeing behaviour. The fibre diameter, shape of cross-section, surface structure (scale structure) and the dyeing behaviour of animal hair fibres have an influence on the shade obtained in dyeing.

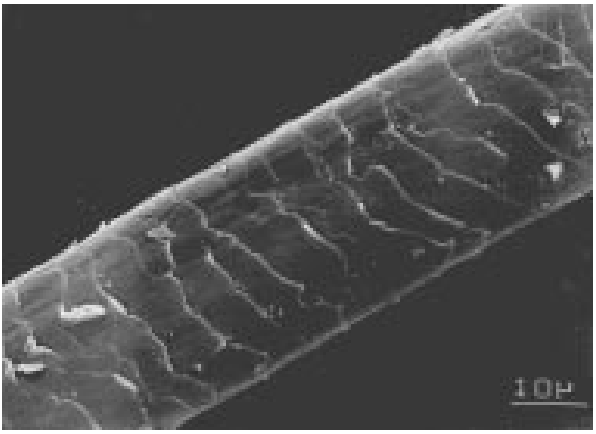


Fig. 4: REM photograph of an alpaca hair.

Photomicrographs of fine animal hair fibres clearly reveal the different fibre structures which must be responsible for their variable behaviour in finishing processes. Thus cashmere has a similar structure to wool. Mohair is partly medullated and oval to round in cross-section. The fibre has a lustrous surface and appears deeper in shade than wool after dyeing due to its surface reflection. The air-filled medullations in angora produce a different light refraction than wool (optical phenomenon) as a result of which light is reflected from the air enclosed in the medullated regions. As a result, the fibres appear much paler after dyeing in comparison to those without medullae. Fibres of this type, which have very marked medullae, contain insufficient cortex to take up adequate amounts of dye. The more or less large proportion of coarse and short bristly hairs, which are difficult to process and dye, and which, as a rule, remain paler in shade after dyeing, must also be taken into consideration. On the other hand, however, even the short bristly hairs (e.g. mohair or reindeer hair) are also used to advantage in blends for the production of special effects (Flensberg and Hammers).

Animalization Treatment to confer wool-like properties on regenerated cellulosic fibres with the aim of developing an affinity for wool dyes. Achieved by making suitable additions to the spinning solution (e.g. proteins, glue, casein, gelatine) or, alternatively, through the addition of, or an aftertreatment with, ethyleneimine and finally carbon disulphide (CS_2). Another technique involves a causticizing treatment with a 25% caustic soda solution containing an addition of β-aminoethylsulphuric acid.

Anionic Salts dissociate in water to give a positively charged hydrated cation and a negatively charged hydrated anion so that such solutions are electrically conductive. If, in the presence of an anode or cathode (direct current) the anions and cations migrate, they are active, i.e. they have an affinity for each of the opposite poles: anions migrate to the positively charged pole and are therefore anion-active (anionic). Opposite term → Cationic.

Anionic-cationic compounds → Electrically neutral compounds.

Anionic dyes → Dye ions.

Anionic exchanger → Ion exchanger.

Anionic retarders are retarding agents with dye affinity and are used in the dyeing of polyacrylonitrile fibres with cationic dyes. → Retarders.

Anionics contraction for anionic active → Surfactants (Anionic surface active agents).

Anionic surface-active compounds → Surface-active compounds, having one or several functional groups which ionize in aqueous solution to form negatively charged organic ions that are responsible for surface-activity.

Anionic surfactants Surfactants that are anion-active → Surfactants.

Anions → Ions.

Anisomorphic (Greek: an = not, isos = equal, morphe = shape/form), non-uniformly configured, in contrast to → Isomorphic.

Anisotropic (Gr.: *an* = not, *isos* = equal, *tropos* = direction), having different properties in different directions, e.g. the capacity of a dye in solution to dye only the fibre surface or only certain internal regions of the fibre due to various reasons (fibre structure, fibre damage, dye characteristics, etc.). See also → Isotropic.

Annealing Common term for the effect of moist heat on wool fabric. After-stretching of synthetic fibres and monofils mainly at high temperature (different depending on fibre type, use etc., dry, in steam, hot water etc.), aimed at improving orientation, as is particularly important for tyre cord ply yarns, e.g. by increased tear strength (in the case of polyamide filaments from about 44 to 70–80 cN/tex) and reduced elongation at break (from about 22 to 12%).

Anode →: Electrode; Electrolysis.

Anodic oxidation A problem encountered e.g. in yarn package dyeing machines. Metal dye tubes or package spindles become oxidized through the anodic action of two different metals used in the dyeing machine construction, thus causing a higher consumption of reducing agent in vat dyeing or premature oxidation of vat dyes. Rarely occurs nowadays due to the fact that dyeing machines are, without exception, constructed from stainless steel.

Anomaloscope An optical instrument for the testing and classification of anomalous and defective colour vision. It consists, in principle, of a direct-vision spectroscope. The examination involves the mixing of two spectral colours on an illuminated matt surface and matching the result with a third; i.e. the standard anomaloscope presents two halves of a circular field in contact. The lower half of the field consists of relatively pure yellow light connected to a dial which varies *brightness* only. The upper half of the field is filled with a mixture of two lights, red and green, the ratio of which can be varied by a second dial all the way from pure red to pure green. The testee is asked to obtain a perfect match between the two halves. The respective deviation in the amount of yellow used to obtain a match indicates the degree of anomalous colour vision. The anomaloscope provides reliable information on colour discrimination ability and suitability for colour matching in dyeing, etc. (screening test for new entrants to the colour using industries, career advice, etc.).

Anomalous colour vision (colour anomaly), congenital → Defective colour vision, which manifests itself as deviant → Colour vision. Two main types of anomalous colour vision can be distinguished: Individuals with a weakened sensitivity to mid-band wavelengths (green) are described as deuteranomalous trichromats and those with a weakened sensitivity to long wavelengths (red) are described as protanomalous trichromats. In colour matching work, the former type require more green to produce a colour match with yellow than individuals with normal vision whilst the latter type require more red.

Anormal fibre (wool) Originating from sick animals, displays anomalous thickening and necking.

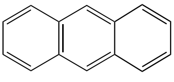
ANSI, abbrev. for: American National Standards Institute, New York → Technical and professional organizations.

ANS unit A colour difference unit in the → Colour difference formula of Adams, Nickerson and Stultz.

Antagonism A term used in environmental protection to describe the total effect of two harmful pollutants which is less than the sum of the individual pollutants. → Antagonistic.

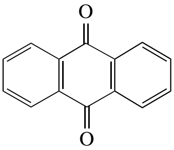
Antagonistic (Gr.), contrary, the combined effect of mutually opposed influences. Antagonistic effects are encountered in textile finishing when, e.g. water-repellent finishes are applied to textiles that are not free of wetting agents.

Anthracene is a linear condensed homocyclic hydrocarbon. It forms colourless plate-like crystals which sublime readily and have a blue-violet fluorescence. Used in the manufacture of → Anthraquinone, the parent substance of many synthetic dyestuffs.



Anthranol → Over-reduction.

Anthraquinone, $C_{14}H_8O_2$, MW 208. Oxidation product of → Anthracene. Outstanding reduction catalyst which increases the activity of reduction products (sulphoxylates). Used in the discharge printing of cationic dyes, naphthols, mordant dyes and bromoindigo.

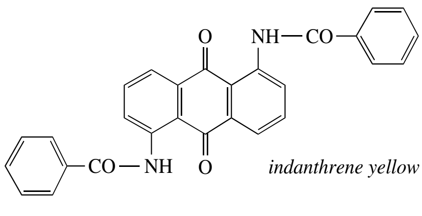


Anthraquinone dyes are derived from the parent compound → Anthraquinone, and belong to the quinonoid class of dyes. Simple anthraquinone derivatives are coloured when at least two further donor substituents (–OH, –NH_2) are present in addition to the basic anthraquinone structure. The more donor substituents that are available, the greater the adsorption of light in the long wave region of the spectrum. Quinone dyes based on the parent anthraquinone structure include disperse and mordant dyes, water-soluble quinone dyes, quinonoid vat dyes (Indanthren), acid, direct and reactive dyes.

The following systematic classification of some historically important anthraquinone dyes also includes details concerning their derivation:

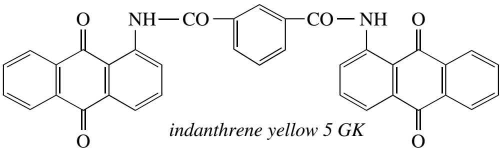
I. Chain-substituted and chain-linked anthraquinone derivatives:

a) Acylaminoanthraquinones:
- C.I. 61725 (F. Nölting, W. Wortmann, 1906; J. Deinet, 1909); Bayer; from the condensation of 1,5-diaminoanthraquinone with benzoyl chloride.



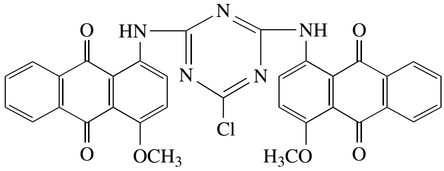
indanthrene yellow GK

- C.I. 65 410 (K.-H. Mayer, H. Hopff, A. Krause, 1925); BASF; from the acylation of 1-amino-anthraquinone with isophthaloyl chloride in dichlorobenzene at 145°C.



indanthrene yellow 5 GK

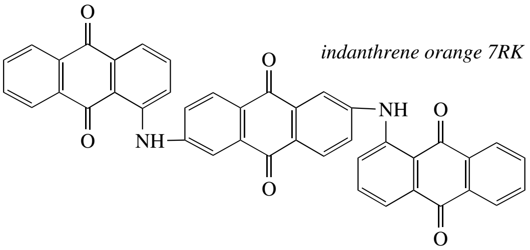
b) Anthraquinonylaminotriazine:
- C.I. 65 705 (1921); Ciba; from the condensation of cyanuric chloride with 2 mol. 1-amino-4-methoxy-anthraquinone.



cibanon orange 6R

- C.I. 65 710. Cibanon Red G. Chemical structure as for C.I. 65705 above but with an NH_2 group attached to the cyanuric ring in place of chlorine.

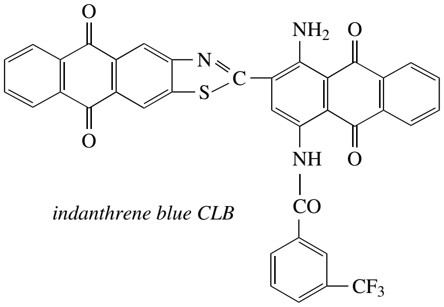
c) Anthraquinonylamine or anthrimide:
- C.I. 65 205 (M.-H. Isler, F. Kacer, 1907); BASF; condensation of 2,6-dichloroanthraquinone with 2 mol. 1-aminoanthraquinone in the presence of cuprous chloride and sodium acetate in nitrobenzene solution.



indanthrene orange 7RK

II. Derivatives of anthraquinone with a fused ring structure:

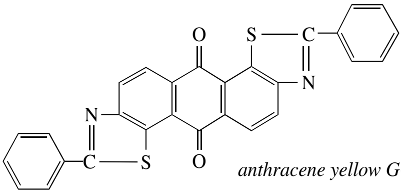
a) Anthraquinone-thiazole:
- C.I. 67 110 (H. Schlichenmaier, L. Berlin, E. Berthold, 1938); condensation of 1-amino-4-nitro-2-anthraquinonecarboxylic acid with 2-amino-3-chloroanthraquinone. From the mercaptan, cyclize, reduce and acylate with m-trifluoromethylbenzoyl fluoride.



indanthrene blue CLB

- C.I. 67 300 (M.-H. Isler and F. Kacer, 1912); BASF,

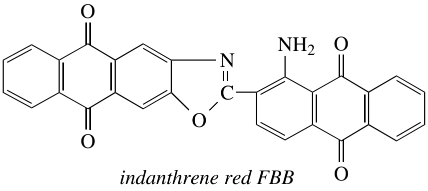
1. Reflux 2,6-diaminoanthraquinone, benzotrichloride and sulphur in naphthalene.
2. Condense 2,6-diamino-1,5-dimercaptoanthraquinone with benzaldehyde in sulphuric acid.
3. Condense 2,6-diamino-1,5-dichloroanthraquinone with benzaldehyde and sulphur.
4. Convert 2,6-dibenzamidoanthraquinone to the iminochloride (2,6-bis (α-chlorobenzylideneamino) anthraquinone), then sulphurize with sulphur and naphthalene or with aqueous sodium sulphhydrate and close the thiazole ring with chlorosulphonic acid.



anthracene yellow GC

(b) Anthraquinone-oxazole:

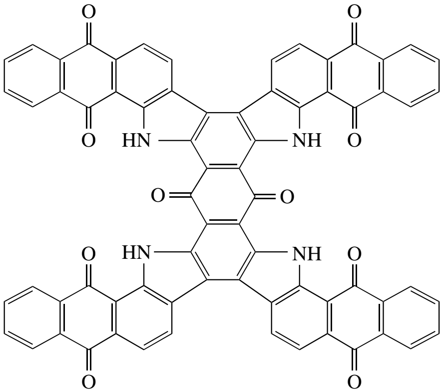
- C.I. 67 000 (M.-A. Kunz, G. von Rosenberg, E. Goffarjé, 1926); condensation of 1-nitro-2-anthraquinonecarbonylchloride with 2-amino-3-hydroxyanthraquinone in o-dichlorobenzene (pyridine, 140°C, 5 h) to the carbonamide; oxazole ring closure in 90% sulphuric acid, 90–105°C, 2 h. Substitution of the nitro group in 15% ammonia at 125°C, 12 h.



indanthrene red FBB

c) Anthraquinone-carbazole:

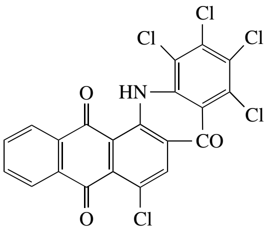
- C.I. 71 050 (E. Hepp, Frobenius, 1911); condensation of 4 mol. 1-aminoanthraquinone with 1,4,5,8-tetrachloroanthraquinone in the presence of copper and sodium carbonate in nitrobenzene at 205°C, 36 h. Cyclization of the pentanthrimide so formed with aluminium chloride and sodium chloride at 160°C, 2–3 h.



indanthrene khaki GG

d) Anthraquinone-acridone:

- C.I. 67 900 (I.G. 1931); conversion of 2-methyl-1-nitroanthraquinone to 1-amino-2-anthraquinonecarboxylic acid, condensation with aniline, cyclization and chlorination.

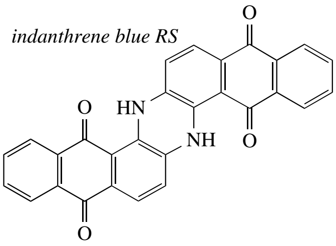


indanthrene brilliant pink BBL

e) Anthraquinone-N-hydroazine or indanthrone:

- C.I. 69 800 (R. Bohn, 1901); BASF.

1. 2-aminoanthraquinone is treated with potassium hydroxide in the presence of KNO_3, $KClO_3$, glucose or a salt of an organic acid such as potassium formate or acetate or a mixture of the two.
2. 2-aminoanthraquinone is treated with potassium hydroxide in the presence of ethanol and the mixture exposed to air.
3. Condensation of 1-amino-2-bromoanthraquinone in the presence of $CuCl_2$.
4. Reduction of 8-nitro-1-anthraquinonesulphonic acid to 8-hydroxylamino-1-anthraquinonesulphonic acid. Conversion to indanthrone disulphonic acid followed by desulphonation.

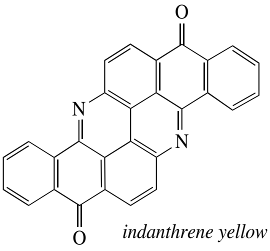


indanthrene blue RS

f) Flavanthrone:

– C.I. 70 600 (R. Bohn, 1901); BASF.

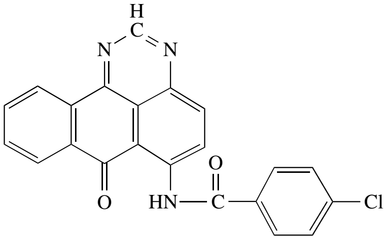
1. Treatment of 2-aminoanthraquinone in nitrobenzene with titanium tetrachloride or antimony pentachloride at 100–175°C.
2. Treatment of 2-aminoanthraquinone with potassium hydroxide in the presence of an oxidizing agent.
3. Conversion of 2,2´-biphenyldiamine into the diphthalimido derivative. Heat with aluminium chloride and cyclize with sulphuric acid.



indanthrene yellow G

g) Anthrapyrimidine:

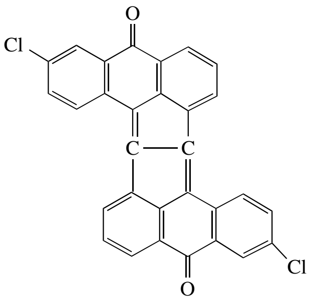
– C.I. 68 400 (M. Kunz, K. Köberle, 1931); I.G. Ludwigshafen; acylation of 4-amino-1,9-anthrapyrimidine with p-chlorobenzoyl chloride in the presence of pyridine.



indanthrene yellow 7 GK

h) Acedianthrone:

– C.I. 59 500 (I.G., 1930); treatment of 2-chloroanthrone with glyoxal sulphate, fusion with alcoholic potassium hydroxide and treatment with sulphuric acid.



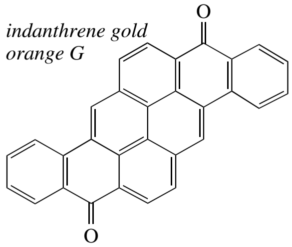
indanthrene red brown RR

III. Anthraquinonoid dyes with a pyrene structure:

a) Pyranthrone:

– C.I. 59 700 (R.-H. Scholl, 1905).

1. Elimination of 2 mol. water from 2,2´-dimethyl-1,1´-bianthraquinone by heating alone at 350–380°C or with dehydrating agents at lower temperatures.
2. Heat an aqueous paste of 2,2´-dimethyl-1,1´-bianthraquinone with or without the addition of ammonia or salts at 230–250°C under pressure for 10–12 h.
3. Heat 2,2´-dimethyl-1,1´-bianthraquinone with alcoholic potassium hydroxide.
4. Fuse 1,6-dibenzoylpyrene with aluminium chloride and sodium chloride and pass in oxygen.

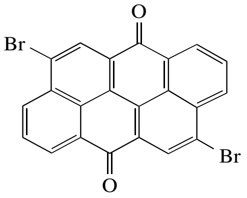


indanthrene gold orange G

b) Anthanthrone:

– C.I. 59 300 (L. Kalb, 1913).

1. Bromination of anthanthrone.
2. Ring closure of 1,1´-binaphthalene-8,8´-dicarboxylic acid in sulphuric acid and bromination.
3. Bromination may precede ring closure in (2) above.

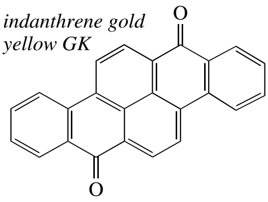


indanthrene brilliant orange RK

c) Dibenzpyrenequinone:

– C.I. 59 100 (G. Kränzlein, M. Corell, R. Sedlmayer, 1922)

1. Ring closure of 3-benzoylbenzanthrone with aluminium chloride and an oxidizing agent.
2. Ring closure of 1,5-dibenzoylnaphthalene in the presence of sodium and aluminium chlorides.



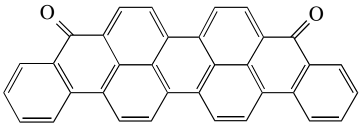
indanthrene gold yellow GK

IV. Anthraquinonoid dyes with a perylene structure:

a) Dibenzanthrone or violanthrone:

– C.I. 59 800 (O. Bally, M.-H. Isler, 1904)

1. Condensation of 9-anthrol with glycerol in the presence of sulphuric acid and fusion of the so formed benzanthrone with potassium hydroxide.
2. Heat 4,4´-dibenzoyl-1,1´-binaphthyl with aluminium chloride.
3. Fusion of benzanthrone with potassium hydroxide in the presence of glucose and an inert high boiling solvent.

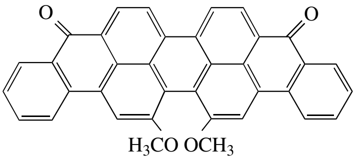


indanthrene dark blue BO

– C.I. 59 825 (A.-H. Davies, R.-F. Thomson, J. Thomas, 1920).

1. Methylation of the oxidation product of violanthrone in nitrobenzene.
2. Fusion of 2-methoxybenzanthrone with potassium hydroxide.
3. Oxidation of benzanthrone with manganese dioxide in sulphuric acid; condensation with alcoholic potassium hydroxide and alkylation.
4. Methylation of 16,17-dihydroxyviolanthrone.

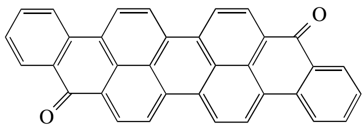
indanthrene brilliant green FFB



b) Isodibenzanthrone or isoviolanthrone:

– C.I. 60 000 (O. Bally, H. Wolff, 1906); BASF.

1. Chlorination of benzanthrone and treatment with alcoholic potassium hydroxide.
2. Heat benzanthrone with alcoholic potassium hydroxide in xylene, chlorobenzene or kerosine.
3. Conversion of 3-chlorobenzanthrone into the corresponding sulphide or selenide and reaction with alkali.

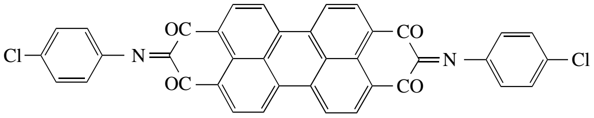


isoviolet anthrone

c) Perylene tetracarboxylic acids:

– C.I. 71 140 (P. Friedländer, 1919); condensation of 3,4,9,10-perylene tetracarboxylic acid with p-chloroaniline.

indanthrene scarlet R

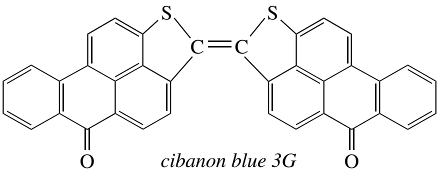


V. Benzanthronoid vat dyes:

a) Thiobenzanthrone:

– C.I. 70 305 (B. Mayer, A. Pfannenstiehl, 1908).

1. Condensation of 3-mercaptobenzanthrone with chloroacetic acid, fusion with potassium hydroxide and oxidation.
2. Technical production: heat 4-methylbenzanthrone with sulphur alone or preferably in the presence of a diluent.

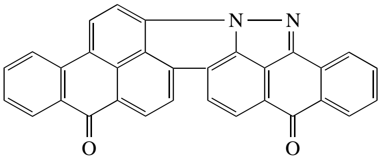


cibanon blue 3G

b) Benzanthronylpyrazole-anthrone:

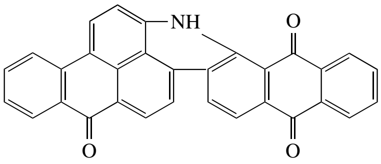
– C.I. 70 500 (K. Wilke, 1925); condensation of 3-bromobenzanthrone with anthrapyrazole and melting the product with alcoholic potassium hydroxide.

indanthrene navy blue R



c) Benzanthronylaminoanthraquinone:

– C.I. 69 500 (H. Wolff, 1908); condensation of 3-bromobenzanthrone with 1-aminoanthraquinone in boiling naphthalene in the presence of sodium carbonate and copper oxide. Cyclization with potassium hydroxide in isobutanol.



indanthrene olive green

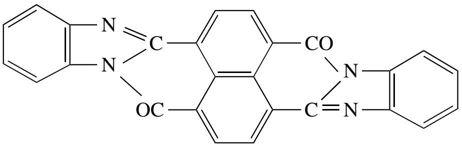
VI. Naphthalene derivatives:

a) Naphthoylene-benziminazole:

– C.I. 71 105 (W. Eckert, H. Greune, 1924)

1. Heat a mixture of o-phenylenediamine and 1,4,5,8-naphthalene tetracarboxylic acid in glacial acetic acid or pyridine solution.
2. Heat 1,4,5,8-naphthalene tetracarboxylic acid with o-nitroaniline. Reduce the nitro groups and cyclize.
3. Treatment of N,N´-diaryl-1,4,5,8-naphthalene tetracarboxylic acid diimide with 2 mol. o-phenylenediamine.

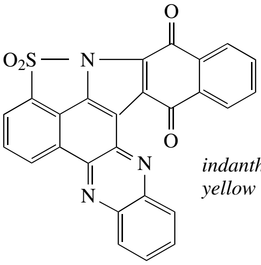
A mixture is formed consisting of 40–45% of the *cis* and 60–65% of the *trans* form. The mixture is heated with ethanol and potassium hydroxide and the so formed addition product is filtered and hydrolyzed with water.



indanthrene brilliant orange GR

b) Naphthoquinone:

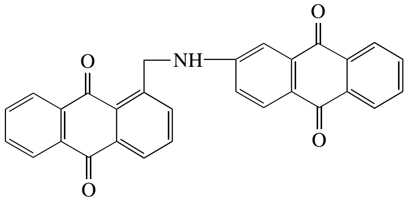
– C.I. 56 080, BASF; condensation of 5-aminobenzo-α-phenazine-4-sulphonic acid with 2,3-dichloro-1,4-naphthoquinone.



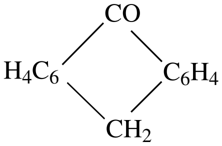
indanthrene yellow 6 GD

Anthrenus beetle protection → Moth- and beetle-proofing finishes.

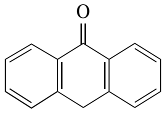
Anthrimides Anthraquinone imines produced from at least 2 → Anthraquinone groups linked by an → Imido group. Anthrimide structures are present e.g. in various Indanthren and Algol dyes, e.g. Indanthren Orange 6 RTK:



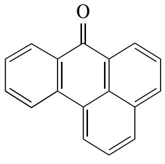
Anthrone Parent substance of a range of valuable anthraquinonoid vat resp. Indanthren dyes which are characterized by their high affinity for cellulose and, for this reason, are dyed without salt by the IN method.



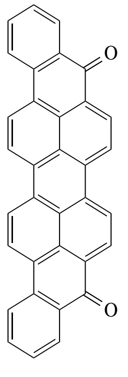
As illustrated by the above formula anthrone, unlike → Anthraquinone, possesses an anthracene molecule with only one keto group (CO). The important dye, dibenzanthrone, is derived from anthrone, e.g. via benzanthrone, i.e. the excellent violet-blue dye Indanthren Dark Blue BO and as iso-dibenzanthrone, the dye Indanthren Violet R extra, with its outstanding fastness properties (both are perylene derivatives):



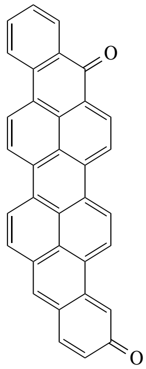
anthrone



benzanthrone

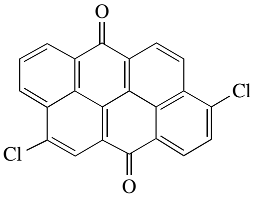


dibenzanthrone
(indanthrene dark blue BO)

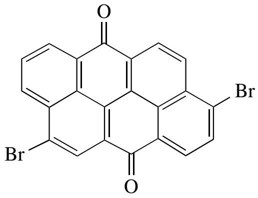


isobenzanthrone
(indanthrene violet R extra)

Instead of illustrating many other examples of this type, it will suffice to mention andanthrone here, a pyrene derivative which, in its chlorine and bromine-substituted forms, yields vat dyes with vivid shades and high light fastness:



indanthrene brilliant orange GK



indanthrene brilliant orange RK

Anthropometry (Gr.: *anthropos* = human, *metron* = measure), the comparative study of sizes and proportions of the human body which are of importance, e.g. in → Method study.

Antiadhesives Special textile auxiliaries which are used to prevent the adhesion of hosiery on metal formers during the postboarding process (→ Boarding). Also facilitates the rapid removal of hosiery from formers. Typical commercial antiadhesives increase the hosiery elasticity and also function as softeners.

Antibacterial → Bacteriostatic.

Antibacterial finishes (→ Antimicrobial finishes). The application of products to textile fabrics capable of preventing the growth of various microorganisms and which, therefore, also contribute to deodorizing. Such products are subdivided into → Bactericides (destruction of bacteria) and bacteriostats (inhibition of bacterial growth). In the literature there is often no distinction made between these terms. Bactericidal finishes are hardly ever used for apparel since the necessary auxiliaries are not compatible to the skin. These finishes are of relatively minor importance for carpets. Antibacterial finishes are effective not only against bacteria but also against → Mycotoxins.

Antibacterial textiles The Institut Textile de France in Ecully Cedex developed what are termed “biotextiles”. In these textiles (Fig.) grafted with antiseptic substances, the molecular chains with antiseptic agents are grafted onto the parent polymers of the raw material. The parent polymers are activated by electron discharge. In the process they open up at certain sites. The graft priming monomers are deposited at these sites. The polymer chains propagated laterally impart the bactericidal properties to the textile. The textiles provide very quick-response bactericidal protection in direct contact and this property is fully retained after laundering. Applications for biotextiles include medical and surgical textiles plus interior furnishings for the contract, hotel and office sector as well as in workwear for the pharmaceutical and foodstuff industries and in speciality fields such as air filtration.

Antibiotics Biosynthetic or chemically-manufactured substances which are capable of inhibiting or destroying vegetable or animal microorganisms (penicillin type). In the textile sector, “antibiotic auxiliaries” are used especially for →: Bactericidal finishes, Fungicidal finishes, etc.

Antichlor Any product which serves to decompose residual chlorine on textile materials following → Chlorine bleaching processes, as a result of which oxidative damage to cellulose is avoided. A distinction is made between antichlor agents used to eliminate residual available chlorine in the form of a) hypochlorous acid and b) protein compounds (→ Chloramines). During the course of a kier boil-chlorine bleach process no significant amounts of a) are formed so that, in this case, post-souring [$NaOCl + 2\ HCl \rightarrow NaCl + Cl_2 + H_2O$] followed by rinsing is sufficient. In cold bleaching without an alkaline prescour, however, residual chlorine of type b) is formed. There are consequently different antichlor agents for a) [= post-souring, hydrogen peroxide], for b) [= sodium or potassium hydroxide, sodium carbonate] and for a) and b) [= ammonia, sodium bisulphite, sodium hydrosulphite, sodium pyrosulphite, sodium sulphite, sodium thiosulphate and sulphurous acid]. Antichlor treatment after a) + b) = cold rinse after chlorine treatment, followed by treatment in 1–2 g/l cold bisulphite for 15–30 min. then post-souring in the same bath with 2 ml/l hydrochloric acid. The 1st phase of the much more commonly used thiosulphate method results in the formation of: sodium sulphate, hydrochloric acid and sulphur [$Na_2S_2O_3 + Cl_2 + H_2O \rightarrow Na_2SO_4 + 2HCl + S$] whilst in the 2nd phase: sulphuric and hydrochloric acid [$S + 3Cl_2 + 4H_2O \rightarrow H_2SO_4 + 6HCl$] are formed; this being the origin of the obligatory final, thorough rinsing treatment to remove residual acid. Neutralization (as above) with hydrogen peroxide and soap under hot conditions (= whites stable to storage).

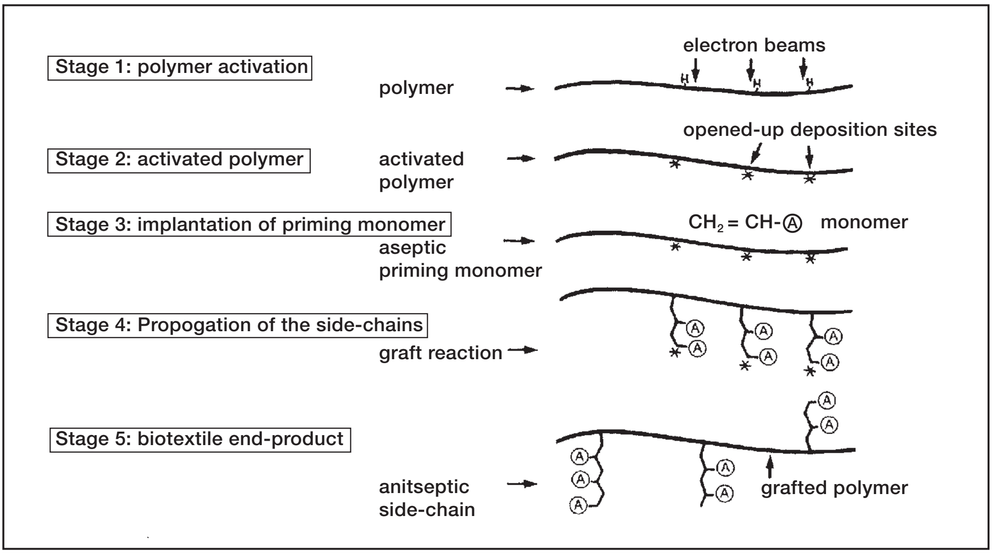


Fig.: The chemical grafting technique of antibacterial finishing.

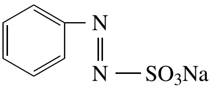
Anti-cling finishes are applied to fabrics made from synthetic fibres in order to prevent garments from clinging to the body. Identical with → Antistatic finishes.

Anti-cockling treatment Elimination of possible loop distortion in garment pieces made from combed wool yarns during subsequent wet processing (→ Chlorine/Hercosett process) by treatment in boiling sulphite or bisulphite solutions.

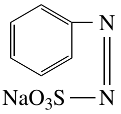
Anti-corrosive → Corrosion inhibitors.

Anti-crease finish → Resin finishing of cellulose for reducing creasing tendency to the lowest possible dimension.

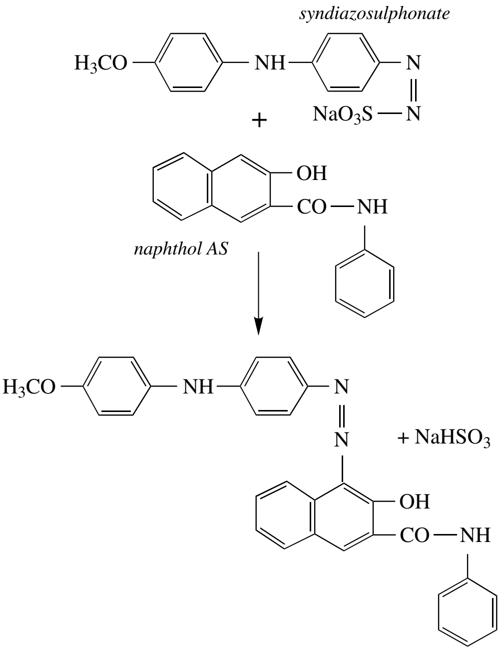
Antidiazosulphonates play a role e.g. in combinations with naphthols. In this case, they act as components which are not capable of coupling of the type:



After printing, this structure undergoes rearrangement due to the action of steam or light energy into the syn-diazosulphonate which, from now on, is capable of coupling with naphthols:



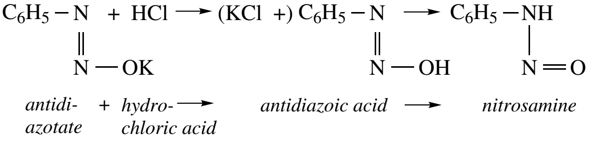
such as takes place, e.g. in the formation of an insoluble azo dye from the coupling of Rapidazol Blue IB with Naphthol AS:



A remarkable property of compounds of this type is that the all-important rearrangement reaction is also initiated by the action of light. In this process, oxygen carried along with the fabric can be activated by powerful light energy, especially with the addition of sensitizers, which then results in a photochemical rearrangement and coupling. This type of reaction forms the basis of photographic printing.

Antidiazotates (isodiazotates). These products were originally described as → Nitrosamines. They are representative of fairly stable naphthol diazonium salts (no longer capable of coupling) in solid form and are derived from → Amines with very weak basic properties. As reaction products of alkalies (NaOH) on diazonium salts they offer the advantage that the nitrosamine necessary for coupling is only formed after an acid treatment (→ Naphthols in printing).

Principle:



$$\underset{\text{N}-\text{OK}}{\underset{\|}{\text{C}_6\text{H}_5-\text{N}}} + \text{HCl} \longrightarrow (\text{KCl} +)\ \underset{\text{N}-\text{OH}}{\underset{\|}{\text{C}_6\text{H}_5-\text{N}}} \longrightarrow \underset{\text{N}=\text{O}}{\underset{|}{\text{C}_6\text{H}_5-\text{NH}}}$$

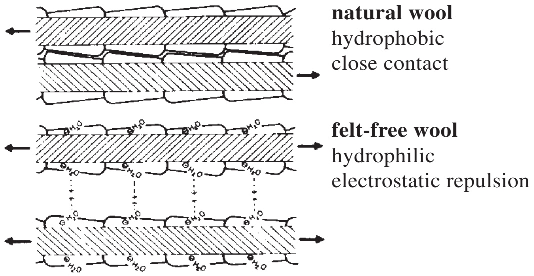
Antifelting finish The typical scale structure of the wool fibre can be affected by means of different processes so that it is no longer detrimental in terms of felting. A distinction is drawn between various processes:

I. Subtractive process: in the exocuticle A, wool scales are hydrophobic, whilst the endocuticle is hydrophilic. Hydrophilisation of the exocuticle A by oxidation of the 35% cystine there with hypochlorite results in the oxidised outer fibre areas containing cysteic acid being covered by a film of water when they are washed. This water film results in neutralising the ratchet effect (as the innermost parameter of the felting process).

II. Additive process: masking the scales with polymers (forming a film-like cover). The additive process enables woven or warp knitted fabrics to be finished from an aqueous or organic medium. Synthetic resins are applied to the fibre by padding (or sometimes also by the exhaustion process). Their action is mainly based on the so-called "spot weld effect", i.e. the polymers, in condensing, glue the individual fibres together at their contact points (unsuitable for tops), providing good shrink-proof effects at low cost.

III. Combined process, like the → Hercosett process for example.

The action of chemical antifelt finishing is therefore no longer explained merely by the morphological degradation of the wool scales (→ Wool felt), but also by the introduction of ionised groups. The surface of natural wool contains only a very few ionised groups, and is hydrophobic, which produces very close fibre contact in the aqueous felting medium. The formation of ionised and hydrated groups in antifelt finishing makes the fibre surface hydrophilic; at the same time, an electric double layer is produced. Both factors together reduce fibre contact in the aqueous medium, and prevent the longitudinal anisotrophy of the frictional characteristics responsible for felting from being effective on wool fibres (Fig. 1).



[← → favoured direction of movement under the effect of mechanical energy]

Fig. 1: Electrostatic relationships with natural and antifelting finished wool in water.

Subtractive antifelting finish: mainly represents oxidative antifelting finish. The oxidative decomposition reaction on main chains, cystine bridges and some other side chain remnants must be regarded in terms of the different chemical composition of the morphological components. Whilst the peptide group concentration in all components is of about the same dimension, the cystine content of the exocuticle is approx. 20%; in contrast, the orthocortex contains only about 8%. The Allwörden reaction demonstrates the favoured reaction of the chlorine with the scale cells. Chlorine penetrates the intact epicuticle, and attacks the underlying layers. Osmotic swelling results in the formation of external blisters and scales. This explains the special position of chlorine in antifelt finishing with its specific action on the peptides in the exocuticle, which is expressed in selective splitting of the peptide bonds near the tyrosine remnants. The fragments are still high-molecular of course, but water-soluble. Since they cannot pass the epicuticle, they induce osmotic swelling of the scale cells as soon as the fibre is immersed in water. Consequently, chlorinated fibres have higher coefficients of friction both in the tip and root directions, and reveal a less pronounced differential friction effect (DFE) than natural fibres. In practice however, this results not only in plasticisation but also decomposition. In chlorination, the sulphur-rich cuticle proteins, which provide soluble products, are preferably decomposed. The amino acid compositions of proteins in chlorinating liquors and exocuticle are coincident, but there is a whole series of other hypotheses on the action mechanism of oxidative antifelting finishes: the original hydrophobic fibre surface becomes hydrophilic due to the introduction of ionic groups. At the same time, an electric double layer is formed. This reduces fibre contact, increasing the DFE. According to Speakman, the antifelting effect of chlorine among other chemicals is explained by the oxidative splitting of cystine bridges, and the consequent reduction in wool fibre elasticity.

Additive antifelting finish: these processes operate with polymers or prepolymerisates which cross-link under specific conditions after being applied. Additive antifelt finishing is effected therefore in two stages:

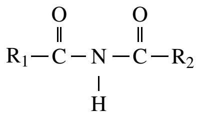
a) Polymer application (exhaustion or application process);
b) Cross-linking reaction.

The polymers employed must therefore be soluble or dispersible in their original form. The formation of three-dimensional networks is supposedly of advantage in obtaining effects fast to washing and dry-cleaning. Most effective antifelt finishing agents therefore contain either a prepolymer or a cross-linking component with a functionality of at least 3. Additionally, the polymer must have a low brittle temperature in order not to impair handle. Satisfactory tear strength plus elasticity and the ability to swell must guarantee the resistance of the polymer film to mechanical action. It has been unequivocally established that cross-linked polymers can provide acceptable antifelting effects only through covalent bonds. For this reason, suitable polymers contain reactive groups.

The most important additive antifelting finishes are produced with the aid of a polyurethane polymer. This finishing agent consists of a concentrated solution of a polyether/polyurethane mixture with an isocyanate content of approx. 4 weight percent in organic solvent. The sensitivity to hydrolysis of the isocyanate group necessitates application from an organic solvent. Finishing can be carried out both continuously and in batch form. Cross-linking is effected by the action of moisture or by steaming.

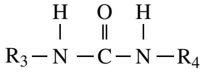
$$R\text{–}NCO + H_2O \rightarrow R\text{–}NH_2 + CO_2\uparrow$$

The formation of biuret and urea groups etc. can be assumed.



$$R_1-\overset{\overset{\displaystyle O}{\|}}{C}-\underset{\underset{\displaystyle H}{|}}{N}-\overset{\overset{\displaystyle O}{\|}}{C}-R_2$$

Biuret group



$$R_3-\overset{\overset{\displaystyle H}{|}}{N}-\overset{\overset{\displaystyle O}{\|}}{C}-\overset{\overset{\displaystyle H}{|}}{N}-R_4$$

Urea group

One water-soluble polyurethane for antifelt finishing is the 50% aqueous solution of a prepolymeric aliphatic polyurethane which contains a number of carbamyl sulphonate groups. This product is produced by the accumulation of sodium hydrogen sulphite on the polyurethane isocyanate groups:

$$R{-}NCO + NaHSO_3 \rightarrow R{-}NHCOSO_3^-Na^+$$

Use from aqueous solution is possible with this modification; cross-linking takes place in the alkaline medium:

$$R{-}NHCOSO_3^- + OH^- \rightarrow R{-}NHCOOH + SO_3^{2-}$$

$$R{-}NHCOOH \rightarrow R{-}NH_2 + CO_2$$

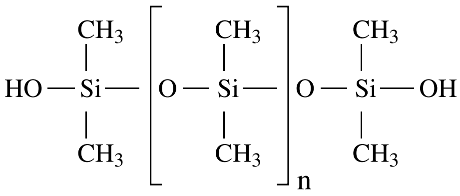
$$R_1{-}NH_2 + R_2{-}NHCOSO_3^- \rightarrow R_1{-}NHCONH{-}R_2 + HSO_3^-$$

The prepolymers are bonded to each other via the urea groups. The water-soluble polyurethane is used together with an acrylate or polyurethane dispersion, since this combination has a synergistic effect. The product is particularly suitable for the additive antifelt finishing of fabrics and made-up products, adequate felting resistance being achieved without prechlorinating.

Two exhaustion processes have been developed in addition to the application process. With both processes, it is possible to cross-link the polymer as early as in the finishing bath. This is necessary in finishing knitted fabric, which is dried under gentle conditions in a tumbler after a wet process, and then steamed for just a brief period. The rate of exhaustion is controlled by the temperature in the drip feed process, and, in the isothermal method, via the salt concentration. Another product is based on a 50% water-soluble polyurethane prepolymer with carbamyl sulphonate groups, which cross-links in the alkaline medium. In the interest of greater production reliability and short processing times, the following padding variants are recommended for piecegoods:

a) Condensation process: padding (80% liquor uptake), drying (100°C), condensing (5 mins at 140°C), decatizing.
b) Wet cross-linking process: padding, rotational dwelling (16 hours at 25 ± 3°C), rinsing/washing, drying.
c) Moist cross-linking process: padding, drying to 30–40% residual moisture content, rotational dwelling (shorter than b), rinsing/washing, drying.

In the condensation process, the liquor contains cross-linking agent, sodium hydrogen carbonate, the water-soluble polyurethane, a polyurethane emulsion and a silicone-based soft handle agent.



$$HO-\underset{CH_3}{\overset{CH_3}{\underset{|}{\overset{|}{Si}}}}-\left[O-\underset{CH_3}{\overset{CH_3}{\underset{|}{\overset{|}{Si}}}}-\right]_n O-\underset{CH_3}{\overset{CH_3}{\underset{|}{\overset{|}{Si}}}}-OH$$

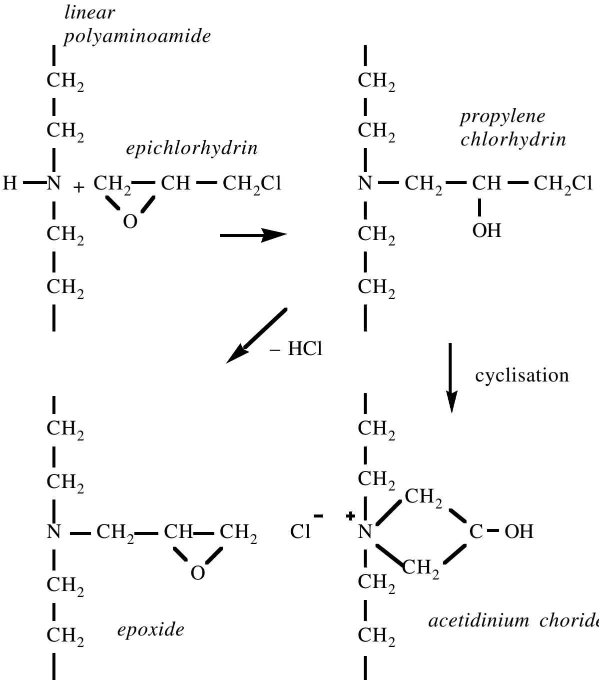
Silicone elastomer

With identical polymer concentration however, the handle turns out softer in the exhaustion process, a fact which is attributable to migration during padded fabric drying. Intensive rewashing and treatment with a softening agent should provide a remedy in this respect. In the wet and moist cross-linking process, a starch and cellulose-based thickening agent is added to the liquor, a factor which should improve the cross-linking effect, levelness, running characteristics and liquor uptake. This thickening agent displays a certain extender action, whereby the quantity of antifelting polymer can be reduced. It evidently makes the handle harsher in cross-linking with the polymer, but this can be compensated by wet-on-wet finishing with silicone elastomer I. The dwell time can be substantially shortened by adding magnesium chloride. In comparison with the condensation process, both the wet and the moist cross-linking processes engender better antifelting behaviour.

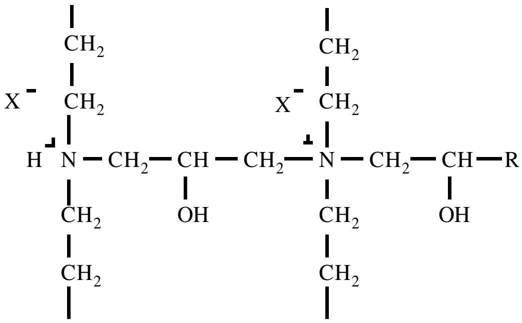
Electron microcope photographs reveal adhesion points between the wool fibres. A fibre immobilised in this way can no longer move, and consequently no felting can take place. The reduced DFE plays merely a subordinate role. The mechanical characteristics of the polymer, its tear strength and also adhesion to the fibre surface are of particular importance. The adhesion between polymer and fibre is occasioned by van der Waal forces, electrostatic interaction and possibly by the penetration of polymer segments into the scale cells. The subject of covalent bonds between resin and wool is controversial. It has however been shown that these are not essential for a good antifelting effect.

Combined antifelting finish: this process consists of a combination of additive and subtractive methods. The most important combined process is doubtless the Hercosett process, consisting of chlorination and additive resin application. Tops are mainly antifelt finished by this process. The Hercosett polymer is obtained from adipic acid and diethylene triamine with the addition of epichlorhydrin.

$$n\,[HOOC{-}(CH_2)_4{-}COOH + H_2N{-}(CH_2)_2{-}NH{-}(CH_2)_2{-}NH_2] \rightarrow -[CO{-}(CH_2)_4{-}CONH{-}(CH_2)_2{-}NH{-}(CH_2)_2{-}NH]_n$$



The epoxide groups and acetidinium cations already react during synthesis with the secondary and tertiary amino groups, producing cross-links between the polymer chains:



In order to prevent uncontrolled additional cross-linking, the reaction mixture is acidified, hydrolysing the free epoxide groups. The product is a partially cross-linked, but still water-soluble polymer which contains acetidinium cations as reactive groups. The operational sequence is as follows:

- acid prechlorination (NaOCl or Cl_2),
- neutralisation and antichlorine treatment (Na_2CO_3 and $NaHSO_3$),
- rinsing,
- resin application (polyamide-epichlorhydrin resin),
- softener application.

In top finishing, it is most particularly important that the fibres are completely covered by a polymer film. Uniform dissemination of the cationic polymer is made possible by oxidative pretreatment, by which the critical surface tension of the wool fibre is increased, and anionic groups are formed. Polyamide-epichlorhydrin resin applied to the untreated wool has no effect on felting tendency, because it is aggregated. The action is explained as follows: the resin swells substantially in water, and reduces the DFE, which is insignificantly changed by the weak chlorination. Another theory is that a water film on the swollen polymers reduces the frictional differences in consequence of a lubricating effect. The best results are obtained with combined antifelting finishes; the washing test results on purely additive antifelting finishes are worse (Fig. 2).

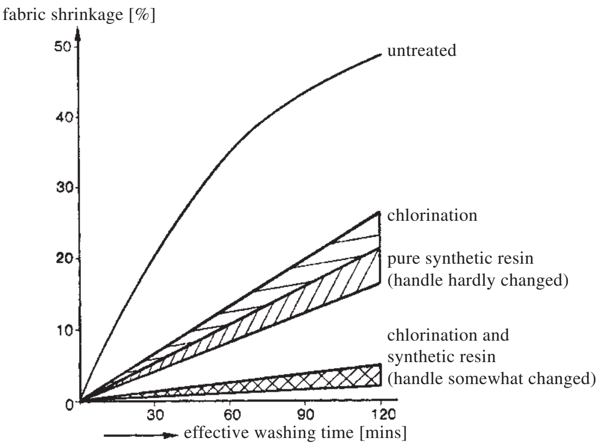


Fig. 2: Fabric shrinkage over time of knitted test specimen pieces in felt testing in accordance with DIN 54 321.

Antifoamers → Antifoams.

Antifoams In package dyeing as well as in sizing, finishing and, above all, printing, problems can arise due to the foaming of liquors or print pastes. Universally applicable antifoams as well as antifoams for specific applications are available based on a wide variety of chemical types. Tributyl phosphate (TBP) in particular, is an excellent antifoam agent. In exceptionally problematic situations, well-proven combination products are recommended, particularly in the case of print pastes, where further valuable properties can be incorporated, e.g. to improve flow properties, prevent doctor streaks and provide a simultaneous lubricating and protective action on printing rollers and doctor blades in roller printing. → Defoamers.

Antifoams in drycleaning are used in the form of e.g. organic halogen compounds to overcome distillation problems due to foaming which can be caused by e.g. dissolved silicones from drycleaned articles.

Antifrosting agents Textile auxiliaries based on alkylaryl polyglycol ethers for the prevention of → Frosting.

Antifungal, generic term for → Fungicidal and fungistatic finishes.

Anti-greying agents → Antifrosting agents.

Antimetabolic substances block the formation of products important for the life of cell structures, e.g. even the structure of bacteria cells (e.g. in → Bacteriostatic finishes).

Antimicrobial A term used to describe the action of growth inhibition, or the destruction of, → Microorganisms, e.g. as a property of man-made fibres which have been spun with antimicrobial compounds (→ Antimicrobial fibres) or as in → Antimicrobial finishes.

Antimicrobial agents, bacteriostatic, bactericidal, fungistatic, fungicidal textile protective agents especially for rot-proofing applications. Phenolic compounds, quaternary ammonium salts and organometallic compounds (Hg) are among the most important antimicrobial agents.

→ Antimicrobial finishes are of particular importance in the household sector, e.g. for those types of article that are seldom or never washed or drycleaned, such as fitted carpets, upholstery fabrics and mattress ducks. In addition to their action in preventing the transmission of pathogenic microorganisms, antimicrobial finishes should also be capable of counteracting the development of odour from the bacterial decomposition of perspiration in clothing (linings, socks, etc.). For such applications, as well as for household textiles, the descriptions: deodorized and → Sanitized finishes are also used.

Antimicrobial fibres (medical fibres), are man-made fibres with antimicrobial properties which include: inhibition of microbial growth, prevention of pus formation, acceleration of wound healing and reconvalescence. Used in the production of bandages, medical gauze, cotton wool and tampons.

Antimicrobial finishes, are effectively produced on textiles by e.g.:

1. Addition of microbicidal substances to the spinning solution in fibre manufacture.
2. Modifications involving grafting or other chemical reactions.
3. The finishing of textiles with suitable active substances. Such substances are fixed on textile materials after a thermal treatment (drying, curing) by incorporation into polymers and resin finishing agents.

Antimicrobial effects, resistant to washing resp. drycleaning, are obtained e.g. by the incorporation of microbicides into spinning solutions as well as by chemical modification of the fibre itself. As a result, the textile material is protected from microbial attack and can no longer serve as a culture medium. It is, however, also necessary for the active constituent to be carried to the microorganism cells being targeted, either by water, e.g. after hydrolytic breakdown, or by leeching out of the textile material. This is an important prerequisite for an effective antimicrobial effect.

Many active substances suffer reduced effectiveness or even inactivation as a result of chemical reaction with e.g. the fibre. For this reason, finishing processes, which apply substances that can be incorporated into textile auxiliaries, and which do not crosslink with, but rather exhaust on to the fibre from where they are slowly released during use, have gained increasing importance. In this case, of course, resistance to washing and drycleaning is limited. This limited resistance is actually desirable in terms of effective germ-resistance. Probably the oldest substances with an antimicrobial action are the salts of mercury (mercuric chloride) and silver (silver nitrate). The introduction of antiseptic wound disinfection and the disinfection of bandaging with phenol can also be regarded as early efforts in the campaign to eliminate the germ-carrying potential of cellulosic textiles through the addition of active substances. The wide application of chlorinated phenols, pentachlorophenol and 2,4,6-trichlorophenol for rot-resistant finishes on tarpaulins and tent fabrics was a later development, although these are now no longer used because of their toxicity.

No sooner had measures for hygiene and disinfection become firmly established, than the original rot-resistant finishes for heavy fabrics composed of cellulosic fibres was further developed in the application of antimicrobial resp. sanitized finishes to apparel and household textiles. As the most important active agents, quaternary ammonium compounds, as well as products based on phenylmercuric acetate, hexachlorophene and salicylanilide, have found wide application in such finishes. Finishing treatments with these products are less effective in affording protection to textile materials against decomposition (rotting) under unfavourable conditions at high temperatures and high air humidity. They are, rather, of much greater value in preventing the transmission of pathogenic organisms and, through inhibition of microbial growth, in counteracting the decomposition of skin fats and perspiration, without actually interfering with their natural formation, thereby checking the development of undesirable odours.

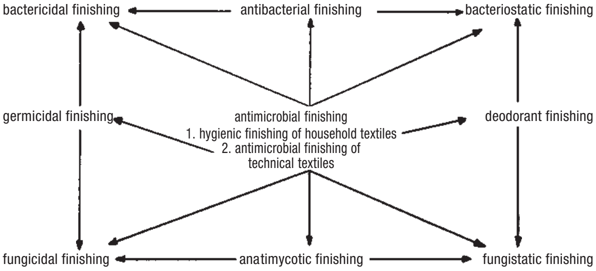


Fig.: Breakdown of antimicrobial finishing.

Antimicrobial finishes may be subdivided into the following types (see diagram):

- Germicidal finishes: germ-destroying finishes. The term is mainly used in connection with rot-resistant finishes.

- Hygienic finishes (hygiene = the science concerned with the maintenance of health): sanitized finishes. Elimination of pathogenic microorganisms by the application of appropriate finishes.
- Antibacterial finishes: include both bactericidal and bacteriostatic finishes.
- Bactericidal finishes: have the effect of causing the destruction of all bacteria.
- Bacteriostatic finishes: have the effect of inhibiting the growth of bacteria already present without causing their destruction.
- Antimycotic finishes: finishes designed to kill moulds or prevent their growth.
- Fungicidal finishes: the use of active substances capable of killing moulds already present.
- Fungistatic finishes: the use of compounds which have the effect of inhibiting mould development only, i.e. the moulds or their spores are not killed.
- Algicidal finishes: the growth of algae on textiles can be prevented by the application of suitable active substances.
- Deodorizing finishes: finishes designed to prevent the development of unpleasant odours.
- Rot-preventive finishes: finishes designed to protect textiles against the action of bacteria and moulds under unfavourable storage conditions, i.e. at high humidities and temperatures.

The purpose of an antimicrobial finish is therefore:

a) to prevent the transmission and spreading of pathogenic (disease-causing) microbes (hygiene sector);
b) to inhibit odour development resulting from microbial degradation (deodorizing);
c) to avoid loss of textile serviceability resulting from fibre decomposition due to microbial attack.

A distinction is made between hygienic finishes on apparel and household textiles and antimicrobial finishes for technical textiles. The requirements given under a) and b) are crucially important for hygienic finishes, whilst c) is particularly relevant in the technical textiles sector.

“Sanitizers” are products capable of limiting microbial attack to a certain extent only.

Applications of such products to textiles are described as → Sanitized finishes. The use of formerly well-known products is no longer permitted due to the introduction of statutory regulations. Suitable non-toxic products, resistant to washing and drycleaning, are difficult to find. Attempts have therefore been made to attach suitable products to the fibre through covalent linkages: e.g. by employing reaction products of cyanuric chloride and halogen derivatives for cellulosic fibres; or the attachment of nitrofurylacrolein and p-nitro-chlorocinnamic aldehyde to wool; and various derivatives for polyamide and polyvinyl alcohol fibres.

Antimicrobial finishing of carpets Application of compounds capable either of destroying or inhibiting the growth of moulds and bacteria to textile floorcoverings by padding on one side or spraying. They consist mainly of products based on phenol derivatives, heavy metal salts, formaldehyde-releasing agents and quaternary ammonium compounds.

Antimicrobic → Antimicrobial.

Antimigration, opposite of → Migration. Measures taken to influence, inhibit or prevent the undesired migration of dye by physical, e.g. drying, or chemical means by the addition of suitable products. → Migration inhibitors.

Antimigration agent, textile auxiliary designed for → Antimigration. e.g. as in pigment-pad and continuous dyeing processes. → Migration inhibitors.

Antimony (Sb), atomic weight 120, mp 630°C, density 6,7. White or bluish white crystalline metalloid, lustrous, brittle and stable in air. Not attacked by hydrochloric acid and soluble in sulphuric acid. Used in alloys as a hardening component (hard lead, tin-antimony). It forms antimonic compounds in its + 5 oxidation state and antimonous compounds in its + 3 oxidation state, most of which are colourless, exceptions are yellowish orange. Sb(III) compounds: the oxyhydrate (also known as antimonous acid, $Sb_2O_3 \cdot H_2O$) forms salts with strong acids and alkalies. The cold-water soluble trifluoride SbF_3 and its double salts are also of importance, as well as antimony oxalate. Sb(V) compounds: the dark red double sulphide ($Na_3SbS_4 \cdot 9\ H_2O$) is particularly important as an accelerator in the vulcanization of rubber.

Antimony potassium oxalate → Potassium antimonyl oxalate.

Antimycotic finishing subdivided into → Fungicidal and fungistatic finishes. For clothing material, fungicidal finishes are hardly ever considered because the skin cannot tolerate the required finishes. → Antimicrobial finishes.

Anti-odour finishes Textile finishing for inhibiting the smell of oils and greases etc in textiles by substances applied during production, or for producing special fragrances (lilac, lavender etc). A deodorant effect during wear is not of course associated with this finish. The technique of micro-encapsulation for anti-odour garment finishing is meant in this connection. (→ Sanitized finishing).

Antioxidants (oxidation inhibitors). These compounds inhibit, or even prevent, oxidation processes (→ Inhibitors). Antioxidants are of practical importance, e.g. in the form of a small additions to drying oils used in oil sizing to prevent the evolution of heat and attack on the fibre due to an excessively rapid self-oxidation or autoxidation. For this purpose, certain substances with OH and NH_2 groups capable of being oxidized such as e.g. phenols, amines, aldehydes, ketones, benzyl alcohol, diphenylamine, hydroxydiphenylamine, hydroquinone, etc. are used. Antioxidants perform the same function with textile lubricants, subject to spontaneous combustion, which have poor → Mackey test values.

Antiperspirants (deodorants). These products mainly contain mildly astringent and acidic salts, e.g. aluminium chloride (15–30% solution). The effect is based on the observation that these compounds prevent the decomposition of perspiration in the alkaline range. Antiperspirants also contain antiseptics (e.g. formaldehyde). Antiperspirants based on aluminium chloride, in particular, represent a potential source of damage to textiles (30% solution = pH 1; acid content by titration calculated as hydrochloric acid = approx. 13%, which corresponds to a degree of acidity equivalent to a 1:2 dilution of conc. hydrochloric acid).

Antipilling Processes intended to minimise or prevent → Pilling (pill formation), mainly applicable to fabrics produced from high-tenacity, man-made fibres and their blends. The pilling propensity can be detected by means of an abrasion test. Pilling may be prevented by initial heat-setting, total shrinking and singeing, besides impregnation in finishing with film-forming products capable of inhibiting fibre migration. Such products are generally based on acrylates or polyurethanes. The films formed with these products must be as resistant to abrasion as possible in order to be effective. Another antipilling possibility is fibre modification.

Antipodal pair → Optical activity.

Antiredeposition agent Additional component of a → Washing agent for increasing the → Soil suspending property; also called "builders".

Antirheumatic A term generally applied to textile fibres which are effective against rheumatism, e.g. pain relief achieved from the use of polyvinyl chloride fibres in underwear and quilt fillings. Wool also possesses antirheumatic properties.

Antirotting preservatives Used in textiles exposed to moisture to protect against rotting by microorganisms. They are similar products to → Preservatives.

Antiseptics are agents with a powerful antiseptic action. They find general application for the protection of all materials where the growth and further development of bacteria must be arrested or inhibited (→ Preservatives).

Antishrink setting → Heat setting.

Anti-slip and anti-snagging agents These serve to reduce the slippage of open set woven fabrics, to prevent the formation of ladders in warp knitted fabrics and the so-called → Snags in stockings and finished fabrics of fine synthetic yarns. The effect is based on the production of a thin, rough, adherent film on the fibre surface of the treated fabrics. Preparations of plastics (e.g. polyvinyls, polyacrylates, polymethacrylates and polystyrene) and natural resins or silicic acid.

Antislip finishes These finishes are used to avoid the shifting of crossing warp and weft threads in fabrics containing a low number of yarns or woven in open constructions to prevent the formation of holes, splitting of seams, etc. (→ Slip resistance). Antislip finishes involve the application of antislip finishing agents by wet processing.

Fabrics for technical applications (e.g. geotextiles, glass-fibre wallpaper) are often woven with such thin constructions that there is a great risk of yarn slippage as they are delivered from the weaving machine. In order to overcome this problem, a finish applicator device, consisting of an applicator, hot air and drum drier and rising roll batcher, is installed directly at the weaving machine. Suitable antislip finishes include film-forming polymer dispersions or silicic acid hydrosols. Additional auxiliaries, such as antistatics etc., may also be applied at the same time.

Antisnag finish for velvets A finish applied to velvet or plush fabrics in order to prevent the pile becoming detached from the warp. The effect is similar to that of an antislip finish and involves impregnating the back side of the fabric with starch products, cellulose derivatives or various synthetic resins.

Antisoiling finish, are finishes designed to achieve active → Stain blocking. The term is also used to describe various technical measures applied in finishing to keep soil away from textiles. Soiling propensity is dependent on the fibre material, the technological structure of the yarn and fabric as well as the finish. Crease-resist finishes and water-repellent treatments increase soiling propensity. The man-made fibre producer's solution to the problem is to create a "clean fibre", e.g. by the incorporation of additives into the spinning solution.

Anti-soiling finishes A distinction is drawn between:

I. Dirt repellent finish for preventing wet soiling, based particularly on → Water repellent finishing and, if necessary, a swelling-resistant finish.

II. Dirt repellent finish against dry soiling, based on principle on the fact that fibre surface unevenness due to specific soiling, mainly inorganic metal oxides, Al_2O_3, SiO_2 or so-called white pigments, is evened out, producing a specific rebound effect as a barrier against dirt.

III. Dirt repellent finish against oil soiling: → Soil release finish.

Antisoiling finishes on carpets Finishes applied to textile floorcoverings by dipping, slop padding or spraying with substances capable of reducing the soiling propensity of carpet materials (→ Stain blocking). There is also a close relationship with → Antistatic finishes. Fibre origin, cross-section, delustring and carpet construction have no significant influence on the degree of soiling. Coloration, however, has a considerable influence on soiling. In finishing, the application of fluorocarbon-based products by spraying is the most widely used method up to now. In the case of wool carpets, the pretreatment has been found to influence soiling propensity. Antisoiling finishes are of particular importance for carpets in rooms with underfloor heating (dryness). In addition to the application of antisoil finishes, the use of special pile material is also necessary.

Anti-soil redeposition Prevention of redeposition on textile materials of already dissolved or dispersed soils in wash baths → Soil release finishes.

Antistatic agents Textile auxiliaries (anionic, cationic or non-ionic) used to prevent the development of electrostatic charges during the processing and use of synthetic fibres and yarns (which also includes some natural fibres such as e.g. wool). In the case of anionic and cationic antistatic agents, the antistatic effect becomes greater with increased chain length of the fatty acid residue. Presumably this is because a marked molecular adsorption, perpendicular to the fibre surface, becomes possible with longer chains. Antistatic action is essentially due to the combined effects of increased ionic conductivity, increased water absorbing capacity and, possibly, a fibre lubricating effect as well. Antistatic agents have only a very limited effect on soil-repellency. Wash-resistant antistatic agents are based on the principle of applying to the fibre, e.g. polymer compounds whose water solubility is due to the presence of hydrophilic side-groups, after which the water-solubilizing groups are blocked by salt formation or esterification.

Antistatic fibres To eliminate the build-up of electrostatic charges on textiles (especially textile floorcoverings), permanently antistatic polyamide or metallic fibres are used. By using antistatic polyamide fibres, the electrostatic charge is reduced to a level below the sensation limit (2000 V) even at a relative air humidity of only 20–30%. The man-made fibre industry has introduced numerous antistatic polyamide fibres to the market (Fig. 1) based on different principles, e.g. embedded carbon particles, metallized fibres, copper sulphide deposition on the fibre surface besides the incorporation of antistatic agents into the spinning solution, etc. Antistatic polyamide fibres with a graphite core (Fig. 2) are already used to a considerable extent in women's clothing, including nightwear, as well as technical textiles (e.g. for the EDP sector).

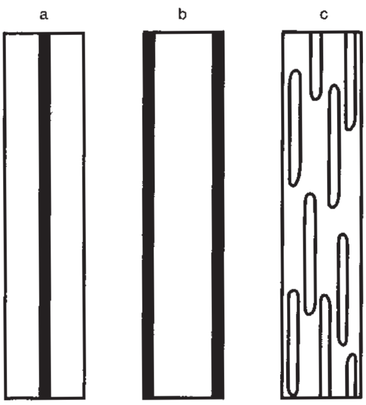


Fig. 1: Antistatic fibres: a) conductive core, b) conductive mantle, c) fibrillar distribution of the antistatic product.

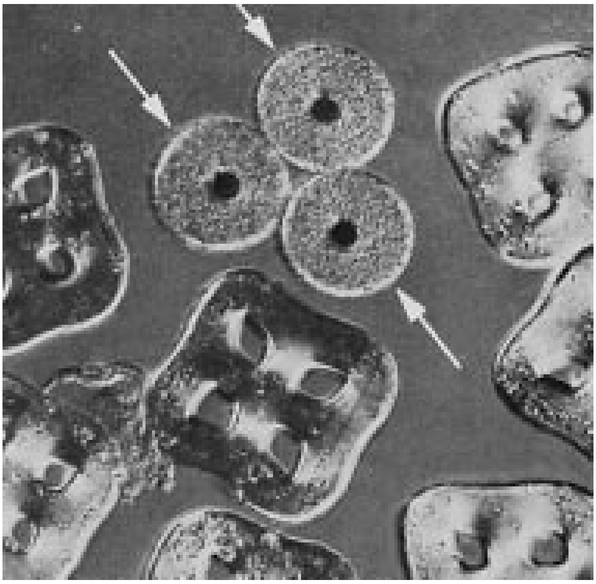


Fig. 2: Antistatic fibres with a conductive core (IFK 500 : 1): Dupont Antron-III-HF-hollow fibre with which graphite fibres with a polyamide mantle are mixed.

Antistatic finishes on carpets The application of electrostatic finishes to textile floorcoverings by:

I. Slop-padding or spray application of antistatic agents.

II. Incorporation of steel fibres into the carpet construction.

III. Addition of electrically-conductive products to the carpet backcoating.

IV. Use of antistatic pile fibres in the form of synthetic fibres with hollow spaces and electrically-conductive additives.

V. Use of electrically-conductive adhesives to facilitate the discharge of static electricity.

Antistatic agents are effective on practically all types of fibre, especially polyamide, polypropylene, polyethylene and polyacrylonitrile. Application quantities are dependent on the carpet structure, in which intermediate layers of metallic fibres or powders as well as carbon black may assist the discharge of electrostatic charges but cannot entirely substitute the use of electrostatic agents. Antistatic finishes for floorcoverings in rooms with underfloor heating demand special consideration. In this case, the pile fibres must also possess antistatic properties. At present, there is still no ISO walk test for testing such carpets. Investigations have revealed that a specific base material behaves differently with different carpets; even the test person alone has an influence on the test. Poor reproducibility of test results is therefore unavoidable. Considered as a whole, the antistatic finishing of carpets is still problematic, which is why there is great interest in intrinsically antistatic man-made fibres.

Antistatic finishing The treatment of textiles with special chemicals to increase surface conductivity in order to prevent the build-up of electrostatic charges (especially at relative air humidity levels below 30%) during spinning, combing, sizing, weaving, knitting and also for finished goods. These finishes cause a reduction in friction associated with increased softness and smoothness. The antistatic finishing of clothing materials for persons working in situations involving the risk of explosion is an area of increasing importance. The prescribed maximum concentration for each product must on no account be exceeded in any process application (problem of adhesion to machine parts). A permanent antistatic finish for polyamide still awaits development, and the main effort is concentrated on the production of intrinsically → Antistatic fibres.

Antistatics in drycleaning for prevention of spontaneous ignition of spirit in drycleaning, increase its conductivity and prevent fires and explosions (resulting from frictionally generated electricity or electrostatic charging). Antistatics used include anhydrous magnesium oleate products, (magnesia soap), drycleaning soap and drycleaning detergents.

Anti-swelling agent Finishing product for → Swelling-resistant finish, Resin finishing agent.

AOX A term for adsorbable organic halogen compounds. Most natural fibres can be treated with hypochlorite solutions (for bleaching cotton and treating wool either for print preparation or fluff removal), so inherent impurities in cotton and substances from skin and cellular cement in wool are halogenised and carried away in the waste water. When cotton is bleached with sodium hypochlorite, compounds are formed which, in accordance with DIN 38 409 H 14, can be shown to exist as AOX in the bleach bath. The AOX content demonstrates a significant dependence on the initial condition of the cotton used. The more goods that are in the bath and the dirtier the goods, the higher the AOX content after the bleaching process. The highest AOX concentrations are measured when untreated goods are placed directly into the hypochlorite bleach. The period of AOX formation is coupled directly to the success of the bleaching process. It is certainly interesting to note that an alkali boil before bleaching reduces the AOX content to a fraction of that from untreated goods.

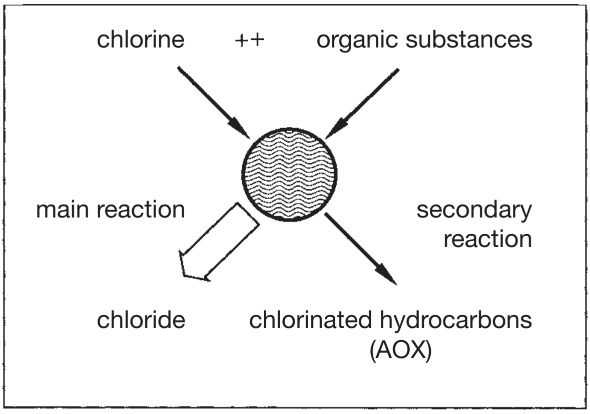


Fig: Possible reactions of active chlorine with organic substances.

Active chlorine, for example, can, in certain cases, lead to the formation of AOX in a side reaction with organic compounds. For this reason, the indirect discharge rules state that a license is required for waste water that contains more than 0.2 mg/l and 4 g/h of active chlorine (this level is similar to that of drinking water). Although there is a correlation between active chlorine and AOX, the acceptable level for active chlorine is independent of the acceptable level for AOX because the latter can originate from multiple sources, e.g. from

- Dirt from washing, e.g. waste oil (petrol stations), or disinfectants
- Washing powders and liquids
- The side reactions of active chlorine already mentioned
- The fresh water used.

The chlorine donor dichloro-isocyanuric acid, although it is itself a chlorine containing organic compound, does not react as an AOX since the chlorine is only loosely bound; that is to say, it can be compared to inorganic hypochlorite in this respect.

The AOX content of waste water is one of the fundamental criteria for judging the quality of industrial waste water. This is even more important since legal regulations such as the "Order for Licensing Requirements for the Release of Substances into Waterways, their Regulation (German abbrev. VGS)" of 27.9.1985 set very low acceptable levels and increased pollution taxes. The release of organic halogen compounds into the water is undesirable because of their immense potential for endangering the drinking water supply. Therefore, as a precaution, the legislators have set very low limits for the emission of organic chlorine compounds into the water. Given the multitude of possible compounds, regulations concerning single substances have little meaning so adsorbable organic halogen compounds (AOX) are measured as a single group. The measuring procedure is carried out during the cleaning process which is used to remove the halogenated hydrocarbons in the preparation of drinking water. Pollutants are extracted from the water by adsorption onto active carbon for analysis. The adsorbed organic halogenated compounds are burned (in a stream of oxygen) along with the active carbon and the resulting hydrochloric acid is titrated microcoulometrically.

1. Adsorption onto active carbon:

$$CH_3\text{–}CH_2\text{–}Cl + C_n \rightarrow [C_n \cdot CH_3CH_2Cl]$$

2. Washing out of chloride.
3. Incineration:

$$[C_n \cdot CH_3CH_2Cl] + (n+3)O_2 \rightarrow$$
$$2\,H_2O + (n+2)\,CO_2 + HCl$$

The AOX determination is in accordance with DIN 38 409 H 14 e.g. using the column technique with a TOX-analyser. The analysis is performed by taking an aliquot of the bleach bath, diluting 1:100, reducing excessive active chlorine with sodium sulphite and acidifying with nitric acid. Until the completion of the AOX determination, the samples are stored at 4°C in the dark in closed glass containers in accordance with the DIN regulations.

AOX value of waste water The AOX value describes analytically a definite quality of the effluent; it is a → Total parameter, i.e. it does not cover a single chemical, but a group of substances contained in the effluent. A range of substances is covered which differ widely in their ecological and toxicological properties: volatile chlorohydrocarbons (e.g. Dichloromethane, Tetrachloroethene) along with Polyvinylchloride, Green pigments and Chlorophenols, reactive dyes with Chlortriazine rings and Chlorine in the chromophore.

The procedure for analysis includes:

a) Adsorption onto activated carbon,
b) Washing out the chloride,
c) Incineration and measuring the HX (X = Halogen).

All of the organic substances present in the effluent are adsorbed onto activated carbon. The carbon is washed with a dil. Sodium Nitrate solution to fully remove any chloride ions. During the incineration, Hydrogen Halide is formed from the adsorbed organic halogenic compounds which is measured separately.

The parameter AOX occurs in the effluent tax law as well as in the regulations of the various German states; it is thus of equal importance for direct and indirect discharges. It is also certain that future effluent control provisions under the amended § 7a of the water purity law will include the parameter AOX among the "Dangerous Substances" (i.e. remove to the limits of available technology).

The AOX value of effluent from textile processing results from:

1. Auxiliaries with organically bound halogens; these are seldom used nowadays (e.g. Polyester dyeing carriers on the basis of chlorobenzene).
2. The use of Chlorine or Chlorine precursors which can lead to an AOX content in the effluent through reaction with other substances present in the water. Chloroform is often formed during this process.
3. Preservatives on the basis of Chlorophenol or other aromatic chloro compounds are for example present in several natural thickeners.
4. Dyestuffs frequently contain organic halogens so that if any dyestuffs get into the effluent, they can contribute to the AOX content. Such dyes are
   - some vat dyes
   - some disperse dyes
   - reactive dyes
   - a few pigments
   - occasional anionic dyes
   - cationic dyes

Water insoluble dyes are of particular interest here. On account of their low solubility, these dyes have limited toxicity but due to the AOX parameter, some of them could be rated as "Dangerous Substances" with respect to the disposal of effluent. In practice, water insoluble dyes can be easily eliminated by conventional methods of purification (precipitation/flocculation or adsorption onto activated sludge) and after suitable effluent treatment (e.g. in a municipal sewage plant which works in accordance with generally recognised processing rules), they therefore cause no AOX contamination to the outfall.

Still unclear is the contribution of reactive dyes to AOX. On the one hand, most reactive dyes contain an organic bound halogen in the reactive moiety: on the other hand it is expected that the reactive halogen splits off under dyeing conditions to become halide. In the chromophore of reactive dyes, organic bound halogen will occur with the same frequency as in anionic or cationic dyes. The problem of the elimination of reactive dyes has nevertheless not been satisfactorily solved.

The application of German state regulations which set a threshold concentration of 0.2 mg/l for AOX causes problems in some cases: In order to ensure the necessary total adsorption of all organic matter onto the active carbon, the sample under test must contain a max. of 10 mg/l → DOC; the detection limit for AOX is then 0.01 mg/l. In the textile industry, but also in other branches of the economy (e.g. the food industry), effluent can contain a DOC of 1000 mg/l (or higher). A water sample with a DOC of 1000 mg/l would have to be diluted by a factor of 100 for AOX determination; the detection limit for AOX thus becomes 100 times higher at 1g/l. In such a test it cannot be analytically proven whether the threshold limit of 0.2 mg/l AOX (for a release of effluent without further approval from the local water authorities) has been adhered to or exceeded.

Ap, → Alpaca, → Standard abbrev. for textile fibres, according to DIN 60 001 until 1988. From 1991 → WP.

APCA, abbrev. for: Air Pollution Control Association (USA).

APEO Alkyl phenol ethoxylates were, for a long time, recognised as having good biodegradability. The biodegradation essentially stopped at the level of the alkyl phenol or double ethoxylated alkyl phenol. In toxicological tests, however, these metabolites were shown to be fish toxic. In further studies it was also shown that the degree of degradation is significantly decreased at lower temperatures for higher levels of ethoxylation e.g. in winter. Once this ecological failure of APEO became known, the producers and users of these products in Germany subjected themselves to a voluntary self-regulation. The Association of Tegawa (Registered Association of Textile Auxiliaries, Leather Auxiliaries, Tanning and Surfactant Raw Materials Industries) has, since the end of 1988, willingly abandoned the use of APEO in the wetting and washing agents used in the textile industry.

As an alternative, the fatty alcohol ethoxylates were developed. In contrast to the alkane sulphonates, all nonionic surfactants based on ethoxylation are not composed of a single substance but are a mixture of molecules with different numbers of ethylene oxide blocks which in turn can occur in different distribution patterns. During the chemical reaction of the base alkyl phenol or fatty alcohol with ethylene oxide, there are large differences in the reactivity of the components (Fig. 1).

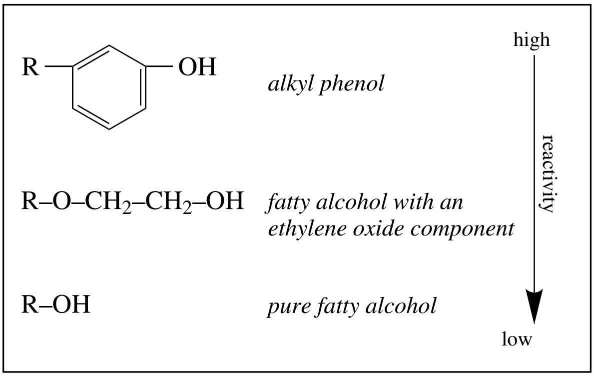


Fig. 1: Reactivity of basic materials for surfactant production.

Alkyl phenols possess the highest reactivity (Fig. 2) and thus it is possible to synthesise an end product which contains a high percentage of the desired substance, whether or not a high or low degree of ethoxylation is sought. Since fatty alcohols are the reactants with the lowest reactivity, all fatty alcohol ethoxylates always contain a considerable proportion of unreacted fatty alcohol. Fatty alcohols are not water soluble and reduce the alkali stability of the final products.

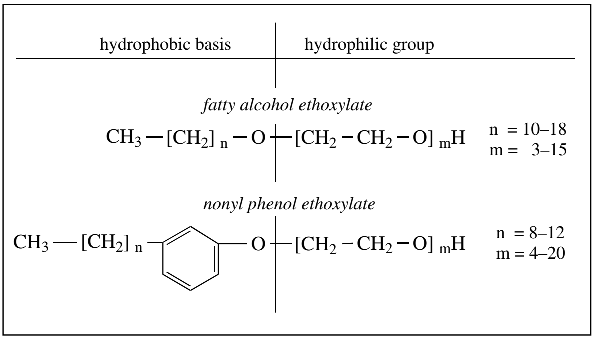


Fig. 2: Nonionogenic surfactants, chemical structure.

Aperture (Latin: opening) In optics, aperture is the moderating part of lens systems. For the finest details, the brightness and definition of the microscope objective increases with increasing aperture. In micro-examination with immersion fluids, the numerical aperture increases, e.g. with the use of monobromonaphthaline, to 1.6 (air = 1). The total usable enlargement, which determines the value of the microscope, should, according to the Abbe rule of thumb, lie somewhere between 500 and 1000 times the numerical aperture of the objective lens at maximum objective power.

Ape skin (velveteen) Raised, closely shorn or sanded cotton sateen or twill with short, close velvety pile (imitation velvet). →: Duvetine; Apricot skin).

Apochromatic objectives Microscope objective lenses with maximum resolution and consequently outstanding image quality.

Apollotex Electron Reactor Pad-roll system especially designed for heterogeneous alkaline hydrolitic surface saponification of polyester fibres to produce a handle similar to that of natural silk, alkaline treatment and weight-reduction. The process is based on the fact that the chemical structure of polyester fibres allows hydrolytic degradation in the presence of acids or alkalis. The nature and severity of this treatment produces different degrees of modification in the structural make-up of the fibre, with effects on the utilitarian properties especially the otherwise high mechanical strength. On the other hand, alkaline hydrolysis of polyester fibres in textile finishing is used specifically to modify certain properties. The best known and most widely used in terms of product volume is the alkaline treatment of polyester with caustic soda solution, in which a fine denier fibre is obtained by hydrolysis taking place on the fibre surface. This method is based on early patents by ICI and Dupont. It is also a known fact that cationic surface-active agents accelerate degradation, i.e. in the presence of these auxiliaries the same weight reduction is obtained in appreciably shorter dwell times and/or at low NaOH concentrations. At the same time the fibre surface is "roughened" in such a way that pigment binder adhesion is superior to that in untreated fibre. The procedure sequence is alkali impregnation (10–30% NaOH), liquor pick-up 75%, heat-zone dwell (100°C, 10 min) incorporating saturated steam and microwave heating (300 MHz). Weight reduction as high as 50% can be achieved with the Apollotex Electron Reactor. Maker: Ichikin.

Application methods When textile finishing products (dyestuffs, auxiliary products, chemicals) are employed on textile fabrics on the basis of capillary suction forces, these finishing substances have to be brought into contact with the textile fabric in dissolved, solid or paste form (this does not include application from the gas phase).When the products have been applied in a suitable form they are fixated.

Application processes:

I. Dwell process: principle: minimum application with a moving fabric (with an aqueous liquor), stationary development. Woven or warp knitted fabric impregnated on a padder (padding) and batched in open width, i.e. crease-free; with beginning and end.

After this pre-treatment:

a) Cold dwell process: dwell (lengthy dwell time) for developing the dye by rotating the cloth beam under atmospheric conditions.
b) Hot dwell process: dwell (short dwell time) by rotating the cloth beam in a steamer.

II. Continuous process: principle: minimum application, development and after-treatment in one operation with running fabric. Woven or warp knitted fabric, fed in open width and spread; infinite length. Treated on: continuous dyeing machine in accordance with:

a) Pad-steam process: padding on pad mangle (from an aqueous dye liquor), fixation in steamer. Washing unit.
b) Thermosol process: (for woven polyester/cotton fabric); padding on padder, infra-red pre-drying, finish-drying, fixation.

III. Printing:

a) Screen printing: fabric moves intermittently: two-dimensional pattern stencils are applied and doctored.
b) Roller printing: fabric constantly moving; engraved and doctored rollers apply the colour.
c) Transfer printing: fabric constantly in motion; dye compounded with simultaneously moving paper. Print transferred by temperature action.
d) Rotary screen printing: fabric in constant motion; rollers perforated in accordance with the pattern apply the colour, the dye being doctored inside the rollers. → Padding process.

Applicator Device for applying dye, fixation, treatment or coating liquors.

Applicator roller (metering roller, slop padding roller, tip roller), in the case of a twin-roller padder, the bottom padding roller with controllable liquid immersion depth; embossed or dot engraved (thousand point roller). Used for finely dosed, singlesided liquor application to piece goods in the squeeze nip. In coating by the reverse roll process (Fig.), the roller running in the application direction, from which excess of molten polymer is doctored at each revolution, is described as the applicatior roller (in contrast to the metering roller, which runs at a different speed against the paste application direction).

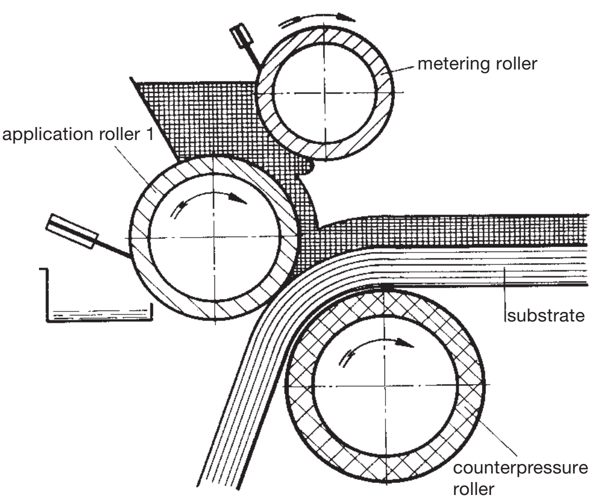


Fig.: Metering and application principle of the reverse roll process, with which highly viscous, thixotropic media are largely processed.

Appliqué Decorative materials, e.g. piping, pearl cotton yarn, cord sewn onto textile fabrics with special patterned effect.

Appliqué carpets Hand-made non-pile carpet comprising a base fabric to which are stitched are affixed by adhesive pieces of fabric and/or yarn. Used for floorcovering and wallcovering.

Apposition dyeing or deposition dyeing, in which only the periphery of the fibre cross-section and not the inner core of the fibre is dyed. In printing this may be called → Surface print, and the opposite in which only the inner core of the fibre is dyed is → Intussusception dyeing.

Apricot skin (peach skin) similar to → Ape skin. Usually cotton warp and Schappe silk or woollen yarn weft.

Aprotic solvents inert neutral → Solvents (with low dielectric constant) containing no ionisable proton in the molecule e.g. benzene, chlorobenzene and chloro hydrocarbons.

AP, USP, abbrev. for: American patent (United States patent).

AQL, abbrev. for: → Acceptable Quality Level.

Aqua fortis (Lat.: literally: strong water). An obsolete name for conc. → Nitric acid which dissolves all metals with the exception of gold.

Aquagraphics A development on a 600 years old Turkish dyeing technique called Ebru. A multi-coloured design is produced using a fluid medium thickened with a synthetic auxiliary in which a prepared dye with fastness to light and washing is incorporated at number of sites. These are then intermingled by stirring, in accordance with the pattern determined by the designer, and by this means a non-repeatable design can be created. The design is applied by introducing the textile to the mobile mass and removing it, with subsequent fixation by techniques specific to natural or synthetic fibres. Transfer printing is also possible using this technique. Maker: Lamlee Studio, New York.

Aqua regia (Lat.: literally: royal water). A yellow, fuming, corrosive mixture of 1 volume conc. nitric acid and 3 volumes conc. hydrochloric acid. Dissolves all metals including gold.

Aquatic (Lat.: *aqua* = water), growing, living or found in water, e.g. aquatic ecosystems, aquatic organisms (e.g. fish), aquatic toxicity (e.g. fish toxicity).

Aquatic fungi (phycomicetes) → Moulds.

Aqueous emulsion An → Emulsion of the oil in water (O/W) type.

AR → Aramid fibre → Standard abbrev. for textile fibres, according to DIN 60 001 T4/08.91.

Ar,

I. chemical symbol for argon (18).

II. abbrev. in chemical formulae for → Aryl, e.g. benzene sulphonic acid: $C_6H_5–SO_3H = Ar–SO_3H$; alkylaryl sulphonates: type $R–Ar–SO_3H$.

Arabic gum → Gum arabic.

Arabinic acid Main component of Gum Arabics, belonging to the → Polysaccharides. Also occurs to a greater or lesser extent in the form of Calcium, Magnesium or Potassium salts in most other plant rubbers. Amorphous substance, colourless, transparent, shiny, brittle, odourless and tasteless. Easily soluble in water to a glutinous consistency, insoluble in alcohol, ether, fats and etheric oils. Aqueous solutions are optically polarised to a sinistra rotation, and are thickened by Sodium Tetraborate. Decomposition by Nitric acid leads to Oxalic acid, and by warming with dil. Sulphuric acid leads to Dextrin and Glucose.

Identifying reactions:

1. Aqueous solutions are precipitated by alcohol.
2. With Caustic Potash and a few drops of Copper Sulphate solution, a blue precipitate appears (Arabin and Copper Oxide) which does not turn red-brown on heating.

Arachidic acid (eicosanoic acid), $C_{19}H_{39}COOH$. A widely distributed but minor component of the fats of peanut and rapeseed oils.

Arachin fibre A fibre belonging to the group of → Man-made protein fibres, derived from the vegetable protein arachin which is present in peanuts. Produced by the wet spinning process (coagulation bath: sulphuric acid, sodium sulphate) to give a wool-like fibre with a tenacity of 6–8 cN/tex and 40–60% elongation. Now very seldom used in mixtures with wool or cellulosic fibres, e.g. in the making of hair felts.

Aralkyl A term used to describe compounds containing both → Aryl and → Alkyl structures, e.g. of the toluene type (methylbenzene) $C_6H_5CH_3$. Not to be confused with → Alkyl aryl compounds.

Aralkyl sulphonates → Alkylaryl sulphonates.

Aramide (fibres) The word Aramide comes from “aromatic polyamide” (Polyaramide) and means that it has to do with polyamides that contain aromatic six carbon rings in the polymer chain (Fig. 1).These make polyamides, which would otherwise soften and burn at 260°C max., into unmelting and temperature stable compounds of a slightly yellowish colour. They can be converted into textile fibres by a special spinning process and thus form the basis of asbestos substitutes in many application areas. They are of high strength because the crystalline content is high due to the intensive interaction between the highly structured polymer molecules. The chemical properties are similar to those of Polyamide 6.6.

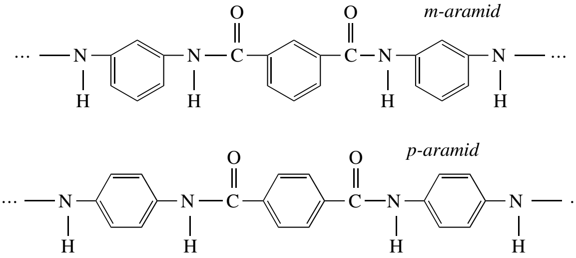


Fig. 1: Aramid fibre structure.

Dupont has developed and marketed two families of fibre products on an aramide basis under the names of “Kevlar” and “Nomex”. Both are extraordinarily resistant to heat, stable at elevated temperatures and posses a high electrical resistance. Their structures and additional properties are however very different.

Nomex was the first aramide fibre, commercialised by Dupont in the mid 60’s. It is a meta orientated aramide, based on poly-m-phenylene-isophthalamide. The meta orientation of the carbon-aramide bonds gives a relatively supple molecule which gives textile properties to the fibre. The areas of use therefore include protective clothing, filter cloths for hot gases, papers for electrical insulation and honeycombs for composite components for aircraft and rockets. Kevlar: the para orientation of the benzene ring and the symmetrical arrangement of the amide bridges in the resultant molecule leads to a linear polymer chain of high rigidity which is directly responsible for the great stability of this product. Kevlar is, chemically, a poly-p-phenylene-terephthalamide and is produced by the condensation of terephthaloyl chloride with p-phenylenediamine. It exhibits the same excellent thermal and electrical properties as the m-aramide, but in addition offers high resistance to tearing and cutting and a high modulus of elasticity. It is therefore used for cut-resistant substances, for ballistic materials, as a replacement for asbestos in brake and clutch linings and to reinforce rubber products and laminates.

The theoretical knowledge that para orientated fully aromatic polymer systems, particularly polyamides, must lead to fibres of high linear strength and modulus of elasticity, due to their rigid molecular structure, can be wholly confirmed by the development and industrial production of Kevlar. It may however be mentioned that, because of the insolubility of poly-p-phenylene-terephthalate in conventional organic solvents, the production and spinning of the polymer into fibres are extraordinarily difficult and took many years of development.

The polycondensation is carried out with p-phenylenediamine and terephthaloyl chloride, by reacting both monomers in a solvent e.g. methyl pyrrolidone in the presence of a relatively high amount of $CaCl_2$ (Fig. 2). The polycondensate is freed from the solvent, dried and dissolved in conc. sulphuric acid at about 80°C for spinning. Prerequisites for good fibre properties are the concentration of the polymer in the sulphuric acid and the temperature of the spinning solution so that the polymer solution exhibits a liquid crystal structure. Spinning is done by the usual wet spin process. The use of an air break between the spin jets and the spin bath can be advantageous. Direct spinning methods are impractical. After drying, the thread filaments are stretched at a ratio of 1:1.001–1.021 in a secondary process at 250–550°C in a Nitrogen atmosphere and under a tension of 4–6 cN/dtex. The filaments then possess a higher modulus of elasticity than the spun wares and with the same strength and stretchability and can be used in the production, particularly, of high performance composites.

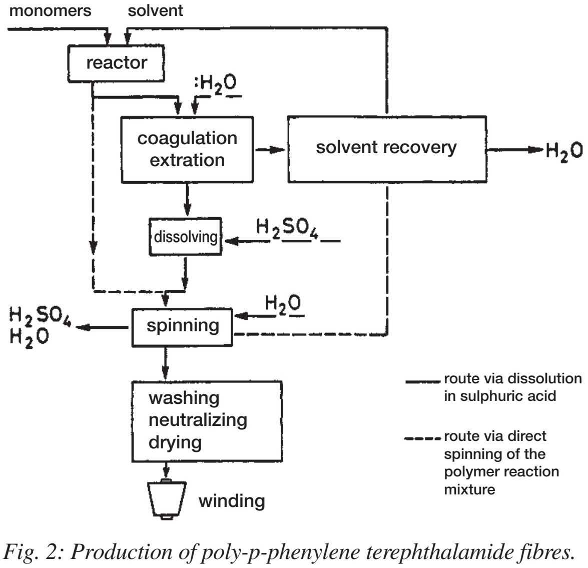


Fig. 2: Production of poly-p-phenylene terephthalamide fibres.

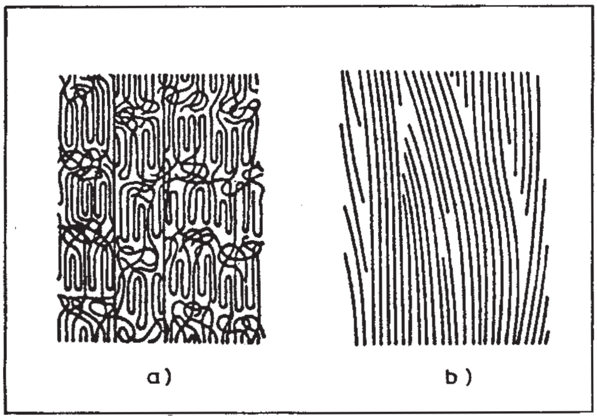


Fig. 3: Microstructure of a) polyester and b) aramid fibres.

The structure of the poly-p-phenylenediamine fibres shows some characteristics differing from those of other synthetic fibres. The distribution of orientation of the polymer chains is very narrow on account of the wet spin process; this leads to a high initial modulus of elasticity of 70 Gpa which can be raised to 140 Gpa by the aforementioned stretching. The high linear strength is caused by the extreme elongation of the very long polymer chains and the rigid rod shaped form of the monomer units which can crystallise in spite of the rigidity because hydrogen bonding and the planar phenyl and amide groups make possible a high degree of structure. The size of the crystallite varies between 20 and 100 nm in the direction of the fibre axis and between 4 and 10 nm radially. The quality of the crystallite is far better than can be inferred from the lattice deformation parameter. The relevant values vary between 1% for thermofixed and 3% for untreated fibres. Since no X-ray diffraction is observed in poly-p-phenylenediamine fibres, they do not possess the usual 2 phase structure; they are paracrystalline and monoaxial (Fig. 3).

Aramide laminates are superior to steel and aluminium, particularly in respect of strength and modulus of elasticity. However in mechanical bending, their properties under pressure play a large role in most constructive uses. Thus, in all situations where the material is flexed, compression is also present. By experimental determination, the compression strength of aramides is only 20% of their tensile strength and this low value represents a significant limitation to their use in structural components. This can be remedied by the use of a hybrid composition (carbon fibre in the compression zone and aramide in the tensile zone). With respect to malleability, aramides are significantly superior to carbon fibres. The poly-p-phenylene-terephthalate fibres possess good resistance to heat and oxidation which allows them to withstand relatively high temperatures for a reasonably long time, and still suffer only insignificant losses to their properties (Glass transition temperature approx. 300°C, Heat shrinkage at 160°C approx. 2%) (contributed by von Falkay).

Aramidimide, in analogy with Aramide and, a contraction for fibres from polyaryl amidimides. Typical members are e.g. organic → High temperature fibres.

Aramina fibre → Urena fibres.

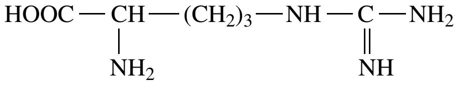
ARBE, (Ger.) abbrev. for: Arbeitsgemeinschaft Bekleidungsindustrie e.V. (German Clothing Industry Study Group); → Technical and professional organizations.

Archil → Natural dyes.

Arch steamer → Continuous steamer as a mainly floor-mounted, vertical, semi-circular type machine, through which the fabric to be steamed is passed over side rollers; particularly for two-stage printing processes.

Area bonding Descriptive term for the production of nonwovens where adhesion takes place over the entire surface. See also → Point bonding.

Arginine (guanidine aminovaleric acid; amino-4-guanidovaleric acid). A basic → Amino acid present in wool (10,4%) and silk (1,05%).



$$\mathrm{HOOC-\underset{\displaystyle NH_2}{\underset{|}{CH}}-(CH_2)_3-NH-\underset{\displaystyle NH}{\underset{\|}{C}}-NH_2}$$

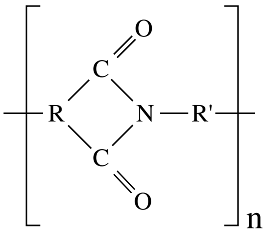
Armoured woven fine cloth Metal woven filter fabric with the finest orifices (max. 17 µm). This fabric is therefore employed in areas where it appears to be suitable for fine filtration without auxiliary filtering agents.

Aromatic compounds (aromatics, alicyclic or cyclic compounds). In the widest sense they are derivatives of benzene *inter alia* → Hydrocarbons. Also includes the → Cyclic hydrocarbons and their derivatives (cyclohexene type), heterocyclic compounds (pyridine type), as well as their derivatives. The name "aromatic" is due to the strong and not unpleasant odour characteristic of most substances of this nature derived originally from natural sources (balsams, resins, etc.). See also → Aliphatic compounds.

Aromatic nuclei → Cyclic hydrocarbons (benzene type).

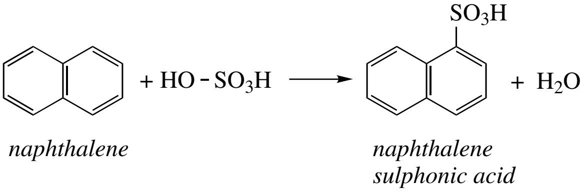
Aromatic polyamide fibres → Aramide fibres.

Aromatic polyimide fibres in analogy with → Aramide fibres, this is the commonly accepted term for fibres based on aromatic polyimides: → High temperature fibres, whose chemical base module is characterised by aromatic rings connected by imide bonds.



Through their properties and areas of use, they are classified with the Aramides (e.g. Nomex), the Aramidimides (e.g. Kermel) and the polybenzimidazole fibres (PBI-fibres). Use area: equipment for aircraft, space craft and rescue craft, upholstery material, hot gas filters, electrical insulation, life jackets and the like.

Aromatic sulphonic acids and sulphonates are produced from aromatic hydrocarbons by sulphonation resp. the introduction of sulpho or sulphuric acid groups. Example:



The soap-like properties as well as their foaming, wetting, dispersing, emulsifying and softening characteristics increase with increasing size of the molecule. Aromatic sulphonic acid products have good stability to water hardness salts and acids and may be used in alkaline as well as neutral liquors. Uses: versatile wetting agents for desizing and dyeing, also for pasting and dissolving dyes in vat dyeing (also naphthols). Further uses in carbonizing, milling, oiling auxiliaries, finishing, sizing, etc.

Arrhenius equation Describes the temperature dependency of the speed constant k. The following formula applies:

$$k = A \cdot e^{-\frac{E_A}{RT}}$$

R is the gas constant, E_A is described as the activating energy of the reaction. From experience, it is almost independent of temperature over a wide temperature range. The pre-exponential factor A can be regarded as the limit value of the reaction speed constants for T → ∞. It is also called frequency factor or impact factor. For many reactions, the Arrhenius equation represents, with a good degree of approximation, the dependency of reaction speed on temperature. For determining activation energy and frequency factor, it is used mainly in the form

$$\ln k/k^+ = \frac{-E_A}{RT} + \ln A/A^+$$

k^+ and A^+ have the numerical value 1 and the dimension of k. If ln k/k^+ is plotted against l/T on a graph, the activation energy E_A can be determined from the gradient m of the straight line curves, and the frequency factor A from the axis intercept.

Arrowroot (curcuma starch), West Indies (W) so-called arrowroot flour; East Indies (O): Bombay or Malabar arrowroot (cheapest); Brazilian (B); also cassava starch, small translucent lumps (tapioca/sago). Outward appearance: A + O = matt, white; B = matt, greyish white. Feel: A = highly scroopy; O = less. Arrowroot very often appears adulterated. Water content is approx. 15–20%. It swells up at approx. 50°C, while it sticks together around 70°C. Paste: A = clear bluish, mucilagenous; O = pure white; B = like potato starch. Finish handle: differs greatly, but like potato and wheat starch. Use like starch.

Arsenic (As), atomic weight 75. Arsenic is a typical transitional element which exhibits metallic and non-metallic characteristics. Silver-grey, yellowish, brownish or black powder with a metallic lustre. Arsenic is very poisonous and starts to burn when heated in air (garlic odour).

Compounds: with hydrogen = arsenic hydride (arsine) AsH_3 (extremely poisonous) which is made use of in the analytical detection of very small traces of arsenic (→ Arsenic traces, test for); with sulphur = sulphides, halogenides, etc. Uses: arsenic salts are used in the preparation of hides and skins; as a colour pigment (copper acetoarsenite, Schweinfurt green, Paris green – toxic); as a depilatory in tanning, etc.

Arsenic film consists of a brownish-black coating of metallic arsenic which is deposited on the surface of glass test apparatus e.g. by heating arsenic hydride, or arsenic and carbon. → Arsenic traces, test for.

Arsenic sulphides → Orpiment.

Arsenic traces, test for Marsh's test for arsenic. Hydrogen gas is produced in a gas generator vessel by the action of sulphuric acid on zinc and the solution to be tested is poured in. If arsenic is present, arsenic hydride AsH_3 is formed which, after drying, is passed through a hot zone where the AsH_3 decomposes with the preciptation of arsenic as a dark lustrous film and hydrogen is burnt off. In contrast to antimony film which can also be formed in a similar manner, the arsenic film is soluble in sodium hypochlorite solution.

Arsenometry Titration method for detecting pure hypochlorite chlorine (active chlorometry).

arté Term for insect fretted silk.

Artefact (Lat.: *ars* = skill; *facere* = to make), e.g. microscopical structure not present in an original substance but which is formed after a preparation treatment (comminution, solution, swelling, electron-beam action).

Article When, for example, the textile pattern designer of a woven or knitted fabric manufacturer is assigned to create the season's new range, each type of fabric is given a designation in the form of a number, often with an additional fantasy name. Each new fabric quality thus produced is referred to as an article, this being subdivided into designs in the case of patterned fabrics and into colours with plain fabrics. Where printed fabrics are concerned, a design is also produced in different colourways (colourations).

Not only clothing fabrics are referred to as articles; in other areas too, like garment manufacture, specific materials (dyed, printed, coated and/or finished) that belong to the finished article are purchased from the fabric manufacturers. Hence, the textile finisher plans the disposition of his product range according to the article directory pertaining to the next step in the production chain, i.e. garment manufacture, wholesale and retail. The catalogue of requirements stems from the article directory and is what the process technology for textile finishing is based on. The finisher must, however, take into account the fibre type in the article directory to suit the respective field of application.

Article specific designs Fabrics produced for a specific end-use and incorporating a design of dimensions appropriate to the item being woven (as opposed to designs continuing through the piece for goods sold by the metre or by the piece) in the form of a centre piece, corner design or border, as for example in blankets, towels, headscarves, handkerchiefs, tablecloths, serviettes and carpets.

Artificial flower finish Stiff finish predominantly on woven viscose fabrics for producing artificial flowers. The finish may not impair dip dyeing.

Artificial fur Woven → Imitation furs from woven pile fabrics (e.g. astrakhan, karakul, sealskin), high-pile → Plush (previously of mohair or wool), mainly from synthetic fibres.

Artificial intelligence covers the science of endowing machines with intelligence similar to human intelligence. Naturally a system, a science or a machine cannot be intelligent, but they can be made to use similar deductive processes to those of human beings, even if only to a very limited extent. This means that a computer should be able to understand the state of the system from one or several sources of information, and on the basis of the relationships known to it, to decide what is the best action to take. The intelligence of a computer is therefore directly proportional to the knowledge and relationships that have been entered into it. This is nothing other than knowledge of the functional dependence of a target value on a set of individual parameters together with all the interactions associated with them. The practical application of artificial intelligence is in → Expert systems; these should mimic skilled personnel. The design and construction of an expert system is called knowledge engineering. Knowledge engineers ask experts for specialist knowledge of their trade and formulate the knowledge so that it can be structured and arranged in knowledge diagrams. The knowledge gleaned in this way from the specialists is stored in knowledge databanks where it can be accessed quickly.

Artificial leather → Coated textiles in accordance with DIN 60 000 having leather-like characteristics and/or a leather-like surface structure, e.g. embossing. Main types: fibre, woven fabric, film, nonwoven fabric and warp knitted fabric artificial leather. Artificial leather is mainly produced from polyvinyl chloride and polyurethane, less often from polyacrylates and polyamides. Relevant important details: paste production, filling material, viscosity control, stabilizers, dyestuffs and pigments, adhesive agents etc. Machine park comprises: a) paste producing machines, b) coating equipment, c) printing and lacquering or spraying equipment, d) embossing calender, e) raising machine, f) tumbler or creasing machine, g) re-rolling, inspection and cutting machine. Despite great efforts, no one has succeeded in producing a substitute equal in quality to natural leather. The problems of moisture absorption and air permeability have not yet been satisfactorily solved.

The largest proportion of artificial leather produced goes into the automobile and leather goods industries and also into the production of awnings, tarpaulins and roller blinds. Only some 10% is taken by fashion sectors like clothing and shoes. Compared with natural leather, artificial leathers have the same appearance, but are to some extent independent products with specific advantages like low weight and easy care. → Imitation suede.

Artificial silk Obsolete term for regenerated cellulose filaments.

Artificial soil (3 component combination) → Soiling test.

Aryl (Ar), aromatic → Alkyl: monovalent aromatic hydrocarbon radicals, e.g. from benzene C_6H_6: → Phenyl C_6H_5; from naphthalene $C_{10}H_8$: → Naphthyl $C_{10}H_7$.

AS,

I. → Asbestos fibre, → Standard abbrev. for textile fibres, according to DIN 60 001 T4/08.91.

II. abbrev. for: Australian Standard.

III. (Ger.) abbrev. for: Auslegeschrift (patent specification). In addition to important bibliographical data in a patent application, it also contains the description, patent claims, and design. Available for reference purposes in Patent Offices.

As,

I. chemical symbol for → Arsenic (33).

II. → Asbestos fibre, → Standard abbrev. for textile fibres, according to DIN 60 001 until 1988, from 1991 → AS.

Asbestos (Gr. *asbestos* = inextinguishable). A fibrous variety of magnesium silicate. Its particular value is due to a combination of 3 properties: i.e. the material is stable to temperatures up to 1000°C and above, it is resistant to acids and also forms fibrous crystals with good tensile strength. Asbestos occurs in nature in the form of fibre bundles. The fibres are strong and flexible so that spinning into yarn is possible with the longer fibres. It has a long history of use as a raw material for fireproof clothing, heat insulating jackets, heat shields and heat insulation boards in the space, aeronautical and building industries. It has also found wide application in brake linings. Since 1. 1. 1987, however, the use of asbestos in new automobile brake linings is no longer permitted. The inhalation of fine asbestos fibres can, over the long term, cause cancer in humans. It is for this reason that research has been directed towards finding less hazardous substances with asbestos-like properties. In this regard, certain textile fibres have been developed possessing similar properties to asbestos but without the health risks since they have been manufactured in such a way that, unlike asbestos, no lung-threatening fibres are formed from the outset. Depending on the field of application, the natural raw material asbestos can be substituted by glass and ceramic fibres, aramid and carbon fibres.

Properties: Asbestos is, in fact, incombustible. Depending on the variety, however, asbestos fuses at high temperatures, i.e it becomes hard and brittle depending on how much chemically-bound water is removed. The chrysotile variety gives up water slowly at 315°C but at 650°C it becomes water-free, friable, and loses strength. Even when heated frequently at high temperatures, white asbestos (Canadian) exhibits only a slight loss in strength but a considerable loss in extensibility. The strength of blue asbestos (East African) falls on first heating by approx. 12% and again on subsequent heating by the same amount. Chemical properties: only the brown and blue African asbestos varieties are stable to acids, all other varieties have limited stability. Dilute mineral acids have a more intensive action here than the conc. acids. Asbestos is attacked only slightly by alkalies and oxidizing substances at normal temperatures.

Asbestos fibre, further developments Asbestos fibre dust has proved to be dangerous to health (highly toxic by inhalation of dust particles – a carcinogen). The American company Raybestos/Manhattan has developed an automatic process for the manufacture of asbestos yarns which even meets the stringent OSHA Regulations. Similar further developments from Eternit AG with Hoechst and Kuraray Synthetic Fibers as substitutes for asbestos are Kolanit 10 (Hoechst) and Kuralon (Kuraray) as well as modified polyacrylonitrile and aramid fibres.

Asbestos fibres Naturally occurring → Mineral fibres (Europe, Russia, Africa, America, Canada) as hydrated silicate of magnesium $Mg_6Si_4O_{10}(OH)_8$ in fibrous varieties of *Serpentine* resp. *Chrysotile,* which were of chief importance for textile purposes, or as the weathered products of hornblende (complex silicates of calcium, iron and magnesium). The fibres consist of long, fine, soft crystalline needles in a chain silicate structure. X-ray investigations carried out as long ago as 1930/32 already revealed the fine structure of these fibres (see Fig.). The basic building block of asbestos minerals is, as for all silicates, the SiO_4 tetrahedron. The oxygen possesses the characteristic property of being able to belong to two different tetrahedrons at the same time. The various arrangements and linking of SiO_4 tetrahedrons in combination with different metal atoms is a characteristic feature of the fundamentally variable structure of asbestos minerals (*Serpentine* and *Amphibole* asbestos). The density varies according to origin, e.g. *Chrysotile* 2,2–2,8 and blue South African asbestos 3,2–3,6. Depending on mineral impurities, the colour varies from white to grey, green and brown. Fibre length in the raw mineral is 15–25 cm (the most valuable are the very long curled Bostonite and Canadian asbestos fibre varieties). Fibres of 2–5 cm are used in spinnable form. There is virtually no limit to the fineness of asbestos fibres; the crystals may be subdivided until they are so fine that they cannot be seen through an optical microscope. Fibre lustre is extremely variable depending on origin. Amianthus is silky with a mother of pearl-like translucent appearance; Chrysotile has a metallic shot-like waxy or matt lustre. The fibres have a more or less waxy smooth handle. Good quality asbestos fibres should be soft and flexible. Uses: Nowadays the use of asbestos has been largely forbidden because of its carcinogenic properties. Formerly, asbestos rovings were spun on conventional spinning frames (ring or flier) frequently mixed with other fibres before spinning, e.g. often with 2–10% cotton. Its main applications were those in which its resistance to heat and burning were all-important, such as fireproof fabrics (furnishing fabrics, theatre curtains and scenery, fireproof clothing), heat insulation, seals and packings (flanges, manhole gaskets, glands, etc.).

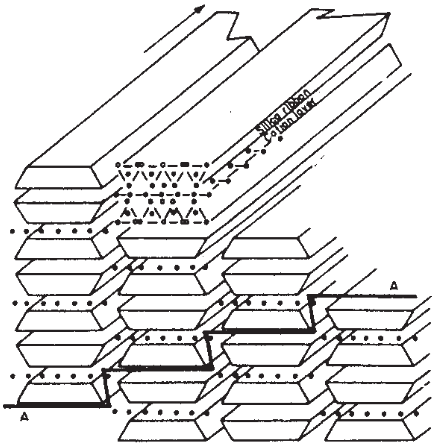


Fig.: Schematic diagram of the structure of an asbestos fibre (arrow = fibre axis direction).

Asbestos substitutes These include fibres that are suitable for use as substitutes for asbestos. For most fields of application, asbestos can only be substituted by fibrous materials. Packings and gaskets are an exception, however, since flexible graphite films are used for these applications. In order to qualify as possible substitutes, synthetically produced fibres must:

- be able to satisfy physico-technical requirements,
- be available in sufficient quantities at an acceptable cost,
- have either a low biological effect or none at all.

An overview of possible fibre substitutes is given in the Fig. Each specific property of asbestos can be covered by a different fibre material. Evaluation from the technical and economic points of view indicates that all inorganic amorphous fibres are suitable, e.g. textile and non-textile glass fibres. Substitution by crystalline

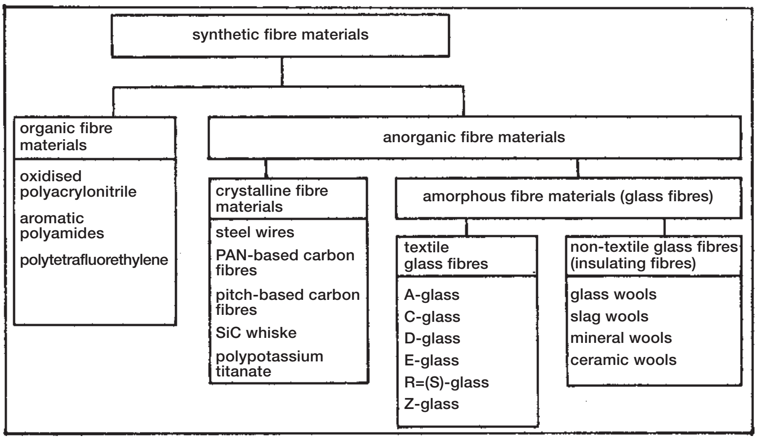


Fig.: Survey of types of synthetic fibres suitable as asbestos substitutes.

inorganic as well as organic fibres is likewise an acceptable alternative, although comparatively higher costs must be reckoned with in this case. From the technical and medical standpoints, oxidized polyacrylonitrile and carbon fibre products can be used in all fields of asbestos substitution.

ASBL, (Fr.) abbrev. for: Annales Scientifiques Textiles Belges (Belgian Scientific Textile Records), Belgian textile research centre. → Technical and professional organizations.

Ascending design Pictorial carpet motifs which are mainly discernible only when seen from one viewing direction.

Asche test For the verification of electrostatics eliminated in synthetic fibres by soft rinsing agents.

Asclepias fibre → Akund.

ASD, (Fr.) abbrev. for: Association Suisse de Documentation (Swiss Association for Documentation), identical with → SVD.

ASDC, abbrev. for: Associate of the Society of Dyers and Colourists; professional qualification of the → SDC, Bradford, U.K.

ASENET, (Fr.) abbrev. for: Association Suisse des Entreprises de Nettoyage à sec et d'Entretien des Textiles (Swiss Association of Drycleaning and Fabric Care Enterprises), (analogous to the VSCTU); → Technical and professional organizations.

Aseptic, germ-free condition, → Sterile. Opposite of septic.

Ash non-volatile mineral residue in powder form produced when matter is burnt.

Ash content Ash residue remaining after the complete combustion of a specific material. The ash content of wood pulp is 0,2–0,3% and of viscose approx. 0,1%.

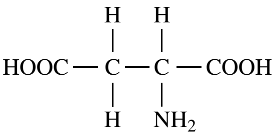
Ash tests, specifically for the detection of metals in dyeings; →: Aluminium, Chromium, Iron and Copper in dyeings, detection of.

Asiatic gums → Vegetable gums, with a greater or lesser content of arabin and bassorin. They are generally only swollen in hot water, but are dissolved by pressure boiling to give thick, viscous liquids with excellent flow characteristics. Asiatic gums include Ghatto, Karaya and Shiraz gums which are used as industrial gums for textile printing thickeners (alkali-sensitive).

Karaya gum, which mostly contains over 50% bassorin, is similar to Bassora gum and Tragacanth, somewhat more readily soluble than the latter it is often used for the adulteration of these gums.

Asociación Espanola de Quimicos y Coloristas Textiles (AEQCT) Spanish Association of Textile Chemists and Colourists. → Technical and professional organizations.

Aspartic acid A naturally occurring → Amino acid (asparaginic acid, asparagic acid, aminosuccinic acid, monoamino dicarboxylic acid) which is present in wool (up to 7,27%) and silk (up to 2%).



$$\mathrm{HOOC-\underset{H}{\overset{H}{C}}-\underset{NH_2}{\overset{H}{C}}-COOH}$$

Asphalt A dark brown to black cementitious material, solid or semi-solid in consistency, in which the predominating constituents are bitumens which occur in nature as such or are obtained as residues in petroleum refining. Melting range 70–150°C. Asphalt is soluble in benzene, chloroform, carbon disulphide and turpentine. Uses: special paints, adhesive in electrical laminates, insulation primers and leather lacquers.

Aspirated psychrometer → Psychrometer.

ASQ, (Ger.) abbrev. for: Arbeitsgemeinschaft für statistische Qualitätskontrolle (German Study Group for statistical quality control). Since the end of 1972 → DGQ.

Assimilated carbon In biological clarification systems for waste water an assimilation, which is independent of light, takes place with some strains of bacteria through chemosynthesis.

The required energy is obtained through the oxidation of ammonia, nitrite, iron oxide, hydrogen sulphide, etc. The assimilates (products of assimilation) are further broken down to some extent by mineralization (at first with an increasing and later a decreasing number of bacteria), see Fig.

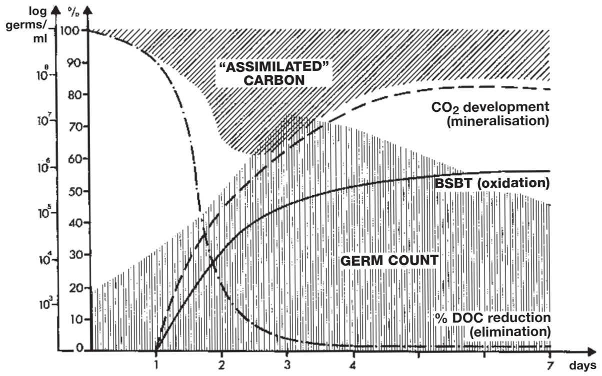


Fig.: Elimination, oxidation and mineralisation of citric acid in the GF test.
Assimilated carbon = 100% – (% DOC + % CO_2).

Associate The result of → Association. An associated compound.

Association (Lat.: *associare* = to ally with). Chemically: combination of molecules of the same type to form molecular associates such as e.g. micellar colloids. The stability of such associates varies greatly:

decomposition takes place sooner or later on heating into the individual molecules. In the case of dyes, association allows a concentration of dye to form in close proximity to the fibre, e.g. an important factor for dye exhaustion on cellulose (therefore a high tendency to form associates = good → Substantivity). Dyes which form weak associates or none at all are e.g. → Acid dyes.

Association colloids (micellar colloids) → Colloids.

Association, degree of Amount of → Association, which increases as the electrolyte content (salt addition) rises and falls with temperature for direct dyes. For dissolved cationic and acid dyes, the Degree of Association (according to Roth) is about 1.1–2.6, for substantive Benzopurpurine 4B (dependant on concentration and salt content) 6–800, and for Chicago Blue 6B between 3 and 37. → Aggregation, degree of.

Association des Chimistes de l'Industrie Textile (ACIT). French Association of Chemists of the Textile Industry. → Technical and professional organizations.

Association Internationale de la Soie (AIS). Worldwide organization for the entire field of silk cultivation (silk trade, finishing, garment making) with headquarters in Lyon. Founded in 1947. → Technical and professional organizations.

Association Internationale de Savonnerie et de la Détergence (AIS). International Association of Washing Agent and Detergent Manufacturers in the European Community. → Technical and professional organizations.

Association of surfactants The physico-chemical principles underlying the rheological properties of surfactants in aqueous solutions have been thoroughly investigated. As illustrated schematically in Fig. 1, surfactants form micelles in aqueous solutions which exist in different geometrical forms and which can aggregate to form mesophases resp. liquid-crystalline phases depending on the concentration, the presence of electrolytes and the addition of co-surfactants.

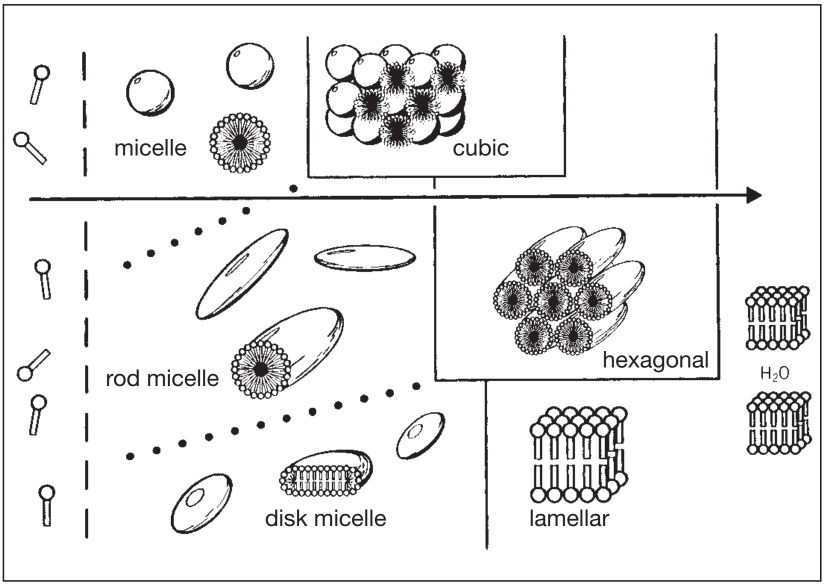


Fig. 1: Phase diagram of surfactant association in aqueous solution (Henkel).

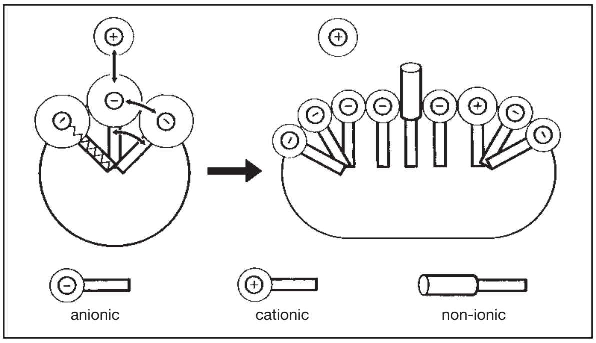


Fig. 2: Diagrammatic view of the transition from spherical to rod micelle (Henkel).

The viscosity and rheological behaviour of such a system depends on which way has been taken in changing the parameters represented in the phase diagram. In dilute anionic surfactant solutions a transition from isometric spherical micelles to anisometric rod or wafer micelles takes place (Fig. 2) on the addition of co-surfactants (fatty acid alkanolamides, amphoterics, fatty alcohol ethoxylates *inter alia*, additives of low molecular weight). As a result, a state is reached in which the anisometric surfactant micelles constantly collide with each other due to thermal mobility thereby preventing their free rotation. A dynamic network is formed which manifests itself macroscopically as an increased viscosity of the surfactant solution.

The parameters influencing the transition from a spherical micelle to a rod micelle are quite diverse. In the main, however, they may be attributed in a graphic model to the geometrical properties of the surfactant, i.e. their molecular structure and the spatial relationship of the hydrophilic head groups to the hydrophobic carbon chain, and by electrostatic effects such as the screening of mutually repellent charges and hydrate clouds of neighbouring head groups of ionic surfactants. For a given chemical structure, the probability that anisometric micelles will be formed is increased by any measure which results in a reduction in the distance between neighbouring ionic head groups (Behler, Hensen, Raths, Tesmann).

Associazione Italiana di Chimica Tessile e Coloristica (AICTC). Italian Association of Textile Chemists and Colourists. → Technical and professional organizations.

ASTI, (Ger.) abbrev. for: Arbeitgeberverband der Schweizerischen Textilveredlungsindustrie, Zürich (Employers' Association of the Swiss Textile Finishing Industry). → Technical and professional organizations.

ASTM, abbrev. for: American Society for Testing and Materials. Industrial standards organization. → Technical and professional organizations.

Astrakhan

I. The skin of still-born or very young lambs (originally from Astrakhan in Russia), the fine grey or black curly hair of which resembles fur.

II. Real astrakhan is a curly lamb's fleece (Persian). Substitutes are lambskin imitations like woven plush fabric (frieze velvet) with an uncut (mohair) pile warp; also produced in jute and acetate filament yarn. Loop height is determined by round wire inlay. A distinction is drawn between production methods, a) woven astrakhan (plush), fulled astrakhan and tricot astrakhan (warp knitted fabric). There are also the so-called adhesive-bonded polyamide astrakhans. Used for ladies' overcoats, caps and fur trimmings.

Astrakhan yarn Wool crimp yarn. Forced crimping can be fixated by cross-linking so as to be washfast.

Astrakin Compound woven and warp knitted fabric; base fabric of raw crêpe georgette with a different top fabric glued on. Crêping produces a → Cloqué-like surface.

Astro-dyed Licensed process for dyeing non-repeating effects (→ Space dyeing) on yarns by injection of dye liquor into the inner layers of wound packages up to a maximum of 5 colours with special dyeing equipment (used for carpets and upholstery fabrics). Production rate = 50–60 kg/h. Manufactured by Astro Dyeworks, USA.

Asymmetry Lack of uniformity, i.e. non-uniformity, e.g. the asymmetrical distribution of certain groups or forces (hydrophilic, hydrophobic) in the molecule of a textile auxiliary.

Asymptotic (Gr. *asumptotos* = not falling together) approaching infinity, e.g. the curve of a graph.

At, chemical symbol for astatine (85).

at Technical atmosphere, replaced in the → SI system by Pa (Pascal). 1 at = 0,981 · 10^5 Pa = 0,981 bar.

ATA,

I. abbrev. for: anthranilamide.

II. abbrev. for: aminotrimethylcarboxylic acid resp. → Nitrilotriacetic acid.

III. (Fr.) abbrev. for: aminotriacétique acide.

ATE process (anthrasol-thermosol development process), dry development process for leuco vat ester dyestuffs with the use of an activator and a levelling agent for woven cellulose and cellulose/polyester blend fabrics.

ATF, (Ger.) abbrev. for: Arbeitsgemeinschaft textiler Fachvereinigungen (Working Group of German Textile Organizations). → Technical and professional organizations.

ATI, abbrev. for Associate of the Textile Institute. Professional qualification of the Textile Institute, Manchester, U.K.

atm abbrev. for standard atmosphere, a former practical unit of pressure now replaced in the → SI system by Pa (Pascal). 1 atm = 1,0133 · 10^5 Pa = 1,0133 bar.

ATMA, abbrev. for: American Textile Machinery Association. → Technical and professional organizations.

ATME, abbrev. for: American Textile Machinery Exhibition (held in Greenville, SC, USA).

Atmospheric air is composed of 78,06 vol.% nitrogen, 21 vol.% oxygen, approx. 0,03 vol.% carbon dioxide, variable amounts of water vapour, traces of volatile organic and inorganic substances, dust etc., as well as 0,94 vol.% rare gases.

Atom (Gr. *atomos* = that cannot be divided) the smallest particle of an → Element (chemically incapable of being further split up) which can combine with similar or different atoms to form → Molecules and chemical compounds.

Atomic absorption spectroscopy (AAS). An analytical technique similar to flame emission spectroscopy (FES) for the detection of trace metals in different matrices. The technique is suitable for the qualitative and quantitative determination of metallic elements but does not extend to their stages of oxidation or the structure of their molecular environment. Both methods are preferred for the micro and trace analysis of solid, liquid and gaseous samples.

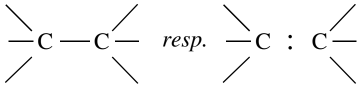
The light beam of a lamp which emits the atomic spectrum of the element being determined, is conducted through a flame or graphite tube in which the metal being analyzed is converted into its ground state atoms by thermal dissociation. As a result, a part of the radiated light is absorbed. The quantity of absorbed light is proportional to the metal concentration. The detection limit of the graphite tube method is lower than the flame technique by a factor of 10-100, and the volume used for analysis is many times smaller than the pore volume for the flame technique. A lengthy calibration with elemental standards at different concentrations is necessary for both analytical methods.

Atomic bond (electron pair bond, homopolar bond, covalent bond, co-ordinate bond, nonpolar bond). Virtually all compounds (with the exception of salts) not containing ions, i.e. nonelectrolytes, consist of molecules built up from atoms held together by very strong bonds. Such bonds are referred to as → chemical bonds *per se*, e.g.:

a) monovalent = single bond, e.g. ≡CH–C≡
b) bivalent = double bond, e.g. =C=C=
c) trivalent = triple bond, e.g. –C≡C–

The atoms are bound to each other by a shared pair of electrons (electron pair bond) which belong to both atoms at the same time. In more precise terms, one positively charged atomic nuclei provides one negative bonding electron so that two together can form an electron pair: H + H → H : H. From this it follows that

– a single bond consists of one shared electron pair:

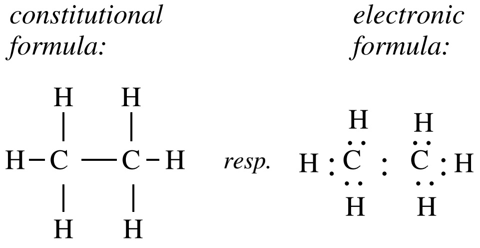


– a double bond contains 2 electron pairs:

– a triple bond contains 3 electron pairs:

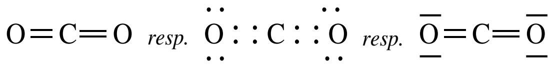
$—C\equiv C—$ *resp.* $—C\ :::\ C—$

If all the shared valence electrons of both atoms are included, then each atom will always have 8 electrons (octet theory of electron shell structure for elements like noble gases with the exception of hydrogen which has 2 electrons = doublet):



$H-C\equiv C-H$ *resp.* $H:C:::C:H$

Free electron pairs (i.e. not shared) can be indicated by a horizontal line thus:



$O=C=O$ *resp.* $\ddot{\underset{..}{O}}::C::\ddot{\underset{..}{O}}$ *resp.* $\overline{O}=C=\underline{O}$

From these formulae it follows that an atomic bond is built up by attraction forces acting through shared electron pairs which are relatively localized in the region of the two nuclei. Bonding forces of this kind are normally very strong, such as e.g. the C–C chains in organic chemistry and, in the widest sense, all primary valency chains.

Atomic mass Relative atomic mass of an isotope resp. nuclide. Defined relative to ^{12}C as exactly 12,0000 (reference basis). The atomic mass rounded off as a whole number is referred to as the mass or nucleon number and indicates the sum of nucleons (neutrons and protons). Since the atomic mass of a proton (1,007276) and that of a neutron (1,008665) are approximately equal, the following relationship is valid; atomic mass ≈ mass (nucleon) number.

Atomic number (proton number), symbol Z. The number of protons (positively charged mass units) in the nucleus of an atom or the number of electrons revolving around the nucleus. The atomic number determines the chemical properties of an element and the element's location in the → Periodic system (atomic theory). It is always the same as the number of negatively charged electrons in the shells. The order of atomic numbers begins with the lightest element, hydrogen with 1. The number of protons and electrons also increases with the atomic number from element to element by 1 each time. All the isotopes of an element have the same atomic number although different isotopes have different mass numbers.

Atomic theory As far back as the history of science permits the basic structure of matter has been a constantly recurring theme as has the search for the most fundamental particles on which matter is based. The Greek philosopher Empedocles postulated the four elements (earth, air, fire and water) as integral and immutable. Aristotle, on the other hand, regarded them as transformable one with the other. Leucippus and Democritus originated the theory that matter is made up of indivisible, infinitely small atoms ("atomos"). It was only in the 19th century that this concept was scientifically substantiated when it was recognized that, to each of the 92 (chemical) elements known at that time, an "atom" had to be allocated; a concept which is still valid even today. Compounds of several atoms form molecules from which substances are built up.

In 1911 the English physicist Lord Ernest Rutherford demonstrated that the atom is similar to a planetary system with the atom nucleus as the sun and electrons as the planets. An entirely new universe had been discovered – a universe of unimaginably small dimensions. Even up to about 40 years ago the world appeared to be relatively simple. The physicists traced back 92 atomic species back to protons and neutrons, which were recognized to be the building blocks of atomic nuclei, and electrons which orbitted the nuclei in shells. However, a series of particles (approx. 300) were next discovered, first in cosmic rays and later in accelerators, which did not fit in the scheme as then understood. Strange names were found for these particles: mensors, hyperons, etc. Attempts to classify them have occupied the most capable theoreticians of the world for 2 decades. It soon became clear that the many particles described as “elementary” up to then, even including the proton and neutron, must in reality be composed of other yet more elementary building blocks. Since 1974 experimental results from particle accelerator laboratories have come thick and fast. These, together with the theoretical knowledge already available, have given an entirely new picture of the fundamental building blocks of matter as well as the forces acting between them. The greater part of today’s main interest in this subject did not exist at all in 1974.

There are currently 2 important questions here: a) whether the variety of matter can be traced back to a few fundamental building blocks and b) what forces act between these fundamental building blocks and are therefore responsible for their stability or reaction.

In the course of time, attempts have also been made to break matter down into smaller and smaller particles (see Fig.). The researcher has progressed through molecules, atoms, atomic nuclei and, finally, protons and neutrons to smaller and smaller units. In order to do this it appears that the smaller the unit the more force is required to break down these particles. To split them further it is necessary to bombard them with energy-rich particles produced in larger and larger particle accelerators. The advance into the microcosmos has proceeded largely parallel with the development of more and more powerful particle accelerators. These are, so to speak, similar to the microscope with which it is possible to penetrate deeper and deeper into the structure of matter. Through bombardment with high energy particles it has been proved that smaller “bodies” are contained in the proton, of which there are 3. Originally they were called “partons” and now “quark” particles. Today, these truly strange elementary particles are the focus of the particle physicist’s attention. Virtually all of the many “elementary” particles have now emerged as double or triple compounds of these elementary bodies. Particularly interesting is the fact that up to today there are no indications of structures even smaller than quarks. They behave as dot-like “sources” of their energy fields. Apart from quarks, only one other type of indivisible particles is known at present: the leptones of which the main representative is the electron. These particles also have no internal structure and, to a certain degree, represent a parallel family to the quarks. They lack only the characteristic nuclear forces of quarks.

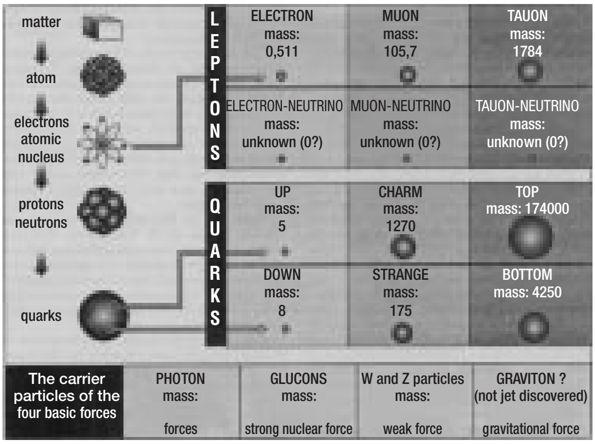


Fig.: Like the chemical period system of the elements, the standard model of physics arranges the elementary particles in groups with identical characteristics. The masses (as far as is known) are indicated in million electron-volt units (eV) (according to CERN). (1 eV is equivalent to the energy which an electron contains after passing through a voltage of 1 volt).

At present 4 different types of interactions between the particles are known. They differ principally in their strength, i.e. the “nuclear interactions” which only arise in connection with quark particles; the “electromagnetic” interactions which are associated with electrical charges; “weak” interactions which occur in radioactive decay and, finally, the “gravitational” interactions which occur with particles (and bodies) having mass. One of the greatest successes of physics in the 19th century was the recognition of electrical forces and magnetic forces as 2 forms of a unitary force, i.e. electromagnetic interactions. This theory formulated by James Maxwell represents the basis on which today’s electronics, radio and television technology has been built.

To the same end, Werner Heisenberg attempted to combine the 4 known interactions into one elementary force in his “world formula” during the 1950s. Today, it is realized that this attempt was made before its time. It is necessary to be content on reaching this objective step by step. With the discovery of the J/psi particle in November 1974, a period full of unimaginable new discoveries and successes opened up both for experimentalists at the DESY particle accelerator as well as quark theoreticians. Since it proved impossible, despite all efforts, to fit the J/psi particle into the accepted 3-quark model of the time, it was finally concluded that a 4th quark must exist differing from the 3 known ones by a new charge with the name “charm”. It is postulated that the J/psi particle consists of one charmed quark and its antiquark. If this assumption is correct combinations of charmed quarks with the well-known quarks must exist, namely the combinations cu, cd and cs. These combinations have been named D°, D+ and F+.

It has now been recognized that it is possible to represent the electromagnetic and the weak interactions as different forms of a general interaction. More and more experimental results have confirmed this theory or, to be more precise, no experiment has disproved it up to now. Interesting experiments on this theory have been carried out in storage rings. Only as a result of the extremely high energies achieved by this means are combined "weak-electromagnetic" interactions to be expected. The same high energies have opened up interesting test fields for details of the quark theory. Successful experiments in storage rings have demonstrated this repeatedly over the past few years. Since November 1974 the so-called J/psi "quark-antiquark" combination has been investigated.

Atomic weight Mass constant of the → Elements. Former name for relative atomic mass. Originally based on naturally occurring oxygen, the atomic weight of which = 16.

Atomizer High performance system using → Jets. A mist of water droplets is formed with an atomizer which, due to the large surface area of the water curtain, is suitable e.g. for the sorption of gases.

In the stenter exhaust air system shown in the Fig., exhaust air is led through a duct containing a water atomizer. This produces large quantities of water droplets and the exhaust air is conducted through the water curtain in a counter-current direction. Due to the resultant cooling to approx. 50°C, the pollutant vapours condense. The pollutants as well as (to some extent) undesirable odours, are consequently adsorbed and the soluble pollutants are partially dissolved in the water droplets. The pollutant-laden air is then passed through a mist collector in which the water droplets, condensation products and pollutants are separated out. In a water container fitted with a filter the non-soluble pollutants are finally separated off and must, if necessary, be disposed of as special waste. The cleaned water is then recirculated back to the atomizer. It is also possible to supply the atomizer with water from wet processing machines where it may be used for exhaust air scrubbing. → High pressure atomizer.

Atomizer nozzles Multi-component nozzles in which a mixture of air and a liquid is formed.

ATPUL, (Fr.) abbrev. for: l'Association Technique pour la Production et l'Utilisation du Lin et autres Fibres Libériennes (French textile research organization for linen and other bast fibres). → Technical and professional organizations.

Attagenus beetles, protection against → Mothproofing.

Attapulgite A hydrated aluminium-magnesium silicate mineral from Attapulgus (Georgia/USA), the chief ingredient of fuller's earth. It is related to meerschaum and has highly adsorbent properties. Used, *inter alia,* as bleaching earth.

Attraction forces Water molecules have a strong attraction for one another. For a molecule on the surface, however, attraction forces only act from the sides and underneath as there is no attraction between molecules of air and those of water. As a result, a force which is directed from the surface to the interior is active, i.e. surface tension. Although the forces acting between the water molecules (hydrogen bonds) are relatively strong, the surface tension of water is particularly high (see Fig.).

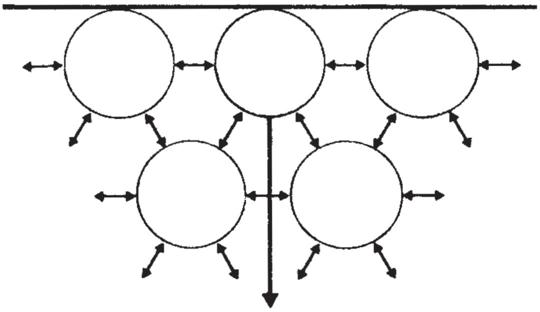


Fig.: Nuclear attraction of water molecules.

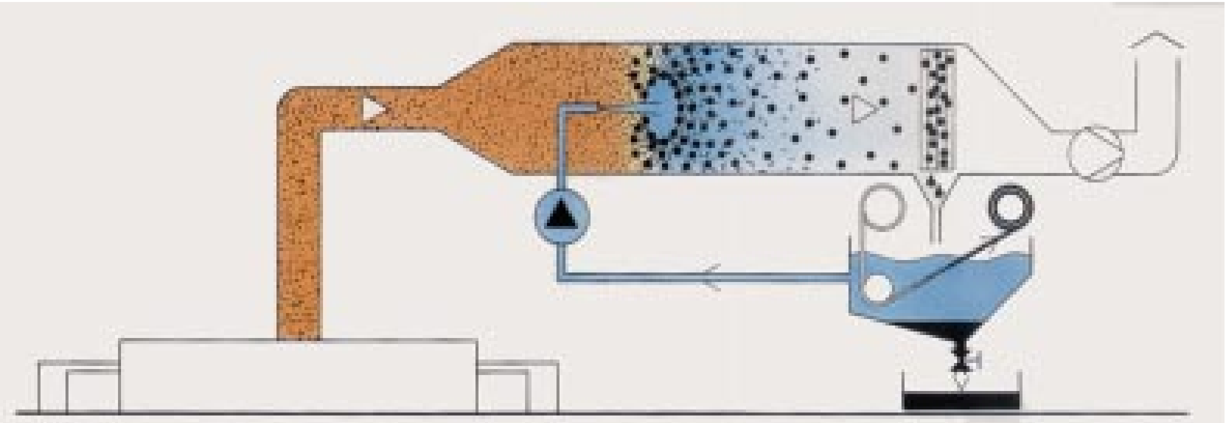


Fig.: Atomizer for stenter exhaust air cleaning (Prött).

ATV, (Ger.) abbrev. for: Abwassertechnische Vereinigung (German technical association for waste water). → Technical and professional organizations.

Au, chemical symbol for → Gold (79).

Au portique (= AFNOR method). French flammability standard which takes the form of a vertical test for upholstery and furnishing fabrics. Visual assessment: burning behaviour and smoke development. Measurements: time of burning after extinguishing the alcohol flame, and length of charred zone.

Autoclaves Pressure vessels constructed of thick-walled steel (usually alloy steel or frequently nickel alloys) of welded, drawn, forged or composite construction, generally in the form of circular kiers. They are always provided with a pressure gauge, thermometer and safety valve for control purposes. Maximum operating pressures are specified for all autoclaves which, if exceeded, can result in explosion. Uses: pressure scouring, high temperature dyeing.

Autoconer Automatic cross-winding machine for rewinding yarn from spinning cops on to cross-wound packages (Fig. 1). Electronic yarn clearers as well as automatic splicing of yarn breaks are state-of-the-art features. Both the spinning machine and the Autoconer can be equipped with automated transport systems (Fig. 2). Manuf.: Schlafhorst.

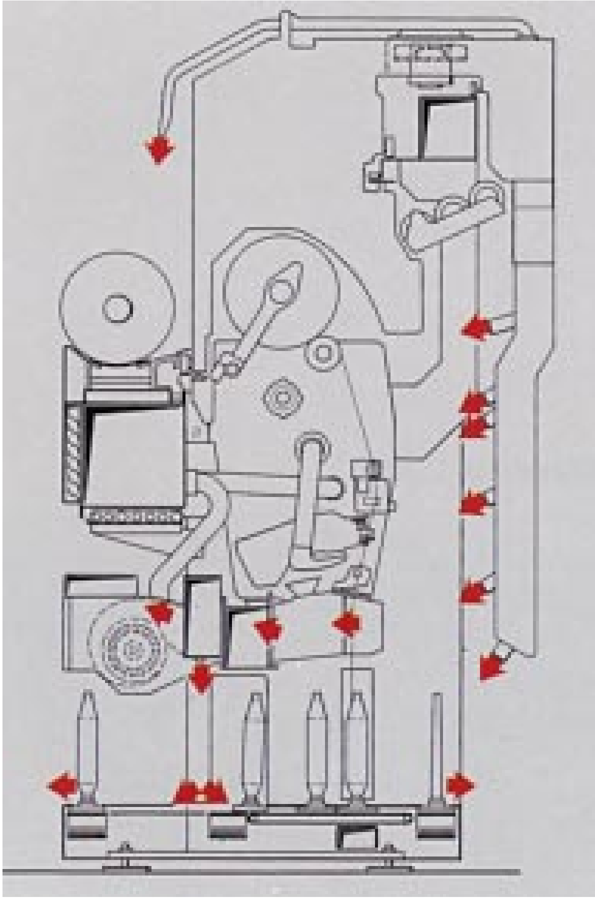


Fig. 1: Autoconer principle sketch.

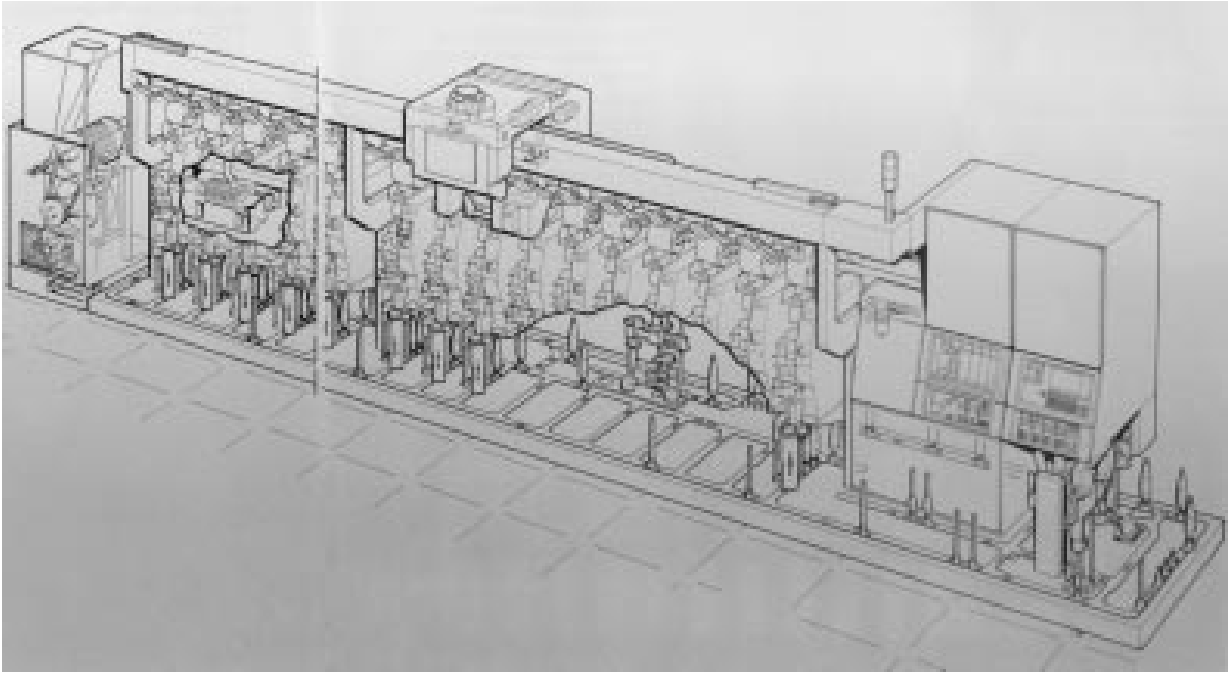


Fig. 2: Schlafhorst Autoconer System 238 with integrated Caddy transport system.

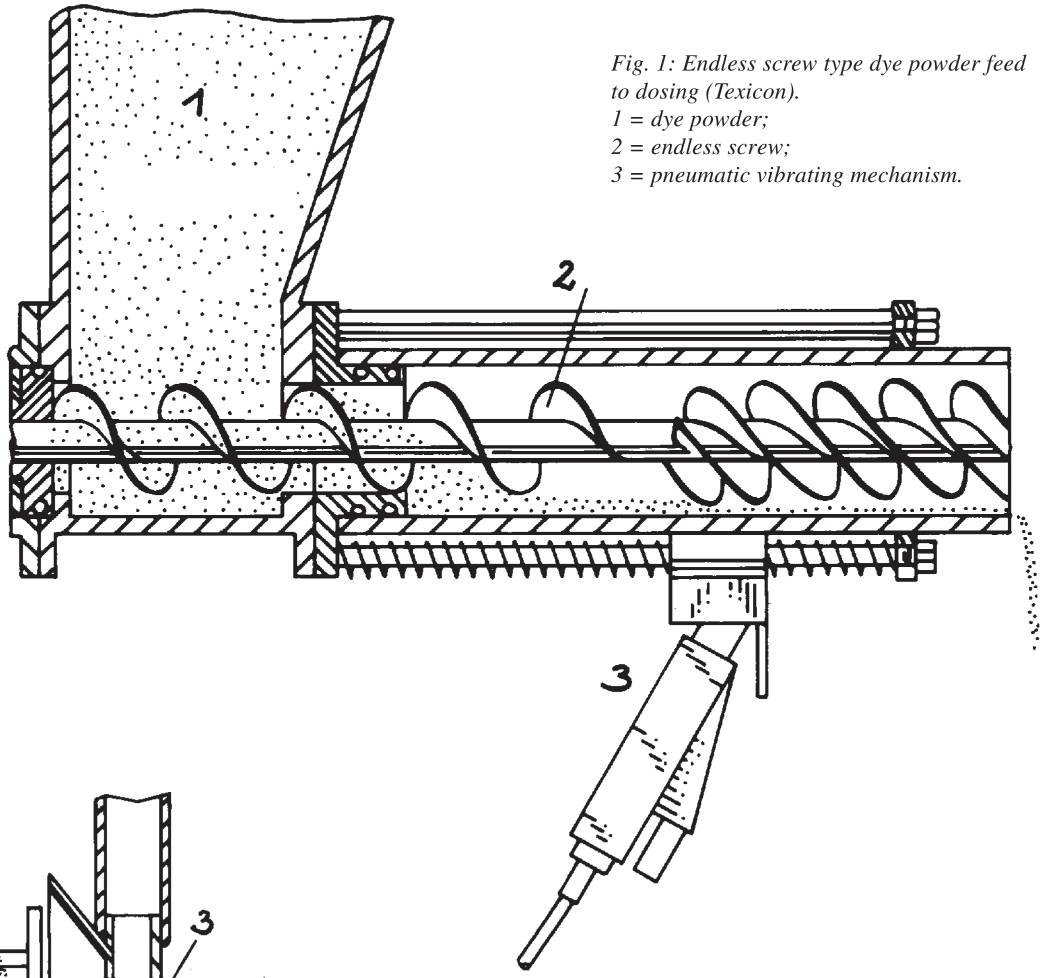


Fig. 1: Endless screw type dye powder feed to dosing (Texicon).
1 = dye powder;
2 = endless screw;
3 = pneumatic vibrating mechanism.

Automated dye weighing and dispensing systems An example of such a system (Figs. 1–3) involves the use of coded plastic cards on the dye powder containers and an integrated recipe print-out facility. Such systems are designed to eliminate weighing errors.

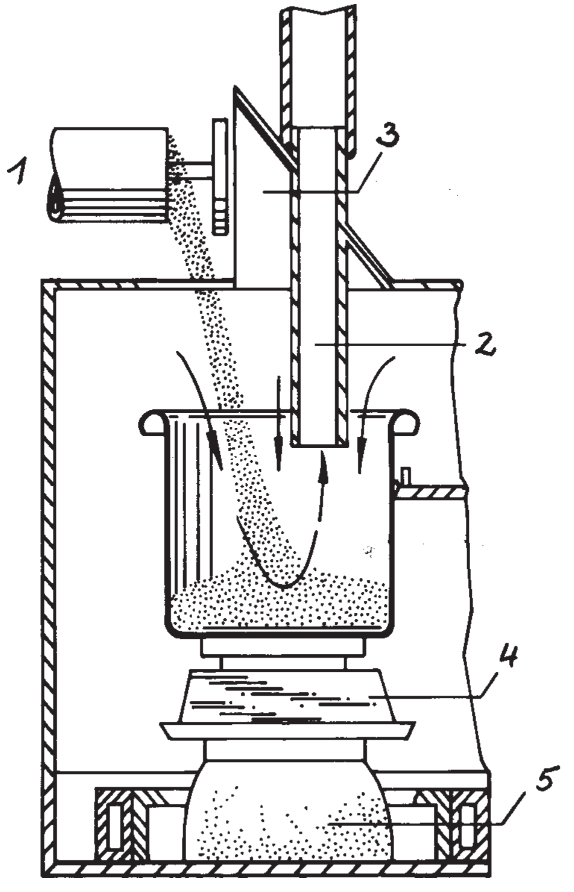


Fig. 2: Dye powder dosing and weighing station (Texicon). 1 = metering valve; 2 = dust extraction; 3 = dust extraction hood; 4 = scales; 5 = pneumatic springing.

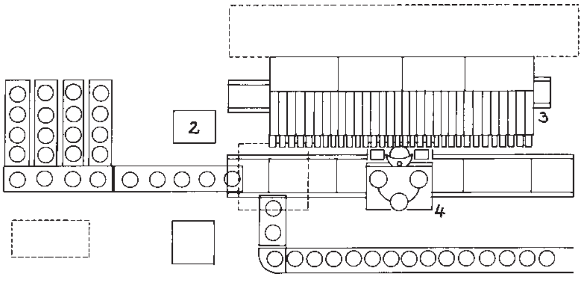


Fig. 3: Typical automatic dye dosing station. 1 = conveyor system; 2 = control panel; 3 = 32 storage containers; 4 = turnable.

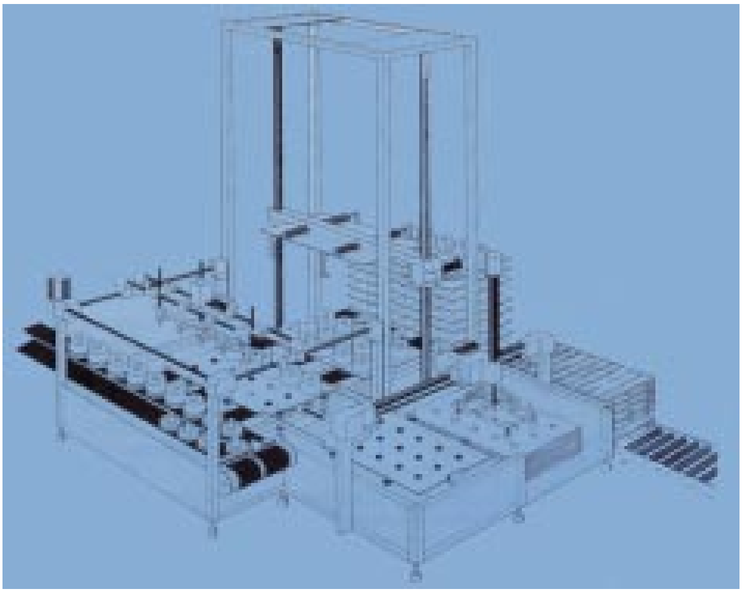


Fig. 1: Automatic palletizing machine for packing cross-wound bobbins (San Grato).

Automated packaging lines Typical examples in textile finishing include: the palletizing of yarn packages (Fig. 1) or rolls of fabric (Fig. 2) and the immediate packaging of fabric rolls in heat sealed polyethylene film (Fig. 3).

Automatic batcher, connected to a stenter; batch changes can be made without stopping the stenter. The goods are cut automatically and cardboard tubes are inserted without batch centres.

Automatic continuous laundering Term for a system comprising → Continuous washing plant, mechanical water extracting unit and an opening/drying unit, fully automatically controlled and technologically interlinked for non-operator assembly line laundering operations, from loading the line through to distribution and transport to the finished area.

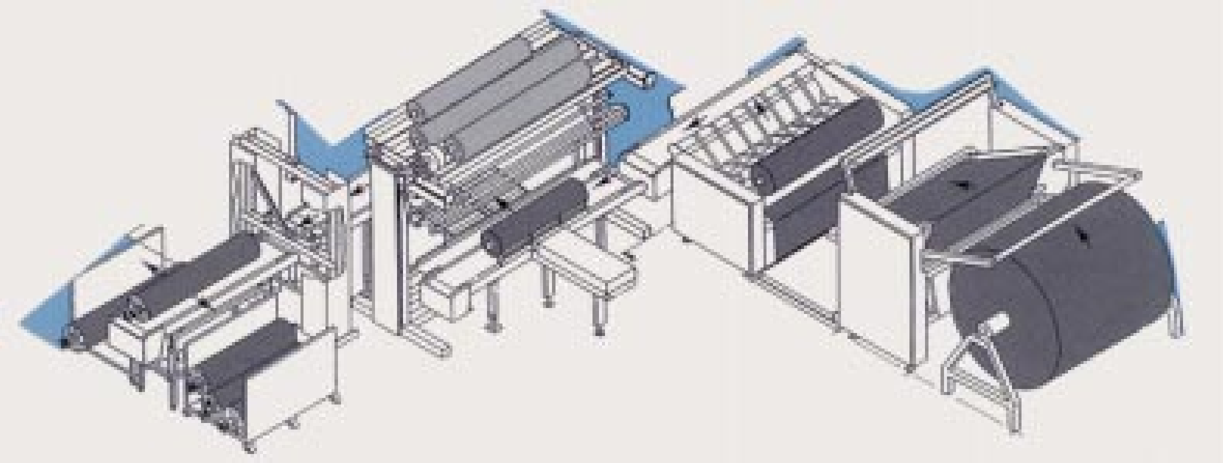


Fig. 2: Campen carpet roll packing.

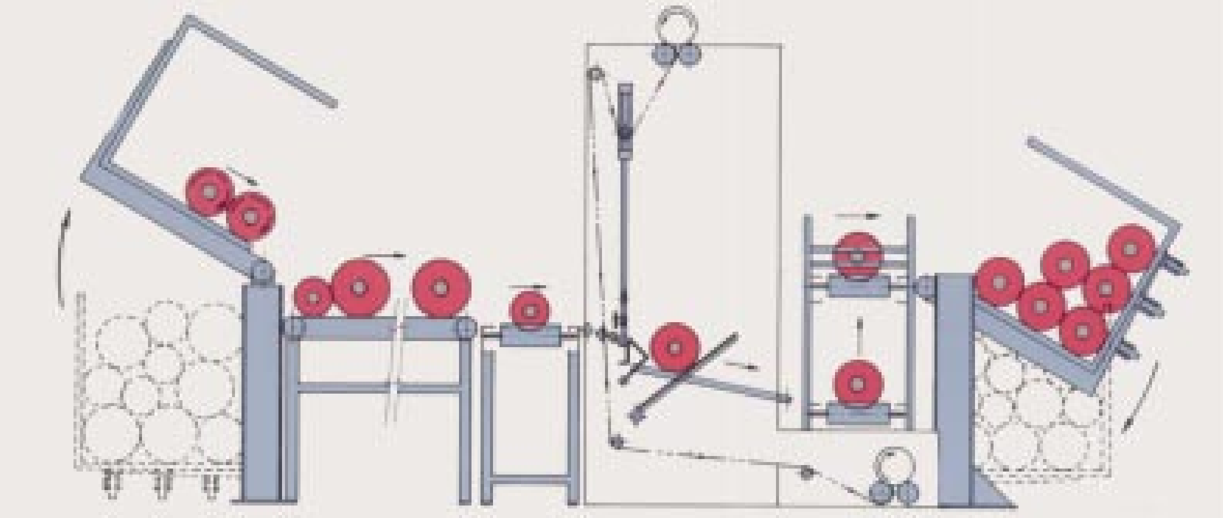


Fig. 3: Welding rolls of woven fabric in film (Krantz).

Automatic control systems processes in a system where one or more parameters (control parameters) are continuously measured by a sensor and the measured value is compared with a preset value, so that the actual value can be adjusted to the set value. A control process works in a circle, a so-called control loop. Fig. 1 shows a simple control loop.

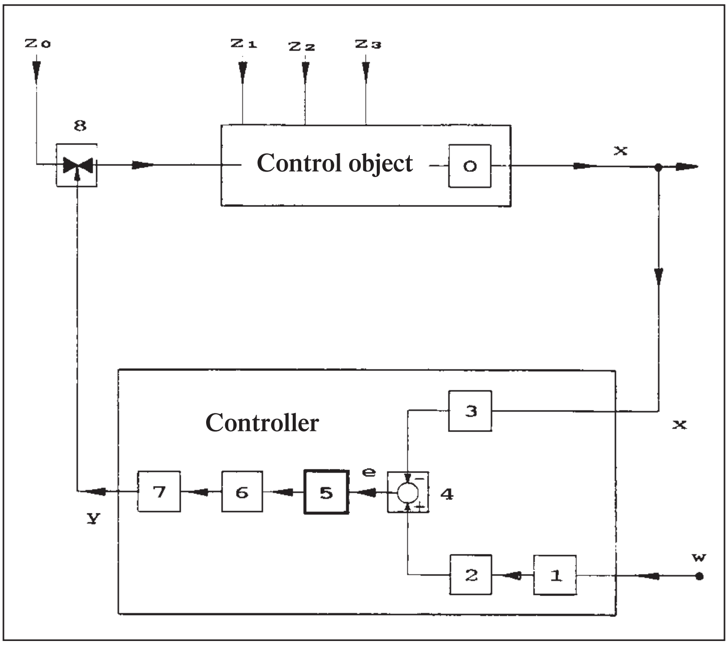


Fig. 1: Control loop. 0: current value detector (x); 1: set value adjuster (w); 2, 3: measured value converter; 4: comparator; 5: controller y = y(e); 6: output amplifier; 7: adjusting drive motor; 8: adjusting unit; Z: disturbance effects.

The principle of a control loop system that has been extensively automated is to eliminate fluctuations as quickly as possible and to bring the „disturbed“ system back to its original stable state. However, while control and adjustment are effected completely automatically and usually quickly in technical or biological control loops, this is not normally possible with industrial management control loops. In general it takes time to recognise a deviation, to decide what measures should be taken and then to put the measures into effect. This reaction time is the main obstacle to flexibility. To increase the flexibility, ways of shortening the reaction time have to be found for all the stages from recognising the deviation through the decision process to making the required corrections. It is appropriate to describe the three main functions of a control loop and to show (Table) how these three functions can be used to increase flexibility.

1. Sensor function: this function is associated with determining the actual or current value of the control parameter. In management economy encoded or operational data take the place of the probes. They serve a two fold purpose, namely finding
   - the current situation, the actual position, e.g. state of orders, stock situation, availability, bottlenecks and so on;

Term	Definition	Heating	Economy
Control loop	Closed feedback system that remains relatively stable to interior and exterior disturbances		
Control object	The object that is to controlled within a system	Room	Production operations
Sensor	Device for measuring the control variable	Thermostat	Operational data and codes
Controller	Controlling equipment	Regulating device	Process control system
Controller variable x	Variable that is to be controlled in the control object	Effective room temperature	Production programme
Guide value w	Set value	Set temperature	State of orders
Adjustable variable y	Values transmitted to the control object by the operation of the controller	Power to valves	Trigger value
Adjusting device	Mechanism for controlling the adjustable variable	Valve	Production systems/purchase
Disturbance variable z	Variables that act from outside the control line	Outside temperature	Customer orders

Tab.: Definitions in management loops (examples: comparison of technical and economic processes).

- an early warning system to detect both interior and exterior changes, such as, e.g. automatic notification of a delay in supply, an increase in the absence rate, material difficulties, changes in customer's orders etc.

In all these cases it is important that this information is sent quickly to the control manager either as encoded or operational data etc. This is carried out in part by operational data collecting equipment and systems. There will be administrative difficulties if the problem involves something which has consequences for material or timing that result in an alteration to a specification or a change in the volume of a customer's order. Above all, valuable time is often lost when changes have to be clarified manually. In these cases well-designed electronic data processing support in the dialogue is invaluable. A prerequisite is of course that the necessary databanks with direct access are available.

2. Control functions: there are three control functions, namely:
   - comparison of the control and set values to detect a deviation;
   - assessment of the deviation and then deciding whether it is large enough to set procedures in motion or if it is so small that nothing needs to be done;
   - deciding what measures should be taken to eliminate the deviation.
3. Regulating function: at this point the measures decided upon are put into effect. These include all activities directed towards eliminating the deviation, e.g. sending a purchase order, repairing a defective machine, arranging overtime, cancelling payment instructions, alteration of works instructions etc.

The control loop of a dyeing system can be represented e.g. as a block diagram (Fig. 2). The object of control is the dyebath. The rate of exhaustion $\dot{c} = dc/dt$ is controlled by the temperature T. There are two control loops, one inside the other, with the inner one (for the temperature) being controlled by the outer (for the rate of exhaustion). In the outer control loop, the rate of exhaustion $\dot{c}$ of the individual dyestuffs in the bath is compared with the current set value, where the set value comes from the critical dyeing rate. The controller for the rate of exhaustion ($\dot{c}$-controller) continuously calculates the set value for the temperature from the difference $\Delta\dot{c}$ between the actual and set values of $\dot{c}$ and from experimental data for both the temperature T_E and the rate of exhaustion $\dot{c}_E$. This set value is compared with the current value of the temperature by the temperature controller (T-controller), and the heating of the dyebath is switched on or off as appropriate. The PD (proportional difference) type T-

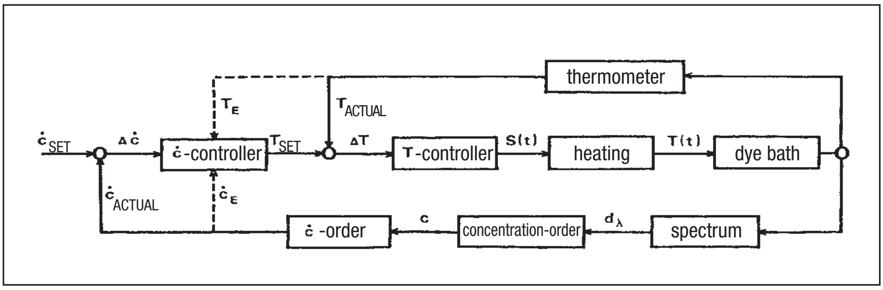


Fig. 2: Block diagram of a control loop.
d_l = optical density as a function of the wavelength, l; S(t) = Set value function for the heating.

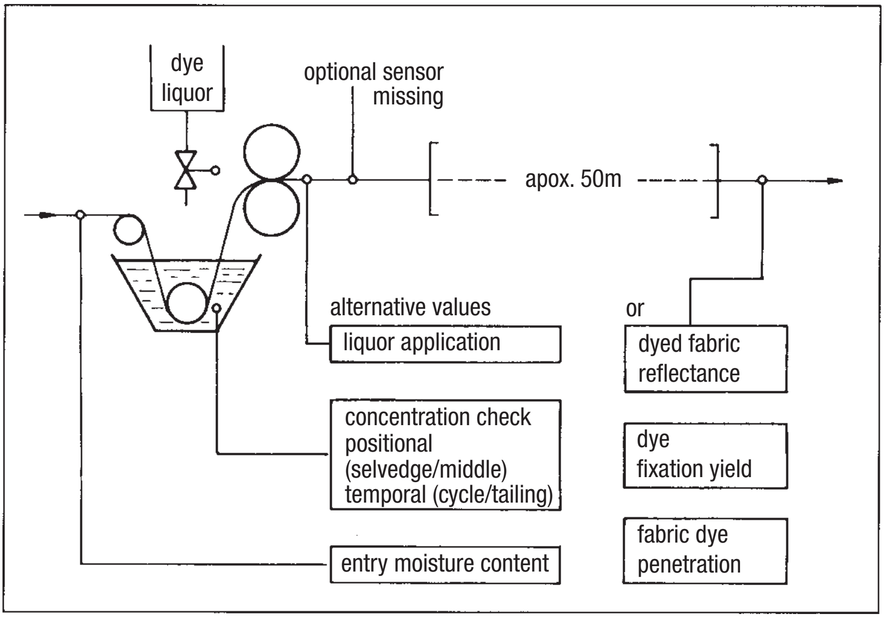


Fig. 3: Optional sensors for the uptake of the dyebath in continuous dyeing (after Rüttiger), uptake in g of dyebath per kg of textile material.

controller works by the normal principles of control engineering.

A management system is distinct from a control system. A management system is a process in a "closed" system in which the target value of a parameter (control parameter) is continuously established from actions based on measurements of this parameter and is kept at its optimum level. Control on the other hand is a process in a "limited" system in which one or several input variables affect other parameters (output variables) according to definite rules. Management is an extension of a control system.

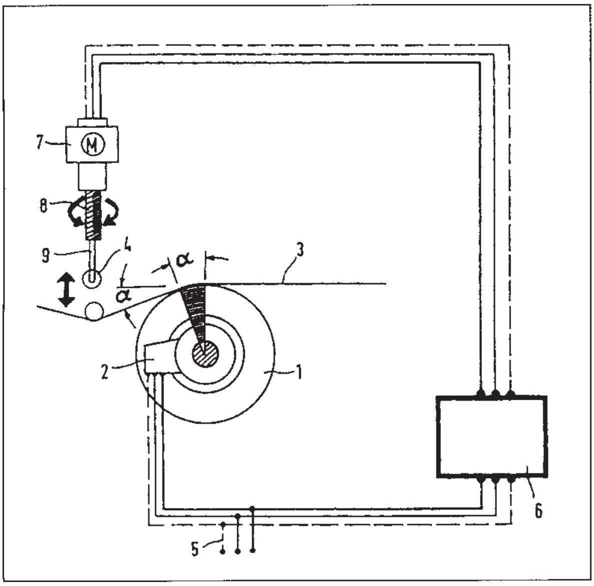


Fig. 4: Control loop for the automatic adjustment of the angle of approach of the textile material to an sueding roller (Menschner).
1 = emery roller; 2 = measurement of friction; 3 = goods; 4 = sensor; 5 + 6 = comparison of set/current values; 7 = controlling motor for adjustable roller; 8 + 9: adjustable roller.

Availability of microprocessors or control units is less critical for the operation of control loops than the existence of suitable sensors, but there is a lack of suitable sensors in textile processing (Fig. 3). However, there are important control loops that involve fabrics. For example, the friction between a fabric being abraded and emery paper on a cylinder can be kept constant in a continuous abrasion process (Fig. 4).

Equipment for this process is fitted with a device for managing the individual abrading surfaces by automatically altering the angle, α, of approach of the fabric to the roller. The required friction at the particular cylinder for the optimum abrasion effect is determined by reference to the current set value. Depending on this value, a motor is operated to readjust the angle of incidence of the fabric, α, until the current being taken by the motor of the particular emery cylinder corresponds to the reference set value. Hence wear of the emery is taken into account. A larger rubbing surface will be required to produce the same degree of abrasion when the emery coating is worn than when it is new. An acoustic or optical alarm can be triggered when the maximum allowed angle of incidence is exceeded, to indicate the degree of wear and the need to change the emery covering.

In a dyestuff uptake measuring system for a pad with adjustable rollers, to keep the control loop from becoming too large (e.g. by measuring the colour of the dried material), the uptake is measured in the middle and at the edges of the fabric directly after the squeeze roller, using wet colour measurement or absorption of microwaves by moisture, and can be adjusted by altering the nip pressure (Fig. 5).

Automatic jigger, → Jigger with control functions which automatically change the direction of running and regulate fabric tension.

Automatic pattern repeat system for screen printing Designed to provide a greater degree of re-

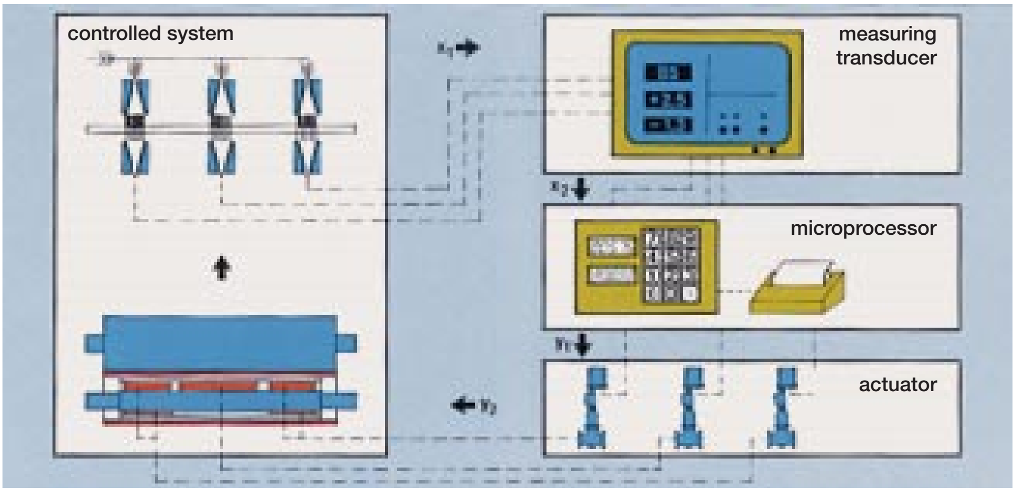


Fig. 5: Control loop for automatic product processing.

peat accuracy as well as time savings in comparison to manual repeat adjustment. In order to set the desired repeat length a movable limit stop is positioned against a graduated scale and fixed. Fixing or releasing of the limit stops is carried out automatically by means of a pneumatic wrench the pressure of which, as well as the advance speed of the screen printing machine, is steplessly adjustable. The automatic repeat system slides along the same guide rails.

Automatic preselector For automatic process control by an industrial computer, which has been simplified for the user by means of manual control panels. The automatic preselector assumes full process control through relevant controllers.

Automatic titration Automatic titration systems are important for routine production control in the continuous pretreatment of cotton and also in continuous dyeing with vat dyes. Development began in the middle 1970's and led to the first automatic titration of small samples. Further developments have resulted in the automatic feeding of concentrates to bleaching baths in which the addition of bleaching agent is controlled via an automatic titrator which operates a control valve by means of a PI controller, whilst the automatic addition of caustic liquor is controlled by electrical conductivity of the bath.

Automation The aim is to control and regulate equipment and processing, e.g. flow of goods, preparation of baths, dosing, temperature and treatment times, by automatic programming. Automation and control can be used in dyeing and printing e.g. in the following processes:

- temperature-time programmes,
- running partial or fully automatic bleaching and dyeing processes, including dye kitchens,
- pH,
- flow pressure/differential pressure,
- dosing of liquid chemicals.

Automation of regulation and control processes in production equipment requires a programme that allows analogue and digital techniques to be mixed on the screen without any problems, the microprocessors that are introduced to be designed so that they can be integrated easily into the bus system, and everything to be managed so flexibly on a PC screen that the user can process and pass on all the information coming over the bus within the framework of the standard programme. In recent years the whole industry has been moving towards more flexible production processes. Newly commissioned plant is equipped with SPC (→ Stored program control) and often also with DDC (direct digital control), so that the computer can make quick change overs in production possible by simple changes to the programme or to a parameter, either on the screen or through a bus system. This equipment provides a smooth, time-oriented flow of information, integrated with quality and monitoring of production costs, as to a large extent the available DDC and SPC controls can be used for the necessary measurement of values, status and flow of material.

In general, automation is the transfer of human activities into the "hands" of machines, equipment, switches or computers, which completely replace the human being, at least temporarily, in a treatment step or sequence of steps. Temporarily here means that substitution of the human being is possible in principle, so long as the automation equipment works perfectly. Complete take over from the human implies that no human intervention is required during the course of production in the tasks or processes for which the automation equipment is being used. Automation in dyeing and printing includes all those measures in which automatic devices replace human mechanical and sometimes thought processes, and in particular those activities that are used to keep given processing and final parameters steady at given values, or to adjust them according to definite programmes. In this sense, automation of dyeing and finishing can be classified as follows:

- regulation and control,
- continuous and batch processes,
- partially automated and computer automated control systems,
- direct and indirect process control.

The following problem areas in dyeing and finishing are probably the most important for introducing automation:

1. Batchwise processing: automatic control of batch processes; control systems in dyeing equipment including monitoring exhaust processes. Process-specific feed-back to the automatic unit to ensure reproducibility, particularly when there are variations in the material. Automatic sampling, calculation of post-additions and switching in shading programmes.
2. Continuous processing: Construction of control loops in continuous stages; regulation and control of connections between continuous stages; automatic input of set values into the control loop; automation of batch changes and intermediate cleaning between small runs to improve flexibility.
3. Bath preparation and transport: automatic bath preparation in finishing- and dye kitchens. Automatic transfer of baths from the make up unit directly to the point of use or into storage vessels in the area where they are to be used.
4. Flow of textile goods: automatic transport of goods between the individual treatment stages of the dyeing and printing operation. Automatic order processes linked to receipt of orders and delivery deadlines. Automated storage (receipt of goods, registration, call off and despatch).

5. Production monitoring: automated determination of process costs. Automatic control of goods (receipt, intermediate steps, despatch). Automated process data acquisition for possible fault tracing and as the basis for development work.

The introduction of → Expert systems as the process control technology (e.g. for stenters or continuous open width washing ranges) has been especially relevant to automation in textile dyeing and finishing. Converting a plant to automatic operation aims to model mathematically the specific knowledge and the actions that experienced operators carry out as a result of it, and to use a computer as an expert system to perform the actions.

In a washing range the following processes can be run automatically (Figs. 1–10: from Brügman):

- control of squeeze rollers,
- pH control,
- dosing of chemicals,
- control of water supply,
- temperature control,

Fig. 1: Squeeze roller pressure control.

Fig. 2: pH control.

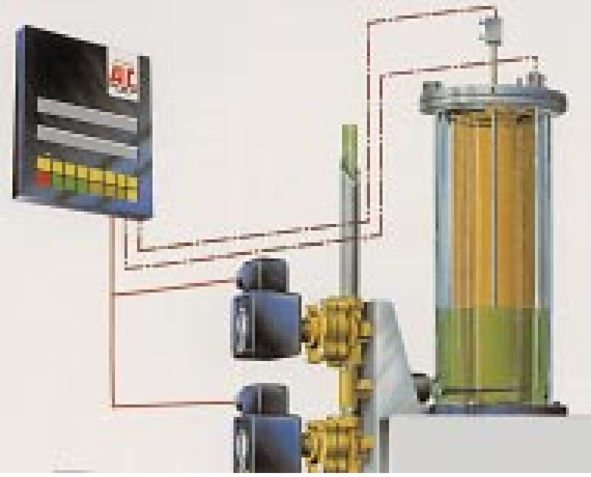


Fig. 3: Dosing chemicals.

Fig. 4: Control of addition of water with a flow meter.

Fig. 5: Temperature control.

- viscosity control,
- control of liquid levels,
- conductivity measurement,
- moisture content measurement.

Fig. 6: Viscosity control.

Fig. 7: Control of liquid level.

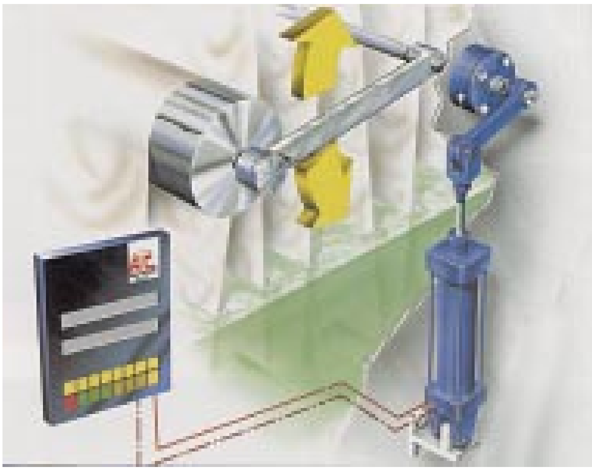


Fig. 8: Control of compensating roller setting.

Fig. 9: Conductivity measurement of padded goods used to control dosing to the pad bath.

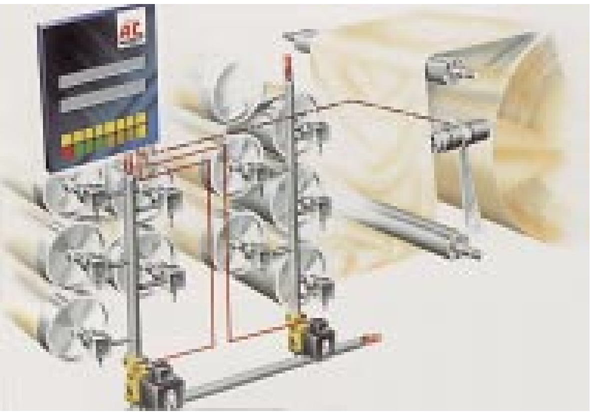


Fig. 10: Measurement of water content of goods used to control steam supply to drying cylinders.

Direct measurements on the goods are not often integrated into automatic systems because of the lack of suitable sensors.

From the economic point of view automation should only be considered by the performance-cost ratio for the user, so the question has to be asked, what is the optimum way of introducing automation to the operation with regard to the use of a specific unit in a plant, i.e. how long it will take for an investment to be repaid? The decision will be made with the individual automation philosophy and taking the unit's importance into account. All the operational, logistical and technical control data from the plant's central computer can only be evaluated as an entity, preferably with the firm's own electronic data processing equipment. The best solution may be to enter and output data individually or in combination using appropriate equipment. If the decision is made in favour of comprehensive automation equipment that can communicate, such an installation can only conceivably be set up with the co-operation of the computer supplier, plant supplier and user. Only in exceptional cases will complete detailed knowledge by one partner about the field of one or even both other partners be required. Working out a programme requires a clear definition of all the necessary parameters, regulations and sequence of events. This means that at least the plant supplier and the user must pool their collected “know-how” on a particular subject.

The chosen computer system must be capable of dialogue in all areas. This includes fitting appropriate interfaces to non-compatible parts of the system. In addition immediate service must be guaranteed in case of faults. For the plant itself, not only must parameters such as provision of steam, water, compressed air and so on be made clear, but also the number of chemicals and the amounts that are used per unit time, as it clearly makes sense to incorporate mixing and storage vessels for chemicals into the automation system. Setting up an appropriate software programme for controlling the plant also fits in here. Arrangements about pipework must be made clear too, as the instrumentation for an automatic plant is much more extensive than for a conventional one. Accessibility for maintenance and inspection should not be ignored.

Loading and unloading, transport and storage can be supervised through a management control system; the manipulation itself is usually manual however. Automatic transport and storage systems (Figs. 11 and 12) are known. Loading and unloading equipment for bobbins and packages and semi-automatic equipment for jets is also available, so that complete automation of the flow of goods is often possible. However, apart from the high price, a big disadvantage so far is the limitation of this system to only a few types of moving goods and operations. Because of this lack of flexibility of the robots, it is to be expected that material in the dyehouse will continue to be moved manually to a large extent. The rate of circulation of the goods and/or pumping capacity can also be adjusted to the requirements of a particular step in the dyeing process: faster circulation in the stage that is critical for levelness, slower in the dwelling and diffusion stages. In this way, the stress on the goods is minimised (Thies Synchron Dyeing System, SDS). Using robots to carry out the processing steps (e.g. in printing) must also be considered during automation.

The automation equipment (microprocessors) is often controlled from a central computer. Because of the lack of suitable sensors, easily measured values, such as temperature, fabric speed, pressure difference and density are used as measuring parameters instead of the actual target values. On-line pH measurement unfortunately still has problems and for a long time has been used only in carpet winch dyeing. On-line control of the rate of dyeing by continuous extinction measurements of the dyebath is available however, but is limited to cases where the extinction actually measures the concentration of active dyestuff in the bath, e.g. in dyeing polyacrylonitrile with cationic dyes. Care must be taken when this principle is used as the rate of dyeing is not always directly related to the levelness: an exhaustion curve that is linear with time is not always the optimum. Equipment of this type is better suited to finding the optimum processing conditions than for automatically guaranteeing each individual dyeing.

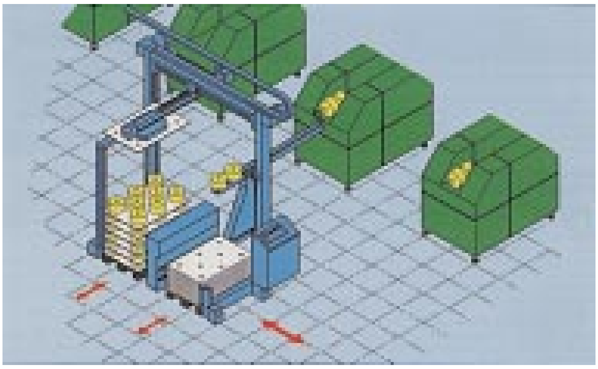


Fig. 11: Automation of transport of goods by putting bobbins on pallets.

Fig. 12: The Jasper automatic system for preparation of bobbins in a yarn dyehouse.

Automation, degree of A measure of the proportion of automatic operations in a particular process related to the total number of operations involved in that process:

Automation, selection of tasks for Selection formulae to help in introducing an automation system. They include regulation and control functions, in particular. The selection of tasks for automation is included in problem solving. There are many reasons for increased automation in production and administration. The most important are increasing productivity or reducing production costs and improving flexibility. Higher quality requirements and moves towards better working conditions are also important.

The rapidly increasing performance of microcomputers and memory banks means that it is now possible to automate complex processes to an extent that was unimaginable only a few yeas ago. However a point has been reached where it has to be asked whether it is sensible to carry out all the automation that is technically feasible. A greater degree of automation in a process does not necessarily lead to higher productivity when parameters such as flexibility, appreciation of the situation, maintenance and the reliability of the overall human being-machine interaction are included. Before starting any automation programme, a list of what is to be automated should be drawn up. The subsequent events are then:

1. Change over from relays in switch-boxes to stored program control (SPC). Enter the set values into the SPC.
2. Identify the interfaces.
3. Choose suitable measuring devices (sensors, units to measure current values), particularly for measurements on the goods.
4. If necessary, change from mechanical or pneumatic to electronic operating devices (transducers).
5. The whole set of measured values should be tested with suitable software. The software should be run by the people who will operate it. The aim is to use the screen to monitor the process.
6. It makes good sense to connect peripheral areas, especially the colour kitchen. Reliable equipment for measuring the flow of material is indispensable.
7. All the effort leads to a process that ensures reproducibility.

Automation technology General term for the processes, equipment and auxiliaries used in → Automation. It is divided into:

- measuring technology,
- regulating technology,
- control technology,
- computer technology.

Automation using these technologies can be split into 3 areas of dyeing and printing:

1. Production control with expert systems,
2. Part automation with closed control loops,
3. Complete automation of transport operations.

The control system carries out the steps “measure – compare – adjust” continuously until a situation is reached where the control quantity x is close to the required set value, $x_i = x_s$, and then it is kept there in spite of changes in other parameters z (z_1, z_2, z_3 in a block diagram) which may affect the process. For a typical textile dyeing or printing process, the set values, disturbance parameters and target values are important. In contrast to this process management in which the actual and set values are compared and fed into an automatic unit for an intelligent intervention in the process to be made, with process control any intelligent behaviour is pre-planned (programmed); the automation carries out the programme in a pre-planned sequence, without regard for anything else that may be happening in the process. The difference is illustrated by 2 examples:

a) A dyeing processes is controlled by a very polished “dyeing management” system, but which does not monitor the whole system. If (in an extreme case) someone forgot to load the dyeing machine with material, this serious mistake would not be noticed by the dyeing machine control, as this control system does not specifically involve the goods in a closed loop control system and the dyeing process is carried out without any measurement of colour changes (transmission of the bath or reflectance of the goods).

b) In textile processing, a real closed control loop must involve the goods and data from measurements on the goods (with suitable sensors) for deciding the operation of the control devices. The dyeing process is controlled meaningfully when the exhaustion of the bath is measured directly by colourimetry, and used to control the shape of the heating curve, which may be specific for each individual dyeing process. In this example however the goods are only involved indirectly (through the exhaustion of the bath).

When the moisture content of the goods coming from a stenter is measured directly, the running speed can be controlled according to the dryness if a set value for the optimum moisture content of the goods has been fed into the controller (by hand or through a microprocessor).

The Triatex “Mafoko” minimum application equipment uses an effective closed control loop; the goods are tested before and after padding for density and water content by radioactivity measurements. The speed is increased or reduced to control the uptake. Control of the temperature of the goods is essential in modern drying technology (by heat balance measurements in convective drying). However measurements of the high water contents at entry are also becoming significant in drying in large scale processes.

Great advances have been made in automating printing processes. Zimmer's Chromojet system represents an extraordinary development. In contrast to the Millitron process in which a stream of dye solution flows continuously but is periodically deflected away from the pile of the fabric by computer controlled air jets, the dye solution is delivered from the jets onto the goods (e.g. carpeting) only when a computer sends a signal. A big advance in screen making has been realized through linkage with computer supported printing systems. Here the submitted pattern is scanned electronically, e.g. with a scanner, subsequently digitized in a computer and transmitted to a screen (where alterations can be made to the pattern) and sent directly from there to laser engraving. In this connection, the Eikonix (USA) company has introduced an interesting computer supported colour design system with its "Design-Master 9000". In the new engraving process, the layer of lacquer is vaporised directly onto a perforated printing screen by a laser beam 0.12–0.30 mm wide. The printing screen is prepared without having to make a photographic film so that the engraving time is reduced considerably. The screen engraving time depends on the width or narrowness of the beam and takes at most 30 minutes for a 160cm screen (Stork).

With such colouristic systems based on electronic data processing, it is important that the respective systems are compatible when the design studios of textile dyeing and printing companies work together with customers' or consulting designers' design studios. The example of the Eikonix colour textile design systems shows how strongly interlinked the coloration processes are. In the future, automation will move towards a fully interlinked system with central guidance, which will also include a fully automated transport system. One pre-condition for the development of such a fully automated transport arrangement is the preparation of a system for controlling handling. In all the euphoria however, it should be noted that there is still no piece identification system that permits automatic location of a particular piece through all its operations and with labelling that can stand up to all the chemical processing.

Automobile safety belts 16 types have been approved to a European standard for use under European conditions. Polyester is the main fibre, although polyamide is also used occasionally. Commercially, both mass-coloured fibres and piece-dyed webbings are used for these applications. Polyester webbings may be dyed with disperse dyes by the thermosol process → Automobile safety belts (polyester), dyeing of. Polyamide webbings are dyed with 1:2 metal-complex dyes by the pad-steam process.

Automobile safety belts (polyester), dyeing of Continuous dyeing by the → Thermosol dyeing process (→ Dyeing of polyester) with appropriate machine combinations, e.g.: entry feed system, padder, IR-predrier, hot flue (for thermosol fixation), cooling zone, continuous washing range (at least 6 compartments if possible), drying unit (generally a cylinder drier) and a batching frame. Requirements include excellent light fastness, very good fastness to rubbing and good fastness to perspiration. A simple afterwash is sufficient for pale shades whilst an alkaline reduction clear aftertreatment is necessary for medium to dark shades. As a padding auxiliary, the addition of a synthetic thickener to the pad liquor is beneficial. Thermosol conditions of 30–90 s at 200–220°C are normally employed for dye fixation.

Automobile textile furnishings, recycling of For the future recycling of automotive textiles it is essential that they are first sorted into products of similar type. Compact system automotive carpeting consists of three layers:

- decorative textile layer (carpet),
- an acoustically effective resilient layer which is supported on
- a soft foam/nonwoven layer.

The composition of this compact system involves a wide variety of polymer types.

In contrast to uniform polyurethane foam, the acoustic layer of the carpet construction consists of several different thermoplastic polymers as shown in the Fig. These differ greatly from one another in structure and, as a consequence, also in their melting points. In order to achieve effective recycling, therefore, a plea must be made for these composites to be made from materials which are as uniform as possible in future.

As a basis for groups of materials of similar type, polyester and polypropylene are appropriate products. Polyurethane remains as the foam material which is separated by a film.

Various recycling procedures are used for textile materials of similar type. For example, after separating the polyurethane foam from the carpet upper layer, it is treated as follows: The foam padding is compacted. After mixing with a resin binder, the particles are either used to produce foam underlays which give improved soundproofing when placed under carpeting or pressed into composites which are used as a substitute for new polyurethane foam by incorporation into new compact system automobile carpets. The thermoplastic upper structure of the carpeting is first shredded then granulated in a further process. Up to now, three valuable applications have been examined for this granulated product:

- It may be incorporated into the recipe of a new batch of low expansion foam for compact carpets in amounts up to 15–25% or

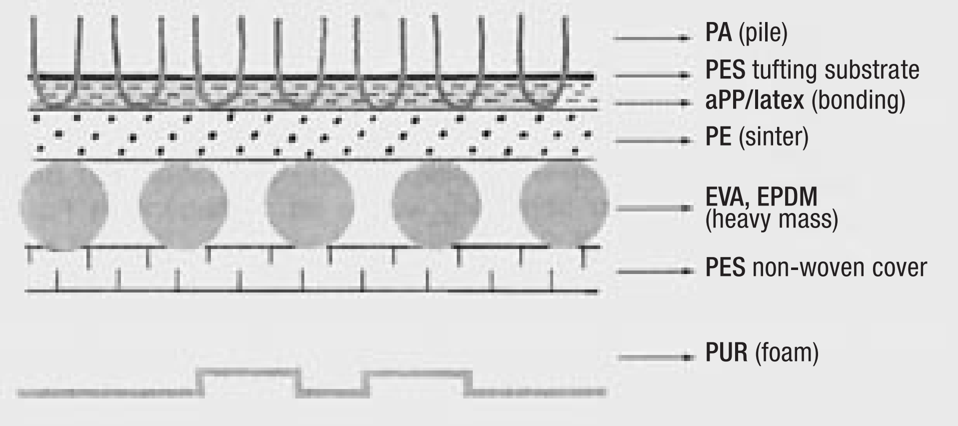


Fig.: Material construction of a carpet compact system.

- It may be added in the same proportion to the coating of carpet tiles.
- Trials made to add this granulated product to asphalt for road building as a bitumen extender have also given good results.

Even components having complex integrated structures (e.g. compact system carpets) can be recycled up to 100% by appropriate pre-sorting of compatible materials resp. the adoption of simple separation procedures for incompatible material composites. Manufacturing costs can be reduced through the use of recycled products in the production of new components. Having regard to the urgent need for recycling, the advantages of floorcoverings made from compatibly integrated materials should not be ignored in future (Laser).

Automotive textiles (car textiles) Since the early days of motor vehicle development producers of textiles and makers of cars have worked together. Over the years there has been continuous progression keeping pace with the changing specialist needs of the car industry in upholstery and trim materials. Since the 1980s there has been a sharp rise in the demand for textiles as a consequence of the greater need for comfort in the private car. Significant new developments such as those in the composites sector or in technical textiles have only been made possible through this spirit of cooperation. A vehicle in the medium quality range is fitted with an average of 10 m^2 of upholstery fabric, in addition there are 8.5 m^2 for floorcoverings and other trim items. This clearly illustrates the status of the car industry as a trading partner for the textile industry along with its suppliers of ancillaries and textile machine makers.

In the automotive industry the constant trend is towards higher quality. This is especially evident in the textiles used in cars. General requirements include:

- use of fibres of similar generic type,
- high lightfastness,
- fully compatible shades and colour uniformity in all consignments,
- optimum design with ideal surface properties for upholstery materials.

Safety and comfort have become important constructional attributes in the car. This is why in recent years there has been a significant rise in textile fabrics used in the interior trim of vehicles, generally at the expense of simulated leather and plastics facing materials. This fashion towards higher quality, luxury trim is continuing. Suitability for purpose and length of useful life are the main critical factors. But also in the technical sector of vehicle parts there is growing use of textiles or fibre products because of their specific benefits for certain applications. One example of extended use is the introduction of the passenger airbag as an additional safety feature. The following list summarises the variety of end-uses and preferred forms of presentation:

1. Seat upholstery fabrics: non-pile fabrics, woven, warp-knit and raschel velours, circular and flat knits, microfibre nonwovens; with or without polyurethane foam backing and secondary backing (generally lightweight polyamide knit), sandwich-laminate, primarily in ployester/wool, polyester, acrylic, polyamide/polyurethane.
2. Upholstery wadding: lightly needled fibrous webs in different fibre compositions including wool, cotton/viscose and synthetic fibres, sometimes with interlay or substrate in polyurethane foam.
3. Upholstery calico: cotton, cotton/viscose or cotton/polyester calico of varying construction.
4. Rubberised hair matting: coarse nonwoven in coconut fibre and hogshair bonded with a synthetic/natural latex mix; layered construction, varying density.
5. Seat trim (sides and back): warpknit and woven velours, raschel plush, knits in polyester and acrylic, generally sandwich-laminated to polyurethane foam.
6. Door and side trim: often the same as the seat upholstery or seat trim, sometimes combined with carpeting and/or plastics foil.
7. Headliner: generally on pre-assembled unit (closed preformed plastics-based unit) in warpknit velours,

non-raised knit, knit laminated to polyurethane foam substrate; in polyester/polyamide (two-tone effect), polyester.

8. A, B and C columns, sun visors: generally in material and colour to match headliner.
9. Carpets: tufted velours, tufted loop-pile, needlefelt almost always moulded and sometimes directly foam-backed (to compensate floor unevenness); various back-coatings, e.g. with solid backing for noise insulation; in polyamide and polypropylene.
10. Parcel shelves: non-pile and loop-pile needlefelts, warpknit velours, woven velours in polyester and polypropylene.
11. Trunk liners: needlefelts, tufted velours, tufted loop-pile often back-coated or impregnated or backed and moulded; in polypropylene, polyamide or polyester.
12. Restraint systems: polyester safety belts, airbags for airbag unit in coated woven polyamide and aramid fabric.
13. Technical nonwovens: Melded nonwovens generally in synthetic fibres, impregnated with the plastics emulsions necessary for the melding function and/or sometimes produced with fusible fibres. Noise insulation, anti-vibration and motion-damping nonwovens, antistatic pads and felts in wool and synthetic fibres with and without polyurethane foam backing,
14. Tarpaulins and covers: tarpaulins in polyester/acrylic outer fabric laminated to cotton fabric sandwiching a dense intermediate layer of chloroprene rubber; coated and impregnated tarpaulins in polyester and polyester/cotton.
15. Tapes, nets, twines: woven tapes, e.g. for edging purposes; in knitted fabric, e.g. for door-edge draughtproofing (in combination with steel inserts and rubber); in felts, e.g. for draughtproofing; securing or separating nets in polyester; sewing twines in polyester, polyester/cotton, polyester.
16. Substrates for simulated leather: knitted and woven fabrics, nonwovens, spunbondeds; in polyester/cotton, polyester, cotton, polypropylene.
17. Tyres, V-belts, hoses, ropes: tyrecord in polyamide and polyester; V-belt liners and hose liners; tow ropes etc.
18. Textile loose covers for seating: knits in polyester.

Car manufacturers have drawn up basic technical specifications which include definitions of the following:

- the scope (with technical demarcation in terms of products and/or techniques);
- the responsibilities of customer and contractor relating to controls on incoming deliveries, in manufacture and on end-product, plus agreement on inspection visits;
- progression of joint developments extending from drafts, pre-production samples and passing samples through to full production , paying particular attention to environmental conservation and industrial safety requirements;
- the technical and testing procedures to be followed for consignments, for example batch sizes, test certificates, labelling/identification, defect description and marking (including indemnity), make-up, packaging and delivery conditions;
- miscellaneous technical requirements, for instance tolerable variability (e.g. of a property affecting making-up due to variations in machinery between two different suppliers making the same product), shelf-life, tolerances and procedure for settling complaints;
- testing procedures which differ the standard methods (DIN, ISO, ASTM, SNV, BS etc.).

Technical specifications include definitions of:

- constructional features (composite items);
- properties affecting making-up: a) elongation, drape, moulding characteristics; b) sewability, adhesion, fusability, bonding potential, vulcanising (curing) characteristics; c) seam strength, needle and stitch tear strength, fraying; d) tear strength;
- end-use characteristics: a) breaking strength, breaking extension, bursting strength; b) abrasion resistance, wear test, simulated service test; d) pilling propensity; e) air permeability, water vapour permeability; f) resistance to compression, recovery from indentation; g) residual and elastic extension, bagging fatigue; h) lightfastness on exposure to high black-panel temperature; i) colour fastness (fastness to rubbing, perspiration, water spotting, water immersion, solvents); k) streakiness, handle, friction index; l) stain resistance, drycleanability; m) delamination resistance; n) dimensional stability; o) flame resistance; p) fogging and odour; r) miscellaneous (residual fatty matter content, extractable matter, electrostatic propensity, pile withdrawal force; s) resistance to weathering and ageing; resistance to environmental influences.

Automotive textiles specifications Textiles are used very extensively in cars, examples of their applications including tyres, hoses, tapes, nets, twines, ropes, V-belts, noise insulation etc. and extending to upholstery materials and carpeting. Textile interior trim in cars is not confined to needled floorcoverings and pile nonwoven covers which are chemically bonded. Laminated woven and knitted fabrics are used as seat upholstery and in side cladding. Flocking also plays a major role in car headliner products.

Five percent of the total annual consumption of textiles comprises use in the car sector. Car comfort has become an important design feature. There is a continuing trend towards luxury textile interior trim of high textile quality. Designers compete to attract the buyer with their ideas. One of the tasks of of the finisher is to convert these ideas into reality whilst taking account of the required end-use efficiency of the textiles concerned. Quality specifications of car manufacturers indicate that the most important colour-related fastness requirements for the end-product in interior trim are associated with lighfastness, the metamerism of dyed shades and fogging. The fact is that the specifications and test procedures called for by car manufacturers vary according to the different substrates and woven or knitted constructions employed. The sometimes extreme demands called for in textiles (ten-year guarantee) are understandable if the stresses involved are considered; for instance, not only light, but also temperatures in excess of 100°C to which the fabric is exposed.

When it comes to scrapping, car textiles are classed as light industrial refuse along with glass, rubber and plastics. Because of the diverse nature of the synthetic materials contained (approx. two dozen types) there is general cause for concern. It is quite possible that toxic fumes will be emitted during incineration. To enable these materials to be recycled they need to be sorted. Under the conditions of current scrapping practices this is not possible. One feasible solution would therefore be to break down the scrapped car into its component parts in the reverse of the production process. To permit recycling of the materials obtained in this way the textile finisher (e.g. producing bonded nonwovens for use as floorcovering) needs to be aware that only thermoplastics can be recycled satisfactorily.

The safety belt is an important feature in the car. Requirements for this are specified in EC Guidelines. Minimum values are prescribed for width and breaking strength. Specifications also cover minimum breaking strength following abrasion and resistance to light exposure, cold, heat and moisture. One important test is a dynamic test simulating an accident which uses a dummy on a sledge, which at a speed of 50 km/h is decelerated over a braking distance of 40 cm. The belt must remain intact. At the end of the test the frontward displacement of the dummy is ascertained. The requirements in this dynamic test do in fact result in increased static strength in safety belts accompanied by reduced belt extensibility. Because of the legal requirements, some car companies have prescribed higher specifications, and some call for additional tests.

Colour fastness to crocking (rubbing) and light in piece-dyed (superficially dyed) belts is governed solely by the dyeing characteristics of the warp yarns used, the quality of the dyes used and the knowhow and dyeing machinery of the dyehouse. As these are inadequate in many cases, car manufacturers in Europe are tending more and more to specify belts made in spun-dyed yarns (Fig.). By this means unforeseeable risks may be avoided because even with good piece dyeing shade variations from batch to batch are inevitable.

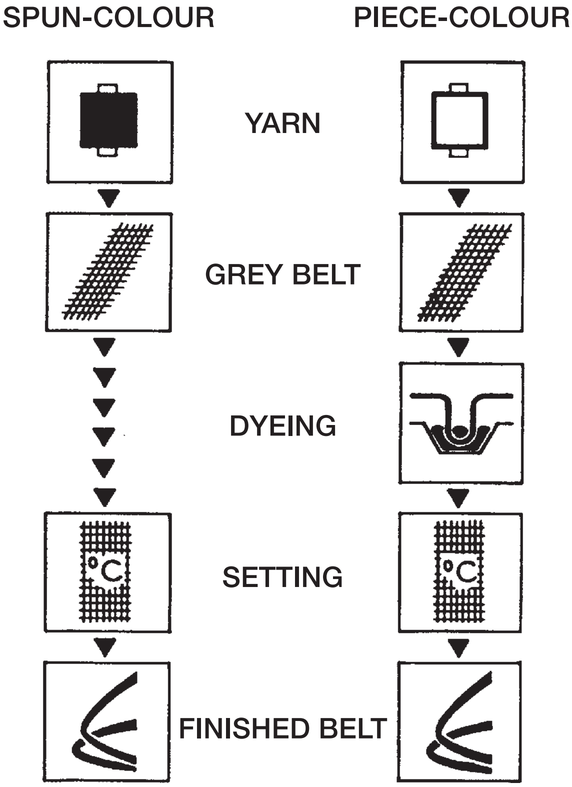


Fig.: Technology of safety belt manufacture.

Crocking and perspiration fastness of spun-dyed products may be regarded as optimum since the dye is fixed on the polymer chemically and physically during fibre production and therefore cannot be rubbed off. In spun-dyed fibre the dye is present not merely on the surface but penetrating its capillaries. The lightfastness of spun-dyed materials is also excellent. Even after 2000 hours exposure, exposed areas of a belt are the same shade as unexposed areas. With piece-dyed belts a distinct shade change is recorded after as little as 200 hours.

Apart from the usual requirements (surface evenness, shade conformity, crocking fastness, comfort) the requirements for lightfastness in exposure to high black-panel temperature are extremely high for car interior trim. These requirements can vary considerably depending on where the material is to be used in the car interior. It is quite possible for different car manufacturers to test using the same test procedure but demand different fastness grades. This means that the test procedures need to be kept strictly separate from what is required in the results. Generally speaking there is distinct trend towards still stricter specifications, though using the same test procedures but over a longer testing time. Another point to be considered is that textile trim materials must be odourless and not be subject to “fogging”. Special additives therefore need to be employed which do not give rise to fogging.

Automotive textiles, light fastness testing Automobile manufacturers have produced their own technical standards which differ from the usual industrial standards and even differ greatly in some respects between manufacturers. This creates problems for producers of → Automotive textiles as well as for the dye manufacturers in recommending a selection of dyes suitable for use in combinations with guaranteed high light fastness properties, since individual dyes can react very differently to external factors (temperature and moisture). As a consequence, the reproducibility and comparability of light fastness ratings in different locations cannot be fully guaranteed. There is thus an urgent need for a cooperative agreement between automobile manufacturers and international fastness testing committees to establish a unique, reliable and highly reproducible test method for automotive textiles. → High temperature light fastness tests.

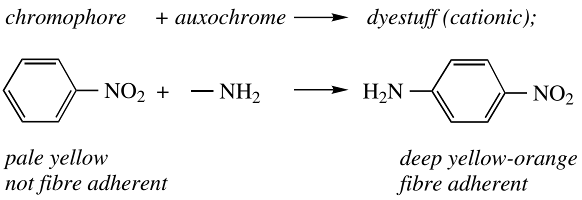
Automotive textiles, recycling of A motor vehicle contains a large number of different materials. Although the proportion of textiles is less than 10%, it is still necessary to use environmentally acceptable and recyclable fibres, to limit the number of different types, and to move away from composite materials with different components. Textile materials should always be viewed in the context of the whole structure and constructions that can be easily dismantled are essential for a successful recycling chain.

Example: Cushioning materials and lining fabrics are frequently combined with polyurethane foams. This combination cannot be used satisfactorily at present. Chemical recycling (alcoholysis, hydrolysis) is possible but expensive and there is no demand for processing foam combined with flock. One solution is to substitute fibrous materials (non-woven fabrics) for the foam, which also allows the flame laminating process with its high emissions to be replaced by adhesive laminating processes. It is also necessary to examine the individual components alone as well as as a part of the whole construction.

Autoradiography is used for the local detection of radioactive substances by means of photographic plates. If, for example, a substance which has been labelled with a radioactive indicator is brought into close contact with a film emulsion, the location of the radioactively labelled areas will be indicated precisely after a suitable exposure time by the black points produced in the film layer caused by the available radiation sources (alpha or beta rays). The method offers the possibility to detect the spacial distribution and location of substances. The photographic plates are interspersed and ionized by radioactive particles over an appropriately wide range. Autoradiography is far superior to methods of detection based on pure chemistry.

Autoxidation The self-catalyzed oxidation of e.g. sulphur dyeings or, to be more precise, the sulphur contained in the dye molecule both on and within the dyed fibre as a result of which free sulphuric acid is liberated causing hydrolysis and destruction of cellulosic fibres through the formation of (hydrocellulose). Autoxidation is promoted e.g. by storage of dyed goods under warm humid conditions. In this case, the valency of the sulphur (at the polysulphide bridges) is chemically changed through oxidation, so that divalent sulphur becomes tetravalent from this point on. → Antioxidants.

Auxochrome A substituent group in a dye molecule having a basic or weakly acidic character which acts as a "colour intensifier" and also confers affinity for textile fibres. The best examples are the groups –COOH, SO_3H, –OH, and NH_2. Only when an auxochrome (electron donor) and a → Chromophore (electron acceptor) are both present is a dye obtained which has affinity for the fibre:



Available chlorine is the chlorine which is active for bleaching (disinfectant-active) and present in chlorine products. In chloride of lime (bleaching powder), for example, it is the quantity of chlorine released by the action of hydrochloric acid: $CaOCl_2 + 2HCl \rightarrow CaCl_2 + H_2O + Cl_2$. Chloride of lime has an active chlorine content of 35–40%; sodium hypochlorite bleach liquor 145–150 g/l and bleaching baths 3–8 g/l. Used, e.g., in → Disinfection washing of textile.

Available chlorine in bleaching baths, determination of 10 ml of the bleach liquor to be tested (diluted to approx. 50 ml with water) is titrated with 0,1n arsenic acid solution until a drop of the liquid no longer turns potassium iodide paper blue. 1 ml of 0,1 narsenic acid is equivalent to 0,003546 g of available chlorine.

Available oxygen content of peroxide bleach liquors Volumetric determination by titration with standard potassium permanganate solution until the end point is reached (faint pink colour).

Average degree of polymerization indicates the average number of monomers contained in a polymer. The mole mass of the polymer is obtained from the product of the average degree of polymerization and the mole mass of the monomer ($M_{Monomer}$). The average degree of polymerization is determined by osmotic methods or viscosimetry. It provides information on polymer hydrolytic breakdown (damage). The specific viscosity ($\eta_{spec.}$) of the solution of a polymer, the average degree of polymerization of which is to be determined, depends on the concentration, chain length (average degree polymerization) and temperature of the polymer (η = polymer solution viscosity) and the solvent (η_0 = solvent viscosity).

$$\eta_{spec.} = \frac{\eta - \eta_0}{\eta_0} = \frac{t - t_0}{t_0}$$

Viscosity is measured in a capillary viscometer (Ostwald, Ubbelode) via the passage time t of suitable solutions. The specific viscosity obtained in this way is connected with the average degree of polymerization as follows:

$$\eta_{red} = \frac{\eta_{spec.}}{c} = K_m \cdot DP$$ (Staudinger equation)

$$DP = \frac{\eta_{spec.}}{c \cdot K_m}$$

c = polymer concentration in g/l,
K_m = constant, depending on polymer structure and solvent,
η_{red} = limit viscosity.

The limit viscosity η_{red} is obtained from the $\eta_{spec.}$ curve against c for c = 0. The average degree of polymerization can be obtained more accurately via the equation of Schulz and Blaschke:

$$DP = \frac{\eta_{spec.}}{K_m \cdot c} \cdot \frac{1}{1 + K_\eta \cdot \eta_{spec.}}$$

K_m = constant for polymer effect,
K_η = constant for solvent effect.

Some values for the average degree of polymerization of fibres:

cotton	3000 – 5000
other natural cellulosic fibres	2000 – 3000
wool	100
silk	1300
viscose	500 – 700
acetate	200 – 300
polyester	12 000 – 20 000
polyamide	100 – 200
polyacrylonitrile	500 – 1500

Average molecular weight (AMW) A term used in polymer chemistry for the mean value of the entire molecular weight range. It affords useful information on the structure of macro- molecules, e.g. oligomers dissolved out of synthetic fibres during specific finishing processes (effect of carriers).

Average value $(\bar{x})$ Statistical parameter in quality control, as the arithmetic mean of an average of random samples from the sum/number of individual values. As an acceptable assessed value, has the practical merit of smallest variance. → Statistical analysis.

AWA, (Ger.) abbrev. for: Arbeitsgemeinschaft Wasser (German Study Group on Water).

Awning cloth or tarpaulin Heavy → Sailcloth; also coated.

Axial drive batcher → Batching drives.

Axial dyeing process Package dyeing in dyeing machines with axial liquor flow.

Axial fans Electric fans used in ducts for the ventilation and extraction of exhaust vapours and steam from inside buildings and industrial plants. They are constructed in such a way that the shaft of the fan is centrally positioned within the duct (see Fig.). The use of glass-reinforced plastics (GRP) ensures excellent resistance to chemicals and can be used at temperatures up to 120°C. The three-phase motor is located externally.

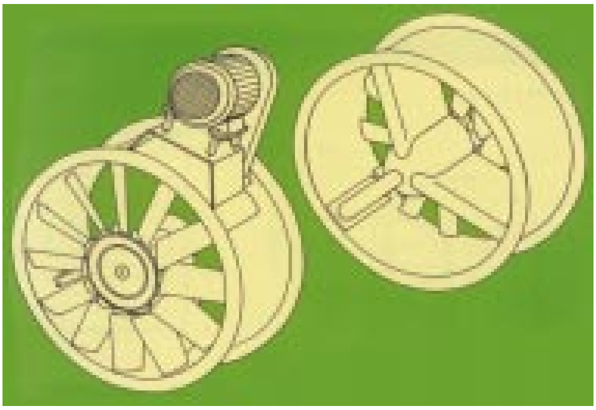


Fig.: Windel plastic axial fan.

Axial-flow pumps With the introduction of high density textile packages, e.g. yarn packages in dyeing machines with press-packed columns through which the dye liquor has to flow (400–500 l/kg) axial-flow pumps are of particular interest. Liquor flow through the pump inlet and outlet sides is axial. In contrast to centrifugal pumps, the load on the motor increases with increasing resistance of the textile material. In the axial-flow pump a rotor is provided for each stator. Multistage axial-flow pumps have several rotor/stator pairs in series. The pump response curve can be changed by regulating the speed of the drive motor.

Axioflexible cylindrical dye tubes In order to produce cylindrical yarn packages suitable for press-

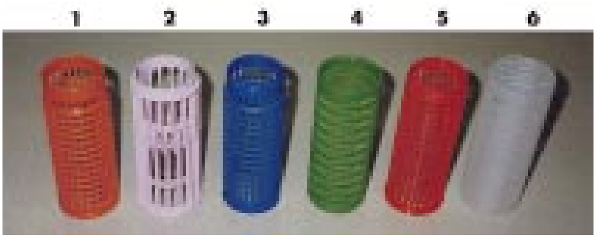


Fig.: Axial-flexible cores from different manufacturers. 1 = Karo core: disposable pressure dyeing core; diam. 54/60 mm. 170 mm (Karo Kunststoffwerke); 2 = Combi-Flex: ribbed core; diam. 54/60 mm, 170 mm (J. Zimmermann-Eisbär Nadelfabrik); 3 = Becker core: disposable pressure dyeing core; diam. 54/60 mm, 170 mm (Karo Kunststoffwerke); 4 = Zet-Flex core: coarse screen core; diam. 54/59 mm, 170 mm (H. N. Zapf KG); 5 = AC dyeing core: coarse screen core; 54/59 mm, 170 mm (J. Zimmermann-Eisbär Nadelfabrik); 6 = "Engel" dyeing core: diam. 58 mm, 170 mm (Engel Multiflex System GmbH).

packed package dyeing machines, plastic → Dye tubes are needed which are capable of compression in the lengthwise direction, either reversibly or irreversibly, without undergoing any significant change in diameter during the press-packing operation. Moreover, the pore volume of the perforations must not be too small so that adequate liquor flow through the yarn package is maintained. From the extensive range of axioflexible cylindrical → Disposable dye tubes and → Reusable dye tubes available in the market a few examples may be seen in the Fig.

Axminster carpets Machine woven carpets, with cut pile, in which successive weftwise rows of pile are inserted during weaving in a prearranged colour sequence. This type of carpet was originally produced in the English town of Axminster. The methods of manufacture enable virtually any type of coloured design to be reproduced, a flexibility which has been particularly exploited in the imitation of oriental carpets. There are four main types of Axminster weave: spool Axminster, gripper Axminster, spool-gripper (gripper-spool) Axminster, and chenille Axminster.

Aza compounds The prefix "aza" is used to denote the presence of nitrogen in an organic heterocyclic ring structure, i.e. when one or more –CH groups are substituted with nitrogen.

Thus pyridine (C_6H_5N) is also azabenzene. Aza compounds are free of sulphonic acid groups and soluble in acids. They are used as (special) coupling components on naphtholated grounds e.g. on wool and silk.

Azeotrope (azeotropic mixture; constant boiling mixture) A mixture of two liquids (or solvents) that boils at constant composition at a specific temperature, i.e. the composition of the vapour is the same as that of the liquid. Azeotropes occur because of deviations in Raoult's law leading to a maximum or minimum in the boiling point composition diagram. When the mixture is boiled, the vapour initially has a higher proportion of one component than is present in the liquid, so that the proportion of this in the liquid falls with time. Eventually, the maximum and minimum point is reached, at which the two liquids distil together without change in their composition. For this reason, separation by simple distillation is not possible. The composition of an azeotrope depends on the pressure. In the case of solvents, the presence of water results in a steady-state temperature which is significantly lower than the boiling point of the solvent.

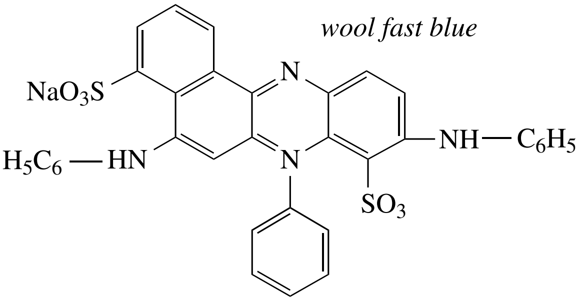
Tetrachloroethylene forms e.g. azeotropes with many solvents:

Azeotropic boiling point in °C (at 1 bar) with:

Water (100,0°C)	87,10	84,0 wt.%
Methanol (64,7°C)	63,75	36,5 wt.%
Ethanol (78,3°C)	76,75	37,0 wt.%
Isopropanol (82,4°C)	81,70	30,0 wt.%
Formic acid (100,7°C)	88,15	50,0 wt.%
Glacial acetic acid (197,5°C)	119,10	94,0 wt.%

Azides Salts of hydrazoic acid, HN_3. The alkali and alkaline earth azides are quite stable compounds whilst heavy metal azides, on the other hand, are sensitive to impact and extremely explosive (detonate violently). The azide group is a good complexing agent. The azide ion is linear. In general, covalent azides are relatively stable.

Azine dyes The first synthetic dye mauveine belongs to this group. Few dyes of this type remain of industrial significance, an exception being safranine (C.I. Basic Red 2). The azine dyes also include acid dyes such as azocarmine and Wool Fast Blue (see Fig.) besides aniline black and a few colour bases (induline, nigrosine) which are oil and fat-soluble.→: Oxazine dyes; Thiazine dyes.

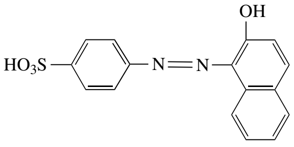


Azo, (French: *azote* = nitrogen) containing the azo group –N=N– which is a useful chromophore in dye chemistry.

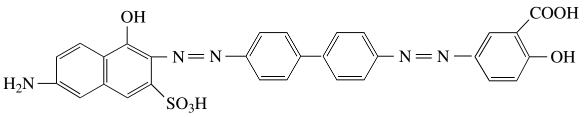
Azo dye coupling The combination of a coupling component with a diazo compound through an azo linkage.

Azo dyes contain the characteristic azo group –N=N– which is present to a greater or lesser degree in nearly all classes of dyes. Over half of all commercial dyestuffs belong in this general category. By varying the chemical composition it is possible to produce acid, basic, direct, reactive, disperse and mordant dyes containing the azo chromophore. This general group of dyes is subdivided into monoazo, disazo and polyazo dyes depending on the number of azo groups in the dye molecule thus:

I. Monoazo dyes with one azo group, e.g. the acid dye, Orange II:

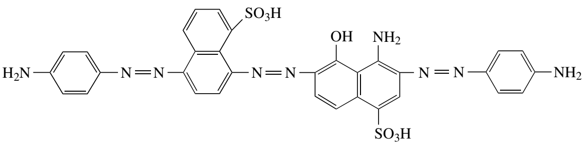


II. Disazo dyes with 2 azo groups must not be confused with → Diazotizable direct dyes. Most of the substantive dyes belong to this class, e.g. Diamine Brown M:



These disazo dyes also contain an amino group (–NH_2) which can be further diazotized so that, exceptionally, a diazo dye is involved here. Furthermore, the carboxyl (–COOH) and hydroxyl group (–OH) can be complexed with metals in this case.

III. Polyazo dyes contain 3 (trisazo), 4 (tetrazo) or more azo groups, e.g. as in the well-known substantive dye Zambezi Black V which contains 3 azo groups:



This dye is also capable of further diazotization (–NH_2) and then becomes a tetrazo dye with 4 azo groups. It can likewise be complexed with metals at the –OH group.

As a rule, azo dyes will not withstand a reductive treatment (see Fig.) and for this reason they cannot be used as vat or sulphur dyes but are particularly suitable for dischargeable grounds in discharge printing.

Direct dyes, in particular, frequently have azo dye structures which are ideally suited for the formation of coplanar configuations with aggregate-promoting properties. Azo dyes are strongly represented in the acid dye class but find only limited application as disperse dyes because of the requirement for low molecular weight. Azo dyes are particularly suitable for the formation of complexes with metal atoms.

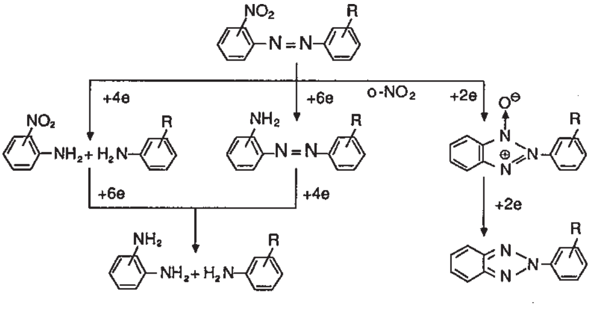
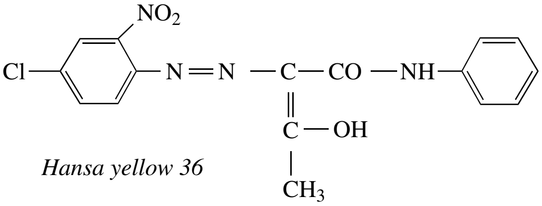


Fig.: Contention reactions for azo splitting.

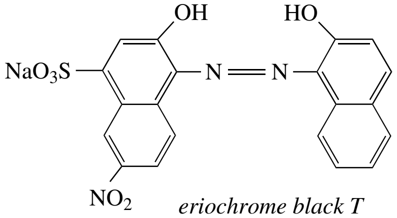
The following historically important azo dyes (with details of their derivation) are intended to illustrate the diversity of this class of colorants:

– C.I. 11670 (H. Wagner, 1909); 4-chloro-2-nitroaniline and acetoacetanilide.



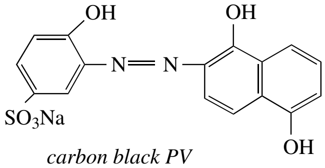
Hansa yellow 36

– C.I. 15710 (I. Hagenbach, 1904); 1-amino-6-nitro-2-naphthol-4-sulphonic acid and 2-naphthol.



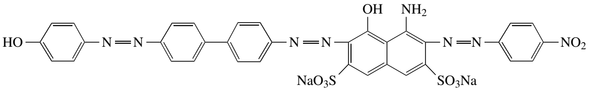
eriochrome black T

– C.I. 16500 (M. Kahn, 1902); 2-amino-1-phenol-4-sulphonic acid and 1,5-naphthalenediol.



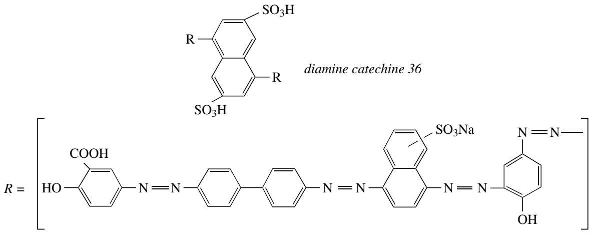
carbon black PV

– C.I. 30295 (M. Hoffmann, C. Daimler, 1891); p-nitroaniline with H-acid, benzidine and phenol.



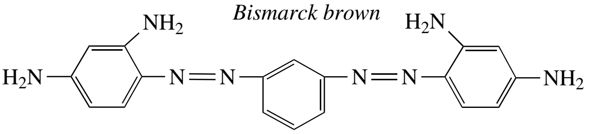
diamine green B

- C.I. 36 300 (1982); benzidine with salicylic acid and 1,6-(and 1,7-) Cleve's acid as well as phenol and 4,8-diamino-2,6-naphthalenedisulphonic acid.



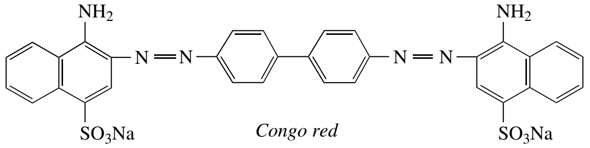
diamine catechine 36

- C.I. 21 000 (C. Martins, 1863); from 3 mol. m-phenylenediamine hydrochloride and 2 mol. nitrous acid.



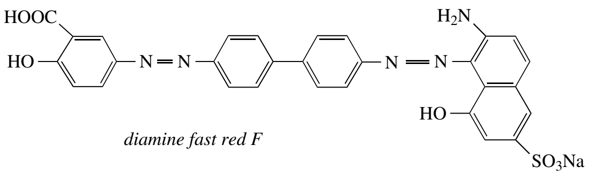
Bismarck brown

- C.I. 22 120 (P. Böttiger, 1884); benzidine with 2 mol. naphthionic acid.



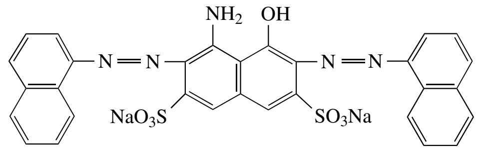
Congo red

- C.I. 22 310 (L. Gans, 1889); salicylic acid with benzidine and gamma acid.



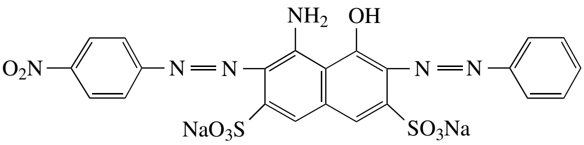
diamine fast red F

- C.I. 20 510; 2 mol. 1-naphthylamine with H-acid. Also contains K-acid as a coupling component.



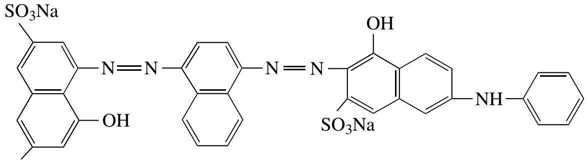
wool black GM

- C.I. 20 470 (M. Hoffmann, 1891); p-nitroaniline, H-acid, aniline.



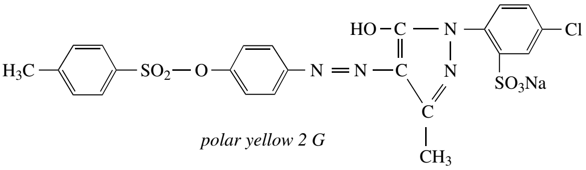
naphthol blue black B

- C.I. 27 950 (O. Günther, L. Hesse, 1906); H-acid, 1-naphthylamine, N-phenyl J acid.



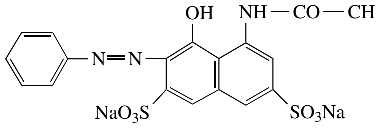
brilliant fast blue GG

- C.I. 18 950 (B. Richard, 1912); p-aminophenol, 1-(4-chloro-2-sulphophenyl)-3-methyl-5-pyrazolone, then treat with p-toluenesulphonyl chloride to esterify the phenolic hydroxy group.



polar yellow 2 G

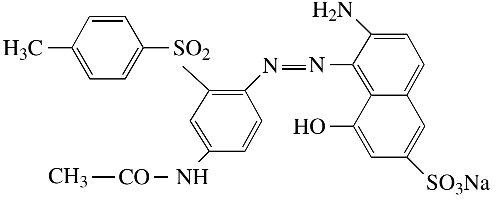
- C.I. 18 050 (1902); aniline, N-acetyl H-acid.



amidonaphthol red G

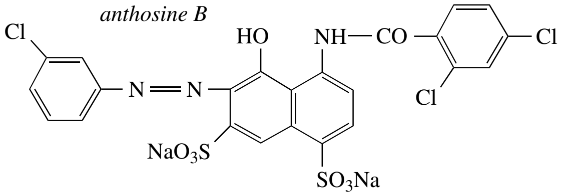
- C.I. 17 080; 4-amino-3-(p-tolylsulphonyl) acetanilide, gamma acid.

Kiton light red 4 BLN

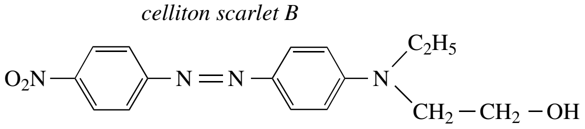


Azo dyes

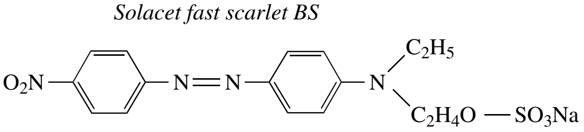
- C.I. 18 020 (L. Blangey, C. Immerheiser, 1912); m-chloroaniline, N-2,4-dichlorobenzyl K-acid.


anthosine B

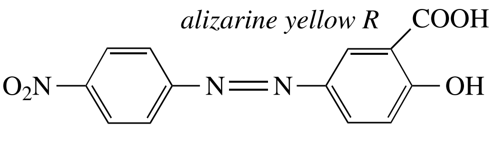
- C.I. 11 110; p-nitroaniline, 2-(N-ethylanilino) ethanol.


celliton scarlet B

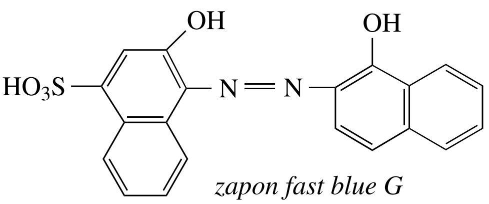
- C.I. 13 055 (A. G. Green, K. H. Saunders, W. G. Perkin, S. C. Bate); p-nitroaniline, 2-(N-ethyl-anilino) ethanol sulphuric ester.


Solacet fast scarlet BS

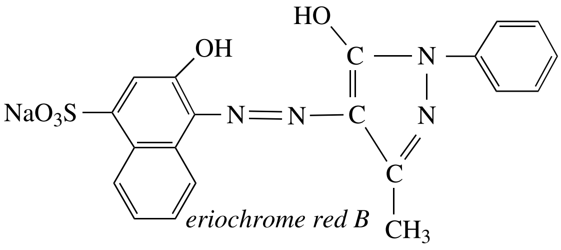
- C.I. 14 030 (R. Meldola, 1885; R. Nietzki, 1887; Walter 1888); p-nitroaniline, salicylic acid.


alizarine yellow R

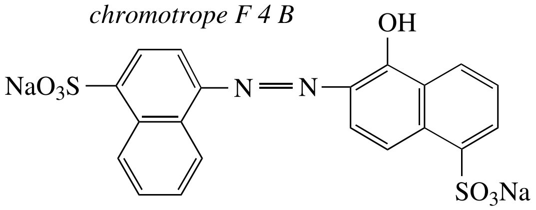
- C.I. 14641.


zapon fast blue G

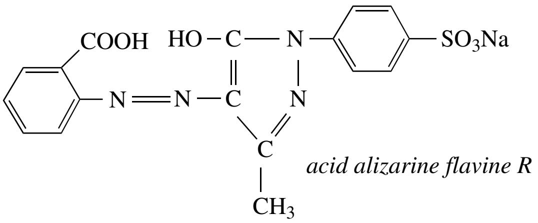
- C.I. 18 760 (H. Hagenback, 1904); 1-amino-2-naphthol-4-sulphonic acid, 3-methyl-1-phenyl-5-pyrazolone.


eriochrome red B

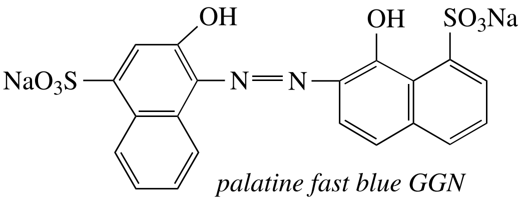
- C.I. 14 835; naphthionic acid, 1-naphthol-5-sulphonic acid.


chromotrope F 4 B

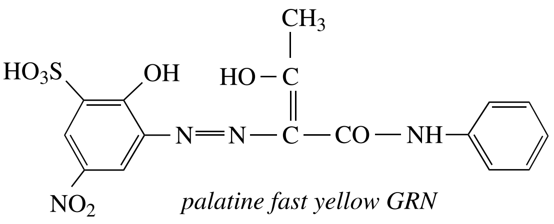
- C.I. 18 821; anthranilic acid, 3-methyl-1-(p-sulphophenyl)-5-pyrazolone.


acid alizarine flavine R

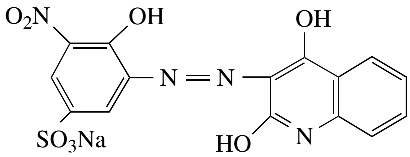
- C.I. 14 880 (H. Kämmerer, 1926); 1:1 chromium complex of 6-amino-4-nitro-1-phenol-2-sulphonic acid and 1-naphthol-8-sulphonic acid.


palatine fast blue GGN

- C.I. 13 900 (F. Straub, G. Montmollin, I. Spider, C. v. Planta, 1924); 1:1 chromium complex of 6-amino-4-nitro-1-phenol-2-sulphonic acid and acetoacetanilide.

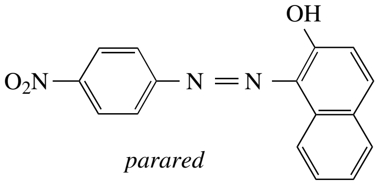

palatine fast yellow GRN

- C.I. 19 355 (H. Kämmerer, K. Holzach, 1927); 1:1 chromium complex of 2-amino-6-nitro-1-phenol-4-sulphonic acid and 2,4-quinolinediol.



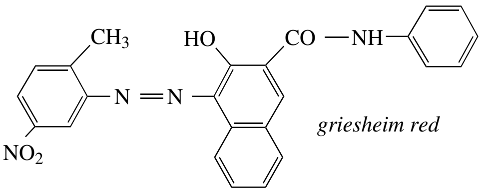
palatine fast red BEN

- C.I. 12 070 (R. Meldola, 1885); p-nitroaniline, 2-naphthol.



parared

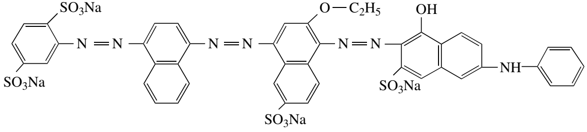
- C.I. 12 315 (A. Winther, A. Laska, A. Zitscher, 1911); 5-nitro-o-toluidine, 3-hydroxy-2-naphthanilide.



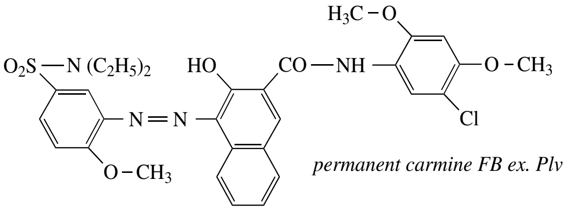
griesheim red

- C.I. 34 230 (H. Schweitzer, 1925); 2-amino-p-benzenedisulphonic acid, 1-naphthylamine, 5-amino-6-ethoxyl-2-naphthalenesulphonic acid, N-phenyl J acid.

sirius blue 6G



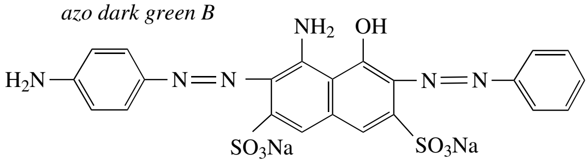
- C.I. 12 490 (W. Neelmeier, W. Lamberg, 1931), N^1-diethyl-4-methoxymetanilamide, 5´-chloro-3-hydroxy-2´,4´-dimethoxy-2-naphthanilide.



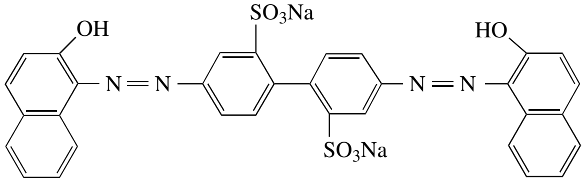
permanent carmine FB ex. Plv

- C.I. 20 495 (1909); by reduction of the nitro group in C.I. 20 470 with sodium sulphide.

azo dark green B



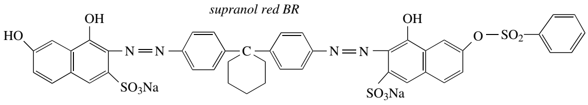
- C.I. 22 890 (1886); 2,2´-disulphobenzidine with 2 mol. of 2-naphthol.



acid anthracene red G

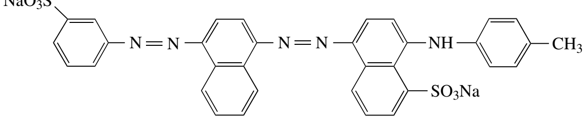
- C.I. 24 790 (R. Schüle, E. Korten, 1928); 4,4´-cyclohexylidenedianiline with 2 mol. 4,6-dihydroxy-2-naphthalenedisulphonic acid then esterify with 1 mol. benzenesulphonyl chloride.

supranol red BR

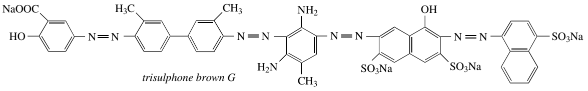


- C.I. 26 400 (P. Ott, 1892); metanilic acid, 1-naphthylamine, N-p-tolyl peri acid.

sulphocyanine GR ex.

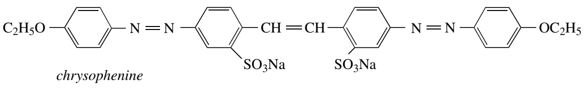


- C.I. 35 670 (M. Böniger, 1897); naphthionic acid with toluene-2,4-diamine and 2R acid, o-tolidene and salicylic acid.

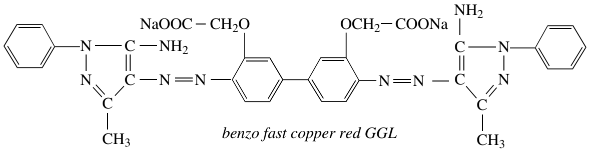


trisulphone brown G

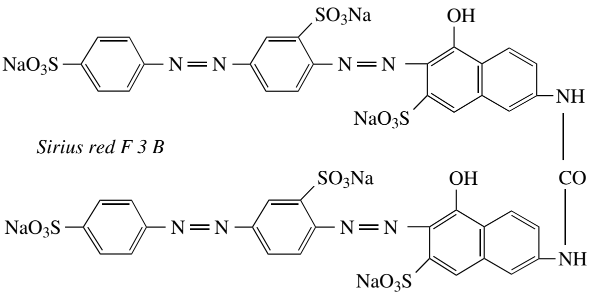
- C.I. 24 895 (F. Bender, 1886); 4,4´-diamino-2,2´-stilbenedisulphonic acid with 2 mol. phenol, then ethylate the phenolic hydroxy groups.


chrysophenine

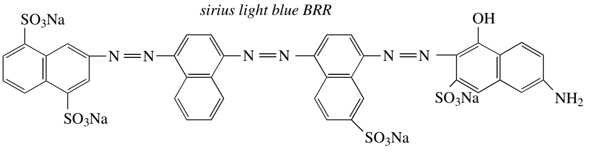
- C.I. 24 565 (C. Taube, H. Rinke, E. Fischer, 1938); (4,4´-diamino-3,3´-biphenylenedioxy) di-acetic acid with 2 mol. 5-imino-3-methyl-1-phenyl-2-pyrazoline; aftertreated with copper sulphate.


benzo fast copper red GGL

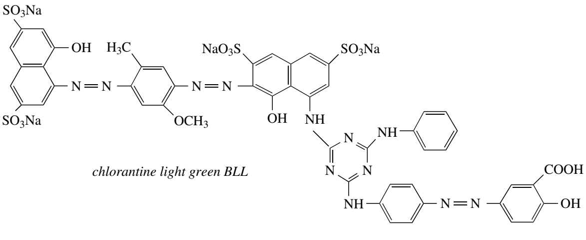
- C.I. 35 780 (J.P. Penny, 1922); a) 4-amino-3,4´-azodibenzenesulphonic acid and N-acetyl J acid then hydrolyze the acetamido group and phosgenate or b) 2 mol. 4-amino-3,4´-azodibenzenesulphonic acid with 6,6´-ureylenebis-1-naphthol-3-sulphonic acid.


Sirius red F 3 B

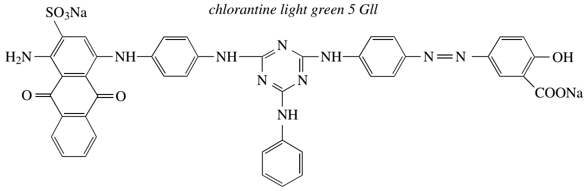
- C.I. 34 140 (W. A. Israel, R. Kothe, 1900; H. Jordan, 1913); 3-amino-1,5-naphthalene-disulphonic acid, 1-naphthylamine, 1,7-Cleve’s acid and J-acid.


sirius light blue BRR

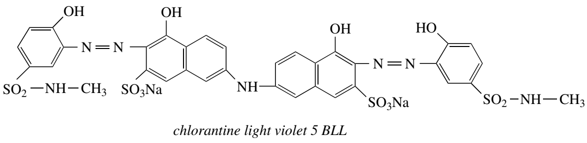
- C.I. 34 045 (H. Fritzsche, E. Krummenacher, H. Gubler, O. Kaiser, 1923); successive condensation of cyanuric chloride with a) H-acid, b) the azo dye obtained from reduced p-nitroaniline and salicylic acid, c) aniline. The product is then used as a coupling component in H-acid and cresidine.


chlorantine light green BLL

- C.I. 14 155 (H. Gubler, E. Bernasconi, 1934); successive condensation of cyanuric chloride with 1 mol. each of 2-amino-5-(4-amino-3-sulpho-1-anthraquinonylamino) benzenesulphonic acid, the monoazo dye 5-(p-aminophenylazo) salicylic acid (C.I. 14 045), and aniline.


chlorantine light green 5 Gll

- C.I. 29 125 (H. Krzikalla, 1926; W. Hentrich, M. Hartmann, J. Hilger, 1926); 2 mol. of 2-amino-N-methyl-1-phenol-4-sulphonamide with 6,6´-iminobis-1-naphthol-3-sulphonic acid and convert to the bis copper complex by treatment with ammoniacal copper sulphate.


chlorantine light violet 5 BLL

Azoic bases Coupling products for development into naphthol dyes. Azoic bases are not dyes themselves but soluble intermediate products with a basic character due to the presence of amino groups (NH_2) which are diazotized before use when they become capable of coupling in a similar manner to → Azoic salts with a naphthol component to form insoluble azo dyes.

Azoic salts These are already diazotized water-soluble coupling components (so-called stabilized diazo compounds) of the corresponding → Azoic bases, used for development into naphthol dyes.

B

B, chemical symbol for boron (5).

Ba, chemical symbol for → Barium (56).

Bacilli, rod-shaped sub-group of bacteria which form → Spores. The terms bacilli and bacteria are often mistakenly confused.

Backbeating An operation which involves beating or vibrating the back side of piece-dyed carpets as they leave a drying machine. Backbeating improves the appearance of acrylic pile carpets, in particular.

Backcoating of carpets (carpet backcoating). In the case of tufted carpets, backcoating is an essential element of their construction. As a result of this process the tufted pile is firmly bonded to the base fabric on the one hand, whilst noise reduction and thermal insulation properties are achieved on the other. The durability of carpets in use is likewise influenced to a significant degree by the type and quality of the backcoating applied. In the classification of carpets, e.g. ability to withstand the effects of castor chairs, the chalking of a pre-coat can cause changes in the appearance of the carpet design itself. If the pile is not anchored satisfactorily, pile shedding and tuft fuzzing occur due to loose threads being pulled out and torn. Fine gauges, fine yarn counts and smooth yarns require just as much attention in the application of a pre-coat as coarse gauges with coarse yarns. In both cases, penetration of the yarn and secure anchoring of the fibres (filaments) is of decisive importance.

In the case of aqueous latices (SBR products) the backcoating is composed either of a pre-coat and foam backing, or a pre-coat and laminated secondary backing. Secondary backings appear to have gained importance because of the ease of laying and carpets with secondary backings offer advantages in many cases with regard to the increased use of underfloor heating.

1. Hot melts: these can be compared with heavy coatings. They consist of thermoplastic compounds with a high filler content which can be applied at high speeds and require no pre-coat since bonding of the pile is outstanding in the thermoplastic state.

a) Ethylene vinyl acetate (EVA): These compounds can be loaded with large amounts of inorganic fillers and therefore fulfil the requirements for backcoatings with good sound insulating properties. A variation of this type of coating is the combination of EVA with polyethylene.

b) Atactic polypropylene (APP): In use since the 1960's principally for the coating of carpet tiles with the object of achieving "self-laying" properties.

c) Polyethylene (PE): These compounds must be regarded as a specialized further development of "hot melts" since (like polyvinyl chloride) high temperatures must not be used in their application. Polyethylene in the crosslinked form can be foamed which, with foam weights of 800 g/m^2 combines, light weight, elasticity and sound absorption.

2. Polyurethane (PUR): These coatings are formed directly on the carpet back from polyhydric alcohols and isocyanates. Typical of all these systems is the low weight per square metre, good flexing resistance of the resultant foam, good edge adhesion and ease of re-use after re-laying.Three systems are offered from different suppliers with the collaboration of certain machine makers.

a) Transfer process: With this oldest technique the polyurethane foam is produced on an intermediate carrier from which it is transferred to the carpet back.

b) Spray coating: This technique uses two traversing nozzles without a knife. Following application, the carpet passes through an infrared zone into a conventional hot air oven.

c) Knife coating: This process can be carried out on conventional plants since the reaction mixture of polyhydric alcohol and isocyanate is foamed mechanically and application is carried out by the usual knife coating process. Fillers can only be applied by this technique and are mixed with the polyhydricalcohols before reaction.

3. Aqueous polymer dispersions: The oldest and by far the most widespread process involves the application of latices, i.e. aqueous dispersions of rubber or synthetic polymers. Natural latices are no longer of much practical significance. Among the synthetic products, SBR latices are used almost exclusively. Cold latices are polymerized at approx. 5°C whilst the carboxylated hot latices are polymerized at approx. 50°C.

Back finishing

a) Pre-coat: With all SBR latices a pre-coat (Fig.) is necessary to lock the tufts into position.The pre-coat is generally applied by means of a kiss-roll and doctor blade; drying is mainly carried out in an infrared zone.

b) Foam coat: The actual foam coat is applied from a trough in which it subjects the foam to a traversing vibration. The latex compound is foamed in a latex mixer, i.e. latex and air are mixed and subjected to a mechanical shear action under pressure. The desired stiffness, flexibility and handle are achieved by mixing a soft and a hard base latex together. The characteristics of the base latice are adjusted by means of the styrene content.

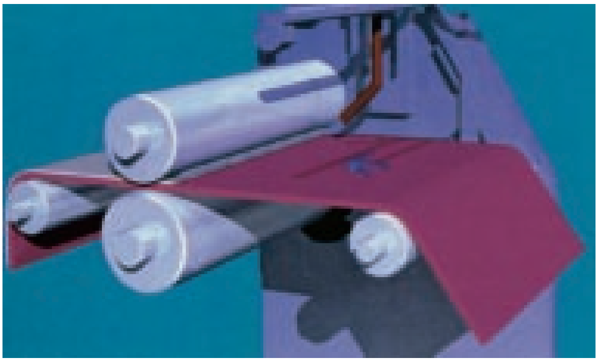


Fig.: Precoat Applicator "Press-Nip" (Küsters) for tufted carpet back coating with foam.

The mixer unit, consisting of a stator-rotor system, produces foam by mixing the latex with a fine and uniformly distributed quantity of air. In order to maintain this structure until it is transformed into the solid state, however, the cell walls of the foam must be stabilized. For gel foams two systems are in use: a heat-sensitive gelation process with a zinc oxide/ammonium salt (ammonium chloride and ammonium acetate) combination as well as a chemically-sensitive gelation process using compounds of fluorine with silicon, tin or titanium. The most well-known are sodium silicofluoride foams. No-gel foams already contain the soaps which are necessary for stabilization during drying from the polymerization stage. Crosslinking occurs either with reactant resins or vulcanizing agents. No-gel foams permit the incorporation of higher quantities of fillers than gel foams. The presence of excess soap represents a risk factor insofar as it can migrate out of the foam on subsequent wetting of the carpet underside.

Foams containing flame-retardants may be produced by the incorporation of halogen compounds or, more simply, by substituting part of the filler content with aluminium hydroxide.

Latex is even applied to woven carpets to provide secure anchoring of the pile. To achieve a firm handle, mixtures with a higher styrene content are used which contain reduced amounts of filler or none at all in order to ensure non-slip properties.

Back finishing The application of finishes to the back side of textiles for material-specific reasons, e.g. preferentially applied to poor quality ribbons and tapes. Also given to velveteen cord and plush fabrics as a so-called tailoring finish (to improve cutting) and in the coating of textiles as back finishes for pile fabrics and carpets.

Back grey This term covers a variety of special cloths used in textile finishing operations as leader cloths, end cloths, back greys and intermediate greys to facilitate the processing of fabrics in jig-dyeing machines, steamers, decatizing machines, roller printing machines, and in screen printing for combining with fabrics (temporary lamination) which would otherwise be difficult to print satisfactorily.

I. Back grey for flat/rotary screen printing machine dryers: woven polyester lattice fabric with good air permeability and therefore rapid printed fabric drying, with practical socket locks for ease of installation/ changing.

1. Model PE 1000 HD: data: woven polyester lattice fabric, mesh 1.0 mm. Wire gauge number 0.5 mm, open area 45%. Heat resistant 160–180°C. Tried and tested standard model for all types of woven fabric, and also for fairly inefficient dryers.
2. Model PE Mono-Multi: data: woven polyester lattice fabric. Wire gauge numbers: warp 0.5 mm, weft special yarn, open area approx. 30%. Heat resistant as in 1. Recommended for lightweight, thin and heavily printed fabrics, especially for synthetics.

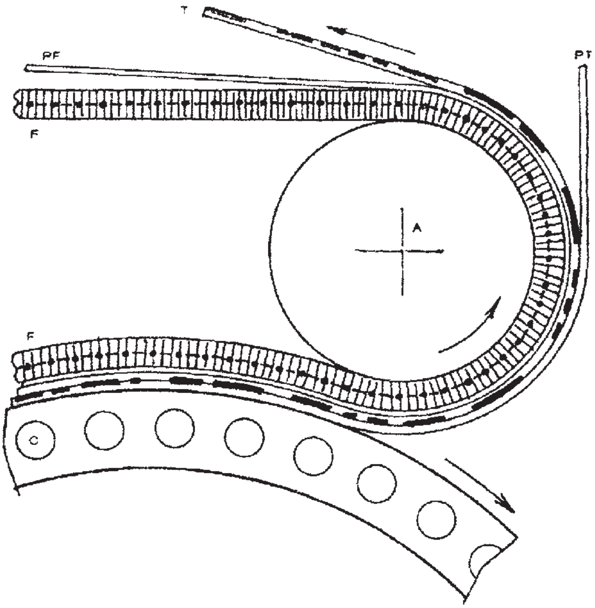


Fig.: Back cloth in a calender.
T = textile fabric; PF = transfer paper; C = heated cylinder; A = roller; PT = protective paper; F = back grey.

3. Model PE Soft: data: woven polyester monofil lattice fabric. Wire gauge numbers as in 2, open area approx. 20%. Specially recommended for lightweight, thin and heavily printed fabrics, particularly for hydrophobic synthetics e.g. discharge prints.

II. Back grey felt in transfer calenders (see Fig.). Functions:

a) Pressing textile fabric (T) and transfer paper (PF) together against the heated cylinder (C) to provide good heat transfer and dye transfer.
b) Conveying textile fabric, transfer and protective paper. Ensuring control in the longitudinal and transverse directions. Keeping flat.
c) Thermal insulation of textile fabric and transfer paper for uniform distribution of heat supply on to the fabric.
d) Roller drive.

Back grey accumulator A system developed for large quantities of back greys in roller printing. Mainly constructed in the form of a channel accumulator on the J-box principle with capacities of 800–5000 m.

Back grey printing In roller printing, a gummed woven fabric which runs constantly tensioned over the printing blanket and lapping covered drum, and is used to support the printing blanket and the fabric to be printed. For gumming piecegoods on screen printing machines.

Back grey washer A unit for the continuous washing of back greys normally located behind or beneath a roller printing machine. An essential prerequisite is the use of back greys composed of fibres that absorb hardly any capillary water and are easily cleaned and (most important) quickly dried; synthetic fibres in blends with cotton are chiefly used for this purpose. The washer is equipped with squeeze rolls and spray nozzles to ensure an intensive washing of the back grey. Drying is carried out either in special compartments or in the print drier itself. A typical unit of this type is the Küsters system. After the printing process, the back grey, which is composed of polyamide/cotton 50:50 (as an intimate blend produced in spinning), first passes through a prewetting zone and subsequently through a “Vibrotex” unit where it is led over a perforated vibrating cylinder and thoroughly washed. The backgrey then passes immediately to a squeezer unit with swimming rollers where it is hydroextracted as it cannot be returned to the printing machine in the wet state.

Back grey washing Depending on the number of passages, coverage of print design and thickness of the textile fabric being printed, used back greys contain greater or lesser amounts of print paste residues containing thickeners, dyes and chemicals. The purpose of back grey washing, therefore, is to remove these print paste residues and make the material soft, absorbent and fit for reuse again.

Back grey washing machines As a rule, winches and heavy-duty rope washing machines are used for washing used back greys. Open-width washing machines are less suitable because of their less intensive mechanical washing action.

Backing → Carpet backcoating.

Back-pressure steam turbine The “classic” method of power-heat coupling, which was also used in many textile mills in the past, illustrates the use of back-pressure steam turbines (see Fig.): a high pressure steam boiler produces superheated steam at 60 bar and, for example, a temperature of 480°C. This steam drives a steam turbine, the exhaust steam connecting stub of which is connected to the plant steam line. In contrast to the → Gas turbine, with which a power parameter of approx. 0.35–0.40 (kWh of power/kg of steam) is produced, a steam turbine process is able to produce a power parameter of only approx. 0.15–0.20. This is one of the reasons for the decline of industrial steam turbine operated, combined heating and power stations which has been observed over the past 20 years.

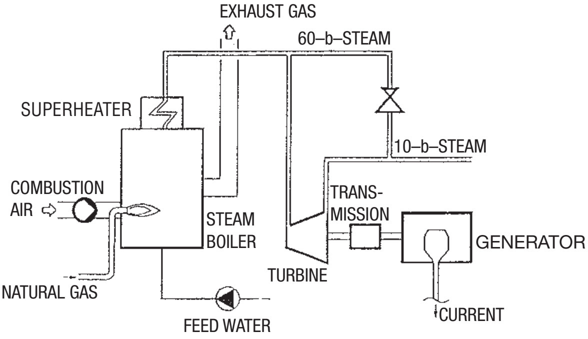


Fig.: Heat-power coupling by means of a back-pressure steam turbine.

Back side (of fabric), i.e. the reverse side of textile fabrics which can also be used as the wearing side.

Back to back Finishing operation for the surface treatment of textile fabrics on a → Table raising/polishing/shearing machine in which both sides of a fabric may be processed in a single passage without a turning arrangement.

Backwash (fleece wash). Commercial term for wool washed on the backs of living sheep with cold water. The treatment is technically worthwhile as the wool stays white longer on storage and its colour is attractive to cloth producers and worsted spinners. The backwash removes the coarsest dirt and impurities thus reducing freight costs. In all cases, however, a subsequent mill wash is necessary to remove wool grease, suint, etc. → Raw wool scouring.

BA cotton Flame-retardant cotton produced by fibre modification with → BAP (American process).

BACPO, abbrev. for: → bis-aziridinyl-chlormethyl-phosphineoxide.

Bacteria, are the smallest unicellular → Microorganisms, and are only visible under the microscope with powerful magnification. They multiply rapidly by simple fission (at an average rate of one division per hour, 16 million bacteria can develop from one bacterium in a day). Types of bacteria include:

I. Spherical bacteria or coccus. These are spherical to oval in shape and 1–2 µm in size.

II. Rodlike bacteria, including spore-forming → Bacilli, with a size of 0,5–2,5 : 1,5–15 µm.

III. Helical bacteria: a) vibrios, curved types. Size 0,3–0,5 : 2–4 µm; b) spiral, with corkscrew-like coils. Size 1–3 : 5–30 µm.

Even these tiny living organisms have their own metabolism. They secrete enzymes with the specific action of breaking down suitable insoluble matter into nutrients (→: Microbial damage to textiles; Microbiological degradation) as in the case of e.g. proteins with the aid of proteases. The products of bacterial metabolism can destroy textiles and, as a source of infection, are extremely toxic as soon as they enters the body's bloodstream. Infections are caused in this way (diseases gain access to the affected body through → Pathogenic bacteria). Certain bacteria can survive adverse conditions by forming highly-resistant spores. Bacteria may be detected microscopically under high magnification of, e.g. x250 up to x600. Their detection is also made easier by special stains.

Bacteria destruction →: Antibacterial finishes; Antimicrobial finishes.

Bacterial damage to textiles → Microbial damage to textiles.

Bacterial desizing agents → Bacterial diastases.

Bacterial diastases The effective → Enzyme (amylases and polyases) is obtained by cultivation of subtilis and mesentericus types (→ Diastases). Bacterial diastases break starches down into glucose with the assistance of sodium chloride as an activator. Compared to → Pancreas diastases the much lower temperature sensitivity of bacterial diastases enables desizing to be carried out at temperatures close to the boil. → Desizing agents.

Bacterial growth inhibition →: Bactericidal finishes; Phenol coefficient.

Bacterial inhibition → Bacteriostatic action.

Bacteria staining → Gram's stain.

Bactericidal finishes, provide textiles with active protection by the destruction of bacteria and → Mycotoxins (→ Antimicrobial finishes). This can be achieved either by the application of copper naphthenate, copper-8-quinolinolate, chlorinated phenols, trialkyl tin derivatives, *inter alia* (→ Fungicidal finishing), or by passive protection, i.e. by preventing the textile material from functioning as a culture medium for microorganisms, which is mainly achieved by the application of aminoplasts (resin finishes). Flame-retardant finishes based on phosphorus compounds also increase rot resistance. The possibilities for applying such finishes to apparel fabrics are extremely limited.

Bactericide A product capable of destroying bacteria, e.g. disinfectants or preservatives.

Bacteriostat A product with bacteriostatic properties.

Bacteriostatic Adjective used to describe products or properties which prevent or inhibit the growth of → Bacteria, e.g. through the use of → Preservatives, etc.

Bacteriostatic finishes (→ Antimicrobial finishes) inhibit the growth of bacteria as well as → Mycotoxins on textiles (→ Fungicidal finishing).

Bagginess A fabric defect especially in viscose and wool fabrics caused by excessive tension in winding, distorted weft threads, etc. which gives rise to tight threads in the weft direction and waviness in the fabric. The effect is further intensified by the influence of moisture.

Bagging,

I. A fabric woven in cylindrical or tubular form on an ordinary cam loom and used for grain bags, etc.

II. A term used to describe the undesirable bulging of fabric caused by extension at the elbows, knees, etc., of a garment lacking dimensional stability.

Bakelite → Phenolic plastics.

Bakelite thickener → Thickeners.

Bakhtiari carpets Strong rustic knotted carpets from the Chahar Mahal region to the south of Isfahan. Bakhtiari carpets are easily identifiable because of their special designs. The field on the carpet is almost always divided into squares or diamonds made to stand out by a plain outline. These geometric figures are decorated either with animal or plant motifs, particularly cypresses and flowering shrubs. Each carpet may contain more than ten different designs. All Bakhtiari carpets are in dark colours, deep red, yellow ochre, bottle green, dark brown and bright blue, with red or natural white grounds. 50 000–200 000 Turkish knots per m^2. The finest qualities of Bakhtiari carpets are also known as → Bibibaff.

Baku carpets Caucasian short-pile, thin, hand-knotted carpets from the region around Baku. They have a marked geometric decoration. Generally the field decoration is of three or four motifs in the shape of diamonds or rectangles and diamonds one above the other which alternate with hooked Greek-key motifs filled in light red or ochre yellow on a light blue ground. The unusually pale colours are characteristic of Caucasian carpets. Also used as prayer mats. Baku carpets contain approx. 100 000 Turkish knots per m^2.

Balanced cloth A term used to describe a woven fabric with yarns of the same linear density and the same number of threads per cm in both the warp and weft.

Bale dyeing This involves taking the fibre in the form of the original bale from the supplier of raw wool, cotton or fibre manufacturer in the case of synthetic fibres. These bales are placed directly in a specially constructed cage designed to hold up to 4 bales (see Fig.). The cage is placed into a conventional dye kier (either vertical or horizontal) and dyeing carried out as usual. After dyeing, the bales are either hydro-extracted or vacuum-extracted to remove excess moisture before drying. The system is ideal for a new installation which processes a limited product range from a minimum of suppliers. The advantages are almost all economic since the stages of bale opening, dye kier loading, and final packing are eliminated, with obvious cost savings.

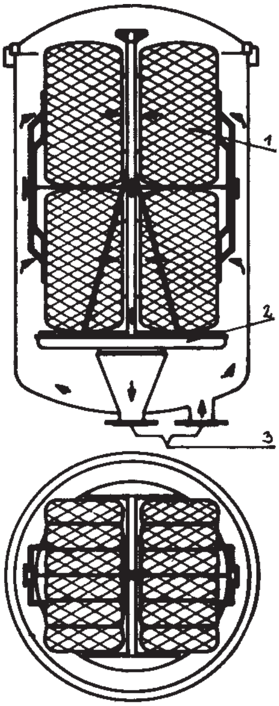


Fig.: Obermaier bale dyeing autoclave (4-bale carrier design).
1 = fibre bale; 2 = special carrier; 3 = circulation pump.

Bale weights → Fabric weight.

Ballard skin Thin layer of electroplated copper on a steel roller for rotogravure printing.

Ball mill A standard method of reducing water-insoluble substances such as pigments or dyestuffs to a fine state of division. It consists of a cylinder, rotating on an axis, partly filled with steel balls, porcelain balls, or common pebbles. The controlling factors are size of balls, relative volumes occupied by balls and substance being milled, type and quality of substance, and rate and time of rotation.

Ball reflectometer (Ulbricht's ball) An accessory unit used in rigid assembly with a photometer, the important component of which is a ball with a matt white inner surface which guarantees all-round, uniform and shade-free light on the test specimen to be examined.

Ball valves The ball valve is a quarter turn valve suitable for gas, compressed air, liquid and slurry service and provides complete sealing in both directions. The use of soft-seat materials such as nylon, delrin, synthetic rubbers, and fluorinated polymers imparts excellent sealing ability. With fluorinated polymer seats, ball valves can be used for service temperatures ranging from –268 to +260°C; with graphite seats, service temperatures as high as 540°C are possible. Also, with metal-backing seats, the valves can be used in fire-safe services. Ball valves are similar to plug valves in operation. They are nonbinding and provide leak-tight closure. The valves exhibit negligible resistance to flow because of their smooth body and port. Major components of the ball valve are the body, spherical plug, and seats. Ball valves are made in three general patterns: venturi port, full port, and reduced port. The full port valve has an inside diameter equal to the inside diameter of the pipe. In the venturi and reduced port variants, the port is generally one pipe smaller than the line size. Stem sealing is accomplished by bolted packing glands and O-ring seals. Valves are also available with a lubricant-seal system which is similar to that available for plug valves.

Ball (yarn) → Yarn package.

BAM (Ger.), abbrev. for: Bundesanstalt für Materialprüfung (German Federal Institute for Materials Testing).

Banana fibre → Manila fibre.

Bandhana (Hindhi: *bandh* = tying). A form of tied batik analogous to the Malaysian → Plangi and the Japanese → Shibori.

Band recorder (strip chart). A recording instrument which produces a graph in strip form.

Band spectrum → Emission.

Bányai system A carpet machine-knotting technique from Hungary.

BAP, American abbrev. for: bromoform allylphosphate (→ BA cotton). The BAP method involves application of an aqueous emulsion of a polymer produced from tribromomethane $CHBr_3$ and triallyl phosphate $(CH_2{=}CH{-}CH_2O)_3PO_4$, which forms crosslinked polymers on cotton with a flame-retardant action.

bar A CGS unit of pressure equal to 10^5 pascal (Pa). It may be used with → SI units, and SI prefixes may be attached to it. Since it describes decimal multiples of the pascal it is convenient in practical use. The millibar (symbol: mbar or mb) is a commonly used unit of pressure in meteorology.

Bare elastane Elastane yarn in the so-called bare state, in contrast to the wrapped form → Core spun yarns.

Barium (Ba), atomic weight 137,4. Silver-white lustrous soft metal. Barium compounds (many of which are very poisonous) are similar to those of calcium. Properties: → Alkaline earth metal. Uses of barium salts: weighting finishes, components in white discharge print pastes (barium sulphate), delustring (barium chloride), analytical reagents, etc.

Barium chloride, $BaCl_2 \cdot 2H_2O$, MW 244,34. Colourless crystals with a bitter salty revolting taste, stable to air, water-soluble (446 g/l at 20°C; 769 g/l at 100°C). With sulphuric acid it gives → Barium sulphate. Uses: as a delustring agent for viscose (two-bath method); weighting and filling agent in finishing (seldom used); reagent for the detection of sulphuric acid and sulphates (= white insoluble precipitate); softening of boiler feed water (calcium sulphate hardness).

Barium in dyeings, tests for Ash the textile specimen and moisten with conc. hydrochloric acid.

I. Green coloration in a flame indicates the presence of barium. Barium sulphate must be reduced to the sulphide in a small flame before moistening with hydrochloric acid.

II. Precipitation as sulphate. Mix the hydrochloric acid moistened ash with dil. sulphuric acid or sodium sulphate = white precipitate in the presence of barium. If insoluble barium sulphate is present in the hydrochloric acid, it must first be decomposed by fusing with 5 times its weight of sodium carbonate and potassium carbonate, followed by washing and dissolving in acetic or hydrochloric acid.

Barium sulphate (barytes, blanc fixe, heavy spar), $BaSO_4$, MW 233,46, density 4,5.

Bark crêpe (tree bark crêpe). Mostly atlas construction clothing crêpe with a woven matt face in a bark-like pattern (produced by embossed printing or construction) made of viscose, acetate, cotton etc.

Bark tannage → Tanning.

Bar marking in screen printing (screen fall-on effect) A problem encountered in printing on flat-bed screen printing machines, whereby the sides of the screen frames at right angles to the direction of printing exert pressure on the preceding print thereby crushing or soiling the printed colours. The problem can be minimised by using screen frames with a triangular profile (i.e. to reduce the area of contact with the printed fabric) and/or by covering the undersides of the screen frames with coarse grains (e.g. wood chippings of approx. 1 mm size) to break up and minimise contact with the fabric during printing.

Barometer (barograph). An instrument for measuring atmospheric pressure, usually in the region of 101 330 Pa (1,0133 bar = normal atmospheric pressure).

I. Mercury barometer: consists of a curved U-shaped tube with a long and a short leg (→ Manometer). The shorter leg of the tube is closed and the lower open end is immersed in a reservoir of mercury. The tube contains no air and the space above the mercury column is known as a *Torricellian vacuum*. The mercury level in the tube indicates the actual barometric pressure in mm. A finely graduated scale also permits readings to 0,1 mm and estimated readings to the nearest 0,01 mm are possible.

II. Aneroid barometer: a device for measuring atmospheric pressure without the use of liquids. It consists of a partially evacuated metal chamber, the thin corrugated lid of which is displaced by variations in the external air pressure. This displacement is magnified by levers and made to operate a pointer against a calibrated scale from 790–670 mm. It is the most common form of barometer. The barograph, a self-recording instrument with a pen which traces a line on a clockwork-driven revolving drum (1, 7, 14, 28 days), works on the same principle.

For more precise barometric measurements the temperature must also be taken into account. Since all chemical constants relating to boiling point, solubility, etc. are always based on a normal pressure of 760 mm, the actual barometric pressure prevailing at the time such laboratory determinations are carried out can have a significant effect on the results.

Barr Textile diffusion resistance to water vapour relative to atmospheric air (1 cm thick calm air layer at 20°C = 1.00 barr). Examples:

air (atm.: 0°C)	1.05
air (atm.: 20°C)	1.00
air (atm.: 40°C)	0.95
nonwoven fabric (20 g/m^2)	2.20
nonwoven fabric (40 g/m^2)	4.20
lightweight suiting fabric	8.50
standard suiting fabric	16.40
sweaters	20.50
blanket material	22.50
overcoat material	40.00
windcheaters	approx. 100.00

The barr value is expressed here in multiples of the barrier capacity of a 1 cm thick layer of calm air.

Barré A term used for

I. Widthwise stripes in textile fabrics, produced by weaving, effect yarns or colours.

II. Irregular stripe defects (so-called bars) in the woven or dyed appearance of fabrics.

Barré effects often occur in warp-knit fabrics produced from textured polyester filament yarns dyed with disperse dyes. This phenomenon is attributed to structural differences in the polyester filaments as a result of texturing.

Barrel pumps → Drum pumps.

Barrel-shaped yarn package A precision wound barrel-shaped package for short lengths of yarn.

Barrier effect of wool fibre epicuticle Prevention of dye from penetrating the fibre interior from a dye liquor at room temperature due to the → Epicuticle layer. Dye can only penetrate through the epicuticle from a heated dye liquor. Chlorination treatment removes the epicuticle which is why deeper dyeings are obtained on chlorinated wool.

Barriness (barry dyeing), longitudinally or transversely striped dyeing of woven or knitted polyamide, polyester and viscose fabrics. Causes:

I. Processing faults such as mixed up yarn and tension and density differences in weaving or warp and weft knitting.

II. Yarn faults: differences in count, yarn twist, lustre and deformational differences.

III. Differences in drawing, crystalline structure and orientation due to varying inner fibre fine structure during production. In texturing and setting: effect of temperature (in the case of polyamide and polyester), moisture (polyamide) on the inner fine structure (microporosity, inner surface).

IV. Chemical differences with polyamide and viscose.

V. Fibre change due to the action of light and chemicals.

Remedy in dyeing: in the case of III and IV only (differences in affinity) possible by means of targeted dye selection, special dyeing auxiliary products (e.g. carriers), dyeing process, intensive relaxation, possibly pre-set at higher temperature.

The phenomenon of "barriness" can be looked at from two basically different directions:

1. Barriness which is attributable to conformational and physical defects.
2. Barriness which is caused by differences in the behaviour of the dyes in their interaction with the active groups in the fibres.

The barriness which is attributable to configurational and physical defects occurs as the result of differences in fibre fineness, lustre, cross-section, thick places in fibre production and also depending on the nature of fabric crossing and other mechanical effects in mechanical processing (spinning, knitting and weaving) and finishing (pretreatment and dyeing). The interaction between the different characteristics which cause barriness is difficult to analyse, since the specific effects of the individual fibre properties of the yarn are difficult to isolate. Each change in the conditions of the production process can cause a simultaneous change in some characteristics; a change in the molecular mass of the polymer, for example, usually produces a change in dyeing power, shrinking power and other physical and mechanical parameters. In addition, there is a level at which barriness is not yet quite clearly pronounced, which makes difficult the possibility of linking the intensity of barriness with the fibre properties.

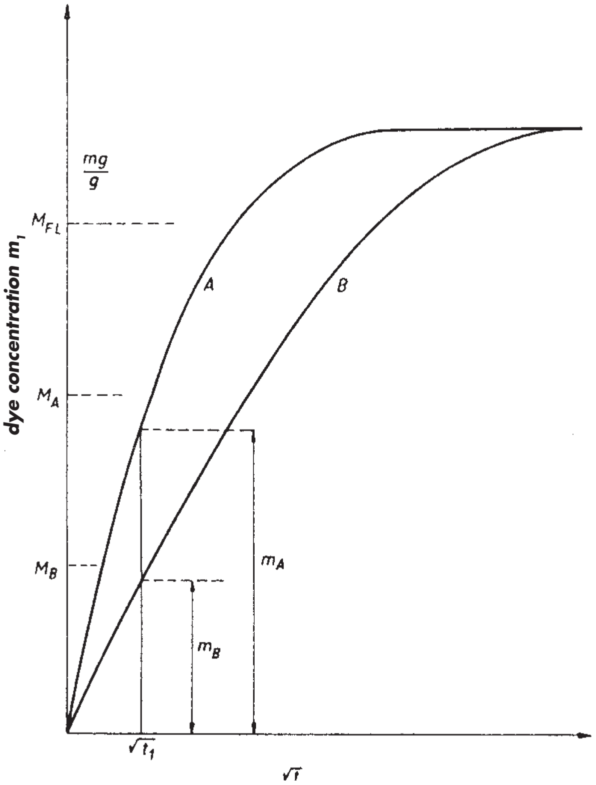


Fig.: Principle of the "single-point measurement" of colour exhaustion rate: dye concentration m_t of the fibre against $\sqrt{t}$ (t = dyeing time). The exhaustion curves of fibres A and B differ in rate of exhaustion, but reach the same saturation value. The measurement values m_A and m_B are approximately proportional to the rates of exhaustion, so that here $m_A > m_B$. M_A and M_B = dye quantities which are taken from fibres A and B in joint dyeing in one dyebath of the total dye quantity M_{Fl} ($M_A + M_B = M_{Fl}$).

Many theoretical studies have been devoted to the problem of barriness which relate mainly to the barriness which is caused by differences in the behaviour of dyestuffs in their interaction with the active groups in the fibre materials. Important in this connection are:

– end-group content,
– degree of order or crystallinity,
– degree of orientation.

With polyamide fibres, the content of end-aminogroups for example is an important parameter, on which the dyeing rate with anionic dyes depends. This parameter is stringently controlled by fibre producers. For determining the end-aminogroup content, there are methods which are suitable for routine laboratory checks, by means of which the aminogroup content is determined. The second parameter, degree of order or crystallinity, embraces the structure and morphology of the fibres which was created in their previous production history, and exerts the one basic effect on barriness and general levelness in dyeing. The effect of the degree of orientation is measured by birefringence (Δn). Each variation in degree of orientation leads to differences in the speed of the dyeing process during its time cycle. The cause of the occurrence of barriness is best represented by the graph: in dyeing two polyamide fibre materials of different structures, the quantity of dye fixated on both substrates prior to reaching the condition of equilibrium is different. When these kinds of fibre material are in one batch, this is characterised by markedly pronounced barriness. The surface layer has a direct relationship with barriness, since it is markedly sensitive to all energetic and thermal effects on the fibre which have been exerted during their previous production and processing history. The surface layer of the fibres plays the role of a surface barrier for the dyestuffs.

Barytes → Barium sulphate.

Basal layer In fibre structure the basal layer is a well ordered active cell layer zone, e.g. in → Wool structure it is the intermediate membrane which acts as the basal layer of the internal scale cell layer. The epidermis in wool fibre structure is formed by the constant growing and dividing of a very active layer of cells called the "basal layer". There is continuous wear on the outermost layer of the epidermis and this is replaced by cells derived from the basal layer. The basal layer is also important bacause it plays a large part in the formation of the wool follicle. At certain positions in the skin the basal layer thickens and begins to grow down into the dermis to form a sort of plug of cell tissue. This plug will ultimately form the wool follicle with its accessory structures.

Basalt fibre A mineral fibre produced from molten basalt at approx. 1100–1400°C. Cheap, very fine, highly ductile, long fibres which are thermostable up to 1100°C. Uses: insulating material against heat, cold and sound; spun and woven for fire-resistant clothing.

Base exchanger → Ion exchanger.

Base material (carpet) → Carpet primary backing.

Base metals In the electrochemical displacement series (→ Standard electrode potential) metals which are higher in the series than hydrogen and metals with negative prefixes.

Base printing → Naphthols in direct printing.

Bases Chemical compounds which dissociate in aqueous solution into negatively-charged hydroxyl ions and positively-charged weak acid or metal anions. They form salts with acids = neutralization. Bases have an alkaline reaction (pH > 7) and turn red litmus paper blue. They have a mainly bitter taste. The number of ionizable OH groups determines whether a base is mono, di or polyvalent etc. Inorganic bases are OH compounds of metals (e.g. sodium hydroxide solution $NaOH = Na^+ + OH^-$, strong base over 50% dissociated; ammonium hydroxide NH_4OH, weak base) which, on losing water, change into the corresponding oxides. Organic bases include e.g. amines (aniline $C_6H_5NH_2$), dye bases and numerous other water-soluble nitrogen (e.g. pyridine C_5H_5N), phosphonium and sulphonium bases. See also → Acids.

Base units The 7 base units as defined in the → SI system (i.e. metre, kilogram, second, ampere, kelvin, mole and candela) for the basic measures (length, mass, time, electric current, thermodynamic temperature, amount of substance and luminous intensity) including their abbrev. forms (m, kg, s, A, K, mol and cd).

BASF, (Ger.), abbrev. for: Badische Anilin und Sodafabrik.

BASF Combi Test Standard method for determining the diffusion properties (diffusion number) of → Disperse dyes under practice-relevant conditions.

Basic alum → Aluminium potassium sulphate.

Basic dyeable polyamide → Differential-dyeing polyamide fibres.

Basic dyes → Cationic dyes.

Basic iron sulphate → Iron (III) sulphate.

Basicity A property of → Bases and basic salts whereby hydroxyl ions of a basic character are formed by dissociation in aqueous solution. See also → Acidity. → Dissociation.

Basicity value The basicity value plays an important role in the weighting of silk, e.g. with basic iron (III) sulphate. The basicity value is obtained by dividing the sulphuric acid content (calculated as H_2SO_4) by the iron content (calculated as metallic iron) = (H_2SO_4 : Fe).

Basics A term used to describe classic jeans fabrics as well as standard jeans qualities which appear regularly each season, in contrast to newly developed styles ("designer jeans"). They include e.g. flats, chambray, blue denim, canvas, toile, cord velvet, scrubbed denim, brushed denim, suedette, duvetine.

Basic salts → Salts.

Basic time According to REFA, all times for fabric processing which occur regularly or frequently, and are determinable in each case by timing or calculation. Subdivided into productive time/non-productive time, processing time/interval, activity time/attendance time.

Basify To adjust the pH of a liquor on the alkaline side, e.g. in naphthol dyeing with fast colour bases or salts to facilitate coupling.

Basinés (basin waste). Silk waste consisting of → Cocoons which have only been partially reeled off due to frequent breaks in the thread.

Basin test Modified → Permeability bag test in which a fabric test specimen is formed into a suitably supported bag and filled with water.

Basolan DC process Wool chlorination under mildly acidic conditions with the sodium salt of dichloroisocyanuric acid, Basolan DC (BASF)) at pH4.

Basolan SW process Superwash finish for wool with the prepolymer Basolan SW (BASF). Crosslinks on drying to form a soft film on the fibre. Application by padding or exhaust methods.

The IWS Superwash Standard was first achieved without any prechlorination, such a treatment is necessary, however, by the exhaust process, e.g. by using a chloroisocyanurate such as → Basolan DC. The Basolan SW process may also be applied to advantage after dyeing. → Anti-felting finishes.

Bassine (Borassus piassava) → Palm fibre.

Bassora gum A tropical → Vegetable gum with a high content of → Bassorin, which has often been used for the adulteration of gum arabic and gum tragacanth. Bassora gum generally occurs in the form of transparent, light amber to brownish-red irregularly-shaped lumps and is only sparingly soluble in water (with a large excess of water it forms a filterable cloudy solution) but swells readily to a thick gelatinous slime.

Bassorin The main → Polysaccharide $(C_{11}H_{20}O_{10})_n$ component of → Bassora gum from which it gets its name. It is also present *inter alia* in gum tragacanth in proportions of up to 60–70%. Bassorin is a tasteless, odourless, yellowish-white, amorphous, brittle, and translucent solid. It is only sparingly soluble in water but swells to a translucent gelatinous paste which dissolves on prolonged boiling.

Bast,

I. Another name for → Phloem.

II. Fibrous material obtained from the phloem of jute, hemp, flax, lime, etc. → Raffia bast.

Bastard vat Combination of the →: Woad vat and sodium carbonate (the first as vat preparation and the second for continuation of the dyeing process). Formerly used for the dyeing of wool with indigo.

Bastella A cellophane product into which narrow cotton threads have been incorporated thereby producing a reed-like appearance. Uses: hat trimmings (braiding) etc.

Bast fibre bundless → Flax stem structure.

Bast fibre cells →: Flax long fibre structure; Flax cell structure.

Bast fibres A sub-group of → Natural cellulosic fibres that form bundles or strands which act as hawsers in the fibrous layer lying beneath the bark of numerous dicotyledenous plants. Principle of construction → Flax stem structure. The strands of bast fibres are normally released from the cellular and woody tissue of the stem either mechanically (green bast fibres) or biologically by a process of natural decomposition called retting (controlled rotting), or by chemical means (→ Cottonizing). The strands are often used commercially without separating the individual fibres one from another.

On a tonnage basis → Jute is the most important of all bast fibres: It is produced in quantities greater than that of all other bast fibres combined. The production of → Flax is roughly one seventh that of jute, but flax is the fibre from which → Linen is made. It is on this basis that flax is considered to be the most important of the bast textile fibres. Bast fibres include →: Flax (linen), Hemp, Jute, Sunn, Kenaf, Urena, Rosella and Ramie.

Bast fibres, differentiation tests,

I. Phloroglucinol/hydrochloric acid reaction: a staining test based on the principle that the higher the degree of lignification, the higher the lignin content, and the deeper the stain: flax and ramie = no staining, hemp gives an irregular pink stain, and jute gives a deep red-violet stain.

II. Aniline sulphate: the fibres are immersed in a 1% solution of aniline sulphate. Depending on degree of lignification, the fibres are stained yellow to yellowish-brown, i.e. no staining with flax and ramie, hemp gives an irregular pale yellow stain and jute gives a deep yellow-brown colour.

III. Cuprammonium hydroxide solution: observation of swelling under the microscope. Flax swells rapidly revealing a fine wavy internal protoplasm thread. Hemp swells rapidly without internal protoplasm thread, often with an accordion pleated cell wall. Ramie has very long individual fibres (60–260 mm).

Bast fibre tow. Flax and hemp waste, etc. Short fibres which arise in the → Hackling process.

Bast layer →: Flax stem structure; Flax long fibre structure.

Bast soap (degumming soap) A term used for the soap used in the → Degumming of natural silk which contains variable proportions of silk gum (sericin) removed from the silk fibres and which is a useful protein material. Bast soap is widely used for dyeing natural silk in “broken bast soap baths”. Bast soap is “broken” by the addition of acid thereby greatly reducing foam formation. Used as a dyeing auxiliary with levelling properties. Even at boiling temperatures, the presence of acids does not cause the complete decomposition of bast soap.

Bast soap substitutes Various products and mixtures, e.g. synthetic →: Fatty alcohol condensation products; Fatty acid condensation products.

Bast tape Tape product consisting of warp ends stuck together, i.e. with no weft ends, e.g. produced from glazed yarn or artificial horsehair.

Batch A group or set of usually similar materials (e.g. fibre, yarn, fabric) for processing at one time as a collective unit.

Batch card (processing card) A progress card used to accompany a batch of material through the entire process of finishing, dyeing, printing coating, etc. It contains all the information necessary for processing the material such as, e.g. the processing sequence, material parameters, processing operations, test requirements, etc. with spaces in which dates can be entered against each stage of processing.

Batch centres In yarn → Packages these are the tubes on which yarn is wound. In the case of piece goods, they are the metal or wooden rollers on which fabric is wound.

Batching device → Roll batcher.

Batching device for screen printing

Batching device for screen printing Removal of the printed fabric from the table is mechanised by means of a "detaching and batching unit", the fabric being batched in spiral form; rods are placed between the individual layers so that the still wet print cannot spot off. The batching unit is run together with the fabric into drying sections provided specially for that purpose.

Batching drives (→ Roll batchers). For various problem solutions there are different versions which differ from one another in certain criteria. As such, the following must be taken into account in the overall range: machine speed setting range, batch diameter range, fabric tension, fabric nature in dimensional terms, fabric type and residual moisture content, plus design data in the form of compensating roller stroke, moment of inertia, friction losses, run-up time and braking time. Peripheral and axial (heavyweight) batcher drive concepts differ for batchers and let-off units. In each case, a compensating roller serves as measuring sensor and regulator (affects the regulating transformer for supplying current to the batcher motor). Various possibilities of tension-free fabric batching and let-off by hydraulic drive.

Batching machine Used for batching piece goods for treatment on perforated beams in (HT) piece beam dyeing autoclaves, jiggers or as large batches for dyeing, printing or finishing; also on cardboard tubes for finished fabrics (Fig. 1).

The following stages are covered in Fig. 2: a) The wind-on head drops over the batching rollers with the cardboard core positioned ready in the loader. The switch is on pile-outside batching. b) The cardboard core is laid in, and the wind-on head is in the operating position. The fabric is fed in, and winding begins. c) The batching process proceeds, and the wind-on head is raised. d) The batching process is finished. The fabric roll ejector starts operation. At the same time, the wind-on head is raised further so that the cardboard core loader can be furnished with a new core for the next batching process.

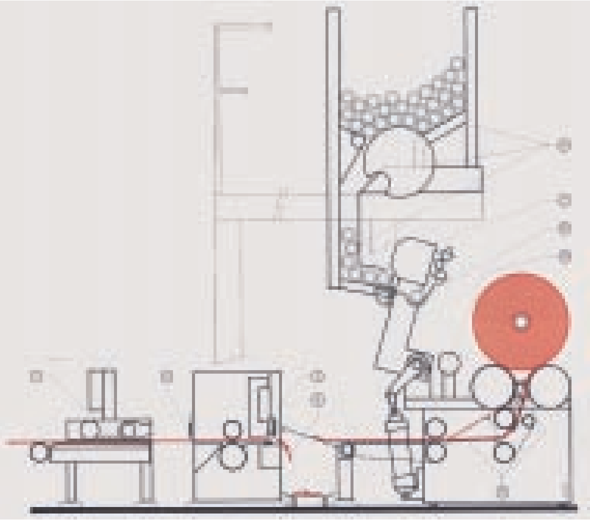


Fig. 1: Finished fabric batcher components.
1 = length measuring unit; 2 = cutting position detection; 3 = motor-operated cross-cutter; 4 = fault point ejection; 5 = pile-outside/pile-inside switch; 6 = cardboard tube magazine and feed; 7 = wind-on head; 8 = cardboard tube loader; 9 = roll ejector.

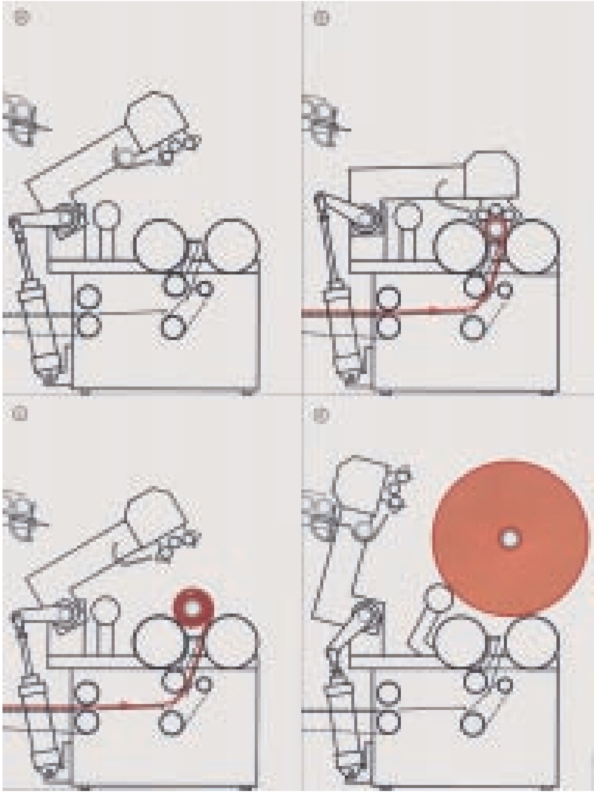


Fig. 2: Finished fabric batching operation cycle.

Batching-off unit A device for debatching textile fabrics from dye beams or giant batch rolls.

Batching roller (batch bearer, batching roll). Cylindrical support (with square inserts) for open-width piece fabric batching.

Batching tension control On a large batch, woven fabrics have to be batched under constant tension. The compensator roller determines the batching tension, and, via a microprocessor (Fig.), regulates the batching speed. In the event of excessive coupling housing temperature, a temperature sensor bridges the batch connection with the housing. In this way, the cut-off signal is fed to the unit without an additional slip ring.

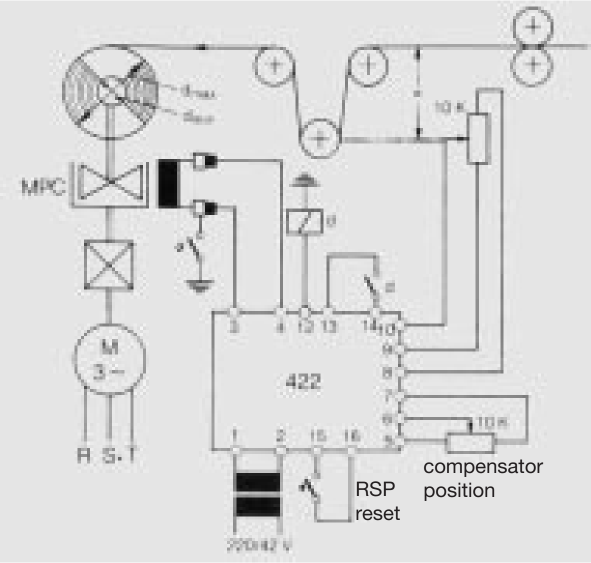


Fig.: Lenze Batcher tension control (x is kept constant). MPC = magnetic clutch; M = electric motor; 422 = microprocessor.

Batch process A batch dwell process, e.g. cold pad batch, etc.

Batch roll (fabric) → Batching roller.

Batch roll system (fabric processing). Offers several advantages compared to single roll processing:

1. Improvement in finishing quality: The beginning and end of each individual piece represents a potential risk for fabric defects. Each time a machine stop occurs the finishing result changes and the effect is impaired, e.g. heat setting.
2. Labour saving: In processing giant batch rolls the number of internal transport operations is reduced to a fraction of the number previously needed so that labour requirements are reduced.
   The same situation applies to batch changes at the machine since, in the case of giant batch rolls, the intervals between batch changes are of the order of one to several hours.
3. Higher throughput of finishing machines: Due to the reduction in machine set-up times and the number of batch changes, the productive output of finishing machines is considerably increased. Examples: a) When giant batch rolls with e.g. 1800 m fabric content are sent for final inspection and separation into merchandisable lengths on inspection machines, batch changes are only necessary every 1,5 h. As a result, the output of inspection machines can be increased by up to 20% due to the reduction in machine stoppages which were formerly necessary for small rolls. b) In the case of sublistatic transfer printing machines the productive output is increased by approx. 10% with giant batch rolls and savings in transfer paper are realized since the formerly numerous piece ends are considerably reduced on giant batch rolls.
4. Extended machine life due to less wear and tear: As experience has shown, finishing machines are subject to wear and tear especially as a result of frequent stopping and starting operations. In continuous non-stop operation over a period of hours, however, both the wear and tear and machine susceptibility to breakdowns are considerably reduced and service life is increased.

In comparison to plaited goods the giant batch roll system (Fig. 1) offers the following advantages:

1. Improved fabric quality: There is always the risk of crease formation with plaited goods which can seriously impair the quality of sensitive fabrics. With giant batch rolls, on the other hand, the fabric is always crease-free. Moreover, the risks of soiling and damage in transport are also less.

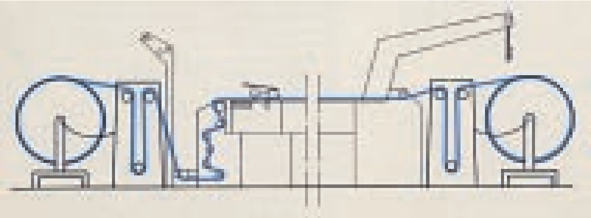


Fig. 1: Typical batch let-off and take-up layout on a continuous finishing machine.

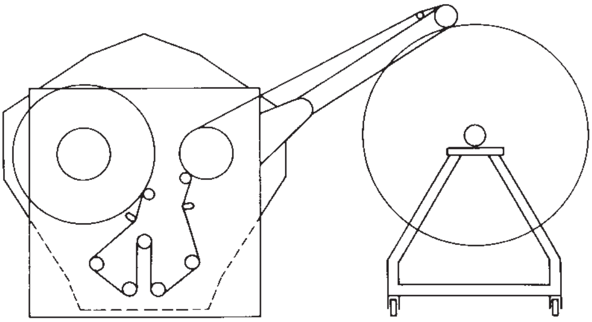


Fig. 2: Batch-type jigger dyeing batch roll system.

2. Reduced floor space requirements: It can be assumed that a giant batch roll with a diameter of approx. 1,6 m depending on type of fabric, contains 3–4 times as much fabric as a typical transport wagon of fabric in plaited form. Moreover, the floor space requirements for a giant batch roll are only marginally greater than those of a single transport wagon (Fig. 2).
3. Tension-free processing (Fig. 3).

Batch roll system for woven fabrics

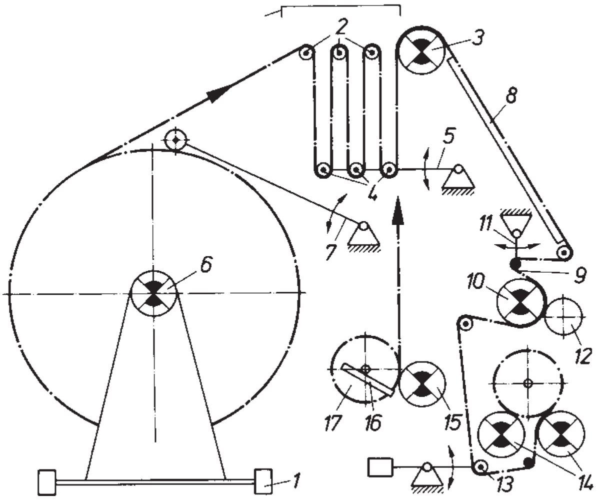


Fig. 3: Large batch roll let-off diagram.
1 = transport frame with large batch roll; 2 = fixed roller; 3 = main let-off roller; 4 = compensating roller; 5 = rocker; 6 = batch roll drive; 7 = sensor arm; 8 = inspection table; 9 = relaxing loop; 10 = draw roller; 11 = pendulum; 12 = measuring wheel; 13 = compensator roller; 14 = twin-roller batching; 15 = contact roller; 16 = rail; 17 = roll.

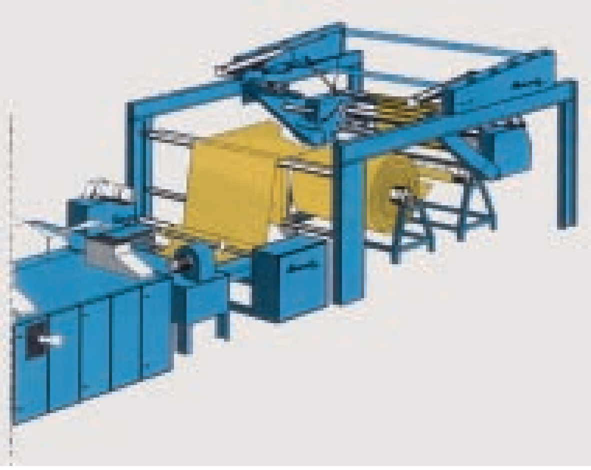


Fig. 1: Quick batch change unit at the exit of a Krantz stenter.

Batch roll system for woven fabrics Batch operation offers advantages over plaiter operation:

- space-saving storage of fabric in circulation,
- protection against soiling and transport damage (especially on plaiting interruptions; with plaiter operation, there is a danger of mechanical damage and soiling in pallet transport),
- no interruption of fabric run due to electrostatic charging of the fabric (which results in plaiting lay creasing in wet processing),
- higher running speeds,
- longer machine running times because of fewer batch changes.

Batch system problems are as follows:

- necessary fabric tension during batching,
- re-batching is necessary in the case of raised products,
- the total quantity of fabric in circulation has to be systematically dealt with; piece identification systems are of great use to this end,
- bulky fabric suffers in batching (raised velvet); necessary under certain circumstances therefore, particularly in decatising, are aluminium trestle-type plaiter trucks, which plait down especially long festoons via stop plaiters, thus preventing pressure creasing,
- high investment cost as regards batches and batching stations on every machine.

Plaiting units are problematic at stenter exits (Fig. 1) precisely because of the high production speeds involved, for which reason special units are also offered.

The basic equipment for installing batch operation in dry and wet finishing consists of so-called batching trestles. A batching trestle has a fixed construction batching roller with parking brake and coupling sleeves for centre drive. For wet fabric, the batching roller can be furnished with a PVC shrink tube. These batching trestles are designed as standard for batch diameters up to 1800 mm, but they have also been built for signifi-

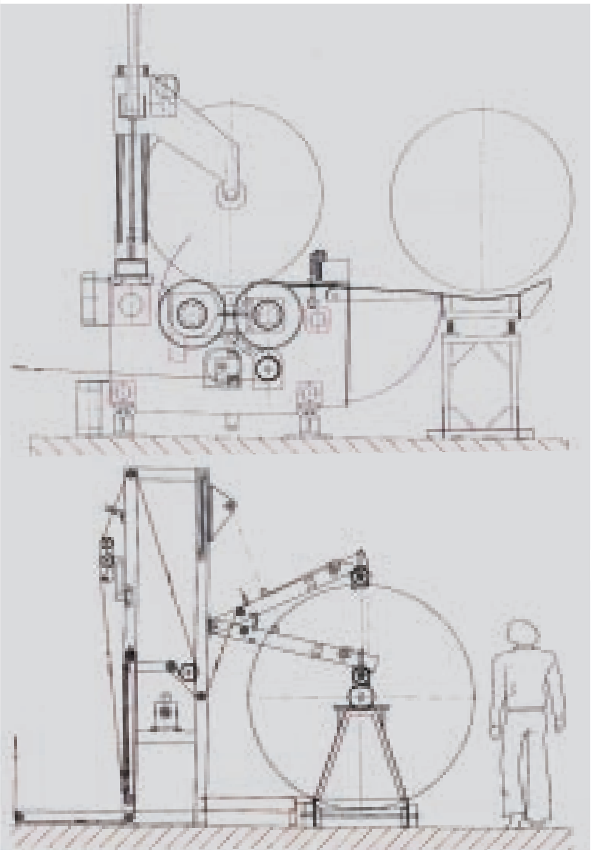


Fig. 2: Surface (peripheral) batcher (above) and hydraulic centre batcher (from Holthausen).

cantly greater batch diameters (up to 3 tonnes load). A batching trestle is transported by means of a crank roller or a standard tractor vehicle. If a batching station is employed, batching must be traversed in order to prevent selvedge build-up. Also to be taken into account is the fact that the tension on the fabric being batched increases as the batch thickness increases. The extent to which this type of tension is problematic for tension-sensitive fabrics must be regulated from case to case. Large batches are normally produced with the aid of hydraulic centre or surface (peripheral) batchers (Fig. 2).

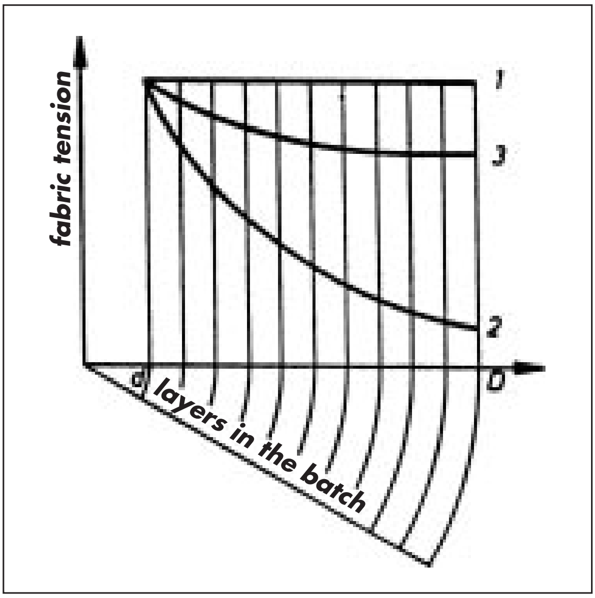


Fig. 3: Characteristic batching curve according to Menzel.

With the surface batcher, the batching process is effected by a driven batching roller which is in contact with the batch; in the case of the centre batcher, a batching motor drives the batch from the core. Constant fabric tension, equivalent to curve 1 in Fig. 3, is produced automatically with the surface batcher, as the batching roller batches with constant torque, which is of course adjustable as necessary. This batching force acts virtually upon the batch periphery only, and therefore has no negative effect on batch quality. With the centre batcher, constantly increasing torque must be applied in order to obtain constant tension. As this increasing moment has to be transmitted outwards via the inner layers in the batch, it is not always advisable to maintain constant tension, since the inner layers are pressed together and squeezed by the unpreventably high tension acting at the greatest batch radius. An ideal fabric tension run will, depending on product and requirement, lie between limits 1 (constant fabric tension) and 2 (constant moment, as with friction drives for example), and follow approximately curve 3, which has largely constant tension at the start of the batch, and a specific tension drop at the end of batching.

A comparison of woven and knitted fabric can be of help in estimating the effect of tension. The large batchers usual for woven fabric are unsuitable for the demands of knitted fabric finishing. Most knitted fabric qualities are sensitive to lengthwise tension. Excessive batching tension results in lengthwise creasing; due to the low degree of fabric stability, the fabric is distorted in the length, and becomes narrower. As a rule therefore, it has to be run under much lower batching tension than is employed with woven fabrics. It is clear therefore that simple centre batchers with constant drive pumps and no output regulation, as are employed in large numbers in the woven fabric industry, are unsuitable for knitted fabric. It can be seen from Fig. 4 that, with such batchers, fabric tension decreases as the batch diameter increases if not manually controlled. Manually controlled tension can be seen from the second characteristic curve of the graph. Apart from the fact that frequent manual regulation cannot be considered on economic grounds, tension varies too much from the ideal line here.

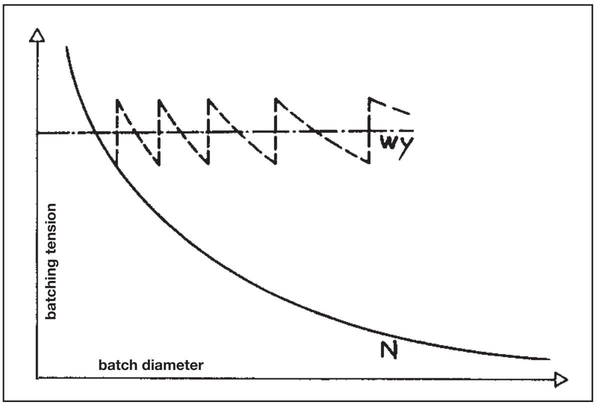


Fig. 4: Diagram with the batching characteristics of a simple hydraulic batcher with (– –) and without manual (N) control; the ideal line drawn in is equivalent to the batching characteristics of the Maier WY batcher.

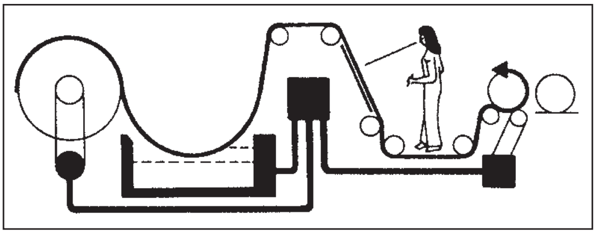


Fig. 5: Use of large batches in fabric let-off and in the microprocessor control of tension-free feed to fabric inspection via selenium cell control.

For operation with tension-sensitive products, batchers can be equipped with a photoelectric control unit (Fig. 5). The fabric is fed in a loop before the actual batching side. The size of the loop is sensed by a photoelectric sensor. Batching speed is then automatically synchronously controlled to the speed of the upstream and downstream equipment via a special electronic-hydraulic control unit. Tension-sensitive fabric can also be controlled during batching by compensating rollers which regulate the power requirement of the subsequent batcher. The batcher is a surface batcher, i.e. the drive roller, fitted to a swivel arm, drives the batch tangentially. In contrast to that are centre batchers, which are generally hydraulically driven. The key plan in Fig. 6 demonstrates oil circulation and shows the motor control unit. The oil drawn out of the supply tank is compressed by the pump (P), and fed to the system. Pressure is adjusted by the pressure reducing valve (A), and can be read off the manometer (M).

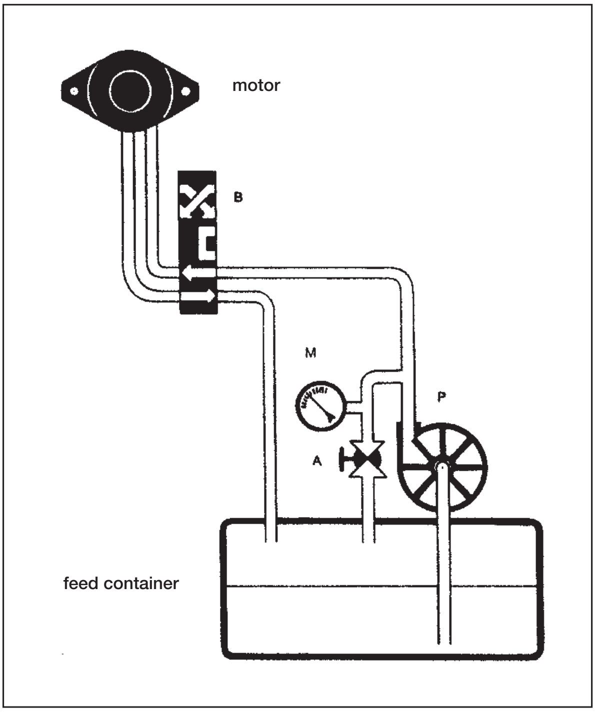


Fig. 6: Hydraulic drive motor (Menzel).

In the position illustrated, the route to the oil motor is opened by the control valve (B), blocked in the middle position, and opened for reverse rotation in the top position. Various variations have proved themselves in operation for centre batching trestle drives. First of all with trestles, direct coupling can be effected by means of through-going hydraulic motor spigots, but with the retrofitting of existing trestles without spigots, a V-belt drive is often fitted because only one hole is then necessary in each trestle for conversion purposes.

The ascending batcher is built in such a way that the full weight of the batch rests on two driven rollers. Also offered for batching and letting-off, however, is a type of ascending batcher where the beam rests on a central axis in swivel arms, while the beam runs against laterally tangential drive rollers (Fig. 2). Batch rotating units are fitted for the rotary dwelling of wet fabric on large batches (in order to prevent water bags during lengthy standing periods).

At the stenter exit, woven fabrics are either batched on large batches or on cardboard tubes for individual piece batching. In both cases, non-stop batchers with a fabric cutting unit are necessary.

Batch rotation Batching piecegoods onto the roller out of the treatment liquor.

Batch steamers Cylindrical steamers in various constructions used for discontinuous steaming processes, especially for printed fabrics, e.g.:

I. Horizontal steamers: front loading with a transportable frame. Textile material in the form of yarn hanks or fabric in book form is suspended on sticks, rollers or square-section rods which rotate during steaming. This type of steamer is generally used for rel. long steaming times of 1–2 hours, also under pressure. Such steamers are also known as cottage steamers.

II. Vertical steamers: various types, e.g. a) universal, Indanthren rapid, or Van-der-Wehl steamers: lid closure at the top. Fabric to be steamed is sandwiched between a back-grey and wound on to a perforated metal cylinder which is loaded into the steam chamber. Direction of steam flow is from outside-to-inside or vice versa, suitable for short runs of fabric, e.g. for small screen printing and hand printing operations; or b) star steamers: in which the fabric to be steamed is pinned to a star frame together with a back-grey on one or both sides. The steam chamber takes the form of a cylindrical pressure vessel, arranged vertically and closed at the top with a door that can be swung into position at its base. The loaded star frame is either raised into the steam or the steaming chamber lowered on to the star frame. Star steamers are preferred by screen printers and for sensitive fabrics, wool printing, etc.

Batch system (charged system). A term used to describe a now obsolete drycleaning process in which predetermined quantities (depending on the type of material) of drycleaning detergent and water were added to each batch processed.

Batch type scouring machine Cycle type/continuous scouring machine for batch scouring. Double drum construction built with five chambers or more (each of 40 kg capacity). Performance range relative to chambers and cycle times and also passage time 200–1600 kg/h. A loading belt divided into sections conveys the individual fabric batches in the set cycle through the adjustable working zones (prescouring, clear scouring, rinsing and starching). Scouring is effected in separate batches, the inner drums moving independently of each other in one direction of rotation. Bridging plates form the passage between the chambers, serving at the same time as large carrier ribs. At the end of the cycle time, the batches are rotated through 360°, transported by bridging plates.

Batch wagon Mobile frame for → Batch loading and internal transport (DIN/ISO 5248).

Bates process A process for the scouring and bleaching of cotton in which fabric impregnated with bleaching chemicals is placed between electrodes and heated to the boil.

Bath The liquid-filled treatment zone in dyeing, washing, finishing, and drycleaning machines. A distinction is made between a standing bath and a circulating bath. In the latter case, liquid is circulated through the textile material by means of a pump and recirculated via a filter. The liquid medium itself is referred to as a → Liquor.

Bath exhaustion A term used for the exhaustion of dye at equilibrium, generally expressed as that percentage of dye originally applied which has been removed from the bath by adsorption on to a textile substrate due to the forces of affinity.

Bathochromic group Colour-intensifying group in a → Dye structure. The presence of a bathochromic group in a dye molecule causes a shift in the absorbed wavelengths from violet towards green (complementary colour) and the colour of the dye in the direction green-yellow–redviolet, i.e. an increase in the wavelength and a reduction in the oscillation frequency. See also → Hypsochromic group.

Bath polarization A method of preventing corrosion in bleaching equipment. Principle: an electric potential is applied to the bleach liquor and the bleaching machine. The bleaching machine is connected to the negative pole of a direct current supply and a positive pole is formed by a carbon electrode in the bleach liquor.

Batik Javanese handcraft technique for the production of characteristic designs and fabrics. It involves the application of molten wax to the fabric by → *Tjanting* (pipe), *tjap* (stamp) or brush as a resist, followed by dyeing, removal of the wax, re-application of wax in the desired areas, followed by a second dyeing and so on. Fine cracks are formed in the wax resists as a result of mechanical action which do not resist subsequent dyeing completely. The typical veining of batik designs is created in this way.

The term batik is derived from a combination of the words “*banyak*” and “*titik*”, which means “many points”. Different types of batik include: mosaic batik, water-colour or sketched batik, ornamental batik and lace batik. The various techniques of batik production are subdivided into:

- the creasing and folding technique,
- the tying and tie-up technique,
- the knotting technique,
- wax batik,
- Shibori alternatives.

Batik pipe → Tjanting.

Batik printing (Real Wax print). Involves the mechanization of traditional batik techniques by retaining the wax resist (→ Wax resists). Principle: fabric is printed with a wax resist, then cooled down quickly in cold water or subjected to a mechanical breaking action in order to achieve the typical crackle effects (fine veining). This is followed by dyeing with indigo (dipping vat), removal of the wax resist by washing or soaping, drying, completion of the remaining colours by screen or hand block printing with the usual dye classes and finally drying and finishing. The production of this style of printing is extremely laborious and expensive. For this reason, a cheaper imitation has been developed under the name of → Imi-Wax, which has now found wide acceptance. → Indigo styles in Africa prints.

Batiste Three types: (1) Cotton or polyester/cotton soft, fine to very fine, tightly woven fabric of the lawn family in plain-weave construction. Produced in various grades from coarse to very fine. Generally woven of fine combed yarns but occasionally of carded cotton. Maco-batiste is a batiste fabric woven from Egyptian maco-cotton. Often highly mercerized, bleached, dyed or printed. Sometimes embroidered. (Coloured-woven batiste is not called batiste but macozefir). (2) Sheer fabric of man-made fibre with dobby woven stripes, jacquard patterns. (3) A light-weight wool fabric in plain-weave similar to plain cambric. It should be of all wool construction unless otherwise described.

Batt-on-base woven felts → Nonwoven materials which are defined in DIN 61 205 as textile fabrics composed of ground fabric/s and one or several fibrous webs which are consolidated and bonded with the ground fabric/s.

BAT value Biological tolerance of workplace toxins, maximum admissible concentration of a workplace toxin or its conversion products (metabolites) in the body (absorbed by the blood or urine through inhalation, swallowing or by skin resorption) which do not generally impair the health of the worker in terms of current scientific knowledge when they are regularly produced by the effect of the work station. In addition to monitoring ambient air in accordance with → TLV values, BAT values serve, within the framework of specific medical check-ups, to protect the health of workers at the work station.

Baumé, degrees (°Bé) A frequently used but unscientific scale for measuring the relative density of liquids by hydrometry (Baumé hydrometer). Hydrometers with direct scale divisions in relative density for liquids are, of course, readily available. Nevertheless, hydrometers with scale divisions in °Bé are still frequently used in practice. The basis of the scale division is as follows: density of distilled water at 4°C = 0°Bé and the density of a 10% sodium chloride solution = 10°Bé; this separation is divided into 10 subdivisions and the scale is continued. Conversion formulae for converting °Bé into specific gravity (ρ):

a) For liquids more dense than water:

$$\rho = \frac{144{,}38}{144{,}38 - {}^\circ\text{Bé}}$$

b) For liquids less dense than water:

$$\rho = \frac{144{,}38}{144{,}38 + {}^\circ\text{Bé}}$$

The formulae are only valid for measurements at 15°C.

Bayer biological tower plant A plant designed for the biological degradation of organic substances in waste water by treatment with bacteria and air in closed towers of up to 30 m height.

Bayonet spiral A term used to describe the upper shearing cylinder blade profile in shearing and cropping machines.

Bazaar dyeing A unique ancient dyeing process still in use today with simple home-produced equipment and almost the full range of synthetic dyestuffs and printing pastes. Mostly as commission dyeing for small weaving mills, 45% of industrial cotton textile products being produced by small plant and outwork production.

BB, abbrev. for: batt on base (nonwovens technology).

BB felt cloths Meaning → Batt-on-base woven felts.

BBP → Butyl benzyl phthalate.

BC Code designation for → Boron (nitride) fibres in accordance with air travel standards.

BCE, abbrev. for: Bachelor of Chemical Engineering; academic degree in the USA and UK.

BCF yarns (bulked continuous filament). Textured continuous filament yarns used for pile yarns in carpets or upholstery fabrics.

BCSIR, abbrev. for: Bangladesh Council of Scientific and Industrial Research (Dhanmondi, Dacca). → Technical and professional organizations.

BDE (Betriebsdatenerfassung) German code designation for "operating datalogging". Electronic data processing: process data, produced by hand, is read into document readers, keyboards and terminals or automatically via sensors.

BE,

I. abbrev. for: Bachelor of Engineering. British professional qualification for graduates of engineering colleges or polytechnics.

II. abbrev. for: Belgian patent.

Be, chemical symbol for beryllium (4).

°Bé → Baumé, degrees.

BEA, abbrev. for: British Engineers Association.

Beam dyeing machines HT autoclaves for piece goods or atmospheric machines for the dyeing of warp beams. Piece dyeing machines are available with internal diameters of 1000, 1200, and 1500 mm and working widths up to 4000 mm. Max. operating pressure 5 bar. Max. dyeing temperature = approx. 135°C. Various dye beam diameters are available depending on weight of fabric batch, e.g. 500, 600, 700 and 800 mm. Blanking collars (to blank off excess perforations in the dye beam) are used to permit the dyeing of narrow fabric widths. Piece dyeing machines are used for dyeing woven and warp-knitted fabrics in open-width. Advantages include freedom from running creases, felting, or fibre loss with surface-sensitive fabrics. In particular, mechanical damage to warp-knits (e.g. stitch deformation, snagging) is avoided. Beam dyed fabrics generally have a firm handle. Short liquor ratios of 10:1 to 12:1 are usual in beam dyeing.

In addition to their use in dyeing, beam dyeing machines can also be used for the hydrosetting and wet decatizing of wool fabrics. Beam dyeing machines are mainly supplied with an external centrifugal pump (and heat exchanger). Alternative models are also available with in-built axial pump and heat exchanger. Batch changes are effected by removing the beam of fabric from the horizontal dyeing vessel on rails and on to a waiting trolley (Figs. 1 and 2).

A reduction in liquor ratio can be achieved by positioning displacement elements in the fabric beam (Fig. 3).

Fig. 1: Running out the dyed fabric beam on a beam dyeing machine (Durand).

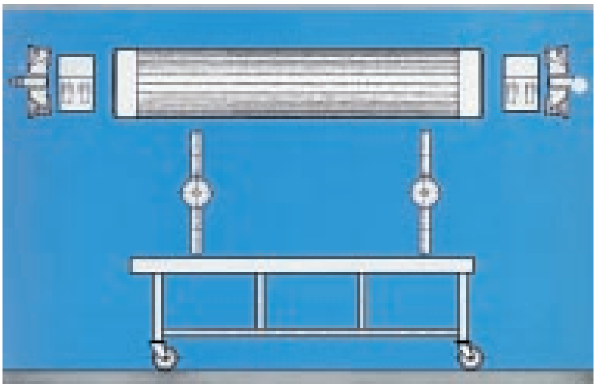


Fig. 2: Dye beam with castors on both cover plates which can run on rails in the dyeing machine and on the transport trolley (Krantz).

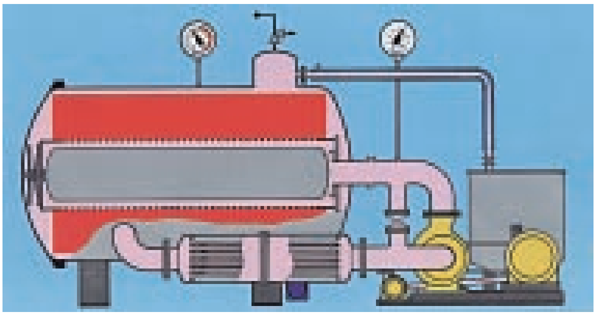


Fig. 3: Beam dyeing machine (Durand) with displacer in the dye beam for shortening the liquor ratio.

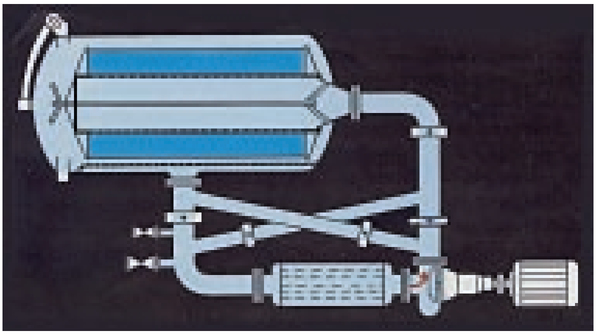


Fig. 4: Lavish piping system with relevant valve controls for changing liquor direction in the centrifugal pump beam dyeing machine.

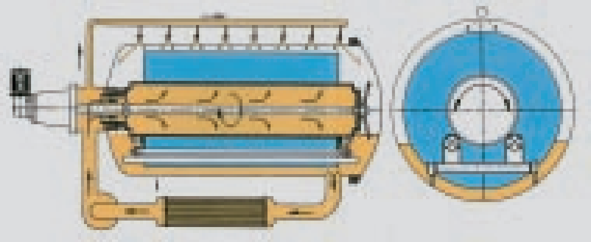


Fig. 5: Alliance-Rotora beam dyeing machine with rotating beamed fabric to reduce the liquor ratio.

With appropriate equipment, liquor flow reversal is also possible which enables the centrifugal pump to run constantly in one direction (Fig. 4). The direction of liquor flow in beam dyeing is normally from inside-to-outside of the beam only. In the case of machines fitted with axial pumps, however, the liquor flow can be easily reversed by changing the direction of rotation (Fig. 5).

Since, in beam dyeing, the textile material is at rest and liquor is circulated through it by means of a pump, the question arises as to whether it is better for the liquor circulation to flow from inside-to-outside or from outside-to-inside of the batch. Liquor circulation from outside-to-inside offers advantages of better uniformity of dye (and chemicals) transport to the fibre surface throughout the diameter of the batch and the virtual elimination of fabric deformation during the dyeing operation (Fig. 6).

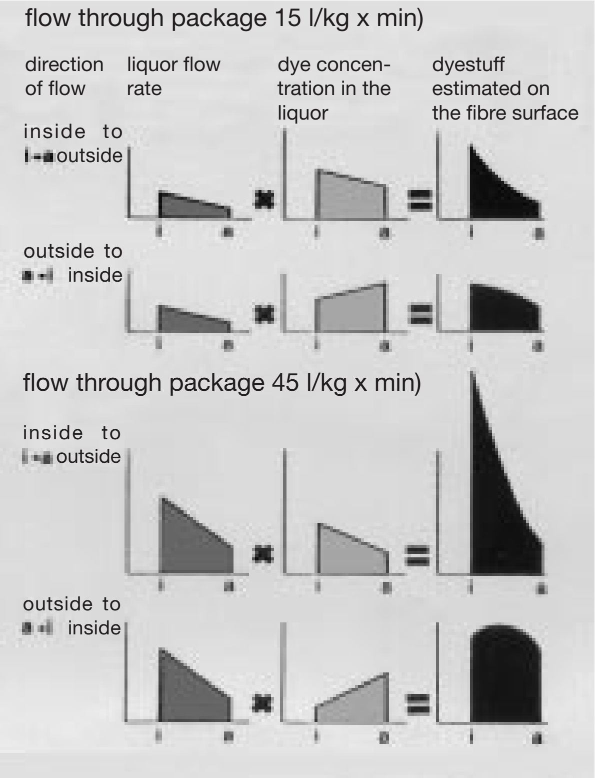


Fig. 6: Dyestuff estimated on the fibre surface in beam dyeing; depending on liquor flow direction (Kretschmer).

This procedure can make a significant contribution to the use of increased batch sizes, even for critical fabric qualities, without sacrificing production reliability. When liquor is circulated from inside-to-outside of the dye beam a pressure loss Δp occurs due to the conversion of mechanical flow energy into friction with the fibres in the interstitial spaces of the material. A distinction is drawn between this differential pressure (or dynamic pressure) and the absolute static pressure within the textile batch which, if excessively high, can cause the fabric to lift off the beam (Fig. 7). It is important to ensure an optimum flow through the textile material in order to save water during the rinsing stages and, to this end, overflow rinsing is carried out in most cases. This is achieved by supplying fresh water from the pressure side of the running circulation pump and allowing the rinse water to flow away via the overflow after passing through the beam so that the dyeing vessel always remains full of rinsing water.

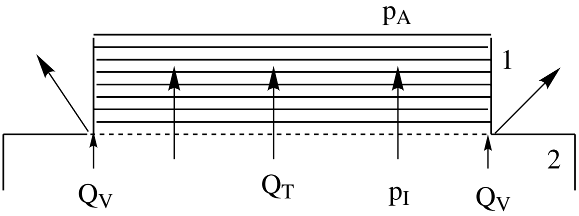


Fig. 7: Differential pressure $\Delta p = p_I - p_A$ in the batch roll in beam dyeing, which can result in liquor losses 2 Q_V by lifting the batch under excessive static pressure p.
Q_T = quantity of liquor in the batch; 1 = batch; 2 = dye beam.

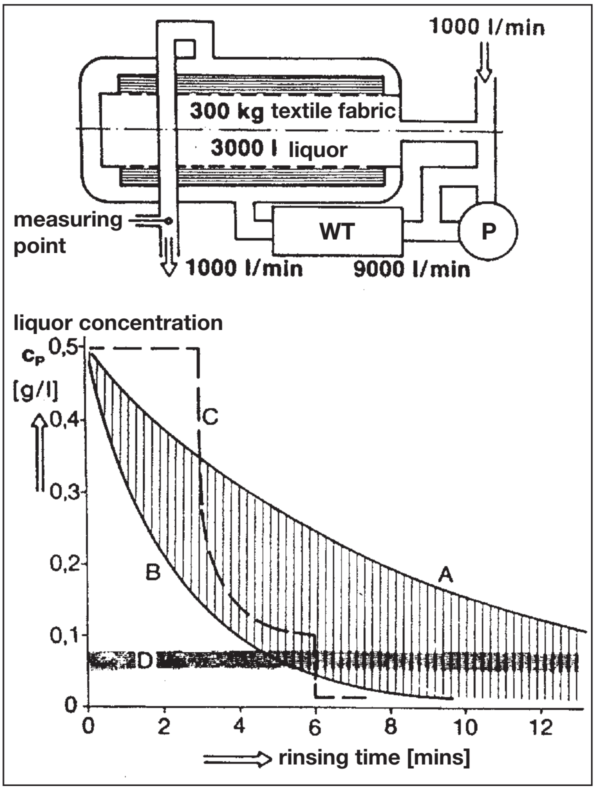


Fig. 8: Liqour dilution and dye concentration reduction relative to rinsing time and rinsing liquor flow in beam dyeing (Kretschmer).
A = intense liquor circulation; B = modest (by-pass) liquor circulation; C = liquor emptying by means of compressed air and fresh liquor filling; D = permissible residual concentration.

In Fig. 8 the reduction in liquor concentration during the rinsing time corresponds approx. to curve A with a closed by-pass, and to curve B with an open by-pass. If the bath has been dropped at the start of the rinsing operation, the proportion of residual liquor remaining in the batch (amounting to approx. 200% by weight) must be diluted with fresh rinsing water. With a closed by-pass, the liquor circulation contributes effectively to a decrease in concentration at the fibre surface and a more uniform dilution of the liquor. The proportion of residual liquor retained in the batch of textile material is reduced to approx. 100% by expulsion with compressed air, especially when liquor flow is from outside-to-inside. On subsequent refilling with rinsing water and circulation, the proportion of residual liquor is then further diluted (curve C, Fig. 8).

Beam dyeing of piece goods Batchwise dyeing of textile fabrics wound in the open-width state on to a perforated beam through which liquor is circulated. Taking a fabric batch as an example, a comparison of the manometer reading with the calculated differential pressure value enables one to recognise immediately whether the batch of fabric has lifted off the dye beam, or whether a secondary flow at the edges of the batch exists which can result in uneven dyeing.

The thickness of the boundary layer decreases with increasing flow rate. A higher liquor throughput can, however, only be used to advantage if the direction of liquor flow is changed so that it flows from outside-to-inside of the batch.

Beater opener Device for opening out fabrics in rope form. The most important component is the rapidly rotating → Beater roller with beater blades.

Beater rollers (vibrator rollers) Employed in open-width washing machines to provide increased mechanical action on the running fabric thereby intensifying liquor movement.

Beating machines (beaters) Two types are in use:

I. Beating machines for the finishing of pile fabrics (velvet, plush, etc.) in which the back side of the fabric

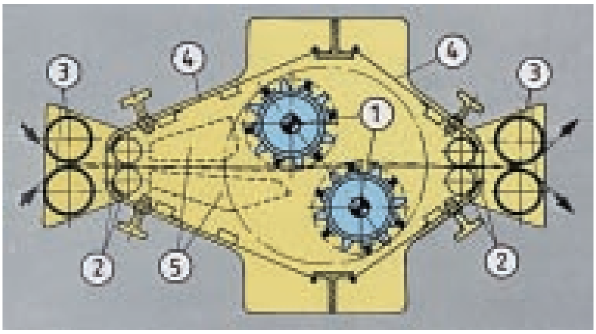


Fig.: Beating and brushing machine (Kleinewefers-Jaeggli).
1 = individually driven brushing and beating rollers;
2 = fabric guiding; 3 = deflector; 4 = housing cover;
5 = extraction ducts.

is subjected to a beating action which results in better alignment of the pile on the face side.

II. Beating machines for the cleaning of carpets and other textiles which cannot be subjected to washing treatments. Dirt is removed by an intensive beating and brushing action (see Fig.).

Beaver cloth A heavy, firm-textured fabric, made from woollen yarns. The lustrous nap of short fibres is produced by milling the cloth and raising the fibres, which are cut level and laid smoothly in one direction. It is intended to have the appearance of natural beaver skin. Soft handle with a longer nap than that of wool broadcloth. Used for overcoating.

Beck → Dyeing vat (a term frequently used in the USA for an open winch dyeing machine).

Bedford cord A woven cord fabric. Plain-weave is usually used on the face of the cords, but other weaves may also be used. → Cord.

Beeswax, raw: yellow-red-brown (African and American beeswax is almost brown), pleasant odour, brittle when cold (accepts chalk marks but not after addition of tallow). It produces a granular fracture. On warming in the hand it becomes plastic. Does not adhere to the teeth on chewing. When bleached it is very brittle and has a rancid odour. Tropical beeswax contains high additions of tallow (permissible amount 3–5%). Beeswax has a melting range of 61,5–68°C (69°C with tallow addition, a higher m.p. is not permissible). Adulteration is mainly carried out with the addition of tallow, Japan wax, stearine, resin, paraffin wax, ceresin, minerals (ochre, heavy spar), pea meal. Beeswax is soluble in turpentine, chloroform, white spirit and hot fats. Very difficult to saponify. Uses: textile sizing and finishing, water-repellent finishes, etc.

Beetling calender A heavy calender usually with 6 bowls, the lower and uppermost of which consist of heated steel rolls whilst elastic cotton bowls are used in the intermediate positions. The fabric passes through all the nips from the lower to the uppermost bowl where it is rolled on to the upper cotton bowl thus producing the → Beetling effect as a result of the pressure exerted by the top steel bowl.

Beetling effect A unique type of lustre finish imparted to cotton or linen fabrics by a calendering treatment on the → Beetling calender or chasing calender.

Behenic acid (docosanoic acid), $CH_3(CH_2)_{20}COOH$, of MW 340,57. Colourless crystalline needles. Sparingly soluble in water but soluble in alcohol. A saturated fatty acid which is a minor component of, *inter alia*, peanut and rapeseed oils. Hydrogenation product of unsaturated C_{22} fatty acids derived from rapeseed oil as well as oils from marine mammals. Uses: the sodium salt (behenate) is used as a foam regulator (its efficiency is dependent on the presence of alkylbenzene sulphonate and pentasodium triphosphate as well as water hardness) and as a foam suppressant especially in washing agents.

Beilstein test Used for the detection of substances containing chlorine or other halogens, e.g. synthetic fibres (such as polyvinyl chloride or vinyl chloride copolymer fibres).

Procedure: A piece of copper wire (or gauze) is heated in an oxidizing flame until the flame is no longer tinged green (= yellow flame); a little of the fibre sample is placed on the copper wire and burnt in a non-luminous gas flame. A green-coloured flame is a positive test for the presence of halogen and is due to the formation of volatile copper chloride through combination of copper with chlorine in the sample. It should also be noted, however, that a positive reaction in this test can also result even in the absence of halogens and in the presence of e.g. volatile copper compounds with oxides of carbon as well as organic compounds containing both sulphur and nitrogen.

Bekleidungsindustrie e.V., Bundesverband → Technical and professional organizations.

Bekleidungsphysiologisches Institut Hohenstein e.V. A textile and clothing research organization in Germany; → Technical and professional organizations.

Bell steamer → Batch steamers.

Belt accumulator → Narrow fabric accumulator.

Belt brushing machines Finishing machines for corduroy fabrics. → Corduroy and velvet finishing.

Belt drives → Motive power engineering by means of transmission belts. The theoretical underlying principle for the calculation of belt drives is the Eytelwein equation:

$$F_1 \leq F_2 \cdot e^{\mu\beta}$$

F_1 = force on taut side of belt
F_2 = force on slack side of belt
e = base of natural logarithms
m = coefficient of friction between belt and pulley
b = arc of belt contact (on the smaller pulley) circular measure by radians

Eytelwein's equation gives the maximum proportion of change in the two belt forces F_1 and F_2 during power transmission, before pulley slippage occurs (the more power transmission, the greater F_1 will be and the smaller F_2 will be) (Fig. 1).

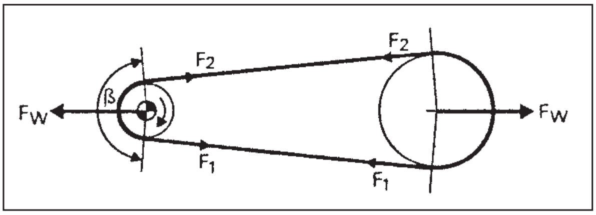


Fig. 1: Forces on belt drive during power transmission F_1 *= force on taut side of belt,* F_2 *= force on slack side of belt,* F_w *= strain on shaft driving small pulley.*

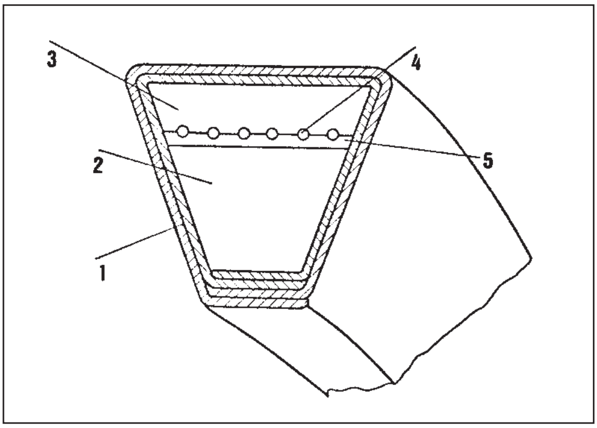


Fig. 2: Narrow V-belt with a cable cord core
1 = encasing fabric, 2 = rubber core, 3 = top layer, 4 = cord, 5 = cushioning rubber

To achieve maximum frictional force, profiled V-belts are used (Fig. 2).

Bending elasticity (crease resistance) Partly elastic, partly permanent shape change of yarns and woven fabrics in the bending test as a criterion of → Creasing (tendency, sensitivity), the so-called angle of recovery (module of elasticity), which occurs after folding or bending under load (effect duration) and subsequent relief, and is at best 180°, playing an important role. → Tensile elasticity.

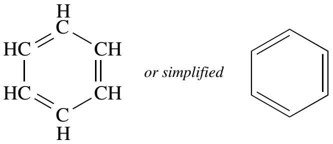
Benedict-Denis reagent (according to Krais-Markert-Viertel) Solution of 25 g of copper nitrate, 25 g of sodium chloride and 10 g of sodium nitrate in 100 ml of water. Used for quantitative sulphur determination in wool.

Bentones Organic derivatives of montmorillonite. Used in printing preparations as a thickener for pigment suspensions etc.

Bentonite Colloidal → Silicic acid (clay, aluminium silicate) composed chiefly of montmorillonite. Very fine white powder which absorbs up to approx. 5–6 times its weight of water by swelling into a gelatinous mass with strongly thixotropic properties. Uses: Thickener for textile printing, also used in the paper, soap and pharmaceutical industries.

Benzanthrone → Anthrone.

Benzene, C_6H_6, MW 78,06, density at 15°C = 0,885, b.p. 80,15°C, f.p. 5,5°C. As a homogeneous chemical compound benzene is not to be confused with → Benzine (special boiling point spirits). Colourless to light-yellow, mobile, non-polar, highly refractive liquid with a characteristic aromatic odour. Forms narcotic vapours which are toxic when inhaled for long periods. Highly flammable, burns with a smoky yellow flame. It forms explosive mixtures with air which sink to the ground. Properties: only very slightly soluble in water (0,82 ml/l) although 2,11 ml water are soluble in 1 litre benzene. Readily miscible with alcohol, ether, acetone, carbon tetrachloride, carbon disulphide and glacial acetic acid. Uses: solvent, spotting agent. → Carcinogens.



Benzene derivatives → Aromatic compounds.

Benzene sulphonates See → Alkylbenzene sulphonates.

Benzene test (for dyeings), specifically for cationic and disperse dyes in → Dye class identification.

Benzidine (4,4´-diaminodiphenyl), $H_2N–C_6H_4–C_6H_4–NH_2$. Aromatic amine, MW 184,2. Properties: greyish-yellow, white, or reddish-grey crystalline powder; m.p. 127°C; b.p. 400°C; soluble in hot water, alcohol, ether; slightly soluble in cold water. Combustible. Readily diazotizes at both amino groups. Uses: parent compound of numerous (direct) dyes as well as diazo compounds for the preparation of mainly brown insoluble azo dyes on the fibre. These dyes are no longer permitted in Europe because of their carcinogenic character. →: Blood, detection of; Carcinogens.

Benzidine test → Blood, detection of.

Benzine Mixture of → Hydrocarbons i.e. not an homogenous chemical compound like → Benzene. Easily mobile, water-white, singular smelling liquid which evaporates relatively quickly at any temperature: petroleum benzine completely below 100°C, leaving behind no odour. Together with air, forms a highly explosive mixture, the explosion limits lying between 1.8 and 8.5 vol.% benzine vapour content. Benzine vapours always sink to the ground, and fans should therefore be installed at floor level. In contrast to benzene, benzine burns without a smoky flame, and also does not dissolve asphalt. The flash point lies between 25 and 55°C; danger class IIIa. Median constants for calculation:

density at 15°C:	0.65–0.79
freezing point:	30–50°C

Various types of benzine differ according to the different fractions (Table). Specific benzine fractions are increasingly used as substitutes for tetrachlorethylene in dry-cleaning machines specifically designed to that end (hydrocarbon systems).

It should be expressly pointed out that the designation of benzine fractions is to some extent differently implemented. Evaporation figures vary between approx. 3–20 times the evaporation time of ether. Properties: insoluble in water, miscible with alcohol, ether, chloroform and other organic solvents. Reduction in spontaneous ignition by benzine soaps and dry-clean-

type	density (15 ° C)	boiling point (° C)
petroleum ether	0,665–0,670	c. 40–70
petroleum benzine light petrol	0,680–0,720	c. 70–90
ligroine white spirit	0,730–0,780	c. 100–135
naphtha	0,735 (12° C)	c. 100–140
heavy petrol	c. 0,770–0,790	c. 140–200
heaviest petrol	0,790 (12 ° C)	c. 180–210

Tab.: Benzine density and boiling ranges.

ing detergents. Application: textile degreasing, dry-cleaning, stain-removing agents for light grease and fresh oil stains, resin spots, dust and light soiling, particularly in conjunction with dry-cleaning detergents; addition to easily foaming printing colours.

Benzine hydrocarbons These mean → Benzines used in dry-cleaning.

Benzine soaps Fat-solvent soaps of various compositions (often highly ethanol-containing) and consistencies (liquid, semi-solid, solid). By reducing the spontaneous combustion of → Benzine (benzol), they facilitate dry-cleaning in organic volatile solvents, and, in benzine cleaning, mostly act simultaneously as an anti-electricum: by increasing electrical conductivity, the electrostatic charge in solvents is reduced in mechanical processing (friction metal/liquid, textiles/metal, textiles/liquid), and consequently effectively opposes discharge with sparking.

Benzothiazolone hydrazone method Spectrocolorimetric method for the quantitative determination of formaldehyde on textiles. 3-methyl-2-benzothiazolone hydrazone reacts with formaldehyde to an azine. The surplus of the benzothiazolone hydrazone method is oxidised by iron(III) chloride to a reactive cation which produces a cationic blue dye with the azine compound.

Benzoylation Introduction of the → Benzoyl group of an aromatic acid residue into a molecule. → Acylation.

Benzoyl group → Acyl (residue) = C_6H_5CO, of benzoic acid. → Benzoylation.

Benzoyl peroxide, $C_6H_5CO–O–O–COC_6H_5$; white crystalline powder with a very faint odour, slightly soluble in water and alcohol, soluble in ether, benzene and chloroform. Produced from benzoyl chloride and sodium peroxide. Highly toxic via inhalation. TLV: 5 mg/m^3 of air. Active oxygen content of 6,3%. Its low moisture content (< 5%) poses a fire risk and for this reason it should be stored under cool conditions and sudden heating or warming with organic substances must be avoided. May explode spontaneously when dry (< 1% water). Never mix unless at least 33% water is present. In burn-out printing, the best effects are obtained in the presence of approx. 5% moisture. Benzoyl peroxide can cause discoloration of dyed and printed textiles. Uses: For the destruction of acetate fibres in mixed fabrics by burn-out printing; burn-out styles; bleaching of cellulosic fibres containing chlorophyll (pandanus straw, etc. for hat braiding) dissolved in gasoline or e.g. alcohol; bleaching materials that are difficult to bleach (hair, feathers, furs, etc.).

Benzyl alcohol, $C_6H_5CH_2OH$; density 1,045, boiling point 205–209°C, flash point 96°C. Colourless liquid with a faintly aromatic odour, sparingly soluble in water but readily soluble in alcohol and ether. Oxidizes slowly in air to form benzaldehyde (odour of bitter almonds). Uses: as a swelling agent and solvent (when heated) for acetate (pigment and metal powder printing); as a solvent for cationic dyes; as a component in fat-solubilizing soaps, etc. because of its good hydrotropic properties.

Benzylating agents Used as printing auxiliaries in discharge printing with vat dyes to form water-soluble benzylated products and leuco compounds which can be easily washed out.

BEP → Break even point.

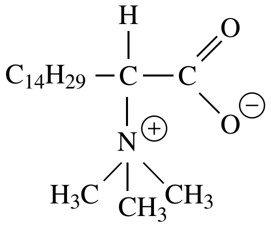
Berber carpets Rustic knotted carpets in natural colour, hand-woven by North African tribes from wool yarn spun by hand from local sheep. They contain a proportion of naturally pigmented wool and may bear simple tribal motifs. The term has also been used in recent years to describe manufactured carpets made from natural coloured wools, or dyed fibre, with a homespun appearance.

Berberine (barberry) → Natural dyes.

Berlin blue (Prussian blue, Paris blue, Turnbull's blue). Hexacyanoferrates (II) and (III). A dark blue solid which is soluble in oxalic acid. Yields a vivid blue which has been used for the blueing of bleached goods. Resistant to light and acids but very sensitive to alkalies.

BESA, abbrev. for: British Engineering Standards Association. → Technical and professional organizations.

Betaine (trimethylglycine). An intramolecular ammonium salt (amphoteric) as a trimethyl derivative of → Glycine. White crystals with a neutral reaction, readily soluble in water, are stable to the action of acids even at high temperatures. Uses: pasting auxiliary either as an addition to the dye itself or to the prepared print paste mixed with glycerol. Substitution of one of the neighbouring hydrogen atoms to the carboxylate group with a long aliphatic chain yields interesting capillary-active textile auxiliaries, e.g.:



Sulphobetaines are formed by substitution of the COO^- group in betaine by the SO_3^- group. The higher molecular weight products are interesting wetting and washing agents whilst the lower molecular weight types are also useful hydrotropic solvents for vat dyes and dispersing agents in dyeing and printing (accelerated fixation, reduced steaming times).

Beta-naphthol (2-naphthol, 2-hydroxynaphthalene, red developer), $C_{10}H_7OH$, MW 144, density 1,21. White lustrous, bulky leaflets or white powder (turns brown on exposure to air) with a phenolic odour. Almost insoluble in water (approx. 1:1000 in cold water; approx. 1:75 in hot water), dissolves readily with its own weight of 33% caustic soda liquor in hot water. Readily soluble in alcohol, ether, chloroform, glycerol, benzene, etc. Concentrated solutions cause skin irritations and inflammation. Uses: developer for navy blue, red, brown, blue and black diazo dyes on cellulosic fibres.

Beta rays → Radioactive emission.

Betriebswirtschaftsstelle Wäscherei-Chemischreinigung (BWC) Industrial laundry and drycleaning management bureau in Germany. → Technical and professional organizations.

BF, official French abbrev. for: “Brevet Française” (French patent).

BFTC,

I. British Fastness of Textiles Committee

II. Belgian Fastness of Textiles Committee.

BHES Abbrev. for → Bis (β-hydroxyethyl) sulphone.

Bi, chemical symbol for bismuth (83).

bi- (or di-). Prefix (Lat.: *bis* = twice or two) used in words such as bicomponent fibres, bifilar, bichromate, etc.

BiAS, abbrev. for → Bismuth active substance.

Biaxial fabric Conventional fabric construction consisting of 1 warp thread system and 1 weft thread system.

Bibibaff The finest quality of → Bakhtiari carpets, with a single weft thread construction.

Bichromate → Potassium dichromate.

Bichromate aftertreatment Treatment to improve the wet fastness properties of selected direct dyes.

Bichromate/copper sulphate aftertreatment Treatment given to selected direct dyeings in order to improve the wet fastness and light fastness properties.

Bichromate of potash → Potassium dichromate.

Bicoflex balanced pressure rolls Flexible elastic padder rolls. The pressure applied in padders with normal rigid rolls is, of course, greater at the edges than in the centre since bowing occurs through lever action due to the application of pressure at the two ends only. This causes edge-to-centre shade variations in continuous dyeing. The Bicoflex roll, (Figs. 1 + 2), on the other hand, consists of a fixed load bearing axle with bearings at each end. Pressure pads are mounted across the full width of the load bearing axle and around its circumference. Each pressure pad is connected to a compressed air supply to provide individual pressure control against the articulated sleeve. Supported on rollers on top of the air-cushioned rubber pads is the flexible outer sleeve which carries the removable shrunk-fit rubber working sleeve. Bicoflex rolls can also be retrofitted into existing padders. Manuf.: Ramisch-Kleinewefers.

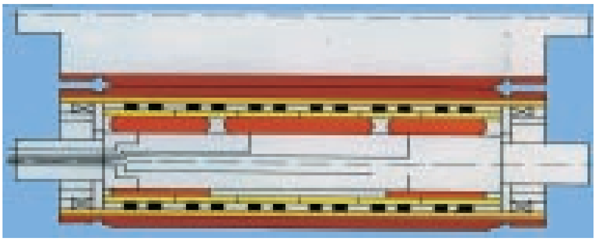


Fig. 1: Bioflex-System (Kleinewefers KTM).

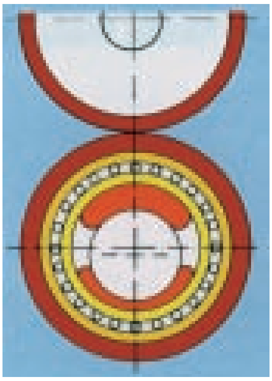


Fig. 2: Inside of a Bioflex-cylinder (Kleinewefers KTM).

Bicomponent fabric crimping → crimping methods.

Bicomponent fibres (bilateral fibres, composite fibres). Man-made fibre combinations composed of 2 distinct and insepararable polymer components having different chemical or physical structures joined together as single fibres either in layers side-by-side or in mixtures with a homogeneous distribution (matrix-fibril types). Bicomponent fibres are products of spin-texturing from the bifilar spinning of heterogeneous spinning solutions (2 different polymers having different shrinkage properties or different solution concentrations of the same polymer), e.g. 2 different acrylic polymers or combinations (acetate/polyacrylonitrile; polyamide 6/polypropylene; polyamide 6,6/polyester, etc.). The various types of bicomponent fibre are classified as follows (see Fig.):

- S/S (side-by-side) having a “bilateral structure” as in wool.
- C/C (centric cover/core) or core-sheath types.
- M/F (matrix-fibril) or fibril/matrix bicomponent fibres, sometimes referred to as biconstituent fibres.

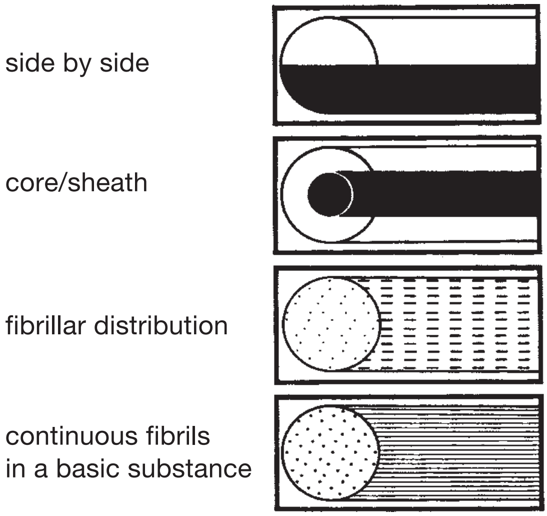


Fig.: Biocomponents fibre structures and cross-sectional forms of synthetic fibres.

According to American convention, only types S/S and C/C qualify for description as bicomponent fibres. Bicomponent fibres having a very wool-like character with a permanent spiral crimp and further combinations of properties are formed after e.g. a simple thermal aftertreatment. Fibres produced e.g. by the combined polymerization (multi or copolymerization) of two monomers, as well as → Heteroyarns are not considered to be bicomponent fibres. The M/F types are, in the widest sense, also bicomponent fibres and consist of very fine fibrils (either continuous or distributed as short fibrils) embedded in a matrix structure. They are also described as biconstituent fibres and are of increasing importance. Up to the present time, however, the S/S types, in which both components are joined excentrically and continue along the entire fibre, are of the greatest importance economically. For this purpose, the components are carefully selected to react in different ways to the effects of heat and moisture or to a combination of both. As early as 1953, such bicomponent-like fibres were already described by Horio and Kondo from the detection of paracortex and orthocortex layers in dyeings of wool fibres. In bicomponent fibres a crimp, which may be reversible or irreversible, is formed by the different reactions of both fibre components to heat and/or moisture. A reversible crimp is lost on washing and regenerated again on subsequent drying. In the case of irreversible crimp, a spiral crimp is developed which becomes permanently set through relaxation of the differential shrinkage potential of both components during the first treatment at high temperature in a dry or moist state. A crimp developed in this way remains largely constant during subsequent dry and wet treatments unless the temperature limit used for the original development of crimp is significantly exceeded.

A reversible crimp, on the other hand, which is lost during wet treatment and can be restored again on subsequent drying, is produced by a different mechanism. The difference in shrinkage results from a reversed swelling of both components; e.g. wool and ionically-modified polyacrylonitrile fibres are typical reversible bicomponent crimp fibres. The latter contain different concentrations of hydrophilic groups in both components. These can cause significant drawing forces to be released at high temperatures in the wet extended state without their final crimp potential being impaired. In this case, the crimp returns on drying which is why decrimping is controlled solely by free movement or tensile forces during the drying process. This is of great practical importance since reversible crimp bicomponent fibres are processed, e.g. under high tension conditions as in package dyeing, and yet their full crimp potential can still be developed during a subsequent tension-free drying operation.

The purpose of all bicomponent crimping is to develop bulk, crease recovery properties and elasticity in yarns and fabrics besides conferring numerous handle variations on textile fabrics.

Bicomponent yarn Spun or filament yarn of two generic fibres or two variants of the same generic fibre. → Textured yarns.

Biconical package A conical yarn package in which the traverse length is progressively reduced to produce tapered or rounded ends; such packages are also described as tapered or → Pineapple cones.

Biconstituent fibres → Bicomponent fibres of the matrix-fibril (M/F) type.

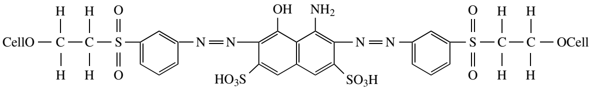
Bielastic, 2-dimensional → Elasticity in knitted textile fabrics.

Bifilar (bi = two; fil = fibre, filament, yarn). A term used for:

I. → Bicomponent fibres/filaments manufactured by bifilar spinning, e.g. the production of polyamide/polyester simultaneously, side-by-side without blending from the same spinneret hole, accompanied by final adhesion to produce a double filament. This is an example of real spin-texturing.

II. In the sense of two thin threads (instead of one thicker one), e.g. as used in knitting/warp-knitting for the production of dimensionally stable, long-lasting men’s underwear (double-thread circular knits).

Bifunctional A term used to describe certain kinds of reactive dyes, i.e. with two reactive groups in the dye molecule. The reactive groups may be identical or possess different reactive properties. Such dyes are also described as → Double anchor types.



C.I. 20 505 reactive black 5 bonded to cellulose

Crosslinking agents containing fibre reactive groups (reactant finishes) are at least bifunctional as well.

Bijar carpets Very densely knotted boardlike stiff carpets from the Persian town of the same name. Naturalistic designs with floral motifs often in a formal interpretation. The ground shades are dark: dark blue, cherry red, bottle green but sometimes camelhair colour, while the colours used for the designs are very vivid. The close-cut pile (10–12 mm high) is of high quality lustrous wool. Approx. 180 000 Turkish knots per m^2.

Bilateral (Lat.), having or involving two sides.

Bilateral fibres → Bicomponent fibres.

Bilateral structure of fibres, relates to the cortical layer present in the structure of wool consisting of the para and orthocortex, as well as the different polymer structure in the cross-section of cotton fibres. Silk which has not been degummed also reveals a bilateral structure.

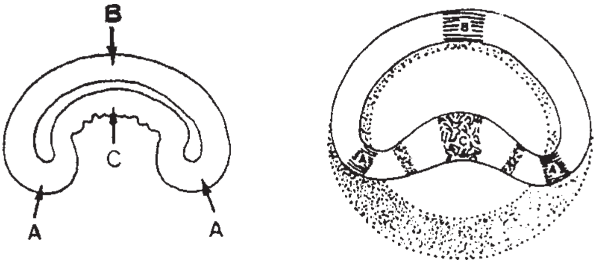


Fig. 1: Bilateral structure of cotton (Kassenbeck).
A = most highly ordered; B = densely packed; C = disordered.

I. Bilateral structure of cotton (Fig. 1): After completion of biosynthesis, cotton is present in the fruit capsule as a cylindrical fibre. The capsule breaks open and the young fibres undergo a drying process. Kassenbeck was able to show that the fibre collapses characteristically depending on its origin (maturity, provenance, fineness), to form the well-known kidney-shaped cross-section. (Another assumption is that the collapsed fibre actually grows in that state). During this collapse (original drying) asymmetrical mechanical tensions are built up that are responsible for zones having different densities. Radial strains acting through compressive forces result in an increased packing density of the fibrils and a parallel alignment of fibril layers in the convex area of the collapsed fibre. The concave internal fibre wall suffers a reduced degree of order due to the compressive forces which act tangentially. From a macroscopic viewpoint, this bilateral structure of the fibre is responsible for the different accessibility of the various fibre regions. This is the reason why e.g. during enzymatic hydrolysis of the fibre (a process, like all finishing treatments, which is associated with a swelling of the fibre wall) the disordered concave region is broken down preferentially; the remaining convex region is only dissolved at a very advanced stage of the hydrolysis. Kassenbeck also showed that this concept also has consequences for fibre crosslinking with formaldehyde. After crosslinking, it was indeed found that far more linkages had been formed in the concave region of the fibre due to its greater accessibility; due to the high degree of swelling during crosslinking, however, the linkages formed were mainly interfibrillar. In contrast, the degree of swelling and accessibility in the convex region of the fibre was so slight that only few (interfibrillar) linkages were formed. These were nevertheless very effective in relation to the desired mechanical stabilization of the fibre. A disadvantage of this aspect of the crosslinking process is the reduction in strength of the already strong convex region of the fibre due to its high degree of orientation. Since the strength of the disordered concave regions is not changed by crosslinking, i.e. undergoes no improvement, the total strength of the fibre decreases.

Kassenbeck has demonstrated that, from a macroscopic viewpoint, swelling of the fibre is dependent on the swelling agent used. Thus, e.g. it was established that, in contrast to sodium hydroxide solution or morpholine, caesium hydroxide has a specific swelling action on the concave regions of the fibre.

II. Bilateral structure of viscose fibres: The usual staple fibre types based on regenerated cellulose fibres in a not very stable crimped form have been known for a long time. In recent years, however, new technologies have been developed, based on special coagulation, regeneration and drawing conditions, which have led to the production of viscose fibres with a "living" reversible crimp. This special spinning technology has the effect of causing the primary external mantle of the newly-spun fibres, formed in the spinning bath during the fibre forming and drawing stages, to tear in small places so that the still plastic fibre core can spread many times along the fibre capillaries to the fibre surface. As a result, a kind of bicomponent structure is formed (→ Bicomponent fibres) in which the elongation and swelling properties induced by the variable fine struc-

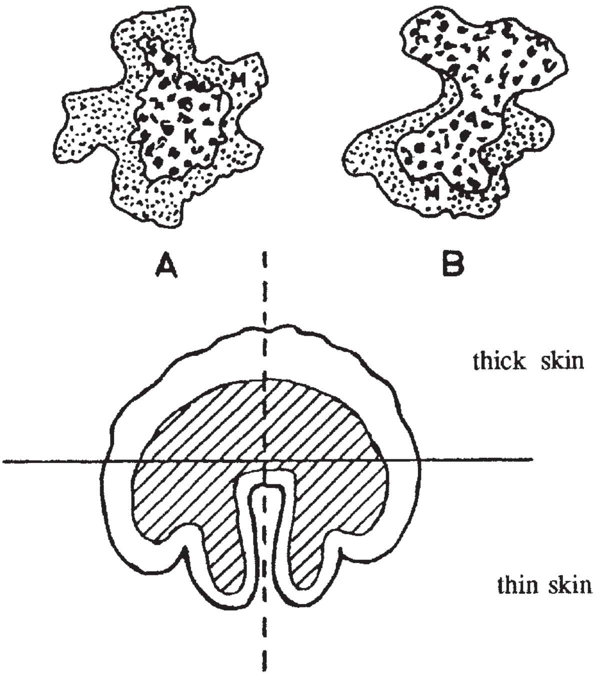


Fig. 2: Bilateral structure of viscose fibres.
Cross sectional structures of normal viscose fibres (A = cord/ sheath; B = highly crimped biocomponent fibre) as developed in accordance with the original Horio and Kondo concept (below) (thick skin = undyeable; thin skin = dyeable).

ture of the core/mantle regions give rise to a latent crimp capacity and crimp recovery properties. The crimp formed in this way is distinguished by the simultaneous presence of overlapping macro and microcrimp characteristics which give these fibres their specific properties. Bicomponent viscose crimp fibres (Fig. 2) were first produced by Horio and Kondo as soon as they had applied the bilateral concept of wool fibres and proved that the existence of the orthocortex and paracortex in wool was responsible for its crimp characteristics.

III. Bilateral structure of wool: In 1953 the Japanese researchers Horio and Kondo found that the cortex of wool fibres does not have a uniform structure but consists of two chemically somewhat different halves, namely the orthocortex and the paracortex. The two portions can be made visible by differences in swelling under the polarizing microscope or by differences in staining. The orthocortex has a higher affinity for cationic dyes, e.g. Janus green or methylene blue. Staining with Rhodamine B is also suitable. The distribution of these cell types within the cortex is variable and extends from a bilateral axial asymmetry to a radial symmetry. The extreme is found in fine, highly crimped merino wool where a characteristic subdivision of the cortex into approx. equal corkscrew-like ortho- and paracortex components lying side by side and intertwined with each other can be observed. The other extreme is encountered in coarse wool sorts, e.g. Buenos Aires wool and Lincoln wool, which are not so highly crimped and in which a core of orthocortex is surrounded in a tube and sheath configuration by the paracortex. Human hair, on the other hand, consists almost entirely of paracortex and the slightly wavy kid mohair almost entirely of orthocortex (Fig. 3). From the finer more highly crimped to the coarser slightly crimped fibres, distribution of the ortho and paracortex changes correspondingly from the merino type with a bilateral asymmetrical structure to the coarse wool type with a centrally arranged orthocortex. In general, therefore, a low

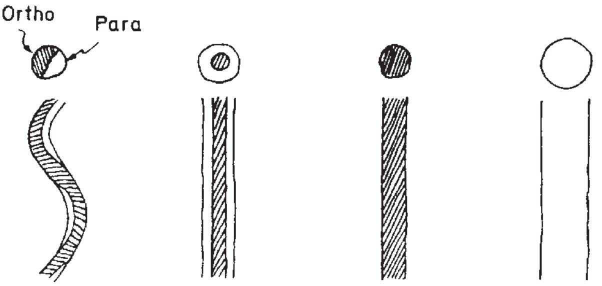


Fig. 3: Cortex forms in keratin fibres with and without bilateral structure.
from left to right: merino wool, Buenos Aires wool, kid mohair, human hair.

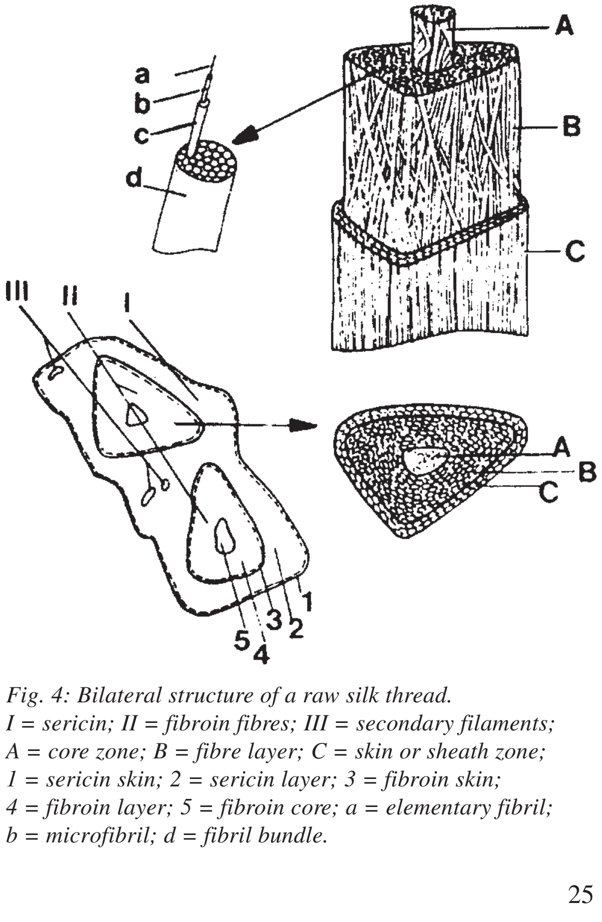


Fig. 4: Bilateral structure of a raw silk thread.
I = sericin; II = fibroin fibres; III = secondary filaments; A = core zone; B = fibre layer; C = skin or sheath zone; 1 = sericin skin; 2 = sericin layer; 3 = fibroin skin; 4 = fibroin layer; 5 = fibroin core; a = elementary fibril; b = microfibril; d = fibril bundle.

degree of crimp corresponds to a more symmetrical arrangement of both components. The orthocortex cells exhibit a distinct subdivision in macrofibrils whilst the macrofibrils in the paracortex appear to have indistinct limits. It has been found that the content of the amino acid cystine is greater in paracortex cells and therefore the paracortex is chemically more stable due to the higher degree of crosslinking.

The high crimp of the merino fibre is consequently due to its peculiar bilateral structure in which one half of the cortex is always found on the inside of the crimp curvature and the other on the outside. The crease recovery of wool fabrics in a moist environment can also be attributed *inter alia* to this phenomenon. Since one half of the cortex swells more than the other because of its somewhat different chemical structure, and to the extent that changes in moisture induce fibre movement and permit recovery of deformations during wear, such changes cause one half to increase in volume more than the other, thereby displacing the other firmly attached half from its position.

IV. Bilateral structure of silk (Fig. 4): Silk also exhibits a bilateral structure before degumming. The two filaments of fibroin are spun together within the sericin so that the fibre cross-section exhibits a distinct double core-mantle structure.

BIL crease-resist process (built-in lubrication). Crosslinking process to preserve the natural mechanical properties of cotton by incorporating stearyl derivatives of 1,3-dichloropropanol-2.

Billinghame's test A test for distinguishing between abaca and sisal. The test, devised by Swett, for the differentiation of abaca (manila) from other fibres used in rope manufacture has certain disadvantages. These are the uneven staining effect, the difficulty in distinguishing at a glance between the colours produced, and the tendency of the colours to fade. The method of applying Billinghame's test is as follows.

1. Wash the sample with methylene chloride to remove oil, and allow to dry.
2. Boil the sample in 5% nitric acid for 5–10 min.
3. Wash out the excess acid with water and immerse the sample in cold 0,25n sodium hypochlorite solution for 10 min.
4. Remove the sample and dry it.

Abaca assumes an orange colour, whereas sisal and other leaf fibres are stained a pale yellow colour.

Bimetallic strip Two metals having different coefficients of expansion riveted, brazed or welded together in the form of strip or wire: an increase in temperature of the strip causes it to bend, the metal having the greater coefficient of expansion being on the outside of the curve. One end is rigidly fixed and movement of the other end can serve to open or close the electric circuit of a temperature control device, or to move the pointer of a pointer-type thermometer.

Bimli jute → Kenaf.

BIN Belgian standards association. → Technical and professional organizations.

Binary Consisting of two components, e.g. of 2 fibres (cellulose/polyester); of 2 solvents (water/alcohol); or chemical molecules composed of 2 elements (CH_4, H_2O, NaCl).

Binary decision A decision between 2 known states, e.g. the two possibilities "yes" or "no", or in telegraphy "character" and "pause" or "current" and "no current" etc. The term → Bit, is derived from "binary digit" (binary code).

Binder and crosslinker combinations for pigment printing In the pigment printing process, pigments are fixed on a textile material with the aid of binders. For this purpose, redispersible condensation binders are employed to produce pigment prints with satisfactory colour fastness for normal usage.These binders are high molecular weight products, i.e. long-chain organic compounds. The softness of the binder film is directly related to the respective glass transition temperature (T_G) or second order transition temperature. This temperature characterizes the transition from a glassy solid to a plastic material. A soft film at room temperature therefore has a low glass transition temperature (see Table).

	film characteristics			
		swells in		glass temperature
monomer		H_2O	LM	T_G ° C
styrene	hard	no	yes	+ 100
acrylate				
(methyl residue)	hard	no	somewhat	+ 5
(butyl residue)	soft	no	yes	– 54
acrylonitrile	hard	no	no	+ 97
vinyl acetate	hard	scarcely	somewhat	+ 32
butadiene	very soft + elastic	no	yes	cis - 102 trans. - 58
methacrylic acid	hard	yes	no	+ 106
acrylamide	hard	somewhat	no	+ 165
ethylene	soft	no	yes	- 125
propene	soft	no	yes	- 8 b. - 13
(di-)chlorethylene	hard	no	yes	+ 81

Tab.: Properties of homopolymers as binder and cross-linker combinations for pigments prints.

Copolymers are produced from these monomers which represent the best possible compromise with regard to their properties since these, in turn, determine the properties required of the actual binder films (linking together of materials by adhesion) and cohesion (the internal molecular cohesion of a substance), softness and elasticity, resistance to hydrolysis, thermoplasticity, ease of fixation, resistance to solvents, stability to light and resistance to ageing. During polymerization, the monomer units are added together to form solid materials which, after completion of polmerization, are present in the aqueous phase (at concentrations of approx. 40–50%) in a finely dispersed state (particle size approx. 100–400 nm). The majority of such binders are acrylate and butadiene binders. The first group have the highest stability to light. Butadiene binders, on the other hand, whilst producing binder films of excellent softness, do not have satisfactory light resistance owing to the action of light and/or heat on the double bonds still present in the polymer which leads to embrittlement and discoloration (browning) of the binder film.

An important requirement for textile printing binders is the balance between ashesion and cohesion. The adhesion of binder film/substrate should be as high as possible with good binder cohesion at the same time. If adhesion is too weak, unacceptable marking of the prints occurs on rubbing. If cohesion is too weak, the pigment particles are detached from the binder film relatively easily on rubbing.

Binders for textile pigment printing contain self-crosslinking free methylol groups which are protected against premature crosslinking by esterification. During drying, film formation of the binder occurs in 2 stages. In the first stage, water and emulsifier are removed from the binder resp. the pigment print by evaporation and capillary action of the fibre whereby the dispersed materials (binder, pigment) coagulate to form an unstable gel layer. In the second stage, the gel layer merges to form a film which, from this point on, bonds (even though loosely) with the textile material. Only after subsequent crosslinking (fixation) does the binder film develop its full adhesion to the substrate and its elastic extensibility. The crosslinking reaction proceeds under acidic conditions (pH < 4) by elimination of water and alcohol to form a 3-dimensional structure. The best fixation medium is hot air treatment at e.g. 150°C for 5 min. (or at 175°C for 45–60 s). Wet steam is not suitable as a fixation medium. Fixation in superheated steam (HT steam) is also less suitable than hot air since only a 60–80% fixation yield is achieved in this case due to partial hydrolysis (HT steam consists exclusively of water vapour).

An additional crosslinking of the binder film is achieved with the aid of so-called external crosslinkers of the esterified melamine type in accordance with the same (condensation) principle (see Fig.). Wet fastness properties, especially on synthetic fibres and their blends with cellulosic fibres, are improved by this further crosslinking although it is accompanied by an increased stiffening of the prints. Due to this undesirable effect on handle, the quantity of crosslinker applied should be limited only to that amount which is absolutely necessary. The binder film, in which the pigment particles are embedded, has a layer thickness of only 8–10 µm, a dimension which is not visible to the human eye. Adsorptive bonding forces are responsible for adhesion between the binder film and the fibre (Wigger).

Binder fibres, are used for the manufacture of composite textiles resp. nonwovens. Synthetic fibres with thermoplastic properties (preferred temperature range 160–190°C) or which are soluble or capable of swelling in specific solvents are used for this purpose. They may be subdivided into the following categories:

1. Soluble binder fibres such as polyvinyl alcohol and alginate fibres.
2. Meltable binder fibres such as copolyamide, bicomponent, copolymer thermoplastic fibres with low melting points. These can function as an adhesive in a web because their softening point is relatively low compared to that of the other fibres in the material.
3. Adhesive binder fibres such as cellulosic fibres (capable of swelling in alkaline solutions) and undrawn polyester fibres which already become tacky at 80°C, shrink markedly and develop their bonding effect under the action of heat and/or moisture in thermo-bonding plants or a hot calendering treatment, etc.

Binder film A film of → Synthetic resin resp. polymers formed around the individual fibres of a textile fabric in pigment printing, and in which the coloured pigment is embedded.

Binder prints on polyester (pigment print) Normally reveal lower rubbing fastness as compared with cotton, since here the binder is surface-abraded, and

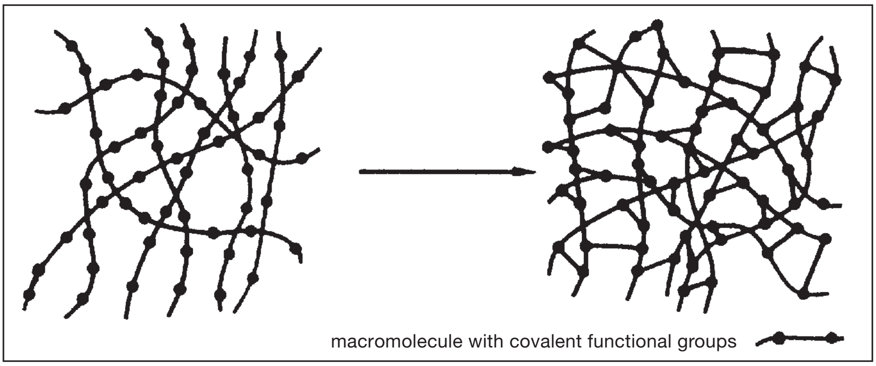


Fig.: Binder film cross-linking in pigment printing.

drawn out from the fibre interior (polyester binder dyeing appears surface blank abraded), while, with cotton, adequate residual binder quantities remain in the fibre cavities (cotton binder dyeing with preserved impression). Fig. 1 shows schematically the distribution and stripping of binder prints on polyester and cotton.

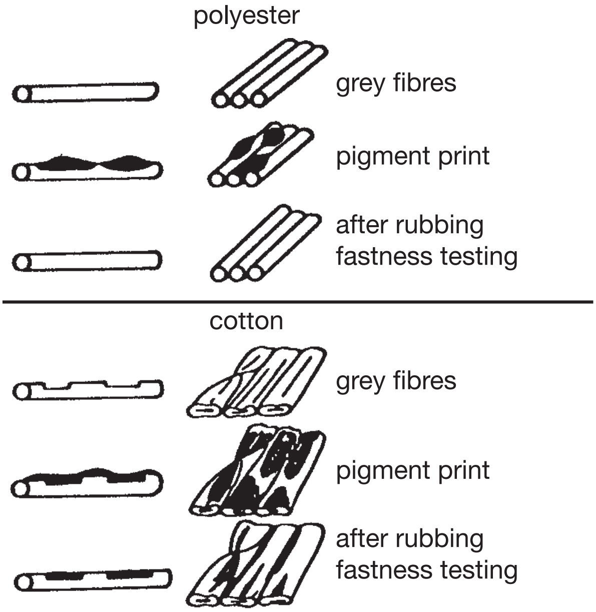


Fig. 1: Deposition of binder in pigment printing on polyester and cotton (Herrlinger).

Mechanical anchorage of the binder film (Fig. 2) can be brought about by the surface modification of chemically raised polyester fibres, by means of which binder print fastnesses identical with those of cotton can be produced.

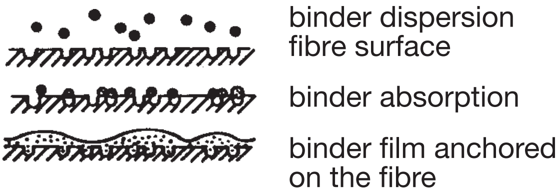


Fig. 2: Embedding of binder and pigment in the pigment printing of alkalised polyester fibres (Herrlinger).

Binders Organic polymer products used for the fixation of pigment prints/dyeings and as adhesive bonding agents for web consolidation in the manufacture of stable composites and nonwovens. They are mainly solid plastic products (e.g. thermoplast powders), plastic solutions and dispersions (also including reactive types, e.g. acrylic ester copolymers). Binder additives based on N-methylol compounds, fatty acid derivatives and polyethers, etc. have binder regulating and/or modifying functions, e.g. for the achievement of elastic resilience, flexibility, absorbency, drycleaning fastness, etc.

Binders for nonwovens Besides thermoplastic materials which, either as fibres or granules (powder bonding) contained in the batt, function as adhesives when the batt is hot calendered, aqueous polymer dispersions are mainly used for the bonding of nonwovens. Actual solutions of binders in water or organic solvents are very seldom used.The main types of polymers, in the form of aqueous dispersions, for these applications are:

- acrylic ester copolymers and homopolymers,
- butadiene-acrylonitrile copolymers,
- styrene-butadiene copolymers,
- chloroprene polymers,
- vinyl chloride polymers,
- vinyl acetate polymers,
- vinylidene chloride polymers,
- natural latex.

The overall properties profile of nonwovens manufactured with the aid of the above-mentioned polymers is influenced to a considerable extent by the type of binder used. Thus, for example, the thermo-bonding of nonwovens based on cellulosic fibres may be carried out if an extremely thermoplastic polymer such as, e.g. polyvinyl chloride or polyvinyl acetate is used.

The choice of binder is dependent on the end-use of the nonwoven material. A wide range of nonwovens is produced by adhesively bonding the individual fibres in the batt with the aid of polymers. In approx. two thirds of all adhesively bonded nonwovens, the actual bonding of fibres in the contact areas is achieved with binders applied in the form of aqueous dispersions. In the remaining cases, the bonding polymers are applied in fibre (→ Binder fibres) or powder form. For the application of polymers dispersions in the bonding of nonwovens, the primary concern is the influence of the respective binder type or dispersion composition on the character of the bonded nonwoven.

This important relationship between dispersion or binder composition and the character of the nonwoven can only be clearly established when the physical and chemical criteria of polymerization on the one hand, and those of the dispersed polymer on the other, are defined. Three temperature ranges are important for thermoplastic polymers:

1. The transition or softening temperature, also known as the first order transition temperature or glass transition temperature: at this point the plastic material is transformed from the solid to the thermoelastic state. This temperature range can be lowered by, e.g. internal softening (copolymerization) or external softening (plasticizer addition).
2. The flow or melting temperature range: at this point

the plastic material is transformed from the thermoelastic to the thermoplastic state.

3. The decomposition temperature: at this point irreversible decomposition of the thermoplast takes place due to thermal decomposition (carbonization).

The glass transition temperature (T_G) provides a great deal of information on the use of thermoplasts as binders for nonwovens. In the first place, it indicates the relative hardness or softness of the polymer. Thus, a high T_G signifies a harder, a lower T_G (–20°C) signifies a softer, and an even lower T_G (–30°C) signifies an adhesive binder film. The T_g is measured by differential thermal analysis. A high T_G also signifies a minimum film-forming temperature. The T_G influences the properties of the bonded nonwoven in various ways. For example, inferences can be drawn from it with regard to the handle of the nonwoven although, in this connection, other factors such as, e.g. the chemical composition of the binder and its additives have a decisive influence here. A relationship between T_g and the dry tensile strength of the nonwoven can also be seen.The T_G can be changed by copolymerization or external plasticizing (e.g. with dibutyl phthalate). Conversely, binders with the same T_G can be obtained from different copolymer compositions (see Table).

binder monomer	T_G (°C)	polymer film character	application method	use
methyl methacrylate	+107	brittle ↑		
acrylonitrile	+105			e.g. nonwoven wadding, filter wadding, needle felt ↓
styrene	+100		↑	
vinyl chloride	+ 83	↓		↑
vinyl acetate	+ 29	hard ↕	spray ↓	milk filters ↓
methacrylate	+ 6	soft ↑	↑	↑
ethyl acrylate	– 24	↓	impregnate ↓	most intensive use ↓
butyl acrylate	– 55	very soft ↑	↑	
butadiene	– 78	↓	stick	adhesives
ethylene	–125	viscous	↓	↓

Tab.: Dependency of T_G and its deducible properties on binder monomer type.

From the number of individual components in the recipe, the preparation of vulcanizable latex mixtures appears to be very complicated. On the other hand, a self-crosslinking polymer dispersion is much simpler to prepare since, as a rule, it only has to be diluted with water. Nevertheless, vulcanizable systems have a range of advantages which self-crosslinking systems are unable to offer. One of the most important advantages has to be the possibility of separating the drying and crosslinking stages from each other. This property makes it possible to manufacture both very thick materials by pressing before vulcanization under pressure as well as specially shaped products by permanent moulding during vulcanization. Technical nonwovens, in particular, are manufactured with vulcanizable latex mixtures. Interesting properties are also achieved with vulcanizable binder mixtures. Such mass-produced articles as disposables or hygiene products are not a field for vulcanizable latex mixtures. Specialized fields such as, e.g. the filtration sector, however, offer a wide range of applications especially when additional requirements for environmental protection are taken into account, e.g. where chemicals, dusts, oils and fats, in particular, must be separated from industrial exhaust air and waste water by filtration methods (partly contributed by Loy).

Binding (edging). Usually a broad tape used as a → Trimming, e.g. as a decorative border for underwear, aprons, national costumes, etc.

Bioactive Term used to describe the function of biologically active substances, e.g. → Biodegradation of surfactants and → Biofouling. → Enzymes are also bioactive.

Biocatalysts → Enzymes.

Biocatalytic exhaust air cleaning in known washing processes for reducing contamination from exhaust air are either → Activated sludge processes used or biological lawns on packing material built. Both processes show in practice for the industrial user significant deficiencies. In particular sludge formation clogging danger and the behaviour/quality/retention of failing nutrition offer in times of plant standstill are some of the unfavourable aspects. By combination of physical absorbers (arranged filling material packets in counter current principle) with a biological carrier recycling water purification plant (Fig.) these disadvantages are avoided and in addition the supervision expenses are limited only to the mechanical part of the system. The contamination in the exhaust air is washed

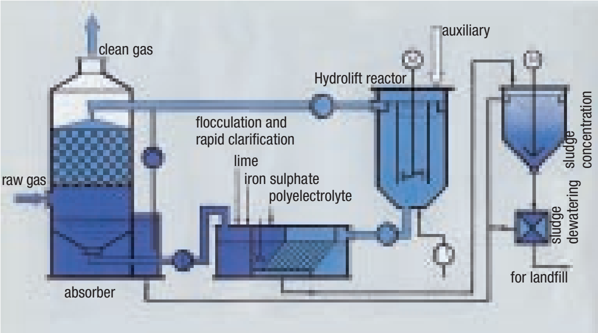


Fig. 1: Biocatalytic exhaust air treatment plant (from Arasin GmbH).

out in the counter current of water. The amount of liquid is adjusted according to the solubility of the contaminants as well as by the partial pressure of the substance in the gas phase and the partial pressure of the substance in the liquid. A part flow of the recycling water is removed continuously. Sand and solid particles are separated in a inclined clarifier; then follows the carrier biological oxidation in a hydrolift reactor. The water treated in this way is led directly back into the washer and recharged with contaminant.

The carrier biology of the activated charcoal offers even more advantages over fixation of bacteria in a reactor. To the possibility of accumulating, large amounts of oxygen contaminants are absorbed temporarily from the wash water. Activated oxygen and contaminants are then available to directly to the microorganisms fixed on the activated charcoal. Likewise exoenzymes are adsorbed on the carrier medium which are necessary for certain degradation reactions. By the immobilisation “bacterial specialists”, which otherwise have a slow rate of growth, also remain enriched, and so are available for substances that are difficult to degrade. The carrier material always remains in the reactor and is practically not used up at all. The reaction event is not determined by the adsorption capacity of the activated charcoal, but by the constant regenerating self oxygen active surfaces of the activated charcoal and the biomass fixed there. The complete, complex degradation process in the fluid bed can be simply summarised by the following reaction equation.

$$C_AH_BO_C + x\ O_2 \rightarrow y\ CO_2 + z\ H_2O$$

Biochemical oxygen demand (BOD) A standardized means of estimating the degree of pollution of water, especially that which receives contamination from sewage and industrial wastes. It is expressed as the quantity of oxygen (in mg) required during the oxidation of decomposable organic matter by aerobic biochemical action in 1 l of waste water. In practice the test is carried out over a period of 5 days at 20°C to give the so-called BOD_5 value which is used as a measure of organic pollution in waste water. A low BOD indicates low pollution whilst a high BOD indicates increased activity of heterotrophic microorganisms and thus heavy pollution. In an optimally functioning biological waste water treatment plant the BOD_5 value of waste water is reduced by 80–95%.

The BOD_5 value is determined in accordance with DIN 38 409 T51/05.87. In this test a series of waste water samples taken from, e.g. the main outfall of a waste water treatment plant, at different dilutions, is injected with oxygen-saturated water containing microorganisms. Optimum physiological conditions, as well as the supply of mineral nutrients, are prerequisites for a correct determination. A so-called nitrification inhibitor is added to the water in order to stop the biochemical oxidation of ammonium nitrogen, since otherwise the results obtained have poor reproducibility and may present problems in interpretation. Measurements of the oxygen concentrations are based on the cathodic reduction of dissolved oxygen on a metal surface in the limiting overload range at constant voltage (amperometric determination). → Chemical oxygen demand.

Biocoenosis A great number of animal and plant species live in a particular → Biotope; they form a living association. Thus, a biocoenosis is the population system of a particular biotope which, due to biological interdependence represents an associated structure (biocoenotic connection). This qualitative and quantitative structure is not only a collection of organisms *per se*, but the basic form of a diverse (heterotypical) collection of organisms that has adapted to a particular biotope. The terms biotope and biocoenosis are as closely related in → Ecology as a lock and key.

Biodegradable textiles Textiles are biodegraded as the final biological treatment in a chain of natural fibre polymer chemical processes (from the raw product via textile fabric production to finishing), when enzymatic breakdown processes of a complex type take place on the fibre polymers. Biological breakdown or biodegradation means the conversion of dissolved or solid substances by organisms into other compounds. Next to assimilation by means of photosynthesis, where dissolved substances are absorbed by the biota, the biological breakdown of organic compounds by micro-organisms like bacteria and fungi is the most important process. In this process, the organic substrates are oxidised, the micro-organisms using part of the released energy for reproduction. This type of respiration (frequently called mineralisation too) consumes oxygen, or, if that is not present, other oxidising agents like nitrates, sulphates or already partially oxidised organic compounds in the sequence reproduced in the illustration.

When a system containing little oxygen is charged with organic components (L) from domestic waste, the following reactions take place:

- oxygen exhaustion; as soon as all the oxygen has been consumed, anaerobic breakdown reactions occur in the subsequent sequence (decrease in free enthalpy):
- nitrate reduction (denitrification)
- reduction of manganese oxide
- reduction of iron hydroxides
- fermentation (e.g. alcohol fermentation)
- methane fermentation.

Other redox reactions are nitrogen fixation and nitrification. Most reactions are catalysed by micro-organisms (bacteria, fungi). The latter are present every-

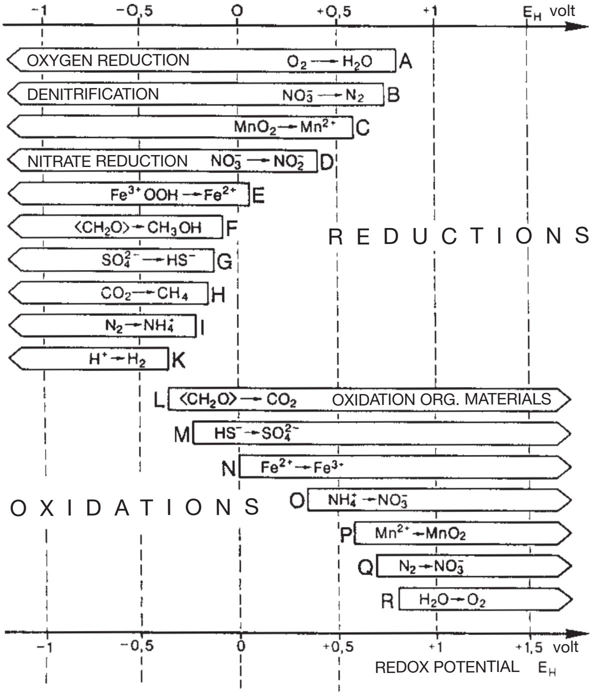


Fig.: Microbial redox process sequences, e.g. in the biodegradation of biologically degradable textiles (according to Kümmert and Stümm).

where, and multiply as soon as suitable reaction conditions are present.

Aerobic respiration: organic substances are oxidised, and oxygen is reduced. In the ideal case, oxidation results in carbon dioxide and water:

$$(CH_2O) + O_2 \rightarrow CO_2 + H_2O$$

Anaerobic respiration: organic substances are oxidised to carbon dioxide, and carbon dioxide is reduced to methane (methane fermentation):

$$(CH_2O) + {}^1/_2\, CO_2 \rightarrow CO_2 + {}^1/_2\, CH_4$$

or

$$(CH_2O) \rightarrow {}^1/_2\, CO_2 + {}^1/_2\, CH_4$$

with nitrate or sulphate:

$$4\,(CH_2O) + NO_3^{\ominus} + 2\,H^{\oplus} \longrightarrow 4\,CO_2 + NH_4^{\oplus} + 3\,H_2O$$

$$2\,(CH_2O) + SO_4^{\ominus\ominus} + 2\,H^{\oplus} \longrightarrow 2\,CO_2 + H_2S + 2\,H_2O$$

The active bacteria here produce enzymes, which, as biological catalysts, make possible (accelerate) the decomposition process. Of the large number of conditions which can interfere with the process of degradation, one can distinguish between two types of finishing chemicals:

1. Anti-catalysts in the form of adherent chemicals.
2. Chemical modifiers of the fibre materials themselves.

In the past, the textile industry has aimed to make finishing as fast as possible, i.e. to bond chemicals and dyes as fast as possible to the fibre, or produce effects against external influences (light, washing water, bacteria, air) by the most permanent finishing possible. Indicated by way of example is antimicrobial finishing, which is used to provide an anti-rot finish for natural fibre textiles. It is necessary to note in this connection that the targeted disposal of textiles by biodegradation, i.e. by biological breakdown, is conceivable only for natural fibres (wool, silk, cotton, linen [flax], and viscose as a semi-synthetic fibre). Synthetic fibres have to be disposed of in other ways; recycling (e.g. by remelting) appears appropriate for these polymers. If we want to pursue the goal of a biodegradable natural fibre collection over the long term, one has to have prior knowledge of textile logistics. The ways in which textile waste is ultimately disposed of have to be clarified. The importance of biodegradation, i.e. ultimate waste textile disposal in refuse by anaerobic (and to some extent aerobic) fermentation (destruction by micro-organisms, i.e. enzymatic hydrolysis as the main process) has to be established in this way.

a) Anti-catalysts or breakdown inhibitors: diverse finishing products, particularly metal-containing dyes, can be anti-catalysts for enzymatic breakdown which is inhibited in the case of textiles dyed or printed with such dyestuffs. If such substances are left out of account, there is a distinction between the biodegradability of these fibre-attendant substances by enzymes with a rough subdivision of the dyestuffs into azo and anthraquinone dyes. Azo dyes can be split by reducing-action enzyme systems, a fact which does not readily apply to anthraquinone dyestuffs. It is not enough just to break textiles down macroscopically, i.e. so that no fibre residues are to be seen; there may be low molecular substances (metabolites) from the textile material to be found in the ground water of the waste disposal site, which may be problematic in this form.

b) Chemical fibre modification: when natural fibres have been compelled to branch at points along the polymer molecules by reactive dyes or cross-linking agents (resin finishing for a low-crease finish) in a polymer-like way, biodegradation can be impeded at those points.

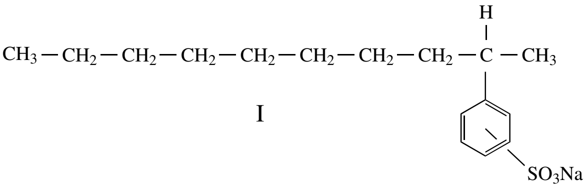
Before non-comprehensive studies on the biodegradation of current finishing products by micro-organisms are carried out, the goal of a biodegradable collection must be pushed a great deal further back. As the first step towards a production line with textiles which are the right target for feasible disposal, one should first of all fall back on such natural fibre products as have been carefully ecologically finished to the state of the art (i.e. with the minimum possible effluent and exhaust air pollution) and also with no significant residues on the fibre material. The equivalent dyestuffs should be as metal-free as possible, and dyeing should abandon brilliance and extreme fastness in order to avoid reactive dyes.

Biodegradation (→: Aerobic degradation; Anaerobic biodegradation). Biodegradation is generally understood to be the sum of all processes which reduce the load or concentration of polluting substances in water courses. As soon as biodegradable pollutants enter a water course the respiration rate increases through the reproduction of microorganisms which are universally available thereby reducing the load or concentration of pollutants. A succession of organisms is therefore built up. This heterotrophic activity is termed saprogenic (intensified decomposition of organic matter).

Organic carbon compounds may be broken down by aerobic biodegradation. Carbohydrates, proteins and fats biodegrade relatively quickly in waste water. Provided oxygen is available in sufficient quantity these substances are broken down into CO_2, H_2O and cell material. Nitrogen originally present in an organically-bound form is encountered as NH_4^+. A good assessment of the possibility for biological purification of a particular waste water can be made if details relating to the degradability of the respective pollutants are known. The following list of substance groupings with their biodegradability behaviour has been taken from Meinck et al:

- Saturated hydrocarbons: virtually non-biodegradable, some are toxic;
- Olefins with 5–7 C atoms: difficult to attack biologically;
- 1-chlorosubstituted hydrocarbons: non-biodegradable;
- Alcohols: readily biodegradable; exceptions are: tertiary butanol, amyl alcohol, pentaerythritol;
- Phenols: in general, readily biodegradable; chlorophenols are, however, less accessible, especially 2,4,5-trichlorophenol;
- Aldehydes: readily biodegradable after adaptation of the microorganisms; exception: benzaldehyde in higher concentrations;
- Organic acids, their salts and esters: readily biodegradable; exception: thio acids;
- Ethers: usually exhibit poor biodegradability or degradable only after adaptation of the microorganisms; exception: methylal (dimethoxymethane);
- Ketones: in terms of biodegradability these fall between organic acids, alcohols and aldehydes on the one hand, and ethers on the other;
- Amino acids: biodegradable almost without exception; exceptions: cystine and tyrosine;
- Amines, amides: readily biodegradable are: monoethanolamine, ethylene diamine, acrylamide, di- and triethanolamine, pyridine, picoline, acetanilide; difficult to biodegrade are: thioacetamide, morpholine, acetyl morpholine;
- Cyano compounds: in concentrations up to 50 mg CN/l biodegradability is usually good after adaptation of the microorganisms;
- Unsaturated compounds: readily biodegradable: allyl alcohol, acrylamide, crotonaldehyde, butadiene, styrene, cinnamic aldehyde;
- Synthetic detergents, alkylaryl sulphonates: with straight side chains in concentrations up to 150 mg/l these still exhibit good biodegradability after adaptation of the microorganisms;
- Alkyl sulphates: easily biodegraded;
- Fatty acid alcohols: easily biodegraded;
- Carbohydrates: simple as well as high molecular weight carbohydrates such as, e.g. dextrin and starch are easily biodegraded.

Biodegradation of surfactants, by means of bacterial oxidation involving the action of aerobic and anaerobic bacteria. Soaps, fatty alcohol sulphonates, alkylbenzene sulphonates with unbranched carbon chains, alkyl poly (oxyethylene) sulphates, fatty acid condensation products and saccharose fatty acid esters are readily biodegradable. In general, surfactants with straight C- chains (= “soft”, formula I) are biodegradable whilst surfactants with branched C-chains (= “hard”, formula II) have very poor biodegradability such as, e.g. alkylarylsulphonates of the tetrameric propylenebenzene sulphonate type:



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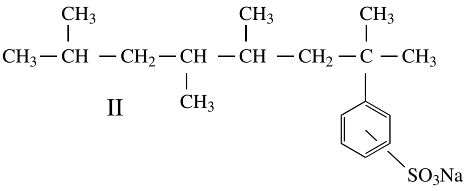
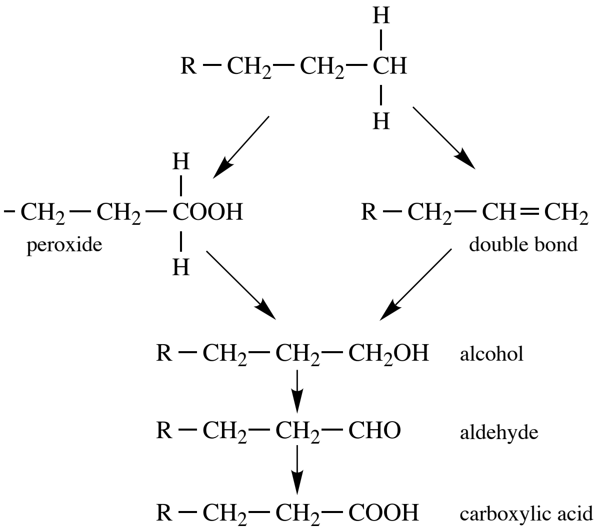


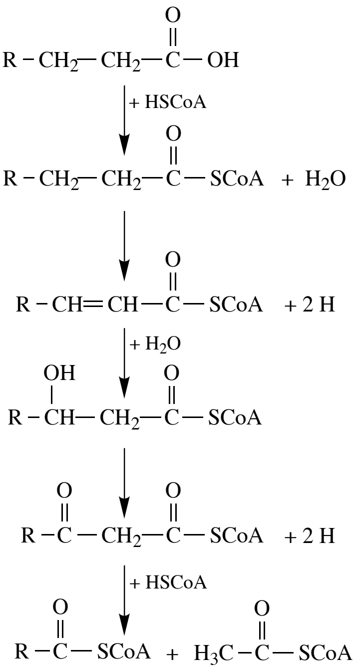
II

Of decisive importance for the degradability of surfactants are their hydrophobes. On the other hand, the hydrophilic groups of surfactants (hydrophiles) have less influence on degradability, although they are important for water solubility (as a water transport medium for bacteria cells). In general, the process starts out from an attachment of hydrophilic parts of the surfactant molecule to the enzyme and oxidation begins at the ends of the chains. There are two possibilities for the biochemical oxidation of chain molecules: ω-oxidation and β-oxidation. The ω-oxidation begins at the hydrophobes (greater than C_6), and β-oxidation at the carboxyl group in the presence of coenzyme A. Expressed with the aid of chemical formulae the reactions proceed as follows:

ω-oxidation:



β-oxidation:



No biodegradability problems exist in the case of anionic surfactants. Alkylbenzene sulphonates as well as alkane sulphonates and α-olefin sulphonates are biodegradable up to 90% and more. The question of metabolites arising from these products and the associated problem of remineralization have also been adequately answered. The same applies to the group of fatty alcohol sulphates, fatty ether sulphates and the alkyl phosphates. Even in the case of nonionic surfactants, straight-chain and partially branched-chain alcohol ethoxylates meet the requirements of the German Detergents and Cleaning Agents Law; i.e. they are more than 80% biodegradable. → Surfactant biodegradability tests.

Biodegradation of textile chemicals The long-term biodegradability of textile chemicals is a subject of great concern to the textile industry and the determination of their biodegradability is therefore very important. The biodegradability of a few chemicals, dyes and plastics in common usage by the industry has been determined over a 30-day period (BOD_{30}) in accordance with the method described below. A solution containing 150 mg/l each of glucose and glutamic acid was used as a comparison in accordance with US standard procedure. The results have shown that various chemicals investigated in this way have poor biodegradability, e.g. resin finishing chemicals based on urea-formaldehyde, melamine and glyoxal resins besides a non-ionic polyethylene emulsion and polyvinyl alcohol. The latter product can, however, be biodegraded up to 60% after 30 days under certain conditions, e.g. depending on concentration and the commercial grade. Over the same time period BOD_{30}:COD values of 92% for acidic potassium phthalate and 73% for butyl benzoate were achieved. The dyes tested also revealed very low degradation with only an insignificant reduction in colour. Pigments and inert substances can be removed by adsorption in a waste water treatment plant with a high sludge content (5800 mg/l) provided a sufficiently long reaction time is given. Measurement principle: since the five-day → Biochemical oxygen demand test (BOD_5) is insufficient for chemicals with low biodegradability the test must be carried out over a longer time period. The → Chemical oxygen demand test should also be used for the determination of degradability. On taking the duration of the test period into consideration, the quotient of both determinations, BOD/COD, gives an indication of biodegradability in most cases.

Bioelimination According to the German Federal Law on Epidemics, the Drinking Water Regulations and DIN 2000, drinking water must be free of substances harmful to human health.

With the refinement of analytical techniques it has been found that pollutants cannot, as a rule, be totally avoided (production of drinking water from riverine sources). Most of these pollutants may be detected in trace quantitites in large volumes of water. Surfactants which are used on such a large scale in domestic, commercial and industrial applications for washing, rinsing, wetting and emulsifying are also of interest here. The commercial production of washing agents and detergents for general use is only permitted if the raw materials and finished products fully satisfy all the statutory requirements relating to toxicological and ecological risks (German Washing Agents and Detergents Law, Hazardous Substances Regulations and the voluntary agreement between manufacturers to cease production of alkylphenol ethoxylates).

Surfactants introduced into waste water treatment plants in waste waters should be eliminated by adsorption or biological oxidation with the aid of bacteria and their enzymatic systems (e.g. the *pseudomonas* family). It is only due to the diverse metabolism of microorganisms that even toxic aromatic compounds (benzene, phenol) can be removed from waste waters. Primary degradation of surfactants is said to occur when it leads to the complete breakdown of biodegradable surfactants into CO_2, H_2O, inorganic salts and “normal” metabolites following bacterial metabolitic processes.

A prerequisite for the classification of a surfactant in terms of its bioelimination is a suitable test method which a) can predict possible consequences to the environment after introduction of the surfactant and b) provides an insight into the biochemical stages of bacterial metabolism (possible formation of toxic metabolites) after introduction of the surfactant (OECD screening test resp. confirmatory test, methylene blue test, bismuth test, BOD, CO_2 formation, reduction in DOC). In addition to soap, linear alkylbenzene sulphate (LAS) is the most important surfactant used in washing agents in the Federal Republic of Germany since ca. 1964 (85 000 t/year).

It is now assumed that, as primary degradation, ω-oxidation followed by subsequent β-oxidation and ring scission rapidly brings about the loss of surface-active properties. However, complete → Biodegradation to CO_2 and H_2O (secondary degradation) proceeds more slowly.

Biofinishing The treatment of cotton fabrics with cellulases (enzymes) which, accompanied by mechanical action, brings about the removal of projecting surface fibres. The treatment results in a softer handle and different fabric appearance, including stone-wash effects (e.g. applied to denim articles).

Biofouling Occurs in industrial pipework and pumps through bacterial adhesion due to contact between an aqueous medium and a solid surface. A boundary layer fauna is formed first of all by the slimy secretions from microorganisms in the boundary layer region. The influencing factors are surface roughness, surface energy, unfavourable flow behaviour, hydrophobicity, pH, oxygen concentration and viscosity.

The growth of adhering microorganisms and embedding of new bacteria is based on chemical bonding through hydrogen bonds. This adhesion is assisted by polysaccharides, proteins and lipids from the cell walls. The affected surface then reaches a state of high colonization through the development of microbial activity. The bacteria in this biofilm have a higher degree of protection against biocides than when present in a suspension. Microbial corrosion is due to the products of bacterial metabolism, organic and inorganic acids, secreted by the microorganisms which, as a rule, depend on the availability of free oxygen as an oxidizing agent (oxidative metabolism). As far as corrosion is concerned, those microorganisms which are capable of producing sulphates resp. sulphuric acid are important, e.g. through the oxidation of SO_2 and elemental sulphur by the genus *thiobacillus* to sulphates resp. sulphuric acid which will corrode virtually all metallic materials. In this regard, it is the sulphate-reducing bacteria which are of greatest importance since they are responsible for pitting corrosion, e.g. in fuel tanks where sulphates and organic compounds have been introduced by water and the bacterial formation of sulphide takes place. Microorganisms with a similar high risk of corrosion are the iron bacteria which, in the presence of chlorides, will even attack high alloy steels. Bacteria of the *pseudomonades* genus break proteins down into mercaptans, other types release acetic acid, butyric acid and ammonia. Even plastics are subject to quite dramatic corrosion damage due to the action of microorganisms. 250 types of microorganisms are known which are capable of attacking plastic materials, although some plastics, e.g., polypropylene and polystyrene, have high resistance to microbial degradation. As a rule, it is the C- or N-sources of the plastic which serve as nutrients for the particular microorganisms; the plastic is damaged and discoloured by the products of microbial metabolism.

Biofouling and the biochemical processes which take place in the boundary layer fauna are highly dependent on the surface topography (and its cleanability). On rough pore-rich surfaces colonization occurs earlier and the films still adhere longer after cleaning treatments. The greater the roughness of a material surface, the greater the boundary layer habitat for microorganisms.

Peptide residues as well as the life-sustaining oxygen of vital importance to the microorganisms are stored by these films. After the fats, particles and colloidal films have become anchored mechanically, and slimes of microorganism metabolism products and proteins have begun to accumulate, the size of these germs is a function of the surface roughness, where sizes of 0,1 μm (bacteria) to 5 μm (yeasts) are relevant.

BIOI method A variant of the → LOI test for testing the flammability of textiles.

Biological filter media In → Biological waste water treatment processing technology with biological filter media, the biomass is immobilised by being anchored on the widest variety of filter media. Slag, lava tuff, activated charcoal, coco slag, plastics and the like come into consideration for filter media. After a running period of some weeks, a biocoenosis is formed on these filter media when charged with effluent. All biological filter media have the following advantages more or less in common:

- relatively low floor space requirements and shorter reaction times due to higher biomass concentrations;
- volume reduction or elimination of the final sedimentation tank due to the favourable sludge index (Mohlmann index: the volume in cm^3, which 1 g of activated sludge dry substance takes in after half an hour's precipitation);
- a lengthy sludge period is possible (beneficial for slowly multiplying bacteria and for specialists);
- no bulking sludge or scum formation;
- due to suitable synergistically acting filter media, like activated charcoal for example, increased process stability and breakdown activity as compared with refractory effluent content substances which are biologically difficult to break down.

Translated into processing technology, these types of biological filter media are used in percolating filters (Fig.), immersion filters and suspension reactors. In the percolating filter process, the effluent is sprayed through stationary or moving nozzles over the large-pore filler with sessile biocoenosis. The water percolates slowly down through the fragmentary material (which may be stratified up to 20 m high), while air is constantly passed through the cavities, supplying the micro-organisms with adequate quantities of oxygen.

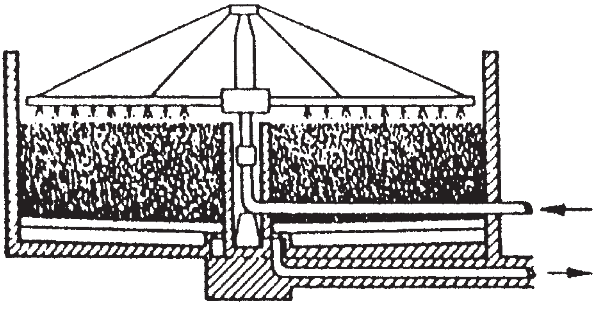


Fig.: Percolating filter.

In addition to favourable growth conditions for micro-organisms, the cleaning power of this type of immobilised reactor is dependent on the availability of geometric surface, on which the biological sward can form. Among other things therefore, performance increases are to be achieved by increasing the specific surface in the reactor. Increased performance in the practical sense however also means process stability, which, in the case of percolating reactors, suffers from the latent danger of choking, particularly with dense, large surface fillers. The following considerations arise when comparing the percolating filter technique with the activated sludge technique:

- With activated sludge plants, performance is identical with that of the percolating filter with more than double the volume charge, a fact which can be explained by the shorter contact time in the percolating filter.
- With the percolating filter process, breakdown performance falls off to a much greater extent as the volume charge is increased than with the activated sludge process, and the percolating filter consequently reacts sensitively to shock loading.
- Maintenance costs are higher with activated sludge plants than with percolating filters.
- In percolating filters, the effluent quantity is moved rather than the air or the biologically active mass.
- Approx. 30–60 Wh of power per m^3 of effluent are required with the percolating filter process, while, with the activated sludge process, the requirement is 150–350 Wh for oxygen supply and thorough mixing, plus some additional Wh for the return sludge.

By immersion filters we mean fixed bed reactors, in which fillers or baffles alternately dip into the effluent and rise into the air. The most well-known representative is the biological disk filter. In the biological section, this consists of plastic disks mounted on a shaft with a biomass clinging to both sides of the disks. These disks dip up to half their length into trough-like vessels (adapted to take the disks) and are traversed by the effluent. By means of a continuous rotary motion, the disks are first of all exposed to the effluent, being impregnated by it; they are then lifted into the air, where oxygen is made available to the bacteria for aerobic breakdown of the effluent content substances.

An interesting variant of the immersion filter system is a system in which a hollow body (cellular wheel), which can rotate about its axis, not only serves as an incrustation surface, but also draws air into the vessel as it rotates. The air then rising from the lowest point also supplies oxygen to the freely suspended activated sludge, increasing the efficiency of the system as a whole. Immersion filters can be employed to advantage with concentrated effluents, since the oxygen supply is good even at high consumption rates. Moreover, by positioning the immersion filters in series, the most favourable biocoenosis can always be established in every case. The immersion filter energy requirement is low, as only the friction loss and the difference in weight between emergent, water-laden disks and the lighter dipping disks has to be overcome.

The suspension filter process, also called the fluidised bed technique, can also be regarded as a special form of biological filter medium. Biological filter media, on which the biomass is fixed, serve as suspension media. Not too heavy granulates, in the 1–4 mm diameter granule size, of plastic, sand, light expanded clay aggregate, pumice stone and activated charcoal come into consideration for this purpose. It is important that the filter media put into the reactors are uniformly fluidised over the reactor volume. As a rule, the up-current (bubble column) technique is used when the filter medium is heavier than the medium to be treated – effluent in this case – or the loop principle (circulating fluidised bed).

Suspension filters offer two important advantages: the inert filter medium offers a large specific surface due to its granulate form, and consequently adequate room for colonisation. To this is added, in the case of so-called active filters (e.g. → Activated charcoal), the geometric factor of the inner surface, and, particularly, a synergetically amplifying and accelerating power, thanks to the qualitative surface nature of specific carbons. The use of activated charcoal as the suspension filter medium in fluidised bed reactors has been familiar for approx. 15 years in the Katox system developed by Krupp.

Biological oxygen demand → Biochemical oxygen demand.

Biological tower Atmospheric oxygen is introduced in increasing quantities in the activated sludge process of biological → Waste water treatment. Micro-organisms convert degradable pollutants into carbon dioxide and water, building up a bacterial mass. Aerobic bacteria require a supply of oxygen to this end. The micro-organisms multiply rapidly in the presence of biologically acceptable substances to form a large quantity of activated sludge, sludge return maintaining the particularly beneficially high sludge concentration. This is followed by accelerated breakdown, so that, in comparison with the simple oxidation ranges, the time required is reduced to approximately one hundredth, and is then only 4–12 hours. In the activated sludge process, the constructional and operational methods mentioned in the list can differ. The most widespread is single-stage biological basin which exists in numerous variants. For example, the type and method of effluent feed and mixing in activated sludge tanks and the type and method of oxygen introduction can be modified, e.g. by means of surface ventilators or nozzles.
Activating process:

- single-stage biological basin (→ activated sludge process),
- multi-stage biological basin,
- biological filter media (Katox, Biokop),
- high-load activated sludge process (compact reactor, turboplan reactor),
- Bayer biological tower,
- Biohoch reactor (Hoechst),
- deep shaft reactor (ICI).

The supply of pure oxygen instead of air (see Table) is variable or the method of construction, e.g. biological tower version. The advantages of the biological process are the mainly low cost, the extensive dispensation with auxiliary agents and the low sludge quantities. The disadvantage lies particularly in the larger space requirement. The chemical or chemical/physical purification processes are extensively independent of quantity and concentration variations and of the presence of bacterial toxins. In addition, the biological degradability of the effluent content substances plays no part. The ratio between BSB$_5$ and CSB, i.e. between the easily degradable proportions and the total pollution, is approx. 2:1 in domestic waste water, while the ratio is less favourable in industrial effluent; typical effluent from textile finishing plants has a BSB$_5$/CSB ratio of 4:1–6:1.

Specific disadvantages of the classic biological basin are also recognisable on account of their widespread distribution: the large space requirement, which is the limiting factor, especially with restricted space conditions, plus aerosol formation, i.e. the occurrence of fine water droplets, accompanied by gaseous emissions of liquid substances, which result as a rule in odours in the clarification plant vicinity. The third disadvantage is the low atmospheric oxygen utilisation factor. Depending on the type of air introduction system, e.g. nozzle introduction or surface ventilation, the utilisation factor lies only between 5 and 10%. In order to cover the necessary oxygen requirement therefore, a larger air supply is necessary, which means a high level of expenditure on electrical energy together with increased aerosol and possibly also foam formation. The above-mentioned disadvantages are avoided by the biological tower. High containers, of steel as a rule, which have a fluid level of 10–25 m, are used instead of the usually flat basin construction. With identical volumes, the base of a 20 m high water level is only 1/5th of that of one with a height of 4 m. The small base also facilitates tank covering, by means of which aerosol and odour problems are solved. The exhaust gases can be cleansed of the stripped, easily volatile substances by suitable methods, e.g. biology, activated charcoal or by combustion.

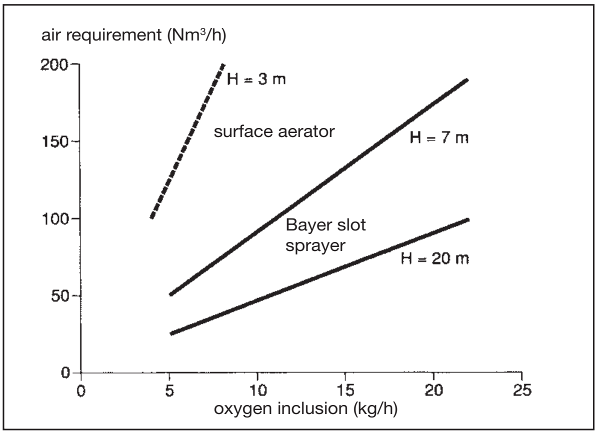


Fig. 1: Air requirement as against oxygen inclusion with various water level heights.

Another advantage of the biological tower is better atmospheric oxygen utilisation in the deep water column. The route of the air introduced through the water is longer, and more oxygen is dissolved under the pressure of the water (Fig. 1). This means approximately double the oxygen yield, which is approx. 3 kg of oxygen/kWh instead of approx. 1.5. The residual oxygen content of the exhaust gas is therefore significantly less than in conventional processes. Air has an oxygen content of 20.95 vol.%. For the usual basin construction, the oxygen concentration in the exhaust air is 19–20%, which means 5–10% oxygen utilisation as against a concentration of 5–8%, i.e. 60–75% utilisation for the biological tower (Table).

	Bayer biological tower	biological basin
oxygen demand (tonnes/day)	45	45
gas absorption	Bayer injector	surface aerator
depth of water	17-24	4
O_2 yield (kg of O_2/kWh)	2,7-3	1,5
air requirement (m^3/h)	10 800	70 300
O_2 in the exhaust gas (% vol.)	5-8	19-20
O_2 utilisation (%)	60-75	5-10

Tab.: Biological tower and biological basin oxygen inclusion.

With comparable oxygen demand, the necessary air requirement is reduced to almost one seventh (Fig. 1). This has positive effects on the energy requirement, on the stripping effect, and (in the event of any exhaust gas cleansing necessary) on the downstream treatment stage.

A relevant gas absorption system has to be developed at the same time in order to be able to utilise to the best effect the advantages of the deep water column for oxygen inclusion. Finely distributed gas bubbles are produced, and the effluent thoroughly mixed at the same time (Fig. 2) by special injectors located flush with the bottom of the activating tank. This also effectively prevents biological sludge sedimentation.

The long injector service life and the absence of moving parts in the activating tower lead to a high degree of processing reliability, ease of maintenance and operating reliability on the part of the air inclusion system. Due to the height of the unit, it is possible to create an additional buffer system, enabling an additional upstream balancing basin to be eliminated in specific cases (Fig. 3).

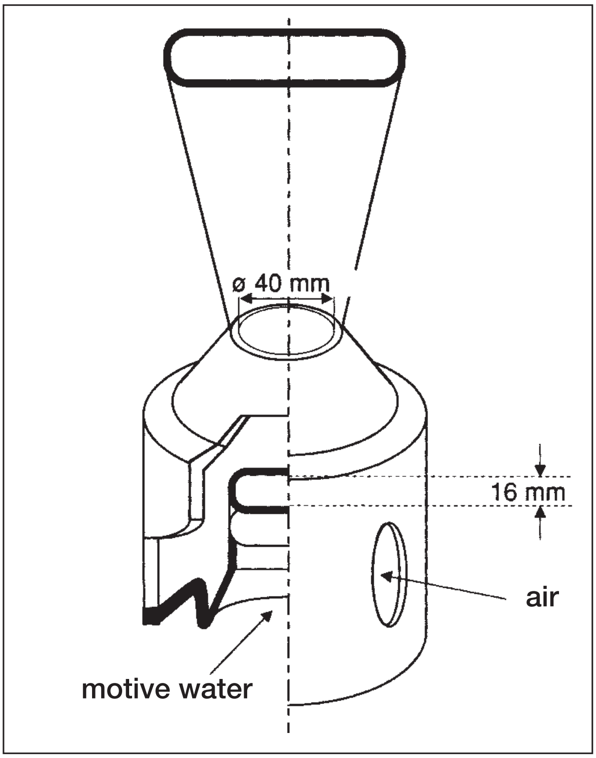


Fig. 2: Bayer injector slot sprayer model.

To the activating stage is connected a biomass separation process in the sedimentation stage. Depending on sludge settling behaviour, sedimentation or gas absorption flotation is suitable to this end.

With sludge separation by sedimentation, cyclones must be incorporated between the biological tower and the sedimentation stage (Fig. 4) in order to degas the gas-enriched water/sludge mixture, so that the sedimentation process can proceed undisturbed. If flotation

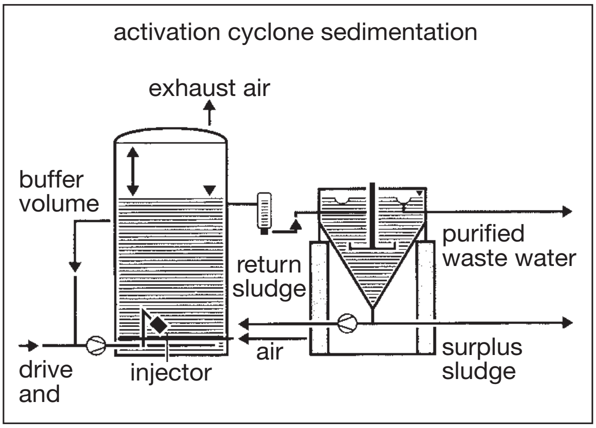


Fig. 3: Bayer biological tower with integrated buffer volume.

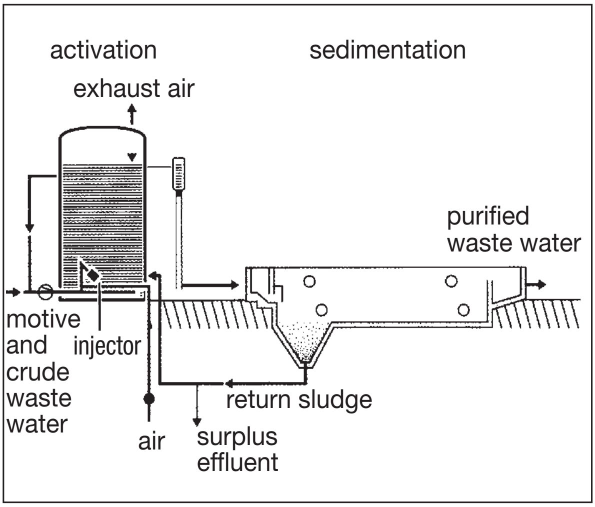


Fig. 4: Sedimentation tanks behind the biological tower.

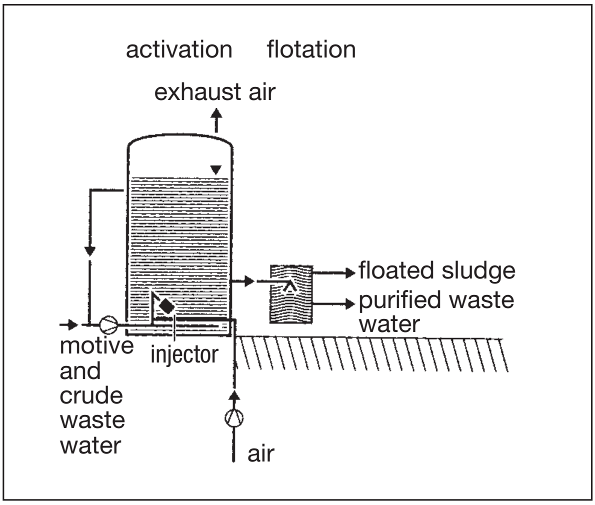


Fig. 5: Biological tower with flotation.

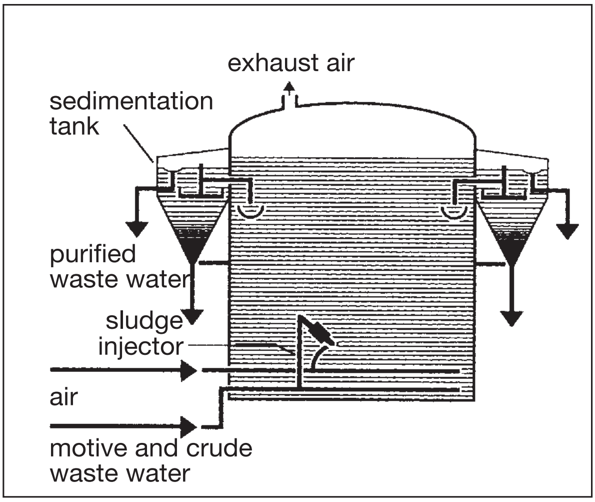


Fig. 6: Bayer biological tower with integrated sedimentation.

is selected for sludge separation, cyclones are unnecessary, since the gases have an additional positive effect (Fig. 5). Flotation is particularly suitable where there is a tendency for the sludge to float (Fig. 6).

An effluent treatment plant suitable for use in textile finishing has a precipitation stage, a subsequent presettling stage, a total of three activating tanks in parallel, each of 1200 m^3 capacity and approx. 12 m high water level, a reduced height sedimentation stage and a sand filter (Fig. 7).

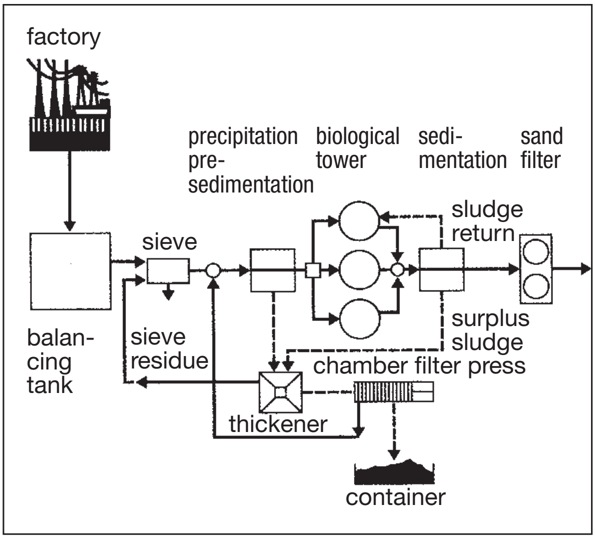


Fig. 7: Flow diagram of a biological tower with physical and chemical pre-purification.

The sludge-containing water from the biological tower must be drained free of pressure and foam, and degassed to the level of the sedimentation tanks in order to effect quiet, foam-free effluent introduction. A plant was designed for a capacity of 7700 m^3/day; the waste water accumulation over a nine month observation period was approx. 150 m^3/h (according to Sewekow and Diesterweg).

Biological waste water treatment This stage of waste water treatment is based on natural self-purification processes. In order to accelerate aerobic degradation, however, the water is enriched with oxygen artificially. The most frequently used treatments are the percolating filter and → Activated sludge processes.

I. Percolating filter. This consists of a vessel containing a bed of filtering material such as broken stone, lava or pieces of plastic covered with a so-called biofilm of algae, bacteria and other microorganisms. The mechanically cleaned waste water is sprayed with a rotating sprinkler above the contact bed whereby falling drops of water absorb oxygen from the air. The waste water seeps slowly downwards between the stones which are colonized by microorganisms. These micro-

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organisms extract organic pollutants from the waste water by absorbing them, breaking them down with oxygen, and multiplying. The percolating filter thus replicates, in the smallest space and under accelerated conditions, the self-purification processes which occur in flowing water courses.

II. Activated sludge process. In this process, a mixture of protozoa and bacteria (activated sludge) is added to aerated waste water to break down organic matter. As the microorganisms use this organic matter for food they multiply, producing more activated sludge. In practice, a brown-grey sludge is kept under constant movement in an aeration tank by surface ventilation or compressed air. If a small sample of this activated sludge is allowed to stand for just a few minutes in a glass cylinder, a grey-brown sludge settles out and the water lying above it is clear. Under the microscope it can be seen that this sludge is composed of countless microorganisms, such as bacteria, funghi, protozoa, etc. This mass is referred to as activated sludge to distinguish it from digested sludge. In an accumulation such as this, all the organisms consume a large quantity of oxygen which must be constantly replenished. This is achieved either by sprinkling or by passing compressed air or oxygen beneath the sludge. These purifying organisms must, however, be retained in the treatment plant and the waste water passing from the aeration tank or the exit from the percolating filter enters a secondary sedimentation tank for this purpose. As in mechanical clarification, the sludge (activated sludge in this case) settles out from the still water in a relatively short time. Whilst the treated waste water then flows from the outfall into a stream, river or the sea, the so-called returnable sludge is pumped back into the aeration tank. This large bacterial culture is therefore in a state of constant circulation. When the mass of activated sludge becomes too great, a part of it can be returned as excess sludge to the preliminary sedimentation tank. There the sludge, together with the coarse pollutant particles which have settled out, reaches the digester and is thus finally removed from the waste water. As a result, pollutants absorbed by the microorganisms are removed from the waste water. → Waste water treatment; Methanation in biogas processes.

Biomass The available biomass is the total quantity of organic substance in the form of living organisms in a given unit of area or volume at time t. The simplest reaction scheme for the photosynthesis (P) of biomass producers and the respiration (R) can be represented by the following chemical equation:

$$CO_2 + H_2O + E \underset{R}{\overset{P}{\rightleftharpoons}} \langle CH_2O \rangle + O_2$$

E = Energy conversion, mainly in the form of sunlight for P and mainly in the forrm of heat for R;

P = Primary productivity through assimilation by means of photosynthesis: i.e. the synthesis of organic material from inorganic compounds;

R = Respiration: the decomposition of organic material by oxygen to inorganic compounds (mineralization);

$\langle CH_2O \rangle$ = Organic material (biomass) which, on average, is composed of the elements C:H:O in a 1:2:1 ratio.

Biopolishing Enzyme finishing treatment for cellulosic fabrics. → Biofinishing.

Biosensors for environmental analysis Enzyme reactions are particularly suitable for the selective determination of environmentally-relevant substances. Thus, for the analysis of e.g. urea (in swimming pool water) the enzyme urease can be used, and for the detection of insecticides the enzyme acetylcholinesterase (AChE) can be employed. In both cases the enzyme is immobilized on the surface of a single stick pH electrode (Fig. 1) by crosslinking with beef albumin.

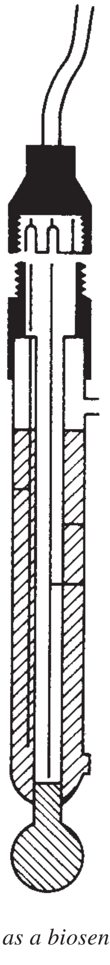

Fig. 1: Enzyme electrode as a biosensor for environment analysis.

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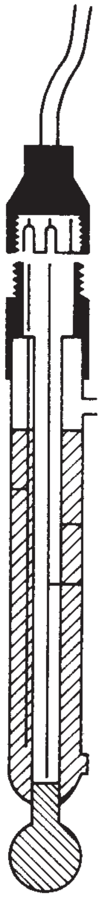


Fig. 1: Enzyme electrode as a biosensor for environment analysis.

A simple screening procedure for residues of crop protection agents is of great interest in environmental analysis. In this context, a rapid test for the presence of insecticides makes use of the fact that the enzyme reaction (catalysis of acetylcholine to choline and acetic acid) is inhibited by these substances. Thus the higher the insecticide concentration in a sample, the lower the decrease in pH (due to the formation of acetic acid). For the practical application of this enzyme single-stick pH electrode (i.e. biosensor technique) a simple analytical scheme including electrode reactivation has been developed to differentiate between insecticides based on phosphoric acid esters, thiophosphoric acid esters and carbamates (Fig. 2).

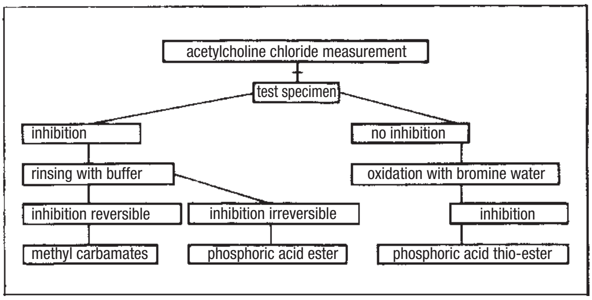
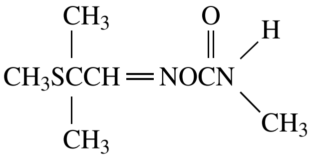


Fig. 2: Analysis plan for the differentiated determination of pesticides by means of the acetylcholine esterase enzyme electrode as a so-called biosensor.

Carbamate insecticides (Fig. 3) cause a reversible inhibition of the enzyme. By contrast, the inhibition caused by phosphoric acid ester insecticides is irreversible and can only be eliminated by a special electrode treatment (reactivation). Thiophosphoric acid ester insecticides inhibit the enzyme reaction only after oxidation to phosphoric acid esters. Even concentrations of a few micrograms per litre (ppb range) of phosphoric acid ester insecticides can be detected with the aid of this biosensor, e.g. in drinking water, ground water and surface water.



$$\mathrm{CH_3SC(CH_3)_2CH{=}NOC({=}O)N(H)CH_3}$$

carbamate insecticide

Fig. 3: Carbamate insecticide for biosensory analysis.

Bioses → Sugar.

Biotechnology At the present time, biotechnology is understood to involve the utilization of biological processes within the framework of technical operations and industrial production. Biotechnologies, in fact, exploit the use of bacteria, yeasts and animal and plant cell cultures for the manufacture of specific substances which depend on the metabolism and biosynthetic capacity of the former. According to the definition adopted by the European Federation of Biotechnology, created in 1978, biotechnologies make it possible through an integrated application of knowledge and techniques of biochemistry, microbiology, genetics, and chemical engineering, to draw benefit, at the technological level, from the properties and capacities of microorganisms and cell cultures. Biotechnology always deals with reactions which, in principle, are of a biological nature. These reactions are performed either by living microbial cells or plant and animal cells and their tissues, or by enzymes from cells or parts of cells. The production of biomass from the organisms or parts of organisms mentioned is also an area of biotechnology.

Applied at the industrial level, these biotechnologies constitute bio-industry. Bio-industry includes, on the one hand, industrial activities where biotechnologies can replace technologies generally or currently in use and, on the other hand, industrial activities where biotechnologies play an essential driving role. In the first instance they include, in the area of chemical industry, the synthesis of flavourings and artificial seasonings, plastics, and products for the textile industry; in the area of energy, they include methanol, ethanol, biogas and hydrogen production; in the area of biometallurgy, they include extraction of certain metallic elements. In the second instance biotechnologies extend to the food industry (mass production of yeasts, algae and bacteria) with a view to providing proteins, amino acids, vitamins, and use of enzymes; to the increase of agricultural productivity (cloning and selection of plant varieties from cell and tissue cultures, bio-insecticides); to the pharmaceutical industry (vaccines, synthesis of hormones, interferons and antibiotics); to environmental protection and abatement of pollution (treatment of sewage, transformation of domestic wastes, composting and the manufacture of biodegradable compounds).

Microorganisms are not only capable of synthesizing very specific molecules but are also capable of making large quantities of simple molecules. Dyestuffs, or at least their building blocks, are structurally relatively simple molecules. The complexity of a biological process is often greater than that of a chemical process. This sophisticated character not only applies to biosynthesis but likewise to the isolation of biosynthesized products and product purification.

The product yield in a bioreactor consists mainly of a solid phase (cells, possible solid fractions from the nutrient solution) and a liquid (aqueous) phase. The target product may be present either in the solid and/or the liquid phase. In some cases the solid phase itself may represent the product (e.g. yeast cells for forage purposes).

At the outset of every biotechnological process is the search for a suitable biological system. This system must (like a catalyst) possess a genetic potential which is capable of promoting the desired biosynthesis. The search for a suitable biological system can involve at least two different aspects. In the first case (a traditional approach), an unknown microorganism population is confronted *a priori* with a problem.

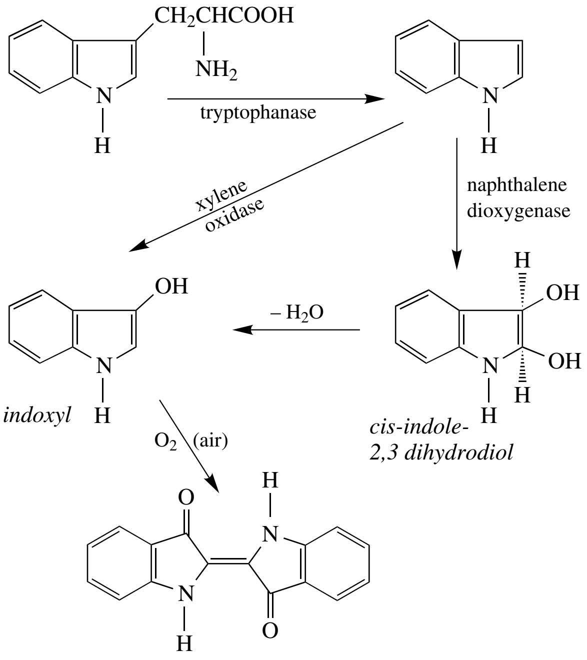


Fig.: Indigo biosynthesis.

Biotechnology is an interdisciplinary science at the frontier between several biologically, biochemically and technically oriented disciplines. At the centre, however, is the application of biological processes to industrial production. The objective of all biotechnical processes is to make use of certain metabolitic-physiological and biochemical capacities of biological systems for technical purposes, i.e. for production purposes. Suitable biological systems are based primarily on microorganisms, i.e. bacteria, yeasts or funghi, occasionally also algae and recently, on an increasing scale, cells of higher plant species, mammals or even human tissues. The potential of these cells for biosynthesis can thus be harnessed to make technically interesting products or convert certain substances into others. The spectrum of these biosynthetic products is very wide and includes foodstuffs, pharmaceutical products and other biologically active materials as well as fine chemicals or new raw materials. By way of example, a carbon source intended to be converted or broken down is brought into contact with different microorganisms. If, amongst these countless microorganisms a subpopulation exists which can break this carbon source down, then this species will start to multiply. The isolation of this specific species no longer stands in the way. This methodology which, in most cases, has emerged after an intensive screening program has produced many of the microorganisms used in technical processes today (see Fig.).

Biotope A small area or habitat of a particular type in a large community defined by the organisms (plants, animals, microorganisms) that typically inhabit it. All organisms are dependent for their life requirements on specific habitats providing the necessary environmental factors for their existence and needs. Compared to its surroundings, a biotope is a habitat which has certain environmental peculiarities that are specific to itself and relatively well characterized. It is the habitat of a → Biocoenosis.

Bipolarity → Dipole.

Bipolymeride Polymeride from 2 types of basic components.

Bird's eye (peacock's eye) Pattern is produced by regular bird's eye type weave effects. Worsted or worsted ply yarns, as far as possible of pure wool or of 70–90% wool content, are used exclusively. There are several types of weave, an eight-shaft crêpe weave being predominantly used. The yarn sequence for warp and weft is 2 dark, 2 light. Finish character: napless.

Birefringence Characteristic of the splitting of light waves in a crystalline mineral. Splitting occurs into two waves of different speeds and vertically opposed directions of oscillation. Thus, with transparent Iceland spar (potassium carbonate) for example, the image appears doubled, for which reason this spar finds use in polarisation equipment (→ Polarized light).

Bis (Old Lat.: *duis* = twice) Prefix meaning "twice" or "again". Used in chemical nomenclature to indicate that a chemical grouping or radical occurs twice in a molecule, e.g. Naphtol AS-BR (Hoechst) is a bis-2,3-2´-oxynaphthoic acid-dianisidide. A bis-azo compound contains 2 azo groups in the molecule and is also indicated in a disazo dye (such as e.g. → Congo red).

Bisage (French, English) Twice-dyed fabric.

Bis-aziridinyl chloromethyl phosphine oxide (BACPO) Flame retardant agent for cotton, applied in accordance with the dry cross-linking process.

BISFA (Fr.) Bureau International pour la Standardisation de la Rayonne et des Fibres Synthétiques (International Bureau for the Standardization of Man-made Fibres), Basle. Since 1928 (analogous to the → RAL in Germany) it has been concerned with drawing up internationally recognized guidelines for the standardization, description and sales of man-made fibres.

Bis (β-hydroxyethyl) sulphone (BHES), β,β′-dihydroxydiethylsulphone, HO–CH$_2$–CH$_2$–SO$_2$–CH$_2$–CH$_2$–OH. A vinyl sulphone used as a reactant resin for wash-and-wear finishes.

Bismarck Brown FR extra A cationic dye used for the differentiation of various textile fibres and fibres which have been subjected to different treatments (according to Herzog-Koch). Similar to the → Methylene blue test.

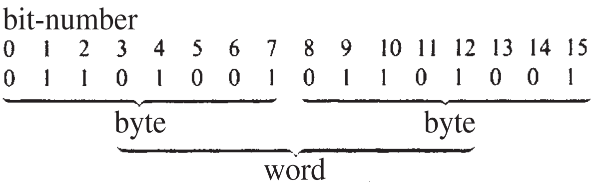
Bismuth (Bi) Brittle, crystalline heavy metal with a slightly reddish sheen. Atomic weight 209; melting point 269°C; density 9,78. Attracts oxygen only on the surface. Compounds: bismuth mainly trivalent. Salts chiefly colourless. Mainly severe hydrolysis in aqueous solution (turbidity, precipitates). Use: alloyed (with lead, tin, cadmium) as low-melt solder for self-acting fire extinguisher closures. Constituent of Wood's and Lipowitz's. alloy.

Bismuth-active substance (BiAS) Term for nonionogenic surfactants, the microbial decomposition of which is of monitoring interest in test on biological decomposition (→ Surfactant biodegradability, evaluation of); supplementary to → MBAS for anionic surfactants. Method of determination (Wickbold method) ion aqueous solution by precipitation with $KBiI_4 + BaCl_2$ and subsequent determination in the spectrophotometer or potentiometrically.

Bisphenol Starting material for the manufacture of → Epoxy resins. Bisphenol A = p,p´-isopropylidenediphenol $HOC_6H_4{-}C(CH_3)_2{-}C_6H_4OH$.

Bisulphites, are acidic → Sulphites resp. salts of sulphurous acid (H_2SO_3) (→ Sulphur oxyacids). Readily soluble reducing and bleaching agents (action of sulphur dioxide).

Bit A contraction of binary digit, in computer technology and information theory, the smallest conceivable unit of information, representing a choice between only two possible states: the presence or absence of a single pulse; + or –; 0 or 1; a switch being off or on. If the letters of an information alphabet are represented by binary characters (e.g. with 0 = no or "off", 1 = yes or "on") then the information content of such a binary character is equal to 1 bit. For simplification a fixed number of bits are grouped together. Thus a unit of information consisting of 8 bits is referred to as a byte (a term in common useage in electronic data processing). Example for large groups of bits with varyious numbers of compositions:



The general term is "word" which is why a "byte" is also a "word" in this context. The capacity, i.e. the number of bits which can be processed by a computer is expressed in kilobytes (kbyte or K). One kbyte corresponds to 2^{10} = 1024 bytes. The likewise frequently used term "megabyte" (mbyte or M) corresponds to 1 million bytes (2^{20}).

Bitumen A term for:

I. A black or brown solid to viscous semisolid liquid meltable mixture of hydrocarbons obtained from crude oil as a distillation residue.

II. The constituents of natural asphalt which are soluble in carbon disulphide.

Biuret (ureidoformamide, allophanamide, carbamylurea) $H_2N{-}CO{-}NH{-}CO{-}NH_2$. Formed by the action of heat on urea (elimination of ammonia). A water-soluble substance which, in alkaline solution, gives an intense violet colour with copper salts. The reaction occurs with all substances containing 2 or more amide groups ($-CONH_2$). → Biuret reaction.

Biuret reaction A simple test for the presence of proteins (e.g. glue), peptides and damage to wool. If urea is heated to temperatures of 150–160°C ammonia is split off and biuret is formed as an intermediate product:

$$\underset{\textit{urea}}{H_2N{-}CO{-}NH_2 + H_2N{-}CO{-}NH_2} \longrightarrow \underset{\textit{biuret}}{NH_2{-}CO{-}NH{-}CO{-}NH_2} + NH_3$$

In alkaline solution this forms a violet-coloured copper complex with copper sulphate. The reaction is characteristic for all substances which contain several peptide bonds. The reaction therefore serves as a test for biuret, oxamide, peptides and proteins.

Bivalent (or divalent). Chemically capable of combining with 2 atoms of hydrogen or their equivalent (→ Valency). Also having an oxidation state of two.

The term has also been applied to bivalent systems as in e.g. compact energy converters with a heat pump and a heating system (solar energy).

Bk, chemical symbol for berkelium (97).

Black component (Black content, blackishness, blackness value), the black component of an object colour of a lower degree of lightness detectable in the sense of the so-called degree of greyness (→ Grey series). The 0–100% black component is equivalent to a blackness value (form differentiation → Lightness) of 0–10 .

Black content → Black component.

Black denim This term has been reserved for → Blue denim which has been overdyed black in contrast to the fast-dyed classical qualities of → Denim, produced by yarn or piece dyeing methods which remain deep black after repeated washing. Black denim becomes blue-grey in colour after washing and may also be given a stonewashed finish. Denims which have been dyed with black indigo dyes have an attractive blue-grey appearance after a stonewash treatment.

Black mordant,

I. A term used for stock preparations of → Aniline salt used in the impregnation of cotton fabrics for the production of oxidation black (aniline black).

II. Also a mordant for logwood black → Pyrolignite of iron and iron (III) sulphate.

Black-out cloth Different types of woven fabric, mostly highly calendered, sometimes raised on one side, dyed to a dark shade (possibly → Camouflage dyed). Also coated as black-out curtain (a carbon coating).

Black-out curtains Roller blinds made from fabrics composed of synthetic fibres to which one coat of carbon black is applied between two polymer coatings thereby producing a virtually total lightproof material.

Blade squeegee The classical shape of → Squeegee in contrast to a roll squeegee.

Blanc fixe → Barium sulphate.

Blank bleach The operation of a bleaching plant with all the chemicals but no textile material in order to check the equipment, controls, etc.

Blank dyeing A "dyeing" carried out on a specific textile material with the omission of dye from the usual recipe. By this means it is possible to check the influence of actual dyeing conditions on the material in the absence of dye which could otherwise, e.g. hide any yellowing or other non-dye-related problem.

Blanket manufacture The so-called pile blanket is woven as a double blanket, the pile yarn connecting the top and bottom fabrics. After the weaving process, the pile ends are cut in the middle on the loom (Fig. 1), simultaneously producing two woven fabrics. It is important that the pile yarn is very firmly anchored, so that the fabric does not break up. Two fabrics (each raised on one side) can be made up side by side to produce high quality blankets.

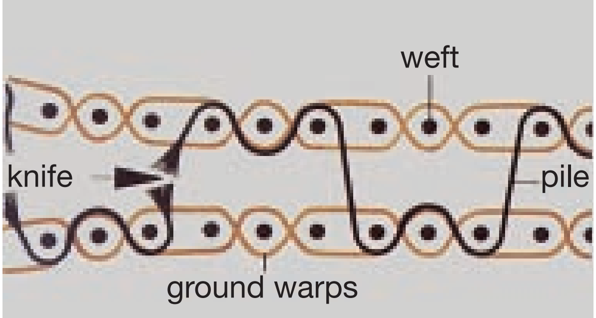


Fig. 1: Separation of top and bottom fabric in blanket manufacture.

The teddy velour process is a patented technology (Fig. 2) which has been extended by a new process (teddy velvet). The pile yarn (which can be raised) is firmly anchored on both sides by the ground warp and the weft. The pile loops on both sides offer the largest possible raising surface. In raising, part of the loop is anchored in the ground weave, producing a firmly set velour which cannot lint. Advantages: high pile, good stability and excellent heat retention.

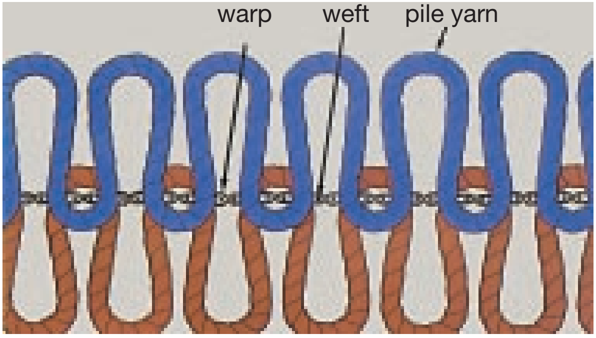


Fig. 2: Teddy velour blanket.

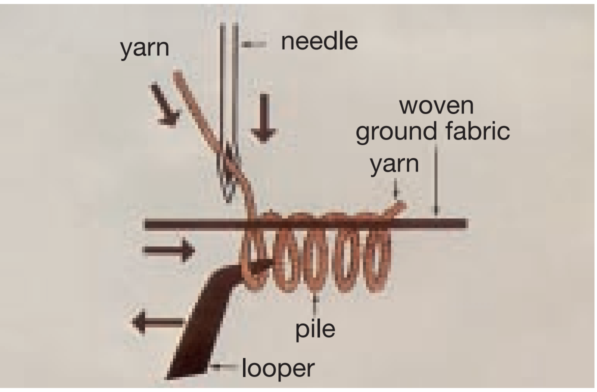


Fig. 3: Blanket tufting.

Strongly patterned, multi-coloured blankets are produced on the jacquard machine. In tufting, there is neither warp nor weft. The pile ends are needled into a ready-made woven ground fabric (Fig. 3). Many hundreds of needles pierce the ground fabric, while grippers take down the ends fed through the yarn eye in the needle. The needle moves back, threading up for the next stitch, while the ground fabric runs through the machine at the same speed. The pile end is secured only by the raising process.

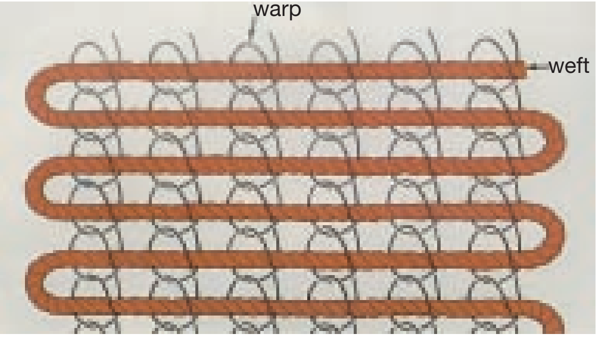


Fig. 4: Raschel blanket.

The Raschel process is based on warp knitting technology with weft insertion (Fig. 4). The warp yarn is very fine, the weft yarn very lofty. The weft is securely anchored by the warp stitch. The weft arches like a cord during fulling; in this way, it can be particularly well raised to produce high long pile bulk.

Blanket finishing comprises the following processes:

1. The controlled grey fabric is fulled and scoured, for the grey fabric has to felt in order to be raised.
2. Piece-dyeing takes place at this point if necessary. Dyeing can be effected in the loose stock state (raw material), in the hank (yarn), after spinning or in the piece (woven fabric).
3. The blanket appearance, i.e. the pile, is produced by raising, the grey blanket running through various passages on the raising machine. The surface, highly felted by scouring, is opened up, and the fibre ends teased out.
4. On the raising machine, the thick, lofty pile is brought to uniform height, levelled, and cut. The fibre material is then stretched and polished on the Polrotor in order to reproduce the hair lustre lost in the numerous operations.
5. The blanket batch is now cut to single blanket dimensions. The current standard size is 150 x 200 cm. There is no standard European dimension.

Blanket seam A printing fault in roller printing characterized by a light-coloured, widthwise stitching mark appearing on the face side of the printed fabric caused by the seam in the rubberized blanket beneath.

Blanket washer A special compact washing machine used in roller printing for continuous washing of the printing blanket during running. It is usually located immediately behind the printing machine.

Blank print A print produced on a textile substrate with a print paste that contains all the necessary chemicals and auxiliaries except the dye and which has been processed in the normal manner. This procedure is often used to check the influence of printing conditions where the presence of dye would interfere with the result.

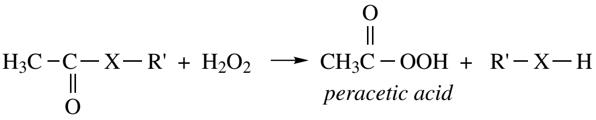
Blank screen A non-engraved screen (i.e. with no design) in rotary screen printing fitted with a squeegee but without print paste supply. It is used either in the "first hand" position to improve adhesion of fabric to the blanket adhesive before reaching the printing zone or in the "last hand" position to level out any unevenness in the print.

Blank vat An alkaline solution of sodium dithionite as used in vat dyeing but without dye. Uses: for stripping and levelling vat dyed materials, and for the development of vat dyeings produced by the pigment-pad process or other two-phase dyeing method.

Blazer Sports jacket. In its original form a fairly lightweight jacket, often striped or in the colours of a sports club, school, etc. with decorative buttons and a badge bearing a coat of arms. In recent years it has also developed into a more anonymous style in plain colours usually without a coat of arms but often still with quilted seams.

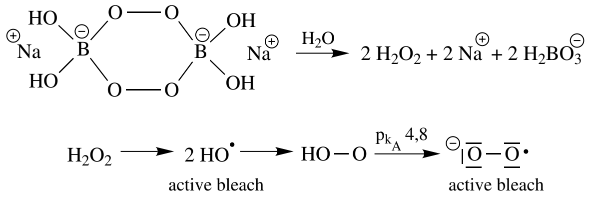
Bleachability In → Bleaching, this represents the optimum degree of whiteness achievable with minimum chemical damage to the fibre (in the case of cotton the → Cuprammonium fluidity should not be higher than 3–5).

Bleach activators (perborate activators) Acetyl compounds which have the capacity to form peracetic acid with H_2O_2 donors in the liquor as an intermediate stage of the bleaching reaction. The reaction is virtually independent of the washing and reaction temperature, and proceeds preferentially at pH 9–12 at significantly lower temperatures than usual:

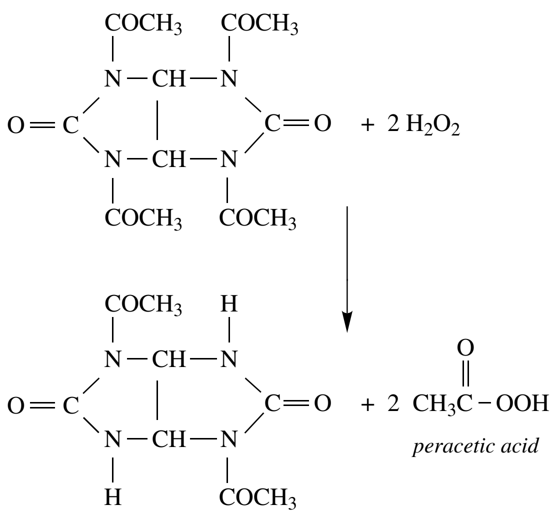


$$H_3C-\underset{\underset{O}{\|}}{C}-X-R' + H_2O_2 \longrightarrow CH_3\overset{\overset{O}{\|}}{C}-OOH + R'-X-H$$

In accordance with this principle, functional bleaching systems are developed with combinations of sodium perborate and bleach activators which (e.g. in the case of heavy-duty detergents) are capable of giving bleaching effects at < 60°C comparable to those obtained at 95°C with sodium perborate alone. Tetraacetylglycoluril (TAGU) is a bleach activator of this type (besides the tetraacetylenediamine types in washing agents) which, with the H_2O_2 donor formed on solution of the heavy-duty detergent,



functions as a bleach activator:



Bleach decomposition When hydrogen peroxide is used as a bleaching agent, the bleaching liquor can spontaneously decompose if it becomes too alkaline due to the inclusion of inadequately washed-out residual alkali from the preceding scouring stage. The practical finisher says “the bleach is decomposing”.

Bleached denim, often garment-washed, i.e. made up → Jeans are washed and bleached. A precisely calculated quantity of a bleaching agent, frequently chlorine-based, is added to the wash liquor in the prewash which bleaches out some of the indigo dye. The garments are finally rinsed with a special softener so that the denim remains soft and without a boardy handle.

Bleaching Chemical treatment of textiles in order to lighten or remove by means of suitable bleaching agents the tinting contained in the grey fabrics due to growth (natural fibres) or production (man-made fibres). In the grey state, textiles generally have a yellowish (sometimes also grey-brown) tint which has a detrimental effect for white or light shades on specific batches. Whilst lightening was effected in the past by natural (meadow) bleaching (particularly with linen and linsey-woolsey, and sometimes with cotton too), stripping is carried out today by chemical processes. The natural dyestuff can be destroyed both oxidatively (→ Oxidation bleach) and reductively (→ Reductive bleaching) and also by a combination of those two processes, where maximum fibre protection is the prerequisite. Sometimes bleaching is combined with other finishing stages like scouring, desizing or dyeing. In order to assist the bleaching effect, particularly with white fabrics, → Fluorescent brightening agents are used additionally. Bleaching is effected either in a long bath (high liquor ratio) or by impregnation bleaching, i.e. the fabric is steeped in the bleach liquor, left to dwell with or without squeezing, and/or exposed to heat. Generally, bleaching is mainly carried out in the pretreatment department; in order to obtain a clear pastel shade or a clear print, the preceding bleach can be regarded as pretreatment for example. Nevertheless, white colouration is principally associated with affecting the sensation of “colour”, for which reason bleaching is also regarded as colouration.

Bleaching agent, hydrogen peroxide Hydrogen peroxide bleaching, particularly of cotton, has gained in importance in view of the effluent problems (AOX) caused by hypochlorite bleaching. Hydrogen peroxide is a chemical compound which reacts as an oxidising agent in most cases. Hydrogen peroxide can also have a reducing effect only against very powerful oxidation agents such as potassium permanganate for example. This reaction is used for determining hydrogen peroxide content. The bleaching action of the H_2O_2 in the liquor on the other hand is causally connected with the oxidation potential of the compound. Various chemical equilibrium reactions are illustrated in Fig. 1 (→ Peroxide bleach process; hydrogen peroxide bleaching).

$$H_2O_2 \xleftrightarrow{K} HO_2^- + H^+$$

$$K_{298K} = \frac{(H^+) \cdot (HO_2^-)}{(H_2O_2)} = 1{,}78 \cdot 10^{-12}\ [\mathrm{mol/l}]$$

$$H_2O_2 + NaOH \rightleftharpoons H_2O_2 + Na + HO_2^-$$

$$2\ HO_2^- \rightleftharpoons O_2 + 2\ OH^-$$

Fig. 1: Chemical equilibrium reactions in the bleaching liquor (Degussa).

As a weak acid in aqueous solutions, hydrogen peroxide itself dissociates into ions in only a very low ratio. We know that the free acid has a very weak bleaching action only, and consequently has to be activated in order to be able to produce an adequate bleaching effect from the economic standpoint. For this reason, hydrogen peroxide bleaching is carried out exclusively in the alkaline range. The activator which is to be employed in the individual case, and the strength in general of the alkalinity of the bleaching liquor to be reached, depend on the type of textile raw material and the pretreatment it has already received. For vegetable fibres (like cotton for example), a caustic alkaline bleaching liquor is preferred. In the case of alkali-sensitive animal hairs (wool), only mild alkaline bleaching conditions can be used. With cotton, sodium hydroxide - in the case of linen also sodium carbonate - is used almost exclusively as the alkali source on cost grounds. On the other hand, buffer systems are often employed when bleaching animal fibres. The well-known tetrasodium pyrophosphate should be mentioned at this point. In addition to the bleaching chemical H_2O_2 and the alkali as activator, the hydrogen peroxide bleaching formulation basically also contains a scouring and wetting agent for improving liquor penetration capacity and also a stabiliser. Stabilising the hydrogen peroxide in the bleaching liquor is of fundamental importance to a uniform bleaching result and largely gentle treatment of the textile raw fibre material. The type and quantity of the stabiliser selected are consequently quite important, since hydrogen peroxide bleaching liquors are not adequately stable under practical conditions for a satisfactory bleaching result without this auxiliary agent. We know that the decomposition rate of H_2O_2 rises sharply with temperature particularly in the alkaline range, and any desire to save stabiliser in the formulation is therefore ruled out for this reason. Stabilisers must be added to the liquor in order to prevent H_2O_2 decomposition in the liquor under textile bleaching

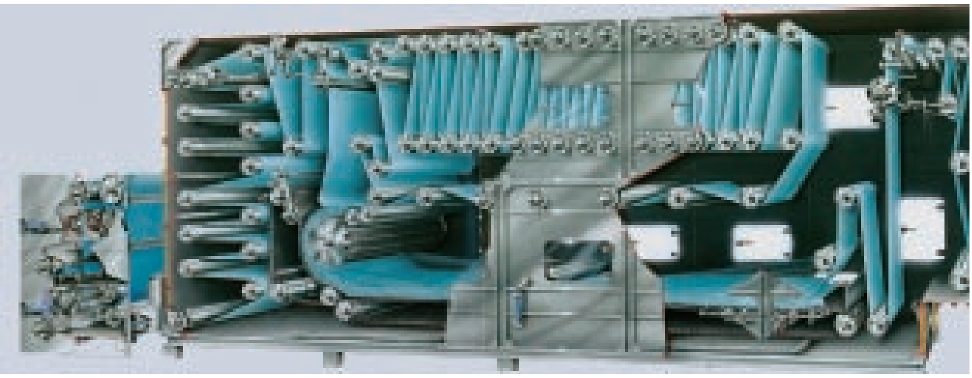


Fig. 2: Brugman bleaching line for the single-stage hydrogen peroxide bleaching of woven cotton fabrics.

conditions (particularly with increased temperature and alkaline activation).

The most important, very frequently used stabiliser systems are organic stabilisers based on phosphoric acids, aminocarboxylates and sodium silicate (waterglass) in combination with alkaline earth metal ions, particularly magnesium ions. Waterglass itself has a stabilising effect only in the presence of alkaline earth metal ions, which are in addition mainly responsible for water hardness. In the bleaching liquor, sodium silicate and magnesium ions form colloids, which act as buffers, and keep liquor alkalinity constant. This is important for a uniform bleaching result. Not to be forgotten is the anticatalytic effect of this classic stabiliser, which is based on the fact that H_2O_2 decomposition catalysts are incorporated in the waterglass colloids, and are chemically inactivated. The stabilising effect of this system as against the H_2O_2 in the liquor is based on colloid chemical processes. This empirically constantly confirmed fact is of great importance in practice. A typical single-stage woven cotton fabric bleach with hydrogen peroxide is shown in the plant in Fig. 2 (with prescouring section for desizing) (Weck).

Bleaching agent, sodium chlorite This is a very gentle oxidative bleaching agent for fibres, particularly for cotton, which, in a long liquor, does not chemically damage the cellulose structure, even with moderate overdosing and fairly lengthy contact times. The reason for this is to be seen in the relatively moderate oxidation potential of the agent regarded as an effective bleacher - chlorous acid ($HClO_2$). Removal of the seed husks and the other coloured impurities of cotton follows, as chlorite bleaching is carried out in the moderately acid zone at an approx. pH of 3.7–4.0. Thus, → Sodium chlorite enables numerous products, which, along with cotton, have alkali-sensitive fibre constituents, such as polyacrylonitrile or regenerated cellulose for example, to be bleached. In addition, various man-made fibres produced from natural polymers, like viscose, acetate or modal for example, are also suitable for bleaching with sodium chlorite. Polyester, polyamide and polyacrylonitrile are to be mentioned in the case of synthetic fibres. With all the above-mentioned textile fibres, chlorite bleaching results in a degree of whiteness which cannot be achieved with hydrogen peroxide in a single stage process.

Sodium chlorite is not suitable for bleaching animal fibres such as wool and silk for example, as the protein structure of these fibres is oxidatively attacked, and irreparably damaged under the conditions existing in chlorite bleaching liquors. Since chlorite bleaching is carried out in the acid pH range, very little swelling occurs with cellulosic fibres, for which reason fabrics sensitive to creasing and folding are preferably bleached with sodium chlorite. Furthermore, this bleaching agent is decidedly less sensitive to heavy metal ions than hydrogen peroxide. For this reason, sodium chlorite is preferred to hydrogen peroxide for bleaching products like poplin for example (catalytic decomposition of the H_2O_2 and fibre damage has to be reckoned with in the presence of specific heavy metal ions in the H_2O_2 bleaching liquor). A further advantage of the chlorite bleaching of cotton or products containing cotton is also to be seen in the fact that, by bleaching in the weak acid range, fewer fats and waxes are dissolved out by soaping vegetable fibres than with alkaline hydrogen peroxide bleaching. On the one hand, this has of course an advantageous effect on the CSB content of the bleaching department effluent, and, on the other, a fabric optically whitened with sodium chlorite has a soft handle.

A glance at the comparatively complicated chlorite bleaching chemistry (Fig. 1) shows where some potential disadvantages of this bleaching agent lie. Chlorite bleaching is carried out as a rule at temperatures of 80–95°C and in pH ranges between 3.7 and 4.0, for sodium chlorite, reacting strongly alkaline in aqueous solution, must be activated with acid in order to enable its bleaching action to be fully developed. The problems begin of course with activation and the formation of complicated chemical equilibria in the liquor due to it (Fig. 2).

$$\begin{array}{ll}
ClO_2^- + H_2O & \rightleftharpoons HClO_2 + OH^- \\
ClO_2^- + H^+ & \rightleftharpoons HClO_2 \\
5\,NaClO_2 + 4\,HCl & \longrightarrow 4\,ClO_2 + 5\,NaCl + 2\,H_2O \\
3\,ClO_2^- & \longrightarrow 2\,ClO_3^- + Cl^- \\
4\,ClO_2 + 2\,NaOH + H_2O_2 & \longrightarrow 2\,NaCl_2O + 2\,H_2O + 4\,O_2
\end{array}$$

Fig. 1: Chemical reactions of sodium chlorite or chlorine dioxide.

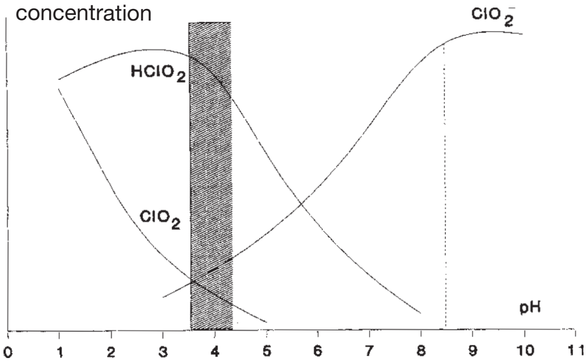


Fig. 2: Reactive intermediate in chlorite bleaching relative to the pH.

The concentration of the chlorous acid ($HClO_2$) acting as the bleaching agent reaches its maximum in the 2.5–3.5 pH range. Below pH 3.0 however, fibre damage becomes noticeable due to cellulose hydrolysis. In addition, the disproportionation of the chlorous acid into chlorine dioxide and hydrochloric acid in an excessively strong acid range, which has a further fall in pH as a consequence, has always to be taken into account. Chlorine dioxide is also very toxic as a gas. In the weakly acid or neutral or alkaline range on the other hand, only the non-bleaching action ClO_2 chlorite anions are dominant. For these reasons, the optimum reaction conditions lie in a comparatively narrow pH range between 3.5 and 4.5, in which relatively mostly activated $HClO_2$ molecules are present in equilibrium. These complicated and outwardly easily affected chemical equilibria are graphically illustrated in Fig. 2. A chlorite bleach does in fact produce a lower AOX content in the effluent, but partial flows can exceed the permitted limits (according to Weck).

Bleaching agent, sodium hypochlorite Bleaches cotton in particular cost-effectively and to a high degree of whiteness, but the AOX value as a measure of organic halogen compounds (accumulation of NaOCl on cotton impurities) exceeds the permitted effluent pollution. The quantities of → Sodium hypochlorite used in textile finishing as compared with the paper industry are in fact small, but are also the cause of critical action on the part of the authorities. Sodium hypochlorite is a powerful oxidising agent with a correspondingly high redox potential. Since hypochlorite consequently reacts relatively unselectively with the fibres, the danger of fibre damage with this bleaching agent is much greater as compared with the others. For this reason, the bleaching processing parameters, particularly the pH value, must be exactly adhered to. Due to its high oxidation potential, hypochlorite bleaching is carried out only in the cold state. Hot bleaching is ruled out on account of the equilibrium displacement in the direction of hypochlorous acids or active chlorine, which would result in drastic fibre damage. For this reason, it is essential to monitor the pH during bleaching, since the active bleaching species, the hypochlorite anion and hypochlorous acid, are present beside each other in the chemical equilibrium. Practical experience confirms that sodium hypochlorite bleach liquor has a preferential bleaching action in an alkaline medium, but is increasingly fibre damaging in the neutral range. The reason for this, that hypochlorite bleaching can be effected only in a narrow pH range (hatched in the Fig.), is attributable to the fact that, with very high concentrations of chlorous acid in the neutral range, they not only react with the natural impurities in the vegetable fibres but also with the polymer structure of the fibre material.

The actual bleaching reactions run more or less parallel to fibre damage therefore, and the question as to what different extent these two parallel reactions take place can only be answered via the pH value. In the 9 to approx. 11 pH range, the active bleaching species concentration and the free molecules of hypochlorous acid are high enough to react preferentially with the natural impurities in the fibre, thanks to the high oxidation potential. At the same time however, the danger of elementary chlorine release does not arise, while an adequate reservoir of still inactivated hypochlorite anions is available. In the higher pH range, the HOCl molecule concentration is so low that this is unacceptable in practice. With the liberation of oxygen during the decomposition of hypochlorous acid, HCl is produced, which then releases elementary chlorine to an increased extent (according to Weck).

Bleaching and catalytic damage The presence of metals in trace amounts, especially iron, manganese and copper, cause the spontaneous release of oxygen in peroxide baths which results in local destruction of cellulose (formation of holes). When traces of such metals are present in cellulosic textiles a preliminary treatment with oxalic acid or complexing agents is necessary. This pretreatment can, however, be omitted if diethylenetriamine pentaacetic acid (DTPA) is used as a stabilizer in the bleach bath instead of silicate.

Bleaching auxiliaries Products designed to improve the reliability of bleaching, accelerate bleaching

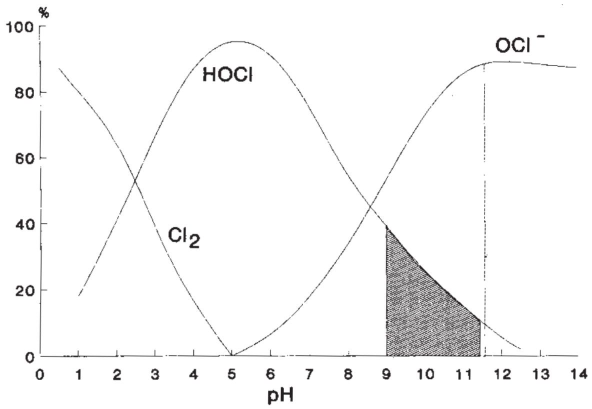


Fig.: Intermediate products with and without bleaching action with the use of sodium hypochlorite solution relative to the pH.

action (especially for peroxide and sodium chlorite bleaching), and provide protection against fibre damage.

1. Wetting agents: these are mainly alkylnaphthalene sulphonates, sulphonated oils, fatty alcohol sulphates, and fatty acid condensates. Wetting agents for bleaching can also contain solvents.
2. Stabilizers: very important for bleaching with hydrogen peroxide. Suitable products include: sodium silicate (water glass), phosphates, organic complexing agents, protein fatty acid condensates, phosphoric acid esters.
3. Activators: for bleaching with sodium chlorite. Suitable products include: inorganic and organic acids, phosphates, nitrates, esters and ammonium salts.
4. Corrosion inhibitors for sodium chlorite bleaching: fatty acid condensates, nitrates, nitrites and phosphates.

Bleaching catalysts → Catalysts which function as oxygen carriers are used in bleaching to activate the bleaching process and achieve savings in the quantities of bleaching agents required.

Bleaching chemicals

I. Chlorine-based products: e.g. chlorine dioxide, chloride of lime, sodium chlorite, sodium hypochlorite.

II. Oxidative products: ammonium persulphate, potassium permanganate, potassium persulphate, sodium perborate, sodium percarbonate, sodium pyrophosphate peroxide, sodium persulphate, sodium peroxide, hydrogen peroxide.

III. Reductive bleaching agents: sodium bisulphite, sodium dithionite, sodium pyrosulphite, sulphurous acid.

Bleaching chemicals, automatic For monitoring and controlling (potentiometric titration principle) the chemical content of impregnating liquors.

Bleaching, degree of → Whiteness, degree of.

Bleaching/dyeing combined process Combination of bleaching and dyeing for cellulosic fibres. The process is restricted to the use of hydrogen peroxide as bleaching agent. Applicable for direct, vat and vat leuco ester dyes.

Bleaching earths (active earths) are colloidal magnesium aluminium silicates with varying iron contents, used as filtering auxiliaries for decolorizing dark mineral oils, fatty oils and fats and similar very finely divided substances. The raw materials are clays which are opened up (activated) by heating or chemical treatment (mineral acids, alkalies). Activation with acids breaks the crystal lattice by dissolving out $Al(OH)_3$, which opens the inner capillary structure and so increases the effective surface area. The activity is connected with direct bonding of OH ions to silicon and the content of water bound to the mineral is mainly responsible for the decolorizing effect, so that combined physical and chemical actions are required for the adsorbing effect with bleaching earths. The earths can however vary considerably depending on their activation. As water is also adsorbed, gels are formed (which do not pass through filters). Today they have no practical significance.

Bleaching fastness →: Colour fastness to bleaching agencies: hypochlorite, peroxide, sodium chlorite.

Bleaching fastness of coloured wovens Colour fastness of → Coloured woven articles to processing. Requirements for cotton are: colour fastness to soda boiling, kier boiling, hypochlorite bleaching, chlorite bleaching and peroxide bleaching. Requirements for viscose are: colour fastness to hypochlorite, chlorite and/or peroxide bleaching. With combined chlorine-peroxide bleaching processes, the order in which both these bleaching chemicals are applied has an influence on the fastness of some vat dyes (black brands).

Bleaching of animal fibres Cold bleaching for dark animal hairs at a liquor ratio of 20:1, pH of 9,2–9,5 and a temperature of 20–25°C in soft water containing 2 g/l sodium pyro- phosphate, 30–40 ml hydrogen peroxide 35% and 20–25 g potassium or ammonium persulphate. The bleaching treatment is carried out for 18–24 hours followed by a final rinse and, if necessary, a reductive aftertreatment. The bleach bath can be reused after freshening with appropriate chemical additions.

Bleaching of coir It is not possible to achieve a white with this fibre. An effective brightening can be obtained, however, with hydrogen peroxide and an afterbleach with sodium dithionite.

Bleaching of coloured woven goods Bleaching carried out on coloured woven goods in accordance with the practical requirements of the → Bleaching fastness of coloured woven goods.

Bleaching of cotton Has the function of removing the dyed impurities which cannot be removed by scouring or kier boiling, particularly the natural dyestuffs of the cotton fibre and also the residual husks. The fibre material is bleached by means of sodium hypochlorite, sodium chlorite or hydrogen peroxide baths, in many cases in a sequence of these bleaching methods in a combination process (hypochlorite-peroxide). The question as to which process has preference depends on various factors, particularly the demands which are made on the bleached fabric. A so-called "semi-bleach" is adequate for batches destined for dyeing or printing. The cellulose is more or less broken down by each bleaching process. This is expressed by a reduction in the average degree of polymerisation (DP). Here, the bleacher must take into account the fact that the loss is to a certain extent permanent. Comprises are inevitable in selecting time, temperature and chemical concentration relative to degree of whiteness and fibre damage and also to environmental protection.

The intensity of bleaching required depends particularly on the inherent colour of the cotton. It is impossible to obtain a uniform white on cottons of different natural colours by bleaching. Shade differences are visible even after bleaching. Pretreatment has a bearing on this. If one is unwilling to scour intensively, bleaching must be correspondingly intensive, increasing the danger of fibre damage. On economic grounds, attempts are made to shorten all treatment processes, and to cut out individual stages wherever possible. In treating woven fabrics, desizing, scouring and bleaching and also optical whitening in the case of white fabrics, are frequently combined into a continuous process.

All bleaching processes, particularly peroxide processes, can be catalytically affected. From this, it follows that cotton must contain no metals prior to bleaching. It must, if necessary, be pretreated or acidified beforehand with complex formers. Bleaching equipment must consist of corrosion-resistant material. Pumps, piping, valves and other fittings must also contain no catalytically active metals like iron, copper, manganese or unsuitable alloys. Stainless steel and earthenware can be used for hypochlorite and peroxide; special alloys, possibly titanium, and earthenware or plastic are recommended for chlorite. Bleaching baths, especially peroxide liquors, must be heated by indirect heating by means of preheaters or closed steam coils.

Cotton can be bleached in various make-up forms, i.e. also in different processing stages:

I. Loose stock: the bleaching of cotton in loose stock form is of subordinate importance, and is carried out in pack equipment with liquor circulation (e.g. the Krantz radial bleaching machine) using peroxide, with hypochlorite in addition in the first stage if necessary. If a fully enclosed unit (HT equipment) is available, scouring and bleaching can be effected in a single stage in a highly alkaline peroxide bath. Waterglass is replaced by an organic stabiliser in order to ensure good spinnability.

II. Card sliver: treatment in bundle form in a pack cylinder has been abandoned in favour of wound batches. A complete card sliver bleaching plant consists of a winding machine, warp beam material carriers, HT bleaching unit and beam centrifuge. The bleaching conditions themselves are the same as for loose stock. For the continuous bleaching of large batches, units have been produced which are similar to those of continuous woven fabric bleaching. After impregnation with the bleaching agent and heating comes steaming, where the material is carried forward by perforated cages or conveyor belts.

III. Yarn: yarns are bleached in cross-wound packages or warp beams in circulation-type equipment, mainly in two stages for full white, first with hypochlorite and then peroxide. In the case of yarns containing few husks, a highly alkaline peroxide bleach alone is sufficient under HT conditions in order to obtain an acceptable white without special scouring processes.

IV. Fabrics: the great majority of cotton is bleached in woven or knitted fabric form. The processes are based closely on those of scouring; bleaching is effected either in rope or open-width form, in batches or continuously, and in the same equipment. Production quantities and fabric quality determine the choice.

Fabric bleaching in rope form:

a) Batch processes: only lightweight qualities with no tendency to crease are suitable for this. Small batches can be bleached in the winch. Liquor circulation vessels are employed for large batches. This bleaching process is called "kier bleaching", and is generally carried out in two stages with a sodium hypochlorite pre-bleach and a hydrogen peroxide after-bleach. A single bleaching stage can be used depending on the quality of the fabric to be bleached and relevant local factors.
b) Continuous processes: the equipment used for continuous rope bleaching is the J box with upstream impregnating section. Hypochlorite bleaching can be effected in an unheated J box. In the bottom of the J box is a bath (sump) which contains approx. half the chemical concentration of the impregnation section (wet J box). Impregnation with the bleaching solution is effected in an impregnation section (saturator). With peroxide and chlorite bleaching, heated J boxes are employed, or the impregnated fabric is steam heated prior to entry into the J box. Depending on the bleaching agent used, the J box consists of stainless steel, titanium, ceramics or plastic (polyester/glass fibre). U-shaped containers with nozzles at inlet and outlet are available for full-bath bleaching. Liquor and fabric run parallel at the entry end, and opposite to each other at the outlet end.

Bleaching fabrics in open-width form: this method is suitable for all woven fabric qualities.

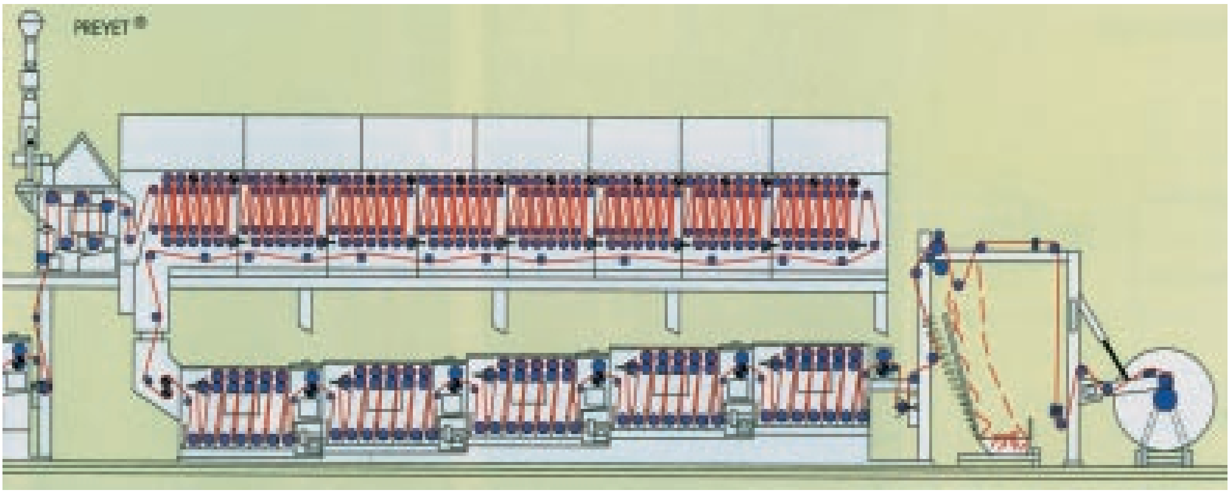


Fig.: One-step continuous bleaching unit for woven fabrics using the Preyet-spray-system, a roller steamer and a roller washing unit from Kleinewefers KTM.

a) Batch processes: batches scoured in a jigger are subsequently bleached in the jigger, hydrogen peroxide being almost exclusively employed. The second possibility of batch bleaching is offered by the “pad-roll”, pad mangle-dwell or batch bleaching process. A batch bleaching line comprises a pad mangle – or better, an impregnating section – a heating unit (steam, air, infra-red) and a dwell chamber. The heater unit can be located inside or outside the chamber. When perforated rollers are employed for batching, scouring can follow in the batch after bleaching. At the end of the bleaching process, the roller is connected to a rinsing water supply. Cold dwell processes are of interest from the energy saving standpoint. All temperature variants are suggested for peroxide. The lower the temperature the longer the dwell time. Practical operation assesses the degree of whiteness obtainable with a single stage peroxide bleach and the fabric wettability differently. Average degrees of whiteness are obtained with the BASF extraction cold bleach. Persulphate ($Na_2S_2O_8$) can also be used for cold dwell bleaching.

b) Continuous processes: these processes are of great importance. The equipment used in them is the same as for the alkali stage in scouring. Continuous process monitoring and a constant quality standard is ensured by using measuring equipment and multi-component bleaching agent dosing units. The processes comprise impregnating the fabric with the bleaching liquor (under certain circumstances in → High wet pick-up system), heating by steam and dwelling in a steam atmosphere with subsequent washing off. One processing variant is dwelling prior to steaming. Qualities which do not tend to crease can be plaited down in J boxes or on to conveyor belts or roller beds. The other qualities are fed in open-width over roller systems (at least in the initial stage) before being plaited down. A batching box is suitable for batches of over approx. 20 000 m of uniform width. Less room is taken up by HT or pressure steamers, in which the bleaching process is carried out within 45 to 120 secs at 130–140°C. Medium term bleaching processes with steaming times of 10–20 mins are more usual. Short bleaching times of 1–3 mins can be achieved with hydrogen peroxide in open steamers with the use of superheated steam (see Fig.). Scouring and bleaching each take 2 mins. In addition to waterglass as a stabiliser, sodium tetraborate or sodium pyrophosphate are to be added to the peroxide bath.

Bleaching of furs →: Fur bleaching; Bleaching of animal fibres.

Bleaching of jute This fibre is difficult to bleach. Hydrogen peroxide or sodium chlorite are used, preferably chlorite first followed by peroxide. A rapid after-yellowing occurs, however, following exposure to light.

Bleaching of knitgoods The processes are closely allied to those for woven fabrics, treatment in rope form being of greater importance than open-width bleaching. Knitgoods are particularly elastic, and do not tolerate lengthwise traction. Installations must be designed for this (see Fig.). Good raw material quality with no husk residues is generally selected for cotton knitgoods, so that the chemical concentrations can be reduced accordingly. Waterglass is only reluctantly used (handle impairment) as a peroxide bleach stabiliser; organic stabilisers in combination with magnesium sulphate are used instead.

Bleaching of linen With flax, the non-cellulosic constituent content, at 25–30%, is significantly higher than with cotton. In order to obtain a full white therefore, intricate treatments are necessary. The loss of weight occurring in scouring and bleaching can be as high as 40%. The old grass bleaching method is very

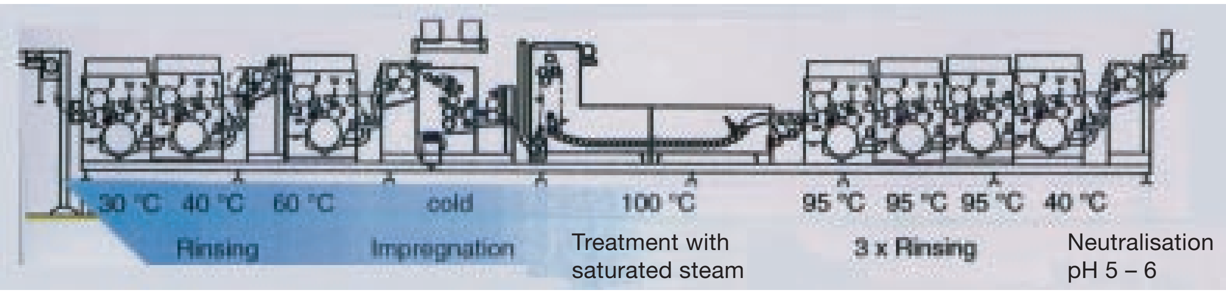


Fig.: Bleaching of knitgoods according to BTM with the Spray-Flour-Unit for rinsing without tension.

rarely used now. This previously widespread bleaching method comprises a sequence of alkaline scouring operations (hot liquors) and hypochlorite baths. 4 sequences (called rounds) were necessary in order to obtain a full (4/4) white. Lower degrees of whiteness are designated 1/4, 2/4 and 3/4 whites; the treatment required consequently comprised 1, 2 or 3 rounds. Attempts were made at an early stage to obtain a full white without the time-consuming 4 rounds. A "short" process is still occasionally used, the principle of which is to destroy the lignin, after scouring, in an acid hypochlorite bath at pH 4–4.5, and then pre-bleach in an alkaline hypochlorite bath, and post-bleach in a hydrogen peroxide bath. In the Ravensberg process, bleaching is effected after scouring with an aqueous chlorine dioxide solution, followed by a bleaching stage with hydrogen peroxide, and, finally, one with hypochlorite. The "LOK" process (Degussa) is carried out without pre-scouring, bleaching first with sodium chlorite and then with hydrogen peroxide. Another process also operates without scouring, first of all pre-bleaching with hypochlorite at pH 11.5, and, following the addition of sodium chlorite to the same bath, post-bleaching at pH 5.5 at 65°C. In practice, a 4-stage combination bleach is widespread: alkaline scouring, alkaline hypochlorite bleaching, chlorite bleaching and peroxide bleaching follow one another.

Bleaching of man-made fibres In contrast to natural fibres, man-made fibres contain no coloured attendant substances. They are already white when put on the market; optical whiteners are sometimes added to the spinning material. For full white, bleaching cannot of course be dispensed with, particularly where yellowing occurs due to the use of heat-stabilisation. Bleaching is mainly restricted to woven and knitted fabrics. Yarns are more seldom bleached, and loose stock rarely. Bleaching chemicals have to be adapted to the different fibre materials. Reducing agents are not damaging to the fibres, and are universally applicable in this regard. Sodium dithionite and also sodium and zinc formaldehyde sulphoxylate are used. Of the oxidative bleaching agents, sodium chlorite is universally employable except for polyurethane fibres. Hydrogen peroxide on the other hand is not suitable for all synthetic fibres. Polyamide in particular is sensitive to active oxygen. Polyvinyl alcohol is a protective agent. Unsuitable too is hypochlorite, which forms chloramine with polyamide, while potassium permanganate is also fibre-damaging. Man-made fibres are bleached in the full bath; the impregnation process, as employed with natural fibres, is unsuitable. J-box equipment is a possibility for continuous bleaching. In the case of synthetic fibres, the delustring agents, stabilisers, optical brighteners and UV absorbers (light protection agents) present in the spinning mass can, under certain circumstances, lead to difficulties in bleaching with sodium chlorite. Thus, the manganese salts contained in polyamide fibres as light protection agents cause pronounced yellowing of stilbene-based optical whiteners when exposed to light in the wet state. Fully delustered polyester fibres, also tend to yellow, and are therefore better bleached with hydrogen peroxide. In chlorine bleaching, some non-delustered polyester fibres acquire a strong red cast, which can be prevented by adding hydrogen peroxide or sodium perborate to the chlorite bath. Acetate and triacetate fibres persistently retain chlorine, for which reason they should be treated with sodium disulphite or sodium dithionite after chlorine bleaching. In bleaching polyamide fibres with sodium chlorite, it can occasionally be observed that the uptake of fluorescent whitening agents is blocked. Elastane fibres are difficult to bleach; the permissible bleaching agents have a negligible effect.

Bleaching of silk Oxidative and/or reductive bleaching processes can be used for brilliant and bright shades. Bleaching generally follows degumming. As a rule, mulberry silk generally already reveals a light colour after degumming, and bleaching is consequently necessary only for a full white. On the other hand, bleaching is almost always necessary for obtaining brilliant shades with degummed tussah silk owing to its inherent colour. Depending on tussah quality, a full white can be obtained only with difficulty, if at all. For full white, optical whiteners can be added to the subsequent reduction bleach bath after oxidative pre-bleaching.

Silk is bleached for example in accordance with the following processes:

1. Oxidative bleaching with 35% H_2O_2 and $Na_4P_2O_7$.

2. Reductive bleaching with stabilised sodium dithionite.
3. Bleaching and brightening (full white): optical brightening is mainly effected after oxidative pre-bleaching in the reduction bleaching bath.

Bleaching of wool Natural wools have a more or less strong inherent colour, which can be bleached out by reductive or oxidative treatments. The two processes are to be employed one after the other for a full bleach. The targeted white is however, even after the best of bleaches, unstable to exposure to light and washing. Yellowing occurs in the course of time. The cause of this is not yet known, and there is no product which can prevent this fault. It has been observed that many optical brighteners act as sensitisers, accelerating yellowing. Yellowing can be delayed by thiocarbamide and formaldehyde. Wool is sensitive to chemical effects, for which reason batches which have been subjected to anti-felt finishing for example should be bleached particularly gently, or it is recommended that bleaching be carried out prior to felt-free treatment. The lowest possible wool residual grease content – approx. 0.1–0.2% for worsted yarns, and 0.2–0.3% for woollen yarns – is important to the bleaching effect. The duration and temperature of the bleaching process have a great deal of influence on the quality of the wool. It is bleached in all processing stages: as loose stock, tops, yarn, fabric, in the full bath or by the impregnation process, continuous or in batch form. Under some circumstances, piece goods are dyed in pastel shades in the presence of bleaching agents.

I. Oxidative bleaching processes: hydrogen peroxide is generally used. Up to now, the waterglass used as a stabiliser in the cotton bleaching process has been found unsuitable for wool, and has been replaced by sodium pyrophosphate or one of the commercially available stabilisers. The pH is set with ammonia (provided that no silicate is employed). 50°C is the optimum temperature, with a duration of 3–4 hours. Cold storage bleaching with peroxide is possible with the aid of specific auxiliary agents. With the sensitivity of wool to alkali, peroxide bleaching in an acid medium is suggested. One such process is the “Prestogen W” process (BASF). Opinions as to the effect of acid peroxide bleaching as against the alkaline method differ. In the latter case, the white should be better and more stable with no greater fibre damage. Wool with a strong inherent colour is treated first of all in a solution of iron sulphate, centrifuged, and then bleached (natural hair depigmentation) in a hydrogen peroxide bath with complex formers added (for removing the iron). With such qualities, the finisher hesitates to use the catalytically intensified peroxide process.

II. Reductive bleaching processes: these are unsatisfactory for a full bleach, and are used only for brightening or as the 2nd stage of a full bleach. Many of the commercially available reductive bleaching agents are provided with an added fluorescent whitening agent.

With all processes, bleaching must be followed by a good rinsing process. Wool stubbornly retains hydrogen peroxide, a fact which can lead to dyestuff damage in the subsequent dyeing process. A reductive bath frequently follows for safety purposes. In a 2-stage bleach therefore, the reductive stage is carried out as the final process.

Bleaching powder vat → Chlorate discharges.

Bleaching soda A term which has a double meaning:

I. → Sodium dithionite.

II. A mixture of sodium carbonate and sodium silicate for water softening capable of binding traces of iron. Used in laundries, etc.

Bleaching stabilizers In hydrogen peroxide bleaching the effect is dependent on the controlled release of oxygen. Fibre damage is likely to occur if oxygen is released too rapidly. Besides the well-known sodium silicate (water glass) stabilizers which exhibit an optimum effect, other stabilizers based on polyorganosiloxanes, sodium borate and magnesium silicate are also used. The disadvantages of silicate stabilizers include difficulty in removal during washing, formation of deposits on the fibre and on processing machinery, harsh handle etc. No fully effective substitute for sodium or magnesium silicate has yet been found, however. If bleaching is carried out over a relatively long period of time (e.g. the cold pad batch process) it is particularly difficult to find an effective substitute for sodium silicate. When sodium orthosilicate is used, a combination of phosphate and a magnesium salt is recommended as a stabilizer. → Bleaching auxiliaries; oxidative bleaching processes.

Bleaching with hydrogen peroxide under acidic conditions In hydrogen peroxide bleaching it is usual for peroxide baths to be maintained under alkaline conditions since the release of oxygen proceeds too slowly in acidic media. However, Degussa has developed a product, Activator SF, which permits bleaching to be carried out at pH 5,5–7,0.

Bleach liquor → Sodium hypochlorite.

Bleach-related fibre damage → Vat dyes and fibre damage.

Bleeder styles Prints with indistinct outlines (→ Flushed prints). Print pastes for this style of printing contain two or more components. One of these components ensures a faithful reproduction of the engraved areas whilst the other components, because of their special properties, flow beyond the confines of the engraving into the unprinted areas where they give mainly contrasting colours at the edges of the printed motifs. Example: cotton fabric prepared with a naphthol and printed with diazo fast colour bases or salts in combination with reactive dyes to give bleeding effects. A two-phase fixation process is used for the reactive dye components.

Bleeding This problem occurs mostly with textiles which have been dyed in deep shades with dyes of poor wet fastness properties. When such materials are washed, or subjected to a wet treatment, the dye bleeds out into the liquor resulting in a lighter shade. In printed goods, dye can bleed into the white (unprinted) areas of the design causing staining of the whites. Bleeding can also give rise to problems in subsequent wet finishing treatments. Causes:

1. dyeings or prints produced with dyes of inferior wet fastness properties,
2. inappropriate washing conditions.

Blending weigher Used in colour kitchens for the preparation of individual print pastes. The system, which consists of both a fixed and a movable concentric dial scale, permits individual taring with the movable scale for the weighing of each component whilst the total quantity can be read off the fixed scale. Weighing errors are largely eliminated by this means.

Blister crêpe → Cloqué.

Block copolymer → Block polymers.

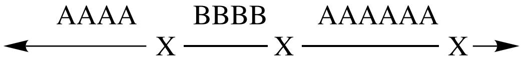
Block cutting Production of the → Hand for block printing. Pattern production by woodworking in accordance with pre-print blocks with fine contours by driving in pins and sheet metal strips. The latter are detailed in a lime wood block by means of red hot punches and babbitting with white metal alloy which serves as a printing knife when nailed on.

Blocked fatty acid groups Masked fatty acid and → Fatty acid condensation products.

Blocking effect in the dyeing of polyamide Mutual displacement of individual acid dyes in the dyeing of polyamide materials within the range pH 3–6. The effect is dependent on dye constitution, dye concentration, fibre saturation value and the dyeing auxiliaries used. The dye constitution is of decisive importance here since, as a rule, polysulphonated dyes are blocked by monosulphonated dyes and, depending on the degree of saturation of the fibre, dye concentration and auxiliaries concentration, are partially or completely displaced thereby preventing them from exhausting on to the fibre.

Blocking filters are used in → Spectrophotometers for → Colour measurement of fluoresecent white samples. This sort of equipment enables the effects of the substrate and brightening agents to be separated. The excitation of the brightening agent can be removed to a large extent with a variable u.v. filter (the measured colour values are those of the unbrightened substrate). On the other hand, with blocking filters for visible light or with a u.v. source, the values for the brightening agent alone are obtained. In this case the apparatus operates as a spectofluorimeter. Complete separation of the two types of light is not possible because optical brightening agents are excited to some extent by short wavelength light in the visible region.

Block polymers (block copolymers). These high polymers are formed from chains of different → Copolymers whereby individual units are joined together in relatively long alternating sequences (see Fig.). An example could be blocks of polyvinyl chloride interspersed with blocks of polyvinyl acetate. Such polymer combinations are made synthetically. They depend on the presence of an active site on the polymer chain which initiates the necessary reactions. Branched copolymers of this type are graft copolymers.



Block printing The oldest printing process – block printing – is mainly of historical interest today (→ Hand block printing). This is operated with so-called blocks which have been produced by striking brass pins and strips into a front bar, forming the pattern in this way. This process has been retained in developing countries, and also finds use in roller production for relief printing machines.

Blocks for printing (printing blocks) For hand block printing the blocks are cut from wood which are then infilled with felt and, where necessary, copper strip and pins (depending on the intricacy of the design) are also incorporated. Fairly hard woods are used for all printing blocks, e.g. ash, box, lime, sycamore, holly and particularly pearwood. To facilitate registration in hand block printing, brass pins are driven in at the corners of the block to indicate the position of the next repeat (→ Block cutting).

Blood alcohol, is measured as a percentage and arises after imbibing alcoholic drinks (ethanol). Blood alcohol has only a very tenuous connection with the states of intoxication induced by the inhalation of solvent vapours (hydrocarbons, chlorinated hydrocarbons, etc.) although it increases considerably if accompanied by the consumption of alcohol as well.

Blood, detection of Important in forensic medicine. Well-known methods include:

I. Benzidine test: involves making a clear extract of the blood stain with a 0,85% sodium chloride solution, then observing the reaction with some benzidine + acetic acid + hydrogen peroxide. Positive result = blue-green coloration.

II. Fluorimetry: blood does not normally fluoresce and appears black. After removal of iron from the haemoglobin and overstaining in haematoporphyrin with sulphuric acid = red fluorescence of high intensity; after removal of the acid with strips of filter paper and spotting with strong ammonia = crimson red fluorescence. Practical procedure: A platinum needle is moistened with conc. sulphuric acid and used to draw a fine line on the stain which is immediately neutralized with ammonia = fluorescent crimson red stripes on the wetted fibres under UV light. After separation of the caked blood which is optically “dead”, blood serum exhibits a weak bluish fluorescence.

Blood stains Red or brown in colour. When fresh, the stains are paler with a sharp boundary. Since the composition of blood varies, stain removal is very difficult and in some cases impossible, especially if the stains have become fixed by the action of heat. Removal: treatments are best carried out as soon as possible under essentially cold to lukewarm conditions; a prebleach with some ammonia and soap as well as diastase solution is useful: (a) bleaching with a 3% hydrogen peroxide solution, if necessary at increased temperature, (b) diastase solution (together with glycerol and possibly some ammonia). Yellow residue = iron (→ Rust stains).

Bloom,

I. In deep dyeings, the fullness or toning with a red, yellow, or blue cast, e.g. “bloomy black”. → Blue brushing.

II. The colour of foam in vat dyeing baths which, in contrast to the generally quite different colour of the vatted dye, appears closer to that of the finished (fully oxidized) dyeing.

Blotch design A single or multicolour printed design in which up to approx. 80–90% of the fabric surface is printed in one colour.

Blotch print In direct printing, a printed design of high coverage. Also used to substitute dyed grounds for discharge printing in cases where no dischargeable dyes are available with adequate fastness properties or where technical problems are encountered in coloured discharge printing.The degree of cover of a blotch print may be low, medium or heavy.

Blotch printing (cover printing). This type of printing is used to provide a background to a design which, unlike the white grounds in normal direct printing, or the plain coloured grounds in discharge printing, consists of a distinct pattern effect. It is produced with a special printing roller either simultaneously, before or after production of the main design, e.g. for imitation weave effects, fine dots, lines, etc. It may be visible over the entire surface of the printed fabric or limited to areas falling over other colours by resist or discharge printing.

Blotch printing machine (cover printing machine). A roller printing machine set up to print the entire surface of a fabric with print paste or a thickened chemical solution by means of, e.g. a completely engraved blotch roller (cover roller).

Blotch roller (1000 point roller), pad mangle roller engraved with recesses, for transferring softening agents and possibly dye solutions during → Nip padding.

Blotting paper effect → Capillary fabric-liquor interchange.

Blouson (Fr.). A short jacket or top having the shape of a blouse reaching to the waist, with either a buttoned or zip front and ample sleeves. The sleeve endings are finished with elastic material.

Blowdown of boilers A cleaning procedure for the removal of solid substances which have settled in the water reservoir of a boiler used for steam raising purposes. The procedure is often carried out with an automatic valve operating at working pressure.

Blown oils Thickened →: Semi-drying and drying oils (especially linseed oil, as well as castor, rapeseed and fish oils) which are already partially oxidized by heat and agitation produced by a current of hot air at 70–120°C. As a consequence of this treatment, drying is more rapid when used as oil sizes. They form reasonably stable light soapy emulsions in water without the need for emulsion-promoting additives.

Blow ratio Can be varied by the quantity of dispersed air brought in during foaming. If for example 1 kg of liquor is foamed to 10 l of foam, this is equivalent to a 10:1 blow ratio, or the foam has a litre weight of 100 g. → Foam application.

Blow test for dye homogenicity The simplest test to determine whether a dye in powder form is a homogeneous dye or a mixture. A small speck of the dye is blown across a piece of filter paper (approx. 10 x 20 cm) which has been completely wetted with warm distilled water, alcohol, benzene or conc. sulphuric acid. A homogeneous dye will produce uniformly coloured dots on the wet surface whilst a mixed dye will produce two or more different colours.

BLRA, abbrev. for (the former) British Launderers’ Research Association (now → FCRA); → Technical and professional organizations.

Blue brushing Surface brushing of the pile in black piece-dyed cord and velvet fabrics with a mixture of linseed oil and Berlin blue to achieve a more intense bloomy black shade.

Blue cast in bleached goods This effect is the result of excess → Blueing of bleached goods to compensate for yellowness. The resultant blue tint or cast manifests itself as an increase in whiteness only up to a certain level.

Blue deficiency A substrate which reflects the incident light falling on it uniformly and to a high degree at all wavelengths appears white to the eye. In general, however, fibres absorb more light in the blue region of the spectrum due to the presence of impurities (natural pigments) than in other regions of the visible spectrum (the effect is more pronounced with natural fibres and is usually less with synthetic fibres). The prevailing yellowish cast in bleached goods is referred to as blue deficiency and appears unattractive to the human eye. In order to achieve increased whiteness, therefore, the blue deficiency of a textile fabric can be cancelled out by applying compensatory measures and/or by increasing the amount of reflection. Both effects are obtained to a certain extent in bleaching. The additional application of a fluorescent brightening agent leads to further compensation of blue deficiency due to a simultaneous increase in lightness thereby producing a more brilliant white. A further improvement in whiteness by compensation which involves the application of very small amounts of suitable blue or violet dyes in the → Blueing of bleached goods is also possible.

Blue denim Strong woven cotton fabric with a warp twill construction, dark coloured warp and light (undyed) weft. Classical fabric for → Jeans. → Denim.

Blue "eating" dye combinations Catalytic fading caused by the action of light on the blue or blue-green components in combination dyeings with yellow and orange dyes which results in preferential and accelerated fading of the former. The problem occurs chiefly with vat dyes.

Blue "eating" yellow dyes These are yellow vat dyes which accelerate the photodegradation of blue (or blue-green) vat dyes. For this reason, they can only be used in combination with blue dyes up to a certain maximum concentration for the production of green shades. → Catalytic fading.

Blueing agents for bleached goods Blue dyes which are generally known as → Tinting dyes (or tints) for bleached goods.

Blueing of bleached goods As a supplementary treatment to correct the yellowish cast of bleached textiles the process is often referred to as the → Tinting of bleached goods.

Blue jeans →: Jeans; Denim.

Blue scale A standard comparative scale from 1 to 8 which is used for assessing the → Light fastness of dyed or printed textiles (1 = very poor, 8 = excellent). It consists of 8 standard blue dyeings on smooth wool fabric with varying degrees of sensitivity to the action of daylight or artificial light. In order to eliminate uncertainties in the evaluation of exposed blue standards and a test specimen, attempts have been made to obtain more precise ratings by colorimetric measurements. It has been found that to achieve the same degree of colour difference from daylight exposure different amounts of light are necessary depending on the season of the year. Use of the present blue scale as a standard comparative scale for light fastness tests has been subject to increasing criticism in recent years, particularly in the USA, where a polyester fabric dyed with a violet disperse dye has been recommended as a substitute.

Blue stone → Copper sulphate.

Blue vitriol → Copper sulphate.

Blue water phase Blue (or green) dyeing of the water phase of dry-cleaning in the water trap after the distillation of tetrachlorethylene. Is caused by copper corrosion.

Boarding The heat setting of hosiery and socks made from polyamide fibres to stabilize the knitted construction and confer a desired shape or size on the entire article. Depending on the type of hose and the stage of finishing, a distinction is made between

a) preboarding: a process carried out as the first stage of finishing at a temperature which is approx. 20°C higher than temperatures employed in subsequent finishing treatments and which are likely to be encountered in use (e.g. 115–130°C, 1,7–2,7 bar with saturated steam for 90–120 s);

b) postboarding: a treatment carried out after dyeing at 115–130°C with saturated steam for 60–90 s in order to achieve the desired shape of the articles.

Pre-setting or presteaming (not identical with preboarding) is carried out at 95–108°C for 10–20 min. Hosiery which has been presteamed is easier to process in subsequent finishing treatments.

Boarding of hosiery → Hosiery setting.

Boardy A subjective term used in the sense of a "boardy handle" for fabrics with very tightly woven and knitted constructions. The term is also used to describe finished fabrics that are excessively stiff or firm and lack suppleness.

Bobbin cleaning device Mechanically or pneumatically removes fibres remaining on the cores.

Bobbinet (English: bobkin = bobbin, net = tulle), so-called English tulle, net curtains and laces with at least 3 yarn systems. Binding or bobbinet ends, which spirally wrap round warp and patterning ends, are characteristic. For distinguishing purposes, mechanically produced English tulle is described as bobbinet tulle, the simplest version of which is so-called honeycomb – also called plain sexangular or hexagonal tulle. It is produced from two yarn systems, warp and weft systems. The warp system runs in the vertical direction in the fabric, with the weft system in the diagonal direction, each weft or bobbin end of the course looping once after each warp end on its diagonal path. Each bobbin end works first on the fabric face rising from left to right, then rising from right to left on the fabric back, forming the honeycomb openwork which is typical of sexangular tulle.

Bobbin lace Net-like openwork fabrics produced with fine threads (by hand or machine) that are fed from bobbins and worked into a pattern by the twisting together and crossing of strong ply yarns. Tulle and net backgrounds are also encountered. Bobbin lace galloons in different widths can be used as edge trimmings.

Bobbin length Length of the thread to be wound.

Bobbin packing machines Automatically pack the individual (yarn) packages in sheets in order to protect the yarns during transport.

Bobbins In worsted spinning these are yarn packages from the ring spinning machine. In carpet weaving they are flanged bobbins or spools.

Bobtex yarns Simulated spun yarns produced by embedding individual staple fibres in a thermoplastic or adhesive coating on a filament yarn. In principle, a thermoplastic polymer is applied to a filament yarn (as the strength component) and coated with staple fibres before the polymer sets in order to improve bulk and textile appearance. Yarn consolidation is achieved by means of false twist. A composite yarn produced in this way does not necessarily have to be twisted after heat setting/cooling thereby giving a flat hairy yarn. Bobtex yarns can be produced automatically and continuously at high speeds (300–600 m/min.) in any desired composition to meet specific requirements.

BOD → Biochemical oxygen demand.

Body and border carpet Wall-to-wall carpeting supplied in widths up to 5 m which is laid up to the wall skirting boards.

Body, climate, clothing In German the so-called 3-K system (Körper, Klima, Kleidung) which forms the basis of investigations in clothing physiology. → Clothing physiology.

Boiler, automatic Fully automatically controlled → Steam boiler. This term says nothing about type of construction, but is applied both to flame tube, smoke tube and Benson boilers.

Boiler feed water → Water requirements for steam raising boilers.

Boiler scale A more or less hard deposit which results from the use of untreated or inadequately treated boiler feed water. Boiler scale adheres firmly to the surfaces of plates and tubes in contact with water in steam boilers. If excessive, it leads to overheating of the metal and ultimate failure. Boiler scale is composed principally of (→ Water hardness salts), calcium carbonate and sulphate (gypsum boiler scale), some magnesium salts and (particularly dangerous) silicates.

Boiling out Unwanted → Kier boiling. Unwanted kier boiling during cotton textile washing occurs as a consequence of vat dyed effects in alkaline oxygen-depleted washing agent at high temperature (boiling) in the presence of reducing substances and under densely packed conditions. Under such conditions, even wash-fast vat dyeings/prints vat into soluble dyestuff/leuco compounds which easily leave an imprint on other articles, and stain them. Remedy: steep/prewash starched vat dyed articles prior to washing in order to remove natural starch as far as possible.

Boiling point All boiling points quoted in the literature, etc., relate to standard atmospheric pressure (1,0133 bar). When a liquid is subjected to increasing heat, a continuously increasing development of vapour on the surface is first observed together with the release of bubbles of vapour which rise from within the liquid. From this point onwards, the temperature of the liquid rises no further; this temperature is referred to as the boiling point. On further heating, the entire liquid is transformed gradually into the vapour state, i.e it evaporates. A pure liquid has a boiling point characteristic for that liquid whilst mixtures of liquids boil in specific sequence one after the other according to the typical boiling points of each component of the mixture, i.e. they are transformed successively into the vapour state (fractional distillation for the separation of mixtures). Thus special boiling point spirits (SBP), formerly known as benzine, is a mixture of different hydrocarbon homologues with no fixed boiling point but a boiling range of 60–120°C which indicates the boiling limits. A clear sharply defined boiling point indicates the presence of a pure liquid of uniform composition, whilst an indistinct boiling point is indicative of a mixture or impure liquid.

Boiling range In contrast to liquids of uniform composition with characteristic → Boiling points (e.g. pure benzene, water, glycerol), liquid mixtures (e.g. special boiling point spirits) have a well defined boiling range which extends from the lower to the upper boiling limits of the components.

Boiling water test (for dyeings) → Dye class identification tests on fibres.

Bolt A roll or piece of textile fabric of varying length.

Bolting cloth (→ screen mesh/gauze). This term covers a variety of lightweight open fabrics characterized by their fine and uniform mesh used for sifting flour and semolina (miller's bolting cloth), voile fabrics, window gratings, etc. as well as screen gauze or silk gauze for screen printing. Both warp and weft threads are accurately spaced and are woven in simple leno or other non-slip construction in order to maintain the mesh size. Bolting cloth contains 50–200 mesh openings/cm in coarse qualities, 200–400 in medium qualities and up to 3 000 in fine qualities.

Bolting silk → Bolting cloth of tightly twisted silk ply yarn, but also of other fibre materials, like cotton, flax and wool for example.

Bombyx mori (Lat.). A species of moth, the cultivated silkworm of which feeds on mulberry leaves and produces the finest quality of natural → silk.

Bond

I. → Chemical bonds.

II. Woven fabric structure, the method of yarn crossing (pattern draft) which forms the fabric. It determines stability, pattern and also external appearance. We differentiate between the following basic bonds (Fig.):

a) Plain weave, calico, tabby weave, taffeta weave, the simplest and shortest types of construction. On both sides of the fabric lie alternately warp end 1 over the weft end, warp end 2 under it, 3 over it etc. The name plain weave is generally used for cellulose

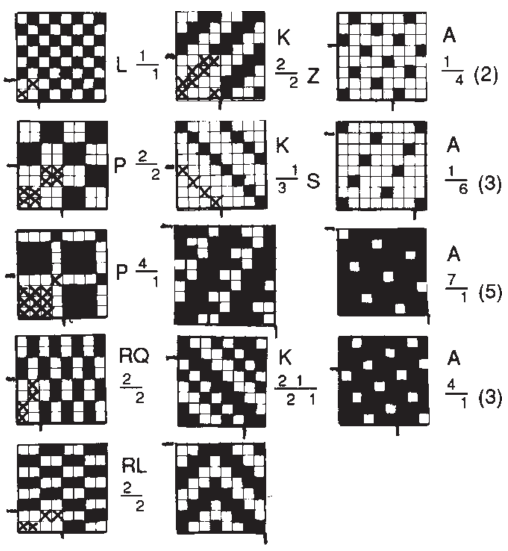


Fig.: Types of ground weave and some derivatives. Left: plain weaves: basket weave, Panama, patterned Panama, warp ribs. Centre: twill weaves: twill of uniform line, weft twill, steep twill (gabardine), stitched twill, zigzag twill. Right: atlas weaves: two weft and two warp atlases.

fabrics, calico is becoming obsolete for cotton fabrics, tabby weave for wool fabrics and taffeta for silk fabrics.

b) Twill weave, reveals diagonal stripes, and also called rib or twill rib. Fainter or more pronounced twills are produced by predominant warp ends on the fabric face = warp twills, or predominant weft ends on the fabric face = weft twills. In the case of right-hand twills, the twill runs from bottom left to top right, and the other way for left-hand twills. Broken or zigzag twills are produced by alternating stripe direction.

c) Atlas weave has uniformly scattered crossing points, where the other yarn crossing points lying between the visible crossing points are more or less covered by the ends lying on top (called floats). There are also (similar to twill) warp and weft atlas constructions, 3, 5, 8 and 10 construction etc.

d) Derived weaves, all other weaves which are derived from a) to c) or are combined from these derivatives; from plain weave e.g. basket weave/hopsack (panama), (longitudinal and transverse) ribs and leno weave; from twill weave e.g. cross, herringbone, wave, fancy twill and honeycomb weave; from atlas weave e.g. double atlas, crêpe and shadow weave.

Bonded fabrics (nonwovens) (Fr.: Tissus non tissés). Generic term for nonwoven and nonknitted bonded textile fabrics produced from fibres (fibre composites), yarns (yarn composites) or fabrics (laminates). They are subdivided into the following categories →: Yarn composites, Fibre composites, Stitch-bonded composites, Swell process nonwovens, Fused bonded nonwovens, Spunbonded nonwovens, Extruded composites, nonwovens, Milled composite fabrics, Knitted composites.

Bonded pile carpets → Pile carpets produced by adhesive bonding a folded material of yarns, webs or fibres to a substrate. Processing possibilities:

I. Single-stage process: simultaneous feeding and adhesive bonding of the pile material to 1 or 2 substrates (textile or plastic), or adhesive bonding two substrates together with pile material and separating them by cutting, so as to produce two identical fabrics.

II. Two-stage process: pile layer is formed in itself, adhesive bonded to a substrate, and then separated by cutting, again producing two identical fabrics.

III. Three-stage process: for colour patterned fabric. The pile material (tow, yarns, webs etc.) is compressed into a block (by freezing for example), cut into sheets across the longitudinal axis in a thickness equivalent to the required pile height, and adhesive bonded to the substrates.

Bonding agent In screen printing, a bonding agent is applied to printing blankets on flat-bed and rotary screen printing machines before coating with a thermoplast adhesive in order to ensure satisfactory bonding of the latter.

Bonding of textiles In order to reflect recent technology, bonding is defined as: the bonding of two textile materials by means of locally applied adhesives (Fig. 1) in contrast to → Laminating which involves the uniform distribution of a binder over the entire surface. Bonding thus represents a technical variant of laminating (Fig. 2). A typical bonding process is the front fusing of outerwear materials with fusible interlinings (point-bonded nonwovens). After both textiles have been joined together in the ironing press or setting press in garment making, the polymer spots applied to the fusible interlining melt and bind both textiles together on cooling into a "sandwich"-like composite. Such fusible interlinings are made by joining several carded webs together by needle punching followed by a

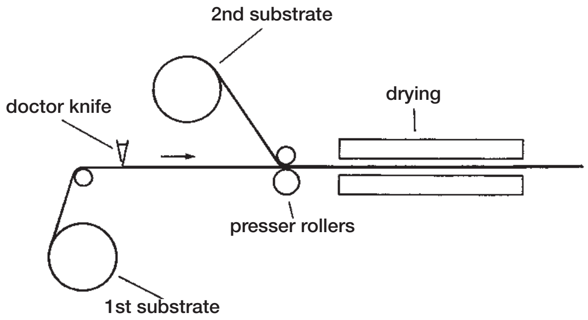


Fig. 1: Schematic bonding process.

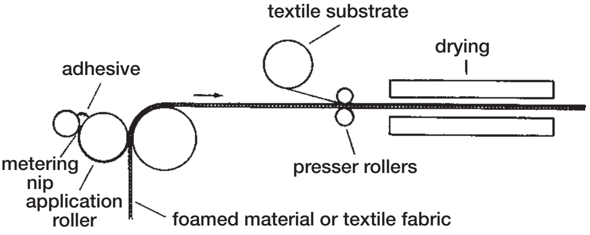


Fig. 2: Bonding/laminating process.

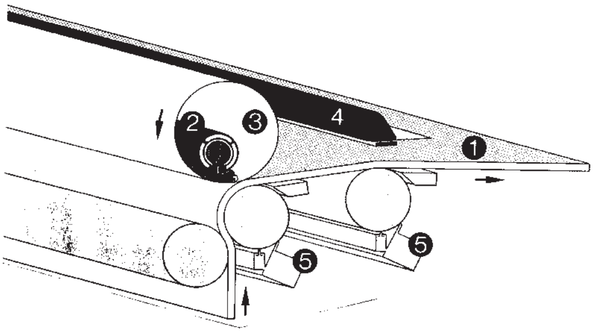


Fig. 3: Stork CT-IV dot coating for bonding setting interlinings.
1 = finished setting interlining; 2 = paste feed; 3 = rotary screen; 4 = infrared drying; 5 = pressing systems.

final chemical bonding with a foamed binder (synthetic resin dispersion). Coating is carried out by powder spray methods or rotary screen printing.

By dividing up the adhesive layer into numerous individual and discrete areas (Coin process) a softer handle and better drape is achieved. The size of the points or pattern and its distribution is variable. Opinions differ as to whether adhesive areas of the same size or different sizes with a uniform distribution are better.

Various methods are used to apply the binder:

1. Roller application: engraved rollers are used for this purpose, i.e grooved rollers for application in lines, thousand point rollers for spot bonding, as well as rollers with engraved designs. Excess binder is removed with a doctor blade.
2. Rotary screen application: this process involves rotary screen printing with a binder dispersion. Heavy gauge rotary screens engraved with a series of dots are used (Fig. 3).
3. Thermobonding: polyethylene powders of different particle size are applied by the spray or powder dot process. The binder melts in a heat zone after which both materials can be bonded together. Meltable binders are also used for nonwoven interlinings in shirt collars and cuffs.

A process known as “Chem-Stich” can likewise be described as a bonding technique. In this process shrinkable and unshrinkable fabrics are used to produce cloqué type effects. A solvent-based adhesive is applied with a design roller to a polyamide fabric which has not been heat-set. After a light drying treatment, a heat-set outer fabric is brought into contact with it by adhesion. A final heat treatment in the stenter (approx. 180°C) causes the base fabric to shrink and the outer fabric takes on a blistered appearance.

Bonding unit For → Bonding and also for → Laminating foamed materials. The application roller is engraved with stripes, dots or other figures.

Bondi process Method of producing textile floor coverings. Yarn sheets or loosely woven fabrics are layered in zigzag form into a low stack, which is stuck on to a backing material, and cut.

Book-fold processing Procedure used in crêpe finishing. Fabrics of e.g. viscose or silk are reeled or plaited into book-form with laps of 90–100 cm; the book of fabric is then sewn with loops of twine through the selvedge on one side of the book only. The loops are about 25 cm long. The fabric is then suspended from a horizontal pole which passes through the loops, so that the weft direction hangs vertically in the soap bath into which the fabric is lowered until it is completely immersed. In this manner, the liquor is able to circulate freely between the folds of the cloth, which is free from creases during the crêping treatment. Excellent crêpe effects are produced in this way. The procedure is also used in the degumming of silk piece goods for subsequent weighting (lightweight georgette and crêpe de chine fabrics).

Booster → Wet steamer.

– (dry-cleaning) → Dry cleaning detergent.

– (laundry) → Detergent booster.

Booster boxes American system of small boxes containing cooled blank vat solutions as built-in units to steamers, e.g. in the pad-steam process. The method has not proved popular in practice. A further development of this principle is the → Wet steamer process of Gerber.

Borassus piassava → Palm fibre.

Borates Salts derived from metaboric acid HBO_2 and polymeric boric acid $(B_2O_3)_x \cdot H_2O$ but generally not from normal boric acid (H_3BO_3). Alkali salts (e.g. → Sodium borate) are water-soluble with an alkaline reaction (hydrolytic cleavage); other borates are generally either insoluble or sparingly soluble.

Borax → Sodium borate.

Bordered fabrics Woven or knitted fabrics with designs running parallel to the selvedge; printed, embroidered, open-work effects, etc. Used for blouses, dress fabrics, home furnishings and household textiles.

Boric acid, H_3BO_3. Salts = borates. Colourless, smooth, flake-like crystals; sparingly soluble in cold water (40 g/l at 20°C), readily soluble in hot water (approx. 290 g/l at 100°C) and in alcohol (1:25) and glycerol (1:5). Volatile in steam. Solutions have a very weak acidic reaction. Uses: As a preservative for textile finishes (inhibits bacterial growth in 1–3% solution but does not destroy bacteria); flame-retardant finishes; tanning, etc.

Boric acid, identification test, e.g. as foreign matter or residue on the fibre:

I. Ash the specimen, mix with calcium fluoride and moisten with conc. sulphuric acid. Heat in a Bunsen flame; presence of boric acid = green flame.

II. Soak the ash with dil. hydrochloric or sulphuric acid. Moisten a piece of turmeric paper with the mixture and dry; presence of boric acid = red-brown coloration (titanium, molybdenum and zirconium salts also give a brown coloration).

III. Mix the ash with a little conc. sulphuric acid and a little methanol. Heat in a test tube and ignite the escaping vapours; presence of boric acid = intense green flame.

Boron fibres Industrially manufactured mineral fibres of the following types:

I. Boron fibres: vapour-deposited filaments made by depositing vapour phase boron from a boron halogen compound on a heated tungsten wire. Tensile strength 100–200 cN/tex, E modulus 370–450 kN/mm^2. These fibres have been developed for use in aircraft and space applications; for rotors, turbines, etc. The fibres can also be woven into fabrics.

II. Boron carbide fibres: manufactured by the reaction of boron chloride and hydrogen with carbon fibres at high temperatures whereby a layer of B_4C is formed immediately on the carbon surface (conversion of approx. 50% of the carbon to B_4C). Tensile strength 80 cN/tex, E modulus 340 kN/mm^2, stable to temperatures up to 2200°C, high conductivity. Uses: protective clothing against radiation, heat insulation, etc.

III. Boron nitride fibres: derived by reaction of boron oxide fibres with ammonia through several intermediate stages of increasing temperature (up to 1800°C); they consist of up to 99% BN. Tensile strength approx. 100 cN/tex, E modulus 28–90 kN/mm^2; short-term temperature resistance up to 3000°C; better corrosion resistance than carbon or glass fibres, high electrical resistance. Uses: aircraft and space applications; heat and electrical insulation; protective clothing against atomic heat flows, etc.

Bottom hair Short, fine animal hairs in the hair undergrowth, generally without any medulla, supple, elastic, high crimp, good felting properties.

Bouclé (French = loop),

I. Clothing and overcoat fabrics with a curly, knobby surface due to incorporated fancy burl, kink and loop ply yarns. The name indicates the rough granulated surface of the fabric. The typical bouclé character is produced by so-called loop ply yarns (mostly three-ply) of worsted or woollen yarn, which can be found both in the warp and the weft, but are generally present only in the weft. With high qualities, the loop-forming end consists of mohair, achieving a particularly beautiful lustre effect. Bouclés are woven in simple ground constructions, predominantly tabby weave. Lighter-weight fabrics (in all colours) as dress fabrics, heavier fabrics (mostly in darker shades) as winter overcoat fabrics. The latter are usually reinforced by ground picks, or even have ground warp and ground weft. Despite the rough fabric surface, bouclés are included among napless finish fabrics. The winter overcoat qualities are mostly raised on the back in order to improve heat insulation. So-called bouclé imitations have no loop ply yarns, but only a construction with a consciously rough accent. Bouclé fabrics are generally classic, reasonably hard-wearing dress, costume and overcoat fabrics. Because of their loops, admittedly somewhat sensitive in contact with metallic, rough or sharp objects. Loop fabrics are similar, but not identical with them.

II. Weft and warp knitted fabrics with a structured surface.

Bouclé carpets Carpets with uncut pile loops (loop pile carpets). Since, up to approx. 1960, the pile material in loop pile carpets mostly consisted of hair yarn, bouclé carpet was often, but incorrectly, used as a synonym for hair yarn loop pile carpets (→ Brussels carpets).

Bouclé-ondulé process (Reinhard system) carpet-producing process in which undulated yarns, fabrics or webs are laminated on to a backing fabric. → Bonded pile carpets.

Bouclé yarn Compound yarn produced from coarse wool as well as cotton or man-made fibres comprising a twisted core with an effect yarn wrapped around it so as to obtain wavy projections on its surface.

Bougran (bougram, bougrassin, bugram, tailor's canvas) Gauze-like cotton or spun viscose interlining, grey or black in colour, mostly flat in shade. Preferably used instead of excessively thick and heavy → Buckram.

Bourette (Fr.: *bourette*, *bourré* = full hair or fibre). Yarn produced from (silk) waste and combing noils in schappe spinning which is interspersed with knots and slubs. → Flock silk, frisons.

Bow distortion, correction of Occasionally rollers are used for passive correction of bow distortions in the fabric as it leaves the stenter. These rollers, which do not take up the fabric but merely have an idler function, are less suitable for fabric straightening (with some exceptions). In principle, they also cause a deviation in cloth run similar to the straightening method using bow rollers. A dry fabric, however, is not easily straightened in this way, because it is often comparatively stiff. Moreover, often the distortion cannot be permanently rectified (e.g. with heat-set fabric), and the distortion recurs as soon as the fabric is released. Hence, it is preferable to apply other methods to draw out the lagging middle section of the web by increasing the traction at the stenter exit. This can be adequately achieved by means of the normal take-up or draw rollers, the surface of which should, however, provide a suitable coefficient of friction. If the take-up roller is entirely smooth, it will not have an adequate draft action. On the other hand, if the surface grip is too extreme, i.e. no slippage at all is possible, the straightening effect will also be inadequate, because the fabric edges are pulled along with the middle section. With a medium coefficient of friction, however, the centre of the web is properly transported, and a certain degree of slippage is possible at the edges, as required; the fabric is delivered well aligned. Another option is to use a take-up roller with a variable diameter. Contrary to passive straightening, slight changes in diameter are already sufficient to significantly increase the peripheral speed of the roller centre in relation to the roller edges. A higher peripheral speed, however, means that the web is transported faster at the centre than at the edges; thus the lagging bow is brought forward.

The correction of bow distortions by means of either of the two methods described can be automated by an appropriate system. However, should there be a prominent leading bow, properly aligned fabric delivery will be virtually impossible. This state of affairs is, however, relatively seldom. To meet high accuracy demands, a fully automated weft/course straightening unit in front of the entry is frequently combined with automatically controlled chain/draw roller correction by means of scanners at the stenter exit. This combined straightening system is a necessity, because only minor distortions can be corrected via chain and draw roller control alone, so that it is not possible to dispense with straightening at the entry.

There is a popular straightening option that is often applied in the USA: at the delivery end of the stenter only the lagging bow is measured and corrected, thus reducing the expense for electronic measuring and control systems, as opposed to straightening via stenter chain with differential drive. The question is often raised whether the method of correcting residual distortions by means of the stenter chain and take-up roller can ever be advocated. Experience has shown that the answer must be in the affirmative. When the centre web is drawn forward, this means that with most fabrics the straightening action is not limited to the last few decimetres – which would be tantamount to localised elongation – but that the effect of straightening at the exit extends right into the stenter. Here, however, the fabric is not completely dry and/or not yet heat-set, i.e. it is still ductile. But once the fabric is entirely dry or has completely cooled down after heat-setting, it is virtually impossible to permanently rectify distortions.

The straightening effect is calculated according to the following formula:

$$R = \frac{r \cdot i \cdot L}{v}$$

R = straightening effect in cm,
r = straightening effect per pulse in cm,
i = no. of pulses/min., set with specific v (dependent on the controller, the no. of pulses changes proportional to the change in speed),
L = stenter length in m,
v = basic speed in m/min.

Bow straightener Device for the correction of bow distortion in fabric webs, e.g. with curved rollers.

BP,

I. abbrev. for: British Patent.

II. abbrev. for → Benzoyl peroxide.

BPC, abbrev. for: British Productivity Council.

BPI, (Ger.) abbrev. for: Bekleidungsphysiologisches Institut Hohenstein (German Institute for Clothing Physiology); → Technical organizations.

Br, chemical symbol for bromine (35).

Braid Narrow fabric produced by (→ Braiding); used for trimmings, etc.

Braiding (braided goods). Textile materials produced by interlacing three or more threads in such a way that they cross one another in diagonal formation. A distinction is made between flat braids (→: Braid, gimp), tubular braids (→ Cords) and openwork goods (braided lace).

Braiding fibres The following types of fibre are mainly used in the production of → Braids: palm fibre, leaf fibres, pandanus fibre, straw fibres and bast fibres.

Braids plain or figured narrow fabrics with woven-in velour; also conically woven. Used as velour or clothing (seam) protective edgings.

Bran A waste product from the milling of grain into meal; still occasionally used as a component in fermentation vats (soda vat, woad vat, bastard vat).

Brandom process An English dyeing system for the production of multicoloured yarns. Principle: local dyeing of yarn in the package. The effect is similar to that obtained in → Yarn printing.

Brandon process Pile yarn is wrapped spirally around rectangular metal rods to produce an adhesive bonded carpet. The rods are then pressed into a substrate provided with adhesive. After the windings have been cut, and the metal rods removed, a velour fabric is obtained.

Brazing The process of joining two pieces of metal with the aid of:

a) a low melting point metal (→ Brazing solder) applied between the adjoining surfaces,
b) a soldering flux (zinc chloride-ammonium chloride solution) or sodium tetraborate,
c) ammonium chloride,
d) soldering copper or a gas flame.

Brazing solder Metal alloy used for → Brazing which has a lower melting point than the metal to be brazed; e.g. tinman’s solder (tin-lead solder), spelter or hard solder (copper-zinc, possibly including silver).

Break-even analysis The differing cost behaviour of the cost centres has to be clearly expressed in the costing. It is not always possible to differentiate in terms of cost behaviour when the costs are recorded. In production, there are costs which can only be clearly attributed to the cost unit after they have been incurred, when cost unit rates have been drawn up accordingly. For internal profit and loss accounting, the costs must be shown separately according to their behaviour and their cause. This is only possible if costing and profit and loss accounting have the same structure. In order to assess the behaviour of the costs, a reference point is required – turnover. The question which is always in the foreground is: How do the company’s costs in question as a whole (not those for an individual article) change if the turnover (production) increases or decreases in terms of quantity? Three different behaviour types can be clearly established:

1. Turnover-dependent expenditure (Fig. 1): There are various expressions for this: variable, performance-related, turnover-proportional, production-dependent. What these terms all indicate is that the expenditure is directly dependent on turnover (= direct costs). There is not just a dependence in terms of quantity here, where the costs change if the amount sold changes, e.g. the cost value of the goods sold, in the production, the material consumption, energy, etc. There is also a dependence in terms of value: If the selling price is altered, this gives a different turnover figure for the same quantity, with certain costs also being changed as a consequence. The turnover-dependent costs all have a striking feature: they automatically change necessarily, with any change in turnover. If the turnover increases or decreases by a single unit, the total of these costs changes accordingly in the corresponding period. If one unit more has to be produced, then more raw material is required for this additional unit. At the level of the article, the turnover-dependent costs correspond to the so-called price floor. If the article is sold at the price floor, then the net operating results are not altered, since the revenue is just as high as the costs incurred directly by this article.
2. Expenditure for infrastructure (Fig. 2): Infrastructure includes what a company needs in order to be able to achieve its sales performance (with production), e.g. premises, installations, staff, etc., before sales (turnover) activity and production can be started. All these parts of the infrastructure have a particular capacity. The costs of the infrastructure only change when new components have to be “fitted in”. This adaptation is always carried out gradually. For example: Additional machines increase depreciation, and may even require new premises; wages change as a result of new appointments or redundancies. A feature of these costs is that they are not caused directly by the change in quantity of turnover or production, but by the decision to change the capacity of a part of the infrastructure.

   An additional module of capacity or infrastructure does not come automatically, but always requires a decision by the responsible management. Thus the infrastructure costs are not caused by the turnover. Rather, it is the case that the turnover uses or makes a demand on the existing infrastructure. The various infrastructure modules have differing turnover or

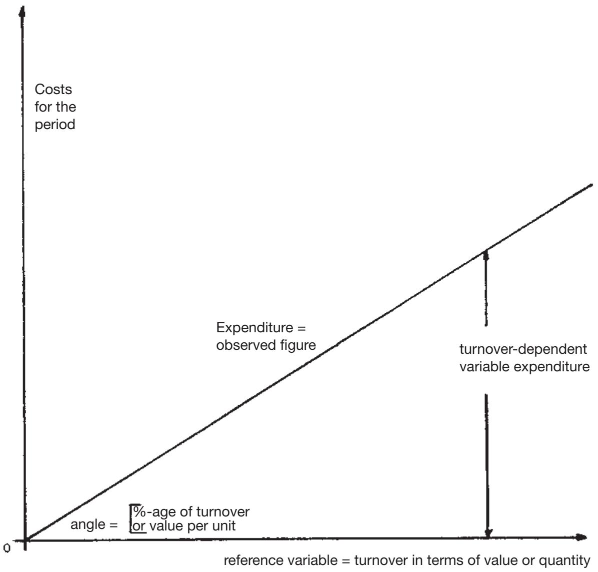


Fig. 1: Graphic representation of turnover-dependent expenditure.

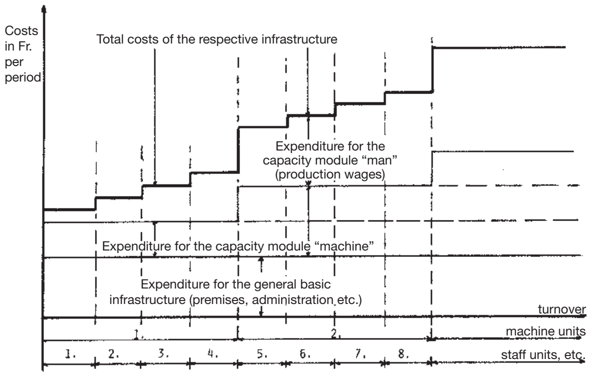


Fig. 2: Graphic representation of the expenditure of the infrastructure (in development).

production capacities. They have to be supplemented accordingly for differing increases in turnover. The supplementation of an infrastructure module leads to cost jumps in the cost profile. This is the peculiarity of fixed costs. We therefore do not have fixed costs and leaps in fixed costs. All infrastructure costs increase in jumps, in contrast to the continuous increase in turnover-dependent costs. Only the range of the individual modules varies.

3. Elective expenditure: There are also costs which are not dependent on turnover, but neither can they be associated with capacity. They have one feature in common with the infrastructure costs, which distinguishes them from turnover-dependent costs. This also has to be decided. Whereas in the case of infrastructure costs, the decision creates costs which recur regularly (e.g. wages, depreciation, rent etc.), with this expenditure group, in the absence of any explicit renewal these costs are incurred only once. They are valid as a one-off event. Examples: Advertising costs, staff training, projects and investigations, which as a rule always relate to the future.

With this clear allocation of costs (1 to 3), the contribution margin can be defined simply: Revenue less turnover-dependent costs equals contribution margin. Or to put it another way: Revenue less all costs incurred directly when one additional unit is produced and sold. These costs are equal to the price floor. The contribution margin is thus always a balance. The term originates from the fact that with this difference, a contribution must be made which covers the infrastructure costs and the elective expenditure. If anything is left over, that is profit.

Separation of costs according to how they behave allows a simple graphic representation of the benefit threshold or break-even point (Fig. 3). Whereas elsewhere the equation “turnover equals total expenditure” was taken as a basis, the break-even analysis (contribution margin calculation) now represents that with the formula “contribution margin equals infrastructure costs plus elective expenditure” (source: Issler).

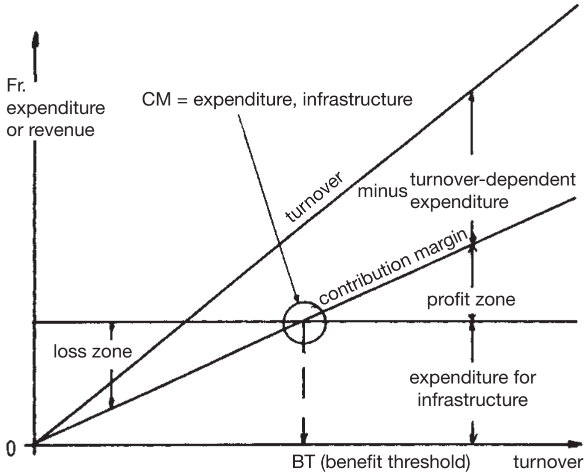


Fig. 3: Benefit threshold (BT), graphic representation according to break-even analysis (contribution margin calculation) (benefit threshold where CM = infrastructure expenditure).

Break even point (BEP) A traditional break even chart shows revenue and costs as a linear function of output or production. As illustrated in the Fig. the total cost is the sum of fixed costs and total variable costs for each level of production indicated along the horizontal axis. Revenue is the product of selling price and the number of units made and sold. If the production output per unit time is represented along the horizontal axis of a graph (see Fig.) with the corresponding costs as well as earnings along the vertical axis, then the BEP is the intersection of the two lines which can be taken as the profit or loss threshold, i.e. the point at which neither a profit nor a loss is made.

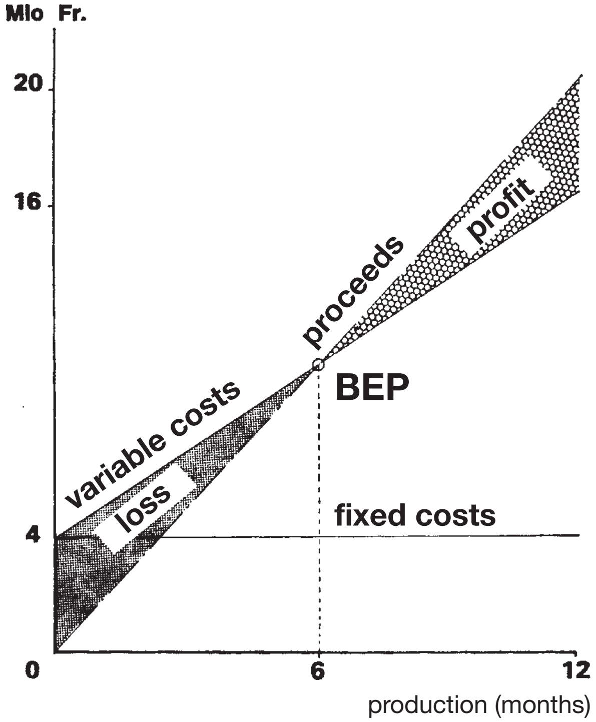


Fig.: Break even point

Breaking force The → Tensile strength test measured immediately prior to complete parting of the test specimen in simple tensile strength testing; it is consequently always somewhat lower than max. tensile load.

Breaking length Dimension (no longer used) for the → Tensile strength of a material. The breaking length denoted the length of a test specimen (fibre, yarn), the dead weight of which was equal to the →

Breaking load, and was indicated as length in kilometres at break.

Breaking load → Tensile force.

Breaking strength → Tensile strength.

Breaking strength in bending → Flexing fatigue limit.

Breaking stress (cross-sectional breaking strength), in the → Tensile strength test, the quotient of the breaking force and the initial cross-section of the test specimen.

Breaking weight → Tensile strength.

Breathability The concept embraces a number of characteristics. Thus, it is used to describe water vapour permeability, waterproofness or water pressure resistance and windproofness or air permeability. The result is an overall picture of heat-regulatory processes which describes the wear comfort of clothing textiles.

The multitude of "breathable" textiles and their different production processes make unambiguous description difficult. The artefacts of end-user advertising reinforce this impression still further. The conceptuality loses further in terms of unequivocalness in the transition of the processes describable as "high-tech" development into the technical textiles application field with sometimes completely different requirements, and it therefore makes sense to segregate the characteristic profile. Only → Water vapour permeability is to be understood by breathability. The parallel testing of water pressure resistance continues however to be indispensable, as there is no utility value without adequate waterproofness. Precisely this interrelationship between waterproofness and water vapour permeability, which appears first of all to be a contradiction, establishes the attraction of these products. In contrast, air permeability or windproofness can be left out of consideration, since it is practically zero in the case of coatings. Thus, ventilation in these types of textiles, e.g. in the case of sportswear or tents, is conditional only on cutting technology, and must be taken into account in model design. Water vapour permeability and air permeability are completely different physical properties, and are not dependent on each other. The latter is not important for moisture conveyance; air movement can of course change the climatic conditions, and consequently indirectly affect breathability too in the individual case.

The development of "breathable" textiles is closely associated historically with a desire for leather-like properties. Synthetic leather production is therefore responsible for the emergence of numerous production methods. A large proportion of water vapour permeable materials, the so-called poromers, work on the leather principle, i.e. water vapour is conveyed by a microporous foam structure. Extended development in the field of breathability also permits other fields of application. To some extent, the now numerous processes represent innovations which are far superior in their requirement profile to the impregnation process employed for many years. They can be subdivided into the following groups, where technology and characteristics can vary greatly relative to the field of application:

- microfibre woven fabrics,
- microporous coatings,
- laminates with microporous membranes,
- laminates with compact membranes,
- compact, hydrophilic coatings.

Breathable coatings Unscientific term for porous coatings which are permeable to air and water vapour. They are produced by various methods: e.g. through the addition of water-soluble salts to the coating compound followed by subsequent dissolving out, or by mixing indifferent solvents with the aqueous coating compound, or through the addition of gas-releasing substances to the coating compound. In another process, nonwoven fabric is coated with a solution of polyurethane in dimethyl formamide followed by subsequent dissolving out of the latter with a non-solvent for polyurethane. → Microporous coatings.

Bridging oxygen → Fatty sulpho acid esters.

Brightening acid A mixture of lactic and tartaric acids. Excellent scrooping agent (no fibre damage) especially for the achievement of a scroopy silk handle (treatment with 1–2 g/l soap followed by 2–6 g/l brightening acid without intermediate rinsing and final drying at low temperature.

Bright radiator drier → Infrared predrier capable of reaching temperatures up to approx. 1950°C.

Brilliancy

I. Physical dimension of → Brightness or the impression of brightness (→ Colorimetry).

II. SI unit derived from candela per square metre (cd/m^2).

$$\text{brilliancy} = \frac{\text{light intensity of a light source}}{\text{luminous area of this light source}}$$

The range of brilliancy runs from the luminophores (→ Fluorescent substances) with approx. 1 mcd/m^2 to the xenon high pressure lamp with 10 Gcd/m^2.

Bristles,

I. Natural bristles: white to grey, coarse, stiff hairs of the domestic and wild pig. Used for brushes, paint brushes and brooms.

II. Synthetic bristles (DIN 60 001): coarse, chopped, synthetic monofilaments which, depending on stiffness and length, are suitable for the manufacture of brushes, paint brushes, brooms, etc. Synthetic bristles produced principally from polyamides, polyurethane or polyvinyl chloride are not only considerably stronger than natural bristles, but are also more resistant to water (as well as rotting) and chemicals.

British gum Roasted maize starch (maize dextrine). Excellent thickening agent for textile printing, especially for vat dyes. Other roasted starches, even including those derived from potato starch, are occasionally marketed as British gum.

British Textile Technology Group (BTTG) An independent British textile research and technology organization formed in 1988 as a result of a merger between the former Shirley Institute and WIRA textile research organizations. → Technical and professional organizations.

Brittleness → Flexibility.

Broadloom,

I. Descriptive term for wide carpeting produced in widths of 6 feet (180 cm) and above.

II. In the USA, a statistical term for → Roll carpets.

Brocade A figured heavy fabric often with elaborate large area designs produced on a jacquard loom. Basic weave is satin. The design, on the surface only, often produced with yarns in contrasting colours, may also contain metallic threads. Brocades are made with any major textile fibres and normally include a lustrous fibre (e.g. silk with cotton, viscose, etc.). Used for evening wear, ball gowns, theatre fabrics, furnishing fabrics, upholstery, etc.

Brocade (découpé), An additional effect thread is inserted into the ground weft (→ Lancé). If the structures are far apart from each other due to the pattern, the floats are cut (cropped). This makes it more difficult to extract the floats on the back; the fabric weight is also reduced. Lancé découpé is also referred to as imitation → Broché.

Broché (= interweaved). Fabrics with patterns that look as they have been embroidered on. Genuine broché is produced on swivel looms. Besides warp and weft, these looms have a third thread system which inserts small shuttles controlled by a jaquard loom. The swivel embroidery stay serves to guide and drive the broché shuttles distributed over the width of the fabric. The broché weft is firmly interweaved together with the ground weft. The figuring threads are reversed in accordance with the patterning contours (as opposed to: → Lancé). When the patterns are a short distance apart, the broché thread runs to the next figure; with a greater pattern spacing the thread is cut off on the reverse side of the fabric.

Broken bast-soap Acidic dyebath for natural silk containing the original → Bast soap from degumming which has beneficial levelling properties in silk dyeing.

Broken ends Are promoted by the high productivity of modern weaving machines and the introduction of new products by other production processes (fast spinning etc.). In weaving (see Fig.), warp ends are subjected to high loadings, the physical mechanisms of which are extremely complex. Sizing is necessary for preventing warp fatigue, particularly due to repeated extension.

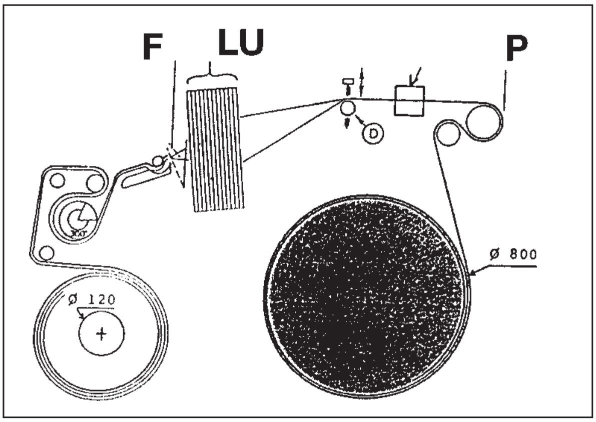


Fig.: Warp yarn path in classic weaving.
F = woven fabric start; LU = heald stafts; P = back rest roller.

The warp sheet is systematically divided into two yarn sheets in order to form the shed and enable the weft to be inserted. After every pick, the position of the ends is reversed so that a cross-over takes place. Each warp end runs through the eyelet of a heald which correctly positions it. The elastic property of the yarn is used to open the closed shed, the result being yarn tension changes in every cycle. Dynamic fatigue phenomena (not static) result in ends breaking in their weak places. For identical max. tension, the fatigue phenomena and the number of yarn breaks is the higher the greater the tension differences between low and high tension. The higher the degree of elongation with identical basic tension, the sooner the yarn breaks.

Broken twill A strong cotton fabric with a warp cross twill weave. The fabric has a high resistance to slippage and is characterized by a particularly “full” handle. Used especially for leisure wear.

Bromate discharges Oxidative discharges, e.g. as coloured discharges on indigo by printing a mixture of sodium bromate or bromite and chlorate of alumina (aluminium oxide), followed by subsequent steaming, washing off and dyeing (with alizarin). Nowadays of relatively minor importance.

Bromelia fibres Leaf fibres of the *Bromeliaceae* family which are indigenous to the tropical and subtropical regions of South America. They form a subgroup of the → Hard fibres and include, e.g. pineapple fibres, caroa fibre or so-called silk grass. In contrast to the agave fibres, they are easily extracted from ripe leaves which have a high fibre content and a low amount of leaf flesh. The fibre strands are approx. 1,5 m long with a tensile strength of up to 60 cN/tex. The better qualities are processed into fine spun yarns and silk-like fabrics in their countries of origin. Coarser and more highly lignified fibres are processed into ropes, braids, etc.

Bromite desizing Process for desizing cotton fabrics by the oxidative degradation of starch with sodium bromite.

Bromothymol blue (BTB). Used as an indicator in desizing with diastases for pH control within the optimum specified range.

Bronze An alloy consisting principally of copper and tin, possibly also containing other metals. Bronze for bearings generally contains up to 84% copper. Phosphor-bronze, which is malleable and can be drawn, generally contains 0,1–0,3% phosphorus, and is used where resistance to corrosion and wear is required. Bronze can be readily melted, it is harder and more elastic than copper and produces a crystalline or granulated fracture. Uses: fittings, machine components (bearings, toothed gears, worm gear drives, etc.).

Bronze pigments These are manufactured from metal granules in special ball mills in the presence of lubricants to prevent cold bonding of the particles. The following types are available:

I. Leafing pigments: so-called leaf-forming "fat-rich" pigments which float on the liquid surface and orientate to give a highly reflecting film.

II. Non-leafing pigments: "low fat" pigments which are completely wetted out and therefore do not float but orientate within the binder film.

III. Special pigments:

a) water-dispersible pigments for aqueous binders,
b) surface-coated pigments (for coating powders),
c) pigment pastes for special applications in plastics,
d) pigment pastes containing printing oils for the graphics industry.

Lubricants in leafing types: saturated fatty acids; lubricants in non-leafing types: unsaturated fatty acids and alkylamines. → Bronze printing.

Bronze powder → Metal powders.

Bronze printing Although described as "bronze" printing, gold-bronze pigments are used which consist almost exclusively of copper/zinc alloys (brass) whilst real bronze is, in fact, an alloy of copper and tin. The gold-bronze pigments are subdivided into the natural colours dependent on their alloy composition:

copper	containing 100% copper
pale gold	containing approx. 90% copper
vivid pale gold	containing approx. 80% copper
deep gold	containing approx. 70% copper

In addition, pure aluminium powder is also available as silver bronze. → Metal powder printing.

Bronzing of dyeings Dyeing fault manifest as a metallic iridescent appearance which is associated with poor rubbing fastness. There are a number of possible causes, i.e.: inadequate pretreatment (wax or oil residues), dye precipitation (e.g. in hard water), over-saturation (excess dye) of dye on the fibre, and the premature oxidation of sulphur and vat dyes during dyeing.

Brown coal Mainly brown to black-brown in colour, seldom black. Brown coal extracted from mines contains 40–50% water and approx. 6% ash components. It is rich in bituminous products and is therefore graded according to increasing bitumen content (benzene-soluble) into fire coal (dark brown) and extraction lignite (light brown). Brown coal briquettes consist of compression-moulded comminuted brown coal with a water content of 15–17%.

Brownian movement The phenomenon of erratic random movements performed by molecular particles of like electric charge therefore preventing collisions (water drop test under the microscope). Law of "ideal disorder". This constant random movement triggers an osmotic pressure causing the migration of e.g. dye particles from areas of high concentration to those of lower concentration thus initiating the diffusion of dye particles within the fibre.

Brushed denim Velvet-like emerized (sanded) cotton twill fabric with a light fluffy surface and soft handle for fashion jeans available in different colours and raw white besides blue. →: Jeans, Denim.

Brushed fabric The name refers to the finished character of the material. Fabrics with brushed finishes may be roughly categorized into a) fabrics with a short close lying pile (e.g. eskimo, doeskin, fine-ribbed woollens) often associated with an enhanced lustre, and b) fabrics with a long loosely ordered pile (e.g. mohair fleece fabrics, brushed loden). These fabrics are predominantly woollen articles and, less frequently, worsted articles in plain-weave, warp cross twill weave, warp satin weave and tricot weave constructions. To achieve the brushed effect, the goods are raised and (wet) brushed. It is important that the brushed effect is adequately set - this applies particularly to those fabrics in category (a) above.

Brush furnisher rollers Used in roller printing machines to transfer print paste to engraved printing rollers: They perform two functions, i.e. to furnish engraved printing rollers with print paste and clean out the engraved areas at the same time. They are chiefly used for print pastes which tend to build up deposits in the engraving ("sticking in"), e.g. pigment colorants, certain vat dyes, as well as discharge print pastes con-

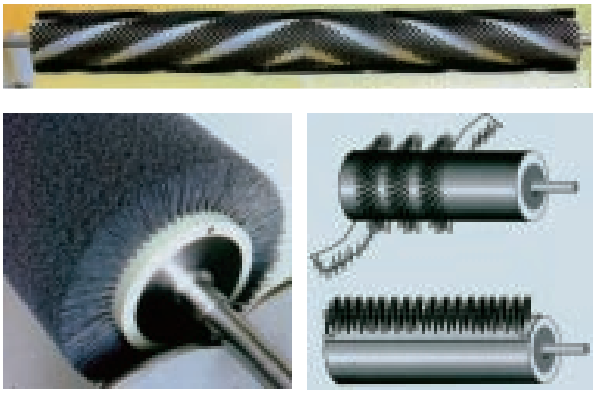


Fig.: Examples from TSI for different brushing rollers for dry and wet brushing taining white pigment. Brush furnisher rollers of a different type were used in a patented process of the now defunct company Kekko for so-called "waste water-free" dyeing (see Fig.).

Brushing

I. An operation in dry finishing which serves particularly the cleaning of woven wool fabrics, but also those produced from other fibres, when fibre fly, dust or threads have to be removed. Furthermore, the raising effect can be affected by brushing, in fact, in such a way that the raised hairs point in a specific direction, or become entangled with each other. Brushing is carried out on so-called → Brushing machines, before or after shearing and before pressing, mostly simultaneous with steaming. Brushing units are also employed between singeing and desizing or dyeing and printing. In the first case, severe contamination of the scouring liquor is prevented, while, in the second, fibre deposition on the roller printing machine roller is avoided. Brushing is of by far the greatest importance in the production of woven pile fabrics, e.g. cord and velvet.

The Fig. shows various brush combinations:

a) blowing, brushing, suction: recommended for removing all kinds of adherent dust;
b) brushing, suction, blowing, suction: recommended for removing imprinted dust from fibre plates, waffle floor coverings, artificial leather etc with a very deep action;
c) beating, suction, blowing, suction: treatment of etched out products; the residues are practically completely removed, and the bath contamination for washing-off reduced to a minimum;
d) suction, blowing, suction: recommended for the contact-free removal of fine and very fine dust from warp knitted fabrics, braided fabrics, muslin; tulle, paper, artificial leather, foils, films, glass etc.

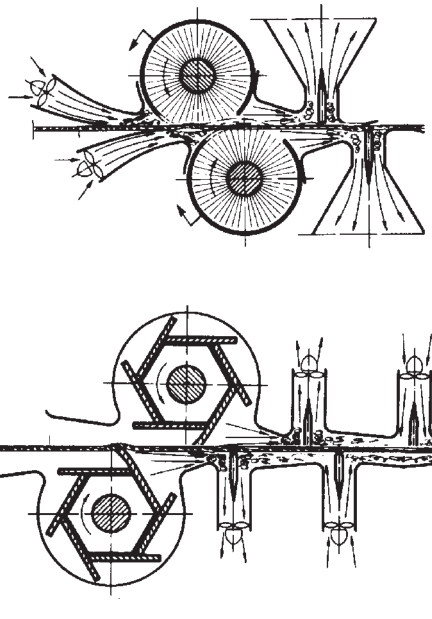


Fig.: Kälin system brush combinations.
top: for removing dust; bottom: for burn-out patterns.

The beating and brushing machine (van Wyk) is of a design similar to a cyclone type beating and brushing machine, but furnished with an incorporated fan with a dust filter bag instead of the cyclone.

II. Felt hats are brushed in the warm, wet state in order to fix the nap in the case of long-haired surfaces, to produce a silken lustre and to improve handle with hair hats. To this end, the hat is placed on a rotating cone, and processed by brush pressure. Felt hat brushing generally follows fulling after the dyeing process, and can take 30–90 mins with interruptions. Brushing and shearing also serves to eliminate the pilling prerequisites.

Brushing machines (brushing and steaming machine) (see Fig.) for the finishing of napped fabrics. The main unit is a large brush-covered drum which rotates against the fabric run in contact with the fabric back. The brushing effect is not only dependent on roller speed but also on the actual clothing material (→ Brushing rollers). A wide steaming table is generally located upstream for simultaneous steaming.

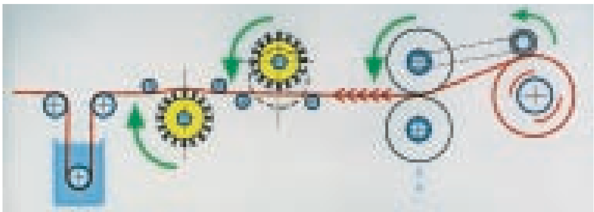


Fig.: Wet brushing machine for pile fabric (TMT).

Brushing rollers Components of brushing, longitudinal shearing, card roller, special wet brushing machines etc. Brushing rollers should run absolutely concentrically so that the brush pressure on the fabric (see Fig.) remains constant, i.e. unchanging.

In the case of the still very commonly used brushes with wooden cores (bristle tufts pressed in or held in by wire), gradual warping or distortion of the wooden core occurs under the influence of varying room humidity, with consequent loss of brush concentricity and disadvantageous effects on brushing process quality. This does not occur with brushes in which the brush material is pressed into a U-sharped spiral metal band, and in which the mounting base is secured by wire. These types of endless brush spirals are slid on to a special iron core to the required length, pressed together at both ends by means of ring nuts, and shorn down to working diameter. With these types of brushes, the brush material can be renewed quickly at any time by replacing the worn spiral.

Fig.: Brushing roller clothing.

Brush pile finishing Analogous to → Lustring. A finishing process given to pile fabrics (cord fabrics, velveteen) to improve lustre and appearance of the dried and finished pile face by treatment in a → Brush pile finishing machine (application of lustre-enhancing products combined with beating, brushing and steaming).

Brush pile finishing machine (waxing and lustring machine). Pile fabrics are run though the machine with the back side against a heated cylinder and the pile side is pressed against polishing rollers rotating at higher speed in the counter direction to the fabric passage, as a result of which a sustained ironing effect is imparted to the pile (see Fig.). The polishing rollers consist of steel centres covered with wool felt. The polishing effect can be varied by the application of lustre-enhancing products (molten wax or other finishing agents) before entry to the polishing rollers. Pile alignment is achieved in the final treatment by steaming or beating. Because of the risk of fabric deformation with pressure-sensitive materials, cord fabrics should be rolled up immediately after cooling and carefully stored.

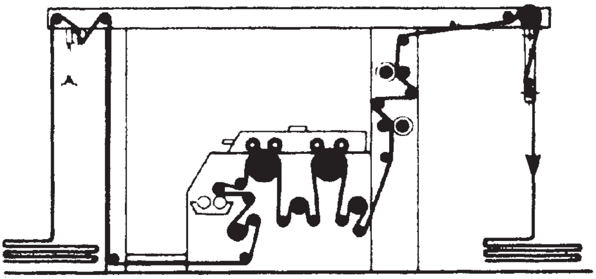


Fig.: Typical twin finishing roller brush pile finishing machine.

Brush roller application Application of finishing liquors, usually in concentrated form (liquor pick-up < 40% = low pick-up system) to textile fabrics by spraying from a brush roller. Liquor is transferred from a roller partially immersed in the finishing liquor to the rotating brush from which it is thrown by centrifugal force on to the fabric in droplet form.

Brush stencil print A cheaper Japanese imitation of a → Yuzen printing which can easily be distinguished from the latter due to the absence of small irregularities and crossovers which are so characteristic of a genuine Yuzen printing as a result of the many repeating stencils used.

Brussels carpet A loop-pile carpet, woven on a Wilton loom, over unbladed wires (i.e. when the cutting blade of the metal strip is absent); originally manufactured in Brussels. Depending on type of pile material, these carpets are described as hair or wool Brussels.

BS,
I. Bachelor of Science (USA), academic degree.
II. British Standard.
III. benzene-soluble (chem.)
IV. binary state (comp.)

BSI, abbrev. for: British Standards Institution. → Technical and professional organizations.

BTTG Abbrev. for: British Textile Technology Group, → Technical and professional organizations.

Bubble coloration process Non-repeating patterned effects in polygon or ring shapes (from burst bubbles) as well as grape-like motifs are produced on textile fabrics from dye-containing bubbles (produced by blowing air through a pad liquor containing surfactant and thickening agent). The bubbles are allowed to impinge on the back side of the fabric or they can float on to the fabric surface (including carpeting materials). Discharge effects, as well as designs produced by the application of Fast Colour Salts on naphtholated grounds, are also possible.

Buckram A → Stiffened fabric, generally linen or cotton, usually of natural colour, with good elastic resilience produced by impregnating a plain-weave opensett fabric with fillers and stiffeners. Its uses include linings, millinery, waistbands and bookbinding.

Buckskin A suiting fabric similar in handle and appearance to, but heavier than, a doeskin fabric, made from fine merino wool, wool/cotton union, closely sett, heavily milled, lightly raised and closely sheared on the face. A distinction is made between summer and winter buckskin depending on fabric weight (the latter is often produced as a double fabric).

Buffer → Buffer solution.

Buffer solution A general term for a solution containing a mixture of an acid reacting salt and a base or an alkaline reacting salt and an acid. The pH of such solutions is not significantly changed on dilution or the addition of H^+ or OH^- ions (acids and bases). The action of buffer solutions is based on the formation of weak acids or bases from intercepted H^+ or OH^- ions. Thus, solutions of weak acids and their salts with strong bases, e.g. acetic acid/sodium acetate (CH_3COOH/CH_3COONa), usually in equivalent ratio or other suitable mix ratio, are used for the buffering of H^+ and/or OH^- ions. Acidic reacting hydrogen salts can also be used instead of weak acids. The same applies to mixtures of weak bases and the salts of strong acids, e.g. ammonium hydroxide/ammonium chloride (NH_4OH/NH_4Cl). The capacity of the system to buffer H^+ and/or OH^- ions is based on the example of acetic acid and the following two reactions:

$$CH_3COO^- + H^+ \rightleftharpoons CH_3COOH$$

$$CH_3COOH + OH^- \rightleftharpoons CH_3COO^- + H_2O$$

Buffer solutions of known pH value can also be used as comparative solutions for measuring the pH of unknown solutions. Commercial standard buffer solutions suitable for the calibration of pH meters are available which cover a range of pH values. Relevant tables of suitable buffer mixtures for the preparation of buffer solutions are also readily available. Mixtures of the following compounds are particularly suitable as buffer solutions:

- sodium dihydrogen phosphate NaH_2PO_4/disodium hydrogen phosphate Na_2HPO_4,
- boric acid H_3BO_3/sodium perborate $Na_2B_4O_7$ and
- citric acid/sodium citrate.

Such solutions possess the characteristic property of changing only very slightly in pH on addition of strong acids resp. strong alkalies since, e.g. the strong acid is "neutralized." An example in dyeing is the use of sodium acetate which can buffer hydrochloric acid:

$$CH_3COONa + HCl \rightleftharpoons NaCl + CH_3COOH$$

or

$$H^+ + Cl^- + Na^+ + CH_3COO^- \rightleftharpoons Cl^- + Na^+ + CH_3COOH$$

Even the dilution of a buffer solution with water, e.g. by a factor of 10, causes no change in the pH value. Comparative buffer solutions are required in pH measurement determinations, e.g. standard acetate solution prepared from 350 ml distilled water, 100 ml of 1N acetic acid and 50 ml of 1N sodium hydroxide: pH value of this solution = 4,62. In a similar manner, amphoteric substances (protein, glue, amino acids) as well as, in a wider sense, protective colloids, e.g. as used in the dyeing of wool with acid dyes, in wool chlorination, bleaching, etc., may also be regarded as buffers. Finally, levelling agents with fibre or dye affinity also offer buffering effects to some extent. → formaldehyde/ammonium salt reactions.

Builders Substances which increase the effectiveness of soaps or synthetic detergents (→ Syndets) by acting as softeners and sequestering or buffering agents. They help to retain dispersed soil in the wash liquor and prevent redeposition. Phosphate-silicate formulations, once widely used, have now been restricted for environmental reasons (→ Eutrophication). They have been largely replaced by → EDTA or → Zeolites, sometimes combined with nitrilotriacetic acid. Certain starch derivatives may also be used as builders.

Build-up behaviour of dyes A distinction is made between build-up behaviour of dyes in printing and in dyeing. In printing, the fact that the effective quantity of dye applied per unit surface area can only be determined approximately is a great handicap and often leads to the application of excess dye. Each application of excess dye is indicative of inefficient working practice since, on the one hand it is a cost factor, and also has a negative influence on subsequent processes such as dye fixation and afterwashing on the other. With the knowledge of dye-specific build-up curves obtained by colour measurement techniques, a step towards the better control of applied print paste quantities has been made (Fig. 1).

The build-up behaviour of dyes is greatly influenced by the:

- substrate,
- substrate pretreatment,
- print paste composition,

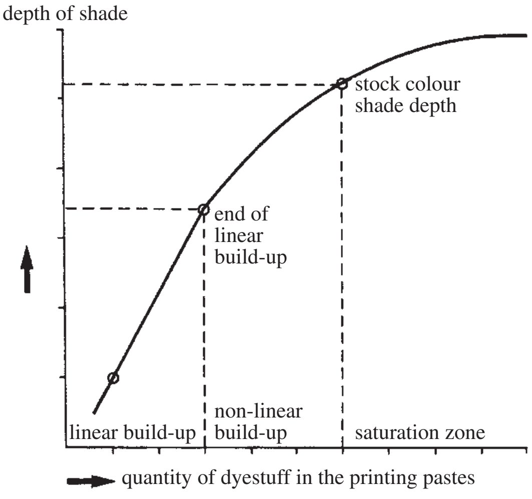


Fig. 1: Example of a dye build-up curve.

- print paste application,
- drying,
- fixation,
- afterwashing of printed goods.

If these parameters are kept constant, build-up curves are an ideal tool for the evaluation and comparison of different dyes. From these curves it can be seen that, in the main, dye build-up may be subdivided into 3 zones:

1. Linear build-up zone: this zone allows reliable strength comparisons to be made between dyes. The end-point of linear build-up provides an indication of build-up behaviour but gives no information on the economic build-up limit achievable.
2. Non-linear build-up zone: this zone begins with a flattening of the build-up curve and extends to the point where an additional quantity of dye is no longer worthwhile from a technical and economic standpoint. The end-point of this zone is called the “stock colour depth.”
3. Saturation zone: this zone begins at the point where dye is applied in quantities above the stock colour depth. It poses high risks with regard to, e.g.:
   - poor reproducibility,
   - loss of economy,
   - afterwashing and colour fastness problems,
   - poor product comparability in terms of strength, shade and application behaviour.

Build-up curves provide a means for the technical and economic evaluation of dyes. Optimum stock concentrations are dependent on local conditions and these should be established accordingly.

In the exhaust dyeing of polyamide fibres for the carpet sector, dyeing equilibrium changes as shown in Fig. 2 if the dyeing temperature is reduced.

A comparison of the build-up behaviour of different dyes as a function of dyeing temperature at a constant pH of 6,0 and a constant dyeing time reveals important differences in the behaviour of dyes with medium, high, or very high neutral exhaustion properties and migration properties which are corresponding very good, average or moderate. Whilst metal-complex dyes require temperatures near to the boil for optimum build-up because of their high molecular weight, acid dyes already exhibit rapid build-up behaviour from 40°C which, from 80°C, can already change gradually into a desorption phase. The well-known pH-selective behaviour of acid dyes is exploited in the controlled pH process; and is especially pronounced with dyes of medium neutral exhaustion properties. Build-up behaviour shifts considerably if the pH is reduced from pH 6 to pH 4; a property which is exploited in the sliding pH process.

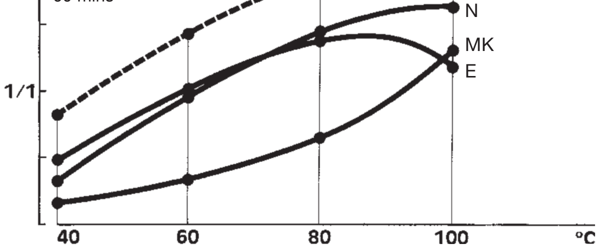


Fig. 2: Effect of dyeing temperature on dye build-up.

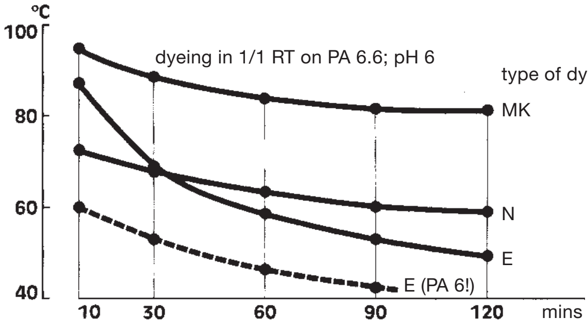


Fig. 3: Effect of dyeing temperature on dye build-up.

As shown in Fig. 3, the conditions required to achieve a 1/1 standard depth are different for the 3 types of dye selected. The E-type dyes, with medium neutral exhaustion properties, require a dyeing time of 60 min. at 60°C, whilst the N-type require 120 min. and the metal-complex dyes can only be applied in practice at temperatures of 80°C and above. The situation changes if polyamide-6 is used as substrate instead of polyamide-6.6; in this case, exhaustion increases so that, e.g. the E-type dyes build-up to 1/1 standard depth within 10 min. at 60°C.

Built soaps → Syndets.

Bukhara carpets Extremely fine hand knotted carpets made chiefly by nomads of the Turkoman tribe of the Tekkeh who live on the Trans-Caspian steppes. The motif used for Bukhara carpets is by far and away the best known of all those used for decorating oriental carpets, i.e. the Gul, which means rose in Persian. It is an octagonal motif with slightly rounded angles. Typical motif colours are blue, black or, more rarely, green with red and orange. The band between the outer edge and the central motif is wholly in ivory or alternating ivory and light red. The ground and border colour is almost always red, but in different shades, ranging from violet to orange. Wool warp and weft. The weft thread is very fine and is invisible even when used double. The pile is also in wool of excellent quality; soft, silky and hard-wearing. The quality of the wool is, in fact, one of the reasons why Bukhara carpets are so famous. The Persian knot is used with a very high density of between 350 000 and 600 000 knots per m^2.

Bulk development The development of bulk in

HB yarns (→ Textured yarns) of polyamide, polyester and polyvinyl chloride fibres either continuously, in hank form, super packages or as knitted fabric. The aim is to produce maximum bulk in textured or latent crimp yarns or in fabrics made therefrom. The essential conditions are heat, lubrication, movement, and the absence of tension. Bulk development may be accomplished during wet processing or may be a separate operation such as hot air tumbling, steam-injection tumbling or drycleaning.

Bulked Yarns → Textured yarns.

Bulking plants Used for the continuous bulking of HB yarns (high-bulk yarns). Bulk development is achieved by means of saturated steam, superheated steam or hot air.

Bulk/volume in textured yarns Filling capacity of a → Textured yarn per unit of weight (mass) measured under defined conditions.

Bulletproof vests Intended to provide the wearer with protection against small arms fire. They are of lightweight construction to afford maximum wearing comfort over long periods and provide protection against small to medium calibre bullets. Fabrics made from aramid fibres are mainly used, which offer the greatest degree of safety and the possibility of joining fabric layers together and producing combinations with thin sheets of hard material to give flexible laminates combined with the water repellency of aramid fibres.

Bump yarn Coarse, thick cotton yarn (sized) produced from cotton waste by the condenser yarn process. Frequently used for ground warps in carpet manufacture.

Buna rubbers Synthetic rubbers developed originally by Harries resp. Mathews and Strange as far back as 1910 and manufactured (at first in Germany by BASF) by polymerization of butadiene with finely divided sodium as catalyst (hence the name Buna, derived from the abbrev. of *Bu* + *Na* used as a trademark) for which the viscosities were given as attached numbers (so-called “number buna”). Further development by Bayer and the introduction of emulsion polymerization (1929, Bock and Tschunkur) led from these types to so-called “letter suffix buna”, i.e. Buna S, SAR (→ Styrene-butadiene rubber) a copolymer of butadiene and styrene as well as Buna N, NBR, GR-N (→ Butadiene-acrylonitrile rubber), or nitrile rubber, a copolymer of butadiene with acrylonitrile. As a result of further process modifications, e.g. the development of Ziegler-Natta catalysts and the use of other monomers for copolymerization (e.g. isoprene) etc., a whole variety of buna types (also in latex form) became available with optimum suitability for different applications. Uses: similar to natural rubber; especially for container linings; seals; swell-resistant printing rollers; protective coatings etc.; laminating; coating; foam rubber, etc.

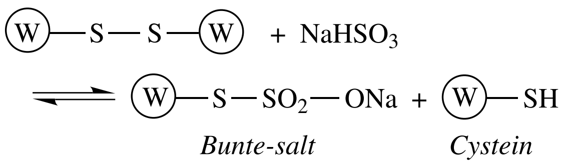
Bundesmann test A test used to determine the water repellency of fabrics by means of the Bundesmann Water Repellency Tester in accordance with DIN 53 888. → Water sprinkling apparatus Pfersee.

Bundle pack Method of packing yarn in hank form. In the English numbering system, 1 bundle = 10 lbs (10 English pounds = 4.536 kg). In metric numbering, 1 bundle = 5 kg. (→: Skein, Hank). Bundle pack variant units are usual to some extent. Bundle packs are produced in a bundle press.

Bunsen burner (chem.) A gas burner consisting of a tube with a small gas jet at the lower end, and an adjustable air inlet by means of which the heat of the flame can be controlled (air/illuminating gas mixture); used as a source of heat for laboratory work.

Buntal This → Palm fibre is made from stalks of the unopened leaves of the Buri palm of the Philippine Islands. It is a light fibre used to make hat braiding.

Bunte salt Formed by the sulphitolysis of cysteine in wool:



Bunte salt dyes, are a special group of sulphur dyes which, due to transformation of the mercapto groups into thiosulphato groups, are converted into a soluble form which has no affinity for cellulose. However, the addition of barium hydrosulphide during dyeing causes a gradual reverse transformation to take place into a form having affinity for cellulose.

The term has also been applied to a type of reactive dye for wool, which contains alkylthiosulphato groups. It has been postulated that these dyes attack cysteine groups when applied to wool and the asymmetrical disulphide formed largely disproportionates into symmetrical dye disulphides which are relatively insoluble.

Bunting A soft, flimsy, loose-textured, plain-weave cloth most frequently used in flags. Bunting was originally made from cotton or worsted yarns, but today’s flags are made primarily from polyamide or acrylic fibres.

Burette Apparatus for measuring the quantity of a liquid or gas in a chemical operation. In volumetric analysis the burette generally consists of a vertical transparent glass tube graduated in fractions of a millilitre provided with a glass stopcock or rubber tube pinch-cock at the lower end, by means of which the amount of liquid which is allowed to flow from the graduated tube may be controlled. Used for → Titration.

Burette test Used for testing small fabric specimens to determine the effect of waterproof/water-repellent finishes. The lower end of a → Burette, or metal cylinder is sealed with a small specimen cut or stamped out of the fabric to be tested. A water column of predetermined height is then allowed to act on the test specimen for a specified period of time.

Burgundy pitch → Colophony.

Burling iron Tweezers used in → Slubs.

Burning A → Combustion related process. → Burning behaviour of textiles.

Burning behaviour of textiles → Pyrolysis, i.e. the destruction into breakdown products by heat, is the first stage of every burning process. Not only does the fabric itself burn but so too do its pyrolysis products, and this determines the burning behaviour. The oxidation of these products develops either sufficient or insufficient heat to pyrolyse more of the material, i.e. to support the burning or to allow it to die out, i.e. the endothermic pyrolysis needs to be supplied with heat from the exothermic oxidative burning. Volatile flammable gases are produced on pyrolysis of the substrate and they rise into the flame through the preheating zone and provide new fuel for the flame (Fig. 1).

The energy balance for the burning process (Fig. 2):

1. Energy is required for
   - heating the fibre to the pyrolysis temperature (melting processes with thermoplastic fibres),
   - the pyrolysis reaction,
   - evaporation of the pyrolysis products,
   - heating the breakdown products to the ignition temperature,
   - compensation for the heat lost to the surroundings.

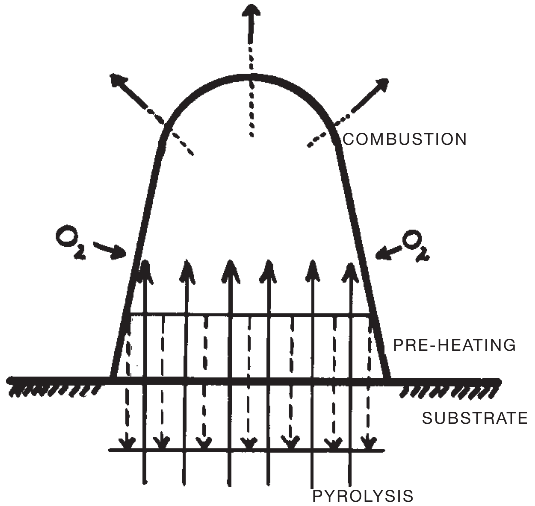


Fig. 1: Model of the stationary state of burning and pyrolysis in the burning process of textiles. The endothermic pyrolysis is supplied with energy in the form of heat from the oxidative exothermic combustion. In pyrolysis of the substrate volatile flammable gases are produced which rise into the flame through the pre-heating zone and provide new fuel for the flame.
——→ = combustible gases; - - -→ = heat transfer.

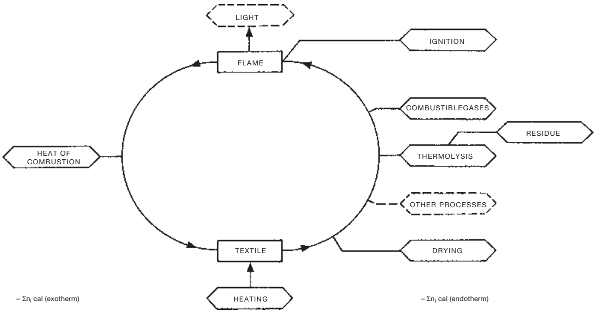


Fig. 2: Diagram of ignition of textiles (steady state).
Sn_i cal = total of the heat energy taken up or given up in the individual phases.

2. Energy is produced by
   - exothermic reaction of the breakdown products.

If the heat of combustion of the fibre is compared with this energy balance, the value obtained relates to the rate of propagation of combustion in this system. (see Table).

fibre material	combustion heat (kJ/g)	max. flame temperature (°C)	pyrolysis temperature (°C)
cotton	16,3	860	350
wool	20,5	680	325
polyamide	33,1	875	390
polyester	23,9	700	390
polyacrylonitrile	31,8	850	250
polypropylene	46,5	840	375

Tab.: Burning behaviour of textiles.

Factors which promote the rate of propagation of combustion of textiles:

- rate of the pyrolysis reaction,
- the melting behaviour of the fibre material,
- the oxygen requirement of the decomposition products during burning,
- the weight per unit area of the material,
- the nature of the surface,
- the fit of clothing (tight or loose),
- the number and nature of the layers of under and outer clothing,
- finishes (e.g. oil-containing preparations).

The effect of dyes is of minor importance in this connection. It is possible that they (e.g. metal complex dyes) may occasionally have a significant wicking effect, which does not significantly increase the rate of propagation however.

Burning properties

If an organic material is heated, it decomposes at a definite temperature into gases that burn, i.e. combine with the oxygen of the air with a flame, if they ignite spontaneously or a source of ignition is available. Thus cellulose decomposes into low boiling flammable alcohols and ethers which are oxidised in the presence of oxygen (from the air) to carbon monoxide and/or dioxide and water. This releases energy which heats up more cellulose and the process is continued. If the amount of energy released in this process is greater than the energy necessary to heat and destroy, the burning accelerates. On the other hand, if it is smaller the flame goes out. In the first case the material is readily combustible and in the latter case it is difficult to burn. If the combustion proceeds uniformly, the material burns normally. The change in burning behaviour of a particular material is obviously blurred. Division of materials into different grades of combustibility applies only at normal ambient temperatures i.e. for burning the original phase. If the temperature of the surroundings increases sharply all the combustible (organic) material is destroyed and a flammable gas mixture is formed. Fire spreads rapidly in this phase, flashover occurs. The rate of combustion of a flat textile material increases with:

- alteration of the spatial disposition from horizontal to vertical,
- increase of the inner volume,
- change in construction from single layered to multi-layered (particularly with thermoplastic fibres).

Below, several variables are set out that have been found from experience to affect the burning behaviour of textile products:

- the structure and the nature of the surface,
- the fibre material,
- preparation, finishing, dyeing,
- soiling,
- arrangement in use,
- combination of textiles,
- the ambient conditions,
- heat conduction.

Properties that characterize the burning behaviour of products can be listed:

- flammability,
- the rate of spreading of flames,
- the development of heat,
- shrinkage and melting,
- the development of smoke,
- the formation of toxic gases.

In testing and evaluating the burning behaviour of textiles, the following variables are important:

1. Minimum ignition time: the time that is required to ignite a test sample of the textile material under defined conditions, i.e. to produce persistent self-supporting combustion.
2. Burning time: also known as the after-burn time or the after-burn period, i.e. the time over which the test sample continues to burn independently after ignition and removal of the source of ignition.
3. Rate of flame spread: the distance that the flame travels on the burning test sample in unit time. It should be noted that this variable depends largely on which section the burning is timed over.
4. Glow time: also known as after-glow time or after-glow period, i.e. the time over which the material continues to glow after the the flame goes out or the source of ignition is removed.

During the burning process an equilibrium (steady state) is set up between oxidation (combustion) at the solid/gas phase boundary and pyrolysis (in the solid textile material). Oxidation with a supply of air is exothermic and supplies heat energy into the textile material among others, during which endothermal pyrolysis (destruction in the absence of oxygen) produces flammable gases (and tarry residues). These gases rise into the flame and feed it with flammable material.

Burning properties These include all the physical and chemical changes which take place in materials subjected to the action of fire. The most important burning properties of a selection of textile fibres are listed in the Table in the order of their limiting oxygen index (→ LOI value) and corresponding heats of combustion which are relevant to the important maximum flame temperatures and pyrolysis temperatures.

fibre material	limiting oxygen index	combustion heat (kJ/g)	inflammation temperature (°C)	melting point (°C)
polyacrylonitrile	18,2	31,8	465-530	235-320
cotton	18,4	16,3	255	does not melt
triacetate	18,4	–	450-520	293
2.5 acetate	18,6	–	450-540	255
polypropylene	18,6	46,5	570	164-170
viscose	19,7	16,3	420	does not melt
polyvinyl alcohol	19,7	–	–	does not melt
polyamide	20,1	33,1	485-575	160-260
polyester	20,6	23,9	485-560	252-292
wool	25,2	20,5	570-600	does not melt
modacrylic	26,8	–	–	160-190
aramids	30,0	–	–	soft from 316
polyvinyl chloride	37,1	21,4	–	100-160

Tab.: Properties of various fibres relative to burning behaviour.

Burning tests for fibre identification A qualitative analytical scheme (according to Agster) for the identification of unknown fibrous substrates by observing their burning behaviour, having regard to flame, smell and residue (see Table).

odour	burning behaviour, residue	fibre material
odourless	asbestos remains unchanged, glass fibre melts to form pearls	mineral fibres (asbestos, glass fibres)
like burning paper	quickly burns away, whitish grey ash	vegetable fibres (cotton, flax, hemp, viscose and cupro fibres)
like burning hair	slow burning, ash first of all bubbly-coal-like, later whitish grey; ash skeleton with weighted natural silk	animal fibres (wool, natural silk, regenerated protein fibres)
acidulous (vinegar)	burns rapidly, first of all small molten balls, later whitish grey ash	acetate
pungent, irritating to the point of provoking coughing (HCl)	liquates, does not continue to burn outside the flame, smoky, white smoke drifts after quenching, black, brittle residue	polyvinylchloride
faintly like burning hair, not pungent	liquescent at first, then burning, continues to burn outside the flame, not smoky, vitreous, yellow to brown thready melt	polyamide
unpleasant, like mouse droppings	liquescent and burning, continues to burn outside the flame, not smoky, hard, brown residual melt	polyurethane
sweetish and aromatic	at first liquescent, then burning, continues to burn rapidly and smokily outside the flame, black, brittle residue	polyacrylonitrile
sweetish and aromatic, not pungent	at first liquescent, then burning, smoky flame, does not continue to burn outside the flame, vitreous, yellow-brown, thready melt	polyester
like burning paraffin candles	at first liquescent, then burning, continues to burn outside the flame, light brownish, brittle residue	polyethylene
like burning paraffin candles	liquescent, does not burn, white smoke drifts, yellowish brown melt	polypropylene
like burnt sugar	liquescent, then rapidly burns away even outside the flame, not smoky; light brownish brittle residue	polyvinyl alcohol

Tab.: Burning tests for fibre identification.

Burning time → After-burn time.

Burn out lace → Burn out styles.

Burn out printing (devoré printing) The process of printing a design on flat fabrics composed of different fibre types with a paste containing chemicals capable of dissolving or destroying one of the fibre components. Fabrics resembling lace have been produced in this way for shirtings and other fashion articles.

As shown in the Table, sodium dihydrogen phosphate is a virtually universal burn out agent for fabrics containing fibre mixtures with polyester. Aluminium sulphate also gives good results when favourable conditions exist with regard to the substrate structure and composition. The considerably more aggressive sodium dihydrogen phosphate can even be used successfully on woven and knitted fabrics produced from yarns composed of intimate fibre blends. Sodium dihydrogen phosphate cannot be used on fibre mixtures containing polyamide, however. In these cases, aluminium sulphate must be used, preferably on core-spun yarns. Sulphuric acid is used as an extremely aggressive burn out agent (for the all over process). Sodium hydroxide solution is used to burn out the wool/silk components in mixtures with polyester or polyamide; protein fibres are broken down hydrolytically under conditions of high pH which results in their complete removal.

	aluminium sulphate	sodium hydrogen phosphate	caustic soda	benzoic peroxide
cotton	+	+	–	–
viscose	+	+	–	–
linen	+	+	–	–
polyester	–	(–)	(–)	–
polyamide	–	+	(–)	–
triacetate	–	+	(–)	+
acetate	–	+	(–)	+
wool	–	–	+	–
silk	–	–	+	–
fibre is: + destructible, - resistant, (-) partially resistant				

Tab.: Burn-out agents and fibre materials.

Burn out styles (devoré styles, à jour effects, chemical embroidery). These styles are produced on fabrics composed of different types of fibres by the (local) action of chemicals capable of destroying a selected fibre followed by its subsequent removal. The effects include all-over or printed open-work designs on blend fabrics or burn out lace produced by machine embroidery on a subsequently burnt out base fabric of a different fibre type and → Burn out velvet effects. The simplest example is a mixture of silk and cotton or viscose. In this case, aluminium sulphate or chloride is used to carbonize and dissolve out the latter component (by saturation, mild drying, heating, final brushing out). With acetate/viscose mixtures the latter is dissolved out by boiling alkali. A treatment in cold 70% sulphuric acid can be used to dissolve out the cotton in polyester/cotton fabrics (with no effect on the polyester).

Burn out velvet (velours dévorant). Velvet fabric with designs produced by fibre-selective chemical burn out action. → Burn out styles.

Burnt alum → Aluminium potassium sulphate.

Burnt farina (roasted starch) → Dextrine.

Burnt gas fumes, colour fastness to → Colour fastness to atmospheric contaminants; burnt gas fumes.

Burnt magnesia Magnesium oxide.

Burnt-out embroidery A machine embroidery technique producing fabric comprising embroidered motifs in accordance with DIN 6000. This embroidery technique creates simulated true lace. Embroidery is applied to a base material (paper or linen cambric). The embroidered motifs are linked by the required number of cross-over stitches so that the subsequent burning-out of the base material produces lace material (or motifs) in the form of piece goods. The embroidery machines are of the two-thread type and the density of the stitches determines the nature and plasticity of the lace.

Burr removal → Carbonizing.

Bursting strength Defined as the multi-directional resistance to rupture of a circular fabric specimen. Testing of flat materials (textile fabrics, paper, films, etc.) is carried out under two-dimensional stress by applying a load perpendicular to the test surface. Both the effective pressure at the moment of bursting in N/cm (bursting strength) and the bulge-height in mm (bursting distension) are measured.Test specimen sizes are 10 or 100 cm^2. The test gives a useful indication of material serviceability with regard to wearing performance resp. wear and tear.

Bursting strength tester Apparatus or instrument for the determination of → Bursting strength.

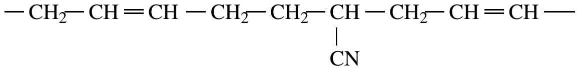
Burst stitch damage Faults occurring in making-up (significantly more serious in the case of solvent cleaned fabric) especially with wool and wool/synthetic double jersey fabrics. Cause: fibre puncturing by needle points during sewing, stitches bursting due to the use of needle sizes unsuitable for the fabric density, or synthetic fibre yarn melting. Soft finishes (solvent type) are suggested as an effective countermeasure.

Butadiene, represents the simplest example of the → Dienes:

$$CH_2{=}CH{-}CH{=}CH_2$$

Butadiene is the starting material for the manufacture of butadiene rubbers (→ Buna rubbers).

Butadiene-acrylonitrile rubber, synthetic rubber consisting of a copolymer of → Butadiene with → Acrylonitrile:



$$-CH_2-CH{=}CH-CH_2-CH_2-\underset{\displaystyle CN}{\underset{|}{CH}}-CH_2-CH{=}CH-$$

Properties: Shore hardness range 40–95, good adhesion to fabrics and abrasion resistance, good stability towards acids, solvent resistance is excellent (aliphatic hydrocarbons) to poor (aromatic hydrocarbons), good resistance to oxidation (moderate to ozone), poor stability to sunlight and fire. In contrast to natural rubber that starts to soften at high temperatures, butadiene-acrylonitrile rubber hardens because of further polymerization. Tends to distort permanently under tension. Machinability is more difficult because of somewhat poorer abrasion of the material and this also applies to adequate adhesion to fabrics. Uses: container linings, non-swelling pressure rollers, protective clothing, thickeners, oil-resistant hose pipes etc.

Butadiene-sodium rubber → Buna rubbers.

Butane → Saturated hydrocarbons.

Butanol (butyl alcohol), C_4H_9OH. Generally available as the primary or normal butanol. Density 0,8; b.p. 114–118°C. Colourless highly refractive liquid with an alcoholic odour. Flammable (very luminous flame). Miscible in 12 parts of water, readily miscible with ethanol, ether, etc. Uses: excellent solvent for dyes (especially in printing), resins and lacquers (spotting agent); also used as a defoamer in dye liquors, etc.

Butene (butylene) → Olefins.

Buttons Depending on the material concerned, buttons can cause various dry cleaning problems. Some certain types of buttons can be very expensive; damage or loss due to dissolution can be prevented by prior knowledge of the material composition, or by removing before dry cleaning. The most important types:

I. Buttons of mineral origin:

a) Glass buttons: resistant to all types of treatment, but are easily damaged by knocks or blows (e.g. in a tumbler).

b) Mother of pearl buttons: similar characteristics to Ia; a misted appearance which may develop as a result of redyeing processes can be rectified by polishing.

c) Metal buttons: usually made from non-ferrous metal, galvanized to protect from corrosion. Very susceptible to stripping prior to dyeing and to acid dyeing (liable to turn black or stain due to oxidation). Prior removal is advisable.

d) Fabric-covered buttons: often with metal base, sometimes with cardboard insert. Show similar reaction to Ic. High risk of damage during wet treatment (oxidation stains); fabric-covered buttons should, therefore, be removed before redyeing processes, unless they are sewn onto separate fabric patches.

II. Buttons of vegetable origin:

a) Wooden buttons: are easily recognized. Dry cleaning can cause the surface to dull; washing often causes marks resulting from the wood stain; redyeing almost always causes a loss in lustre. Removal is, therefore, advisable.

b) Ivory nut buttons: used almost exclusively on men's outerwear, usually with artificially structured surface, harder than IIa (ringing sound when knocked together; strong impact will cause the buttons to shatter). Surface colouring often achieved with direct dyestuffs (light ground visible when back of button is cut and dampened). Are considered to be resistant to washing and dry cleaning.

III. Buttons of animal original:

a) Bone buttons: used on overalls, for example, generally very robust.

b) Buffalo horn buttons: can be recognized by the coloured annual rings or layers and transparency to light; stability generally very good, however, the buttons are easily deformed during dyeing.

c) Cornungula buttons: light coloured horn, bleached and often dyed (often irridescent) transparent, seldom seen these days. Characteristics similar to IIIb.

d) Leather buttons: usually very sensitive to moisture and heat (mark off onto light fabric), often also affected by dry cleaning (chlorinated hydrocarbons), often resulting in fabric staining or marking; thus removal (or preliminary testing) is always advisable.

IV. Plastic buttons: made from various synthetic resins, such as → Casein plastic (Galalith). Usually good imitations of IIc und IIIc (recognizable by the ringing sound when knocked together). Likely to become slightly deformed and porous and lose their lustre in redyeing processes. There are buttons of this type on the market that are resistant to dry cleaning and others that are freely soluble in solvents. The dissolving tendency can be tested by rubbing the buttons with a rag soaked in solvent. Experience has shown, however, that this precautionary measure is unreliable, because during dry cleaning the buttons are subjected to the solvent in question for a much longer period, during which time dissolving and stickiness of the surface (so-called syrupy buttons) may occur . In case of doubt, therefore, removal is advisable.

Butt seam sewing machine Serves to compensate differencies in elongation (= smooth seam), chiefly used in front of the entry of stenters, calenders, padders, raising and shearing machines, and also for stitching fabric into a tube for washing and dyeing. Industrial sewing machines for butt sewing of fabrics without overlapping. The seam is flat and can be undone by simply pulling the thread.

Butyl → Alkyl.

Butyl alcohol → Butanol.

Butyl benzyl phthalate (BBP) → phthalates.

Butyl cellosolve → Ethylene glycol monobutyl ether.

Butylene → Olefins.

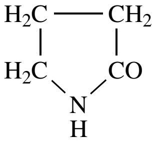
Butyl glycol → Ethylene glycol monobutyl ether.

Butyl rubber (isobutylene-isoprene rubber). Synthetic rubber obtained by copolymerizing isobutylene and isoprene. Properties: good fabric adhesion and abrasion resistance. Good to excellent resistance to acids but generally poor to solvents. Excellent resistance to atmospheric ozone and good resistance to sunlight. Poor fire resistance. Uses: for seals and coatings. Less permeable than natural rubber and used in tyre inner tubes.

Butyric acid (n-butyric acid; butanoic acid; ethylacetic acid; propylformic acid) C_3H_7COOH. Occurs as an organic fermentation product of butter and animal milk fats. Colourless liquid with a penetrating and obnoxious odour. Strong irritant to skin and tissue.

Butyrolactam (2-pyrrolidone). Uses: a monomer for the manufacture of polyamide-4, starting material for → Polyvinylpyrrolidone (dye-stripping agents, adhesives, binders).

Butyrolactone A → Lactone (intramolecular cyclic ester) used as an intermediate in the manufacture of textile and dyeing auxiliaries.



Bw → Cotton, → Standard abbrev. for textile fibres, according to DIN 60 001 until 1988. From 1991 → CO.

By-pass A system for directing flow around a fixture, vessel, connection or pipe, instead of through it, controlled by means of valves. In stenters e.g. (see Fig.), the overdrying or oversetting of fabrics as a result of short duration stoppages can be prevented by a by-pass control system. In the event of a machine stop, the air flow is immediately diverted from the fabric to the heat exchanger without interrupting the air circulation cycle. On restarting the machine, full air flow and temperature conditions on the goods are immediately restored.

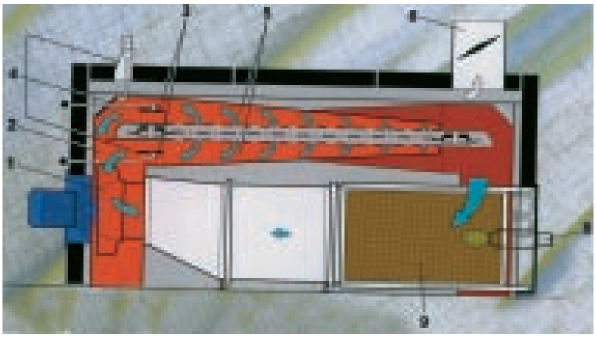
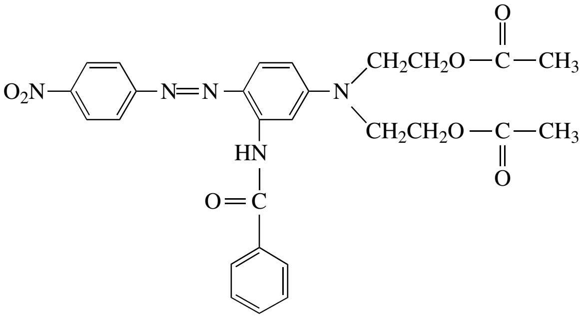
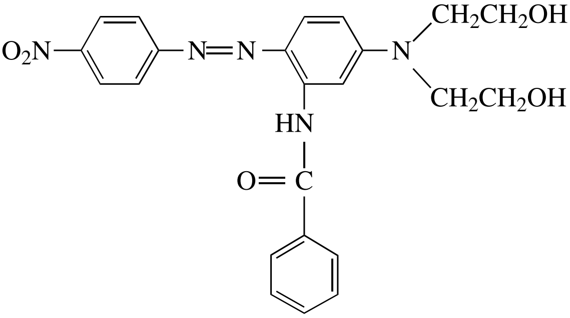


Fig.: By-pass (no. 4) in the classic-flow-stenter from Brückner
1 = fan; 2 = distribution of air to upper and lower nozzle; 3 = throttle valve; 4 = by-pass-system; 5 = nozzles; 6 = exhaust air out-let; 8 = gas burner; 9 = filter screen.

By-product level In dye synthesis, by-products are formed in addition to the desired dye. If these are not removed before sale of the finished product, the resultant by-product level can give rise to problems in subsequent dye application. Example: the following disperse dye



has a rating of 5 in the multifibre strip wash test (at 1/1 standard depth). However, if the dye contains only 0,4% of the following by-product based on 100% of dye exhausted from the bath,



which actually corresponds to a 0,008% dyeing of this product, the wash fastness of the entire dyeing at 1/1 standard depth is then reduced to a rating of only 1–2.

Byssinosis An industrial respiratory disease among workers in the vegetable fibre industry (principally cotton) which takes the form of a feverish bronchitis, often characterized by chest tightness on returning to work after a period of absence. It is not the fibre itself which is responsible for Byssinosis but the → Endotoxins contained as impurities in the fibre dust. Attempts to free the raw cotton of endotoxins before spinning by washing or lye treatment have proved to be uneconomic and spinnability is considerably impaired. Similarly, attempts to remove the endotoxins by treatment of the cotton with steam or various chemical vapours have met with little success.

Byssus silk → Mussel silk.

Byte A fixed number of bits (now almost always 8 bits) that can be handled and stored as a single unit of data in a computer.

C

C,

I. abbrev. for Celsius, as in temperatures expressed in °C (degrees Celsius).

II. symbol for → Carbon.

c, prefix for → Centi (hundredth), or 10^{-2}, e.g. as in cN/tex.

CA,

I. → Acetate fibres ($2^{1}/2$), → Textile fibre symbols according to DIN 60 001 T4/08.91.

II. → Hemp, standard abbrev. according to the → EDP Code (→ Textile fibre symbols).

CA^{+} → Acetate fibre deacetylated (saponificated).

Ca, symbol for → Calcium.

Cabinet steamer A cabinet-type steamer set up in various ways for the steaming a) of vigoureux or tops printing (in steam boxes or drawers, max. 1.25–1.5 bar); b) when pleating (material hanging).

Cabinet steam finisher Steam finisher for the batch steam treatment of outerwear in textile cleaning.

CAD in textile printing The colour management in a print shop consists of the engraving section and the coloration section (Fig. 1).

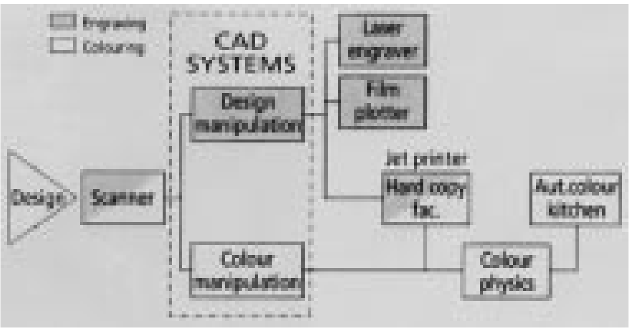


Fig. 1: Processing a design scanned on to a monitor screen (CAD) and printing screen (laser) and printing paste creation (Stork).

A CAD system (Computer Aided Design; → Computer application in textile finishing), with the help of a scanner, takes in the design which is to be modified in terms of shape and colour, to enable on screen working. The laser engraver and the colour kitchen are then also connected to the CAD system. However, this requires a special system configuration in textile printing. Here, the route of on-line printing is being developed by all suppliers, i.e. computer-controlled patterning and colouring, including colour formulation and printing of patterns and colour designs on paper or fabric, automatic colour kitchen, pattern printing units equipped with production parameters, right down to reproducible production on the printing machine.

With the CAD system, two fundamental aims are pursued:

- supporting the patterning and design department in the development of fashionable designs, and
- providing design and production data for faster conversion of production for designs which have been developed.

The aim is to support the pattern designer and to reduce the number of rejections. The representation of draft designs on screen or by means of printouts allows early submission to the client, and agreement with the partners on the fine details of the draft designs. The following factors have a positive effect on the design and production process:

- reduction of routine activities,
- shortening of planning and processing phases,
- easier execution of modifications,
- utilisation of older designs with new colour schemes,
- faster realisation of customers' wishes and ideas,
- faster presentation and market presence with fashionable designs,
- archiving of patterns and colour designs which have been used and designed,
- comparison and pre-selection of draft designs without production on the sampling table,
- automatic creation of technical documents and production specifications,
- better monitoring,
- cost reduction in the design department and in the production of colour designs,
- consideration of in-house specifications and standards in the development process.

In order to achieve these aims, a program package with the following modules is required:

- colour management,
- management of stencils and designs,

- coloration,
- processing of models and studio pictures,
- production of design and production documents including control data for textile machines.

Since CAD systems are intended to achieve not just a visual support in pattern design work, but also to address extensive administrative work, aspects of quality assurance and presentation tasks, the choice of a robust hardware platform with connection options to existing data processing facilities, connection options for standard peripherals and a step-wise construction of the system is necessary. In order to store large amounts of data, such as is generally necessary with the various stencils of a pattern design or numerous pattern designs which are in production or development, large storage capacities are required, in particular also to enable storage of older collections.

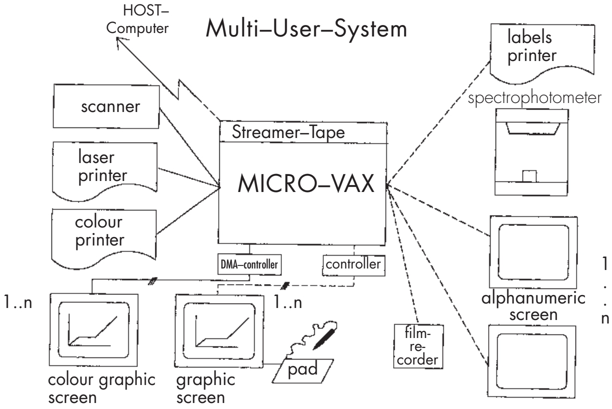


Fig. 2: System configuration CAD textile printing.

Fig. 2 illustrates a typical system configuration. With this, the print sequence of colour separations can be displayed, taking into account the current colour of the respective stencil. Within the program module, different colour designs of the same pattern design can be coloured in. Up to 9 colour designs can be shown on the screen simultaneously, depending on the size of the pattern design or the pattern repeats, in order to construct harmonious colour sequences or colour-matched colour designs on the screen. The pattern designs can be laid over different fabrics. The structure of the woven fabric, which has been built-in or read-in via a scanner, appears clearly, so that for example the effects of fancy textures or jacquard weaves become visible as part of the design. After completion of the various colour designs, production documents can be printed out on a laser printer for the sample table. The colour designs themselves can be printed on a colour printer. The article master data can be sent to the computer. Coloured samples can be scanned in with the aid of a scanner and displayed on the monitor. Via an automatic colour reduction program, the multitude of colours can be reduced to a number of printable colours. In stages, the user can examine at what number of colour separations an interesting, graphic motif can be obtained. At the same time, the results of different reduction stages can be shown on screen.

Cadoxen solution contains 5% cadmium, 28–30% ethylene diamine and 0.5 mole caustic. Uses:

1. Determination of → Fluorescent brightening agents on cellulosic materials.
2. Determination of the cellulosic content in cellulose/synthetic fibre mixture yarns (especially cellulose/polyvinyl alcohol).

Cake dyeing Dyeing of synthetic, viscose, acetate and triacetate filaments on → Pack system dyeing machines with cylindrical material carriers or creel system dye tubes. Problem: levelness, through-dyeing; partly due to swelling of the material. Cake dyed material is usually made into multicoloured products; high wet-fastness requirement.

Calcined Synonymous with anhydrous. Salts designated as “calc.” (e.g. sodium sulphate and sodium carbonate) have lost their pure water content through heating or roasting (calcining). For practical applications, this results in correspondingly greater efficacy with the same salt amounts for the “calcined” salt quality, i.e. smaller amounts of this are required. Comparison ratios are usually stated for the individual salts.

Calcite Chemically pure → Calcium carbonate in the form of sharp-edged crystals. When deposited on textiles they exert a destructive “abrasive” action.

Calcium (Ca), a soft, silvery-white metal, stable in air, very reactive, most important member of the → Alkaline earth metals with their typical properties; atomic weight 40. In water the calcium ion forms salts which are soluble (bromide, chloride, iodide, nitrate), sparingly soluble (sulphate) and insoluble (phosphates, with decreasing hydrogen ion concentration resp. increasing pH).

Calcium acetate (acetate of calcium), $Ca(CH_3COO)_2 \cdot H_2O$; MW 176. Uses: for silk dyeing (addition to calcium-deficient water, freedom from iron is required) and water-repellent impregnations.

Calcium carbonate (carbonate of lime, chalk), $CaCO_3$; white crystals or powder; MW 100; density 2,72. It is very slightly soluble in water containing carbon dioxide (0,14 g/l at 25°C). It acts (as a “base”) by neutralizing acids with the formation of water-soluble calcium salts. Uses: in wool dyeing (production of pastel shades), alizarin red dyeing, naphthol dyeing (neutralization of acidic baths), removal of hair from leather skins, building industry, cleaning agents, chalk, putty, etc.

Calcium content of cotton This results from compounds which are stored during fibre growth. Depending on the provenance, the calcium content of the ash fluctuates between 1.18 and 3.99%, which corresponds to 0.06–0.24% calcium in relation to the cotton. Higher values can be attributed to artificial irrigation, the use of fertilisers containing calcium (e.g. lime-nitrogen), treatment of the cotton with herbicides or defoliants containing calcium. An increase in the calcium content due to defoliants based on calcium cyanamide ought to be low these days, since the cultivated areas treated thus are small (<3.5%). It is not known to what extent the emulsifier calcium dodecylbenzol sulfonate, which is frequently used in plant protective agents, contributes towards an increase in the calcium content of the cotton fibre.

In the case of mature seed capsules of cotton plants which have been treated with herbicides and artificially irrigated in greenhouses, it has been possible to determine 0.13% calcium. Calcium content of various cotton qualities:

Flock, raw	0.09%
Yarn, raw	0.06%
Yarn, bleached	0.02%
Fabric, raw	0.06%
Fabric, bleached	0.04%
Tricot, raw	0.04%

Calcium hardness → Water hardness salts.

Calcium hydrogen sulphite $Ca(HSO_3)_2$; colourless or pale yellow solution, smelling of sulphur dioxide. Used as a bleaching agent, e.g. for sponges.

Calcium hydroxide (Slaked lime), $Ca(OH)_2$; → Calcium oxide.

Calcium hypochlorite (Chlorinated lime, bleaching lime), $Ca(OCl)_2$, salt of the hypochlorous acid (HOCl), MW 127. White, loose powder (no lumps), typical chlorine smell, avidly attracts carbon dioxide from the air (under decomposition, runs into a greasy mass; store dry, cool and well sealed). Good calcium hypochlorite contains 75.8% activated chlorine. Soluble in cold water (large residue). Used for: bleaching cellulose fibres (sodium chlorite and chlorine bleaching processes); chlorination of wool (reduced felting and shrinking properties, increased dye affinity, silky handling, silky lustre) and carpets (carpet antique effect).

Calcium oxide (Quick lime, caustic lime, unslaked lime), CaO, MW 56. White (grey-yellow) porous mass, hygroscopic (with heat generation) and strongly attracting carbon dioxide (conversion to calcium carbonate, therefore store well sealed). With water, with intense heating (up to approx. 450ºC), forms highly alkaline calcium hydroxide $Ca(OH)_2$: $CaO + H_2O \rightarrow Ca(OH)_2 + 63.69$ kJ. However, calcium oxide is only slightly water-soluble (at 15ºC 1.3 grammes per litre, 100ºC 0.65 grammes per litre) to form "lime water"; under the action of water, "slaked lime" results (calcium hydroxide); the watery white, milky suspension is called "milk of lime". Used for kiering agents, boiling agents (cotton), vat dyeing (zinc-lime vat), calcium mordant in dyeing (cotton); water purification (lime-soda process); construction engineering, furnace lining, reference value for calcium hardness etc.

Calcium sulphate → Gypsum.

Calcium sulphate hardness → Water hardness.

Calender bowls, commissioning of → Conditioning of calender bowls.

Calender coating Method used when coating the 4-roller calender with rubber, etc. To obtain good rubber coatings the rubber sheet is pulled into two rolls by calender rollers running at the same speed, and then on the last calender roller fabric is pressed onto the rubber sheet by means of a rubber roller.

Calender crease Typical crease which appears on both sides of tubular knitted fabric which has been passed in the flat state through a calender. The calender crease, like the ladder, can be used as an orienting line for slitting.

Calender felt Technical endless wool felt compound fabric approx. 7–9 mm thick as a continuous back grey for felt calenders etc.

Calendering Important finishing operation for most types of woven fabric (except wool), narrow fabrics, etc. Treatment of open-width fabric with pressurized bowls or rollers on the → Calenders to influence the surface appearance, pore density, smoothness, lustre/matt effects, handle and, if required, produce additional patterning effects (embossing, moiré, chintz, etc.).

Calenders A multi-roll machine (2–16 rollers or bowls) for → Calendering. The bowls rotate under adjustable mechanical, pneumatic or hydraulic pressure. The principle of operation is based on at least two adjacent calender bowls, one or more being a) a metal bowl (usually steel or chilled iron), the surface of which (ground, polished, chromium-plated or engraved) can be heated if required (steam, gas, electricity), with b) resilient bowls (one or more). To prevent damage to the surface of the resilient rolls when particularly thick seams pass through, "seam detectors" are provided, which effect instantaneous pressure relief = "skying" (e.g. air cushions). Calendering effects are varied by various factors (Fig. 3)such as number of bowls, arrangement of the bowls, bowl material (e.g. a + b), bowl pressure (varies according to fabric type and width, usually up to approx. 50 tonnes; can be over 100 tonnes), metal bowl temperature (up to 300°C depending on fabric and effect), rotational speed and the degree of friction (e.g. up to 300 per cent friction by having an inclined fabric-filled bowl or faster running metal bowl), fabric state (dry, damp, wet), cloth run and number of passages.

Fig. 1 shows typical calender bowl configurations: On the 3-bowl rolling or swissing calender (configuration B, C, D) all rollers have the same rotational speed

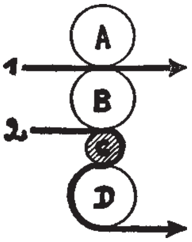


Fig. 1: Bowl arrangement options on calenders.
A, B, D = resilient rollers; C = heatable metal roller.

and create a rolling pressure. In this example, the heatable metal bowl (C) is positioned between the two fabric-filled bowls (B, D). Besides a smooth finish, a cloth run as shown in configuration 2 produces a semi-glaze (without heating) or a high lustre (with heating) on one side of the fabric. The → Friction calender (glazing calender) operates according to the same arrangement (B, C, D), with the difference that the middle, heated metal roller runs at a higher adjustable speed, thus producing a high lustre (for satin and chintz) by means of frictional pressure. On the rolling and friction calender, both effects can be achieved alternatively by shifting the metal bowl (C) to the bottom {delustring calender (configuration A, B, C)}, and a matt effect can be achieved on one side by having the cloth run between the resilient bowls only, according to configuration 1. To suit higher demands, multi-bowl rolling and delustring calenders as well as combined rolling, delustring and friction calenders with a 4-bowl arrangement are available (configuration A, B, C, D).

The → Chasing calender has an additional guide roller system (so-called chasing unit, e.g. 6–12 rollers), through which several layers of fabric are guided, resulting in the beetle effect (the fabric surface is closed, the threads retaining their rounded structure), as is usual on cotton and linen fabric (white goods, damast, bed ticking, shirt fabrics, lining fabrics). → Embossing calenders serve to produce various embossed effects on grey cloth (crepe calender), and on finished fabrics (embossing calender). The latter usually has two or three bowls, the heatable engraved embossing bowl being located above the resilient bowl. This group includes the ciré calender, the moiré calender and the → Schreiner calender (silk-finish calender). All the above embossing functions can be achieved on multi-purpose embossing calenders by changing the bowls, with an additional drive for the lower bowl to achieve high-lustre effects (chintz finish), too. All calendering effects can be achieved on 5-bowl universal calenders (up to 50 t pressure, operating speed max. 100 m/min.), which are available as swissing, delustring, friction, chasing and embossing calenders. For glazing damp cotton fabric, the calender for simili mercerizing is used, whereas the so-called water calender serves to express liquids (max. 45 per cent) from cotton and linen fabrics suitable for this process, at the same time achieving a certain surface sealing effect. The latter (usually 3-bowls = configuration B, C, D), e.g. with 2 jute-filled bowls (B, D) between which is a heatable, chromium-plated steel or bronze roller (C) (alternatively a non-heatable steel roller with hard rubber covering). Normal pressure up to approx. 30 tonnes (with hydraulic system up to 60 tonnes), operating speed approx. 50–100 m/min. and more. Water calenders with more than 3 bowls help to even out the effect and increase the throughput speed. The design of the felt calender, which is used for drying light-weight cellulosic fibre and union fabric blends as well as tricot fabrics, deviates from that of the above mentioned constructions. First of all, the fabric passes through an expander unit for weft stretching (so-called Palmer unit) consisting of two wheel rims which can be skewed in relation to the cloth passage (with combined holding devices to obtain the required tentered width independent of the entry width), on which the fabric selvedges are held fast by endless rubber or leather straps, prior to fabric feed on a felt backgrey to the rotary drying drum and subsequently to the plaiter or batching unit. The felt backgrey causes the liquid that is evaporated during drying to stay in contact with the fabric longer, resulting in the typical felt calender finish, e.g. a pleasant, natural lustre and soft, full finish on wool fabrics. In order to increase performance, a predryer in the form of a cylinder drying machine can be fitted between Palmer and felt calender. A further special type of calender worth mentioning is the so-called rubber coating calender (3–4 chilled iron rolls with heating and cooling facility, synchronized or with friction) used for coating and laminating of extremely long production runs requiring a heavy coating (industrial fabric, rainwear and protective clothing fabrics, etc.) and serving to calender-on the rubber layer (coating; skimming). On the “doubling” calender (steel and paper-filled or rubber roll) duplex fabrics, for example, can be produced by pressing two webs together with the rubber layers facing.

On their 2-bowl, all-purpose calender, Küsters use their “swimming roll”, while on their 3-bowl calender

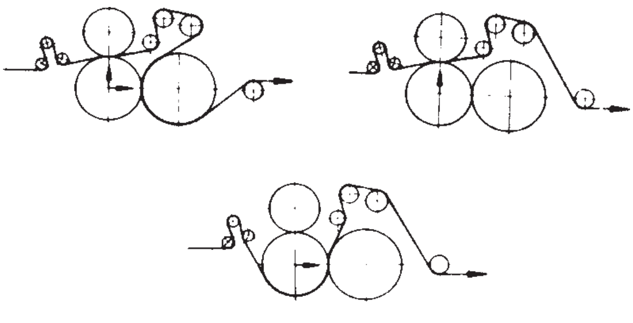
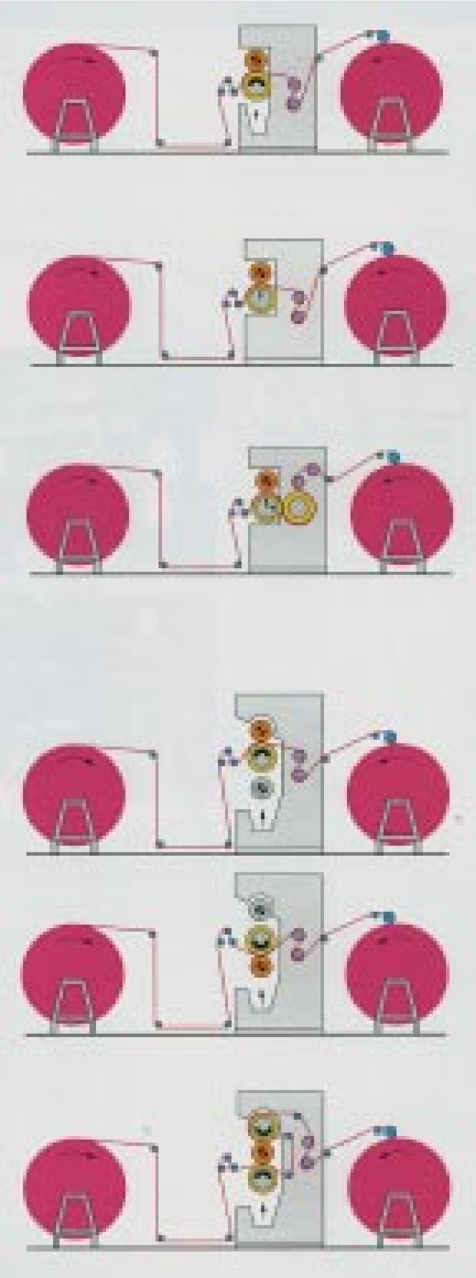


Fig. 2: L-shaped bowl arrangement on calenders with Nipco roll from KTM Kleinewefers.



2 roll textile calender with S-Roll
- steel roll, heated
- swimming roll Küsters

Effects: gloss, smoothness, condensing

2 roll textile calender with hydro flex roll
- steel roll, heated
- hydro flex roll

Effects: gloss, smoothness, condensing

3 roll textile calender with hydro flex roll
- steel roll, heated
- hydro flex roll
- elastic roll

Effects: gloss, smoothness, condensing, handle, matt

3 roll textile calender with S-roll
- engraved roll heated f. e. Schreiner
- swimming roll Küsters
- steel roll, smooth, heated

Effects top nip: Schreiner, embossing
Effects bottom nip: gloss, smoothness, condensing

3 roll textile calender with two S-rolls
- swimming roll Küsters
- steel roll, smooth, heated
- swimming roll Küsters

Effects: high gloss, smoothness, high density

Fig. 3: Calendering.

KTM Kleinewefers have incorporated a “Nipco” bowl as the middle roller, which adjusts to the deformation of conventional mating rolls. On this universal calender, the 3 bowls are arranged at an angle of 90° to each other forming an L-shape; at the top an oil-heated steel roll, in the middle a Nipco roll with its special cover, behind which is a special cotton-filled bowl. The hydraulic pressure application is effected by means of supporting or pressure elements pressing against the inside of the Nipco bowl sleeve and acting on the heated steel roller on top and independently on the cotton-filled bowl behind. The pressure elements follow the flexion line of the mating rollers, so that cambering is unnecessary. With this arrangement, typical calendering effects can be achieved by means of the various bowl combinations (Fig. 2).

Calibration curve A measuring curve which is recorded for comparison with a reference curve.

Calico,

I. (Calicut). Printed → Plain weave cotton fabric or percale (highly finished = bookbinder’s calico) produced from grey, plain (e.g.) woven cotton fabrics; named after the East Indian city of Calicut (today Calcutta).

II. Plain weave cotton fabric, single-colour or printed. Is the finest of the three grey cloth qualities with an average in each case of 15–28 ends/cm (warp and weft) from Nm 50–70 (20–14 tex) cotton yarn. → Plain weave cotton fabric.

Calorie (thermal unit), quantity of heat required in order to heat 1 g (“small” or “gramme calorie” = cal) or 1 kg of water (“large” or “kilogramme calorie” = kcal) from 14.5 to 15.5°C. Replaced as a unit in the SI system by → Joule: 1 cal = 4.1868 J.

Camayeux effects Light and dark effects in the same shade which are achieved at the same time in one dyebath, on the same fibres with a different affinity for dyestuffs (→ Tone-in-tone dyeing). This can be achieved by processing untreated wool with treated wool, e.g. unchlorinated/chlorinated and non premordanted/mordanted, to make yarn, woven and knitted fabrics, followed by dyeing with selected chrome dyestuffs. The chlorinated and premordanted wool has a much higher dye affinity than the untreated wool, thus producing the light-dark effect. On silk, the same effect can be achieved by processing degummed, unweighted silk yarn with mordanted, degummed, unweighted silk yarn, which is dyed with chrome dyes.

Cambium (sapwood layer). So-called growth tissue, also called growth layer (→ Procambium), by which is understood the layer in the process of lignification in wood (cambium rings = annual growth rings) and also with bast fibres (→ Flax stem structure), lying, in the latter case, between the bast and wood layers, producing bast outside and wood cells inside. In retting, the cambium is the layer separated from the stem wood.

Camel hair Fibres in the → Natural protein fibres group coming from the Bactrian or two-humped camel or sometimes also from the dromedary (Africa, Asia, Australia). The hair of the camel, moulted in clumps, is collected and the guard hair is combed out. The annual yield per camel is around 3–4 kg. The guard hair is classed as a coarse animal fibre and is smooth, stiff and lustrous, about 50–60 mm long and of 70 µm average fineness. The undercoat which is classed as a fine animal fibre consists of soft, slightly lustrous, crimped fibres of characteristic “camel” sandy to light brown colour or occasionally dark brown to black. They are about 60–100 mm long and of fineness 14–26 µm. Camel hair is usually processed in its natural colour as it is difficult to overdye. In unblended form it is mostly used in the worsted sector (knitwear and thermal underwear). Blended with sheep’s wool, alpaca, cotton and synthetic fibres, it is used predominantly for fine soft woollen-spun yarns with brushed or hairy effects (blankets, loden cloth, ladies dress goods, coatings) and for thermal underwear. Camel hair with guard hair intact is often used in slipper cloth. The guard hairs which are difficult to spin are used in coarse blankets, felts and coatings.

Camel hair cloth Because the hair of the camel, especially the fine undercoat, is of higher quality and more expensive than sheep’s wool it is often imitated using wool dyed to camel shades. Wool fabrics dyed to camel shades are piece-dyed with a solid-shade appearance whilst genuine camel hair cloths can be distinguished by their slightly mottled appearance which has high fastness, especially to rubbing and to light exposure, and they also withstand standard dye stripping tests. A camel hair cloth must therefore always consist of original camel hair. Camel hair fabrics are virtually all made with woollen-spun yarns. Finishes include velour (upright napped or laid pile) or as a pilot cloth with long brushed pile. Weight between 450–750 g, providing good thermal insulation. Used in high quality outerwear.

Camlet A fine lustrous yarn resembling camel hair or a corresponding plain-weave fabric made from linen or cotton with worsted or silk plied yarns.

Camouflage dyeings and prints have to meet the strictest requirements for military equipment (uniform fabric, tent awnings, camouflage nets, vehicle paints and so on), not only to prevent them from being visible to the naked eye but also from being detected by technical equipment. Camouflage and deception systems have been developed intensively over the last 50 years:

- camouflage nets,
- u.v. reflecting winter camouflage,
- radar scattering nets (Fig.),
- computer controlled mosaic printing,
- thermal winter camouflage,
- wide-band radar camouflage,
- radar winter camouflage,
- multispectral camouflage.

Effective camouflage dyeings must have reflectances that correspond to the natural surroundings for every colour in the visible and invisible regions. Multi-coloured patterns corresponding to natural colours provide camouflage for normal vision. It is considerably more difficult to meet the wider requirements of effective camouflaging against i.r. observation at the same time.

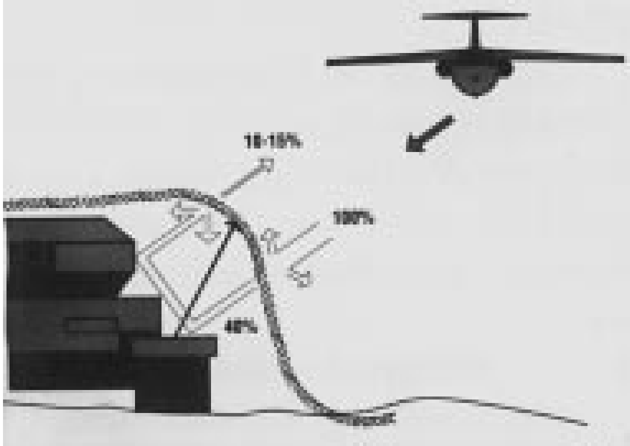


Fig.: The principle of radar scattering.

The object of camouflage against i.r. radiation is the same as it is for visible light: avoidance of contrast and elimination of contours by patterning. For this purpose, it is necessary to know how the i.r. reflectance of the camouflage dyeings/prints compare with the natural background in the spectral ranges of the three types of i.r. observation. These have different i.r. ranges: i.r. photography 800–850 nm, i.r. night vision searchlights 900–1000 nm, i.r. camouflage glasses (red filters) for visual observation 700–730 nm. The effectiveness of i.r. camouflage also depends on the contrast between the spectral characteristics of the camouflaging material and those of the natural surroundings. The i.r. reflectance of natural objects is strongly affected by the moisture content: bright yellow sand has a moderate i.r. reflectance when it is dry but it absorbs just like soil when it is damp. The reflectance of green foliage has a maximum at around 550 nm and a sharp increase around 700 nm; meadows and deciduous trees appear bright in an i.r. objective; conifers appear much darker.

If the reflectance curves of camouflage dyeings match the curves of the natural objects, unwanted contrasts will be eliminated for all modes of observation. However the reflectance curves of most organic dyestuffs are quite different: the sharp increase at 700 nm that is desirable for green shades is almost always missing, and most dyes do not absorb strongly enough in the long wavelength region. Hence it is necessary to use combinations of several dyestuffs (for the colour in the visible region, application properties and especially fastness properties) to get the required reflectances for all modes of observation.

The i.r reflectance of textile materials is greatly affected by bleaching (i.r. reflectance of bleached goods is 70–90%, falling to 50–30% for unbleached goods). The i.r reflectance is increased by titanium white and decreased by carbon black. Aftertreatments and finishing can also affect the i.r. reflectance. Requirements (% reflectance and the range of wavelengths over which these reflectances are to apply) vary according to which military service has placed the order, e.g. 25–30% reflectance at 900–1000 nm for night vision equipment, 35–60% for green or 35–35% for brown in the 800–850 nm wavelength range for i.r. photography.

Camphor $C_{10}H_{16}O$. Molecular weight 152; density 0.98–0.996. Colourless or white, granular, crystalline or powder. Only slightly soluble in water; good in alcohol, acetone, chloroform, fatty oils etc. Gradually vaporises at room temperature. Burns easily. Use: especially for the celluloid industry, for moth protective finishes (toxic fumes) etc.

Candela (cd), formerly called "standard candle". Photometric unit of intensity of light: a black body at the temperature of solidifying platinum (2042.5 K) emits, in a perpendicular direction, a light intensity I of 60 cd per cm+ flat surface. This unit of measurement (basic unit of the SI system) was introduced internationally in 1948. Conversion of the outmoded terms HC and IC: 1 cd = 1.107 HC (Hefner candle) = 0.981 IC (international candle).

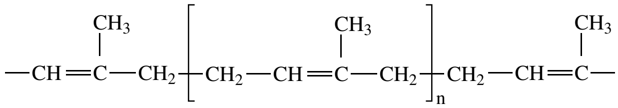
Candle filter → Sewerage-filter-system.

Cannetilles spirally wound → Fancy metal yarns.

Cantala fibre Agave fibres (Philippines, Indonesia, Mexico) similar to → Sisal, but softer and more elastic.

Canvas (duck). A strong firm fabric (flax, cotton, viscose) woven with square interstices using hard-twist warp and weft threads. Used as ground for embroidery, carpet knotting, tapestry and suchlike and as a stiffening material.

Caoutchouc Milky juice of tropical Hevea varieties (density = approx. 0.93), which is in the trade as → Latex, and produces the solid so-called raw rubber by coagulating agents (acetic and formic acid), which is more or less free of water, dark coloured or bleached, mostly in the form of rolled out, rolled up "fleeces" or as fine powder. Caoutchouc is a polymerisation product of isoprene:



$$-CH=\overset{CH_3}{\overset{|}{C}}-CH_2-\left[CH_2-CH=\overset{CH_3}{\overset{|}{C}}-CH_2\right]_n-CH_2-CH=\overset{CH_3}{\overset{|}{C}}-$$

Properties: lighter than water, almost odourless, outstandingly elastic and very extensible, poor conductor of heat and electricity. Paracaoutchouc is brittle at 3–4°C, sticky at 145°C, deliquescent at 170–180°C, and burns with a very smoky flame. Soluble in ether, benzol, petroleum ether, oils and fats, carbon bisulphide, carbon tetrachloride, turpentine oil etc, mostly undissolved residues remaining. Diluted alkalis and acids bring about no change. The effects of light and air lead to considerable changes. The natural stickiness is eliminated by masticating with sulphur and the like (→ Vulcanize, to), by which means the familiar rubber is made, abrasion resistance, insensitivity to heat, electrical data etc. This lies in the peculiar nature of the formulation, i.e. variations in softeners, filling agents, sulphur, accelerators, ageing agents, dyes, carbon black etc. Use: the production of rubber yarns, foam rubber, for covering textile yarns (latex too), impregnating woven fabrics (laminating), coating applications, as an adhesive for leather and synthetic leather, as a rubber solution (dissolved in benzol) etc.

Cape gum South African. Vegetable type rubber with a high arabin content, which has only limited uses on account of its poor quality and inadequate water solubility.

Capillaries → Individual fibrils.

Capillarity Generic term for all physical phenomena which occur in consequence of the → Surface tension of liquids in capillaries and cracks and in porosity.

Capillary activity (interfacial activity, surface activity). The ability of adsorbent substances to reduce interfacial or surface tension in the dissolved state, and, in fact, with a simultaneous concentration increase at the surface. Relative to fibres, capillary activity causes displacement of the air in the macroscopic and submicroscopic fibre capillary spaces (water conductors) which is extremely important for numerous finishing operations (scouring, bleaching, dyeing etc), providing for the wetting out and penetration of dissolved, adsorbent substances (dyes and auxiliary agents with scouring, wetting, dispersing and emulsifying properties). Ionogenic products (anionic soaps, cationic soaps) and, quite particularly, nonionogenic products come into consideration for this purpose.

Capillary analysis In dyestuff levelness tests, an approximately 20 cm long strip of filter paper is suspended from a stand, and 1.2 cm of the bottom end immersed in the dye solution. Assessment in terms of relevantly differently dyed strips and zones of the faster and slower rate of rise of individual dyestuffs at issue. Improvement of this method by paper chromatography. Separating processes for colloids of variously high degrees of adsorption on porous masses (→ Chromatography) are described as capillary analysis, different colloid charges also being capable of determination.

Capillary dehydration According to Messik, a wet and a dry woven fabric are brought in close contact in a relevant device (Fig.) by means of a capillary squeeze roller so that moisture is exchanged between the fabrics in consequence of capillary forces. Dehydration effect of up to 10% of water content possible, dependent on fabric type and number of passages (→ QS-process).

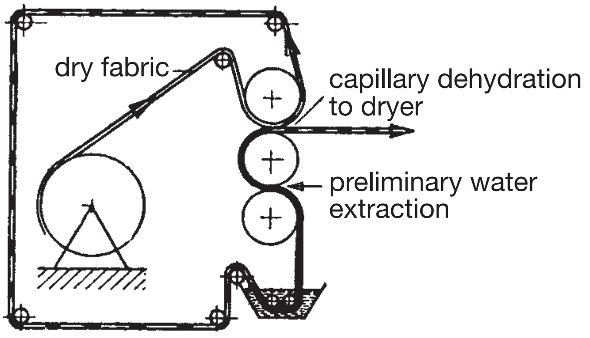


Fig.: QS (squeezing-suction) capillary dehydration according to Messik.

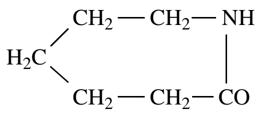
Capillary fabric liquor interchange Exchange of moisture through the contact of 2 fabrics with different moisture contents, blotting paper effect (→ QS-process).

Capillary viscometer → Viscometers.

Capillary water Water held in capillaries (→ Water of crystallization), which is present as a natural water content in fibres, and which has to be protected in drying in order, as far as possible, to retain the natural fibre characteristics (handle, appearance, strength, elasticity etc).

Caproic acid (hexanoic acid, hexylic acid, hexoic acid), $CH_3(CH_2)_4COOH$; oily, colourless or pale yellow liquid with an unpleasant rancid sweat-like odour. Glycerides of the acid occur naturally in cow and goat milk in small amounts and in some vegetable oils, e.g. coconut oil; it is also formed in the fermentation of butyric acid. Uses: manufacture of textile auxiliaries.

Caprolactam Starting product for the manufacture of polyamide-6 (nylon 6) obtained commercially by various methods from aromatics (benzene, toluene). All methods of caprolactam manufacture result in the production of ammonium sulphate as a by-product.



Caprolactam melt process in dye identification Melt sample (polyester or polyamide) with approximately 3 g caprolactam in a porcelain crucible. Allow to cool, stirring continuously, add a little ether, stir and filter. Filter residue is tested using vat dye, filtrate is tested using a different dye group.

Caprylic acid (octanoic acid), $CH_3(CH_2)_6COOH$; clear, colourless liquid fatty acid with a slight, unpleasant, rancid odour and burning taste. Occurs free in sweat, as esters in fusel-oil, from which it is most easily prepared, and as glycerides in the milk of cows and goats and in coconut and palm oils. Used in the manufacture of textile auxiliaries.

Caracul Asiatic variety of the broad tail sheep which owes its name to the town of Kara Kul in eastern Bokhara, but which is not only raised in that region but also in Persia for example. The caracul sheep has also found a new home in Southwest Africa. Apart from a very coarse wool, caracul sheep provide the familiar Persian lambswool.

Carbamates Systematic term according to IUPAC regulation C-431 for esters and salts of carbamic acid, which therefore includes the group $H_2N–CO–O$. The esters are frequently still called by their historic name → Urethanes, and the term → Polyurethanes has also become generally prevalent for polymer carbamates.

Carbamic acid Can be described as a "half amide" of carbonic acid (HO–COOH). Like this, it does not exist free, but only in the form of salts or esters. Example: Ammonium-carbanide ($H_2N–CO–O–NH_4$), which is present in technical ammonium carbonate

$[(NH_4)_2CO_3]$ as an equilibrium component, and is associated with a proportion of the wool protection effect in dyeing and washing.

Carbamic acid esters → Urethanes.

Carbamide → Urea.

Carbamide group (carbonamide), –NHCO–. The typical grouping in proteins, polyamides, urea, polyureas etc.

Carbamide peroxide Solid hydrogen peroxide, urea peroxide, contains 16% active oxygen. White, easily water soluble crystals, which decompose at 50°C in the presence of moisture: When dissolved, neutral peroxide solutions are formed. Application: as bleaching and oxidizing agent.

Carbamide resins (urea resins) → Urea-formaldehyde compounds.

Carbanions Anions with carbon atoms as the carrier of the negative charge (cf. example formula under → Carbenium ions). Carbanions are intermediate stages in many electrophilic substitution reactions. Due to the negative charge their structure is influenced by cations, by substituents and, in particular, by solvents.

Carbazole → Heterocyclic compounds.

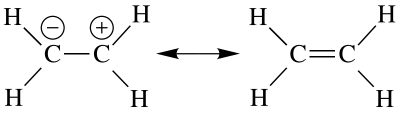
Carbazole-sulphuric acid reaction is used for

I. Formaldehyde detection: Dissolve 1–2 granules of carbazole in 2 ml concentrated sulphuric acid, add the solution under investigation drop by drop. Carbazole-sulphuric acid solution is stable for a maximum of 30 min. Dyeing: a) Formaldehyde = deep blue; b) Acetaldehyde = greenish blue; Glyoxal = green.

II. Anti-crease finish detection: Boil fabric sample in test tube with 5% sulphuric acid. After cooling the solution is poured off into another test tube and freshly prepared solution of 0.1% carbazole in concentrated sulphuric acid is added drop by drop. If blue colouring, or later a cornflower blue deposit occurs, this confirms anti-crease finishing.

III. Casein fibre detection, Undyed casein fibres do not result in staining with acidified water: Boil out sample in test tube and perform reaction with watery extract.

Carbenium ions Cation with a positive charge on a carbon atom. If we take as an example a mesomeric resonance formula of ethers



then this materializes because a C atom also takes on the π electron of the other (“carbenium-carbeniate” formula). Therefore, according to Dilthey and Wizinger, triphenylmethane dyes can also be interpreted using the carbenium formula: $(H_2N–C_6H_4)_3≡C^{\oplus}$. The presence of an unsaturated system (→ Chromophore) is the prerequisite for the presence of mobile π electrons, i.e. for the occurrence of mesomerism, which is encouraged by auxochrome (electron donor) on the one hand and by antiauxochrome (electron acceptor) on the other (–E or +E effect). The elimination of such functional groups has a shortening or interrupting effect depending upon this, which either causes colour change or the complete disappearance of the colour.

Carbides (acetylides). They are compounds of carbon with metals (e.g. calcium carbide), boron or silicon (→ Carborundum). Carbides formed with elements close to carbon in the periodic table, e.g. SiC, B_4C, are essentially covalent and are generally extremely hard and infusible (→ Boron fibres).

Carbinol Synonym and obsolete term for → Methanol.

Carbinol group $R–CH_2OH$, is the typical group in e.g. → Fatty alcohols.

Carbocyclic Any organic compound whose “skeleton” is in the form of a closed ring of carbon atoms. This includes both alicyclic and aromatic structures. → Cyclic hydrocarbons.

Carbohydrases Group of carbohydrate splitting → Enzymes belonging to the main group of hydrolases. They also split di- and polysaccharides and glycosides. According to this we differentiate between a) polyases and b) glucosidases.

Carbohydrates This large and important group of organic vegetable products was given its name at a time when, of the chemical construction of these substances, virtually only the total formula $(C_x(H_2O)_y$ was known, which is invalid for all carbohydrates in the light of current knowledge, and, incidentally, also covers other compounds which do not represent carbohydrates, e.g. acetic acid $(C_2H_4O_2)$, lactic acid $(C_3H_6O_3)$ etc. Today, we also know that carbohydrates are not hydrates (and should therefore be more correctly defined) but the primary oxidation products of polyhydric alcohols. Included among the carbohydrates today are not only so-called simple sugars (like grape sugar) but also higher molecular sugars (like cellobiose, cane sugar and the like). The fact alone that cellulose is the most frequent organic compound in the world, and occurs in cotton and viscose, the textile fibres most produced, indicates the importance of the carbohydrate types:

I. Monosaccharides (grape sugar type): subdivision in each case in accordance with the number of available O atoms in bioses (two O atoms, like glycoaldehyde $CH_2OH-CHO$), trioses, tetroses, pentoses, hexoses (six O atoms, like grape sugar/glucose) etc. (polyoses).

II. Oligosaccharides: produced from 1–4 monosaccharides with elimination of water, e.g. disaccharides, which also almost always contain hexoses (c.f. above); these include for example cane sugar (of glucose and fructose), malt sugar (maltose), milk sugar (lactose, of glucose and galactose) and cellobiose.

III. Polysaccharides: constructed of many monosaccharide residues like dextrin, starch, agar-agar, chitin, pectins and especially cellulose of 1000–3000 glucose residues. This group is no longer classed with the so-called sugars.

Carbohydrazides → Hydrazides.

Carbol fuchsin, Ziehl's stain is used in microscopic work for staining bacteria directly (in concentrated form) and in → Gram stain (diluted 1 : 4). Consists of 1 g of fuchsin + 5 g phenol dissolved in 90 ml of distilled water and made up with 10 ml of 95% alcohol. Before use, the sediment is filtered off as it interferes with the microscopy. Depending on their state and form, most bacteria can be shown up with carbol fuchsin solution (400–600 fold increase); there is a smaller increase for mould fungi.

Carbolic acid → Phenol.

Carbon (C). Atomic weight 12. Non-metalloid, free element as diamond, graphite and amorphous coal, odourless/tasteless. High melt point metals are the sole solvents. With air admission, burns to carbon dioxide (with insufficient air: to carbon monoxide with soot separation), with sulphur to carbon bisulphide, with nitrogen (under relevant conditions) to cyanogen. Almost reactionless at temperatures below 500°C. Amorphous coal is already reactive below 100°C (activated charcoal). Extraordinarily capable of transformation (approx. 300 000 known compounds) in chemical compounds; basic element of all organic compounds. Compounds: with oxygen = carbon monoxide CO and carbon dioxide CO_2, which produces carbonic acid with water; with nitrogen = cyanogen CN (prussic acid HCN); with sulphur = carbon bisulphide CS_2; with metals = carbides (calcium carbide CaC_2); with hydrogen = coal gases and heating gases, motor vehicle fuels etc.

Carbon, activated → Activated carbon.

Carbonate of lime → Calcium carbonate.

Carbonate of soda → Sodium carbonate.

Carbonates Salts of → Carbonic acid H_2CO_3: so called "acid" salt (Sodium hydrogen carbonate) and normal salt (ammonium, calcium, potassium, sodium carbonate). Only alkaline salts are easily soluble (hydrogen carbonates more difficult), remaining slightly soluble in a solution strongly alkaline (hydrolysis). Decomposition involving the generation of CO_2 is caused by acidification.

Carbonato chelate is a term for CO_2 in complexes.

Carbon black is the product of thermal decomposition of acetylene or the residue from burning coal tar, tar oils, naphthalene, natural gases, and from combustion engines etc. It is deep black, very fine carbon in the form of graphite crystals (2–6 nm in diameter) (Fig. 1). It is completely insoluble in water and is used as black pigment for mass coloration, Indian ink, typewriter ribbons, leather etc. Carbon black is used in elastomers as a pigment and filling agent (motor vehicle tyres, rubber conveyor belts and so on) for bonding the elastomeric material, and also for making it cheaper.

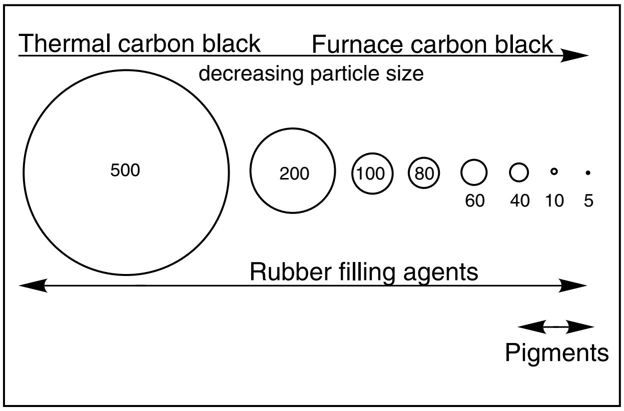


Fig. 1: Particle sizes of carbon black in mm with application areas.

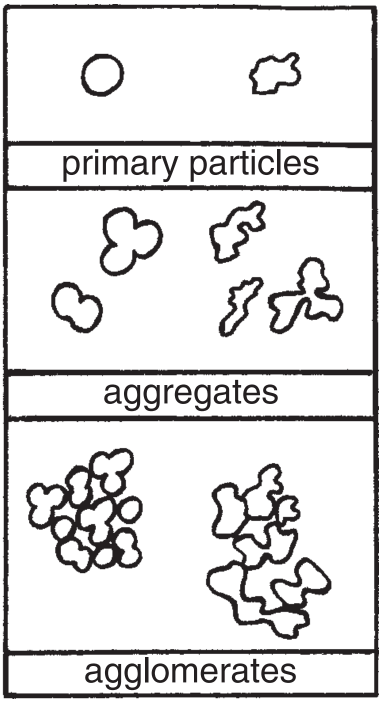


Fig. 2: Carbon black: primary particles, aggregates and agglomerates.

As increasing amounts of synthetic carbon black are added, the network of carbon becomes more continuous (Fig. 2) until electrical charges can be conducted. The electrical conductivity as a function of the filler concentration drops sharply at the percolation point (Fig. 3).

Apart from high concentrations of 10–20 weight-%, the carbon black can accumulate in definite tracks, e.g.

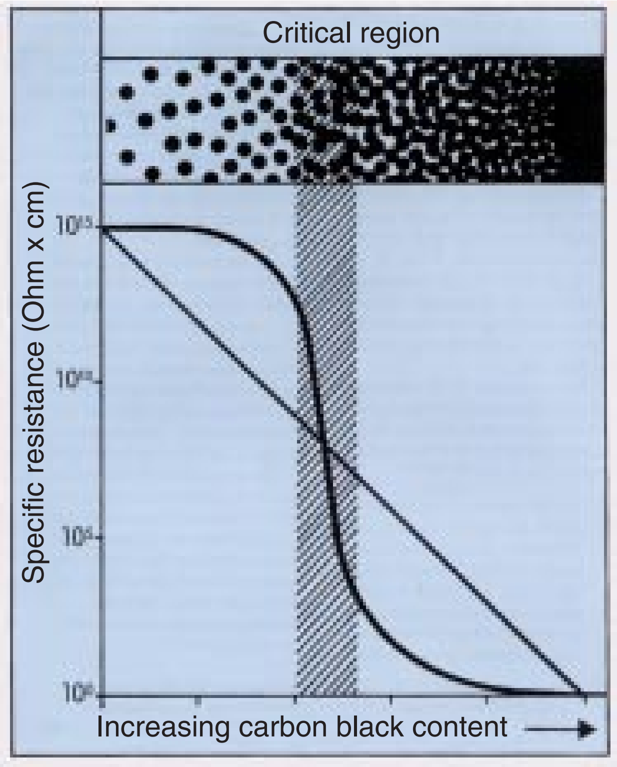


Fig. 3: Change of resistance of rubber with increasing carbon black content.

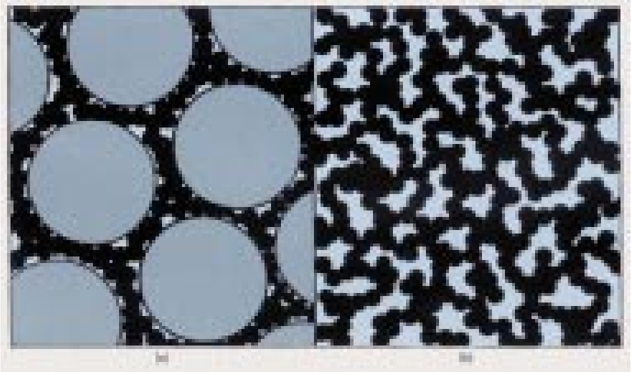


Fig. 4: Diagram of the distribution of carbon black in conductive rubbers (a) with core/shell structure, (b) with homogeneous carbon black distribution.

along the granule boundaries in pressed discs, so that continuous networks may form even with less than 1% of carbon black (Fig. 4) (contributed by Zeppernick and also by Röttgers).

Carbon-chain fibres Synthetic fibres having only carbon atoms in the main chain of the macromolecule such as polyacrylonitrile, polyvinyl chloride, polyvinyl alcohol, polyolefin and fluorine-containing (polyfluorinated) fibres.

Carbon dioxide (CO_2). Molecular weight 44.01. Colourless gas with a slightly acid odour (anhydride of → Carbonic acid), water soluble, non-combustible in air, heavier than air. Compressed under pressure at 0°C, forms commercial "liquid carbon dioxide" (in steel cylinders: for refrigerators, fire extinguishers, fireproof tank loading), from which comes flocculent, white "carbon dioxide snow" by pressure removal and under latent heat. This is pressed under pressure into solid blocks (so-called "dry ice").

Carbon dioxide, supercritical Diverse liquid extraction methods are employed for producing natural substances or for separating out undesirable attendant substances from natural substances, carbon dioxide in the supercritical (liquid) state being enlisted to an increasing extent. The technically favourable position of the critical point (Fig. 1) of CO_2 at $p = 7.3858 \pm 0.005$ MPa and $T = 304.20 \pm 0.05$ K favours industrial use.

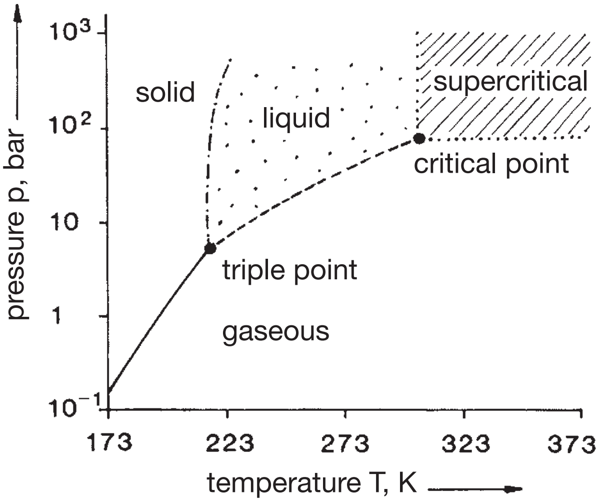


Fig. 1: Carbon dioxide phase graph.

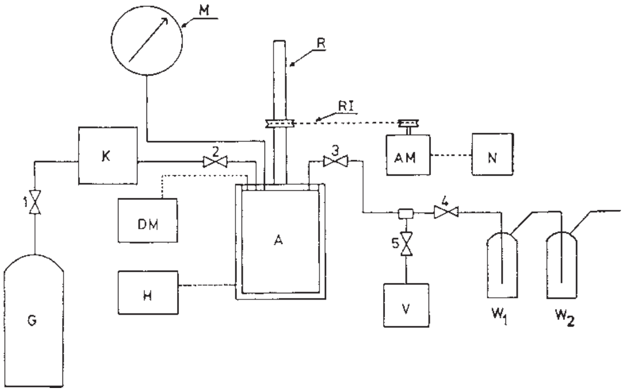


Fig. 2: Schematic view of static high pressure equipment (Schollmeyer).

With liquid CO_2, extraction can be carried out easily in an autoclave (Fig. 2) in which the liquid is periodically extracted on the Soxhlet extractor principle (Schollmeyer).

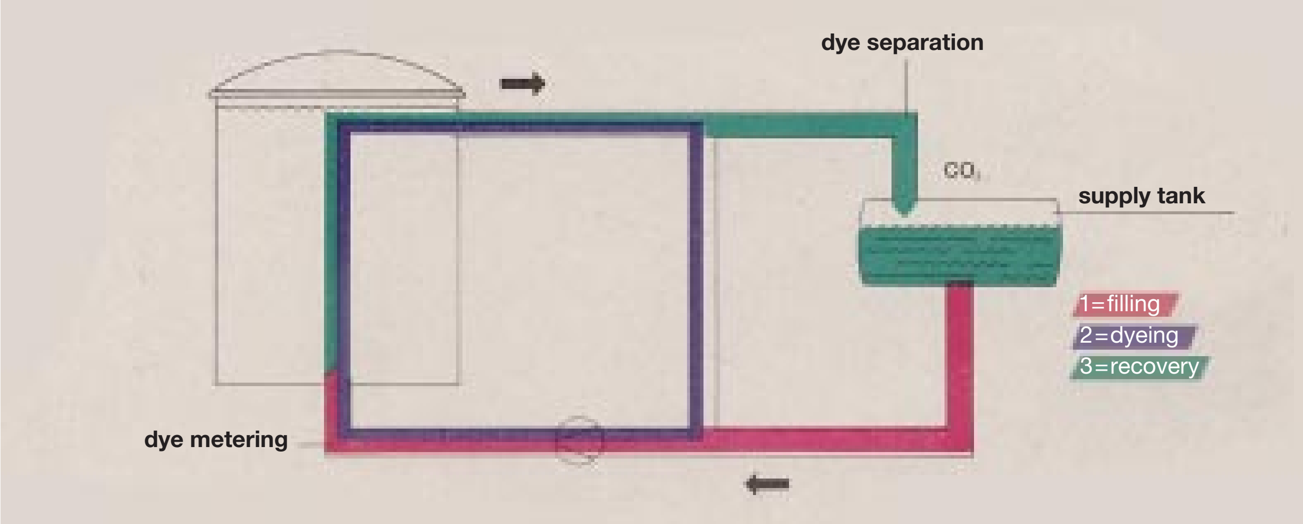


Fig. 3: Circulation in dyeing with supercritical CO_2 (Jasper).

For particular emphasis is the ability of supercritical carbon dioxide to dissolve disperse dyes, which is not the case with hitherto used aqueous dye liquors. It can be handled despite the high pressure, from which it can be seen that coffee or hops for example have been extracted with it on the industrial scale in the food industry for years. Ciba-Geigy has developed polyester dyes suitable for dyeing in supercritical carbon dioxide. As another partner, Jasper has built an engineering concept for a 3 kg sample machine with a liquor volume of 20 l. This design (Fig. 3) provides for putting the material to be dyed into a dyeing autoclave, and pumping the supercritical carbon dioxide required into the dyeing machine from a CO_2 supply tank. The dye is added via a metering lock. The supercritical carbon dioxide is transferred back into the supply tank after passing through the fabric for approx. 10–20 min in a specified pressure/temperature programme. The dyeing machine is ventilated, and the fabric can be removed.

Practical laboratory trials at Ciba-Geigy reveal that a degree of dye exhaustion of up to 98% can be reproducibly achieved. CO_2 losses may lie in the 2–5% range. This means that only minimal quantities of the CO_2, taken from the atmosphere anyway, and approx. 2% of the originally used dyestuffs occur as waste in powder form, and can therefore be easily disposed of or reused.

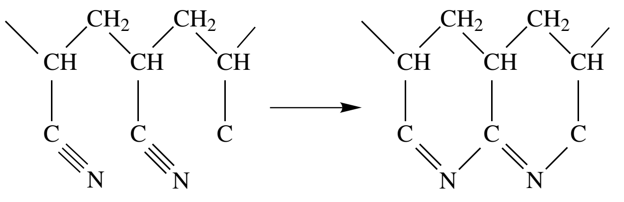
Advantages of this process:

- no effluent, since CO_2 is reused; residual dyestuff occurs in concentrated form as powder; no dispersing and levelling agents;
- approx. 80% less energy requirement for heating up the liquor; fabric drying eliminated;
- higher investment cost for the dyeing machine, but saving on the investment cost of dryers;
- reduced personnel costs, since no drying.

Carbon disulphide CS_2; mol. wt. 76.12; density 1.262. Water white liquid, colourless to slightly yellow (especially under the influence of light), very mobile, highly refractive, very volatile (should be stored under water); the smell is aromatic in the pure state, but is usually repugnant and penetrating (impurities); inhaling leads to symptoms of poisoning; on contact with skin, it penetrates into the blood stream (later: neuralgia, loss of appetite, trembling etc.); extremely flammable (boiling point 46.2°C; auto-ignition temperature about 235°C), forms explosive gases; even radiant heat from a near-by beaker of boiling water can cause ignition, a flame 5 m away can ignite air/vapour mixtures; burns with a blue flame (to give sulphur dioxide). Insoluble in water, soluble in alcohol, ether, chloroform. Uses: cleaning agent (for all kinds of fats, spots of asphalt, varnish, resin, rubber, paraffin, pitch, sulphur, sealing wax, tar and wax etc.).

Carbon-fibre-reinforced plastics (CFRP). Plastics with interpolated carbon fibre woven fabrics, nonwovens or ropes for technical use in stringent requirements. They have high specific strength, stiffness, resistance to fatigue, high thermal resistance, low coefficients of friction. Use: in ultra-quality construction (jet motive power units, rocket construction, space ship construction etc.). For the purpose of internal bonding between fibre and plastic (mostly 50 : 50), the fibre surface is refined by acid oxidation (chemical activation), plasma treatment or by polysiloxane treatment.

Carbon fibres (C fibres). Starting basis (Fig. 1) from regenerated fibres (viscose filaments with/without drawing) and synthetic fibres (polycarbonate, polyamide, polyacrylonitrile, polyvinyl alcohol), which are first of all oxidised by pyrolysis (Fig. 2), and then, with drawing (in nitrogen), are carbonised (Fig. 3), and "graphitised" at 1500–3000°C. The carbon fibres so formed consist of 80-90% carbon, C atoms forming ribbon-like C hexagonal planes, e.g:



ring formation in "graphitisation"

C fibre

Production of carbon fibres:

1. Stabilisation (180–300°C): oxidative and/or chemical treatment with or without fibre drawing as a precondition for solid phase pyrolysis.
2. Carbonisation (300–1600°C): thermal decomposition of the stabilised, unmeltable fibre intermediate product.
3. Graphitisation (1600-3000°C): high temperature treatment with or without fibre drawing.

So-called HS carbon fibres and isotropic carbon fibres are obtained as products of the second stage. The third stage produces HM carbon fibres.

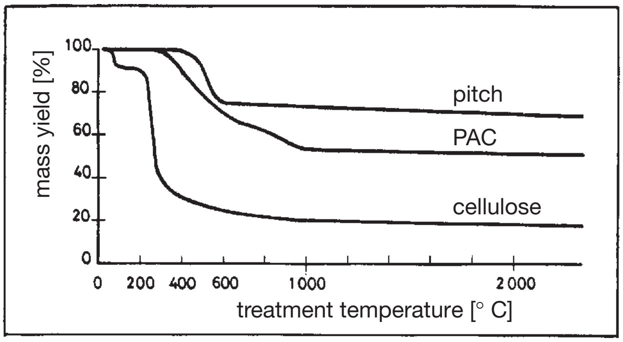


Fig. 1: Pyrolysis behaviour of different starting materials for carbon fibres.

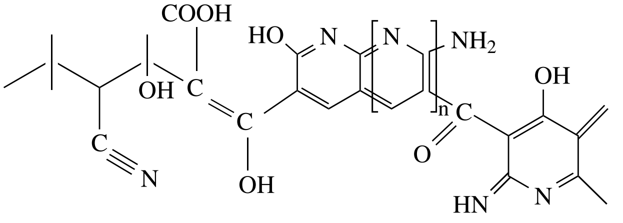


Fig. 2: Reaction of polyacrylonitrile with oxygen.

One imagines linear thread molecules from 2 atom chains occurring, connected by main valency bonds, forming superimposed graphite-like structures in the form of layer lattices (mutually displaced) in a polycrystalline structure. In addition to greater thermal stability (fireproofness, infusibility), such structural systems (Tab. 2) also have higher strength (Tab. 1), i.e. approximately 3 times the strength of glass fibres and steel (and tear strengths, starting from polycarbonates, up to 2500 N/mm^2, starting from viscose filaments even up to 3000 N/mm^2), and also absolute chemical resistance and hydrophobic characteristics.

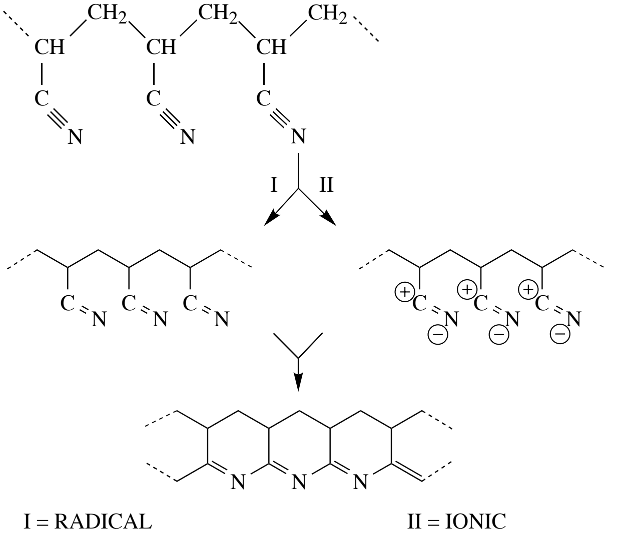


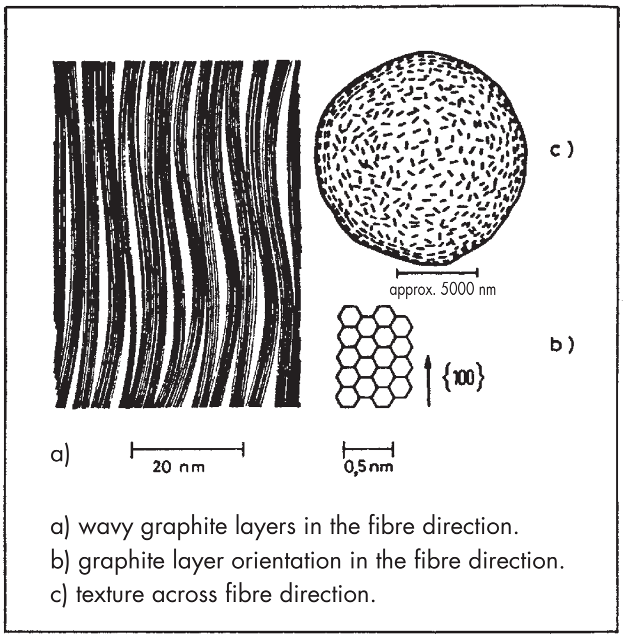
Fig. 3: Mechanism of the ionic and radical cyclisation of polyacrylonitrile-based carbon fibres.

	C fibres	Glass fibres	Steel fibres
Density g/cm^3	1.6-1.8	2.54	7.9-8.1
Strength cN/tex	120-180	36-90	30-35
E-modulus kN/mm^2	220-500	45-75	140-200
Elongation %	0.5-1.3	3-4	1.0-1.8

Tab. 1: Characteristics of carbon fibres in comparison with glass and steel fibres.

Structural features	Fibre type
Layer planes predominantly parallel with fibre axis little long-distance arrangement	High strength (HS) C-fibre
Layer planes predominantly parallel with fibre axis good long-distance arrangement	High modulus (HM) C-fibre (graphite fibre)
No recognisable first draw orientation very poor long-distance arrangement	Isotropic C-fibre

Tab. 2: Classification of carbon fibres on their structural basis.



a) wavy graphite layers in the fibre direction.
b) graphite layer orientation in the fibre direction.
c) texture across fibre direction.

Fig. 4: Model of the structural build-up of anisotropic carbon fibres (W. Ruland).

Highly interesting from the fibre technology standpoint in the case of viscose filament origin is the extensive retention of the microfibrillar structures of the cellulose structure, despite the extraordinarily high pyrolysis temperature.

Appearance: black, lustrous, slippery handle, greater stiffness than glass fibres. The most important textile technological characteristics result from the typical structures of the fibres (Fig. 4). Use (in the textile sector): production of fireproof woven fabrics, filter cloths, electrically conductive woven fabrics for heating, thermally insulating felts, composites (CFK).

Carbonic acid (H_2CO_3). Unknown in the free state. Combined in nature as → Carbon dioxide (CO_2) in the form of carbonic acid salts (→ Carbonates), e.g. in calcium carbonate ($CaCO_3$). From this production by conversion with acids:

$$CaCO_3 + 2\ HCl \rightarrow CaCl_2 + H_2O + CO_2$$

The hydrate of CO_2 (+ H_2O = H_2CO_3) is the true carbonic acid. A bivalent weak acid (blue litmus slightly reddened), weakly ionised.

Carbonizing Employed for removing vegetable fibres and impurities (burrs, straw fragments etc) from wool. Wool may be carbonized in the form of fibre stock, piecegoods or rags/shoddy. Procedure: Treat the wool with carbonizing liquor, remove water by squeezing, suction extraction or centrifuging, dry, bake, crush/shake and neutralize.

1. Carbonizing liquor: Generally sulphuric acid (up to approx. 7%), less commonly hydrochloric acid (up to approx. 4.7%) or aluminium or magnesium chloride solution (7–11%). By adding an acid-resistant wetting agent it is possible to reduce acid concentrations to half. Aluminium or magnesium chloride is less harmful to the wool.
2. Centrifuge at constant speed (fibre stock, shoddy, rags) or squeeze out (fibre stock, shoddy, rags, piecegoods) or suction extract (piecegoods) to approx. 40–50% moisture content.
3. Dry at 140°C.
4. Bake in the dryer at 140°C.
5. Shake, i.e. mechanically remove the baked (carbonized) cellulosic fragments (hydrocellulose) in a beater-opener (fibre stock, shoddy, rags) or in a milling machine fitted with flanged rollers (piecegoods). It is relatively easy to remove carbonized matter here.
6. Neutralize (eliminate the acid present in the material) in a scouring machine (fibre stock, shoddy, rags) or a dolly (piecegoods).

Mistakes and damage may be avoided by taking care with the factors critical to the result. Irregular carbonizing becomes evident in piece dyeing in the form of skitteriness. Differences in dye affinity occur from one lot to another and therefore different batches should not be mixed together. The thorough rinsing out of the sulphuric acid requires large volumes of water. An alternative method is to pad first with tetrachloroethane and then with dilute sulphuric acid, dry and bake (Sperotto Rimar). The CSIRO method of carbonizing is a controlled sulphuric acid process. The card sliver is soaked in sulphuric acid at room temperature, dried at 80°C and baked at 130°C. A specially designed stuffer device which avoids damage to the wool is used for releasing the vegetable matter. The sliver is finally rinsed, neutralized with ammonia and again rinsed.

In principle, wool textiles of any kind can be carbonized as fibre stock, yarn or fabric before and after dyeing. However, in the carbonizing process the wool protein undergoes such severe chemical modification that the interrelationships of the functional groups and the corresponding reactivity of the protein can be modified. This phenomenon is very important when carbonizing is to be followed by dyeing since the presence of a certain number of acid or basic groups in the wool protein relative to the dye used is one of the factors governing the quality of a dyeing.

The following reactions have an influence on the basic and acid groups in carbonizing with sulphuric acid:

a) Peptide chains are broken, crosslinking occurs and isopeptide bonds are split during the carbonizing process.
b) The sulphatization of serine, the N to O peptide shift in the carbonizing-drying phase.
c) The hydrolysis of serine-O-sulphate during the dyeing process.

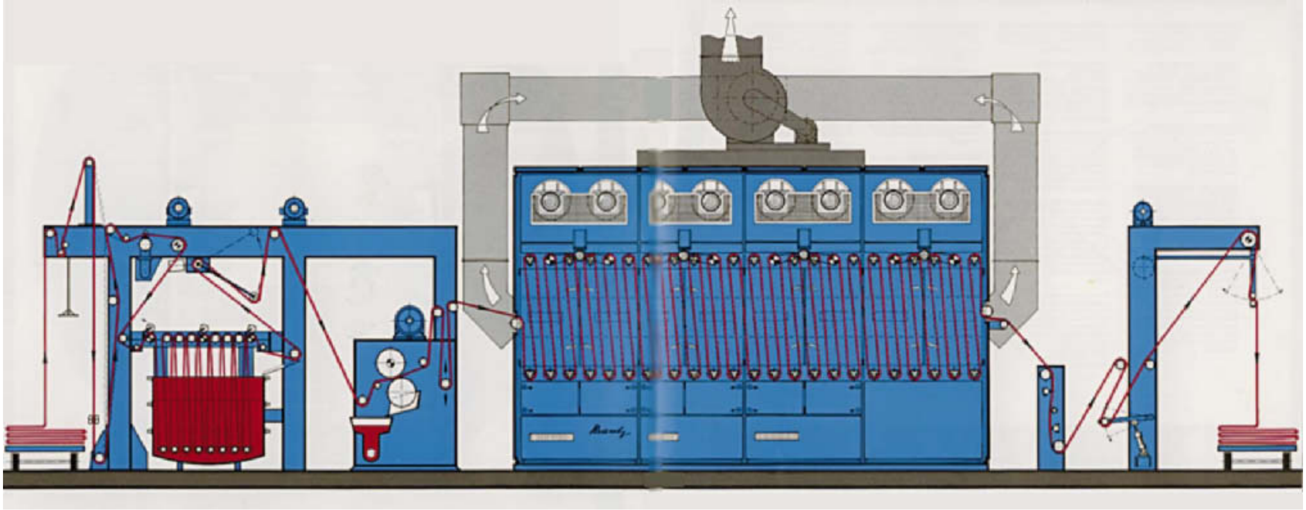
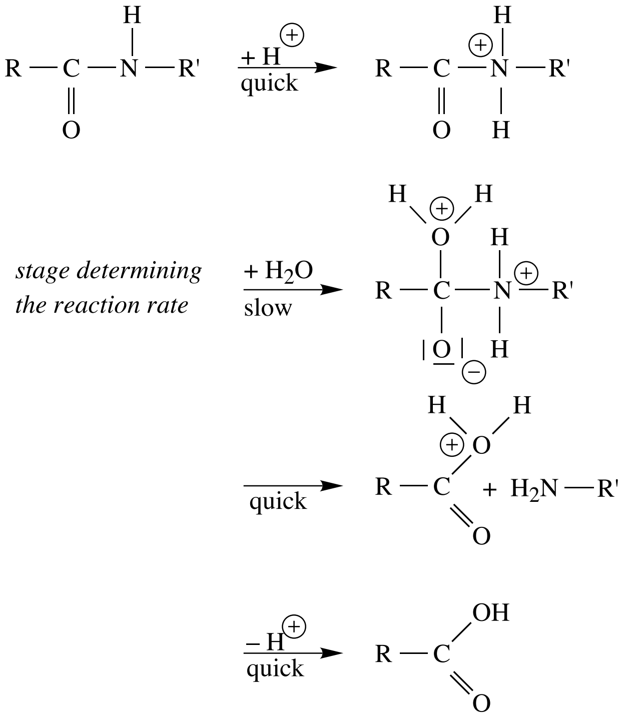


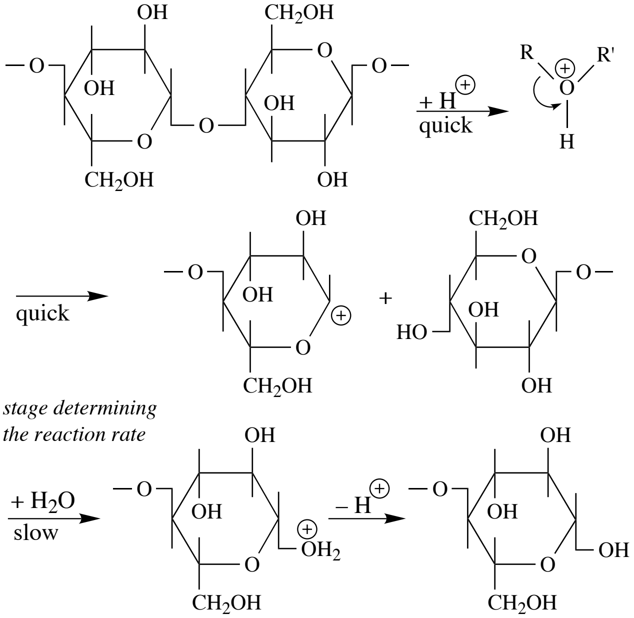
Fig. 1: Carbonizing line (Krantz) with sulphuric acid roller vat and hotflue drying/carbonizing range.

All these factors include a change in the balanced acid and basic groups, with the formation of sulphate groups regarded as predominant, thus affecting the dye affinity of wool. If for economic reasons it is decided to carbonize before dyeing then the above factors may be regarded as critical. Major defects will occur especially if there is an irregular distribution of acid on the material and the drying process associated with carbonizing is not correctly performed, all of which can represent a variable degree of "damage" to the material. However, carbonizing after dyeing (post-carbonizing) has the following disdvantages:

- unavoidable shade variations in post-carbonizing;
- further acidity emanating from dyeing is introduced into the carbonizing process, making it difficult to neutralize to tolerable residual acid levels (below 1%),
- wool already degraded by dyeing appears to be especially susceptible to further damage in post-carbonizing,
- lower economic viability due to high chemical consumption,
- fabrics with a high burr content must be milled between baking and neutralizing, interrupting the continuity of the process,
- maximum speed is approx. 10 m/min.

In carbonizing by chemical routes hydrolytic degradation of the vegetable matter (cellulose) occurs, whilst if





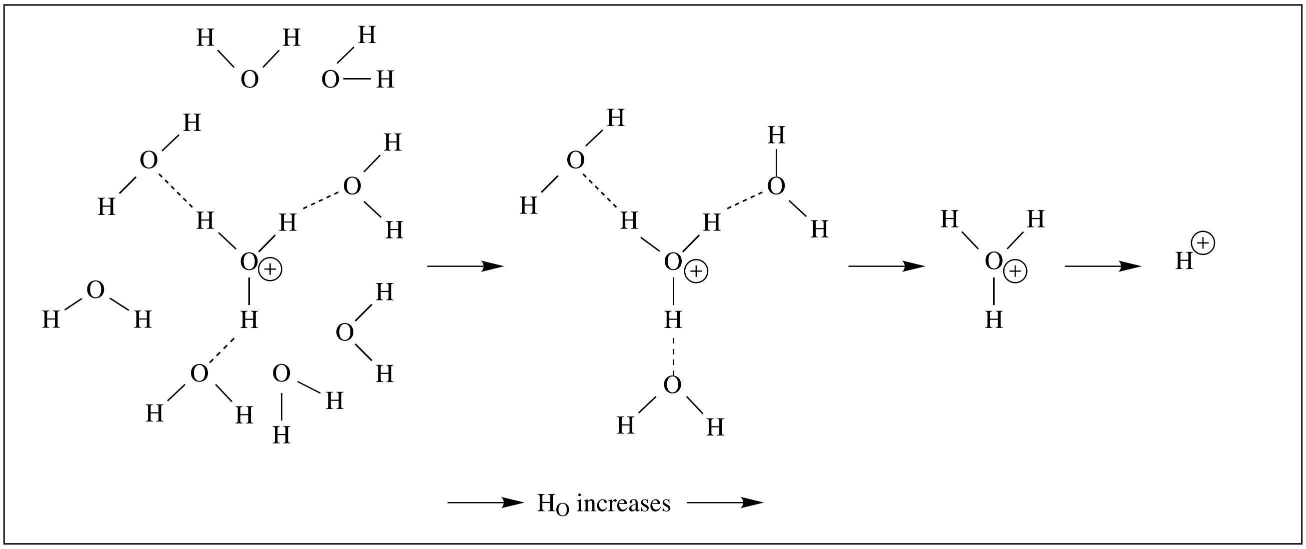


Fig. 2: Effectiveness of protons of conc. mineral acids according to Hanna et.al.

the procedure is correct the wool is protected from hydrolytic damage by its different reaction mechanisms. The R–NH–CO–CHR group of wool created by polycondensation represents an amide group. The following conditions apply for the hydrolysis of amides (and for the wool proteins also):

a) The rate of the acid hydrolysis with acid of moderate concentration is proportional to [amide] · $[H^+]$.
b) There is steric hindrance by groups of bulky configuration.
c) Hydrolysis oocurs as an A-2 mechanism.

In concentrated acid solutions the rate of hydrolysis of an amide passes through a maximum (the hydrogen ion concentration corresponding to this maximum is different for every amide). Further addition of concentrated sulphuric acid then only causes water molecules to be bound in the solvate sheaths of the protons and anions, so that the amount of “free” water capable of attacking the carbonyl-carbon atom declines. Consequently concentrated acids have a damaging effect on wool proteins only when water is present, i.e the principal duty of a good carbonizing plant is to impede the reaction rate limitation phase by rapid drying. The glucosidic bond of cellulose is an acetal bond which reacts especially sensitively to hydrogen ions. The hydroxyl groups of cellulose together form strong hydrogen bonds and a large number of cellulose molecules are densely packed together into a larger unit by crystallographic aggregation. It is difficult for chemical reactions to occur because the supermolecular structure of the cellulose first has to be loosened in order that the reaction can continue through to the innermost chain molecules. The periodic loose spots are preferentially split by the action of mineral acids and also statistically the β-glycoside bonds. In the course of the reaction the degree of polymerisation declines considerably. The homopolymer series of hydrocellulose is created. Of the reaction equilibrium of the hydrolysis process it is only possible to express the view that at a first approximation the course of the reaction is dependent on the number of bonds available for splitting in the easily accessible zones. As far as these are concerned a reaction of the first order in terms of time takes place. Once these reactions have taken their course, further reaction in the still difficult access zones is governed largely by diffusion processes. It has been established that the diffusion processes come clearly to the fore when a weight loss of approx. 5–10% has occurred. The mechanism of chain splitting in acid hydrolysis is the consequence of a hydrogen ion catalysis process.

The technological consequence of this is that because in the case of wool, water participates in an early rate-determining reaction stage but does much later do so in the case of cellulose, to prevent unwelcome wool damage drying of the sulphuric acid soaked goods must be implemented as quickly as possible. Earlier carbonizing systems (hot-flue with several successively hotter chambers) did not permit such a procedure. Today there are high-performance dryers for this purpose (Fig. 1). These machines represent the only means of substantially restricting the action of the hydroxonium ions to the cellulose in the hydrolysis context, with the water being removed from the reaction system as quickly as possible. In the absence of water the hydrolysis of wool is suppressed and the H_0 function (Fig. 2) of the sulphuric acid is simultaneously increased to such an extent that the cellulose is quickly and substantially degraded.

For economic reasons it would be meaningful not to neutralize pre-carbonised wool before dyeing but to perform the dyeing with the sulphuric acid present. This can cause the dyeing process to be uncontrollable because more and more acid gets into the dyebath with increasing dyeing temperature. Despite carefully conducted pre-carbonising providing appreciable cost advantages, the risk of skittery dyeing or “marbling” detracts from the process reliability in some cases.

Carbonizing agent In accordance with TEGEWA nomenclature, those textile auxiliary agents which facilitate and accelerate penetration of the carbonising acid into the vegetable impurities in the wool, promoting destruction of the vegetable impurities. Carbonizing agents also enable the quantity of acid and the duration of carbonizing to be reduced, thus protecting the wool fibre. Furthermore, nonionogenic surfactants also have a protective action on the wool. Prerequisite: maximum acid and heat resistance in the case of aluminium chloride impregnation, otherwise relevant resistance. For consideration: nonionogenic products.

Carbonizing chamber Part of the drying device for temperatures above 100°C used in carbonisation.

Carbonizing, fastness to Assessment of the effect on the shade of a dye by the carbonizing process, by which foreign vegetable fibres are removed from wool by means of diluted sulphuric acid and aluminium chloride solutions. When acetate or polyamide fibres are to be removed from wool, carbonising must be effected with aluminium chloride. Test implementation: 15 mins at room temperature with
a) 60% sulphuric acid solution,
b) 60% aluminium chloride solution,
with a 20 : 1 liquor ratio, squeezing/centrifuging to 80%. Drying: approx. 30 mins at 60°C. Carbonizing: 15 min at 105 °C for the sulphuric acid process, and 15 min at 115°C for the aluminium chloride process, rinsing test specimens in cold flowing water for 5 min. Then dry half at 60°C in hot air, and neutralise the other half – with sodium carbonate in the case of the sulphuric acid process, and with ammonia after using the aluminium chloride process. Rinsing, drying. Grey scale assessment of the two halves.

Carbon monoxide (carbon oxide, CO). Molecular weight 28.01. Hardly water-soluble, colourless, tasteless and odourless poisonous gas: lethal dose approx. 1 g (= less than 1l); 0.3% in inhaled air = death after approx. 15 mins. Occurs for example in coal combustion (even with excess air) as the first stage:

$$2\,C + O_2 \rightarrow 2\,CO + 2 \times 109\ \text{kJ},$$

similar to coal gas, oil, motor vehicle fuel (as exhaust gas from the Otto motor approx. 5 vol% CO). Burns from approx. 700°C with a bluish flame to carbon dioxide:

$$2\,CO + O_2 \rightarrow 2\,CO_2 + 570\ \text{kJ}.$$

Use: including for synthesis (hydrocarbons, alcohols) and heating fuels (producer gas, mixed gas, water gas) and the like.

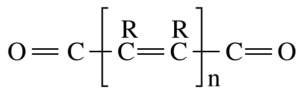
Carbon oxo-acids,

– H_2CO_3 = carbonic acid; salts = carbonates.
– H_2CO_4 = percarbonic acid; salts = percarbonates (Na_2CO_4 sodium percarbonate)
– $H_2C_2O_6$ = peroxycarbonic acid; salts = peroxycarbonates ($Na_2C_2O_6$), oxidising agents.

Carbon oxychloride → Phosgene.

Carbon tetrachloride (Tetrachloromethane), CCl_4. Colourless liquid, water-clear, neutral, without free chlorine, non-combustible, sickly sweet smell, highly narcotic. → Chlorinated hydrocarbons.

Carbonyl dyes Large class of dyes which have at least two carbonyl groups standing in conjugation with one another (>C=O):



$$O{=}C-\left[\overset{R}{C}{=}\overset{R}{C}\right]_n-C{=}O$$

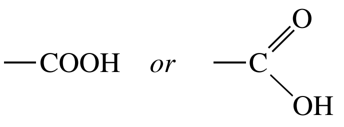
These include in particular indigo (thioindigo) and anthraquinone compounds as vat dyes. Also, higher anellated carbonyl compounds, which are exclusively vat dyes (e.g. acyl amino anthraquinone). Other carbonyl dyes refer to, amongst others: quinacridones (pigment dyes), benzo- and naphthoquinone derivatives (vat and dispersion dyes), and perylene carbonic acid derivatives (vat dyes). Classification by application: ionic carbonyl dyes (with water-solubilising substituents of an anionic or cationic nature); a large number of wool, polyacrylonitrile and acetate dyes; dispersion dyes (dispersion dyes used these days are mostly anthraquinone-carbonyl dyes), also some reactive dispersion-complex-forming carbonyl dyes (mordant dyes); reactive dyes; vat dyes; vat leuco ester dyes.

Carbonyl group The >C=O group in such compounds as aldehydes, ketones, metallic carbonyls and phosgene. In most cases identical with the → keto group.

Carborundum (Silicon carbide), SiC. Manufactured at above 2000°C from carbon and quartz. Characteristics: Multicoloured (reddish, greenish blue, black) crystals, extremely chemical and heat resistant, similar hardness to diamonds, density 3.2. Application: As grinding and polishing material, for the manufacture of fire resistant bricks and electrical resistors.

Carboxyl extra group produces ∅ amino acids e.g. in keratin molecules. The carboxyl extra group determines the behaviour of wool and silk towards alkalis, by reacting as acids.

Carboxyl group Monovalent typical acid group:

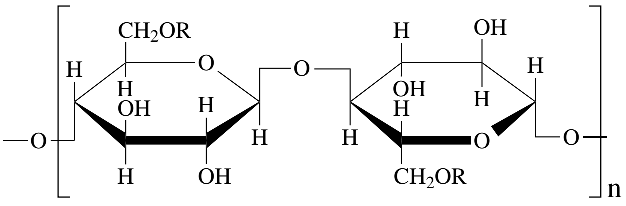


which is represented in organic acids and transfers its marked acidic character to the remaining compound (carboxylic acids, fatty acids), and to the textile assistants (fatty acids-carboxyl group), dyes (auxochrome), etc. The ionizable H atom can be exchanged for a metallic cation, creating salts of the carboxylic acids, or can be exchanged for organic radicals, which leads to the formation of esters. If, instead of the acid H, the OH group is composed differently , then the entire remaining residual acid R–CO is transferred to the new compound as so-called → Acyl.

Carboxylic acids Carbonaceous organic acids, which are made up of → Alkyls and the characteristic carboxyl group –COOH, e.g. CH_3–COOH (acetic acid), derived from the hydrocarbon CH_4 (methane), also as → Polycarboxylic acids. Mono, di-, tri- etc., aliphatic, aromatic, saturated and unsaturated carboxylic acids exist. Opposite → Mineral acids.

Carboxymethylcellulose (CMC). CMC is generally understood to mean sodium carboxymethyl cellulose (carboxymetholcellulose-sodium salt, in technical language also abbreviated to NaCMC). This is a colourless, water soluble cellulose ether, which swells and forms a gel when stirred into water and forms a viscous colloidal solution. The viscosity can be altered by reducing the molecular weight of the alkali cellulose in the reaction. CMC reacts as a polyelectrolyte and can be precipitated from watery solution in flakes by multivalent metal ions, e.g. Cu^{2+} and Al^{3+}. The addition of mineral acid causes free water insoluble cellulose glycol acid (commonly abbreviated to HCMC) to form. CMC is largely stable in an alkaline environment. Due to the manufacturing process, technical CMC contains sodium chloride and sodium glycolate, washing out with a weak alcohol yields cleaned products with a salt content below 0.5 %. Manufacture: In the treatment of cellulose with caustic soda liquor. Reaction with chloroacetic acid or its sodium salt at increased temperature (possibly in the presence of an organic solvent) yields CMC in addition to sodium glycolate and sodium chloride. Depending upon the intended application the end products are neutralised and cleaned.

Application: As water soluble thickener, suspending assistant and protective colloid in the dyeing industry, in washing agents and soaps as an antiredeposition agent, in the textile industry as chemical finishing, in filtering, sewerage and flotation processes, as a printing assistant and for thin-layer and ion exchange chromatography. The greying inhibiting effect of CMC is only limited on hydrophilic fibres, e.g. cotton, i.e. it is inferior to that of cellulose mixed ethers, e.g. Methylhydroxypropylcellulose.



alkalicellulose: R = Na
carboxymethyl-cellulose sodium salt: R = CH_2COONa
cellulosexanthogenate: R = CSSNa

Carboxymethyl starches Important starch ethers as reaction product of starch with chloroacetic acid (in the presence of alkali), also mixed ether with other etherification substances (dimethylsulphate, ethylene oxide or propylene oxide). Substitution or etherification degree 0.3–0.5. Cold water soluble carboxymethyl starches are generally highly substituted, so-called cooking types, on the other hand, are rarely substituted.

Carcinogenic (Gk.: karkinos = cancer, genan = cause). Cancer-causing → Carcinogens.

Carcinogenic substances → Carcinogens.

Carcinogens (Gk.: = cancer-inducing; equivalent to the Latin cancerogen). Cancer-inducing substances; very heterogeneously composed group of substances which can cause cancer in animal experiments and/or in human beings. To be considered here for example is interaction between cancer-inducing working materials and nucleic acid (constituent of cell nuclei), where, by triggering mutations, a defective information chain can form in cell division. Cancer-inducing working materials include in particular so-called alkylating compounds (cross-linking chemicals), condensed aromatic hydrocarbons and numerous, very different types of organic and inorganic compounds. There is no parallel between cancer-inducing working materials and general toxicity and also intensity, which can be regarded as still completely harmless, can be indicated for substances, the effect of which, according to the current state of knowledge, means unequivocal danger of cancer for human beings. Such lists therefore contain no TLV values for safe carcinogenic working materials for humans. All new carcinogenically suspect substances included in the TLV list have no TLV value. Since 1976, there have been groups A1, A2 and B for cancer-inducing working materials, and, since 1980, a quantitative danger classification in groups I-III as a yardstick for differentiated protective measures in practice, out of which bottom threshold values are available for cancer-inducing working materials. (Especially → dangerous substances). In the Federal Republic of Germany, Technical Guidelines have been cited by way of a supplement in order to reduce as far as possible the risk of health impairment in the production/processing of cancer-inducing working materials. Furthermore, not all carcinogenic substances can be predicted from animal experiments. In the case of substances recognised as highly cancer-inducing in humans, it is necessary to eliminate these substances as working materials or to change over to other non-dangerous substances. In the Federal Republic of Germany, the latter consideration has led to the disappearance from the market of a whole range of dyestuffs for the production of which benzidine or 2-napthylamine were necessary. On the other hand, strong measures are required for protecting employees against starting and intermediate products regarded as cancer-inducing; the technical expenditure necessary for this increases sharply with the danger of the substance. This applies even more to safety conscious behaviour/methods of operation in laboratories, where operations are carried out with chemically cancer-inducing working materials; this applies for example to laboratory clothing (do not enter dining rooms, monitored clothing), laboratory premises, laboratory waste, general cleanliness checks, liquid pipetting (never with the mouth), weighing out, working under extraction hoods, spills/residues, glass apparatus cleaning (chromic-sulphuric acid mixture as an unspecified oxidation reagent should inactivate practically all organic carcinogens by decomposition). Basically, do not eat, drink, smoke or store any foodstuffs in laboratories. Constantly bear in mind: even one-off contact can result in tumour formation; no limit dose can be set. The effects of different carcinogens can add up/multiply, and resorption through the skin is to be reckoned with in addition to oral and inhalatory intake.

Dangerous working substances include:

butyrolactone
DDT
diazo compounds
expoxy
hydrazine sulphate
nitrosamines
phosgene
carbon tetrachloride
resins thiourea
thionyl chloride.

Analysis of the currently available data, e.g. in accordance with IARC (International Agency for Research in Cancer) criteria, shows that adequate experimental proof of carcinogenic effect on animals is available for approx. one dozen dyestuffs. For a number of colouring agents, principally dyestuffs, there is evidence of a justified suspicion of a carcinogenic effect, e.g. certain azo dyes, for which it can be shown that they can be metabolised in a substantial quantity in the organism into proven carcinogenic aromatic amines (like for example benzidine dyes into benzidine). The use of such colouring agents in areas with greater and not easy to control exposure, e.g. hair dyeing, finger nail colouring, home dyeing, and also in industrial areas with inadequate work hygiene, can result in increased risk. No benzidine nor its primary metabolites (N-monoacetyl and N,N'-diacetyl benzidine) were detected in the urine of exposed workers when good work hygiene was implemented. In contrast, these metabolites could be detected in the urine of workers in poor work hygiene conditions. These potential risks were the occasion for the decision of the leading dyestuffs manufacturers to remove these dyes from their ranges at the beginning of the seventies. In general, it can be concluded that azo compounds, which, in reductive metabolic splitting, can form carcinogenic amines which are suspect in the absence of relevant experimental data, also have carcinogenic potential.

Card,

I. The seed head of the teazle plant or more commonly an assembly of wires protruding from a base structure, both used for raising or napping the surface of a cloth, generally a woollen cloth.

II. Distinction is made between the flat card (short-staple system) and the roller card (worsted and woollen systems). In the former the prepared cotton lap is opened up to single-fibre state, the fibres extended and assembled into the → Card sliver.

Cardboard tubes (winding tubes). Used for the crease-free batching of pressure-sensitive fabrics (velvet, imitation furs etc).

Card clothing Used to clothe the flats of cotton cards and the rollers of woollen and worsted cards and also as card fillet for the rollers of napping or raising machines. Pins are set to protrude from one face of a fabric foundation. This foundation is a composite multi-ply structure consisting of a woven cotton back with maximim stability and a pliable rubberized blanket face. The flexible ply ensures that the tips of the heavily stressed pins always return to their initial angle.

The fabric plies are bonded to form the multi-ply cotton foundation by rubber macerated with toluene. The isoprene rubber compounds dissolved with toluene in agitating mixers are spread onto the fabric. In the heater duct following the applicator head the toluene present in the compound is evaporated off and subjected to a solvent recovery process with the recovered toluene being largely recycled. The rubber remaining on the fabric is substantially the same as that in the original recipe. Dissolving in toluene is solely for the purpose of applying it in controlled amounts onto the fabric. The procedure is repeated for the required number of fabric plies (on both sides of the inner plies and on one side of the outer plies). Singly or doubly rubberised fabrics are produced which are cold-laminated on the calender, i.e. pressed together adhesive-to-adhesive. The rubber solution is likewise applied to a substrate fabric by the same procedure, but in this case the compound recipe and the nature of the blanket produced differ. In the preparation of the rubber solution acrylonitrile-butadiene or styrene-butadiene rubber is used because an oil-resistant surface is essential for fillet to be used in the spinning process (the oils used in spinning would soon destroy an isoprene rubber blanket). The recipe is prepared in a compounding room. The rubber is worked by the rubber mill and the vulcanizing agents added to the compound which is then dissolved with toluene in a kneader to form rubber solution. The subsequent spreading process is a fabric bonding proc-

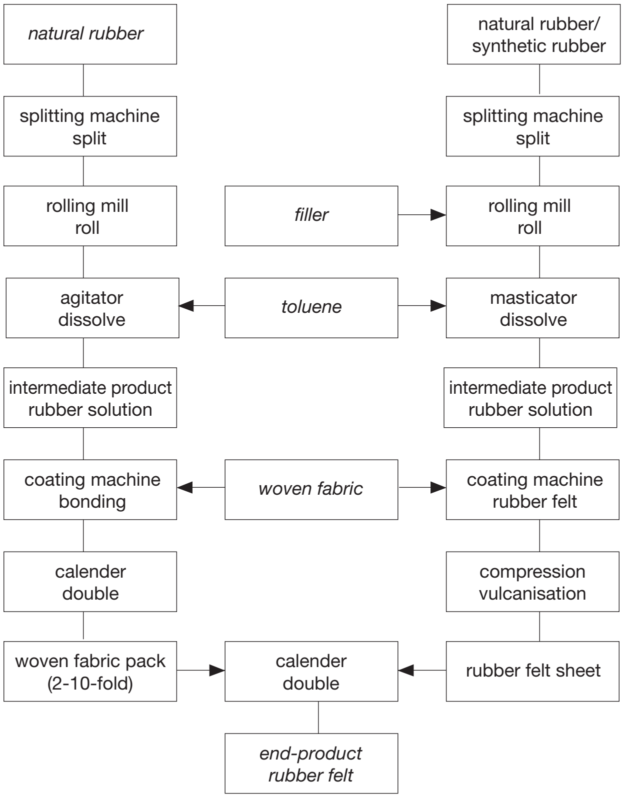


Fig.: Schematic representation of the card clothing production process.

ess. The painted blanket is vulcanized on a vulcanizing press at 120–170°C. Incorporation of a blowing agent has the effect of distending the compound to provide higher bulk and softness. The final vulcanized blanket has rubber painted on the back. Finally the assembly of fabric plies and the rubber blanket are bonded together on the calender (Fig.).

Increasing the degree of crosslinking in the flexible ply enables the following properties to be improved:
- permanent elongation,
- permanent compressive set,
- dynamic damping at high temperature,
- resistance to expansion,
- breaking extension,
- tensile stress,
- tear strength,
- fatigue resistance,

With less improvement in:
- resistance to abrasion,
- vapour permeability,
- electrical resistance,
- cold flexibility,
- breaking strength.

The following vulcanizing agents and fillers are used in the vulcanizing process:

a) Masticator for the rubber milling process: to impart good pliability and absorbency to the types of rubber.
b) Plasticiser: to obtain a high degree of softness in the finished blanket and a high plasticity factor in vulcanizing.
c) Sulphur: the actual vulcanizing process is brought about by chemical crosslinking with sulphur.
d) Chalk: filler for increasing the bulk.
e) Carbon black: filler, colorant, and to increase the abrasion resistance of the face.
f) Benzene-sulphohydracite: blowing agent for increasing bulk and adjusting the softness of the rubber.
g) Tetramethyl-thiuran disulphide: vulcanizing agent (semi-accelerator).
h) Mercapto-benzthiazyl disulphide: vulcanizing agent (super-accelerator).
i) Triethanolamine: vulcanizing agent (super-accelerator).
k) Various fillers.

The interaction between vulcanizing agents, sulphur and fillers enables vulcanizing times to be specified precisely. It is thus possible with carefully planned recipes to cover all required end-uses and card clothing specifications.

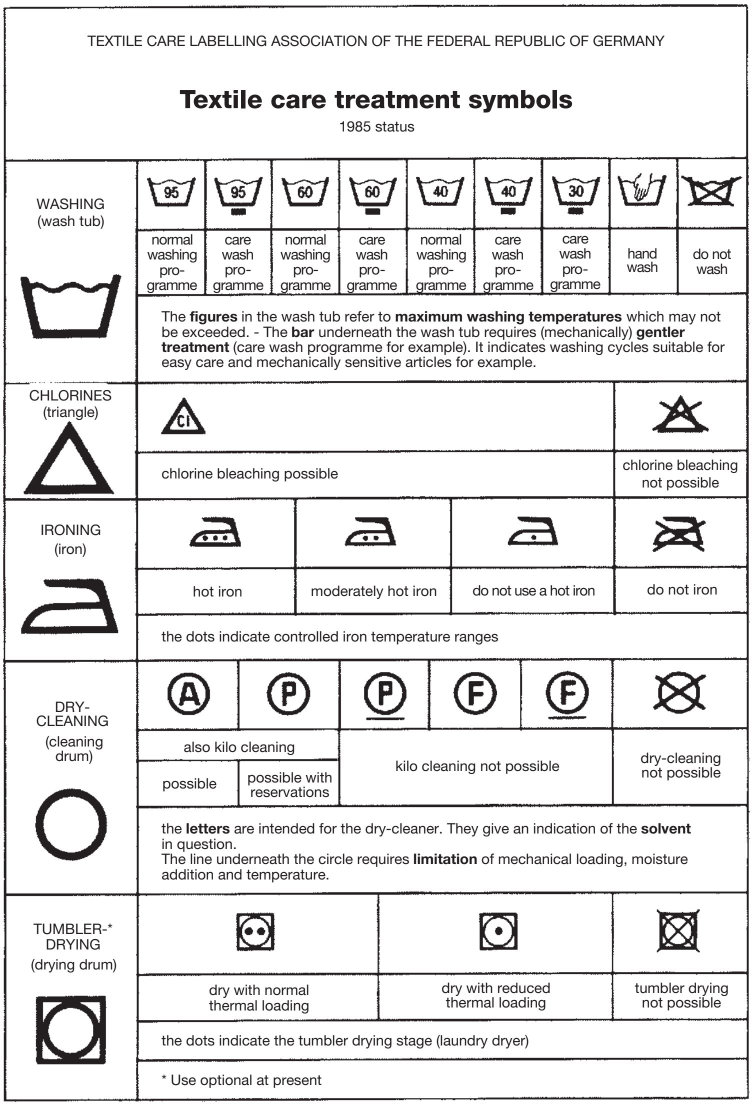
Carded yarn Manufacturing term for yarns produced by woollen spinning system, characterised by their bulkiness and a more or less hairy surface. The fibres are not fully parallellised, but only carded (carded without the additional combing process as with → Worsted yarns), then spun by means of web formation, twisting etc. (not drafted). The process is suitable for almost all fibre types, from the shortest waste materials to medium-length, fine crimped fibres (particularly strongly crimped wool, good felting properties), and used in a variety of blends (mixture or melange effects) for cheap to good quality end products. Mainly for ladies and mens outerwear fabrics, uniforms, blankets, carpets, etc.

Card lap winding machine Winds card lap on to perforated beams for dyeing and bleaching.

Card raising machines Rod and roller card raising machines using teasels as raising tool. → Raising machines.

Card sliver Semi-manufacture in the spinning of cotton and viscose. A web of fibres in ribbon form comprising fibres in parallel alignment (similar to top on the worsted spinning system). Card slivers are for example dyed (→ Pack system dyeing machines) packed into compact balls or wound onto beams in dyeing machines. Card sliver passes via drawframe and speedframe before being spun into yarn.

Care labelling of textiles The purpose is to provide the end-user and purchaser of a textile product with information on the fibre composition and care of the textile. This is contained on two sewn-in labels or frequently one joint label. If any of this information is absent, caution is advised or even non-purchase recommended. Raw materials labelling and care labelling dif-



The **figures** in the wash tub refer to **maximum washing temperatures** which may not be exceeded. - The **bar** underneath the wash tub requires (mechanically) **gentler treatment** (care wash programme for example). It indicates washing cycles suitable for easy care and mechanically sensitive articles for example.

the dots indicate controlled iron temperature ranges

the **letters** are intended for the dry-cleaner. They give an indication of the **solvent** in question.
The line underneath the circle requires **limitation** of mechanical loading, moisture addition and temperature.

the dots indicate the tumbler drying stage (laundry dryer)

* Use optional at present

Fig. 1: Textile care labelling symbols.

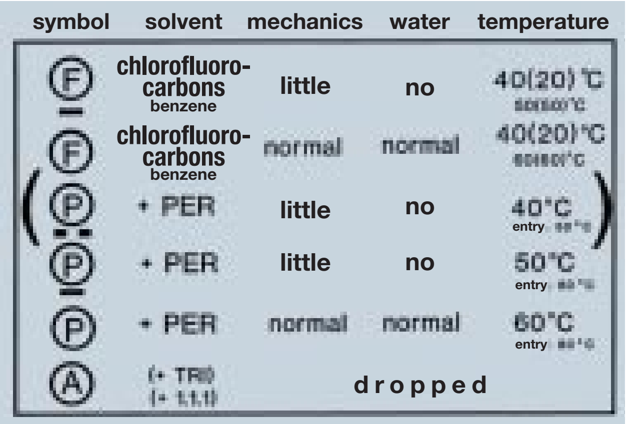
fer both in principle and legal basis. Raw materials labelling must conform with the legal obligations of → Textile labelling regulations (in Germany and Britain for instance) whilst care labelling is undertaken on a voluntary basis. The consumer who regards the absence of care labelling as unimportant does so at his own peril. Nor is care labelling entirely above the law. The copyright of the symbols used is held by the "Groupement International d'Etiquetage pour l'Entretien des Textiles" (Ginetex) in Paris. The trademark rights for Germany for example are in turn held by the Arbeitsgemeinschaft für Pflegekennzeichen für Textilien, a Ginetex member which comes under the auspices of Gesamttextil, the leader association in Frankfurt/M, and similar arrangements exist in other member countries. A number of trade and commercial bodies operate within the working group, including a consumer organisation and various research institutes.

Fig. 1 summarises the care labelling code for textiles. The system is generally available free from licence fees but three conditions are attached to its use:

1. The symbols must be depicted exactly in their original form.
2. They must not be associated with arbitrary symbols.
3. With the exception of the optional tumble-dry, there must be a full set of symbols.

The label must give information on the wash method and on the ironing temperature and also indicate whether dry cleaning is possible. Composition and care labels are no less important than the maker's brand as a medium for manifesting the integrity of the producer. As the nature of the textile trade becomes increasingly global, the fibre composition is generally stated in a number of languages. This is unnecessary for care symbols which have international recognition (ISO 3758:1991, EN 23758:1994). However, care labelling does not represent a quality mark.

Fig. 2 describes procedures defined for dry cleaning. The care symbol not only describes the nature of the cleaning medium (solvent, added water) but at the same time it defines the severity of the cleaning action, cleaning and drying temperatures and the maximum permitted treatment times for avoiding irreversible damage. For instance "F" not only indicates the use of a very mild solvent, but at the same time also low drying temperature and because of the high volatility, short drying time and consequently low mechanical action.



symbol	solvent	mechanics	water	temperature
F	chlorofluoro-carbons benzene	little	no	40(20) °C [illegible]
F	chlorofluoro-carbons benzene	normal	normal	40(20) °C [illegible]
P	• PER	little	no	40 °C entry [illegible]
P	• PER	little	no	50 °C entry [illegible]
P	• PER	normal	normal	60 °C entry [illegible]
A	(• TRI) (• 1.1.1)	dropped		

Fig. 2: Dry-cleaning symbols and technical content of the basic processes, in which chlorofluorocarbons are prohibited in the Federal Republic of Germany, and are replaced by benzene in special machines (PER = tetrachloroethylene; TRI = trichloroethylene; 1.1.1 = trichloroethane).

With the exception of “A” which for ecological reasons will probably no longer have any future significance in Europe, for each basic symbol there are in principle two stages of treatment for textiles of different sensitivities, or in the case of “P” in future with the demise of the fluorinated hydrocarbons as many as three stages.

The “F” symbol is important not just due to the use of fluorinated hydrocarbon but because of the flashpoint (flashpoint for Stoddard solvent = white spirit). The drying temperatures also given apply to the use of white spirit.

Care of textiles Necessary care taken to guarantee → Wearing comfort over a period, in fact in the sense of work simplification and reduction. Simple washing by hand or machine, easy dirt, stain and skin grease removal. Most possibly bacteria eradication too by washing and dry cleaning; centrifuge, and hang on the line without having to be afraid of dimensional changes. Quick drying (therefore fresh daily).

Carmine azurol Colour reagent for differentiating between fibre materials in the textile, chemical pulp and paper industries. As a supplement to → Neocarmine, particularly for protein and synthetic fibres. Implementation: free test specimen of adherent foreign matter, perfuse with carine azurol solution, dye for 15 mins at 80–90°C in a water bath, rinse. Findings:

stained grey = polyamide 11, polyester, polyvinylidene copolymers
pale greenish blue = modacrylic
pale blue = triacetate, polyvinylchloride (post-chlorinated = stronger), polyacrylonitrile
light medium blue = capok, polyamide 6 and 6.6, wool
dark blue = jute
dark blue-violet = silk, wild silk, polyvinyl alcohol, casein fibre
reddish violet = copolymer
dark red = natural and man-made cellulose fibre (excepting capok, jute, acetate, alginate).

Carnauba wax (palm wax). Most important vegetable wax, which is obtained from the surface of the Carnauba palm leaf (South America). Brittle, fragile, greyish yellow, slight lustre. Types: fatty grey, refined (paraffin additive), also bleached and brightened. Melt point 80–86°C, light qualities lower, refined 70–72°C. Difficult to saponify, necessary to emulsify. Soluble in benzine, benzol, xylol, chloroform, turpentine oil, chlorinated hydrocarbons etc. Used for sizing and chemical finishing for example.

Caroa fibre (craua, croa, coroa). Source: a fibre from the leaf of the plant *Neoglazovia variegata*, indigenous to Central and South America, grows wild in Brazil in large quantities. The Brazilian plant yields a fibre that can be used for suitings and coatings in tropical countries, as well as for rugs, paper, light rope and twine. The fibre is creamy white in colour, strong, flexible and fairly soft to touch. It contains a high proportion of lignin. Compared with jute, caroa is 3 times as strong, and fabric, sacking or twine made from it is about half as light as similar articles made from jute. → Bromelia fibres.

Carob is the active content of → Locust bean flour (the fruit of the locust or carob tree). Contains high molecular weight carbohydrates and hemicelluloses, principally → Galactomannan (mannogalactan).

Caro’s acid (peroxysulphuric acid, sulfo monoper acid, persulphuric acid), H_2SO_5 or $HO–SO_2–O–OH$. In its pure state, white crystals, soluble in water as strong, monobasic acid with slow decomposition (develops ozone-rich oxygen even at room temperature). In the presence of larger amounts of sulphuric acid, rapid splitting into sulphuric acid and hydrogen peroxide, according to the following equation:

$$H_2SO_5 + H_2O \leftrightarrow H_2SO_4 + H_2O_2$$

Caro’s acid is to be regarded as a hydrogen peroxide whose H atom is replaced by the SO_3H group; it thus has the structure: $HO–O–SO_3H$. Caro’s acid oxidises aniline into nitrobenzene, and it instantly releases iodine from potassium iodide solutions. Used for making wool shrink-resistant.

Caro’s acid process for anti-felting finish Experience gained from the CSIRO wool research laboratories has demonstrated the connection, shown in the table, between processing method and wool area shrinkage.

Working method	Wool area shrinkage
untreated	40 %
5% solution	21 %
5% solution, previously neutralised to pH 6-7	11 %
5% solution, pH 6-7, saturated with sodium sulphate	4– 5 %

Table: Relation between processing method and wool area shrinkage when given an anti-felting finish using Caro’s acid.

In the last case, the oxidation reaction appears to be limited specifically to the outer cortex cells of the wool, and is therefore suitable for print pre-treatment of the wool fabrics.

Carousel centrifuge Used on the carousel principle for centrifuging individual cross-wound packages creeled on special spindles.

Carousel motif printing machine Circular screen arrangement with fully rotating printing tables, central drive and fully pneumatic control. Easily interchangeable printing tables for printing different sizes of motifs. - producer Maag Flockmaschinen GmbH.

Carousel printer Screen printing machine for the automated printing of finished textiles, carousel system.

Carousel screen printing machine Semi-automatic screen printing machine, on which the screens are accommodated in a rotating frame, which runs between two short tables, so that two fabrics can be printed next to each other by two printers by swinging in the screens.

Carpet ageing Artificial ageing of carpets, achieved by chlorination, which brings about an intensification of the appearance of colour, pile and lustre, usually associated with simultaneous damage to the fibre.

Carpet back coating → Back coating of carpets.

Carpet back singeing Carpets are singed before foam application, allowing the primary coat to be reduced by 10% (with improved tuft anchorage) and the foam application by as much as 35% to approx. 1.5–2 mm thickness (= shorter cure time, faster production speed, better final quality). The carpet back singeing unit in a continuous carpet backing line is situated between the entry and the primary coating module.

Carpet base material → Carpet primary backing.

Carpet beating and dust extraction machines With suction, working area adjustable to carpet width, up to 4 m working width. Mechanical action by vibration causing beater waves; dependent on the manufacturer may be fitted with metal tappets, metal sprung plates, plastic or leather plates, brushes.

Carpet beetles Beetles whose larvae feed on and cause damage to wool carpets. → Textile parasites (see Fig.).

Fig.: carpet beetles with larvae (enlarged) (source: Bayer).

Carpet binding machine Used especially for the edge-binding of cut, tufted floor coverings which are laid “wall-to-wall”.

Carpet cleaning Process:
- dust removal (vacuum cleaning),
- dry process (e.g. powder),
- hot water/steam vacuum cleaning,
- shampooing (pile wash, foam cleaning),
- wet wash,
- solvent process,
- special process (stain removal, disinfection, etc.)

Depending on the type of carpet, suitably adapted processes should be selected or combined.

Carpet comfort →: CF-value; Tread comfort value.

Carpet – contaminant tested The registered quality mark of the “Association of Environmentally Friendly Floor Coverings” (GUT: Gemeinschaft umweltfreundlicher Teppichböden), which was established by reputable European carpet manufacturers. Carpets and floor coverings of GUT members have displayed this quality mark since autumn 1991. GUT certifies that the carpets awarded this mark are tested for the presence of contaminants (“schadstoffgeprüft”), i.e. only raw materials are used which contain no health-threatening pollutants such as pentachlorophenol, formaldehyde, asbestos, vinyl chloride, CFCs or pesticides. The carpets are also manufactured under the most environmentally friendly conditions. Routine monitoring by the Carpet Research Institute at Aachen (TFI: Teppichforschungsinstituts Aachen) help to guarantee this.

Carpet continuous dyeing plant For the dyeing of carpet lengths of up to 5 m in width, with running speeds of 5–20 m/min. Pad-steam processes are separated by the method of application of the dye liquor. Continuous carpet dyeing plant can be fully integrated, i.e. to contain pretreatment, dye liquor application and fixing, as well as washing off (Fig. 1).

The additional pretreatment wetting system, “Fluicon II” (Fig. 2), with integrated vacuum extraction removes finishes, spinning oils and fugitive dyes, and enables the extracted washing solution to be reused at the final washing off stage. The presteamer gives the carpet the required volume.

The “Quick-Change” dye liquor application system (Fig. 3) is used for both for plain colours and for rinsing after printing for light to heavyweight carpets. Changing from one colour to the next requires less than 0.5 m without stopping. The “Quick-Change” colour change is carried out without stopping the dyeing or rinsing process and with a minimum of lower quality production.

In the “Cloud” steamer (Fig. 4), a steam volume control delivers the correct amount of steam fixing the dye. This control leads to a substantial reduction in steam consumption. The washing stage after fixation

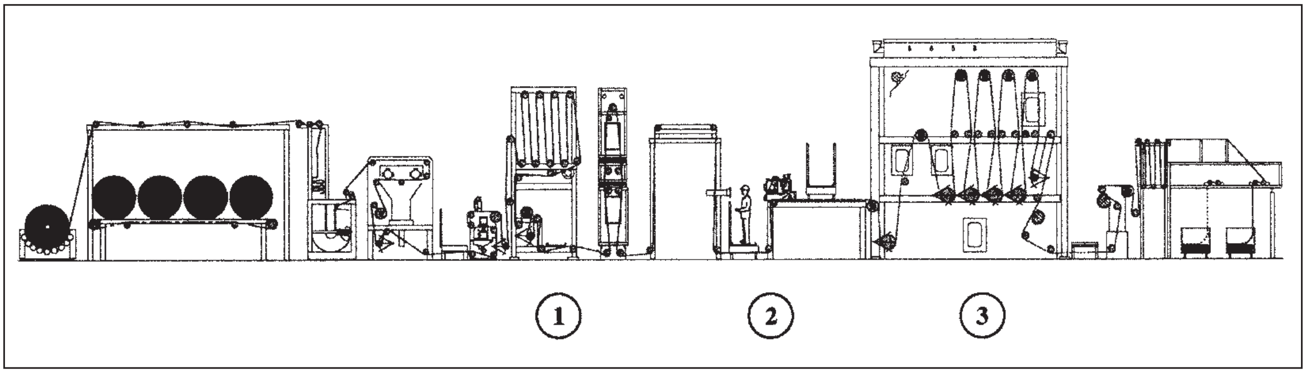


Fig. 1: Example of a continuous carpet dyeing plant (Küsters).
1 = pretreatment with "Fluicon II" application system; 2 = "Quick-Change" dye liquor application system; 3 = "Cloud" loop steamer.

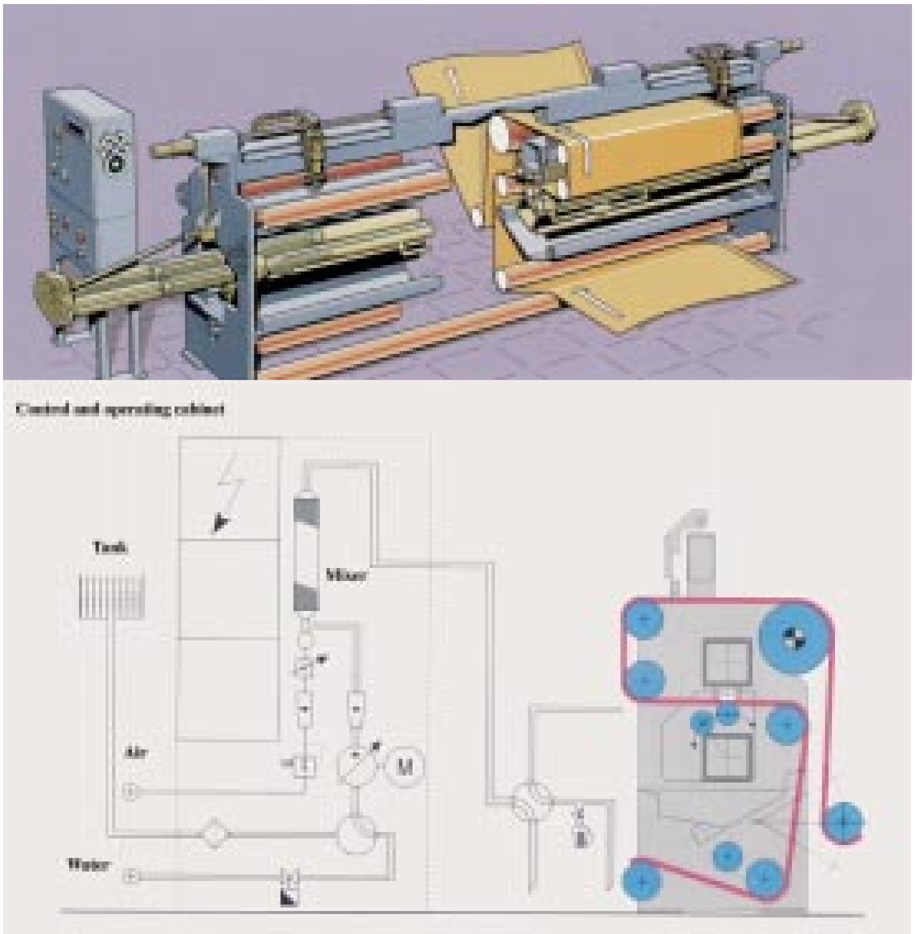


Fig. 2: Fluicon application system for carpet pretreatment (Küsters).

has been optimised for economic and ecological performance. At the exit from the steamer, residual liquor is extracted from the carpet at boiling temperature by a suction system without the addition of cooling water.

Carpet drying machines Automatic through-feed and festoon machines, with forced hot air circulation for drying washed, rinsed and dewatered carpets.

Carpet dust and water extractor Transportable vacuum cleaner, normally combined for dry and wet application, especially for extracting dry foam. → Foam cleaning.

Carpet dyeing Apart from carpet piece dyeing, materials which are to be made into carpets can in principle be dyed at all processing stages (spun dyed, as tow, loose stock, tops or yarn). Carpet piece goods are dyed batchwise or continuously (see Fig. 1: carpet dyeing plant from Mitter). Discontinuous processes include the dyeing of small carpets (e.g. bath mats, toilet sets) using paddle or drum dyeing machines; carpet pieces up to 5 m in width are dyed using carpet winch dyeing machines, beam dyeing machines and carpet continuous dyeing plants. Needle pile carpets and espe-

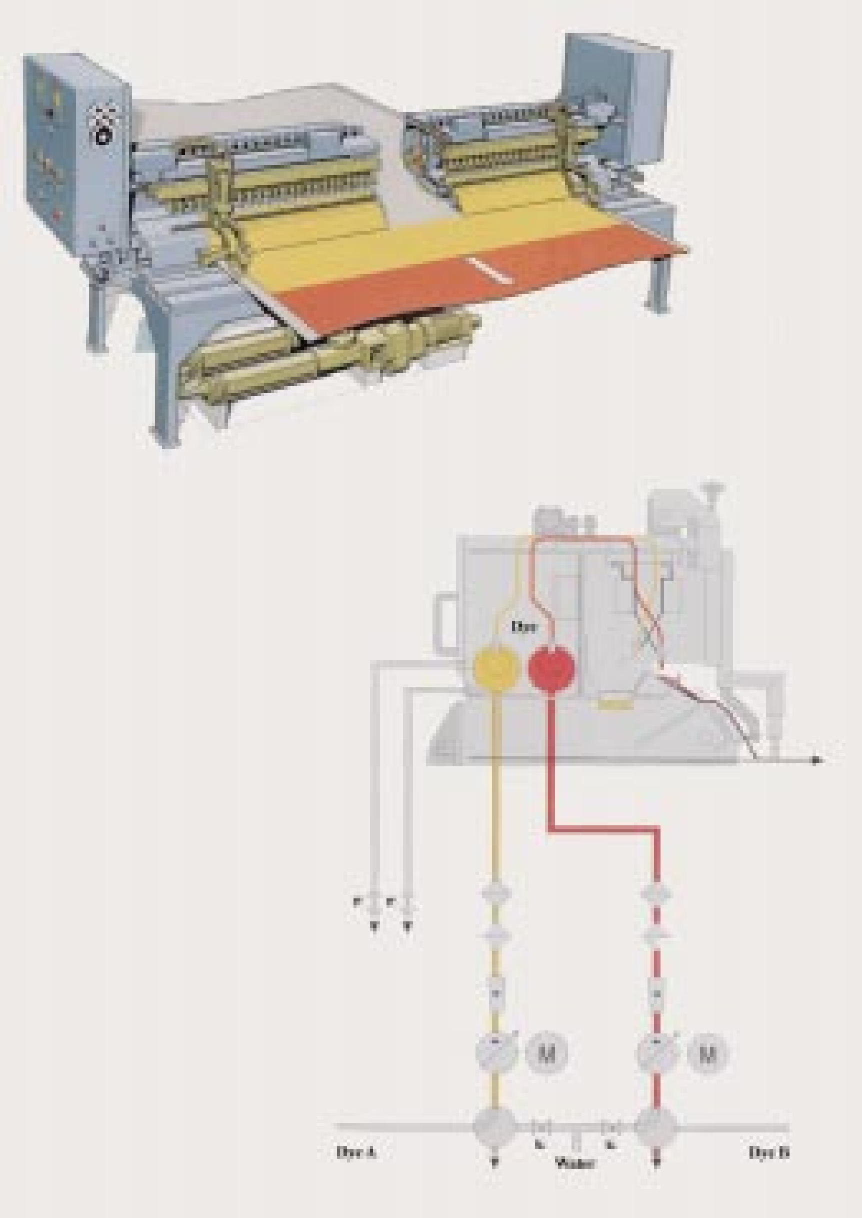


Fig. 3: "Quick-Change" application plant (Küsters).

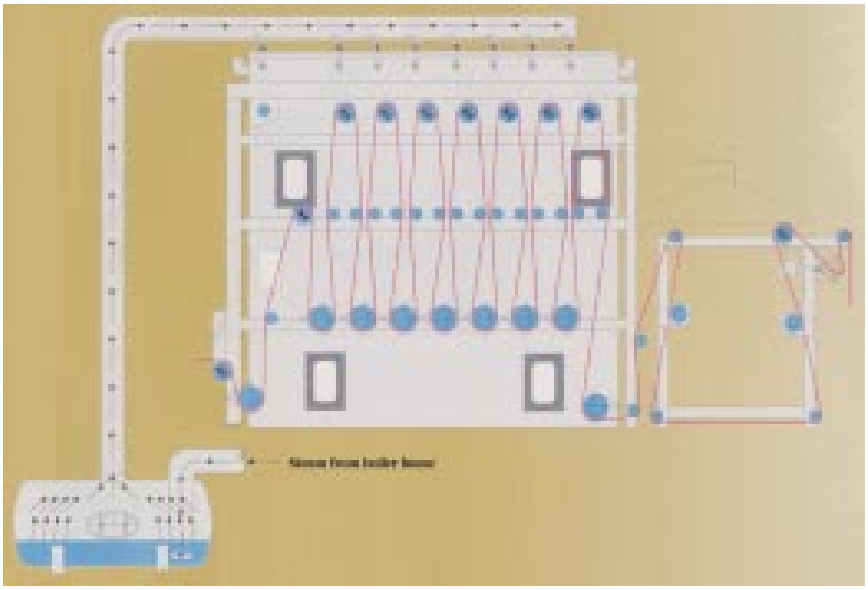


Fig. 4: "Cloud Control" steamer for carpet dyeing (Küsters).

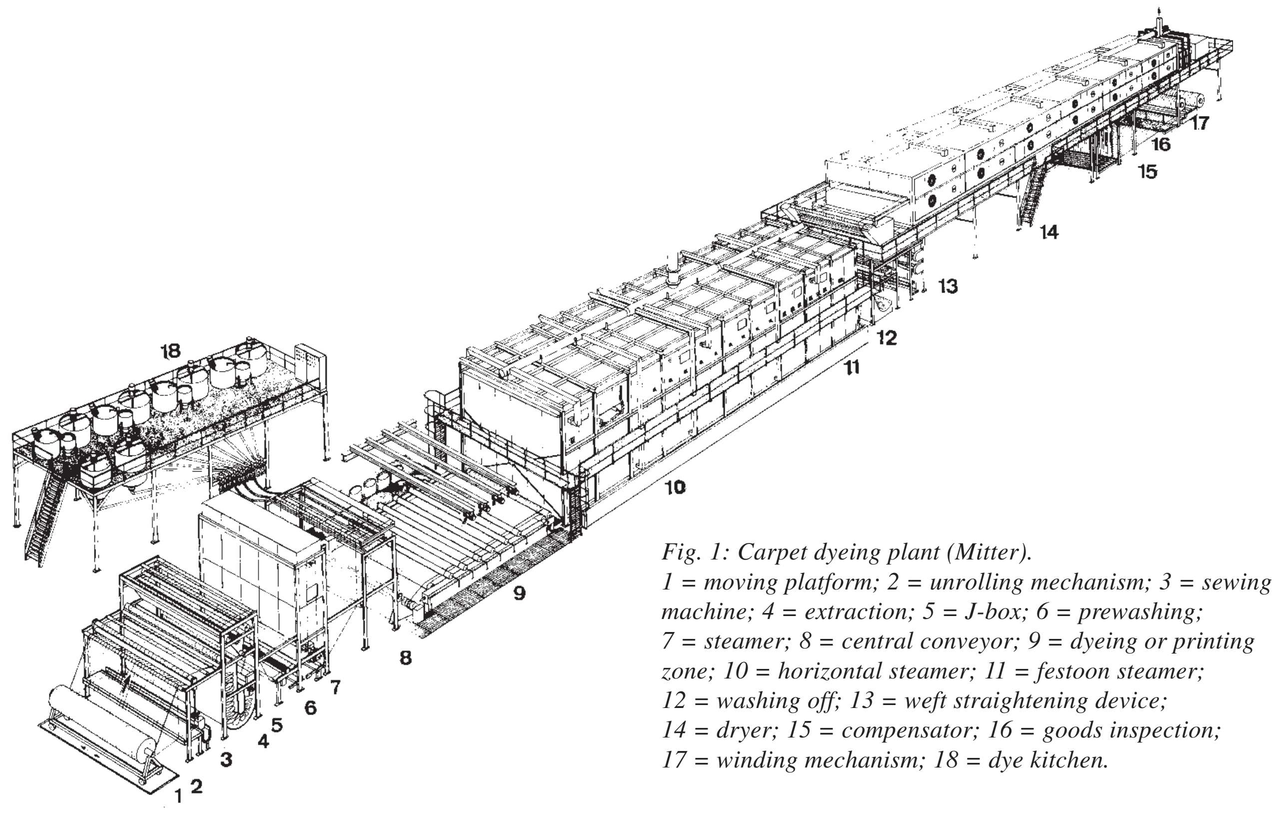


Fig. 1: Carpet dyeing plant (Mitter).
1 = moving platform; 2 = unrolling mechanism; 3 = sewing machine; 4 = extraction; 5 = J-box; 6 = prewashing; 7 = steamer; 8 = central conveyor; 9 = dyeing or printing zone; 10 = horizontal steamer; 11 = festoon steamer; 12 = washing off; 13 = weft straightening device; 14 = dryer; 15 = compensator; 16 = goods inspection; 17 = winding mechanism; 18 = dye kitchen.

cially those with a polyamide or polyester pile are well suited to piece dyeing; those of polyacrylonitrile and wool less so.

The demand for better control of the environmental impact dyeing of carpets has lead to the optimisation of the dyes and auxiliaries used with regard to their biodegradability and the processes used with regard to water and energy consumption, thus minimising as far as possible consequent environmental impact. Disperse dyes were mainly used for the dyeing of polyamide carpets. This resulted in low exhaustion levels and heavy coloration of effluent. The development of suitable acid dyes has satisfied a substantial proportion of the environmental demands. A balanced range of dyestuffs with high exhaustion rates, good levelling and migration properties, suited to both batch and continuous applications, has brought about the required improvements in quality for production and commercial demands.

However, a high exhaustion rates with acid dyes requires a suitable auxiliary/chemical application system. Correct pH control including the use of buffer systems and minimal levels of auxiliaries with fibre affinity is needed to achieve the lower effluent loading in terms of colour content. Further improvements can be made e.g. by replacing phosphate buffer systems with ammonium acetate/aAcetic acid systems although this raises the TOC content. An initial step in the direction of this aspect of the more environmentally friendly dyeing of carpet piece goods is represented by the DOSACID system (controllable bath exhaustion by pH control and acid dosing) for winches with liquor circulation. Rationalised working procedures and larger dye batches were the original reasons for the increase in use of continuous dyeing machines. Earlier machines with the so-called uncontrolled liquor pickup (500–700%) were further developed to liquor pickup of 350–500%, with required suitable pumps with controls and dosing. This control and reduction of the application volume led to a reduction in effluent loading by excessive use of dyes and auxiliaries.

The oil crisis induced further developments aimed at energy savings as well as reduced effluent loading. In this context, 1979 saw the introduction of foam application, which enables processing with dye application volumes of 150–350%. Development is not yet complete (see Fig. 2), as the following examples relating to the production of more efficient continuous plant show:

- Modification to improve penetration (Fluidyer),
- Reduced liquor loss on colour changes (Quick Color-Change),
- Steamer with reduced energy consumption

(source: Bouwknegt).

Carpet finishing may be undertaken at the end of the carpet manufacturing process or together with other finishing or manufacturing processes. Its purpose is to improve the carpet and give an increase in quality. Carpet finishing is varied due to the varied types of carpet

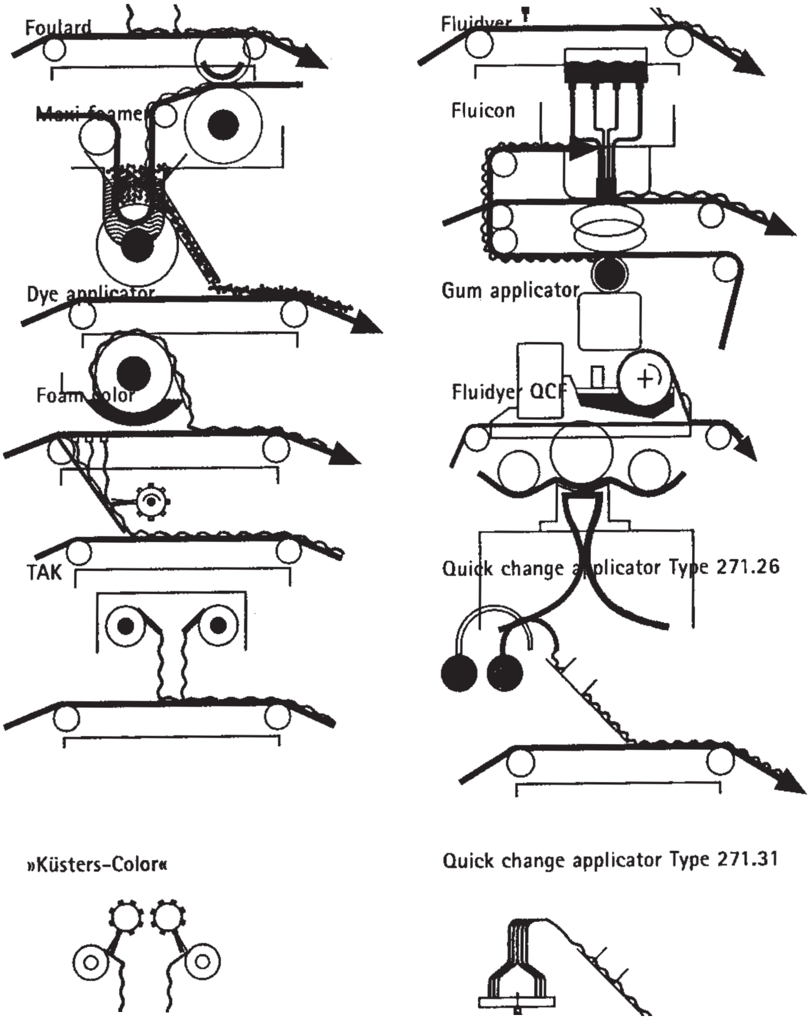


Fig. 2: Carpet dyeing systems from Küsters.

manufacture and design. The different finishing methods are:

1. Dry finishing processes: brushing, shearing, backcoating.
2. Wet finishing processes: antimicrobial, antisoiling, antistatic, flame-retardant and softening finishes.

The desirable properties for a carpet finish are:

– simple application,

- no effect on coloration,
- temperature resistance,
- high abrasion resistance,
- no increase in the soiling tendency of the textile floor covering in comparison with goods without an antistatic finish.

The following aqueous application processes are used: spraying, roll-transfer coating and padding. Application by spraying is the most common method. If the solution, e.g. of an anti-electrostatic is sprayed on to the pile side, it is essential to run the goods over a roller or rounded edge at the point of spraying (Fig. 1). This opens the pile, so that the product can penetrate down to the base material rather than merely reaching the upper surface of the pile. When spraying from the backing, the concentration must be selected so that sufficient product penetrates to the pile. A decrease in concentration towards the upper surface cannot be avoided, but does not affect the antistatic effect (Fig. 2). It is essential when using this working method to ensure that the effectiveness of subsequent coatings for securing the pile is not affected.

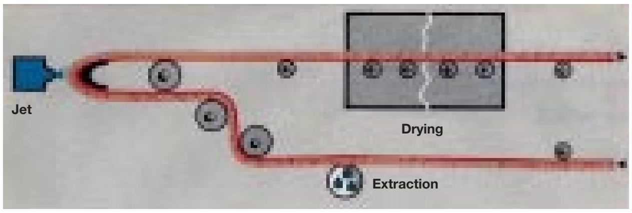


Fig. 1: Carpet finishing: Spray application on the pile side (Reich).

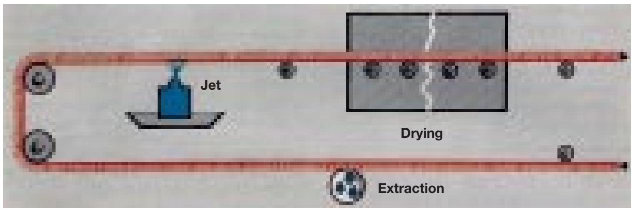


Fig. 2: Carpet finishing: Spray application on the backing side before the backcoating (Reich).

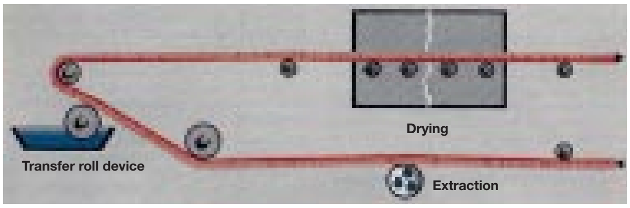


Fig. 3: Carpet finishing: Transfer roll application on the pile side (Reich).

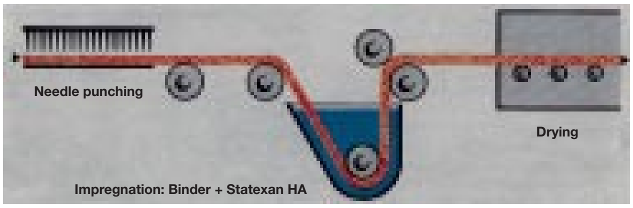


Fig. 4: Antielectrostatic finish of needle-punched floor coverings (Reich).

Transfer-roll application (Fig. 3) can be applied from the pile or reverse. Inconsistent deposit levels caused either by poor quality or deficiencies in the spray equipment can be avoided by using this method.

Pad application is only used for pile goods in exceptional cases, as the pile can be damaged by the pressure of the mangle. This method is extensively used for needle-punched floor coverings. For technical and commercial reasons it is necessary for the product to be brought together with the binder (Fig. 4). Good compatibility of applied finishes with the binder is necessary. Flooring materials must have a long life and great importance is attached to the fastness of the dyeing. Any finishing products applied must not affect this fastness, nor the quality of the colour.

Textile floor coverings are exposed to considerable temperatures during the production process, e.g. when vulcanizing the back coating. Applied products must not decompose, volatilize nor diffuse into the fibres under these conditions. A finish for textile floor coverings must not affect the abrasion resistance of the carpet, nor the soiling behaviour of the carpet. Many finishing agents can be oily or viscous substances which bind dust and dirt particles, thus leading to more rapid soiling.

An antistatic coating of 0.4–0.5% (Figs. 5–7), based on the pile weight of the carpet material, reduces possible personal electrostatic charges even at relatively low humidity (say 30%). The low add-on rate also reduces the effect on shade or soiling behaviour of the floor covering.

The abrasion resistance of the finish is surprisingly high. After five hours' abrasion in a friction charging apparatus an increase in the surface resistance of max. half power of ten resulted. For this test rubbing cloth sample, made of a knitted fabric of the same fibre type as the floor covering to be tested, is rubbed against a test piece at a force of 100 N. The rubbing cloth sample is renewed every 5 mins during the first half hour, and every 15 min thereafter for the remainder of the test, in order to prevent the accumulation of finishing agents on the rubbing cloth sample, which would lead to a state of equilibrium between the test piece and rubbing cloth sample. The high resistance to abrasion is confirmed by usage under real use conditions. The explanation for this behaviour should lie in the fact that after the abraiding of the upper layer of the pile, enough product remains in the deeper layers of the pile to ensure sufficient conductivity, i.e. transverse conductivi-

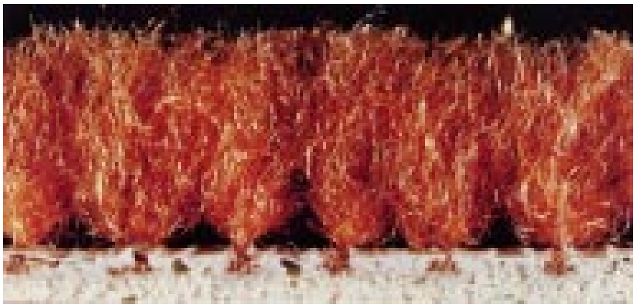


Fig. 5: Untreated, polyamide cut-pile carpet with backcoating after use (Reich).

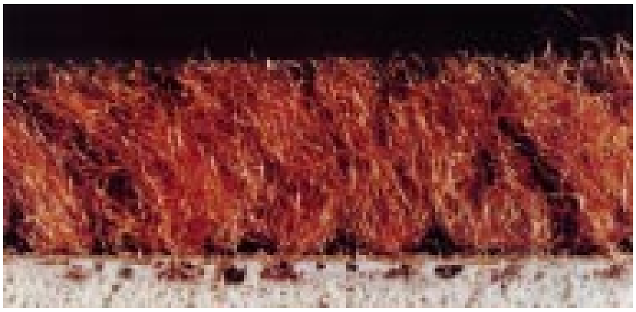


Fig. 6: antielectrostatic finished carpet subjected to wear (Reich).

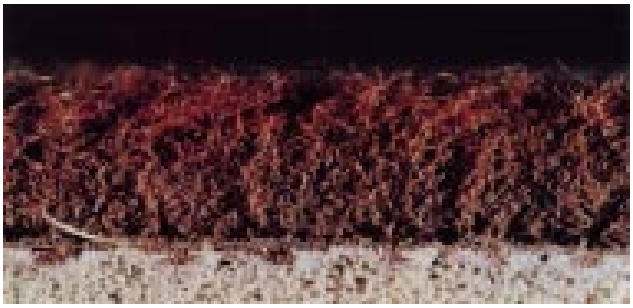


Fig. 7: Carpet without finish, subjected to wear (Reich).

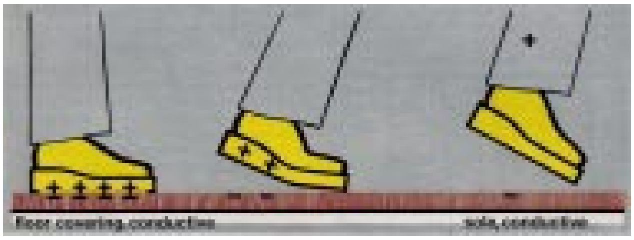


Fig. 8: Electrostatic behaviour when walking on textile floor coverings (Bayer).

ty. By treating with an effective antielectrostatic agent the surface resistance of textile floor coverings is reduced to such an extent that the electrical charges generated by walking are dispersed in a sufficiently short time. The floor covering can no longer be regarded as an electrical isolator. Account must be taken of the fact that when walking, in contrast to running, at least one foot is always in contact with the floor. When raising a shoe, if all the charge generated cannot be dispersed through the last point of contact, then in the case of conductive footwear, a charge interchange may take place through the body and the other shoe which at that moment is in contact with the floor covering (Fig. 8). The charge generated in a person by electrostatic induction after raising the shoe is therefore neutralized. Charges on the underside of the shoe are neutralized at the next step by the charges flowing from the conductive floor covering by adjustment of the state of equilibrium referred to above. By determining the friction charge, and as a result the traffic test, it can be shown that by means of surface conductivity to the extent mentioned above, an effective electrical short circuit exists between floor covering and person, and thus the conditions for the build-up of problematic electrical charges when walking on a textile floor covering are not present (Reich).

Carpeting → Fitted carpets.

Carpet mark Quality mark registered by the European Carpet Association for Germany (ETG: Europäische Teppichgemeinschaft für Deutschland e.V., Wuppertal) in conjunction with the manufacturer's brand/trademark or company labelling of carpeting in regard to their fibre composition under the Textile Labelling Act (TKG: Textilkennzeichnungsgesetz) and their end-use suitability symbols (divided into three areas of use: bedroom, living and working environments plus additional attributes: wheel-chair suitability, usable in damp areas, suitable for stairs). Carpet squares require only fibre composition. Licence for use issued by Carpet Research Institute (TFI: Teppichforschungsinstitut, Aachen) on behalf of the ETG.

Carpet pile → Pile layer.

Carpet presteamer Used for tufted carpet in continuous printing and dyeing lines to relax the cloth and to maintain volume after pretreatment in the prewash (→ Carpet prewashing and bulking unit). Vertical construction enables large fabric capacity and maintenance of an uncontaminated steam atmosphere. With automatic steam volume regulator. After leaving the steam atmosphere still in the hot state, mechanical pile finishing by beater roll Machine maker: Fleissner.

Carpet prewashing and bulking unit Compact unit designed for continuous treatment of tufted carpet comprising perforated drum wash bath and an annular arrangement of baffle plates with slits across their effective width for directing jets of the controlled circulation liquor onto the pile surface of the carpet before final through-flow washing of the fabric (see Fig.).

Suction-slot extractor arm at the delivery end. Optional jet application of hot liquor promotes bulk in the carpet pile and allows tensions in pile yarn and substrate to relax. With special water/lint separation be-

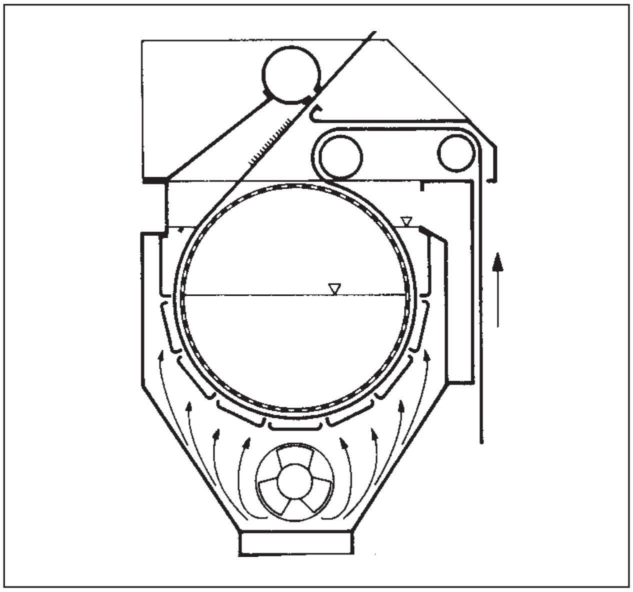


Fig.: Carpet pretreatment machine by Fleissner.

tween suction slot and pump. The short distances travelled by the fabric result in linear, low-tension and crease-free fabric transport. – Manuf.: Fleissner.

Carpet primary backing According to DIN 61151: the primary carrier for the pile or surface layer. Formerly almost exclusively of woven jute, today made of polypropylene and polyester, woven or bonded-fibre nonwoven.

Carpet printing Printing, especially of → Tufted carpets with dyestuff classes determined according to the fibre content by screen-printing tables or special → Carpet printing machines, with the objective of dyeing the pile down to the backing material. The principal difference from conventional printing processes lies in the fact that a printed carpet is continuously coloured without intermediate drying, with washing immediately afterwards. The following basic carpet printing techniques are defined (see Fig.):

I. Direct printing: This comprises the printing of all colours contained in the pattern. Printing is carried out on white goods using large-area or rotary printing machines.

II. Applied printing/overprinting: This is similar in its application to direct printing. Not all colours in the design are printed, but dependent on the process are present either as a result of previous dyeing (applied printing on a previous dyeing) or by means of the wet-on-wet method using dye liquor application equipment such as the pad, Fluidyer, sprayer, applicator or all-open screen. With this process, dyestuffs are not destroyed as is the case with discharge printing, nor is their fixing impeded as is the case with resist printing. Light displacement effects may arise with the wet-on-wet process.

III. Discharge printing/Discharge resist printing: Discharge printing involves removing the dye from a previously dyed layer in the places to be printed. The

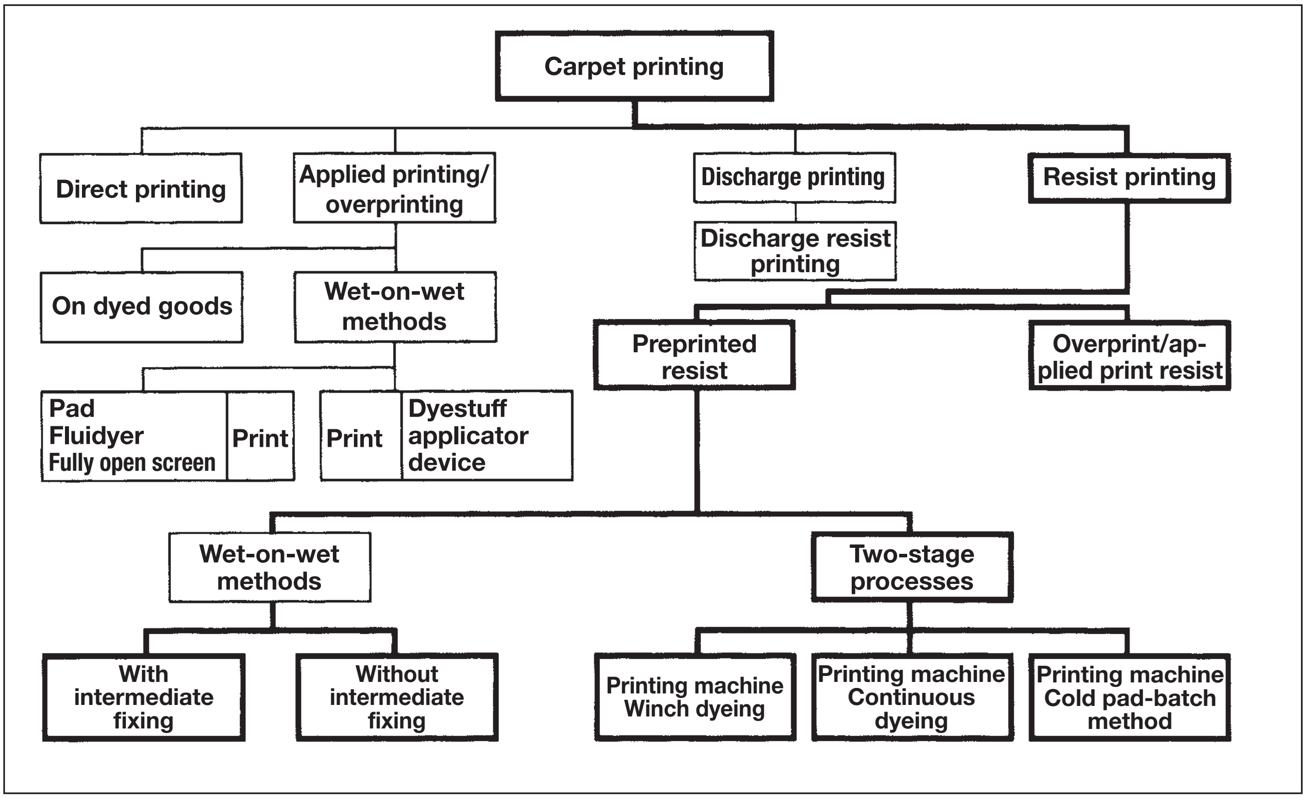


Fig.: Types of carpet printing (Bayer).

term discharge resist printing is applied to the technique whereby dyes are locally removed prior to fixing, so that they are not present on the fibre at the fixing stage.

IV. Resist printing: This method used to have a high prominence in the field of textile printing (e.g. batik-bandanna method), but now has only limited application.

V. Pre-printed resists: After application of the resist printing pastes, the printed places accept little or no dye from the liquor at the subsequent dyeing stage. The methods can be subdivided into single-stage wet-on-wet processes with or without intermediate dye fixing and two-stage processes, by which printing is carried out first, and the goods are subsequently continuously or batch process overdyed.

VI. Overprint/applied print resists: this refers to the removal of a dye previously mechanically applied to the fibre by the subsequent application of a printing paste. These may be viewed as chemically-enhanced "displacement prints"; it is not only a mechanical displacement which takes place, which at best gives rise to tone-in-tone brightening. Special chemicals or auxiliary agents, which possess dye or fibre affinity, given the relevant pH, may in addition prevent the fixation of the dye of the previously applied background dye. The background can hereby be applied using a pad or Fluidyer, 100% or using a blotch printing template if required. The resist printing technique uses practically all the methods already referred to. New developments are heading in the direction of pre-printed resists using fibre reactive auxiliary agents (source: Wirtz).

Advantages for carpet printing:

- Independence in coloration of substrate and carpet structure, giving rise to independence of the pre-dyed yarn and no limit to the pattern in production.
- Enhanced profitability due to restricted types of grey goods.
- Quick, easy production of similar patterns in different colourways.
- Printed pattern means less visible soiling sensitivity of the floor covering.
- Possibility of overprinting second-class quality carpets, thereby improving their quality.
- Fast adaptation of pattern and colourway to suit customer requirements and fashion trends.

Disadvantages/difficulties for carpet printing:

- Printing plants are generally set up for large-scale production; this requires substantial investment and possibly under-utilisation of capacity.
- Substantial possibilities for variation in the colourway conceal greater risk of fragmentation of tasks into different processes.
- Material consumption in patterning, commencement of printing and change of pattern may be considerable, both in terms of goods and dye paste.
- Machine set-up times may be quite lengthy, especially for designs involving several colours, and can only be shortened as a result of high investment costs.
- Under certain circumstances print penetration problems causes coloration or technical printing problems material qualities.
- It is difficult to design continuous carpeting which may be adapted for the production of tiles.

Carpet printing machines Special printing machines for → Carpet printing (Fig. 1), e.g. the following types:

- Aljaba carpet printing machines: constructed on the principle of conventional roller printing machines with rotary screens made of rounded bronze wire with internal squeegees, in place of normal copper rollers. – Manuf.: Aljaba.
- BDA carpet printing machines: This carpet printing system involves the application of the dye paste using sponge or twin squeegees, whereby printing paste can be sucked up from below by means of a vacuum, giving good pile penetration. – Manuf.: Singer-Cobble.
- BTM carpet printing machine (by British Tufting Machinery Co.): Works with surface printing rollers (patterns embossed on the printing roller), whereby the patterns to be printed are also given a foam coating, which after the passage of a press roller soaks up a new charge of low-viscosity print paste from the dye paste trough. – Manuf.: Singer-Cobble.
- Deep-Dye printing machines: restricted single-sided dip dyeing process, whereby the pile is repeatedly brought down into contact with a dye paste trough divided up to form the pattern. – Manuf.: Deep-Dye Processes.
- Stalwart carpet printing machine: Printing by passage between an embossed dye paste application roller (several in the case of multi-coloured designs) and a driven counterpressure roller. – Manuf.: Pickering.

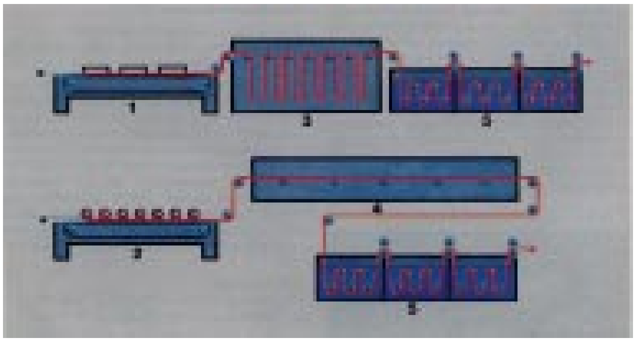


Fig. 1: Carpet printing process (by Bayer).
1 = flat bed printing machine; 2 = rotary printing machine; 3 = loop steamer; 4 = horizontal steamer; 5 = washing machine.

- P. Zimmer flat bed carpet printing machine, TDA 62, 74: works with magnetic contact pressure of a roller squeegee or double roller squeegee application system. – Manuf.: Zimmer, Kufstein.
- Mitter rotary carpet printing machine: dye paste is applied by friction (2–15%) between a rotary screen and rotary squeegee. – Manuf.: Mitter.
- J. Zimmer rotary carpet printing machine: works by means of a magnetic rotary squeegee. After intermediate drying it is overprinted with colourless or lightly coloured dye paste, in order to achieve the final penetration. – Manuf.: Zimmer, Klagenfurt.
- Carpet spray printing plant → Millitron process. Manuf.: Deering Milliken.

The designer of a carpet printing machine has to solve a number of technical problems specific to carpets:

- Large working widths (up to 5 m) and large repeats. This has resulted in special screens (Fig. 2) and complicated mechanisms for screen changing (Fig. 3).

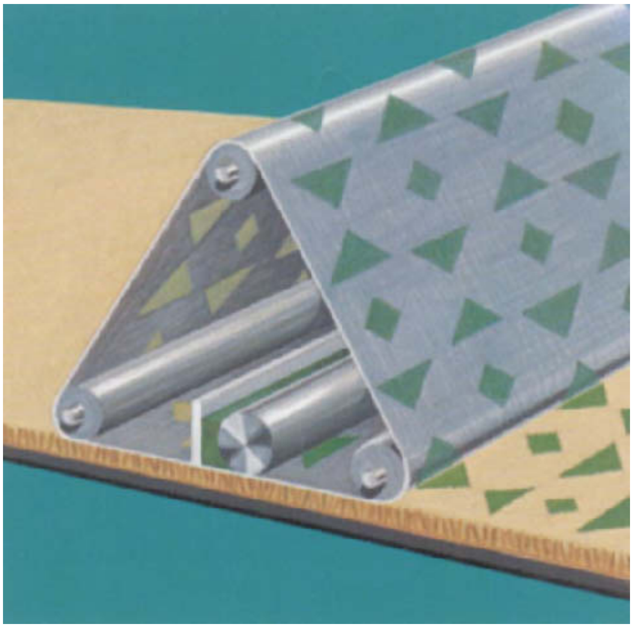


Fig. 2: "ROTAFILMPRINT" device for repeats of up to 4m (Mitter) (source: Bayer).

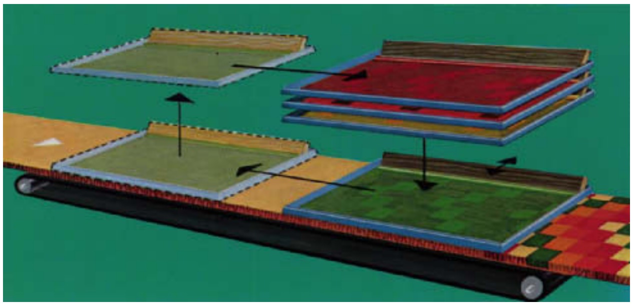


Fig. 3: "SEMIMATIK" compact flat bed carpet printing machine (Zimmer).

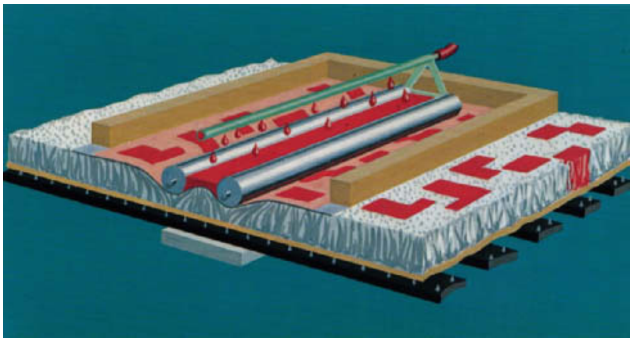


Fig. 4: Zimmer TDA carpet printing machine.

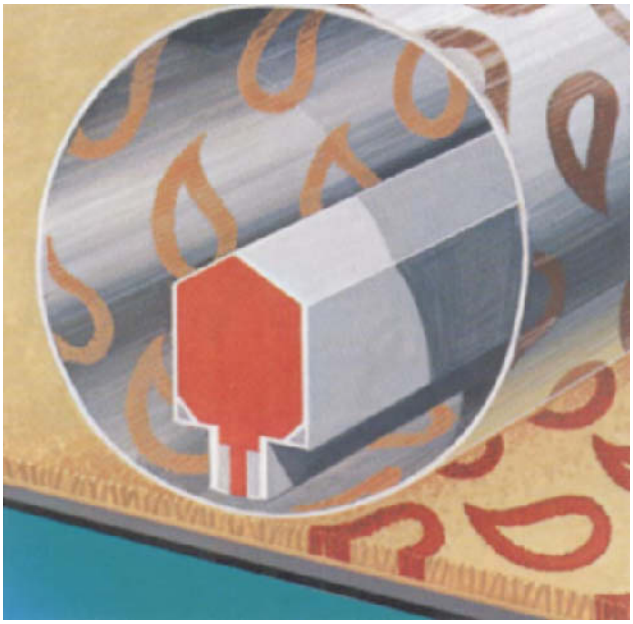


Fig. 5: TRSDM (1) rotary screen carpet printing machine with HYDROSLOT (Zimmer).

- The presence of the voluminous and pressure-sensitive pile requires a special roller squeegee using magnets with pressure control for flat bed printing. (Fig. 4) or a slot squeegee with vacuum suction from the reverse of the carpet. The adoption of magnetically-operated systems have also proved useful in rotary printing with large widths and the pile problem (Fig. 5) for the precise positioning of a slot squeegee within a rotary screen, using two or three rollers of standard size in one colour giving partial repeats which are brought together (intermittent printing) to give the desired large repeat.
- Several stage processes seek to enhance the pile penetration by carrying out the dye paste application and penetration stages separately (Fig. 6).
- Spray printing involves computer-controlled dye paste application from microjets (without screens or print rollers). The pattern to be reproduced is input and (controlled via a colour display screen) saved

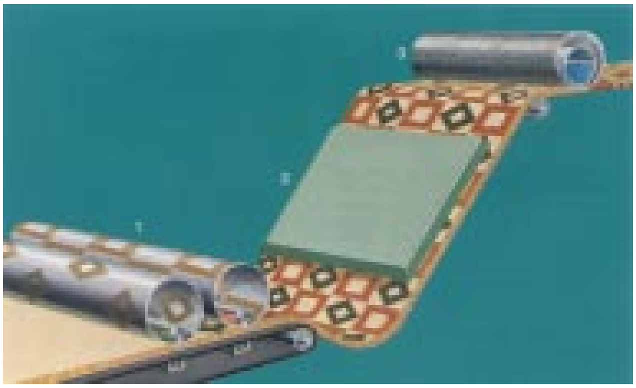


*Fig. 6: Rotary screen printing machine for carpets (3-stage process) (source: Bayer).
1 = Printing machine; 2 = Infrared heater; 3 = Penetration screen.*

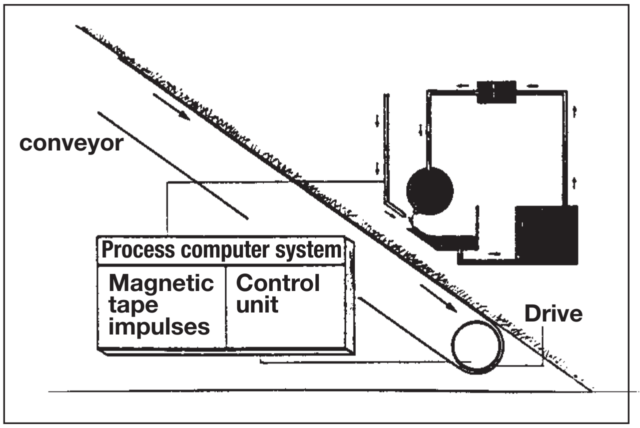


Fig. 7: Millitron spray printing: by applying the dye liquor jet using compressed air the liquor is deflected to the collecting basin, so that the pile is not patterned.

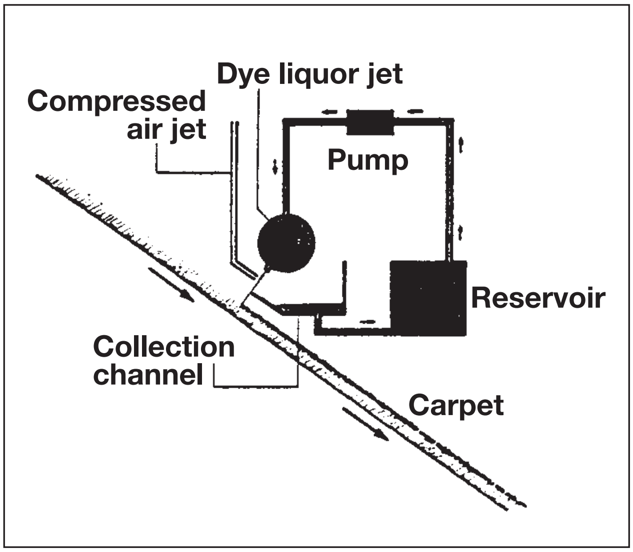


Fig. 8: Millitron spray printer: The pattern is formed as the carpet pile absorbs the thickened dye liquor jet.

on magnetic tape. The tape is used to control the printing machine, the main component of which is the system of jets extending across the whole width of the machine (Figs. 7 and 8); the carpet passes beneath these at a rate of 6 m/min.

Carpet quality labels The individual designation and marking of textile floor coverings. Carpets must contain a certain amount of pile fibre per unit area and have a specified resistance to wear. E.g.: DuPont 501 label; Enkalon; Monsanto-A (Acrylan) label; Bayer-Dralon label. Similar quality labels are also offered by carpet yarn manufacturers and also those awarded by consumer advice bodies, e.g. British Consumer Council swing-ticket, and by carpet manufacturers, e.g. → Carpet mark of the TFI or GUT environmental label.

Carpet raschel knitting machine Knitting machine used in the manufacture of → Raschel carpet. Integral backing comprising cotton, viscose, jute, paper or synthetic yarns is knitted simultaneously with the pile surface.

Carpet roll paternoster Storage and display apparatus for carpet rolls.

Carpets Textile floor, wall or ceiling coverings. According to DIN 61 151, the following features are used for classification: type of manufacture, manufactured controlled surface dimensions, material in the pile or surface layer, surface form, colour, carpet backing material.

I. Type of manufacture: knotted, woven, knitted, stitch-bonded, tufted, needle-felt, flocked, bonded carpet.

II. Surface: flat, pile, bouclé (loop pile), velour (cut-pile) carpet.

III. Colour: plain, multi-coloured carpet.

IV. Supply form: rugs, roll goods, carpet tiles.

V. Origin: Oriental, Balkan, Bavarian, Dutch carpets. Certain marks of origin have become generic names.

VI. Application: bedroom, living room, workplace; indoor, outdoor, contract, automotive carpets.

Carpets, dust extraction Mechanical beating, suction or brushing, possibly both sides of the carpet, in order to remove as much loose dirt and dust as possible.

Carpet shampooing (Carpet pile wash), as defined in RAL 991-A is customarily applied to fitted carpet. Comprises mechanical dust removal and subsequent treatment of the pile surface with a carpet detergent which is stable in hard water, can be converted into dry foam without wetting out the carpet foundation (substrate fabric) and leaves behind non-sticky residue that is easily removed by vacuuming. There then follows quick extraction of foam and moisture, drying (suction drying), brushing, etc. for finishing → Foam cleaning.

Carpet shearing machine Is suitable for shearing soft velour carpets. Up to 6000 mm working width.

Carpet singeing Modifying the pile of oriental carpets using a flame or chemical agents in order to harmonize the overall colour impression. → Carpet ageing.

Carpet spray printing Process in which print solutions are applied to pile fabric, not by means of stencils, but in a diluted form by spray jets. Typical examples: Chromojet (Zimmer), Millitron (Milliken); → Spray printing.

Carpet squeeze rollers Squeeze rollers for removing the water from washed, wet carpets. Working width approx. 3.5–4 m. With rinsing facility.

Carpets, static charge A separation between two nonconducting materials gives rise to an electrical charge, this also applies to carpets with normal usage. Under certain circumstances → Static charge may build up which are so great that discharge between 2 surfaces occurs with a spark; this is felt as an unpleasant shock (see Fig.). With a relative humidity of > 50%, however, most carpets have a very low tendency to build up static charges. The shock sensitivity limit for most people lies in the region of around 2000 V.

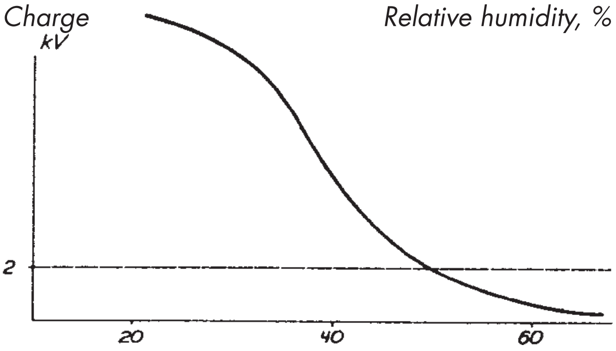


Fig.: Carpet charge in relation to the relative humidity.

Carpet steamers,

I. Steaming machine for continuous dye fixation when dyeing carpet lengths using the pad-steam process.

II. Plant for the stretching and steaming of carpet lengths to improve the appearance (flattening the pile, bulking).

Carpet steamers in continuous plant must be designed in accordance with the process, i.e. printing, dyeing or a combination of both, product speed and fixation times. Combined carpet steamers consist of standard, horizontal and loop compartments running together as individual units with automatic steam volume control.

Carpet suitability for underfloor heating In order to be suitable, a floor covering should not alter quickly under the influence of heat (backcoating) and should only emit a low level of odour. The degree of heat stability must be suited to the heating system, underfloor temperature, efficiency, heating requirements and must be made with suitable stability.

Carpets, walk test → Walk test.

Carpets, weft-patterned Machine-woven carpets, the pattern of which is produced by the relevant insertion of coloured weft yarns.

Carpet testing Testing textile floorcoverings for construction and suitablity for use, including:
- determination of weight and thickness,
- pile density,
- reduction of airborne and impact noise,
- sound absorption,
- thermal conductivity,
- fastness to light, water and rubbing,
- thickness loss under compression,
- dimensional stability,
- resistance to dynamic loading,
- resistance to wear by a walkwheel,
- resistance to wear by a steel ball in a rotating drum,
- resistance to wear by castor chair,
- burning characteristics and
- electrostatic characteristics.

Carpet transfer printing → Transfer printing of floorcoverings.

Carpet washing Comprises mechanical dust removal, washing of the pile surface and underside of the whole carpet with carpet detergents (→ Shampoos) followed by final thorough rinse.

Carpet washing machine Continuously operating open-width washer for carpets up to 5 m effective width.

Carpet winch dyeing machines Stainless steel equipment for the dyeing of carpet in piece form of 100–250 m in length, up to 5 m in width. The open width carpet is loaded via the winch roller into the winch vessel containing 20–30 l liquor and the ends sewn together. It is dyed during 3–6 hours at up to 98°C, during which time the carpet is constantly run over the winch in open width or rope form. Modern carpet winch dyeing machines have dye circulation systems with heat exchangers outside the dye bath. For carpets with polyester pile, pressurised winches are used up to 140°C.

Carpet yarns Filament yarns for the carpet sector are produced manily by the BCF process, which produces in one operation from the granulate via extruder spinning, drawing, texturing, interlacing and winding (Fig.). The crimp structure is obtained by braking the filaments in a heated chamber (stuffer box), producing yarns in the 500 to 4000 dtex count range. Maximum production speed is 4000 m/min (polyamide) and 3000 m/min (polypropylene).

Great efforts has been made to improve quality, and there is a continuing development target of increasing dyeing uniformity in such a way that stripe-

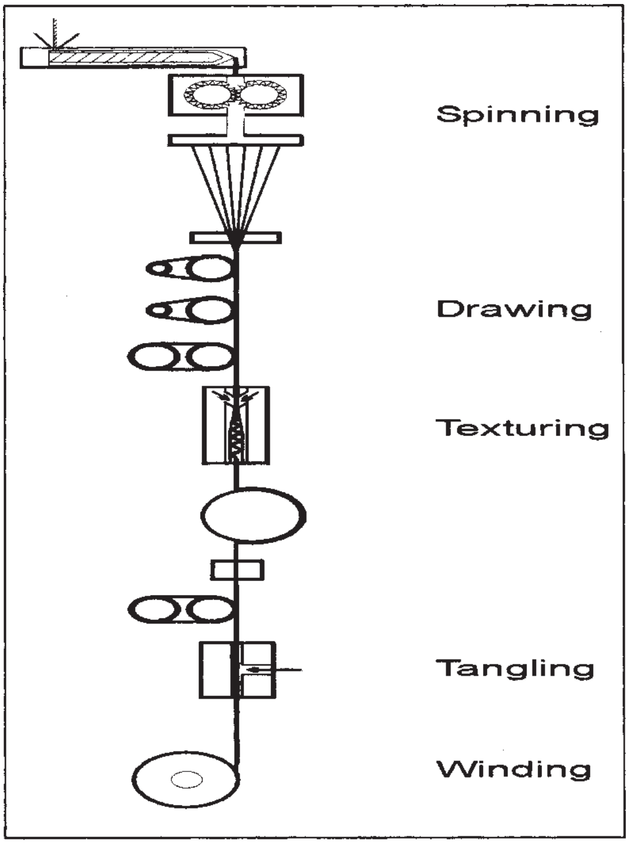


Fig: BCF process.

free cut loop carpets can be produced from BCF carpet yarns.

Carpet yarns, setting The twist of wool carpet yarns can be set with sodium bisulphite in a continuous process; for polyamides: → Heat setting of carpet yarns.

Carragheen (Irish moss, pearlmoss, kelp). Dried seaweed (North Atlantic), negligibly or extremely ramose, wide and narrow, pointed, with fine fibres, 7–15 cm long, bleached, hard and cartilaginous, almost odourless, reddish blue to violet, bleached yellowish and browned. Approx. 80% mucilaginous substance content; since it is used as a handle finishing agent, no incrustation should occur. May not react acidically when bleached. Swell in cold water, and then dissolve by boiling. Solutions: 25 : 1 still jelly-like, 30:1 stiffening mucilage (does not colour blue with iodine solution as does Iceland moss; produces sugar-like compounds when boiled). Use: as a chemical finishing agent ("natural finish" for cotton = supple-voluminous stiffness, with no real hardness; also for wool), used as a clarifying, stiffening or gelling agent.

Carrier (Dyeing accelerators, accelerators, carrier substances, carriers). Chemical compound for increasing the dyeing speed and the thorough dyeing properties of synthetic fibres (particularly polyester, triacetate, PVC) at or below 100°C. Numerous theories exist concerning the mode of action, of which the following are the most likely:

1. Carriers act as dye solvents: a strengthening of the dye occurs at the fibre/liquor phase interface.
2. Swelling action of the carrier: loosening of the van der Waals forces or hydrogen bonds between the fibre chains.
3. Lubricating action by the carrier on the dye and the fibre.
4. Vein or hole formation in the fibre structure (supporting the formation of free volume).

X-ray investigations showed that even with water treatment at 100°C, a noticeable rise in the degree of crystallinity occurs. In the presence of carriers, this increase is even more significant. It was also possible to establish structural improvements in the crystalline areas. The increase in the degree of crystallinity appears to take place, to a considerable extent, at the expense of the originally present mesomorphic areas which were poorly or moderately organised. The remaining amorphous areas thus become more accessible, and the dye uptake capacity increases.

From infra-red spectroscopic measurements made on polyester, it can be concluded that the pre-diffusing carrier is absorbed by the material, but above all (insofar as it is constitutionally capable of this) it is relatively strongly bonded to the polyester molecule through hydrogen bonds. This is apparent from the OH valency variation band, which displaces itself after the longer frequency range. The pre-diffusing dye displaces a more or less large proportion of the bound carrier. A requirement for this is that the dye itself likewise carries groups which, possibly more strongly than the carrier, are capable of hydrogen bonds or dipole interaction with the polyester. The dye molecule will penetrate deeper (possibly also faster) into the material the less the dye is held up on its diffusion path by polar centres or by dye/polyester hydrogen bond interaction. The pre-diffusing carrier has the task of blocking the bond-ready centres of the polyester molecule to a certain extent. The dye is thus not hindered on its diffusion path, or only slightly; it penetrates faster and more deeply. At the same time, it makes way more quickly for post-diffusing dye molecules; the dye uptake is increased.

The following requirements are made of carriers: cheap, effective at low concentrations, easy and safe to use, low odour, colourless, neither toxic nor skin-irritant, no effect on fastnesses and nuances of the dyeing, not sublimable out of the liquor bath, not very soluble in water and with good emulsifying properties, not too strongly bound to fibres (see Fig.), ecologically justifiable.

Main groups of carriers (Tab. 1):

I. Hydrophobic swelling agents, e.g. benzene, chlorobenzene, diphenyl, o- and p-phenyl-phenol, m-cresol: due to their good affinity to fibre, these products have excellent swelling action and can be effectively applied even in small amounts. A disadvantage in most

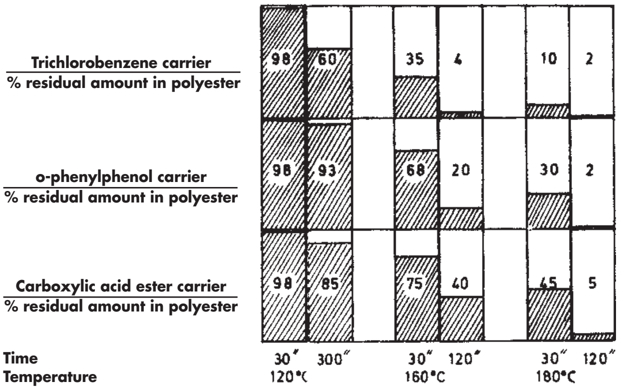


Fig.: Removability of carriers from polyester textiles in drying and thermofixing (shaded area: amount of carrier taken up by or remaining on the fibre).

	Chloro-benzene	Di-phenyl	Ester	Methyl-naphth.	o-phenyl-phenol
Levelling effect, dispersing action	I, II, III	I, II, III	I, II, III	I, II, III	I, II, III
Removability	III	II, III	II, III	I	I, II
Dye yield	III	II, III	I, II, III	II, III	II
Odour	II	II	I, II, III	I	II, III
Handling	III	I, II	III	II	II
Stability in storage	III	II	III	II	II
Mixed fibre reserve	III	II	I, II, III	II, III	II
Wetting, washing action	I, II, III	I, II	I, II, III	I, II, III	I, II, III
Ecology, toxicology	I, II	II	III	II	II
Compatibility	III	III	III	III	I
Volatility in steam	I	II	I, II, III	II	III

Tab. 1: Carrier examples.
I = critical; II = possibly problematic; III = non-critical.

Carrier type	Active substance %	Emulsifier %	Auxiliary solvent, other additives %
Chlorobenzene	70–80	10–20	10–20
Di-phenyl, type a	85	15	—
Di-phenyl, type b o-phenylphenol methyl naphthalin	30–60	10–20	60–30
Ester carriers	40–70	10–20	40–20

Tab. 2: Examples of carrier formulations.

of these substances is their toxicity and carcinogenicity, as is the poor lasting properties of the emulsion (forms a cream after boiling for a longer period).

II. Hydrophilic swelling agents, e.g. benzoic acid and its esters, benzyl alcohol: these substances are usually only effective when larger amounts are used, but have the advantage of being less toxic and, as a consequence of their simple emulsifying properties, they do not lead to drop formation even in open equipment.

For even distribution in the liquor bath, carriers mostly contain various added emulsifiers, and very often also other additives as well as solvents, in order to improve the emulsification behaviour, including storage stability (Tab. 2).

Carrier compounds Basic compounds or chemicals used as vehicles for other active substances performing a specific function (e.g. hydrogen peroxide on pyrophosphate = perpyrophosphate). They serve as a basis for certain compositions (e.g. in → Fragant finishes).

Carrier-free dyeable polyester fibres As is well known, the normal polyester fibre (polyethylenterephthalate) can be dyed at boiling temperature and normal pressure only if prior to that, carriers have facilitated the penetration of the dispersion dyes by loosening the fibre structure. After dyeing, these auxiliaries disperse partly into the air, partly into waste water, and can cause environmental problems. The remedy of reducing the amount of carrier, or eliminating it entirely, by using higher dyeing temperatures is precluded for sensitive fibre blend components. The obvious solution was therefore to develop a polyester fibre which already has the loosened structure, which can be created by carriers, to start with.

Polyester is a condensate of terephthalic acid and ethylene glycol. Of the numerous possibilities for increasing its dye affinity by incorporating additional components, the condensing of polyethene is of particular interest. Copolymers are created with statistically distributed polyalkylene oxide blocks, whose length and concentration determine the effect. Both the composition of the polymer and its processing into fibre must be carefully balanced in order to obtain the maximum advantageous characteristics. With the loosening of the polyester structure, there is the risk that valuable properties of the fibre which determine the good processing and performance behaviour are reduced. The desired high dye affinity of the fibre is to be achieved without seriously impairing important properties, such as e.g.

- modulus,
- fibre strength,
- shrinkage,
- fixability,
- dyeability in all shade depths,
- good light fastness and wet fastness of the dyeings.

The processing properties of the fibre, as well as the quality, e.g. wear resistance, shape retention, crease recovery of the resulting article must be preserved.

Carrier residues, removal Since residues of carriers can impair the light-fastness of dyeings, particularly on polyester, they are best removed through reductive final scouring with soda lye and sodium dithionite.

Carrier rollers Provided in order to prevent slippage of the rollers.

Carrier stains When working with carriers, darker dyed stains (carrier stains) can occur on the textiles to be dyed. These stains can be difficult to remove, and are due to inexpert working practices. Causes:

- poorly dissolved or poorly dispersed carrier;
- carrier is volatile in steam, condenses on colder dyeing unit parts and drips back onto the textile material;
- in the case of poorly cleaned dyeing units, the carrier dissolves out residues of grease, dirt and dyes, which end up on the textile material.

Carrier stains are hard to remove, particularly in goods of polyester/wool. In some cases, stripping helps removal of carrier residues.

Carrier system Relates to yarns (dyeing machine suspension system) for ladies' hose, which are treated in specific hose dyeing machines suspended over sticks in bundles. Sometimes also usable for hank yarn.

Carrotting The steeping of hare and rabbit hair in mordant. A term from the hat-making industry. The best mordant for this is the mercury nitrate mordant, where mercury is not released (incorporated into the hair keratin). Consequently there is an increase in weight and stable setting. No pre-treatment is required for dyeing, since the material is kneaded for several hours at 90°C with sulphuric acid (pH 3). All peroxide mordants damage the material; this results in weight loss, unstable setting, carrotted material is not stable in storage, felts lose stability, i.e. become loose over time.

Cartridge filter Consists of fine-pored, specially impregnated paper with activated charcoal additive (for tetrachlorethene, on account of the greater danger of marking off) or without activated charcoal. Cartridge filters differ from precoated filters particularly in dispensing with filter powder (this eliminates a precoating operation). Cartridge filters are used for dry-cleaning machines up to 18 kg charge weight (minimum throughput of 1500 kg of normally soiled fabric per pair of cartridges). → Sewerage-filter-systems.

CAS, abbrev. for: Chemical Abstracts Service. → CAS Index Number.

Case cord Continuous filament case cord yarns and steel cord yarns are woven to form the load-bearing plies forming the carcass or body of a vehicle or aircraft tyre or heavyweight conveyor belting, drive belts etc.

Casein Protein product of animal (milk) or vegetable (legumes) origin. Powder and small granules, horny, almost white to dull yellow. Water-soluble (if necessary with the addition of sodium tetraborate, ammonia, soap and the like). No coagulation when heated, cold coagulation by mineral acids. Solution: gelatinous, slightly foaming (prevented by glycerine, turpentine oil, Turkey red oil). Conservation necessary (formaldehyde). Precipitation by acetic acid (soluble in excess), hydrochloric acid (soluble in excess of diluted casein solution, greater excess = renewed precipitation), decomposition by tannic acid, metal salts, enzymes. Use: as size and print thickener.

Casein fibres → Man-made protein fibres of animal origin (milk protein). The casein is separated from the whey, dissolved in caustic soda, and spun in a precipitating bath with sulphuric acid, sodium sulphate, sodium chloride and, if necessary, formaldehyde (harden in formaldehyde). Casein fibres were the most important regenerated protein fibres, as they have a certain similarity to sheep's wool, and are consequently particularly suitable for blends with it. Use is limited however due to their rather moderate strength and elongation values (8–11 cN/tex, 50–70%), and their high strength loss and plasticity in the wet state.

Casein plastics (Galalith). Horn-like plastic of paracasein hardened with formaldehyde, which is used mainly for buttons. Density 1.32; burns with difficulty. Yellowish white and dyed in the mass or later (in the latter case, white ground visible on scratching with a knife) also coloured in layers, marbled, low lustre (sprayed with cellulose lacquer) or high lustre (bleach liquor process). Properties: insoluble in water, acids, alcohol, benzene, chlorinated hydrocarbons (cellulose lacquer is soluble); thermoplastic. Subsequent dyeings are often brightened in a soap wash; shade loss mostly with hot alkali treatment. Casein plastic buttons should be detached prior to wet treatment and redyeing.

Cashgora Although fine animal hair makes up only about 0.11% of the total world production of textile fibres, due to their high raw material price these fibres (see Tab.) have attained particular economic importance. In general parlance, no distinction is made between wool and fine animal hairs; nevertheless the German Textile Labelling Act provides for "wool" to mean the fibres of the coat of the sheep. Fine animal hair types are named with or without the suffix "wool" and hair. Animal hair fibres.

Cashmere means the fine bottom hair of the cashmere goat, which is separated out from the bristly hair by combing. Mohair means the hair of the angora goat, which consists of long, glossy, wavy fibres and which is obtained by shearing. Both types of goat were intro-

Fibre	Fineness (µm)	Length (mm)	Price level (£/kg)	Producing countries
Mohair	24 - 40	75 - 100	6 - 18	South Africa, Texas, Turkey, Australia
Cashgora	19 - 22	50 - 60	8 - 20	New Zealand, Australia
Cashmere	15 - 19	25 - 90	35 - 70	Tibet, China, Mongolia, Iran, Afghanistan, Australia, New Zealand
Camel hair	18 - 26	29 - 120	10 - 12	China, Mongolia
Alpaca/llama	22 - 25	75	12 - 15	Peru, Chile
Vicuna/guanaco	10 - 20	30 - 50	150 - 200	Peru, Chile
Angora	11 - 15	25 - 50	20 - 30	China, South America, France
Yak	19 - 21	30 - 50	15	Tibet, China, Mongolia

Tab.: Characteristics of fine animal hair fibres.

duced into New Zealand from Europe and Asia. Cashgora means the fine bottom hair of the cashgora goat, which is the result of cross-breeding female cashmere goats and male angora goats in New Zealand. It was only in the 19th century that the finest bottom hair was discovered in some of these wild goats. Cross-breeding trials of these animals were first undertaken in order to reduce the proportion of coloured bottom hair, since it is with the genes of the male angora goats that the feature "white colour" is passed on to descendants.

Cashgora goats have a thick, white coat of a coarse coat and fine bottom hair, which is obtained by shearing. The cashgora quality can be divided into three categories, depending on the degree of cross-breeding, with the first cross yielding the finest fibres. Each further cross with angora goats leads to a coarser quality, similar to mohair. Classification is thus according to fineness, which lies between that of cashmere and mohair, at 17-23 μm. Like all keratin fibres, fine animal hair fibres too have all structural elements such as cuticula, matrix fibrils and microfibrils; although their proportionate distribution differs.

A comparison of the dyeing behaviour of cashmere and cashgora shows that both animal hair types can be dyed with the most conventional wool dyes, under corresponding dyeing conditions, in the same manner. There are no significant differences with regard to evenness, shade, depth and fastnesses. The changes in properties which the fibres may suffer during dyeing or in subsequent processes depend, amongst other things, on pH and temperature, and as a result of the attack on the fibre lead to substance losses, loss of strength and yellowing. In the changes in properties, detected by the usual analytical methods, in each case it is shown that the change in property depends more clearly and starkly on the treatment conditions than on the animal species. Greater differences do occur in individual values, but these cannot be interpreted in the form of a clear demarcation between cashmere and cashgora. The heavily deviating ratio of matrix-forming to helix-forming protein components between the Mongolian cashmere and cashgora from New Zealand does not have any consequences for practical dyeing, whilst the differing structure of the scale layer and the fibre finenesses becomes apparent in the differing felting behaviour.

Cashmere Goat hair, belonging to the group of natural protein fibres, from the cashmere goat, which is native to the Kashmir mountains and which these days is also bred or lives wild at great altitudes and in extremely cold conditions in northern India in the Himalayan region, southern Russia and Asia Minor. The cashmere hair is obtained at the time of moulting by pulling, combing out or shearing. It is subsequently sorted and classed. The fleece weight per goat per annum is about 0.3–0.6 kg downy hair, which usually has to be washed. The bristly hair (50–75%) is up to 300 mm long, coarse and smooth, and is separated from the valuable bottom hair by combing. The downy hair has a silky lustre, and is wavy and soft. The colour is rarely white, usually grey, brownish and blackish. The length is 40–90 mm, the fineness 10–20 μm, which corresponds to the finest merino wools. The tensile strength is relatively low. The handle is particularly soft and pleasant. The quality is determined by the colour (the lighter it is, the more valuable), and by the proportion of bottom hair. Cashmere is spun in pure form and in blends, primarily of finest merino wool, natural silk, cotton and synthetics. Worsted yarns are used for knit goods, necktie fabrics and hand-woven shawls; carded yarns are more frequently produced and used for fine cloths and fabrics for ladies' wear, with a napped or fleece-like surface. Animal hair fibres.

Cashmere wool → Cashmere.

CAS Index Number Chemical substance identification number according to CAS (Chemical Abstracts Service). It is used in virtually all international chemical documentation systems and affords quick access to further data on the respective substance.

Caster chair test → Castor test.

Casting resins → Polyester resins.

Cast iron → Iron.

Castor oil Viscous oil from the castor bean, light yellow to brown, odourless. Dries slowly in air, transparent alcohol soluble. Contains the triglyceride of ricinoleic acid: $C_{17}H_{32}(OH)COOH$. Density 0.960–0.964. Use: production of soaps, Turkey red oil and as an additive to printing pastes.

Castor oil soaps Use as an auxiliary agent product, e.g. hard soaps and for brightening and chemical finishing.

Castor test Mechanical carpet testing machine for investigating whether carpets are suitable for being subjected to office chairs with wheels. Changes in visual appearance are graded 1–5. In the course of this, the carpet backing can be damaged. In the case of high-filled foams (up to 300%), the foam strength is too low (foam is loosened from the carpet). Fundamentally, castor-proof carpets have to be glued over the entire area; wheeled chairs should contain rollers in accordance with DIN 68 131 (other rollers can cause considerably more damage).

Casual wear Synonymous with → Leisure wear, progressing in the mid 1970s to cover unconventionally more flamboyant garments combining greater comfort with more youthful style features, being lighter in weight and more yielding to the body, with highlighted stitching (of collars, pockets, belts etc.) and above all easy-care properties.

Catalysis (Gk.). Accelerating a chemical reaction by reducing the activating energy with the aid of catalysts. The reaction rate is changed. Types of catalysts:

I. Homogeneous catalysts: the catalyst has the same state of aggregation as the reacting substances.

II. Heterogeneous catalysts: the catalyst is generally solid, and the reaction partners are liquid or gaseous.

Many processes take place in nature in the form of catalysis, enzymes acting as catalysts (biocatalysts). Catalytic processes play an important role in industry.

Catalyst There are chemical processes which have states of equilibrium which lie largely on the product side; but as they reach equilibrium only very slowly, they are of little practical value for substance synthesis. In many cases however, the time required for reaching a state of equilibrium can be greatly reduced by the addition of a substance which in fact participates in the reaction but is not consumed in it. These substances are called catalysts. The way in which a catalyst participates in the mechanism of a reaction remains unknown in some cases, but the following generalised statements can be made as regards its action: a catalyst reduces the activating energy of the reaction process, a much larger proportion of the molecules participating in the reaction achieving the necessary energy E_a.

In this way, the reaction rate increases under otherwise unchanged conditions. The activating energy of the opposed reaction – the so-called back reaction – is also reduced. As both the rates of the reaction and the back reaction are affected by the catalyst in the same way, the time required for establishing equilibrium is reduced (Fig. 1).

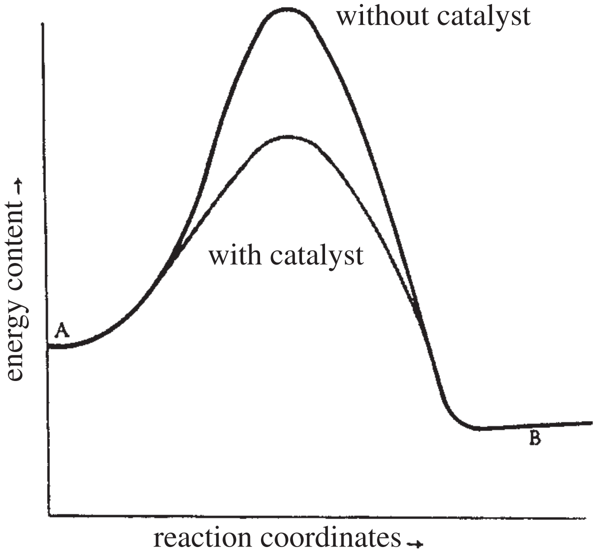


Fig. 1: Energy profile of a catalysed and a non-catalysed reaction.

Conversely, there are also substances which, when added to a reaction mixture, slow down the reaction by increasing the activating energy; they are known as negative catalysts or inhibitors. A catalyst can be a solid metal surface on which the reaction takes place, a hydronium ion (H_3O^+) in aqueous solution or any other substance.

Catalytic processes can be divided into four groups:

1. Catalysis in the flame, particularly thermal catalysis.
2. Homogeneous catalysis in solutions, particularly acid or base catalysis.
3. Heterogeneous catalysis, particularly with redox systems on large surfaces.
4. Enzyme catalysis, particularly on the key/lock principle.

Catalytic exhaust air purification is a process that is applied when catalyst poisoning can be excluded (Fig. 2). A new generation of catalysts expand the industrial field of application. In spite of the high resistance to catalyst poisons, no heavy metals should be contained in the exhaust air, as this would substantially reduce the normally very long lifetime of the catalyst.

Dürr Ecopure-KAR units can be applied for low pollutant concentrations, and they achieve excellent combustion efficiencies. The raw gas is pre-heated to the catalyst start-up temperature by a heat exchanger tailored to the specific application, and subsequently ducted through a high-performance precious metals catalyst. At temperatures between 200°C and 350°C the hydrocarbons are oxidized and are transformed into harmless H_2O and CO_2. A catalytic system is only suitable when pilot tests have shown successful results. For such tests Dürr has several different compact pilot units.

Catalysts for resin finishing The cross-linkers commonly used in resin finishing are used only with the addition of catalysts, which act as cross-linking reaction triggers and as reaction accelerators. The action of these catalysts is based on the freeing of hydrogen ions. Catalysis (acid), breaks the carbon/oxygen linkage of the N-methylol groups, and a reaction takes place with the hydroxyl groups of the cellulose with the discharge of water. The catalyst has three basic functions:

1. Establishing equilibrium between the N-methylol compound and the formaldehyde split off from it.
2. Dispensation of the formaldehyde consumed by cross-linking.
3. Catalysation of the cross-linking of the N-methylol compounds and the formaldehyde with the cellulose.

The reaction mechanism should be in accordance with the following diagram.

The catalyst increases the hydrogen ion concentration during condensation, increasing the reaction speed. All catalysts used in the resin finishing of cellulosic fibres in combination with N-methylol compounds are either latent or potent acids. The latent catalysts develop their acidity (acid content) only when heated (condensing); the potent acid catalysts already

Catalyst for resin finishing

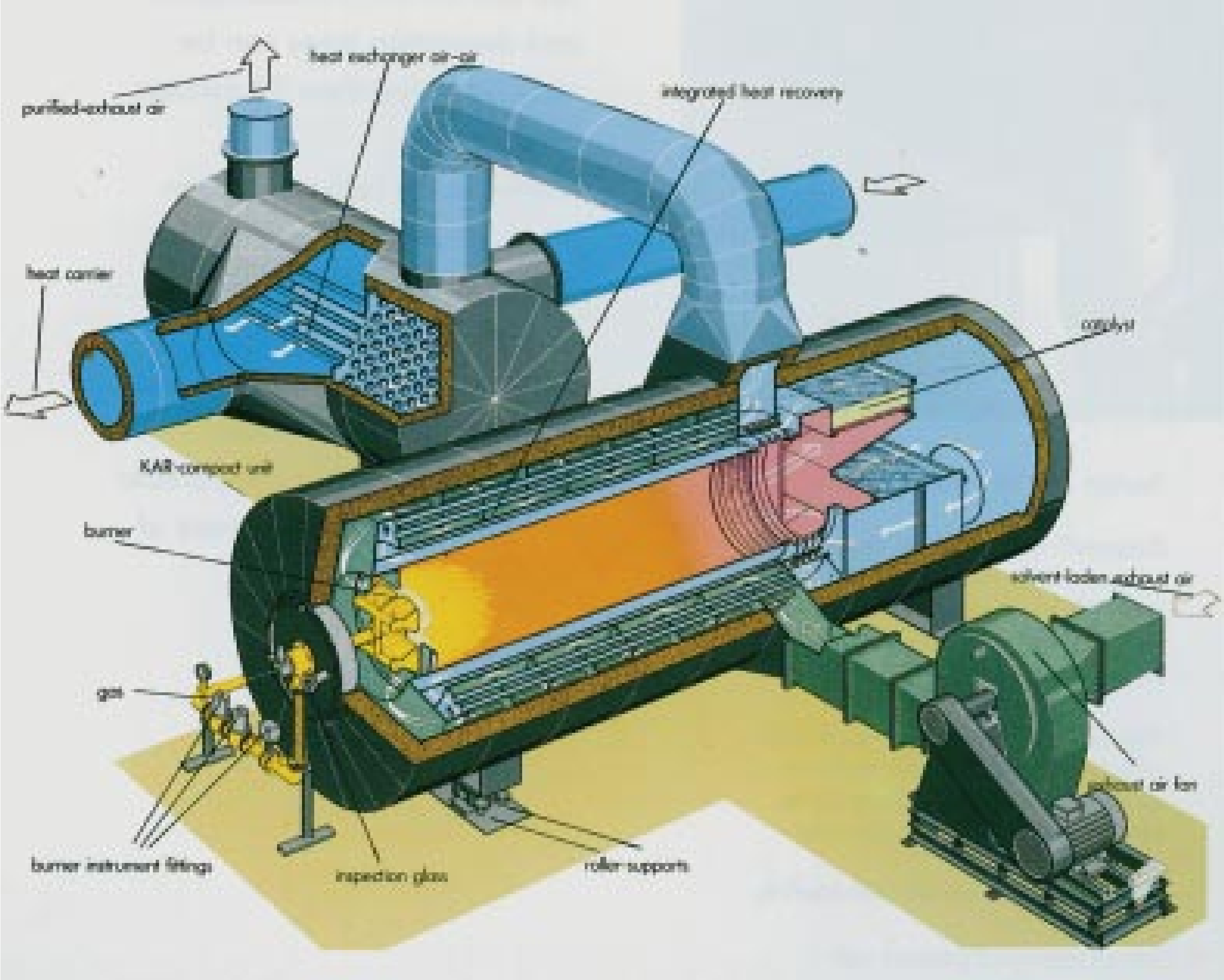
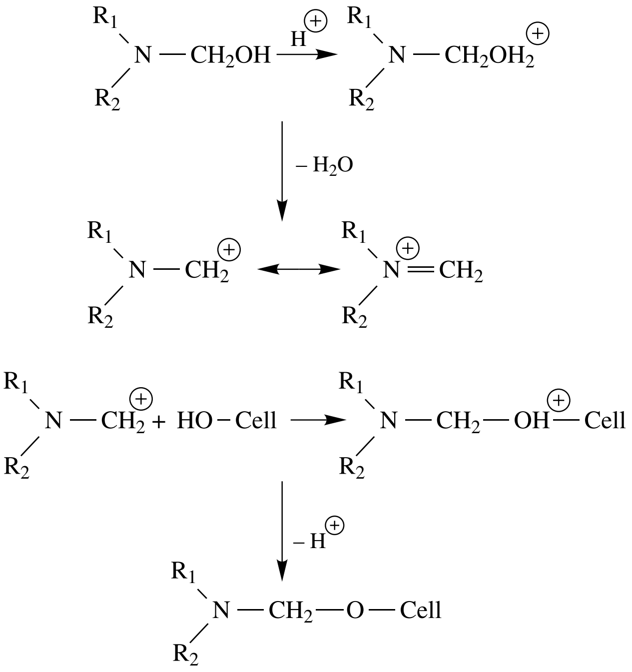


Fig. 2: Catalytic exhaust air purification.



react acid in the bath. In order to obtain optimum finishing effects, the type of cross-linker, the type of fibre to be finished, the condensation conditions, the requirements on the finished fabric plus possible fabric shade changes should play a part in catalyst selection. From the technical processing standpoint, the catalysts, like the cross-linkers, are divided into three groups:

Type of finishing (Fibre swelling state)	Type of catalyst	pH
Dry cross-linking (not swollen)	metal salts ammonium salts	3– 6
Moist cross-linking (partially swollen)	mixed catalysts free acids	1– 2, 5
Wet cross-linking (swollen)	free acid free alkali	0– 1,5 10– 12

Tab.: Common catalysts for dry, moist and wet cross-linking.

1. Catalysts for dry cross-linking,
2. Catalysts for moist cross-linking,
3. Catalysts for wet cross-linking.

Important for catalyst selection is the technical processing implementation of cross-linking and the state of fibre swelling (Tab.).

In addition to so-called complex catalysts, metal salt catalysts or ammonium salt catalysts are predominantly used for dry cross-linking. These types develop their full effectiveness only when heated or condensed.

Complex catalysts	high reactivity
Ammonium nitrate	
Ammonium sulphate	
Ammonium chloride	
Zinc nitrate	
Monoammonium phosphate	
Diammonium phosphate	
Ammonium oxalate	
Zinc chloride	
Magnesium chloride	lower reactivity

a) Complex catalysts are mixtures of metal salts of strong acids with complex-forming hydroxycarbonic acids (tartaric or citric acid). Small additions of these medium strength organic acids have a great effect, since the hydrogen ions are distinguished from the metal ions by their “minuteness” and great mobility. The organic acid (citric acid) is also catalytically active on its own, and one cannot therefore use the term synergism with this catalyst combination; added effectiveness on the part of the two components is involved here.

Complex catalysts are used mainly for cross-linking N-methylols with cotton and natural cellulose fibres. Fast reaction times and high temperatures can be selected owing to the high degree of acidity of these catalysts; moreover, loss of material tear strength due to hydrolysis is not to be excluded.

b) Ammonium salt catalysts are used predominantly for bathotonic resins on regenerated cellulose woven fabrics. With the use of these products, care should be taken to ensure that liquor stability is delimited, since the ammonium salts change the liquor pH, and condensation can therefore be triggered in the liquor. If the particle size of these precondensed contents has increased to such an extent that it can no longer penetrate the fibres, so-called deposition occurs. This leads to detrimental effects, to brittleness, and consequently to reduced abrasion resistance. Liquor stability decreases from ammonium sulphate, via ammonium chloride and ammonium nitrate to ammonium oxalate. The pH can change from pH 6 to pH 3.5 within a few hours when using ammonium chloride for example.

The reaction method of the ammonium salt catalysts is based on the following principle:

$$6\ HCOH + 4\ NH_4Cl \rightleftharpoons (CH_2)_6N_4 + 6\ H_2O + 4\ HCl$$

Formaldehyde reacts primarily with the ammonium ions to methenamine (hexamethylenetetramine, urotropine), releasing the relevant acid (hydrochloric acid). On the other hand, the ammonium salts split off in heating ammonia (NH_3).

– Ammonium nitrate NH_4NO_3: due to the high degree of reactivity, there is a danger of shade changes with dyeings which are oxidation sensitive. Optical whiteners can be impaired in terms of their light fastness. Fibre damage may be caused in addition if excessive condensation conditions are selected.

– Ammonium chloride NH_4Cl and ammonium sulphate $(NH_4)_2SO_4$: the two are about equally reactive, and are used in finishing polyamide/cellulose blends. They can replace ammonium nitrate owing to their low “aggressivity” levels.

– Monoammonium phosphate $(NH_4)H_2PO_4$: used for cotton, regenerated cellulose and their blends with polyester and polyacrylonitrile fibres. Also suitable for obtaining wash resistant calendered and pleated effects on cotton.

– Diammonium phosphate $(NH_4)_2HPO_4$: a buffer action catalyst which is frequently used in finishing cotton or regenerated cellulose with dimethylol urea.

– Ammonium oxalate $(NH_4)_2C_2O_4$: for special finishing processes such as stiff finishing on white polyamide fabric. Owing to its low reactivity, there is no yellowing.

c) Metal salt catalysts are used for preference in the finishing of cotton and its blends with synthetic fibres; in general linguistic usage, metal salts are also termed substances which give off acid. The action of most metal salt catalysts develops only on heating to above 100°C, i.e. in the unswollen state of the cellulose fibre. Magnesium chloride ($MgCl_2$) and zinc chloride ($ZnCl_2$) require condensation temperatures > 140°C; zinc nitrate ($Zn(NO_3)_2$ already reacts from 130°C. In decreasing activity sequence:

$$Zn(NO_3)_2 > ZnCl_2 > MgCl_2$$

The catalytic effectiveness of the salts is a complex result of different factors, and the acidity of the cation plus the nature of the anion are equally relevant. If one varies the cation within a group of the periodic system, e.g. of group 2a, with Mg, Ca, Sr, Ba with the same anion, e.g. the chloride, one observes decreasing effectiveness with increasing atomic weight.

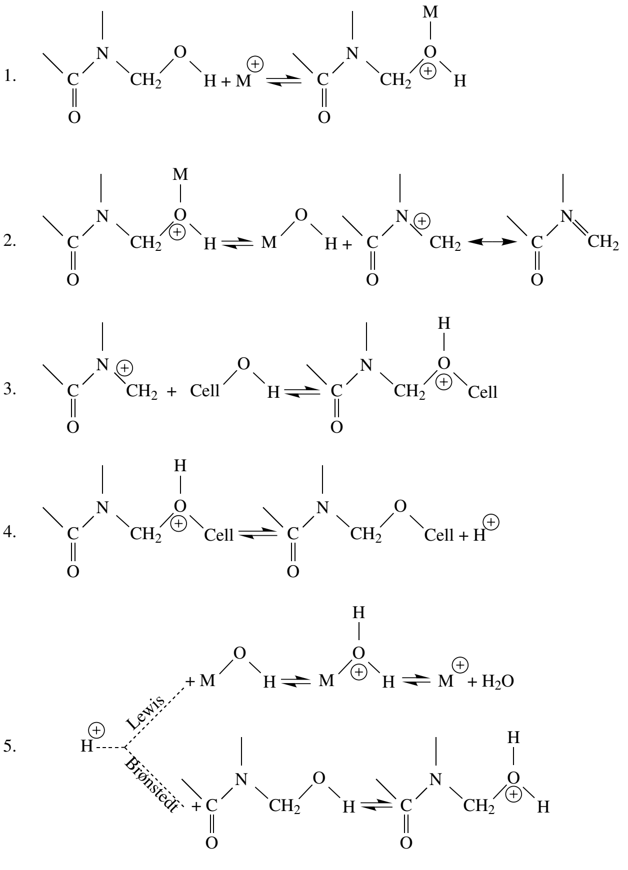
$$Mg^+ > Ca^+ > Sr^+ > Ba^+$$

This could be based on the fact that, with increasing atomic weight and presupposing the same anion, the acidity, i.e. the electron affinity, decreases, and mobility is also reduced due to the increasing ion size. The importance of the anion in the case of metal salt catalysts is revealed by magnesium and zinc salts in the following sequence of effectiveness:

$$NO_3^- > Cl^- > SO_4^{2-}$$

It should be noted with regard to the action method that magnesium chloride for example decomposes into magnesium oxide and hydrogen chloride only at temperatures above 800°C (conditions which do not in any case occur in dry cross-linking). Catalysis via self-forming acid (hydrochloric acid) is improbable therefore for metal salts. The salts must be catalytically effective in another way. Basically, one starts from the fact that metal salt catalysts catalyse cellulose cross-linking with N-methylols in the first place in accordance with the Lewis acid mechanism. Lewis defined the acids generally as molecules or ions which are capable of coordination with solitary pairs of electrons. He defined bases as molecules or ions which make solitary pairs of electrons available for coordination.

In principle, this mechanism is the same as in normal acid catalysis. The difference lies in the fact that the N-methylol-oxygen is protonised on the one hand by metal ions instead of hydrogen ions, while, on the other, metal hydroxide and not water is split off with the formation of the ureidomethyl ion (carbonium-immonium ion) stabilised by isomerism. The next step is the reaction with nucleophile hydroxyl groups of the cellulose to protonised cellulose ether.



The ureidomethylation reaction is concluded by hydrogen ion loss. The split off hydrogen ion can now either protonise the next methylol group directly in accordance with Brønsted catalysation, or, in accordance with Lewis, react with the metal hydroxide to form metal ions and water.

- Zinc nitrate $Zn(NO_3)_2$: is the most effective metal salt catalyst of the metal salts used. It is suitable for natural cellulose fibres and their blends with synthetics. Shade changes and the impairment of optical whiteners are possible.
- Zinc chloride $ZnCl_2$ and magnesium chloride $MgCl_2 \cdot 6H_2O$: predominantly for cotton and its blends with synthetics for low-crease finishing. Both are suitable for white fabrics and chlorine-fast finishes; the light fastness of optical whiteners is not affected.

Catalytic damage Oxidative changes or cellulose destruction (hole formation) caused by catalysts, thus reducing textile product service value. This fibre damage is attributable to the local enrichment of iron-containing compounds. If, e.g., cotton contaminated by minerals containing heavy metals is processed into yarn in the OE spinning process, it can become enriched due to the centrifugal forces of the mineral dust in the rotor, falling back from there as small compact particles on to the yarn as it forms. The high degree of punctiform enrichment has concentrations which amount to a multiple of the total iron compound content. It is not the total content therefore which is decisive, but the distribution and frequency of the catalytically acting particles in the textile product. Local enrichments are predominantly found in uneven distri-

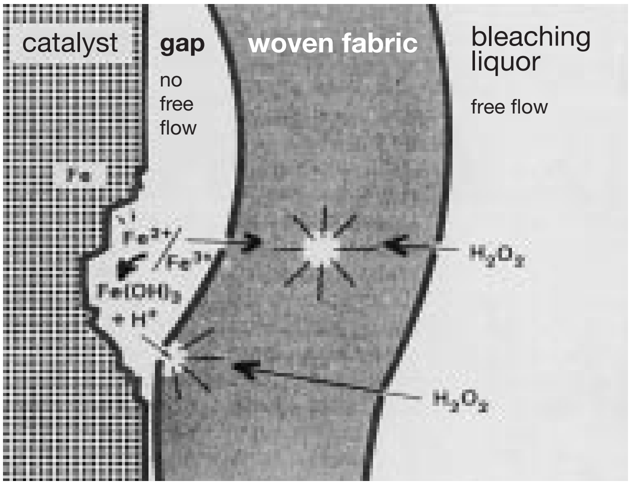


Fig.: Schematic diagram of catalytic damage occurrence (Meyer).

bution in rotor yarns, whilst an almost uniform distribution of iron compounds is present in ring yarns.

Catalytic damage in the bleaching process (→ Bleaching and catalytic damage) occurs in that, in addition to a local drop in pH due to the release of protons in the conversion into iron hydroxide, dissolved iron salts are formed. The prerequisite for catalytic damage is particles which quickly destroy either the fabric itself (e.g. protons, oxidising agents) or the peroxide, e.g. due to the meeting of iron ions (Fig.). This occurs when the active particles are locally present in a higher concentration, and the damage point of the fabric can be reached without difficulty.

It is difficult to imitate catalytic damage in the laboratory, since the severe catalytic corrosion of iron presumes first of all rust formation. Rust is formed in accordance with the formula

$$Fe + {}^{1}/2\, O_2 \rightarrow FeO$$
$$2Fe + {}^{3}/2\, O_2 \rightarrow Fe_2O_3$$

This is equivalent to an iron tube which decomposes after a few weeks in a moist atmosphere. Rust formation passes through the following phases:

- adsorption of oxygen (from the air) to the metal surface,
- migration of iron atoms with oxide formation at the surface, which leads to gaps in the molecular lattice of the metal,
- migration of iron atoms to deeper layers,
- further rust formation on the surface.

In this way, the initially compact crystalline structure gradually disintegrates.

Peroxide disintegration is accelerated by a multitude of substances and substance mixtures. The presence of such so-called catalysts in the bleaching liquor and/or in the textile product leads to spontaneous bleaching agent decomposition. Associated with this is extreme fibre damage which is expressed in such a way that the cellulose is oxidised to oxycellulose, and subsequently depolymerised. In peroxide decomposition, the peroxide is split into the radicals:

$$H_2O_2 \rightarrow HO^{\cdot} + HO^{\cdot}$$

due to the considerably reduced activating energy.

In addition to enzymes, bacteria, the textile substrate and dirt, heavy metals in particular, which occur in a number of valency stages, iron, copper, manganese, chrome and nickel for example act as catalysts. Iron compounds represent the largest proportion in cotton attendant materials. Heavy metals can make their way into or on to the textile product and/or the bleaching liquor in various ways. This happens mainly:

- due to the cultivation, growth and harvesting conditions of the different cotton sources,
- during textile material transport and storage,
- due to metal abrasion during production of the yarn and its processing into fabrics,
- due to corroding steam and water pipes,
- due to the feeding of technical chemicals,
- due to corroding stainless steels with locally damaged surfaces.

As regards catalyst action, a distinction is drawn between two types:

1. Contact catalysts.
2. Transfer catalysts.

Type 1 acts mainly by adsorption (chemisorption) of the peroxide on to active surfaces or centres. In the case of type 2, a distinction is drawn between: a) a catalyst which forms an unstable intermediate product with no change in valency, and which decomposes again with catalyst regeneration (with the splitting off of oxygen in the case of peroxide); b) a redox mechanism, i.e. the catalyst has two or more valency stages (e.g. iron), and is transferred by the peroxide from a lower to a higher valency stage, which then decomposes the peroxide by the splitting off of oxygen when the catalyst recovers its initial form.

The radical chain reaction can be explained by the Haber-Weiss mechanism with the example of bivalent iron:

Start: $Fe^{++} + HOOH \rightarrow Fe^{+++} + {}^{\cdot}OH + OH^{-}$

Chain: ${}^{\cdot}OH + HOOH \rightarrow H_2O + HOO^{\cdot}$

$Fe^{++} + HOO^{\cdot} \rightarrow Fe^{+++} + HOO^{-}$

$Fe^{+++} + HOO^{\cdot} \rightarrow Fe^{++} + O_2 + H^{+}$

End: $Fe^{++} + {}^{\cdot}OH \rightarrow Fe^{+++} + OH^{-}$

This mechanism applies to both iron(II) and iron(III) ions.

For the activity of a catalyst, i.e. for the quantity of peroxide decomposed in the unit of time, not only the type, the surface, the particle size and its structure are of prime importance, but also the pH of the liquor, its temperature and the dilution of the peroxide. The presence of a number of catalysts frequently results in the rate of decomposition being considerably greater than is equivalent to the sum of the individual components or partial reactions. This effect is described as a catalyst promoter effect or as a synergetic effect. A mixed hydroxide of copper, manganese and iron results for example in a hundred times quicker decomposition of peroxide. On the other hand, there are also substance combinations which depress peroxide decomposition. The reaction processes are much more complex in the case of a mixed catalyst, and sometimes are not precisely explained.

Promoter effect with the example of iron and copper ions:

$$Cu^{++} + HOO^{\cdot} \rightarrow Cu^{+} + O_2 + H^{+}$$

$$Cu^{+} + Fe^{+++} \rightarrow Cu^{++} + Fe^{++}$$

The $HOO^{\cdot}$ radical formed in accordance with the Haber-Weiss mechanism reacts with copper(II) ions with the formation of oxygen, the copper(I) ions occurring reducing iron(III) ions to bivalent iron on their part. This again triggers the radical chain reaction. In connection with mixed catalysis, even inactive substances or substances with very little activity, such as alkaline earth hydroxides for example, are of interest, becoming highly active catalysts through adsorbing metal ions. An example of this increased activity is the calcium, iron and copper(II) hydroxide three-substance system, where the calcium hydroxide itself is inactive. There is also the possibility, in the presence of alkaline earth ions or hydroxides, of reducing the activity of the mixed catalyst in terms of peroxide decomposition, e.g. in conjunction with silicate ions.

Catalytic damage in bleaching → Bleaching and catalytic damage.

Catalytic fading Mutual negative influence on the light-fastness of dyes in combination dyeing. The light-fastness of the combination dyeing is less than that of the components. Above all with some vat dyes, but also with some substantive and dispersion dyes (Blue eaters). A marked catalytic fading effect is present when for example two dyes with light fastnesses of 7 fall to grade 3–4 when combined. Occurs particularly with azo blue; less strong with anthraquinone blue dyes when combined with azo yellow, azo orange, azo brown, azo red brands. In the case of anthraquinone dyes, between them one finds no mutual reduction in light fastness, or only a very slight one. The impairment varies according to the proportion of the components.

CATCC, abbrev. for: Canadian Association of Textile Chemists and Colorists.

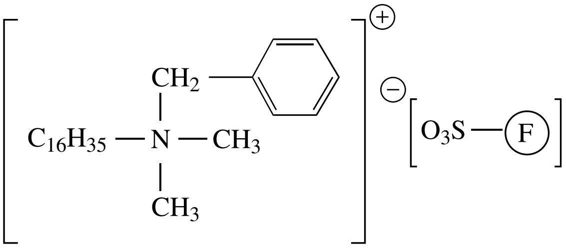
Catechu (cachou). From the Indian “Kati” plant and “chuana” = distil. Extract of the aqueous extract of the Indian tanner’s acacia. No longer used brown dye, formerly used for tent and covering fabrics, as the fabric was simultaneously endowed with natural waterproofing, increased weight and a fuller, harder handle.

Cathode (Gk.: kathados = a downward path). Derived term for the negatively charged → Electrodes (negative pole), through which the negative current in the electrolytes emerges (into which the positive current from the electrolytes enters). During current passage, the cations move to the cathode, and are charged there, cathodic reduction processes etc possibly taking place. Working materials frequently used in cathode technology are precious metals, iron, copper, zinc, aluminium, lead, cadmium, titanium and graphite.

Cation exchanger → Ion exchanger.

Cationic General term in the surfactant field for positively charged, surface active, hydrophobic carbon compounds with ionically reacting groups. Antonym: anionic.

Cationic aftertreatment The most important method for improving the fastness of dyeings made with direct and union dyes and which can have a very considerable effect on fastness to water, washing, perspiration, wet ironing and cross-dyeing (usually by 1–3 fastness ratings). Principle: conversion of the anions of the dyestuff on the fibre into sparingly soluble or insoluble salts of the dyestuff acid, e.g.



Although the principle applies to all anionic dyes, the improvement in fastness differs to some extent, depending on the molecular weight of the dyestuff and the number of sulpho groups. In addition, a definite minimum amount of the cationic product is required, which may vary according to the product, so that specified average amounts should be used in all cases. Cationic products are therefore fastness improving agents.

Working method: after dyeing, rinse well, apply 1–4% for an exhaust process, 5–20% for a continuous process, at pH 5–6 for 15–30 min at 20–60°C, according to the cationic product. Rinsing is usually required. Processing faults: use of too little product, insufficient rinsing after dyeing (poorer rubbing fastness), sometimes the water used for rinsing is too hard (reduced fastness to rubbing and washing; for this reason it is better to rinse with soft water at first and, if necessary, add hard water gradually). It must also be taken into account that different products have different sensitivities to sodium sulphate and hard water and will have a greater or lesser effect on the shade of the dyeing and may possibly lead to poorer light fastness. With products that affect the light fastness, combining aftercoppering with the cationic treatment can often compensate because of their opposing effects on the light fastness. The same idea lies behind the cationic resin-metal salt aftertreatment for simultaneously improving the fastness to light and wet treatments.

Cationic polymers react with anionic dyestuffs to form salts, so-called polymer salts. The primary driving force is purely electrostatic in nature, with binding forces of 30–60 kJ/mol. This type of polymer salt is insoluble in water as well as in organic solvents, and it is primarily this insolubility that produces the good contact fastnesses of dyeings after fixation. Apart from the pure electrostatic interaction, however, when two molecules approach one another sufficiently closely, other binding forces also come into play; these are hydrogen bonding, van der Waals' attractive forces and above all hydrophobic interactions. Hydrophobic forces have a significant effect on the washing fastness of dyeings. If the aftertreating agent has other functional groups apart from the quaternary ammonium groups, e.g. –OH; =NH; $–NH_2$; –C≡N or guanidine groups, a complex can be formed with metal-containing anionic dyes. This type of bond is very stable, hardly affected by external variables and leads to very high contact and washing fastnesses with metal-containing reactive or substantive dyeings. Atomic bonds can also be formed between the aftertreatment agents, the dyestuff and sometimes the fibre as well. The binding forces in these cases are 3–4 kJ/mol. This sort of bonding can take place when the aftertreating agent is modified with reactive groups and the dyestuff and fibre also have functional groups such as –OH or $–NH_2$. This type of bonding can produce high fastnesses, up to being fast to washing at the boil. It can be a serious disadvantage that this type of product cannot be removed from the fibre in practice and cross dyeing is extremely difficult. However, reactive products are being used increasingly in sulphur dyeing where they react mainly with the –SH groups of the dyestuffs and there is scarcely any reaction with the cellulose.

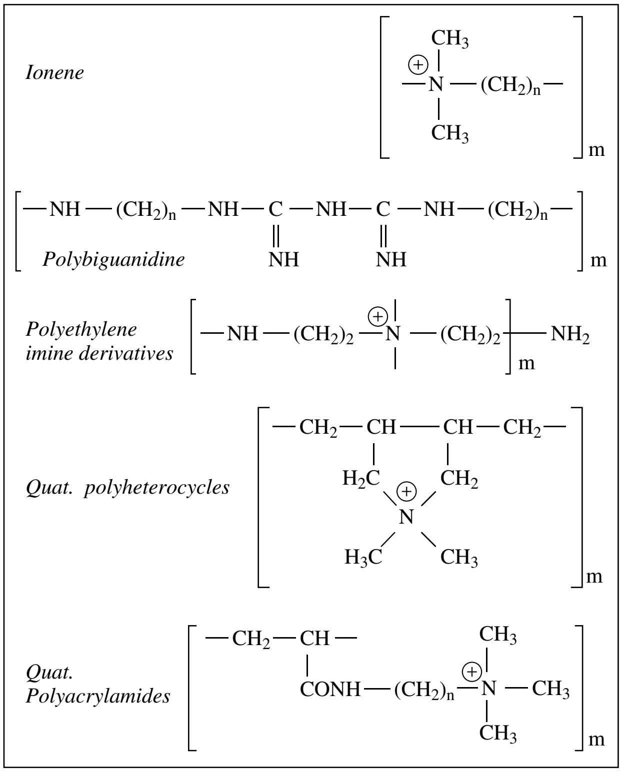


Fig. 1: Structural features of some aftertreatment agents.

A common feature of all cationic aftertreatments is the presence of at least one quaternary ammonium group in the molecule; this gives affinity to the fibre as well as reacting with the dyestuff. Apart from these, other polar or even reactive groups, the molecular weight as well as the supramolecular structure of the cationic polymer play a role.

Fig. 1 shows structural features of some of the aftertreatment agents that are in current use. The list is not complete as many variations with heteroatoms such as oxygen and sulphur are possible within these basic structures.

The quaternary ammonium groups give the affinity for the fibre as well as reacting with the anionic dyestuffs. Cellulosic fibres have a negative zeta potential, so that positively charged ions are attracted to the surface of the fibre. This takes place very rapidly. The positive ions neutralize the negative charge centres at the fibre surfaces and can even lead to an inversion of the charge to a positive zeta potential.

Fig. 2 shows zeta potential measurements on cotton fibres in the presence of cationic polyelectrolytes.

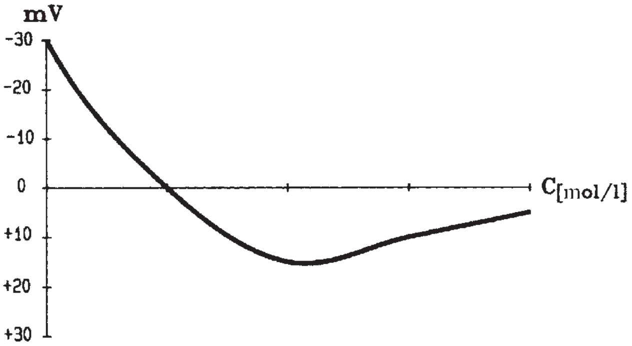
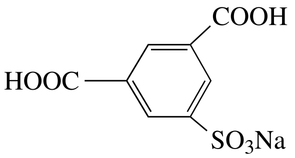


Fig. 2: Dependence of the zeta-potential of cotton fibres on the concentration of cationic polyelectrolyte.

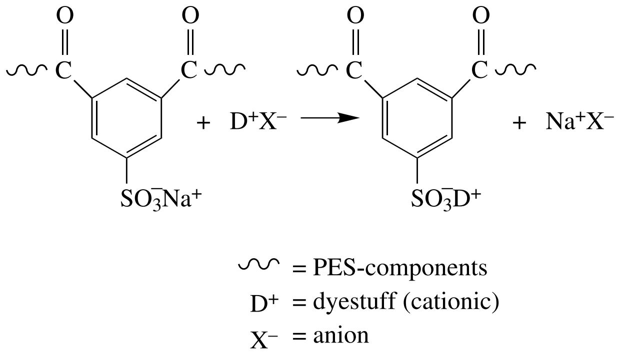
This situation however means that only a limited amount of cationic polymer can be bound to the fibre surface, as the change in potential of the cellulose fibre surface very quickly leads to repulsion of subsequent cationic molecules. The amount that is bound is almost independent of the structure of the compound and of other parameters, such as time, temperature or pH. The saturation value depends on the fibre and is reached quickly, assuming that diffusion into the interior of the fibre does not occur or only occurs very slowly (Contributed by Fischer).

Cationically dyeable polyester fibres Polyester fibres can be modified into cationically dyeable polyester fibres by the copolycondensation of terephthalic acid and 5-sodium sulphoisophthalic acid with ethylene glycol.

Cationic-dyeable polyamide



Dyeing mechanism:

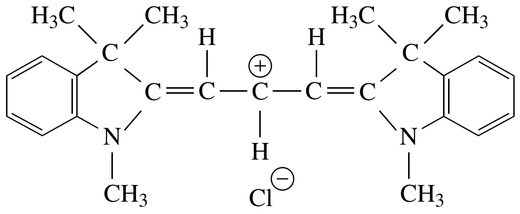


Cationic-dyeable polyamide → Differential dyeing polyamide fibres.

Cationic dyes (basic dyes). Included here are all salts of organic dye cations applicable in accordance with an ion exchange mechanism. They belong among the oldest synthetic dyes, can be fixated on practically all natural fibres, and were therefore of great importance in earlier days. The most important textile application field today is polyacrylonitrile dyeing and, to a lesser extent, anionically modified polyamide dyeing. Among the cationic dyes strongly represented are anthraquinone and azo dyes with quarternary ammonium or phosphonium groupings, plus cyanine and hemicyanine dyes, the methine groups of which are partially or completely substituted in the cyanine chain by nitrogen. Cationic metal complex dyes have been suggested in the patent literature for dyeing polyacrylonitrile fibres. Anchoring principles on polyacrylonitrile and anionically modified polyamide: the anionic nature of polyacrylonitrile fibres is based to some extent on the sulphuric acid semi-ester groupings which are derived from the persulphates used as starters in polymerisation. To this are added sulphonate groups of comonomers which substantially improve the dyeability of the polymerisate. These ionic substituents will not be associated with protons, even in a strongly acid medium. Ion exchange, i.e. the absorption of the cationic dye, cannot therefore be controlled by dyebath pH. In the interest of levelness therefore, one operates in accordance with the principle of "concurrence around the bonding points" with cationic retarding agents (retarders). Anionic retarders, which the dye cations virtually freeze in the form of difficult-to-dissolve finely distributed salts in the presence of dispersing agents, operate on the opposite basis. Of advantage for most cationic dyes is the conspicuous brilliance due to a narrow, steep absorption band, which goes along with high colour intensities and favourable production costs. The disadvantage is unsatisfactory light fastness, which impairs finish dyeing particularly on hydrophilic fibres.

Dyes, the total molecule of which is positively charged in dissociation in water, qualify as cationic. Typical representatives are:

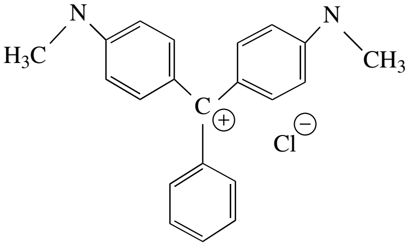
1. Cations in carbenium structure form:
   - Polymethine dyes as cation cyanines.



Carbenium structure

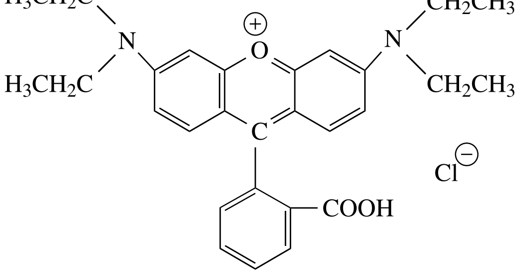
   - Triphenylmethane dyes, e.g. malachite green.

Carbenium structure



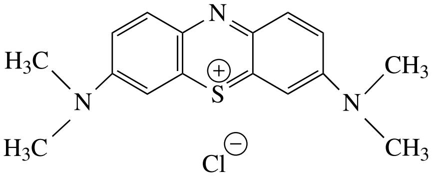
2. Cations in oxonium structure form:
   - Xanthene dyes, e.g. Rhodamin B.

Oxonium structure

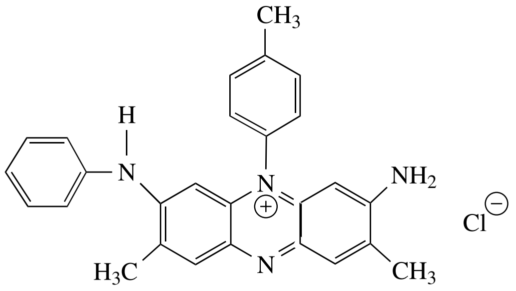


3. Cations in sulphonium structure form:
   - Phenthiazine dyes, e.g. methylene blue.

Sulphonium structure

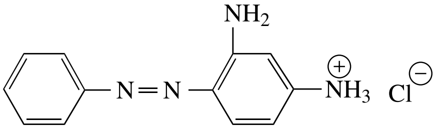


4. Cations in ammonium structure form:
   - Phenazine dyes, e.g. mauvein



Ammonium structure

or chrysodine.



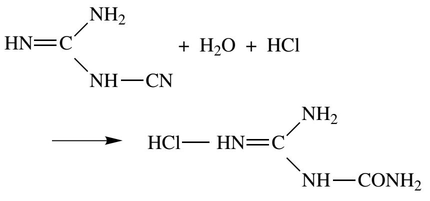
Cationic pretreatment This treatment – also called mordanting – is used with cellulose fibres in order to make them absorptive to cationic dyestuffs. Such mordants are tannin, sulphuretted phenols etc.

Cationic protein derivatives Quarternary "Croquats" for hair care cosmetics with polypeptide chain and fatty alkyl groups are also interesting from the textile chemical standpoint. 3 types of different alkyl groups:

Type L: contains the $C_{12}H_{25}$ alkyl group;
Type M: contains the $C_{10}H_{21}$-$C_{18}H_{37}$ alkyl groups;
Type S: contains the $C_{18}H_{37}$ alkyl group.

Have marked surface activity properties (wetting, foaming), biocidal activity (slightly germicidal), and at the same time are much more substantive than conventional protein derivatives.

Cationic resin Salt-type but high molecular condensation product synthetic resins of similar construction to cationic textile auxiliary agents, which are more or less water-soluble despite a high degree of cross-linking, have available adequately salt-forming groups with acids, and are therefore split into ions to some extent in aqueous solution, the resin-forming components being present as cations. Thus for example, dicyandiamide can be condensed with formaldehyde in the presence of hydrochloric acid, part of the dicyandiamide becoming saponified to dicyandiamidine salt:



$$\mathrm{HN{=}C(NH_2)(NH{-}CN)} + \mathrm{H_2O} + \mathrm{HCl} \longrightarrow \mathrm{HCl{-}HN{=}C(NH_2)(NH{-}CONH_2)}$$

The condensation product obtained is water-soluble. Through suitable mixing of the amine salts of more strongly basic amines in acid condensation with formaldehyde one obtains the most favourable proportions in terms of solubility and cross-linking. Such cationic resins also react on the principle of → Cationic aftertreatment as compared with anionic dyestuffs, insoluble salts forming from the resin cation and the dyestuff anion. Tendency to a lower degree of shade change than with cationic textile auxiliary agents, the softness of which is achievable with a small addition of cationic softener. With relevant dye selection (copper after-treatment dyestuff and sulphur dyes too in part), cationic resin combination products with copper salt provide good light fastness in addition to very good fastness to washing up to 60–75°C in the dyeing of spun glass yarns, in wet and dry strength improving preparation for glass fibres, in washing and cross-dyeing fast delustring, and with water-repellent agents, flame retardant agents (phosphoric acid counterions) etc.

Cations → Ions.

Cat's eye resin → Dammar resin.

Cattle hairs (cows' hairs). The most valuable from the technical spinning standpoint is the tail hair, similarly also curry comb hairs. In contrast is tannery waste hair, which is mainly used for felt and cheap coverlets etc., highly enriched with lime salts which have to be removed prior to finishing (dyeing etc.).

Cause and effect diagram Work analysis tool that enables the systematic structuring of problems. If, for example, the question is asked: what are the influences on achievable production results? the answers can be structured and organised with the aid of this tool. It is best to divide problems roughly as a first step. This can be done under the headings as shown in the Fig.:

- people (knowledge, training),
- methods (processes, recipes),
- materials (consumables),
- machines (equipment, tools),
- standards (specifications, instructions),
- information (what has changed).

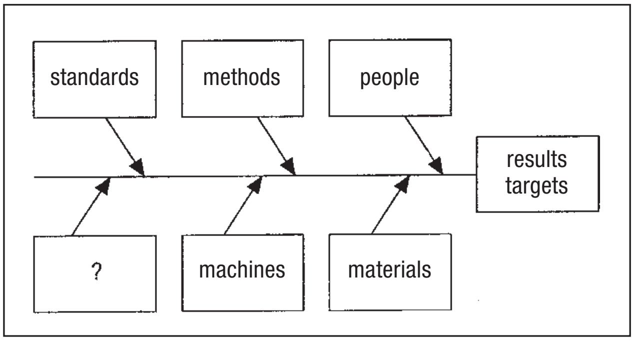


Fig.: Cause and effect diagram.

Additions or deletions can be made at any time. It is also possible to single out an individual point and to divide it up again. The advantages of this method of working are:

- contributions of individual colleagues can easily be classified,
- gaps in the collection of materials are recognised more rapidly,
- allocation to the individual points of view invites further contributions,
- the diagrammatic presentation facilitates communication.

Causticaire method is used for assessing the ∅ ripeness of cotton by treatment with alkalis of different concentrations.

Caustic alkalies → Alkalies; Caustic soda; Potassium hydroxide.

Caustic ammonia → Ammonium hydroxide.

Caustic discharges → Alkaline discharges.

Causticizing Treatment of cellulosic fibre woven fabrics with approx. 15–30°Baumé caustic soda without tension. The lye temperature is kept low to advantage – approx. 10–20°C. Causticizing shrinks and compacts the woven fabric, and increases dye uptake in dyeing and printing. Special machines (Fig.) of any make are used for this purpose. There are also special causticizing machines, comprising a padder and a short expander roller unit. The fabric, impregnated with lye, remains in the roll for some hours, and is then rinsed off. For regenerated cellulose fibres, the treatment is carried out in open width and without tension. Lye concentration moves between 2 and a maximum of 10°Baumé at a temperature between 15 and 25°C. Cotton fabrics are impregnated with lye on a padder, rolled up, left to dwell if necessary, then washed and neutralised. Lye concentration 10–30°Baumé. Used for example for producing imitation suede leather on warp knitted fabrics (described as “Limbach products” or “simplex”), and also in the chemical finishing of woven cotton stretch fabrics and → Crêpe prepared by steeping in caustic soda (crêping).

Causticizing number Test process which is based on the differing affinity of a mixture of green and red substantive dyes for untreated and causticized or mercerised cotton. Cannot be used in the presence of unripe fibres. The difference can be determined in figures by colorimetry.

Caustic potash solution → Potassium hydroxide.

Caustic printing process → Crêpe prepared by steeping in caustic soda.

Caustic recovery plants For recovering lyes from used liquors, increasing processing efficiency, and reducing effluent loading.

Caustic shock process Wet fixation process for reactive dye prints. Principle: print fabric with printing paste, dry, pass for 20–60 s in open width through a strong, boiling alkali bath containing electrolytes (roller vat), and then wash off. Variants as steam-wet fixation processes for viscose: brief presteaming for 3–5 min before the caustic shock process produces a deeper shade on viscose.

Caustic soda → Sodium hydroxide.

Caustic soda liquor → Sodium hydroxide.

Caustic soda, soda process for water softening A simpler process than the Lime-soda water softening process (i.e. without lime saturators), but involves higher costs for chemicals. Here, the principle used is that of calcium exchange through caustic soda (sodium hydroxide), which during softening to some extent forms soda (sodium carbonate), and consequently requires a lower addition of soda.

Caustic soda solubility test Test used for chemical fibre differentiation. Action of caustic soda (sodium hydroxide) 1 : 10. Result: insoluble = viscose, slightly

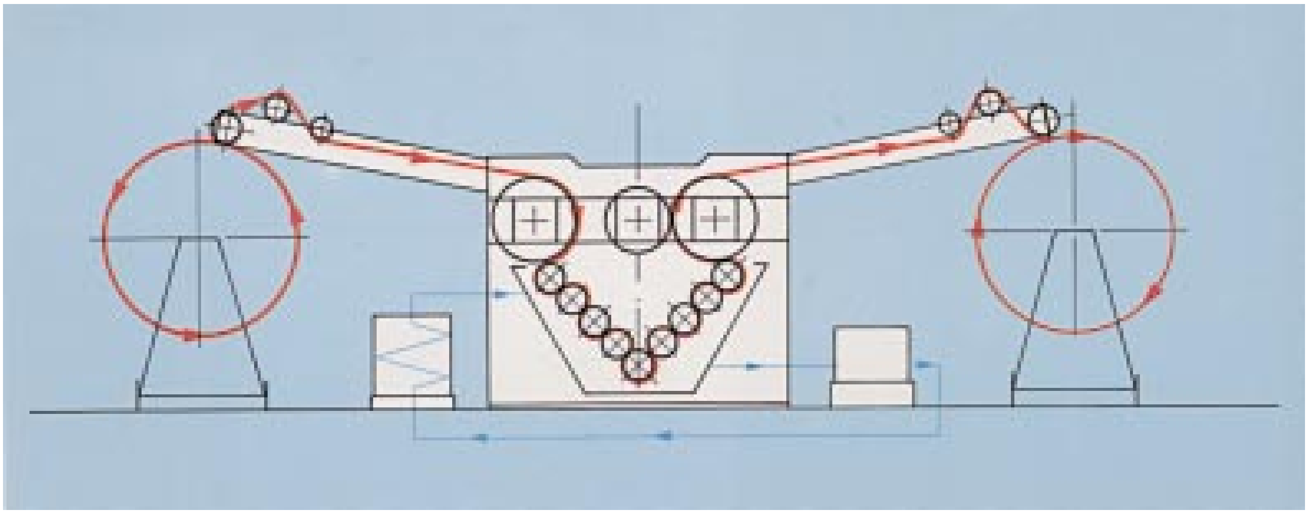


Fig.: Cibi causticizing machine.

yellowed; acetate somewhat swollen; cotton, flax = yellow; jute = brown; soluble in a cold medium = wool and soluble in a hot medium = silk.

CAV, abbrev. for: critical add-on value.

Cavitation (Latin). Hollow space formation, e.g. as a wear phenomenon due to the hollowing of material components (wood, metal, masonry) by liquid droplets like pitting etc. Cavitation is also familiar in dye liquor, where for example vapour pressure at 85–100°C increases so quickly that normal centrifugal pump action is no longer guaranteed. On the suction side, i.e. in the low pressure zone, liquid vapour tension can then result in the formation of vapour bubbles, reducing pump efficiency, which can fall to zero. This cavitation is encountered in HT dyeing.

Cb, former symbol for the element Columbium which is now known as Niobium (Nb).

Cb fibre (chemical bonding fibres) → Binder fibres.

CC,

I. → Coconut fibre, → Standard abbrev. for textile fibres, according to DIN 60 001 T4/08.91.

II. → Cupro fibres, → Standard abbrev. for textile fibres, according to DIN 60 001 until 1988. From 1991 → CUP.

cc, abbrev. for: cubic centimetre.

CCC, abbrev. for: Central Classification Committee/NL, The Hague, Holland (FID/CCC-UDC) = international Central Classification Committee of the FID (Fédération internationale de documentation); → Technical and professional organizations.

CCM, abbrev. for → Computer colour matching.

CCol, abbrev. for → Chartered Colourist.

CCS, abbrev. for: Comisiade Standardisonea; Rumanian Standards Institute; → Technical and professional organizations.

Cd, symbol for cadmium.

Ce, symbol for cerium.

Ceiba fibre It is a yellowish, silky, seed hair of the South American bombax tree, also known as silk cotton. Mainly used as a stuffing material. → Fruit wall hairs.

CELAC, abbrev. for: Centre de Recherche et de Contrôle Lainier et Chimique, Verviers, Belgium (Belgian Research and Testing Centre for Wool and Wool Chemistry); → Technical and professional organizations.

Cellobiase An enzyme occurring in malt, germinating spinach, oats etc., which degrades → Cellobiose to glucose. It is encountered *inter alia* as a secretion of certain bacteria particularly in fish nets, etc. (→ Microbial damage to textiles).

Cellobiose Disaccharide produced on partial hydrolysis of cellulose, made up of two glucose units joined by a β,1,4 linkage. → Cellulose.

Cellophane (Cellulose skin, cellulose film). Transparent cellulose film. Practically impermeable for air, bacteria, organic solvents, grease, etc. Application: as packaging, bottle tops, adhesive tape, as safety glass, textile fashion material and basketwork, etc.

Cellosolve (ethylene glycol monoethyl ether), $C_2H_5O(CH_2)_2OH$, colourless liquid, practically odourless, miscible with hydrocarbons and water. Combustible. MW 90, density 0,93, b.p. 130–138°C, flashpoint 40°C, evaporation number 43. Does not dissolve acetate fibres. Uses: solvent in dyeing and printing for cationic, acid and indigo dyes, solvent for nitrocellulose, natural and synthetic resins.

Cellular Resembling or consisting of cells; multicellular = having many cells.

Cellulase is an enzyme (polyase) that degrades cellulose to cellulose dextrins. It is extracted from certain bacteria, among others, and together with → Cellobiase leads to fibre damage in cotton (→ Microbial damages to textiles). Cellulose is the most commonly encountered compound in the biosphere and more than half of the total organic carbon is held in cellulose. Cellulose is an unbranched polymer of glucose units that are joined to one another by β-1,4-bonds. Mammals do not produce cellulase and so they cannot digest wood and vegetable fibres. However some ruminants have cellulase-producing bacteria in their digestive tracts and can therefore digest cellulose.

There are several micro-organisms that can grow using cellulose as their only source of carbon and energy. Apart from certain bacteria, e.g. cellovibrio, cellulomonas, pseudomonas, actimycetes and some anaerobic strains, these are mainly fungi that produce mycelia. The most active cellulose-degrading strains of fungi known to date are trichoderma viride (reesei), trichoderma lignorum, trichoderma koningii, penicillium funiculosum, penicillium iriensis and fusarium solani. These micro-organisms play an important role in the Earth's carbon cycle.

Investigations into enzymatic cellulose hydrolysis, mostly carried out with certain strains of fungi, show that there are at least the following three enzyme systems involved in the process (Fig. 1):

1. Endo-β-1,4-glucanases split the chains of native cellulose in the middle. Structures with lower degrees of crystallinity are destroyed in the process and a lot of free chain ends are formed.
2. Exo-β-1,4-glucanases (cellobiohydrolases) split cellobiose units from the ends of the cellulose

A natural cellulose $\xrightarrow{\text{endoglucanase}}$ cellulose*
B cellulose* $\xrightarrow{\beta\text{-glucosidase}}$ cellobiose
C cellobiose $\xrightarrow{\text{exoglucanase}}$ 2 glucose

Fig. 1: System of cellulases for cellulose decomposition. (with numerous free chain ends).*

chains and hence work in synergically with the endoglucanases.

3. β-1,4-glucosidases hydrolyse the cellobiose to glucose.

The endocellulases produce amorphous cellulose from crystalline cotton.

If an enzymatic degradation of the cotton chains is being considered, it has to be noted that the activity of cellulases falls with increasing lignin content (Fig. 2) (contributed by H. Sahm).

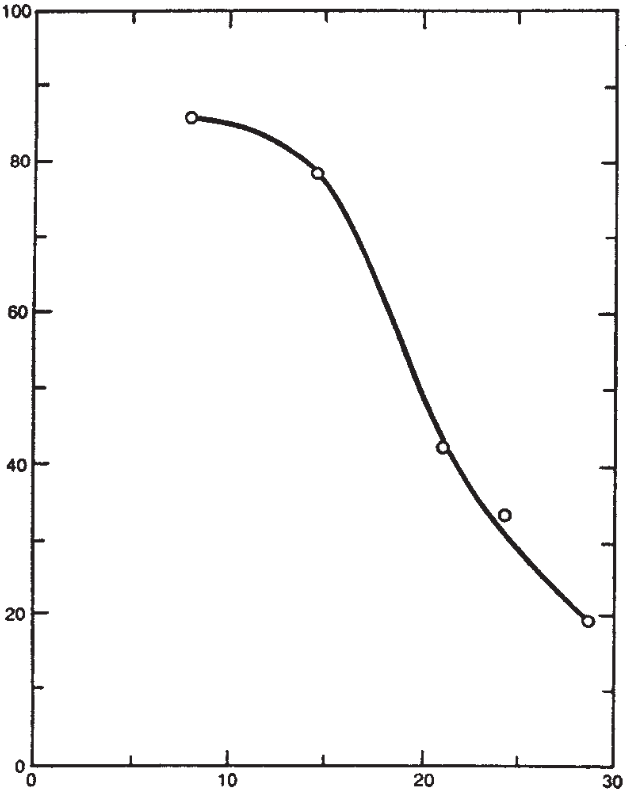


Fig. 2: Prevention of the cellulose decomposition of wool burrs with cellulase (of T. viride) in the presence of lignin. ordinate = cellulose splitting [%]; abscissa = lignin in the cellulose material [%].

Celluloid is a “solid” solution of → Camphor and → Collodium cotton. Glassy, transparent, strong and elastic in the pure form, softening at 80°C, often coloured (moulded products). Highly flammable. Uses: moulded articles of all types (as a substitute for horn, tortoise shell, ivory). In the textile sector used for buttons, washable glazed clothing (celluloid collars), oilcloth and so on; also in bronze printing (e.g. in so called zapon varnish).

Cellulose is the most important component of plant cell walls. The term “cellulose” has different meanings in the various branches of science. In 1847, the botanist Payen originally called the main component of plant cell walls cellulose. Botanists still use the word in this sense, no matter whether the plant is a flowering plant, a fern or an alga. Fibre technology understands cellulose to mean the material that can be isolated from a small number of plants by definite chemical processes. For chemists, celluloses are high molecular weight substances made up of D-glucose residues, joined together in the β-position. Finally crystallographers use the word cellulose to describe a crystalline substance with a well defined unit cell.

Only a few celluloses fulfil all these definitions. If the non-cellulosic components of the cell wall are removed one after the other by boiling with water, hypochlorite (to give halocellulose) and treatment with 4N caustic potash, so called α-cellulose can be obtained as microfibrils with the minimum loss of weight. The microfibrils are long, fine fibres with diameters of about 10–20 nm. The α-celluloses are made of pure glucose units only in very rare cases, e.g. in the algae valonia and cladophora. All other α-celluloses contain small amounts of other sugars. For example, apart from 1.5% xylose, cotton contains smaller amounts of mannose, galactose and arabinose. The α-cellulose of the red alga rhodymenia palmata on the other hand contains 50% of xylose. Even in this case the x-ray pattern is exactly the same as that of the α-cellulose from valonia. There must be a paracrystalline layer of the other sugars surrounding a crystalline core of eucellulose (100% glucose).

Cellulose is found in a fairly pure form in the seed hairs (cotton) and stems or leaves (flax, hemp, ramie) of many plants. As only mechanical separation is needed for technological purposes, such processes have been used for thousands of years. In more recent times cellulose has also been obtained from hard and soft wood as well as from the stems of annual plants using non-mechanical separation processes. Cellulose is found with non-cellulosic components, making up up to 40% of lignified cell walls. These non-cellulosic components consist of up to about 70% of lignin and up to about 30% of the so called hemicelluloses (short chain polysaccharides made of non-glucose sugars such as mannose, galactose, xylose, arabinose, uronic acid). Cellulose is built up from D-glucose residues (→ Glucose). D-glucose is one of the $2^4 = 16$ possible hexoses. The aldohexose group consists of the sugars allose, altrose, glucose, mannose, gulose, idose, galactose and talose.

The constitution of cellulose was proved by total hydrolysis, which gave more than a 95% yield of glucose. When the cellulose is permethylated with dimethyl sulphate before the hydrolysis, 2,3,6-trimethyl glucose is obtained. The glucose residues must therefore be joined in the 1,4-positions. Cellulose is degraded enzymatically only by β-glucosidases: the bonds are therefore β-glucoside. The optical rotation of the disaccharide cellobiose also supports the presence of β-glucoside bonds. Cellobiose is obtained by de-

Modification	Source (natural)	Production (synthetic)
Cellulose I (native cellulose)	Cellulose-containing algae	From III with H_2O under pressure
Cellulose II (cellulose hydrate)	Helicystis algae	Dissolution and reprecipitation of I; mercerized fibres
Cellulose III	–	Careful decomposition of cellulose-ammonia
Cellulose IV	Coltsfoot	Heating II in glycerine to 290°C

Tab.: Cellulose modifications.

grading cellulose with acetic anhydride. The specific rotation of cellobiose is + 35º, compared with + 136º for the diglucoside maltose. In the D-series, the rotation of the α-form is always more positive than that of the β-form. For example the rotation of α-methyl-D-glucoside is + 159º compared with – 34º for β-methyl-D-glucoside. In addition, x-ray analysis also shows β-glucoside bonds.

The molecular weights of native celluloses are very high. If cotton is harvested before the capsules have opened and is kept away from light and oxygen, the degree of polymerization, DP = 13 000. Cellulose is not soluble in water. The reasons for this are intramolecular hydrogen bonding as well as the high x-ray crystallinity of about 60% and the consequent high enthalpy of melting. However, cellulose can be dissolved in metal complexes such as cuoxam ($[Cu(NH_3)_4]^{2+}$), cuen ($[Cu(H_2NCH_2CH_2NH_2)]^{2+}$) or sodium iron tartrate (a complex of $[(C_4H_3O_6)_3Fe]Na$ with HOOC–CHOH–CHOH–COOH). This is less sensitive to oxidation than are cuoxam and cuen. Hydrate complexes of cellulose may be present in this solvent.

Cellulose can occur in various crystal modifications that have different dimensions and angles of the unit cell (see Table). The exact positions of the hydrogen bonds in the various modifications are not known. Both the glucopyranose residues in cellobiose are in the chair form and all the OH and CH_2OH groups are directed equatorially. There is an intramolecular hydrogen bond between carbon atoms 3 and 5 and there are also 7 intermolecular hydrogen bonds. Two fibre molecules are present in the elementary cell of cellulose I. They probably run antiparallel as both ends of the microfibrils reduce silver ions.

A density of 1.59 g/cm^3 is accepted for the closest packing. However because of the volume fraction between the micelles, cellulose fibres have densities of only 1.50–1.55 g/cm^3. The density of native fibres in much lower because of this intermicellar volume. For cotton, it is only 1.27 g/cm^3.

The different methods for determination of the crystallinity give different values for cellulose. The differences are due in part to the different ways in which the methods take averages and in part to the fact that when chemical methods are used, the original physical structure can be altered to some extent (swelling and so on). The crystallinity of cotton cellulose is 60–70% (contributed by Elias).

Cellulose acetate (Acetate cellulose, acetyl cellulose, cellulose esters of acetic acid). Differentiated according to the number of bonded acetic acid residues, into diacetate and triacetate (see Table).

Structural principle: → Cellulose derivatives. In chemical terms, the so-called diacetate, the raw material of the acetate fibre, is a chemical $2^1/2$-acetate, which is to be regarded as a mixture of various esterification stages between di- and tri-acetate. In terms of manufacture, there are close connections between both cellulose acetates. → Acetate fibre.

	Triacetate (primary acetate)	2 1/2-acetate (secondary acetate)
Formula	$[C_6H_7O_2(CH_3COO)_3]_n$	$[C_6H_7O_2OH(CH_3COO)_2]_n$
Acetic acid content	60–62%	53–56%
Typical solubility:		
org. solvent	rather insoluble	rather soluble
acetone 80%	insoluble	soluble
acetone	partially soluble	immediately soluble
glacial acetic acid	only soluble when boiling	soluble even when cold
Used for (e.g.)	triacetate silk, fibre foils lacquers raw materials for drive belts	acetate silk, fibre foils films, lacquers for paintwork fixing agents for bronze-and pigment printing

Tab.: Comparison of cellulose $2^1/2$-acetate and triacetate.

Cellulose acetate in textile printing As thickening agent and substance carrier (→ Metal powders) which is fixed by heat (steaming), e.g. in → Pigment printing.

Cellulose combustion It takes place in 3 main phases of pyrolysis:

1. Formation of → Laevoglucosan.
2. Formation of volatile gaseous or liquid decomposition products.
3. Combustion/afterglow of the resulting carbon residue.

Cellulose, degree of polymerization The → Average degree of polymerization of various cellulosic fibres is as follows:

Cotton approx.	3000–6500
Ramie	(>) 2700
Flax	2500–9200
Hemp	2200

Cotton, spun	approx. 1200
Wood pulp	700–3000
Cupro filament	400–600
Viscose filament	(>) 200–460
Acetate filament	175–360

It should be noted that, in the case of regenerated cellulosic fibres, chain lengths above DP = 800 are no longer capable of being spun. The DP values of cellulosic fibres decrease rapidly as a result of strong oxidation and hydrolytic action, together with the tensile strength. Thus hydrocellulose for example rapidly reaches values of 300–200; below 150–100 disintegration to powder already occurs.

Cellulose derivatives These include cellulose ethers and cellulose esters. The Fig. shows a schematic comparison of the structural principle.

I. Cellulose ethers: created through the exchange of the H or OH group with → Alkylenes, therefore alkyl cellulose. Characterised by evenness and purity, resistance to temperature, fermenting, moulding etc. Depending on the degree of alkylation, excellent stiffening agent for sizes, finishes, print thickeners, also emulsifiers, etc. →: Methylcellulose; Oxy ethylated cellulose; Carboxymethylcellulose. Also serves as a water repellent.

II. Cellulose esters: derivatives with substituted → Acyclic compounds. Inorganic cellulose esters are best known as → Nitrocellulose for collodion cotton, nitrocellulose lacquers, artificial leather and wax cloth manufacture. Organic cellulose esters are very important for the manufacture of chemical fibres, monofilaments and foils, such as e.g. acetate cellulose and triacetate fibres; for the production of immunised, passive and amine yarns (immunisation); more important as wash-resistant water-repellent effects; for permanent finishes; also for lacquers, finishing agents (formerly for coatings), print thickening agents, and binding and fixing agents for pigment printing.

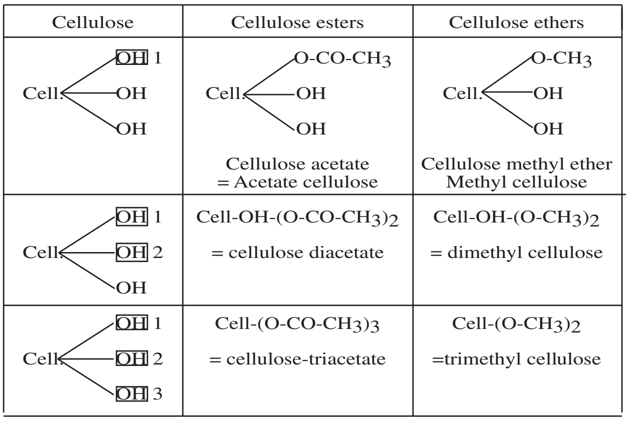


Fig.: Structural principle of cellulose ethers and cellulose esters.

Cellulose diacetate →: Cellulose acetate; Acetates.

Cellulose dyeings, identification tests → Dye class identification on fibres.

Cellulose dyes An overview of the relative market shares for various dye classes suitable for cellulosic fibres is given in the figure. The areas occupied by the respective dye ranges correspond to sales volumes converted to quantities of comparable effect. The centre point of each area corresponds to the assumed average costs along the horizontal axis. The shape of the areas has been estimated. The value of these comparisons can be demonstrated by taking direct dyes as an example. At the lower left of the figure are pale dyeings for which dyestuff costs can be ignored since, for practical purposes, only the process costs need be considered here.Towards the middle of the area there is an upwards protrusion which represents the area occupied by aftercoppering dyes. At the far right of the area are deep dyeings involving an aftertreatment.

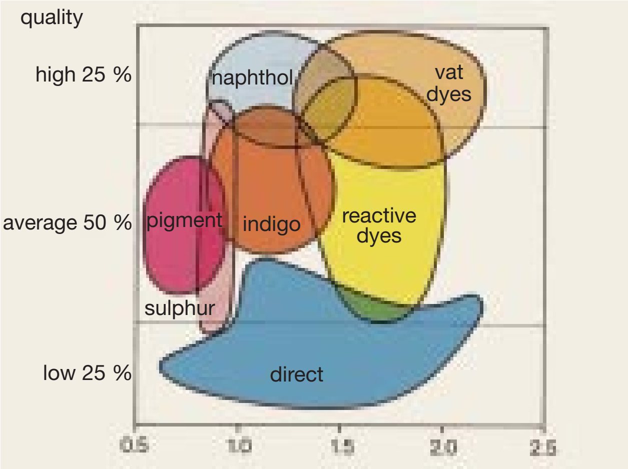


Fig.: Cellulose dyestuffs 1983.

The overlapping zones are clearly recognizable. In these areas there is intense competition. A typical example here is the transition zone from medium to high quality where, in the main, reactive or vat dyes are used which also provide an alternative to naphthol dyes. Pigment colorants are a cost effective choice for the medium quality zone but only if they meet the specified quality criteria. When additional criteria such as, e.g. fabric handle, are involved, the relative positions may change (Christen and Horstmann).

Cellulose esters → Cellulose derivatives.

Cellulose esters of acetic acid → Cellulosic fibres, regenerated, e.g. acetate and triacetate fibres (cellulose ester fibres).

Cellulose ethers → Cellulose derivatives.

Cellulose fibre creasing behaviour → Creasing behaviour of cellulose fibres.

Next Page

Cellulose glycol ether → Oxyethylated cellulose.

Cellulose glycolate → Carboxymethylcellulose.

Cellulose methyl ether → Methylcellulose.

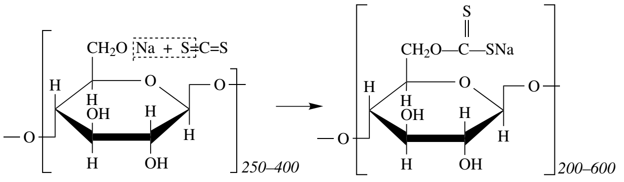
Cellulose nitrate → Nitrocellulose.

Cellulose, oxyethylated → Oxyethylated cellulose.

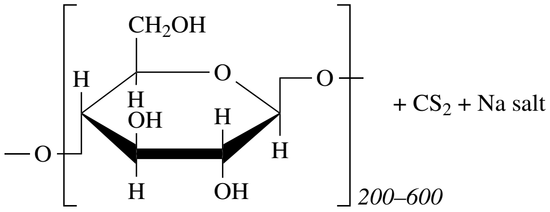
Cellulose synthetic fibres, old term for → Cellulosic fibres, regenerated.

Cellulose triacetate →: Cellulose acetate; Triacetate fibres.

Cellulose xanthate is formed as an intermediate product in the manufacture of viscose by the action of carbon disulphide on alkali cellulose (soda cellulose):



It is an orange-yellow, sulphur-containing, cellulose intermediate product and is dissolved in caustic soda to give the highly viscous viscose solution. During subsequent spinning through spinnerets and coagulation in a sulphuric acid bath the sodium cellulose xanthate is converted back into cellulose:



Cellulosic fibres Consist predominantly of → Cellulose and can be divided into:

I. → Natural cellulosic fibres;

II. → Cellulosic fibres, regenerated;

III. modifications, such as e.g. → Modal fibres.

Cellulosic fibres – latent damage Oxidation processes that cause an increase in the instability of the 1,4-bonds amount to latent fibre damage. These bonds are sensitive to alkali and can be broken in alkaline processes (including alkaline washing). The capacity for taking up dyes and the mechanical properties deteriorate. Measurement of differences in → Chain length is suitable for estimating this alkali sensitivity.

Cellulosic fibres, regenerated The group of → Man-made fibres includes textile fibres made of natural plant polymers. Classification (see Tab.):

I. Regenerated cellulosic fibres: →:Viscose fibres, Cupro fibres, newer regenerated cellulosic fibres, spun with the aid of newer types of solvent.

II. Cellulose ester fibres: →: Triacetate fibres, Acetate fibres, Alginate fibres, Rubber fibres.

III. Vegetable protein fibres: →: Zein fibre, Arachin fibre, glycine fibre.

Cellulosic man-made fibres are jet-spun, silk-like fibres made of regenerated or esterified cellulose, i.e. made of chemically soluble cellulose (cotton linters, straw, wood), which is extruded through jets and obtained as a solidified fibre structure by precipitation or evaporation,. They are used as filaments (including monofilaments such as artificial horsehair), or cut (staple fibre).

CEMATEX, abbrev. for: Comité Européen des Constructeurs de Matériel Textile (European Committee of Textile Machinery Manufacturers), Zürich. Founded in 1953. The main body is the Central Committee composed of delegations from associate members of 8 countries.

Amongst other functions, CEMATEX is responsible for organizing the ITMA international textile machinery exhibition.

Fibre groups		Density	Moisture regain, %	Tensile strength		Elongation at break	
				cN/tex	wet %	dry	wet
Alginate	(F)	1.73–1.78	20–35	10–11	25–27	10–14	26
Protein	(F+S)	1.25–1.31	12–15	6–11	29–46	40–70	45–80
Viscose	F-type	1.52	11–13	13–27	42–65	15–30	20–35
	high tenacity			40–49	55–70	6–21	6–30
	S-type			13–8	55–65	11–31	12–38
	high tenacity			24–34	65–75	14–21	16–20
Cupro	F-type	1.52	11–13	14–21	45–67	10–20	17–33
	S-type			13–19	45–72	14–35	17–45
2 1/2 acetate	F-type	1.29–1.33	6–6.5	10–14	56–68	20–30	26–40
	S-type			10–12	58–70	16–39	26–45
	saponified	1.5	10.7	54–63	85	6	6
Triacetate	(F/S)	1.28–1.3	4–4.5	10–13	52–80	18–30	30–40
Cotton		1.53	6–8	27–40	100–130	9–15	7–11
Sheep’s wool		1.31	14–16	9–15	30–97	25–54	25–62

Tab.: Physical characteristics of regenerated cellulosic fibres, also compared with cotton and wool.

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Cement,

I. Building material.

II. Artificial gold threads (→ Metallized yarns).

III. Interfibrillar cement: → Wool structure.

IV. With raw silk → Sericin (silk gum) is occasionally described as cement.

Cemetery-Kula carpet (Masarli-Kula). Anatolian → Prayer mats with typical designs showing small houses, cypresses and pines in yellow ochre, pale red and light green on a dark blue background, reflecting the atmosphere of a typical cemetery from southern countries.

CEN, abbrev. for: Comité Européen de Coordination des Normes (European Standardization Committee) with headquarters in Paris. → Technical and professional organizations.

CENATRA, abbrev. for: Centre National d'Assistance Technique et de Recherche Appliquée (Belgian Research Centre for Fabric Care and Drycleaning), Anvers/Antwerpen. Liquidated in January 1978. → Technical and professional organizations.

Centi- Unitary prefix for one hundredth = 10^{-2}; e.g. 1 cm = 0.01 m.

Central atom → Complex compounds.

Central cylinder,

I. A smooth hollow roller, sometimes covered with wool or wool felt material (→ Printing cylinder) used in roller printing. Driven by contact pressure with the printing rollers.

II. The central main cylinder of raising machines and spinning machines (carding, combing machines).

Centre drive batcher Compared with a → Rising roll batcher, the batching roller on the centre drive batcher is powered, so that the batch in fixed bearings is driven at a variable speed. It is important for the tensile stress to remain constant, this being achieved by special drives. →: Batch drives; Hydraulic batch drive.

Centre lamella →: Flax long-fibre structure; Flax cell structure; lamella.

Centrifugal damping machine Centrifuge in which the material is pre-wetted or wetted during running, and where the wetting fluid is collected once more.

Centrifugal pumps (→ Pumps). Centrifugal pumps draw liquor from a horizontal intake into the pump casing (Fig. 1) from where it is discharged into circulation by an impeller mounted on a horizontal shaft which rotates at high speed. In a typical centrifugal pump, the liquor enters the pump axially into the centre of the eye of the rotating impeller and is discharged tangentially upwards into the outlet of the casing. As the liquor moves progressively from the eye to the periphery of the impeller, its velocity, and hence kinetic energy, is continuously increased by centrifugal forces. The pump and motor together form an integral block (Fig. 2).

Fig. 1: Cross section of a centrifugal pump.

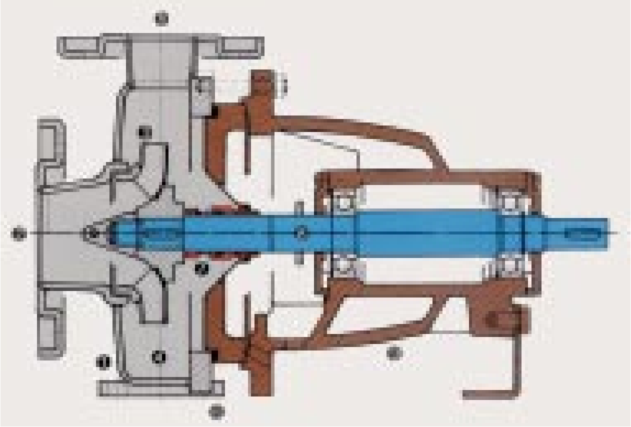


Fig. 2: Block construction of centrifugal pump and motor (Hilge).
6 = pump base; 7 = axial face seal; 8 = short shaft;
9 = three-phase A.C. motor and motor base.

For dye liquors containing dispersal particles which are likely to undergo irreversible changes under excessively high shear forces (e.g. disperse dyes), impellers with a special geometry are necessary so that contact between the walls of the pump and the liquor is minimized (Fig. 5).

To achieve a more gentle liquor transport, impellers with several curved blades are used so that the fluid particles in the rotating impeller zone are more loosely associated (Figs. 3 and 4).

Due to the nature of centrifugal pumps, the direction of liquor flow (Figs. 8 and 9) cannot be changed by changing the rotational direction of the motor. The characteristic curve of a Krantz centrifugal pump (Fig. 6) can be changed over a wide range by altering the

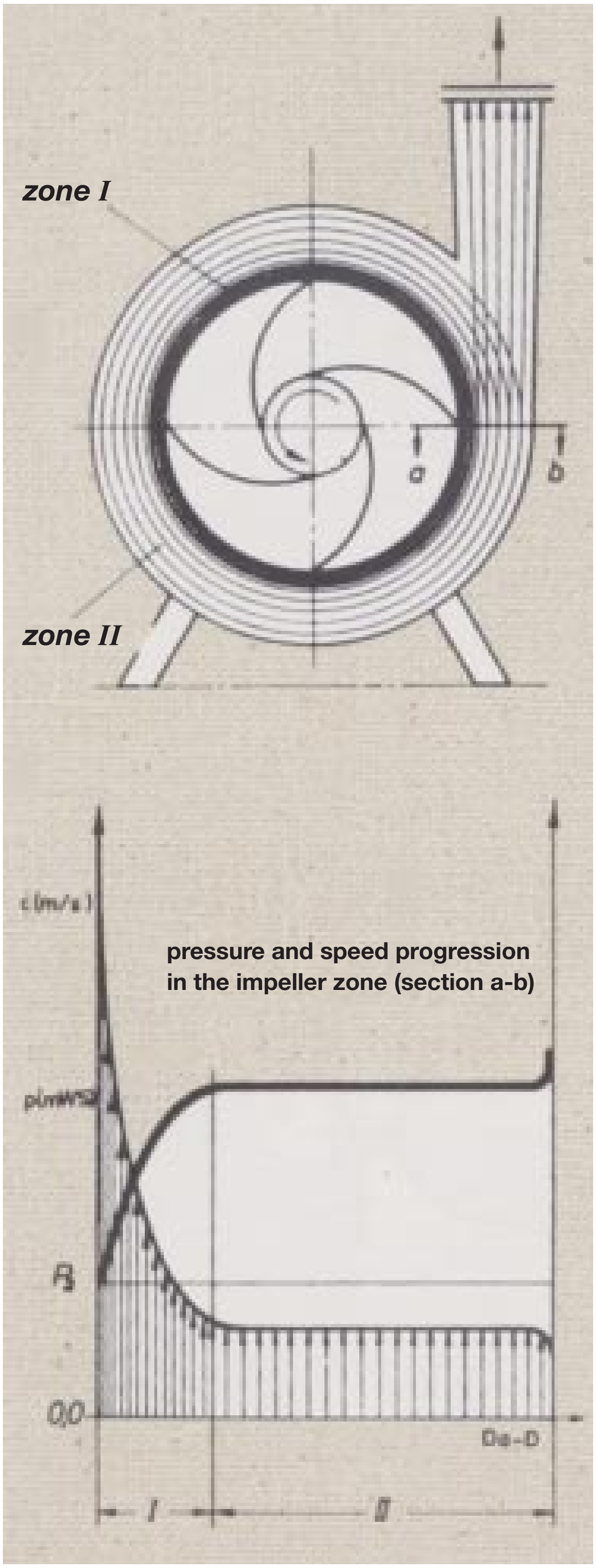


Fig. 3: The fluid particles are loosely associated in a rotating ring of liquid (Hilge).

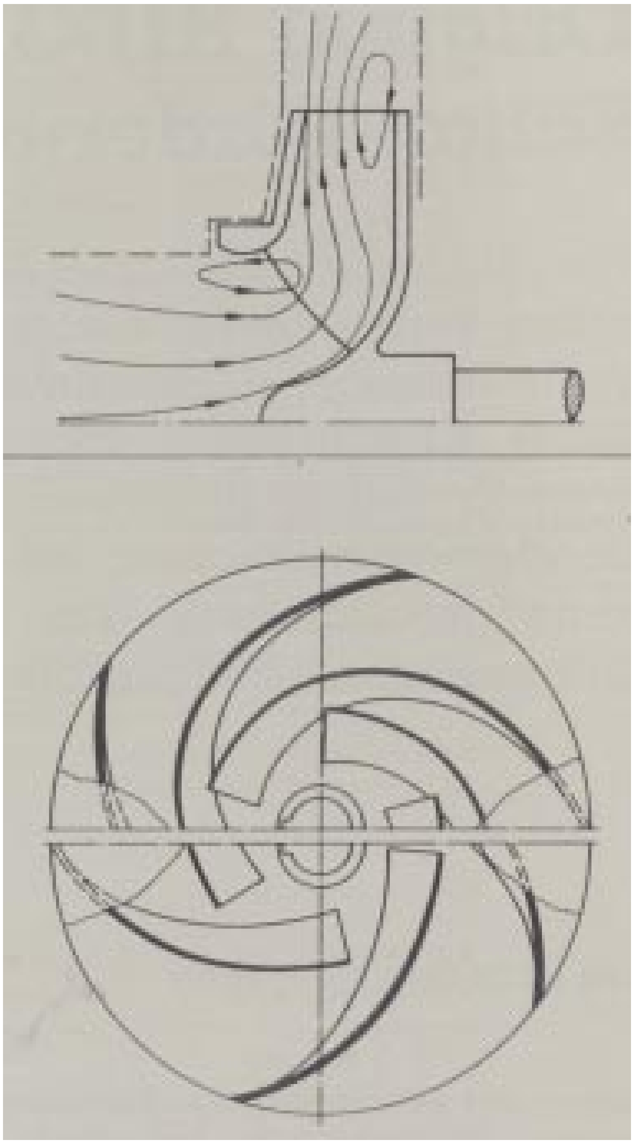


Fig. 4: Flow curves in a centrifugal pump (Hilge).

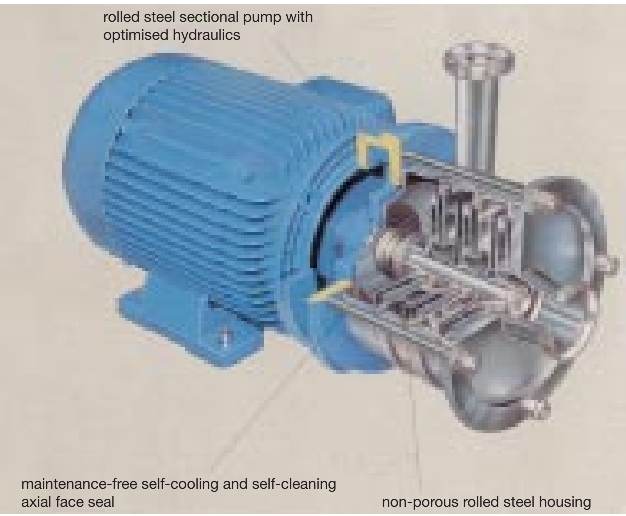


Fig. 5: Multi-stage impeller (Hilge).

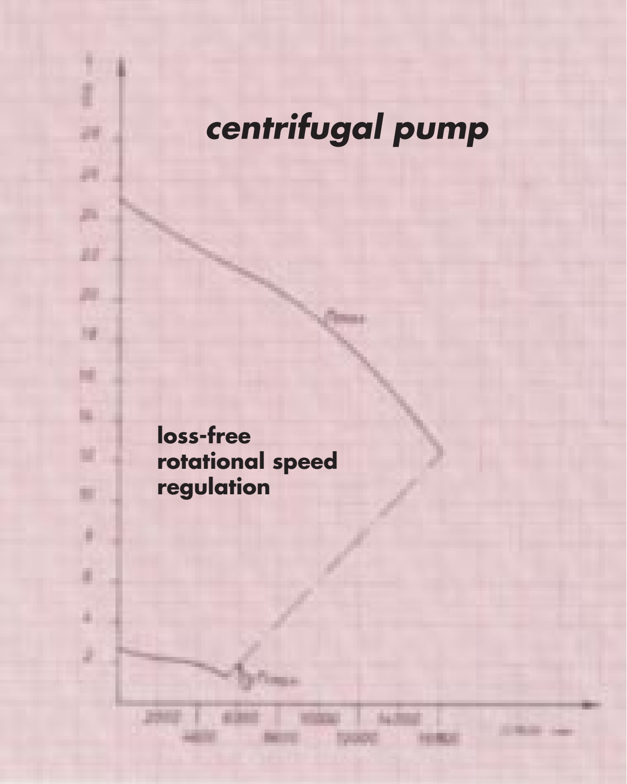


Fig. 6: Characteristic curve of a centrifugal pump.

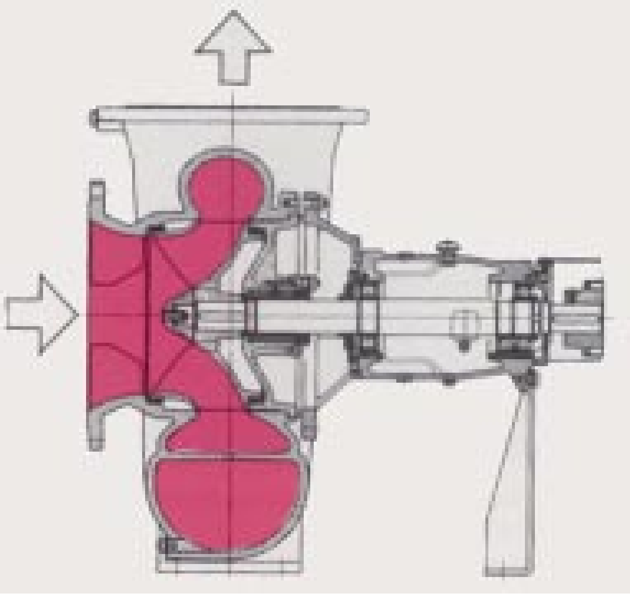


Fig. 7: Centrifugal pump for large volumes of liquor.

speed of the motor (an almost parallel shift is achieved) so that even very large volumes of liquor can be handled. Constructions in the periphery of the pump chamber are available to vary the direction of liquor flow without changing the rotational speed of the pump (Figs. 8 and 9). The liquor is fed e.g. to the suction side of the impeller via a hinged elbow. Several curved guiding vanes are arranged concentrically at the outlet. With this type of arrangement, the axial loads on the pump shaft counterbalance each other which is particularly important for trouble-free performance of the axial face seal and considerably reduces the load on the pump shaft bearings. Depending on the position of the elbow, which is driven by a servomotor, the illustrated functions (Fig. 9) are put into effect.

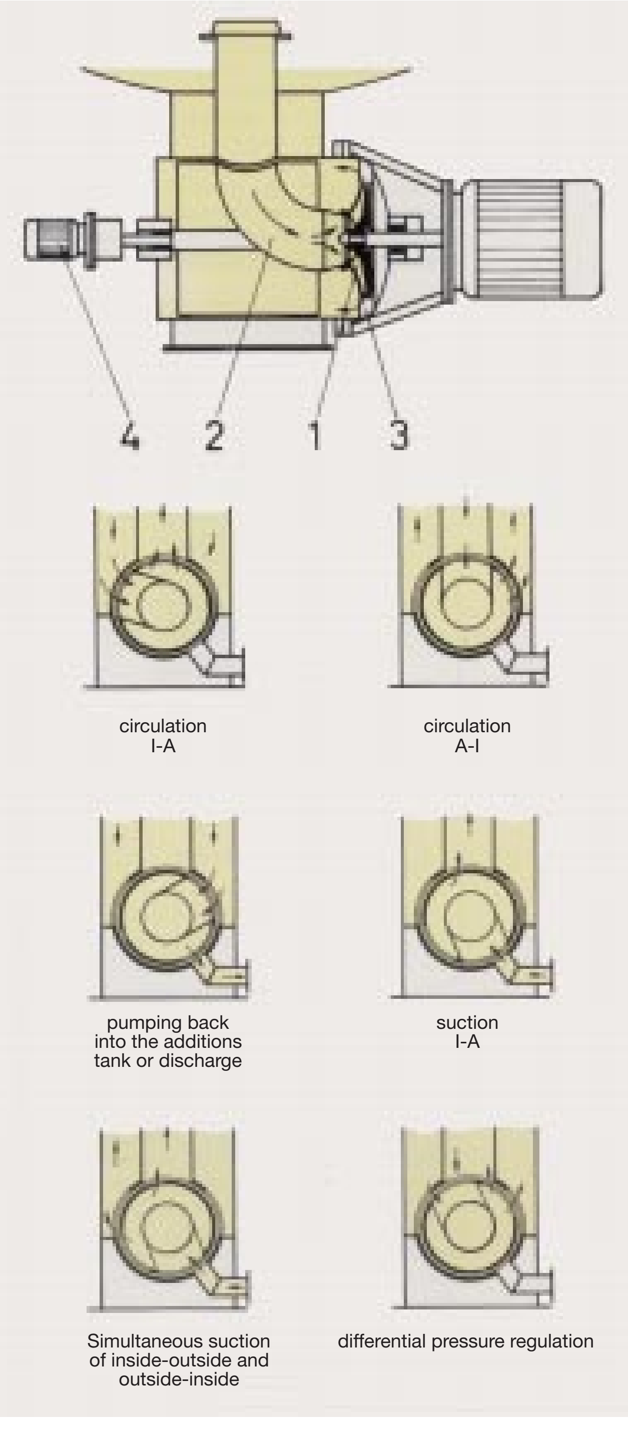


Fig. 8: Arrangements for changing direction of flow (Jasper).
1 = impeller; 2 = elbow; 3 = guide vane; 4 = servomotor.

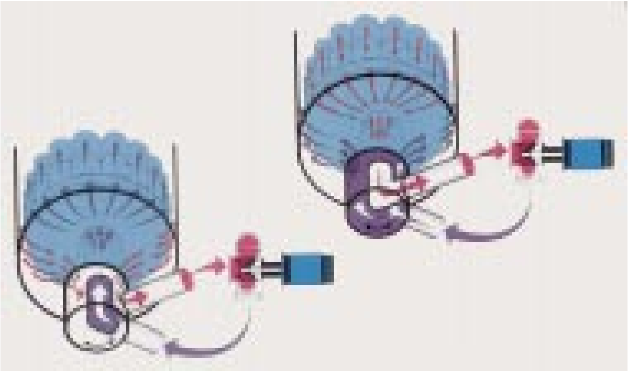


Fig. 9: "Alterator" of Krantz for change of liquor flow direction.

Centrifuge dyeing A new process for dyeing, bleaching, washing, softening and centrifuging in one machine (Fig.) , is possible. The centrifuge, which was jointly developed with the assistance of practical dyers from the textile industry, is suitable for the treatment of loose fibres (loose stock) as well as hanks of yarn in processing liquors. Most types of fibres in common use can be dyed by this process.

The machine layout of the centrifuge is represented schematically in the Fig. The Centri-Dye consists of the following components: dyeing centrifuge, preparation tank with pump, addition tank for the liquor and liquor pump, filter, heat exchanger, all necessary valves and other essential parts. The control system for the dyeing and centrifuging process is built into a floor-mounted service cabinet which is equipped with a frequency converter, an energy restorage unit for the braking operations as well as a programmable logic computer (PLG) for the running program which includes a monitor screen on which the actual state of the process is displayed.

In order to dye loose fibres they must first be press packed resp. wet stamped into cakes and lifting frames as for dyeing in conventional dyeing machines, after which they can be loaded, together with the lifting frames into the dyeing drum of the centrifuge. Hanks of yarn for dyeing can be loaded into the dyeing drum of the centrifuge in loose layers. Compared to the combination of conventional dyeing machine and centrifuge, considerable savings of water, dyes and auxiliaries, as well as energy, are achieved when dyeing is carried out in the Centri-Dye due to the lower liquor ratio and the smaller liquor pump which is only required to supply liquor to the centrifuge. These savings amount to: 30 to 40% of water, up to 50% of dyes and auxiliaries, 20% of energy and 20% dyeing time. Moreover, the transfer of material from dyeing machine to centrifuge is eliminated with this system.

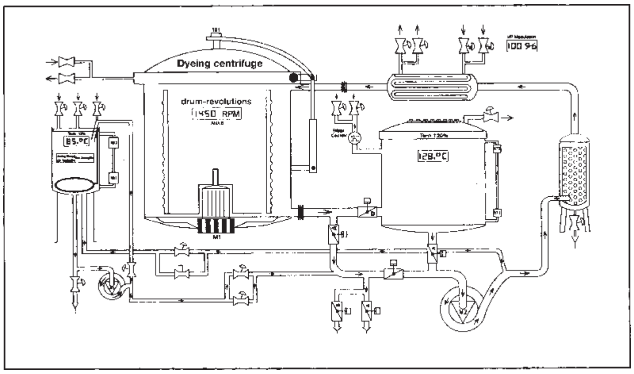


Fig.: Schematic representation of the dyeing centrifuge Centri-Dye from E. Mühlmann GmbH.

In the dyeing operation, liquor is pumped through the filter and heat exchanger into the dyeing drum of the centrifuge, where it is forced through the loose fibres/hanks of yarn by centrifugal force, then hydro-extracted from the drum to the additions tank from where it again circulates through the filter and heat exchanger back to the centrifuge. A level dyeing is also achieved due to the uniform centrifugal force produced in the centrifuge. A further advantage is that the drum does not need to be fully loaded. Good dyeing results are still achieved even when the centrifuge is only 20% full. Consequently, this centrifuge is also flexible for small batchers without the need to use liquor displacing elements. Also of advantage is the fact that the price of the Centri-Dye is lower than a combination of centrifuge and conventional dyeing vessel. Moreover, the pay-back period is quite short due to the high savings of water and energy. At present, this newly-developed dyeing centrifuge is available for 100 to 500 kg of loose fibre and 50 to 200 kg of hanks.

Centrifuge hydro-extraction → Water extraction.

Centrifuges (hydro-extractors). Centrifuges are used for → Water extraction (dewatering, pre-drying) of textile materials. Values of approx. 15% for residual moisture content can be achieved depending on the type of textile fibre. Centrifuges with perforated drums or baskets (Ø up to approx. 2000 mm) which oscillate vertically in ball-and-socket joints suspended on three points are produced in various designs as pendulating, suspension, cage and vertical centrifuges, also with so-called gliding support bearings as gliding support centrifuges or in horizontal resp. vertical arrangements as open-width, horizontal and warp-beam centrifuges, etc. Most centrifuges have electric drives for speeds of approx. 750–1200 rpm and are generally provided with automatic control over various ranges. For safety reasons, an interlocking lid is essential on a centrifuge so that the motor cannot be started until the lid is locked, nor the lid raised until the basket is stationary again after the machine has been stopped.

When used for dewatering loose stock, the cake of loose fibres is transferred from the dyeing machine to the centrifuge and hydro-extracted before it is run into

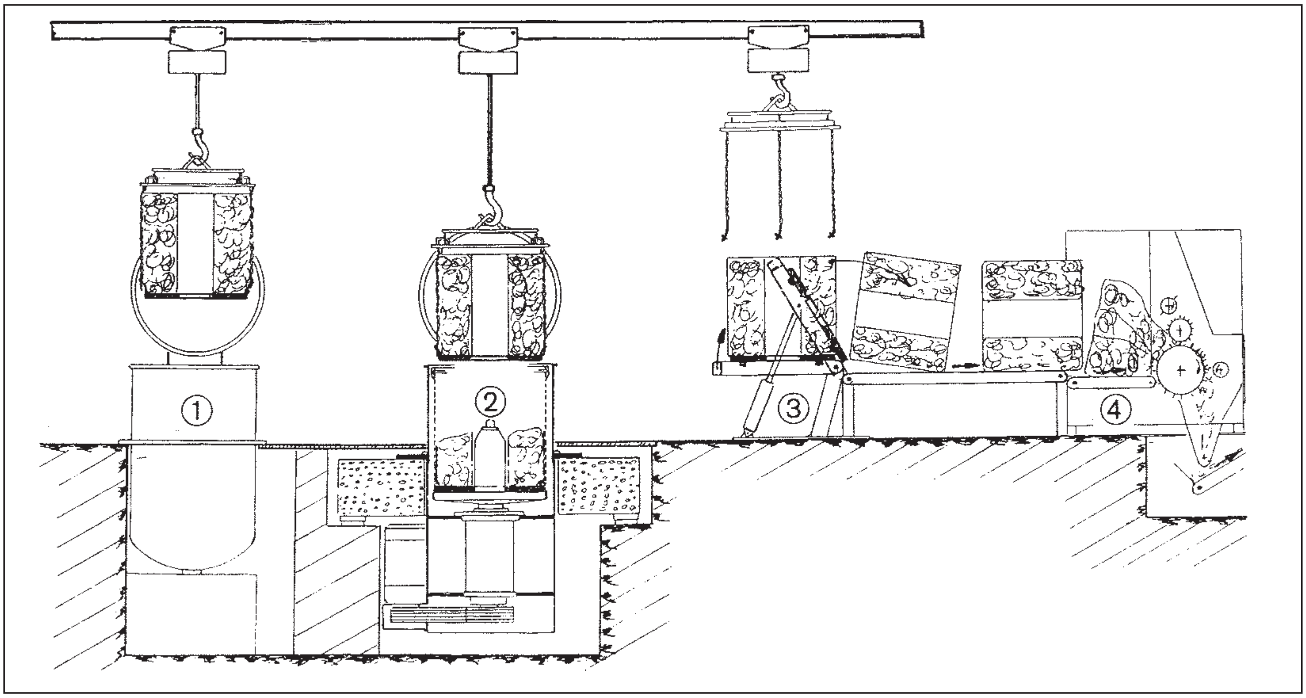


Fig. 1: Incorporation of a centrifuge in a working procedure for the treatment of loose fibres.
1 = bale removal from dyeing machine; 2 = hydro-extraction in centrifuge; 3 = removal of material carrier; 4 = bale opening.

the fibre opener as a preliminary stage of drying in a perforated drum drier (Fig. 1). If an immersion centrifuge is used, impregnation of the loose fibres with a spinning lubricant is also possible. In this case, the material is loaded into the centrifuge, liquor is then pumped in (until it covers the material), and the goods are finally hydro-extracted. The advantage of such a procedure lies in the fact that a separate treatment of the textile material in an impregnation vat and the reloading of wet goods into the centrifuge are eliminated (Fig. 2).

Impregnation of textile material in the impregnation basket of a centrifuge is generally quicker and more effective for all processes than in a vat. The centrifugal force which drives the liquor through the goods during centrifuging accelerates penetration. It is possible to carry out several processes one after the other in an immersion centrifuge. In this case, however, separate drain channels and liquor tanks must be provided. The basket of an immersion centrifuge has an outer casing without perforations which surrounds the cylindrical basket of a normal centrifuge (extended conically at the top). By this means, it is possible to fill it with liquor to the level of the upper rim. Only when the basket is set in motion does the liquor, which is driven outwards by centrifugal force, rise up the basket casing and run over the upper rim. Such impregnation processes can also be carried out on columns of yarn packages with the Krantz spray dosing system (Fig. 3).

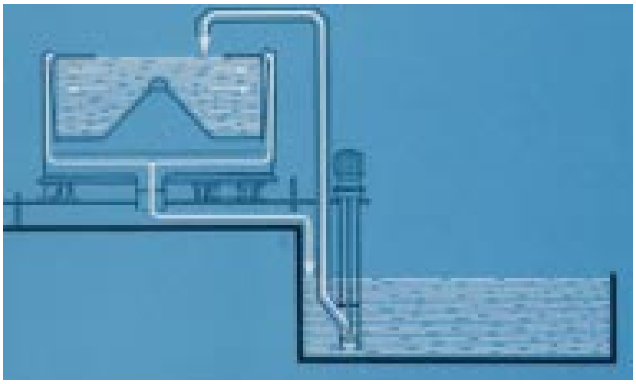


Fig. 2: Immersion centrifuge from Krantz.

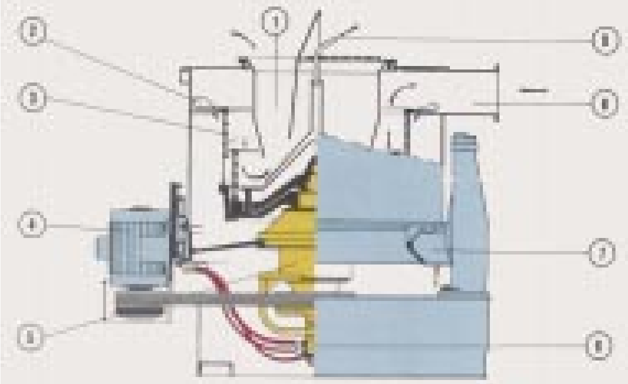


Fig. 5: Continuous centrifuge (Rousselet).
1 = fibre feed hopper; 2 = ejection container; 3 = extractor basket with slits; 4 = drive motor; 5 = bearing housing; 6 = direction of rotation; 7 = outflow; 8 = fibre ejection; 9 = feed for processing liquors.

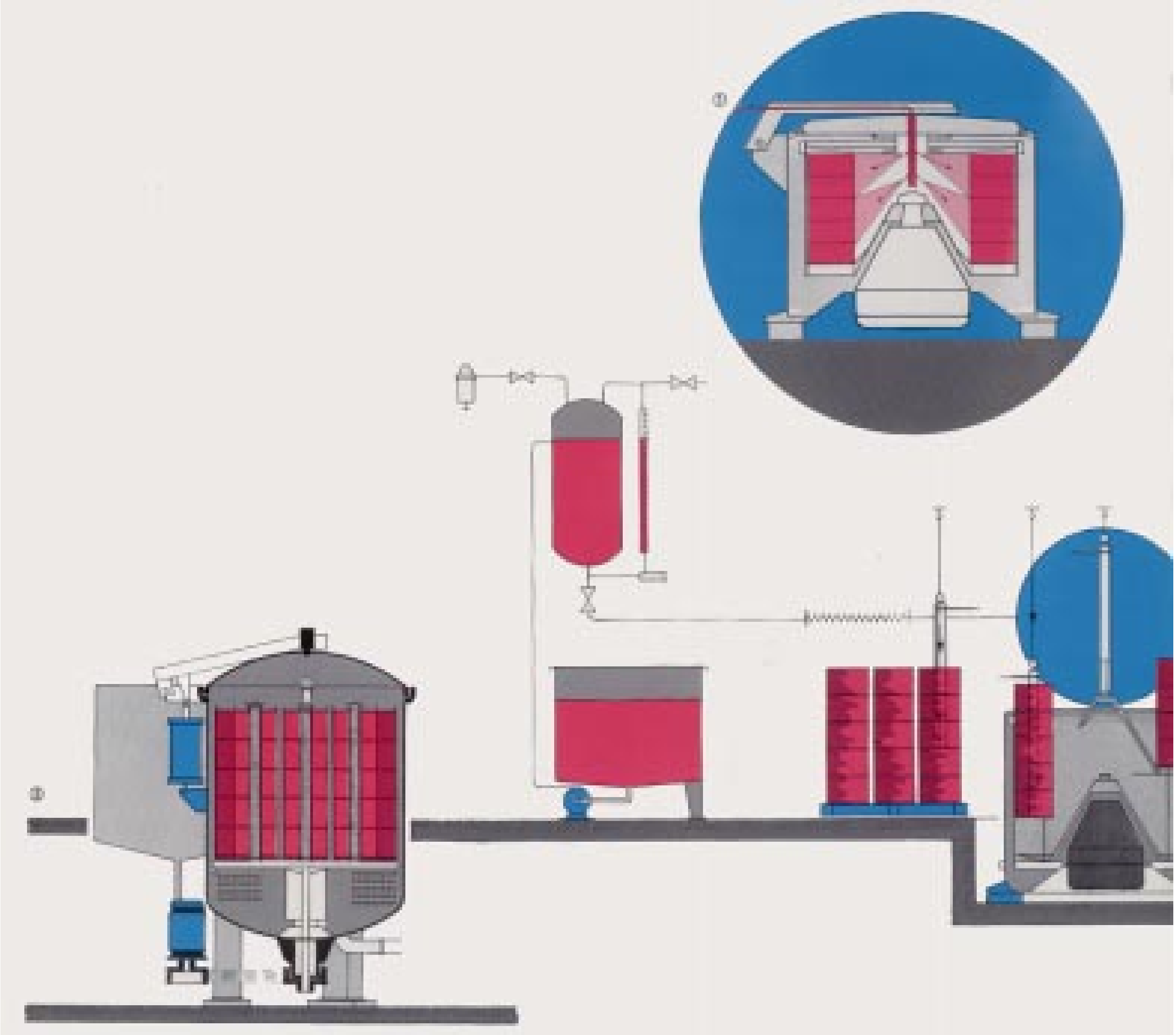
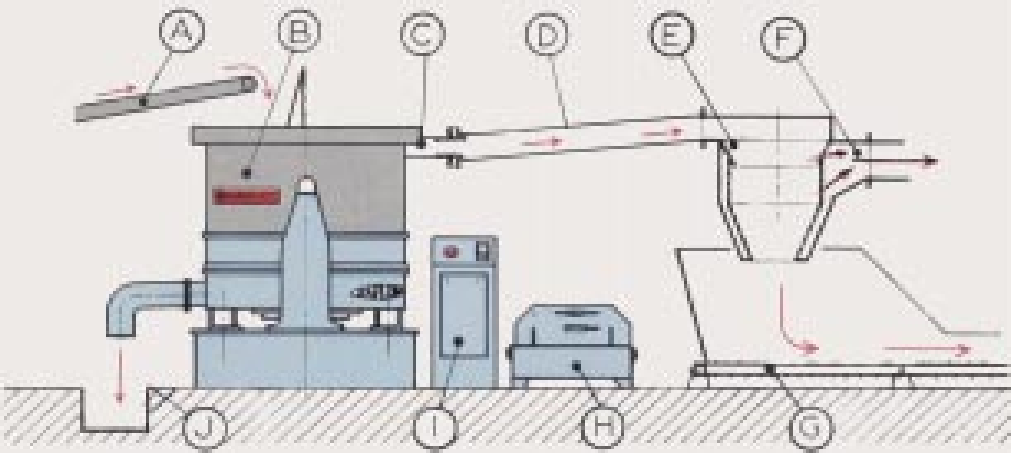


Fig. 3: Immersion centrifuging for columns of yarn packages:
1 = sectional view of the application system; 2 = schematic representation of a complete plant (HT yarn dyeing machine, spray dosing system and gliding support centrifuge) for the application of spin finishes (Krantz).

Fig 4: Centrifuge for continuous dewatering of loose stock (Rousselet).
A = fibre feed conveyor;
B = centrifuge; C = tangential fibre ejection;
D = pneumatic transport channel; E = separating device; F = air separation;
G = onward transport;
H = hydraulic system;
I = control cabinet;
J = water drain.



Centrifuges for yarn packages

Fig. 6: Dyeing centrifuge (OBEM).

Loose fibre material (loose stock) can also be centrifuged continuously (Figs. 4 and 5).

For the dewatering of yarn packages, other possible options besides the asymmetrical dewatering of columns of yarn packages in suitably shaped compartments of the centrifuge (Fig. 6) include symmetrical dewatering by the rotation of individual packages (Fig. 7) or columns of yarn packages (Fig. 8) which involves less risk of package deformation.

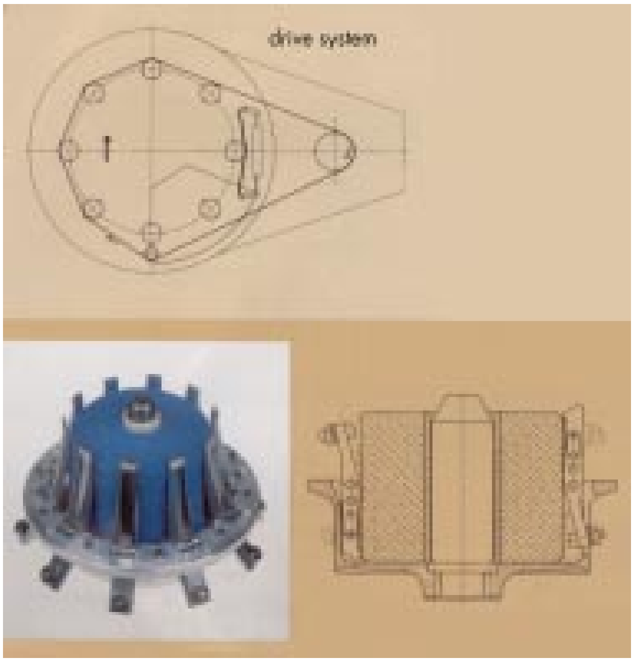


Fig. 7: Centrifuge for individual yarn packages (Frauchinger).

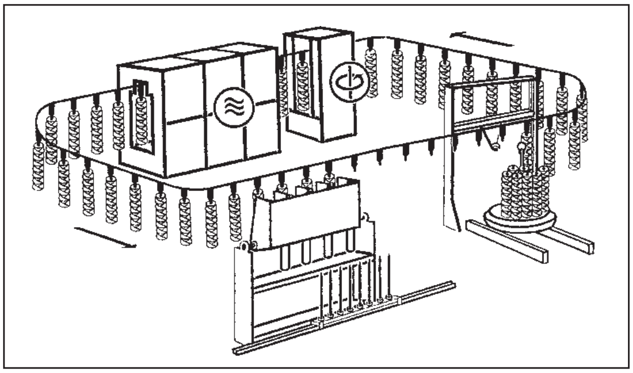


Fig. 8: Centrifuging system for columns of yarn packages (Thies).

Centrifuges for yarn packages,

I. → Centrifuges for removing water from cross-wound yarn packages on individual heads.

II. Standard centrifuges with special cone holders.

Centrifuges swelling The weight of water retained after centrifuging by a textile sample which has been impregnated with a swelling agent and centrifuged under standard conditions expressed as a percentage of the weight of material.

Centrifuging (printing paste). Are a → Print paste sieving machine in which the application of centrifugal forces enables impurities to be separated out of the print paste (clearing, separating and emulsifying cylinders).

Centring device An electronic device installed at the fabric entry of a flat-bed screen printing machine to balance out any irregularities in the dimensions of woven patterns for printed hand towels, neckwear and headscarves by the formation of transverse folds in the border separation areas before the fabric is glued to the printing blanket.

Centripetal action A developmental action (e.g. force, acceleration) starting at the outside and working towards the centre (i.e. the opposite of centrifugal force), e.g. flow phenomena in vortex or whirlpool formation. Centripetal filter → Filtration plants.

Ceramic fibres Industrially produced organically based fibres; artificial → Mineral fibres. These include silicium oxide and silicium carbide fibres, and aluminium oxide and aluminium silicate fibres for example. They are all resistant to high temperature, and find use in special technical fields.

Cerasin (Latin: cerasus = cherry; also metarabin). Cerasin is named after the source of this polysaccharide component in cherry tree gum (35–50%), but it is also found as at least α of the water insoluble fraction of normal rosaceous gums. The chemical composition should correspond largely to → Bassorin. However with nitric acid less mucic acid is produced than with bassorin. Solutions are produced after prolonged boiling, probably as a result of degradation of the material. It is known that with cerasin, as with arabic acid, the viscosity gets higher with increasing pH and then goes down again with excess alkali.

Ceresin wax (ozokerite, earth wax, mineral wax). Wax-like hydrocarbon mixture, mostly paraffins, high boiling point petroleum fractions and resinous substances. The wax is only of commercial value after purification. White or yellow waxy cake with a fine-grained fracture, virtually odourless and tasteless. The purified wax has a melting point of 60–85°C. Ceresin wax is not saponifiable. Uses: waterproofing textile fabrics, production of batiks, textile sizes, substitute for carnauba and beeswax.

Ceric sulphate (cerium IV-sulphate), $Ce(SO_4)_2 \cdot 4H_2O$. Water-soluble, yellow, crystalline powder. Density 3,91. Strong oxidizing agent in acidic solutions (similar to potassium permanganate). It is even stable to heating in solutions of sufficiently strong acidity. Uses: for volumetric analysis as a substitute for $KMnO_4$ in potentiometric tritrations (“ferroin” indicator). Occasionally used in dyeing aniline resp. diphenyl blacks.

Certification Certification in accordance with DIN ISO 9000 provides evidence that a company is capable of meeting consistent quality standards. This commitment to quality must be supported by following an effective quality assurance system. Certification and quality management (→ Quality assurance) are additional elements (Fig. 1).

The requirements for a particular product are set out in specifications which the producer undertakes to comply with. Agreement on specified requirements is mainly necessary in problem cases and can only be

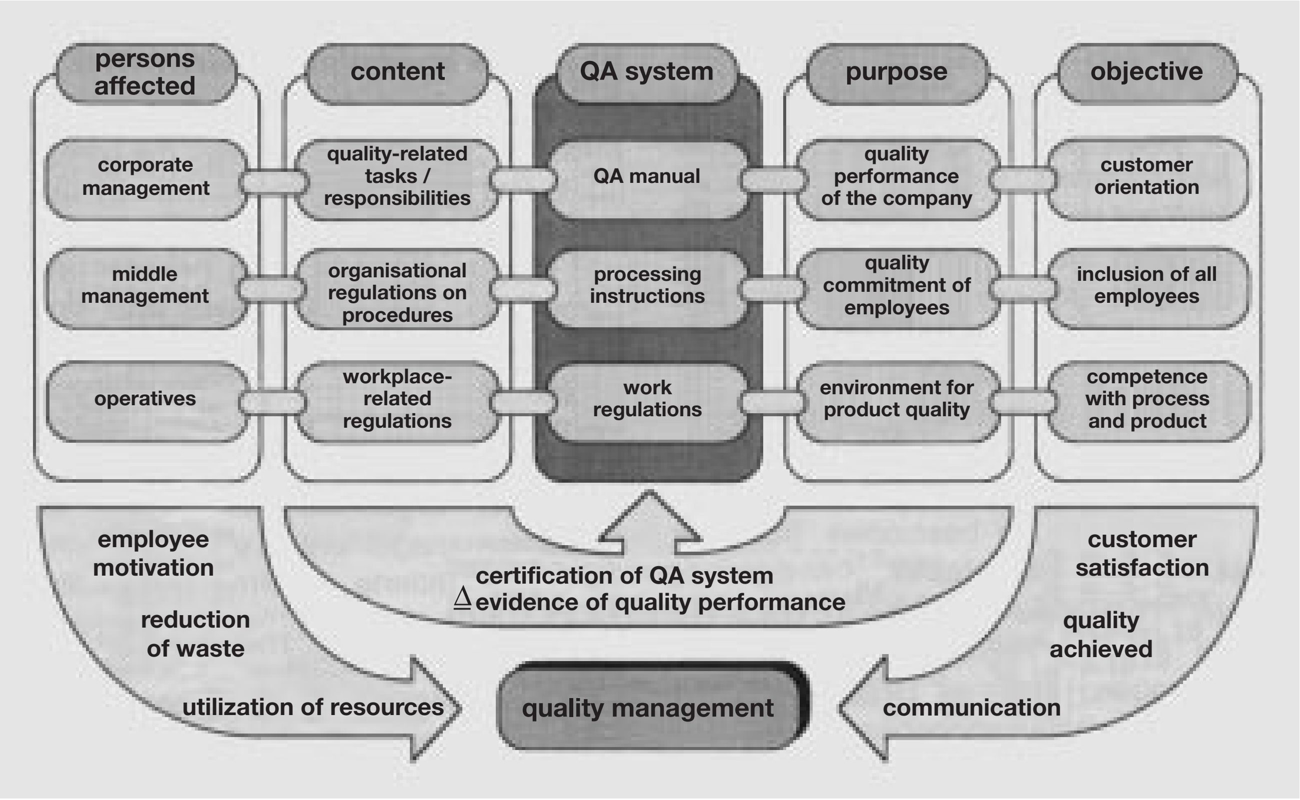


Fig. 1: Relationship between certification and quality management.

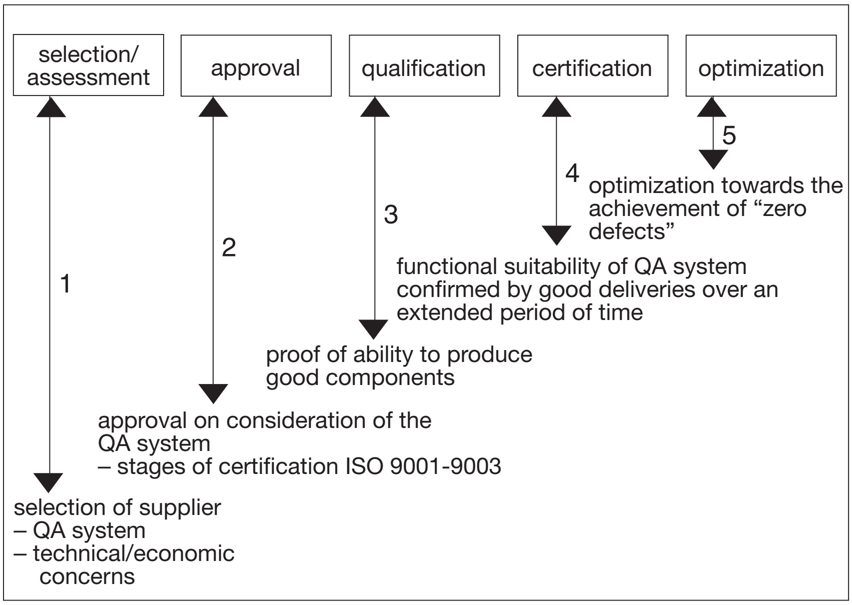


Fig. 2: 5-phase concept for quality assurance (IBM).

achieved through an intensive dialogue and exchange of information between customer and supplier.

The supplier is primarily assessed as to whether or not he meets the requirements of DIN ISO 9000. To this end, he must guarantee that he is applying the necessary quality standards at all levels and in all fields of his production. He is then in a position to transpose the customer’s requirements into his manufacturing operation and, by virtue of his technical competence, produce and supply routinely inspected goods of faultless quality. The procedures are thoroughly documented in written form, e.g. in a quality assurance manual and are subject to scrutiny at any time.

Accreditation to DIN ISO 9000 provides no guarantee of fault-free goods. As a qualification, therefore, evidence is given that the manufacturing operation is capable of producing goods of consistent quality.

A qualification plan includes these requirements which must be complied with:

- processing competence and process control on the part of the supplier,
- workmanship in manufacturing,
- reliability and reliability record.

The objective of qualification is also to determine and evaluate the interaction of all components in a manufacturing operation such as the materials, processes, machines, etc. as well as their compatibility at all stages of production. The data obtained is documented in writing and forms the basis for the product qualification. The supplier then has an obligation to inform the customer of any modifications to his processes such as optimized procedures, relocation of processing, etc. as well as any organizational changes which could have a negative impact on the function of the quality assurance system. After qualification, the capability of the supplier is assessed over an extended period of time. Particular attention is paid here to translation of the established quality assurance system into the current manufacturing operation.

A positive evaluation of the following criteria is decisive for certification of the supplier:

- delivery according to specification,
- quality,
- quality performance,
- processing competence,
- workmanship.

A summary of the 5-phase concept from selection of supplier to optimization is given in Fig. 2.

After the certification stage, the company undertakes to optimize the process in such a way that an ongoing increase in quality is possible. This is achieved by:

- continual checking of processing competence,
- audits (both external and internal),
- statistical process control techniques.

(source: Hein).

CETIH, abbrev. for: Centre d’Etude Technique de l’Industrie de l’Habilement, Paris and Lyon (French Centre for Technical Studies of the Clothing Industry); → Technical and professional organizations.

Cetyl pyridinium chloride (1-hexadecylpyridinium chloride, CPC), white powder, soluble in water (neutral reaction), alcohol, chloroform. Typical → Pyridinium compounds. Used in, amongst other things, 0.1 and 1% aqueous solution for titration (methylene blue method) of the content of anionic-active substances in dry cleaning liquors which contain cleaning promoters.

Cetyl trimethyl ammonium bromide (CTAB), $[C_{16}H_{33}N^+(CH_3)_3]Br^-$, white, powdery, voluminous, foam-forming, cleaning and disinfectant cationic surface-active agent. Water soluble 1 : 10 (= pH 5–7). Used as: antiseptic (0.2–1% solution) and dyeing auxiliary (e.g. retarder, stripping agent, white resist in printing).

CF, → Carbon fibres, → Standard abbrev. for textile fibres, according to DIN 60001 T4/08.91.

Cf, symbol for Californium.

CFC, abbrev. for: chlorofluorocarbon. A type of compound in which some or all of the hydrogen atoms of a hydrocarbon (usually an alkane) have been replaced by chlorine and fluorine atoms. Most chlorofluorocarbons are chemically unreactive and are stable at high temperatures. They have been used as aerosol propellants, refrigerants and solvents, and in the manufacture of rigid packaging foam.

Because of their chemical inertness, chlorofluorocarbons can diffuse unchanged into the upper atmosphere where photochemical reactions cause them to break down and react with atmospheric ozone causing → Ozone layer depletion. For this reason their use has been discouraged.

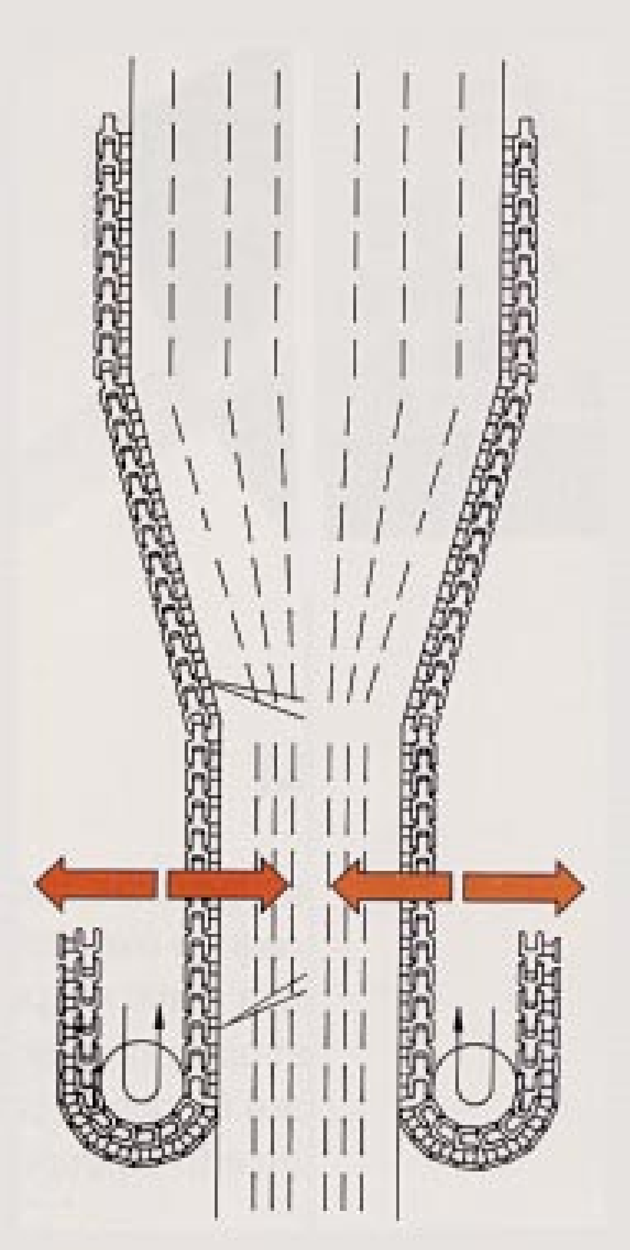


Fig. 1: Stenter chain guiding (US patent).

CFS value, abbrev. for: “Cycle Felting Severity”, an IWS Standard for the felting of wool in washing.

CF value → Comfort factor.

CG Plastic White Scale → Ciba-Geigy White standard.

Chafer fabric External strengthening of the shoulder of car tyres, where the tyre and the wheel rim come into contact. In tyres with inner tubes flexibility, (shear) stability and adhesion are required; with tubeless tyres air has also to be prevented from escaping between the tyre and the wheel rim. Fabrics with coatings of adhesive applied to them are used.

Chagrin fabric is a description for:

I. strongly grained leather, hides from horses, camels, sharks etc.

II. embossed material, e.g. from an embossing calender.

Chagual gum Vegetable gum from Chile and Peru with a high content of → Bassorin. It is found in various forms: voluminous pieces, crystalline, cylindrical and hollow, up to 15 mm in thickness. Chagual gum is only partly soluble in water. The insoluble component swells to form a crystal-clear gel with high refrangibility and low adhesive properties.

Chain On stenters: pin links are linked together into an endless chain for fabric transport purposes. Two chains (vertical or horizontal return) take up the fabric by means of pins or clips, passing it through the stenter processing zone (Figs. 1–4).

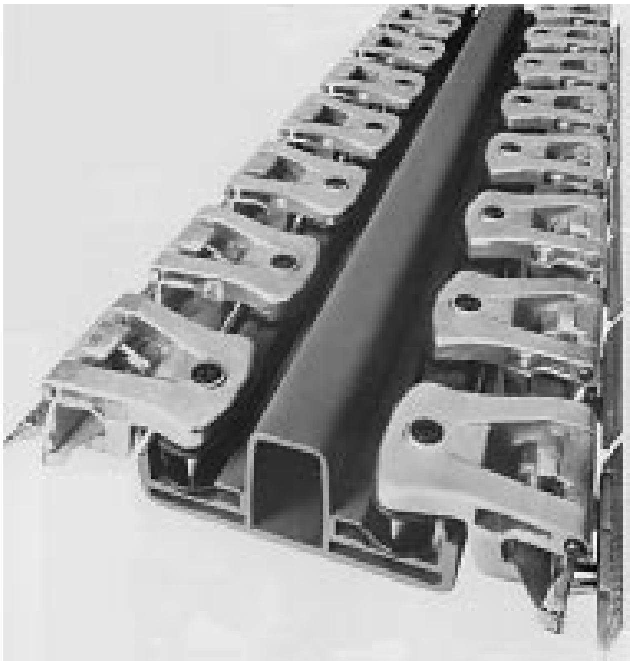


Fig. 2: Horizontal chain guiding (Babcock).

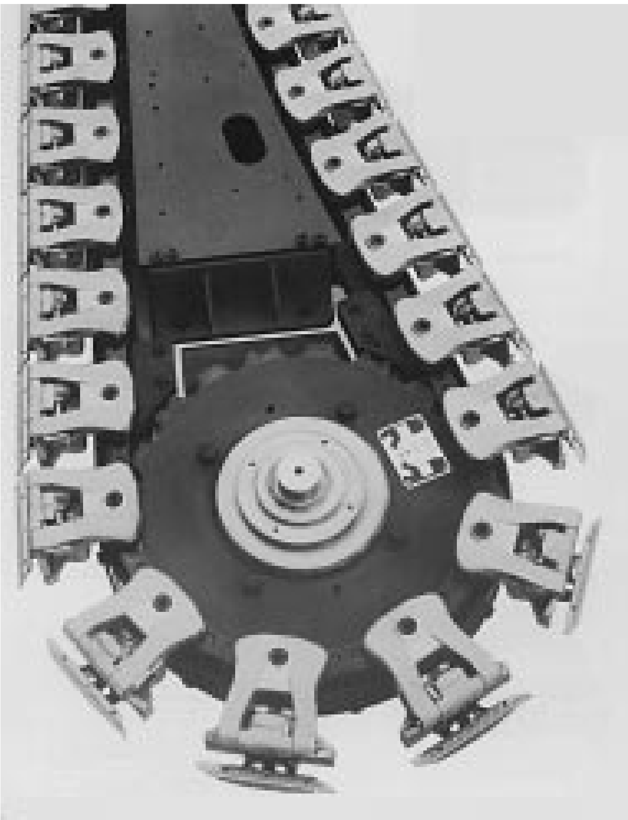


Fig. 3: Horizontal chain return (Babcock).

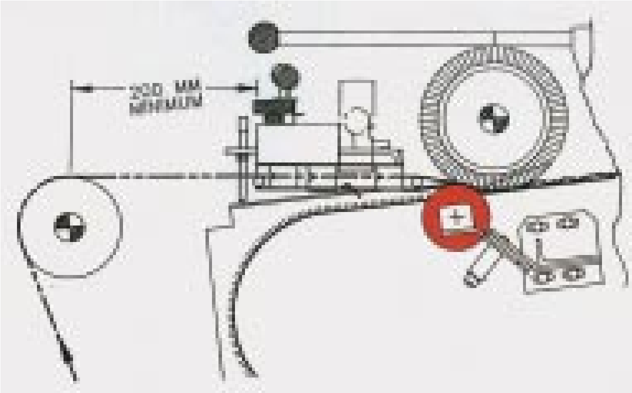


Fig. 4: Vertical tenter frame chain.

Chain adjuster Tensioning unit which is adjusted in the event of slack running transmission chains.

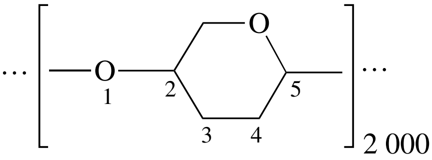
Chain lattice → Pleated sheet structure.

Chain length The greatest molecule length produced with the greatest possible extension of the macromolecule (zig-zag chain) whilst maintaining bond angle and the atom spacing.

Chain length difference in cellulose The values for the → Average degree of polymerisation DP are different depending on the measuring process. The nitrate values (decomposition by nitration) are almost always 10% higher than the cuoxam values (decomposition by solution in cuoxam). Staudinger described this phenomenon as chain length difference CLD, and suggested the following simplified formula:

$$\mathrm{CLD}\ [\%] = \frac{\mathrm{DP}_{\mathrm{nitrate}} - \mathrm{DP}_{\mathrm{cuoxam}}}{\mathrm{DP}_{\mathrm{cuoxam}}} \cdot 100$$

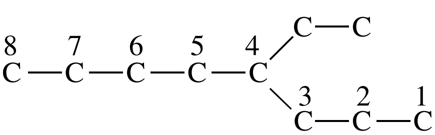
Chain link number According to Staudinger, the number of atoms in a principal valency chain. Since each glucose ring in a cellulose chain molecule consists of 5 primary valency type concatenated chain links,



one obtains the cotton cellulose chain link number by multiplying the degree of polymerisation by 5 = 10 000, viscose cellulose 300 x 5 = 1500.

Chain molecules Like filamentary molecules or linear molecules, this is a collective term for molecules (mostly of a high molecular weight) with a chain structure, with or without branching. The diameter of the chain molecules (calculated from the axis of the stretched chain) is only about 1 molecule dimension, and is minuscule compared with the length. The chain molecules can occur in fully stretched form, but the non-stretched forms, particularly in solutions, are much more frequent; the deviations range from a simple kink through a helix to a random ball. →: Chains; Macromolecules; Polymers.

Chains, chemical combinations of atoms (chain atoms or chain units) covalently bound together in a row, and which are the basic structural elements of a series of molecules (→ Chain molecules). Such chains usually consist of the same or similar building units; they can be "open" or "closed" depending on whether the end units are free or joined to one another. The chain is said to be branched when an atom that is part of the chain is also the starting point for one or two new chains. The most important chains consist exclusively of carbon atoms. They are found e.g. as open (linear) chains of the form -C-C-C-C-C- in, among others, the n-alkanes, alkenes and so on. Branched chains have the form:



In this case the ethyl group (as the shorter chain) substituted on the C-atom in position 4 is also described as a side chain of the n-octane; the numbering is in accordance with IUPAC Rule A-2. Lengthening the chain by adding further chain units is called homologization. Closed chains are present in e.g. cyclic compounds and these may also be branched. This sort of chain where the chain units are atoms of one and the same type, as shown above, are often described as iso-chains in distinction to hetero-chains, which have hetero atoms in the chain. In general use the term "chain" is usually limited to molecules with open chains; this applies above all to macromolecular chain molecules. The characteristic quantities in this case are the number of chain atoms (→ Chain link number) and the chain length.

Chain stitch Ornamental stitch made by connecting loop stitches to form a distinct line resembling the links in a chain. Used especially to edge and join braids as well as for elastically joining up knitted goods.

Chair leg test A serviceability test for textile floor coverings that imitates the load from chair legs. A statistical pressure test in accordance with DIN 54 316. Measurement of impression depths in mm and appearance in grades 1–5.

Chalcogens The elements oxygen, sulphur, selenium, tellurium, polonium of group VI. Their compounds are known as chalcogenides.

Chalk → Calcium carbonate.

Chalking Usually goods which have been treated with excessive quantities of filling agent (kaolin etc.). Textile surfaces (woven and knitted fabrics) display light markings to the surface, often when the material is creased (hand testing or wearing), folded, or pressure is applied by a hard object, from a measuring wheel or the foot of a sewing machine to a fingernail; the material is said to display a writing or chalking effect. Generally, this writing effect is a concealed and therefore undesirable quality defect. It may become apparent during the finishing of goods, thus immediately following dyeing, but also after finishing. To a limited extent this writing effect may show more or less strongly dependent upon the moisture content of the fabric. The main fabrics affected are those with relatively even surfaces and of uniform shade, in mid to deep tones; less susceptible are prints and heavily structured fabrics. Woven fabrics and knitted goods are equally susceptible. Essentially, investigations show up two different causes. Common to both is the fact that mechanical changes to the surface cause a change in the refraction of light thus giving rise to line markings. Line-type, localised destruction of threads or fibres on the surface, e.g. as if caused by a pin or needle, give rise to bearding-type cracking which leaves a single sided mark (chafe marks). The cause of the removable fault in a fabric displaying the chalking effect is caused by a possible superficial thread or fibre displacement. The diffuse reflection of the light from the normal threads is suddenly transformed into directional reflection due to surface flattening resulting from mechanical causes and the line shines. The textile is marked by lines that stand out clearly from the surrounding fabric surface. If this affects several threads in a direction diagonal to the weave, it is known as lateral yarn displacement, or mesh displacement in the case of knitted goods (see Fig.). The surface relief and thus the reflection of light are changed. The displaced fibres or threads remain deformed and do not return to their original positions. Such a fabric is too strongly susceptible to plastic deformation due to its structure, yarn twist, yarn lie, yarn stiffness, inner inelasticity, fibre softness and insufficient internal lubrication, sometimes also dependent on the finish.

Fig.: Surface-sensitive, relatively hard, plasticizable knitted fabric. Threads and meshes are permanently displaced by mechanical influences, causing a change to the reflection of light. Flattened areas shine, the surrounding surface gives a diffuse reflection (top = right side; bottom = reverse side) (source: Steinbrecher).

The deformability of the surface is a clear characteristic specific to each material type and does not independently correct itself. In the second case, generally found in finished textile goods, usually with a discontinuous surface film (finishes rarely form a fully-enclosed film on the threads and fibres), the thin patchy film areas of the finish break, and the breaks reflect the relatively directional light diffusely, causing a matt line. Such faults are not essentially typical of certain finishing products or types; they may arise following any application methods and in practically any product category. On the contrary, the formation of the effect and thus the appearance of the fault is dependent on the qualities of the partial film, thus the finish or product add-on. If this film is easily broken or splintered by localised, mechanical influences, a number of small breaks are formed. The straight-line, mechanical influence causes the stripe-like formation of numerous small particles that reflect the light in a diffuse manner, giving a line that is usually matt in appearance. Such effects can be avoided or removed during finishing; both knitted and woven fabrics affected can be repaired. In the case of the first type of fault referred to, the deformability (plasticizability of the material) must be removed by increasing the "inner" softness, lubrication and flexibility or elasticity. This should result in the material returning to its original condition quickly, preferably spontaneously. In successful cases the lie of the fibres or threads return immediately to position due to the elasticity obtained. This is possible using a flexible soft finish, smoothing finish to increase the internal lubrication, or mechanically by tumbling. In the latter case a possible solution lies in standardising the reflection of light by breaking up the isolated areas of film equally, therefore spreading the breaks evenly over the whole surface of the fabric. For this purpose, calenders, felt calenders or tumbling may be used. The surface film coating is evenly broken giving equally diffuse light reflection from the numerous small breaks. The isolated areas of film-like finish must be as flexible and thin as possible whilst avoiding brittleness as much as possible. The film builds up on the surface to a minimum extent if the application method gives good penetration into the thread giving as low surface coating as possible. This depends on the "impregnation" strength, the absorptive capacity of the finishing agent, the wetting capacity of the finishing liquor and not least the volume, concentration and composition (proportion of film former). The addition of action-enhancing wetting agent (n-alkyl phosphate) may help (source: Steinbrecher).

Chamber acid → Sulphuric acid.

Chambré fabrics are made of 50:50 polyester/cellulose in which the warps are made of cellulose and the wefts of polyester. They are dyed with reactive dyes first, the polyester remaining undyed, and then printed with disperse dyes.

Chamfering Removing the edges of cross-wound bobbins before dyeing in order to avoid dark patches. Done by hand or using chamfering machines.

Changeant (glacé, shot silk). Fabrics made of natural silk or synthetic fibres, in which the warps and wefts are different colours. Filament yarn fabrics are usually piece dyed in a single bath process, viscose or cupro being the first fibre and acetate filament the other. The changeant effect is most effective in plain weave fabrics when the moving light-dark contrast of the individual components effectively enhances the changing colour effect to give an attractive interchange when the angle of incidence of the light changes. Used as clothing, overcoat or lining material.

Change in colour Device for assessing the degree of change of colour by → Grey scales for colour fastness testing (change in colour).

Change of state in textiles From the point of view of thermodynamics, textile material is in a state of equilibrium.

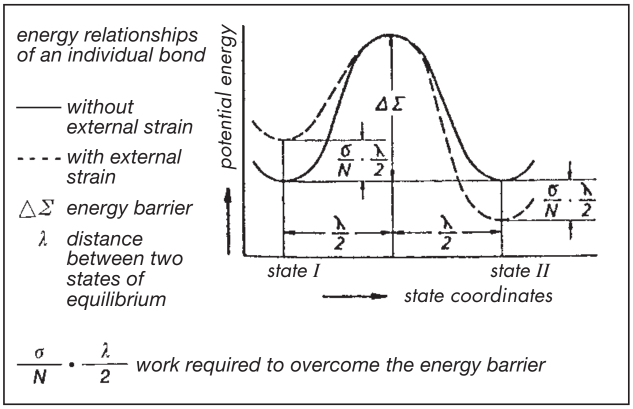


Fig. 1: Principle of stable states and associated changes of state through the "rearrangement" of bonds between cellulose molecules (source: Rüttiger).

If the material changes into a different state of equilibrium (Fig. 1) as a result of certain external influences (tensile stress, heat, swelling), then the progression of this change of state takes place over a period of time because of the necessary activation energy barrier, i.e. the rate of "rearrangement" determines the time for the mechanical progression (e.g. the breakdown and reformation of hydrogen bonds (Fig. 2).

Compared to processes from derived but often readily accessible variables, states are to be regarded as kinetic, which is an essential characteristic:

a) states: equation of state, state variables. Typical examples for indications of states in practice: textile material is finished, bleached, calendered, afterwashed, dried as a final stage, conditioned, made-up, etc.
b) processes: transitory change of state variables, i.e. changes of state as kinetic and/or physico-chemical processes. Typical examples for processes in practice: textile material stretches, shrinks, swells, wets, dries, or is cured, heat-set, embossed, ironed, broken, steamed, stretched, relaxed, sanforized, etc.

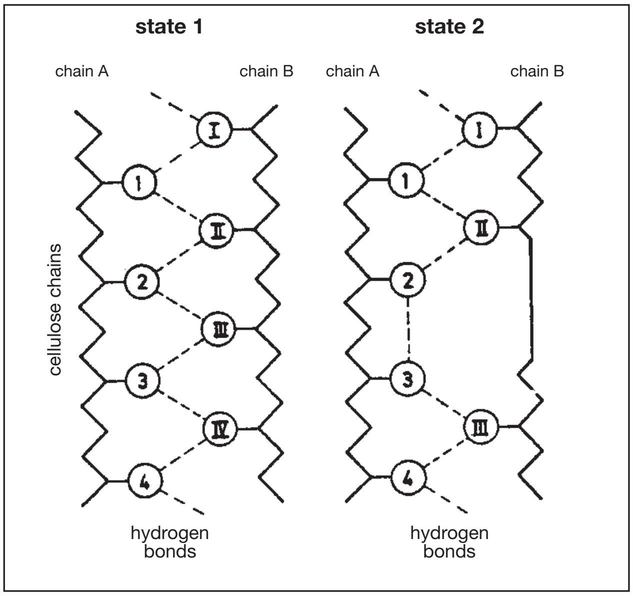


Fig. 2: Hydrogen bonds between the –OH groups of cellulose for different arrangements (states) of the chains. Air-dried cellulose contains one water molecule for each 3rd hydrogen bond which can facilitate the "rearrangement" from state 1 to state 2 (source: Rüttinger).

Important changes of state which occur during practical textile finishing:

1. Modulus of deformation through variations of
   - stages of stress,
   - rates of stress,
   - states of swelling,
   - degree of crosslinking.
2. Recovery, contraction after mechanical stress has ceased:
   - spontaneous: amount, modulus, (elastic resilience),
   - delayed: amount, rate.
3. Elongation after a tensile stress:
   - f (stress, time, swelling, temperature),
   - creep, relaxation of deformations,
   - permanent (creeping) and pseudo-permanent component.
4. Manifestations of rupture:
   - tensile stress,
   - abrasive stress.
5. Stretching-setting processes:
   - relaxation of tension
   - retardation of tension
   - equilibrium point,
   - release of "frozen-in" internal tensions.
6. Shrinkage processes (thermal and swelling contraction):
   - washing shrinkage,
   - pressing shrinkage,
   - processing contraction (free, and with counter tension),
   - max. swelling contraction (free, and with counter tension),
   - inversion effect on mercerizing.
7. Thermal and swelling changes (reversible components only):
   - heat expansion,
   - swelling dilatation, de-swelling contraction.
8. Transitions, 1st and 2nd order:
   - crystalline – amorphous,
   - crystal type I – crystal type II,
   - glass-like – rubber-elastic state.

During the tensile stress of fibres, the following changes of state can occur: firstly, deformation of the fibres takes place mainly due to bending of the bond angle, strain on the loops without opening them, and other reversible processes. This is also accompanied by strain on, and partial breakdown of, the → Tie molecule which is joined to each other in the crystalline regions via the non-ordered (amorphous) regions. For each step of elongation, the number of additional unstretched loops decreases. With an increasing rate of elongation, a few chains (those participating in reversible deformation) can reach their state of equilibrium. More force strands therefore participate in the elongation which results in a steeper rise in the stress-strain curve. In the middle region, irreversible deformations are also involved such as disentanglement, drawing, unhooking, i.e. transposition processes. Large forces are necessary for this. In the end region, the chains are so highly stretched that flow processes take place, as a result of which the macromolecules lose their role as tension carriers, e.g. by displacement, folding, withdrawal of chains from the crystallites, and the scission of crystallites so that molecules, and molecule segments, which have not yet been subjected to strain up to now, are included together in the transfer of energy. As a result, the number of chains participating in the transfer of energy is only slightly increased.

For processes and states involved in tensile stress and recovery, as well as the analogous relationships in creasing, the micro-states and changes associated with them are explained in the Table. They reveal the relationships between the individual variables and the means of determining them. Determination of material-specific constants from derived functions of the state parameters for the complete characterization of a textile material is the purpose here (source: Rüttinger, Beier and Schollmeyer).

Characteristic Statistical concept for a characteristic property which makes the evaluation of units possible (→ Statistical analysis).

Chardonnet, H. (1839–1924). A native of France, he has been called the father of rayon because of his successful research in producing what was then called artificial silk from nitrocellulose.

Charge (batch). The total quantity of a product

	Textile process	*Representation by the relevant equation of state*
Tensile stress (crease formation)	Sample history (drawing, conditioning)	Determined by n_F, n_U, n_S as long as the sample is in a state of equilibrium.
	Clamping length	The length of the calculated example is in the ground state ($n_S = 0$) due to the selected standardization $L_0 = 10$ cm. For comparison purposes, conversion to the effective clamping length must always be carried out. Real samples have the length for calculation $L_0 = (1\,000 + n_S) \cdot 10^{-2}$ [cm].
	Deformation (crease formation) up to a certain extension or tensile stress with different rates of deformation	The main characteristic is the extension of the free segments and the modulus of deformation (M_D); For the constants n_F, and n_S, the following equation applies as a first approximation $M_D = \frac{E_0}{n_F}(1000 + n_S)$. Second criterion; The increase of n_S which, after extension beyond the elasticity limit (yield point), no longer completely recovers even if an equilibrium has been established. As n_S begins to increase: applies; $\sigma_a \approx E_0$. The time-dependent factors are determined by dn_F/dt; dn_S/dt and dn_U/dt; Fine adaptations are possible by applying *Eyring's* three-element model.
	Tension or deformation relaxation (creep)	A) Reduction of external tensile stress with constant length of sample due to increase of n_F. As a result, there is a reduction in the extension of the F-segments and consequently the tensile stress. B) Increase of sample length with stress time due to an increase of n_S. The equilibrium is determined by: $\frac{dn_S}{dt} \approx K \cdot \Delta n_S$
Mechanical recovery (crease recovery)	Spontaneous contraction (elastic recovery)	The rate is primarily dependent on the sample's mass inertia (characteristic oscillation) and the extent by n_F. The modulus of contraction is characteristic. As a first approximation, applies where n_F and n_S are constant; $M_K = \frac{E_0}{n_F}(1000 + n_S)$
	Delayed contraction (creep recovery)	Δn_S determines the extent of creep recovery. The time progression with constant temperature and swelling is given by: $-\frac{dn_S}{dt} \approx K' \cdot \Delta n_S$. Normally , the further the sample has been deformed beyond the elastic region, the greater the value of Δn_S.
	Tension retardation	The tension which builds up in a sample relieved of stress up to $\sigma_a = O$ over time is mainly limited by Δn_S and E_0. The amount is calculated from Δn_S, E_0, n_F and λ. If a blocked segment under tension is released (S→F) then a corresponding (blocked and frozen-in) tension is also released.
	Permanent extension (elongation, crease angle)	The permanent extension is given by that component of n_s which remains constant after tensile stress. The greater Δn_S was after tensile deformation, then the greater the permanent extension.
	Swelling recovery (washing shrinkage)	Swelling recovery occurs in relation to the extent that n_s is converted by swelling processes into n_F, or n_U.The resultant swelling contraction tension is determined by Δn_S (swelling), n_F and E_0.The reversible change in the length of l_0 during swelling is superimposed on this process.

Tab.: Relationship of micro-states with changes of state in textiles.

manufactured under specified conditions which is understood to be of homogeneous composition.

Charged system → Batch system.

Charge reversal The ability of ionic colloidal electrolytes in aqueous solution to transfer their electrical charge, e.g. to fibres with the opposite charge (negative charge on protein and cellulosic fibres) or to chemicals adsorbed by the fibre (auxiliaries for improving fastness).

Charging of machines In industrial production, a distinction is made between when a machine is running and non-running times. During the latter period, the

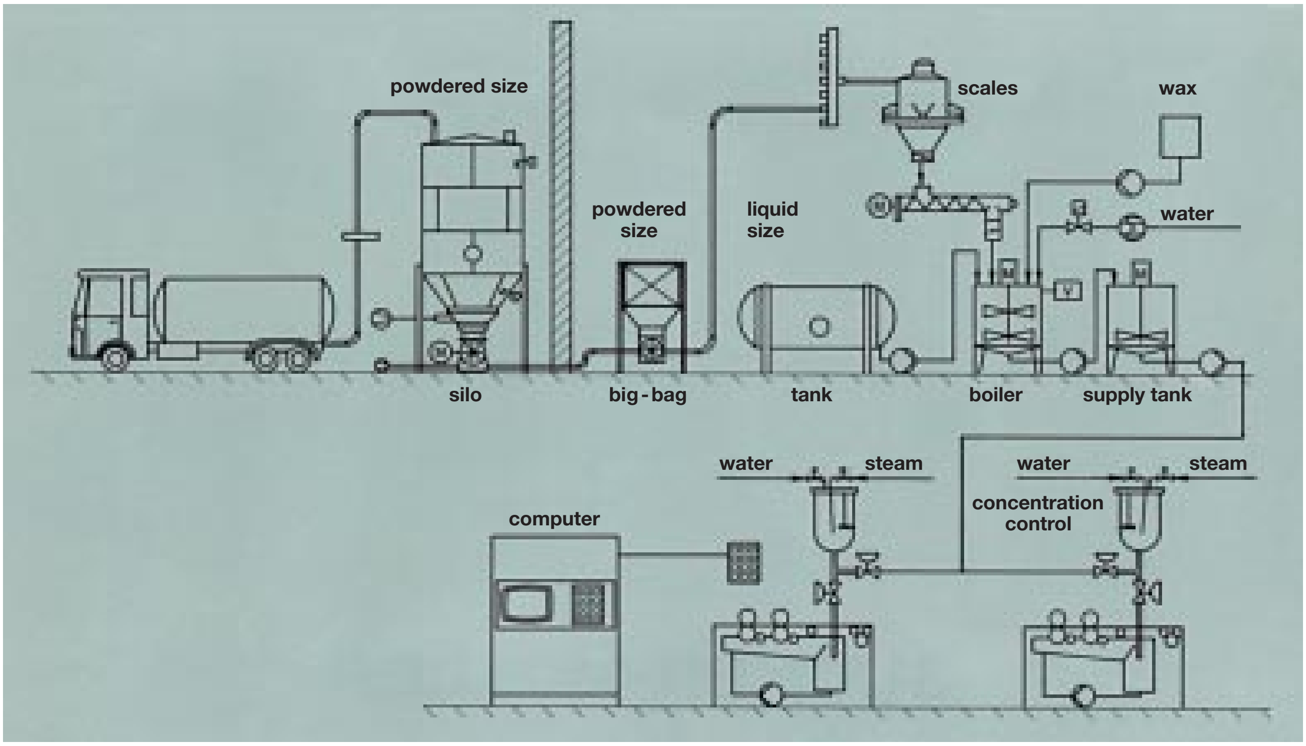


Fig.: Charging of a sizing line.

machine is unloaded and loaded for the next process cycle. This process is known as charging. It also includes charging the machine with the necessary auxiliaries, chemicals and dyestuffs. Every textile finishing plant which for example applies finishing products to textiles must be logistically organised including outside supply of raw materials to reduce any standing time to a minimum (see Fig.).

Char length Length of the torn, carbonised area in → Flammability testing (vertical test). It is determined after the recorded afterglow period on the same test sample. 89 mm is the required average limit value for textiles with flame retardant finishes (mean value of 10 measurements); the max. individual value is 114 mm.

Charly is a → Copper man of size 50 at the Hohenstein clothing physiology institute and can imitate the temperature regulation of a person (→ Clothing physiology): the legs can be moved at the hip and knee joints and the arms can be moved at the shoulders and elbows, it can sit, lie, stand and also imitate walking and running movements. It is heated by warm water (pipe system). External evaporation can be measured with water (body cooling, sweat evaporation). A complex control system is used for comparative clothing studies, physiological work measurements etc.

Charmeuse Fine, soft warp-knit in silk, viscose or polyamide filament yarn, finely corded, very fine-meshed, invariably two-threaded and run-resistant, generally having more lustrous face and crimped back. Tricot charmeuse has a face of tricot character, used for underwear.

Chartered Colourist Technical qualification of the → Society of Dyers and Colourists, Bradford, England.

Chasing calender The fabric is fed in a spiral through the calender by a roller device. The goods are arranged in 7 layers one above the other in the roller system, and are led over a board into the middle of the calender. The goods run spirally towards the outside, so that the last outer layer leaves the upper nip and is led to the winding up (Figs. 1 and 2).

The goods are compressed in the circulation

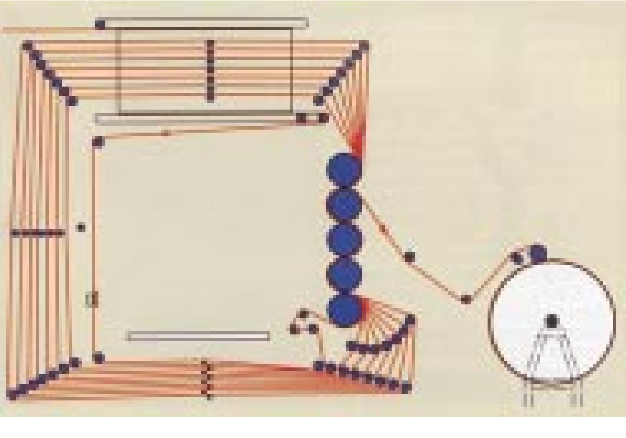


Fig. 1: Fabric control in a chasing calender (KTM Kleinewefers).

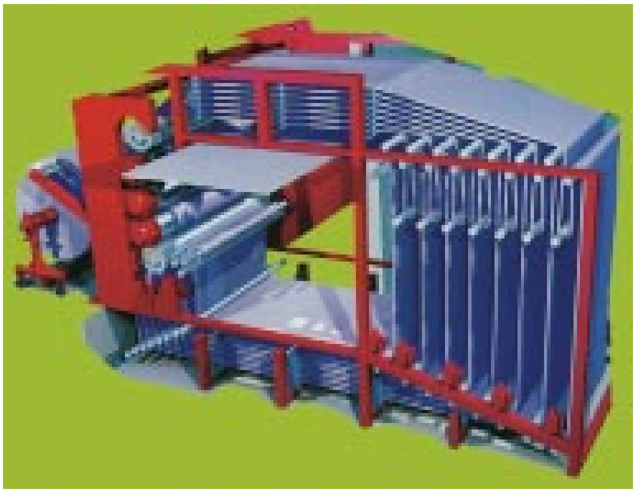
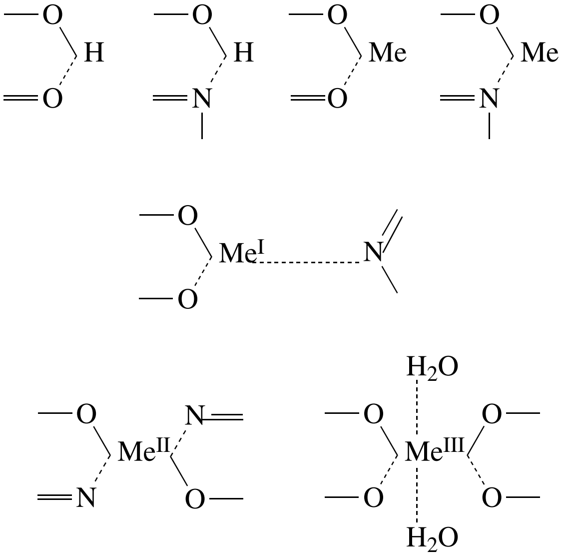


Fig. 2: Chasing calender for high-quality bed and table cloth made of cotton and linen (Küsters).



through the chasing calender. The aim of the treatment is to get the required density and air permeability at the same time. Because there are multiple layers of fabric in the press the fibres remain round and bulky.

CHC process (Calendered Heat-Set). Caustic soda treatment for polyester knitgoods to improve the surface characteristics.

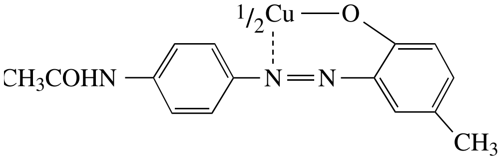
Check list A statistical registration and evaluation system for counting and measuring results, with headings such as the following: size classification, absolute frequency, % frequency, % frequency total. Each individual value, assigned in advance equidistantly to a pre-determined size classification, is marked in the relevant row by a vertical mark. The ultimate count of the check marks enables immediate conclusions to be drawn on frequency distribution.

Cheese cloth Lightweight cloth of open structure in plain weave. The net appearance is created by the very open interlacing of warp and weft. The fabric has low structural stability and an appropriate finish is generally necessary to prevent warp/weft slippage.

Chelate An inorganic complex in which a ligand is coordinated to a metal ion at two (or more) points, so that there is a ring of atoms including the metal, i.e. a metal-complex. The process is known as → Chelation.

Chelate bond, complex (Latin: chelae = claws). Chelation arises from an → Atomic bond as primary valence and a → Coordinate atomic bond as the secondary valence, so that a metal or hydrogen atom is joined to two positions in an inner complex compound.

Such bonding (semi polar) plays an important role, e.g. in deactivating water hardness, very frequently in various metal complex dyestuffs, in phthalocyanine ring systems as well as extremely numerous textile chemical processes in the form of hydrogen bonds. In the case of chelated metal atoms, the terms metal-, copper-, chromium chelate etc. are used. For reserving disperse dyes in reserve printing on polyester disperse, dyes that are suitable for chelating with metals are used; they form complexes and lose their affinity for polyester. Suitable metals are copper, chromium, cobalt, iron and aluminium. In practice, copper acetate or copper formate are used according to the principle:



Chelate resist printing A process for the production of resist prints on polyester whereby functional groups such as –OH, –NH, –COOH, >C=O or >NH in disperse dyes are able to form chelates with heavy metal cations such as Cu, Cr, Co, Fe or Al from the corresponding heavy metal salts. Penetration of disperse dyes into the polyester fibre is prevented by chelate formation. The best results are obtained with copper compounds in the following order: copper acetate, formate, sulphate and phosphate.

Chelation Formation of metal-complexes in which a metal cation is held by coordinate bonds within one or more molecules containing several electron-donating groups in a closed ring structure. → Chelate bond.

Chemical affinity is the driving force behind chemical reactions that results in mutual absorption and reactivity, such as e.g. between a fibre and a dyestuff or textile auxiliary (→ Affinity, dye affinity). The affinity between reactants generally increases with differences in the electrochemical characteristics (→ Electrokinetic interfacial potential). According to Pauling, affinity is a question of the energy differences and the probability of the state (entropy). A system in equilibrium has no driving force, i.e. it has no inclination to react in one direction or the other. However, if e.g. the concentration of one of the substances or the temperature is increased, a force is created which drives the system towards a new equilibrium for the reaction. If the substances on both sides of the reaction have the same heat content (equal enthalpy), the reaction goes in the direction of the greater probability (entropy). On the other hand, the reaction goes in the direction in which heat is liberated if the substances on the left and right of the equation have the same entropy. At equilibrium, the driving force arising from the change in heat content (change in enthalpy) in the course of the reaction is exactly balanced by the driving force arising from the change in probability (change in entropy).

Chemical bonding fibres (cb fibres) → Binder fibres.

Chemical bonds Electrical bonding forces between atoms and molecules which can have very different types and effects, depending on the state and structure of the molecule. The following principal types are distinguished:

I. → Ionic bond (electrostatic, polar, heteropolar bonds, electrovalency).

II. → Atomic bond (electron pair, homopolar, covalent, unitary, non-polar bonds) as the principal valence bonds.

III. → Coordinate atomic bond depending on → Secondary valence forces in the form of dipole moments, hydrogen bonds, van der Waal's forces, induction forces and dispersion forces (sometimes without secondary valence forces). In the majority of cases one type of bond predominates although transitions to other types of bond have certainly been observed, just as forces of different natures can be present at the same time, as in e.g. → Chelate bond (atom and co-ordination bonding).

Chemical characteristics of wool Because the chemical nature of wool is that of a protein, it can be characterized with simple, rapid tests and can also be analysed exactly with more expensive methods, to detect any alterations in the fibre caused by finishing treatments. The amino acid composition is characteristic for a given wool; the compositions of an individual fibre can be different at the root and the tip, e.g. from weathering. In tips that have been weathered, the content of histidine and tyrosine is lower as a result of photooxidation (Table).

The cysteine content also changes along the length of the wool fibre (Fig. 1), partly from a break down of cystine by weathering at the tips, and partly by incomplete keratinisation in the root.

amino acid	tip	root
tyrosine	3,66	4,19
histidine	0,72	1,02
lysine	2,99	2,90
proline	7,72	7,58
serine	11,42	11,07
glutamine	13,07	12,47
asparagine	7,23	6,92
leucine	7,87	7,56
isoleucine	3,10	2,93

Tab.: Effect of exposure to weather on the characteristic amino acid content in defined fibre sections of Cape wool (data in mol %) (Klee).

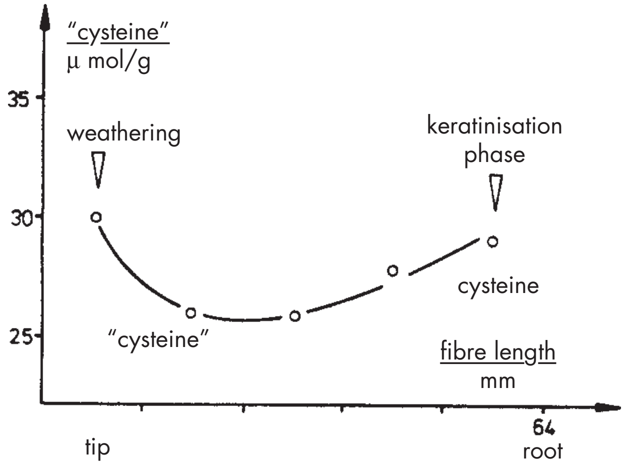


Fig. 1: Effect of weathering and the keratinisation phase on the "cysteine" content of fibre sections of an Australian wool (medium fibre diameter 18.8 mm)(Klee).

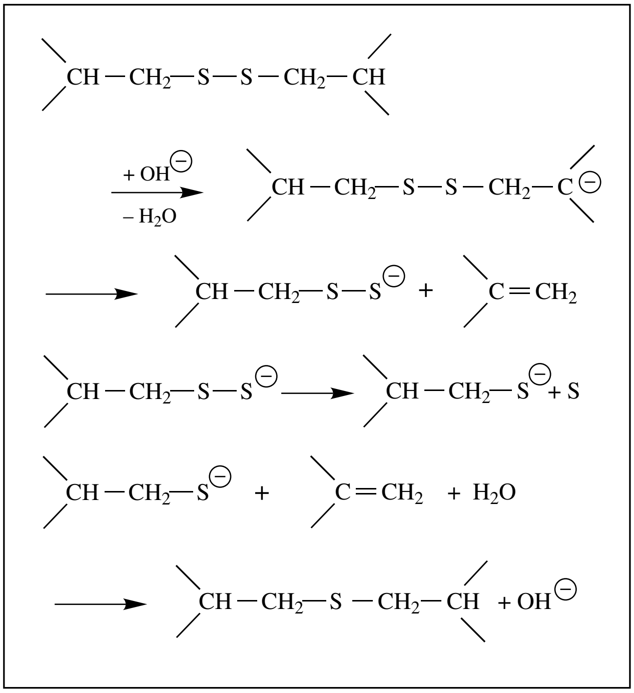


Fig. 2: Lanthionine occurrence in an alkaline medium.

Chemical characteristics of wool

The lanthionine content is a characteristic product of certain cystine degradation processes (Fig. 2).

On oxidation of wool, the cystine content decreases in favour of cysteinic acid (Figs. 3 and 4).

Apart from the carboxyl and amino end groups, the amphoteric character of the keratin molecule depends on the side chain functions. The side chains are characterized by their content of bifunctional acidic and basic amino acids. At the isoionic point, the carboxyl groups in the protein have donated protons to the amino groups so that exactly equal numbers of anions and cations are present. The isoionic point was found to be pH 4.9 by Elöd. The value measured by electrochemical methods is called the isoelectric point and is only slightly different from the isoionic point.

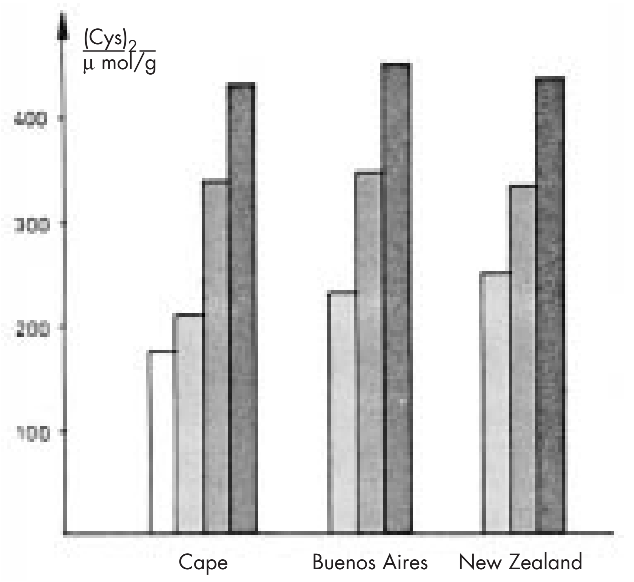


Fig. 3: Cystine content of fibre sections of Cape, Buenos Aires and New Zealand wool (bar graph explanation in Fig. 4).

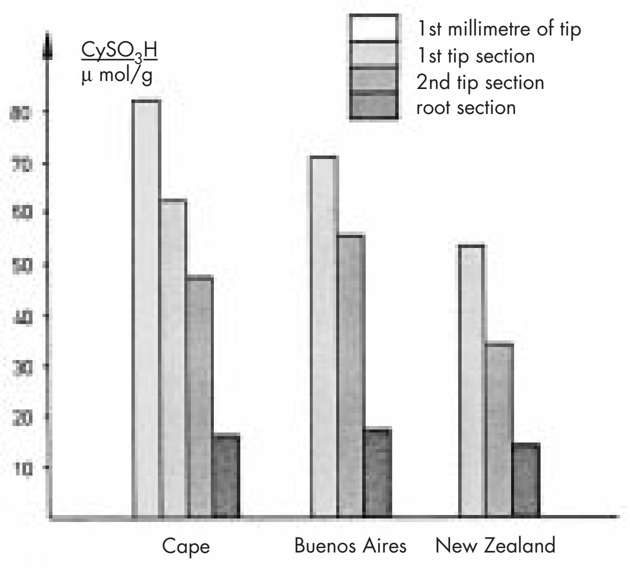


Fig. 4: Cysteic acid content of fibre sections of different wools.

Wool fibres are stabilized by salt bridges as well as by disulphide bridges (Fig. 5).

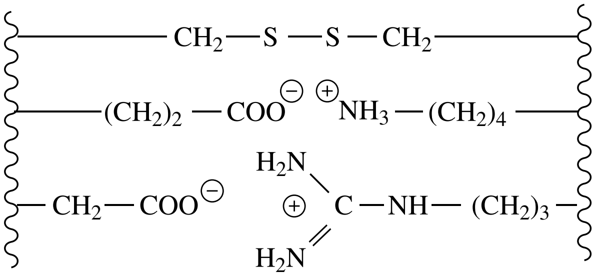
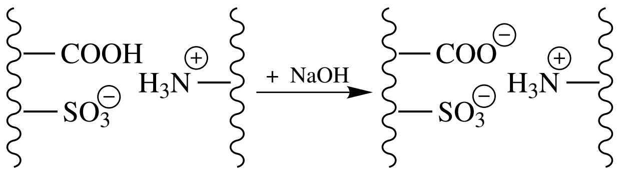


Fig. 5: Salt bridges in undamaged wool at the isoionic point.

Wool oxidized by bleach still shows good stability but, in the test for solubility in alkali, the osmotic pressure is higher because of the new charge distribution, so that the solubility in alkali is high (e.g. 70% with bleached wool compared with 20% for dyed wool). Normally high values for the solubility in alkali (over 30%) indicate acid damage (at the peptide links), whereas the solubility in urea-bisulphite shows alkali damage. However, the increase in the solubility in alkali and also the decrease in the solubility in urea-bisulphite (from about 60% for untreated wool to 0–10% for alkali damaged wool) can also be associated with decreased stability (Fig. 6).



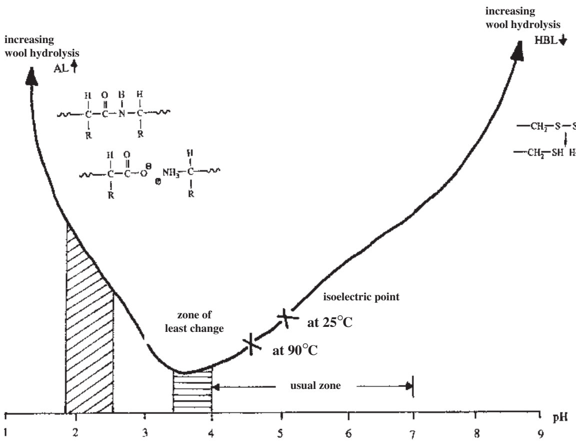


Fig. 6: Wool hydrolysis and zone of least wool change relative to dyebath pH at 100°C.

Chemical compounds Substances formed by the combination of → Elements in fixed proportions. The smallest typical unit of a compound is the → Molecule. Chemical compounds are subdivided into inorganic and organic compounds.

Chemical decatizing Finishes of a chemical nature to impart form retention, in contrast to normal decatizing which involves mechanical and/or physical treatments.

Chemical detergents Incorrect term for → Synthetic detergents.

Chemical displace technique for reserve printing of carpets Chemical blockers affect the fixation of selected acid dyes on polyamide fibres or wool and on cellulosic fibres, so that white, tone-on-tone and contrast dyed or printed effects can be achieved.

Low-affinity dyestuffs should be used for background dyeings. Their affinity is further reduced by the blocking agents. For cross dyeing, dyes with good build-up and fixation characteristics should be chosen so that they are not displaced by the blocking agents or by the alkaline application conditions. It is possible to apply the blocking agent first and then overdye or vice versa. The first method gives less sharp colour definition than the second.

With the blocking technique many design ideas and colour effects can be achieved, e.g.:

- tone-in-tone effects on polyamide or woollen carpets in carpet printing or space dyeing, and also on pile goods made of cellulosic fibres;
- negative space effects on polyamide fibres and wool;
- light contrasting effects on a dark background, both in carpet printing and in space dyeing on polyamide, wool and cellulosic fibres.

Chemical embroidery → Burn out styles.

Chemical engineering A scientific engineering discipline concerned with the techniques for carrying out processes in which substances are changed by variety, property or composition. The main application is in the chemical industry (hence the name chemical engineering), but it also applies to all industrial fields which involve chemical, thermal and mechanical conversion of inorganic/organic substances and supplying the necessary equipment and machinery. The function of chemical engineering is to set up industrial scale processes in which the properties of the substances that are being treated are changed. This can be contrasted with mechanical processing of workpieces in the solid state to alter the exterior form of the articles (mechanical engineering). The following are examples of objectives for individual processes in textile dyeing and finishing, e.g.:

- The objective of washing is separation of materials, i.e. an alteration of the interior structure by extraction and by desorption of contaminating substances, possibly coupled with chemical breakdown reactions. In some cases so-called structural development can take place at the same time by changes in the physical macro- and microstructures.
- In weight reduction of polyester fibres the objective is a chemical reaction at the fibre surface and subsequent removal of material. The result is a change in the macrostructure resulting from the increase in surface area.
- The objective in drying is separation of materials. However there is also a change in the physical micro- and macrostructures which may be desirable or undesirable.
- In thermofixation, there is an alteration of the physical properties by recrystallization of the fibre material.
- Dyeing is a mixing of materials, sometimes with additional chemical reactions.
- Similarly, finishing is a combination of mechanical effects with chemical reactions with the aim of altering the physical and chemical properties.

Model representations of material, heat and mechanical transformations in textile dyeing and printing systems are important prerequisites for technical descriptions of processes and for operating dyeing and printing processes. It is still not possible to describe any system in textile processing completely quantitatively by direct relationships. Control of a system is performed (if not by hand) by adjusting devices (e.g. adjusting motors, regulating transformers, potentiometers). To provide the control signals needed, a parameter must be measured with a sensor and used to generate information about the course of a transformation from knowledge of technical relationships. Hence, from the point of view of textile production with its many and diverse property transformations, measuring and control technology is a vital auxiliary science. It can however only become effective if there is at least a model concept and the dominant parameters that affect the transformations in a system are known (contributed by Schollmeyer).

Chemical finishing Textile finishing gives a textile its final commercial character with regard to appearance, shine, handle, drape, fullness, usability etc.; takes place in a wet state as → Wet finishing or in a dry state as → Dry finishing. Nearly all textiles are finished. The finishing auxiliaries are applied using finishing machines, padders or mangles with one- or two-sided action or by impregnation. Altering the composition, rheology and viscosity of the finish applied can vary effects.

Finishing includes all processing stages such as bleaching, dyeing and printing (especially fabrics), that contribute to the final appearance and handle that convert the textile into a saleable article (aftertreatment). In a wider sense, processes that occur before dyeing such milling, carbonising, mercerising etc. are also regarded as finishing processes since they also have a fundamental effect on the final appearance of the textile (preparation). Few fabrics come directly from the loom ready for sale. After weaving they are simply examined and knots and loose yarns are removed. Special finishing effects may be given to such coloured goods in a finishing process. For both yarn and piece-dyed fabrics the dyeing must withstand the finishing treatment without bleeding or change of shade (process fastness). The final result of the finishing process is dependent upon the prior processing stages. Previously unnoticed faults may become apparent at this stage. It is extremely important that woollen materials are well shrunk and enter the finishing process with their natural moisture content. The success of the English woollen finishing process was not so much in the machinery as the individual work processes because the material had time to "recover" between the individual stages, i.e. to absorb moisture and "relax".

The individual finishing processes are many and varied. Their order and detail will not be described at this point. In general it can be said that during the finishing of synthetic fibre fabrics, difficulties arise due to the material's low moisture regain. Processes used for natural fibres will not necessarily give good results on synthetic because it is often impossible to apply sufficient product to the fabric or achieve the desired effect.

The finishing department includes a finish preparation kitchen that should be separate to the dye house kitchen. This is where the finishing formulations are prepared, and is equipped with storage tanks, measuring devices, scales, heated mixing tanks with stirrers and transport containers. In large-scale systems the formulations can be fed directly to the machines by pipes. Otherwise closed mobile vessels made from stainless steel or plastic are suitable.

Yarn finishing is less important than piece goods finishing. In particular sewing thread made from mercerised cotton, linen and mixtures with synthetic fibres and silk require finishing. These yarns must have a low-friction character. To achieve this they are impregnated with wax, paraffin or silicone derivatives and also undergo mechanical treatment by means of stretching and brushing (polishing). The treatment takes place in thread form, in batch or continuous processing. The machines used to stretch or polish the threads consist of pairs of heated and polished rollers that act on the threads. They are enclosed in a chamber that is supplied with steam. During stretching the rollers rotate slowly so that no deposits occurs. This process is also known as brillianting.

In order to make dyed silk threads easy to unwind; the hanks must held in a straight and untangled form. This takes place between the individual finishing stages and as a final treatment. Hanks are suspended from a horizontal bar and then stretched with another bar. This hand process can be performed by a machine. During silk finishing, lustring also takes place, whereby the silk threads pulled with a stick whilst hanging from a pillar and twisted alternately to the left and right. Machines are also available for this treatment. Cracking (crunchy handle, Craquant) handle treatment of natural and regenerated cellulose fibres and polyacrylonitrile fibres is also considered to be yarn finishing. Oil emulsions and organic acids or ethoxylated derivatives of saturated fatty acids or fatty alcohols are used.

Finishing is intended to guarantee perfect processing of materials, above all sewing capability during clothing manufacture. The high speeds of modern sewing machines generate more needle friction, which can lead to local fabric damage. A suitable softening finishing provides help. Another process is to re-align the weft, which may become distorted during processing and no longer runs at a right angle to the warp or may be bowed (curved across the width of the fabric). The dyed material should be checked prior to each finishing process, particularly if the finish is to be permanent. Correction of faulty processing can be difficult or even impossible.

Chemical finishing auxiliaries Auxiliaries combined with → Chemical finishing agents in formulations to improve compatibility and bath stability and to modify the finishing effect in a particular way. Special fats, waxes, sulphated oils and compounds on a similar basis. The additional use of non-ionic or anionic detergents assists in penetration of the textiles. Included are organic and inorganic humectants; and also products for improving the water repellency of finishing agents that are not resistant to wetting, such as urea- and melamine-formaldehyde compounds, formaldehyde-releasing products and the like.

Chemical fixation Stabilization of a polymer state by crosslinking with bifunctional reagents.

Chemically-embossed floorcoverings Continuing developments in printing techniques as well as the patented Kongoleum process have made it possible to produce an extremely wide range of imitations of all sorts of tiles as well as novel designs for floor coverings (Fig.). Glass fibre non-woven fabrics or mineral papers as used as the backing material onto which a polyvinyl chloride plastisol is applied together with a foaming agent, and is set below the activation temperature of the foaming agent. Then it is printed in the required colours (usually a multiple intaglio printing) with or without the addition of an inhibitor, and a coating layer of compact plastisol is applied after a short exposure to air. The whole construction is then fixed at a higher temperature, so that the agent in the foaming layer decomposes and creates foam. Trimellitic acid anhydride (TMAA) is predominantly used as the inhibitor in concentrations of about 10–20% on the weight of the print paste.

For high production rates, equipment up to 4 m wide is used, often using an in-line process. This process runs continuously, from the backing material, through

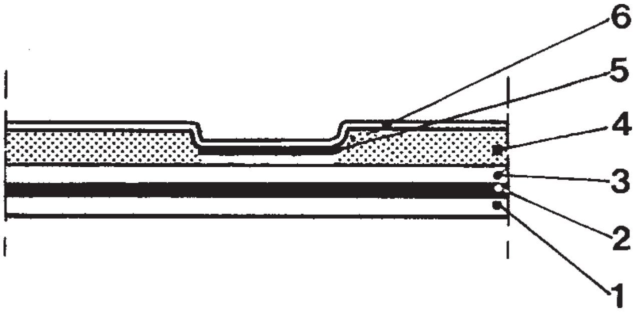


Fig.: Drawing of a structured floor covering.
1 = back coating; 2 = substrate; 3 = ground coat; 4 = foam coat; 5 = print colour coat with inhibitor; 6 = top coat.

the coating and the printing and the application of the covering layer, to the final ready-for-sale rolls.

Equipment of this type has the disadvantage of being less flexible in the type of product that it can produce than are off-line processes, in which the coating and printing are carried out in different units.

Chemically pulped waste jute material is a jute wool.

Chemical/Mechanical finishing of textiles General name for piece goods finishing. Includes all textile material processing procedures after the fabrics leave the weaving, hosiery or knitting mill until finishing is complete. In most cases the raw goods will need to have their final characteristics applied or developed to suit further processing and eventually make goods that are ready for sale. This includes all the work remedy faults from the fabric forming process and/or to give the goods the required characteristics of handle, lustre, weight, surface structure or reduce susceptibility to creasing, shrinking, sensitivity to water etc. The finishing works must give the goods mechanical and/or chemical treatments that maintain the characteristics of the textile fibres, and to provide added value to the goods suitable to the intended end-use.

Textile finishing is widely varied from the mechanical and chemical aspects and requires good knowledge of the raw material and fabrics. It is not possible to draw up a general finishing work plan because the processes depend on the raw material, the origin of the fabric and the desired effect. Wet finishing consists of individual wet finishing processes (bleaching, mercerising, carbonizing, milling, dyeing etc.); dry finishing consists of dry handling processes (decatizing, calendering, pressing, roughing, shearing, singeing etc.

Whereas fashion changes have dominated by colour changes in the past, current fashion is mainly characterised by finishing effects. The finisher must pay attention to two main items of surface finishing:

- using mechanical means such as emerizing, raising, crushing and creasing, chintzing, calendering, pressing, milling, crinkling and crêping.
- using chemical means such as cross-linking, setting, thermosetting, softening, glazing and providing a handle.

In the TEGEWA sales statistics (1988), the main materials used were softeners with 12 500 tonnes, followed by fillers, stiffeners and weighting agents (8500 tonnes). This means: 20 000 tonnes/annum of handle adjusters are used in the Federal Republic of Germany. Approximately 10 000 tonnes/annum of resin finishing agents clearly indicate the importance of low-creasing, swell-resistant and crush setting finishes.

Approx. 2000 tonnes/annum of hydrophobic auxiliaries based on paraffin products, silicones and fluorochemicals. 2000 tonnes/annum of flame retardant auxiliaries show that consumer protection is important, particularly in the use of textiles in the public sector (public transport, public buildings). Sewing thread lubricants (500 tonnes/annum), anti-electrostatic agents (500 tonnes/annum) and antimicrobial auxiliaries are intended for special purposes, but still constitute 2000 tonnes/annum. Light fabrics and knitwear (less than 200 g/running metre) require more and more use of antislip and ladder resistant auxiliaries (1000 tonnes/annum). Because of environmental problems during finishing and the new requirements for biodegradable textiles, enzyme-based finishing is becoming increasingly important. Electrical-based finishing (high-frequency drying, plasma and corona treatment) will be used more frequently in the future.

Chemical metering for fully automatic dyehouse Liquid chemicals are metered directly into the mixing hoppers or chemical tanks of the machines from stock tanks through metering equipment that consists of several groups of dosing units, the number depending on the number of associated dyeing machines. A dosing unit consists of n chemical valves, 2 dosing pumps, 2 electronic counters, 1 feed distributor with a regulating motor and 1 valve for rinsing water. The dosing program is started from the process controller when a chemical is required. If the dosing group for a required apparatus is occupied, the demand is put into a

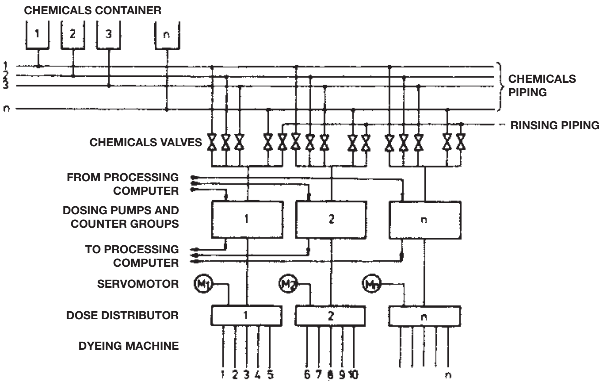


Fig.: Dyehouse dosing unit.

waiting queue. On the other hand, if the particular dosing group is free, the appropriate chemical valve is opened by the dosing program and the feed distributor is put into the correct position. Then the number of strokes for the 2 dosing pumps involved is calculated from the amount of chemical to be dosed, these values are fed into the appropriate electronic counter and the dosing pumps are started. When the last chemical for a unit has been dosed, the dosing program runs a rinsing program for this unit. The amounts are determined and used in the final program exactly as for the dyestuff dosing program (Fig.).

Chemical metering station Modern measuring and control techniques enable processes to be supervised and controlled. In most cases a simple and safe dosing system is required for economical operation. A possible arrangement of a chemical dosing station for feeding bleaching chemicals is illustrated in the Fig.

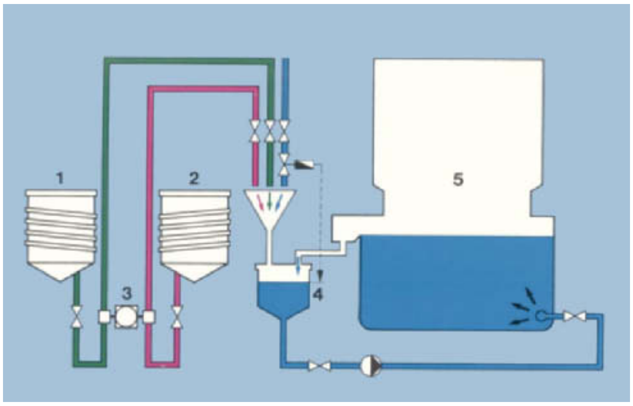


Fig.: Bleaching chemicals dosing station.
1 + 2 = chemicals containers; 3 = dosing pump; 4 = level control; 5 = impregnating section.

To avoid premature reaction, the components are prepared separately in vessels (1 and 2). The concentrations correspond to the ratios that are to be mixed in the recipe. The required amount is then delivered by a two channel pump (3) so that the amounts of the chemicals put into the impregnating unit (5) are adjusted according to the weight of the goods and the speed. The bath is circulated by a chemical pump and is then kept at the required level by an automatic feed of fresh water. The float regulator (4), outside the impregnation unit, works through a magnetic valve.

Chemical oxygen demand (COD), is determined as a → Summation parameter. COD determinations are generally used for assessing effluent as well as water in exhaust air scrubbers, to determine the COD for an effluent stream, and to estimate the loading of the scrubbers and hence prevent possible over-saturation or to check the efficiency of its operation. To determine the COD of all oxidizable organic components, the sample is boiled in a strong sulphuric acid medium with an excess of potassium dichromate ($K_2Cr_2O_7$). After 120 min. under reflux, the solution is cooled and back titrated with ferrous ammonium sulphate ($(NH_4)_2Fe(SO_4)_2$) solution. The amount of potassium dichromate consumed is proportional to the amount of oxidizable organic material in the sample.

The COD value is the formal oxygen requirement in the reaction with the strong oxidizing agent, potassium dichromate.

COD (Chemical Oxygen Demand)

$$3\ H_3C\text{–}COOH \xrightarrow[\substack{-\ 4\ Cr_2(SO_4)_3 \\ -\ 4\ K_2SO_4}]{\substack{+\ 4\ K_2Cr_2O_7 \\ +\ 16\ H_2SO_4}} 6\ CO_2 + 22\ H_2O$$

The BOD value (→ Biochemical oxygen demand) is the oxygen required in an oxidation that is similar to the processes that take place in aerobic clarification plants.

BOD (Biochemical Oxygen Demand)

$$H_3C\text{–}COOH + 2\ O_2 \xrightarrow{enzyme} 2\ CO_2 + 2\ H_2O$$

In determining the COD, the acetic acid is reacted with chromium in the hexavalent state and the chromium(VI) is reduced to chromium(III). The chromium(VI) required is determined and converted to the equivalent amount of oxygen. The summation parameters of the various measurements cannot be converted from one process to another; this is illustrated in the three examples in the Table.

Acetic acid contains organic carbon and can be oxidized both by chemical and by biochemical methods; therefore there are values in all three columns of the table. As biochemical degradation takes significantly longer than oxidation with dichromate, the COD is larger than the BOD. Urea also contains organic carbon, however it cannot be oxidized either chemically or biochemically. Sodium sulphide contains no carbon; as this substance is toxic, a BOD value cannot be measured; on the other hand, chemical oxidation is possible.

	total organic carbon [mg C/g]	biological oxygen demand [mg O_2/g]	chemical oxygen demand [mg O_2/g]
acetic acid CH_3COOH	400	720	1060
urea $O{=}C(NH_2)_2$	200	0	0
sodium sulphide Na_2S	0	(tox.)	820

Tab.: COD, BOD_5 and TOC compared in examples.

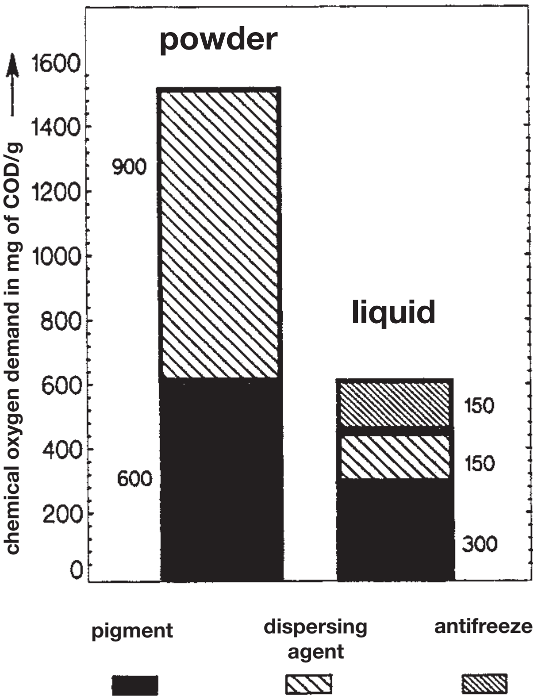


Fig. 1: Disperse and vat dyestuffs and their effect on COD.

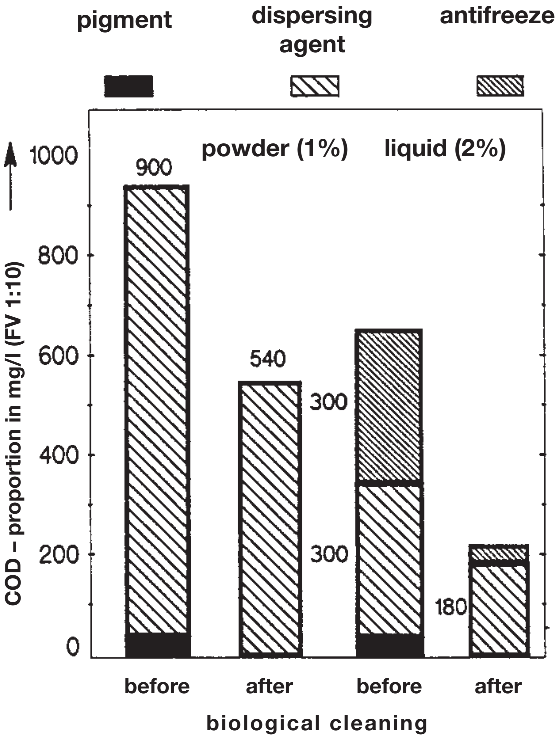


Fig. 2: COD pollution of effluent due to dyestuff after the dyeing process.

In the German environmental regulations, the COD is usually taken as the summation parameter for the organic loading and used as a limiting value for permitted discharge and also as a measurement for calculating effluent charges. The majority (up to 60–70%) of the COD loading in the effluent from textile processing is due to sizes and preparation chemicals. However dyehouses and printworks can also make a significant contribution to the COD loading. In dyeing with disperse and vat dyes, not only the choice of auxiliary but also the choice of the form of the dye is significant (Figs. 1 and 2).

Powder dyes have COD values from about 1500 mg/g, of which only about 40% comes from the dyestuff itself and about 60% from the dispersing agents. With liquid dyes, the average COD value is around 600 mg/g, of which about half comes from the dyestuff and 25% each from the dispersing agent and the antifreeze. If equally strong dyeings are made with a powder dye and with a liquid dye that is half the strength, the following results are obtained: the actual dyestuff in both cases is practically all taken up by the textile material, the dispersing agents and antifreeze on the other hand remain completely in the bath. Because of the higher content of dispersing agent, the COD loading of the exhausted dyebath is significantly higher when the powder dye is used; after a biological effluent treatment the difference is even more pronounced as the antifreeze used in the liquid dye is biodegraded very easily.

Ratio of BOD/COD: the BOD shows how readily a substance can be degraded biologically (e.g. in a clarification plant) under given conditions (free of heavy

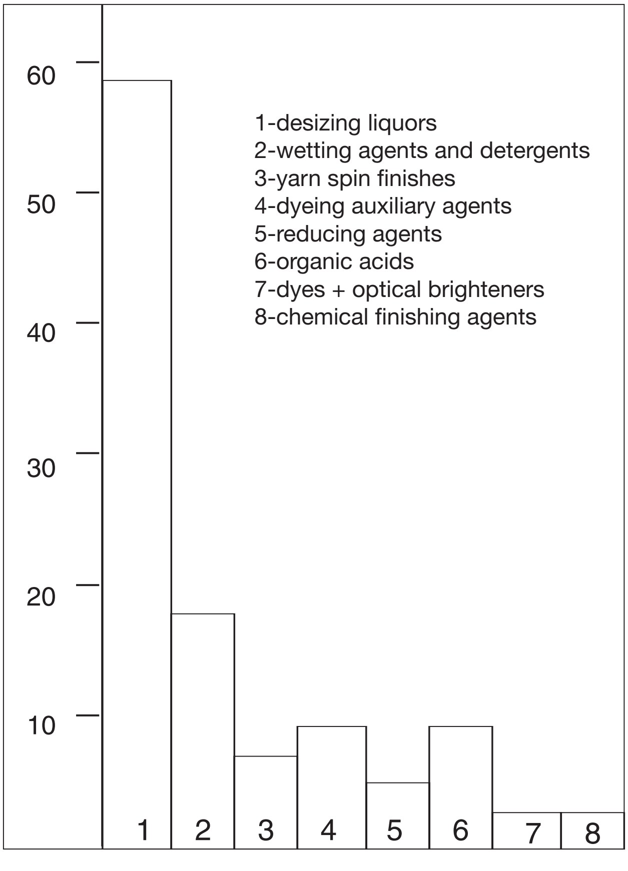


Fig. 3: Diagram of COD pollution in dyehouse effluent from woven fabric finishing.

metals and so on). However the ratio of COD/BOD is more meaningful, as it can be estimated from the COD how high the ultimate BOD must be. In domestic effluent, the ratio is about 2 : 1; in effluent from the dyeing and finishing industry it is around 4 : 1 or 5 : 1, sometimes even worse. The aim is to get the ratio down to about 2 : 1 (ideally 1 : 1). However, a lot of the polluting substances removed in textile processing come from previous textile preparation processes. About two thirds of the effluent loading for which the textile processors are responsible to an increasing degree is size, preparation agents, spooling oils and spinning auxiliaries that are necessary for washed and wetting (Fig. 3). Up to the present time, the most important factors in the development of textile auxiliaries have been the effects of assisting the processes with regard to quality and yield. In the future biological degradability or eliminability of these materials will be demanded, and this will in turn require changes in spinning and weaving.

Chemical pad Padder used exclusively for the application of chemicals.

Chemical products Generic term for all technical materials obtained by the chemical modification of natural raw materials or pure synthesis.

Chemicals. Chemicals manufactured for industrial or laboratory use as →: Fine chemicals; Heavy chemicals; Textile chemicals.

Chemicals, sampling of (Sampling). They must correspond to the average of the whole or a specific part in accordance with DIN 50 001. To this end, dependent on the substance type, thorough shaking, stirring, grinding or similar is essential. Organisation: Specialist Committee for the Taking of Specimens in the Association of German Engineers Process Engineering Section.

Chemiluminescence → Luminescence.

Chemisches Apparatewesen (Ger. association for) → Dechema.

Chemistry (Gk. *kemia* = transmutation). The branch of physical science concerned with the composition (→ Analysis), structure (→ Synthesis), properties, and reactions (→: Elements; Atoms; Molecules; Chemical compounds) of substances. The main branches of chemistry are →: Inorganic chemistry; Organic chemistry; Physical chemistry. For the textile technologist, the chemistry of dyes, fibres, colloids, textile auxiliaries, etc., are also important. According to classical definition, a chemical reaction occurs when a permanent change in the state of a substance takes place, e.g. by pouring dilute sulphuric acid on zinc whereby a new chemical substance, zinc sulphate (a salt), is formed from a metal and an acid.

Chemosensors are used to identify chemical substances and determine their concentrations. The imperfect selectivity of the currently available chemosensors is a significant disadvantage; apart from the sensitivity to the required substance, they also respond to other substances. An example of an electronic sensor is ELECOS (Electronically Controlled Sensitivity) in which the multi-dimensional signals from arrays of sensors are evaluated by the mathematical methods of pattern recognition so that an "electronic sensitivity" is reached. In contrast to the conventional gas measuring techniques, in which the analysis of complex atmospheres is carried out by determining the individual components, in electronic selectivity with arrays of sensors, a complex mixture is correlated to a signal pattern (finger print), in the same way as the sense of smell works. If this pattern is stored in a teach-in process, gas mixtures can be analysed without having to analyse each of the components individually.

Chemothermal is a term for the combined effect of chemicals and heat; e.g. → Chemothermal disinfection of clothing.

Chemset process for wet treatment of carpet yarn (washing, mothproofing etc.) with integrated fixing, drying and winding. Carpet yarn is normally delivered on bobbins. Before further processing on tufting machines, it must be washed (freed of spinning oils and contaminants) and set (twisting). If these wet treatments can only be carried out in hanks, preliminary unwinding and subsequent rewinding are necessary. In the Chemset machine (Fig.) from Andar (Annett & Darling Ltd) and Wronz, the yarn is taken from up to 24 bobbins in 2 "levels" (coilers), passed through the required wet treatment, dried and then wound up again in a 12 spool winding machine. Without the labour intensive hank handling, the process can be controlled better and the treatment is more even. A further advantage is that a mothproofing treatment can be integrated with the washing.

A definite yarn twist is a prerequisite for the surface appearance of the yarn. The bending and torsional tensions produced in the sheet of yarn are released in the setting process. This involves a reordering of the molecular structures of the individual fibres. In the Chemset process, the relaxation of tension comes principally from breaking disulphide bonds of the cystine in the wool by the nucleophilic attack of the hydrogen sulphite anion. The equilibrium reaction is shown by the following simplified equation:

$$\textcircled{W}-S-S-\textcircled{W} + HSO_3^- \rightleftharpoons \textcircled{W}-SH + \textcircled{W}-S-SO_3^-$$

Breakage of the disulphide bond accelerates with increasing temperature in hot water or steam and also with increasing pH. From the equilibrium equation, the cystine bond can be reformed (thiol exchange reaction) by an oxidative treatment, and the stability of the molecule is restored. This can be done simply by rinsing the yarn in a warm water bath.

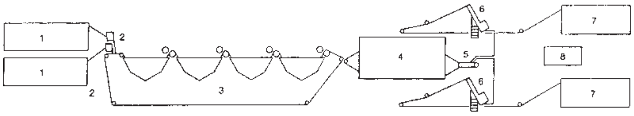


Fig.: Functional diagram of the Chemset machine.

The Chemset machine (Fig.) consists of (1) a double sided creel with 24 spindles and a rotating bobbin holder for 3 bobbins per spindle; (2) Gilbos bobbin winders with a normal working speed of 300 m/min, which set a 250 mm ceiling on the width of the output sheet; (3) baths for the wet treatment with efficient nips (washing, setting and rinsing); the first two baths have integrated liquor suction with a controllable liquor recycling through heat exchangers; (4) an Andar high efficiency drier; (5) a short run of yarn from the output of the drier where the yarn is split into two bands for storage and winding up; (6) Superba MAT yarn storage to allow spindling and repairing without any breaks; (7) 12-bobbin winding machine (Gilbos TU 1) with automatic bobbin winding; (8) a process regulator for automatic control with fault indication and process supervision

Chenille (Fr. = caterpillar),

I. Yarn with projecting fibres resembling a caterpillar. Yarn produced by first "weaving" in plain gauze or cross-weave interlacing and then cutting up the fabric warp-way. Distinction is made between flat chenille which is cut longitudinally on the chenille cutting machine, and scroll chenille which is produced as a plied yarn on chenille machines. The core generally consists of a plied wool or viscose yarn and the pile for example of silk, wool, cotton or viscose. End-uses: for (Axminster, chenille) carpets, apparel, upholstery, furnishing fabrics, scarves etc.

II. Woven velvet-like fabric the weft of which consists of chenille yarn. Multicolour, fancy or hollow chenille may be produced depending on the design. With this form of manufacture colour combinations are limitless. On shuttle and rapier weaving machines as many as thirty or forty different colours can be used. The characteristic features of chenille velvet are the high bulk and soft handle. This is why chenille fabrics resemble terry fabrics. Because of the complex time-consuming manufacturing technique these fabrics are relatively expensive.

Chenille Axminster carpet Chenille is the most expensive of the machine-woven Axminster carpets, and it offers the widest range of possibilities with respect to depth of pile, design, colourings, and width. Chenille may be constructed as wide as 9 m without a seam, and can be made as a single unit to fit irregularly-shaped areas. It can be produced with a pile up to 25 mm in height. This height, when supported by a heavy cushion back, gives a luxuriously soft and resilient quality to the carpet as well as excellent durability. The woven chenille construction requires two separate weaving machine operations. First, soft or hard-twisted yarns are woven in a blanket containing cotton warp threads with leno crossings. This blanket is composed of soft or hard-twisted weft yarns bound together by the cotton warp. Another machine cuts this weft halfway, producing furry strips that are held together by the cotton yarns in the centre. This strip, which resembles a caterpillar, is pressed into a V-shaped form, and the separate ends are tied together forming a continuous chain. This chain is subsequently used on the second weaving machine as a weft for the final weaving of the chenille carpet. A well-constructed chenille uses a fine-quality yarn and a densely-packed high pile, which results in the high durability of this weave.

Cherry gum → Rosaceae rubber.

Cheviot Term used originally for long, coarse and lustrous wool from Scottish Cheviot sheep. Nowadays the term also applies to lowland and → Crossbred wools.

Cheviot fabrics Named after Cheviot wool but today mostly made from crossbred wools, in other words wools of a relatively coarse nature. Cheviot fabrics are made from either worsted or woollen yarns. The worsted forms have a clear finish and are mainly sold in piece-dyed form. The woollen forms are frequently in lively designs and have a somewhat "woolly" cover. Weaves: twill, zigzag twill, plain and fancy weaves. Because of the relatively coarse strong wool these fabrics are substantially wrinkle-resistant. With their naturally harsh handle Cheviot fabrics are primarily used in menswear. A particular advantage of crossbred and Cheviot wools is their high resistance to pressure, creasing for example, but these wools withstand mechanical abrasion less satisfactorily than the fine merino wools, so taken as a whole their wear characteristics are not especially good.

Chicopee non-wovens Stabilization of nonwoven fabrics by water jets (making holes); a binder is also necessary.

Chiffon Transparent sheer fabric produced from fine highly twisted yarn in a plain-weave construction (e.g. cotton chiffon, mostly bleached with a matt finish, silk chiffon is generally similar to voile). Extremely lightweight but very strong. Used for evening dresses, lingerie, blouses and scarves. Chiffon velvet is a very lightweight silk velvet.

China clay → Kaolin.

Chiné printing → Warp printing.

Chinese rugs Antique Chinese rugs were made with the Persian or Senna knot, making possible a large number of knots per cm and a close shearing of the pile. Later, rugs were made with large, coarse designs and a deep pile. In more recent years, Chinese rugs have been made in plain colours as well as in the floral and dragon patterns characteristic of Chinese design. The pile of

Chinese rugs is unusually deep, making these rugs remarkably durable.

Chintz (Hindi, *chint*, from Sanskrit *citra* = gaily-coloured). A plain-dyed or printed cotton or viscose plain-weave fabric with a highly glazed finish produced by friction calendering (→ Chintz finish). Used for draperies, slipcovers, upholstery.

Chintz calender A → Calender for the production of high gloss and closing of fabric yarns. The finish effect is produced by bringing the cloth into contact with a heated, polished, chilled-iron bowl which is travelling at a faster speed than the cloth itself. Three-bowl heavy friction calenders are suitable for highly glazed finishes. The bottom bowl is usually made of close-grained cast-iron, the middle bowl of cotton (which is of greater diameter than the others to allow for wear; the top, or glazing bowl, is made of highly polished chilled-iron and is heated by steam or gas. An arrangement of spur wheels enables the top bowl to achieve a friction ratio of up to approx. 300%. The cloth enters the calender through the bottom nip and passes round the middle bowl (which is revolving at the same surface speed as the bottom bowl) and the friction effect is produced by the top bowl with its higher surface speed which imparts a high polish.

Chintz finish High glaze finish produced by friction calendering cellulosic fabrics previously impregnated with wax or paraffin emulsions, dried, and adjusted to an appropriate residual moisture content. Permanent chintz effects are produced on fabrics to which resin finishes (mainly melamine-formaldehyde compounds) have been applied prior to friction calendering, followed by subsequent curing. The finishing procedure is similar to → Embossing. Nowadays, depending on market requirements, higher demands are placed on the wash fastness of chintz finishes; in these cases, reactant resins are applied together with fluorocarbon or silicone derivatives.

Chintz prints (partial or local chintz). Localized glazed effects produced by screen or roller printing, e.g. single, multicolour or non-coloured designs with high glaze on white, black or multicoloured grounds without glaze. Pigments are used as colorants. The chintz effects are resistant to washing up to 40°C.

Chip,

I. Commercial form of plastics and fibre polymer starting materials (granules).

II. Electronic component as, e.g. a tiny wafer of semiconductor material, such as silicon, processed to form a type of integrated circuit or component such as a transistor.

Chip coloration → Mass coloration.

Chips Chips of synthetic fibre polymers (polyamide, polyester). Produced by shredding tapes of the polymerisate melt/polycondensate melt, to reduce to the required size. Undyed or dyed (chip dyeing), they are re-melted and extruded during spinning (known as the chip-melt-spin method).

Chitin (Gk. *khiton* = shell), $(C_8H_{13}O_5N)_n$. A polysaccharide comprising long chains of N-acetylglucosamine, a derivative of glucose. Chitin is structurally very similar to cellulose and serves to strengthen the supporting structures of various invertebrates being the principal constituent of the shells of crabs, lobsters and beetles. It is also found in some fungi, algae and yeasts. It is used as a raw material in the manufacture of → Man-made protein fibres of animal origin.

Chloramine bleach → Chlorine-peroxide bleach.

Chloramines In → Chlorine bleaching processes, protein impurities in the cotton and chlorine from the hypochlorite solution combine to form greenish yellow chlorination products (chloroproteins of the type R–NH–Cl). They are soluble in alkalis and precipitated by acids; hence they are not removed by acidification after bleaching but remain on the fibre and can lead to fibre damage on drying (release of hydrochloric acid).

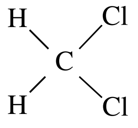
Chloramines become pale yellow during storage. For this reason they must be destroyed. This can be done effectively with an → Antichlor. On the other hand, chloramines (and proteins) act as stabilizers in alkaline hydrogen peroxide solutions; many combination bleaching processes have been based successfully on this principle (chlorine oxygen bleaches, → Chlorine-peroxide bleaches).

Chlorate of alumina → Aluminium chlorate.

Chlorate-steam process Steaming process for the development and fixation of vat leuco ester dyes in direct printing. The print pastes contain an addition of sodium chlorate as oxidizing agent.

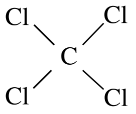
Chlorides Metal salts of hydrochloric acid and chlorine compounds of nonmetallic elements or organic radicals, a typical chloride is → Sodium chloride (common salt). Properties: mostly crystalline compounds which are water-soluble (except the chlorides of silver, mercury, lead), and colourless (except the chlorides of chromium, cobalt, copper, iron, nickel, etc., which are coloured).

Chlorinated hydrocarbons (CHC's). Chlorine substituted → Hydrocarbons of the dichloromethane type,

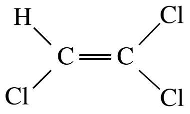


which play an important role in degreasing, dry cleaning, detergents, fat solvents (soaps) etc. High mol. wt. members (e.g. polyvinyl chloride, polyvinylidene chloride) are used in the production of thickening agents, plastics, synthetic fibres etc. A more important chlorinated hydrocarbon in textile chemistry is tetrachloroethylene, which is used for dry cleaning. 1,1,1-trichloroethane is used in white board cleaners. Because of its higher toxicity, carbon tetrachloride is no longer permitted in textile cleaning/textile industry.

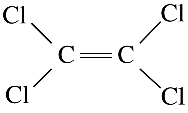
Chlorinated hydrocarbons: comparison of structures:



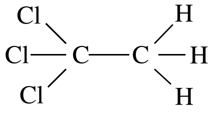
Carbon Tetrachloride



Trichloroethylene



Tetrachloroethylene



1.1.1-Trichloroethane

Chemical properties: the chlorine in tetrachloroethylene, carbon tetrachloride and trichloroethylene (that were the most used at one time), is in neutral bonds, but they are not completely stable. For this reason suppliers provide so called stabilizers to increase the stability. Decomposition can occur in the presence of moisture (especially with carbon tetrachloride: after prolonged contact with undissolved water and in the presence of oxygen, there is a gradual release of phosgene and hydrochloric acid [metal corrosion]; tetrachloroethylene and trichloroethylene are practically unaffected by undissolved water), light (storage in dark rooms or opaque glass bottles; solvent vapour continuously removed from the air in the room, or else unprotected iron and steel articles will rust very quickly), elevated temperatures (decomposition starts about 30–40°C above the boiling point; carbon tetrachloride and trichloroethylene above 110ºC, tetrachloroethylene above 140–150ºC). Contact with heated surfaces at these temperatures must be avoided also in indirect distillation (vapour pressure of carbon tetrachloride and trichloroethylene above 3 bar, of tetrachloroethylene above 6–7 bar) and traces of acid. More severe decomposition is evident from the pungent smell from the release of hydrochloric acid (test: shake with distilled water, blue litmus paper should not turn red; aqueous solution + several drops of nitric acid + silver nitrate solution should not give a white precipitate of silver chloride; nail test). Decomposed chlorinated hydrocarbons can be regenerated by filtering slowly through calcined, pulverized sodium or potassium carbonate.

Chlorinated hydrocarbons – neutralization No matter how CHC's have become acidic, they can be neutralized by bringing the pH back to 7.4–7.8 (e.g. with alkanone) by distillation with an addition of calcium carbonate, calcium hydroxide or 2% sodium carbonate solution. In no case can sodium or potassium hydroxides or calcium oxide be recommended: they can lead to the formation of chloroacetylene, which reacts vigorously on contact with air.

Chlorinated hydrocarbons – physiological effects Most chlorinated hydrocarbons evaporate quickly. Their vapour-air mixtures act to a greater or lesser degree as narcotics. At the beginning there is merriment and intoxication, fatigue and unconsciousness follow and can lead to death. Prolonged inhalation, even of small amounts, can lead to chronic damage to the nervous system and other organs. Symptoms of acute carbon tetrachloride poisoning are: dazed state, vomiting, coughing, irritation of the mucous membranes, belching, diarrhoea, in severe cases unconsciousness, convulsions, pulmonary bleeding, kidney damage, serious liver damage, jaundice, death. Warning symptoms are fatigue, drowsiness, sleeplessness etc. Trichloroethylene poisoning acts insidiously, often only after a long time, e.g. nervous illness, visual impairment, loss of teeth, trembling, loss of smell and taste etc. Tetrachloroethylene is counted as the "most harmless" , but the symptoms of poisoning are similar to those of trichloroethylene, although not nearly so severe. The highly toxic CHCs are carbon tetrachloride, tetrachloroethane and especially pentachloroethane.

With CHCs, the human skin loses its lipids and becomes dry, brittle and then cracked and very susceptible to infection, which can lead to inflammation and even to extensive skin disease. The protective measures must be strictly observed and the precautionary measures recommended by the suppliers should be checked constantly.

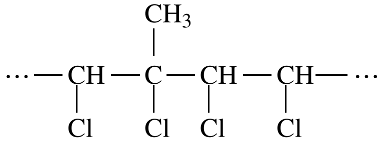
Chlorinated hydrocarbons – solvent monitoring CHCs straight from the factory are stabilized (→ Chlorinated hydrocarbons – solvent stability), but they can be contaminated by additions that get in while they are being used. The solvent should be checked at least with universal indicator paper (the solvent is shaken vigorously with an equal amount of distilled water and the separated water tested) or with Bromothymol Blue solution (0.05% alcoholic solution) in a test tube (fitted with a clean stopper): 5 ml of solvent + 2 ml of distilled water (must be neutral i.e. pH 7) + 2 drops of Bromothymol Blue indicator solution is shaken well and the upper aqueous layer examined: factory fresh solvent = strong blue (pH above 7.5); usable: = colour towards a light green (pH above 6.4) shows that the solvent is still free of impurities; when the colour changes over a short time from green to yellow: the cause of the fall in pH must be identified before it is stabilized again with fresh solvent. The causes could be: introduction of acids from outside or localized overheating with unsuitable stabilizers.

Chlorinated hydrocarbons – solvent stability Chlorinated hydrocarbons are decomposed by the action of light, air, heat and moisture, depending largely on the molecular structure (polar/non-polar). The stability decreases from tetrachloroethylene through trichloroethylene to 1,1,1-trichloroethane; because of their unsaturated character the first two are more prone to an oxidative attack, whereas 1,1,1-trichloroethane is more susceptible to hydrolysis. Stabiliszer combinations (corrosion inhibitors) overcome these different instabilities very effectively. Because of these considerations, only stabilized CHCs are available commercially: up to 0.02% by weight in tetrachloroethylene, somewhat more in trichloroethylene, and up to 6% by weight in 1,1,1-trichloroethane. Testing of factory fresh tetrachloroethylene sometimes gives pH values of almost 9, i.e. definitely alkaline (with a consequent risk of corrosion to copper and tin), although pH 7.5 would be enough. In modern dry cleaning equipment the pH of tetrachloroethylene can at times move slightly into the acid range, and this can promote corrosion. These difficulties can be eliminated by using combinations of kieselguhr and special silicates as the filtering agent.

Chlorinated hydrocarbons – storage CHCs are stored for long periods in storage tanks made of sheet iron, steel or galvanized iron. Rusting is prevented by application of a CHC resistant coating. Tanks made of V4A steel are especially suitable. Aluminium tanks are not suitable for trichloroethylene and 1,1,1- trichloroethane (alloys). The rule of thumb for the storage capacity of a tank is: capacity at least 50% greater than the anticipated volume to be stored. Larger tank installations require sealed take off points. Every CHC tank must be clean, dry and free from contamination.

Chlorinated paraffins Chlorination products of → Paraffins resp. high boiling point synthetic hydrocarbons or petroleum fractions. They are nonflammable and function as excellent wash-resistant flame retardants which also prevent after-glow. Chiefly available nowadays in the form of emulsions (more favourable effect on handle).

Chlorinated rubber $(C_5H_6Cl_4)_x$, density 1.66. Produced by chlorination of over-milled, irradiated, oxidized or vulcanized natural → Caoutchouc:



$$\cdots-\underset{\text{Cl}}{\text{CH}}-\underset{\text{Cl}}{\overset{\text{CH}_3}{\text{C}}}-\underset{\text{Cl}}{\text{CH}}-\underset{\text{Cl}}{\text{CH}}-\cdots$$

or also from synthetic material (e.g. from → Buna). White to pale yellowish substance (granules, powder or emulsions of different viscosities), with 60–68% chlorine content, with no taste or smell, non-flammable, insensitive to water, alkalis, acids, salts, petrol etc.; decomposes above 130ºC losing chlorine and turning brown. Soluble in benzene, hydrocarbons, carbon tetrachloride, trichloroethylene, chloroform, methyl-, ethyl- and butyl acetates and so on, partially soluble or swellable in acetone and ether. Uses: → Chlorinated rubber paints, for protective coatings of various types, protective coverings, flame resistant impregnation, for thickening and fixing (with softeners) in pigment and metal printing, laminating fabrics etc.

Chlorinated rubber paints Used as fixing agents in bronze printing (with the addition of plasticizers, as they would otherwise be too brittle) and as universal protective coatings against all kinds of corrosion for iron, metal or wooden constructions, walls, coverings, walls, concrete bases, pipework etc. They are (→ Chlorinated rubber) free of oil, available in any colour, harden quickly, stable to temperatures up to 100ºC (up to 60ºC when wet) resistant to bacteria, insulating, non-toxic, mechanically more resistant than red lead coatings; easy to clean by spraying with soap and water and similar solutions.

Chlorinated water fastness assesses the resistance to chlorinated water. A sample is wet out in distilled water, dewatered to 100% water content and placed in an aqueous solution containing 20 mg/g of active chlorine (from sodium hypochlorite) at a liquor ratio of 100 : 1 for 4 hours at 20ºC. Assessment with the grey scale.

Chlorination of wool leads to an increase in swelling and wettability, dyestuff affinity, lustre and to reduction in the felting and shrinkage (anti-felting and shrink resistant finishing). The principle is: the action of aqueous solutions which develop “active chlorine”, e.g. sodium hypochlorite, hypochlorous acid and chloraminated compounds. Uniform chlorination of wool requires control of the chlorination of the wool and careful supervision of the process. Increasing the temperature or reducing the pH accelerate the reaction and lead to irregular, unlevel, treatment. Temperatures below room temperature and higher pH’s slow the chlorination reaction. However the latter is associated with increasing damage and yellowing of the fibres. Slow and level chlorination is achieved with compounds like chloramines, e.g. with alkali metal salts of di- or trichloroisocyanuric acid.

No striking differences can be seen in an electron microscope between alkaline chlorinated wool (pH 9) and untreated wool. However, large parts of the exocuticle are removed from wool that has been chlorinated at pH 1, and the endocuticle, which is susceptible to hydrolysis, becomes part of the wool surface (Fig.). The fraction of liberated wool gelatine in the acid chlorinating liquor (exocuticular protein) is about ten times as great as the protein liberated from the inside of the fibre during alkaline hydrolysis. In addition, similar amounts of keratin proteins are liberated in acid chlorination but remain held in the wool in the form of salts, and are only liberated on alkaline treatment. The chlorinated, soluble wool protein increases the AOX content of the effluent.

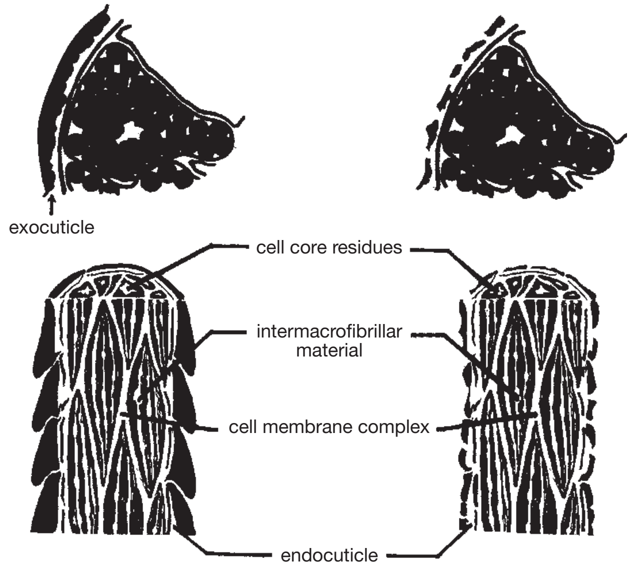


Fig.: Schematic diagram illustrating the morphology of not very cross-linked non-keratin proteins (shown in white) in wool and chlorinated wool, which can be preferentially weakened in subsequent hydrolysis (dyeing conditions, fastness tests), and can be released as wool gelatine. The hydrolytically resistant keratin proteins are shown in black (Baumann).
Top: cross-sectional sector of wool according to Mercer et al.
Bottom: longitudinal view of the bond structure of wool.
Left: untreated wool and alkali-chlorinated wool. No significant morphological differences visible in the electron microscope.
Right: pH 1, chlorinated wool. After a large part of the exocuticle has been removed, the hydrolytically more easily corrodible endocuticle is part of the wool surface.

Differences between wool fibres that have been chlorinated to different degrees are shown up sharply in subsequent dyeing processes. The lightly crosslinked, non-keratin proteins (endocuticle, cell membrane complex, residues of the cell nuclei and intermacrofibrillar material) are the reason that wool is so susceptible to hydrolytic attack in all practical dyeing processes at the boil or under HT conditions. Part of the morphologically specific non-keratin proteins liberated will remain in the bath as wool gelatine in a combination that is characteristic for the particular dyeing conditions. Another part will remain held in the wool and only be freed by a change in pH. Apart from the oxidatively loosened keratin proteins, in dyeing chlorinated wool, non-keratin proteins (weak spots) are also liberated. Acid chlorinated wool has an open structure (the endocuticle is part of the surface); the surface of alkaline chlorinated wool is largely intact, similar to that to untreated wool. For this reason, it is understandable that the dye fastnesses of untreated wools are generally 1–2 points better than those of acid chlorinated and wool that has had an antifelting finish and been dyed. Possible applications:

1. Increasing the dyestuff affinity and wettability: 1–1.5% of active chlorine (calculated on the weight of fibre) in a weakly acid liquor below room temperature for about 20–30 min, then anti-chlored and bleached in a fresh bath with 1–2 g/l sodium dithionite. Liquor ratio about 30 : 1.
2. Anti-felting and crease resistant finishing: 1.5–3.5% active chlorine is used as described in 1.
3. This treatment can produce a significant increase in the lustre.
4. Giving carpets an antique appearance: intensive surface treatment with chloride of lime solution (8 g/l active chlorine) for 30 min, intermediate rinsing, then another surface treatment with 0.6% caustic solution. The carpet is left in the alkaline solution for 20 min, then well rinsed and dried.

The process requires a lot of experience and has also become something of a problem from the ecological point of view.

Chlorination/resin finish → Antifelting finish of wool on the base of synthetic resins which is preceded by a chlorination.

Chlorine (Cl), atomic weight 35,5. Nonmetallic halogen element. Dense greenish-yellow poisonous gas with a pungent, very irritating odour, soluble in water. Forms explosive mixtures with hydrogen, especially in sunlight (chlorine detonating gas). Chlorine is a very reactive element and combines directly with most other elements. It is noncombustible, but supports combustion (strong oxidizing agent). Compounds include hydrochloric acid HCl, and chlorides as salts. Compounds with oxygen include monoxide, dioxide and heptoxide (Cl_2O, ClO_2, Cl_2O_7) which form → Chlorine oxoacids with water. Characteristic (for analytical chemistry): silver chloride is insoluble in water and dilute acids but soluble in dilute ammonia solution. Calcium chloride is readily soluble. Uses: as a disinfectant (water sterilization) and oxidative bleaching agent for textiles. Its salts are used in bleaching, carbonizing, delustring, dyeing (sodium chloride); as oxygen carriers in dyeing and printing; dye mordants; chemical analysis, etc.

Chlorine bleaching, → Oxidative bleach for cellulosic fibres, chiefly used on natural cellulosic fibres such as cotton and linen (→: Bleaching; Bleaching agents).

I. → Hypochlorite bleach: calcium hypochlorite $CaOCl_2$ (bleaching powder); sodium hypochlorite NaOCl.

II. → Chlorite bleach: sodium chlorite $NaClO_2$.

III. → Chlorine dioxide bleach: ClO_2.

Chlorine carriers for dry bleaches Organic chlorine compounds which, e.g. split off available chlorine resp. hypochlorite at elevated temperatures. They find application in bleaching detergents, wool detergents, sterilizing washing agents, antifelting finishes for wool, etc. Examples →: Chloramines; Chloroisocyanuric acids.

Chlorine/chlorate discharges These are examples of oxidative discharges:

I. Acid-chloride of lime process for discharging Turkey red and indigo.

II. Chlorate-red prussiate of potash process for discharging indigo, indigoid vat dyes, cationic dyes and mordant dyes.

Chlorine content of bleach liquors → Available chlorine.

Chlorine dioxide bleach Bleaching with an aqueous solution of chlorine dioxide which, during the process, is freshly prepared on a continuous basis in special equipment. It finds only occasional application, e.g. in the Ravensberg linen bleaching process. A chlorine dioxide bleach process on the cold pad batch principle has been used in France.

Chlorine fastness → Hypochlorite bleach fastness.

Chlorine generators They are used to ensure the controlled → Chlorination of wool. They are able to bind free chlorine initially in the form of a buffered chlorine carrier, e.g. alkali-metal salts of dichloroisocyanuric acid (DCCA).

Chlorine-Hercosett process Antifelting finish for wool based on the application of synthetic resins to prechlorinated wool, e.g. → Hercosett process.

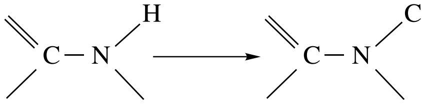
Chlorine oxoacids are a series of very weak to very strong acids: hypochlorous acid (HClO), salts: hypochlorites, strongly oxidising bleaching agent; chlorous acid ($HClO_2$), salts: chlorites (sodium chlorite bleach); chloric acid ($HClO_3$), salts: chlorates; perchloric acid ($HClO_4$), salts: perchlorates ($NaClO_4$).

Chlorine-peroxide bleach (Ce-Es bleach, chloramine bleach). "Ce-Es" is the abbreviation (from Böhme) for a combined chlorine peroxide bleach. This process was originally developed to avoid bucking. As compared to the old → Kier boil-chlorine bleach, in site of the satisfactory full white, there are significantly lower losses in weight and stability. Principle: pre-wetting, impregnation with hypochlorite solution, squeezing, layering in a peroxide bleaching unit and (without intermediate rinsing) peroxide bleaching. The term "chloramine bleach" comes from the chloramines that are formed with chlorine and which act as stabilizers in the subsequent peroxide treatment. Use: only sporadically for cotton workware.

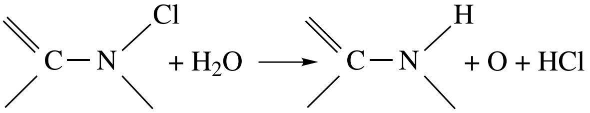
Chlorine products → Bleaching chemicals.

Chlorine resistance of resin finishes The resistance of resin finished textiles to available chlorine , e.g. in bleaches (→ Chlorine retention) is largely dependent on the chemical type of resin finish applied. Finishes based on e.g. DMPU, are resistant to chlorine.

Chlorine retention The capacity to hold chlorine; the behaviour of finished textiles towards baths that contain active chlorine (so-called chlorine washing, usually as an addition to the actual washing process to improve the whitening effect or to disinfect; the requirements for industrial laundries differ in different regions, e.g. in USA and Spain, and also in domestic washing). Depending on their chemical constitutions, the finishing agents fixed on the fibre combine to a greater or lesser extent with chlorine to form chloronitrogen compounds,



which, in subsequent heat treatments (e.g. ironing, steam pressing), damage the goods by oxidative and hydrolytic decomposition: more or less intense yellowing or browning, reduction in the tensile strength. Testing normally by AATCCC 92-1971.



In finishing with nitrogen-containing finishing agents, urea-formaldehyde derivatives, such as DMEU, DMDHEU, are particularly prone to chlorine retention; dimethylol compounds, such as propylene urea and DMPU and carbamates, such as dimethylol methoxyethyl carbamate, do not retain chlorine. There is no loss in strength when methoxy melamines are used in finishing, only possible yellowing; hence they are used as a buffering addition to other finishing agents, such as DMEU. Nitrogen free finishing agents do not retain chlorine.

Chlorine, test for → Potassium iodide starch paper.

Chlorine test for dyeings on cellulosic fibres Procedure: the dyed or printed textile specimen is placed in sodium hypochlorite solution (7–8 g/l available chlorine) acidified with a little dilute hydrochloric acid. The nature, intensity, and speed of bleaching are observed.

a) Substantive dyes (including aftertreated dyeings): bleaching is generally complete; original colour no longer returns on rinsing. Certain yellows are chlorine-resistant.
b) Cationic and sulphur dyes: the colour is likewise completely bleached out and is no longer restored on rinsing. Certain sulphur dyes are fast to chlorine.
c) Vat dyes and naphthols: no change. Indigo dyeings are bleached to a slight extent.
d) Reactive dyes: slight to complete bleaching occurs; original colour is no longer restored on rinsing.

Chlorite bleach (→ Chlorine bleaching). The reaction mechanisms involved are well known. According to Agster the following processes take place:

1. liberation of the bleaching agent:
   $NaClO_2 + HCOOH \rightarrow HClO_2 + HCOONa$
2. bleaching reaction:
   $HClO_2 \rightarrow HCl + 2\,(O)$
3. decomposition of the bleaching agent:
   $5\,HClO_2 \rightarrow 4\,ClO_2 + HCl + 2\,H_2O$
   $2\,ClO_2 + H_2O \rightarrow HClO_2 + HClO_3$
   $3\,HClO_2 \rightarrow 2\,HClO_3 + HCl$

The concentration of the effective bleaching agent, chlorous acid, reaches its maximum at pH 2.5–3.5. Below pH 3.0, fibre damage becomes very noticeable. The decomposition of the weak acid, $HClO_2$, generates the strong acids $HCl + HClO_3$, which hydrolyse the cellulose. Hence the optimum conditions are in the range of pH 3.0–4.0. To buffer the reaction medium against becoming too acidic, phosphate buffers are used as stabilizers, so that no more chlorous acid is liberated than the goods can use. Otherwise the treatment is unlevel and there is more decomposition of the bleach liquor with all its consequences (Fig.).

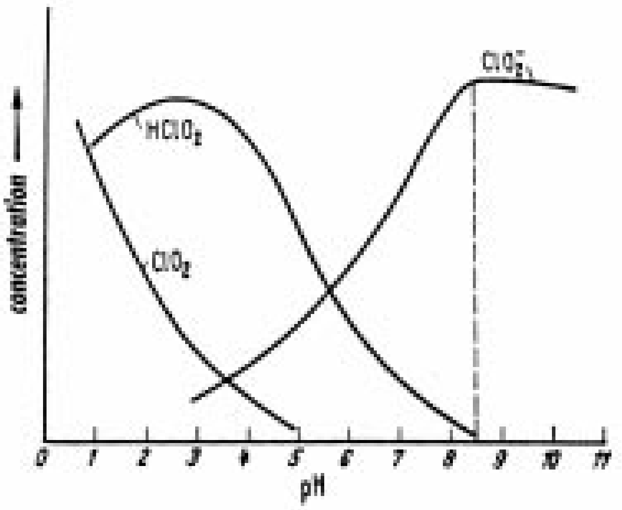


Fig.: Products of decomposition in chlorite bleaching relative to pH.

Chlorite bleach fastness assesses the stability to sodium chlorite bleach solutions.

I. Light: treatment with 1 g/l sodium chlorite (80%) at pH 3.5 (addition of acetic acid) for 60 min. at 80ºC, liquor ratio 50 : 1. Subsequently rinsed for 10 min. in running water.

II. Severe: with 2.5 g/l sodium chlorite (80%).

Assessment with the grey scale.

Chlorites Salts of chlorous acid $HClO_2$ → Chlorine oxoacids. Properties: on heating they undergo sudden or explosive decomposition; in solution they are strong oxidizing and bleaching agents, e.g.→ Sodium chlorite.

Chloro-, prefix for compounds with complex bound chlorine.

Chlorobenzene (monochlorobenzene, phenyl chloride), C_6H_5Cl. Colourless volatile liquid with unpleasant almond-like odour. Toxic (avoid skin contact and inhalation, good ventilation necessary). Density 1,1, b.p. 132°C. Insoluble in water but soluble in alcohol, ether, benzene. Uses: as a solubility reagent for synthetic fibres (soluble cold = polyvinyl chloride including post-chlorinated types; soluble at the boil = polyethylene); formerly used as a carrier in the dyeing of polyester textiles with disperse dyes.

Chloro(-fibres) is an incorrect abbreviation for chlorinated polyvinyl fibres. →: Polyvinyl chloride fibres; Polyvinylidene chloride fibres.

Chlorfluoroalkane → Chlorofluorocarbons.

Chlorofluorocarbons (CFCs), best known as derivatives of methane or ethane, where the hydrogen is wholly or partially replaced by fluorine or fluorine and chlorine. With a low boiling point, non-flammable and of relatively low toxicity, chlorofluorocarbons are used as coolants, propellants for aerosols and blowing agents for foams, degreasing agents and formerly as solvents in special dry cleaning plant for furs, leather and delicate articles. The gentle action of CFCs made them suitable for: maintaining colour brilliance, increasing the range of items which can be cleaned and reducing the risk to delicate items (reduction in the rate of damage); official directives have forbidden the establishment of CFC plant in Germany.

CFCs for dry cleaning: there are certain requirements that must be fulfilled by a dry-cleaning solvent. It must be capable of cleaning textiles well without damaging them. It must be economically efficient to use; when used correctly it should not decompose, nor should it endanger the health of people or pollute the

solvent	time	problem
turpentine oil	1825–1840	hardly volatile strong smell
benzene	1830–1860	cancer-inducing
petroleum ether	1850–1950	combustible
heavy benzine	1925	combustible
carbon tetrachloride	1900–1950	toxic
trichloroethylene	1925	restricted
tetrachloroethylene	1930	restricted (ground water danger)
1,1,1 trichloroethane	1965	restricted
fluorocarbon 113	1960	reactions in the stratosphere
fluorocarbon 11	1970	

Tab.: Historical development of dry-cleaning agents.

environment. These requirements have become so stringent over the years (see Table) that the use of CFCs has now been forbidden in Germany. CFCs are highly volatile, evaporate into the atmosphere, and there decompose. According to current knowledge, a large proportion of tetrachloroethane (hexachloroethylene) is decomposed in the troposphere, the lowest atmospheric layer. It is assumed that the chlorofluorocarbons or at least a part thereof, penetrate undecomposed through to the layer above, the stratosphere, and reach the ozone layer (see Fig.). The effect of the ultra-violet rays which are strong at this level is thought to cause chlorine atoms to separate off from the fully halogenated chlorofluorocarbons (i.e. those without hydrogen atoms), which then break down the ozone molecules to leave molecular oxygen. Thus the ozone layer is reduced and its effectiveness as a filter against UV radiation is weakened. Consequently, UV radiation to the earth's surface is stronger, which could cause biological changes. CFC 11 (trichlorofluoromethane) and CFC 113 (trichlorotrifluoroethane) are thought to pose particular risks as chlorine-containing and fully halogenated CFCs.

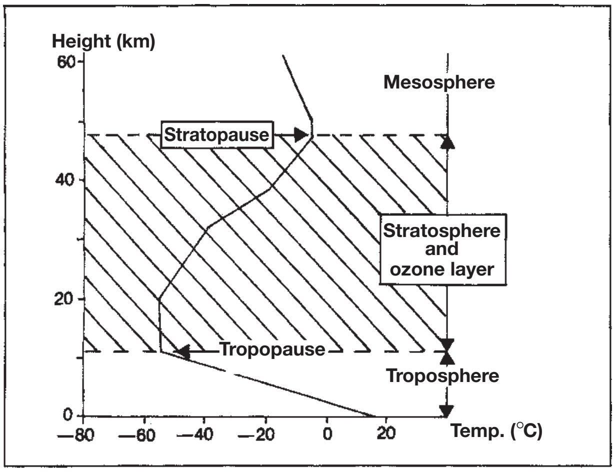


Fig.: Division of the atmosphere. Chlorofluorocarbons penetrate the stratosphere where they reduce the ozone content.

Chloroform ($CHCl_3$). Colourless fluid, mobile, volatile, sweetish smell (anaesthetizing), can cause blistering of the skin, suspected of being carcinogenic, noncombustible, gradually decomposes in the presence of light and air (store in brown bottles). Slightly soluble in water, easily miscible with alcohol, ether, petrol etc. Dissolves acetate fibres, rubber, fats, oils, resins, tar and suchlike. Used as: solvent and stain remover (stains of light fats and oils, dried-on oil paint, varnish, lacquers, resins, rubber, tar, iodine; in difficult cases mixed with ether); tends to leave a mark at the edge (rework with petrol) in the case of lacquers, glues, etc.

Chlorohydrins Organic compounds containing one or more C(OH)·CCl groups. Reactive group for crosslinking reactions, e.g. with cellulose in the presence of alkaline catalysts (sodium hydroxide solution) with at least 2 functional groups. Used *inter alia* as resin finishes, e.g. →: Dichlorohydrin, Epichlorohydrin.

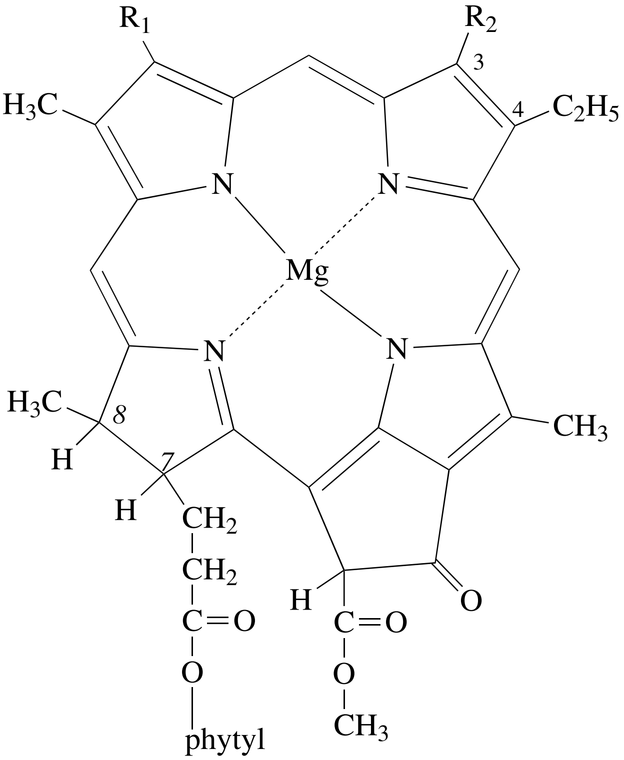
Chloroisocyanuric acids In the form of the tri- and dichloroisocyanuric acids, as well as sodium and potassium dichloroisocyanurates, they are important as chlorine generators in cleaning detergents and antifelting finishes for wool. Chloroisocyanuric acids are formed by the chlorination of isocyanuric acid resp. cyanuric acid whereby both tautomeric forms are present in the chlorination products with the iso-form predominating.

Available chlorine content in comparison with other chlorine generators:

Eau de Javelle, conc.	149–159 g/l
Chloride of lime (bleaching powder)	365–390 g/l
Trichloroisocyanuric acid	850 g/l
Dichloroisocyanuric acid	700 g/l
Potassium dichloroisocyanurate	600 g/l
Sodium dichloroisocyanurate	590 g/l

Advantages compared to other chlorine bleaching agents: higher available chlorine content, readily soluble, bleaching action already effective at low temperatures. The stability of chloroisocyanuric acids increases with decreasing chlorine content.

Chlorophyll is obtained by extraction of ground leaves. It is a mixture of the blue-green chlorophyll a and the yellow-green chlorophyll b:



chlorophyll a:	R_1: $CH=CH_2$, R_2: CH_3
chlorophyll b:	R_1: $CH=CH_2$, R_2: CHO
bacteriochlorophyll a:	R_1: $CO–CH_3$, R_2: CH_3; hydrated in 3.4 position
chlorophyllide a:	R_1: $CH=CH_2$, R_2: CH_3; H instead of phytyl

Both types of chlorophyll contain complexed magnesium (they are structurally similar to the red colouring in blood, haemoglobin, an iron complex). They consist of a coloured component (chlorophyllide) and a high mol. wt. alcohol (phytol). Chlorophylline is produced on saponification. This is the cause of the spontaneous deodorizing effect originally ascribed to chlorophyll. The deodorizing effect of chlorophyll is only significant with butyric acid; with other strongly smelling substances, there is no or only a slight effect. Use → Chlorophyllines.

Chlorophyllines are the coloured acids or their water-soluble salts produced on saponification of → Chlorophyll. General name for mixtures of different composition, with complexed magnesium, more usually however with copper (commercial preparations have 0.8–4.7% copper) to increase the greenness and the light fastness. The deodorizing properties of the various chlorophyllines differ in intensity, occurrence of the optimum effect and duration of the effect. The copper complexes seem to be rather less effective. Use: colouring soaps, oils, cosmetics; as deodorants and textile odour improvers.

Chlorovinyl fibres → Polyvinyl chloride fibres.

Chlorzyme process is a special chlorination process for crossbred wool to give it a soft structure like merino wool. Treatment with dry chlorine gas and subsequently with the enzyme, papain. The scale structure is eliminated, leading to a flat, silk-like handle. As the chlorination does not reach the inside of the fibre, the fibre is not thinned.

Chol- (Gk. *khole* = bile or gall). Prefix as a combining form before a vowel, e.g. as in choline, cholesterol, etc.

Choli Short-sleeved bodice, usually of silk, as worn by Indian women. Frequently decorated with embroidery and mirror appliqué work.

Cholic acid → Gall extract.

Choline is an organic base, deliquescent crystals, strongly alkaline, readily soluble in water and alcohol, absorbs considerable amounts of carbon dioxide from the atmosphere. Component of lecithin. Produced synthetically by the action of ethylene oxide on trimethylamine. Betaine is produced on mild oxidation. Interesting textile auxiliaries of the fatty acid-choline ester type are obtained by esterifying the alcoholic hydroxyl group with a fatty acid. Solutions of these esters foam like soap solutions; they are fairly resistant to sodium carbonate (but not to strong alkalis) and acids in the cold (hydrolysis takes place at higher temperatures). Alkylene or aralkylene substituted cholines and their derivatives are used as pasting and auxiliary agents in vat printing.

Chromate discharges → Oxidative discharges for the production of coloured discharges on indigo grounds. The discharge print pastes contain sodium bichromate and alkali.

Chromate dyeing process Single bath chroming process for chrome dyes.

I. Wool: selected chrome dyes (mordant dyes) are dyed together with a chromium salt in the same bath. This process is used especially in cases where iron or copper is present in the water or in the dyeing equipment.

II. Wool/cotton unions: special dye mixtures (wool/cotton chrome dyes) are dyed together with a chromium salt in the same bath.

Chromatic Relating to, or characterized by a colour or colours; monochromatic = one hue or colour, trichromatic = three colours, polychromatic = multicoloured.

Chromatic adaptation Adaptation of the sensitivity of the retina to the predominant colour in the → Field of vision. Has a large effect on the judgement of → Colour and leads to the colour of an object being perceived very differently, e.g. according to which other, interfering colours there are around the sample. This effect is at its greatest when the second, interfering colour is in the centre of the field, i.e. directly surrounding the sample in question, and decreases the further the second colour is from the centre of the field of vision. When an original and a reproduction dyeing with the same colour are being compared, chromatic adaptation plays no role because it changes the character of the perception of the colour, but does not affect the equality of the two colour sensations. When there is a colour difference between the two samples, however, difficulties arise with the introduction of a second colour into the surrounding field of vision of the observer. The second colour affects identification of the direction of the variation, so that mistakes in the selection of the dyes needed for correction arise: for this reason it follows that an inspection table that is completely free of other samples of every type is essential for comparing samples (→ Adaptation).

Chromatic circle This is a circular representation of the → Hue of so-called chromatic colours which are formed by combining additive colour mixtures. The chromatic circle is restricted to a maximum of 200 different pure shades which can be produced e.g. using perceived equal saturation and brightness values. The commonly used 24-section chromatic circle contains 8 principal colours each in 3 levels (light, saturated/full, dark) and each ordered with the so-called colour coefficient (also referred to as a colour point), starting with yellow (colour coefficient 1, 2, 3) through orange (4–6), red (7–9), violet (10–12), ultramarine blue (13–15), ice-blue (16–18), sea-green (19-21) to leaf green (22–24). The complementary colours of the first order are located 180° opposite each other in the circle (e.g. yellow 2 and ultramarine blue 14). These always give black when mixed subtractively. Complementary colours of the second order are understood to be trichromatic groups which are always located at 120° to each other (e.g. yellow 2, violet 10 and ice-blue 18). Subtractive mixtures also give black here (photographic principle), whereas additive mixtures give white (→ Colorimetric measures). The colour coefficients of the chromatic circle and the letters of the grey series give the Ostwald standard code for the colour (→ Pure spectral colour).

Chromaticity coordinate Normal chromaticity coordinates (x,y) are values that define a colour without reference to the lightness (→ Colorimetric measures).

Chromaticity diagram (CIE colour diagram, colour triangle). Geometric representation of colour in its various mixtures derived from the → Colorimetric measures. The Ostwald colour triangle is determined from the three triangular points white (a), black (p) and pure spectral colour (pa). According to standardised international representation (DIN 5033 and 6164) as per the CIE or IBK triangle, a right-angled form of an open triangle is used with x as the abscissa and y as the ordinate (→ Colorimetry). Within the triangle is the bell-shaped curve of the so-called spectrum locus of the monochromatic light wavelengths, beginning at 400 nm (= violet blue) to 520 nm (= green), 575 nm (= yellow), 600 nm (= orange) up to 700 nm (= red). The trace of the curve closes at the bottom between 700 nm and 400 nm with the so-called purple boundary with the purest possible purple colours, i.e. mixtures of red-violet-blue (Fig.). The achromatic point E lies at the lower centre (for equi-energy light; $x, y, z = 0.333\overline{3}$), which must be fixed here as normal white C. As the curve therefore clearly shows all pure shades, all standard colours must fall within the area enclosed within the curve, any colour therefore will be on the straight line between point of illumination C and the corresponding spectral colour, a colour mixture will be on the straight line between these two components. Complementary colours consequently lie on either side of the connecting line, spectral colour/point of illumination. If the 24 shades of the Ostwald chromatic circle are sequenced according to the corresponding shade wavelengths, then the colour lines 1–24 radiating outwards from the centre C are formed, e.g. yellow 1 at just 575 nm would represent the homochromatic range from outside to inside from the pure spectral colour to white with the relevant blue complementary colour on the other side of C. Lines S 1–15 which are similar to the annual rings of a tree are the saturation curves which represent all shades (1–24) from 1–7. After determining the colour measures for a specific colour by colorimetry, the chromaticity co-ordinates y (green fraction) and x (red fraction) are entered in this co-ordinate system and thus the so-called colour point or colour location which uniquely defines the colour is obtained as z (the blue fraction) follows from the equation: $z = 1 - (x + y)$. The latest trend in colorimetry is to shift the achromatic point by illuminating from standard illuminant A to illuminant D_{65}.

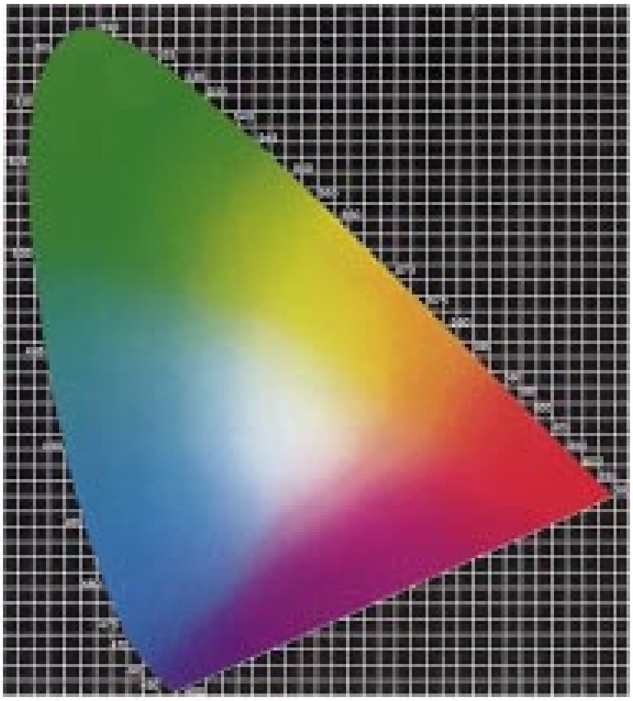


Fig.: Chromaticity diagram.

Chromatic colours According to Ostwald, so-called pure spectral colours in yellow, red, blue, green and intermediate → Shades; in practice mostly mixed with white and/or black. → Chromaticity diagram.

Chromatin → Protoplasm.

Chromatogram A graphical record of a completed chromatographic separation by paper, thin-layer or gas chromatography. The Figure illustrates examples of chromatograms produced from extracts of mercerized cotton dyed with a (monofluorotriazine) reactive dye as a function of fixation times from 0–28 min. (pH 11, 40°C, 200 g/l Na_2SO_4).

The chromatograms clearly show that, under the given fixation conditions, the concentration of intact reactive dye on the fibre decreases rapidly whilst that of the hydrolyzed dye, on the other hand, only increases very slowly. This indicates preferential reaction of the dye with the fibre.

Chromatography (Chromatic adsorption analysis). Separation procedure for isolating individual com-

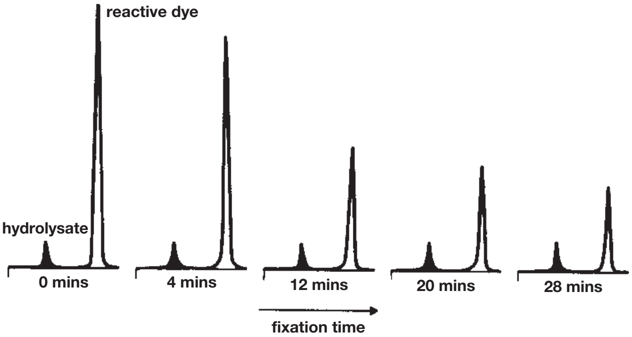


Fig.: Demonstration of the reaction of a reactive dye with cellulose by chromatography of a respective fibre extract on paper.

ponents from mixtures of substances with similar constitutions (related derivatives, isomers and the like) but having different adsorption power. First used by Tswett in 1906 in the analysis of mixed dyestuffs. A distinction is made between different kinds of chromatography depending on the physio-chemical basis of the method.

Method and classification in accordance with separation function:

I. Adsorption chromatography: an equilibrium occurs between the molecules adsorbed on the solid surface (powder or fibre) and those that are present in the flow of solution or gas. The separation function is nonlinear (result: diffuse stain edges).

II. Separation chromatography: based on the distribution of mobile and stationary liquid phases (whereby the fixed carriers may not react with the phase). The substance is dissolved in both phases. Stationary phase: usually water or polar organic solutions, including gel with enclosed liquid. Advantage: linear separation function (the distribution coefficient is independent of the concentration of the substance dissolved in both non-mixable liquids). → Paper chromatography usually means distribution chromatography.

III. Chemical chromatography: extremely stable bond between the carrier and the solids that are to be separated. The position of the bonding zone is extremely dependent on substance concentration.

IV. Column chromatography: special case of III where substances that are to be separated come into contact with the adsorbent that is fixed to the carrier. Example: silver salt fixed in the column, dissolved in a flowing solution of sodium chloride and potassium chromate, forming a silver chloride zone (top) and a silver chromate zone (bottom).

V. Ion exchange chromatography: normally using resin columns that exchange ions with the solution.

VI. Salting-out chromatograph: salting out with electrolyte reduces solubility in the mobile phase.

VII. Electrochromatography: substances are separated by means of differing mobility in the electrical field and different adsorption capacity. Also called paper electrophoresis if paper is used.

VIII. → Thin layer chromatography: same method as paper chromatography regarding the introduction of the mixture of substances to be separated, the use of the carrier and the way in which the separated substances are made visible, but the adsorbent sensitivity is considerably greater. The individual components separate much more rapidly and the process is therefore more practical.

Adsorption chromatography exploits the edge zone appearance of the adsorption of constituents of a liquid solution into a solid surface. The accumulation of a substance on the solid edge zone of a solid/liquid system is based on the reaction between the molecules adsorbed from the solution and the solid surface. The forces occurring between the particles in the liquid and those in the solid substance determine this reaction. For any given solid this force depends on the structure of the molecules in the solution and the solvent, whereby differing degrees of adsorption may occur and affect the separation of the dissolved substances. In this case, minor structural differences are often enough to create different adsorption behaviour. A general quantitative description of this phenomenon is difficult, since it is extremely dependent on the respective experimental conditions. It must also be taken into consideration that as well as the desired differing adsorption of the dissolved substances the solvent is also frequently adsorbed. However, empirically gained experience is usually enough to solve many separation problems using chromatography.

Chromatographic analysis is usually divided into 3 stages. First the substances to be examined are separated. These substances are then dissolved in a suitable solvent. The solution is allowed to flow through a vertical tube that is filled with the adsorption agent. This is where the dissolved substances accumulate in various places in the column as per their respective adsorption behaviour. A so-called → Chromatogram forms that is visible if the substances have different colours. Nonpolar substances such as ether, n-alkanes, carbontetrachloride, benzene etc. are normally used as solvents. Sugar, aluminium oxide, calcium carbonate, silica gel etc. are often used as adsorption agents. In the second stage the substances on the adsorption agents in different zones of the column are removed again. A suitable elution agent is run from the top to the bottom of the column in order to do this, causing the individual substances to leave the separating column one after the other, allowing them to be collected individually. This process is called the development of the chromatogram. Polar solvents such as methanol, ethanol, acetone etc. are used as elution agents. The final stage is the quantitative analysis of the individual materials gained in the previous stage, whereby normal physical methods are used.

Dye mixtures can usually be easily and reliably detected and isolated from the different coloured zones using the described method. Only a few products have proved themselves to be effective adsorption agents for dye identification, since neutral, aqueous dye solutions have to run through quickly but still provide wide, clearly separated adsorption zones. According to Schaeffer, this requirement is efficiently fulfilled by an extremely homogeneous mixture of aluminium oxide and talc, in a ratio of: a) 80 : 20 for most cationic and acidic dyestuffs, b) 90 : 10 for non-levelling acidic and chrome complex dyestuffs; c) 95 : 5 for direct dyestuffs. Mixtures of amino acids, plastics, carbon hydration products, sugars, fats, oils etc. are also chromatographed, whereby other adsorption agents and solvent are normally used.

Chrome alum → Potassium chromium sulphate.

Chrome development of dyes → Chroming of dyes.

Chromed wool Stabilisation of woollen yarn against fungus and bacteria by blind chroming using the single-bath chroming process. The same applies to an even greater extent to afterchromed wool, which has shown a resistance after 75 days during a soil burial test. By taking electron microscope pictures of chromed wool (ultra-thin layers) it was proven that most of the chromium moves into morphological wool areas that are rich in carboxyl groups and basic groups, i.e. endocuticle, cell core residue, cell membrane complexes and intermacrofibular cement. A direct comparison of chromed wool that has been previously enzymatically treated using pronase it was found that pronase treatment only as an effect on the endocuticle.

Chrome dyeing Afterchrome dyes are still widely used in wool dyeing in all stages of wool processing. The benefits are good to excellent colour fastness in all process and wet fastness requirements, good levelling and a low price level. Traditionally, dark shades are dyed, particularly black and navy blue. When dyeing wool with afterchrome dyes, acidic dyes with groups that can be sequestered are applied and aftertreated using potassium dichromate. After Cr^{6+} has been reduced to Cr^{3+} by the functional groups of the wool it is probable that a 1 : 2 metal-dye complex is formed. A final chroming liquor can contain tri- or hexa- valent chromium, whereby the latter represents the most problematic component because of its cellular toxicity. For this reason, hexa valent chromium compounds are replaced by tri valent chromium compounds in leather dyeing. In wool dyeing this is not possible, since the salts in tri valent chromium do not absorb or only absorb to a limited extent under the weak acidic application conditions.

Afterchrome dyes have come under pressure because of the increased stringency of the effluent laws. This is even more of a problem because no suitable alternative has been available to date, particularly in cases where a high degree of fabrication fastness is required. The terms of the effluent anti-pollution legislation (38th administration regulation) specify an extremely low total chromium level (old 38th administration regulation: 2 mg/l; new 38th administration regulation: 0.5 mg/l) for effluent discharges to the sewage system by wool dyeing companies that use chromium dyes. The threshold values for having to treat partial current effluent as required by the authorities may be as much as 5 times greater than the required general value for collected mixed water when entering the public sewage system (chromium (III) 2 mg/l; chromium (VI) 0.5 mg/l).

As far as treating a liquor containing chromium is concerned from a chemical point of view, with a daily total of 1000 m^3 of effluent in the mixing lagoon, a chromium content of 0.5 mg/l is much more difficult to treat than 10m^3 of partial flow effluent with 5 mg/l (both total: 50 g chromium) because the chemical balance is much easier to move to the right. However, chromium also occurs in the effluent when using metallic complex dyes.

Comparison of residual chromium content in sewage:

– traditional afterchrome dyeing	20–150 mg/l
– theoretical chromium factor (i.e. in relation to the stoichiometric dye quantities for binding to wool)	1–6 mg/l
– 1 : 1 metallic complex dyeing	3–13 mg/l
– 1 : 2 metallic complex dyeing	< 13 mg/l

Chromium dye binding via the chromium probably takes place in the low-sulphur range during afterchrome (microfibrous surface) and the non-keratin range (see Fig.).

The residual chromium quantities in the sewage from chromium dyeing can be reduced as follows:

- increase the bath exhaustion.
- adsorb excess chromium (III) from the dye solution on the wool.
- the optimum pH of 3.5 cannot be achieved using

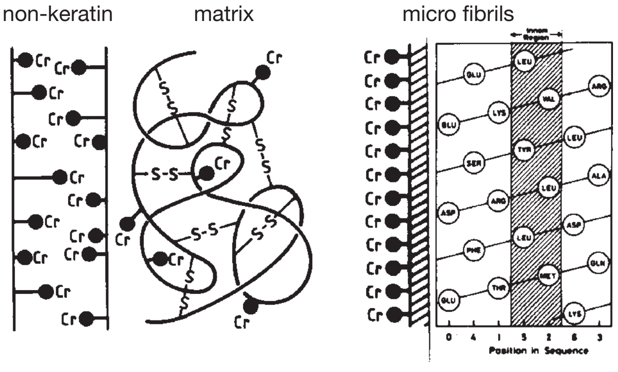


Fig.: Chromium dye binding from a chromium dyeing in morphological consistuents of wool (according to Fraser).

normal dyeing methods as the pH drifts towards 4.5. This means that formic acid can be used as a replacement using (using pH controlled dosing if possible).

- sulphate has a detrimental effect. In the "Glauber's salt" process sodium sulphate is therefore added at a later stage.

Chromium dyeing on loose wool leads to poor running characteristics in the spinning process. In order to optimise the original damage to the fibre and the loss of surface friction, dyeing can take place as follows: a) use chromium dyes at 80º with Baylan NT (special product made by Bayer AG); b) afterchrome in a fresh vat with theoretical chromium factor level; c) aftertreat with thiosulphate according to the relevant IWS method.

If possible, the loss of surface friction can be reduced using the soft flow technique (Wronz) by using less fibre flow during flock dyeing. An alternative to chromium black dyeing is dyeing with metal-free, dual-function bromo acrylide-based reactive dyes. This kind of dyeing is three times as expensive as chromium dyeing (excluding effluent costs) because two or three times as much monofunctional or dual-function reactive black is required to match chromium black dyeing.

Chrome dyes Chrome dyes are acid dyes with a complex-forming group, normally 2 OH groups on aromatic ring in an o-position to an azo-group (Fig.). With transitional metal ions, particularly chromium or cobalt, this produces a stable dye complex (dye pigment) with the fibre, which considerably improves the durability of the dye and the fastness of the dyeing (→ Chroming of dyes).

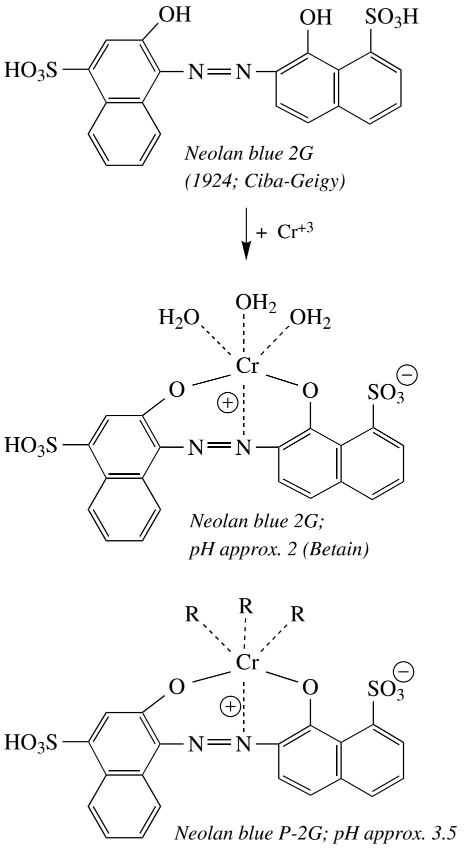


Fig.: Structural formula of a chrome dye.

After chromium salt treatment has taken place, a distinction is made between:

I. Pre-chroming process (wool): pre-chroming with potassium dichromate/acid, 1–1.5 hours at the boil, rinse; apply acid dyes suitable for chrome dyeing in a fresh bath.

II. Single-bath chroming process (wool): simultaneous dyeing and developing (chroming) in a slightly acidic bath. Suitable chrome dyes are applied together with special chromium mordants or potassium dichromate so that the slowly forming chromic acid pigment is absorbed into the fibre.

III. After-chroming process (wool, silk, polyamide): the chrome dye is applied to the fibre similarly to an acid dye. Add potassium dichromate to the depleted dye bath, whereby the chromium lacquer forms on and in the fibre. The most commonly used dyeing method for practically all chrome dyes.

Chrome dyes are seldom used on silk and polyamide.

Chrome gelatine Used in the manufacture of film printing screens using the photochemical process. It is used in the coatings in which light energy is used to trigger chemical reactions that lead to property changes and allow roller markings to be fixed. When mixed with chromium salts and illuminated for a long period, gelatine turns into an insoluble mixture called chromium gelatine. This knowledge is exploited and a carrier layer is applied onto the gauze of the screen, containing both gelatine and a chromium salt. After drying and illuminating through a partially covered transparent positive or negative, the non-illuminated parts can still swell, whereas the illuminated parts harden and are therefore no longer soluble during subsequent rinsing in water.

Chrome leather → Leather.

Chrome photoprinting Under diffuse light (using an opaque glass filter) fabric made from viscose filaments is impregnated with a solution such as 5% potassium dichromate for 20 minutes at room temperature, squeezed out, dried in the dark, exposed through a photographic negative, thoroughly rinsed (diffuse light) and then dyed using chromium mordanting dyes. Some of the dye is fixed to the illuminated, prechromed areas of the fabric. This has a certain wash-resistance, and the positive appears in its shading, naturally in a single colour only. Finished by thorough rinsing and drying.

Chrome tanning Animal hide is tanned into "wet blue" after cleaning by cross-linking the collagen chains with chromium. The expression describes wet, swollen leather that is subsequently dyed and re-fatted. The tanning serves to convert rot-susceptible hide into rot-resistant leather, so that the hide fibres no longer swell or shrink due to the absorption or loss of water, and become more temperature resistant and more resistant to the effect of chemicals.

Only the tri-valent salts in the chromium have a tanning effect, such as chromium (III) chloride and chromium (III) sulphate; e.g. $[Cr(H_2O)_6]Cl_3$ hexaquochromium (III) chloride (cationic). Chromium is in a position to form complexes using 6 coordinative binding options (Fig. 1).

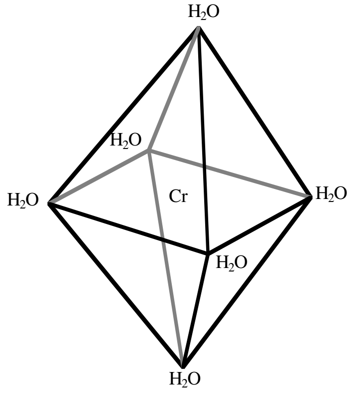


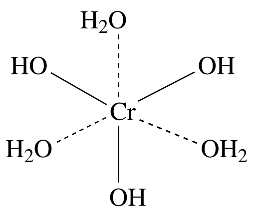
Fig. 1: Chromium complex octahedron.

The hydrolysis of hydrated cations in the chromium salt produces basic complexes and may result in insoluble chromium hydroxide.

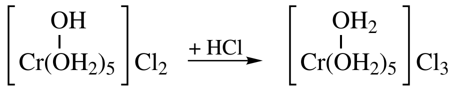
$$[Cr(H_2O)_6]^{3+} \longrightarrow [CrOH(H_2O)_5]^{2+} + H^+ \longrightarrow$$

$$[Cr(OH)_2(H_2O)_4]^{+} + 2\,H^+ \longrightarrow [Cr(OH)_3(H_2O)_3] + 3\,H^+$$

as a complex chemical structural formula:

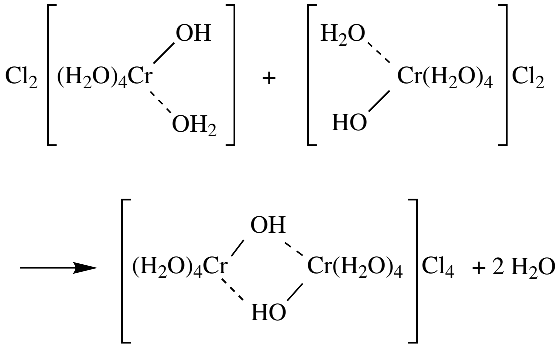


The solution itself becomes more acidic because of the release of H⁻ ions. Hydroxy compounds only form from chromium salts that can coordinatively bind water. This formation is prevented by adding acid and the old hydrous compounds are formed again.

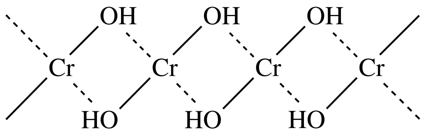


$$\left[\overset{OH}{\overset{|}{Cr(OH_2)_5}}\right]Cl_2 \xrightarrow{+\,HCl} \left[\overset{OH_2}{\overset{|}{Cr(OH_2)_5}}\right]Cl_3$$

Hydrous compounds tend to condense into multinuclear complexes. The prerequisite for this is the presence of a hydroxy group and a water group in the participating mononuclear components. The procedure takes place as shown in the following diagram:



As long as free OH groups are available, growth continues until polyhydroxyl compounds are formed during olating.



A certain degree of basicity must be guaranteed for such polyhydric alcohol compounds to occur. Increasing the temperature, adding alkali and ageing the solution lead to the formation of polyol compounds with an increase in molecule size leading to a colloidal state. Adding concentrated acids and boiling has the reverse effect called de-olating.

During chrome tanning an attempt is made to allow small molecule and low basicity cationic chromium complexes to diffuse into the hide, which allows the tanning conditions to be adjusted so that binding with

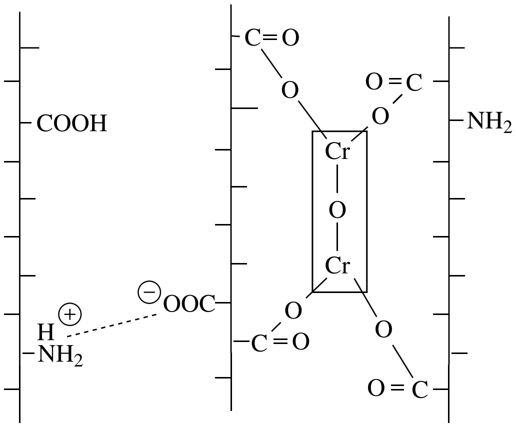


Fig. 2: Cross-linkage diagram of collagen chains caused by chrome tanning.

collagens can take place after previous olating, without scar tanning or surface cross-linkage occurring. The chromium complexes must be linked to the carboxyl groups (–COO⁻) in the collagen slowly in order to guarantee that the hide is tanned evenly (Fig. 2).

Tanning is an endothermic process and is assisted by heating, since a limited number of dissociated carboxyl groups are present in collagen at a pH of 4.5 to 5.0. Anionic tanning substances can be used, but only on a small technical scale, and do not provide any shrinkage values.

Many chromium complexes are technically masked in order to counteract precipitation during neutralization. The ligands are occupied by acid groups with complex affinity and therefore compete with the groups in the hide with complex affinity.

Chrome test for dyeings,

1. Ash the fabric to be tested (ash colour yellowish-green to black-green ash), and then melt the ash in a porcelain crucible with a 1 : 2 mix of sodium carbonate and potassium nitrate - produces a yellow liquid (aniline black; chromium mordant dyeing or chromium after-treatment; catechu brown or mineral colours such as chrome yellow to orange).
2. Liquefy the ashes of the fibre sample in 5 times the quantity of sodium carbonate/potassium nitrate (1 : 1) = chromium colours the melt green. Dissolve part of the melt in acetic acid and add lead acetate = yellow deposit of lead chromate. Dissolve the second part of the melt in dilute sulphuric acid, add a layer of ether and add a few drops of hydrogen peroxide. Chromium = blue perchromic acid, which dissolves into the ether layer when shaken.

Chroming The coating of copper print rollers with a layer of chrome to protect against damage and chemical influence.

Chroming of dyes Used to form chromium complexes in the fibre, which develops the final shade and improves light-fastness, especially wet fastness. A prerequisite is the presence of complex-forming groupings in the dye molecule, mainly OH- and COOH-groups in the ortho position. Most → Chrome dyes are soluble in water. These are azo dyes, which have OH-, COOH- or NH_2-groups in ortho position to the azo group, and azo and triarylmethane dyes with salicylic acid groups and anthraquinone dyes with OH- groups. Dyes with these groupings form complexes with trivalent chrome, with the displacement of the H atoms in the complex-forming groups (Fig.).

The chrome atom can form 6 saturated bonds building stable rings with 5 or 6 atoms.

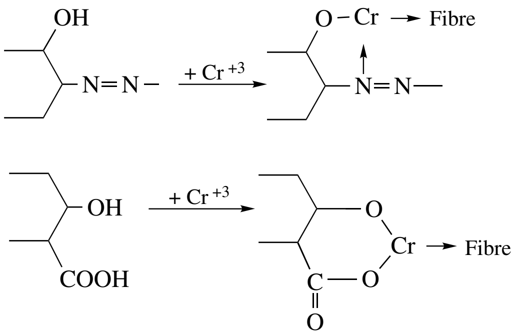


Fig.: Dye molecule structure.

I. Pre-mordant process: with wool (mordant dyes; chromium dyes) the application of the dye onto the premordanted wool provides immediate permanent colouring and therefore makes shading easier. However, only a relatively small number of dyes are available for this process. The process is fairly time consuming, provides little fibre protection and is hardly ever used.

II. Single-bath chrome dyeing process: the simultaneous application of dye and chromium salt to wool, and therefore the dyeing and development of the shade is made possible in a slightly acidic bath. Here also dyes with the most rapid complex-forming are selected, having good levelling and similar exhaustion properties from a slightly acidic bath. Special chromium mordants or potassium dichromate and ammonium sulphate is added. The process is important because of the relatively short dyeing time, good fibre protection, low sensitivity to the presence of other metal ions in water, equipment etc. The dyes have good balance and extremely good process and end-use fastness. With dark colours there is a tendency for the dye liquor to show lower exhaustion, which often results in poor rub and wet fastness. Colour levelness is much more difficult for slightly damaged wool. Union fabrics are dyed using union fabric chromium dyes in the single-bath chroming process. These are dye mixtures made from substantive dyes, using chromium dyes in the single-bath chromium process. Union fabric chromium dyes are only of minor significance.

III. After-chroming dyeing process: achieves the good process and end-use fastness for wool. Dyeing takes place in a slightly acidic bath. After complete exhaustion of the bath, a hexa-valent chromium salt is added (usually potassium dichromate), and the chromium pigments build up on the fibre during the rest of the dyeing process. The final colour is only seen after successful chroming, which makes shading more difficult. Before adding the chromium salt the dye bath must be extremely well exhausted so that only the dye that has been absorbed into the fibre is complexed. Before chromium salt is added, the dye bath is cooled to 80°C, brought to the boil again after adding the chromium salt and, depending on the darkness of the colour and the ease of development of the dye, treated by boiling for 30–40 min. until complete shade development has taken place. During the after-chroming process the dye may be more sensitive to metal, particularly iron (colour dulling). Adding sequestering agents to the dye bath can compensate for these metal-influencing effects. After-chrome processes are no longer used for polyamides (with the exception of black).

Chromium (Cr), very hard, brittle, silvery metal; atomic number 52,01, m.p. 1530°C. It readily forms alloys with other metals, e.g. with iron to give chrome steel with increased hardness, tenacity and corrosion resistance. Chromium can form bi-, tri- and hexavalent compounds. Chromium (II) hydroxide is a typical base, chromium (III) hydroxide is a weak base, whilst chromium (VI) hydroxide is a strong acid after water has been split off. The → Chromium salts are mostly coloured. Uses: for the production of numerous important chrome dyes having exceptionally high light fastness, chrome dyeing, important oxidizing, mordanting and tanning agents.

Chromium-complex dyes → Metal-complex dyes.

Chromium complexes Chromium compounds in which the element chromium is present as the central atom.

Chromium oxide, Cr_2O_3, MW 152,2. Starting product for chrome mordants.

Chromium (III) potassium sulphate (Chrome-alum, potassium chrome-alum), $KCr(SO_4)_2 \cdot 12H_2O$, molecular weight 499.4; dark violet crystals or light violet powder; soluble in water, violet-coloured solution, colour changes to green when heated. Usage: dye mordanting (particularly with some acidic dyes for increasing washing and bleeding fastness); manufacture of chromium mordants; waterproofing impregnation; lime insolubilization; KS colour delustring (transformation using alkali molybdate or wolframate solution); leather tanning. No longer used.

Chromium salts Compounds of 2, 3 and 6-valent chromium in a great variety of colours (white, green, violet, yellow, red, blue). The colour is dependent on the mode of attachment of the anions, as well as water molecules, to the chromium atom. Thus complex ions exhibit different colour reactions to the same individual ions outside the complex. Examples:

chromium (II) chloride $CrCl_2$
= white, blue when dissolved in water,
chromium (II) acetate $Cr(C_2H_3O_2)_2H_2O$
= red,
chromium (III) acetate $Cr(C_2H_3O_2)_3$
= green, solution turns violet later,
chromium (III) chloride $CrCl_3$
= violet,
potassium chromate K_2CrO_4
= yellow,
potassium dichromate $K_2Cr_2O_7$
= orange-red.

Chromium salts are highly toxic in waste water. Fish toxicity is detectable in the presence of very small amounts.

Chromium salts in dyebaths, colour fastness to →: Colour fastness; Chromium salts.

Chromium, test for on chromed wool Procedure: approx. 0,5 g of the textile material is ashed and the ash melted with 4–5 times its quantity of a mixture composed of equal parts soda ash and potassium or sodium nitrate. A yellow coloration of the melt indicates the presence of chromium. On dissolving the melt in approx. 3 ml of 30% acetic acid and adding a few drops of lead acetate solution, a yellow precipitate is likewise indicative of chromium.

Chromogen → Chromophore.

Chromogen black Specific indicator for → Complexometry.

Chromojet printing of carpets Polyamide pile goods can be sprayed with dye liquor in patterns so that printing is possible without using screens. The dye liquor, which is under pressure, is injected into the carpet pile via valve and jet systems. The valves are mounted on a movable slide block which, controlled by computer, moves to and fro cross-wise to the run of material (pile tiles). The colour change takes place outside the spraying area. The spraying area can be extended to 120 x 120 cm^2. Up to 8 colours are available. The pattern resolution is 600 dots per metre. Designing proceeds as follows:

The designs can be produced interactively by means of design computers (see Fig.). This makes it possible to respond quickly to customers' wishes. Similarly, keeping finished goods in stock becomes superfluous, as production is only to order. The patterns are stored on conventional diskettes, so no screens are required. Patterns can be changed in the space of seconds. Pattern repeats are possible with runs of up to 30 metres. Registering the colours to one another is not necessary. Colour printing can be controlled to a great extent, ensuring full penetration in all standard qualities. Directly

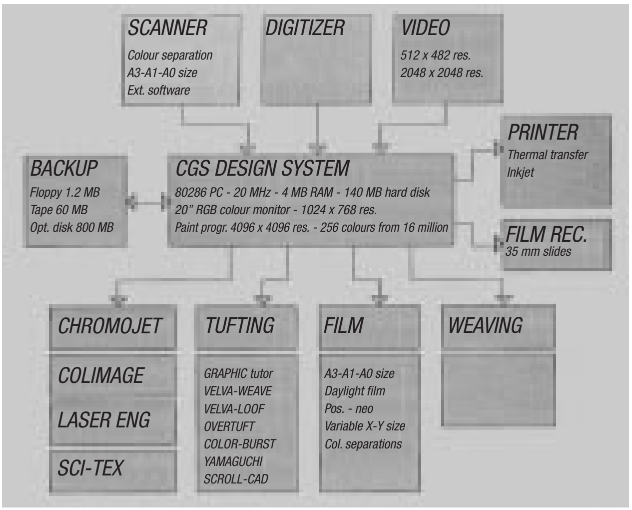


Fig.: Chromojet printing of carpets (Zimmer).

timed valves (jets) are used, which perform up to 400 opening and closing movements per second, so that optimum pattern sharpness and colour separation (weaving effect) is ensured. The pattern fineness is limited due to the digital system: half-tones and colour runs can be simulated to a limited extent.

The mechanical system is effected in a modular construction method, so that the correct plant can be optimally designed for each application purpose. Variable widths, numbers of colours, pattern resolutions and production outputs are possible. The production output is less than for rotary printing. Spray printing is suitable for patterning goods for the contract carpeting sector, where what matters is an individual design and good penetration, and not the yardage output. In contrast to screen printing, with spray patterning the problem is rather that too much dye liquor is applied. For this reason, a lower limit is set for the pile weight used. In practice, carpets and tiles from a weight of about 400 g/m^2 and upwards are patterned. The range has been tested at up to 1800 g/m^2. Thus for the textile area, it can be economical to use.

Chromophore Colour carrier or colour-carrying group in dye molecule = electron acceptor. Important as a link, bridge or corner pillar. The presence of chromophores in chemical compounds produces colour (chromogen = colour producer). Important chromophores are a) double bonds (–C=C–C=C–N=N–, –N=O), the accumulation of which gives the dye substantivity; b) so-called intersections of forking or branching double links, the accumulation of which leads to colour shifts in the direction of yellow - red - violet and causes the colour to shift darker to black as the molecules become larger.

Examples:

1. Azo group (–N=N–); identifier for azo dyes, represented in direct, acid, cationic, mordant dyes etc. Frequent occurrence affects colour intensity: chrysoidine (1 double bond between 2 benzene nuclei), Bismarck brown (2 double bonds, 3 benzene nuclei), naphthylamine black D (2 double bonds, 6 benzene nuclei).
2. Azine group (+N–N=): present in safranine and azocarmine, for example.
3. Nitro (SO–) group (–N=O) or $-NO_2$; represented in Oxford blue R, naphthol green B, naphthol yellow S, for example.
4. Carbonyl group (>C=O): characteristic of anthraquinone and vat dyes, alizarin etc. (present at least two times).
5. Other groups: >C=NH, typical for cationic dyes (auramines): C-bonded benzene nuclei, typical for cationic (fuchsines, malachite green) and acidic dyes (brilliant indo cyanine 6 B, patent blue A); –CO–C=C–OC–, typical for indigo and indigoid vat dyes (indanthrene brilliant pink R, Ciba violet B, Algol scarlet GG); –S–S, the typical disulphide group for sulphur dyes etc.

Principle:

hydrocarbon + chromophore = chromogen

C_6H_5 + $-NO_2$ → $C_6H_5-NO_2$

benzene (residual) *nitro group* *nitrobenzene*

colourless pale yellow

Chromotropic acid (1,8-dihydroxynapthalene-3,6-disulphonic acid). Intermediate for azo dyes and analytical reagent. As the latter it forms the basis of a very sensitive test for formaldehyde (limit concentration 1 : 500 000). Procedure: 1 drop of the test solution, 1 ml of 72% sulphuric acid and a few grains of solid chromotropic acid are heated for a short time in a test tube over a naked flame. The presence of formaldehyde is indicated by a red-violet colour.

Chundri (Chunsi). (Indian) same as → Bandhana. Red fabric with extremely coarse, mainly white, yellow and green scattered patterns.

Churning effect → Orthinetic coagulation.

Chuzen Japanese process for manufacturing reserve dyeings with indigoid vat dyes or naphthols on folded woollen fabrics that are printed with a reserve paste, compressed into a block and have dye liquor poured over them. Used as Kimono materials.

C.I., abbrev. for → Colour Index.

CIA, abbrev. for: Instituto Agronomico, Secão de Tecnologia Fibras, Campinas, São Paulo, Brazil (Brazilian Agricultural Institute, Section Fibre Technology); → Technical and professional organizations.

Cibafast W Brand name of a UV absorber for photochemical wool protection developed by CSIRO, IWS and Ciba-Geigy. It gives wool a more resistant basic whiteness, makes dyed materials more stable to light (1–2 grades) and slows down the photochemical degradation of wool. Cibafast W is a sulphonated o-hydroxyphenylbenzotriazol derivate; soluble in water, excellent (hot) light stability, dye bath stable, colourless on wool; maximum absorption at approx. 335 nm. It is used as a “colourless, acid dye” and can be applied directly from the dye liquor; only used for aftertreatment in exceptional cases, e.g. for reactive dyeing; solubility in water approx. 10 g/l at 40ºC; approx. 80 g/l at 85ºC. The application quantities are 1–2.5 percent by weight; good absorption capability at a pH of 3–5 (yield approx. 85–95%). If dyeing takes place at a higher pH, the addition of acid is recommended. Has good levelling and migration capability and good wet, hand washing, shampoo and dry cleaning fastness. Combination with selected dyes recommended. UV absorbers are becoming more important in this area, where textiles and skin are increasingly under threat because of the destruction of the ozone layer; this mainly concerns Australia and South Africa at present.

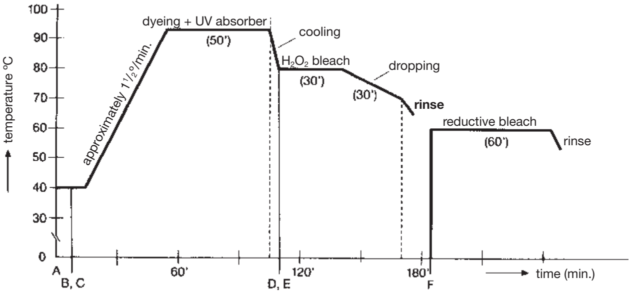


Fig.: Acidic single-batch dyeing/bleaching process with reductive aftertreatment using Cibafast W.
A = 2% acetic acid, 80% concentration (pH 5.2), 1 g/l sodium acetate. 1% Albegal A; B = selected dyes; C = 2% Cibafast W; D = Bleach activator; E = 25 m/l hydrogen peroxide, concentration 35%; F = 2% sulphuric acid, concentration 96%, 2.5 g/l Erioclarit B (or 1.5 g/l sodium metabisulphite).

Ciba-Geigy white standard Tool for the visual or instrumental assessment of white samples. Interpolation is possible and, in the case of instrument evaluation, extrapolation. The Ciba-Geigy white standard is used in the textile and washing auxiliary industry.

The Ciba-Geigy white standard for wool is mainly used in the paper and plastics industry. The white standard is made using cotton cretonne, bleached and brightened in a washing bath with an alkyl aryl sulphonate-based detergent. Consists of 18 visually equidistant grades of 10 units each, with a whiteness scale of 70–240 units, i.e. mainly extends on the yellow-blue axis in the colour space, whereby the differences in nominal degree of whiteness must correspond with the visually discernible differences using average daylight illumination (standard light type D_{65}). A finely graduated scale is required for visual assessment; a few grades suffice as the calculation basis for instrumental assessment.

The Ciba-Geigy plastic white standard (CG plastic standard, plastic white standard) for determining whiteness consists of 12 one-sided matted plates made from compressed melamine resin. Plates 1–4 contain decreasing concentrations of a yellow pigment and do not fluoresce. On the other hand, plates 5–12 contain increasing concentrations of an optical whitener. Grades 1–12 cover the whiteness scale of 20–210 Ciba-Geigy units. As well as whiteness, colour (green or red layers) can also be assessed. Can be cleaned using lukewarm water. Application: in the paper and plastics industry and in the manufacture of less resistant white standards made from textiles and paper.

CICS, abbrev. for: Committee for Index Cards for Standards, Holland; → Technical and professional organizations.

CID, abbrev. for: Comité International des Dérivés Tensio-Actifs; Secretariat: Paris, France. (International Committee on Surfactants); → Technical and professional organizations.

CIE, abbrev. for: Commission International d'Éclairage (International Commission on Illumination), with headquarters in Paris, France.

CIELAB Colour difference units (evaluation) obtained from colour measurement procedures and calculated with the aid of → Colour difference formulae are generally expressed in CIELAB units today. According to the CIELAB system, the CIELAB coordinates L, a, b, are represented in colour space as mutually perpendicular axes with L representing lightness (from white to black) with a and b representing red/green and yellow/blue colour differences respectively. → Colour measurement.

CIETEX, abbrev. for: Conference Internationale de l'Enseignement Textile (International Conference on Textile Education), Villeneuve d'Asq-Flers, France. A permanent international conference of textile teaching and training establishments which has achieved great importance for management trainees and advanced vocational training across the entire textile sector. Objective: the further development of teaching methods at all levels within the textile sector.

CIE whiteness formula → CIE recommendation for standard identification of the degree of whiteness. The formula should only be used for a relative comparison of similar samples measured at the same time on the same device because of the technical difficulty in measuring fluorescent dyes (absolute precision, precision of adapting the sample lighting to the spectral distribution of daylight). In relation to D_{65}, 10 degrees, the CIE whiteness formula is:

$$W = Y + 800 \cdot (0.3138 - x) + 1700 \cdot (0.3310 - y)$$

As well as the whiteness formula, a formula for identifying the tint of white samples is recommended:

$$T = 900 \cdot (0.3138 - x) - 650 \cdot (0.3310 - y)$$

T is positive for samples with a green tint, and negative for samples with a red tint.

Cigarette test → Flammability testing.

CIM (Computer Integrated Manufacturing). Full integration of the data from all systems involved in industrial manufacturing, i.e. measuring data is not just recorded but also processed and used for process control. The associated software must be extremely user-friendly in order to do this when an individual department such as colour metrics is to be integrated into the CIM network. To begin with there will only be isolated cases of CIM factories, such as a fully automated cotton combing plant where many spindles are operated by just a few employees. Quality and material flow will be monitored by a central computer station. → Computer applications in textile finishing.

Circular dichroism Light contains left and right rotating components that are absorbed to differing degrees by optically active compounds (→ Optical activity). The dependence of wavelength on the varying absorption of right and left polarised light (ΔE) is called circular dichroism. For example, it can be used as a measure of the degree of correctness of amylose iodine associates, which reaches an extremely high value with an average degree of polymerisation (DP) of 50 and drops off again towards longer chains. When the solutions are left to stand after adding iodine, there is considerable increase in dichroistic absorption over a standing period of 2 hours (Fig.).

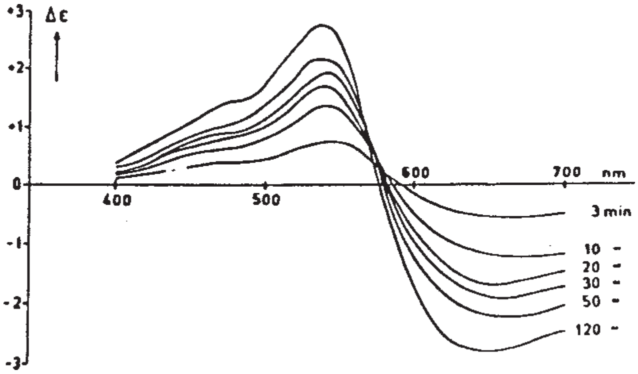


Fig.: Circular dichroism of amylose iodine solutions: temporal increase of the solutions by standing (DP 47).

Circular knife cutting machine Unit with which printed fabrics etc, particularly printed nonwovens are cut or parted to a specified width.

Circular knit goods Fabric knitted in tubular form, which is mostly also finished in this form, and only afterwards slit open.

Circular-knit pile fabric (Nicky) → Plush cloth, of smooth or textured yarns, with closed loops (plush loops), similar to → Terry fabric. If the loops are cut, → Cut-pile plush is obtained. The ground of the fabric is usually cotton, possibly reinforced with polyamide or polyester yarns, the pile of cotton. Loop size 3–4 mm. Special shearing machines are used to cut the pile (loops). Before shearing, the goods are tumbled. Different finishing processes for circular-knit pile fabric:

I. Piece-dyed goods:	II. Yarn-dyed goods:
Dye,	Scour and soften,
Hydroextract,	Hydroextract,
Slit,	Slit,
Tumble dry,	Tumble dry,
Precrop,	Precrop,
Soften,	Steam and tumble dry,
Hydroextract,	Final crop,
Tumble drying.	Stenter finish (stenter frame).

Circular-knit pile fabric finishing Circular-knit pile fabrics are generally finished by cutting the loops to give → Cut-pile plush, with the majority of articles piece dyed. In the case of yarn-dyed articles (usually of polyester), the tube is cut open, tumbled dry (to open up the pile) stentered, cropped and heat set. In the case of piece dyed articles the necessary processing stages must be adapted to the material (usually cotton/polyester). Pre-treatment and dyeing take place on the winch (to avoid permanent creasing). The pre-treatment for cotton consists of the boiling process, possibly followed by peroxide bleaching. After dyeing the goods are centrifuged to physically remove water. In order to raise the loops the goods are tumble dried, stentered and in the case of cut-plush fabric, cropped. Polyester or polyester/cotton qualities are steamed (pre-setting) after cutting, followed by precropping and scouring (winch), centrifuging and drying. Before dyeing, heat setting must take place at 185–190°C. After winch dyeing the goods are tumble dried; wet shearing then takes place to make the pile stand up and become more even. Variations of the sequences described above are possible. Circular knit pile fabric finishing is complicated and requires a good deal of experience. Its cost may represent up to 40% of the value of the fabric.

Circular singeing → Singeing machine for tubular knitgoods.

Circulating air drier → Drying systems.

Circulating hot oil unit (Circulating oil thermal unit, oil heat transfer boiler, forced oil-circulation boiler, thermal oil boiler, heat transfer plant, in accordance with DIN 4754), Heating process using a closed oil-circulation system. Heating below boiling point, therefore no pressure. Heating medium in tube boiler (vertical or horizontal). Source of heat provided by burners in which fuel oil or gas is burned, occasionally also electrical energy. Heater must be fitted with all control and safety devices. Heat transfer medium conducted by circulation pump (centrifugal pump) from the heater to the points of use and back. Heating time according to size of plant and volume of heat transfer medium minimum 15 mins. No acceptance or inspection obligations for heat transfer heating systems. A full load of thermal oil lasts some 4–5 years or more in a well-built plant; after this reclamation and where applicable topping up should be carried out as necessary. Installation costs are higher for larger diameter pipe systems and more complicated control mechanisms (3 distributing valves). For closed dyeing machines, specifically suited programmable controls are necessary. With in-between switching of a circulating hot oil unit-steam converter, additional steam is made available (up to 20 bar) with good overall efficiency (in comparison with simple steam boiler operation, no loss of condensate, no loss of heat, no operating personnel, no corrosion in the pipework and boiler installation, no water treatment). Application: wherever heat is required (heat exchangers) where automatic, maintenance-free operation is required. Operating range starts at heat transfer medium temperature of 130°C, main range 150–300°C, in exceptional cases up to 320°C. Specifically for steam/hot water heating systems, for dyeing machines (e.g. beam, winch, HT becks), for air heaters, for stenter frames, for drying or fixing machines, etc.

Circulating liquor machine It is necessary to differentiate between types of textile processing machinery. A distinction can be made between textile machines and machinery for processing textiles. Textile machinery can carry textiles on a fabric carrier in a horizontal or vertical manner and liquors flow through stationary fabric.

Circulation drying Principle of solvent regeneration in the case of dry-cleaning machines and solvent degreasing and finishing machines, where air is blown by fans in a circle over a cooler, a heater and through the solvent-containing machine section (e.g. drum). The heated air evaporates the solvent on the textile material. In the cooler, the absorptive capacity of the air is reduced as against the solvent gas contained in it, and the gas is therefore condensed into liquid solvent, which flows through the water trap into the clean solvent tank.

Circulation machines → Dyeing machines.

Circulation of dye liquor As a result of rationalization in yarn preparation and coning, larger and larger yarn packages, and therefore higher package weights than hitherto, are now being dyed although demands on the technical quality of the yarn and the levelness of dyeing have not been lowered. This requirement can only be satisfied by employing an alternating circulation of liquor for yarn packages of this type (Fig. 1) which commences immediately after filling the dyeing vessel. The alternating circulation, achieved with liquor reversal systems which do not require the liquor pump to be switched off, ensures level exhaustion of the uniformly distributed dye within the yarn package from the beginning of the dyeing process. This type of circulation also ensures a uniform supply of dye in both flow directions with a short fixation phase.

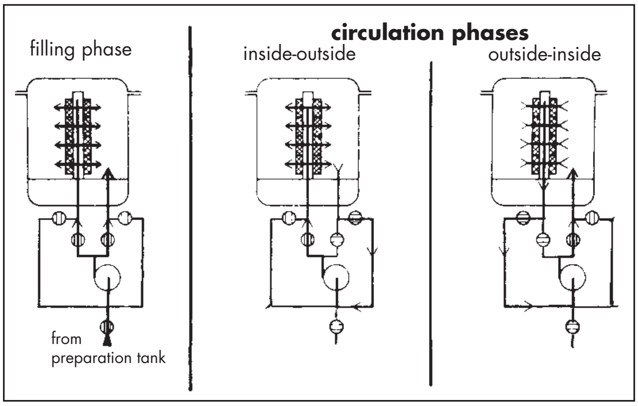


Fig. 1: Liquor flow in the Rapidcolor process (Hoechst/Then).

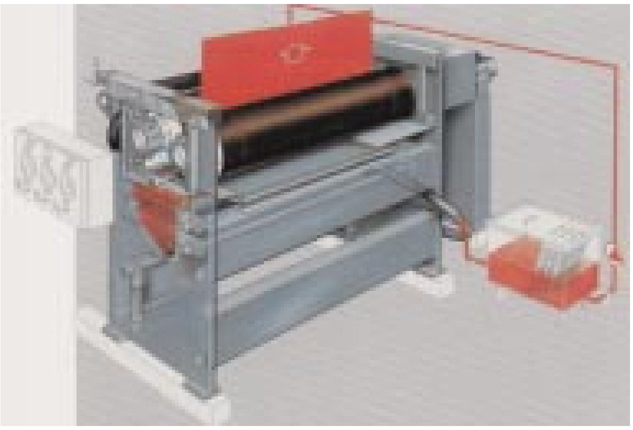


Fig. 2: Unipad dye padder for dyeing pile fabrics with liquor circulation to remove lint by filtration (Ramisch-Kleinewefer).

Liquor circulation may also be necessary on dye padders (Fig. 2) in continuous dyeing processes so that the dye liquor in the pad trough can be constantly filtered when, e.g. pile fabrics are being impregnated with dye liquor (lint separator).

Circulation pump A pump used to circulate dye liquor in dyeing machines for cross-wound yarn packages (see Fig.).

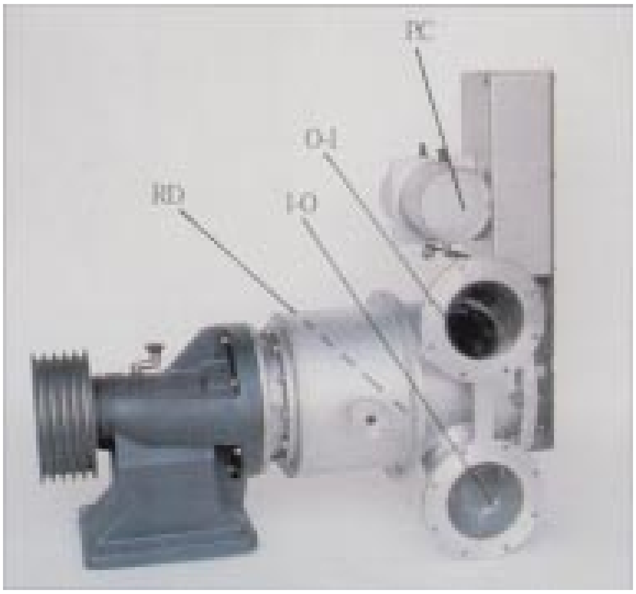


Fig.: Electronically-controlled circulation pump from Bellini with changeover of liquor flow direction from inside/outside (I/O) to outside/inside (O/I) without changing the rotational direction of the motor and without stopping the motor. This is achieved by means of a special liquor reversal valve (RD).

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Ciré (Fr. wax, waxed; also oilskin rainwear). A brilliant patent leather effect produced by the application of wax, heat and pressure. Fabrics are mostly impregnated with paraffin or wax emulsions followed by a passage through the → Friction calender. The result is a supergloss almost metallic in appearance. (A shiny surface given by a hot calendering alone to a fabric made from thermoplastic fibres is also called ciré).

Ciré calender Crêpe calender with lightly engraved embossing bowl.

Ciré effects → Embossing.

CIRFS, abbrev. for: Comité International de la Rayonne et des Fibres Synthétiques (International Rayon and Synthetic Fibres Committee), Paris, France; → Technical and professional organizations.

Ciselé A grainy plain-colour silk crêpe fabric with a scroopy handle and good draping properties, not unlike a → Moss crêpe in appearance. Shrink-resistant, crease-resistant and water-repellent characteristics are imparted by the finish.

cis-form (Syn-form) (lat: this side), isomer structural form of chemical compounds where the radicals in the spatial molecular arrangement are "neighbouring on the same side", as opposed to the trans-form (anti-form), where the radicals are "spaced out, alternately to the right and left" (see Fig.).

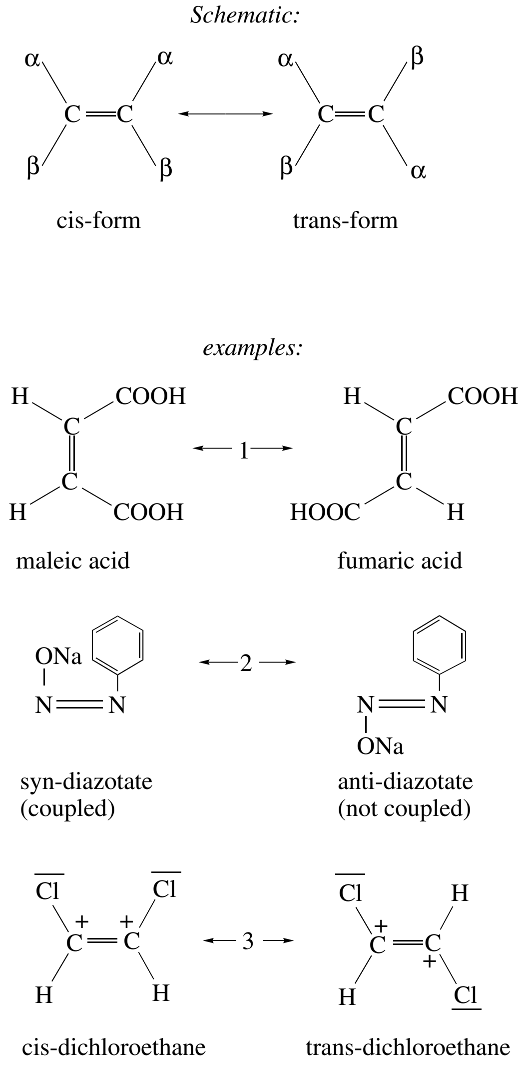
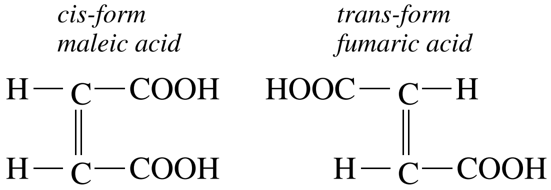


Fig.: Cis-form.

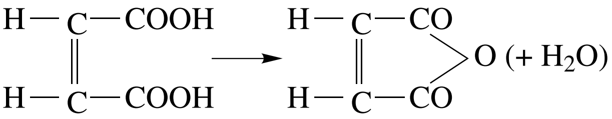
The compounds in examples 1–3 are used frequently in textiles and each have special significance. For example, they play a part (Type 2) in certain azo dyes. Example 3 is even more significant. This is the type of chemical compound that has a clear dipole moment in the syn form (1.8) but not in the trans form (dipole moment = 0).

Cisterns (tiled pits). Open pits (usually rectangular) constructed of brickwork or concrete, faced with ceramic tiles, used in wet processing as temporary storage units for piling down cotton fabrics in rope form between the individual process stages of alkali scouring and bleaching. Cisterns are occasionally provided with a liquor circulation system.

cis-trans isomerism Concerns → Cis-form and trans-form isomerism, a phenomenon that is widespread in organic chemistry and always occurs when the two atom groups linked to each of the two carbon atoms in a carbon double bonding C=C are different (see diagram example under → Cis-form). This isomerism, which is based on various spatial molecular arrangements, is defined in maleic and fumaric acid by the two C atoms that can no longer be freely rotated against each other, whereby the two carboxyl groups only lie on the same side (cis) of a plane or at opposite sides (trans).



Both forms can be mutually transposed. Both turn into Bernstein acid when catalytic hydration occurs, but only maleic acid produces an internal hydride when heated (as proof of the cis-form):



whereas fumaric acid also turns into a maleic acid hybrid if subjected to considerable heating over a long period of time. Because of the two neighbouring carboxyls the double bonding of this anhydride is strongly activated, meaning that it can easily splice into cyclic polymers with dienes. The cis-trans isomerism is not restricted to unsaturated compounds but also occurs in many different forms in cyclically created compounds.

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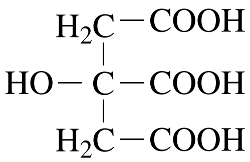
CITEN, abbrev. for: Comité International de la Teinture et du Nettoyage (European Professional Organization of Dyers and Drycleaners); → Technical and professional organizations.

Citric acid (citric acid, ß-oxitricarballyl acid), $C_6H_8O_7$; salts = citrate. Occurs as a water of crystallisation free, light powder and (usually) as colourless crystals (+ 1 Mol H_2O; mol. wt. 201; density 1.542). Surface decomposes to white power at 30–40ºC when water is added. Odourless, sour taste and acid reaction, citric acid is considered to be a strong acid that attacks cellulose fibres when it vaporizes. Soluble in water (approx. 1.350 g/l of crystallised acid dissolve at approx. 20ºC), soluble in 80% alcohol and ether.



$$\begin{array}{rcl} & H_2C & -COOH \\ & | & \\ HO- & C & -COOH \\ & | & \\ & H_2C & -COOH \end{array}$$

Nitric acid oxidizes citric acid into oxalic acid. Usage: lubricant for viscose and silk (seldom); in acidic discharge printing; with antimony salts for resisting cationic dyes; as a scouring aid (5% solution); removal of berry stains, ferro-gallic ink stains, coffee stains, red wine stains, tea stains etc.; may be damaging to dyes, has tendency to form stubborn yellow stains on white materials.

CL → Polyvinyl chloride fibres, standard abbrev. according to the → EDP Code (→ Textile fibre symbols); → CLF.

Clarification temperature With nonionogenic surfactants with → Turbidity point, the temperature below which the mixture of the two liquid phases has become homogeneous due to cooling.

Claws → Clips.

Cleaning → Washing. Also as a widespread abbrev. for → Dry cleaning.

Cleaning ability Expression of the behaviour of textile material against → Dry cleaning. Assessment and recommendation by → Care labelling of textiles (textile care symbols).

Cleaning action of dry-cleaning detergents With the dirt removing mechanism of organic solvent drycleaning detergents, the method of operation covers more or less the following functional system of compounds, depending on the type of dirt:

a) solvent soluble/water insoluble or water emulsifiable (e.g. oils, fats, waxes and tar);
b) solvent insoluble/swelling in water (e.g. starches, pectins and some types of protein);
c) solvent insoluble/water soluble (e.g. salts, sugar, urea and dyeing auxiliary agent residues);
d) solvent insoluble/water insoluble (e.g. pigment dirt).

Cleaning activity Functional principle of → Drycleaning detergents.

Cleaning and shearing machines Used for removing yarn residues prior to fabric finishing.

Cleaning cloths Different types find use in the home:

- high quality, random web type floor cloths for long-term use in the 100–400 g/m² weight range.
- 10–100 g/m² longitudinally laid web dishcloths for short-term use (disposables).
- spunbonded or wetlaid disposable cloths.
- multi-purpose or dry webs of regenerated or natural cellulose in the 40–80 g/m² range.
- cross-laid, synthetic, nonwoven dusters approx. 100 g/m² in weight.
- approx. 50–80 g/m² mop cloths for floor cleaning.
- cellulose fibre or polypropylene polishing and cleaning cloths for furniture, upholstery, shoes, metal components etc.

Cleaning performance test American soil test of the IFI.

Clean room clothing This, which has to be worn at specific work stations for protecting sensitive products from contamination by fluff or skin particles, has hitherto predominantly been developed in accordance with this protective function standpoint. The routes followed to this end however have frequently led to textile and clothing constructions which are to some extent at variance with physiological requirements. Under the physiological aspects of clean room clothing, a distinction is to be drawn basically between outerwear and under clothing and between clean room clothing systems, operative job difficulty and environmental climate. With clean room clothing, physiological requirements with simultaneous protection for the product can be very extensively met with the right construction, although certain guidelines should be followed as regards both textile and clothing construction. In the case of clean room outerwear, the problem, when worn in direct contact with the skin, of its adherence to the skin on perspiring due to the smooth surface caused by the synthetic filament yarns employed, has not yet been completely solved. With many products, this results in the wear comfort being impaired or even the occurrence of an unpleasant skin sensation. The climatic conditions set up in the clean room must be absolutely adapted to the clothing in order to create a physiologically good situation for employees. At 22°C and 35% relative air humidity, and with an airflow speed of 0.3 m/sec, the majority of clean room clothing systems is capable of providing good physiological wear comfort in terms of the job difficulty obtaining in practice.

Clean room clothing should therefore act as a barrier against particle-form contamination given off by human beings (including fibres and fibre fragments). As long as porous material, preferably woven fabrics, are

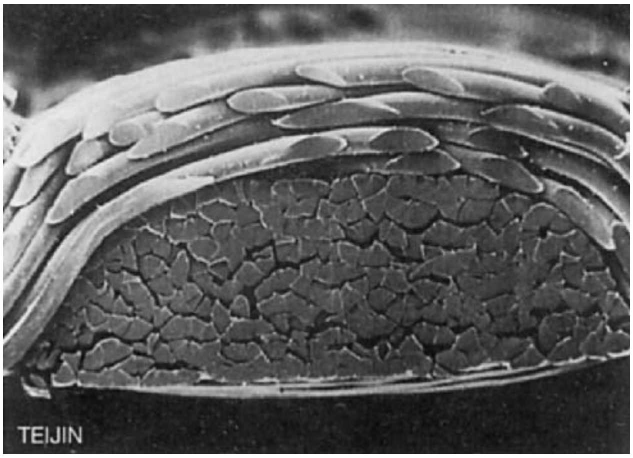


Fig.: Compactness of a clean room clothing woven fabric.

used for the task, it must be assumed that particles will penetrate this barrier. The hitherto usual concept of barrier action is based on the assumption that airborne particles may be involved. From the textile standpoint, this assumption is not quite correct in two respects:

- from experience, clean room clothing has some residual contamination even in favourable washing and decontamination treatment conditions, i.e. in the fabric are lodged particles which can be released by movement.
- when a clean room coat or overall rubs against underclothing due to movement, it must be assumed that particles on the underclothing will penetrate into the pores of the outerwear fabric, and will pass through the pores mechanically on further movement.

These migration effects also occur in the case of padded outerwear and beds.

Clean room clothing fabric (Fig.) also functions as an accumulating barrier against particles. This has a

		TEX 1	TEX 2	TEX M		TEX U
		I-76350	T-85884	T-303	T-300	T-85895
		2 cm strips	0.7 cm strips	0.5 cm strips	0.5 cm screen	0.6 cm strips
clean room class		≥ 100	≥ 100	≥ 10	≥ 10	≥ 10
yarn construction	warp	75 denier/36F	100 denier/48F	75 denier/72F	75 denier/72F	75 denier/72F
	weft	100 denier/48F	150 denier/130F	64 denier/144F	64 denier/144F	150 denier/640F
weft insertion/10 cm	warp	740	410	650	650	570
	weft	340	260	400	400	300
woven fabric structure		twill	plain weave	plain weave	plain weave	plain weave
width (cm) x length (m)		122 x 50	122 x 50	122 x 50	122 x 50	108 x 50
weight (g/m^2)		110	95	90	90	125
yarn		100%PES	100%PES	100%PES	100%PES	70/30%PES/Nylon
antistatic yarn		carbon	copper (T–25)	copper (T–25)	copper (T–25)	copper (T–25)
% filtration effect with 0.3 µ particle size		81	72	90	90	99
% filtration effect with 0.5 µ particle size		82	80	95	95	99.5
air permeability (cc/cm^2/sec)		11.7	3.8	0.8	0.8	0.8
static charge capacity (µc/m^2)						
NY		3	3			
AN		2.9	3.1	2.6	2.6	3.1
surface resistance (Ohm/sg.)		3.5 x 10^6	3.4 x 10^7	1.6 x 10^7	1.6 x 10^7	2.8 x 10^7
water vapour permeability (g/m^2/24h)		10080	7440	8640	8640	8640

Tab.: Construction of different clean room clothing fabric qualities (Novitex).

limited effect; in addition to small, airborne particles, large, mechanically transported particles also undoubtedly penetrate this layer. As regards airborne particles, the fabric behaves like a surface filter (caking). The particles at first retained in filter cakes can be mechanically transported through the fabric. As an accumulating barrier, the fabric has characteristic properties which depend on its porosity. In comparison with a porous fabric, a dense fabric is difficult to decontaminate and has a high degree of residual contamination after washing or decontamination treatment. Based on these findings, particularly dense fabrics cannot be recommended without qualification for stringent clean room clothing requirements.

From both the aspect of filter capacity and the standpoint of clothing physiology therefore, it is advisable to take a targeted requirement profile as a basis (Tab.).

Clear Ready-to-use pigment print paste based on kerosene emulsion or synthetic thickener which contains all the necessary auxiliaries except pigments.

Clear colour In contrast to → Dull colours, contains, in addition to colour contents, either just white (light clear range) or just black (dark clear range). Details: → Pure spectral colour.

Cleavage of dyes involves the following:

I. The readiness of azo dyes to split at the azo group, for which reducing agents, such as e.g. sodium dithionite, are required. Two cleavage products are formed from splitting the dyestuffs, both of which are amines and each one of which has a nitrogen atom from the original azo group. The cleavage of dyestuffs is often the basis of discharge and resist printing.

II. The possibility of hydrolysing an ester group in a dyestuff molecule into the corresponding carboxylic acid by using acid or alkali. This is made use of in alkaline discharge resists of disperse dyes on polyester.

Cleavage products result from cleavage of chemical compounds. So, e.g. azo dyestuffs are broken at the azo group, in several reaction steps, by reaction with strong reducing agents into two compounds that contain amino groups (→ Cleavage of dyes). In discharge and reserve printing processes, it is important that the dyestuff cleavage products are readily removable. The structures of dyestuffs can be elucidated by isolating and identifying the cleavage products.

CLF → Polyvinyl chloride fibres, → Textile fibre symbols according to DIN 60 001 T4/08.91.

Cling propensity of textile fabrics End-use property. In wearing all-silk and synthetic garments for example, clinging to the body can occur as a result of electrostatic charging, a phenomenon that may sometimes give rise to complaints. Clinging of textiles to damp skin may inhibit the transmission of perspiration.

Cling property (F_K), The force expressed in cN required to detach a textile from a water boundary surface. Relates to the subjective sensation of a textile worn next to skin bathed in perspiration, the discomfort becoming greater with higher cling properties. Skin model measurements produce the following F_K comfort indices:

< 25 cN = very good
25–50 cN = good
> 50 cN = unsatisfactory.

Cling test Measuring instrument which measures the adhesion of a test fabric charged with static electricity by friction to a metal plate. The time taken for the test specimen to fall is measured. AATCC Test Method 115-1965, 115-1969.

Clingy A term used in the USA for undesirable adhesion of textile materials to the body during wear. It occurs, eg. with garments made from unweighted pure silk as well as polyester. → Cling test.

Clip marks Defective lighter or darker marks on the fabric when heat setting synthetic piecegoods, due to subsequent variable dye absorption, caused by → Clips.

Clips Continuous holding devices for anchoring woven fabric selvedges (stenters) during drying, heat setting, shrinking, mercerising etc, enabling fabric to be tensioned or relaxed as necessary

Classification:

I. Clips: generally preferred for lighter-weight woven fabrics which pass quickly through the stenter, the fabric being tightened in the clips by the wedging action of a flap, the light-tight fit holds the fabric without damage, and all the clips in the chain clamp uniformly. Speeds over 200 m/min. They are distinguished as follows, depending on design: a) hammer clips, which operate by means of a simple slamming mechanism. b) feeler clips have feelers on their flaps (in the case of mercerising machines, with iron flaps, possibly also with a hard rubber cover etc), which release the fabric selvedge at a specific distance from the flap knife edge, enabling uniformly wide edge clamping to be achieved. Malleable cast iron or light metal alloy is used as clip body material. Clamping edge and table consist of rustproof steel. The clamping edge almost always has but one knife edge; fluted knife edges are also used in special cases. With later clips, attention is paid to ease of fitting, and flaps and chain bolts are detachable (use of circlips, spring washers, clamps etc. rather than rivets). Krantz has designed a “two-storey” double clip, by means of which two fabrics can be fed through the machine one above the other in the case of mercerising machines and stenters. Air Industries has developed a clip in which the mass is reduced and the surface enlarged by ribs, providing for quicker heating up and improved selvedge drying.

II. Pin links: are preferred for operating with overfeed (max. tension-free drying and shrinking, in the heat setting of synthetic woven fabrics), especially in order to prevent glazing due to clip marking; the woven fabric selvedges are pinned on by separate brushes. Pin size and numbers are oriented to the nature of the fabric. The pins, made of hardened standard or rustproof steel, are set in pin bars (brass), in part surface protected (chrome or nickel plated), and screwed on to pin links (malleable cast iron) for ease of replacement, which, on their part, are linked together by bolts and bushes (hardened steel). Roller link connections are rarely encountered, as pin chain speeds do not generally exceed 100 m/min.

III. Combined clips: are used to provide the two functions of pins and clips in one clip. There are fixed and movable types. In the case of fixed combinations, a pin bar is screwed on in front of the clip. There is another design for vertical return chains, on which the pin bars are located behind the flaps. Movable combinations can be designed in various ways, either the pin bars being swung out of the way in principle, or clip operation can take place. Special devices on the stenter serve to actuate these combinations. They are designed in such a way that the pin bars can automatically be swung in or out while the chain is running. Such clip/pin combinations identify machines which have to combine high fabric speed (approx. 200 m/min) with high performance.

CLOC Concentration of Limit of Oxygen for Combustion = minimum oxygen concentration above which a fibre will burn. Values usually lie between 18 and 28%; higher in polyamidimides at 31.9% and polyvinylchlorides at 37.1%. Other methods produce similar values. The behaviour of fibre mixtures is often unpredictable, since they may be easier or harder to burn; each fibre mixture should be treated as an independent system.

Cloqué A blister effect crêpe fabric woven in double-cloth construction with a thin crêpe georgette-type base and a generally plain-weave face having blister-like relief effect (woven or embossed). Distinction is made between the following forms:

I. Woven cloqué: Unshrunk or minimum-shrunk weft yarns are woven grouped in a particular order with a warp consisting of either shrunk or unshrunk yarns or alternatively a combination of the two. The differences in shrinkage characteristics are obtained by pre-setting the yarns at different temperatures. Yarns with different rates of drawing are also woven to achieve the same result. It is also possible to use yarns of different twist characteristics in warp and weft. Another method of weaving cloqué fabrics is to employ polyamide threads having different shrinkage potential. The cloqué effect, resembling the crêpe finish produced by caustic soda printing, is created in subsequent setting and other finishing processes. It is also possible to produce woven fabrics similar to sand crêpe and other relief effects. Although the effect in woven cloqué does not offer such a wealth of options as II., it is the most popular in terms of the amount of fabric produced.

II. Chemical cloqué: Created by the action of chemicals on polyamide fibres. The polyamide fibre can be caused to shrink by the action of swelling agents (e.g. phenolic substances, organic acids, calcium thiocyanate, aliphatic alcohols). Resorcinol and phenol in 20–25% solution are applied, usually thickened with Senegal gum or gum arabic (also in combination with glycerine), by machine printing. Film printing allows appropriate breaks to be made. The durable cloqué finish is produced by subsequent tensionless steaming for 5–10 minutes or by briefly heating up to relatively high temperatures (e.g. 2–3 minutes at 130°C) in a fixation machine. If required the finish is capable of effectively withstanding a subsequent dyeing process and with careful treatment will adequately withstand ironing. An advantage that a chemically produced cloqué finish on polyamide has over the crimp in a caustic soda produced crêpe on cotton is that here it is possible to apply any desired pattern, i.e. not only stripes, since in the swelling and shrinkage processes involved both warp and weft react virtually equally.

III. Bonded cloqué: An imitation of woven cloqué. It is produced by spot adhesive-bonding unfinished viscose or cotton georgette with a smooth dense fabric, e.g. taffeta. Two plies of fabric are thus bonded together, one of which must be very lightly constructed and also have shrinkage potential, for which purpose the unbleached high-twist georgette crêpes mentioned earlier are suitable. The taffeta on the other hand needs to be the densest possible so that the adhesive applied cannot strike through. The adhesives are usually applied by printing using zinc screens, in dots of variable size or in patterns which then determine the appearance of the cloqué finish. It is important for the adhesive paste to be of the correct viscosity. It must not be so thin as to strike through the taffeta, nor so thick as to risk clogging the screens. The substances applied must possess good adhesive power combined with adequate durability and the dot-printed sites must retain satisfactory elasticity in the finished fabric.

Closed loop control → Automatic control systems.

Cloth beam Serves as a take-up device on the loom (→ Weaving) for the finished woven textile.

Cloth guides Fixed guiding apparatus, which operates on a length of fabric passing over it. There are retarder guides, expander guides or deflector guides, depending on use.

Clothing felt → Felt fabric.

Clothing physiology Physiology is the science of the functions of living organisms. Clothing physiology is defined as the science of those phenomena involving mutual interaction between body and clothing and manifested in the comfort, efficiency and health of the wearer. It involves aspects of physics, chemistry, medicine, physiology, psychology and textile technology. The generic term → Clothing technology is used by some authorities.

The expression “physiologically engineered clothing” is meant to imply that the clothing performs to best advantage whilst an activity is being pursued. This function represents the sum of all properties influenced by fibre composition, spinning and weaving or knitting history, by thickness, density, weight, coloration and finish, and also by garment fit and make-up technology and by clothing systems.

Clothing physiology is based on the three basic criteria of body, climate and clothing which must be intercompatible, but which in turn are each made up of a large number of separate factors:

1. Body:
   - skin type and skin temperature,
   - release of heat and moisture,
   - activity level,
   - health status and standard of nutrition,
   - psychosomatic stress,
   - body weight and body size.
2. Climate:
   - air temperature and relative humidity,
   - air movement,
   - solar irradiation and moisture factors,
   - effects of other substances (dust, liquids).
3. Clothing:
   - thickness and density,
   - air retention, air permeability,
   - water vapour or humidity permeability,
   - moisture absorption and transport properties,
   - waterproofness,
   - thermal insulation,
   - skin compatibility,
   - elastic properties,
   - electrostatic characteristics,
   - fit and make-up,
   - number of textile/garment layers worn.

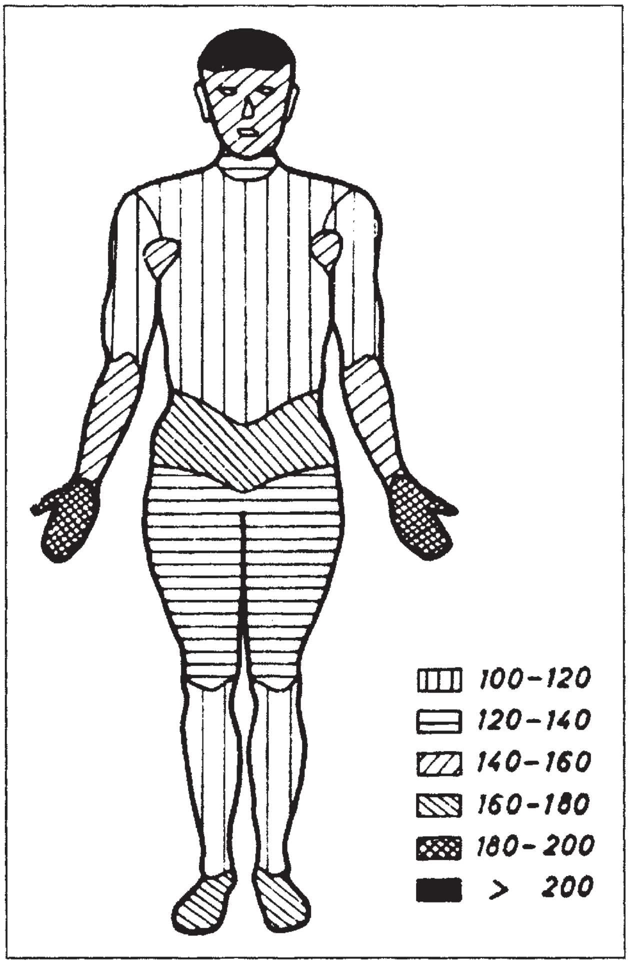


Fig. 1: Distribution of active sweat glands per cm^2 in an adult person of middle age.

The function of clothing is to assist the body’s inherent thermal control processes and thus relieve the circulatory system and maintain efficiency in mind and body, including under adverse environmental climatic conditions. Wearer comfort must also be maintained with the clothing worn in rapidly fluctuating climatic conditions, in other words with changes in temperature, humidity and air movement, and equally with the body at rest and in movement, or during heavy manual activity. Nevertheless it does not suffice for clothing to be suitable only for one type of climatic condition and only one particular activity, since body activity as well as weather and climatic conditions vary within a wide range. Physiologically efficient clothing must be capable of coping with these variations within reasonable limits, i.e. it must cover a wide thermophysiological control range. Clothing must furthermore undertake ergonomic functions. i.e. it must not hinder movement of the wearer and in the case of protective clothing must be capable of adequately protecting the wearer from certain hazards. The wearer also expects his clothing to have adequate mechanical strength, satisfactory resistance to cleaning and care processes, and to be colourfast and fashionable.

Through its basal metabolism and work metabolism the human body produces excess heat depending on the level of activity. This is dissipated via the breath and via the skin. Production of perspiration (Fig. 1) maintains the cooling threshold temperature at about 37°C. Heat production in the following activities, expressed in Watts is:

sleeping	85 W
standing speaking	165 W
jogging	480 W

Maximum variation: basal metabolic rate:work metabolic rate = 1 : 10.

Heat release M is obtained from:

- breathing (approx. 10 %) as H_{res}
- dry heat flow as H_c
- vaporisation heat flow as H_e

H_c and H_e jointly account for 90%.
These indices inter-relate in the following manner:

$$M = H_{res} + H_c + H_e \pm \frac{\Delta s}{\Delta t}$$

$$= H_{res} + \frac{(T_{skin} - T_{outside}) \cdot a}{R_c} + \frac{(p_{skin} - p_{outside}) \cdot a \cdot d}{R_e} \pm \frac{\Delta s}{\Delta t}$$

d = discomfort factor
R_c = thermal insulation
R_e = vapour permeation resistance (must be sufficiently low)
Δt = time segment
Δs = heat content
T = mean temperature
p = mean water vapour pressure

Since H_c does not vary much, heat release is flexibly controlled mainly by R_e. Moisture dissipation as a means of regulation occurs in this context via five routes:

1. Water vapour diffuses through pores in the clothing.
2. Swellable fibres in the clothing absorb liquid perspiration which diffuses slowly via the hydrophilic fibres and finally desorbs at the outer surface of the garment.
3. Fibres that are capable of being thoroughly wetted-out (microfibres with large surface area) adsorb liquid water on their surface. This migrates by wicking action to the outer surface of the textile article and there desorbs.
4. Capillary condensation occurs in the random fibre assembly with outward dissipation by capillary forces. Good wetting-out characteristics are necessary for this purpose.
5. Fifty percent of water vapour released by the skin can be dissipated via convection by a good rate of air exchange if the clothing is suitably constructed. Clothing construction (Fig. 2) is therefore a factor of greater influence than type of fibre.

Clothing comfort is expressed particularly effectively by the "discomfort factor" d. If the skin is dry d approaches zero; if the skin is wet then d = 1. Comfort occurs at $d \approx 0.3$ and $T_{skin} \approx 32–29°C$. If it is not possible to achieve thermal equilibrium, the heat content Δs changes with time Δt, which is possible to a limited extent by adjusting the extremity temperatures and the core temperature.

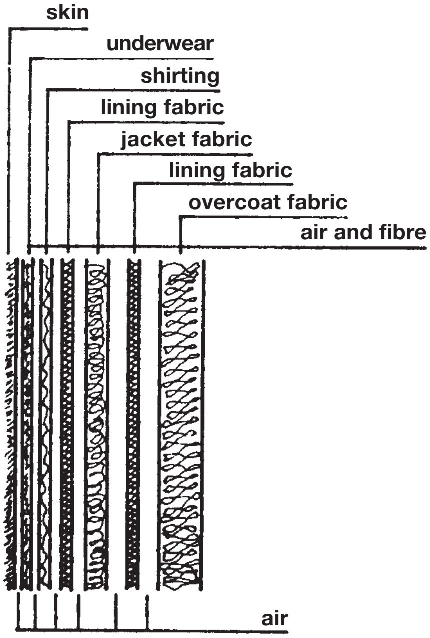


Fig. 2: Engineered clothing construction with adequate space between the various layers.

Apart from having good thermophysiological wear characteristics, the physical sensorial reaction to textiles worn next to the skin must be satisfactory. This involves the sensations aroused by the contact of textiles with the skin, for example softness or suppleness. There can also be unpleasant sensations such as scratching and stinging, or the adhesion of textiles to skin wet with perspiration. Skin irritations of this kind, often mistaken for allergies, can be eliminated by the right surface characteristics in next-to-the-skin textiles, controllable by adopting appropriate fibres and fabric or garment structures and assemblies (spacers). The following rules apply to the "engineered" design of physiologically correct clothing:

a) Thermal insulation, moisture transport and air exchange (convection and ventilation) of a clothing system are influenced both by the characteristics of the textile materials and by the fit of the garments.
b) The actual thermal insulator is the air trapped in the clothing, i.e. the more is trapped the higher the thermal insulation.
c) Moisture transport and moisture permeability are critical in the case of variations in the environmental climate or the work level of the wearer across the full span of the thermophysiological control range.
d) The control range or the end-use range of a clothing system is all the greater when none of the garments worn lie close to the skin.
e) Water-repellent textile layers within a clothing system should be thin so that sufficient water vapour can permeate by diffusion.
f) Air permeability in textiles need not necessarily also imply good moisture permeability.
g) Good skin compatibility in materials is important. It prevents skin irritations which are otherwise caused by mechanical irritation or by moisture build-up.

Application of this system permits logical selection of textile materials under consideration and of clothing systems. Laboratory tests performed in stage 1 on the skin model (thermoregulatory model of human skin) with pieces of fabric and in stage 2 on a manikin with made-up garments produce indices characterising the fabric or garment. Computed predictions provide information on the probable wearer comfort of a particular clothing system under different conditions of climate and activity of the wearer which also need to be taken into account.

The clothing systems selected in these two initial stages are then examined in stage 3 (wearer trials in a climatic chamber) mainly for the performance of the clothing and wearer reaction with regard to moisture dissipation. It is closely examined whether certain clothing parameters in stages 1 and 2 have been correctly assessed in respect of actual wear. Wearer tests in the field in stage 4 (restricted practical test) and stage 5 (test marketing) are as a rule limited to a few already optimised clothing systems which have been systematically selected in the preceding stages. (Source: Mecheels).

Clothing technology Term used by some authorities as an alternative to → Clothing physiology. Self-explanatory generic term covering the physical, chemical and medical aspects of clothing having the following functions:

- Research of the relationships between the human body, its clothing and the environmental climate.
- Determination of the influence of the variables involved in the manufacture of clothing, such as type and form of fibre, and yarn and textile construction.
- An aid to ascertaining the optimum clothing for different end-uses, for example leisure and occupational clothing, sportswear, uniforms.
- Improvement of man's lifestyle, giving particular consideration to health, hygiene and comfort.

Cloth make-up Textile finishing includes the treatment

- of loose fibres (e.g. flock dyeing in Fig. 1),
- of yarn package (e.g. cheese and cone dyeing in Fig. 2),
- of hank yarn, warp beams and continuous yarns (in continuous operation),
- of fabrics such as nonwoven fleece, knitted goods or woven fabric (e.g. piece dyeing on the hank, as depicted in Fig. 3, or on the beam, as depicted in Fig. 4)
- of ready manufactured parts (fully-fashioned finishing, such as stonewashed jeans).

Textile finishing therefore treats textiles in any type of cloth make-up.

Cloth press Special padding mangles for wool and wool blend fabric for impregnating and dewatering, e.g. when acidifying (carbonising), finishing (e.g. weighting), etc.

Cloudpoint Refers to the temperature at which liquids, oils, solutions become visibly cloudy. Impor-

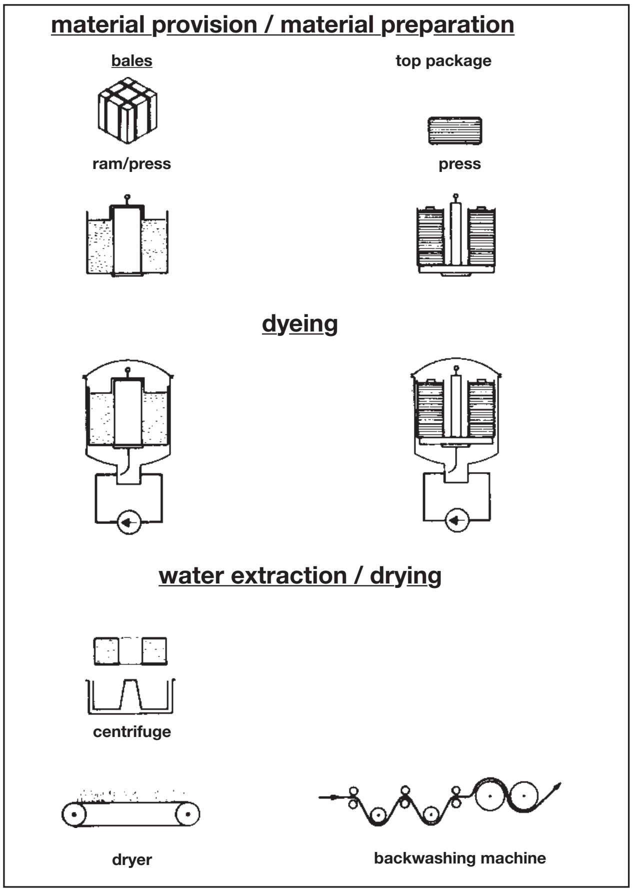


Fig. 1: Loose stock and top dyeing (Quas).

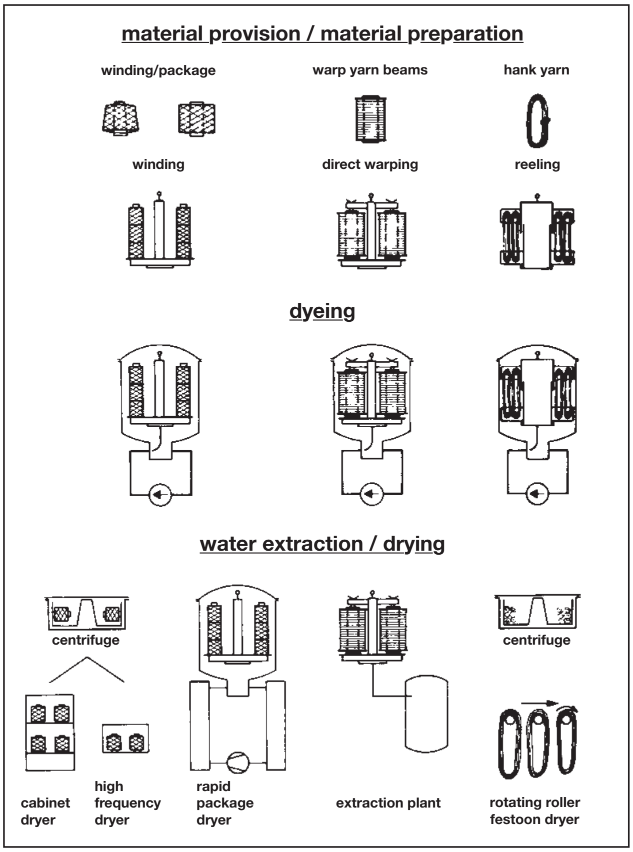


Fig. 2: Yarn dyeing (Quas).

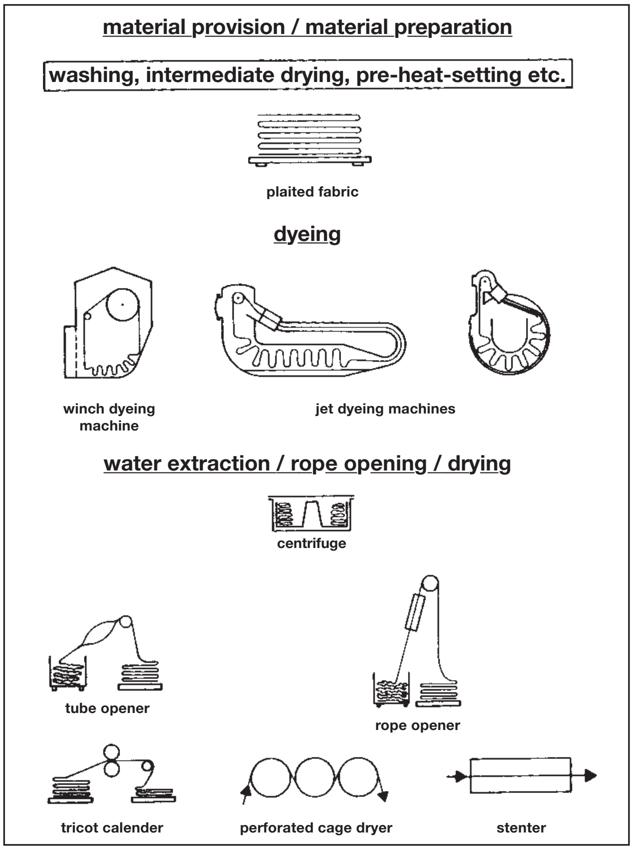


Fig. 3: Batch type rope dyeing (Quas).

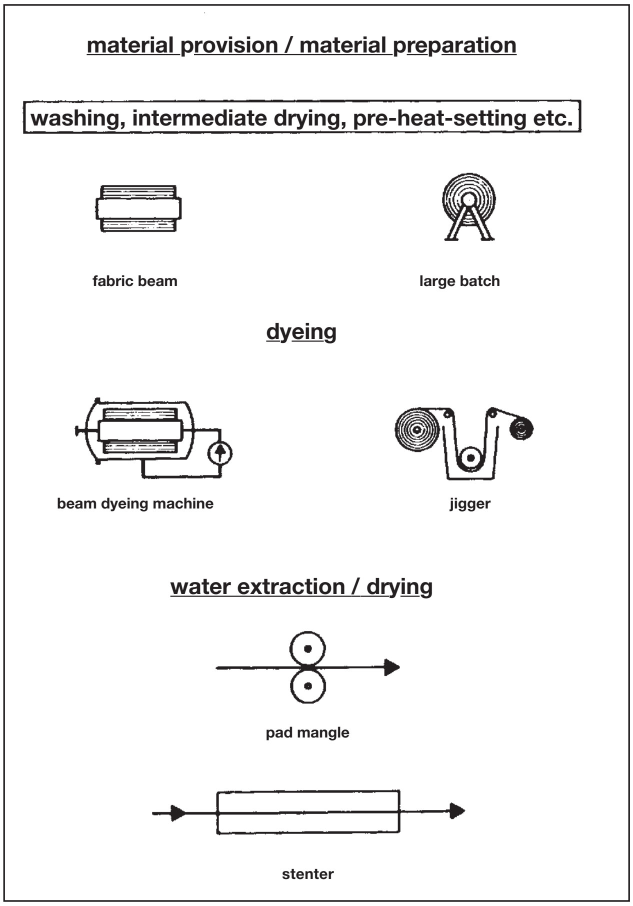


Fig. 4: Batch type open-width dyeing (Quas).

tant e.g. as → Titre of soap solution and for surfactant solutions (→: Clarification temperature; Krafft point). The cloudpoint occurs only in the case of nonionic surfactants (see Fig.). It is the point at which the solution of a nonionic surfactant becomes cloudy when it gets above a certain temperature. The phenomenon is reversible, i.e. when it cools down the solution becomes clear again at the same temperature. The reason for the occurrence of this phenomenon is linked to the hydration of the hydrophilic nonionic groups. This hydration is exothermic; when the temperature increases partial dehydration takes place and thus a new phase forms. This explanation is backed up by the fact that the cloudpoint is almost independent of the total concentration of the surfactants. The cloudpoint of nonionic surfactants can be determined in accordance with DIN 53 917.

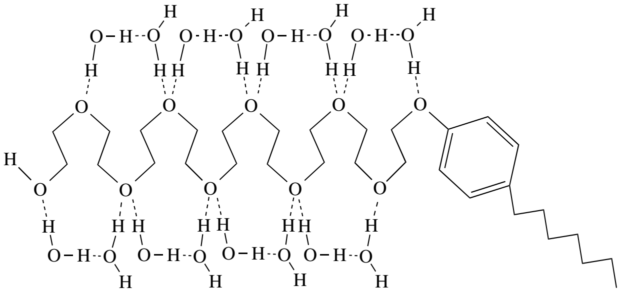


Fig.: Mechanism of the orientation of water molecules on the ethylene oxide oxygen atoms of a nonionic surfactant. Above the cloudpoint the hydrogen bonds are broken and the surfactant becomes insoluble in water.

Experiments on the effect of electrolytes on the cloudpoint of dilute solutions of nonionic surfactants show that the alteration to the effective → HLB value depends not only on the type and amount of the electrolytes added but also on the length of the polyoxyethane chain in the surfactant molecule.

Cloud point index Index for characterising nonionic surfactant raw materials with a low number (< 5) of orientated ethylene oxide molecules. The cloud point index corresponds to the amount of water in ml that will turn cloudy a solution of 1 g of surfactant in 10 ml of n propyl alcohol at 30°C. The method has good reproducibility and is very sensitive.

Cloud temperature In certain nonionic → Surfactants, the temperature above which their aqueous solutions become heterogeneous as two liquid phases form.

Cloudy dyeing Unlevel, mottled appearance dyeing. → Unlevel dyeings.

Cluett process → Compressive shrinkage processes.

Cm, symbol for curium.

CMC, abbrev. for:

I. → Carboxymethylcellulose.

II. → Critical micelle concentration.

CM cotton Cotton treated with monochloroacetic acid and then sodium hydroxide is converted into CM cotton. Two distinct types can be made in this way. One type of CM cotton has a “starched” appearance and handle. It absorbs water more readily than cotton and can accept crease-resisting treatments with greater effect. The second form of CM cotton disintegrates readily in water. It can be used as a temporary yarn for making fabrics from which the unwanted yarn can be easily removed. The insoluble CM cotton can be produced easily in mercerizing equipment at very low cost. The product can be made crease-resistant with particularly good effect.

CMD → Modal fibres, → Textile fibre symbols according to DIN 60 001 T4/08.91.

CMR, abbrev. for: Continuous Maximum Rating.

CNB, abbrev. for: Central Normalisatic Bureau, Holland; → Technical and professional organizations.

CNS Spanish Standards Association; → Technical and professional organizations.

CO → Cotton, → Textile fibre symbols according to DIN 60 001 T4/08.91.

Co, chemical symbol for cobalt.

co-, prefix meaning “together with”, e.g. coenzyme, cocarcinogen, copolymer, coagulation, coalescence, cohesion.

Coacervate (coacervated phase). Concentrated phase of a system subjected to → Coacervation.

Coacervated system Totality of the phases of a system subjected to → Coacervation.

Coacervation Mixing of a solution into two phases in equilibrium with each other, which contain the same components, but in different quantity ratios.

Coacervation system Two-phase system comprising two aqueous, immiscible phases (coacervate and equilibrium liquid). The coacervation system principle was the basis of the Cibaphasol process for the continuous dyeing and vigoureux printing of wool.

Coagulating thickeners Thickeners which coagulate with sodium tetraborate and alkalis. Special maize starches, carob seed grain ether derivatives or high-viscosity alginates are suitable for this purpose.

Coagulation (Latin: coagulatio = coagulate). Coagulation or flocculation of colloidally dissolved particles by accumulation, flocculation, small lump formation and settling to the bottom as insoluble gel. Occurs by heating or the addition of electrolytes or oppositely charged colloids. Examples: production principle of viscose filament by hardening in an acid precipitation bath; chemical purification of effluent etc. (Fig.).

Coagulation plant In the coated textiles sector, polyurethane transfer coating has made progress as opposed to rubber or polyvinyl chloride coating: the resultant composite material is water vapour permeable (incorrectly described as “breatheable”), without transporting liquid water. These types of microporous coatings can be produced on coagulation plant.

The textile substrate is sprayed or coated with a

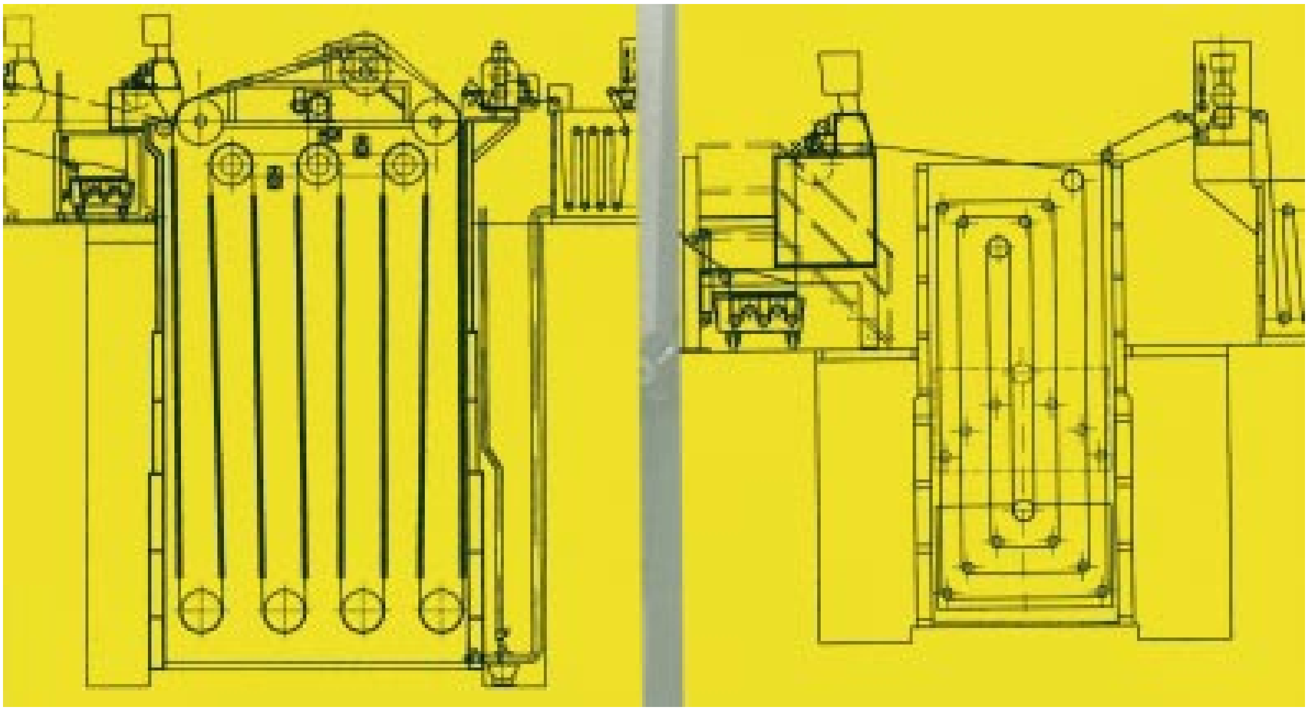


Fig.: Left side: Chain coagulation tank for very soft products (garments, hand bags); right side: Vertical coagulation tank with cylinders for a wide range of products (garments, hand bags and shoes).

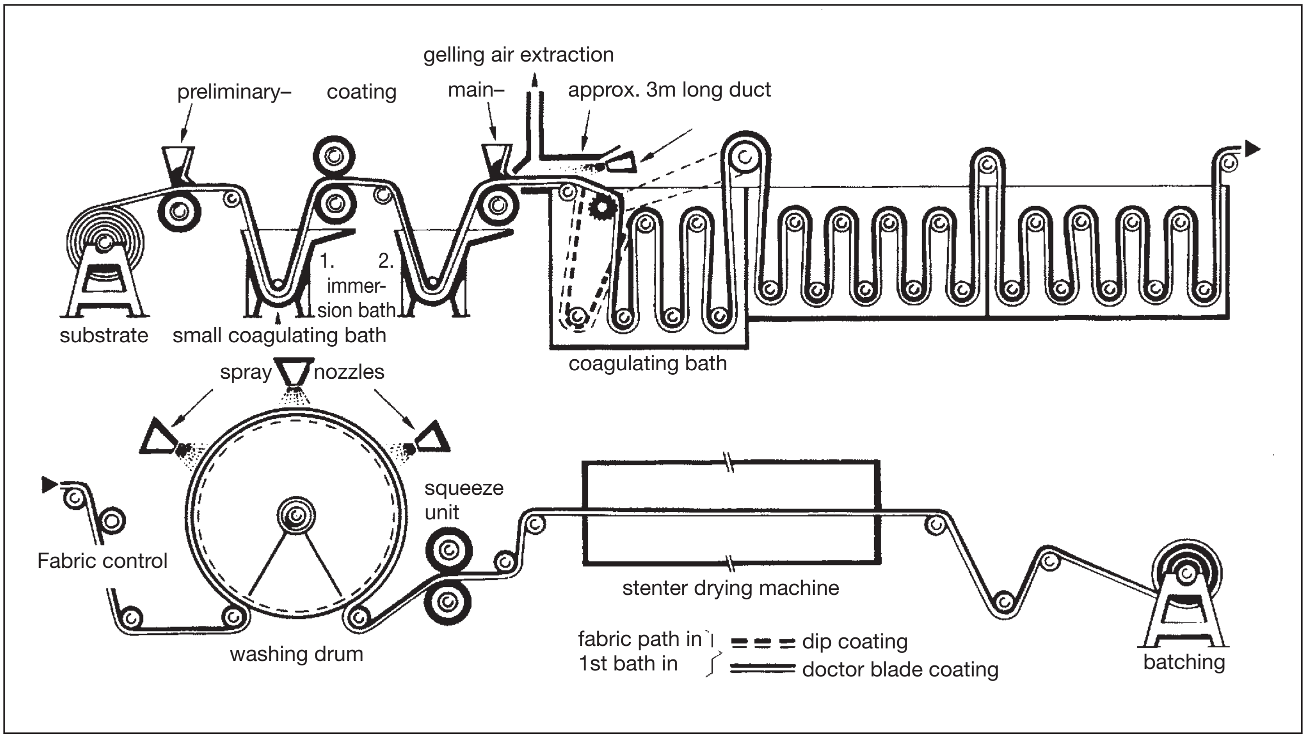


Fig. 1: Coagulation plant with coating or spray application (Bayer).

polyurethane solution (Figs. 1 and 2), the polyurethane then being coagulated into a microporous mass in a precipitating bath.

The dimethyl formamide used as solvent is unrestrictedly miscible with water. In the aqueous coagulating bath, the solvent is gradually extracted from the polyurethane so that a definite pore structure is obtained relative to the coagulating conditions (precipitating bath temperature and solvent content). These so-called poromerics have won a secure place, particularly in the shoe industry. The combination of water vapour permeability and water impermeability required in many cases cannot of course be automatically obtained with this technology. This requirement profile can be better achieved by later techniques, e.g. a) a polyurethane solution is mixed with a defined quantity of water in evaporation coagulation. The solvent is selected so that it is the first to be evaporated when the substrate is dried. The concentration of the solutiser therefore constantly decreases, while that of the non-solutiser - water - constantly increases. Finally, as with classic precipitation coagulation too, the polyurethane precipitates in microporous structure form. The pores are precisely formed so that they are large enough to allow the passage of water vapour, but not so big as to allow water droplets to pass through. b). With the aid of classic coagulation, a polyurethane which contains hydrophobic, silicone or perfluorocarbon based components is applied. c) Specific hydrophilic polymers have the power to transport water vapour by means of compli-

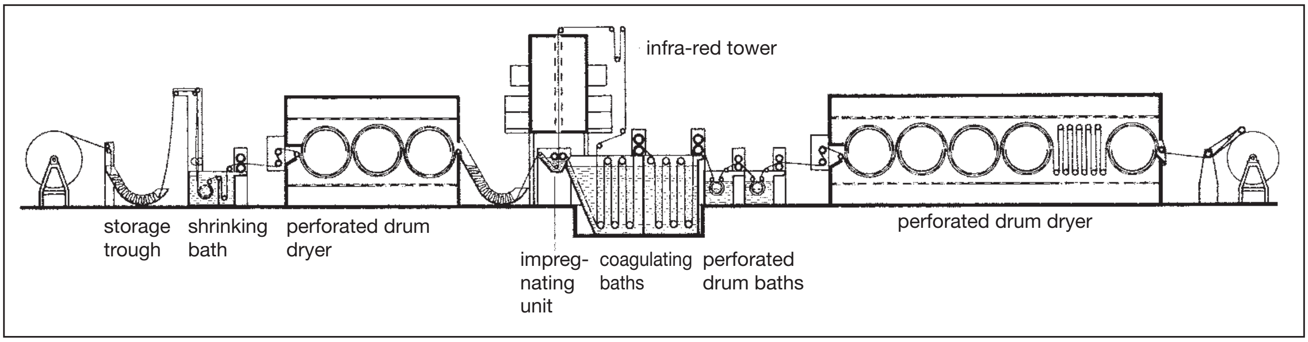


Fig. 2: Fleissner continuous line for bonding synthetic leather nonwoven substrates for latex (with infra-red tower) or for polyurethane impregnation (with no infra-red tower) with coagulation stage.

cated molecular mechanisms. This characteristic is used in reverse osmosis for example. Unfortunately, many polymers with these properties are either water-soluble (polyvinyl alcohol, polyethylene oxide) or are too stiff for textile coating. Success has been achieved in synthesising polyurethanes, which, even when applied as a compact layer, are water vapour permeable, are otherwise useful only for microporous coatings.

Coalescence Confluence of the droplets of an → Emulsion. In most cases, aggregation precedes coalescence. Coalescence leads to emulsion breaking. Macroscopic emulsions should be regarded as stable only relative to time, for there is no such thing as a thermodynamically stable macroemulsion, because they represent multi-phase systems with very large interfaces and interfacial tension which does not disappear; they are accordingly thermodynamically unstable, i.e. sedimentation or creaming of the discontinuous phase, and, finally coalescence, can occur (Fig. 1).

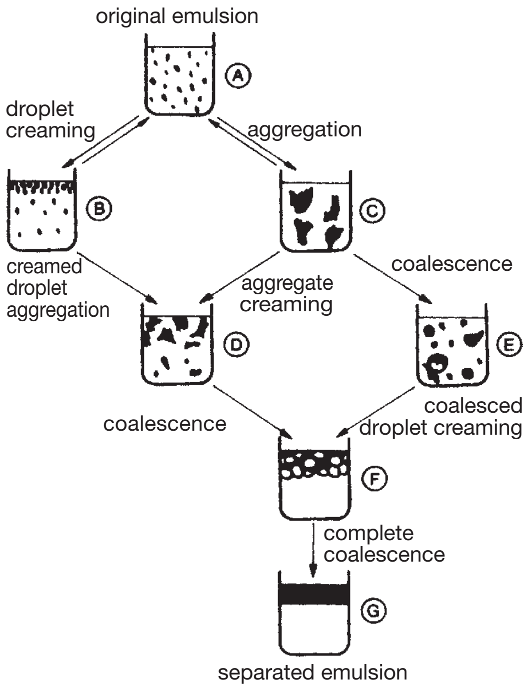


Fig. 1: Development of coalescence.

The rate of sedimentation of aggregated droplets is higher than that of individual droplets, but this applies only to diluted emulsions. Highly viscous emulsions do not settle, as these emulsions are found in any case in sediment or cream (oil and water emulsion) condition. The individual character of the droplets is maintained in the aggregates, disappearing only by oil droplet confluence (coalescence) (Fig. 2). Coalescence also takes place in the sediment or in the cream.

Coalite A product of lignite distillation. Burns, once ignited, without flame or smoke formation by incandescence (→ Thermal value).

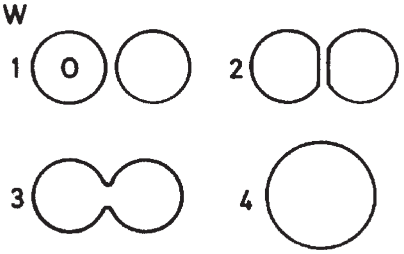


Fig. 2: Individual phases (1–4) of the coalescence of two oil droplets in water.

Coated textiles According to DIN 60 000 and DIN 16 922: fabrics produced with a surface coating on one or both sides (not always a surface coating in the visual sense) with coatings that are homogeneous or cellular in structure (synthetic polymers, natural rubber etc.) e.g. → Artificial leather, Foam laminated textiles.

Coating One- or two-sided application (Fig. 1) of coating compounds or foam films to woven fabric, knit goods, non-woven fabrics or yarns by means of coating machines, rotary screen printing or by means of the spray, hot-melt and transfer coating methods. The coating compounds are formulated on the basis of rubber or film-forming synthetic polymers, with hydrocarbons and water being used as the liquid phase. However, tighter environmental protection conditions demand a move away from products containing solvents. Coating compounds with high solids content can be replaced by powder coating systems. Adhesive lamination of foam foils can be replaced by → Flame Laminating. Coating lends textiles completely new qualities, and thus opens up further application options for them, e.g. artificial leather, rain wear, tent fabrics, tarpaulins, wax cloths, bookbinding fabrics, bag-making goods and technical woven fabrics (see Table). A distinction is made between airtight/watertight coating and water vapour permeable coating. Coating is also used to produce composite materials: →: Bond process; Laminating.

In technological terms, coating can be explained as follows: application of a layer of defined chemicals onto a carrier, so that the carrier's physical qualities or surface are altered as desired. Accordingly, coated textiles are textile carriers that are finished on one or both sides with coating formulations, as long as the textile

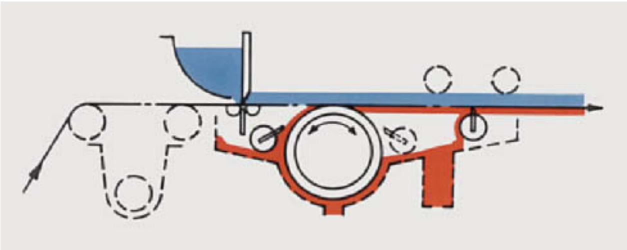


Fig. 1: One-or two-sided coating.

Article	Application method Knife-Air	Knife roller/ table	Knife-rubber blanket	Release paper coating	Hot Melt method	Reverse roll coating	Roll coating with knife	Roll coating with air brush
Fine coating	+			+				
— anorak materials PAN								
— rainwear PES/CO								
— umbrella cloths								
Heavy coating		+	+	+	+	+		
— tarpaulin covers								
— awnings/blinds								
— artificial leather								
— carpet back coating		+						
— sports articles								
Back coatings						+	+	
— pile fabrics for pile fixing and stabilisation								
Paper coating								+
Foam coatings	(+)	+						
— curtain fabrics								
— black-out curtains								
— mattress materials								
— upholstery fabrics								
— carpet back coating								
Extensible substrates				+	+	+		

Tab.: Application methods for coating different articles.

nature is not lost. As a rule, coatings are constructed of several coats (Fig. 2) of different formulations, each of which have to fulfil characteristic tasks.

The first coat serves to create adhesion between the coating and the carrier material. It partially penetrates into the woven fabric, and is thus decisively responsible for the handle and the resistance to further tearing, as well as the initial tearing resistance and stitch tear strength of the future product. The penetration depends on the paste viscosity, the method used, and the substrate. Complete penetration should be avoided in coating, but the coating weight of the base coat should be sufficient to prepare a smooth surface for the subsequent coats, which has as few faults – such as light spots – as possible. For the base coat, as a rule soft, highly viscous pastes are used, which penetrate only up to about one third into the cross section of the textile carrier, in order to avoid stiffening. The cover coat or topcoat is the core of the coating, since it essentially determines the characteristics of the coated material. It absorbs mechanical forces and, like the base coat, is matched to the substrate in terms of strength and elongation strength. The elongation strength of coating films makes a particular contribution to their adhesion, but is also jointly responsible for rubbing resistance and flexural fatigue behaviour. The final coat or finish coat of a coating on the one hand lends the product its surface character, for example through embossing, coloration or the like. On the other hand, it also contributes significantly to the fulfilment of the given requirement profiles, since it is the first to come into contact with other influences such as water, acid or UV light etc., and thus represents the first barrier for hydrolysis, fading etc. The durability of the top coat is often superior to that of the previous coats.

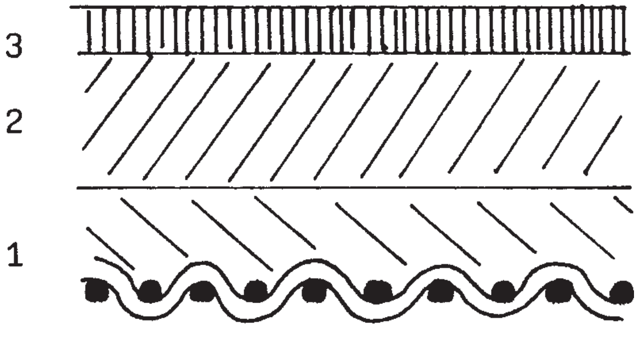


Fig. 2: Construction of a woven fabric coating.
1 = base coat; 2 = cover coat (top coat); 3 = final coat (finish coat).

In some cases, selected topcoats of sufficient hardness and dryness, or after-treatments such as e.g. waterproofing, make it possible to dispense with a finish, thus allowing a simplified procedure. Depending on the paste composition, the process technology and the requirement profile, the coating structure can be varied considerably, although it must always be taken into account that this is a system whose components are matched to one another, and whose tasks are interconnected. Due to the numerous possibilities for variation via the substrate, polymer and technology (Fig. 3), there is a broad range of applications for coated articles, ranging from fashion materials to “high-tech” ones. The technological requirements and the desired durability of the coated products vary widely, depending on the application area. Currently, mainly polyvinyl chloride, polyurethane and polyacrylate which are used, each of which has its own advantages and disadvantages.

The construction of a coating starts with the selection of the appropriate carrier material, which must be suitable for the stresses during processing and for the requirement profile of the end product. Depending on what is required, woven fabric, knit goods and nonwoven fabrics are used. For purely technical applications such as tarpaulins, conveyor belts, containers, tents etc., woven fabrics of polyamide or polyester fibres have proved successful: these are characterised by good strength and durability properties. The Construction and the weight of the woven fabrics are based on the requirements made of the finished product in terms of strength, elongation and wear, as well as on the chemical and mechanical stresses on the grey cloth during pre-treatment and processing. Thus for tent fabrics, for example, linen weave, hopsack weave and satin weave fabrics with a surface weight of 120–200 g/m^2 are the main fabrics under consideration.

The selection of a particular quality is made accord-

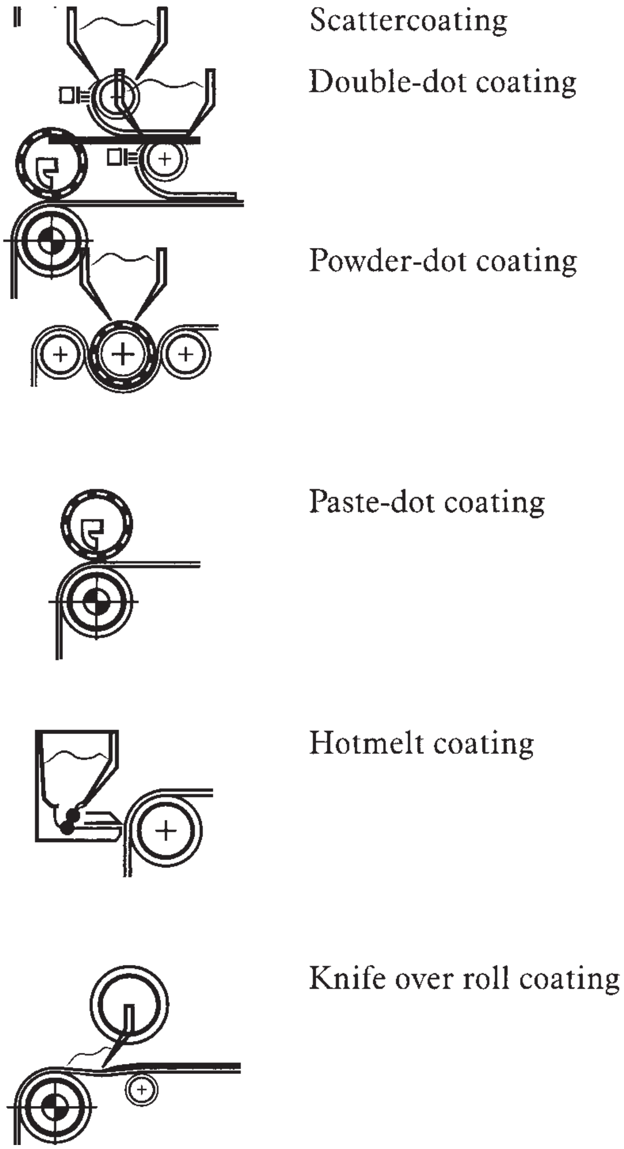


Fig. 3: Coating technologies.

ing to the specifications of the requirement profile, with the coating substrate being the main carrier of the mechanical properties of the finished article. The loom-state woven fabrics are generally subjected to different pre-treatment. These textile finishing processes accordingly serve to

- eliminate weaving faults, knots, impurities, thick yarns, surface fibres and chemicals;
- achieve fashionable effects, such as e.g. ground dyeing;
- ensure the required properties for down-stream processes, e.g. shrink resistance;
- various product parameters such as handle, coating weight, depth of penetration of the coating compound etc.

For all works processes, account must be taken of possible damage to the carrier material, e.g. reduction of mechanical strength, so that the substrate should be subjected not only to an incoming goods check, but also to intermediate checks.

Pre-treatment of the woven fabric can take place in various work cycles:

- singeing,
- treatment with alkali,
- hydrophilic finish,
- hydrophobic finish.

Singeing before coating serves to avoid knife streaks and drop formation through individual fibres that may remain hanging on the knife. A more even, pill-free surface prevents the film density from being reduced by small projecting fibres. The advantages of more even coating results can be lost with irregular fabric surface or uneven singeing that can lead to end colour variations. The 20–30% reduction in weight and the surface structuring of the alkali treatment changes the regain characteristics of polyester woven fabric in such a way that the moisture absorption rises by about 50%. The losses in stability and slip resistance of alkali-treated woven fabrics are disturbing. Hydrophilic treatments also increase the moisture regain capacity, i.e. the wettability of the woven fabric. It is produced by the use of hydrophilic films or surface active compounds, e.g. wetting agents, detergents. Some hydrophilic treatments also take on further functions such as handle, sewability, soiling behaviour or electrostatic charging. The surface characteristics are changed in the opposite way by hydrophobic finishes, i.e. moisture regain, migration and capillary transport drop. The application of silicones or fluorocarbon compounds is frequently used to create the “pearling effect”, and specific combination products achieve additional effects, such as e.g. better dry soiling repellency or oil repellency. The synthetics used in coating are present in solution, dispersed, or as a powder or a melt. In mixing the coating paste, as a rule additives are used which complete or support its characteristics with regard to the requirement profile. Besides the chemical composition, the physical properties of a coating agent, as well as those relating to safety engineering, are decisive in the choice of the system to be used. An important factor is viscosity, which as a technical parameter has a significant effect on the coating and on the flow behaviour of coating agents.

Coating compounds Used for → Coating with:

- starch paste,
- cellulose derivatives (-ethers and -esters),

- natural and synthetic rubber,
- plastics, especially polymethacrylate, polyamide, polybutadiene, polyisobutylene, polyurethane, polyvinylacetate, polyvinylchloride, foamable plastics,
- elastomers for special coatings.

A coating compound based on a polyurethane solution may be prepared as follows: The previously determined colour pigment recipe is stirred directly into the polyurethane solution with a high-speed mixer, dissolver or disperser. Under these conditions a good predispersion can be prepared. Finally the whole paste is ground on a roller mill (Fig. 1). A good, fine distribution of the pigments is obtained on a 3-roller mill. This process has the disadvantage of a substantial solvent loss through evaporation due to the large surface area. 3-roller milling machines are difficult to clean. For these reasons a single-roller pigment mill is often used for the milling of polyurethane coating pastes; the resultant solvent evaporation is reduced and it is easy to clean. The design of the single-roller mill enables it to sieve the paste. The fineness achieved depends on the setting of the roller bar. As heat is generated during the milling process, the roller and hopper must be cooled. If used carefully the single-roller machine yields a satisfactory dispersion. It is particularly suited when certain pigments must be milled several times. This should be taken into account when formulating the recipe. The method is used predominantly for two-component coating compounds. Its main disadvantage is that the whole paste must be milled. For the production of a colour concentrate (Fig. 2), the pigments are dispersed in a 10% binder solution. The predispersion is carried out in the dissolver or disperser and then the final dispersion takes place on a 3-roller machine or suitable alternative dispersion equipment. The dye concentrates must be sufficiently stable in storage and should have no tendency to flocculate. Particular attention must be paid to the precise final appearance and intensity of the shade, otherwise subsequent shading of the polyurethane coating compound is inevitable.

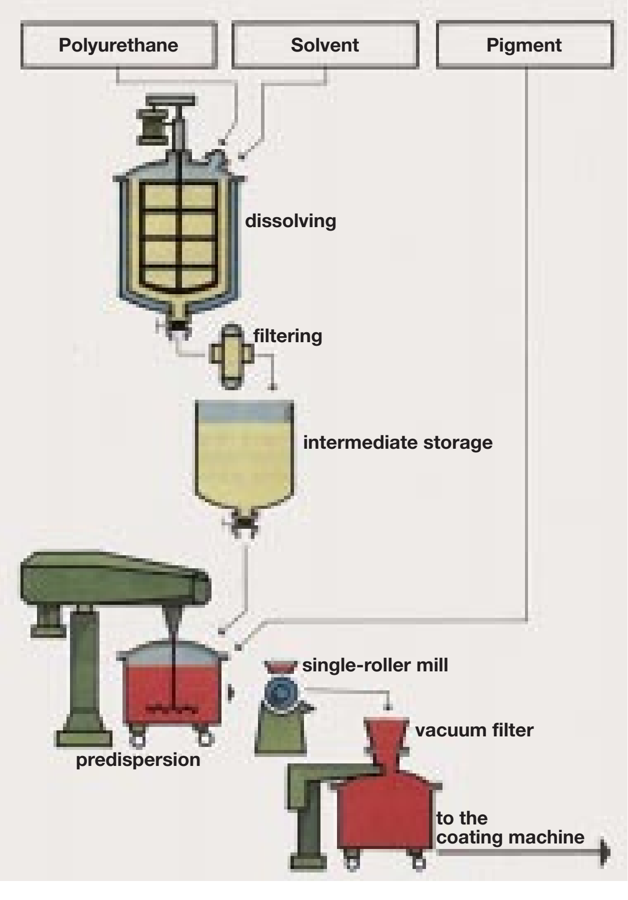


Fig. 1: Dye pigment addition to polyurethane dispersions (source: Bayer).

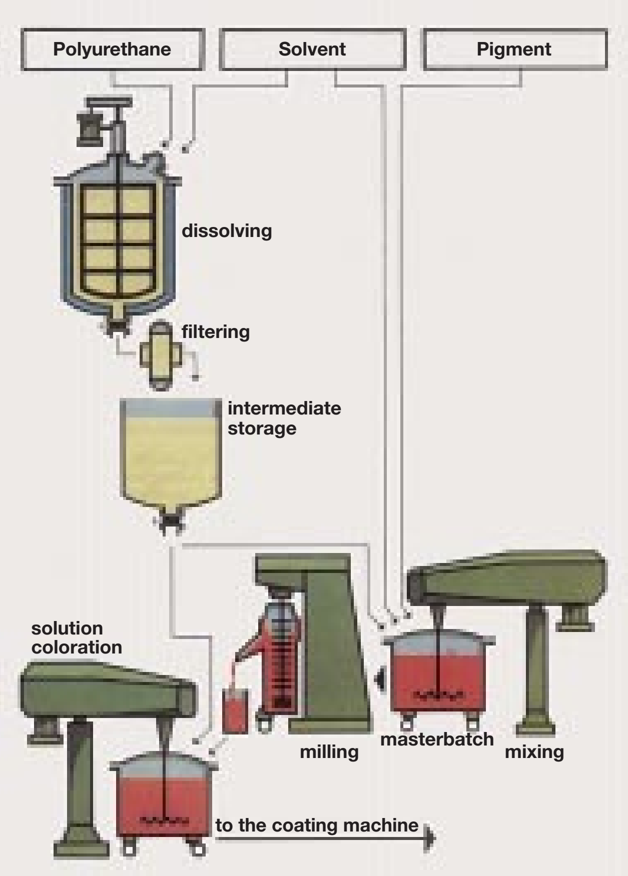


Fig. 2: Addition of colour pigments to polyurethane dispersions by masterbatch (source: Bayer).

Further additives to coating compounds include: plasticizers, fillers (inorganic and organic pigments), colour pigments. Formulations and coating methods vary according to the type of goods and the desired effect, e.g. a single, one-sided coat for down-proof, firm pile, anti-skid, non-slip finishes. For waterproofing effects one or more coats may be necessary, often using coating compounds of varying composition, e.g. a) base coat (soft film formers) for good textile adhesion; b) filling coat (soft film formers and fillers, pigments); c) final coat (harder, tack-free film formers) for surface stability of the coating. In addition to this coating based on solution or dispersion methods, there is also the possibility of film coating using various processes on the calender. → Laminating of similar or different fabrics or combinations is usually carried out using man-made materials. The adhesion properties increase as laminates are added. Fillers have an adverse effect on the adhesion. Coating compounds vary according to the goods and the application: one or more coats on the backing cloth, then (dry laminating) drying or doubling, pressing or (wet laminating) doubling, pressing, drying.

Coating finish Coating with → Coating compounds.

Coating knife Also known as a → Doctor blade; in the form of a steel blade sharpened at the application end, or a rubber blade, which is less precise in its application. Given a constant angle of application, the more pressure applied to the coating knife, the wider is the mass of coating compound before the coating knife, where it changes viscosity before flowing beneath the blade.

Fig. 1: Coating knife type: knife-over-roll.

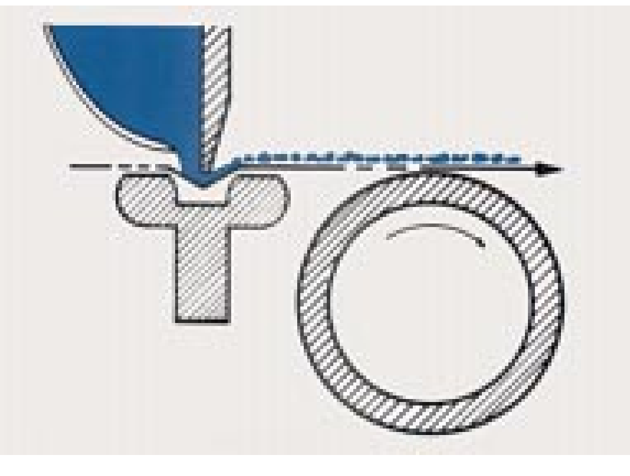


Fig. 2: Coating knife type: knife-over-hollow bed.

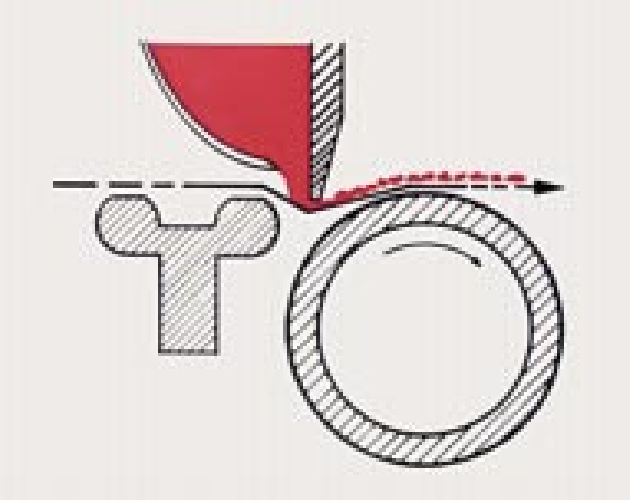


Fig. 3: Coating knife type: knife-over-air.

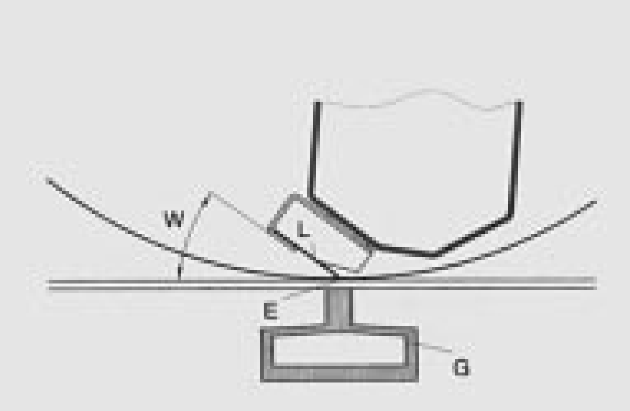


Fig. 4: Structure of the "Isoprint" coating knife system. L = blade; E = point of application; G = counterpressure system; W = blade angle.

A device is often used to supply the bank of compound before the coating head and thus provide control over the wedge of compound formed by the movement of the fabric. (Fig. 1). Different coating effects are given if there is a table underneath the fabric to be coated (Fig. 2), or an air space (Fig. 3). The nature of penetration of compound into the fabric is changed. The use of a rotating screen with control of the knife pressure by means of a magnet system (Fig. 4) ensures extremely precise metering of the paste.

Coating machine (Knife-coat machine). For coating with → Coating compounds. Consists of compound trough, coating head with adjustable height (incl. offset blades the stripping off the excess finish), fabric and guide roll systems (see Fig.). There are various types of doctor blade (→ Knife-coating principle*)*.

Fig.: Coating machine (Mascoe) with the following elements: 1 = individual side adjustment of the coating blade; 2 = vertical height adjustment of the blade; 3 = horizontal adjustment of the blade; 4 = coating table adjustment; 5 = oscillating compound supply system; 6 = display showing horizontal blade settings; 7 = blade holder; 8 = flexible cable.

Coating machine for rotary printing screens For the mechanised application of photoemulsion to rotary screen sleeves. After centring the screen, the emulsion is poured into the squeegee, and squeegeeing is started from top or bottom.

Coating machines Knife coating machines which apply coating compounds as base-, filler- and surface-coatings, at a controlled thickness, on smooth woven and knitted fabrics, usually combined with cylinder or float dryers for curing the synthetic polymers or for evaporating organic solvents (hardening the coatings), possibly for eventual embossing or smoothing (chintz) calendering (Fig. 1).

There are three different versions of squeegee available for the screen process. Two of them can be used for paste coating, the third is also suitable for coating with stable foam. The most simple execution has holes, through which paste is distributed. This type of squeegee is meant for pastes with a straightforward flow behaviour. For pastes that distribute less easily, Stork can offer a patented squeegee system with paste supply through a double slot. This squeegee sees to an optimum distribution of the paste across the entire width of the screen and thus increases the accuracy of delivery and uniformity in width direction. The application volume and penetration can be controlled via the squeegee pressure and squeegee position. The paste or the stable foam, once applied through the screen, can be levelled by an optionally available whisperblade (Fig. 2). When coating with stable foam, the foam will have to be crushed after it has dried. For this Stork offers a crusher as an optional extra.

By using an engraved screen and choosing a coloured printing paste, the CFT can be used for one-colour rotary printing.

A paste or stable foam can be applied to the substrate so as to obtain a layer of glue on interlinings for instance, the glue being distributed in a dot pattern (Fig. 4). For this one uses a screen with a relatively low mesh count. One can choose between a screen with a regular hole pattern or a screen with a random pattern. The latter makes for a more supple grip in case of laminates.

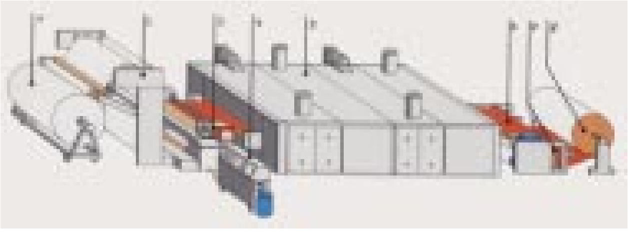


Fig. 1: Coating plant (Stork). 1 = batching-off device; 2 = insert device; 3 = coating unit; 4 = foam generator; 5 = drier; 6 = cooling cylinder; 7 = compensator; 8 = batching device.

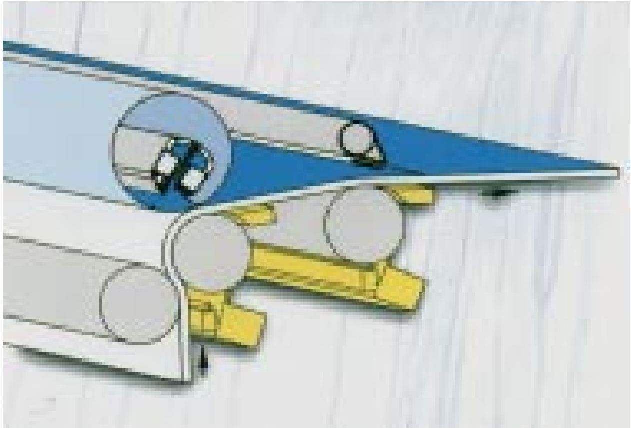


Fig. 2: Paste coating with screen and whisperblade.

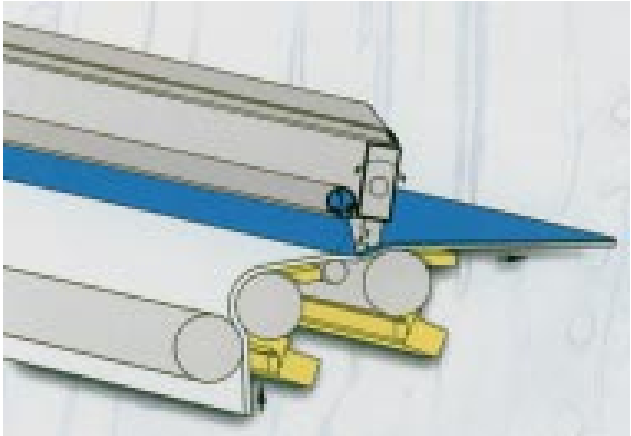


Fig. 3: Paste coating with knife (knife on air).

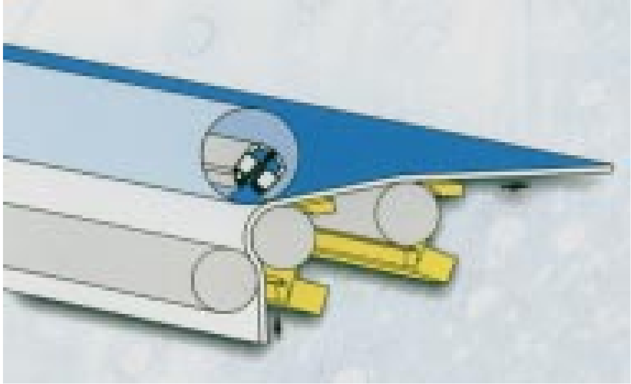


Fig. 4: Paste dot coating with screen.

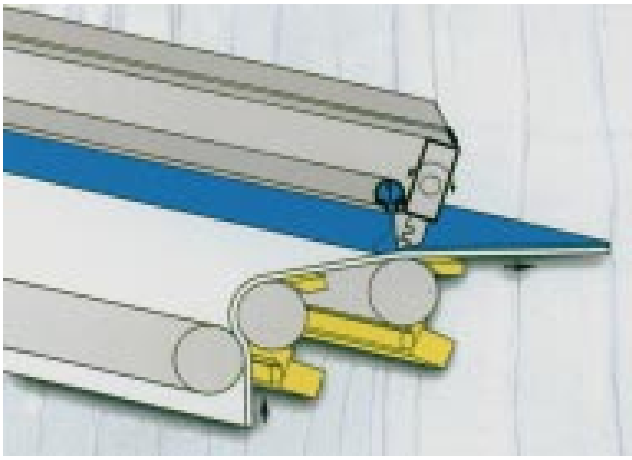


Fig. 5: Paste or stable foam coating with knife (knife over roll).

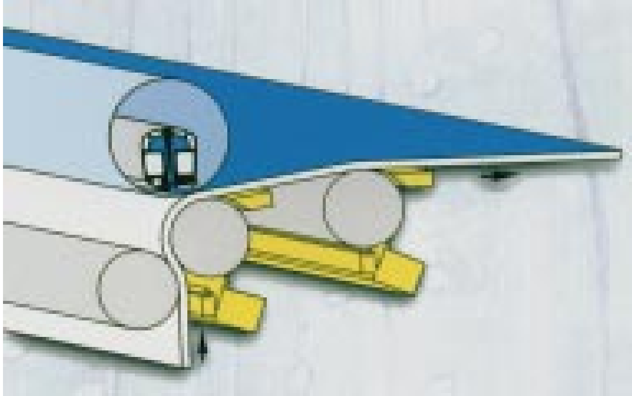


Fig. 6: Foam finishing.

For finishing with unstable foam one uses a special closed sqeegee, in which the foam is contained under pressure until it is applied to the cloth through the screen (Fig. 6). As foam enables an even distribution of the chemicals, very small amounts can be applied. Because of this it is, for instance, possible to impregnate a substrate on one side or to realise complete penetration. With one-sided applications this may yield large savings on chemicals. Furthermore, the use of foam enables the application of only a limited amount of moisture, allowing a much higher production speed with an existing drying capacity. These techniques are also referred to as low add-on or MA techniques.

Knife over roll coating (Fig. 5) is mainly done when higher add-ons are desired. An air knife (Fig. 3) is used for fabrics that need to combine a closed surface with a minimum coating weight. Also for the knife coater Stork developed a special distribution system for paste or stable foam, this system being based on the concept of the time-tested and patented extrusion squeegee that guarantees a balanced supply across the full width of the knife. The standard knife coater version has a digital height adjusting facility and is suitable for knife on air and knife on roll coating techniques. In addition to the standard version there is a heavy duty version for large widths; this latter version has been specifically designed for the coater that sets very high requirements and mainly uses knife applications. With this heavy duty version all settings can be motorised and read from a digital display. Separate arrangement of the screen unit and the heavy duty version of the knife coater is possible as well.

Coating of carpet backs → Carpet back coating.

Coating of yarns Woven fabrics made of coated yarns have characteristics different from those of coated woven fabrics, i.e. a more open structure. Thermoplastic and thermosetting polymers in solid or liquid form are used. For example, the yarn is encased by a film strip of such products and fused with it or stuck to it.

Coating polymers The synthetic polymer dispersions and solutions used in the textile industry are manufactured on the basis of urethanes, acrylic esters, vinyl chlorides, vinyl ethers, vinyl esters, isobutyls, isoprenes, styrols and butadienes. Natural latex is the only natural product in this range. The chemical and physical properties of the dispersions are varied and a suitable choice must be made according to the application area. The following are relevant to processing: chemical reaction mechanisms, particle size, stability, coating properties, viscosity and the pigment binding properties of the dispersions. The minimum film formation temperatures, hardness and elasticity of the films, as well as their resistance to water and to organic solvents, must not be ignored. Inadequate ageing stability and possible unwanted smells from the dispersions when applied to textiles are important and are often the source of customer complaints.

In the base coating of tufted carpets, the following requirements are made of dispersions:

- A high pigment binding capacity is absolutely necessary for price reasons.
- The applied film must demonstrate sufficient elasticity with corresponding hardness, and must have good adhesion to the fabric. It is responsible for the handle, the erect positioning of the pile and the quality of the pile anchoring.

- Unwanted smells and poor ageing stability can make the product unsaleable.
- The water resistance must be good, whilst resistance to organic solvents is not necessarily required.
- The coating properties and stability of the dispersions must be ensured in processing.

The viscosity of the synthetic polymer is important but even with high solids products it is normal to additionally use thickeners. Taking these factors into account, natural latex, butadiene-styrol and butadiene-acrylic copolymers, as well as their derivatives, have been successfully introduced as synthetic latexes in the back coating of tufted carpets. As regards the question of whether one should use dispersions or solutions, the decision has been clearly for dispersions. → Dispersions in coating have a low viscosity with a high solids content of approx. 50–60%, whereas solutions have high viscosity with a relatively low solids content. The problem of solvent costs, recovery with an average loss of 5%, and special working arrangements to avoid explosions when handling solvents, have led to more widespread use of dispersions. Dispersion films have the disadvantage, however, of a certain water solubility, due to the emulsifiers that remain in the film on drying.

Coating polymers on technical textiles Technical textiles are coated on a large scale with the goal of obtaining waterproof and strengthened textiles. Applications among other things are technical tarpaulins for buildings and vehicles as well as tents, conveyor belts and home textiles. Despite the outstanding price-performance ratios of PVC-coatings on technical textiles there is increasing interest in alternatives which do not contain chlorine, because of their ecological acceptance. PVC is being discussed, because it is suspected, that the monomeric vinylchloride is carcinogenic and there are problems with the recycling process due to the chlorine. Hydrogen chloride is released and the building of dioxine is possible under unfavourable conditions. Chlorine-free coatings, for instance polyacrylates and polyurethanes, have already been successfully applied in some special fields. However, the new replacement coatings with equivalent properties to those of PVC, have not been able to achieve the economic efficiency of PVC-plastisoles. The properties of PVC-plastisoles have only been reached, after the addition of additives, such as coupling agents, softening agents and anti-agers. These products are able to diffuse out of the coatings and they are partly toxic. The advantages and disadvantages of PVC-, PUR- and acrylate-binders are outlined in the Table.

Coating preparations → Coating compounds.

Coating substrates Textiles in piece or sheet form, nonwovens, film, felts, paper, etc. that are coated.

Coating technology The coating of textile substrates is divided into the following processes:

1. Application: Transfer of a liquid, highly viscous,

binders	*Advantages*	*Disadvantages*
PVC-plastisole	• good price-performance ratios • simple processing • broad application • non-ageing • weldable	• problems by the recycling process (it is not possible to completely seperate the coatings from the support) • danger of dioxine formation by uncontrolled burning • formation of hydrogen chloride during thermal disposal • good properties obtained only after the addition of additives (coupling agents, softening agents, anti-agers)
polyurethane-dispersions	• high extension at break and elasticity • good wear properties of clothes • good abrasion resistance • high flexibility at low temperatures (without softening agents) • low specific weight • wash and try cleaning resistance	• high price • possibility of recycling is restricted • disposal through burning • defects in the waterproofness
polyacrylate-dispersions	• good weatherability • good light fastness • resistent to bacteria and moulds	• high price • tendency towards stickiness • disposal through burning • defects in the waterproofness

Tab.: Advantages and disadvantages of already used binders.

molten or powder compound made of synthetic polymers onto a substrate.
2. Film formation: Solidifying of the synthetic polymer coating to form a closed film, with a certain durability to form a composite with the substrate.

Accordingly, coating plants subdivide into the following components:

- unrolling device, with suitable width control,
- application device,
- drying or gel formation oven,
- fabric take-up device, possibly with fabric cooling.

As a rule, coating plants are run continuously. However, depending on the application process, batch processes may be used e.g. in the coating of leather. The most diverse systems are to be found among the application devices and drying tunnels and gelling ovens; these differ in their suitability for certain products. The choice of system is guided by

- the application form of the synthetic polymer and its property, e.g. viscosity,
- the amount applied,
- the type of substrate,
- the required tolerances and uniformity of the product.

The most frequently used method is coating by means of knife blade coating. The coating compound can be applied directly onto the substrate (direct coating) or by means of an intermediate transfer sheet (transfer coating or transfer process). As transfer sheets, release papers are used almost exclusively, although occasionally steel bands or metal drums are still found. The decision to work using the direct coating method or the transfer method depends on the requirements of the article to be produced. Thus for example most knit goods and other elastic materials can only be coated using the transfer process, since the tensile stress acting on the substrate in direct coating is too high for these textiles. Preferably, transfer coating is used for open weaves, in order to apply a continuous film. Coating weights of 40–250 g/m^2 can be realised, whereas direct coating ranges from 10 g (finest coating) to 500 g (technical articles).

Besides the classic knife application methods, there are also numerous other methods:

1. Flow coating process: dosed pouring on of the coating paste, with no contact between the carrier and the applicator taking place; for this reason, very thin, even layers are possible, independent of the irregularities of the substrate.
2. Impregnation or dipping method: The carrier material is led through an immersion trough which holds the liquid coating compound.
3. Slop-padding process, roll coating: The carrier material takes on the coating compound from a roller that turns through a bath (direct roll coating). This can also take place via roller systems. Dosing is by wiping off the slop-pad roller or the coated goods. If the paste reservoir is located in the angle between two rollers, this is termed the roll coating method (reverse roll coater).
4. Calender application or hot melt method: With this method, granules and powders are melted between two rollers or prepared viscous plastic compounds are used, which are plasticised by the heat of the rollers. Between the calender rollers, which can be arranged in various ways, films form which can be transferred to the goods via the rollers.
5. Powder application method: Here, powder thermoplastic synthetic polymers are scattered and formed into adhesive melts. This coating technique can be subdivided into two groups: the dry method and the wet method, which are used particularly for interlining fabrics for clothes.

In addition, there are other coating techniques, which derive from combinations of known principles. These include for example the Accugravure method, which combines the working method of rotogravure printing with the technique of the reverse roll coater; or the Stork plant (Fig. 1), which has been developed from screen printing technology and is also known as rotary screen coating.

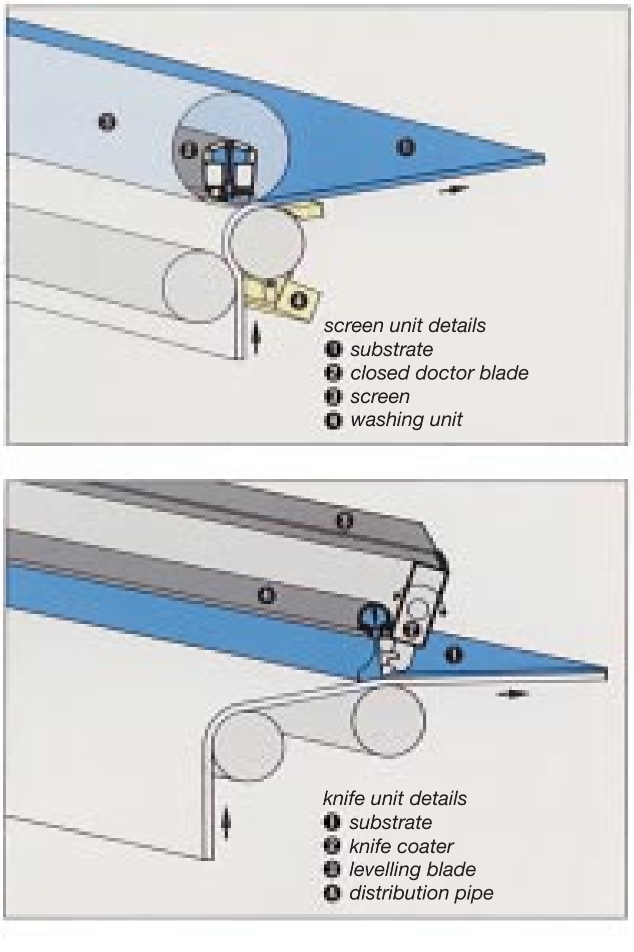


Fig. 1: Stork MCC-V combined coater unit with doctor knife or screen coating.

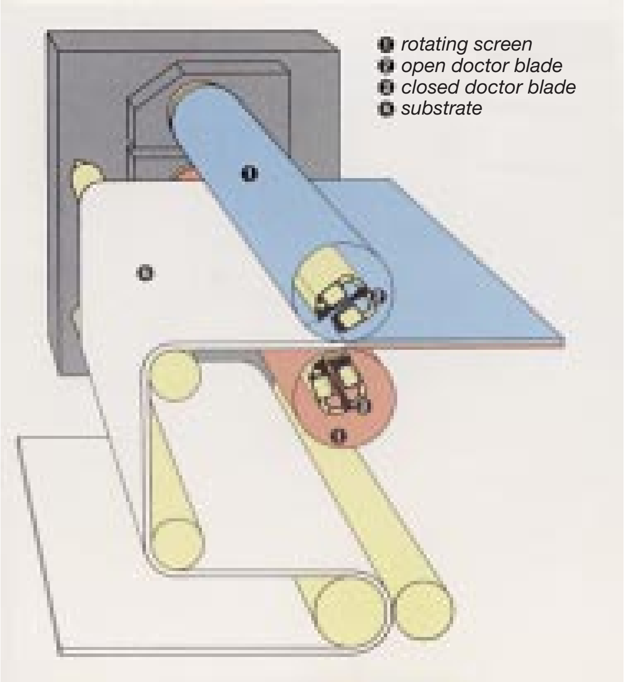


Fig. 2: Duplex coating (Stork).

The simultaneous coating of both sides of the fabric using the duplex method may also be of interest (Fig. 2).

It is a simple transition from these processes to related processes such as painting, where it is a case of straightforward surface treatment or laminating. In the case of laminating, in one working cycle the film can be formed and the lamination of the film – which is usually still viscous – on the substrate can be carried out, so that it can be counted among the coating methods. If however complete synthetic films are to be subsequently combined with the carrier, then in the stricter sense this is to be distinguished from coating, since a planar connection of two runs of material takes place. Tandem plants permit the application of two coatings one after another. These coatings can also be dried in-between stages or pass through a short gelling stage. In order to guarantee a diversity of articles, those carrying out the coating must have access to various coating technologies

Cobalt (Co). Reddish white, lustrous metal, very hard, resistant to atmospheric influences, can be polished and magnetised, atomic weight 59; density 8.5; melt point 1478°C. Slowly soluble by diluted mineral acids, more quickly by nitric acid to cobalt (II) salts. Cobalt (III) in particular tends to form numerous complex compounds. Use: cobalt salts = dye mordants, colour production, analytical chemistry, hygrometers.

Cobalt salts Qualify as carcinogenic working materials in difficult-to-dissolve form as breatheable dusts.

COBOL, abbrev. for: common business-oriented language. Term used in electronic data processing.

Cobweb finish A synthetic pilling effect achieved on → Stitch-bonded fabrics for coat linings through raising, steaming and subsequent tumble drying.

Co-carcinogen Possible cancer-inducing substance that activates potential → Carcinogens in such a way as to form a cancer that would not occur without co-carcinogens, or if just co-carcinogens were present. Co-carcinogens are therefore hazardous to humans if they affect human tissue that has been exposed to carcinogens (even years beforehand) even below the threshold dose levels.

Cochineal A fiery red → Natural dyes (mordant dye) consisting of the dried bodies of the female insects of Coccus cacti, another species of the shield-louse family, largely cultivated in Mexico. 1 kg of dye = approx. 140 000 insects. The colouring principle is carminic acid, $C_{22}H_{20}O_{13}$ (an anthraquinone derivative). It is tinctorially 11 times stronger than → Kermes which it quickly replaced. It was formerly much used on a tin mordant for the scarlet or "grain" dyeing of wool and silk and was also used to dye Morocco leather and, later, cotton. Its use as a textile dye declined due to the fact that it could no longer compete with acid scarlets such as synthetic ponceau. It is still used as a food colorant.

Cochineal reaction For demonstrating the presence of oxycellulose. Place the specimen in lead acetate solution, subsequently stain with → Cochineal. Oxycellulose takes up lead oxide, traces of which turn cochineal from red to magenta. The depth of colour corresponds to the degree of damage.

Cocoon A sort of yarn ball silkworm housing, which is spun from the protein thread of → Silk.

COD, abbrev. for: → Chemical oxygen demand.

COD in g/kg fabric → Pollution index.

Coefficient of variation (Factor of variation, v). In → Statistical analysis, the characteristic value of variation (property or measured value) as the ratio of a standard deviation s to the mean $\bar{x}$:

$$v = \frac{s}{\bar{x}} \cdot 100\,\%$$

Co-enzymes/ferments Particularly occur among → Desmolases as a so-called prosthetic group and are enzymes that are catalytically almost ineffective. These are relatively low-molecular, non-protein-like, heat-resistant, dyalizable substances such as organic phosphoric acid esters. However, co-enzymes are activated if they occur together with enzymes or ferments that often contain heavy metals (complex catalysts) as colloid carriers of proteins that are always highly complex. This kind of total ferment is called a holo-enzyme or holo-ferment.

COFREET, abbrev. for: Comité Française de l'Etiquetage pour l'Entretien des Textiles (French

Committee for Textile Care-Labelling), Paris; → Technical and professional organizations.

Cohesion (Lat.: cohaere = cohere). Based on the reciprocal attraction of chemically related molecules, which is brought about by the complex combination of the secondary valence forces (intermolecular interactions) like hydrogen bridge bonds, van der Waal forces and dipole interactions. Cohesion energy (in J) from the combined values of each chain atom (increments), which produce the following typical values (melting or decomposition point in brackets), is regarded as a measure of the secondary valence forces:

polyethylene (130°C)	1300
polyvinyl chloride (180°C)	2500
polyvinylidene chloride (180–220°C)	3500
polyvinyl alcohol (140°C)	5100
polyamide 6 (264°C)	3400
polyester (250°C)	1900
polytetrafluoroethylene (400°C)	1600

Polyester and polytetrafluoroethylene do not fit into this series. Other factors besides cohesion energy have a part to play here. In the case of polyester, the stiffening of the molecule chains associated with the incorporation of benzol rings (π-π-interactions) appears to offer an explanation, which also manifests itself with other similarly natured polymers. We see however that high cohesion energy and stiffness actually mean a high melt point. → Adhesion.

Coir fibres Coconut palm fruit fibres classed in the → Hard fibre group. Obtained from the husk of the coconut by retting, squeezing, hackling and cleaning (possibly bleaching too). Strength 12–15 cN/tex, elongation 25–30%. The fibre is lighter than water (density 0.945 g/cm^3), and has a high degree of abrasion resistance and rot-fastness, and picks up little dirt. Use: for runners, mats (possibly together with wool), carpets, drive belts, ropes, upholstery purposes, brushes etc.

Coir matting Matting woven from coconut fibre.

Cold batch process Another name for → Cold pad batch process, especially for reactive dyestuffs.

Cold dwell process This name is frequently used for the plaiting down and storing of impregnated fabric when not batched. → Cold pad batch process.

Cold dwell unit (Cold pad batch unit). For storing impregnated fabric, mainly for short-period continuous hypochlorite bleaching between scouring and peroxide bleaching processes. Short-time and combined steamers and also pad roll batching trucks are used as upstream and downstream units. The quantity of caustic soda or peroxide can be reduced by up to 50% (reduced catalytic damage) with a cold dwell unit. Despite this, better husk decomposition, better bleaching out of knops, smoother fabric appearance and a degree of whiteness up to full white can be achieved.

Cold dyeing dyes According to the → IK dyeing method, cold dyeing vat dyestuffs. There are also highly reactive cold dyeing dyes under reactive dyestuffs.

Cold dyestuffs or dyeings → Infrared-reflecting dyeings.

Cold latex (Cold rubber, cold caoutchouc), American name (now international) for Buna-S types in the cold polymerisation manufacturing process (starts at 5ºC with redox activation) for butadiene/styrene (e.g. 70 : 30). This kind of cold latex is considerably better than Buna-S (with regard to oxidation resistance, tensile strength, friction wear) and is particularly suitable for coating (excluding car tyres). Opposite: hot latex.

Cold pad batch bleach Peroxide bleaching process characterised by a high concentration of hydrogen peroxide (> 40 ml/l) and a long reaction time (24 h). Under these conditions, bath stabilisation is particularly important, and silicates, phosphates or organic stabilisers can be used for this purpose. Hot washing off with the addition of alkaline surfactants must be implemented in order to obtain absorbent fabric. Dwell time can be reduced (to 4–6 h) if a 1 minute steaming process follows storage. → Peroxide-padder-dwell process.

Cold pad batch dyeing,

I. For polyamide tufted carpet dyeing: dyeing with monofunctional acid dyes with similar combination code. Adequate liquor quantity, 180–250% necessary. Complete immersion is to be avoided, therefore pour on dye liquor. Batch must be rotated at 3–10 rpm. Dwell time is 16–24 hours.

II. → Cold pad batch process on rotating batches for reactive dyes.

Cold pad batch dyeing with reactive dyes (Hoechst). Principle: dye and alkali solution are prepared separately, and reach the padder trough only after passing through a mixer. Impregnated fabric dwells a few hours batched in open width, during which the dye is fixated. The so-called CPB pump is used as a metering, conveyance and mixing unit.

Cold pad batch printing process for wool → IWS cold-dwell print process for wool.

Cold pad batch process Process in which textile material is impregnated (padded) and usually rolled up (batched), whereupon the finishing agent that has been applied to the material is given time at room temperature (approx. 15–25°C) to be absorbed or react. Textile material is generally left to dwell for 3–48 hours. Cold pad batch processes have proved their worth in finishing textiles of various compositions and various presentations, and are gaining in importance due to the savings on energy. They run semi-continuously. Principally two types are distinguished:

1. Short processes with setting times of 2–6 hours.
2. Long processes with setting times of greater than 20 hours.

In reactive dyeing, there is a relationship between hydrolysis stability of the pad liquor on the one hand and the minimum fixation time on the other hand:

Liquor stability	Minimum fixation time
5–20 min.	2–4 h
20–40 min.	4–8 h
40–90 min.	8–20 h
90–180 min.	> 20 h

In short processes, in order to achieve sufficient reactivity the alkali addition must be so strong that within minutes more than 10% of the dye hydrolyses, and is thus lost for the purposes of dyeing. The use of a dosing pump is unavoidable in this case. Fixation times greater than 20 hours enable recycling of the alkali and thus a stabilisation of the padding liquor at 2 hours and above. In other words, if no dosing pump is available, only cold pad batch processes with longer setting times (> 16 hours) can be carried out. However, these remarks apply mainly for moderate climate zones (e.g. central Europe). In hot countries, e.g. in Asia where water and air temperatures are clearly higher, other relationships apply. Here, cold pad batch processes are considerably more difficult to carry out with a good level of shade duplication.

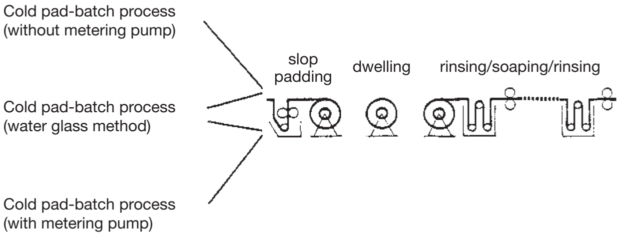


Fig. 1: Reactive dye cold pad batch setting (machine unit) on cotton fabric.

The general view is that only reactive dyes with high reactivity should be used for cold pad batch processes, e.g. in the short cold pad batch process (Fig. 1). A considerable advantage of this method is that only sodium carbonate is used as alkali, and the unwanted white or light edges, which frequently occur with the usual sodium hydroxide activation, are usually avoided. There are however problem cases where the long process represents the better solution:

- dyeing mercerised material,
- dyeing regenerated cellulose,
- seam impressions (e.g. towelling),
- heavy, closely-woven fabric,
- dyeing of raw goods.

In all these cases, reactive dyes, which require large amounts of alkali and long reaction times (24 hours), are preferred. An example of the long cold pad batch process is the combination of cold pad batch process plus exhaust method on piece-dyeing beam or jet for knit goods of cotton/polyester or cotton/polyamide (Fig. 2).

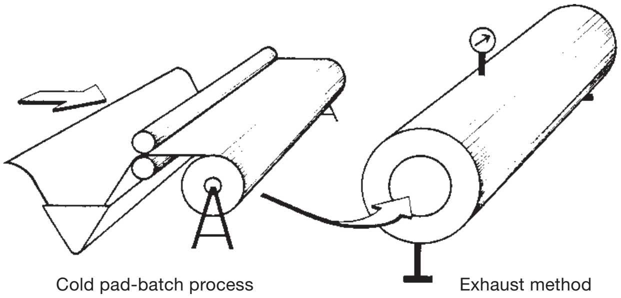


Fig. 2: Dyeing of cotton/polyester blended goods. Cold pad batch process: reactive dyeing of the cotton; exhaust method: beam dyeing of the polyester portion.

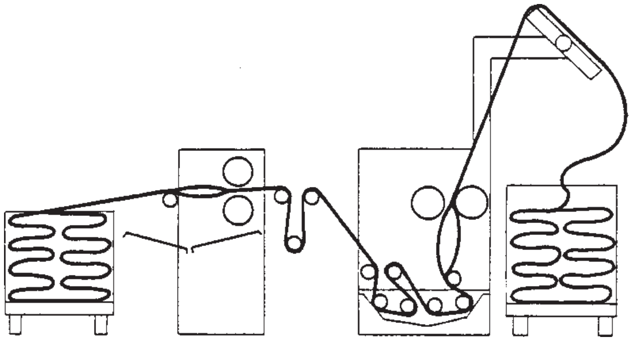


Fig. 3: Cold pad batch process for knit goods.

First of all the grey cloth is dyed with the reactive dyes in a roll batch system, and subsequently the synthetic fibre portion is dyed by exhaust method on a beam-dyeing machine (Fig. 2) or a jet dyeing machine (Fig. 4) (reverse process). Here it is apparent that reactive dyes, which require large amounts of caustic for fixation, are at a clear advantage in the dyeing of grey cloth. The impurities found on the fibre, which are to some extent dyed, are more easily and more completely removed during intermediate rinsing. This results in a considerably higher level of fastness.

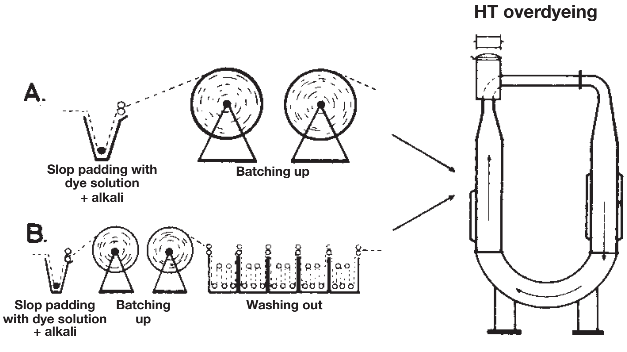


Fig. 4: Machine diagram of the cold pad batch dyeing/jet method.

When the cold pad batch process is used for circular knit goods with the roll or plaiting-down system (Fig. 3), the main problem lies in setting bowing-creases, which must no longer be visible after dyeing. Although this problem has not been satisfactorily solved for all qualities, level dyeing can be achieved by delaying the fixation or through the use of slow-reacting reactive dyes. Since the dye does not fix within a few minutes, but can migrate over the course of several hours, the chance of tone-in-tone dyeing on the "bow" is considerably greater. Advantages of the method:

- low cost for machinery,
- simple process,
- rapid colour changes,
- good dye penetration,
- high degree of levelness,
- low energy requirement.

Disadvantages:

- Relatively large metreages are dyed, and it is only after some hours, and frequently only the next day, that one can establish whether the shade is correct and that no dyeing faults have occurred. No shading corrections are possible, and correcting off-shade results or unlevel dyeings is difficult.
- Poor shade reproducibility between laboratory and dyehouse. Laboratory fixation takes a great deal of time.
- Shade reproducibility is poor with fluctuating temperatures, both of the pad bath as well as in the batch storage.
- In the case of large fabric batches, the inner layers of a batch have far greater temperature stability than the outer layers and this also leads to unlevel results.
- Other faults such as white edges, tailing, centre to edge variations are common and lead to considerable process loses.
- Where larger amounts of material are put through the works, handling the cloth batches is awkward, time-consuming and labour-intensive: cutting off, transporting, developing, transporting, sewing on, washing etc.

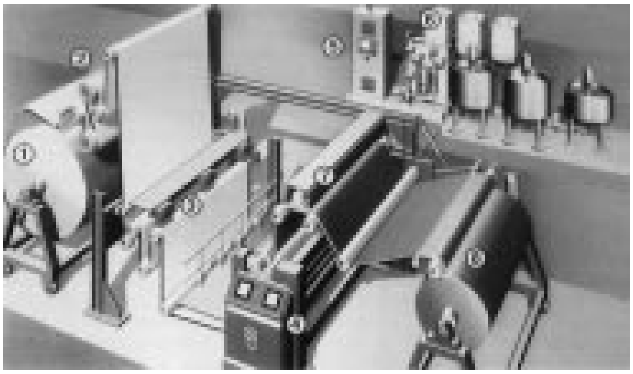


Fig. 6: With the cold pad-batch dyeing centre small lots can be economically dyed, too.
1 = low-tension batch unwinder; 2 = cooling zone;
3 = moisture measurement; 4 = "flexhaft" padder;
5 = central PC control; 6 = "Contidos SF" with colour preparation station; 7 = colour depth measurement;
8 = low-tension batcher.

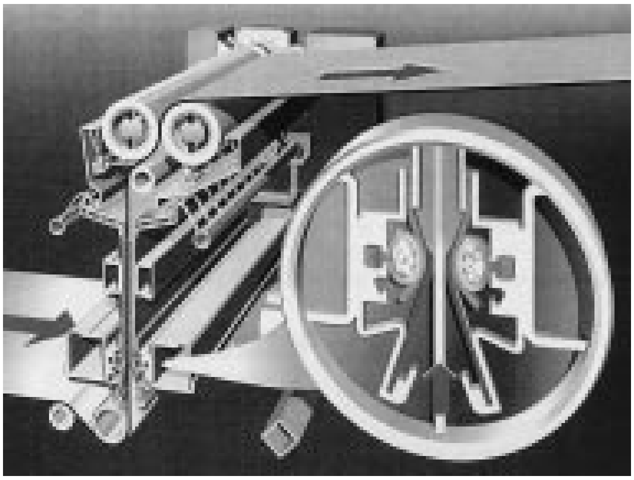


Fig. 5: Dye padder with "flexshaft" liquor application.

More modern versions of cold pad-batch dyeing are developed by Küsters (Figs. 5 and 6).

Cold peroxide bleaching The process is subdivided into application of the bleaching liquor, reaction phase, and extraction phase. Besides the term cold peroxide bleaching, in practice the expression extraction bleaching is also frequently used. This designation is used in the case of recipes free of sodium silicate, and with a high alkali content. The term is misleading, since during the bleaching process, in which 1000–5000 metres of impregnated fabric is wound up on a roller, extraction definitely does not take place, but only in the subsequent washing process.

Constituents of a cold peroxide bleach recipe, e.g.:

a) Essential ingredients:
  - magnesium ions ($MgSO_4 \cdot 7H_2O$),
  - activator (NaOH),
  - pH buffer system (sodium silicate),
  - stabiliser,
  - oxidant (H_2O_2);

b) useful supplements:
  - surfactants,
  - auxiliaries with an affinity for dyes (only for colour-woven goods),
  - persulphates (to improve de-sizing),
  - optical brightening agents (for full white effects).

Advantages: due to the low temperature of 20–40°C, the natural waxes of the cotton are not removed, or only to a small extent. For many articles, especially in the case of towelling qualities and knit goods, this yields an excellent soft handle, which allows a reduction in applied softeners. Emulsification of fats within the framework of cold bleaching is in principle only possible if the fats are present in liquid form on the goods. If they are paraffin waxes that are solid at the stated temperatures, de-greasing does not take place until the washing process, with the effect achieved being dependent to a high degree on the duration and the concentration of the chemicals. The large amounts of electrolyte which are necessary in the cold bleach recipes (caustic soda, sodium silicate and persulphate) prevent emulsion formation so strongly that large amounts of surfactant are necessary in order to achieve satisfactory de-greasing results. The risk of catalytic damage, which is ever present with peroxide bleaching processes, can be reduced to a minimum by adjusting the recipe accordingly. Compared with all other processes, significantly lower investment is required for cold peroxide bleaching processes.

Disadvantages: insufficient degrees of whiteness, even when large amounts of peroxide are used; poor absorbency; insufficient removal of sizes; poor shade r, especially in the case of commission finishers with varying raw material; high space requirement; silicate deposits on the machines when silicate is used.

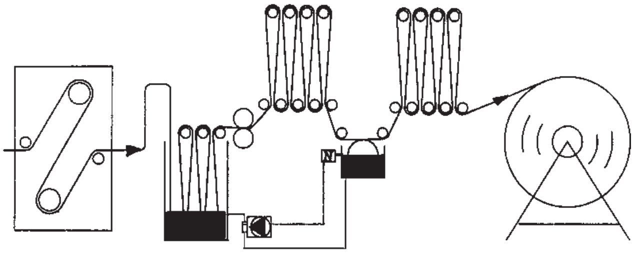


Fig.: Schematic illustration of an impregnation unit for grey cloth, consisting of a singeing machine, a small roller vat with 4–6 metres draft and low liquor content, 2 passages air run for wetting the goods and – located in between – a slop-pad mechanism to increase the liquor uptake (N = level regulator).

It is understandable that a very gentle bleaching process (see Fig.) with a maximum of operational safety in respect of the avoidance of catalytic damage cannot achieve a maximum degree of whiteness, since all the reserves which a bleaching process with hydrogen peroxide can offer are deliberately not exhausted. The majority of cold peroxide bleaching liquors are applied immediately after the singeing machine, wet-on-dry, on a multi-dip range holding 20–30 metres of fabric. Such impregnation systems often hold 1500–2000 litres, which results in an uncontrolled accumulation of sizing agent, alkaline earth- and heavy metal ions taking place in the impregnation liquors. The time taken to come to an equilibrium is determined by the production rate in kg per hour and the volume of the impregnation bath, and can be as much as several hours. The accumulation of size has various effects on the bleaching process. First of all, the viscosity of the bleaching liquor is raised so that the liquor cannot fully penetrate the fibre. The consequence of that is a low liquor pick-up of only 50–65%. Since in the case of wet-on-dry processes, a great deal of air is imported into the treatment baths, the liquors begin to foam (even when low-foaming surfactants are used), which leads to loss of liquor through overflow, and thus to a further reduction in the chemical application.

In the impregnating compartments, the accumulation of alkaline earths leads – depending on the cotton quality – to values of 25–110°d. In the reaction phase, the cold bleaching fabric beams are wrapped in plastic sheets in order to avoid surface evaporation. Single shift production at 40 metres per minute and 4000 metres per fabric beam, then one work will use at least 16 000 metres of plastic sheet per year, all of which ends up as waste. If on the other hand the fabric beams are stored in a specially prepared area with a low ceiling height and humidity control, then a direct saving can be made.

For storage the fabric beams must stand absolutely horizontal, so that the liquor is unevenly distributed and edge/middle/edge differences do not arise. Each fabric beam should be kept in rotation by its own drive. In many works 4 or more fabric rolls are placed so close together that they keep one another moving. The friction and rubbing that occurs in the transmission of the mechanical energy leads to loss of liquor in the outer layers, and thus to differences in the degree of whiteness between the beginning and end of batches.

Cold-stirred soap Soap which is produced by saponifying molten fats (mainly coconut or palm oil) by mixing with cold concentrated caustic potash lye. The heat released by the exothermic lye solution is used for completing saponification.

Cold system optical brightener Optical brightener with an optimum white effect at scouring temperatures up to 60°C. → Hot system optical brightener.

Cold unit Dry cleaning machine so called in the USA (so called WD type = washer-dryer) with a centrifuging operation but with no hot air drying (therefore “cold machine”). Fabric is merely cleaned and centrifuged. Drying is effected separately, mostly in a recovery tumbler which can also be directly incorporated. This processing method is widespread in the USA because cleaning capacity can be utilised most economically with it.

Collagen The union of a number of amino acids leads via peptide bonding to polypeptides like collagen for example.

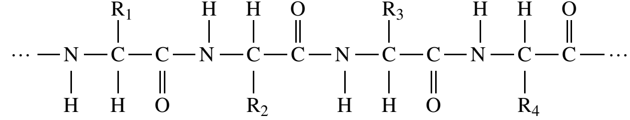
Collagen is mainly a supportive and protective element in the skin of a living animal. Chemically, it is classed as a protein, i.e. it should be regarded as a conglomerated polymer of amino acids with a colloidal

Collagen

Peptide bond:

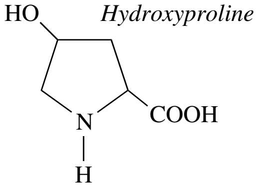
—NH—CO—

Polypeptide:



$$\cdots-NH-CHR_1-CO-NH-CHR_2-CO-NH-CHR_3-CO-NH-CHR_4-CO-\cdots$$

nature. Of the 19 different amino acids of collagen, 3-hydroxyproline is typical of this.



Amino acid composition of an untreated collagen (mol per 100 mol of amino acids) according to K. Kühn:

aspartic acid	4.65
isoleucine	1.41
glutamic acid	7.68
leucine	2.66
glycine	33.10
phenylalanine	1.26
alanine	10.56
proline	13.18
serine	3.18
hydroxyproline	8.96
threonine	1.79
histidine	0.58
tyrosine	0.39
lysine	2.84
valine	2.08
hydroxylysine	0.60
methionine	0.31
arginine	4.82

The most repeating amino acids glycine, proline and hydroxyproline represent a sequence within the polypeptide. Formation of the polypeptide chain by principal valency bonds characterises the primary structure. Some 1000 amino acids are combined in the form of an α-helix in the collagen peptide chain (Fig. 1)(sec. structure).

The α-helix structure is additionally characterised by 3.6 amino acid radicals per turn, 0.54 nm lead, 1.05 nm total diameter and stabilisation by hydrogen bonds between the O and N atoms of the peptide bonds. The tertiary structure represents the stabilisation of the spatially compact arrangement due to interactions between the side chains of the amino acid radicals (Fig. 2).

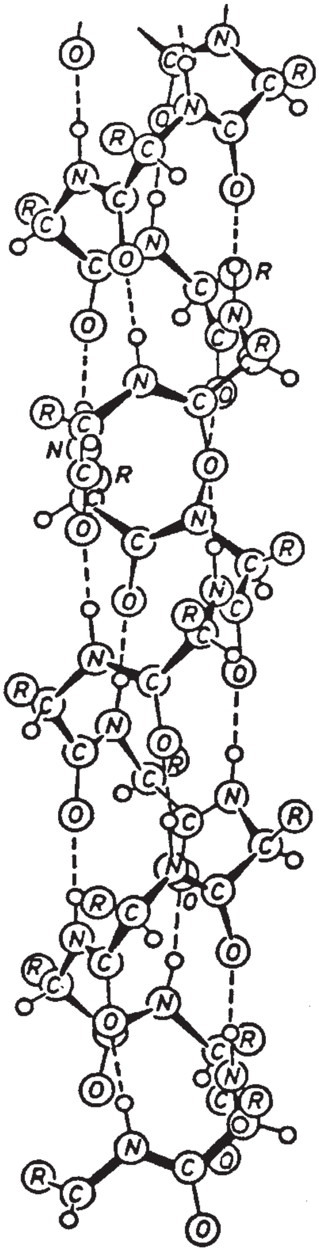


Fig. 1: Secondary structure (a-helix) according to Pauling.

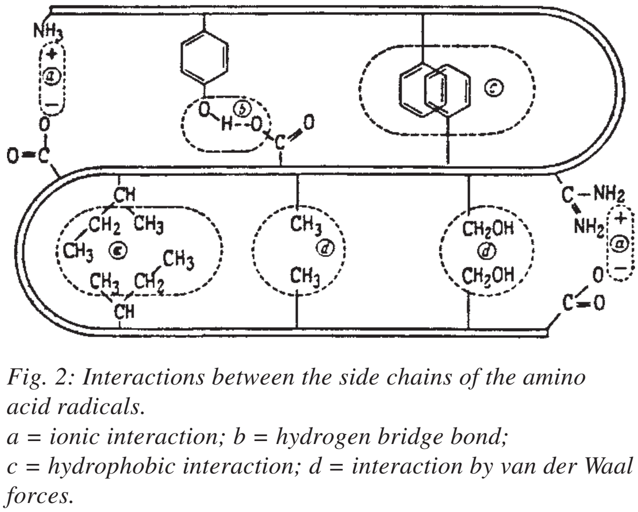


Fig. 2: Interactions between the side chains of the amino acid radicals.
a = ionic interaction; b = hydrogen bridge bond;
c = hydrophobic interaction; d = interaction by van der Waal forces.

A quaternary structure is present in collagen, consisting in fact of three polypeptide chains twisted around each other, which are called superhelix or tropocollagens (Fig. 3).

Fig. 3: Three-chain helix according to K. Kühn.

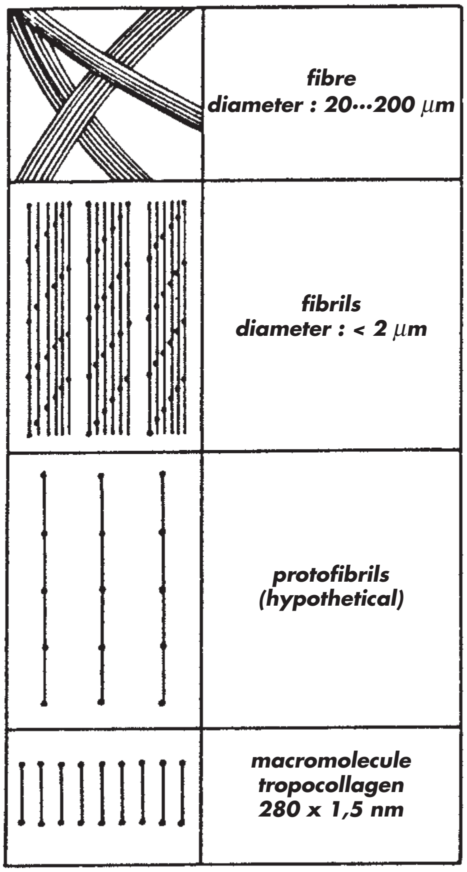


Fig. 4: Schematic diagram of collagen fibre structural elements.

With the formation of intermolecular bonds, tropocollagen molecules are arranged together as fibrils. Protofibrils are presupposed at first as an intermediate stage. The fibrils then come together as fibres and fibre bundles, out of which comes the insoluble, three-dimensional collagen fibre structure (Fig. 4).

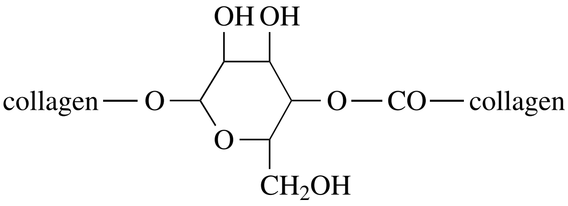


Fig. 5: Hexoses as collagen bridge links.

Classed among the intermolecular bonds is also the covalent bond, which occurs with continuous carboxyl and amino-group side chains. Hexoses also serve as bridge links, being bonded glucosidically to the hydroxyl groups of the collagen, and, like esters, to the carboxyl groups (Fig. 5).

The chemical/physical behaviour of collagen is important in leather production in its reaction with water, acids and alkalis, and against temperature and enzymes. Collagen is able to hold water (in the form of capillary water and as hydration water). The capillary water is stored in the fibre interstices, the hydration water on the collagen functional groups, particularly the carboxyl, amino and hydroxyl groups, and also on peptide groups which are not present in hydrogen bonding. As a consequence of tautomerism and mesomerism (Fig. 6), peptide groups are present as dipoles, and can hold water in this form.

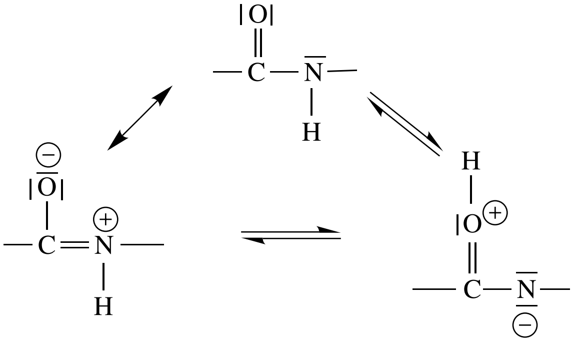


Fig. 6: State of equilibrium of the peptide group.

Collagen behaves as an ampholyte in reaction with acids and alkalis. There is equilibrium between the polar and unpolar form in the neutral zone.

$$\mathrm{H_2N{—}collagen{—}COOH} \rightleftharpoons {}^{+}\mathrm{H_3N{—}collagen{—}COO^{-}}$$

ACID REACTION:

$${}^{+}\mathrm{H_3N{—}collagen{—}COO^{-}} + \mathrm{H^{+}} \longrightarrow {}^{+}\mathrm{H_3N{—}collagen{—}COOH}$$

ALKALI REACTION:

$${}^{+}\mathrm{H_3N{—}collagen{—}COO^{-}} + \mathrm{OH^{-}} \longrightarrow {}^{+}\mathrm{H_2N{—}collagen{—}COO^{-}} + \mathrm{H_2O}$$

The same polarities in collagen mutually repel each other; the structure slackens in consequence of polar bond splitting, swelling following with the entry of water. The isoelectric point lies at pH 7.0–7.8. High temperature effects can denature collagen, intermolecular cross-linking, hydrogen bridges and hydrophobic bonds in particular being broken, and the crystalline helix structural arrangement being lost. Such processes characterise the shrinking temperature, which is 62–65°C with natural collagen. There is reverse propor-

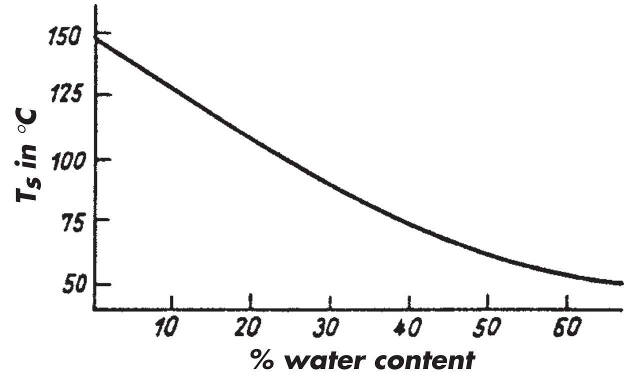


Fig. 7: Relationship between collagen shrinking temperature T_s and water content according to Witnauer.

tionality between shrinking temperature and water content (Fig. 7).

Enzyme action in collagen primarily causes attendant substances to decompose, and, secondarily, splits off amino acids into telopeptides. Splitting of the polypeptide chain into peptides by proteases like trypsin, pepsin and papain is not possible. Only the enzyme collagenase has a splitting effect, splitting resulting, via peptide bridge splitting, in small-chain peptides. The optimum effect here is at pH 6–8. The action of enzymes is put to good use in leather tanning. The collagen fibrils appear in calcined leather (Fig. 8).

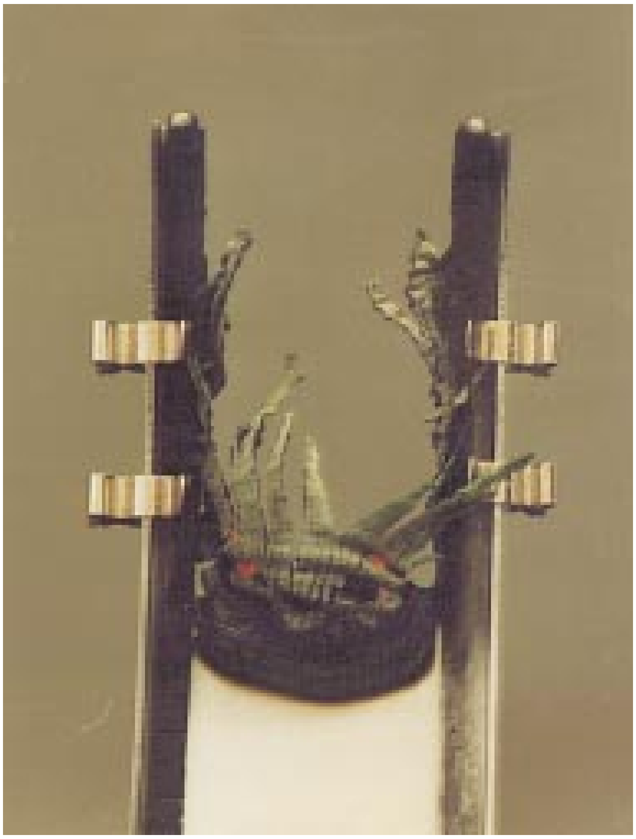


Fig. 8: Carbonised fibrils in calcined leather.

Collective sample A collection of individual samples.

Collodion Viscous solution of collodion cotton in 1 part alcohol and 2 parts ether. Use: sealing and coating agent (bottles, signs etc), adhesives, paint manufacture (cellulose lacquer), thickeners and setting agents for metal powder, pigments, lacquer printing.

Collodion cotton (cellulose dinitrate, colloxane, tyroxylin). A nitric acid ester of cellulose; cotton nitrated in a nitric acid/sulphuric acid mixture, where 2 of the 3 glucopyranose OH groups are replaced by NO_3 groups, equivalent to 10–11% nitrogen content. Therefore easily flammable (dry = explosive; moistened with alcohol/ether = steadily combustible). Similar to cotton in fibre form. Density 1.42. Otherwise largely analogous to → Nitrocellulose, but, in contrast to that, soluble in an alcohol/ether mixture (→ Collodion) and also in amyl alcohol, amyl acetate, acetone, glacial acetic acid etc. Basis of the production of the first → Man-made fibres. Use: collodion production, celluloid, adhesives, paints (cellulose lacquer); fixating thickener for pigment and lacquer printing, body colour for leather dyeing etc.

Colloid (Gk. kolla = glue), in contrast to → Crystalloid a non-crystallising substance like protein, gelatine, rubber, glue, starch and cellulose for example. Colloids are not therefore substance classes, but a concept for the dispersion conditions of the substance (→ Dispersivity).

I. Classification:

a) Dispersion colloids, produced by comminuting coarser substances into particles of a colloidal order of size, character hydrophobic (e.g. paraffin, phenolic resins); with → Protective colloids produce a colloidal “solution”, e.g. paraffin emulsions.
b) Molecular colloids, individual molecules of colloid dimensions, either “low molecular” (up to approx. 1000 atoms) or “macromolecular” (over 1000 atoms). Inorganic macromolecules: e.g. colloidal silicic acid; organic, e.g. protein (glycogen), rubber, polyvinyl products, silk, wool, cellulose (derivatives) etc. All molecular colloids are, in contrast to a), hydrophilic, and are therefore subject to swelling in water, producing, as required, concentrated → Colloidal solutions (by solvation or hydration).

II. Classification according to formation into:

a) spherocolloids: e.g. starch, protein, aminoplasts or phenoplasts in water;
b) linear colloids, like solutions of rubber, polyacrylonitrile and polyvinyl products, cellulose (derivatives) etc. Further classification according to the number of chain links into: hemicolloids (50–500 chain links, low viscosity linear molecules), mesocolloids (500–2000 chain links in the linear molecule) and eucolloids (over 2000 chain links, high viscosity, capable of swelling).

c) micelle colloids: hydrophilic individual molecules which combine in the solvent into variously large groups (micelles) of colloid particle dimensions, e.g. soaps or dyes in water, an electrical charge function (→ Colloid electrolytes).

III. All colloids appear in two different forms, the → Sol (= solution) or the → Gel (= flocculation, coagulation, concretion). Transitional form → Peptisation. Jelly (gelatine or glue swollen in water) is a lyophilic (hydrophilic) colloid gel.

Colloidal electrolyte → Colloid (more precisely: colloid-like substances between colloids and electrolytes), the particles of which contain electrical charges in aqueous solution or dispersion, i.e. form anions or cations. Numerous textile auxiliary agents for example are ionogenic, and, within the meaning of the word, so are textile fibres (cellulose fibres as anions; protein fibres: below pH 5 as cations, over pH 5 as anions).

Colloidal solution (colloid solution, sol). Suspension colloid, i.e. a finely dispersed solution. A considerably refined form of dispersion in terms of degree of dispersivity. This includes almost all dye solutions (though not disperse dyes), starch solution, glue solution, soap and detergent solution, synthetic resin solution etc. All these “solution forms” are also described by the generic term → Sol, and describe the uniformly fine distribution of a colloid in water = hydrosol, in alcohol = alkosol, in organic solvent = organosol, in air = aerosol (smoke, mist).

Colloid mill Term for a fine-milling dyestuff mill.

Colloresine process The original two-phase printing process for vat dyes. The principle is based on printing vat dyes from a thickener (originally Colloresine thickener DK) which undergoes coagulation on subsequent application of alkali and heat (steam). After printing and drying, the goods are padded with an alkaline solution (sodium carbonate or caustic soda) of a reducing agent such as Rongalite C (sodium formaldehyde sulphoxylate) after which they are steamed, with or without intermediate drying, in a conventional steamer for 3–8 minutes. Due to the high degree of coagulation of the thickener, no marking-off or smearing of the printed colours occurs in the steamer even though the fabric is in contact with the guide rollers on both sides. This process has now been almost completely replaced by the more economical → Flash ageing.

Colophonic acids → Resin acids.

Colophony (Burgundy pitch). Natural resin product. Distillation residue of pine resin or turpentine oil manufacture. 80–90% comprised of → Abietic acid. Density 1.045–1.10, saponification number 165–198. Unsaponifiable 4–14%. Pieces, brittle and with a glassy lustre, or powder, light yellow to almost black. Weakly acid. Softens at 70°C, semi-liquid (not clear) in boiling water, liquid at 120–135°C. Easily soluble in alcohol, benzine, acetone, chloroform, carbon tetrachloride etc. Saponifiable to resinates (soaps of resin) with hot alkalis. Most important use for resinates; emulsified (possibly partially saponified) as a stiffening agent; also modified (with synthetic resins etc.) for slip-proof finishing, for coarser water repellency etc.; as a resist for batik printing and in silk printing (resin resist printing); putty; for drying agents and paints. Also as a basic material for synthetic resins of the alkyd resin type for paints.

Colophony soap → Resin soaps.

Colorado Continuous overflow machine for the treatment of fabrics in rope form with up to 12 trough-shaped liquor compartments. The fabric rope is piled into the first compartment via a swimming tube from where it passes in spiral form through all compartments. The dwell time in each compartment can be controlled by selection of the rope capacity and accelerated or delayed fabric passage. Besides its use for prewashing and afterwashing treatments, combination bleaching processes are also possible with the addition of a small J-box unit. Manuf.: Brückner.

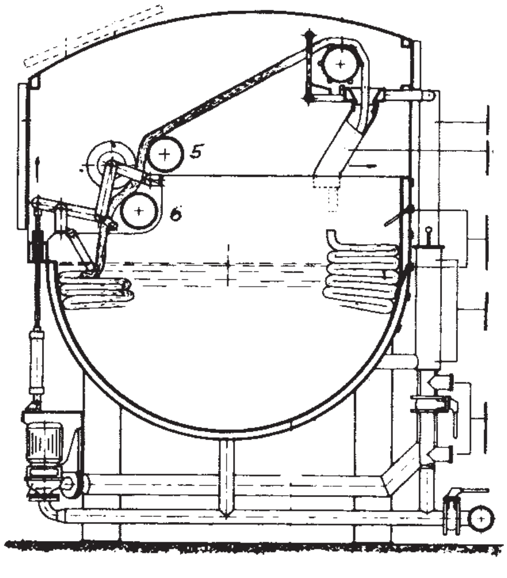


Fig.: Colorado rope washing machine (Brückner).

Colorant Standard term for chromophoric materials. This includes dyestuffs, colour lakes, pigments etc.

Colorant binders These are used in pigment printing and pigment dyeing to fix wash durable pigment dyestuffs on the textile.

Colorant channel Corresponds to the height of the space between the warp and weft yarns of a flat screen, or the depth of the perforations a rotary screen.

Coloration This is the bond between fibre and dyestuff. It comes about e.g.:

1. By heteropolar ionic bonds (salt compound) between basic fibre groups (wool, silk) and acid dye-

stuff groups (acid dyestuff, metal complex dyestuff) or vice versa between acid fibre groups (wool, silk, and acrylic and polyester containing sulpho groups) and basic dyestuff groups (cationic dyestuffs).

2. Covalently by ester or ether bonds between OH cellulose and reactive dyestuff groups or by amide bonds between NH_2 groups and wool and reactive dyestuff groups (reactive dyestuffs).
3. By developing dyestuffs which have low solubility or are insoluble, e.g. by forming dyestuffs of low solubility from soluble preliminary products (naphthol dyestuffs, phthalogen dyestuff) or by forming a low solubility colour lake from dyestuffs with groups having an affinity for mordants and metal salt mordants or by converting dyestuffs supplied from a soluble into an insoluble form (vat dyestuff, sulphur dyestuff).
4. Using van der Waals force (e.g. disperse dyestuff in polyester fibres; these forces are stronger in polyester than in polyamide fibres due to the benzene rings present in the fibre). They also play a part in dyeing cellulose with direct dyestuff or with the leuco form of vat dyestuffs.
5. Purely mechanically by “sticking” the dyestuff on the fibre using a binding agent (synthetic resins) (pigment dyestuff). → Dyeing theory.

A distinction is made between discontinuous (→ Exhaust dyeing process) or continuous processes (→ Pad process) depending on the mode of operation. Dyeings between these methods are found in the print works. Dyeings are carried out in the manufacture of man-made fibres by dope-dyeing and spin dyeing. Dyeings carried out on manufactured articles are called “fully fashioned” dyeings (Garment dyeing).

Colorex Control device for the photometric measurement of concentration changes in dye liquors. Consists of a measuring component in the form of a photometer and a component for measuring the speed at which dye is absorbed. As well as the main rate of absorption control component the Colorex system also contains a conventional, preselectable temperature program with appropriate control accuracy. In the preheating phase a preselected temperature can be reached at a maximum heating rate and controlled using an adjustable heating time. The preselectable dye absorption phase can take place using the above-described absorption control or, if this cannot be used, using a temperature program with two adjustable heating speeds (minimum heating speed 0.2°C/min. with a max. control deviation of ± 5%) and a variable temperature. The dye temperature that is selected is controlled to a fixed value during the preselected holding time and then switched to the cooling phase, which cools the dye to a fixed final temperature value at a variable cooling speed.

The preselected program runs automatically. This kind of design means that as well as performing absorption control the Colorex device can also replace an existing temperature controller or be integrated into existing general control systems. This device has not established itself in the dyeing industry - Manuf.: Sedo.

Colorimter →: Spectrophotometer; Colorimetry.

Colorimetric measures Colorimetric measures are the measures resulting from colour measurement for → Colour stimulus specification. To clearly identify these it is necessary to supply three independent figures which can be structured differently depending on the set-up of measuring instruments and which accordingly either give exact colorimetric measures or measures which deviate slightly, adjusted to the eye (→ Colour vision) in order to imitate the colour stimulus specification to be measured using additive colour mixtures.

I. Trichromatic colorimetric measures: in accordance with the international agreement (1931) three so-called standard colorimetric values (for hue, lightness, saturation) are used which are designated as X, Y and Z and also referred to as CIE tristimulus values. In line with the spectral response characteristic of the eye, the green fraction Y (luminance-brightness value) is used here to determine lightness. For surface colour, Y equals 100 for pure white with any form of lighting, and X and/or Z are correspondingly reduced. The mixtures of the CIE tristimulus values required X, Y, Z are referred to using the chromaticity coordinates x, y, z whose sum is x + y + z = 1, so that it is sufficient to determine x and y as z can be deduced from this. It follows for measured radiation = trichromatic sum X + Y + Z,

$$\textbf{for } x = (X\text{: } S \textbf{ or } x =) \frac{X}{X+Y+Z}$$

$$\textbf{for } y = (Y\text{: } S \textbf{ or } y =) \frac{Y}{X+Y+Z}$$

$$\textbf{for } z = (Z\text{: } S \textbf{ or } z =) \frac{Z}{X+Y+Z}$$

The graphical representation of the chromaticity coordinates takes place by entering the so-called colour points in the → Chromaticity diagram. The trichromatic system is exact, admittedly, but has the disadvantage of being difficult to understand for those who are not familiar with it, as the appearance of the colour does not give any real impression.

II. Helmholtz colorimetric measures are based on identification of the dominant wavelength, the luminance (lightness) and the spectral colour density (saturation) in accordance with DIN sheet 5033.

III. Luther colorimetric measures take into consideration the lightness Y and the two so-called colour moments M1 as Y–X and M2 as Y–Z. From these index numbers, which clearly represent red-green or blue-yellow, the geometric sum M

$$\sqrt{M\,{}^{1}/_{2} + M\,{}^{1}/_{2}}$$

The so-called brightness moment is formed as a measure of colour. The subsequent colorimetric measures are regarded as less exact as they are always dependent on the spectral colour stimulus condition and will tend to give more or less varied colour values for similar colours.

IV. Ostwald colorimetric measures: The shade N_{24} (chromatic circle) is expressed here together with white w and black content s, with the fraction v of the pure spectral colour resulting from $w + s + v = 1$. The measures obtained can be calculated using tristimulus values X, Y, Z and trichromatic coefficients x, y and compared with values obtained using other measuring systems. Thus e.g. yellow $N_{24} = 2.8$, $w = 0.348$, $s = 0.352$ would correspond to the following values (in brackets for comparison with spectrophotometric method): X = 57.4 (54.1), Y = 54.7 (52.2), Z = 41.1 (44.2), x = 0.373 (0.360), y = 0.357 (0.347).

V. Agahd colorimetric measures are based on measures with three colour filters which consist of second level complementary colours as described in the chromatic circle, i.e. Ostwald colour 1 = yellow 1, Ostwald colour 9 = red 3 and Ostwald colour 17 = blue 2. Accordingly, each colour consists of a max. 4 fractions a) % yellow, b) % red, c) % blue, d) % white and 100 - (a + b + c + d) energy-free % black. Reference is always made to overlaps of colour (rather than to fractions in white). Colours result from a + b or b + c or a + c = 0; mixed intermediate colours, as long as a or b or c = 0.

VI. Hunter's colorimetric measures: Conversion of CIE tristimulus values X, Y, Z into valuation constants L, a, b; form the basis of the current CIELAB formula.

VII. Colorimetric measures in colour atlases, similar to the Ostwald colour atlas (IV), → DIN colour chart, Munsell system etc.

Conversions of I–IV take place in accordance with standard DIN 5033 and can be represented either as chromaticity coordinates or graphically in chromaticity diagrams for comparison. →: Colour measurement; Colorimetry.

Colorimetric system (Colour system). This is a colorimetric ordering system to define each colour precisely, e.g. with reference to the three colour qualities of hue, saturation and lightness.

Colorimetry This is the science of dimensional relations between the colours. For this, it is necessary to describe and measure the colours clearly by means of dimension figures (→ Colorimetric measures). However, colour is not a physical property of a body, but is a sensory perception transmitted by the eye. Colour perception cannot be measured directly; it is only possible to measure the light emitted from a source that is reflected from a body and falls on the human eye. This can be physically recorded. By testing the colour vision of a fairly large number of people at the same time, the results can be related to the physical measuring results. In colorimetry, therefore, the sensory impression of colour is recorded objectively by the radiation of a body. Using the colorimetric measures obtained in this way, the world of colour can be portrayed systematically. This forms the basis for the assessment of colour differences, colorimetric formulation calculations and also has an impact on the area of art.

Colour perception takes place via radiation that, starting from a light source is reflected from a body and falls on the receptors of the human eye. This radiation is known as colour stimulus. The spectral distribution of the light source therefore has a significant influence on colour perception. For colorimetry, only the relative energy distribution is of interest, i.e. the relative radiation ratio within the entire visible spectrum. Some illuminants with their relative energy distribution have been standardised. An important example is the standard illuminant D_{65} with an energy distribution corresponding to that of average daylight.

A reflectance curve can be produced from each object. It is also possible to determine the ratio of the light reflected from the body to the light reflected from an absolute white surface depending on the wavelength. The colour stimulus is therefore determined by the spectral distribution (S_{λ}) of the source of light and the reflectance of the body (R_{λ}). The observation of the colour stimulus across the entire spectrum of visible light is described as colour stimulus function. The colour stimulus reaching the eye is transferred into nerve signals. It is thus assumed as a model that there are three reference stimuli with different spectral sensitivity on the retina, determined by three types of cone. Colour perception via the three types of cone is referred to as "trichromatic vision". If the sensitivity of the reference stimuli is viewed across the entire visible spectrum, spectral perception functions are obtained. They are expressed as CIE spectral distribution curves $\bar{x}$, $\bar{y}$, $\bar{z}$. The CIE spectral value $\bar{z}$ is particularly sensitive to blue light, $\bar{y}$ for green light and $\bar{x}$ is predominantly red-sensitive with a slight maximum in the blue range. In colour perception, they form a homogeneous effect, colour stimulus specification. The colour stimulus specification can therefore be described unambiguously using three measures. The assessment of a colour results from the portion of colour stimulus that is transmitted by the individual cones. For each type of cone, it is determined from the following, in relation to the spectrum of visible light:

$$X = \int_{400}^{700} S(\lambda) \cdot R(\lambda) \cdot \bar{x}(\lambda)$$

$$Y = \int_{400}^{700} S(\lambda) \cdot R(\lambda) \cdot \bar{y}(\lambda)$$

$$Z = \int_{400}^{700} S(\lambda) \cdot R(\lambda) \cdot \bar{z}(\lambda)$$

The quantities X, Y and Z are termed as CIE tristimulus values. They are dependent on the observer's field of vision as well as on the illuminant and reflectance of the sample. The observer's field of vision influences the CIE spectral distribution curves, as the distribution of the types of cones on the retina is altered by the presence of rods when the visual angle is above 2°. Two fields of vision have therefore been standardised by the CIE (Commission Internationale l'Éclairage):

a) 2° field of vision: the visual angle of the observer is limited to ≤ 4°. The light therefore falls only on the fovea of the retina, which only contains cones. The observer with a 2° field of vision is described as "2° Standard Observer".
b) 10° field of vision: to conform with practice, an observer with a visual angle of > 4° was introduced in 1964. Due to the different CIE spectral distribution curves, different CIE tristimulus values are obtained than those of the 2° Observer. CIE spectral distribution curves and CIE tristimulus values are identified with the "10" Index. It is not possible to convert between the CIE tristimulus values from each type of observer.

Representation of the colours in a colour space: the standard tristimulus values X, Y and Z are not very precise. To portray the colours in a more comprehensible manner, the CIE chromaticity co-ordinates x, y, z are calculated. They give the size of the fraction of each CIE tristimulus value with the total of all three values. Hue and saturation can be found using the CIE chromaticity co-ordinates x and y, which are summarised in the term "chromaticity". As 1 = x + y + z, the CIE chromaticity co-ordinate z is not required to identify a colour, as it can be calculated using the other two. As the third quantity to represent a colour stimulus specification, lightness is expressed using the CIE tristimulus value Y. This can be compared with the CIE chromaticity co-ordinate z for the 2° observer. Lightness is plotted perpendicular to the colour plane. If the CIE chromaticity co-ordinates x and y of pure spectral colours of the visible spectral range are input into a diagram, with x as the abscissa and y as the ordinate, a continuous arched, non-closed curve is obtained, the spectrum locus (→ Chromaticity diagram; Fig. 1). The straight connecting line between the two ends forms the purple boundary with the secondary colours of the spectrum.

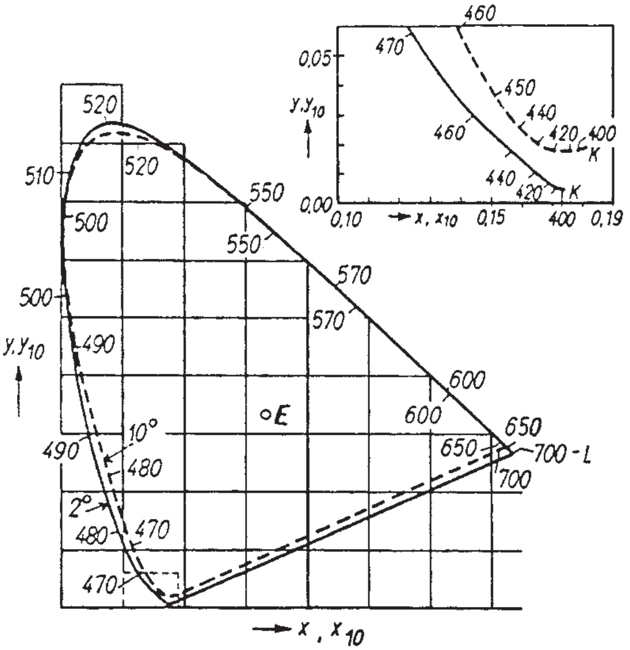


Fig. 1: CIE chromaticity diagram for the 2° system (extended line) and for the 10° system (broken line).

The achromatic point, which indicates the chromaticity of white, grey and black colours, is located in the centre. Colours of the same hue, but different saturation, which increase with the distance from the achromatic point, lie on the straight line between the achromatic point and spectrum locus. This chromaticity diagram has been standardised by the CIE and is also included in the DIN standard. It is known as the CIE tristimulus diagram or chromaticity diagram. According to DIN, hue is understood to mean "the property which distinguishes a chromatic colour from an achromatic colour. In colour stimulus specification measurements, it is generally described by the dominant wavelength λ_f. As described above, this gives the wavelength of the corresponding spectral colour that lies on the projected line between the colour location and the achromatic point. DIN states that saturation is "the degree of brightness of a colour in comparison to a grey of the same lightness". In colour stimulus specification measurements, it is given as the spectral component of colour Pe, which gives the proportion of spectral colour in the mix with neutral.

Definition of CIE tristimulus values: These can be determined using three different methods stipulated in DIN 5033 sheets 4–6. With the spectrophotometric method, it is determined using spectrophotometric measurement to give the colour stimulus function. As the spectral energy distributions S (λ) are known for standard illuminants, only the spectral reflection is measured. Next, assessment using valency measurements is carried out incorporating the CIE spectral distribution curves. This is determined using a spectrophotometer. Other methods include visual colour matching, in which colour measurement is based on comparison of a colour with unknown colour stimulus specification with colours where this is known, and the triple zone method, in which the CIE tristimulus values are measured directly. Due to lack of accuracy, they are less important in practice. In all three cases, the result of a colour measurement depends to a large extent on the measuring geometry used. Measuring geometry is understood to mean "the path of a ray from the illuminated source of light to the plane on which it falls." The direction of incidence of the light onto the sample and the direction from which the sample is being observed are important here.

In order to obtain comparable results, three measuring geometries are standardised:

a) With the 45/0 measuring geometry, directed light falls on the sample at an angle of incidence of 45°. Observation is carried out at an angle of 0°. This measuring geometry is mainly used for bright samples, as the luminosity can be eliminated.
b) With the d/8 or d/0 measuring geometry, the sample is placed in an integrating sphere. With diffuse, semi-reflected light incident on the sample, observation is carried out at an angle of 8° or 0°.
c) With the 0/d measuring geometry, the sample is illuminated vertically. The light diffusely reflected is collected in the integrating sphere and measured.

When measuring textiles, the integrating sphere is generally used, as the measuring value is independent from the direction of the textile structure to a large extent.

Colorimetric measures: according to DIN 5033 sheet 3, colorimetric measures serve "to uniquely identify a colour stimulus specification. For this, three independent figures are always required and are sufficient. If it is only necessary to identify the chromaticity, then two of the measures independent of the brightness are sufficient". The DIN standard recommends the "Trichromatic colorimetric values in accordance with the CIE standard colorimetric system". The CIE-UCS chromaticity diagram was developed in 1960 to increase conformity between the geometric distances and the visually perceived colour differences. It represents a transformation of the CIE standard colorimetric system. The co-ordinates u' and v' are determined using the co-ordinates x, y from the chromaticity diagram. This distorts the chromaticity diagram to such an extent that the green area of the diagram is shrunk and the red area is stretched. The discrepancy between the geometric difference and the perceived difference was not eliminated as a result of this, but it was possible to reduce the incongruity from 1 : 20 in the chromaticity diagram to 1 : 2. In the CIE system, colours are identified using the CIE tristimulus values X, Y and Z. When comparing two colours, the CIE system only gives information concerning the uniformity of the colours. Statements concerning the differences or distances between the colours cannot be made, as the geometric distances in the colour space do not correspond to visually perceived differences. Numerous colour difference formulae have been developed to date in order to identify differences in colours with a good correlation to the visual assessment. A distinction is made here between two starting points:

- Based on the CIE tristimulus values, a colour difference value ΔE is defined using empirical constants;
- The colour difference ΔE is determined on the basis of an equidistant colour system.

Having critically compared the formulae developed to date, M. Richter comes to the following conclusion:

- The calculated results of the various formulae are not proportional to one another. It is not possible to convert between the formulae. It is therefore necessary to quote the formula used in addition to the colour difference.
- For each formula there are areas with good correlation to the visual assessment and others with poor correlation.
- The choice of formula is secondary in in-house assessment of colour difference. The formula used should however always be the same.

Just as there is no uniform formula to calculate colour difference, the units differ for each formula. In a large number of formulae, they are adjusted to the NBS unit, however. The name of the unit comes from the NBS (National Bureau of Standard, Washington) colour difference formula. A second common unit is the MacAdam unit (MAE). On average, this is approximately half of the NBS unit. This is used to calculate colour differences using the Simon-Goodwin method and using the Friele-MacAdam-Chickering formula.

Here is a description of three of the many colour difference formulae that have been published:

1. In Hunter's colour difference formula, the valuation constants L, a, b for the colours to be compared are calculated from the CIE tristimulus values X, Y, Z using the following formulae:

$$\begin{aligned} a_L &= 17{,}5\,(1{,}02\,X - Y)/\sqrt{Y} \\ b_L &= 7{,}0\,(Y - 0{,}847\,Z)/\sqrt{Y} \\ L &= 10 \cdot \sqrt{Y} \end{aligned}$$

The colour difference ΔE_H is calculated from the differences between the two colours:

$$\Delta E_H = \sqrt{(\Delta a)^2 + (\Delta b)^2 + (\Delta L)^2}$$

2. The CIELAB formula is used to assess small colour differences and is recommended for use by DIN 6174. The colour difference is determined using a colour difference formula from the colorimetric measures L^*, a^*, b^* which result from the CIE tristimulus values X, Y, Z.

With this method, the correlation between the calculated distances and the perceived distances is very high. The determination of the colorimetric measures L^*, a^*, b^* is shown in Fig. 2. The CIE tristimulus values X_0, Y_0, Z_0 refer to the totally matt white surface with appropriate illuminant and standard observer. The L^*-value indicates the position on the light/dark axis in the L^*, a^*, b^* system, the a^*-value gives the position on the red/green axis and the b^*-value the position on the yellow/blue axis.

According to DIN 6174, the ΔE^*_{ab} colour difference is calculated as follows:

$$\Delta E^*_{ab} = \sqrt{(\Delta L^*)^2 + (\Delta a^*)^2 + (\Delta b^*)^2}$$

The colour difference ΔE^*_{ab} can be split up into a lightness component (ΔL^*), a saturation component (ΔC^*_{ab}) and a colour shade component (ΔH^*_{ab}). Lightness L^*, saturation C^*_{ab} colour shade H^*_{ab} can be represented more clearly in graphical form. The shade of a colour is found on the chromatic circle of spectral colours. It is determined using the colour shade angle h_{ab}, which increases in size for the shade sequence red, yellow, green, blue. The saturation or degree of brightness is identified by the distance from the origin of the coordinates, the achromatic point, to the chromatic circle. On the chromatic circle, the saturation is 100%. The lightness is plotted vertically. The saturation component ΔC^*_{ab} is therefore described by the various distances of the colour location from the achromatic point. This also applies to the lightness component ΔL^*. The colour shade component ΔH^*_{ab} is defined by the alteration in the colour shade angle h^*_{ab}. The mathematical calculation of the components is carried out as follows:

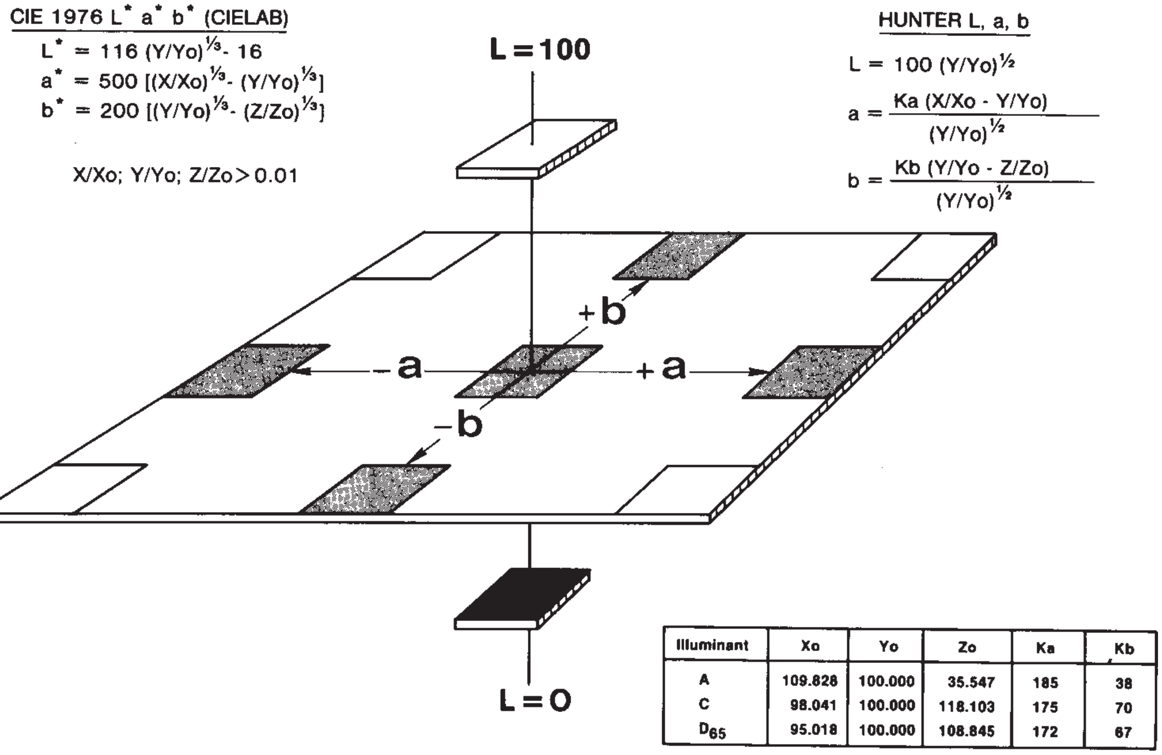
$$\Delta E^*_{ab} = \sqrt{(\Delta L^*)^2 + (\Delta C^*_{ab})^2 + (\Delta H^{*}_{ab}{}^2)}$$

$$\Delta L^* = L^*_P - L^*_B$$

$$\Delta C^*_{ab} = C^*_{ab,P} - C^*_{ab,B} \text{ mit } C^*_{ab,P} = \sqrt{a^{*2}_P + b^{*2}_P}$$

$$C^*_{ab,B} = \sqrt{a^{*2}_B + b^{*2}_B}$$

$$\Delta H^*_{ab} = \sqrt{(\Delta E^*_{ab})^2 - (\Delta L^*)^2 - (\Delta C^*_{ab})^2}$$



CIE 1976 L^* a^* b^* (CIELAB)

$$L^* = 116\,(Y/Yo)^{1/3} - 16$$
$$a^* = 500\,[(X/Xo)^{1/3} - (Y/Yo)^{1/3}]$$
$$b^* = 200\,[(Y/Yo)^{1/3} - (Z/Zo)^{1/3}]$$

$X/Xo;\ Y/Yo;\ Z/Zo > 0.01$

HUNTER L, a, b

$$L = 100\,(Y/Yo)^{1/2}$$
$$a = \frac{Ka\,(X/Xo - Y/Yo)}{(Y/Yo)^{1/2}}$$
$$b = \frac{Kb\,(Y/Yo - Z/Zo)}{(Y/Yo)^{1/2}}$$

Illuminant	Xo	Yo	Zo	Ka	Kb
A	109.828	100.000	35.547	185	38
C	98.041	100.000	118.103	175	70
D_{65}	95.018	100.000	108.845	172	67

Fig. 2: Schematic diagram of the L-a*-b* system.*
X, Y and Z are tristimulus values; X_0, Y_0 and Z_0 are tristimulus values for perfect transilluminators when they are used as illuminators. Ka and Kb are chromatic coefficients relating to the illuminator.

The indices P and B refer to sample (P) and reference (B). The algebraic sign for ΔH^*_{ab} is:

– positive, where $a^*_P \cdot b^*_B - a^*_B \cdot b^*_P \leq 0$

– negative, where $a^*_P \cdot b^*_B - a^*_B \cdot b^*_P > 0$

The CIELAB formula represents a modification to the Adams-Nickerson-Stultz colour difference formula (ΔE_{AN}). The differences are as follows: the colour differences are on average larger than those in the AN formula by a factor of 1.21. The division of the colour difference only relates to the CIELAB formula. Calculation using the AN formula is more difficult for a computer than using the CIELAB formula. The question of which formula gives the better correlation with the visual assessment continues to be discussed in practice.

3. Other colour difference formulae are the CIELUV formulae also recommended by the CIE whose initial co-ordinates are u', v' of the 1960 CIE-UCS chromaticity diagram, and the Adams-Nickerson-Stultz colour difference formula which is based on Adams' measuring system. Simon-Goodwin method for determining colour difference thresholds and the method of determining colour difference arising from this is also worth mention. Using experimental tests, D. L. MacAdam ascertained that the colour locations that can still be distinguished from a target colour are arranged as an ellipse with the target colour in the centre. The ellipses determined vary in size depending on the chromaticity (Fig. 3). If the lightness is also varied, ellipsoids are also obtained in the x, y, Y colour space.

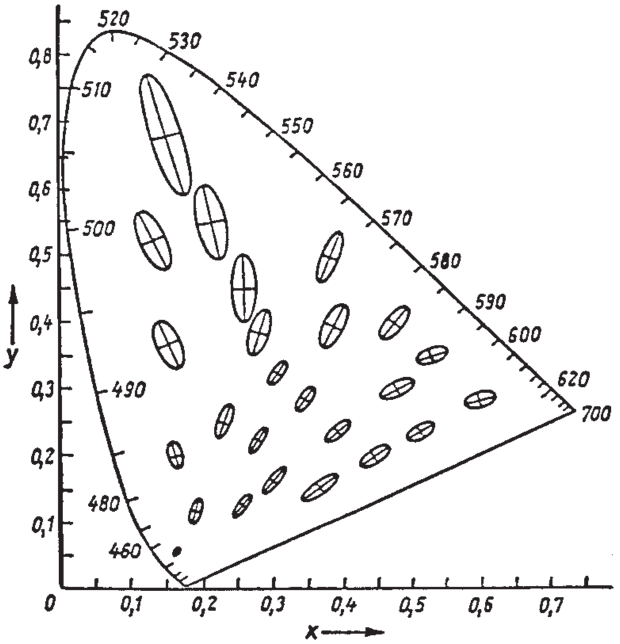


Fig. 3: Colour triangle with MacAdam threshold ellipses (the ellipses are magnified lenfold in comparison with the scale of coordinates x and y).

Simon-Goodwin determines the colour difference with the aid of charts consisting of subdomains of the chromaticity diagram as an oblique co-ordinate system. The MacAdam ellipses thus become circles. The chromaticity difference is determined using these and the total colour difference is determined using another table, including brightness. This method (where used at all) is used where only a small number of colour differences are being defined. The new CMC (I:c) formula is currently being introduced to complement the CIELAB-formula. → Colorimetric measures; Colour measurement.

Colorimetry, colorimetric analysis A process for determining the concentration of coloured solutions. Colorimetry is based on the fact that part of a light beam is absorbed on passing through a coloured solution. According to Lambert-Beer in this respect, the quantity of light absorbed is proportional to the concentration (c) of the colouring substance in the solution and the layer density (d = distance covered) which the light beam has to travel through the solution. Solutions of the same substance but of different concentrations then give rise to the same light absorption when their layer thicknesses behave conversely to their concentrations.

$$c_1 \cdot d_1 = c_2 \cdot d_2$$

The concentration of coloured solutions can now be determined by the light loss occurring due to absorption being determined visually (optically) by means of a colorimeter or photometrically with photocells.

Colorthek A colour atlas produced by BASF containing a systematic arrangement of shades from yellow to black. Dyeing recipes and colour fastness ratings are given for the combination dyeings. Volume I: 1320 shades on wool and synthetic fibres, Volume II: 2580 shades on cellulose acetate and synthetic fibre filaments.

Colour,

I. Coloristic: hue, saturation and lightness, shades. Terms used in practice for describing the perception of colour → Hue (state, difference) in sample dyeing and colour matching. Colour also relates to e.g. →: Colour sample; Colour kitchen and Colour Index (C.I.) etc.

II. Physical: An optical perception arising as a result of → Colour stimulus (state) that is transmitted via the eye to the brain where colour perception is triggered (→ Colour vision). Colour is therefore primarily an effect of the light. A distinction is made between:

a) Coloured light or spectral colours which are characteristic of a specific illuminant, e.g. as a coloured light source or illuminant. Typical for this is the composition of white daylight as an additive mix of spectral colours, i.e. the sum of all colours that make up white, and includes the fluorescent effects of optical brightening agents.

b) Surface colours arise when visible light falls on coloured, non-luminescent objects causing colour perception by selective absorption and reflection, i.e. where there is complete absorption by the exposed object, it appears black, but where there is complete reflection, it appears white. Where there is selective absorption, only part of the incident light appears as a reflected → Complementary colour. Not only insoluble mineral dyestuffs but also in a wider sense soluble dyestuffs and their dyeings are included amongst surface colours as sensory impressions. Separation into → Hue and → Achromatic colours that seem to be opposites differ only insofar as hues show a spectral colour. Ostwald defines every surface colour using a number from the chromatic circle and two letters from the → Grey scales for fastness testing. For the dyer, it is important to know that there are no truly pure colours because reflected light is not monochromatic.

Colour affinity → Dye affinity.

Colour anomaly → Anomalous colour vision.

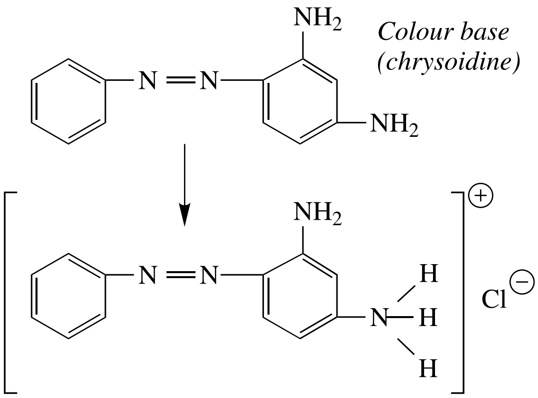
Colour aptitude →: Colour blindness; Defective colour vision; Anomalous colour vision.

Colour aptitude test (Am.). Using a 48-part colour scale consisting of individually pigmented synthetic plates; the ability to sort colours into the correct order is assessed.

Colour aptitude testing → Anomaloscope.

Colour atlas (Colour chart, colour card, shade card). Although sample cards from dye works and dyehouses generally give limited recipe collections from certain points of view or are oriented towards this, it is also possible to provide the colour sample with relevant colorimetric measures and to use them in the sense of colorimetry as subjective direct comparisons, to ascertain colour tolerances, to assess cross-dyeing, to calculate costs etc. The procedure is as follows: a colour which is to be measured at specific lighting (standard illuminant) is to be directly compared with the colour atlas. The colorimetric measure and preferred number of the corresponding sample is then made into the identifying colorimetric measure for the dyeing. Using the same principle, individual colour atlases can be formed systematically, e.g. using the DIN colour chart. This method appears very simple, however, it is always dependent on the observer and can only be used where there is no need for particular accuracy. In addition, where the colour atlas is incomplete, it is often necessary to rely on interpolations between two ordered samples which considerably increases the subjective factor of uncertainty still further. Each colour atlas also has a tendency to temporary limited light fastness and ageing which means that checks are required from time to time. The highest requirements are therefore to be made of colour atlases: they must contain all colour used in practice as far as possible, including various brilliant and gloss variations. Similar adjacent colours must be equidistant as far as possible and clearly perceivable as different by the eye. Each colorimetric measure should give reliable details of the index number (converted using DIN 5033) under specific lighting, together with details concerning light fastness etc. if possible.

Colour bases (dyestuff bases). Organic → Bases consisting of dyestuff residue with free or substituted amino groups ($-NH_2$, $-NHX$, $-NX_2$) incorporated as an auxochrome. These amino groups transfer their basic character and positive charge to the dyestuff residue that therefore receives cationic properties. These types of colour bases lack solubilising groups; however, they are frequently fat-soluble and/or alcohol-soluble. Only their salts (colour salts), usually acidified with hydrochloric acid and known as → Cationic dyes, are of any significance with respect to textiles. These salts form the prototype of cationic dyes according to the ionic properties of the salts in aqueous solution.



Colour base (chrysoidine)

Chlorine hydrate

They therefore react oppositely to dye acids and their salts (→ Dye ions). Colour bases must not be confused with → Azoic bases.

Colour blend (mixture, mix). Produced after doubling and drawing differently dyed tops, or after blending stock dyed woollen yarn wool, i.e. generally after blending differently coloured (dyed) fibres. A dyeing expression rather than a quality term.

Colour blend prediction by colorimetry The conventional recipe production of colour blends is effected in the following steps:

1. Analysing the model.
2. Recipe production in percentages.
3. Producing the test sample.
4. Comparison between model and adjustment (test specimen).
5. Optimising the recipe.
6. Producing further test samples with subsequent comparison.

7. Recipe composition for production in units of weight.

Here, depending on the complexity of the model, operational stages 2–6 can be repeated a number of times in loop form. It is by no means rare for this section to be repeated 4–6 times in practice, and even 10 times in extreme cases. In producing the test sample, this is first of all weighed on a precision balance in component terms depending on the recipe, and then blended in a laboratory blending machine (sample card). The blend is then treated with a soap solution, brought into felt form on a laboratory plate fulling machine, and finally washed. After a 10–15 minute drying period the test sample is ready for comparison. Comparisons are made in an illuminated chamber, in which metameric tests can be carried out. This expensive production process takes 20–40 min as a rule.

In worsted yarn spinning, blending is effected in the drawing passages; in woollen yarn spinning on the other hand, the blend is prepared in blending bed form and then further processed on a card. Independently of the blend production method, production of the blend recipes for both spinning areas can be implemented equally. New formulation methods have been made possible for blenders only by the colorimetry standards in the dyehouse, which have made it possible to effect the formulation process by colorimetric methods in addition to well-tried conventional blending.

The colorimetric interrelationships in a subtractive textile colour mixture and the interrelationships between colour components and the resultant colour blend can be described as follows: if two liquors of a cyanine and a magenta dye are produced, and the same quantity of stock is dyed in each solution, the remission curves in Fig. 1 are produced after the two samples have been measured colorimetrically by means of a spectrophotometer.

If the two liquors are put together, and both stock test specimens are dyed under the same dyeing conditions as in the first test, the samples are coloured violet. The associated reflectance curve can be seen in Fig. 2. This curve is produced by subtractive colour mixing.

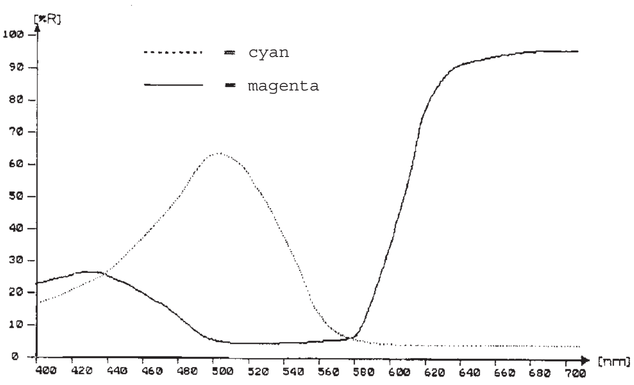


Fig. 1: Cyanine and magenta reflectance curves.

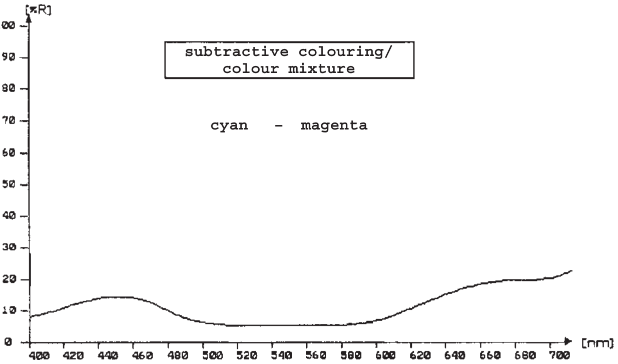


Fig. 2: Subtractive colour mixing of cyanine and magenta.

After repeating the first test, and producing the colour blend composed of the cyanine and magenta samples (50% + 50%), the same shade as in the second test with the mixture of the two liquors is obtained, but brighter and more saturated. After measuring the colour of this colour blend, the reflectance curve shown in Fig. 3 is obtained.

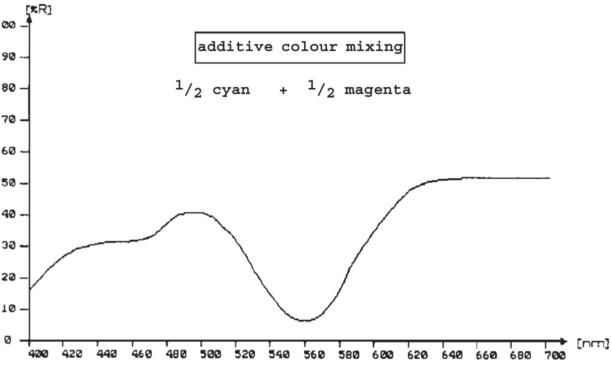


Fig. 3: Superimposition of subtractive and additive colour mixing = colour blend.

Fig. 3 involves an additive colour mixture, but with approximately half the intensity as compared with measuring the individual test samples. Colorimetrically therefore, a colour blend behaves other than a homogeneous textile dyeing, and cannot be analysed by the calculation process valid for subtractive colour mixing. Specially developed software packs are offered for colorimetric colour blending. The two solutions can be classed roughly equally in characteristic terms and as a method. The method of operation of one of these can be explained in the following steps:

1. Reference data set-up.
2. Colour blend formulation.
3. Colour blend recipe correction.

As in textile dyeing, the reference series also serves as a basis here. Only one shade series (Fig. 4) is required for each substrate. The shade series represents a continual mixture of the substrate with the darkest full shade (black) in each case. 11 gradations are produced for ex-

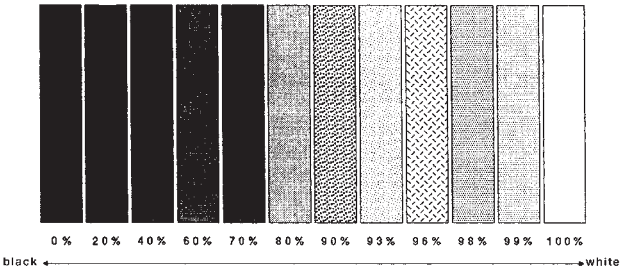


Fig. 4: Shade series.

ample from 0–100% (white), though attention must be paid to graduation in terms of perception, i.e. relative to the brightness-sensitive curve of the human eye, the concentration gradations must lie closer together in the bright range.

For full shades, only one sample is required from the respective stock on hand, which then has to be measured in. In Fig. 5, this is represented as a full shade palette, with which the model can be formulated. The size of the palette is unlimited, and makes it possible to take account of the each special batch outcome. In this way, variations in the outcome of the dyeings supplied can for example be taken into account by the programme by their acceptance into the reference data base by subsequent modification of the original recipe.

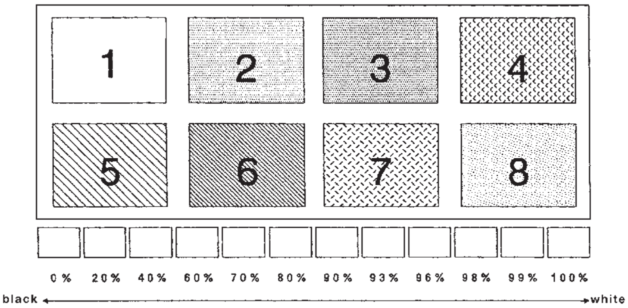


Fig. 5: Full shade palette.

Through an additionally available shade library, there is also the possibility of incorporating residual colour blends during formulation. This means that, in addition to full shades, colour blends can also become reference data, constantly supplementing the palette. This possibility increases the economic use of such a system in practice, since the residual quantities can be further processed. After producing the reference data base, the system is ready for formulation. In formulating a colour blend, not only is its colour decisive, but also its character (appearance) and its effect. Multi-colour colour blends on the one hand, and single colour blends on the other can be regarded as the two extremes. A multi-colour colour blend is understood to be a mixture, the components of which are completely or partially contrasted with each other. In the case of a single colour blend, the overall picture is rather quiet, and can almost equate with a dyeing because of the lower contrast level of the individual components. The transitions to the two forms are fluid however, i.e. in practice there are colour blends which are difficult to classify. In this case, the software offers the possibility of formulating on both effects. Formulation of the colour blends by the system takes place as follows: after measuring in or calling up the model from the memory, the colour blender selects some dyeings, vigoureux prints or colour blends from the reference data palette, and lets the computer calculate the recipe. Here, it does not matter whether the model is measured in first of all or whether the reference data components are selected. As shown in Fig. 6, obtained in the simplest case is a recipe in which the component percentage content is issued for adjusting the model, the sum of all parts being logically 100%.

In the event of brightness discrepancy, the programme automatically produces white in order to obtain the required brightness. In the reverse case, i.e. if the required depth of colour cannot be reached (recipe produced is too bright), the system gives the colour intensity achieved as a percentage of the model. The ΔE CIELAB overall colour difference and the metameric index are issued with the concentrations for the components. From a total of 13 illuminants, those which are to be formulated on can be selected, plus three additional illuminants, for which the metamerism is issued. In Fig. 6, e.g., formulation was effected on illuminant D65 (daylight), and the metamerism calculated for illuminants A, TL 84, and CWF. Illuminants D55, D65, D75, TL 84, TL 83, TL 54, CWF, WWF, ADN, C, BHS, PN25 and CR 84 can be taken into account along with the formulation. The recipes can then be analysed by the 6 colour difference formulae made available. After determining the maximum values for overall colour difference and metamerism with the selected illuminants, plus the maximum number of recipes to be printed out, the recipe variety can be kept within practicable limits. There is also the possibility of formulating colour blends on a mixed substrate basis from pure substrate components.

From the organisational standpoint, stock administration is oriented to the colour blender's method of procedure. In formulation, the first type of substrate (e.g. wool) is calculated first of all. After that, the system converts a selected recipe to the actual percentage of this type of substrate in the mixture, and takes it as a basis for formulating the second substrate (e.g. polyester). This method of procedure makes it possible to optimise recipe adjustment by taking account of the variation between model and recipe of the first type of substrate. Furthermore, each individual component can also be kept constant, or fixed at a minimum figure. The remaining stocks in the store can be incorporated

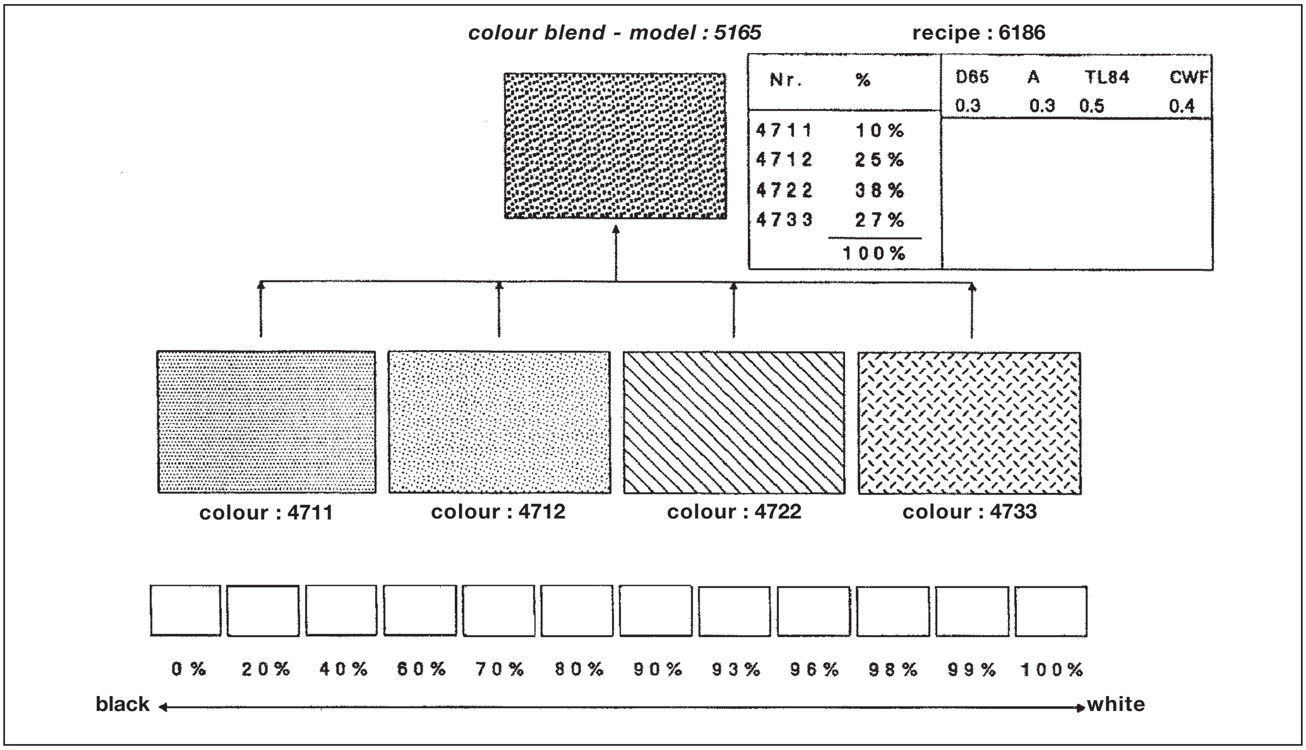


Fig. 6: Colour blend formulation.

in the colour blend in this way by fixation, which increases system efficiency, and minimises the amortisation period.

Recipe correction makes it possible to run through the widest variety of practical conditions. The diagram of a formulation with added recipe correction relates in the special case to fibre addition for shade correction. If necessary, the percentage data of a recipe calculation can be converted (in kg) in production by correction programmes to a batch size specified by the colour blender.

Colour blindness Severe form of → Defective colour vision. A distinction is made between:

I. Partial colour blindness, with little colour perception (→ Colour vision), where the world only appears in two shades of differing brightness and saturation (dichromacy), i.e. one or two bands in the spectrum are seen as achromatic (so-called neutral points). This concerns (mainly hereditary): a) protanopia, where the spectrum is reduced in the longer wavelengths; b) deuteranopia and c) tritanopia or anianthiopsy with probable reduced short wavelengths. Frequency in Germany is a) 1.1% of the male population and 0.02% of the female population; b) 1.8 and 0.02%; c) 0.003% for both males and females.

II. Total colour blindness, with no colour perception (achromasia, monochromatism), where brightness values can be distinguished. This form is rare (approx. 0.003%) and either a) hereditary, with only the rods functioning and so-called achromasia; or b) predominantly contracted – the cones are intact, but the nerves of those affected are disturbed and therefore no longer capable of colour perception (achromasia).

Colour box Rectangular trough-shaped container for print paste in roller printing machines. Print paste is transferred from the colour box via a furnisher roller to the engraved printing roller and thence to the fabric.

Colour build The intensity of colour produced by a dye in the fibre in relation to the amount of dye used.

Colour circle → Chromatic circle.

Colour clarity → Clear colour.

Colour codes → Colorimetric measures.

Colour coding for pipework Colour coding established in accordance with DIN which identifies pipework by full length painting, tags or coloured bands, coloured arrows indicating directional flow, possibly also with printed data (see Table).

Colour competence → Anomalous colour vision; Colour blindness.

Colour computer Together with a scanner, corrects hue and colour value in connection with an optoelectronic scanning process.

Colour coordinate system → Chromaticity diagram with the components of red (x), green (y) and blue (z) as coordinates.

Colour correction An electronically controlled process which takes place on a scanner after colour separation with the aid of the colour computer.

Colourcraft process (→ Space dyeing). Principle based on ombré dyeing of wool yarn hanks (5–6 shades

	Primary colour	Ring mark
Saturated steam	red	
Superheated steam	red	white
Spent steam	red	green
Exhaust steam	white	red
Drinking *water*	green	——
Hot water	green	white
Condensation water	green	yellow
Power water (feed water)	green	red
Dirty water	green	black
Overflow water	white	green
Gas	yellow	——
Town gas	yellow	red
Producer gas	yellow	blue
Water gas	yellow	green
Oil gas	yellow	brown
Fan *air*	blue	——
Hot air	blue	white
Compressed air	blue	red
Acid	orange	——
Conc. acid	orange	red
Lye	lilac	——
Conc. lye	lilac	red
Oil	brown	——
Benzine	brown	red
Benzol	brown	white
Vacuum	grey	——

Table: Colour coding for pipework.

per hank circumference). After dyeing, the yarns are twisted to produce multicoloured effects with 40–50 shades.

Colour data processing is relevant to many areas of the coloration industry. New applications are constantly added to colour data processing every year. Instrumental colour measurement has proven particularly important for quality control. However, it now encompasses the creation of new colours with the aid of the greater ease of use of colour measurement, automation of the dyehouse laboratory with automatic metering of dyes and chemicals in conjunction with computer-controlled laboratory dyeing machines, organisation, calculation of works application, control of weighing and dosing of auxiliaries, and the computerised control of production.

Colorimetry (known for over 50 years) usually refers to the measurement of spectral reflectance values in the visible range of the spectrum. These values are processed according to known methods for determining the chromaticity-scale variables, such as colour differences, colour tolerances and colour intensity. During the past 20 years colour data processing has undergone further expansion to include the calculation of dyeing formulations, formulation corrections and dyestuff additions. The increasing importance of colour data processing in industrial applications ran parallel with the rapid development and availability of computer systems and personal computer during this period. Today colour data processing is an established and indispensable tool in the dyeing industry (see Fig.).

The purpose of each colour calculation is to reproduce a desired colour by selecting the most suitable colouring components (dyes or pigments) and by the quantitative determination of the required amounts of each component to allow the dyeing of a fibre and the eventual production of a dyed sample to reproduce the required colour. This requires that the optical data, i.e. the spectral reflectance values of the colour sample be measured with a spectrophotometer. The properties of the dyes or pigments, i.e. their optical characteristics, light absorption and light diffusion properties, must be known. It is then possible, using the Kubelka and Munk theory, to select the suitable dyestuffs and calculate the quantities required to reproduce a quantitatively measured colour of the sample using the CIE tristimulus value. The purpose of this procedure is so that subsequent dyeing can be suited to all illuminants to conform as closely as possible to the original colour sample and including control of costs.

Colour monitoring is one of the major current problems not only in the dyeing industry but also for the users of dyed materials. There is an increasing requirement between processors and users to agree on colour tolerances. However, such an agreement is not practical on the basis of visual colour evaluations. Visual colour evaluation is subjective and thus sensitive to e.g. psychological effects that will have a significant influence on a tolerance factor for colour difference. An objective, mathematical system is only possible through colour data processing. However, until very recently even the practical implementation of electronic colour monitoring was restricted. The reason is that existing colour difference formulae do not usually restore the colour differences quantitatively to the visual sensation. The tolerances in the three dimensions of brightness, hue and shade are numerically different, the degree of difference is also dependent on the location of the colour in colour space. Under these circumstances electronic colour measurement could only be implemented when a colour could be reproduced sufficiently within a very close tolerance of the original colour. Based on extensive pattern collections used in industry and which were evaluated by different colourists, it was possible to specify mathematically the dependence of colour tolerances on the colour itself. This dependence offers colorimetric colour measurement that enables colour tolerances to be determined specific to the industry,

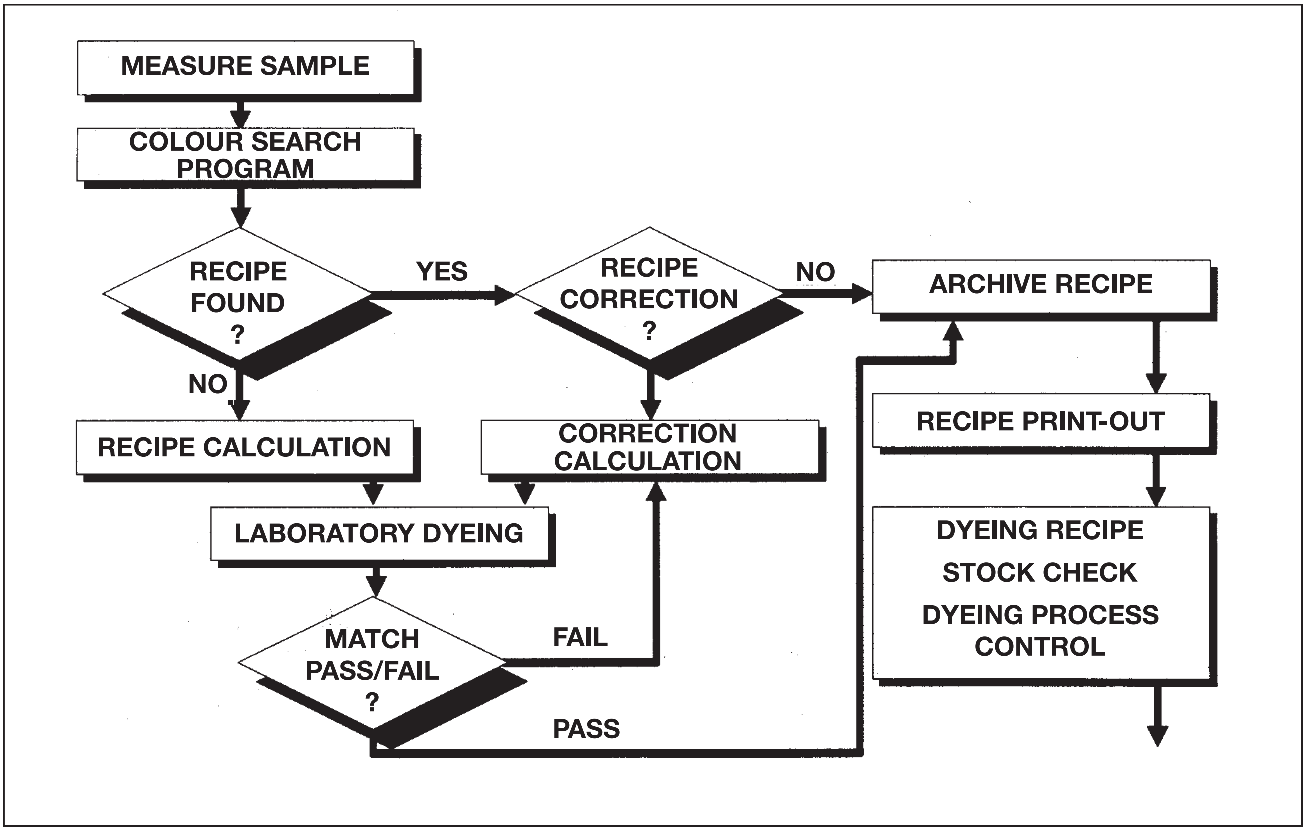


Fig.: Program flow for generating formulation using the OSIRIS program package (datacolor).

product and customer. It is known that colour tolerances are dependent also on the market situation. This circumstance can also be taken into account.

Colour data processing is possible in textile printing. In order to use a printing colour for a specific colour design, it must first be accepted in an in-house printing atlas. A CAD system can manage several printing atlases and these are separated by class of dyestuff and substrate. An atlas is selected according to the colour mode of the design. By simply choosing the required screen and the designated colour a job recipe is produced. The colour menu system is very basic. The introduction of the “English” version with its “Colour Management” brought the system nearer to a true software system. The term CAC system is also occasionally used for “Computer Aided Colouring”. The correct colour representation of printing colours is crucial for the whole of the subsequent program flow; the decision for or against a colour design depends on this correct colour representation which also affects whether the customer will accept or reject the coloration and whether or not there will be a production run.

Colour density, spectral Physical size of the → Saturation and Depth of colour. Spectral colour density is also known as → Eye sensitivity to hue, chroma and lightness.

Colour difference Two identical colours have identical CIE tristimulus values X, Y and Z in the CIE co-ordinate system (→ Colorimetric measures; Standard spectral value). Different CIE tristimulus values correspond to two different colours. However, the difference between the colour co-ordinates does not itself identify the size of the visual colour difference. Using a colour difference formula, the colour co-ordinate differences can be recalculated into one number that is a measure of the visual colour difference. This measurement is also known as the colour difference (ΔE), previously expressed in MacAdam units (→ Colour difference formulae). The calculation was frequently performed with Simon and Goodwin tables. The standardised CIELAB method is now used.

Colour difference formulae Used in the → CIE colour co-ordinates system to define the differences in colour between two dyeings showing an apparent visual difference. A mathematical value is used to correct variations in colour in → Colorimetry. The most significant are:

I. Judd formula, the oldest basis for defining the NBS colour difference unit; it is rarely used.

II. Nickerson-Stultz formula.

III. MacAdam formula, for just noticeable differences between colours (as ellipses in the CIE chromaticity diagram).

IV. Simon-Goodwin charts for practical application of the MacAdam ellipses.

V. Friele-MacAdam Chickering formula rectifies certain disadvantages of the MacAdam formula, better than IV. Computer required, extremely common. The MacAdam colour difference unit is used (1 MAE).

VI. ANS formula (Adams-Nickerson-Stultz) is recommended by the CIE (DIN 61 604). The NSB unit is used and the colour difference formula must be quoted with all details.

VII. CIELAB formula (DIN 6174) is the most commonly used formula today.

VIII. The CMC (I : c) formula of the Colour Measuring Committee (Society of Dyers and Colourists) is also gaining in importance.

Colour difference values according to CIELAB → Colorimetry.

Colour drain back plate of doctor blade Edge plate to turn colour paste back into the bank of paste before the roller.

Colour dulling → Dull colour.

Coloured articles wash All coloured or white textiles of cotton, linen or viscose which must not be washed at the boil but which will withstand washing at up to 60°C with the usual detergents. White knit goods of polyester and polyamide fibres can also be washed as a coloured wash if necessary. In laundries, coloured washes are separated according to type, colour and fibre content. Besides the 4 basic colours – yellow, red, green and blue – light and dark colours are washed separately in order to avoid cross staining.

Coloured bleach goods E.g. shirting fabrics and handkerchiefs, i.e. colour woven materials that are destined for subsequent bleaching. → Bleaching fastness.

Coloured compounds Essentially made up of three subsections: a so-called → Auxochrome group which is connected to a → Chromophore group via a system of → Conjugated double bonds. Auxochrome and chromophore groups displace the longer wavelength absorption bands of the conjugated system → Bathochrome group. Auxochromes and chromophores can be classified empirically for a specific conjugated system in order of increasing bathochromic effect. In the nomenclature, auxochromes are electron donors, chromphores electron acceptors.

Coloured discharge printing For discharge printing of white areas on a ground which contains dischargeable azo dyestuffs, a reducing agent is incorporated into the print paste so that the white ground of the fabric is developed on steaming. If a discharge-resistant anthraquinone dye is added to the discharge paste, then a coloured pattern is developed instead. If the dyes printed on are particularly luminous, then they are termed illuminating dyestuffs in coloured discharge printing.

Coloured pigments Inorganic or organic → Pigments.

Coloured resists In contrast to white resists, where the ground dyeing or the ground printing is prevented from fixing locally, and the white ground thus emerges, in the case of coloured resists another dyestuff is simultaneously fixed at this point.

Coloured woven fabric Fabric woven from predyed yarn.

Colour effect of fibres The reflective and light scattering nature of textiles is influenced by various factors that give rise to lighter or darker colour appearance with the same dye content on the same material. These factors include:

- penetration of the textile structure by the dye (e.g. when printing),
- variable dyeing behaviour of textiles,
- density of yarn and/or fabric,
- internal light scattering capability,
- special finishes, such as e.g. calendering,
- surface structure of the fabric,
- cross sectional appearance,
- fibre surface,
- fibre D'Tex (microfibres!),
- dye penetration of individual fibres.

The increase in the total surface of the fibre brings about an increase in light scattering with fibres that are becoming finer. This can be observed in the form of a lighter dyeing using the Kubelka Munk process.

$$\frac{K}{S} = F(R) = \frac{(1-R)^2}{2R}$$

R = remission,
K = measure of light absorption, predominantly determined by dyestuff,
S = measure of light scattering, determined only by the textile material.

From geometrical relationships, it follows that the specific fibre surface is inversely proportional to the root of the fibre D'Tex.

$$F = c \cdot \frac{1}{\sqrt{T}}$$

F = specific fibre surface,
T = fibre D'Tex.

If 2 different fibre finenesses are now inserted into the ratio,

$$\frac{F_1}{F_2} = \frac{\sqrt{T_2}}{\sqrt{T_1}}$$

F_1 = specific surface of the fibre of titre T_1,
F_2 = specific surface of the fibre of titre T_2,

Thus the ratio of the fibre D'Tex with different specific fibre surfaces can be calculated. Working on the assumption that light scattering is proportional to the specific surface, the ratio of colour strength with different fibre D'Tex is obtained using the Kubelka Munk equation

$$\frac{\text{colour strength}_1}{\text{colour strength}_2} = \sqrt{\frac{T_1}{T_2}}$$

As a conclusion, it can be said that as the total fibre surface increases, the dye absorption capacity also increases and therefore an increased use of dyestuff is required to achieve the same colour depths on articles with finer individual D'Tex than on articles with coarser individual D'Tex. The apparent colour of dyed fibres is dependant upon the dispersion of dyestuff through the fibre. (Fig. 1).

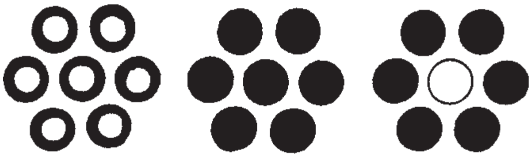


Fig. 1: Dispersion of dyestuff throughout a fibre cross section, resp. yarn cross section.

Ring dyeing and level dyeing through a fibre define the level of dispersion of dyestuff throughout a fibre cross section. Ring dyed fibres show a concentration of dyestuff in the outer areas of the cross section. A distinction should be made between this and unlevel dyeing or poor fibre penetration e.g. in the case of high-twist yarns. Certain fibre models deal with quantities of light absorbed through cylindrical fibres dependant on the form in which the dyestuff is dispersed. A round, non-delustred fibre cross section is illuminated vertically to the fibre axis by parallel beams of light. This causes refraction of the light at the air-fibre boundary (Fig. 2). The beams, which do not pass exactly through the centre of the fibre, are refracted in the direction of the beam of light that passes the centre of the fibre without breaking the boundary layer.

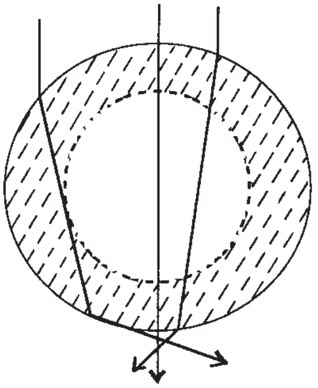


Fig. 2: Refraction of the light in the outer areas of the cross section of a ring dyed fibre.

If there are ring dyeings, those beams of light that pass though the undyed core of the fibre are not absorbed. In the area of the dyed fibre rings, however, absorption is more intense. In contrast, beams of light are absorbed right through the cross section of the fibre when the fibres are equally penetrated. Taking into consideration the diameter of the cross section of the fibre, the thickness of the layer of ring dyeing, the fibre's refractive index and other factors, it follows from this model that a ring dyeing has a lower colour yield than penetrative dyeing with the same quantity of dyestuff. A better dyestuff penetration of the fibre cross section results in a result comparable to the theoretical colour yield (visual colour sensation) where there is complete penetration. If the penetration of the dyestuff in the cross section of the fibre increases from 20% to 70% (with reference to the radius of the fibre), then the apparent (visual) dyestuff content is observed to increase by 30% where the same quantity of dyestuff is used (Fig. 3). However, an even higher percentage of penetration is barely perceivable.

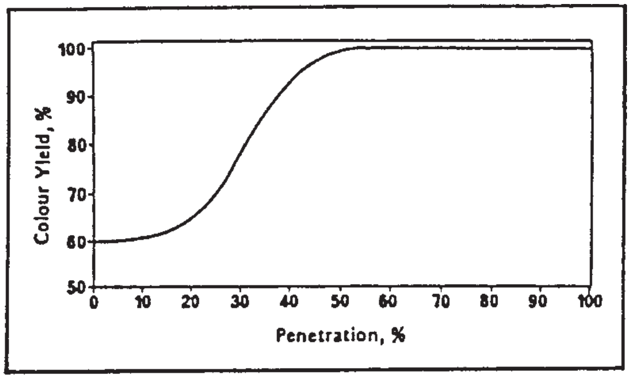


Fig. 3: Effect of the penetration of the dyestuff in the cross section of the fibre on the colour yield using Dacron by Du Pont and dispersol blue D-2R by Zeneca.

If 10% of dyestuff is dispersed through a cross section of fibre (located on the outer cross section), this corresponds to a colour yield of 60–75% of a penetration of equal concentration. The "change in colour" which occurs between ring dyeing and penetration is however larger, the smaller the dyestuff ring. Ring dyeing with approx. 70% dyed fibre radius gives exactly the same colour sensation as penetration. The → Kubelka Munk value is often used to assess the visual colour effect. This value rises as penetration increases with the same quantity of dyestuff. If approx. 80% penetration is achieved, the rise is only negligible, having very little effect on the colour appearance of the material.

Colour embossing →: Embossing; Embossing calender; Emboss printing

Colour fastness In the normal sense this is understood to refer to the resistance of a dyed or printed textile to various types of influences to which they are normally exposed in textile manufacturing and in practical use. In colour fastness tests, changes to the colour of the sample and staining of undyed adjacent fabrics tested at the same time are visually assessed using the → Grey scale and these are then given as fastness values. It is a basic concept of the tests that they are of a high level of reproducibility in result, may be carried out in a relatively short time and have a good degree of relevance to the demands of textile manufacture and use. Nevertheless they will always tend to create an artificial assessment condition and they cannot be expected to give a definitive statement of the potential behaviour of a textile in all the varied circumstances arising in manufacture, use and care of textiles. The test standards form the general basis for the testing and assessment of colour fastness properties. A specific aim of the test methods is to give clear instructions to the personnel carrying out the tests in order to achieve optimum reproducibility. In this respect, developments are to be noted which arise increasingly from the introduction of quality assurance systems and product liability. State, industrial and private testing organisations and institutions carry out colour fastness testing. Employees must be trained and qualified to carry out the testing and the whole process must lend itself to a Quality Audit system as part of a Quality Control process. The test methods can also be used to determine the colour fastness properties of dyestuffs. The dyestuffs are individually applied in specific depths of shade according to appropriate dyeing and printing processes on a suitable textile substrate and then tested for colour fastness. The fastness values obtained are shown on the dyestuff manufacturers sample cards. The changes in colour arising in the colour fastness tests and the staining of adjacent fabrics are now visually assessed in accordance with the standards ISO 105 AO2 (Change of shade) and ISO 105 A03 (Staining). It is probable that colorimetric assessment of test results will be used in the future to complement and/or replace the largely subjective assessment used at present.

1. General use fastness properties: Usually involves testing to light-, weathering- and washing-fastness and may include perspiration and crocking (rubbing) fastness.

a) The test for → Light fastness and fastness to weathering is particularly important for the permanency of the colour. The eight shades of the blue scales; standard dyeings with a geometric sequence of increasing resistance to exposure to light are the generally accepted basis for assessing light fastness. Where time is a critical factor, exposure to actual daylight has become less common due to the long testing time involved. More rapid testing is employed using a xenon lamp as energy source with an emission that is filtered to give similar values to real sunlight. A great deal of attention has been recently devoted to improving the test equipment. In addition, intensive research work has been carried out on measurement and control of the radiation, which will imitate the effects of a naturally variable source from Nature. A suitable testing method to determine the light fastness of interior materials in cars, i.e. car upholstery is → High temperature light fastness. This takes into consideration e.g. the occasionally very high temperatures arising in closed cars and the possible long periods during its use when the vehicle may be parked in the sun, resulting in the light effects being significantly intensified. This gives a requirement for extremely high light fastness. Reliable testing for this is required within a very short space of time, i.e. within a couple of days (ISO 105–B06). It is also possible to test textiles whilst they are exposed to wet conditions. This phenomenon, which is particularly significant for dyeings on cellulose fibres, of the light fastness being impaired by wetting with water should lead to new test processes. It is also possible to assess the effects of stains from cosmetics, sun protection agents or even undiluted washing liquor on textiles in conjunction with light exposure. Efforts are being made to further reduce exposure times that are decreased in exposure testing devices with uninterrupted use by a factor of approx. 1 : 9 in comparison with daylight. Often, the intensity of the emission or the proportion of short-wave radiation is too high and this questions the reliability of tests for light fastness. Such tests can at the most give a certain indication of the light fastness of the samples in individual cases.

b) A decisive innovation has been introduced in → Washfastness testing. Testing with soap as a wash active substance is complemented by washing with a compound detergent, the ECE colour fastness test detergent 77 with the addition of perborate. The use of multiple-fibre adjacent material (“multi fibre strip”) has been widely introduced. Wash fastness testing in accordance with DIN 54 017–C06 is also used as a basis for textile care labelling.

2. With fastness to processing, the → Potting fastness with wool is becoming less important, as the test conditions no longer correspond in their intensity with the relatively mild conditions with continuous crabbing. In contrast, fastness to cross dyeing has become extremely important as a result of fashion (source: Söll) → Fastness testing.

Colour fastness commission → Fastness commission.

Colour fastness improvement → Fastness improvement.

Colour fastness requirements in manufacturing → Fastness requirements in manufacturing.

Colour fastness testing → Fastness testing.

Colour fastness to acids Resistance to the effects of dilute organic or mineral acids. Three types are used with increasing severity of effect. The Standards apply to all fibre types. Treatment types: a) 100g/l crystallised tartaric acid; b) 300 g/l acetic acid 100%; c) 50 g/l sulphuric acid 60°Bé. Acetate is only tested with a) and c). Acid dilutions are prepared with distilled water. Test samples are treated with two drops of the dilutions. Assess any change in colour after 10 min reaction time at room temperature. Carry out a second assessment once the test piece has dried at the same temperature (DEK; ISO: only assessed after drying). Assessment: grey scale/change of shade.

Colour fastness to cross-dyeing → Fastness to cross-dyeing.

Colour fastness to degumming → Fastness to degumming.

Colour fastness to dry heat Synthetic fibres have become extremely important in the manufacture of yarns and fabrics. Thermal processes for setting the fibrous material itself or for thermosetting the dyes onto the material play a substantial role in the processing of synthetic fibres. The development of these thermal processes has lent increasing weight to the testing of the fastness to dry heat of the dyes. In the course of these finishing or dyeing processes the material will pass through temperature zones of 150–220ºC depending on the type of the fibre and construction of the fabric. Many dyes cannot withstand these kinds of temperatures, however, and will undergo change. Particularly with disperse dyes, which are used primarily in the dyeing of synthetic fibres, sublimation of the dye can be experienced in this temperature range, whereby the dye will either be precipitated on other parts of the fabric causing stains or else form deposits in the machines in which the processes are carried out, causing the equipment to become contaminated. It is therefore important that these phenomena are investigated in the laboratory and that the behaviour of a dye at these high treatment temperatures is predicted.

The Fixotest apparatus (Heraeus) has been developed to perform this test. In order to test the colour fastness of dyes to heat setting, ironing and contact heat, the Fixotest involves examining the effect of heated metal surfaces on the textile dyes under investigation. The test fabric is sandwiched between undyed adjacent fabric and then placed between the heated plates of the apparatus. After testing, the colour change and any transfer of the dye onto the adjacent fabric are assessed. Standards are applied in testing the contact heat stability of dyes on synthetic material by means of the Fixotest. This test is described by the International Organization for Standardization (ISO) in its ISO Draft Recommendation 173 “Colour Fastness to Dryheat” and regulated in Germany by the German Industrial Standards (DIN) in DIN 54 060 “Determining the Fastness to Pleating and Setting in Dry Heat of Dyes and Prints”. This fastness test involves the assessment of the resistance of the colour of textiles to the effects of dry heat. Both the Draft ISO Recommendation and DIN 54060 describe the testing of dyes at three different experimental temperatures (150, 180 and 210ºC) over 30 s, in which the contact pressure exerted on the test piece is 4 ±1 kPa. These standards apply to synthetic fibres and blended fabrics containing synthetic fibres, but not to determining the colour change that occurs with synthetic resin finishing processes (permanent press process or thermosol process).

Colour fastness to hot pressing → Dry heat setting and pleating fastness.

Colour fastness to milling → Fastness to milling.

Colour fastness to processing → Fastness to processing.

Colour fastness to rubbing Colour fastness of all kinds of textiles to abrasion and the staining of other textiles in use. Staining due to extensive fibre abrasion is not taken into account here. In the USA, a distinction is occasionally drawn between “crocking” and “rubbing fastness”. “Crocking” is understood to be colour transfer from the surface of a dyed fabric to an adjoining fabric of the same type or to another surface by rubbing; “rubbing fastness” describes the dyeing shade change. → Rubbing fastness testing.

Colour fastness to rubbing, organic solvents Fastness to crocking with organic solvents. This test provides an indication of the resistance of the shade to organic solvents on rubbing. Testing is carried out with the → Crockmeter (which rubs to and fro 10 times in 10 s over a distance of 10 cm with a load of 900 g). A cotton rub fabric is wetted in the organic solvent and squeezed to 100% solvent content before carrying out the test. Dry in warm air (< 60°C). Both the change in colour and the degree of staining are assessed with the grey scales.

Colour fastness to salt water → Fastness to sea water.

Colour fastness to soda boiling → Fastness to soda boiling.

Colour fastness to storage conditions (Colour fastness during storage),

I. Mainly used for → Formaldehyde fastness, as formaldehyde from packaging causes colour change under certain circumstances. Less often for sulphur dyeings, which split off sulphuric acid, and result in fibre damage.

II. → Sublimation fastness during storage.

Colour fastness to washing considerations for dyeings and prints → Fastness to washing.

Colour furnisher roller Used to transport, mostly in thickened, dyestuff or textile auxiliaries to the fabric; also in pigment printing, the roller printing machine.

Colour gate This is a term for a retractable component in roller printing machines. The colour application unit (trough, doctor, counter doctor) is stored in the colour gate, thus reducing the machine set-up times and enabling the colour way to be changed more rapidly.

Colour grinding mill This is used in printing and coating to finely grind print or coating pastes.

Colour in artificial light Visual change to the same colour under different lighting conditions (standard light types). The name for the colour shift that can occur when a material is examined under artificial light. Some dyeings exhibit different reflective properties under artificial light in comparison to daylight.

Colour Index (C.I.), well-known English reference book dealing with dyes (trade names, constitution), optical brighteners, reduction agents and developers. Publisher: Society of Dyers and Colourists. The enormous increase in the number of dyes on the market after mauve was discovered by H.W. Perkin in 1856 soon led to an "identification book" that was published by J.W. Slater in 1870 under the title of "The Manual of Colours and Dyewares". The individual products were listed in alphabetical order, which is one reason why this first classification book was unsatisfactory, as were several of the ones that followed. The new type of coal tar dye classification published by W.R. Richardson in 1885 was an improvement. It contained an alphanumeric list of all commercial names, together with the chemical nomenclature and formulae; however, the dyes were classified in spectral order. The previous most well known book was published in 1888, the "Tabular Overview of Artificial Organic Dyes" by G. Schultz and P. Julius. This was based on the chemical structure of the dyes, which were also listed in spectral order according to their hues. The publication was a great success and was the standard work for more than 50 years. The Colour Index, which was published by the SDC and was well known worldwide as a classification book, appeared for the first time in 1924. After a number of similar publications in English and German the SDC decided to publish "an English version that will provide comprehensive scientific and descriptive information on the subject of all known dyes".

The 1st issue of the Colour Index aroused so much interest among dye manufacturers and users, teachers and researchers that in the late 1940's a decision was taken to produce a second issue based on the following three objectives:

1. Including and organising the different brand names of individual dyes.
2. Providing information concerning usage, fastness properties, solubility, discharge capability etc. and the established application areas of commercial dyes.
3. Providing information on the chemical structure of technical dyes or their components and manufacturing methods, appropriate literature and patent references.

Dye characteristics that were listed under a certain "Colour Index Generic Name" had already been mentioned in the first issue. As a general guideline it may be justified to assign these characteristics to a certain chemical constitution, thus identifying them; but it must also be pointed out that the characteristics of the individual commercial products that are based on this structure are not necessarily identical. This deviating behaviour has become more and more frequent in recent years. In practice, it has shown dyers and printers time and time again that commercial dyes with the same basic chemical structure do not necessarily have to have the same properties. Solubility, dispersion, fastness and other properties may differ considerably in commercially available dyes with different history, even if they are based on the same colour index name and structure. On the whole, dyes that are exactly the same (this refers to a sole manufacturer's production, not traded dyes) are fairly rare.

Dyes always differ in the degree of purity, type and quantity of diluents and other additives, particle size, crystal structure, formulation, solubility, sensitivity to external influences etc. In recent years these kinds of differences have been even more clearly evident for two reasons; a) various manufacturers have adapted their products and manufacturing methods with regard to raw and intermediate materials, processes and industrial equipment for cost and environmental reasons; b) the products have been specifically revised as a result of increased demands for easy handling and quality in research and production and therefore tend to show differences in certain properties from those of the original product, whilst maintaining the chemical structure. The demands made of dye characteristics and the relevant testing methods have changed since the Colour Index was created; they have both become more numerous and more stringent (source: Schmid).

Colour in fashion textiles This is understood to mean the production of fashion colour effects on all types of fibrous materials using a wide variety of methods. The following processes are possible without use of engraved rollers or stencils, i.e. they are not typical print processes: tie-dyed batik, skeining process, Art-colour-Method, shock process, scattering of synthetics, burn-out styles, bubble coloration process, coloured effects, craquelé effects, degradé articles, denim, dye-weave process, crease techniques, flow-form process, grill, kasuri, warp dyeing, kiss dyeing process, knit-deknit process, Küster's colour method, multicoloured effects, multicoloured process, multi-TAK, museka, ombré dyeing, polychromatic dyeing, powdered dye scatter process, Rema colour process, reverse coloration process, shadow dyeing, space dyeing, space treating, TAK-dyeing.

Colour intensity of dyeings/printings (→ Depth of shade). The colour intensity of a shade can be determined using the simplified Gall-Riedel formula with reference to the absolute scale of the STD.

$$B = K + Sa_{(\lambda f)} \cdot \sqrt{Y} - 10\sqrt{Y}$$

B = colour intensity,
K = colour intensity dependent factor (K = 20 for $^{1}/_{1}$ STD, = 29 for $^{1}/_{3}$ STD, = 37 for $^{1}/_{6}$ STD, = 41 for $^{1}/_{9}$ STD, = 48 for $^{1}/_{12}$ STD, = 56 for $^{1}/_{25}$ STD.
Y = lightness (= CIE tristimulus value Y),
S = linear distance of the colour locations from the achromatic point (CIE triangle),
a = shade-dependent factor.

To determine S and a, the CIE tristimulus values X, Y, Z or the resulting chromaticity co-ordinates x, y are required. The S and a values can also be taken from colorimetric tables of measured values. This gives a good basis to prepare exhaustion curves. This is tested in practice.

Colour intensity, tinctorial This is the amount of a dyestuff determined by tests required to replace a reference dyestuff, in contrast to → Depth of shade that is used to evaluate the dyestuff fastness (but which is often approximately equal to the colour intensity).

Photometric determination of tinctorial colour intensity of a dyestuff.

I. Dyestuffs with unknown and known tinctorial colour intensity are applied at known concentrations C_S and C_P. The reflectance data of both dyeings R_S and R_P are determined. The ratio

$$\frac{F(R_P)}{F(R_S)} \cdot \frac{C_S}{C_P} \cdot 100$$

gives the tinctorial colour intensity in %.

$$F(R) = \frac{(1 - R)^2}{2R}$$

is taken from the Kubelka-Munk model.

II. Measuring dissolved dyestuffs. The transmission T (%) is determined. The concentration c is derived from the Beer-Lamberts law:

$$\text{Extinction } E = \log\frac{1}{\tau} = A \cdot c$$

E is taken from tables or supplied directly from the colour measuring instrument. τ is the transmission factor. The intensity ratio between the sample P and standard S can be calculated using the following formula:

$$\frac{E_P}{E_S} \cdot \frac{C_S}{C_P} \cdot 100, \text{ in } \%$$

Colourist The Latin root “colour”, still alive in many languages today, leads logically via colouration (dyeing, colouring) to the colourist, who is specifically concerned with it. The true domain of the colourist is textile printing, and the designation is largely in common use in many textile printing works today. In a more general sense (bleaching, dyeing, finishing), the professional term “textile chemist” is used.

Colour kitchen Work room for the preparation of print paste thickening and the formulations of colour pastes (Fig. 1). The way in which the colour kitchen is organised in many cases determines the productivity of the entire printing plant. Economizing in investment here is definitely false economy. A rotary printing machine running to capacity can e.g. achieve up to 5000 kg/h colour paste consumption, i.e. approx. 80 t printing paste are required in two-shift operation, for which e.g. approx. 1.5 t thickening powder must be processed. This significant amount of printing paste is under normal circumstances divided by on average 6 colours per colour design and pattern. Depending on the number of colours of the printing machine, there must be at least two printing paste containers of corresponding volume. The first container serves to feed the printing machine, and the second to prepare new printing paste. In addition a number of containers of differing volumes is required in order to formulate the appropriate quantities of printing paste economically. Care should be taken that containers with stirrers fitted must be charged with at least $^{1}/_{4}$ of their possible volume in order to ensure perfect processing of the print paste; i.e. a 3000 l tank must have a minimum of 1000 kg of printing paste, and a 1000 l tank a minimum quantity of 300 kg. It must be possible to alternately charge and combine the containers from one to the other, i.e. the containers should be inter-connected by pipes. To effectively manage the transport of the large amount of printing paste and the associated quantities of dyestuff, auxiliaries and thickeners, a system of pipes is used. The chemical storage, in the form of a tank, the dyestuff store in the form of containers, the weighing area, the solvent and paste formulation station and the metering station also form part of the colour kitchen.

Chemical store: Larger containers which can be refilled from the tanker are generally used for the chemical store, containing approx. 3–5 t. The store for fluid products is generally specifically arranged below the working level. The liquid products are transported to

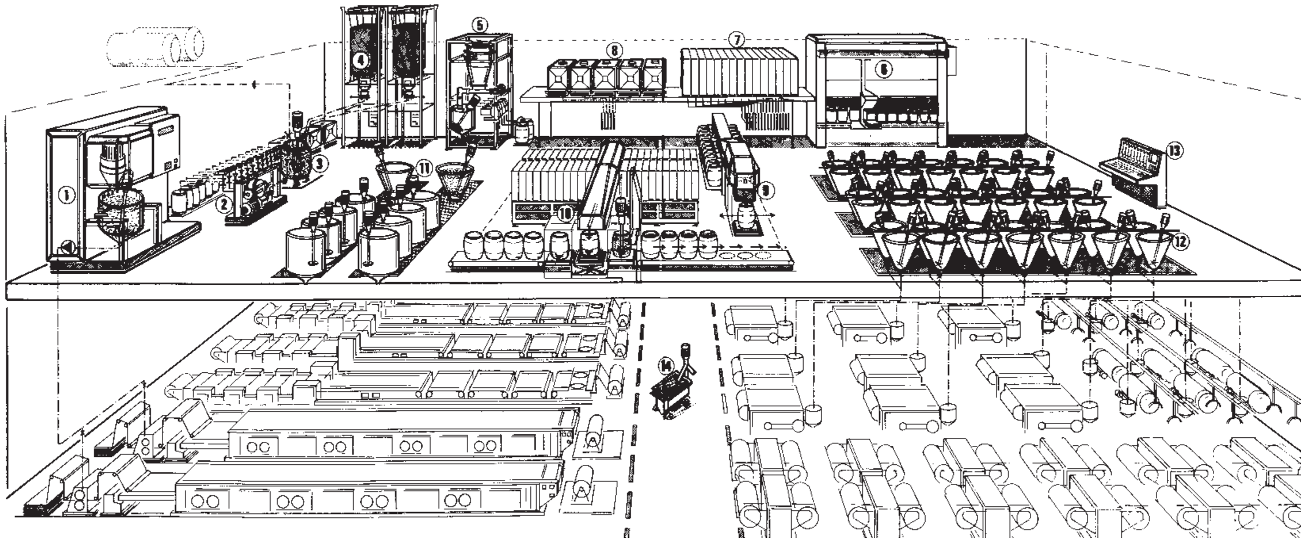


Fig. 1: Van Wyk printing and dyeing colour kitchen details.
1 = colour paste stirrer; 2 = metering unit; 3 = mixing tank; 4 = metering unit; 5 = sodium dithionite station; 6 = paternoster; 7 + 8 = chemical metering; 9 = small batch stirrer; 10 = paste metering; 11 + 12 = dissolving tanks; 13 = control cabinet; 14 = salt metering.

the working level or to the formulation station by means of feed pumps. The pipework is made of plastic. Glass fibre reinforced polyester resins, if necessary with polyvinyl chloride lining are gaining in importance as a material for this type of formulation vessel. The position of the filling station on the outer wall is particularly important so that filling can take place directly from the tanker. Chemical metering takes place in so-called measuring cylinders or plastic containers (suitable for chemicals). The quantities are accurately measured by shared metering pumps. Dyestuffs and auxiliaries are delivered in solid and liquid form in sacks, barrels, containers and tankers. The supply of salt, required for dyeing cotton with reactive dyestuffs, has developed to the point where salt is delivered using large bulk food transporters, storage takes place in large volume and space-saving storage bins. It is transported from here to the dyehouse by means of screw conveyors. In many dyehouses, brines produced in-house are used. A concentrated salt solution, the so-called brine, is manufactured in large basins and is then metered via pumps to the relevant areas where it is required.

Dyestuff store: The main store for the dyestuff required is chosen to ensure its smooth transportation. The climatic conditions (cool and dry atmosphere) of the store is adjusted such that the products cannot bond together or clump together. The dyestuff store should be set up in a manner which facilitates the handling of the fluids. A variety of packaging is available for liquid dyestuffs: barrels, canisters, cans or containers. With cans, a larger opening than with canisters is preferred so that a small mechanical agitator can be used for stirring. As moisture must be avoided, the dyestuff store is separated from the actual colour kitchen where the dyestuffs are weighed out and dissolved. When storing dyestuffs and chemicals, specific guidelines are to be observed to avoid certain risks. It is not universally known that dye powders are highly flammable. Dye powder fly is also toxic under certain circumstances.

Weighing area: The weighing area and dissolving plant should if possible be situated close together. In the intermediate storage, paternoster systems or dyestuff carrousels have proved their worth compared to stacking shelves. In the weighing area, the heart of a colour kitchen, electronics have revolutionised weighing. A significant factor in the successful reproduction of dyeing processes is the precise adherence to the quantities of dyestuff and chemicals prescribed in the recipe. Electro-mechanical scales connected to a computer are used.

Dissolving plant: This is a working area in which the dye solutions and print pastes required for dyeing and printing textiles are prepared. Efficient production operations have central mixing and dissolving plants equipped with state of the art equipment. Walls and floors have ceramic tiles. Slatted floors above the floor help to increase cleanliness and prevent accidents. The actual formulation station consists of groups of containers which correspond to the machine types and assemblies. Each production machine should generally contain at least one dissolving tank to avoid periods of overlap and waiting time in the formulation and feed stages. The force of gravity aids the transportation of formulated liquors through glass pipes.

Automatic dye metering plant (Fig. 2): The process requirements of dye metering plants have increased considerably, as substantially higher precision is re-

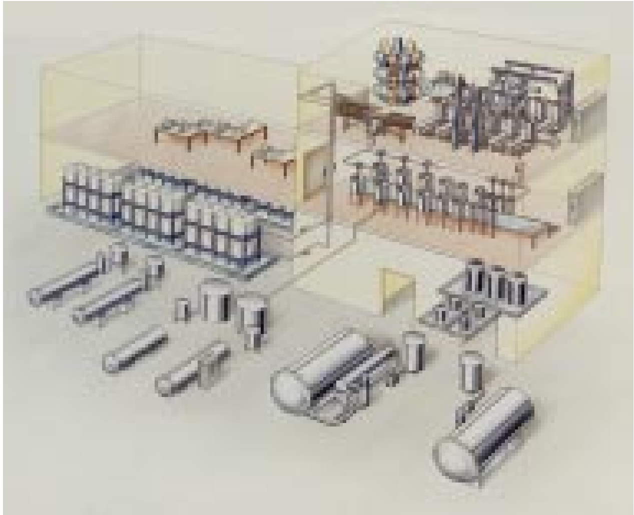


Fig. 2: Colour kitchen for open-width dyeing.

quired. To achieve this aim, a metering combination is used. The metering head can be fitted with two or three metering devices. The working volume of the metering devices used is fixed at 0.1 over 1.0 to 10.0 cm^3 per stroke. A distinction is made between a central valve arrangement with stationary scales and valves arranged in rows with movable scales. Three-stage dye metering valves can be arranged in groups or in rows and thus be adapted to the spatial requirements. A distinction is made between the following metering systems:

a) pump metering using volumetric pumps;
b) metering where the weighing receiver is installed securely,
  - with rotating metering head
  - in annular form securely mounted ("cluster");
c) linear metering with movable scales;
d) combination of the above systems for dye houses and finishing.

Purely gravimetric plants: This method is dependent on a number of parameters which can be defined as follows

a) inner precision of the scales;
b) external influences on the scales (vibrations, air blasts etc.);
c) type of metering valve.

Scales must achieve the required precision tolerances. First, it is necessary to define the over-run. Without wishing to go into the details of the laws which influence automatic metering, the significance of the following factors should be emphasised:

- the product rheology,
- the metering quantity,
- the relative height between the container and the metering valve,
- the inertia of the scales.

This operation requires the correct software. In gravimetric metering in practice, there is the problem of over-run: The flow dynamics cannot be interrupted abruptly without a slight surplus. A classic gravimetric device is composed predominantly of a liquid feed pump. When choosing such a pump, it is important to note that this must have a constant feed capacity. An elegant technical alternative is possible by choosing a pump capable of precise feed capacity by means of computer-control. Regulation of the feed capacity can be optimised by adjusting the main metering slide valve, altering the inflow to a greater or lesser extent to adjust the feed capacity of the pump.

Volumetric metering: This can be divided into two categories:

1. Volumetric metering using metering pumps: Due to the high costs involved in achieving sufficient precision, metering pumps are not used where several components are to be metered. Metering pumps can only be successfully used when precision is not an important factor and when average production rate is required.
2. Volumetric metering using impulses: With this method, the product to be metered is introduced into a calibrated chamber before being released into the processing container. An example of this is piston metering. This permits a 100% metering or a multiple of this metering by repetition. A method derived from this principle consists of using several metering chambers (modules) of varying volumes in order to achieve metering of different volumes, e.g. 110, 10.1 and 0.1 cm^3. Thanks to this system, a high degree of precision can be achieved. With a metering module of e.g. 100 cm^3 the tolerance is ±5%, which corresponds to 0.005 cm^3. The rheology of the products naturally impairs the smallest possible metering quantity.

Gravimetric-volumetric metering: A combination of both the systems discussed above. This enables high and precise performance to be achieved, taking advantage of the benefits of both basic methods. In practice, it should be noted that gravimetric-volumetric metering sometimes eliminates one or more work stations. It is possible to achieve metering of e.g. 0.1 cm^3 on one work station when a batch of 1 t is being metered.

The textile industry requires a high degree of precision from colour kitchen manufacturers on the one hand, and on the other a high performance (speed). Even in order to dilute dyestuffs, it is necessary to be able to meter very small quantities, if possible, smaller than or approximately 0.1 g. These conditions lead inevitably to a volumetric-gravimetric solution.

Colour kitchen installation (for printing). Machines and equipment for the preparation of print pastes, e.g. boiling kiers for thickening agents with or without stirrers, sieves and screens, vacuum filter machines etc.

Colour lakes Metal-dyestuff compounds which arise e.g. during cationic dyeing and mordant dyeing processes or when developing dyes using metallic salts (→ Chroming of dyes). The low solubility of this type of compound and their strong adhesion in or on the fibre determines the relative high fastness to processing and wear resistance of such dyes. Pre-prepared colour lakes are → Colour lake substances.

Colour lake substances Partially water-soluble dyestuffs, and also frequently not real dyestuffs, but → Colour lakes, and then correctly subordinated to → Pigment colorants. Use: dyeing lacquers, plastic masses, metal foils etc. Frequently in pigment printing (flock, lacquer and porcelain); dyeing coating masses; for spraying and stencilling (edging) coir matting etc.

Colour location (Colour point). The → Chromaticity diagram includes colour locations of different → Type of colour. Colour locations of the same shade are located on straight connecting lines between the achromatic point (= colour location of the physical ideal white) and the demarcations of the chromaticity diagram. As the hue moves away from the achromatic point, the colour becomes more saturated.

Colour manipulation The work of a colourist in the printing plant also includes determining the colours used in a design. Of the many colours that can be perceived by the human eye, he must select the ones which best suit the design he is preparing and harmonise these with one another. Fashion, trends and market developments must be taken into consideration. His choice determines the success of a specific design. There is also the problem of increasing time pressure due to the fact that different collections are being released in more rapid succession. If 5–6 collections are to be brought out every year, it must be possible to decide which designs and which colorations go into production quickly and sensibly. The modern colourist cannot allow designs to be printed without control. The time pressure already mentioned together with financial considerations force him to make a selection in advance. For these reasons, it is logical that there is a need for computer systems that support the colourist in his work (Fig.).

Colour manipulation is integrated into the system: Design (e.g. purchased); this design is taken into the computer system using a scanner; Colour and form are manipulated on-screen, the design is printed out on paper or fabric as a strike-off for approval, recipes are formulated for the printing plant (colour physics); weighing-off of the dye pastes in the colour kitchen and printing in the print area.

1. Reading-in: A creative draft on textiles or paper can be read-into the CMS-2000 system (Stork) in two ways: firstly with the aid of an online connection to a scanner and secondly by reading-in digital information from a videodisk which has been produced e.g. by the engraver.
2. Reducing: When a design is keyed in, the number of colours can be reduced, the number of half tones defined and the overlap determined. The Stork CMS-2000 system can carry out these processing stages.
3. Coloration: After reduction or reading-in the actual work of composition of the colours can begin. The user can call up thousands of different colours using the CMS-2000 system and assign these to the design. When selecting the colours, several colour charts stored in the memory can be used.

Colour Atlases provide various colour models such as RGB, CIELAB and HSV. The various colour atlases can be matched to dye groups, substrate, client, season etc. This enables the colourist to work quickly and selectively for various clients or target groups. The user can compile these colour atlases himself and make changes where necessary. If a spectrophotometer is connected to the system, colours can be measured with greater accuracy and these colours can be added to the colour atlases. During the colouring process, a selection can be made from the various colour atlases and these can be added to colour cards. These colour cards can be displayed on the screen with the colour atlases if required. With the aid of the printer, it is possible to print out colour atlases on paper or on fabric with Stork ink jet printing which implies that the system automat-

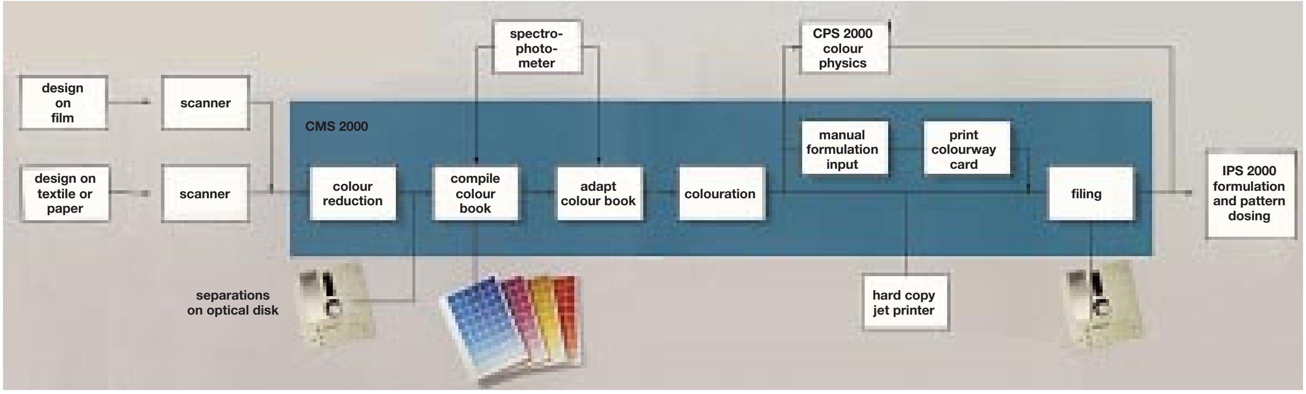


Fig.: Colouration in the printing system (Stork).

ically adjusts the colours used by the printer. The client receives a total overview of the possible colours. This provides the client with the opportunity to state which changes he would like. After compilation of the various colorations, this information can be printed out or stored on the videodisk for archiving. The information can also be transmitted to the Stork Screens Image-3000 engraving system.

Colour matching lamp This is used for colour matching with a specific illuminant. The most common example is the → Xenon arc lamp. With inert gas high-pressure discharge lamps, e.g. the spectral energy distribution corresponds almost entirely with that of the cloudy sky and the solar radiation and shows a practically constant light. This type of systematic illumination is therefore suitable for → Colour matching of dyed/printed samples.

Colour matching of dyed/printed samples Comparison of dyed materials to a standard sample. Usually takes place in colour matching cabinets under specific lighting conditions, D_{65}, TL 84, (→ Standard illuminants). In order to support subjective visual colour matching, colour measuring devices are usually used. Some colour matching still takes place in daylight (north light, walls and equipment in neutral grey). Problems are revealed using different sample surfaces (e.g. glossy, textured etc.) and the matchers' different subjective sense of colour (deviation from normal colour perception).

In order to remove the influence of the varying composition of daylight (see Fig.) on colour matching, standards and dyeing samples are viewed under technical light sources. Here the colour matching cabinet has the advantage that it narrows the colour matcher's field of view to the area that is important for colour matching, and shuts out the surroundings that affect colour perception. Daylight lamps or xenon colour matching lamps are used in colour matching cabinets.

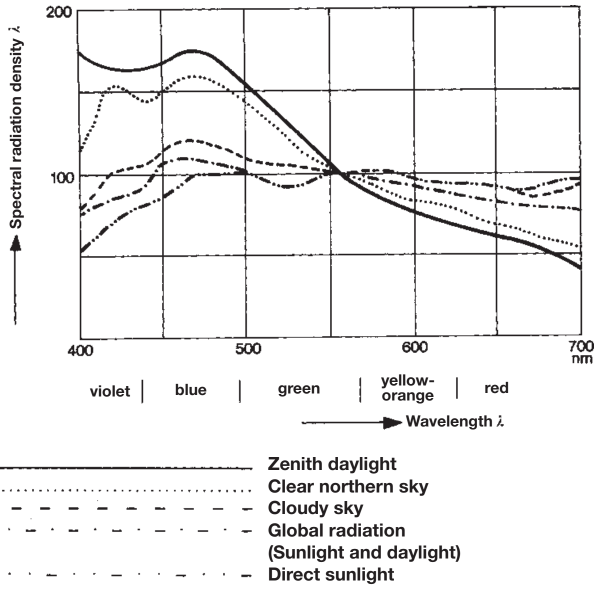


Fig.: Relative spectral radiation density distribution of natural daylight (source: Taylor and Kerr).

I. Daylight lamps: these provide extremely good colour reproduction characteristics, since the relative spectral energy distribution is adapted to the daylight phase D_{65} (colour temperature 6500 K). The Original Hanau daylight lamp is designed to be suspended from the ceiling. It is housed in a special anodised aluminium reflector. 2 special neon tubes with an output of 40 W provide the radiation source. The relative spectral energy distribution of the radiation, which remains constant over the entire lifetime of the neon tubes, is particularly beneficial. The manufacturer recommends replacing the neon tubes because of intensity fluctuations after 2500 hours of operation. Special mention must be given to the low operating costs of the radiation source with an output of just 80 W and immediate readiness for use, since no warming-up time is required. The operators do not have to put up with smells or heat since neither ozone not nitrous oxide are formed, not does heat radiation occur.

Entire rooms or material webs can be illuminated using the daylight lamps, e.g. examination tables, tensioning machines, printing and coating machines. The light intensity is 1150 lux at a distance of 80 cm from the material and with an illuminated area of 18 x 81 cm.

II. Colour matching lamp: The colour matching lamp can be used where high qualitative demands are made of the daylight phase D_{65}. The radiation source also efficiently adapts itself to the daylight phase D_{65} in the UV range. This means using colours that also absorb radiation in the UV range during colour matching, because they contain white colours (optical brighteners), for example, or when illuminating white materials. In the above-mentioned field the xenon colour matching lamp has benefits compared to the Original Hanau daylight lamp. D_{65} daylight has been standardised for colour matching in the spectral range of 300-700 nm in the German standard 6173 in the FRG. This standard assigns colour matching lamps to quality categories with regard to adaptation of the spectral distribution to standard light type D_{65}, whereby adaptation in the UV range is also evaluated. For this reason the colour matching lamp complies with quality class 1, whereas the daylight lamp is assigned to quality class 2. Other points concerning the colour matching lamp must be highlighted:

- the light intensity is 2500 lux in the centre of an illuminated area of 25 x 25 cm with the colour testing lamp at a distance of 50 cm from the observation plane.
- the colour testing lamp is supplied with direct current via the fluorescent lamp transformer so that the spectral energy distribution does not change when

mains power fluctuations occur. This guarantees colour reproduction conditions that can be repeated time and time again.

- the device consists of a housing with a 150 W Xenon radiator, an ignition device and a fluorescent lamp transformer and rectifier. Light types D_{55} (colour temperature 5500 K) and D_{75} (colour temperature 7500 K) can be realised using appropriate adjustment filters. Preference should be given to the use of a xenon colour matching lamps if only absolute balancing of artificial radiation to global radiation is expected during the colour testing of white materials and dyes with absorption in the UV range.

III. Colour sampling cabin: the colour sampling cabin contains 4 types of radiation for comparing colours under optical conditions, such as those occurring in daylight, standard light A (evening light), department store light or long-wave UV radiation. This universal arrangement allows metameric colours to be investigated by observing them under two different types of light and simulating department store light conditions. Furthermore, the UV radiation sources allow fluorescence appearances to be checked in fibres, dyes and all materials treated with optical brighteners. The Variolux colour sampling cabin is also a UV analysis lamp.

The 4 types of light in the colour sampling cabin:

- daylight with a colour temperature of 6500 K, good adaptation to standard light type D_{65} and an illumination intensity of at least 1000 lux.
- standard light type A (evening light) with a colour temperature of 2800 K and an illumination strength of approx. 3000 lux.
- department store light, a cool white fluorescent light with a colour temperature of approx. 4400 K and an illumination intensity of approx. 2000 lux.
- long–wave UV radiation with the maximum radiation intensity of approx. 0.1 mW/cm^2 at a wavelength of 360 nm.

The specified illumination intensities apply for an illuminated area of 80 x 60 cm at a distance of 80 cm from the material. In order to avoid intensity fluctuations the manufacturer recommends replacing the lamps after 2500 hours of operation. All 4 types of light have a separate time recorder. Other features of the colour sampling cabin should be mentioned:

- the light types are mutually interlocked in order to avoid mixed light if erroneous operation occurs.
- the UV radiation can be separately adjusted or added to any other kind of light.

The Variolux colour sampling cabin is used in the textile, paint, plastics and car industries and by material testing bodies.

Colour matching to pattern The dyer's principal aim is to produce, using the dyestuffs available, problem shades that are a perfect colour match to the pattern. This aim is to be achieved not after several attempts but first time, even for each new dye formulation. A change in the dyestuff batch or source should not be noticeable.

As colour is a sensory perception, all its intrinsic significance must be detectable by the human eye. On the one hand colour differences that are undetectable to the eye are meaningless; on the other hand colour differences that the eye recognises with any degree of clarity are also to be rejected. Hence the requirement that variations in dyeing strength and shade within the tolerance range must not give rise to noticeable colour differences. It is important here to specify objectively what a detectable or acceptable colour difference is.

One of the basic tasks of → Colour measurement is to help determine colour differences. Determining the colour differences from physical measuring data is a complex task, because the colour vision of the human eye must be simulated. Of the various colour difference formulae in existence the CIELAB formula in its modified form of CMC (2 : 1) can be used. Therefore it is used for making estimates. A value of 0.3 units is applied as a limit value for a colour difference that can still be tolerated. This value is only a guide value. It must in no way constitute a generally accepted tolerance, since in practice the tolerance range (limit of acceptability) depends on requirement, substrate/item and shade.

By calculating the colour recipe it is possible to investigate the effect of the colour strength tolerance on the dyed result. Starting from a reference shade the resulting deviation from the reference shade is calculated by varying the concentration of the dye.

The "acceptable" variation in dyeing strength can be read directly off the boundary line $\Delta E = 0.3$.

In the case of single dye shades, for 10% variation there is colour interval of a maximum of 0.7 CMC (2 : 1) units, that is a value for the "acceptable variation" of approx. 4%. This intrinsic significance is based on calculations using a number of dyes of different shades and different brilliancy. The effect of the colour strength is somewhat less for yellow shades and generally somewhat greater for matt colours. For mixed shades the effect is, as one would expect, greater, by approximately a factor of 2–2.5 maximum.

It depends on the colour range (colour location) how sensitive the effect of the colour strength variation is. In the range of saturated colours the effect is hardly greater than for single shades; it increases inversely, i.e. in the direction of unsaturated colours, and is most pronounced for almost neutral shades, i.e. for grey (source: Broßmann).

Colour measurement This is used to determine the chromatic impact (→ Colour stimulus) of body colours, coloured fluids etc. The purpose of colour measurement is to establish the term "Colour by means of

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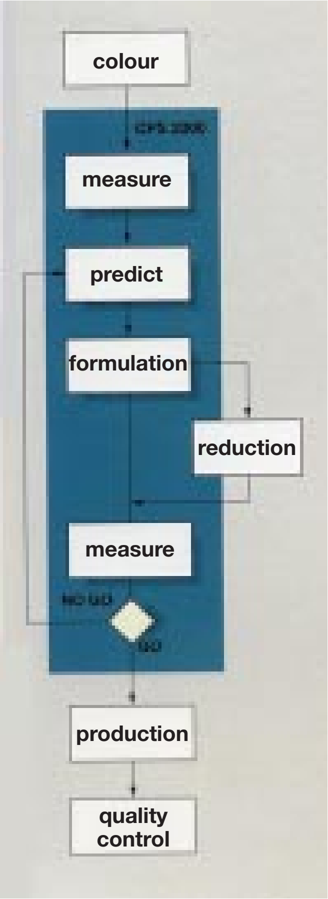

Fig.: Stork method of colorimetry in printing for checking a print colour produced with a colour model with the possibility of correcting printing paste formulations.

reproducible variables", i.e. → Colorimetric measures. Obviously any attempt at establishing exactness in colorimetry needs to be based on important working rules (DIN standards), with matters such as colour and contrast vision (→ Adaptation) also being taken into account in subjective colour measurement. The methodology of colour measurement (see Fig.) is defined by a wide variety of measuring devices and procedures. The operating principle and numerical assessment of these tend to vary from one to the other to a greater or lesser extent. Depending on the requirements, either photometric or visual comparison measurements can be selected. This results in either subjective or objective colour measurement.

Objective methods use physical measuring methods followed by valency evaluation: they eliminate interfering effects to a large extent and are therefore the most accurate and offer easily transferable internationally accepted colour measurements (CIE tristimulus values or CIE chromaticity coordinates). It is also possible to transfer these into monochromatic colour coordinates which can be understood in practice as fundamental calculations for colour matching tolerances as well as between sample and dye bath. A distinction should be made between the following:

1. Spectrophotometric methods measure the luminance factor or the transmission factor of tested dyeings, dyestuffs or dye baths using spectrophotometers (monochromatic or trichromatic). This method only requires a small quantity of the specimen, though it generally requires expensive equipment.
2. Brightness methods measure the comparative brightness against ideal white as a luminance factor that can easily be converted into CIE tristimulus values by means of successive photometry through three colour filters. Due to the difficulty of filter designs that correspond exactly to CIE spectral distribution curve, the accuracy of the spectrophotometric method is generally not achieved, and the accuracy of eye sensitivity is only achieved in special cases.

Subjective methods work empirically on the basis of comparison. They therefore require the observer to have correct colour vision and brightness response in the eye. It is also always dependent on the spectral difference in colour stimulus, although not only on colour stimulus specification as is the case with the objective methods.

1. Visual colour matching methods measure an unknown colour photometrically through coloured filters with known comparative values that are mixed additively in the measuring device. The mixing ratio read from the device gives trichromatic (standard values) or monochromatic colorimetric measures depending on the scale. A variant is the compensation method in which the measurable additive mixture is compensated to neutral (half-shadow photometers according to Ostwald); white and black content measurements can naturally also be carried out using the same principle.
2. Colour atlases are used to make subjective direct comparisons with patterns with known measured values.

The practical application of colour measurement in textiles must be decided for each individual case taking into account the required measuring accuracy that governs the choice of the method and its limitation. However, it continues to gain in importance even if it is not possible to totally replace assessment and valuation of colours by the human eye. From the wide range of applications, the following examples should be mentioned: creation of ordering systems for colours, colour formulations etc.; presetting new formulations; stipulating colour tolerances for pattern conformity; operational testing of differences in shade depending on the type, trend and degree of deviation; colour tests, determination of dye solubility, dye concentration, dye resistance, dye affinity, the effect of aftertreatments and loss of fastness, as well as degree of scouring and bleaching etc. Colour measurement also has its limits however. These concern personnel, size of samples, sample structure, multifilament yarn mixes, special dyestuff categories, variations in shade and end test. → Colorimetry.

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Colour measuring instruments These are spectrophotometers and consist of four basic elements: light source, sample holder, monochromator (filter, prism or grating) and photocolorimetric receiver. The light from the lamp falls on the sample and the white standard (ceramic, porcelain, opal glass or barium sulphate) that are measured under the same lighting and observation conditions (measuring geometry). Classification:

I. Triple (zone) filter photometer for colour measurement using the brightness process (Fig. 1): The light reflected from the sample and white standard is measured consecutively with three filters. Sensitivity distribution of the filter/receiver system corresponds to one of the CIE spectral distribution curves $\bar{x}$, $\bar{y}$, $\bar{z}$ (sensitivity of the human eye). As the source of light always supplies standard illuminant, the CIE tristimulus values X, Y, Z for this standard illuminant are always obtained directly. The majority of devices operate with standard illuminant D 65. Photoelectric cells or photoelectron multipliers with constant sensitivity over a long period of time are used as receivers (the long-term consistency of the equipment is dependent on this). Suitable for all measurements where CIE tristimulus values X, Y, Z do not need to be very precise, e.g. to recipe correction, for dye house production control, assessment of degree of whiteness etc.

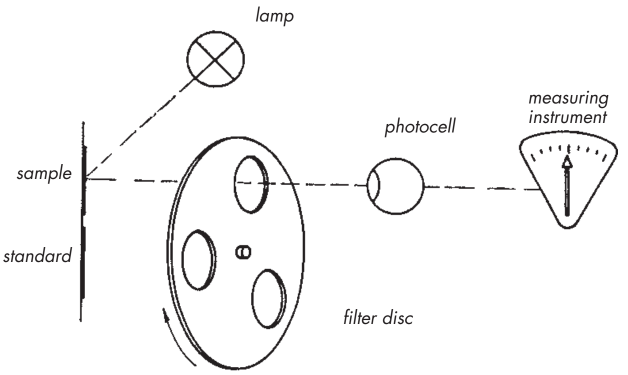


Fig. 1: Diagram of the Triple zone method.

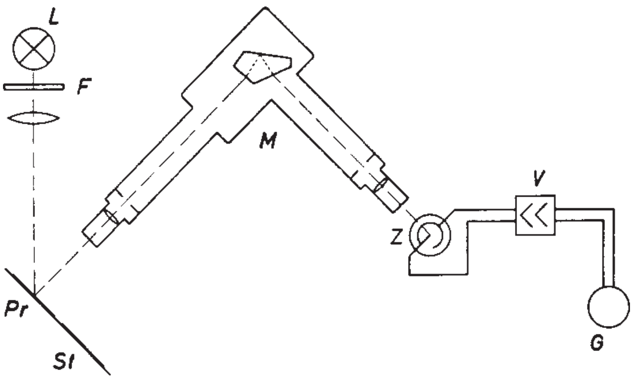


Fig. 2: Diagram of the spectrophotometric colour measurement.
L = light source; M = monochromator; Pr = sample;
St = standard (white); Z = photocell; V = amplifier;
G = galvanometer.

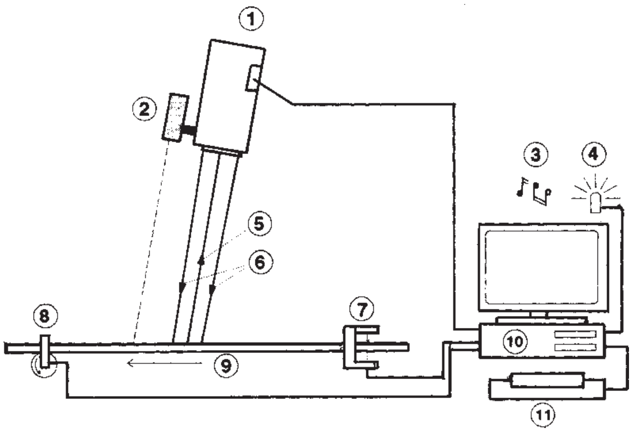


Fig. 3: Layout of the system components of a colorimeter.
1 = photometer (0.5–6 m spacing); 2 = pyrometer;
3 = acoustic status signal; 4 = optical status signal;
5 = measured light; 6 = photometer flash; 7 = light barrier and movement sensor; 8 = metre counter; 9 = moving fabric;
10 = computer; 11 = printer.

II. → Spectrophotometer for colour measurements using the spectrophotometric method (Fig. 2). This is the most accurate method of colour measurement. It takes place in two stages:

a) Spectrophotometric measurement to determine the spectral energy distribution and b) calculation of the actual colorimetric values. The first stage is a purely physical measurement that is often carried out outside the visible spectrum (IR, UV) for analytical purposes. The second stage is an assessment using the colour vision function of the human eye. Using the spectrophotometric method it is possible to measure the colour of primary light sources and the colour of non-self luminous colours reflected from or transmitted through an object. Colour measuring instruments on moving conveyors are also available (Fig. 3).

Colour migration on drying → Dye migration in drying.

Colour mixtures A distinction is made between additive and subtractive mixing.

I. Additive or optical colour mixtures arise from the almost simultaneous overlay of colour stimuli perceived by the eye that are therefore perceived as one colour. Example: If a beam of white light is passed through a blue filter and a yellow filter side by side, then both coloured beams of light produce white once again when they are recombined. Evidence: the complementary colour, yellow, absorbed in the blue filter now supplies the yellow filter, which has absorbed the complementary colour of blue, so both beams of light when mixed contain all the colours of the white spectrum and therefore must give white light. The theory follows: two colours are complementary when white is formed from their additive mixture. This only applies to respective colour stimulus specifications, not to the spectral nature of the colour stimuli. By additive colour mixtures, a linear relationship can always be formed between four colour stimulus specifications. This is based on the adjustment of uniformity of colour mixtures made up of A, B, C, the results of which can be predicted as a sum of the colour equation. Specific colour measuring devices (→ Anomaloscope) are used for the experimental adjustment of such colour equations.

II. Subtractive or material and substantial colour mixtures arise by directing a beam through several coloured bodies. The beam is altered between each body. Examples: Production of a green colour from blue and yellow dyestuffs. The same occurs if a beam of white light passes through a blue and a yellow filter consecutively: first the complementary colours yellow and red are absorbed (blue filter) and then blue (yellow filter), with the result that only green remains. Subtractive colour mixtures (in contrast to additive colour mixtures) are therefore dependent on the spectral nature of the components, the colour stimulus specifications of which are therefore not able to give information concerning the colour stimulus specification of a subtractive colour mixture.

Colour mixture triangle Chromatic concept; when a shade is to be dyed in trichromatics, i.e. in the yellow, red and blue shades, the dyes employed are arranged schematically in triangle form (Fig.), and as many intermediate shades as required are dyed within the triangle in gradations of the three dyes.

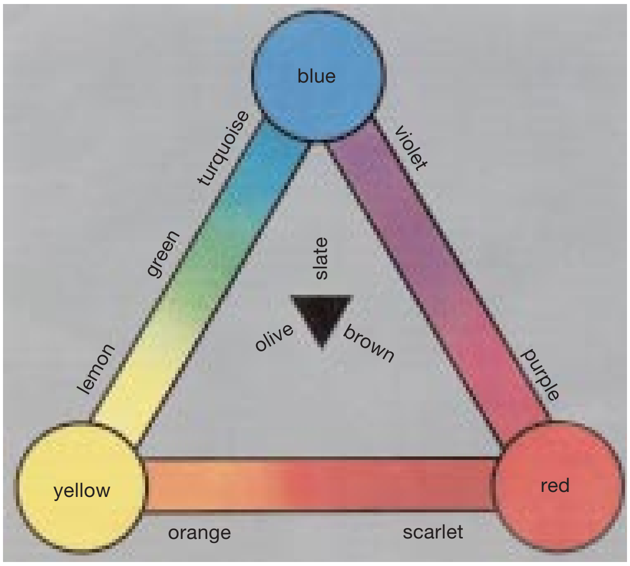


Fig.: Dyes colour mixture triangle for organising dyeings in accordance with the trichromatic process (Otto's colour mixture triangle).

Colour quality This is a term used in colorimetry for three-dimensional changes in direction of a colour relating to →: Hue; Saturation; Lightness.

Colour sample (Sample pattern). Colour sample as per order for →: Sample dyeing; Colour matching of dyed/printed samples.

Colour sampling device Used for testing dyes, textile auxiliaries, flat screens, working methods, electrically operated doctor blades for the laboratory, etc.

Colour saturation (depth of shade) → Saturation.

Colour scanner → Scanner as a piece of electronic equipment for reproduction technology. The structure of the colour scanner for paper printing is essentially adapted to trichromaticity (+ black = quadrochromaticity) and is generally used to produce coloured output on films.

Colour screen → Screen.

Colour separation,

I. This is a process in the automatic production of colour separation from a multi-coloured sample with the aid of a scanner. After passing through a sampling drum, the coloured beam of light is captured by an optical head which disperses it via screens, prisms, interference filters and colour separation filters into 3 reference beams in yellow, red and blue.

II. Transfer of individual colours from a colour submission to the printing rollers and/or screens from a pattern submission in textile printing. Manually prepared, it is a time-consuming operation. Resolution of the original pattern drawing as a pure contour film for each colour with the rest of the surface blacked out by hand painting.

Colour separation, electronic Colour separation as a fully automatic procedure with the aid of colour scanners utilising → Optoelectronics, shade and colour value corrected by colour computer and directly recorded onto a film via a printing head. Has the option of increasing or decreasing the pattern size as well as displaying motif and correcting partial images.

Colour simulator Represents hues for digital transmission that can be subsequently visualised or used as numerical values. Reproduction by numerical data on digital display.

Colour soiling,

I. Term with multi-colour printing machines for uncontrolled "migration" of dye from the printing trough into other printing paste containers, the affected dye soon reaching such a concentration that it soils other printing pastes, and changes the shade, which, at high fabric speeds, can easily reduce the value of large quantities of fabric. Colour soiling is ascertainable by adding radioactive tracers to the suspect printing paste. Located before the next printing roller is a stripping roller which tests the radioactive radiation of the stripped colour, and triggers off a warning signal at maximum deviation.

II. Colour soiling can occur in multi-colour roller printing if the rollers in the second, third and subsequent printing rotations pick up small quantities of moist printing paste on places which have not been engraved from fabric which has already been printed by preceding rollers. This paste then enters the dye paste trough via the dye paste applicator rollers. Remedial measures can be taken by a) fixing a counter doctor, b) attaching a water roller in sequence, c) adding chemicals in the dye paste trough which dissolve the dyestuff drawn in to the trough, but not that contained in it. The principle of roller printing should also apply: “The smallest dye (in terms of lightness and cover) should be in the first printing roller.”

Colour soiling test → Methylene blue method.

Colour specks → Specky print pastes.

Colour splashes Colour splashes due to the rapid lifting of a printing screen doctored with excessive printing paste. The cause is screen or fabric sticking, and the local splashing of printing paste on pulling loose.

Colour spray process This method was chiefly developed in non-textile sectors (such as facsimile copying, silent printers and typewriters). Activity in the textile sector has grown through multicolour fashion. The dye liquor is sprayed on to the fabric either in a random manner or according to a pattern.

Colour stimulus This is the luminous radiation recorded by the eye that, according to its energy distribution, stimulates the colour-sensitive cones (→ Colour vision). This colour stimulus is not sensory perception however, rather a radiation with colour stimulus function which must be converted into a sensation. The eye functions as a grid-like arrangement of three types of receptive organs each having different spectral sensitivity (→ Eye sensitivity to hue, chroma and lightness). Expressed mathematically, the eye now operates in such a way that it multiplies the colour stimulus function for each wavelength by the corresponding CIE tristimulus values $\bar{x}$, $\bar{y}$, $\bar{z}$ and obtains the three effects caused by integration as colorimetric measure coordinates X, Y, Z (→ Colorimetric measures), which then combine in the perception of a uniform colour effect, the colour stimulus.

Colour stimulus specification Determined as a consequence of “colour stimulus function” when comparing two colour stimuli (→ Colorimetric measures). The colour stimulus specification is particularly significant in regard to the nature of the shade of so-called additive colour mixtures.

Colour temperature Thermal radiation, expressed in → Kelvin. As the temperature increases, the waves emitted become shorter. The colour temperature scale covers the entire wavelength region from infrared to ultra-violet. Short wavelengths (bluish light) have a high colour temperature, long wavelengths (reddish light) a low colour temperature.

Colour tolerance This is an allowed colour deviation from a standard.

Colour transfer belt Used in Vigoureux printing to transfer the print paste from the frame to the engraved roller.

Colour triangle,

I. → Chromaticity diagram.

II. Triangular classification of colour patterns, in which the standard dyeings of selected dyes occupy the corner points of a colour triangle. In the colour triangle illustrated (trichromatic dyeing) these are e.g.: yellow, red, blue (Fig.). The numerical values relate to the percentage applied for each dye in the combinations and each colour pattern consists of the 3 values, % yellow dyestuff + % red dyestuff + % blue dyestuff. In the example all dyeings are set up for a total of 1% dyestuff. The proportion of relevant dyestuff therefore decreases as the distance from the corner point in question increases, which greatly simplifies the patterning.

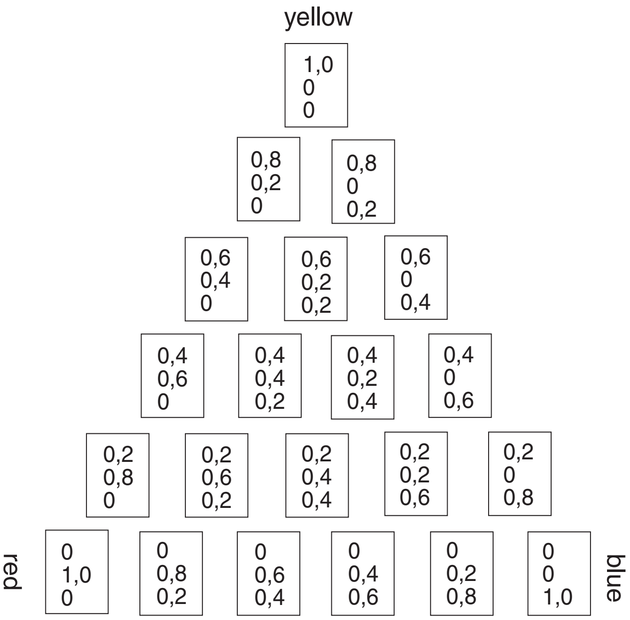


Fig.: Colour pattern classification system in the form of a triangle.

Colour trough Contains the printing paste on printing machines or dye solution on dyeing machines. Usually made of copper or stainless steel.

Colour vision Light entering the eye falls on the net-like arrangement rods and cones of the optic nerves (retina) causing → Colour stimulus. The eye functions as follows:

1. Colour sensitive cones (approx. 7 mill.) lie within a 2° radius of the vertical angle of incidence where the actual colour vision occurs. Each of these cones has a selective sensitivity to blue, green or red, so each → Colour arises from a multitude of individual points consisting of a mixture of the 3 primary colours.

2. Lightness-sensitive rods (approx. 120 mill.) cover the entire inner field of vision of the retina and only trigger light-dark perceptions, i.e. non-coloured lightness vision. In e.g. only poor light, the function of the cones and especially the blue sensitive ones are minimal. The disturbance to the ability of the cones to function causes → Defective colour vision. (→ Eye sensitivity).

Colour way,

I. Colouration, colour effect.

II. Textile printing: colour composition with the number of colours determined by the design. Any required number of colourways can be produced per design.

Colour wedge In flat-screen or rotary screen printing, a wedge of print paste is built by the action of the squeegee (→ Squeegee contact angle). The squeegee pressure is important in controlling the push-through of the colour wedge.

Colour yield Quantity of dye fixed on the textile substrate in % by weight of the quantity of dye used.

Column type metering stations → Metering system with proportioning cylinders.

Comb doctor Version of a → Doctor roller, in which a flat doctor blade has comb-like indentations.

Combed top Semi-finished product of → Worsted spinning. Sliver-like web of parallel wool fibres obtained after passage through the so-called comber. Combed top is frequently dyed (in package dyeing machines or on perforated tubes in creel-type dyeing machines) and printed (vigoureux printing, top printing). Further processing in the spinning mill for fine worsted yarns (woven and tricot fabrics).

Combinability of wool dyes → K-value is determined by DIP tests on woven wool test fabrics at a constant pH of 4.5. To this end, the test fabric is pretreated with citric acid and disodium hydrogen phosphate (Na_2HPO_4) for 20 min at 98°C. The quantity of acid or buffer required in each case is determined in a preliminary test:

a) pretreatment: 1 l of Levatit water + 30 ml/l of 0.1 mol citric acid + 4 ml/l of Na_2HPO_4 50 g/l of solution. 6–7 test specimens of 5 g, 20 min at 98°C.

b) DIP test: 6–7 x 5 g material specimens in each case are dyed successively in 250 ml of a dye liquor containing different shades of dye. The shade change is visually assessed.

Standard conditions: pretreated woven wool test fabrics; two combinations, each of 1/1 RT and 5% sodium sulphate calc. pH 4.5 set with 2.15 ml of 0.1 mol citric acid and 2.3 ml of Na_2HPO_4 50 g/l solution. If complete bath exhaustion is required, the last test specimen is acidified during dyeing. 80°C with the first test specimens, 98°C with the others.

Combination bleach → Combination bleach process.

Combination bleach process The alternate action of hypochlorite or chlorite and oxidative bleaches with the aim of an improved and not subsequently yellowing maximum white with maximum fibre protection, as is possible with the aid of a single process. Sometimes a reduction bleaching process is also included.

Combination desize/dyeing A combination process which involves desizing in the dyebath. In individual cases, it is possible on the jig for cotton and blends of cotton with regenerated cellulose.

Combination desize/scour process A single-bath combination of desizing/scouring, particularly for wool and wool blends. Method: e.g. gently heat the liquor to 40°C, set the bath with the normal detergent concentration, add a diastase desizing agent; if necessary, add a fat emulsifying agent, then treat as before, rinse, etc.

Combination dyes Dyes, which are used together in the dyebath, and which exhaust in such a way that their concentration ratio changes little or not at all during dyeing, are easily combinable. Combination dyes should behave like “1” dye in the ideal case. Here therefore, the final shade is built up from the start of dyeing.

Combination milling Alkaline and then acid milling. Provides good felting and excellent handle. Alkali and acid resistant milling agents are necessary.

Combination pretreatment The classic continuous pretreatment of cotton and cotton blend fabrics takes place in 3 stages: de-sizing, boiling off, and bleaching. For some time now, for reasons of economy and ecology, intensive efforts have been made to shorten the conventional 3-stage process by combining it with other processes. Here, particular importance is accorded to the liquor application technique. At ITMA (the international exhibition of textile machines) in 1991, new technologies for combination pretreatment were presented. The Flexnip pretreatment concept (Küsters) provides for a combined boiling-off and bleaching process after a separate de-sizing with recovery of the sizing agent. The addition of the heavily alkaline bleaching liquor without liquor exchange, which takes place by means of Flexnip wet-in-wet, ensures even pretreatment results. A spraying technique using Raco-Yet (Ramisch-Kleinewerfers) makes it possible to achieve dye-ready goods from unbleached cotton fabric within 2–3 min in a single process step, regardless of the sizing agent applied. For this, large amounts of sodium hydroxide, hydrogen peroxide and stabiliser are used, as well as a specially developed multi-functional auxiliary.

Combination process Process in which two operating stages are combined (cost-saving). Examples: sizing + dyeing; desizing + bleaching; bleaching + optical whitening; bleaching + dyeing; shrinking + dyeing; non-crease finishing + dyeing.

Combination steamer In the process of alkaline steaming of cotton fabrics (boiling off, bleaching), in the swelling phase there is a risk of fixing creases; for this reason, the fabric must be guided through the steamer as free of creases as possible (see Fig.). This takes place with fixed cloth guidance via guide rollers. Since this method is very cost-intensive, due to the numerous rollers which in each case are held in expensive external bearings, fixed cloth guidance is abandoned as early as possible, i.e. towards the end of the swelling process, in favour of the cheaper free cloth guidance (laying on conveyor belt, roller bed or other systems). The combination steamer offers both types of cloth guidance: first the fabric passes through the rollers of the fixed cloth guidance system in the upper part of the steamer, and then it is flat-folded through a funnel slit and deposited onto the plaiting-down table. Here, it is necessary to turn the fabric package during plaiting-down at the half-way mark, to ensure even exposure to steam.

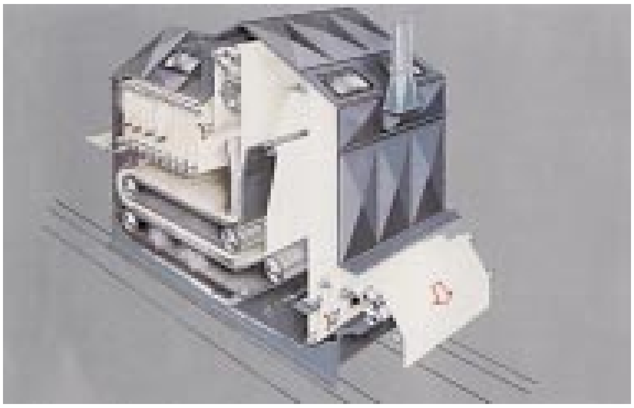


Fig.: Combination steamer (Küsters).

Combined dyeing and finishing Single bath fixation of dyestuffs e.g. pigment dyestuffs, selected vat and reactive dyestuffs (Procion Resin Process) and finishing auxiliaries, particularly for cotton and polyester/cotton.

Combing noils Short fibres separated out by combing in the production of → Worsted yarn.

Combining of print fabric Preparation of lightweight woven fabrics or highly elastic warp knitted fabrics for printing in order to avoid distortion or creasing. In roller printing, a picot or finely hatched roller is installed in the first place, applying adhesive to the endless blanket. In the second place, the first printing roller presses the fabric on to the endless blanket. In screen printing, it is combined on machines suitable for that purpose. Endless blanket and fabric are pressed together after the adhesive has been applied, dried, rolled up, and fed to the printing machine.

Combi-squeegee Combination of a magnetic pressure-application doctor roller and a print paste blade similar to a doctor knife in contact with it, the blade being attached to a print paste feed pipe. The combi-squeegee combines the advantages of both doctor types: effective nip and deep penetration. – Manufacturer: Joh. Zimmer.

Combi-Woolmark, → Woolmark for blend materials containing a minimum of 60% virgin wool.

Combustion Combustion is the reaction of a substance with oxygen (generally in the presence of an oxygen concentration equal to that of air), whereby heat is generated with a consequent burning or → Smoulder.

Combustion characteristics of fibres → Burning behaviour of textiles.

Combustion drying → Remaflam process.

Combustion factor (Substance/time), the amount of material burnt, based on the burn length, during the elapsed time (g/cm per min) (ISO).

Combustion gases Combustion is an oxidation process in which oxygen is used up. When the oxygen content of air falls below a certain value, there is a risk to life. If, for example, the O_2 content drops from 21% to 15%, humans are no longer in a position to escape unassisted. Such values are reached relatively quickly. If for example a large candle is lit in a space of 10 m^3, the O_2 content will drop to 15%. When organic material is burned, CO_2 and CO are evolved. CO_2 is not toxic, but if the CO_2 content in the air rises to 6–7%, even this is fatal. A CO concentration of 0.5% by volume has the same effect. Other toxic gases which can arise during the combustion and decomposition of organic material are HCN, HCl, H_2S, SO_2, NO_2 and numerous organic compounds such as acroleine, acetaldehyde, isocyanates etc. Particularly dangerous is hydrogen cyanide, which leads to death within a few minutes when it is present in the air at a concentration of 0.04% by volume. Testing of combustion gases for toxic compounds can be carried out in accordance with two methods, which are based on different principles:

1. Determination of the chemical composition of the combustion gases: This is generally based on the quantitative determination of the most important and most hazardous toxic compounds such as CO, HCN, HCl, SO_2, H_2S, NO_2 and CO_2. It has the disadvantage of not indicating exactly the connection between the chemical composition and the toxicity of the gas analysed. Whilst the toxic effect of individual compounds such as CO, HCN, $COCl_2$ etc. are well known , little is known as yet about the toxic effects of gas mixtures. The individual compounds may influence the effects of the other compounds, which may result in an intensification or attenuation of the toxic effect. Thus for example in the case of combinations of CO and HCN, synergistic effects were established, i.e. the result was more than an addition of the individual effects. In the case of mixtures of CO and HCl for example, on the oth-

fibre	Products of pyrolisis and combustion.
cellulose	CO, CO_2, H_2O, methanol, ethanol, furane derivatives, formic acid, acetic acid, formaldehyde, acetaldehyde, acrolein, hydrocarbons.
wool	CO, CO_2, H_2O, H_2S, SO_2, ammonia, amines, HCN, H_2, lower hydrocarbons (CH_4).
polyester	CO, CO_2, H_2O, acetaldehyde, benzoic acid, terephthalic acid, acetic acid, hydrocarbons, CH_4, benzene, vinyl benzoate, divinyl terephthalate.
polyamides	CO, CO_2, H_2O, mono and dicarboxylic acids, adipic acid, cyclopentanone, hydrocarbons, ammonia, amines, HCN, acetaldehyde, formaldehyde, caprolactam, benzene.
polyacrylonitrile	CO, CO_2, H_2O, CH_4, ammonia, nitriles, HCN, acrylonitrile, lower hydrocarbons.
polypropylene	CO, CO_2, H_2O, saturated and unsaturated hydrocarbons, propylene, pentene, ketones, acetone, ahdehydes, formaldehyde, acrolein, methanol, formic acid, acetic acid.
polyvinylchloride	CO, CO_2, H_2O, HCl, saturated and unsaturated lower hydrocarbons, CH_4, chlorinated hydrocarbons, vinyl chloride, benzene, toluene.
aramids	CO, CO_2, H_2O, saturated and unsaturated lowerhydrocarbons, acetaldehyde, acetone, HCN, NH_3, benzene, benzonitrile, acetonitrile, NO_2, toluene, acetic acid.
cellulose acetate	CO, CO_2, H_2O, acetic acid, methane, ethylene etc, hydrocarbons up to C_6, furane, vinyl ether, methanol, acetone, acetaldehyde, acrolein, ethyl acetate, benzene.

Tab.: The most important products of pyrolisis and combustion (combustion gases) of various textile fibres.

er hand, an antagonistic effect was found, i.e. the gases counteract one another, and to some extent have an ameliorating effect on their individual potential.

2. Performance of animal trials: Here, in general rats and mice are exposed to the combustion gases in a room of defined dimensions, and the behaviour of the subjects is recorded. This method has the advantage that (without knowing the composition of the gas mixture), the overall toxicity is determined directly on the living organism. The difficulties with this method and its defect lie in extrapolating the results from animals to humans. The effect which specific gases or gas mixtures has on experimental animals sometimes differs considerably from that on humans.

Even where there are clear differences in the toxicity of the combustion gases of different materials, this can hardly lead to a process of selection of textiles, since the fire hazard and the fire risk are co-determined by many other factors, including ignition temperature, combustion speed, smoke density etc. The toxicity of the combustion gases cannot be regarded as the main factor for the fire risk of a material. In the case of modacrylic fibres, for example, considerable amounts of toxic gases occur during decomposition. However, since the material is self-extinguishing, it prevents fires occurring or spreading, and thus also the formation of toxic gases. Wool creates considerable amounts of toxic combustion gases, and is among the less combustible fibres. The prime importance of low flammability with its protective action must not be ignored in the assessment. The table shows the most important compounds which occur in the combustion of the various fibres, and the strongest toxins are underlined or double-underlined, depending on their significance. This table can be used as an initial orientation guide to the combustion gas composition of different fibres (source: Einsele).

Combustion gases of textiles → Combustion gases.

Combustion heat per unit of time The amount of heat generated by a burning body during a unit of time.

Combustion index → Thermal value of fuels.

Comeback wool Wool from sheep back-crossed between crossbred and merino sheep.

Comfort factor (CF value). An index applied to pile carpets incorporating, along with pile mass and number of tufts, a factor quantifying the sensation experienced by walking on the carpet. This produces an objective index of the subjective concept of carpet comfort.

$$CF = 5 \cdot K_H + \frac{m_P}{100} \cdot \sqrt{\frac{NZ + 20\,000}{10\,000}}$$

K_H = tread value (according to Herzog)
m_P = pile mass (g/m^2)
NZ = number of tufts

In 1982 the formula was amended to distinguish between the comfort factor of a) “cut-pile” and b) “uncut pile” carpets:

$$\text{a) } CF = \frac{a_{20,P}}{5} \cdot \frac{m_P}{100} \cdot \sqrt{\frac{NZ + 20\,000}{10\,000}} + 5 \cdot B_i$$

$$\text{b) } CF = \frac{a_{20,P}}{6} \cdot \frac{m_P}{100} \cdot \sqrt{\frac{NZ + 20\,000}{10\,000}} + 5 \cdot B_i$$

$a_{20,P}$ = pile thickness over the carpet primary backing (mm)
B_i = → Tread comfort value (according to DIN 54327)

Comfort finishes Finishes applied to textiles composed of synthetic fibres to reduce the build-up of electrostatic charges and soiling, as well as to improve hydrophilic properties and soil release.

Comingled yarn In aerospace textiles, two or more continuous multifilament yarns, the filaments of which have been intermixed with each other without adding twist or otherwise disturbing the parallel relationship of the combined filaments. Usually consists of a reinforcing yarn, such as graphite or glass, and a thermoplastic matrix yarn. → Intermingling.

Comité International de la Rayonne et des Fibres Synthétics (CIRFS). International head organization of man-made fibre producers with headquarters in Paris, to which the German IVC (Industrievereinigung Chemiefaser) also belongs; → Technical and professional organizations.

COMITEXTIL, abbrev. for: Comité de Coordination des Industries Textiles de la CEE (Coordination Committee for the Textile Industries of the European Community), Brussels, Belgium. The national head associations of the various European Community countries as well as specialized textile associations operating at this level belong to this organization; → Technical and professional organizations.

COMMENTEX International Committee for Fabric Care Meetings, with headquarters in Paris; → Technical and professional organizations.

Commercial forms of dyestuffs The commercial form of chemical products, defined as physical form and composition, is responsible for essential application characteristics from the user's point of view. It is also used for dyes and chemicals in the market place as an essential tool for differentiation. Quality is guaranteed by testing the long term stability of powder, granule and liquid forms using testing and production methods e.g. diaphragm separation and granulation methods. The term commercial forms is also used to describe the overall physical and chemical properties insofar as they are recognised from the chemical plant to the finishing works. The commercial form affects all stages of the packaging, storage, transportation, recipe formulation and liquor preparation, as well as the use and application itself (→ Dyestuff formulations). The optimum commercial form for a particular range and specific area of application is determined by objective market research of selected customers. The priorities thus determined are, for solid forms, freedom from dust, good solubility and lump-free mixing, for liquid forms stability in storage and favourable viscosity and concentration values. The introduction of new forms and qualities is only possible taking account of the production stages from dye synthesis to despatch (Fig. 1).

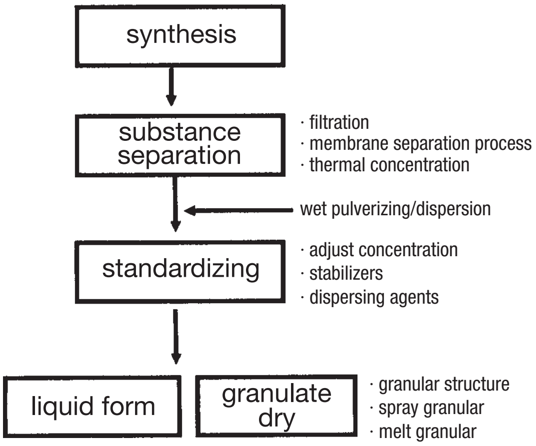


Fig. 1: Commercial dyestuff form production.

Promising requirement profiles of commercial forms generally require several stages of production processes. The additional operations necessary for the fulfilment of higher quality standards increase the cost of the finishing of the products, which accounts for 10 to 20% of the total production costs. Substantial developments have been made by various manufacturers in the production stage for solid forms. Areas for optimization include grain compactness and granule size to give fast distribution and good solubility. In the case of reactive dyes for cellulose fibres, regular improvements in improved constitution came on to the market, with improved ease of application stemming from criteria such as fixing properties, reproducibility, dye yield, ecology. Concurrently with these developments increased demands were placed on the commercial forms. Initially powders which gave off a lot of dust were used commercially; for reasons of working hygiene these were cleaned up with liquid antidust compounds (Fig. 2). The optimization of these require-

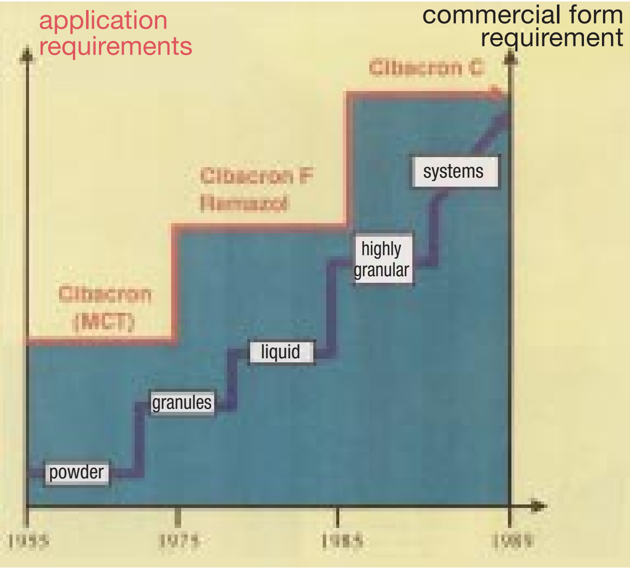


Fig. 2: Increasingly stringent requirements on application properties and on the commercial form, taking reactive dyes for cellulose fibres as an example.

ments lead to a granular form and (depending on the range), sooner or later to liquid form. At present, the so-called high granulate and the particularly promising solid forms are on the increase. The aim is the optimum fulfilment of customer requirements within the scope of ease of application, constitution, commercial form, from supply methods to container disposal.

Manufacturers and users of chemical products agree that workplace hygiene should be given the highest priority; this means reducing the volume of airborne dust to a minimum. The degree of fine dust critical to health is determined by various standards, e.g. in the definition of the TLV (Threshold Limit Value for Chemical Substances and Physical Agents in the Workroom Environment; EC Standards). The practical or operational value for airborne dust is far higher then the TLV; for chemical production it is stipulated that all fine particles < approx. 0.08 mm (TLV 0.008 mm) should either be bound or removed. Taking into account the facts on the one hand of the hygienic and operational nuisance caused by dust at the lower end of the particle size scale, and on the other hand the difficulty of dissolving or distributing larger particle sizes at the higher end of the scale, a practically acceptable range of approx. 0.1–1 mm is used in the area of fine granulates (Fig. 3).

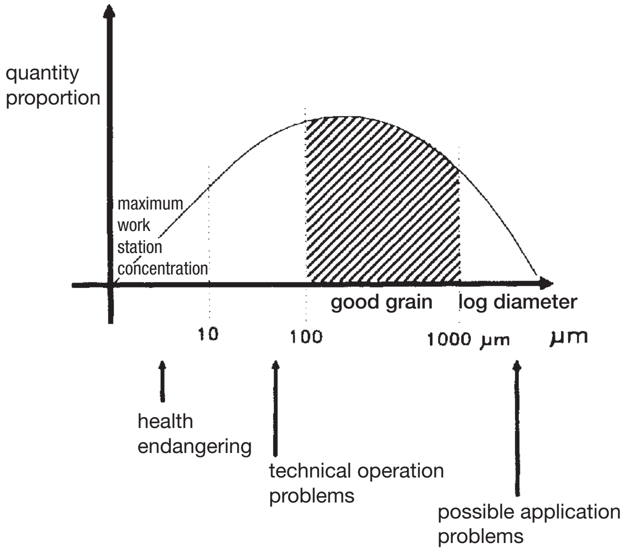


Fig. 3: Grain distribution in solid commercial dyestuff forms.

Liquid forms with good storage stability are characterised in recent years by diaphragm separation processes such as ultrafiltration and reversible osmosis. Accompanying substances from the dye synthesis such as electrolytes, organic by-products and a large percentage of the water are separated by a semipermeable diaphragm and treated by the effluent treatment plant of the chemical works. The purified raw material is refined by the addition of formulation auxiliary materials such as buffer substances, stabilisers, and other functional additives to the desired rheology and stability levels, and the necessary concentration. The cleaning operations (Fig. 4) have a substantial influence on the storage stability of the liquid dye make-up (source: Bruttel).

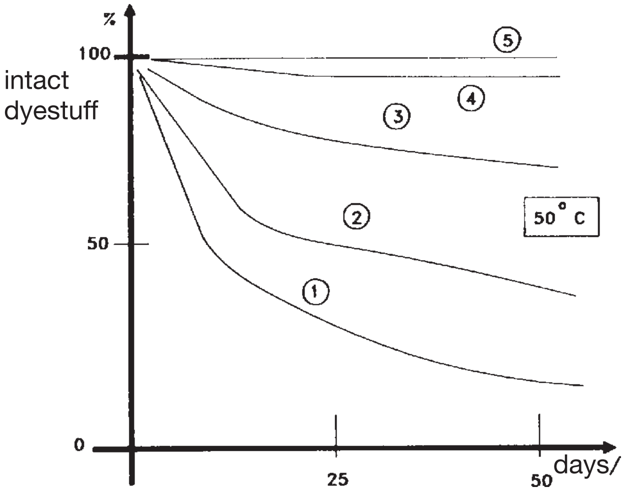


Fig. 4: Cleaning and storage stability (triazine fluoride type). Cleaning time: 1 = crude solution tel quel; 2 = 2 hours; 3 = 6 hours; 4 = 12 hours (extensive electrolyte removal); 5 = stabilized.

Commission dyeing Textile dyehouse which dyes textile fabric to the order of another firm without owning the fabric itself. Also called → Commission finishing.

Commission finishing If a textile finisher takes in for processing textiles that belong to a customer, finishes them as per the customer order and receives “payment” for his work after correct delivery and invoicing (previously known as payment finishing), his work is called commission finishing. The relationship to previous and subsequent stages is shown in the models in Figs. 1–4.

The main difference between a commission finisher and a vertical company is that a commission finisher usually knows little about history of materials for processing, particularly with regard to the composition of sizes and waxes. The finishing process must be adapted according to the goods in process and the require-

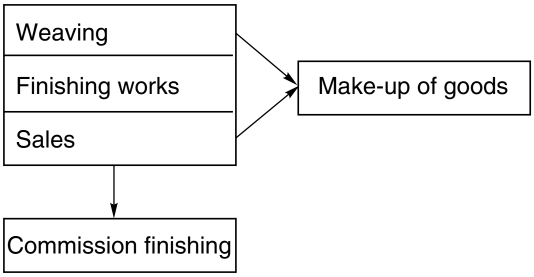


Fig. 1: Structural model 1.

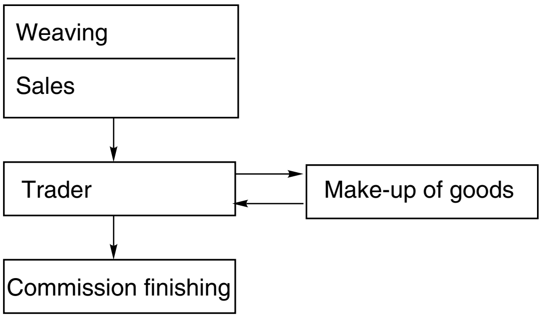


Fig. 2: Structural model 2.

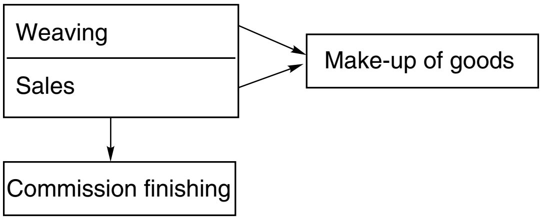


Fig. 3: Structural model 3.

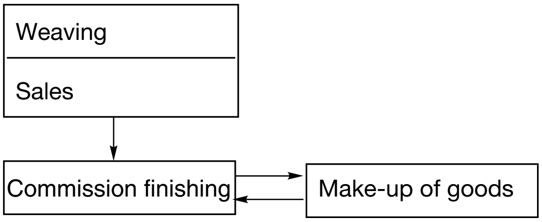


Fig. 4: Structural model 4.

ments of the finished product. This results in the problem of having a wide range of processes due to the many and varied raw materials and finished product requirements → Organizational structures in textile finishing

Commission wash Washed goods belonging to the customer.

Common salt → Sodium chloride.

Comonomers Monomers of different chemical types used, e.g. as chemical modification components to open up the intercrystalline structure of linear polymers, or modification of dye affinity in man-made fibres, etc. Comonomers are currently of interest for "molecular engineering" possibilities in e.g. the production of polyamide fibre modifications (additional acidification to confer affinity for cationic dyes) and polyester fibre modifications (for types with differential-dyeing and stepwise shrinkage characteristics).

Compact foam Smooth, unstructured, foamed back coating for carpets, compact, with smaller pores; term however not precisely delimited as against standard smooth foam (flat foam). Chiefly based on latex or polyvinyl chloride.

Compact package dyeing machine For cones, warp beams, slivers and tow. Pack cylinder for loose stock, muffs and hank yarn. Expansion tank in the dye vessel. Square preparation tank around the dye vessel, or a separate tank (near the compact package dyeing machine). Square structure requires only short connecting pipes, thus saving space. Centrifugal pump under the dye vat. Partial and full flooding. Equipment details effected in the vat (instead of above the lid as usual) (Fig.).

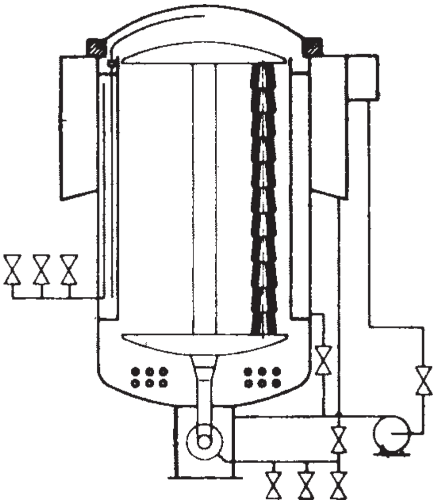


Fig.: Compact yarn dyeing machine (Jasper).

Compartmented (X-compartmenting). Division of drum into four internal compartments, giving four chambers in the drum cross-section.

Compatibility value (CV). A compatibility value, K, proposed by the Basic Dyes on Acrylic Fibres Committee of the Society of Dyers and Colourists to characterize cationic dyes according to their compatibility. It is therefore useful for the classification of cationic dyes with regard to their suitability in combination. The scale of K values ranges from 1 to 5. Dyes with CV = 1 exhaust more rapidly in combinations than those with higher CV values.

Compatibility value K (Bayer). Value for classifying cationic dyes in terms of combinability, the scale ranging from K 1 to K 5, Value K 1 dyes being quickly exhausted, and K 5 dyes slowly.

Compensator in flat screen printing Flat screen printing is effected intermittently, i.e. the printing screens are set down on the stationary fabric, rising up again after the printing paste has been spread (by the doctor stroke) before the fabric is moved on by one repeat by the rubber blanket. This repetitive, phased motion must not be transmitted to the fabric running into the printing zone because otherwise adhesion to the rubber blanket is interrupted each time it stops. A compensator (Fig. 1) is therefore installed so that the fabric is gummed on to the rubber blanket continuously.

The rubber blanket either moves forward from a

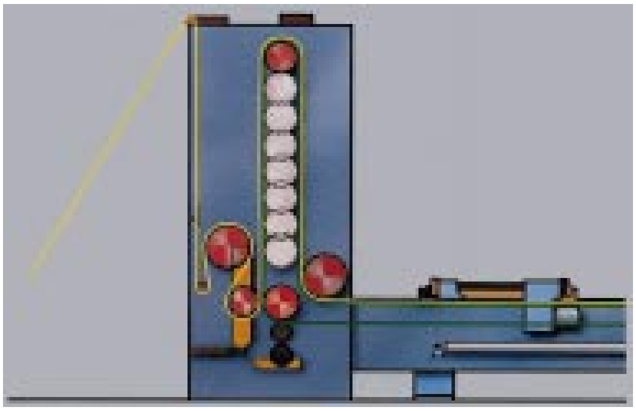


Fig. 1: Fabric entry (Buser Hydromag 6) with compensator for intermittent motion in the vertical direction.

fabric store at the printing machine exit under the table with the screens set down, i.e. stationary rubber belt on the table, in order to be gummed to the incoming fabric in the front fabric store, followed by further movement of the sandwich with the screens lifted; or the fabric only is moved with the screens lowered, before the sandwich is moved jointly with the screens raised (Fig. 2).

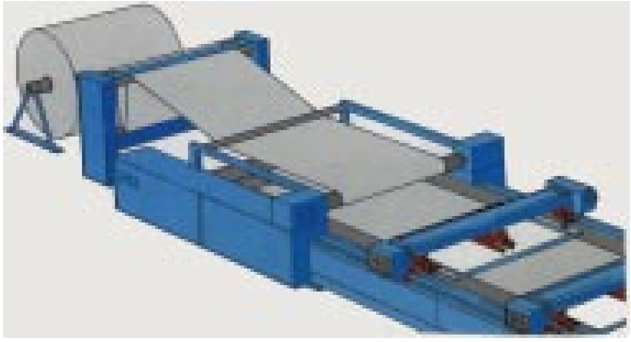


Fig. 2: Fabric entry (Reggiani Avant) with compensator in the horizontal direction.

Compensator roll control The functional principle of tension control by means of a → Compensator roller. (→ Compensator roll device).

Compensator roll device Device for regulating uniform fabric run and fabric speed or machine elements by raising and lowering motions. If two machines arranged in series (e.g. in continuous woven fabric pretreatment) need to be synchronised (Fig.), a compensator roller (or an identically functioning dancer roller as an alternative) is located between the machines.

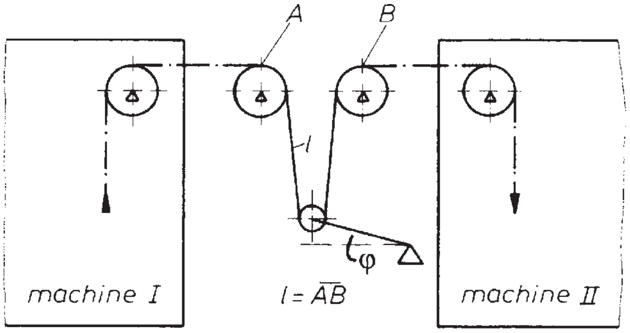


Fig.: Compensator roll device for the synchronisation of two machines arranged in series.

The compensator roller motion is transmitted to the actual value sensor via a chain drive with a transmission ratio of i_K. The angle of deflection φ on the actual value sensor is therefore defined as the controlled variable. A potentiometer, the terminal voltage of which illustrates the compensator roller angle in analogue terms, serves as a measured value transducer. One possibility of affecting the speed of the fixed traction roller, and therefore the fabric speed, is to change the transmission ratio of the steplessly adjustable PIV gear by servomotor. Changing the transmission ratio is possible via the axial displacement of the two bevel wheel pairs. Another possibility is to transmit the potentiometer setting via appropriate pulses to the DC motor (with variable speed via the voltage) or to an alternative AC motor with frequency control in order to let a machine run faster or slower. In this closed control circuit therefore

- the fabric is the controlled member,
- the compensator roller is the sensor,
- the drive to the rear machine is the actuator,
- the speed of the first machine is the reference value, to which the actual value of the second machine "lines up" via the compensator roll.

Compensator roller (dancing roller). Roller which moves up and down on movable bearings for equalising the tension on open-width piece goods between continuous operation finishing machines.

Complementary colour If rays of light visible to the eye meet coloured compounds, the absorption of specific ray zones occurs out of the numerous light pulsations, and the coloured compound appears in its so-called complementary colour (Table).

Wavelength (in mM)	Absorption colour	Complementary colour
approx. 725	magenta	green
645	red	bluish green
590	orange	blue
550	yellow	indigo blue
530	greenish yellow	violet
510	green	magenta
490	bluish green	red
455	blue	orange
425	indigo blue	yellow
400	violet	greenish yellow

Tab.: Absorption colour and complementary colour in the visible wavelength band (in nm).

The eye experiences white when incoming light contains unweakened the wavelength 750–400 nm. Coloured when any one or more wavelengths of this visual band is absorbed or changed (fluorescence) (i.e. are missing) by the body in question. Black, when all the radiated light is absorbed, increasing wavelengths being equivalent to a falling pulsation count, and vice-versa. → Chromatic circle.

Complementary dyeing of partially saponified acetate fibres Saponification of acetate fibres until partial saponification occurs. Then simultaneous dyeing of the unsaponified fibre core with acetate dyes, and the saponified fibre surface with direct dyes, e.g. a brown: red acetate dye and grey direct dye (grey overlaid red shade = brown).

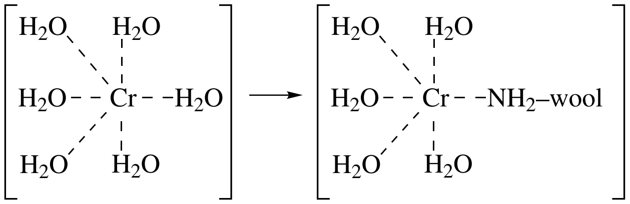
Completition time → Execution time.

Complex (Latin: complexus = enclosure). Composite unit.

Complex catalysts Act as permanent finish catalysts in so-called shock condensation; mixtures of the metal salts of strong acids with complex-forming α-hydrocarboxylic acids.

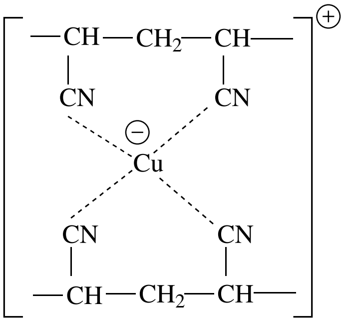
Complex compounds Higher molecular arrangements, in the construction of which not only atoms and radicals (e.g. SO_4 group, NO_2 group) are involved, but also molecules capable of independent existence (e.g. H_2O, NH_3, HCl, and also the wool, polyamide, polyacrylonitrile molecule etc) so that so-called ligands group around a central atom in each case (in the event of a number of central atoms, the term “multi-nuclear” is employed). These types of complex compounds reveal substantial stability, in that the total complex stays together in dissolution, i.e. does not (or only to a small extent) break down into ions. A distinction is drawn according to the type of chemical bonding:

I. Orientation complexes, as occur due to coordinative bonding in the form of partial valencies between ions or between ions and dipoles, e.g. in mordanting wool with chromium salt, the latter first of all forming, with chromium as the central atom, a complex hydrate with 6 H_2O molecules which gradually dissociate on boiling, and coordinatively combine in the first phase with an undissociated wool NH_2 group in the following way for example:

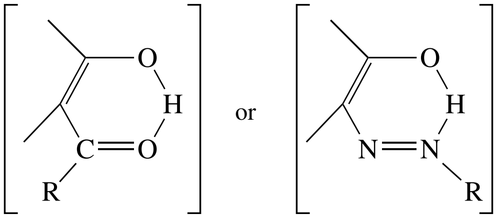


Such complex compounds are not very resistant to heat. The following are much more resistant:

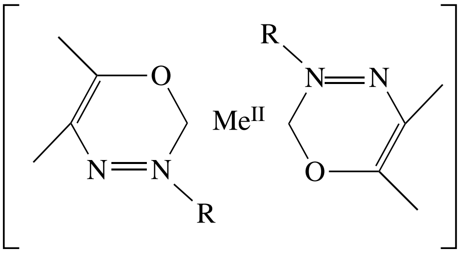
II. Penetration complexes, in which electrons of the partner mutually combine penetratively into an individually positively charged complex compound. Here, a partial valency type of coordination bonding can also exclusively be present, as for example in dyeing polyacrylonitrile with acid dyes by the cupro-ion process:



or atom bonds also occur additionally in principal valency terms in the form of chelate bonding, hydrogen for example occurring first of all so to speak as a monovalent but two digit complexing agent (hydrogen bridges) with approximately the following grouping as with mordant-uptake dyes:



from which (now as a penetration complex) the metal complex compound then results as dyeing:

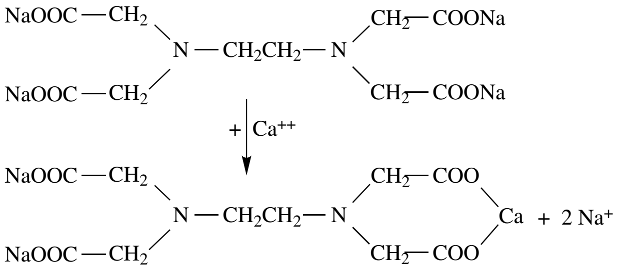


Complex formation The formation of a new ion from a metal ion by the action of molecules which have at least one electron donator group. In practice, the ability of the → Complexing agent to bond cations so that they can change their chemical properties. Example: 2 : 1, 1 : 2 complexes, with metal complex dyes, the usual characterisation of the metal atom to dye molecule relationship, which plays an important role in regard to the associated dyeing properties etc.:

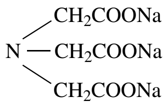
1 : 1 complex = 1 metal atom : 1 dye residue,
1 : 2 complex = 1 metal atom : 2 dye residues.

The production of metal complex wool dyeings by the pre-mordanting single bath and after-chroming process leads to 1 : 1 or 1 : 2 complexes. In essence, premetallised dyes, i.e. commercial metal complex dyes, are either 1 : 1 complexes, which contain soluble-making sulpho-groups, and are dyed highly acid, or it involves a) sulpho-group-free 1 : 2 complexes; b) 1 : 2 complexes with one or two sulpho-groups. There are other mixed complexes, e.g. sulpho-group-free chromium complex dyes with a colourless complexing agent residue (e.g. salicylic acid), i.e. also 1 : 1 complexes. In a similar way, 1 : 1 chromium complexes are also converted with non-metallised dyestuff to asymmetrical or symmetrical 1 : 2 complexes or 2 : 3 complexes.

Complex-forming ability Substances which form undissociated complexes with bivalent and trivalent cations frequently belong to the so-called chelating agent group. The name is derived from the Greek chele = crab's claw, and therefore describes the ability of these compounds to bond a multivalent metal ion by two or more atoms, the ligands encompassing the ion like crabs' claws. The compound on which this phenomenon has been studied most exhaustively is ethylene diamine tetra-acetic acid (EDTA). Two of its acetic acid residues react with the calcium ion in forming the unassociated complex; the other two residues are bonded ionically by sodium.

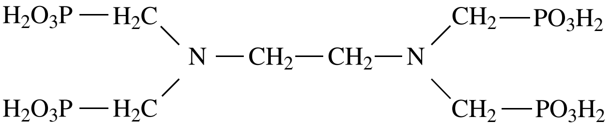


The prerequisite for developing chelates is a specific arrangement of the acid groups of the molecule, as is the case with EDTA and many other organic acids. The type of bonding of the metal ion in the chelates and related compounds is described as "charge transfer" complex bonding; it is characterised by the fact that the metal ion is bonded non-ionogenically, and no longer has any hydrophilic character. The sodium salt of nitrilotriacetic acid (NTA) has similar complexing-forming properties to EDTA, with the added advantage of lower molecular weight and a therefore 50% greater metal bonding capacity.

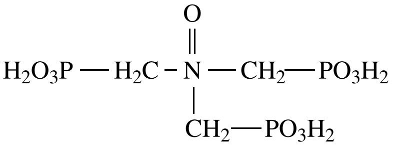


(NTA) molecular weight = 191

The salts of phosphoric acid also have a complex bonding capacity for metal ions:

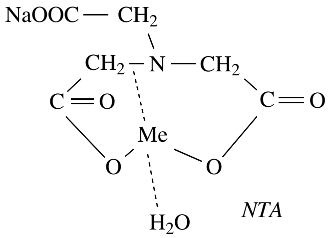


Ethylene diamine tetramethylene-phosphoric acid (EDTMP) molecular weight = 436

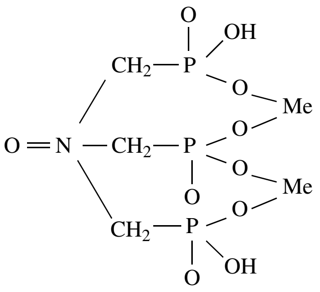


Oxyaminotrimethylene-phosphonic acid (N-OX-ATMP), molecular weight = 315

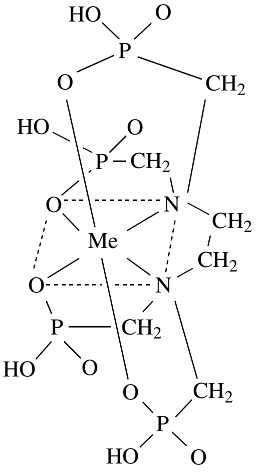
The stability constant of a complex, for Fe^{3+} for example, has the value 15.87 (NTA). The stability constant of the polyphosphonic compounds is higher than that of NTA, and these should therefore be effective complexing agents. Polyphosphonic compounds can be present in sodium salt form with partial or complete neutralisation of the phosphonic acid, and consequently the pH of their solution varies between 7 and 12 in the case of commercial products. These compounds complex one or two metal atoms per mol of polyacid:



NTA



N-ox-ATMP

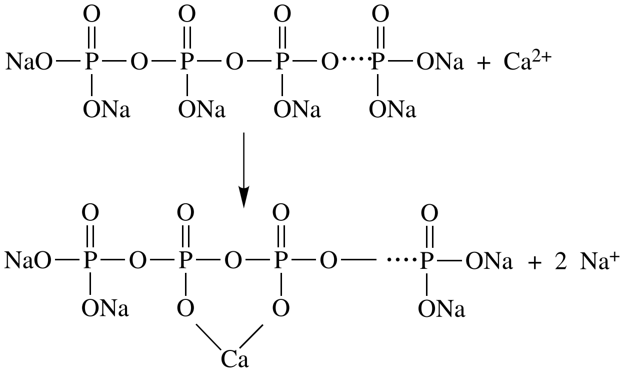


EDTMP

The respective calcium complex of these chelates is more resistant than the sodium complex of the starting substance added to the water, because energy is produced in consequence of an increase in the number of freely movable electrons, if ligands (Na^+) which can take up only one coordinate position are replaced by those (Ca^{2+}) which can have several coordination positions. Since derivatives of phosphoric acid in water courses require eutrophication, phosphate substitutes are of interest in regard to their complex bonding capacity. The tertiary amines especially (as are the quats [quarternary ammonium compounds] too) are not however clarified in terms of their biological degradability, their behaviour in purification plants and their effect on biocoenosis. Whether they remove metal ions from systems, or give off complex-bonded metal to the system, depends on the effect of the system on the complex formation constants. In any case, sequestering agents give rise to environmental problems for that reason. This statement applies also to metal complex dyes, in the case of which little is known about their behaviour in biological systems.

Complexing agent (metal complexing agent, inactivating additive, sequestering agent, chelating agent). Products which are qualified by characteristic functional groups to change metal ions by → Complex formation, and to improve their solubility in a specific medium. This occurs by the coordinative bonding of unwanted metal ions in the soluble complex in order to avoid metal precipitation in the liquor and on the textile product, and to dissolve metal compounds already deposited on the textile product. Classification:

I. Inorganic complexing agents, in which the large group of → Complex phosphates is included, such as sodium triphosphate or higher molecular polyphosphates which form soluble metal complexes in accordance with the following principle (ion exchangers):



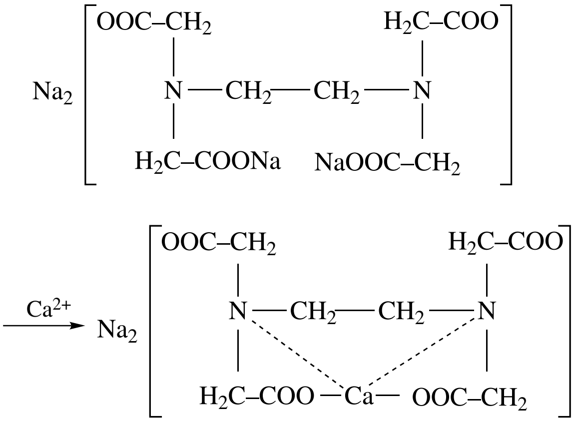
This reaction always presupposes an excess of complexing agents, so that soluble sodium metal polyphosphates form. With an excess of metal ions, all sodium ions are replaced by metal, producing insoluble salts.

II. Organic complexing agents, including oxalic, tartaric and citric acid (aminopolycarbonic/carboxylic acids), nitrilotriacetic acid and ethylene diamine tetra-acetic acid and their sodium salts, soluble metal complexes also being formed in the following way:

with nitrilotriacetic acid:

$$2\ Na_2\left[N(CH_2COO)_3Na\right] \xrightarrow{Ca^{2+}} Na_4\left[N(CH_2COO)_3Ca(CH_2COO)_3N\right]$$

or with ethylene diamine tetra-acetic acid:



Although inorganic and organic complexing agents appear to be very much alike as regards alkaline earth and heavy metal ion bonding, their behaviour under specific conditions (pH, temperature, time) is so characteristic that clear delimitation of fields of application have appeared. In dyeing with metal-containing dyes, demetallisation (shade change, impaired fastness) occurs due to organic complexing agents. On the other hand, inorganic polyphosphates can be used in all dyebaths in common with metallised dyes with the exception of the 1 : 1 metal complex dyes. In general, complexing agents should be added before the addition of dyes and other auxiliary agents. Furthermore, complexing agents act as oxygen stabilisers in peroxide combinations, and as fibre protectors against cellulose. Polyphosphates greatly increase the washing power of soaps or surfactants, for which reason they have achieved great importance in detergent synthesis. → Complexometry.

Complexometry (chelatometry). Simple volumetric process (→ Titration) of universal application, which is used for the quantitative determination of cations (Ba, Ca, Co, Cu, Fe, Mg, Mn, Ni, Pb, Zn etc.) and anions (halogens, phosphates, sulphates etc.) by means of → Complexing agents and special indicators. Quick and easy implementation with a high degree of accuracy has been found of great importance for determining water hardness. Reaction principle: exchange of sodium for calcium and magnesium ions in the water into masked, soluble complexes which are detected by colour reaction.

Complex phosphates Term for polyphosphates as condensed phosphates with a chain structure. The term is used because they display the typical behaviour of complex compounds during dissolution in water and in their type of reaction. In water softening (i.e. Ca ion bonding), the undissociated Na atoms or H atoms in the polyphosphoric acids are always exchanged first of all. The solubility of the complex salts decreases as the calcium content increases. From this, it follows that polyphosphates always have to be metered in a specifically stoichiometric excess in order to obtain soluble calcium (or other metal) complexes.

Complex phosphates are typical complex salt formers which dissolve alkaline earth carbonates and metal oxides etc., thus resulting in metal corrosion. The extent of corrosion of bright metal surfaces depends not only on the polyphosphate type (chain length) but also decisively on the prevailing conditions (pH, concentration, temperature, attendant substances etc.). Corrosion can be controlled by careful polyphosphate selection, and, if necessary, the co-application of suitable inhibitors.

Component fibres Consist of two or more different high-polymer types, e.g. → Bicomponent fibres (Fig.).

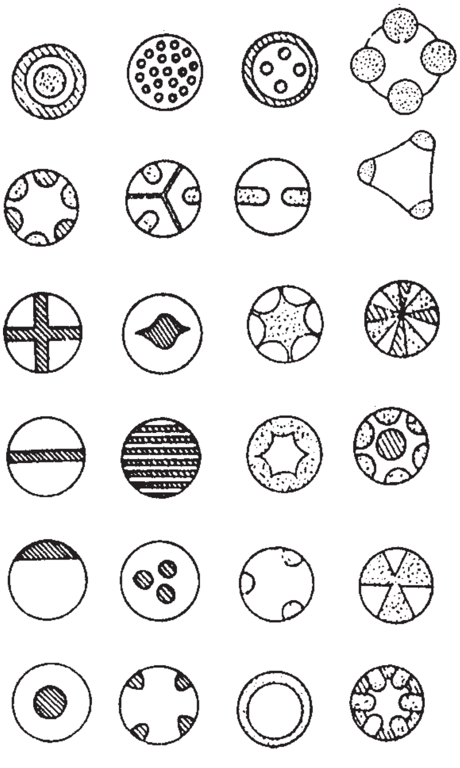


Fig.: Different component fibre types.

Composite,

I. An article or substance of two or more constituents, generally, with reinforcing elements dispersed in a matrix or continuous phase.

II. Hard or soft constructions in which the fibres themselves are consolidated to form structures rather than being formed into yarns. Rigidity of these constructions is controlled by the density, the modulus of the load-bearing fibres, and the fraction of fusible fibres. Strength is cont adhesion and shear-yield strength of the matrix unless fibres are bonded in a load-transferring matrix.

III. A structure made by laminating a nonwoven fabric with another nonwoven, with other materials, or by impregnating a nonwoven fabric with resins.

Composite fibres Fibres composed of two or more polymer types in a sheath-core or side-by-side (bilateral) relation. → Bicomponent fibres.

Composite plastic and textile fabrics Composite fabrics of which at least one layer consists of flexible, textile fabric like woven and warp knitted fabrics, nonwovens for example, and the other layer is a plastic coating with a leather-type (or leather-like) surface; also called → Artificial leather. Depending on the type of textile fabric: woven artificial leather cloth, warp knitted artificial leather cloth, nonwovens artificial leather cloth (DIN 60000, 16922).

Composite plastic material Plastic sheets of two or more layers, at least one of which is of → Plastics, e.g. → Composite plastic and textile fabrics.

Composites Combinations of two or more materials, bonded at the macroscopic level to form a new material which seeks to balance the disadvantages of the first component with the advantages of the second. A microscopic bonding of materials, as with alloys, also creates “compound materials”; these, however, are homogeneous at the macroscopic level. The actual composites, on the other hand, are non-homogeneous and generally demonstrate anisotropic properties i.e. the physical properties are directional dependent. With the isotropic body, in contrast, the sizes of the vectorial properties do not depend on the direction, but rather all directions in relation to their physical properties are of the same value.

I. So-called particle materials: The particle materials (Fig. 1) involve materials in which fillers consisting of one or more materials are embedded in a matrix of another material. The properties of such composites change in a variety of ways compared with the original unfilled state, e.g. by an increase in elasticity and impact resistance, change in viscosity, flame retardancy, etc.

II. Fibre-reinforced materials: In the bonded fibre fabrics or fibre-reinforced fabrics (Fig. 2) fibres are embedded in the matrix. These fibres frequently have much better mechanical properties than the surrounding matrix and even the same material of which the fibre consists in its original form. These fibres improve the performance properties of the composite considerably due to their great strength.

III. Layered materials: The layered materials (Figs. 3–4) consist of at least two different materials that are combined to achieve greater strength, rigidity, resist-

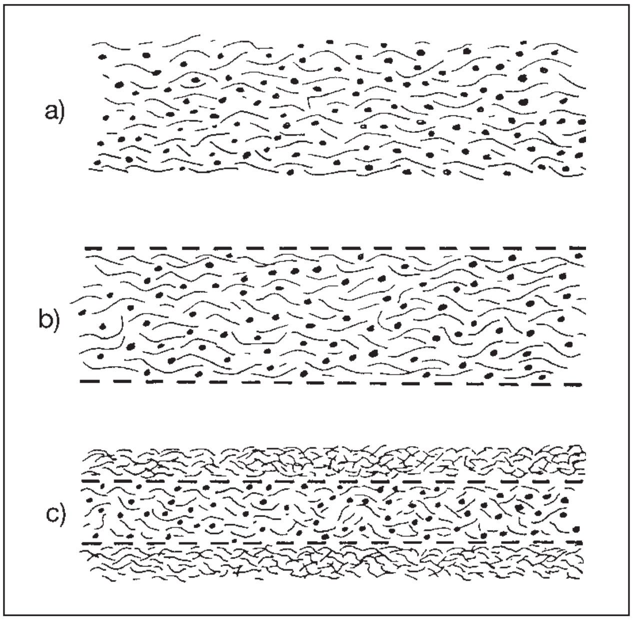


Fig. 1: Particle materials as a form of composite: a) fleece core with inlaid silicic acid particles, where the composite is fixed by needle-punching; b) as a) but with flame retardant fabric on the upper and lower side as a laminate; c) as b) but with fleece covering layers.

ance to corrosion, etc. Often a component will serve to protect the other by sheathing it. The coated fibre-reinforced materials are a special case in point (so-called → Laminates) since these are classified as both layered materials and fibrous materials. On the one hand, the fibre is protected by embedding in a matrix, on the other, the desired properties can be deliberately developed in any direction from the properties of the heavily anisotropic layers by superimposing them to form a multilayered composite.

To clarify the concept of reinforcement, i.e. the improvement of the mechanical properties of an unreinforced matrix material can be demonstrated by reference to the materials‘ stress/strain diagrams. In Fig. 5, left-hand section, two different types of materials, polymer and high-modulus fibre (HM fibre), are depicted in terms of a stress/strain diagram. Polymers are characterized by their high degree of elastic deformability, and high elongation at break. The high-modulus fibres behave in exactly the opposite way, with a high modulus of elasticity, great strength, but low elongation at break. The reinforcement is based on the insertion of high-modulus fibres into a matrix with a high elongation at rupture (see right-hand section of Fig. 5). Ac-

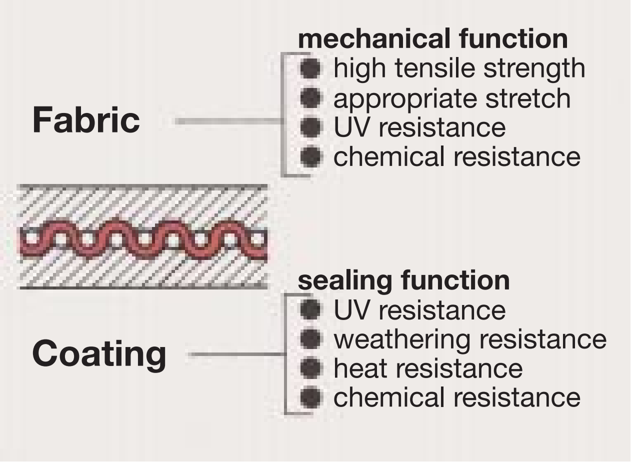


Fig. 2: Schematic representation of a coated fabric.

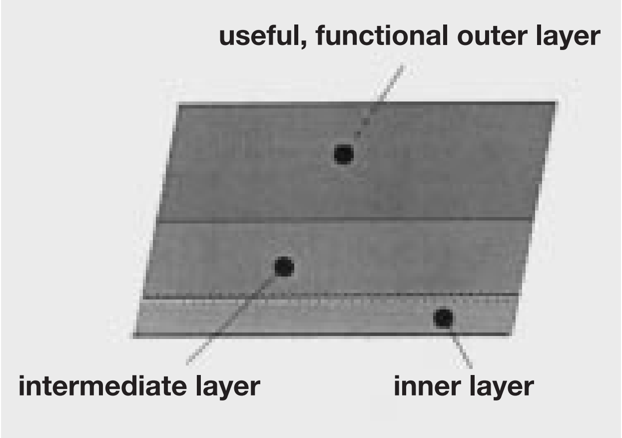


Fig. 3: Structure of the rubber shrinkage cloth with its three layers.

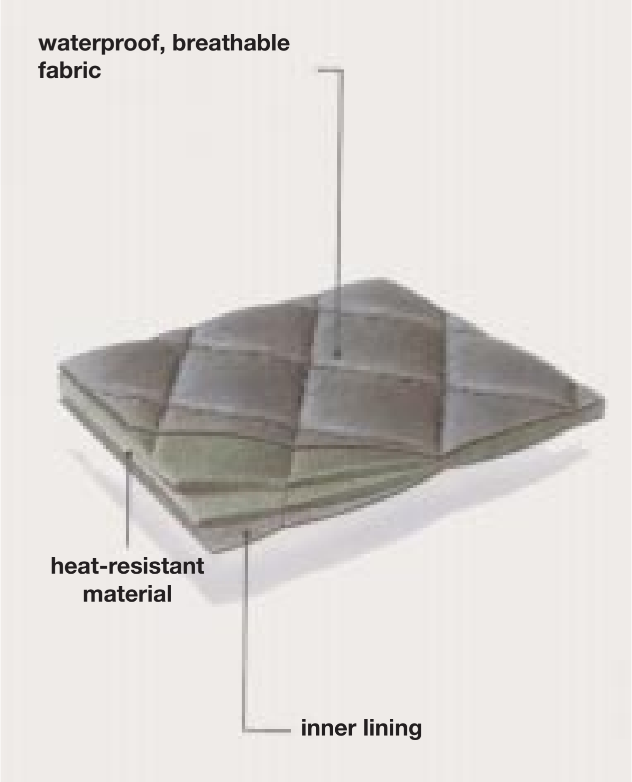


Fig. 4: Layered material as a protective fabric for firefighting uniforms.

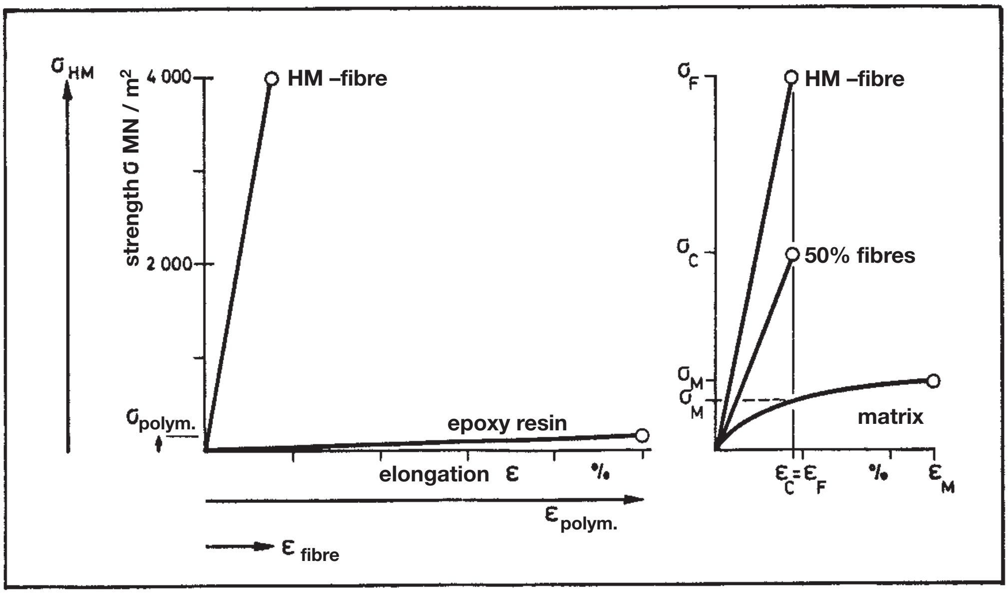


Fig. 5: Tension/elongation diagram of an HM fibre, of an epoxy resin and composite with 50% by vol. fibrous content

cording to the Mixing Rule, the components contribute to the overall properties of the composite body proportional to their share of the volume. The break point is found only when the more brittle components exceed their normal elongation at rupture. The high elongation at break of the polymer matrix means that the brittle fibre's contribution to the material strength of the composite can be exploited to the full. In Fig. 5, on the right, the stress/strain diagram has been drawn for a composite body with 50% by vol. of fibres. From this figure it is possible to derive a crudely simplified requirement profile of the composite or its components, the matrix and reinforcing fibre.

The fibres used should have the following property profile:

a) Requirements of processibility:
  - good wettability,
  - adaptable to the method of processing,
  - no shrinkage or change in length during processing,
  - not sensitive to moisture and temperature conditions.

b) Requirements of ultimate properties: The matrix is the carrier of tension from fibre to fibre in the composite. It should therefore not only be plastic, but also "bondable" with the fibre. In addition it must also absorb any possible breaks appearing in the fibre component of the composite and be able to dissipate the forces responsible.

The matrices should satisfy specific requirements during the manufacture of the composite, or rather in the finished article:

a) Requirements of processibility:
  - good wetting (affinity) of the reinforcing material,
  - low-viscosity system,
  - processibility with lowest possible pressure and low temperatures,
  - sufficiently long life,
  - with polymers: controllability of the polymer structure.

b) Requirements of ultimate properties:
  - good long-term performance with static and dynamic stress,
  - good bonding between matrix and reinforcing materials (requisite polymer compatibility) to avoid delamination,
  - good chemical, heat and corrosion resistance.

Since the matrices always need to be softer than the reinforcing fibres (with the exception of shock-resistant polystyrene), only plastic metals and macromolecular materials can be reinforced in principle. Of the metals it

Polymer structure Behaviour	linear  branched 	cross-linked 
Description	Thermoplast	Duroplast
Solubility	usually good	insoluble, swellable
temperature increase > T_G	become soft, viscous flowing	become soft rubbery, dimensionally stable
Processing	of the finished polymer	low-molecular raw materials
Processing temp.	mostly above 180°C	up to 150°C
Matrix penetration in bundle of fibres	slow	rapid
Process adjustment	difficult	good

Fig. 6: Polymer structures and their most important properties, which need to be taken into account in the manufacture of composites.

is the easily deformable and workable ones especially that are involved: aluminium and magnesium alloys, lead or tin. When selecting the polymers, a choice must first be made between thermoplastics and duroplastics. A comparison of the most significant characteristic features of these types of structure highlights the advantages of cross-linking structures as shown in Fig. 6.

Nevertheless it is the state of the art to reinforce thermoplasts, especially the high-quality technical thermoplasts, with suitable additives, e.g. various fibre combinations. The metallic deformability of such composite systems ought to remain the driving force behind their continued development in future. Cross-linking systems currently enjoy a dominant significance. They are generally composed of low-molecular raw materials, which are transferable to macromolecules through polycondensation, polymerization or polyaddition. Since duroplasts are not deformable thermally, each forming process must take place in a non-cross-linked state during the application process.

In principle there are two possibilities available for the cross-linked structure:

a) cross-linking of tri- or polyfunctional raw materials
b) use of mixtures of bifunctional monomers with tri- or polyfunctional monomers.

While tri- and polyfunctional components are carriers of the cross-linking process, bifunctional monomers affect the degree of cross-linking. At the same time, it is possible to use components which possess two completely independently reacting functional groups, with the result that the network is built up in stages via two independent reaction mechanisms. Since with the manufacture of composites the displacement of low-molecular components is undesirable, cross-linking syntheses proceed by polycondensation reactions. More significant still are cross-linkings via polymerizations and all polyaddition systems.

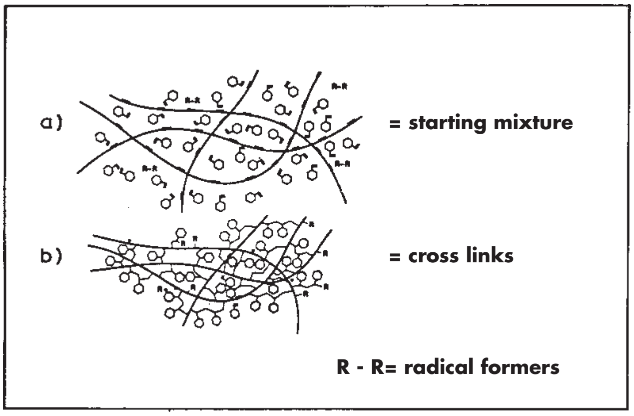


Fig. 7: Cross-linking process of unsaturated polyester with styrene.

Of the family of cross-linked systems brought about by polymerization, the unsaturated polyesters assume an important position. They have the advantage that, as a result of numerous, easy-to-obtain structural variations, their end properties can be easily adapted to a variety of requirement profiles. Their structure is comparatively simple and is illustrated in Fig. 7. The properties of the network can be varied through the composition of the unsaturated polyester and the use of variously structured unsaturated co-monomers. The volume shrinkage of 6–9% by vol. characteristic of these systems with the transfer of the liquid mix into the network can be greatly reduced by the addition of thermoplasts; however, this inevitably leads to a change in the physical properties.

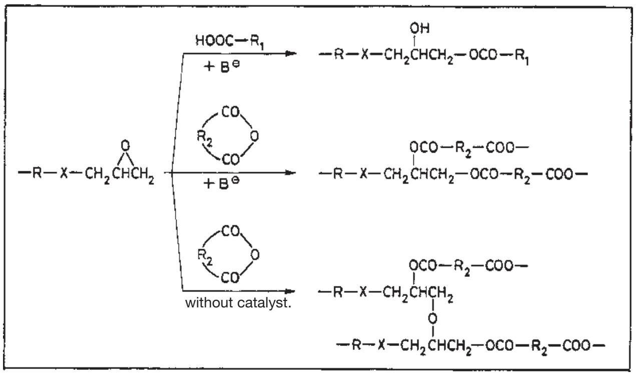


Fig. 8: Additions of carboxylic acids and carboxylic acid anhydrides to epoxy compounds.

Of the matrices gained from the polyaddition principle, the epoxy resin systems dominate. They offer broad opportunities for adapting to required product profiles and processing conditions. These systems are illustrated in the structural fragments of Fig. 8 and Fig. 9. Fig. 10 depicts the polyaddition of bis-maleic-imide taking a diamine as an example of a cross-linking system. Compared with the epoxy resin systems, these systems are characteristically different. The starting components represent crystalline or vitreous substances with high melting and/or glass transition temperatures, which means that they usually need to be applied

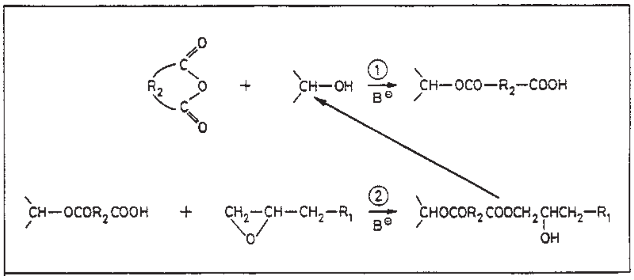


Fig. 9: Development of anhydride cross-linking.

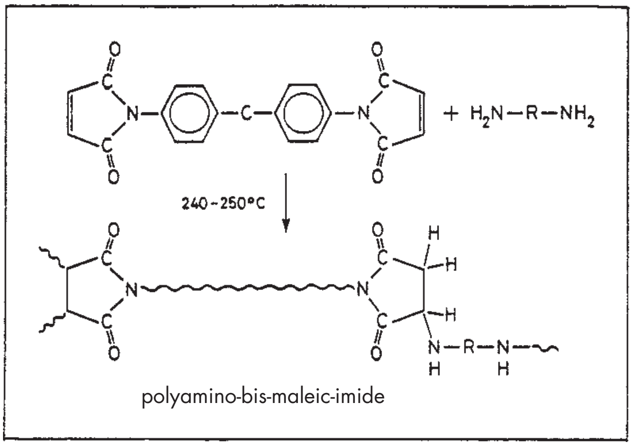


Fig. 10: The polyaddition of bis-maleic-imides taking a diamine as an example.

to the reinforcing fibres from solvents. Finally, the solvent needs to be re-volatalized, a definite resin flow obtained in a preliminary reaction and ultimately the actual hardening achieved with increased temperatures (> 200°C). This requires the use of expensive, explosion-protected plant facilities.

Polypropylene or polyethylene fibres are difficult to wet-out and are plasma or corona treated to give a more hydrophilic surface. A pretreatment of polypropylene sheets by means of corona discharging is associated with an increase in surface energies (e.g. 10^{-3} J/m^2). The station for the corona discharging should be located just before the coating unit because the surface effects are not permanent. The pretreatment via corona discharge is not sufficient for many coating systems. If, for example, coating is to involve non-blocking PVDC dispersions or contact adhesives, then an adhesion promoter needs to be applied first. The adhesion promoter (also → Primer) may be an aqueous dispersion or be in a dissolved form. Thermally cross-linking, 100% solid primers on a PU basis with layers less than 1µm thick are also in use.

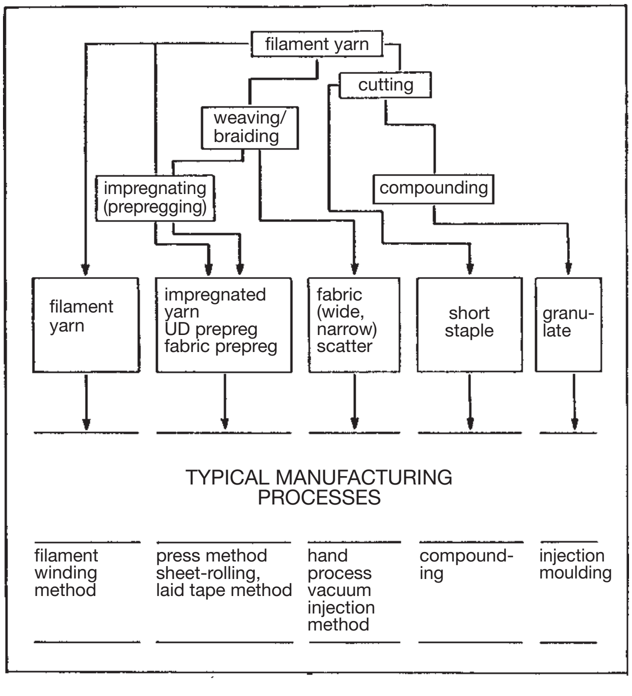


Fig. 11: Semi-finished products and manufacturing processes for composites.

After the pretreatment of the reinforcing materials, the reinforcing materials and matrix polymers are produced as a semi-finished product (Fig. 11).

The hand lamination process (Fig. 12) is the oldest method. Chopped strand mats and/or roving fabric are used as reinforcing material. Depending upon the type of parts being manufactured, mats with powder or emulsion binders are used. Fabric and/or mats are laid in the mould, then manually impregnated with resin and deaerated using a fluted roller. This process is used to manufacture small series of technical parts such as are found in boat building.

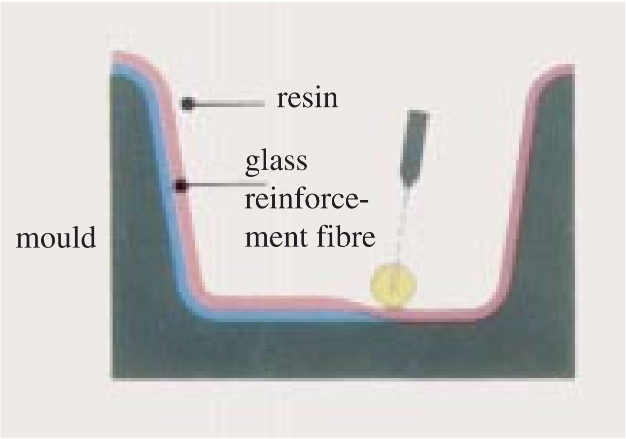


Fig. 12: Hand lamination process (after Vetrotex).

With fibre-resin injection moulding (Fig. 13), a further development of the hand lamination process, the materials are applied with the aid of a spray gun, which will cut the glass fibre and simultaneously inject it into the mould with the resin. Here, too, the mould is finally treated with a fluted roller. The injected layers of fibre may be alternately processed using roving fabric. Careful impregnation and deaeration are crucial for the quality of the moulded part.

With medium-sized batch productions on the scale of 1000 to 10 000 units per year, reproducibility becomes an important aspect. For this reason alone, craft processes and their related disadvantages (large proportion of manual work and a non-smooth surface) are out of the question. To increase the working speed and achieve a smooth appearance for both surfaces, while at the same time retaining a certain freedom in the forming and dimensioning, the manufacturer will decide in favour of the injection or low-pressure moulding proc-

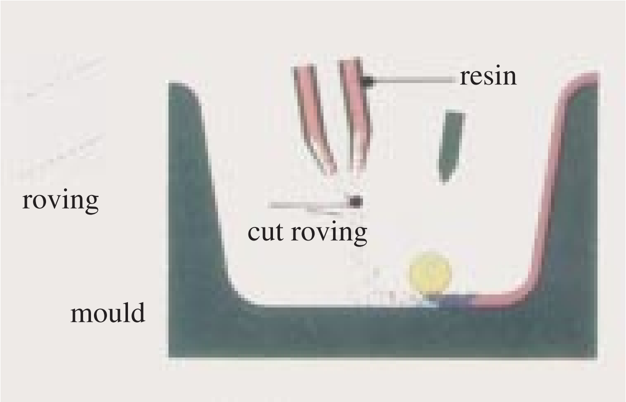


Fig. 13: Fibre-resin injection moulding (after Vetrotex).

esses, which are especially suited to limited-run batch productions. The investment costs required are relatively small since the mould halves are mostly made from composites.

Injection moulding (Fig. 14) involves a process for medium-sized batches. The end product involves components with a good surface appearance that are covered in a fine coating. Continuous filament mat cuttings are used for textile glass reinforcements since they guarantee good mouldability. The mat may also be premoulded. In many cases fabric can be used as well. The reinforcement is integrated between the mould halves. Once the mould is closed, the resin is injected under low pressure. The reinforcing material is impregnated gradually. It is possible to inject the resin into the cold, hand-hot or even hot mould. This process is also possible with a low vacuum, which makes impregnating the textile glass reinforcement easier. The vacuum injection process does require the whole mould to be absolutely leakproof, however.

To acquire the equipment necessary for the low-pressure moulding process (press with low mould clamping force compared with large batch systems and composite moulds) moderate investment is required. Continuous mats are generally used for the reinforcing materials since these can be pre-moulded if need be. Fabric is also suitable. The pressure is between 2 and 4 bar. As with injection moulding, any heating temperature for the moulds is possible, from room temperature up to 80°C. Preforms made of continuous mats involve reinforcement in the form of the manufactured part. The preform is used in injection moulding and wet pressing to manufacture parts with complex shapes or a high proportion of glass. The preform offers the following advantages:

- less time spent on incorporating the reinforcement;
- avoidance of resin-rich zones;
- reduction or avoidance of waste.

For small and medium-format parts of various shapes such as those found in large-scale manufacture, the use of presses or injection moulding equipment is recommended. On account of the high pressures (15–150 bar) and mould temperatures (100–160°C) that occur, the use of metal moulds that are clearly more costly than composite moulds cannot be avoided. The industrial manufacturing processes are characterized by their short production sequences: 1–4 min each according to the thickness and complexity of the moulded part. Hot pressing involves the use of presses between 10 and 20 bar and temperatures around 110°C. Normally continuous mats, but in some special cases chopped strand mats, serve as reinforcement. Preforms and fabric are just as suitable, however.

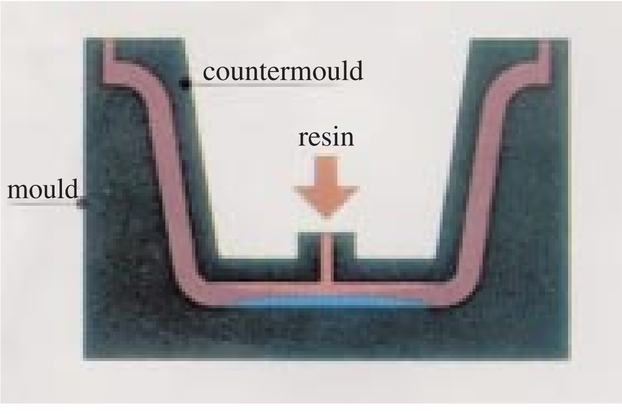


Fig. 14: Injection moulding (after Vetrotex).

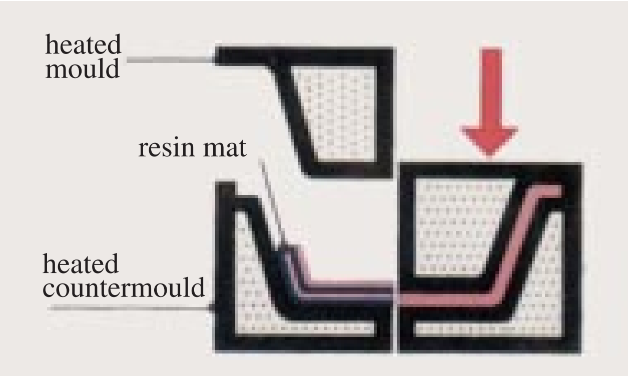


Fig. 15: SMC process (after Vetrotex).

Unlike the other processes described above, the hot pressing of resin mats utilizes an immediately usable material in the form of a pre-impregnated mat, which is generally described as SMC (sheet moulding compound – see Fig. 15). The resin mat consists of cut fibres, 25 or 50 mm in length, which are embedded between two thin foils. First of all, cuttings are made which are smaller in area than the part being manufactured. These cuttings are stacked on top of one another and inserted into the mould. The effects of pressure and

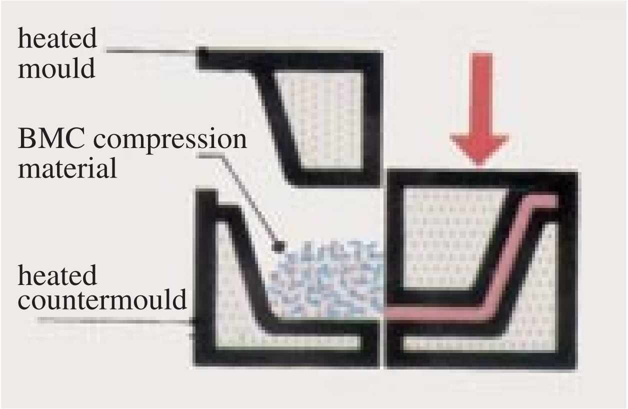


Fig. 16: BMC process (after Vetrotex).

temperature will cause the material to flow and fill up the cavity of the mould. Polymerization is triggered by the heat of the mould. This process allows parts with walls of varying thickness, bridges, undercuts, etc. to be manufactured. The pressures are between 30 and 100 bar, the temperatures between 140 and 160°C.

BMC (bulk moulding compound), a.k.a. as duroplast or premix compression moulding material, is a mixture of cut textile glass, resin and fillers. The processing of BMC and SMC differs in that the materials vary in form. Unlike the sheet resin mats, BMC is a fibrous moulding material with a dough-like, flowing character. The textile glass reinforcement consists of cut fibres of usually 6 or 12 mm in length. The filler content is often higher than with SMC, whereas the textile glass component is smaller. That is why a greater mechanical strength is obtained from SMC than from BMC.

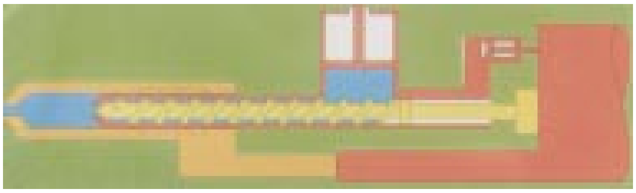


Fig. 17: Injection moulding ZMC (after Vetrotex).

For large-scale manufacture using duroplasts, injection moulding (Fig. 17) is suitable on account of the automation possibilities and the high ejection rate. ZMC does not only describe a material or a process, but also the combination of product and technology (fibre – moulding material – press – mould – finishing stages). With this system, which is characterised by a high degree of automation, the moulded parts produced have an improved mechanical strength compared with the parts manufactured according to the classic injection moulding method using BMC. ZMC allows a high surface quality to be achieved. Processing temperatures around 160°C and injection pressures between 150 and 200 bar are employed. As with hot presses, the heated moulds are made of pressure-resistant steel. Hollow bodies can be manufactured by means of two different processes.

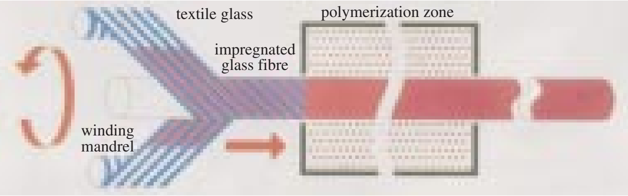


Fig. 18: Winding method (after Vetrotex).

The winding method (Fig. 18) is used to manufacture pipes, flanges, collars, etc. Manufacture occurs by winding resin-impregnated roving strands (in situ or pre-impregnated) around a core turning about an axle (mandrel). The roving strands can be attached either vertically to the winding mandrel (surface-driven winding) or at an angle to the axle (helical-type winding). This method allows high textile glass content levels to be achieved (60–75%), which ensure good mechanical properties. Additional textile glass mats or cut rovings, which are cut and sometimes combined with roving fabric directly before the feed to the winding mandrel, can also be used as reinforcing materials. These kinds of combined reinforcing structures are recommended if the product rigidity is a prime feature. The use of pre-impregnated rovings facilitates the manufacture of parts with a high textile glass component (80% by weight) due to their good processibility. The moulded parts manufactured by the winding method always have a smooth surface regardless of the type of machinery (whether continuous or batch production).

The centrifugal method (Fig. 19) is suitable for manufacturing hollow bodies with smooth inner and outer surfaces. The textile glass reinforcement (usually

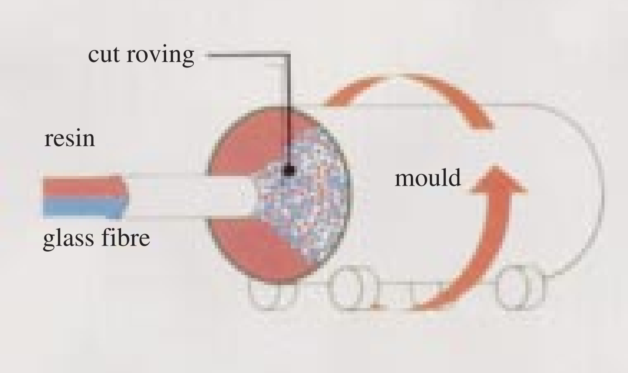


Fig. 19: Centrifugal method (after Vetrotex).

cut roving in situ) and the resin are injected inside a cylindrical mould, which is revolving at great speed. Textile glass mats or textile glass fabric may also be inserted in the mould beforehand. Under the effect of the centrifugal force, the reinforcement is saturated with resin. The centrifugal method is best suited to the manufacture of composite components made of polymer concrete, foam, anti-corrosion film, etc. The centrifugal method is chiefly used to manufacture cylindrical parts (tanks, silos, etc.), although it is equally suited to the production of slightly conical parts such as masts or pillars. With low circumferential speeds (e.g. for parts with large diameters) one talks in terms of “rotational casting”. This technique requires the provision of a vent in the mould.

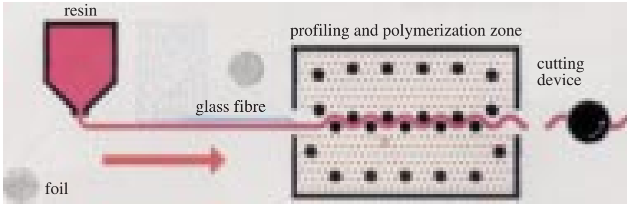


Fig. 20: Continuous plate production (after Vetrotex).

Plates are manufactured in large batches on continuously operating systems (Fig. 20). The textile glass (chopped strand mat, continuous mat or cut roving) and the resin are applied to a sheet which is spread out on a horizontal work-table. The impregnation that follows is supported by compression elements. Following impregnation a second sheet is applied to the surface of the glass/resin mixture. Thus prepared, the material passes through calibrating rollers and subsequently the polymerization tunnel, which contains the moulding elements in the front section. Upon exiting the continuous oven, the plates are trimmed and cut to the desired length. The two sheets do not only serve as carriers, but also allow the plates to obtain smooth surfaces on both sides. This technique, used mainly in the manufacture of flat and corrugated plates, can also be used to produce open profiles with simple forms and sufficient radii.

The pultrusion process (Fig. 21) serves the continuous manufacture of every type of profile. Here the resin-impregnated reinforcing material is drawn through a heated mould in which the profiling and polymerization take place. Roving, mat and/or fabric can all be processed as reinforcement. Impregnation occurs either through submersion in an impregnation tank or by injecting the resin at the nozzle head. Polymerization of the product occurs upon passing through the heated polymerization zone at 120–150ºC. The drawing mould is usually made of smooth-polished and chrome-plated steel. The profile is drawn at constant speed by a device arranged for this purpose behind the drawing mould, which makes for continuous operation. This process allows complicated parts, hollow or solid, to be manufactured with great mechanical strength.

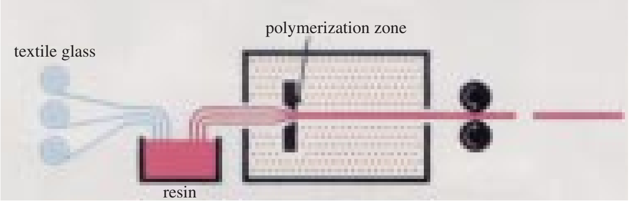


Fig. 21: Pultrusion process (after Vetrotex).

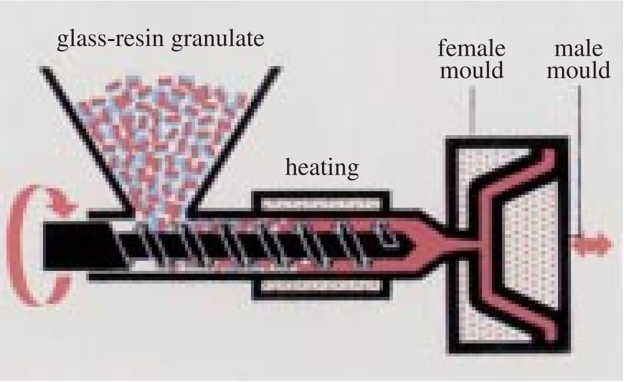


Fig. 22: Injection moulding of granulates (after Vetrotex).

With injection moulding (Fig. 22) of reinforced thermoplasts, in 90–95% of the cases a semi-finished product in the form of textile glass reinforced granulates is used. The textile glass, usually 4.5 mm long cut fibres, can be mixed initially with the pure resin granulate (premix) or can be fed separately to the extruder (separate dosage). In some cases, e.g. with twin-screw extruders, it is also possible to feed the textile glass directly to the resin melt in the form of roving strands. The reinforced granulate is processed in the injection moulding, whereby the same plant facilities can be used as for the processing of unreinforced thermoplasts. Owing to the high injection pressures (> 350 bar) it is only possible in terms of equipment to manufacture parts up to a particular size. The processing temperatures are usually 10–20°C higher than those for unreinforced thermoplasts. Injection moulding also allows complex forms with bridges, overhangs, bore holes, undercuts, etc. with high ejection rates to be manufactured from thermoplasts.

Moulded parts made of thermoplast plates, reinforced with long glass fibres, are manufactured according to the processes of moulding compression and extrusion of reinforced thermoplasts. Different processes are available for the manufacture of these reinforced thermoplast sheets (GMT). The sheets are heated up to the softening temperature of the resin matrix and formed in a cooled mould. In the same way, only by

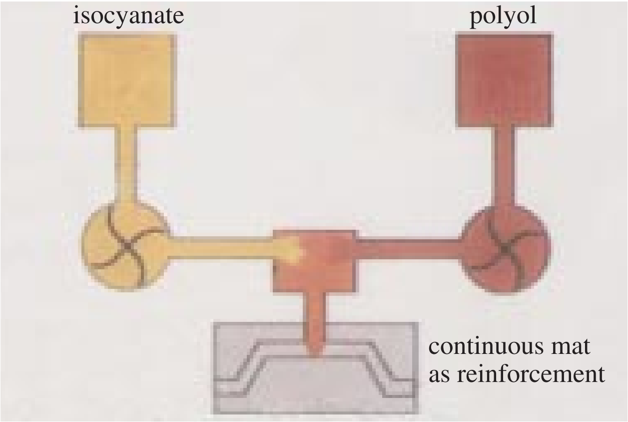


Fig. 23: PUR-M process (mat reinforcement) (after Vetrotex).

altering the cuttings and the moulding pressures, they can also be processed by the extrusion method. The actual pressures used depend on the shape and thickness of the part being manufactured. The pressures with moulding compression are between 20 and 50 bar, with extrusion between 120 and 150 bar.

Textile glass also serves as reinforcement of polyurethane foams. These reinforced foams obtainable in semi-rigid or rigid form are gaining increasing acceptance due to their low weight and easy processibility. Of the wide range of applications, if one takes the case of the automobile industry, here parts made of reinforced foam are chosen for fitting out the interior of cars and commercial vehicles. Through reinforcement with textile glass mats (Fig. 23) polyurethane foams acquire better mechanical properties and greater dimensional stability. The most common reinforcing materials used for this purpose are continuous mats, which can be preformed if need be. A mat is inserted in the mould: the polyurethane resin can now be spread over the mat prior to closing the mould or be injected into the closed mould at a low pressure. The expansion and reaction of the PUR mix occur during its time in the mould. Should the exterior of the part need to be decorated, this can occur directly during the moulding, by inserting the material or plastic film in the mould prior to reinforcing.

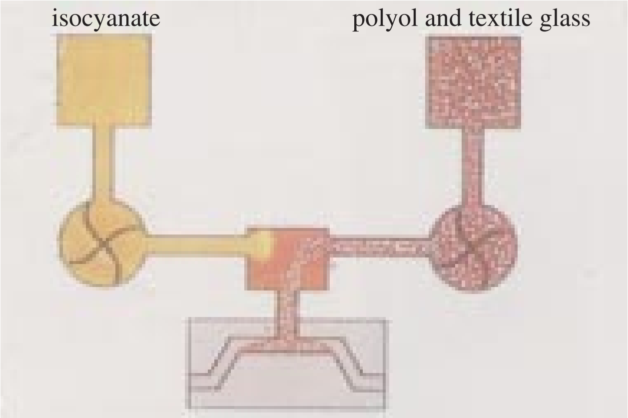


Fig. 24: R-RIM process (after Vetrotex).

The term R-RIM (reinforced reaction injection moulding) describes both process (RIM) and material used (Fig. 24). This normally involves a polyurethane resin that is reinforced with very short glass fibres (short fibres). The textile glass is mixed into one of the polyurethane components (into the polyol) prior to mixing it with the second component (isocyanate). The moulds are heated up to approx. 50°C. This process makes for high ejection rates. Thanks to the textile glass reinforcement, parts are obtained with improved mechanical properties and greater dimensional stability (according to Loy, Gehring, Brüning, Planck, von Falkay, Lehner, Pagendarm and Vetrotex).

Composite yarns →: Flock yarn; Core-spun yarns.

Compound Finished thermoplastic. Many uses, e.g. in the manufacture of tufted carpets for finished recipes for base/pre-coat coating as backing, precoating and foam compounds. Typically includes latex, polyurethane compounds etc. Modified compounds contain, in addition to water, filler (chalk), thickener etc., additional application variants (flame-retardant, antistatic and biocidal).

Compound oils (Compounded mineral oils), greased mineral oils, i.e. mixtures of mineral oil and vegetable or animal fats or oils or fatty acids (olein, castor oil, bone oil, etc.). Uses: as lubricant, greasing agent, preparation agent).

Compounds → Chemical compounds.

Compound threads/yarns Combinations of yarns of different fibre materials, bicomponent fibres, mixed count man-made fibres, core spun yarns, textured combination yarns, metal effect threads etc.

Compressed air Air at higher than atmospheric pressure. Compressed air utilises an important property of gases: i.e. compressibility. It is the energy carrier for pneumatic systems.

Compressed air jet → Jet nozzles.

Compressibility →: Thickness of textile fabrics; Stating loading resistante.

Compressing (Lat.). Compressing, compacting air and gases by means of → Compressors to form compressed air and compressed gas (liquid gas).

Compression (Lat.). Pressing together, compacting (gases, vapours).

Compression channel → Stuffer channel.

Compression, resistance to Resistance to compression (compare → Flexural resistance) of textiles under loading, e.g. of a strip of fabric folded one or more times. In contrast to the ability to recover from compression, the ability in this case to unfold again on release from loading due to the flexural elasticity of the textile. If the compressive force is plotted against the percentage compression (Fig.) curves are produced following a similar pattern to force-elongation curves.

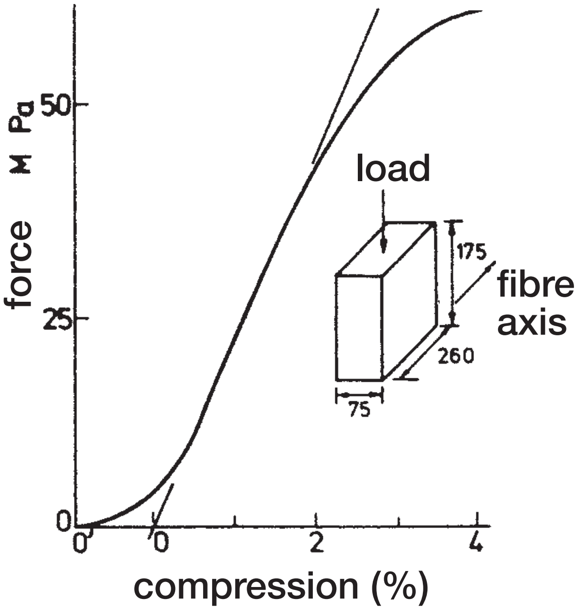


Fig.: Compression curve of a keratin block produced from horse hair at 20°C, 60% relative air humidity and a 3 %/min increase in force effect (Bendit).

Compression-type coolers (cooling units). Housed ready for connection in a compact housing with fan-cooled refrigerating plant together with pump and control unit; connected to one or more water supply tanks (= cold reservoir). Have the following advantages over → Cooling towers: fewer setting-up problems, easier installation, smaller water storage tank required, closed circulation, no water consumption due to evaporation (water cost approx. zero), waste heat usable for space heating, intake air removable from workroom (room ventilation), electronic temperature control optimises current consumption, maintenance-free. Disadvantages in comparison with cooling towers: more energy consumed, greater air throughput (a great deal of fresh air required), running noise (official regulations).

Compressive shrinkage Mechanical process for applying a → Pre-shrunk finish and reducing residual shrinkage in textiles. One of the factors affecting the suitability for purpose of a textile is its ability not to shrink when it gets wet or is washed. → Dimensional stability is required. Increasing consumer demands have compelled the finisher to pay particular attention to this aspect in all textile products. The shrinkage of woven and knitted fabrics is partly attributable to tensions imposed during the manufacturing cycle (Figs. 1 and 2). These tensions are released in finishing.

New tensions should be avoided where possible by operating free from tension in this final stage. The textile engineering industry has catered for these needs by designing tensionless drive mechanisms (Ward-Leonard control), tension-free jigs and driers (e.g. short-loop drier). But tension-free finishing alone is not sufficient for achieving a fully-shrunk finish.

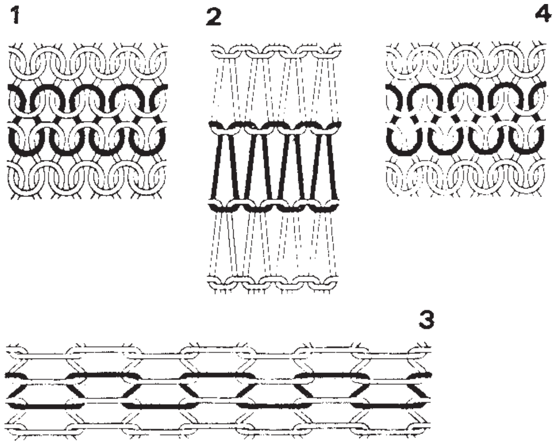


Fig. 1: Knitted fabric elongation conditions.
1 = grey fabric; 2 = stitch shape after length direction loading; 3 = after transverse loading; 4 = relaxed form.

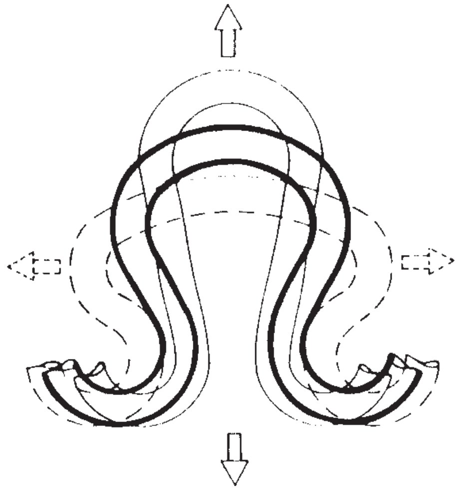


Fig. 2: Configuration of an individual stitch under various elongation conditions.

Methods of compressive shrinking are intended especially for fabrics in 100% cotton and its blends with synthetic fibres. The oldest and most important is the CCS (controlled compressive shrinkage) process of Cluett-Peabody, the Sanforizing process, the principle of which (Fig. 3) consists of stuffing together the fabric along its length (warp-way) on a machine resembling a felt calender and setting it in this state, so that when it is subsequently washed no further shrinkage will occur. Sanforized materials of this kind should if possible be set to a residual shrinkage of max. 1%. During manufacture and especially in finishing, fabrics are subjected to varying degrees of tension in the warp direction. Across the width (weft-way) tension is much lower. It is logical that after Sanforizing (Fig. 4) there must be no further finishing treatment of the fabric. The Sanfor-Plus process represents a combination of mechanical and chemical systems. For repeated laundering at the boil, dimensional stability can be achieved only with a

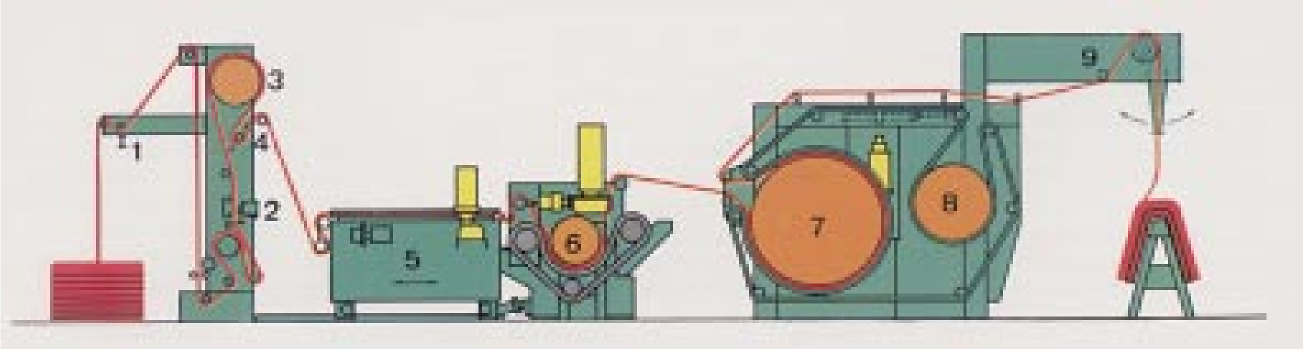


Fig. 4: Monforts shrinking line (Sanforizing).
1 = draw roller (fabric entry) ; 2 = water spray unit; 3 = steaming drum; 4 = skewed fabric straightening roller; 5 = clip type widthwise stenter; 6 = rubber blanket shrinking unit; 7 = felt calender; 8 = felt drying cylinder; 6 = plaiter.

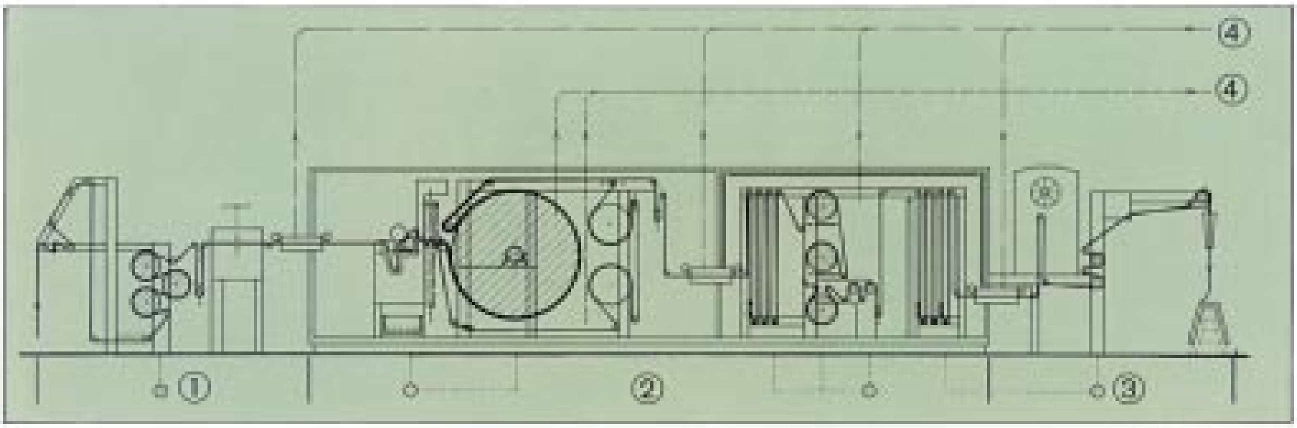


Fig. 5: Sanfor-Set line based on "liquid ammonia" (Monforts).

supplementary resin finish. The Sanfor-Set process is a further development in which the preliminary mercerising treatment takes place in liquid ammonia (Fig. 5).

In principle the fabric is only able to shrink if the hydrogen bonds in cotton are first substantially broken by humidification and steaming. This is brought about by mechanically stuffing the fabric together before the new state is set by drying (locking the hydrogen bonds in place).

The fabric entry to the rubber belt shrinking unit is formed by the sandwich created by a large heated cylinder and a continuous rubber belt (67 mm thick, 40° Shore hardness). The fabric is placed on the extended surface of the rubber belt and is thus forcibly contracted by the shortening of the surface of the rubber belt, with the smooth surface of the cylinder presenting virtually no impediment to this process. The greater the contact pressure of the rubber belt the greater the shrinkage. At the entry point the rubber belt can be compressed at most down to 30% of its normal thickness. The corresponding Sanfor-Knit process is used for tubular knitted fabrics and also for open-width flat knits.

The "Bestan" machine (Fig. 6), used to shrink tubular knits, operates in a similar way to a rotary press. In the Tube-Tex-Compactor (Fig. 7) the fabric is passed over a roller running at higher speed and into the gap it forms with the hot shoe. Because the take-off roller, which has deeply engraved lateral surface grooves,

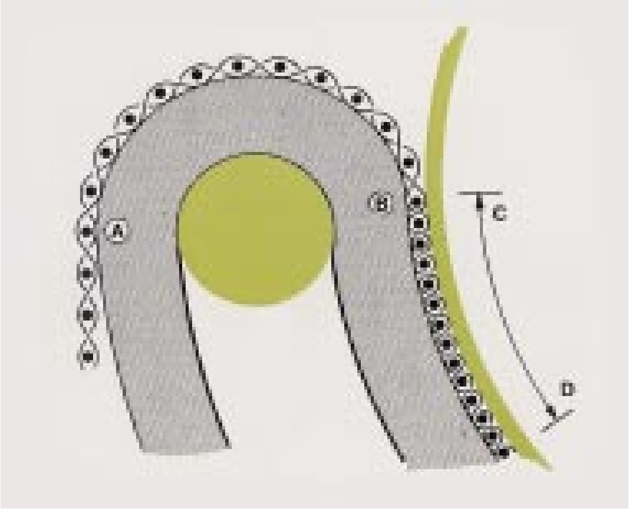


Fig. 3: Functional diagram of fabric path during compressive shrinking.

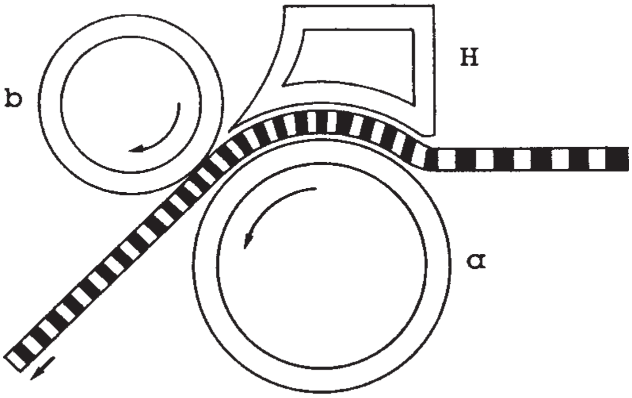


Fig. 6: "Bestan" compressive shrinking machine (Hunt & Moscrop).
a = feed roller; b = delivery roller; H = heater shoe.

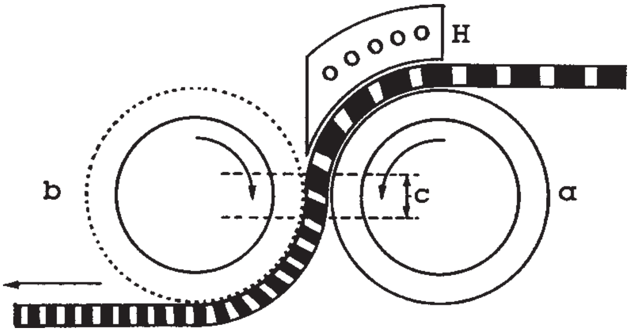


Fig. 7: Tube-Tex compactor, operating principle.
a = high speed feed roller; b = low speed delivery roller; c = compacting zone; H = heater shoe.

runs more slowly the fabric is shrunk in the highly condensed core zone as a result of having been steamed in a twin-jet chamber before entering. Further versions of the belt-shrink type are the Toptex-W system and the shoe-shrink type for tubular fabrics by Monforts, and the Pak-nit-II system and the C 2000 Compactor for open-width knitted fabrics both by Tube-Tex.

Denim fabrics need to be shrunk at the most economic rate possible. To impart the necessary humidity to the fabric for shrinking in the rubber belt shrinking unit it is possible at considerable expense to rehumidify on the padder followed by post-drying to a specific humidity level on cylinder dryers (Fig. 8). It is appreciably cheaper to humidify by low-level foam application without the need for drying and then apply the shrink process.

Tension-free shrinking of wool fabrics is peformed on special machines (Fig. 9).

Compressive shrinkage processes (sanforizing), compressive, controlled shrinkage process, also known as the Cluett process. In 1928 the American, Sanford Cluett, developed the compressive felt shrinkage machine. This was used for the mechanical compression of woven fabrics, mainly cottons, in their length. Machines of this kind are generally known as Sanforizing machines (Fig. 1). The term Sanforizing is now no

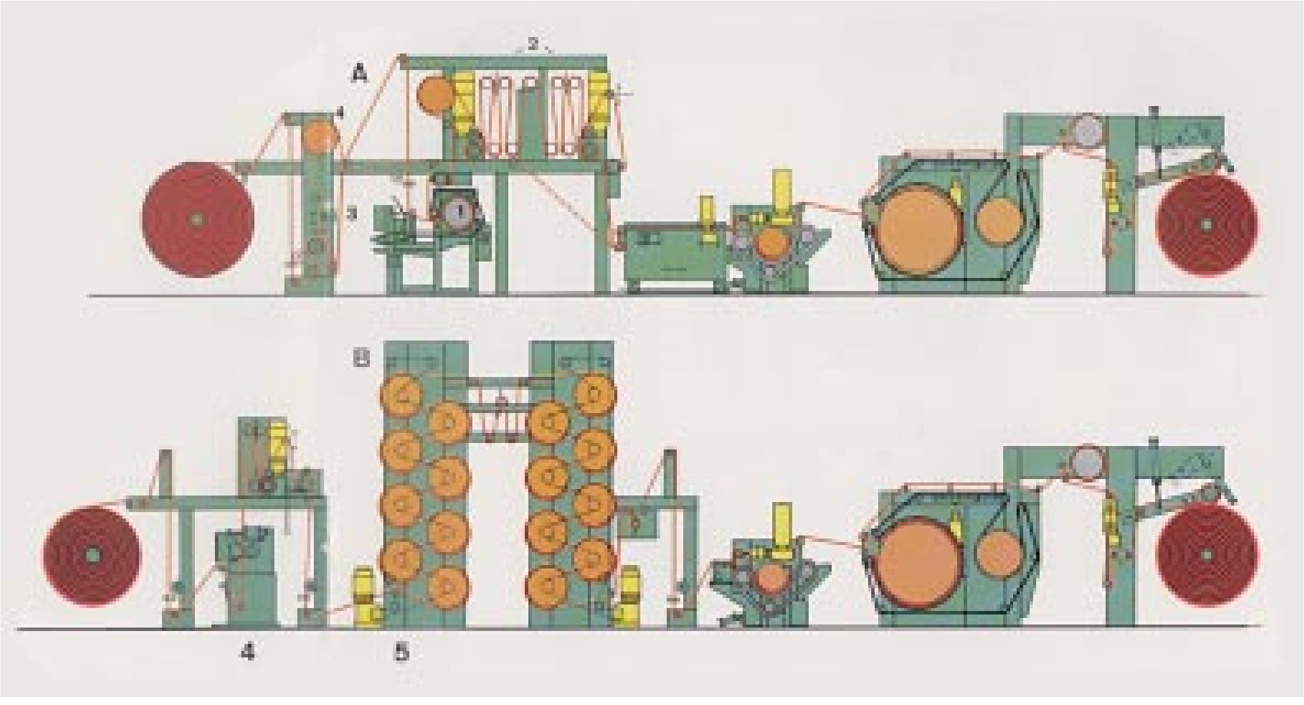


Fig. 8: Conventional (top) shrinking line for woven denim fabric and an equivalent line (bottom) for compressive shrinking with foam (both using the Monforts Top-Tex-System).
A = shrinking by back dampening with foam on the Vacu-Foam line (Monforts).
B = back dampening by padder impregnation with water, and drying on cylinder dryers.

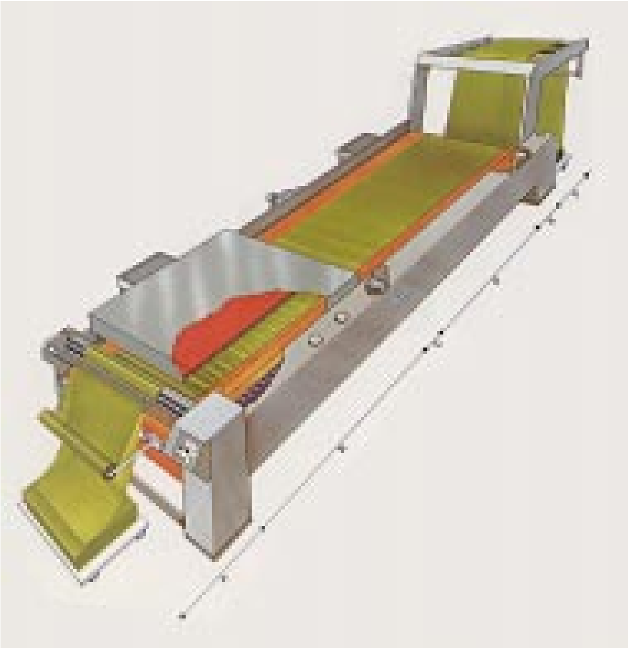


Fig. 9: Woven wool fabric shrinking line (Sperotto Rimar).
A = fabric entry; B = intensive steaming tunnel;
C = conveyor belt vibrating unit; D = resting zone;
F = fabric exit.

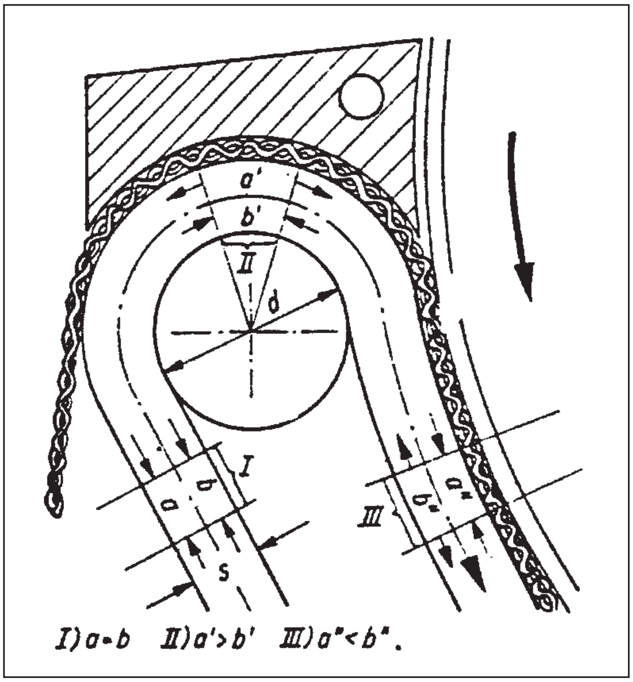


Fig. 2: Shrinking device, shrinking shoe with strong felt or rubber band
a' = draw zone; a" = pressure zone; b' = pressure zone; b" = draw zone.

longer protected by patent. In the classic felt shrinkage plant (made by Cluett-Peabody, USA), as the fabric enters it is sprayed with a fine mist of water, steamed in a steam box and surface-dried on a cylinder drier.

The goods are extended to full width on a short frame at a higher speed before reaching the shrinking device. The shrinkage takes place immediately after passing the hot shoe at a temperature of approx. 180 °C (Fig. 2). The flexural strength of the fibre is decreased, the physical crosslinking is broken, and the textile material is more easily compressed. Drying takes place immediately after the subsequent felt calender. The shrinking capacity of this machine is max. 10%. The degree of shrinkage is determined by the thickness of the felt. The thicker the felt, the higher the shrinkage capacity. The degree of shrinkage is regulated by altering the shrinking shoe.

The conveyance of the goods by the rubber belt shrinking plant is similar to that of a felt shrinkage plant (Fig. 3). Here, however, the shrinkage effect is achieved by the large surface extension and subsequent pressing together of a continuous rubber belt in conjunction with a drum heated to approx. 100–140°C. The rubber belt shrinking plant is more widely used in preference to the felt shrinking plant because of

- the higher shrinking capacity of the textile goods, approx. 17%,
- the attainment of higher production speeds,
- the simpler operation of the machine for setting shrinkage values.

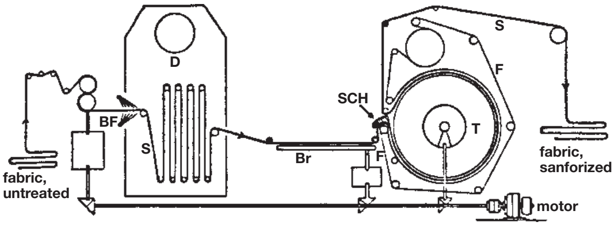


Fig. 1: Diagrammatic section of the compressive shrinkage process.

The system has been developed further by replacing the steam box with a steaming cylinder heated with saturated steam, along with additional improvements such as low-tension fabric feed.

The Sanfor-Set finish (by Cluett-Peabody, USA) is a combination of two finishing stages, treatment with liquid ammonia and shrinking on the Sanforizing or shrinking plant (Fig. 4). The finished cotton fabric is introduced to the treatment chamber thoroughly dry and cool, and soaked in liquid ammonia (NH_3) at approx. –34°C. It is then squeezed and left to dwell in an enclosed space. The liquid NH_3 penetrates the fibre and causes an intracrystalline swelling and release of tension. The ammonia enables a high number of hydrogen bonds to be broken, thus splitting the crystalline structure of the fibre. During recrystallization the crystalline structures are smaller but more numerous. In the subsequent felt calender the swelling agent is removed from the fabric by drying and steaming. Finally, the goods

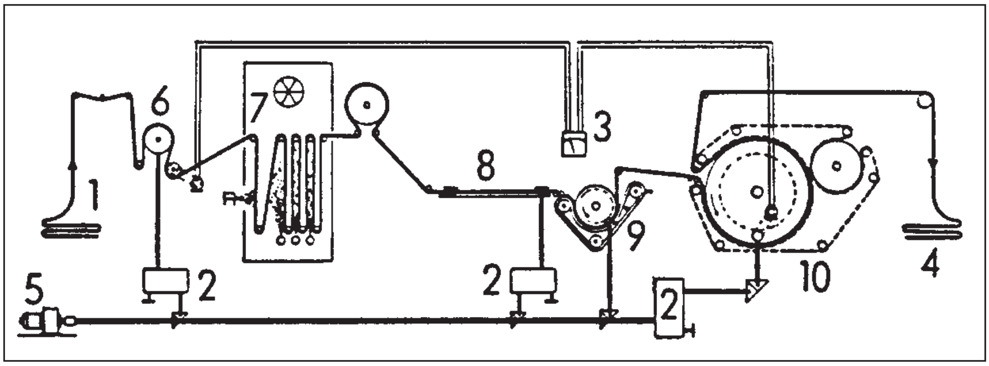


Fig. 3: Diagram of a Cluett rubber belt plant. 1 + 4 = goods; 2, 3 + 5 = synchronization of the different drive mechanisms; 6 + 8 = higher speed sections; 7 = steaming; 9 = rubber belt; 10 = felt calender.

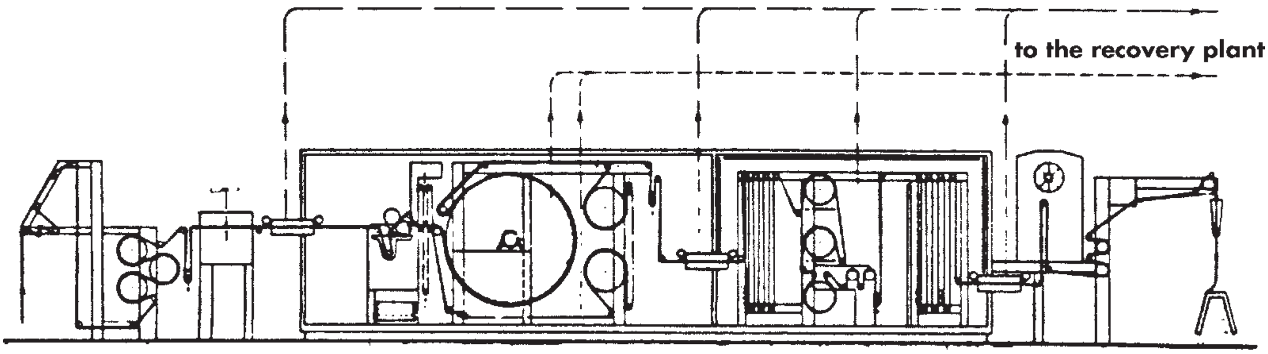


Fig. 4: Sanfor-Set plant without shrinking machine (liquid ammonia basis).

are treated with steam and fed to the compressive shrinkage plant. According to the details provided by the licensor, the Sanfor-Set process gives cotton fabrics the following qualities:

- better technological values,
- improved dry crease recovery,
- improved residual shrinkage resistance after boil wash and tumble drying,
- low, permanent lustre effect,
- smooth fabric surface,
- soft, pleasant handle.

A further combined finishing and shrinking plant is used for denim fabrics. This combines processes such as cleaning, singeing, soaking, drying and shrinking.

The Supatex shrinking machine by the English company of Mather & Platt (Fig. 5) is a variant of the rubber belt shrinking machine; it combines features of the Bestan Compactor and the Evaset MK 3 shrinking machines. The rubber belt encircles two rollers of equal size according to the principle of the open flat belt drive system. Above the feed roller, on the open rubber belt surface, is a heated, smooth shrinking cylinder. The shrinking cylinder and the roller, which provide the guide system for the rubber belt, are driven separately. Once the cloth is introduced to the shrinking plant, it runs through the passage between feed roller, rubber belt and shrinking cylinder. The shrinkage is caused by the pressure of the cylinder and the relative movement of the rubber belt. The distance between the rollers and the pressure exerted by the steel cylinder are infinitely adjustable.

The American Tubular Textile Machinery Corporation makes two compactor plant:

- the C 2000 compactor for open width knit-goods (Fig. 6),
- the Paknit II compactor for tubular goods (Fig. 7),

which are well known worldwide under the trade name Tube-Tex Compactors.

1. C 2000 Compactor: the cloth is steamed without tension in twin chambers and introduced to the compacting zone. The compacting zone consists of the following components:

- an electrically heated, chromed compacting shoe with smooth surface,

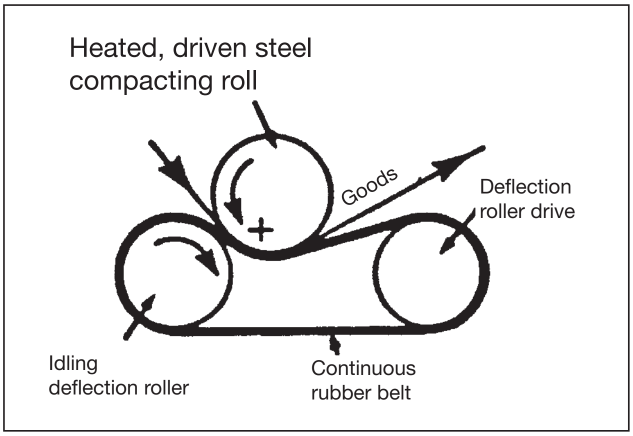


Fig. 5: Diagrammatic section of the shrinking section of the Supatex shrinking machine (Mather & Platt).

- a fast-running, steam-heated feed roll with rough, sandpaper-like surface,
- a steam-heated retarding roll with cross-grooves.

The distance between the roll pair and the compacting shoe is infinitely adjustable. The compacting shoe presses the cloth as it enters the compacting zone at higher speed against the feed roll. The retarding roll lowers the speed of the cloth and controls the degree of shrinkage.

2. The Paknit II has two compacting zones, so that both surfaces of a tubular knit fabric receive the same treatment. There is a second compacting shoe in the compacting zone, designed to back up the retarding roll as the tubular fabric is taken up, so that the layers are not displaced. There is a choice of a plaiting or rolling device at the exit from the machine.

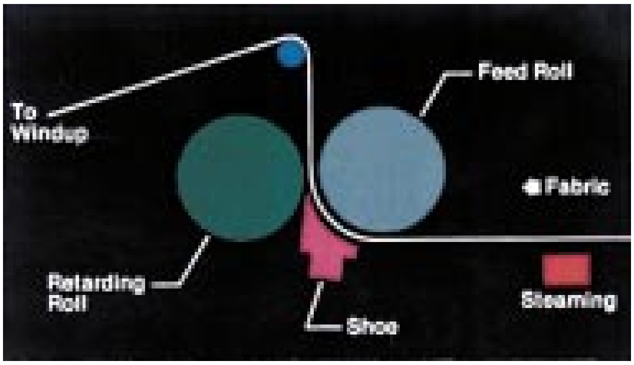


Fig. 6: Diagrammatic section of the compacting principle of the C 2000 Compactor (Tubular Textile Machinery Corporation).

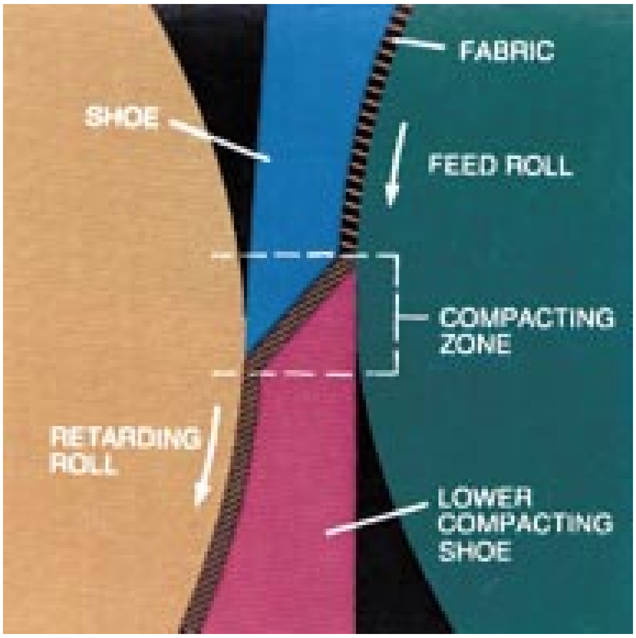


Fig. 7: Diagrammatic representation of the two compacting zones of the Paknit II (Tubular Textile Machinery Corporation).

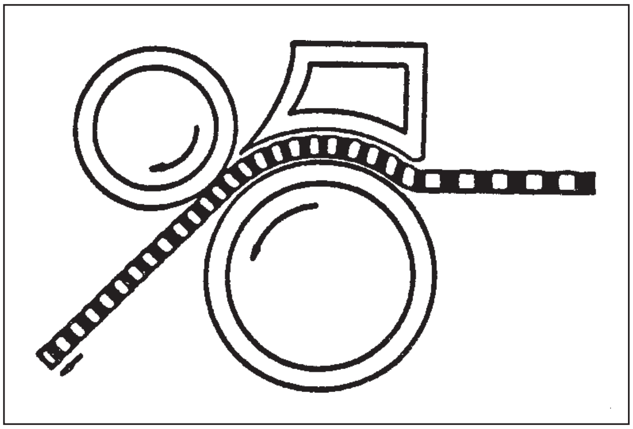


Fig. 8: Operating method of the Bestan machine (Hunt & Moscop).

The Bestan machine (Hunt & Moscop) consists of two rollers and a smooth stainless steel heater (Fig. 8). One roller (pressure feed roller) is coated with ebonite; the heater is positioned above this. As the knitted fabric passes through these two components it is taken up by a slower retarding roller coated with soft rubber. The effectiveness of the compression depends on the differing speeds and the friction coefficients of the rollers. The retarding roller has a comparatively high friction coefficient and a lower circumferential speed than the pressure feed roller.

The Gullwing Stabilizer (Fab-Con Machinery) is similar to the Tube-Tex Compactor; the tubular cloth is stretched to the desired width by two independently adjustable rollers, steamed and then introduced into the compacting zone. The heated compacting triangle consists of two rollers engraved with deep cross-grooves, and a compacting shoe. Feed and retarding rollers rotate in the same direction; the degree of compaction is adjusted by means of the pressure of the compacting shoe and the speed of the feed and retarding rollers (Fig. 9).

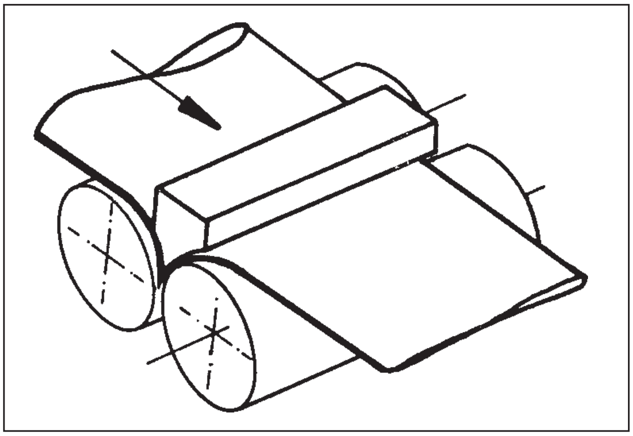


Fig. 9: Diagrammatic section of the compacting principle of the Gullwing machine (Fab-Con Machinery).

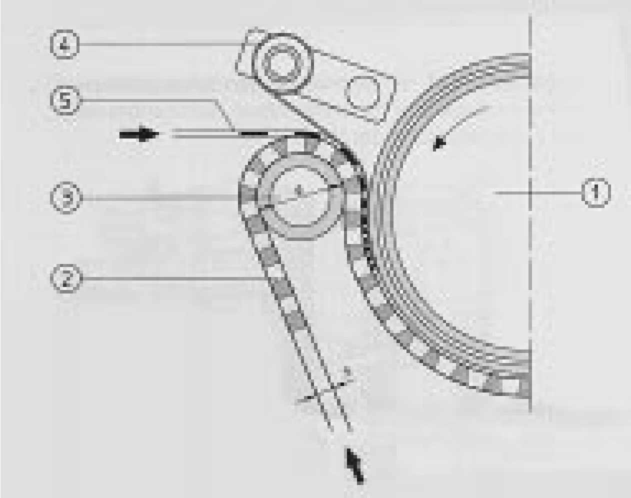


Fig. 10: Compression unit according to the Sanfor-Knit process, constructed by Sperotto-Rimar.
1 = steam-heated steel roller; 2 = continuous belt; 3 = roller for guiding the belt and feeding the fabric (5); 4 = fabric feed unit.

The Sanfor Knit Process (by Cluett-Peabody, USA) for tubular knitted fabrics was developed by specialists in the Sanforizing technique working together with knitted goods manufacturers. The most important components of this plant are:

- a felt calender with 2000 mm diameter,
- a guide shoe, providing acceleration and ensuring even pressure on the felt as the fabric is fed in,
- an expander roller.

After the continuous felt belt has been around the heated calender along with the previously steamed fabric, it travels around a drying cylinder and is then ready to repeat the process with new fabric to be compressed. The dampness is removed from the knitted fabric as it passes around the felt drum; its dimensions are stabilised. Fig. 10 shows the Sanforizing principle as it is applied by Sperotto-Rimar.

The construction of the Top-Tex/W rubber belt shrinking machine (Montforts) comprises the following principal components:

- fabric feed with expander roller,
- steam device,
- rubber belt shrinkage unit, consisting of a heated metal cylinder or shrinkage cylinder and a circulating rubber belt,
- drying cylinder,
- cloth take-off or winding device.

The shrinking process can be explained using this machine as an example: compressive shrinkage takes place when a textile fabric is hydrothermically treated and compressed lengthwise. The degree of shrinkage can be regulated by adjusting the pressure of the rubber belt on the compacting cylinder. The compression of a textile fabric by means of the rubber belt shrinking unit is achieved as a result of the surface extension and immediate surface compression by the rubber belt whilst simultaneously altering the direction of curvature. The pressure of the rubber belt on the compacting roller alters the form of the soft, elastic material. The rubber belt is proportionally thinner in the compacting zone. Because of the constancy of volume of the rubber, the belt must therefore be extended lengthwise, i.e. its surface area is increased. The knitted fabric to be shrunk first reaches the extended rubber belt surface shortly before the compression gap. On leaving the compression zone the forced extension is elastically retracted, i.e. the rubber belt once again becomes thicker and thus shorter. The knitted fabric carried along with it must follow the movement of the rubber belt, as it clings to the surface of the rubber; the smooth, heated compression cylinder is on the other hand able to slide past the fabric. Thus the knitted fabric is forced together, which is evident in a thickening of the fabric.

In order to maintain the achieved compression of the stretchable knitted fabric, the most important prerequisite is the low tension of the fabric feed. As a consequence the fabric guide systems within the plant and on introduction and take-off must be kept as short as possible. The low-tension core winding is controlled by a computer according to the increase or decrease of the batch diameter (up to 20 000 mm), so that at any point in the take-off or winding process the knitted fabric is maintained at the lowest possible tension. In addition, the fabric feed rollers of the double-loop compensators forming part of the unwinding and winding mechanism are controlled by an auxiliary drive, so that the bearing friction is surmounted by the drive and not by the take-off of the fabric. Pneumatically raised and lowered swivel arms ensure winding and unwinding without creasing. These can be adjusted with optically controlled gap regulation, so that the support roller always maintains the same distance from the fabric roll. Variations on this are the side-controlled twin-roller winding device or the twin ascending batch roller, if the edge diameter is not to exceed 500 mm. So that the shrinking or finishing procedure need not be interrupted during cutting or bale change, a conveyor belt is installed before the winder, on which the fabric is stored when the Top-Tex/W is still running but the winding mechanism is stopped. The speed of the conveyor belt is controlled by a photocell, so that the volume of fabric lying on it is kept between a minimum and a maximum. Before the twin ascending batch roller is a fabric centring device which works on the principle of a slatted expander. The whole DC drive system is controlled by a digital network system, so that at every change of speed the preset fabric feed remains constant.

Compressors (condensers, air pumps). Used for compressing and conveying air and gases above atmospheric pressure. Power consumption varies according to size, design, number of compression stages and type of cooling.

Distinction is made between:

I. Reciprocating (piston) compressors (today generally with valve control, vacuum filter and incorporating water and oil trap). Up to maximum pressures (300–400 bar in 4 and more stages). Predominantly with automatic pressure regulator (mechanical or electrical, both pressure controlled by compressed air pressure). Special dry running compressor versions for production of oil-free compressed air. Also in vacuum pump form, one and two stage with slide-valve control = air pump.

II. Centrifugal or turbo compressors (axial-flow condensers): Generally several impellers arranged consecutively radially or axially on the same shaft, rotating at high speed. Suitable for high throughputs (exceeding 5000 m^3/h) and moderate pressures.

III. Rotary compressors (cellular condensers): rotating machines operating on the same principle as reciprocating compressors.

End-uses: Predominantly for producing compressed air (for blowers, compressed-air tools, compressed air motors and pumps for pneumatic conveyor and control systems) and pressurised gas (for pressing and singeing machines, heating and lighting purposes, industrial chemistry processing).

Compressor systems Compressed air is an essential form of energy. Increasing numbers of finishing machines are equipped with pneumatic control. One suggested way of minimising the load on a compressor that has to cater for an increasing volume of air consumption, sometimes experiencing considerable peak loads, is as follows: The existing reciprocating compressor operates for approx. 75% of the time, for which purpose a pressure vessel is required from which the required working pressure can be obtained in the after-cooling phase. A rotary compressor, however, is designed to operate 100% of the time and the greater the load the more economical it is. A rotary compressor should therefore be used to provide continuous compressed air production. The rotary compressor is designed only for the normal air requirement of the mill as a base load provider. Over-specification to cater for peak loads in compressed air consumption is unnecessary since the existing reciprocating compressor can be used as peak load provider. A pressure regulator is fitted between the rotary compressor and the old reciprocating compressor, with the latter cutting in briefly only when sufficient demand occurs (Fig.).

Computer applications in textile dyeing and printing Computers are used in four traditional areas of textile dyeing and finishing:

1. Development of design and print ranges (CAD)
2. Planning of production and control of the preparation of goods
3. Operational economy uses in book keeping, payroll and cost calculations
4. Computer assisted production, principally in colour measurement, control of dyeing and printing machines and automation of dyeing and printing processes.

Some abbreviations used in computer technology:

CAD	Computer Aided Design
CAM	Computer Aided Manufacturing
CAP	Computer Aided Promotion
CASP	Computer Aided Synthesis Planning
CC	Computer Chemistry
CIM	Computer Integrated Manufacturing
MIS	Management Information System
MRP	Material Requirement Planning
PC	Personal Computer
µ-P	Microprocessor
AI	Artificial Intelligence
ES	Expert System

Computers are typically used in dyeing and printing for: research, marketing, administration, production and providing information.

Research: Databases of all types are used in all parts of the world. Among other things CC, e.g. CASP, can be used for finding relationships between structure and

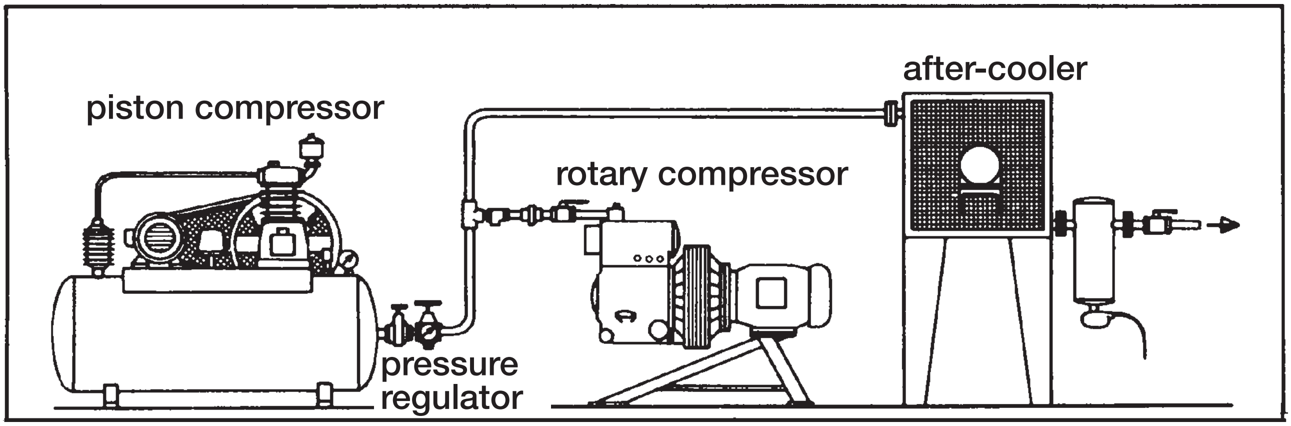


Fig.: Compressed air plant with rotary compressor as the constant load bearer and piston compressor as the peak load bearer.

Computer applications in textile dyeing and printing

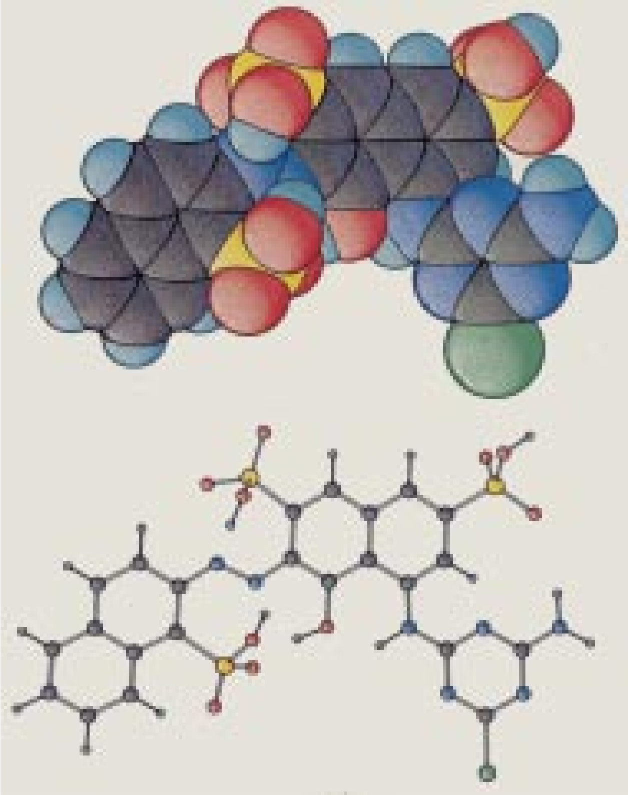


Fig. 1: A computer generated space-filling model of an azo reactive dye (above) compared with the ball-and-stick model (below) (after Dörr).
black = C; cyan = H; red = O; blue = N; green = Cl; yellow = S.

properties. They can save expensive laboratory and analytical work and not least duplication of effort. The chemical industry co-operates in the comprehensive planning of total syntheses through linked expert systems. The information that is collected about all the components is fed into a computer library; by recovering the information, the synthesis can be carried out in reverse on the screen, starting from the required structure (the new product that is wanted), back through the intermediate stages of decreasing complexity down to the necessary raw materials.

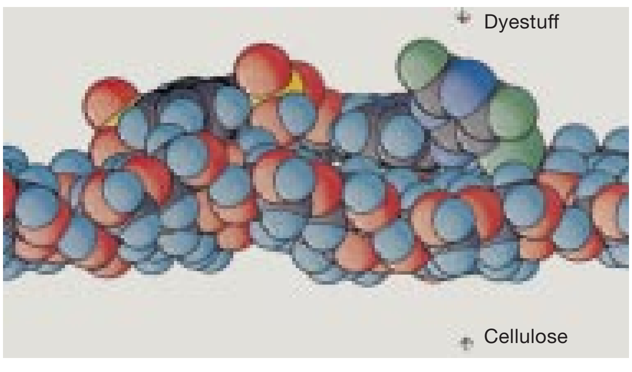


Fig. 2: A space filling model of a reactive dyestuff adsorbed onto cellulose.

Molecular simulations (Figs. 1 and 3) or chemical reactions, for example a reactive dyeing (Fig. 2), lead to a better understanding of chemical processes. The molecule from the terminal is displayed on the screen. With Sybyl, the package most often used in the industry, the user can readily construct the molecule on the screen by putting molecular fragments and individual atoms together. In addition the geometry of the molecule can be altered by making appropriate changes in bond lengths and angles. Then calculations are carried out and the geometry is optimized.

Fig. 3: Computer model of a phthalocyanine dyestuff (green = copper).

Marketing: MIS includes logistical, commercial and technical data about products and has been so widely introduced that it is impossible to imagine being without it. Direct links with computers at suppliers' and at customers' premises to rationalize the running of the business are being introduced. If there are a lot of application packages for different jobs, it is better to use a PC-network so that individual applications can be run without interfering with one another. There is also a series of applications which have to be run continuously. In these cases, the user in a multi-user application has to accept the loss of performance, e.g. graphical presentation of the selling figures with simultaneous and multiple display of customers' orders. A disadvantage is that the typical batch run offs, e.g. bookkeeping evaluations, payroll calculations, final monthly results, have still to be developed for multi-user applications. In general, such diverse applications are better carried out with a network.

Administration/customer service: Apart from colour measurement, which has been the traditional field of application for the computer, new areas are opening up: most importantly, expert systems have been introduced. They allow a pool of knowledge to be held, added to, broadened and used systematically. Laboratory automation is also being introduced into the dyeing laboratory (pilot plant). By connecting commercial and technical data it is possible to get the necessary transparency to make the best decisions for optimizing operating costs. The computer as a storage medium with data banks is the traditional alternative to expert systems. It also provides the opportunity of simulating processes. The computer can also be useful in statistical experimental planning and analysing the results.

The idea of data bank systems is to manage information in a systematic way and prepare it for the user. A data bank system is organised as follows:

a) the data base which is a systematically stored collection of data;
b) the data bank management system that manages and regulates the data and allows access to it;
c) the application programs that can question the data management system through programmable search paths.

In contrast to a data bank system, which essentially manages and organises data according to well known structures, information retrieval systems offer greater possibilities for retrieving information. If a retrieval system is considered as an information system, an → Expert system can be thought of as a prototype intelligent system. The prerequisite for a dialogue with an information system is that the user has to translate his problem, which is naturally expressed initially in normal, everyday language, into a query in a formal questioning language that has been programmed into the computer. To be able to search efficiently, the user must have knowledge of the data arrangement of the system (search fields) and of the formal syntax of the questioning language. The conversion of the query from normal language into the formal questioning language and further support of the dialogue between the user and the information system, so that knowledge of the system would no longer be necessary, would be a sensible application of an expert system. The setting of the query in normal language is a problem that should not be underestimated.

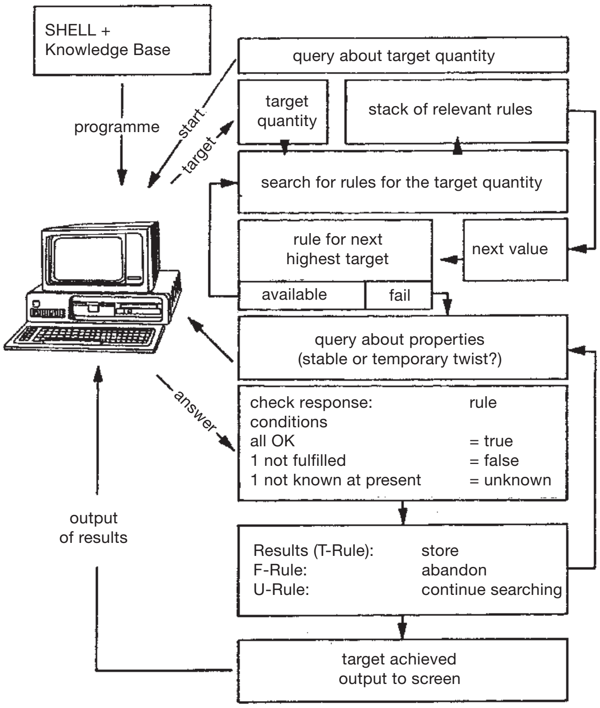


Fig. 4: Working mode of an expert system (after Rüttiger).

Generally an expert system (Fig. 4) supports the solution of complex, trade specific problems by having clarifying and advisory functions: clarifying in that the system can check every step or every question set by the user as well as every result, advisory in that it can come to a definite conclusion based on its viable knowledge base. The problem solving capability of expert systems comes from suitable trade specific systems of rules. The combination of the system of rules with appropriate factual data leads to an intelligent information system, which can be constructed, for example with the help of "expert system shells" which have been developed meanwhile. Hence, the knowledge base of this shell depends on the application background of the user and so is limited to that subject area. 4 functions are interconnected with one another: the problem solving component works on the user's query and amplifies the query interpretation function for the process of reaching a conclusion. The explanatory component records the problem solving process so that solutions that have already been worked out can be recalled. The knowledge acquisition component is used for extending and modifying the information base. Apart from carrying on the dialogue with the user, the dialogue component analyses and translates queries that are set in normal language. Thus, documentary, communication, and professional knowledge and information are brought to work together.

Daisy-Tex-System: with the Daisy-Tex-System, Babcock has shown that significant progress has been made in process simulation. The system covers the introduction of the working media (water, steam, air, chemicals), improves the transparency of all the functions (as far as possible) and gives supervising personnel on-the-spot help in tracing faults.

Routines can be run either at timed intervals or at any moment by pressing programmed function keys and can be used, e.g. for displaying goods, to find the cause of faults. In addition, an end-of-job routine (at the ends of shifts or at batch changes), which is useful for subsequent calculations, is available. In a continu-

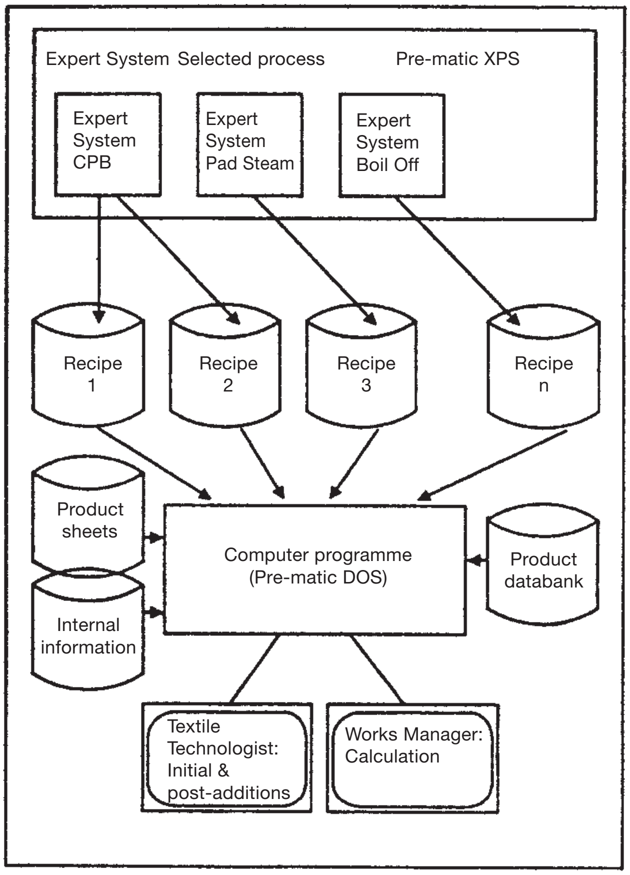


Fig. 5: Linking of a computer programme (Pre-matic DOS) for a textile technologist at the plant with the central expert system of a dyesuff supplier (Pre-matic XPS from Ciba-Geigy).

ous pretreatment plant, for example, the individual parts of the process are synchronised by compensating rollers. After the individual equilibria of such a plant have been set up by step motion of the individual units, an indicator can show when and how often a particular compensating roller deviates from its normal position by ± 15%. The cause of the errors can then be corrected (a particular compensating roller will be shown on the screen) before a stationary compensating roller brings the whole plant to a halt.

Pre-matic (Fig. 5): a software package which was developed by Ciba-Geigy in an interdisciplinary team as a marketing tool for textile processing. The system was conceived specifically as a user-friendly programme for use on portable PC's and to provide a technical information service, readily available advice and on-the-spot solution of problems at customers' premises. The system consists of an expert system (XPS) and a computing programme (DOS). The expert system selects the current bleaching process and optimizes the recipes to the customer's requirements. The computer system, which is built to international specifications, is used for translation of the recipes into practical terms at the customer's premises and, apart from cost calculations, provides data about bath concentrations, amounts of additions, pump settings and allocation of chemicals to the dosing pumps that are specific for the machinery and the goods. However a disadvantage for the technical user is that the advice from the various expert systems is not compatible, as each product supplier has worked on his own assumptions. Griese has shown in a case study that, for the process of wet-on-wet impregnation, four product suppliers have used four different formulae for calculating the liquor exchange for their own expert systems. Unification of the fundamental principles into a generally accessible expert system would be desirable for textile dyeing and printing. The "CASP" system could serve as a standard as it is available to all the large suppliers of dyestuffs for simulation of chemical reactions on a PC.

It should be emphasized that in discontinuous processing the automation will also provide improved control and regulation and data on production machinery. Depending on the software, a CAM system in textile dyeing and finishing can determine the processing conditions using data about the substrate and kinetic values. Data about the goods being dyed, e.g. in an exhaust process, can be used for automatic correction of the process. Obviously, a terminal in the dye kitchen is essential in the concept of automation of the dye works. The value of automation increases with the number of components in the recipe. Consequently e.g. the "WOOLY" expert system has been developed for wool dyers to optimize the range of dyestuffs being used (Fig. 6).

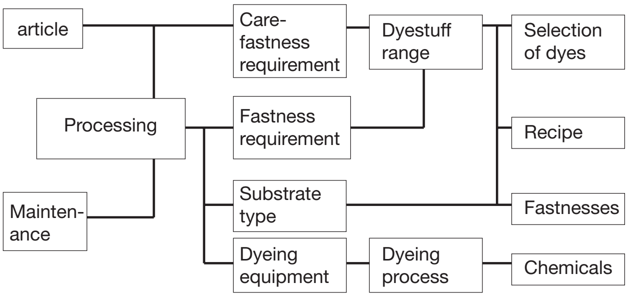
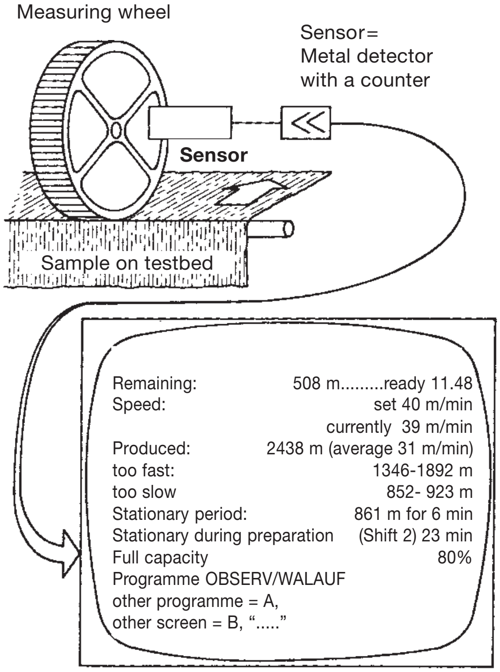


Fig. 6: Structure of the WOOLY expert system (Sandoz/ Clariant.

WOOLY: with this expert system the user enters which woollen articles are to be processed. The program asks for the required care level to be entered (D = only dry cleaning, H = hand washable, M = machine washable); from this the care-fastness profile with all the required fastnesses is obtained. WOOLY contains standard care-fastness profiles which comply with the recommendations of the IWS for a large number of woollen articles. Specific profiles which are not included can be entered at any time. The articles and care and fastness levels required determine the processing route.

Production: introduction of CAM, CIM, MRP and



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Remaining:                     508 m.........ready 11.48
Speed:                                      set 40 m/min
                                      currently  39 m/min
Produced:                   2438 m (average 31 m/min)
too fast:                                   1346-1892 m
too slow                                      852- 923 m
Stationary period:                      861 m for 6 min
Stationary during preparation      (Shift 2) 23 min
Full capacity                                       80%
Programme OBSERV/WALAUF
other programme = A,
other screen = B, "....."
```

Fig. 7: Simple control of machine speed by microprocessors that get information from suitable sensors (after Rüttiger).

other tools can be used to reduce costs, shorten delivery times and achieve constant quality of production. The state of the technology, i.e. that has been installed by about 50 % of the larger companies, is

- colour measurement with utility programmes,
- μ-processor control on single machines/groups of machines (Fig. 7),
- commercial computers.

The following developments are well advanced:

- CAD systems in design, recipe and screen production in printing,
- computerized systems for automatic making up of laboratory dyebaths or dye standards in production,
- departmental CAM for controlling/loading etc. the machines in a whole department,
- integration of technical and commercial data for optimizing operations.

Dyeing and printing carried out by computer is not far away in the future. However, as dyeing and printing is changing from being wage intensive into a capital intensive industry, the computer is becoming more important as a production tool.

CIM stands for Computer Integrated Manufacturing and can be used as an umbrella concept for all the "three letter words" such as CAD, CAM, CAE, PPC etc. A diagram can be drawn with sales and production at the centre and with the other areas represented as sub-systems of the central CIM system. The many links between the central CIM and the production area are not affected by the CIM. This sub-system is not a deterministic data circle inside which the production is optimized by the computer; it is much more that the CIM and MIS systems form independent systems (Fig. 8). The production planning and control system can be viewed as the heart of a CIM system. An order to supply will come from a given sales plan and go into the system. From the order, firm instructions will be sent out which will allow optimum use to be made of the production facilities.

The use of computers in the colouring side of print works is well advanced (Fig. 9): designing – engraving – sampling – print paste production (→ CAD in textile printing). Additionally, textile printing can only react in instant mode (quick response) when the output from production is fast. In coloration CAD encompasses:

- scanning,
- composition on the monitor,
- colouring,
- printing samples on paper.

A technically sound coloration process on textile mate-

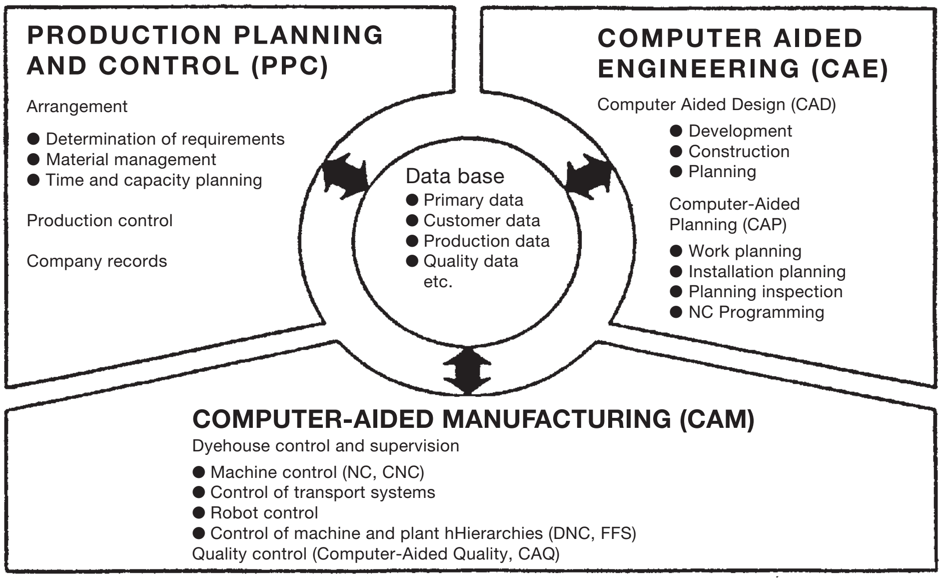


Fig. 8: Arrangement of Computer Integrated Manufacturing.

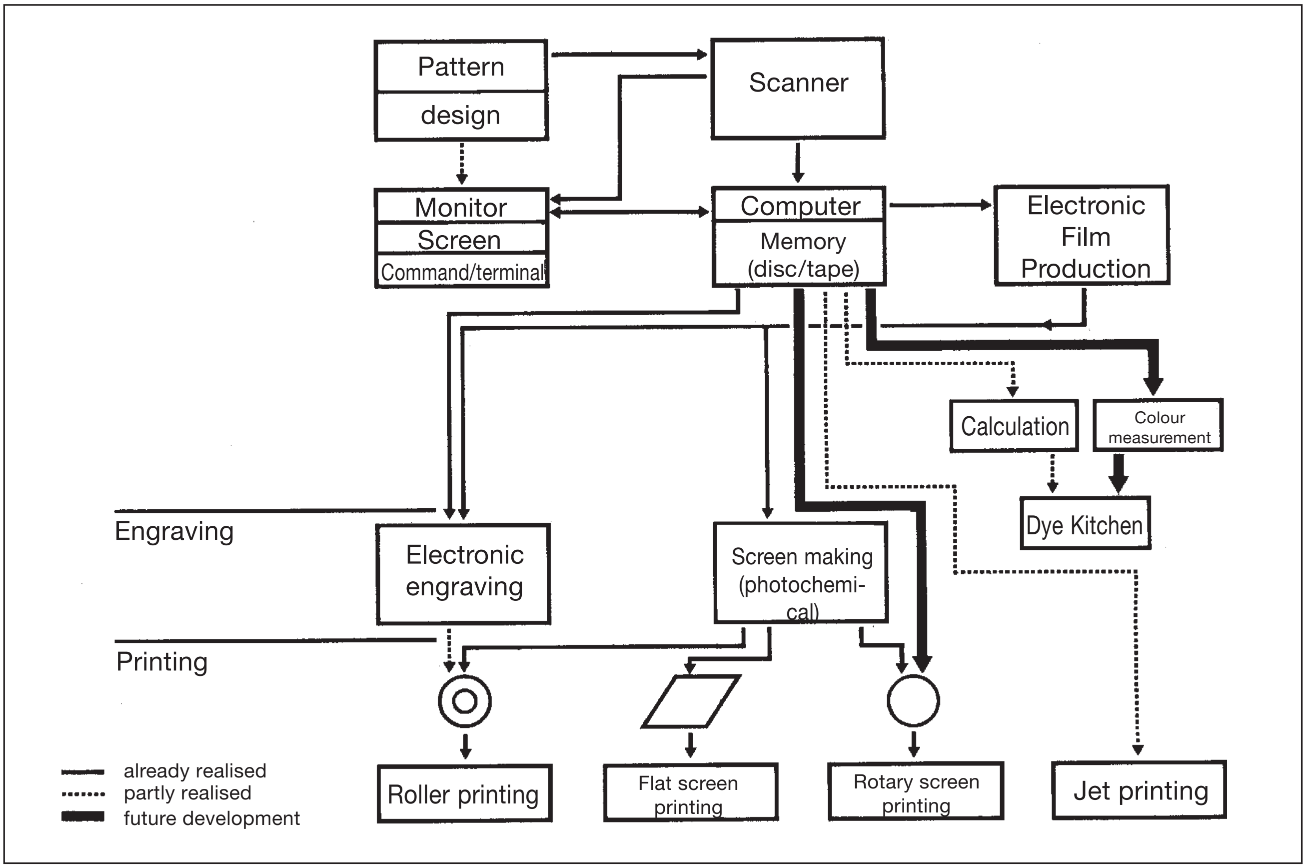


Fig. 9: Scheme of present and future developments in pattern design/screen production/recipe formulation.

rials begins with colour matching. It is very important that the first prints are made with the optimum recipes. The colour atlas can be optimized with the help of computer assisted colour measurement. The CIELAB system is suitable as it demonstrates clearly the distribution of shades on the colour circle and also shows colour build up. A suitable introduction of colour measurement into the printworks enables:

- faultless estimation of the colour values (curves, build up behaviour), establishment of the concentrations of the standard paste,
- the optimum colouristic choice of dyestuffs for producing the core range of colours,
- lowest cost recipes,
- building up the most economical and colouristically and technically flawless colour atlases.

The computer will control the printworks of the future to a large extent. In the first place, it will implement the artistic design and carry out the technical printing, but the economical and rapid production of the printing equipment (rotary screens) by laser engraving will also be controlled by the computer to produce quality. In this connection, two types of quality have to be differentiated: primary qualities can be measured physically and analysed by the computer; they are determined by molecular properties. However, the human being is necessary for the secondary qualities, to perceive them with his senses. So for example, the reflection spectrum of a mixture of dyestuffs can be characterized by its spectrum which can be displayed on a screen (a primary quality), but this spectrum has also a secondary quality: the colour that the human eye sees. Computer and human being must complement one another to create meaningful quality.

Computer colour matching Instrumental colour formulation as colouring process based on recipe calculations using the spectrophotometric properties of dyestuffs and fibres (see Fig. 1). Necessary details concerning reflectance curves are obtained by measuring so-called calibration dyeings.

A computer is required. This gives the following advantages: a) extremely accurate recipe calculations in a very short time; b) most rapid determination of the cost price of dyes for the calculation; c) optimal selection of the cheapest dyestuffs for the intended purpose; d) reduction of the laboratory dyeings previously required; e) reduced addition rate; f) shorter processing time, increased usage of the dyeing machines and more gentle treatment of the fabric as recipe additions are greatly reduced or avoided altogether.

When a fabric has to be dyed to match a new sample, the dyer has to prepare a recipe. With the aid of → Colorimetry this can be done quickly and reliably; classical methods for preparing the recipe could also be considered.

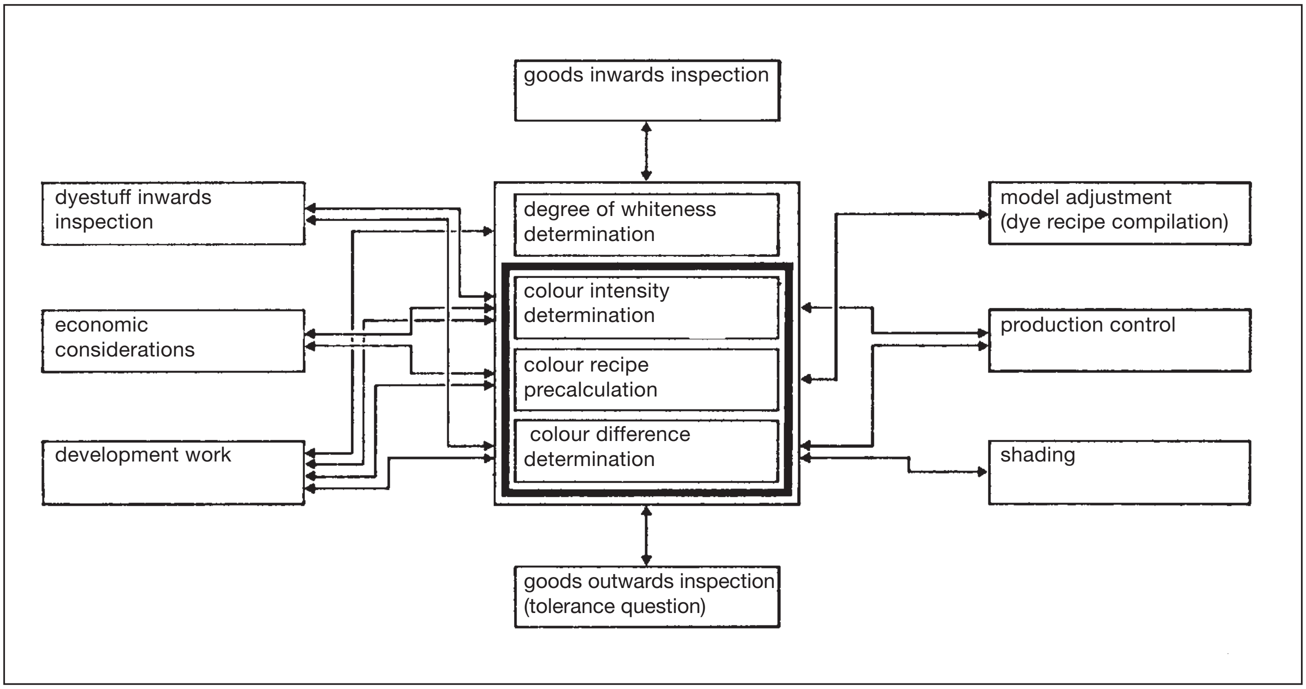


Fig. 1: General colorimetric formulation diagram.

The importance of colour measurement with its many and varied possibilities is no longer in doubt. The advantages of using colour measurement to help in colour matching are obvious and colour measurement systems have been installed in almost every dyehouse. Colour measurement is generally recognized as being useful for preparing recipes and selecting from alternative recipes using price, metamerism and fastness criteria; it can lead to significant savings in dyestuff costs. Evaluating alternative recipes from the technical point of view is a function that is hardly used yet. Automatic colour matching combined with colorimetric control of the dyeing kinetics and choosing the optimum recipe and the optimum dyeing programme will be the basis of rationalized batch dyeing in the future. So the main tasks for dyehouse staff are to coordinate recipes and dyeing programmes or to develop programmes that are specific for a given recipe, so that the reliability of the process and also the time it takes can be optimized. In this process, particular attention must be paid to the compatibility of the dyestuffs.

A flow scheme for a colour matching calculation (also see Fig. 2):

1. Measurement of the sample with a colour measuring instrument.
2. Choice of dyestuff:
   a) by colouristic and economic principles: class of dye (according to substrate), fastness, dyeing properties, suitability of certain dyeing processes, compatibility, concentration limits, price;
   b) by optical characteristics.
3. Entering the data into a computer.
4. Calculation process in the computer.
5. Choice of results from colouristic and economic angles.

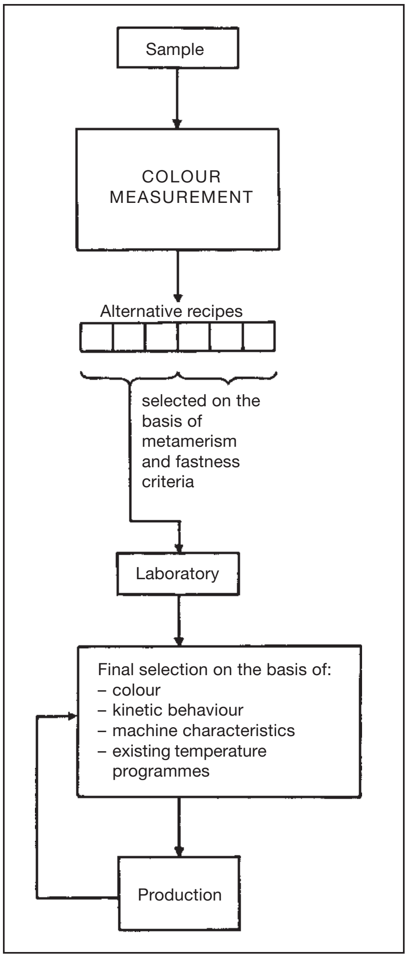


Fig. 2: Production of dyeing recipes using colour measurement and laboratory testing.

6. Dyeing the first recipe.
7. Correction of the first recipe:
   a) measurement,
   b) calculation of correction.
8. Dyeing the second recipe (corrected recipe).

Automatic colour matching together with colorimetric control of the kinetics of dyeing are used by the dyeing technician to help in reaching a decision on the final choice of recipe and dyeing process. The optimum recipe should be used in combination with the optimum dyeing programme. Several of the alternative dyeing recipes generated by the computer can be ruled out by the dyer in a first stage, because of high metamerism or unsuitable fastness properties. If e.g. three alternatives are left for a given shade, the most economical does not necessarily correspond to the most technically reliable or the most rational.

An important aspect known to every dyer is the degree of compatibility. The different kinetic behaviour of dyestuffs in combination, the effect of auxiliary chemicals and the different dyeing conditions obviously make selection difficult. In this context, it should be noted that real tertiary combinations (compatible dyestuffs that exhaust at absolutely the same rate, irrespective of the proportions in the mixture or of auxiliary chemicals that might be added) strictly speaking do not exist at all. This obviously does not apply to dyestuffs with good migration, but only for those with good fastness properties (which have poor migration by definition), where the poor levelling ability means that in practice the result is determined in the adsorption stage. Moreover, given shades can often not be achieved at all with so-called compatible dyestuffs. Compatibility is always an important criterion for the final selection of a recipe.

An obvious precondition is that standard curves and other basic information about the particular dyestuff are available. The more accurately the standard data have been prepared and the better the dyeing conditions in the production of the standard correspond to those in the bulk dyeing, the better the results that can be expected from a colour matching calculation. However it must be appreciated that in practice in many cases the second condition in particular, i.e. the conformity of the dyeing conditions and hence identical results from dyeings on small and large machines, cannot be completely satisfied. This often depends on the technical conditions.

Transfer of results from the laboratory into practice is important. In the laboratory recipes can be dyed by a temperature programme used in production. It can then be established whether the process reliability of the existing programme is suitable for the new recipes. At the same time the laboratory can contribute to optimization of the programme by eliminating unproductive time etc. If a new recipe cannot be carried out directly with an existing programme, it is the job of the laboratory to set up a new temperature/circulation programme or temperature/time programme. This may be a very simple programme that will ensure the necessary reliability and will in general also be suitable for a larger group of recipes. Programmes suitable for specific recipes may be established to optimize the time as well as the reliability of the process. This contribution to process rationalization is one of the most important functions of a dyehouse laboratory. Automatic dye recipe prediction takes certain routine tasks away from the colourists, so that more time is available for the more important aspects of making the final decision about the recipe and process (contributed by Carbonell, Hasler and Walliser and also by Thurner).

Computer graphics (CG), is highly regarded in the field of information technology. This is based upon its special features that distinguish it from the other information technology disciplines. It offers methods and techniques for producing and manipulating images, these images representing a special type of computer data. This different type of output and input gives computer graphics a special role in the field of man – machine communications, as images are used to impart more information that can in turn be more quickly assimilated by man, more quickly than tables of figures or bodies of text (conventional electronic data handling). The high cost of graphics equipment and high computer processing demands has delayed the spread of graphic application systems. Improved computer processor power capability will allow computer graphics to be used economically. Computer graphics is incorporated into the IT systems used. It offers a broad base for the practical application of knowledge and methods of other areas. Its tasks include techniques for the description, output, and modification of graphic representations and their applications. The ISO definition describes computer graphics as "Methods and techniques for converting data to and from graphics displays via computer". Computer graphics was divided into the separate aspects of data, visual displays and computers contained in this description some 10 years previously (Figs. 1 + 2), and into the sub-areas of generative computer graphics, image processing and picture analysis.

INPUT OUTPUT	IMAGE	DESCRIPTION
IMAGE	IMAGE PROCESSING	GENERATIVE COMPUTER GRAPHICS
DESCRIPTION	IMAGE ANALYSIS	ALL OTHERS

Fig. 1: Rosenfeld's graphic data processing classification.

Generative computer graphics	Image analysis	Image processing
Input		
formal description programme data structures	unstructured image photography/video pixel quantity	unstructured image pixels
Output		
image drawing, table plans	formal description data structures context description	image
(Data) structures		
graphic types - lines - areas - texts formal types - segments - objects - primitives	produced or scanned images quantity of colour dots	scanned images quantity of poorly distinguishable colour dots
Purpose		
image production image output image manipulation	image structuring image recognition	image improvement contour recognition
Advantages to users		
display of results produced dialogue on image and symbol level	manipulation of formerly unstructured images identification of images	recognise images

Fig. 2: Graphic data processing zones.

Generative computer graphics involves the processing of artificially produced pictures which are available in the form of picture descriptions (data formats) and are produced by the computer (i.e. the program).

The actual data may
- be input by the user,
- be produced or compiled by the computer,
- result from user commands in a graphics-working environment.

The generative computer graphics are divided into two areas:
- passive systems,
- interactive systems.

Passive systems are to be regarded as a subset of the interactive systems. Passive generative graphics concentrates on the problems created by the output of graphic data. Once the picture has been represented, no further modification is possible. Prior manual redefinition of the data and subsequent complete regeneration of the picture can only achieve this. The term interactive graphic system is applied to systems consisting of appliance configurations and program systems suited to generating and reproducing graphic output and which in addition have hardware and software components which support an interactive working method. The interactive system describes the processes used to carry out a dialogue between man and machine which overall represents passage through a decision network of representations and commands, or actions and reactions. In contrast to the passive systems, interactive graphic systems allow the user to have a dynamic influence on the image or image object.

The imaging methods provide processes and techniques for altering the generation of an image in such a way that, for example, the human perception of the information content of an image is easier. Pictures used are obtained by digitalisation of photographs or TV pictures. The process of altering the image is based on unstructured images. This is also the essential distinguishing feature between graphics systems and image processing systems (Fig. 3). The processed data in generative graphics are a structured volume of output elements. In image processing an image is regarded as a volume of n by m picture elements (pixels), whereby each picture element has a grey value or colour. Otherwise an image does not have a structure. For this reason, image processing is often regarded as the application of algorithms to numerical fields.

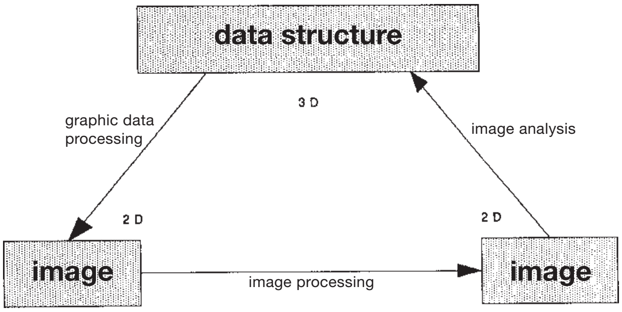


Fig. 3: Relationship between image processing and graphic data processing.

The principal tasks of image processing are represented by the following disciplines:
1. image enhancement, e.g. by increased contrast or suppression of background disturbances,
2. image evaluation, i.e. size determination, contour recognition, recognition of particular image qualities,
3. character recognition, i.e. the extraction and classification of image qualities.

In image analysis, unstructured images (pixel groups) are investigated in order to discover structures and objects and place these in relation to one another. The image analysis is concerned with the breakdown of images into proto-images, i.e. into known graphic objects (such as triangles, circles etc.), so that known data structures can be built up. Images can be recognised by subsequent comparison with known breakdowns. The image analysis thus uses image processing methods for the breakdowns, and generative computer graphics techniques for the composition of the proto-images.

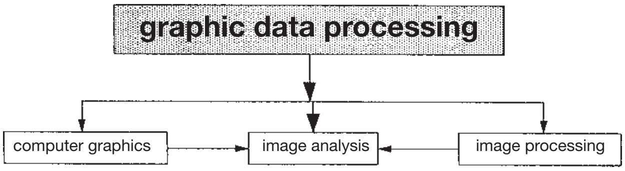


Fig. 4: Dialogue between graphic data processing zones.

This exchange between the sub-areas of Computer graphics is clarified by the diagram in Fig. 4.

The techniques of Computer graphics are used in numerous branches of industry, management, public areas such as administration, training and for entertainment purposes. The number of applications is constantly on the increase, not least because graphics output equipment is being developed into affordable mass products. The following shows examples of some typical areas of application of computer graphics (Fig. 5).

a) Plotting systems for producing drawings: in the commercial sector, science and technology, 2D and 3D graphics systems are used to represent mathematical, physical and even economic functions. The results are presented in the form of histograms, bar charts, functional diagrams, pie charts, flow charts etc. and thus presented in a clear, structured way. Computer graphics are used in this area to give an overview of complex systems and their contexts and to support decision-making.

b) Cartography: graphics systems are used to compile precise representation of geological and geographical data. The output is given on paper or film. This makes it possible to generate several drawings from one data structure and to use the graphic substructure for the production of different images and different sizes (e.g. in different colours). Examples include maps, layout plans, relief maps, weather maps etc.

c) Computer Aided Design (CAD): interactive graphic systems are used here for design purposes. One such application is for design systems in the area of textiles (see Fig. 5). In CAD systems which are regarded as the application of a graphic system, structures are built up and manipulated, such as houses, cars, production plant, machine components or textile designs. CAD systems support both the draft phase and the compilation of parts list descriptions or production specifications arising therefrom.

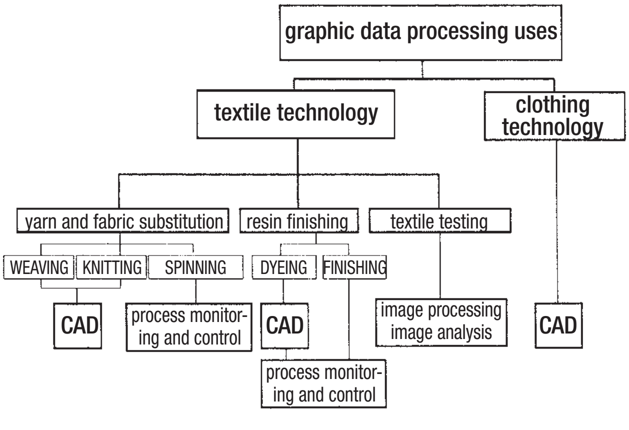


Fig. 5: Uses of graphic data processing in the textile and clothing sectors.

d) Simulations: processes which happen quickly, e.g. deformations, chemical reactions (molecule design) etc. can be simulated and shown in a series of images as calculated time studies. The chronological progression of a chemical process can thus be represented using the sequence of the time studies. Flight simulators enable image generation to be realised in real time by means of interactive graphic systems.

e) Process monitoring: in the process control system, sensors detect a large number of measurement values that are transferred to a control centre. They are combined here to form a representation of the actual process, and shown on control screens. Critical values or situations are shown to the operatives by means of special optical signals (colours, flashing etc.), so that the operative can take any necessary action. These methods are used to control technical processes in nuclear power stations and chemical works, but also in dyeing plant.

Graphic systems are therefore subject to certain prerequisites, depending on their field of application:
- passive systems (with/without real time requirements, on-line/off-line),
- interactive systems (with/without real time requirements),
- resolution and colour characteristics,
- image data types, image types,
- 2D, 3D, surfaces, vectors etc.,
- image structures, relationships between partial images,
- image manipulation logarithms.

The wide range of criteria, which may be applied to a graphics system because of the extent of possible application systems, cannot generally be fulfilled by a "universal system". For this reason, graphics systems are configured according to requirements, i.e. selections are made accordingly from a range of hardware and software components.

Computer language Electronic data processing is based on the use of the binary number system. The "internal" language of the computer (1st generation language) is called computer language. From the technical standpoint, the numbers 0 and 1 can mean "yes" or "no", or "open" or "closed" for example.

Concave (Lat.: concavus = annular hollow). Hollow, recessed, inwardly arched. Antonym → Convex.

Concave frames Are screen frames (in screen printing) with a specific outward curvature, by which flexure caused by gauze tension can be compensated.

Concentrate High percentage → solution.

Concentration of desizing When woven fabrics are desized, the washing liquor, which contains water-soluble size (polyacrylates, polyvinyl alcohols, soluble polyesters), is concentrated (Fig. 1) in order to enable it to be re-used for sizing subsequent to a post-starching process. One possible method of size concentration is to evaporate washing liquors.

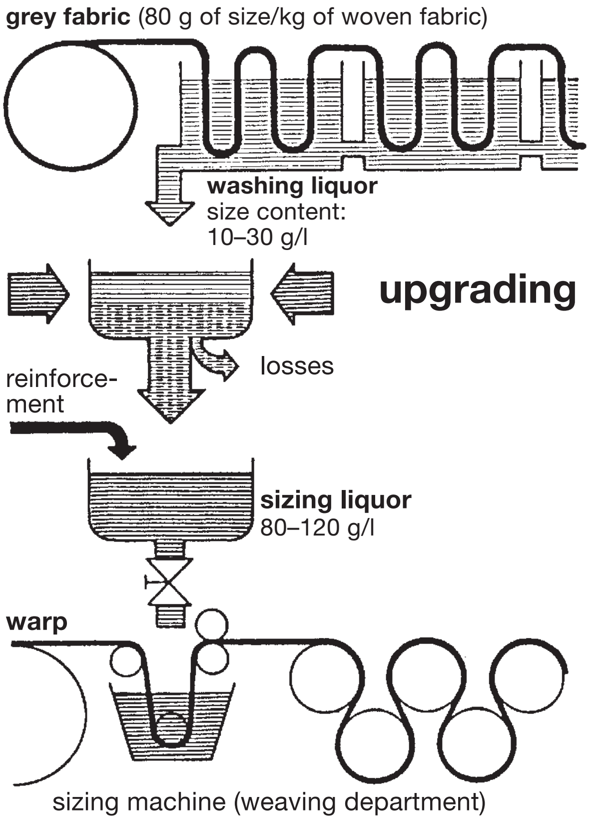


Fig. 1: Size washing liquor upgrading.

The hygroscopic concentration technique (Fig. 2) is used in accordance with the Recupra process by bringing averagely concentrated washing liquors into contact with the fabric to be sized by means of an impregnating roller, the dry fabric exhausting water from the liquor on account of its capillary forces without absorbing the polymer molecules from the fibres.

Concentric Having a common centre point; e.g. in fibre cross-sections (e.g. flax, wool), means concentric layering and the layer-like structure from the centre point (cell lumen) to the periphery.

Condensate (condensation water). Atmospheric water or exhaust steam water from steam pipes and vessels. Valuable as soft water, and used particularly for dissolving dyes, chemicals and auxiliary agents. Available only to a limited extent in the works. As a rule, condensate is returned to the steam boiler and recycled.

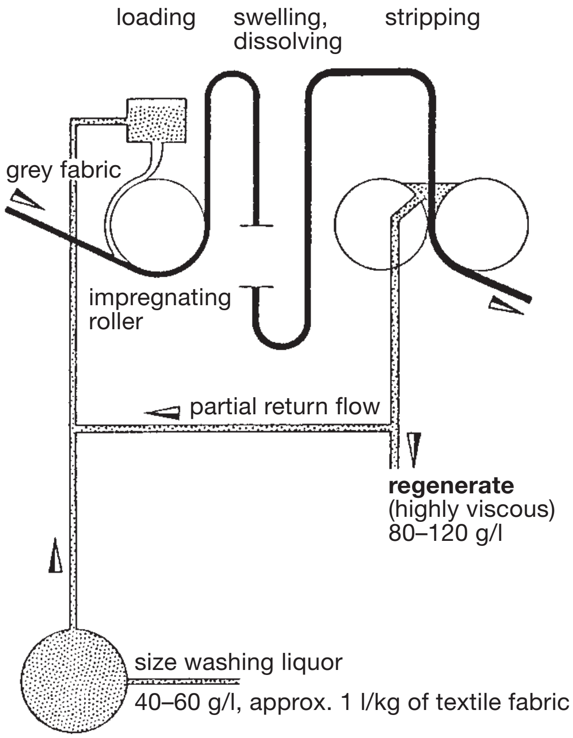


Fig. 2: Technique of the hygroscopic upgrading of desizing wash liquors in the case of acrylate sizes (BASF and Benninger).

Condensate return Important savings can be made by returning (Fig. 1) as much as possible of the condensate (→ Steam trap) occurring in the works.

Simple condensate return methods cannot generally be employed in practice (gravity condensate return) or are not economic in consequence of their associated shortcomings (steam pressure condensate return). Thus, for example, steam pressure condensate return - regarded as economic - is in fact possible, and even necessary, in selected cases, but has slightly more disadvantages than advantages: lifting or returning condensate gives rise to counter-pressure in the steam trap (approx. 0.15 bar per 1 m of lift), reducing the differential pressure in the steam trap, and therefore its power. If this is not taken into account, both too small and too

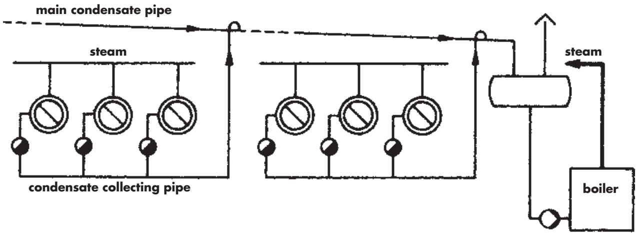


Fig. 1: Condensate return to boiler.

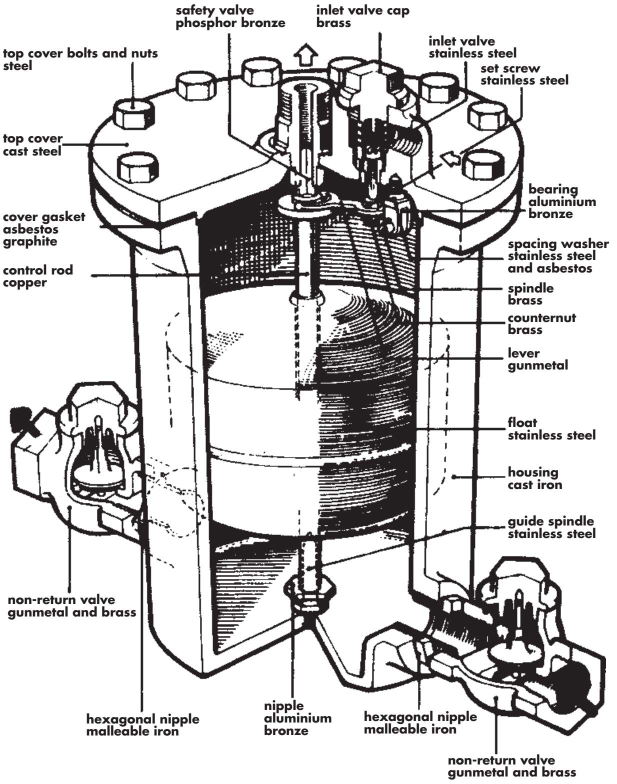


Fig. 2: Condensate lifter (Spirax Sarco).

large steam trap dimensions can be uneconomic; too high a counter-pressure in long condensate piping renders this method of operation no longer applicable. In addition, in the case of steam pressure condensate return, the pipelines cannot be emptied when out of operation (risk of corrosion and destruction), and noise nuisance is to be reckoned with on starting (hot steam = cold condensate), while slower starting impairs efficiency. Feeder stations (pumps or pumping stations) are an economic and operationally reliable alternative: they enable the plant to be emptied, and prevent corrosion, steam or water hammer, noise nuisance etc, and can often be financed by smaller nominal condensate return dimensions in the case of large plants.

Since steam or compressed air is available in most works in any case, steam or compressed air-operated condensate pipe systems can be preferentially employed (condensate lifters or condensate lifting stations for example), the simple and robust construction of which is very suitable (Fig. 2).

In the event of greater heights, larger quantities and greater distances due to multi-branched plant, or the necessary operating pressure for steam or compressed air operated condensate lifting stations being unavailable in the works for steam traps, electric condensate return feed equipment is recommended.

Condensate return piping Piping for returning condensate from steam pipes and steam consumers, mainly to the ventilated boiler feed water tank. At the end of the condensate piping, there is usually a receiver which is either under atmospheric pressure or subject to a slight overpressure of 1.1–1.2 bar due to the thermal degassing unit. The pressure in the condensate piping must be somewhat higher than in the receiver so that the condensate definitely flows to the receiver.

Condensate water softening unit Used for preventing residual hardness in boiler feed water as a pressurised “safety filter” in condensate piping. Incorporated in the piping for degassing or as a feed water tank. Must be designed to be resistant to hot water, and should be checked regularly at 4-week intervals; regeneration unnecessary.

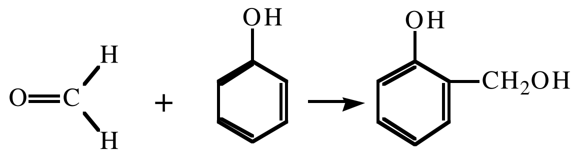
Condensation (Latin: condenso = condense),

I. Physical: change of state from vapour or gaseous form into liquid form (moist air = dew, mist formation), in contrast to → Votalization

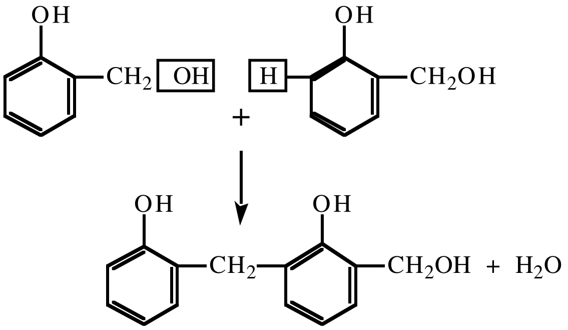
II. Chemical: combination of two molecules into a bigger one with the occurrence of water. If this process takes place into large molecules, it is called → Condensation polymerisation.

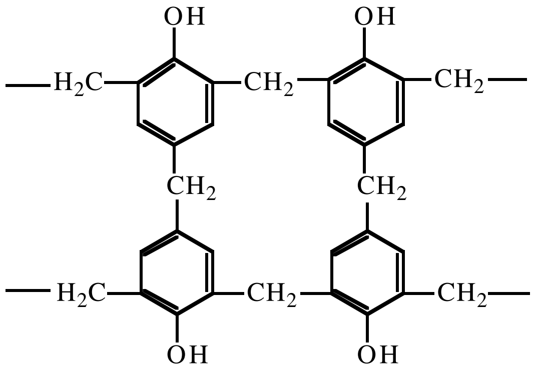
Condensation heating Heat exchange system by means of which condensation heat released in steam condensation is utilised. In contrast to heat exchange via circulating fluid heat transfer media (e.g. circulating oil system), in which turbulence frequently cannot be prevented, uniform temperature distribution is achieved even on large contact surfaces (like transfer calender cylinders for example).

Condensation polymerisation Combination of molecules with the splitting of – mostly - water. Phenolic resins (→ Phenolic plastics) are a classic example of condensation polymerisation, new phenol molecules constantly combining with the emergence of water as follows:

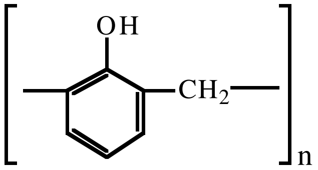


1 mol formaldehyde + 1 mol phenol = phenol alcohol (o-methylol)





In the final state, practically all phenol alcohol molecules are bonded to each other into three-dimensional macromolecules with the emergence of water. This type of condensation polymerisation is represented in simplified form by the following constitutional formula:



Similarly, with the involvement of other phenol and urea functional groups, urea resins (aminoplastic resins), and, of 1,6-diaminohexane and adipic acid, → Polyamide fibres (→ Polycondensation fibres) etc. are produced.

One example in nature is the condensation polymerisation of cellulose or starch under the action of sunlight from carbon dioxide and water (photosynthesis) from the three elements carbon (C), hydrogen (H) and oxygen (O) into an annular self-closing glucose molecule:

$$6\,CO_2 + 6\,H_2O \rightarrow C_6H_{12}O_6 + 12\,O$$

→ Polymerization reactions for fibre-forming macromolecules.

Condensation process for exhaust air cleaning Gases in the exhaust air from stenters can be condensed out by cooling the exhaust air. A relevant Behr unit (Fig.) cools the air to approx. 100°C at first in air to air heat exchangers. Further content substances are condensed out in the second stage by air to water heat exchangers. In stage 3, other contaminants are removed by electrofiltration. Odoriferous substances are particularly difficult to remove by condensation.

Condensation resins → Polycondensation products with a synthetic resin nature.

Condensed ring systems → Cyclic hydrocarbons.

Condenser Equipment for condensing the moisture contained in a medium, e.g. in a hot airflow, either by indirect condensation (i.e. water-cooled heat exchange) or by direct condensation (by spraying in water).

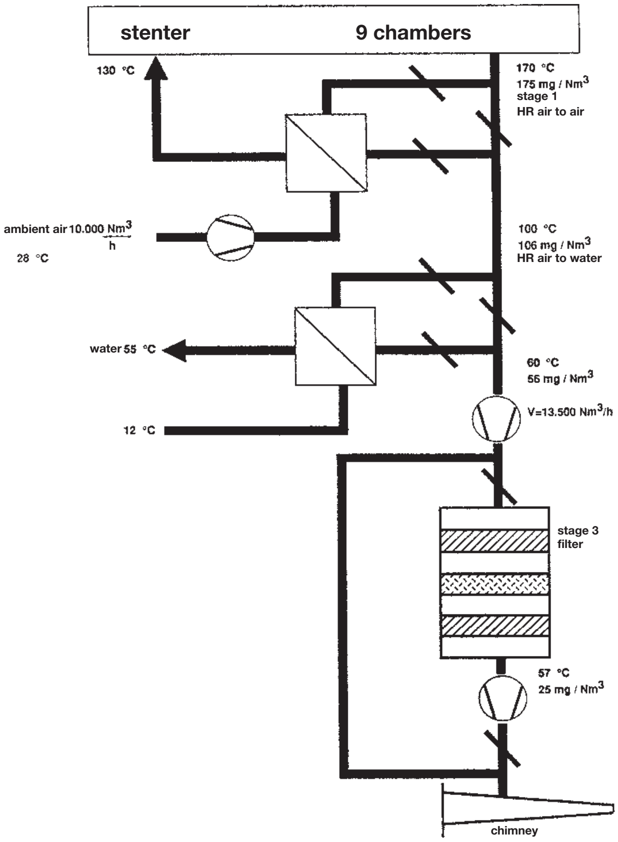


Fig.: Functional diagram of a plant for cleaning exhaust air by condensation and heat recovery (HR) (Behr system).

Condenser yarn,

I. Low grade cotton yarn (waste yarn) in high linear densities usually made from East Indian (Bengal) cotton (→ Imitation yarn).

II. Generally, woollen yarn produced by the so-called double condenser spinning process, spun from roving collected from strips of card web by rubbing in a tape condenser.

Condensor → Compressors.

Conditioning,

I. Allowing materials to come to hygroscopic equilibrium with a standard atmosphere, e.g. for textiles 20 ± 2°C and 65 ± 2% relative humidity.

II. Term for establishing the moisture content of textile raw materials and yarns in conditioning apparatus. Since textile raw materials due to their hygroscopic properties absorb varying amounts of moisture, the trade has agreed on regains and allowances to be applied for commercial transactions. To test the moisture regain, samples are taken and dried at 105–110°C. The commercial mass is obtained by adding the standard regain to the oven-dry mass (BS 1051, DIN 53 822 and ITMA, IWTO and BISFA standards).

Conditioning of calender bowls Preparations for commissioning paper or cotton calender bowls in order to even out the wrappings especially in the case of freshly covered bowls on which the subsequent durability and (for paper bowls) accurate, perfectly embossed effects, as well as the elimination of embossing damage due to engravings being too sharp are dependent. When recommissioning, the surface of the covered bowls which is still rough after turning off must first be smoothened and strengthened. For this purpose, a smooth steel bowl heated to approx. 120°C is used: the bowl is moistened during running (exit side to avoid accidents) with softened water or condensate at approx. 50°C, plus a little neutral soap or detergent containing a fatty alcohol sulphate using a natural sponge, but only to the extent that it becomes dry again after a few rotations. This moistening treatment is repeated. In order to condition all the bowls (apart from engraved embossing bowls), the pressure is increased over 10–20 h to the normal subsequent operating pressure, as a result of which the bowl surface becomes noticeably smoother. By contrast, engraved embossing bowls are conditioned initially without pressure (so that the roller surface can take up water) and only then run in at full working pressure and operating temperature, since the steel bowl expands under the influence of temperature and a bowl which would have shrunk when cold would cut the fabric when running warm later on. For engraved embossing bowls, it is therefore incorrect to condition them with slowly increasing pressure, which can also cause the design to become "fixed". During the course of subsequent bowl maintenance, they should be conditioned again at least once a week for a few hours (after first cleaning off any residual finishes). Slight indentations (e.g. due to the passage of seams in the fabric) can be effectively removed by daily afterwashing at the normal working pressure and operating temperature, which does not usually take much time. The conditioning process has been carried out correctly if, during continuous observation from a certain distance, the steel bowl (and also the paper bowl) appears equally bright (with no matt areas) across the entire width, i.e. with no shading or darker areas.

Conductance, electrical → Electrical conductance.

Conductivity The sodium chloride and sodium sulphate salts used in dyeing dissociate into anions and cations in aqueous solution.

$$\mathrm{NaCl} \underset{-\,H_2O}{\overset{+\,H_2O}{\rightleftharpoons}} \mathrm{Na^+ + Cl^-}$$

$$\mathrm{Na_2SO_4} \underset{-\,H_2O}{\overset{+\,H_2O}{\rightleftharpoons}} \mathrm{2Na^+ + SO_4^{2-}}$$

When an electrical voltage U is applied, a current I flows over the electrically charged ions through the salt solution (Fig. 1), the ions discharging on to the electrodes (electrolysis).

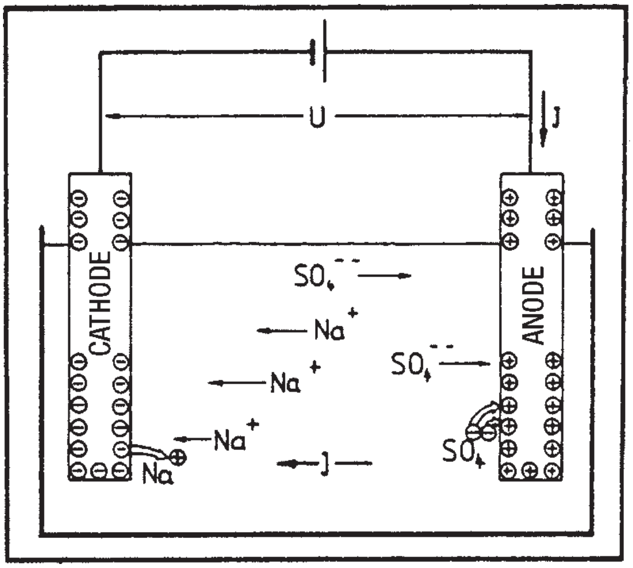


Fig. 1: Electric conduction in an electrolyte.

The parameter which is suitable for determining an electrolyte concentration, and is obtained by electrical measurement, is conductivity. It is the reciprocal of specific resistance, with Siemens per metre (S/m) as its unit. With a homogeneous conductor in a homogeneous electric field, the electric current intensity I depends on the externally applied voltage in the following way:

$$I = \chi \cdot \frac{f}{l} \cdot U$$

f is the cross-section, l the length and χ the conductivity of the conductor. With mixed phases, the dimension χ depends on the composition, the temperature and (insignificantly) on the pressure. With the resistance value

$$R \equiv \frac{1}{\chi} \cdot \frac{l}{f}$$

ensues Ohm's law for the given special case:

$$I = \frac{1}{R} \cdot U$$

Electrical resistance $R = \frac{U}{I}$

Specific resistance $\rho = \frac{R \cdot A}{l}$

Electrical resistance $\chi = \frac{1}{\rho}$

In the case of measurements on solutions (e.g. with dipped electrodes), the geometric dimensions of the arrangement are summed up by introducing a cell constant

$$C \equiv \frac{l}{f}$$

and

$$R \cdot \chi = C$$

is obtained.

This relationship is used for measuring resistance R with known conductivity χ for determining cell constants C, and for determining conductivity χ at a known cell constant C.

The equivalent conductivity $\wedge$ of an electrolyte is defined by

$$\Lambda \equiv \frac{\chi}{c^*}$$

c* is the equivalent concentration of the electrolyte, which, in the case of electrolytes each with one sort of cation and anion, results from a concentration (substance quantity concentration) c as follows:

$$c^* = z_+ \nu_+ c = -z_- \nu_- c$$

z_+, or z_- is the sum of the charge number of the cations or anions, and v_+ or v_- the decomposition number of the cations or anions, by which is understood the figure for the complete dissociation of cations or anions originating from the neutral electrolyte molecule. With 1 : 1 valent electrolytes, which are considered below,

$$z_+ \nu_+ = |z_-| \nu_- = 1$$

$$c^* = c$$

for the limit of equivalent conductivity $\wedge^o$ with infinite dilution

$$\lim_{c \to 0} \Lambda = \Lambda^o$$

is valid:

$$\Lambda^o = \lambda_+^o + \lambda_-^o$$

λ_+^o and λ_-^o are the limits of ion conductivity λ_+ and λ_- with infinite dilution:

$$\lim_{c \to 0} \lambda_+ = \lambda_+^o \, , \quad \lim_{c \to 0} \lambda_- = \lambda_-^o$$

For a given solvent and fixed temperature, the limits of ion conductivity λ_+^o and λ_-^o are a characteristic parameter of the relevant type of ion. From experience, it is independent of the nature of the counterion in each case. This statement is described as „Kohlrausch's law of independent ionic migration". From the physical standpoint, this means that the ions of the electrolyte in the solution are so far removed from each other in the infinitely diluted solution that their interaction can be ignored.

For electrolytes, electrical conductivity runs linearly to concentration in concentration ranges of a few hundred milligrammes per litre. If the concentration increases in ranges which are taken into account for textile chemical finishing processes (up to several hundred grammes per litre), linearity comes to an end; it can even result in reduced conductivity.

Non-linearity in true electrolytes is caused by a) reduced dissociation as the concentration increases, and b) interionic interactions. a) means that the number of electrically charged particles does not increase linearly with the quantity of dissolved salt. In the case of b), the interactions impede ionic mobility. Apart from the concentration, this is determined by the ion dimension and the hydrate envelope covering the ion. Dye molecules for example are particularly large ions.

The temperature of an electrolytic solution has a great deal of influence on conductivity. Both dissocia-

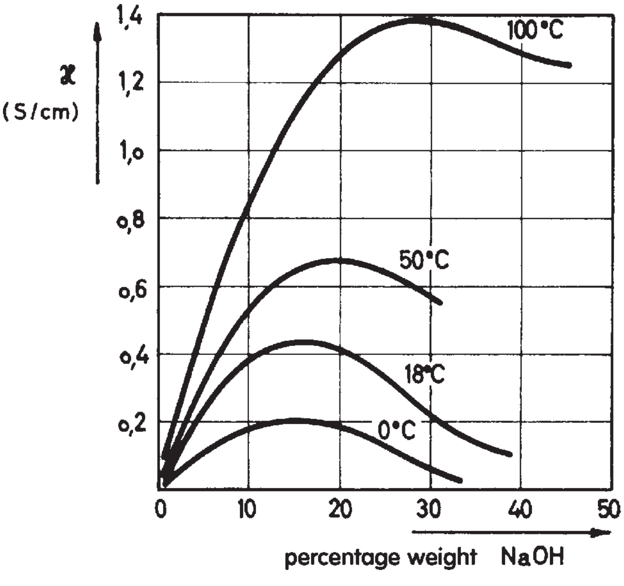


Fig. 2: Specific conductivity of caustic soda.

tion and ionic mobility are affected by temperature (Fig. 2).

A temperature correcting link b serves to integrate the temperature in the conductivity values. b can assume values of 1–6% per degree. Calculation of the temperature coefficients with

$$\chi_R = \frac{\chi}{1 + b\,(\vartheta - \vartheta_R)}$$

ϑ_R = reference temperature

Like equivalent conductivity $\wedge$ (and conductivity χ), ion conductivity values λ_i depend on electrolyte concentration, and, to a lesser extent, on pressure. Concentration dependency is different with weak and strong electrolytes. The ion conductivity values of strong electrolytes change as the concentration changes, whilst, with weak electrolytes, which are also incompletely dissociated with increased dilution (α <1), they are approximately independent of concentration. Under this premise, the Arrhenius formula

$$\alpha = \frac{\Lambda}{\Lambda^0}$$

is valid in diluted solutions for the degree of dissociation α. With diluted solutions of weak electrolytes, the degree of dissociation α can therefore be determined by conductivity measurements. The ion separation and concentration change at the electrode surfaces caused by electrolysis poses a technical measuring problem. Conductivity is reduced by an apparent increase in electrolyte resistance. This effect, which falsifies measured values, is called polarisation. Polarisation diminishes

- on measurement with an alternating voltage of increasing frequency,
- with an increasing electrode surface.

Non-contact conductivity measurements (inductive, capacitive) reveal no polarisation. Four electrode or multi-electrode measurements produce very little polarising effect. Virtually currentless voltage measurement ensures control of the electrode current, which is then dependent only on the actual electrolyte concentration.

Water (if only a little dissociated) is also a weak electrolyte. Moisture content differences in textiles change conductivity by powers of ten. The water content and electrical conductivity of fabrics containing cellulose are linked with each other via an exponential function, and can be measured on the fabric under certain circumstances (Fig. 3).

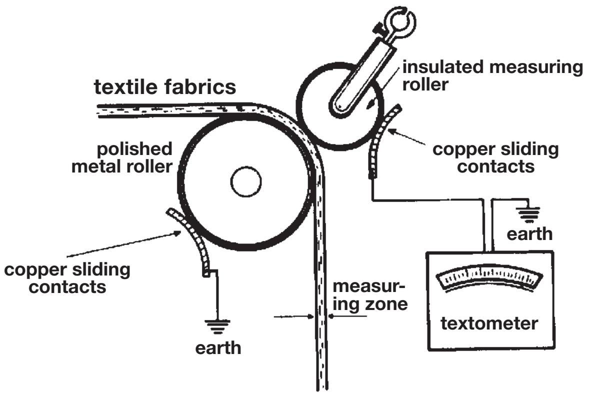


Fig. 3: Mahlo conductivity moisture measuring unit.

In the residual moisture content range, neither the fabric weight nor the properties of the water, and neither the thickness of the fabric to be measured nor the liquor composition have only approximately as great an effect on electrical conductivity as the quantity of water in the fibre. For this reason, determining the residual moisture content in textiles by measuring electrical conductivity (or its reciprocal - electrical resistance) is relatively insensitive to disruption. The exponential link between moisture and conductivity exists exclu-

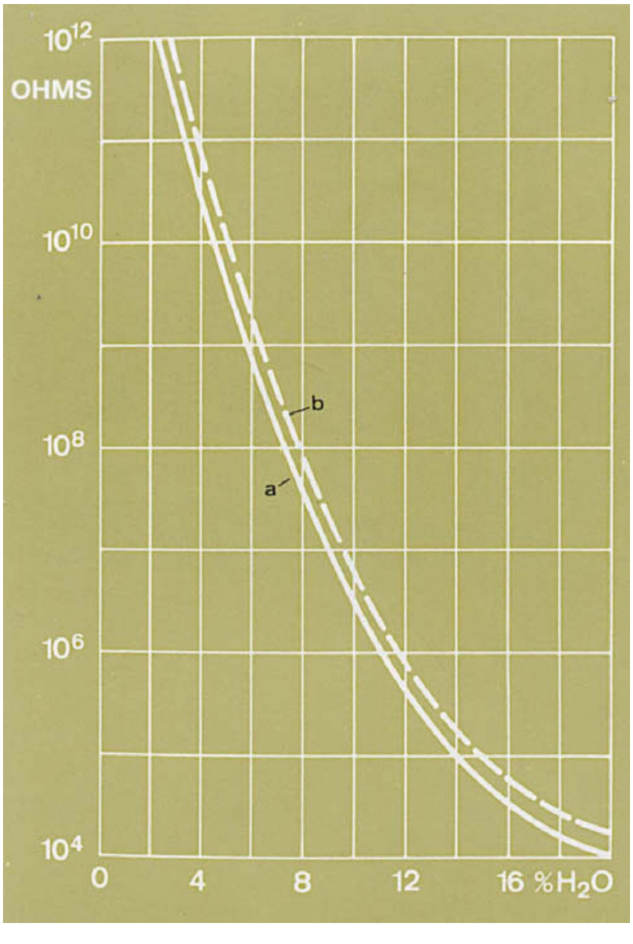


Fig. 4: Relationship between the moisture content and conductivity of a textile fabric (fabric weight a = 120 g/m^2; b = 240 g/m^2).

sively in the residual moisture range (Fig. 4). If surface water appears, and the fabric feels perceptibly wet, the exponential function becomes linear, and cannot therefore be used for moisture measurement.

Conductivity, measurement of Conductivity is measured by the electrical resistance of a solution. The measurement has to be carried out with an alternating current as the electrolyte decomposes when direct current is used. To determine the electrical conductivity of a fabric, a sample has to be extracted with distilled water at an exact liquor ratio of 20 : 1. The conductivity of the distilled water used for this purpose should not be greater than 2µS/cm. The conductivity measured in the extract is used for characterizing the fabric (Fig. 1). When the washing efficiency of preparation equipment is compared, the values determined from the extraction must be compensated to allow for the absolute amount of the fabric.

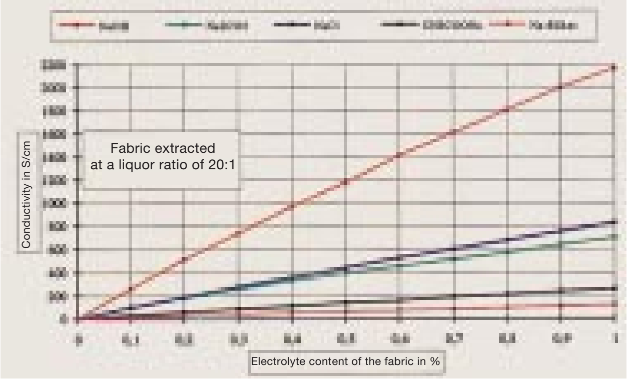


Fig. 1: Relationship between the electrolyte content of the fabric and the conductivity.

In Fig. 2 and 3, the conductivities of various samples of process water as well as a sample of river water are shown. It is interesting that water that has been passed through an ion exchanger has a significantly higher electrolyte content than untreated town water. If this ion exchanged water is exchanged again through an H-ion exchanger the conductivity is about a three times higher, because the solution has a very acid reaction as the Na have been exchanged for H ions. After neutralization with caustic soda, the conductivity shown is reached (contributed by Hipp).

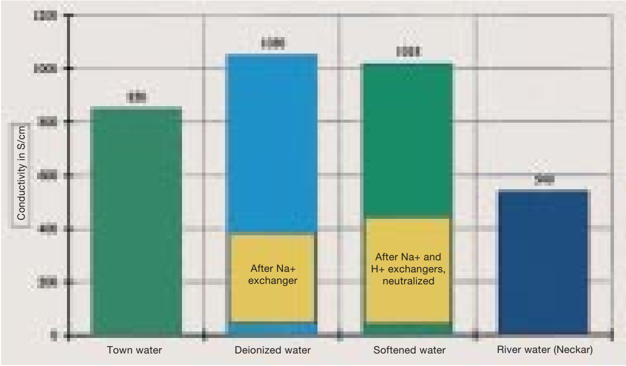


Fig. 2: Conductivities of various process water (work diagram).

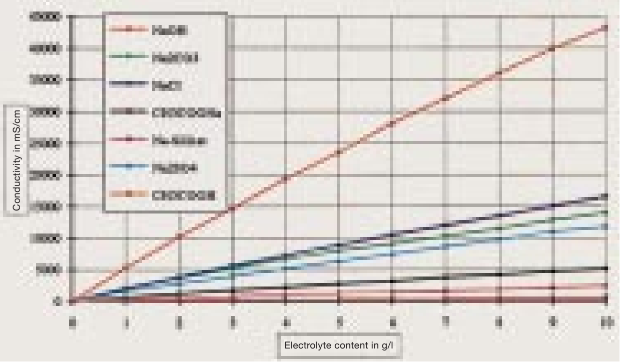


Fig. 3: Dependence of conductivity of various electrolytes on concentration.

Conductivity measuring instruments are used a) for moisture measurement; b) for measuring static charges; c) for measuring pH; d) for measuring the r_H value.

Conductometric measurement For determining the ion concentration c by measuring specific conductivity

$$\chi = \frac{c\, n_e}{1\,000} \cdot (l^- + l^+)$$

n_e = electronic valency,
l^-, l^+ = anion and cation mobility (constant for given electrolyte).

Limitations: only for dual component systems, possible complications at higher concentrations due to the effect of the activity coefficient. Particularly suitable for washing bath control.

Cone →: Package; Conical.

Cone changers Are used for changing the cones of conical cross-wound bobbins, e.g. to replace stainless steel cones with cardboard cones for further processing.

Cone dyeing machines Dyeing machines used for dyeing (hat) stumps. They prevent the formation of heat creases otherwise easily occurring in loose dyeing; the hat shape is completely retained, and even the most difficult stumps are perfectly dyed in a short time with no consequential disaggregation. For dyeing, the stumps, carefully made to measure, are drawn on to a perforated cone, through which the dye liquor is then pressed. In the case of open machines, the dyeing temperature is approx. 95°C, and with enclosed machines,

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up to 110°C (temperatures above 100°C should as a rule be avoided on quality grounds). 1 : 1 and 2 : 1 metal complex dyes and acid levelling dyes for example are used.

Cone loading and unloading unit For the automatic loading and unloading of cone centrifuges and yarn package dryers. Continuous package feed and removal, star-shaped bar grid and package presser operating at intervals. Replaces high cost manual loading; suitable for creel-type and porcupine systems.

Cone mill Dye kitchen device for mixing and milling printing thickener and prepared printing pastes.

Cone thrust lock Sealing unit for the continuous inlet and outlet of textile material in endless rope form. Has the form of a double truncated cone, and is generally produced from elastic material. In a special version, the ends can twist against each other, the cross-section of the two superimposed truncated cones then being altered.

Confidence factor (statistical probability; Px). Probability that a statistical statement is correct, e.g. that a parameter is within the → Confidence interval.

Confidence interval Interval of values used in statistical evaluation to calculate on the basis of random sample findings the unknown value of a parameter of an assumed distribution. The interval includes all parameter values where the random sample finding appears in the range of random scatter with a specified probability γ. Thus, for example, the limits of the confidence value $\propto_{un}$ and $\propto_{ob}$ are calculated for the unknown mean value μ of a parent population with normal distribution, on the basis of a sample of scale n with an arithmetical mean value $\bar{x}$ and standard deviation s, as follows:

$$\mu_{un} = \bar{x} - t \cdot \frac{s}{\sqrt{n}}$$

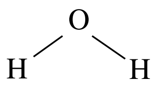
$$\mu_{ob} = \bar{x} + t \cdot \frac{s}{\sqrt{n}}$$

Here t is the limit value of the "t-distribution" (also referred to as the "student number"), dependent on the sample number n and the predictive probability P_A (following which $P_A = 95\%$):

sample number	n	5	10	15	20	25	30
	t	2,8	2,25	2,15	2,1	2,07	2,05

The confidence interval becomes smaller with increasing scale n of the sample, i.e. the mean value $\bar{x}$ calculated for the sample increasingly approximates the actual mean value $\propto$ of the parent population.

Configurational formula (geometric formula). Characteristic formula of three-dimensional configuration. Example: in contrast to the → Structural formula of water (H–O–H) for example, the configurational formula takes account of the fact that both H atoms form an obtuse angle of approx. 105° to the O atom:



(→ Spatial formula).

Conforming to type,

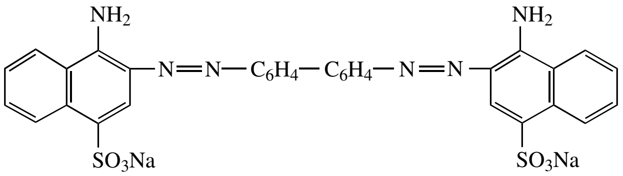
I. Expression of grade in the dyeing and auxiliary industry and the textile finishing industry for products that correspond to a standard type as regards concentration, physical, chemical and application behaviour and shade. Producers make use of quality control in order to attain standardisation tolerances.

II. Expression used in textile finishing for dyeing, printing and finishing effects that correspond to a specified standard type.

Synthetic organic dyestuffs, show by their synthesis process that a typical by-product presence is found and that their reproducibility from batch to batch changes very little. When the → Formulations of dyes can also show good reproducibility, it can be assumed that the composition of the dyestuff is constant from one delivery to another, i.e. the dye conforms to type. It must be borne in mind that dyestuff diluents may be hygroscopic, which means that the moisture content of dye powders may vary according to storage conditions.

Conglomerate (Lat.). Mixture of numerous individual particles, mainly of different or similar types.

Congo red Red direct dye (Böttger 1884). Benzidine-bis-1-naphthylamine-4-sulphonate:



Dissolves reddish brown in water, colloidal; a blue precipitate occurs with hydrochloric acid, and a reddish brown one with caustic soda; it dissolves blue in concentrated sulphuric acid. Use: as congo red paper and as a concentrated solution in dye microscopy for differentiating between viscose filament (dyed light) and copper filament (dyed dark). – Manuf.: Bayer.

Congo red paper Colour indicator on acid traces, colour change interval pH 3 (bluish violet) to 5.2 (reddish orange, brownish).

Conical (Lat.: conus = cone) tapered.

Conical packages → Crosswound yarn package.

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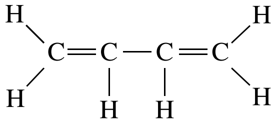
Conidia (Gk.). Fungus spores, → Moulds

Coning oils → Spin finish to improve the winding performance of yarns and thus increase the flexibility and low friction properties of yarns for winding and knitting processes. In spinning mills coning oils may cause corrosion of needles. The products are based on oils or water emulsifiable oils, which can be formulated with surfactants. They are commercially available with various suffixes from different manufacturers.

Conjugated (Lat.: coniugare), alternately bonded.

Conjugated double bonds Molecule construction system of alternating double and single bonds, e.g.



Such bonding systems endow relevant substances with increased reactivity, and play an extremely important role in the synthesis of numerous textile auxiliary agents, solvents, plastics (rubber, buna), dyes etc.

Consolidated shrinkage Compaction shrinkage. Delayed → Relaxation shrinkage. The (additional) shrinkage following the latter under dynamic (active) conditions, e.g. in the scouring process, unless this shrinkage is already identical to → Felting shrinkage.

Consolidations strengthening, compaction.

Constituents Chemical term for the number of substances differing from one another, from which a (phase) system is constructed. The number of constituents can be lower than the number of phases, as in the 3-phase system of the closed vessel with air, water and ice, where 2 constituents can be selected, namely air and water or air and ice, since the two phases water and ice are produced from one substance (ice or water). The number of constituents can also be greater, however, as in the 1-phase system of a salt solution, as this consists of just one phase – the solution – which has 2 constituents, namely salt and water.

Constitution (Lat.: constituere = compose). Sequence of atoms in the molecules of a chemical compound. →: Structural formula; Spatial formula (→ Formula).

Consumption prediction Because of the typical machine designs, residual liquor after padding is unavoidable. Environmental concerns are demanding the elimination of residual liquors (residual bath minimization). Effluent water that accumulates during the overall dyeing and finishing process, largely from residual liquors, involves extra costs because of the value of the products lost in the effluent (chemicals and dyes) as well as the continuously rising costs of disposal. It is therefore scarcely surprising that more and more often the question of how to deal with the effluent is asked. There are two basic solutions: the volumes of effluent that accumulate can be reduced by various subsequent processing. Large volumes of effluent can also be avoided from the beginning e.g. by minimizing the amounts of residual liquors in finishing, preparation, dyeing and sizing. There are many opportunities to minimize the amounts of residual liquor: the choice of products and recipes, knowledge of the goods, the arrangement of fabric and liquor, the methodology of preparation of the bath, re-use of residual baths. Measurement and control equipment is required for determining all the relevant parameters associated with applying the liquor, and information systems are required to manage other data that affect the amounts of residual liquor and to enable the optimum use to be made of these data.

In the course of a pad application, consumption is predicted with the help of three signal generators (liquor level in the bath, length of fabric and liquor input) that send the continuous liquor requirement of a machine to a central control unit. The system analyses the data produced and after a short time predicts the amount of liquor that will be used. A running rapid calculation means that even after a few metres an exact prediction of the liquor requirement per 100 m can be made. The additional liquor can then be made up exactly, to keep the residual to an absolute minimum. Full baths and half filled addition tanks left after the application process has finished are eliminated. The system can only react to the total liquor requirement prediction if the production run lasts long enough and the liquor can be made up quickly.

A system for predicting the requirement (Fig.) consists of three components or part systems which control mixing of the solution. The first part is combined with the coating unit. It determines and minimizes the liquor requirement of the unit. Large volumes of liquor to provide adequate safety margins then become superfluous. A second component that is purely software serves as a management and information system for all data relating to the application, such as chemicals, recipes, arti-

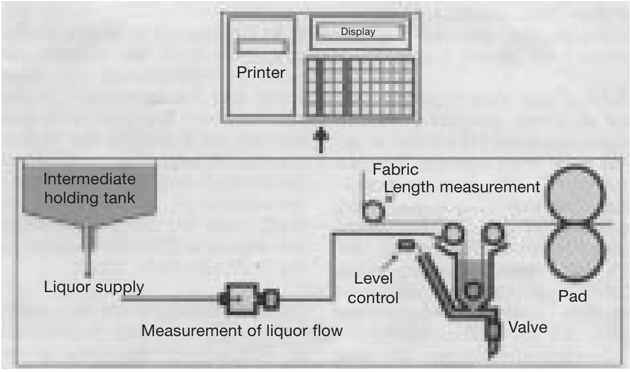


Fig.: Diagram of the "Alux 9000" and "Alux 9090 Cart" equipment for consumption prediction.

cles and application units. The third component unites the first two parts into an integrated system that takes account of all aspects of liquor management. The aim: to be able to supply the right liquor at the right time in the right amount in the right place (contributed by Frey and Wyss).

Contact angle In a plane which is vertical to a boundary line formed by three phases, the tangents laid on the two curves limiting a phase are examined. The angle formed by these is the contact angle of this phase relative to the other two (→ Wetting angle).

Contact corrosion Special case of → Corrosion, where, with direct contact between two different metals, a corrosive fluid is present acting as an electrolyte, under the influence of which the electronegative or baser metal is generally quickly destroyed (→ Electrolytic corrosion). In this respect, one can assume that there is no danger of corrosion in putting stainless steel with copper, bronze, brass and light alloy, if these metals are completely resistant in relevant solutions, as is stainless steel. In accordance with this principle, rustproof steel sheets can, without misgivings, be put together with brass coverings or brass rivets or nickel silver in washing machine construction. Where these factors do not exist, insulating layers should instead be interposed between different types of metal materials.

Contact drying Drying is implemented here by contact with heated cylinders or plates. →: High temperature contact process; Drying systems.

Contact-free measurement Under certain circumstances it can be of interest to scan textiles for a measurement value without contact taking place. An example would be the contact-free measurement of the speed of the goods (see Fig.): This is a correlation-optical process with grid sensors. The measurement information is obtained from the relative movement between the image and the grid. Through the choice of the representational scale and the grid constants, the work distance, the speed measurement range and the resolution can be freely selected, within certain limits. The only requirement which must be fulfilled in order to ensure the functioning of the measurement process is that the measurement object must have an optical structure. This could be random colour structures or weak light-dark differences, such as occur in almost every object to be measured; sometimes the contrast points are not discernible to the naked eye and appear only when suitable lighting is applied.

During measurement, the beam of light from the optical system transmits the object image onto a prism grid. With the relative movement of the sensor, the contrast points of the measurement object are modulated in such a way that a speed-proportional frequency arises via the photo-receiver system.

Contact heat resistance → Thermo stability of dyes.

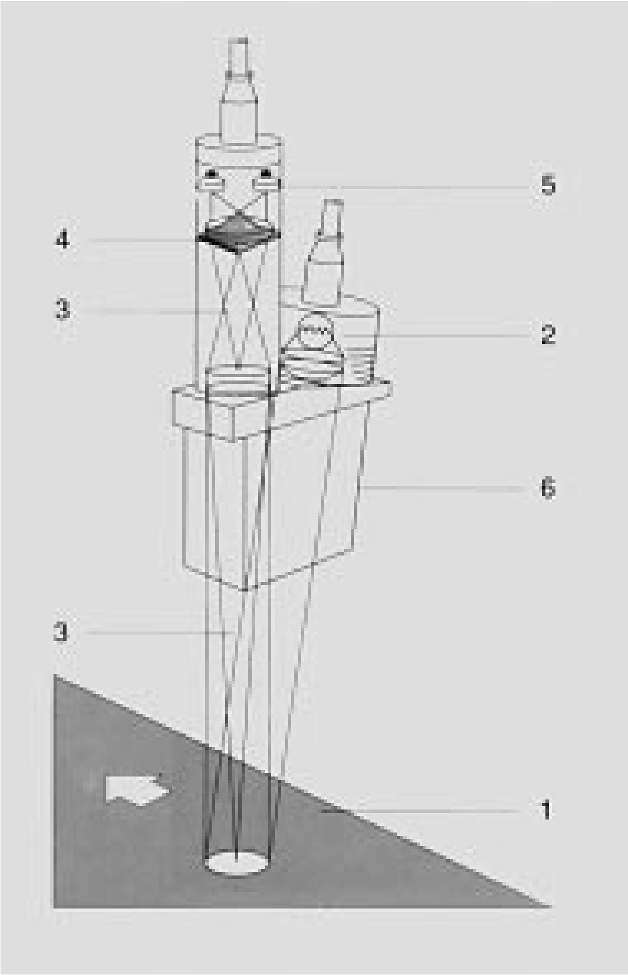


Fig.: Principle of operation and structure of the Correvit-L4/75 optical length and speed sensor for non-contact measurement.
1 = test object; 2 = illuminating system; 3 = optical beam path; 4 = measuring grid; 5 = photodetector system; 6 = spray protection.

Contact poison Contact poison in contacting textile pests as an immobilising/destroying neurotoxin. → Mothproofing.

Contact pressure Pressure applied to the pressure table by the pressure plate in thermal printing presses, using electro-hydraulic power transmission.

Contact printer In the half-tone process, the screen, which is necessary for better adhesion of the printing paste in the engraving, and for preventing the doctor blade from “dipping into” the engraving, is produced either in photography by inserting a glass/engraving contact screen, or by direct use of contact screen films, or also by screen films on a contact printer. → Half-tone screens.

Contact printing process A colour extract is transferred to flat or rotary screens in the contact printing process, the two-dimensional image of the transparency master being projected on to the copying layer, in which a three-dimensional pattern appears with the image produced whereby print shoulder and print flank are evaluated for copying definition.

Contact time in transfer printing Time span of the effect of the contact heat issuing from the transfer unit on to the printed transfer printing paper in close contact with the textile product.

Contaminants The textile process produces waste such as end fents and off-cuts that have no commercial value and indeed may be contaminated with process chemicals or oil. They may be contaminated with chemicals or waste products or may contain waste products from thermal processes such as oils, fats and waxes condensed from exhaust gas control processes. Similarly there are wastes such as the condensates from flame laminating processes. Many types of packing material will also result in contaminated wastes.

The disposal of such waste is linked to high administrative cost. It is important to define and separate waste or accept the high cost of "worst case" control of the hazard. For this reason there is a precise commercial advantage in sorting and separating waste into defined categories for disposal. It is normally the case that the polluter pays, so the responsibility for overseeing the process of disposal through to the final stages is a requirement.

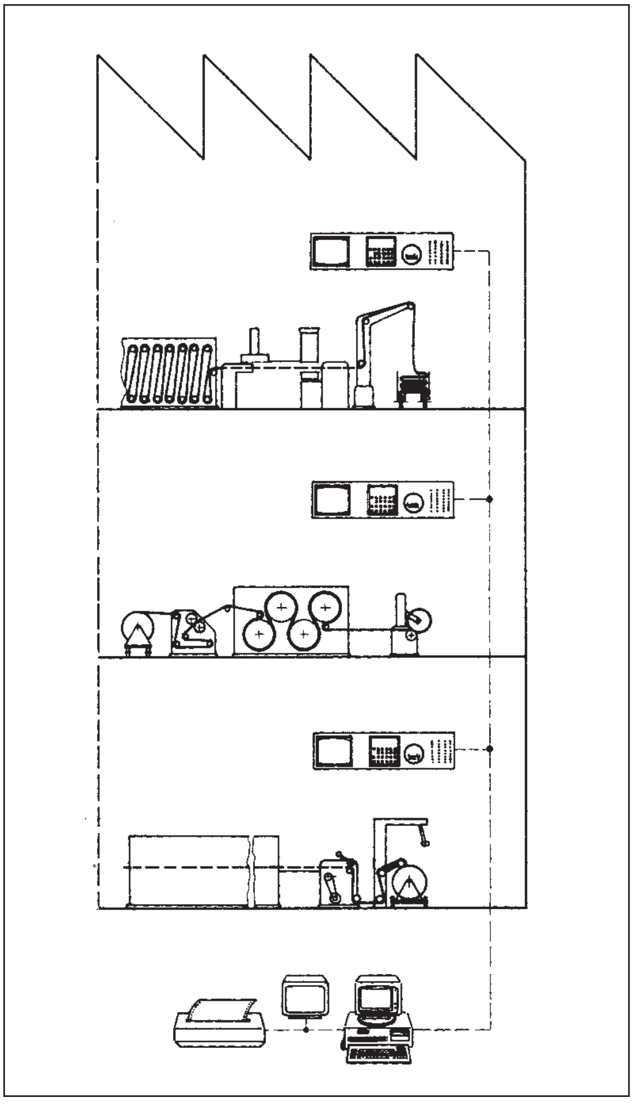


Fig.: Diagram of an operational monitoring system in a textile finishing plant.

Monitoring production helps in recognising waste at an early stage. The figure shows centralized monitoring of the individual stages of processing in a textile finishing plant. The operator observes e.g. mainly the automatic setting processes. Set values and actual values can thus be compared on the computer screen. After the batch is processed the computer produces a batch report or these data are copied onto other computers by file transfer.

It is a normal requirement that all processors carry a responsibility to control the waste they produce from processing. The control of recording the isolation and eventual disposal of waste is an important aspect of this responsibility, extending even to monitoring the efficiency of a sub-contracted waste disposal agent. (partly according to Marzinkowski).

Contaminant-tested textiles The letter T in a circle representing the globe (the inner section may be interpreted as a tree, protected by the surrounding bracket) with the legend "contaminant-tested textiles" (Schadstoffgeprüfte Textilien) (plus control number = "Kontrollnummer") (Fig.), used as a manufacturer's mark of the German textile industry; → MST (Markenzeichen schadstoffgeprüfte Textilien = "Contaminant-tested textiles mark").

Fig.: German "Contaminant-tested textiles" mark.

Conticrabbing Continuous wet finishing machine without conveyor belts (see Fig.). Cloth speed 8–24 m/min; length without wash section 5.50 m; width 3.20 m; height 4.75 m; water capacity in treatment compartment 3500 l, in cooling bath 1000 l; installed power 15 kW; incorporating pressure reduction and level control. For permanent-set finishes on wool fabrics. Setting prevents creases forming in rope dyeing, permitting even difficult fabrics to be rope dyed without problem. Irregularities in quality in the loomstate fabric can be compensated by water treatment at 110°C. – Manuf.: MAT di A. Bertoldi S.p.A.

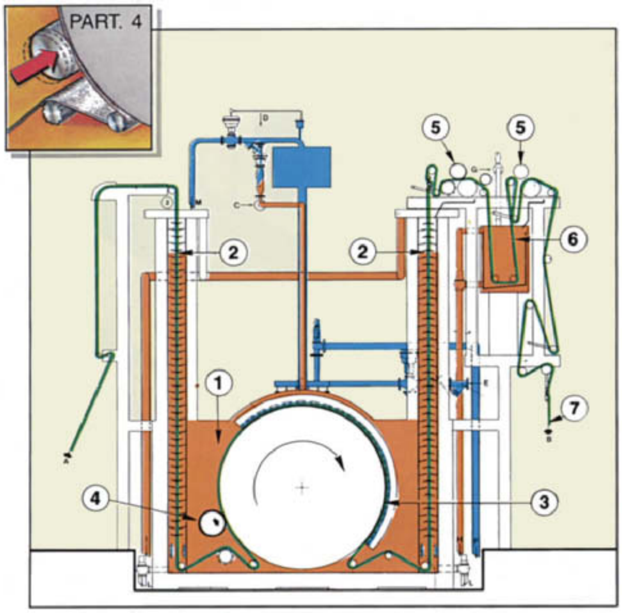


Fig.: Principle of MAT Conticrabbing machine.
1 = treatment compartment; 2 = water heads; 3 = main cylinder; 4 = counter-pressure roller; 5 = squeeze rollers; 6 = cooling bath; 7 = cuttling.

Continuous ager A continuous steamer or ager, rapid steamer and screen-print steamer.

Continuous bleaching plants Consist of a J box (rope form), impregnating machines (open width form) steaming systems and rewashing lines (see Fig.). The uniformity of the bleaching effect depends largely on the consistency of the chemical concentration and treatment time and temperature. Relevant measuring and control units are essential.

Continuous boiler → Steam boiler.

Continuous decatizing (Am. decating). Dry decatizing: Continuous decatzing processes improve wool and mixed-fibre fabrics, especially in respect of handle and appearance. The fabric is exposed to steam in either expanded or cooled form (suction principle) or controlled humidity is applied to the cloth in the treatment zone and this is converted into steam by applying pressure and heat (vaporizer principle Fig. 1).

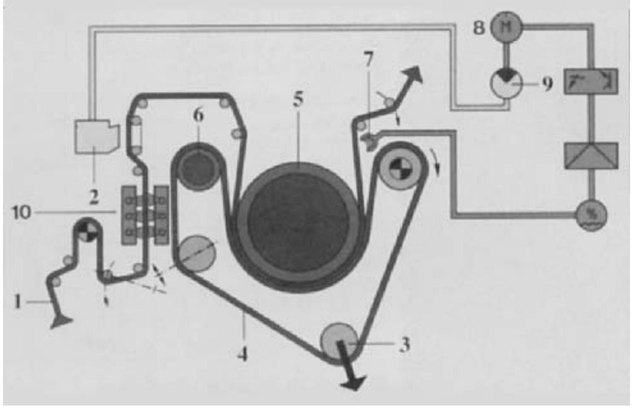


Fig. 1: “Superfinish” by Menschner.
1 = cloth path; 2 = controlled humidification unit (rotor-spray device); 3 = tensioner device; 4 = compression belt (wrapper); 5 = heated counter-roller; 6 = heated roller (compression belt); 7 = sensor for measuring released steam cloud; 8 = drive motor; 9 = supply pump; 10 = auxiliary special steam-lock.

The “Superfinish” (Menschner, Fig. 1) and the Multiset (Sperotto Rimar, Fig. 3) produce their own steam, constantly adjusting the rate of application to the moisture content of the entering cloth. This creates relatively high temperature through to the core of the cloth (125–140°C) depending on the pressure exerted on the cloth in the vaporization process (Figs. 5 and 6). This is 20–35°C higher than in conventional decatizing machines operating on the suction principle. Higher temperature means better set in the cloth. As shown in Fig. 1 controlled humidity is applied to the cloth immediately before pressing and decatizing treatment. Pressing and decatizing then follow with contact pressure on the counter-roller being applied via the compression belt (wrapper) pre-tensioned by the tensioner device. Controlled heat is applied to both faces of the cloth by heating the compression belt and the counter-roller. The heated compression belt is impermeable and sealed from the environmental atmosphere, so under these circumstances, i.e. under high-temperature conditions, the moisture applied to the cloth is converted into steam.

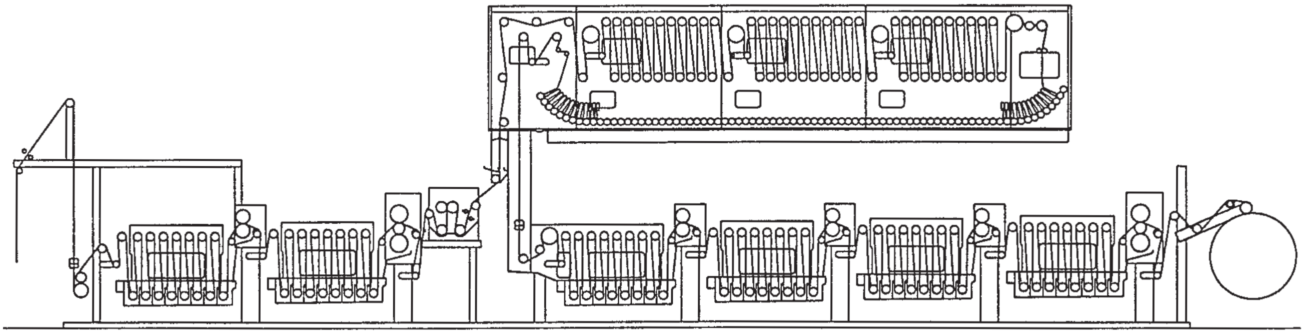


Fig.: One-stage-pretreatment range for cotton fabrics from Goller.

The “Hygromat” sensor system of the “Superfinish” measures the steam released using a special sensor which establishes its degree of saturation. The results obtained are amplified to produce proportional output signals for controlling the amount of steam applied. Water supply is metered by controlling the speed of the supply pump drive motor. This method of steam measurement enables influences of factors such as cloth density, amount of air trapped in the cloth, sorption characteristics, initial moisture content, treatment temperature and cloth throughput speed to be taken into consideration. The moisture content is established during treatment by pre-entering the target degree of steam saturation. The moisture necessary for producing the finish is applied to the cloth in the vaporization system. The sensor analyses the moisture content following vaporization and compares it with a pre-entered reference value. As shown in Fig. 1 a special rotor-spray device enables useful steamed finishes to be obtained. With materials having lower absorption characteristics or with sensitive materials such as piece-dyed goods, it is advisable to incorporate a special steam-lock before the actual spray device. This combination enables the efficiency of humidification to be improved.

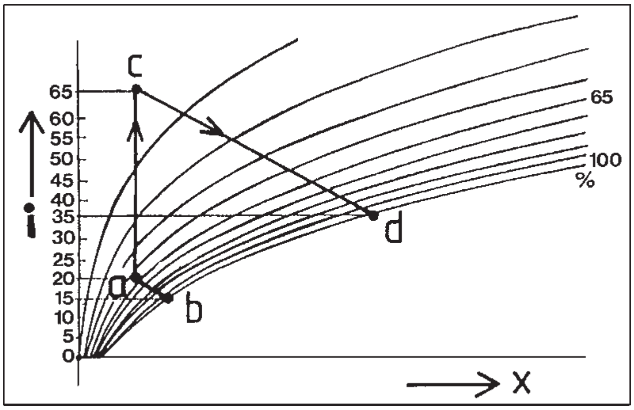


Fig. 2: Mollier diagrams for moist air (source: Menschner).

The Mollier diagram (Fig. 2) illustrates the benefits of steaming followed immediately by spray application of water. Applying steam to the cloth heats it up (points a–c), and at the same time the relative humidity of the air trapped in the textile material is reduced. With the fibre assembly in this state it is possible to apply a great deal of water (points a–d) before the 100% saturation point is reached. It also needs to be recognised why spraying the cold textile material (points a–b) produces a relatively low absorption of water. A relatively low amount of water already causes dew to form. Since the air trapped in a woven fabric can account for as much as 80% of the volume, the result of humidification of the air evenly distributed throughout the cloth means that humidification is efficiently performed.

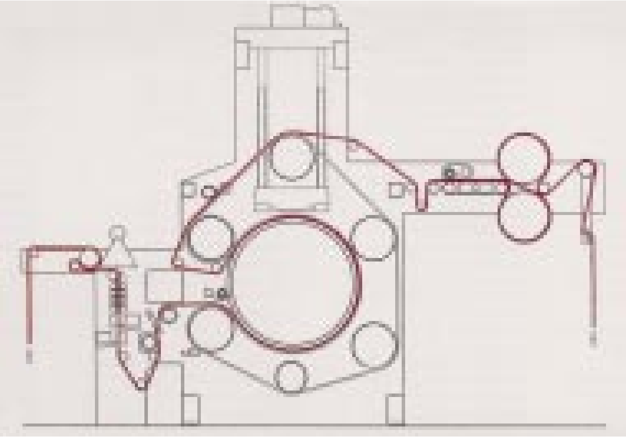


Fig. 3: Multiset continuous decatizing machine by Sperotto Rimar.

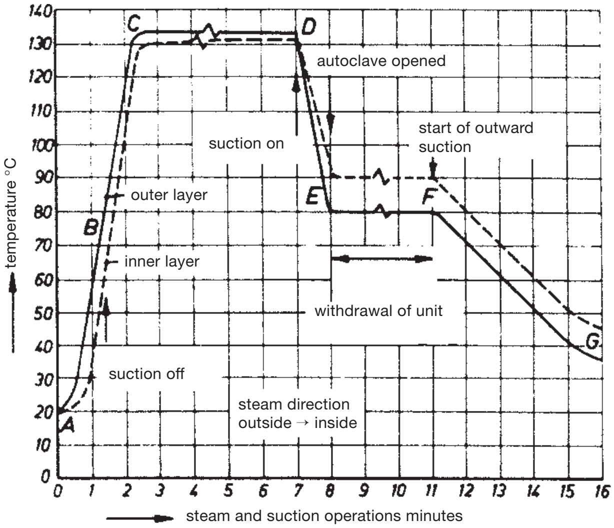


Fig. 4: Temperatures during steam and suction operations in the outer and inner parts of the roll for steam pressure ρ = 2.0 bar in batch kier decatizing (source: Sustmann).

Results with and without steam-lock demonstrate that, depending on water pressure and cloth weight, a moisture content increase of 6.2–18.7% can be achieved with rotor humidification and 7.5–19.7% with auxiliary steam-lock. Incorporation of the steam-lock thus produces a further increase in moisture content of 2.2% (otherwise 1.0–2.2%). But it is significant that with the steam-lock uniformity is far better along the length and across the width of the cloth, thereby preventing undesirable streakiness. Another favourable point noted is that steaming and humidification causes the cloth temperature to rise to 58°C. Temperature and humidity levels created by this procedure are maintained through to the “Superfinish” virtually without dropping at all and under the prescribed conditions of pressure and temperature in the press treatment zone are converted into steam.

In the vaporizer principle far higher temperatures

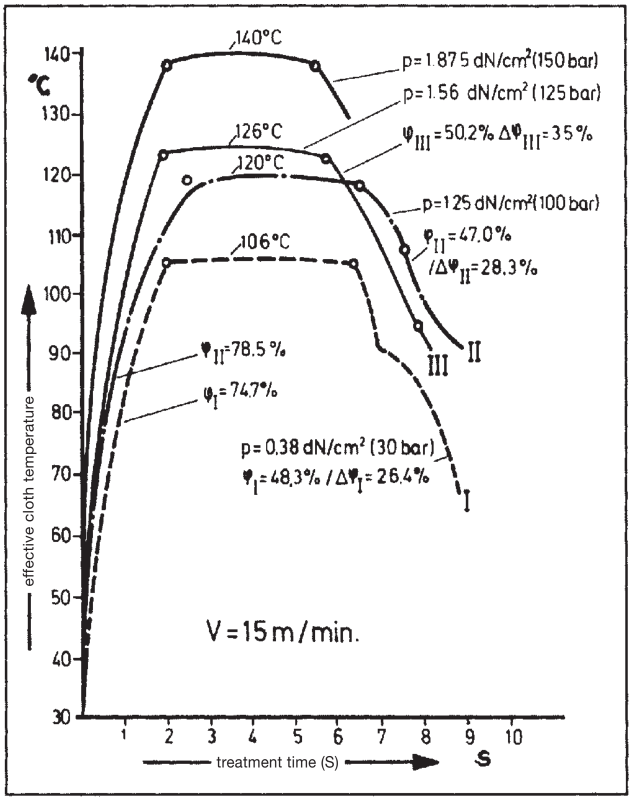


Fig. 5: Effective cloth temperatures in relation to treatment time with v = 15 m/min (counter-roller/compression belt heated to 185°C). (Source Michels – measurements made on a Menschner "Superfinish").

are achieved in the core of the cloth than in current methods of continuous decatizing operating on the through-flow principle and achieving a maximum of 105°C. The effective cloth temperature during "Superfinish" treatment has been measured using a cupronickel thermocouple. Diameter and length of the sensor wire permit smooth passage of cloth and thermocouple, with the cloth folded double and the thermocouple being passed all the way through the treatment zone sandwiched in the folded cloth. During treatment measurements can be taken every 5 seconds, fed into a minicomputer and reported. Figs. 5 and 6 show the relation between the effective temperatures measured inside the fabric sandwich and treatment time. It is evident from these experiments that the contact pressure from the compression belt (wrapper) has a major influence on the effective temperature. For instance at a stress of 30 bar and a surface pressure of approx. 0.38 dN/cm^2 the water applied (moisture in the cloth) is heated to steam temperature between the heated counter-roller and the heated compression belt, creating a temperature of 106°C in the cloth. With every increase in stress there is a rise in effective temperature. The corresponding treatment time is approx 4 seconds before the cloth running at a speed of 15 m/min emerges from the sandwich. The spontaneous temperature rise in the relatively damp cloth is surprising, reaching its maximum after just 1.0–1.5 seconds. This may be compared with the temperatures achieved in a kier decatizing machine (Fig. 4).

In a continuously operating decatizing process (Contidec – Superfinish 2 – Menschner) the machine need not be stopped for replenishing the treatment unit or changing the cloth roll. This is performed by the cloth accumulator located above the machine. The positively driven feed roller can either replenish the accumulator in fast mode or synchronously to maintain a uniform amount of cloth in reserve. The "Correfix" weft straightener then comes into operation and passes on the cloth for treatment by the "Superfinish 2" . Stage 1 is humidification, with water in the cloth under contact pressure being converted into steam and the cloth thus set. In stage 2 the cloth, still under contact pressure, is subjected to suction extraction and cooling. For stage 1 an impermeable compression belt is provided which is capable of exerting high pressure, whilst for suction extraction a permeable compression belt is used, likewise with controllable contact pressure. The peforated cooling cylinder is subjected to vacuum so that the cloth being treated is pressed against the cylinder by the compression belt and suction extraction applied. The purpose of this stage is to improve cloth handle following the actual decatizing process. This is especially important in cases where a solid or relatively

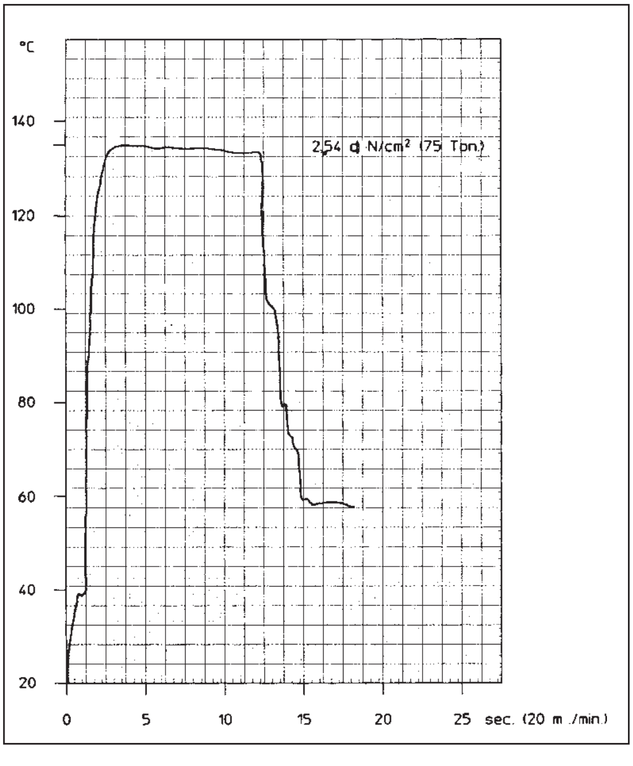


Fig. 6: Effective cloth temperature in a "Multiset" decatizing machine by Sperotto Rimar in relation to dwell time in the sandwich (see Fig. 3) at 2.54 dN/cm^2 contact pressure.

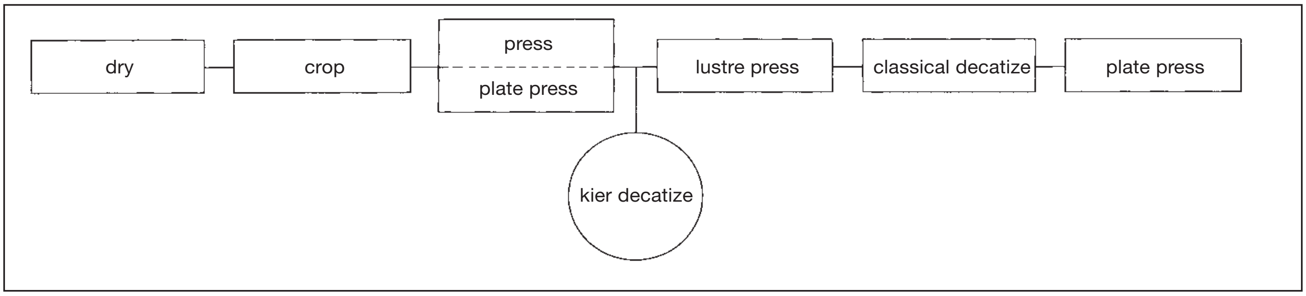


Fig. 7: Sequence of processes in traditional dry finishing of fabric of all-wool and wool mixtures.

crisp handle is required. From practical experience with this machine it may be suggested that stage 1 substantially produces the classical decatized finish and stage 2 the classical pressed lustre finish. Reducing the contact pressure in suction extraction enables finishes of an intermediate nature to be produced. However, without changing the passage of the cloth through the machine it is possible to obtain the classical decatized finish, for example by switching off the vacuum in the cooling cylinder and by reducing the contact pressure of the compression belt in stage 2 to almost zero. In these respects it is possible to employ the “Superfinish 2” as an all-purpose continuous decatizing machine for both conventional decatized and pressed lustre finishes.

Fig. 7 illustrates the sequence of different treatment stages in dry finishing. It should be remembered that on the one hand the best pressed finishes are created by treating dry cloth and on the other hand the best decatized finishes are obtained by treating thoroughly humidified cloth. In the “Superfinish 2” the two processes can be run consecutively non-stop simply by switching the humidification device on or off, with no need for resetting the machine or changing the way in which the cloth passes through. Such machines can be used for the following processes:

– as a pressing machine to precede conventional decatizing, e.g. before kier decatizing;
– to obtain a pressed lustre finish (comparable with the finish on on the classical batch decatizing machine);
– to obtain a classical decatized finish (comparable with the finish on on the classical batch decatizing machine);
– to follow kier decatizing;
– as a setting machine to perform the durable-press process;
– to produce a finish comparable to flat-plate pressing.

The wide versatility, especially the facility for switching from pressing to decatizing without having to rearrange the sequence of pieces or readjusting the machine, makes these machines attractive even for relatively small finishing plants. The travelling cuttler unit, i.e. laterally mobile cuttling device, makes a major contribution to the non-stop operation of the machine. The benefits of the vaporization system need not necessarily be combined with stage 2. If the conventional decatized finish is required then the suction extraction and cooling sections are omitted. These variants are provided by the “Contidec-Superfinish-1” (Fig. 8) where the actual setting unit is preceded by just one cooling zone for the effective cooling of the cloth.

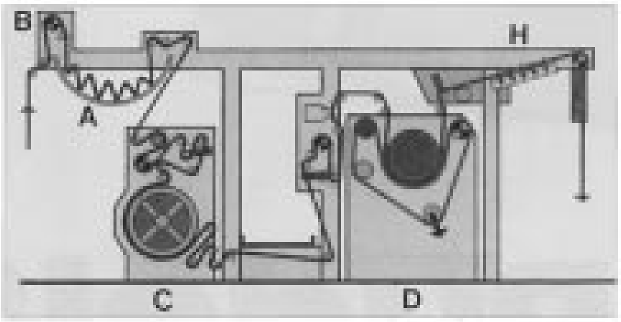


Fig. 8: “Superfinish-1” continuous decatizing machine by Menschner.
A = cloth accumulator; B = driven transporter roller;
C = “Correfix” weft straightener; D = “Superfinish” ;
H = cooling zone.

Apart from finishing wool cloth, continuous decatizing may also be employed to advantage for finishing polyester/wool, polyester/viscose, cotton/viscose, linen and mixed-fibre fabrics in a very wide variety for the outerwear sector and for improving the handle and crush-resistance of speciality upholstery materials. In the treatment of cotton a high-temperature stage is required (possibly oil-filled heating for compression belt heater roller and counter-roller). The variety of decatized finishes obtainable may be compared to classical batch decatizing, in many cases it is even superior. Cloth handle is decidedly improved, e.g. it is possible to modify the handle of wool cloths to resemble cashmere and wool/polyester mixtures to resemble all-wool. Lustre and bulk in the cloth can be positively varied within a wide range by control of cloth moisture content. For solid and relatively crisp handle the essential feature is a suction extraction system with a variable degree of contact pressure. The pressed finish of the cloth can also be accentuated by increasing the temperature.

Continuous → Wet decatizing: In continuously operating systems it is impossible to maintain the strict conditions of temperature, humidity and time by which means sulphide bonds are broken and permanent set finishes produced. The setting propensity of wool must be supported by treatment with chemical reagents. In chemical decatizing, agents releasing SO_2 for example are used which reversibly break the disulphide linkages in wool in a sulphitolysis reaction. Cysteine and cysteine-S-sulphonate residues are formed:

$$\textcircled{W}-CH_2-S-S-CH_2-\textcircled{W} + HSO_3^-$$
$$\rightleftharpoons \textcircled{W}-CH_2-SH + \textcircled{W}-CH_2-SSO_3^-$$

As in kier (batch) decatizing, it is possible here to utilize the properties of steam at 140°C for the disulphide exchange process if the compression belts (wrappers) used are impermeable to the steam pressure occurring in the sandwich (Fig. 9).

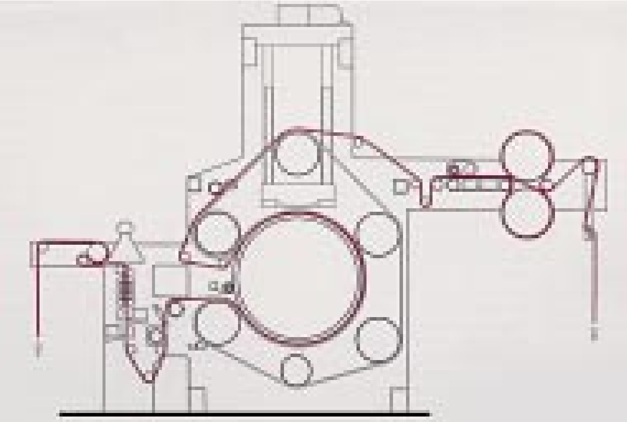


Fig. 9: Multiset continuous decatizing machine by Sperotto Rimar.

The necesary humidity can be applied by a spray device such as that supplied by Weko. In two-phase decatizing wool cloth is remoistened using a purpose-designed device on the capillary active principle, and then decatized in two phases (wet and dry) (Fig. 10).

The optimum decatized finish is obtained when the cloth reaches its normal moisture content shortly before the conclusion of the drying stage. As soon as the moisture content is too low following the end of the wet phase, it must be remoistened. The necessary mechanical pressure is produced by a compression belt (in silicone polymer and polyester fabric) which also makes the sandwich airtight so as to create high-temperature conditions. The necessary dwell of the cloth in treatment is obtained by it passing over a number of cylinders.

Continuous desizing Suitable for woven cotton and blended cotton/synthetic fabrics. Although enzymatic starch decomposition is time-consuming, continuous desizing can be effected with bacteria-diastases (other amylases are unsuitable): fabric is impregnated with hot enzyme solution and deposited in a heated J box for 3–5 min. Liquid absorption must be high (100% and over).

Continuous dyeing Dyeing process in which the dye liquor is applied to a moving fabric.

Continuous dyeing of woven PES-containing fabrics A distinction is particularly drawn between the continuous dyeing of woven fabrics of 100% polyester and blended polyester/cellulose fabrics.

I. Thermosol process for 100% polyester: thermosolling is used for tow, sliver, belts, above all woven fabrics and some knitted fabrics. The padding liquor contains the dye, a thickener or migration inhibitor, and possibly a hydrotropic agent (urea, thiourea) and possibly a substance giving off acid. Liquor uptake is 30–40%. Various units are employed for drying: jet dryers, stenters, cylinder dryers. Pre-drying by infra-red heating elements is recommended in any case in order to forestall dye migration. The dye deposited on the fibre

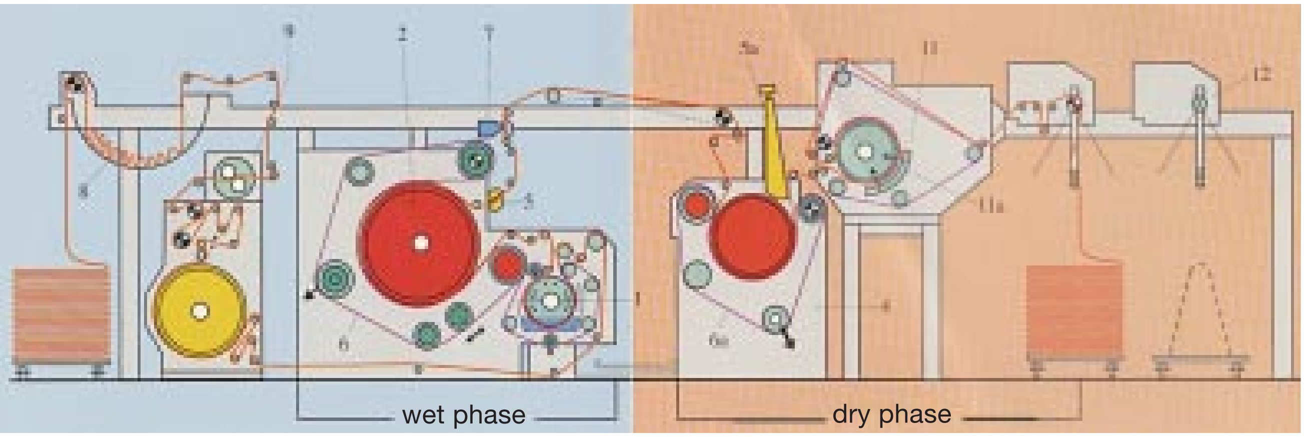


Fig. 10: Two-phase decatizing (Menschner).

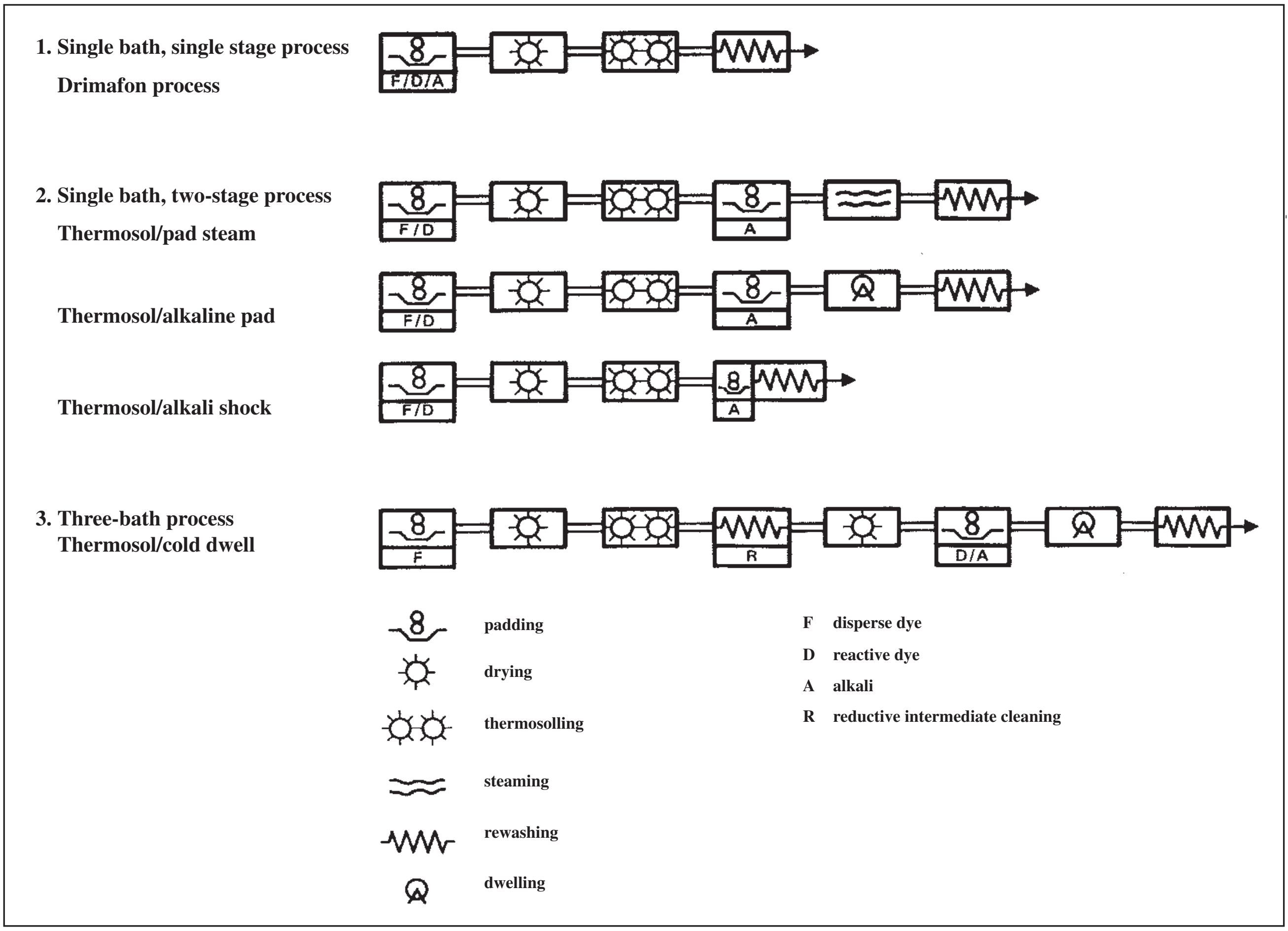


Fig. 1: Survey of processes suitable for disperse/reactive dye systems.

surface and also located to some extent in the skin now diffuses into the fibres. Diffusion takes place to some extent via the gas phase. Thermosolling conditions should be selected in such a way that each dye is provided with optimum temperature and time (attention should be paid to this in combination dyeing). It has been shown that the optimum values of the individual disperse dyes in combinations can be changed by reciprocal effects. The dye manufacturers' sample card data is therefore to be strictly observed. With too high temperatures, part of the dye already in the fibre can sublime off again. Thermosolling can be carried out in hot air or superheated steam, by contact heat or irradiation. Hot air fixation is the most important. Here, it is important that the fabric is subjected to the same conditions over its full width, for temperature differences are marked by colour differences in the dyed fabric. Where this is not guaranteed, dyes which are least susceptible to temperature differences should in any case be selected. The fabric should not be dried to the absolutely water-free state before themosolling. Some moisture is necessary for achieving max. dye yield, but there should not be too much, as otherwise dye agglomerates (specks) can form.

II. Padding process for woven polyester/cotton fabrics: in padding, cotton takes up almost twice as much disperse dye per unit of weight as polyester. Dye migration from the cotton to the polyester already starts during dyeing. Most of the dye migrates however only by contact transference and sublimation during heat setting; smaller quantities also migrate of course into the cotton fibre interior, so that complete removal becomes difficult. Cotton staining by disperse dyestuff is therefore greater in the thermosol process than in the exhaust process. With the exhaust process, however, it is particularly a question of the molecular weight of the dye. The fastness of this staining is limited. Intermediate cleaning must be carried out in the case of exacting requirements. A distinction is drawn between single and two-bath processes. In the two-bath process, the disperse dye is padded first of all, and fixated by thermosolling before reactive dye, for example, is applied separately (continuously or in batches). The reverse sequence is also conceivable of course. In the single bath process, there is a distinction between single stage and a two-stage processing, reactive dyes being extremely important for the cotton content. The true continuous processes are of special interest from the economic standpoint, but the fact that two different fibres are blended must be taken into account: the hydrophobic

Continuous dyeing of woven PES-containing fabrics

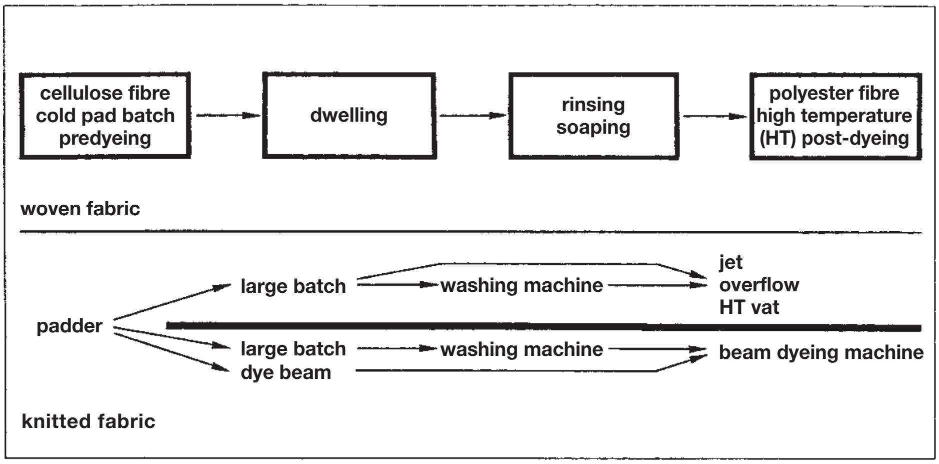


Fig. 2: Cold pad batch dyeing.

polyester fibre, the dye fixation of which requires dry heat, and the hydrophilic cotton, which requires steam, or in dry heat fixation, at least a hydrotropic agent for dye fixation (Fig. 1). For cotton, cold pad bad processes and semi-continuous cold dwell processes (Fig. 2) are useful if polyester is post-dyed.

The different fibres (cotton and synthetic fibres) require different conditions for fixating their dyes in each case in the → Pad-Steam Process (Fig. 3); cellulose fibres need steaming times from 16 to 60 s, while polyester fibres are not actually fully fixated in saturated steam. The short loop steamer was developed for the superheated steam fixation of polyester. In the heat fixating/setting/thermosol process, the reactive dyes are bonded to the cellulose only when highly polar substances (Fig. 4) promote diffusion of the dye into the fibre interior. Urea is not so suitable here, since it can decompose under the effect of heat. Here, dicyandiamide is of interest with the use of reactive dyes, because it enables reactive dyes to be fixated to cellulose

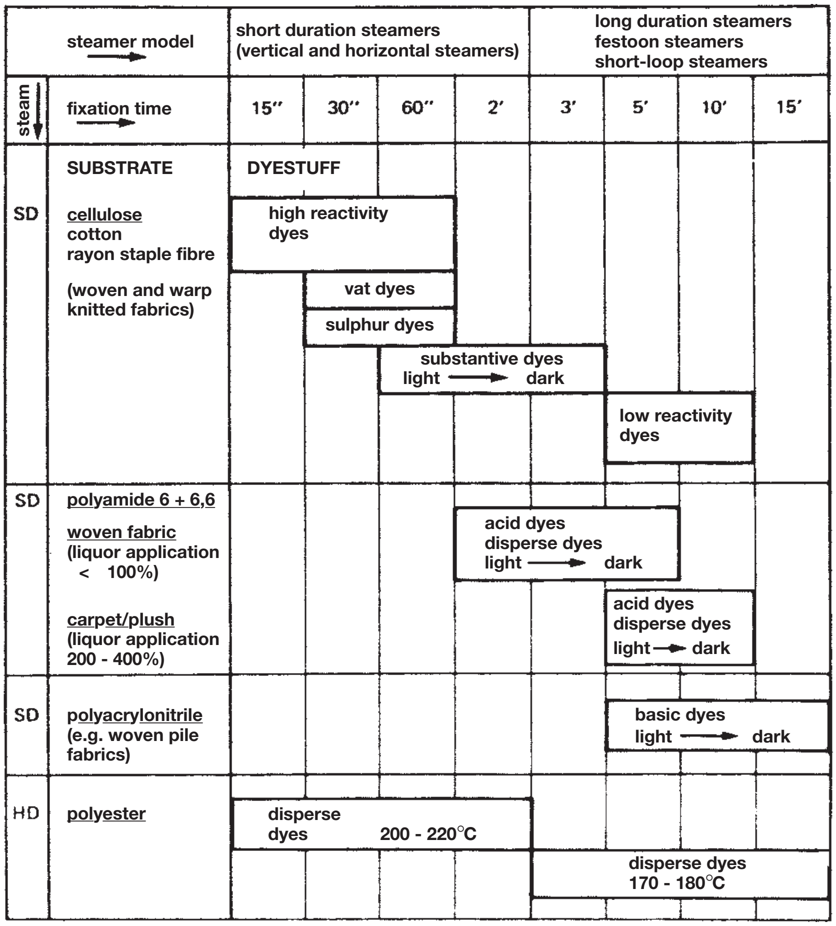


Fig. 3: Steaming times relative to substrate, type of steam, steamer model and dyestuff. SD = saturated steam; HD = superheated steam.

even without alkali when used as a slightly basic compound in the acid thermofixation process (Fig. 5).

$$H_2N-CO-\boxed{NH_2+H}-NH-CO-NH_2 \rightarrow$$

$$NH_2-CO-NH-CONH2 \;+\uparrow NH_3$$

$$OC(NH_2)_2 \rightarrow \uparrow NH_3 \quad + NCOH$$

$$3\ NCOH \rightarrow (NCOH)_3$$

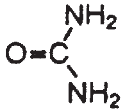
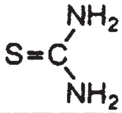
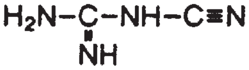
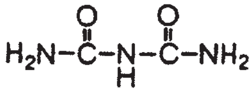
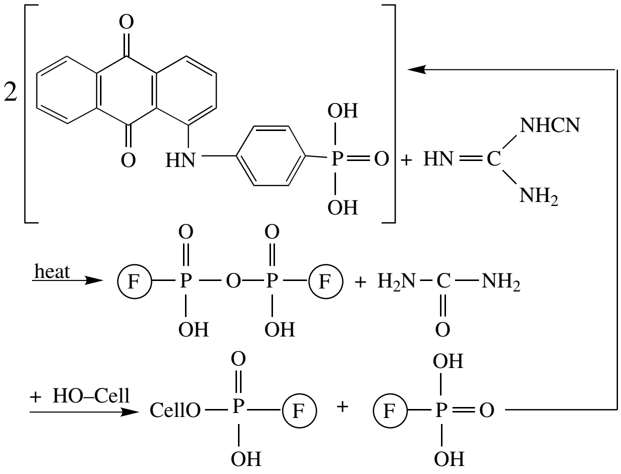
compound		melt point
urea	 $O=C(NH_2)_2$	133
thiourea	 $S=C(NH_2)_2$	180
dicyandiamide	 $H_2N-C(=NH)-NH-C\equiv N$	209
biuret	 $H_2N-C(=O)-NH-C(=O)-NH_2$	193

Fig. 4: Decomposition of urea under the effect of heat and alternative products for use in the TT process (Bayer).

Dicyandiamide also has the special function of activating reactive dyestuff:



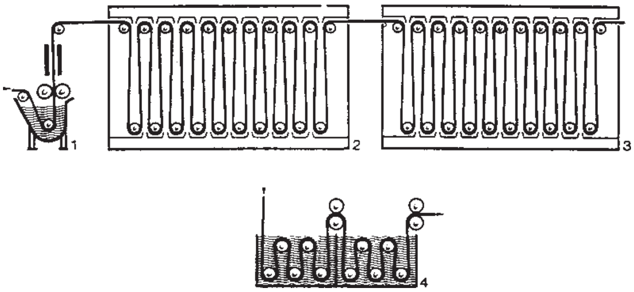
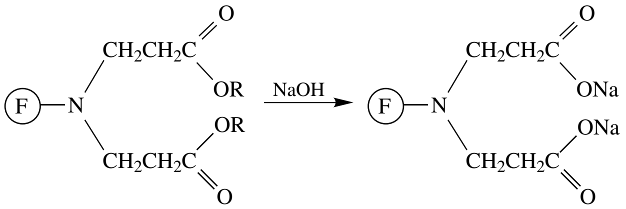


Fig. 5: AT process sequence.
1 = padding and pre-drying; 2 = drying; 3 = thermosolling; 4 = rinsing, soaping.

Depending on the reaction method, the reactive dyestuff is padded together with the disperse dye (for polyester) in order then to be fixated to the cellulose by thermosolling. In the subsequent re-washing process, 4 g/l of caustic soda are added to the first bath in order to hydrolyse the unfixated disperse dye, and enable it to be washed off better:



Combinations of continuous and batch dyeing processes are shown in Fig. 6. There are also special processes which have advantages depending on local circumstances:

- Process 1: Mixed dyes dye both fibres to the same depth in the thermosol process.
- Process 2: Limited to lighter to medium shades. Not all disperse dyes are resistant to the large quantities of urea and alkali necessary for reactive dye fixation. Rapid intermediate drying at approx. 140°C is advisable. Reactive and disperse dyes are matched to one another, and are fixated under identical conditions. Reductive after-treatment should be unnecessary. Some processes also operate without alkali: in its "2-DA" process, Sandoz uses dicyandiamide and sodium acetate, and Hoechst/USA sodium formiate, in the padder bath instead of urea and alkali.
- Process 3: In the case of disperse and leuco vat ester dye mixtures, the disperse dyes employed are oxidation-resistant. The Hoechst A.T.E. process is a similar process. The simultaneous use of disperse dyes can be dispensed with in the case of pastel shades.

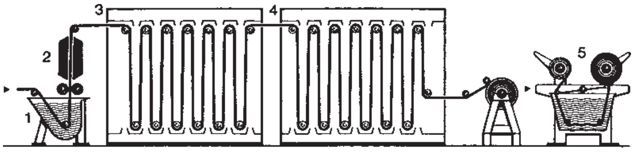


Fig. 6: Thermosol-jigger development process.
1 = padding; 2 = pre-drying; 3 = drying; 4 = thermosolling; 5 = jigger development.

Continuous dyeing plants

- Process 4: Instead of single bath processes, the cotton can also be dyed as usual by ground dyeing with the naphtholate, intermediate drying and coupling with the fast base, and then padding with the disperse dye, drying and thermosolling. In this way, the naphthol dye residue on the polyester fibre migrates to the cotton so that better rubbing fastness is obtained.
- Process 5: The dye mixtures mentioned in process 2 come into the picture for this. If combinations of the two dyestuff types are made up, allowance should be made for the alkali sensitivity of many disperse dyes. Yellowing of the cellulose fibre, caused by the alkali, can be prevented by adding 5 g/l of sodium tetraborate.
- Process 6: With the thermosol/pad/steam process, good cooling of the blank vat should be ensured. The bath temperature rises due to the passage of the disperse dyes into the bath. With the thermosol/alkali shock process (Fig. 8), the cellulose fibre material used must have a high degree of substantivity.

The diversity of the plant offered by all the large machinery manufacturers for dyeing blended polyester/cellulose woven fabrics is well known. One large dyeing line (Fig. 7) comprises fabric entry, padder, infrared dryer, hot flue, fixating/setting machine, steamer, washing machine and dryer (cylinder dryer or stenter); many different manufacturers come into consideration for this (Fig. 9).

Continuous dyeing plants Depending on class of dyestuff, they comprise padder, dryer (cylinder, hot flue dryers), continuous steamer and open-width washing machines.

Continuous dyeing range Machinery range for padding, setting/steaming/drying, wash-off of suitable dyestuffs (e.g. disperse, vat and reactive dyestuffs) in correspondingly large dye batches for increased productivity and economy in dyestuffs, chemicals and energy usage. Process generally uses a liquor ratio of 1 : 1, i.e. the pad-liquor pick-up = 100% = 100 kg dye liquor/100 kg fabric.

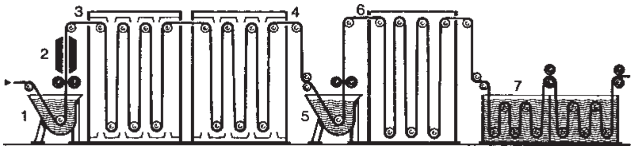


Fig. 7: Thermosol-pad-steam process.
1 = padding; 2 = pre-drying; 3 = drying; 4 = thermosolling; 5 = chemical padding; 6 = steaming; 7 = after-treatment.

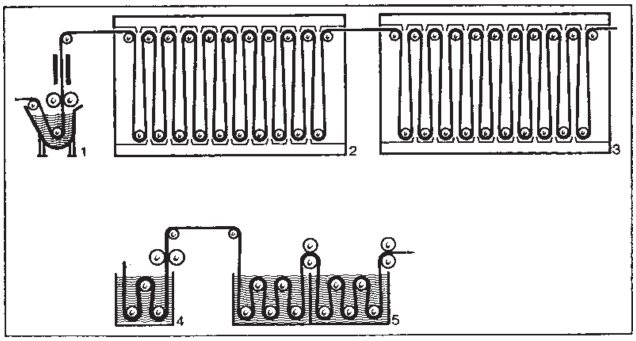


Fig. 8: Process diagram of the alkali shock process.
1 = Padding/pre-drying; 2 = drying; 3 = thermosolling; 4 = shock bath ; 5 = after-treatment.

Examples for plants with open-width piece goods are shown in the Figure.

I. Semi-continuous:

a) → Pad-Jig Process: pad the dyestuff/chemical liquor on the pad mangle, fix, wash off (jigger).

b) → Pad-Roll Process: pad the dyestuff/chemical liquor on the pad mangle, take-up on special beams, develop on the beams in steam fixation chambers, wash off (open-width washer).

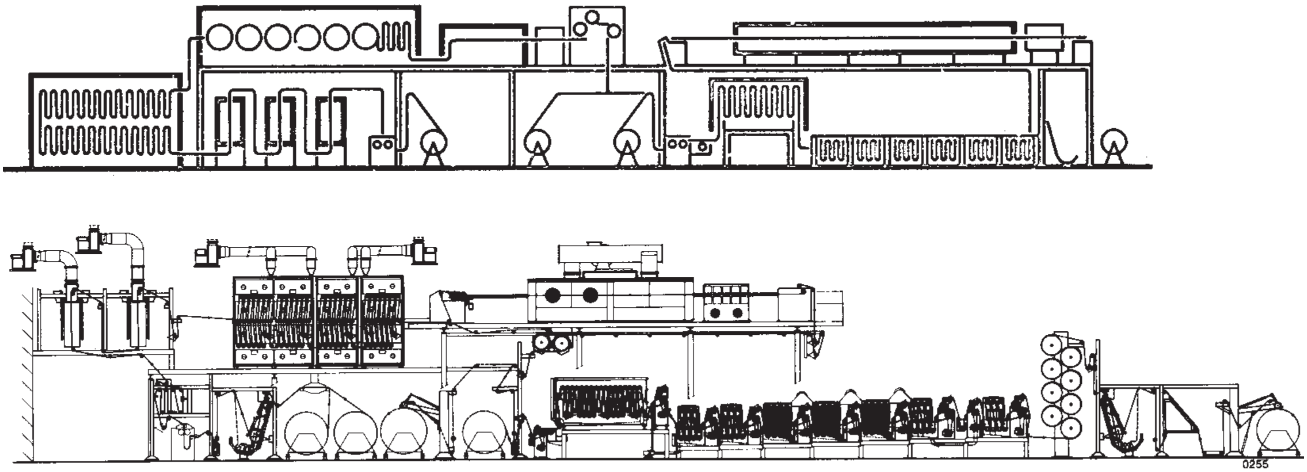
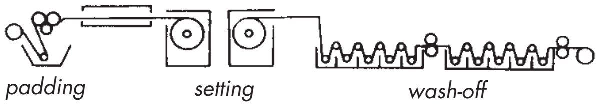
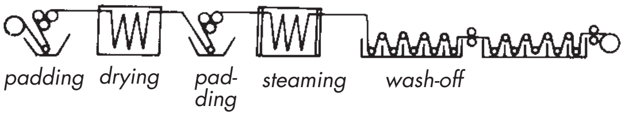


Fig. 9: Fleissner continuous dyeing plant (top) and a line comprising variously composed machines (bottom) for dyeing woven blended polyester/cellulose fabrics.

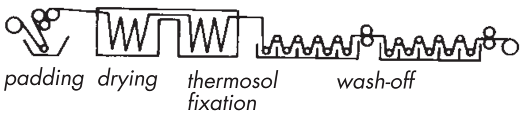


1 Pad-roll process

2 Cold-dwell process



3 Pad-steam-process, double dip



4 Heat-setting process

Fig.: Examples for plants with open-width piece goods.

c) → Cold-dwell process: pad the dyestuff/chemical liquor on the mangle, batch on special beams and hold at room temperature to develop, wash-off (open-width washer), especially suited to reactive dyestuffs.

II. Continuous:

a) → Pad-Steam Process: single-dip:
Pad the dyestuff/chemical liquor, dry. Double-dip: Pad dyestuff, intermediate dry, pad chemical liquor on a second mangle, set on the steamer, wash-off (open-width washer).

b) → Heat setting processes: pad the dyestuff/chemical liquor on the mangle, dry and thermosol in one process wash off (open-width washer).

Continuous filament → Elementary filament.

Continuous filament yarn A continuous → Filament yarn which, according to DIN 60 000, is composed of one or more → Elementary filaments with/without the insertion of twist. The antonym is → Spun yarn. With pure silk, only the reeled silk from the cocoon can be described as a continuous filament yarn whilst schappe silk, on the other hand, is a spun yarn.

Continuous finishing processes For treating woven and knitted piece-goods of unlimited length, the fabric passing only once through the machinery necessary for finishing. A defined quantity of finishing agent is applied to a generally open-width moving fabric in separate stages (mainly successive). In contrast to → Exhaust dyeing processes, all continuous finishing processes have a high finishing agent concentration and little liquor. The fabric/liquor ratio averages 1: 0.5–1 (except in washing processes).

Continuous ink jet printing A coloured ink jet process with dye solution (non-contact dye application system) in which the stream of coloured ink is squirted continuously from a tiny nozzle. Printing is controlled by withdrawing or interposing a baffle plate (Electrocolor process) or by deflecting the ink jet with compressed air (Millitron process).

Continuous laundering line (Washing pipes) → Continuous washing plant, consisting of a 4–7 m long, slightly inclined, tubular inner and outer drum, with 12 washing and rinsing zones based on the contraflow system, with subsequent squeeze water extraction and contraflow/shaking step drier. The laundry is transported by means of rotation, drum inclination and a ribbed carrier, along with reversing of perforated inner drum. Dewatering to approx. 60% residual moisture. Output of various sizes of continuous laundering lines approx. 400–1000 kg/h dry product. Total laundering time 30–45 min.

Continuous liquor flow laundry wash process → Flow washing process.

Continuous rope treatment plant For the continuous pretreatment, bleaching, dyeing (Fig. 1) and after-treatment preferably of cotton knitted fabrics.

Counter liquor flow in up to 12 fabric stores; operat-

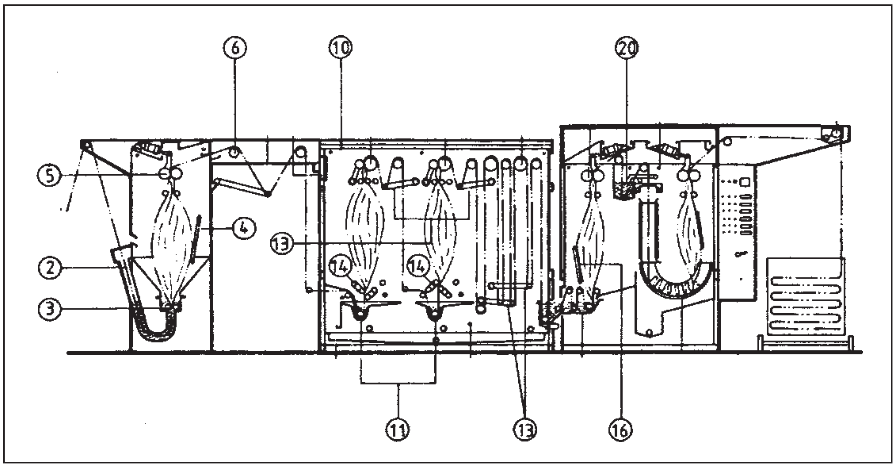


Fig. 1: Tubocolor plant for dyeing knitted fabrics (Brückner).
2 = padder trough; 3 = twist control; 4, 14, 16 = Tublow tube inflating unit; 5 = squeeze rollers; 11 = booster; 13 = compensator roller; 20 = trough for the application of oxidising agents.

ing speeds from 10 to 100 m/min. With depository for optimum fabric shrinkage/relaxation. Rope washing on a continuous jet (Fig. 2) is especially suitable for improving efficiency in the continuous after-treatment of static bleaching and dyeing processes.

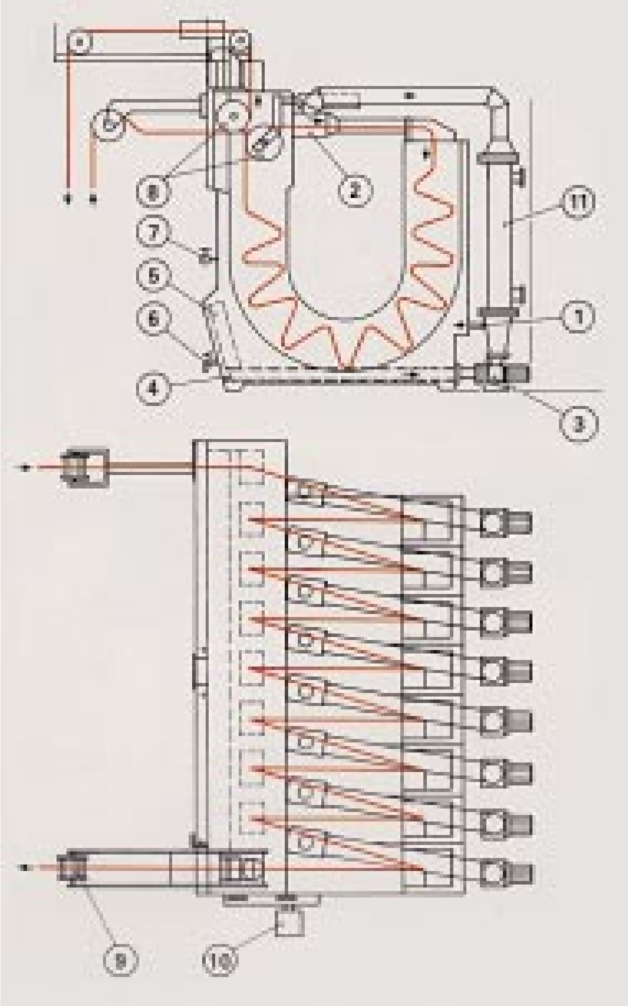


Fig. 2: Rope scouring jet (ITM).
1 = counter current; 2 = jet; 3 = circulation pump; 4 = filter; 5 = overflow; 6 = drain valve; 7 = water inlet valve; 8 = squeeze roller; 9 = unloading winch; 10 = motor; 11 = heat exchanger.

Continuous steamer So-called continuous ager for printed fabrics and large-scale production, mainly for short or long steaming times. There are various steamer chamber designs, e.g.:

I. Fabric transport by means of running rails or a few larger diameter idling rollers in the case of festooned fabrics (festoon steamer), especially for screen printing.

II. With guide rollers top and bottom as a rapid steamer (flash ager).

III. Similar to I, festoon design but with a continuous pin chain, as a screen print festoon steamer.

IV. Tower steamer: fabric path 10–20 m once up and down (entry, reversing and exit rollers), also particularly suitable for screen printing.

Continuous tumbler In contrast to classic → Tumbler drier, the continuous tumbler (Fig.) provides for uninterrupted fabric throughput. Technical processing alternative to the shrink tunnel. Whereas the fabric runs in open width in that process, the fabric runs in rope form in the continuous tumbler. The line consists of a perforated stainless steel drum with reversible drum drive for continuous rope detwisting; water/chemicals spraying, wetting zone and infra-red radiator. Main areas of use: relaxing high pile fabric, crashing warp knitted and woven velours, crushing coating products with embossed effects. Especially interesting for achieving low-shrink effects.

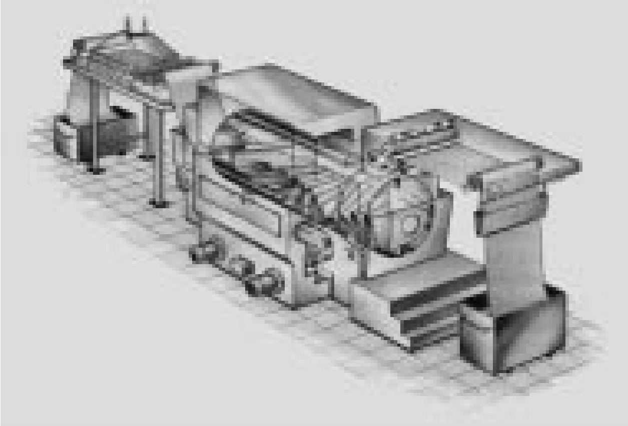


Fig.: Continuous tumbler (Obermaier).

Continuous washing plant Automatic flow throughput of the wash between separated loading and unloading bays, generally using the counter current washing process (water intake at the laundry exit) using a mechanically or electrically controlled washing programme, intermittently or continuously through the individual technologically linked working stages, with pre-wash, main wash, hot and cold rinses always occurring at the same place. Classification:

1. Continuous washing plants without batch separation as so-called washing tubes, with wash throughput through a tube-like washing drum which is either open or divided into sections. Examples: washing conveyor, steam-line washer.
2. Continuous washing plants with batch separation, wash throughput through processing sections which are separated from one another, connected in sequence and linked together securely.

Contipress process Combines the finishes imparted to woven and knitted fabrics by setting machines and rotary or flat presses. The finish is obtained by a high-strength continuously circulating compression

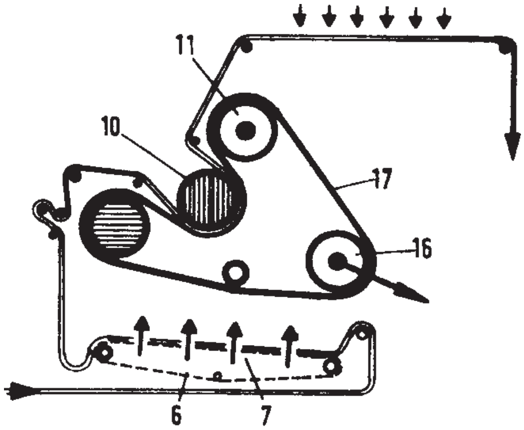


Fig.: Path taken by cloth in Contipress (Menschner).

belt. Contact pressure variable between 0 and approx. 120 bar. Temperature 100–150°C (Fig.).

Contract carpet (Fitted carpet, wall-to-wall carpet, textile floor covering). Textile floor covering in the form of fitted carpet (usually wall-to-wall carpet) in widths or carpet tiles (glued or self-adhesive) or as fitted carpet. Made in large lengths/widths or in the form of lengths sewn together: woven, needle-punched (→ Needle-punched carpets), tufted (→ Tufted carpets), pressed/glued (bonded loop carpets), knitted, flocked. Carpet fibre materials include: wool, sisal, viscose, polyamide, polyacrylonitrile, polypropylene, etc.

Contract cloths, name for “uniform cloths”.

Contraction (Lat.: contrahere = come together). To be understood particularly as shrinking processes in the textile context.

Contraction, take-up and twist,

I. Take-up: a contraction of the yarns used in weaving caused by the interweaving of warp and weft. Calculation: L_1 = length of the stretched yarn taken from the fabric, L_2 = the same length of yarn in the piece.

$$\text{contraction (\%)} = \frac{L_1 \cdot L_2}{L_1} \cdot 100\ (\%)$$

II. Twist contraction: the shortening of a thread caused by a twisting process (yarn twist). Calculation as above (length of the individual thread L_1, length of the twisted yarn L_2).

Contract textiles Sometimes also termed uniform textiles, or named according to their intended end-use. Collective term for all trouser, blouse, jacket and coat cloths for authorities such as postal, railway and customs services, armed forces, police etc. Namely materials intended for uniform purposes. These must be manufactured to precisely defined specifications. The specifications issued by the different authorities are so extensive and varied that they are outside the scope of this publication. The materials are normally not available to the trade in general.

Contrast colour → Complementary colour.

Contrast reduction Poor reproduction of fine contours in the production of screen printing screens; effect of → Underexposing photosensitive screen.

Control charts Management tool for ongoing operational statistical → Quality control. Examples of their use include immediate quality reports per unit time, quality assessment of personnel, of trends at respective control points and suchlike. Control charts must be clear and capable of quick evaluation. Graphic presentations are especially appropriate, e.g. test results over the course of time (marker zones for permitted tolerances) or statistical reports (defects, yes/no). Also include important printed forms with such as date, time, fabric, batch, personnel, machine, defect classification and suchlike. Numerous control chart systems exist, designed for customised report data. Standard control charts for every testing position would include for example: number of samples, target value, actual value, variation, mean, plus assessment information such as random sample, sampling procedure, range width, standard deviation and coefficient of variation.

Control equipment (control and regulating technology). Automatic control equipment makes possible convenient use with simultaneous protection for the operational plant. Control equipment is used for maintaining specific conditions (pressure, quantity, mixing ratio, temperature, speed etc.) independently of contingencies, i.e. control in accordance with a predetermined plan. Pulses mainly weak, but diversely amplified, reach the servomotor via an actuator which carries out the necessary adjustments. Power conversion: a) hydraulic, by jet pipe nozzle (acts on a piston valve by a membrane-directed oil jet). b) pneumatic, with 2 bar compressed air as auxiliary power, especially for maintaining pressure, temperature, flow and fluid level. The controller’s power switch sends digit pulses by way of pressure changes to the control valve, which is provided with a diaphragm drive. c) electric, with servomotor and electrical energy as auxiliary power. The advantage is a simple means of control for various combinations (e.g. boiler and feed water control). Often only optimum performance through combination with a) or b); numerous types for different purposes. d) electronic, with photocells, electronic valves and amplifying valves. Important for time switches and speed control in the 20 : 1 range (machine drive with DC motor), up to 60 : 1 (with additional voltage change at the generator), where the voltage is to be increased from 0 to maximum instantaneously. Braking can be effected by current reversal. Adjustment of the unit to a specific speed also automatic by physical or chemical effect, electron stream transmission being controlled accordingly. Principle of operation of electron exchange in valves (thyratrons filled with inert gas or mercury vapour, with several electrodes); electron emitter is a cathode, the receiver an anode, and, in between, a grid for controlling the electron stream. → Automatic control systems.

Controlled coloration Market dynamics have had a considerable impact on the textile supply chain as a means of service differentiation from commodity imports which focus principally on cost. Market segmentation, late stage coloration with minimum inventory, and monitoring of sales to meet customer demand, have resulted in shorter production runs, vastly reduced lead times, and improved speed of response to the customer. In order to meet the demand for shorter lead times, a radical change in philosophy has developed in which an expectation of Right-First-Time production through the control of the coloration process is now the norm for progressive dyeing operations. Efficiency of production, elimination of the cost of non-conformance (whilst minimising the impact on the effluent loading) has led to the development of "Controlled Coloration." Controlled Coloration is the fusion of three technologies which must complement each other (Fig.1).

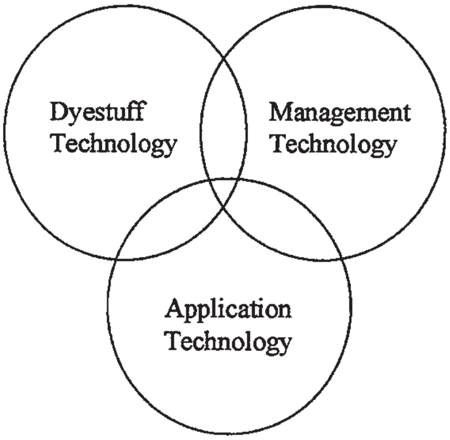


Fig. 1: Controlled Coloration.

To reach this target future developments are the following:

1. The ultimate goal for the coloration of cellulosic fibres must be to achieve 100% colour yield from an environmentally friendly application which produces a high fastness result to the new generation of detergents based on TAED activated peroxy compounds.
2. Research work continues to study means of overcoming the negative-negative reaction between ionised cellulose and reactive dye by cationising the cellulose fibre. However the problems associated with control of reaction, migration (in exhaust application), effect on light fastness and shade and soiling have not been resolved.
3. Other studies have focused on the esterification of cellulose using benzoyl chloride via a Schotten-Baumann reaction to enable the application of disperse dyes. Limitations on this technology are again fastness to the modern detergent formulations and also a restricted shade gamut.
4. Developments on more conventional reactive dye chemistry have focused on increasing the number of reactive groups to enhance the probability of reaction and thereby increase the colour yield, increasing the substantivity by incorporating aliphatic linking diamines with the bis-chromophore structure to reduce electrolyte concentration (but counter effective in the wash-off process), and by increasing the chromophoric strength to achieve depths of shade at a lower applied concentration of dye (thus achieving higher fixation levels from a lower position on the build-up-saturation curve).
5. The future progress in the coloration industry rests with those companies committed to research and innovation which should be supported by the whole textile chain - for if the funding in research is curtailed, so will the progress in developing the highest performance dyes to meet the ultimate goal.

New measuring and control methods allow for safe and reproducible dyeing and are field-proven today. Data of the humidity to be controlled are loaded as signals into Programmable Logic Controller (PLC) and will acti-

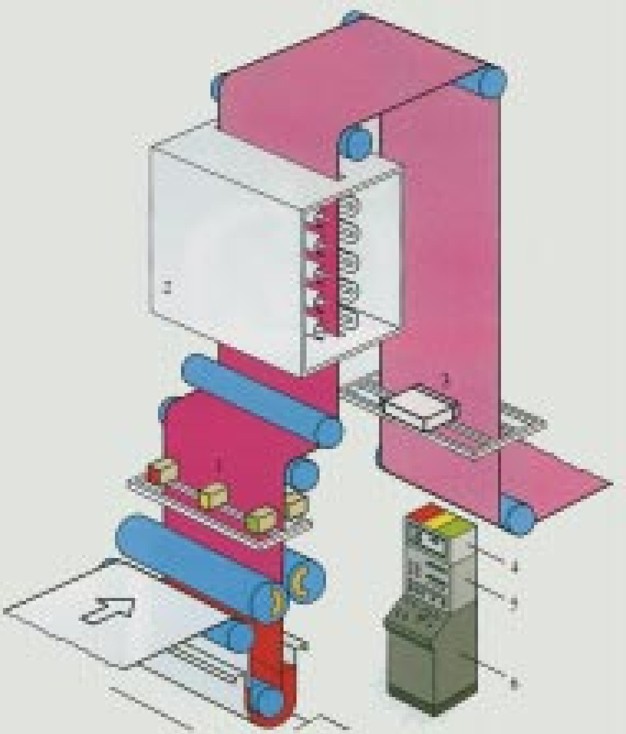


Fig. 2: Controlled Coloration.
1 = measuring heads; 2 = IR-wall; 3 = measuring of residual moisture; 4 = digital difference display; 5 = PLC memory of control signals; 6 = padder control, alternatively automatic/manual.

vate the control by way of pressure control impulses (Fig. 2).

Controller A term originating in the USA for a member of the board of directors, or at least senior management, whose responsibility involves control of the entire business operation. His remit is to achieve optimum collaboration between all departments of the business by making use of all the information available to him. The controller's task must involve the comparison of planned and actual production levels. In order to achieve an optimum utilization of information, an integrated monitoring system capable of evaluating and interpreting all relevant captured and recorded data is necessary. The controller's entire responsibilities are subdivided into the following specific categories: accounting and statistics, planning and planning control, and reports. It appears to be necessary for the "controlling" function to be placed directly under the authority of senior management or have it structured as a staff department. In any case, however, it must be absolutely independent of normal official channels.

Controller, control unit → Automatic control systems.

Control limits are the limits of variation which must not be exceeded that are entered in the → Control charts.

Controlling The term is not identical with the control of business activities and those responsible for it. Controlling is to be understood rather as a dynamic organizational leadership involving sophisticated planning of all activities and comparison with actually achieved results, precise and rapid analysis of deviations from target to actual data and a rapid introduction of appropriate control measures. Essential preconditions for the introduction of controlling are a clear organizational structure and the precise acquisition of performance and cost data. The individual duties, responsibilities, and fields of competence of the various leadership roles, as well as the hierarchical structure and lines of communication, must be clearly laid down by the organization.

Control sample In textile investigations, the comparative value for an untreated initial product.

Control systems for dyeing plants Development of control systems has led from fully automatic control of individual functions to electronic, microprocessor-based multi-process control, i.e. a central control system. This is not limited to the control of dyeing plant, but also includes integrated data capture. → Automatic control systems.

Control technology in dyeing Essential for control of the dyeing process. An instrumentation and control system (see Fig.) provides a comprehensive control

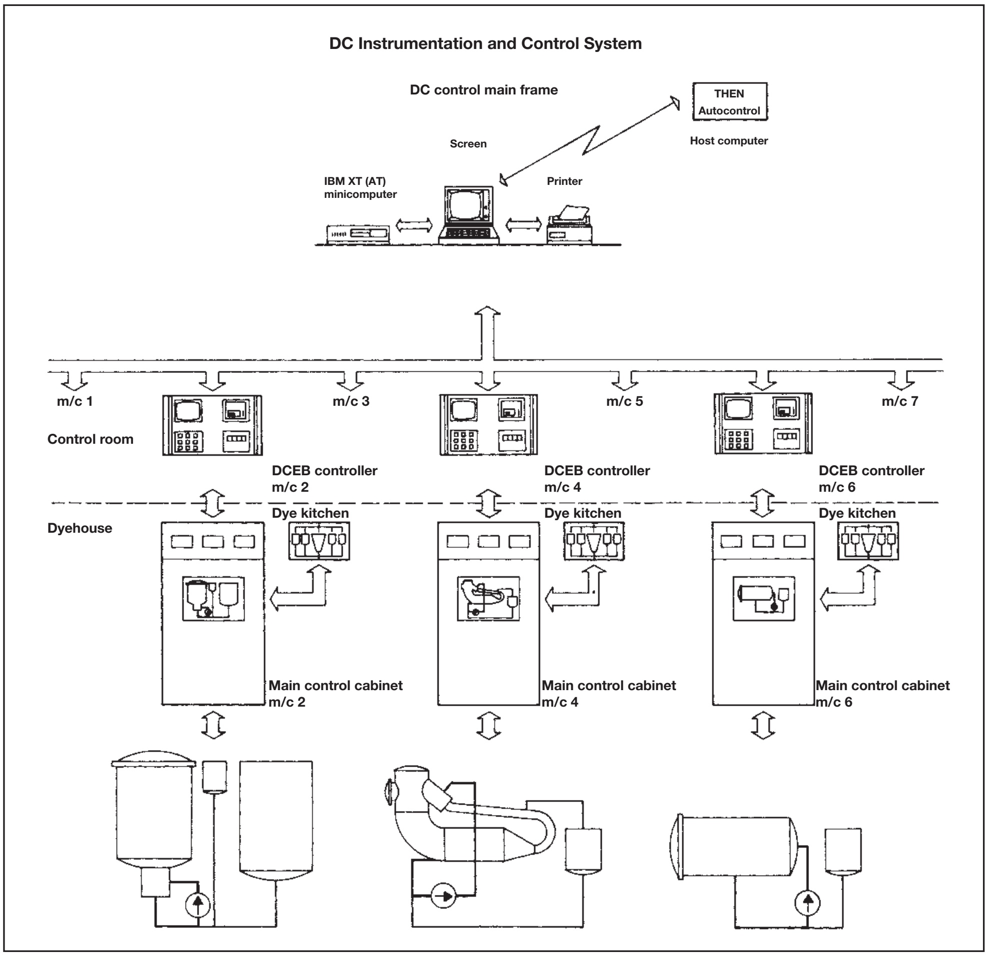


Fig.: Then-Datacomp control system.

system built up on a modular basis, i.e. all levels of automation are included, from simple temperature / time control through fully automated systems to the control main frame with data capture and data processing. The control elements are all capable of expansion, from the basic levels to the central control level. With individual machine process controls and automatic valves it is possible to avoid manual control of the machine i.e. semi-automatic control. With fully automatic dyeing processes, the individual machine control system is replaced by a fully autonomous microprocessor-controlled system with the possibility of program defining and saving options.

Several machines can be controlled from the central control system. The program compilation and saving is then carried out at the terminal of the control main frame. Data is also collated here for the various commercial, technical and production requirements. In addition, it is possible to communicate with a mainframe computer or with additional PCs in the dye kitchen and colour measurement and recipe calculation department. The individual controllers can be installed initially as a simple temperature / time control system and later upgraded to give fully automatic control.

Hardware is built up using a system of standardised plug-in cards. The programs are keyed by a menu-technique with an alphanumeric keyboard and displayed on a screen. The programs are saved on the usual computer data storage systems. When establishing a dye-program the operator is led through a dialogue by an interactive menu, he/she requires neither computer programming experience nor knowledge of coding lists. All controllable functions appear on the screen in clear text. The automatic system will not accept any illogical steps; errors can be corrected.

Before beginning a dyeing operation, the desired program is loaded into the program memory, where it is automatically controlled and displayed on the screen. After loading the program, the time-elapsed machine status appears on the screen with program and equipment reference number, time, date, and actual and desired values for temperature, gradient, dwell time, status etc. together with a superimposed display of the running programme.

Control variation → Variance comparison.

Convection (Lat. convectio = carry along with). Heat transfer (temperature equalization) by flow movements according to the buoyancy principle resulting from different temperature and different density. Since warm air rises in cold air and cold air falls in warm air, masses of different heats intermix and their temperatures are equalized by convection.

I. Convection drying → Convective drying.

II. Convection as a means of accelerating mass-transfer in fabrics.

1. As a batch process forcing liquid through fabric as it passes overs rollers in open-width washing machines (Fig. 1). In the wedge-shaped slot formed by the roller and the textile passing over it a slight pressure rise can be detected which causes transverse convective flow through the fabric. When the fabric emerges from this zone a vacuum is created which causes convective flow in the opposite direction. This convection phenomenon influences the efficiency of an open-width washing machine.

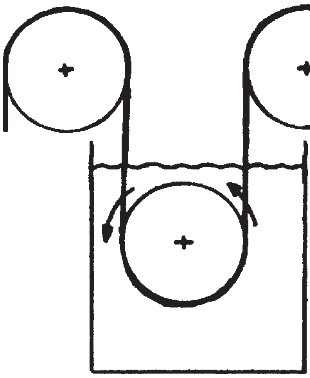


Fig. 1: Flow penetration (convection) of textile fabrics in open-width washing machine roller nips.

2. As a continuous forcing of liquid flow around the thread structure of fabrics in centrifugal washing machines (Fig. 2). Diffusion due to fibres and threads is simultaneously combined with convection around the thread structure.

3. As a forcing of liquor around and into thread structure in Mach slots (Fig. 3). The fabric is passed

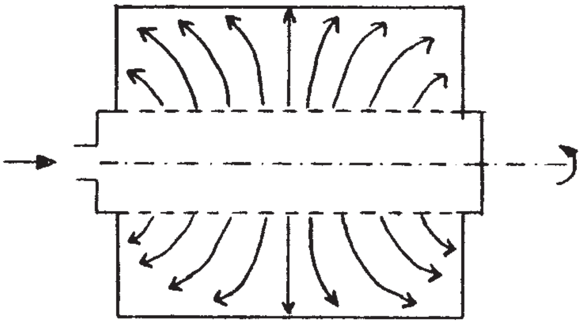


Fig. 2: Flow penetration (convection) of a woven fabric batched on a perforated roller as a consequence of centrifugal force when the batch is rotated.

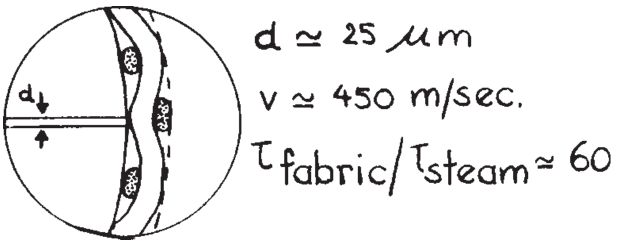


Fig. 3: Mach nozzle principle.

through the slot of approx. 25 µm. Air or preferably steam is introduced into the slot and under certain pressure ratios steam then emerges from the slot at subsonic velocity. With the dwell time before the slot being much greater than the dwell time in steam, the thread structure is also penetrated.

Convective drying The most common method of drying using air as the drying medium (→ Drying systems). The advantage of convective drying is that the conditions under which drying is performed can be varied at will. Two variants have gained wide acceptance over the course of time:

- air impingement drying and
- air circulation drying.

The air impingement technique, when applied to both faces, has the advantage of managing to avoid any contact during the drying process. The diagram clearly demonstrates the relationship between the measured drying curve (above, drying time plotted against cloth moisture content) and the drying rate curve (below). The drying rate calculated from the slope of the drying curve is plotted against the percentage moisture content of the cloth. The division of the convective drying process into three phases is clearly evident.

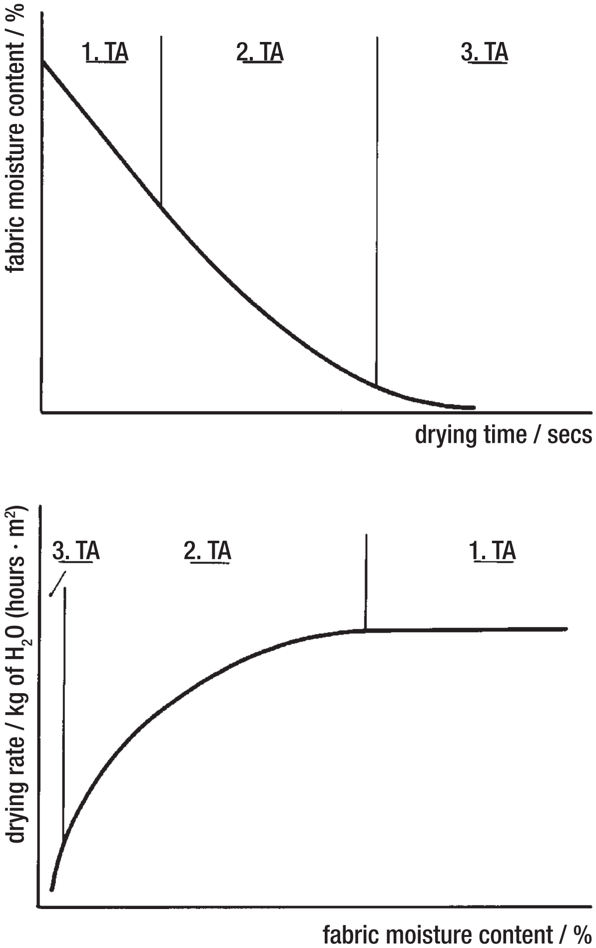


Fig.: Textile fabric drying curve.

Since at high moisture contents a liquid level occurs at the surface of the cloth, in phase 1 of the drying process the conditions prevailing resemble those of evaporation at a water surface. Due to constant partial pressure and temperature differences there is constant evaporation of water per unit time. The drying rate which has its maximum in phase 1 is thus constant. Once capillary transport is no longer capable of transferring sufficient water to the surface, the drying rate declines. The salient point marking the transition to phase 2 is not so distinct with textile fabrics (especially thin fabrics) as it is with other materials that are dried. Instead the transition is smoother. The reason for this undoubtedly lies with lack of homogeneity. With hygroscopic materials phase 3 starts at low cloth humidities with the drying rate declining further and approaching zero. However, this zone is of minor importance in the drying process for textile materials since it is not or at least not fully completed (after Meyer).

Conversion (Lat.: conversio = conversion), reversion, transformation.

Conversion print Multi-colour overprint, e.g. produced by means of overprinting rollers, where colour change is achieved by the overprint print paste taking over the development and fixation of the pre-print print paste, places not overprinted therefore remaining colourless, and, without pre-printing, patterns of the second print paste developing in the intrinsic shade of the second colour print. These kinds of patterning effect presuppose dyes which can be mutually resisted and discharged, and also possess different development and fixation characteristics.

Conversion styles Textile fabrics printed by the → Conversion print.

Convex (Lat.: convexus = convex). Bellied, arched outwards. Anonym → Concave.

Conveyor belt Endless belt for transporting goods without stress.

Conveyor belt shrinking machine To relax woven or knitted fabric, the fabric is placed on a perforated conveyor belt, which runs through a tunnel. Vi-

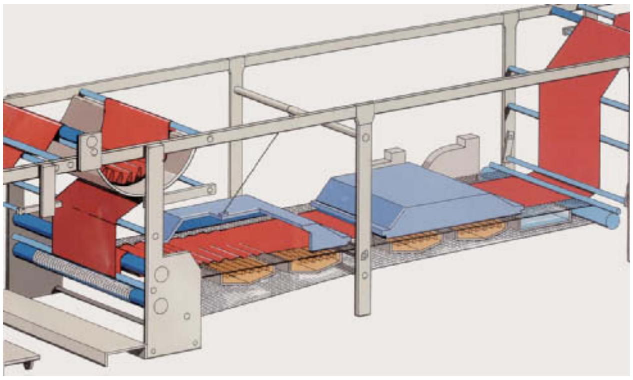


Fig. 1: Conveyor belt shrinking machine (Menschner).

Fig. 2: Montex-Dyn-Air conveyor belt dryer by Monforts.

brating elements or bursts of steam keep the fabric appropriately moving (Figs. 1 and 2).

Conveyor drier Circulating air drier as a) drier for loose material which is carried through the drying room on brattice conveyor; b) piece goods drier, in which the goods are carried through the drier on a conveyor belt. Particularly for knits and other cloths in piece form that are susceptible to tension. → Drying systems.

Conveyor dwell section → Dwell units.

Conveyor installations → Transport equipment.

Cooking salt → Sodium chlorite.

Cooling cylinder A perforated roller through which cold air is drawn. Serves to cool down decatized goods during unloading after a full steam process.

Cooling towers (evaporation towers). Used for recooling water. By evaporating a small proportion of the circulating water, heat is extracted so that water cooling is possible depending on dewpoint. Only the quantity of water lost in the evaporation process is added. Up to 98% water saving can be achieved in this way. Cooling tower efficiency depends on relative humidity and external air temperature. The absorptive capacity of the air for water vapour falls as the moisture content rises. Less heat of evaporation can thus be extracted from the water to be cooled. The maximum cooling limit in high summer is 20–22°C. Provision should always be made for installation possibilities for feeding in colder mains water or well water as a safety factor in the event of unsatisfactory cooling. Use in textile cleaning and solvent textile technology.

Cooling unit Unit for cooling fabric (DIN/ISO 5250).

Cooling zone On stentering and drying machines, the section between the heat treatment zone and the machine exit zone. The fabric can be rapidly cooled in the cooling zone (DIN/ISO 5250).

Cool Wool Quality brand assigned to extra-light wool fabrics (no precise weight range), created specifically in Woolmark qualities in tropicals, gabardines, wool poplins, crêpes and estamenes. Reducing the weight per unit area is achieved by a) using extra-fine wool fibres (< 20 µm) (Fig. 1); and b) weaving singles yarns in warp and weft (warp sizing necessary) (Fig. 2).

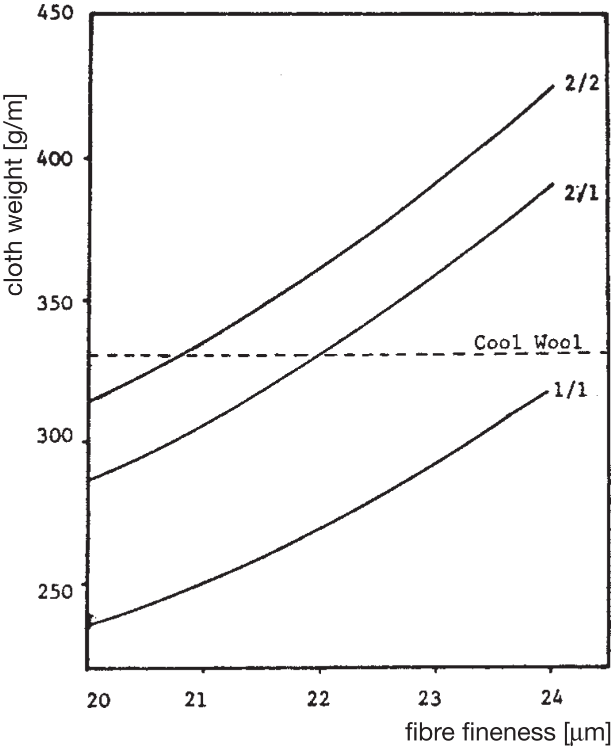


Fig. 1: Cloth weight (in g per running metre) for fibres of different fineness and different weaves in Cool Wool products.

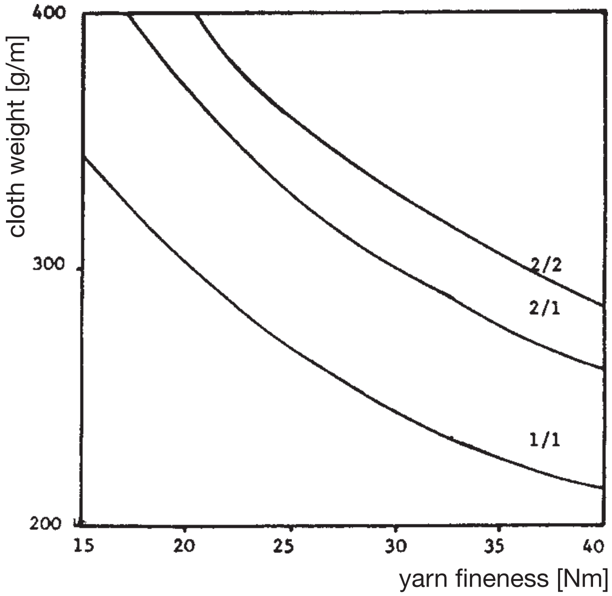
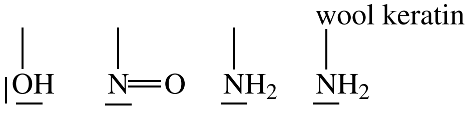
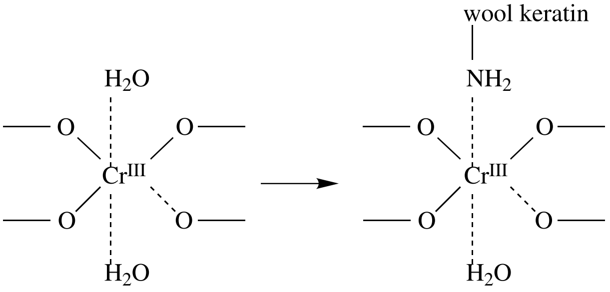


Fig. 2: Cloth weight (in g per running metre) in relation to yarn fineness in Cool Wool products with different weave structures.

Coordinate atomic bond (coordination compound). A bond based on → Secondary valency forces as a special → Atomic bond. Occurs in molecules mostly of a higher order (complexes), in the structure of which atoms, radicals and even molecules capable of independent existence (e.g. H_2O), NH_3, wool keratin molecules etc) participate in the same way as mostly monovalent partners. Whilst however in the case of normal atomic bonding each atom partner contributes a valency electron in each case to the common pair of electrons in principal valency style, here, only one partner provides the bonding electron pair, which consists of two free valency electrons or "solitary" electrons. These are symbolised at the relevant atom by horizontal lines e.g.



In the last example therefore, an undissociated wool NH_2 group is readily available for coordination. A suitable partner would for example be a chromium-containing mordant dyestuff. The chromium atom is available as a so-called → Chelate bond, i.e. in this case also three-fold coordinatively bonded on its part (in addition to a 3-atom bond).



Coordinate system Latin coordinare = coordinate) System of vertical axes (ordinates) and horizontal axes (abscissa). In a right-angle coordinate system, the numerical position of each point in a graph can be determined from the spacing of successive intersections.

Coordinative (Lat.), involved in the same way or in equal value.

Cop Term used for a yarn package spun on a spinning frame. The package generally has tapered ends (→ Biconical package) and is cop-wound (→ Cop winding).

Copals Mostly semi-fossil → Resins, e.g. Australian Kauri copals, which also include amber. Wine yellow to reddish brown, very hard, granules or flat pieces up to 20 cm in length, lustrous to matt, fracture concoidal and lustrous, more or less with a balsam odour (heating). As copals are not homogeneous crystallised compounds, simple melt point data is insufficient. Solubility: Zanzibar copals (after lengthy steeping) completely in an excess of alcohol, but only partially soluble in other solvents; soft (mock) copal dissolves directly in hot alcohol and turpentine oil. Use: (only in combination) for viscose filament oil sizes; in many countries also for finishes, coatings; for oil or resin paints.

COPANT, abbrev. for: Comisión Panamericana de Normas Técnicas (PASC = Pan American Standards Committee) with headquarters in Buenos Aires, Argentina; → Technical and professional organizations.

Copolymer fibres (multipolymer fibres). Synthetic fibres manufactured according to the principle of → Copolymerization. They are produced for the purpose of achieving or enhancing specific properties, e.g. dye affinity, hydrophilic/hydrophobic characteristics, thermostability, etc.

Important examples include modacrylic fibres, modified polyvinyl chloride fibres as polyvinyl chloride copolymers and polyvinylidene-dinitrile fibres.

Copolymerization Many monomers can form polymers not only with monomers of their own type but also with other monomers. This opens up the range of possibilities enormously. For example, radical polymerization converts styrene to polystyrene, methyl methacrylate to polymethyl methacrylate and vinyl acetate to polyvinyl acetate. A mixture of styrene and methyl methacrylate gives polystyrene-co-methyl methacrylate even at a very low extent of conversion. However a mixture of styrene and vinyl acetate will give practically pure polystyrene at first and then when all the styrene has been used up, almost pure polyvinyl acetate. That is to say, a mixture is produced and no copolymer. On the other hand stilbene does not give any homopolymer on radical initiation and maleic anhydride only gives a polymer of low molecular weight. However a mixture of the two monomers leads to a copolymer of the two monomers in a 1 : 1 ratio.

Copolymerization is technically extremely important. By introducing a small amount of a second monomer certain properties can be improved (e.g. dyeability, adhesion etc.). Copolymers generally do not have the same composition as the original monomer mixture. The composition depends on the reactivity (measured by the rate constants) and the concentrations of initiator (e.g. radicals) and monomers. During copolymerization, the reactive monomer will polymerize preferentially. The copolymer formed at low conversions will therefore depend on the composition of the monomer mixture and the reactivities of the reacting monomers. As the more reactive monomer is used up, its concentration in the remaining monomer mixture is reduced. Hence the copolymer made on further conversion must have a different composition to that of the initial copolymer. The composition of the copolymer will be the same as that of the starting mixture only with a definite combination of reactivity and concentration.

To get a relationship between the composition of the monomer mixture, the reactivity and the composition of the copolymer it is assumed that both monomers 1 and 2 react by the same bimolecular mechanism. Four rate constants for the growth of the polymers can be defined:

$$\ldots M_1^* + M_1 \rightarrow \ldots M_1M_1^*\,;\ v_{11} = k_{11}\,[M_1^*]\,[M_1]$$
$$\ldots M_1^* + M_2 \rightarrow \ldots M_1M_2^*\,;\ v_{12} = k_{12}\,[M_1^*]\,[M_2]$$
$$\ldots M_2^* + M_1 \rightarrow \ldots M_2M_1^*\,;\ v_{21} = k_{21}\,[M_2^*]\,[M_1]$$
$$\ldots M_2^* + M_2 \rightarrow \ldots M_2M_2^*\,;\ v_{22} = k_{22}\,[M_2^*]\,[M_2]$$

These equations assume that the penultimate unit in a growing polymer chain does not affect the polymerization. The so-called copolymerization parameters (reactivity ratios) are defined (according to Elias):

$$r_1 = k_{11}/k_{12}\ ;\ r_2 = k_{22}/k_{21}$$

Copolymers → Polymers consisting of two or more → Monomers (→ Copolymerization) for creating new product characteristics. A distinction is made between

- → Block polymers in which larger “Polymer pieces” constructed from a monomer alternate with “pieces” from another monomer.
- → Graft polymers in which other monomers or polymers are linearly added as side chains (grafted on).
- Statistical copolymers with various monomers in a “random” arrangement.
- Alternating copolymers, whereby two monomers are installed in the chain alternately.
- Crosslinked copolymers, with polymer bridges belonging to another monomer installed between the individual chains of a polymer.

Copolymers made from two monomer components are called bipolymers, those made from three are called terpolymers and those made from four are called quaterpolymers.

Since the largest group consists of bipolymers, this is the group to which the expression copolymer usually refers. The previously used name of “mixed polymer” should no longer be used because of the risk of being confused with polymer mixtures.

Copper (Cu). Atomic weight 63.6; melting point 1065°C. Red, semi-precious metal, quite soft; extensible, malleable, can be rolled; a malachite green-like surface layer (patina) forms in moist air containing carbon dioxide. Quickly dissolves in nitric acid and hot concentrated sulphuric acid, and slowly in diluted hydrochloric, sulphuric and acetic acid, and also ammonia. Excellent conductor of heat and electricity.

Use as a metal for armatures, plant and machinery components, sheathing, containers, wire (electrical technology). Non-metallic compounds: oxygen carriers, fastness after-treatment, antiseptics, analytical chemistry (oxycellulose identification), impregnation, dye and colour production, electroplating etc.

Copperas vat (iron vitriol vat), obsolete type of reduction vat for → Indigo.

Copper complexes → Complex compounds with copper as the central atom.

Copper detection in fabric dyeing Incinerate a woven fabric test specimen, dissolve in hydrochloric acid, and implement the following reactions:

I. Add excess ammonia: deep blue colouring = copper. Concentration limit 40 000 : 1.

II. Add some sodium acetate and potassium hexacyanoferrate (II): reddish brown colouring = copper. Concentration limit 90 000 : 1.

III. Mix some pyridine and a few drops of potassium or ammonium rhodanide solution with some sodium acetate: greenish yellow precipitate (pyridine copper rhodanide) = copper. Soluble in chloroform with a greenish yellow colour. Concentration limit 800 000 : 1.

Copper dyes Expression for → Aftercoppering dyes.

Coppered block In contrast to the → Blocks for printing with carved wood relief in hand printing, the coppered block has brass strips and pins as pattern elements. Coppered blocks, much better as regards fineness and accuracy, are used, on the basis of their artistic fineness and the inimitable character of their patterning, in printing wool fabrics and also in silk discharge printing.

Copper electroplating Galvanic process for refurnishing repeatedly machined printing rollers with an adequately thick copper layer. Copper is electrolytically precipitated on to the printing roller from a sulphuric copper sulphate bath.

Coppering → Copper sulphate after-treatment of direct dye dyeings.

Coppering dyes Direct dyes which have to be after-treated with copper salts in order to achieve the correct shade. → Aftercoppering dyes.

Copper man Jointed doll in human form (→: Charly; Termoman) of copper sheeting used for trial purposes in → Clothing physiology with a more or less sophisticated heating system with temperature control for head, trunk and individual limbs etc for testing the heat insulating properties of clothing.

Copper mannequin Highly developed electrical → Copper man of the US Army Natick Laboratories.

Copper naphthenate Copper salts and → Naphthenic acids. Formerly the usual solvent for oil-soluble products for the rot-inhibiting, mildew-proofing and weather-resistant finishing of heavyweight fabrics and cordage.

Copper number Expression of the degree of damage especially of overbleached fabrics (→ Oxycellulose), which have not been boiled during or after bleaching. Principle: determination of reductive capacity by treating the test specimen with Fehling’s solution, dissolution of the deposited cuprous oxide, and titrimetric determination as to how much copper has been precipitated on 100 g of test material: unchanged cellulose (copper number) 0.2–0.3, pure oxycellulose 14.2.

Copper-8-oxyquinoline $Cu(C_9H_6ON)_2$. Olive green powder with 18% copper content. Effective preservation agent for good weather and wash resistant mouldering effects. Insoluble in water and many organic solvents. Used mainly in aqueous dispersion form; not common nowadays.

Copper salt aftertreatment → Copper sulphate aftertreatment.

Copper salt dyeing method → Cuprous ion dyeing method.

Copper-sensitive dyes → Aftercoppering dyes.

Copper sulphate after-treatment Of direct dyeings, for the purpose of significantly improving light fastness, and mainly at the same time too the washing fastness of appropriately suitable dyeings (→ Aftercoppering dyes).

Implementation:

1. Rinse after dyeing.
2. Treat fresh bath for 30 min. at up to 50–60°C with 1–3% of copper sulphate and 2–3% of 30% acetic acid or 0.46% of 85% formic acid.
3. Final rinse (or saponify at 50–60°C with 5 g/l of soap).

Cop tube Tube onto which a Cop of yarn is spun, of cylindrical or slightly tapered form or as a former for a "hollow cop" with or without base. Cops used to be made in cardboard, alloy and steel, both varnished or unvarnished. Nowadays plastics-coated steel, some with textured surface (smooth, matt, grooved, "orange-peel").

Cop winding Created (e.g. on the ring spinning frame) by the rapid upward travel and slow downward travel of the ring rail with a gradually shifting deposition of the wound coils, i.e. the winding density and angle of the coils formed by the traversing motion are varied. The traverse of the outer coils is smaller than that of the inner coils, thus forming tapered ends to the cop.

Copying definition Depends on the perfect formation of the print shoulder in conformity with the object and the vertical run of the print flank. Is affected by the path of the rays (possibility of under-radiation), but not by radiant intensity in a given direction and the spectral distribution of the radiated light.

Copying ink pencils (Crayons). These contain clay, graphite, water-soluble coal tar dyes (methyl violet, methylene blue) and carrier media (tallow, traganth).

Copying lamp Exposure unit for producing printing screens. Various light sources can be used as copying lamps: xenon, mercury vapour, halogen and fluorescent lamps.

Copying process In producing a printing roller or screen, only one transparency is required for the copying process. After exposure, this is moved in terms of height and width around the relevant repeat dimension, thus adding repeat to repeat.

CPB, abbrev. for: → Cold pad batch process.

Cord,

I. Term applied to woven rib fabric with weft yarn floats creating pronounced cord-like raised lengthway ridges; a plain fabric without pile warp or pile weft (contrast with → Corduroy).

II. String-like round braid (→ Braid), in contrast to tape braid. Cord tape braid: tape braid edged with cord.

Corded velvet → Corduroy.

Cord yarns Mostly plied yarns of relatively high resultant linear density, in viscose (high-tenacity) or synthetic fibres (generally filaments). Employed in textile casing (→ Case cord) for car and aircraft tyres, conveyor belting, drive belting etc. Have progressively replaced cotton cord yarns in general use since the 1930's.

Corduroy Today often wrongly referred to as → Cord. Corduroy has a ribbed velvet face with cut weft pile. Warp-way rib structure produced by weaves with weft floats (e.g. Genoa cord, Manchester velvet), can also be modified to piqué form (with weft-way ribbing).

Cotton corduroy: Robust tough cotton fabric with characteristic (dense) warp-way ribbing. Along with piece-dyed and yarn-dyed qualities a marl effect warp is now often used. The marl effect is also often imitated by discharging a piece-dyed fabric. End-uses: for workwear trousers which are invariably heavily napped on the back; for leisure wear, generally with yarn structure well-defined on face and back; jackets, coats, suits, sports jackets and trousers (bengaline) in men's and ladies' outerwear.

Wool corduroy: All-wool qualities with worsted in warp and weft or with worsted warp and woollen weft, low-quality fabric with viscose warp and woollen (shoddy) weft. close-napped finish. Mostly stock-dyed or yarn-dyed; often marl yarn warp. Used for sportswear, riding breeches, workwear, upholstery covers.

Corduroy and velvet finishing This is undertaken by relatively few finishers since it calls for a pur-

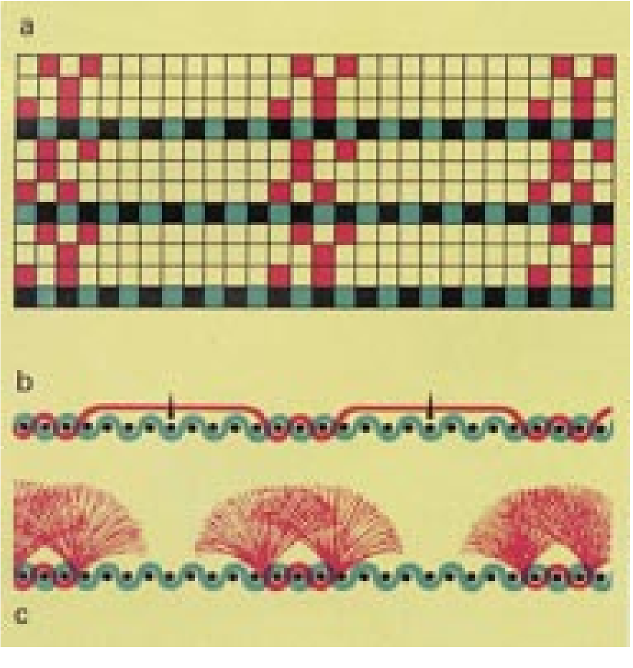


Fig. 1: Principle of corduroy manufacture.
a = weave design; b + c = weave cross-sections; c = cut ribs.

posely-designed range of machinery that cannot be used for other textiles, plus well-trained technical staff.

In weaving terms, corduroy is a heavyweight form of ribbed velvet. The weft-float weave is a characteristic feature, representing the transition from a two-thread system (warp and weft) to a multi-thread system. The warp is generally a plied yarn and the weft a singles yarn. With “binding ends” (shown in green in Fig. 1) incorporated as the third thread component, the ribs are caused to emerge from the woven fabric structure in the form of undulations and the characteristic structured finish is thus shown to best advantage. Genoa cord has relatively broad ribs; breeches corduroy incorporates additional filler warp ends.

The Table illustrates the basic sequence of the exceptionally diverse finishing processes. In practice there are a large number of variants.

“Normal” cord 100% cotton medium wide rib	Fine cord 100% cotton	Stretch cord with PUE content
grey fabric inspection reverse face raising cutting recutting desizing washing out water extraction brushing drying brushing singeing inspection scouring/bleaching dyeing drying colour check brushing reverse face raising chemical finishing/ resin finishing drying/shock drying (condensing) (waxing) (brush pile finishing) brushing final inspection	grey fabric inspection reverse face raising soaping/nap drying cutting inspection/recutting brushing singeing (desizing) washing out scouring/bleaching dyeing drying possibly printing brushing chemical finishing/ resin finishing (shock) drying (waxing) brush pile finishing brushing final inspection	grey fabric inspection relaxing (soaping) cutting inspection/recutting washing brushing drying/heat setting (singeing) scouring/bleaching dyeing water extraction brushing drying brushing chemical finishing/ resin finishing drying/condensing (shearing) shrinking brushing final inspection

Tab.: Standard variants for current qualities to produce appropriate finishes.

The loomstate fabric is inspected, burled, mended where required and allocated a piece number. For downstream finishing it is absolutely essential to identify the beginning and end of each piece.

Napping, emerizing (mechanical cleaning and softening): Napping the back of the fabric imparts a fuller handle, better uniformity and greater suppleness, which is important for the cutting process which follows. Corduroys with up to 40 ribs/10 cm are generally napped on the back. Finer qualities are emerized in order to make subsequent cutting of the ribs easier. If the weft in the loomstate fabric contains impurities, a light pass on the emerising machine can greatly assist the cutting process. To obtain a clean stable cut in fine corduroy it is advisable to pre-treat the pile face with a soap and caustic soda solution. But care must be taken that there is no strike-through of solution, and the fabric must be dried on the cylinder dryer immediately after pre-treatment.

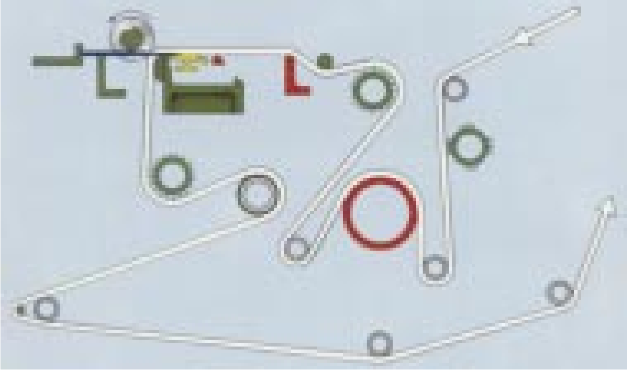


Fig. 2: CR-2 corduroy cutting machine by Sucker-Müller.

Cutting: This is performed on the corduroy cutting machine (Fig. 2). The correctly prepared fabric is cut on the corduroy cutting machine, i.e all ribs up to a density of 48/10 cm can be cut in one pass. Densities greater than 48/10 cm and up to a maximum of 55/10 cm are cut in two passes, i.e. ribs 1/3/5 and so forth in the first pass and 2/4/6 and so forth in the second pass.

The circular knives used for cutting are arranged on a cutter shaft which rotates at high speed. The number of knives is equal to the number of ribs to be cut. The knives are set to cut only the pile thread floats. Each knife is guided by a forked needle. The needles (Fig. 3) are guided through the channel formed by the pile weft yarns and the warp yarns. The size of the cutter needle depends on the width of the rib. For standard corduroy qualities in which all ribs are of the same width, the needle is forked in the centre. If the needle is forked asymmetrically then the rib is not cut in the centre but

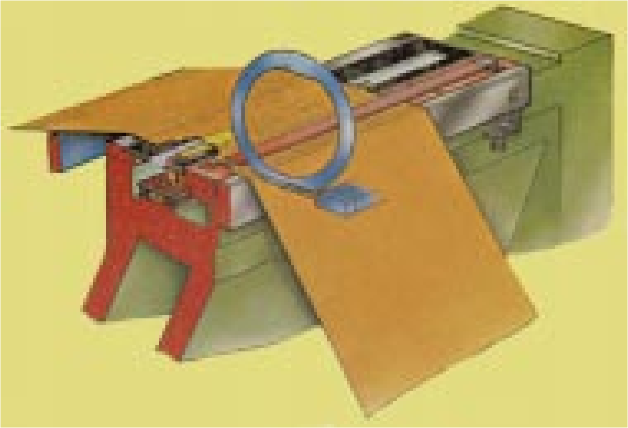


Fig. 3: Fine corduroy/velvet cutting machine by Sucker-Müller.

offset to one side, thereby creating pile ribs of different widths (fancy corduroy). As it is impossible to guide the fabric in an absolutely straight line the knives on the knife shaft are able to move freely axially and are thus controlled by needles and fabric. Weaving defects or impurities in the fabric cause needles to be pushed out, resulting in automatic stopping of the machine. In about 90% of all cases of needles being pushed out it is possible to reposition the needle at the point where it was pushed out, obviating any subsequent need for cutting by hand. In cases where repositioning is not possible the site must be marked and cutting at this site must then be performed manually on the inspection table.

For fabrics with rib densities of 55/10 cm and greater the velvet cutting machine must be used. This operates on a totally different principle. Whereas on the corduroy cutting machine there is a knife with guide needle for every rib to be cut, the velvet cutting machine uses only one cutter element consisting of guide needle with knife, i.e. every rib is cut separately. However, the cloth speed is appreciably higher. It can be varied from 250–500 m/min. A special piece-sewing technique enables pieces to be assembled for a piece to be cut continuously in a spiral in rope form.

Desizing and washing: This process must be as thorough as possible in order to effectively swell the pile and substantially remove the twist from the yarn tips. Inadequately desized fabric creates problems in downstream processes since the size residue penetrates the pile and sticks it together, which can cause streakiness in cross-brushing for example. Open-width washing is generally employed, often incorporating intermediate brushing units. The wet-brushing machines optimise the cleansing action with the result that higher speeds are possible in subsequent brushing passes or brushing passes can even be omitted.

Dewatering of the desized washed fabric: As a rule high-performance squeezers are used. The aim is to reduce residual moisture to 65%.

Brushing processes:

a) Wet-brushing machine (Fig. 4): The aim is to pre-orientate the ribs in an aqueous medium.

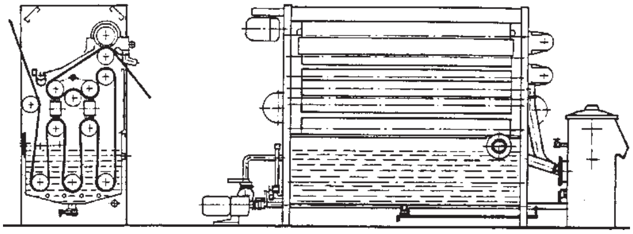


Fig. 4: Wet-brushing machine for corduroy .

b) Diagonal-brushing machine (Fig. 5): The ribs are orientated in the wet state. Mainly used for corduroys of medium to coarse qualities.

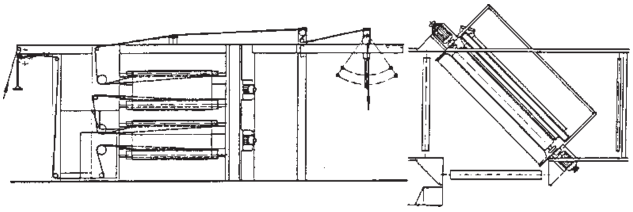


Fig. 5: Diagonal brushing machine for corduroy.

c) Cross-brushing machine (Fig. 6): Brushing open the orientated dried ribs, any residual twist in the pile weft is further released.

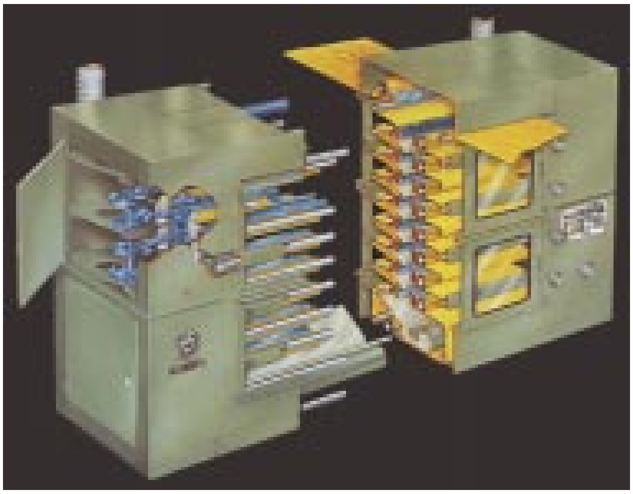


Fig. 6: Cross-brushing machine for corduroy (Sucker-Müller).

d) Belt cross-brushing machine (Fig. 7): The brushed-open ribs or pile are levelled and brushed out.

e) Rotary brushing machine (Fig. 8): For levelling and orientating the pile in a warp direction and to impart a smooth even surface appearance to the fabric.

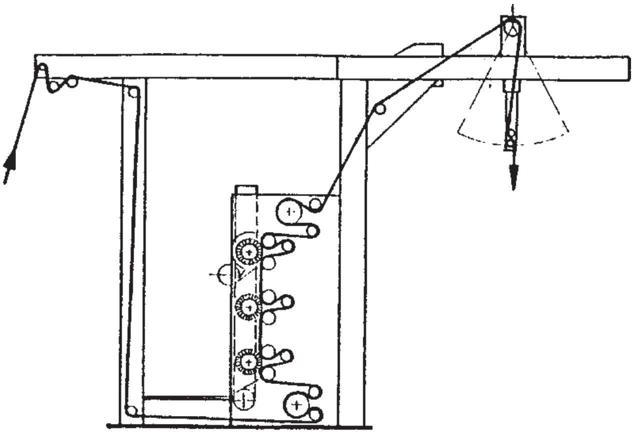


Fig. 8: Rotary brushing machine for corduroy .

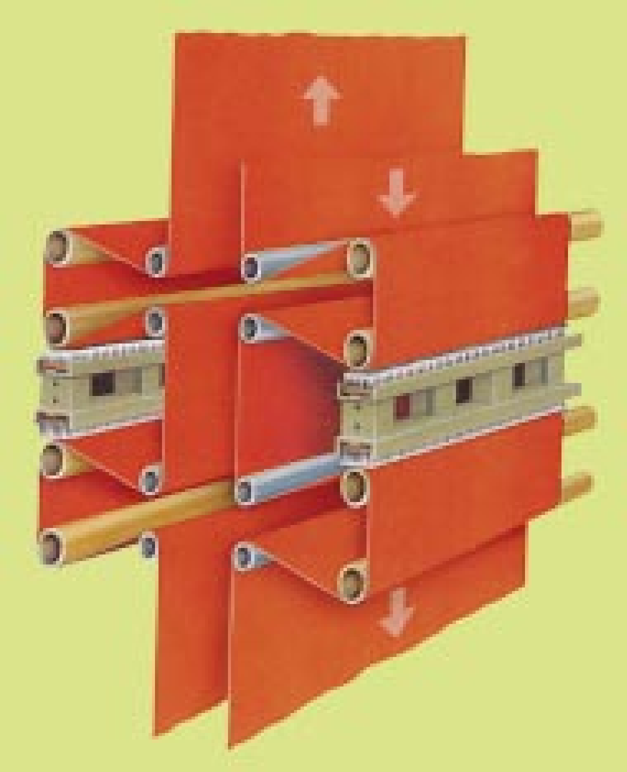


Fig. 7: Belt cross-brushing machine for corduroy (Sucker-Müller).

f) Combination brushing (Fig. 9): For relatively small batches it is advisable to use a combination brushing process comprising steamer, cross-brushing machine with eight cross-brushes, belt cross-brushing machine with four belts with two-fold brushing action and rotary brushing machine.

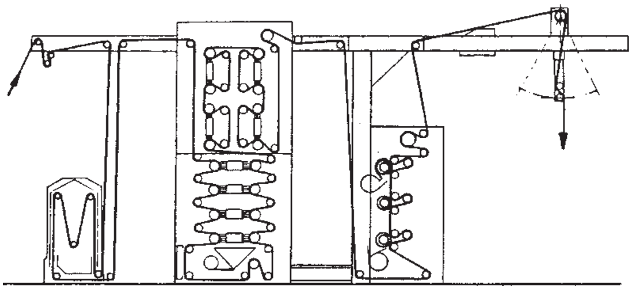


Fig. 9: Combination brushing process for corduroy.

Washing and final finishing (Fig. 10): To impart its highly desirable soft handle and lustrous finish to corduroy, a thin film of wax is applied to the pile face (except for proofed fabrics). The wax film is pulverised in subsequent final finishing. Lustre can also be imparted by incorporating silicones in the dyebath but the handle is gritty. The final finishing machine operates with two high-speed finisher rollers covered with a tubular felt. The pressure of each of these two rollers can be adjusted individually to produce higher or lower lustre. This stage concludes the finishing process for corduroy.

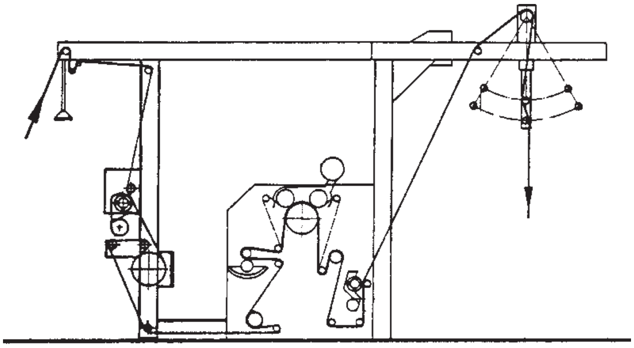


Fig. 10: Wax finishing machine for corduroy.

Corduroy cutting machine Machine used for cutting open the pile weft in cord fabrics (Fig.). Uses revolving blades running between twin needles.

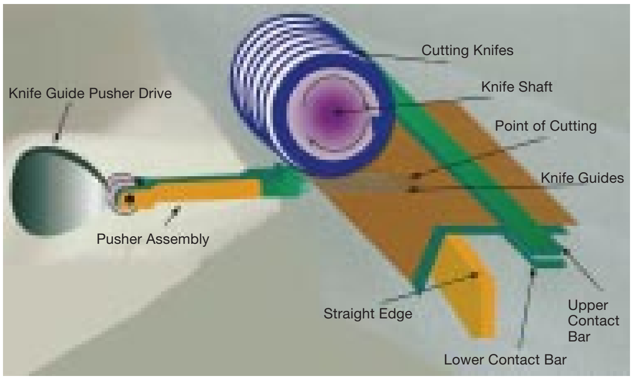


Fig.: Corduroy cutter (West Point).

Corduroy wet brushing machine Corduroy finishing machine for a smooth transition from wet to dry finishing. Used for wet shaping the rib, takes place immediately behind the washing areas: integrated wet band brushes, brush coating. A rotary brush is installed at the end of the machine in order to give the fabric the required nap before it runs into the rolling machine.

Core The term applied to a central core, e.g. spinning core for → Core-spun yarns.

Core-sheath bicomponent fibres → Bicomponent fibres.

Core-sheath fibres → Bicomponent fibres.

Core-spun yarns (“Hetero” yarns, core threads), since the early 1960’s “core-sheath” textile yarns have had special “stretch yarn” significance. In principle, a core thread (core), usually highly elastic, is used as the source of mechanical properties, and has a sleeve fibre wound round it that determines its appearance and feel. The core material should preferably consist of elastomer threads, rubber threads or non-shrunk chemical fibre filaments. Almost any kind of natural

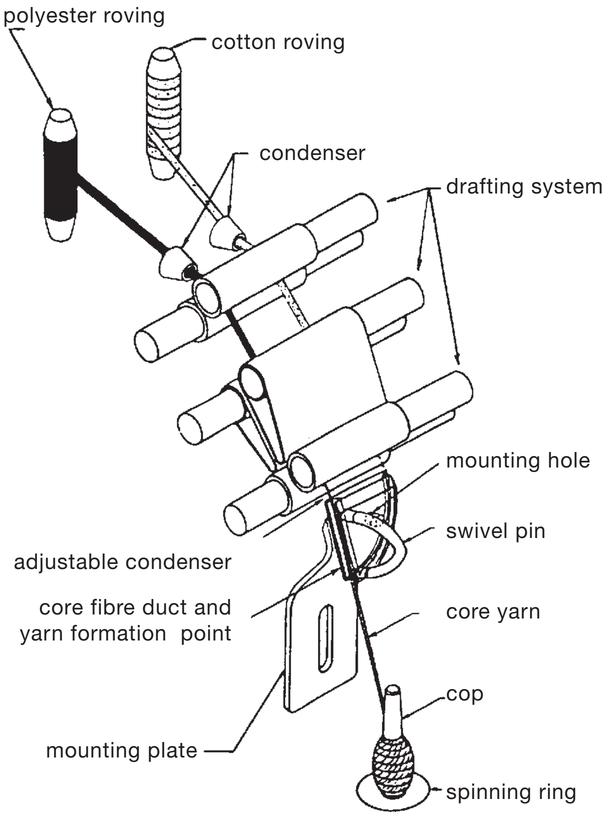


Fig.: Ring spinning machine principle with special core yarn unit.

or chemical fibre is used as sheathing material, including textured filaments and mixed fibres; elastomer threads sometimes occur in the sheath rather than the core (see Fig.).

Further processing into elastic woven fabrics, hosiery, and knitwear. Used in ladies, men's and children's clothing, sports clothing, pullovers, blouses, shirts, swimwear, etc. Core-spun yarns should be thermofixed (177–195°C for 10–20 s depending on sheathing material) before wet finishing takes place, since without thermofixing there would be too much contraction and the textile material would be too dense.

Core yarns → Core-spun yarns.

Corona discharge Weak current discharge under atmospheric conditions that occurs when a high voltage is applied to electrodes, but an isolator between them prevents a spark from discharging. In order to trigger a corona discharge a high field strength must be produced at one of the electrodes. The electrons that are produced by this electrode are accelerated towards the isolator by a high voltage that is directly beneath the substrate that is being treated, e.g. a woollen fabric. On its way to the substrate the electrons collide with air particles, forming ozone and nitrous oxide. The electrons that reach the substrate can split covalent bindings because of their high energy level (approx. 5 eV). This produces radicals on the surface of the fibre that react with ozone and nitrous oxide, i.e. the surface of the fibre is oxidised and therefore becomes more polar.

Corona discharge polymerization Enables certain finishing effects to be achieved, e.g. the antifelt finish of wool. → Corona treatment, in the presence of monomers on the fibre surface, initiates polymerization leading to film formation.

Corona treatment Method of influencing fibre properties using corona discharges. The use of gas discharging in technologies that modify the surface properties of high polymer materials is being discussed for the textile area, among other things. Technological improvements to the process of corona discharging, i.e. brush-like electrical discharges at atmospheric pressure and low temperature plasma, i.e. glimmer discharge in a vacuum, are becoming more important. These technologies are used to treat fibres such as wool, mohair and cotton and textiles made from synthetic fibre materials in order to achieve certain effects such as improving the adhesion of coatings. Previous investigations on wool and mohair showed that corona treatment made considerable improvements to yarn strength and shrinkage behaviour. The yarn strength of cotton was also improved, which is particularly important in OE yarns. Positive results were also achieved in the areas of cross-linking, creasing behaviour and dirt retention. Similar property changes can be achieved by treating with low temperature plasma. The fine fibre structure of the surface layer was also able to be modified by giving polyester fibres → Plasma treatment, which led to a clear increase in dye absorption. Plasma processes are not just used to modifying but also coating if the treatment chamber contains a gaseous polymer (plasma polymerization) or if the long-life radicals produced during the treatment are used to initiate graft polymerization (plasma grafting, SAC process). These techniques open up the following application areas:

- Making wool lint-free.
- Making chemical fibres hydrophilic,
- Increasing cross-linkage and adhesion capability of fibres for dyeing and printing
- Improving the adhesion of textile laminates, e.g. web bonding, laminates made from sheet materials and films etc.

Coronizing process Glass fibre fabric finishing:

1. Heat passage for approx. 5–15 s at 650°C (impurities are burned off, fabric weave is fixed, simultaneous fibre relaxation).
2. Pad with resin solution (acrylonitrile) possibly with dye pigment, thermal polymerisation at 160°C.
3. Pad with stearic acid chromium chloride, thermal treatment at 170°C.

The finishing effect should provide the best possible shearing resistance and excellent washing stability and water-repellent properties.

Corporate wash Bulk wash in the corporate sector, e.g. armed forces, hospitals, hotels, for industrial concerns, department stores etc.

Correction of faulty dyeings Correction of shades in the same dyebath in order to obtain the specified final shade. Correction treatment: term for correcting unlevelness and, if necessary, poor fastness (inadequate fixation, inadequate wash-off), and also creases. Since this type of fault is discernible only after the fabric has been dried, another treatment operation is virtually necessary. Redyeing: in the event of failure of shade correction and correction treatment, it is necessary either to cross dye the entire batch darker, or redye it after stripping. All three concepts are measures for eliminating faulty batches, which have a significant effect on production costs.

Correction of shade → Levelling in finishing.

Corrosion (Lat. corrodere = to gnaw). Destruction of materials (generally metals but sometimes plastics) resulting from chemical or electrochemical reactions with their environment. One of the most important corrosion processes from the practical aspect is the rusting of iron. The surface nature of a material is the factor having the greatest influence on its suceptibility to corrosion since it is on the surface that the protective inactive film is formed, a non-porous oxidic coating. Cracks and roughness inhibit the formation of a continuous inactive film.

Chrome-nickel steels for instance corrode at the sites where this protective film 0.10–0.12 µm thick is interrupted by pores of diameter greater than the thickness of the protective coating or by roughness. Therefore the lower the three-dimensional surface area of a material, the better its corrosion characteristics. Under certain circumstances these surface areas also become aniodic in relation to the inactive areas of the surface. Interruption of the natural oxidic film thus results in electrolytic corrosion and consequently pitting due to chlorine ions (Fig. 1). Acid having an oxidizing action depolarizes large cathiodic areas and accelerates pitting. Also in cases of stress crack corrosion (often triggered by casting strain) the protective coating becomes cracked and in the course of crack propagation there is a shift in the elctrochemical potential to the more base side (Fig. 2). →: Contact corrosion; Pitting corrosion.

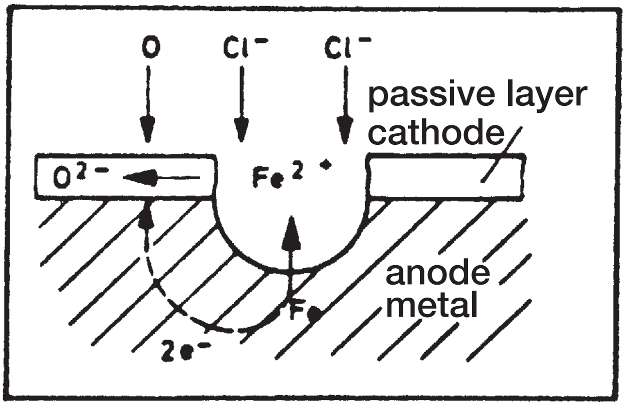


Fig. 1: Corrosion due to pitting by chlorine ions.

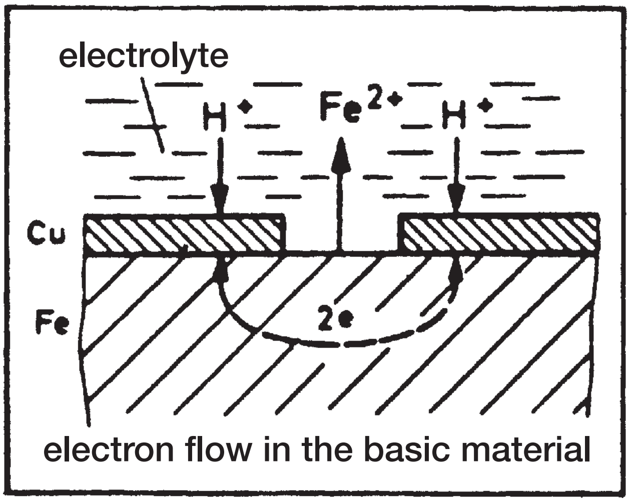
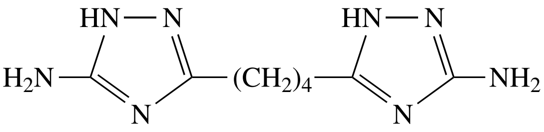


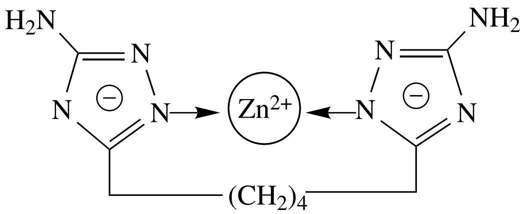
Fig. 2: Corrosion due to local element formation with different metals.

Corrosion inhibitors (anti-corrosion agents). Apart from specific → Rust prevention, corrosion inhibitors (Fig. 1) are paid considerable attention, especially in regard to universally applicable raw synthetic washing materials and such combination products in washing machines. Here, soluble silicates are the most used corrosion inhibitors for preventing corrosion in light metal alloy and copper/zinc, copper/nickel alloys etc. by carbonates, orthophosphates and polyphosphates in synthetic detergents. Condensed phosphates have the greatest corroding action. It is certain that most synthetic detergent liquors promote the corrosion of base metals, and also, oddly enough, the non-ionogenic ethylene oxide addition compounds, in many cas-



1.4 bis[3-(5-amino-1,2,4-triazolyl)]-butane

BAT 4



BAT 4-complex

Fig. 1: Corrosion inhibitors.

Reaction		Standard potential E/V (SHE)
Anodic corrosion:	$Zn \rightleftharpoons Zn^{2\oplus} + 2e^{\ominus}$	–0,763
Oxide formation:	$Zn + 2\,OH^{\ominus} \rightleftharpoons ZnO + H_2O + 2e^{\ominus}$	–0,893
Cathodic hydrogen development:	$2\,H_2O + 2e^{\ominus} \rightleftharpoons H_2 + 2\,OH^{\ominus}$	–0,828
Cathodic oxygen reduction:	$O_2 + 2\,H_2O + 4e^{\ominus} \rightleftharpoons 4\,OH^{\ominus}$	–4,401

Tab.: Possible reactions on zinc electrodes in aqueous solutions.

es more so than the anionic ones. Alkyl phosphates for example are an exception. Despite this, surface-active substances like fatty alcohol sulphates, secondary alkyl sulphates and alkyl aryl sulphonates are added to rust prevention baths because they increase corrosion-inhibiting activity without reacting directly with the metal, i.e. iron rust is "equalised", thereby repressing holing.

Particularly effective and easy to handle are inhibitors which are added to liquids or gas phases too. Benzotriazol (BT) and 3-amino-5-heptyl-1,2,4-triazol (AHT) have proved themselves as copper corrosion inhibitors. The Table provides a survey of the most important corrosion reactions of zinc in ventilated solution. This involves anodic decomposition to Zn^{2+}, oxide formation, and oxygen reduction and hydrogen development as the cathodic reaction. The associated equilibria potentials depend of course on the concentration and the pH in any one case.

The structure of the phase boundary between the electrolytes and the zinc (Fig. 2) depends on the pH at any one time. The metal surface is either blank or covered with oxide. In the presence of inhibitors, the phase boundary is considerably more diverse. The inhibitors can cover the electrode in adsorption layers on the blank metal surface or in three-dimensional protective coatings (Wippermann et al.).

Corrosive poison Substances which cause localised corrosive injuries to the body, e.g. caustic potash (potassium hydroxide), caustic soda (sodium hydroxide), soda lye, hydrochloric acid, sulphuric acid and the like.

Cortex (Lat. = cover, bark, shell),

I. In wool structure, the cortical or spindle cell layer.

II. In silk structure, the cortical layer in the fibroin filament and the fibroid interior of the sericin layer.

Cortex skin (cortex sheath). Identical to the intermediate membrane in → Wool structure.

Cortical layer,

I. → Flax stem structure.

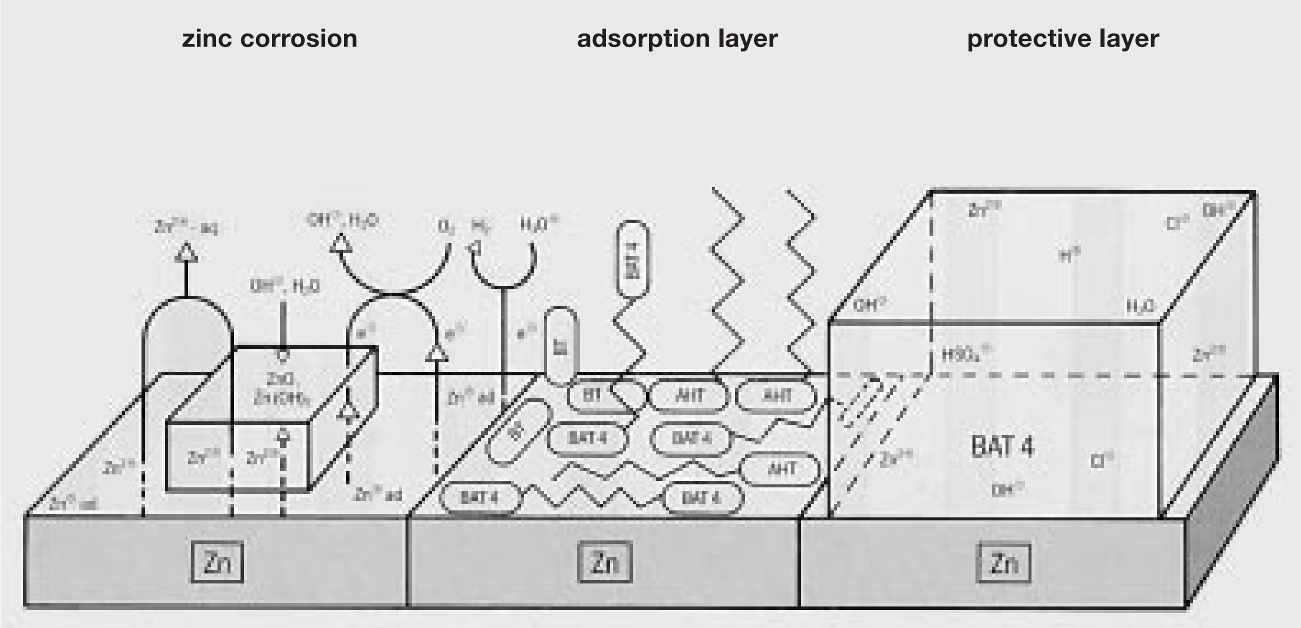


Fig. 2: Model of the zinc/inhibitor/electrolyte phase boundaries.

II. Cortical (cell) layer, in → Wool structure, the largest internal layer of spindle cells.

Corundum More or less impurified → Aluminium oxide, water-free, extremely hard, insoluble in acids and alkalis. Pieces, grained, powdered. Melt point approx. 2000°C. As natural corundum (melted in electrical ovens), fused corundum and (with bonding agent) sinter corundum. This also includes the so-called special fused alumina, natural and synthetic precious stones like rubies and sapphires. Use: abrasive material, matting/delustring brushes, fireproof building materials, chemical apparatus etc.

Co-spun yarn Produced by the simultaneous spinning of two different types of polymer to give an enclosed mixed fibre.

Cost accounting The so-called → Break even point (BEP) is applied in order to obtain a productivity comparison based on pure cost comparison. If the production quantity per unit of time is traced in the abscissa of a graph, with the relevant costs plus the relevant proceeds in the ordinate, a point of intersection occurs which can be described as the profit or loss threshold (BEP). The cost product unit is necessary in order to make cost comparisons between plants or between alternative products in a plant. This is understood to include the assignment of costs to the product unit. A distinction is drawn between cost product time unit and cost product piece unit.

I. Cost product time unit: here the costs of the total output over a specific period are determined in order to compare them with total output. This is a period-related plant profit and loss account, and can be carried out in two ways: in accounting form on the class 9 plant trading result account (bookkeeping treatment) or in tabular form on a cost product time sheet (statistical treatment). The cost product time unit compares the costs of an accounting period with its output. There are two different processes:

a) Turnover cost process: only the cost of the products actually turned over are compared with the proceeds. The arithmetic determination of the plant trading result is effected as follows (according to Olfert):

$$G_B = U - x_{ai} \cdot k_{si}$$

$$G_B = x_{ai}\,(p_i - k_{si})$$

G_B = plant trading result,
U = turnover,
x_{ai} = quantity of product type i sold,
p_i = product price i,
k_{si} = prime cost per piece.

Since the proceeds and the cost of identical products are compared with each other in the turnover cost process, there is an advantage in that one obtains the trading result contribution per product unit or group. In addition, the exclusion of stock on hand from the plant result enables short-term profit and loss accounts to be produced at short intervals as required. The disadvantage is that this process can hardly be incorporated in the double entry bookkeeping system, since the individual cost types are charged to the cost centres or product units with the aid of the plant statement sheet.

b) Total cost procedure: here, all cost types occurring during an accounting period are compared with the turnover proceeds of the outputs attained. One must of course take account of the fact that a correct trading result can be achieved only if all products produced have actually been sold, that is to say that there have been no changes in stocks of finished and unfinished products. These (possibly) occurring stock changes have to be taken into account in determining the trading results. Mathematical calculation (according to Olfert):

$$G_B = U - (+\,(x_{pi} - x_{ai})\,k_{hi}) - k_j$$

x_{pi} = production quantity per product type i,
k_{hi} = production cost per piece of product type i,
k_j = cost types used.

The advantages of the total cost process lie both in the ease of incorporation in the double entry bookkeeping cost system, the possibility of tabular representation, and in producing the annual profit and loss account in the financial accounts department by amalgamating the 12 (monthly) produced trading results. The disadvantage of this process is that the physical stock has an effect, particularly in plants with a number of production stages and an extended production range. Divergence errors, which are more noticeable over short periods than in the annual accounts, occur, particularly in recording semi-finished goods stocks.

II. Cost product piece accounting: here, the costs for the individual piece (product units product unit groups) are determined, i.e. the prime costs of the individual product or the individual order unit; for this reason, this form is also called cost accounting. Companies which produce piecegoods use the number of pieces produced as accounting units, a distinction possibly being drawn between multicomponent and single-component piecegoods. Single-component piecegoods are screws, bolts, brackets etc. Here, the piece costs of the individual end-product can be directly calculated. For multi-component goods such as in the vehicle and electrical industries for example, individual component accounts have first of all to be produced for the in-house produced individual components, from which the piece costs of the end-product can only be directly compiled. In mass or production line companies such as those in the chemical industry, spinning mills, cloth-producing mills etc. weight, length, area or capacity units are

Account	*DM/m²*
Individual material costs + material overhead costs	
= Material costs	
Direct costs + production overheads + special individual costs of production	
= Manufacturing costs	
= Production costs	
Administrative overheads + sales overheads + special individual sales costs	
= Prime costs	

Fig.: Basic accounting diagram (Kilger).

mainly used in accounting. In multi-stage companies which manufacture marketable intermediate products, the products of the stages following each other in the production process must be separately accounted for, the piece costs of the preliminary products going in each case as accounting prices into the accounting process of the following stage. A generally applicable accounting process cannot be produced for all areas, since it is greatly influenced by the technological product structure and the manufacturing process employed. The same cost type groups go however into each account in a specific sequence, so that a generally applicable basic diagram is produced (Fig.).

Cost calculation in textile finishing The textile industry is obliged to split up at any one time the largely automated and clearly arranged production of yarns, woven and knitted fabrics and nonwovens over very widely differentiated market demands as regards colours, design, surface effects and wear and care properties, with corresponding smaller order slots. In order to meet all these requirements and yet still be able to produce competitively, chemical finishing plants must have available a comprehensive machine park and qualified staff. Chemical finishing to order is therefore a pure on-call industry, which is both personnel and capital intensive.

1. Cost classes: approximate share of individual cost classes in total finishing costs:

personnel	42–45%
process materials	16–20%
energy, water/effluent	15–21%
repairs, maintenance etc.	4%
capital	8%
other costs	8%

In order to achieve the most accurate calculation of production costs it is essential to apportion the variable proportions of cost classes to the individual production stages, all costs which are involved in work in progress being basically regarded as variable.

a) Personnel costs: despite increasing capital intensity, personnel costs in the textile finishing industry are the largest production cost components. In order to calculate the precise cost of an operation therefore, it is necessary to relate the personnel costs to the „output“ of the relevant cost centres, i.e. to their associated machine running times. Essential here for the most accurate determination possible is the retiming of all the plant's work stations in order correctly to work out the activities associated with production in progress, and to define relevant work station parameters and/or personnel loadings in the case of cost centres with multiple machine work.

b) Process materials: this covers all materials necessary for chemical finishing, including all additives such as chemicals, dyes, sewing materials etc. In this way, process materials are directly involved in production in progress, have to be allocated to the production cost centres of the individual operations, and charged to the hourly machine rate.

c) Energy, water/effluent: precise allocation of these costs to the individual production stages is also a prerequisite for accurate cost accounting This means that the variable energy, water and effluent costs have to be determined per net machine hour or per unity of quantity. This is possible at a relatively low and justifiable cost by in-house or external personnel by means of meters incorporated in the consumption cycle (e.g. intermediate electricity meters and intermediate water meters).

d) Repairs/maintenance and spare parts: these costs are easily ascribed to the production cost centres, i.e. the operations or machines in which they occur. In this way, the allocation of these costs to the hourly machine rate presents no problems.

e) Capital: the important elements of capital and calculatory costs are calculatory depreciation and calculatory interest. Means of production such as machinery and tools have a specific working life, period of use or service life, during which their value diminishes. Reasons for this reduced value are: a) technical wear; b) technical supersession; c) economic supersession. This loss of value of means of

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production is taken into account in depreciation. Interest is also included in cost calculation along with depreciation. In so far as the calculatory and capital costs of a specific machine – and therefore a production stage – can be allocated, they are included in calculation of the hourly machine rate.

2. Short interval performance and cost calculation are necessary in textile finishing because strong seasonal swings plus other lasting but unforeseeable variations are typical of order books. Other characteristics are greatly varying order sizes per colour classification, constantly changing colour palettes, comprehensive performance patterns in pretreatment, dyeing (e.g. fastness), printing (number of colours and degree of severity), after-treatment and service together with different raw materials. In commission finishing, there is no possibility of producing for stock, thereby incorporating a buffer between market requirements and plant production potential. Owing to the above-mentioned peculiarities, cost and performance planning are subject to difficulties for textile finishing firms, but are indispensable. In order to be rapidly informed and to be able to act quickly if necessary, cost and performance calculation is necessary at short intervals, e.g. monthly, rapidity being more important than absolute accuracy. For this reason, it is still usual to calculate specific overhead costs relative to other cost figures, i.e. in the form of percentage surcharges. This calculation method produces extreme inaccuracy. Calculating percentage surcharges always requires two attuned amounts, i.e. the basic amount and the surcharge amount. Significant differences may occur if the value of either amount is changed. Additionally, this method does not conform with the cause-justified calculation otherwise aimed for. The purpose of cost calculation aided by electronic data processing is to eliminate the above-mentioned inaccuracies.

3. Graduated costing: the complex performance requirements on textile finishing, which can comprise up to 20 operations, require sophisticated, graduated costing, which should be built up of as many costing components as there are finishing operations. The main influencing factors are the order quantity per colour, the depth of shade, the fastness required, the design, the fabric weight in the case of fabrics, incidental finishing operations and service. Thus, with fixed order costs of 100–400 DM/order, there is already a difference if a customer's order is 100 or 1000 kg. A precalculation matched precisely to the performance requirements, i.e. a graduated precalculation, is the basis for market-oriented, cost-covering pricing.

4. Costing in accordance with individual orders, product ranges and customer groups is becoming increasingly important in textile finishing despite the sometimes not inconsiderable cost of calculation. The function of costing is a test bed for current revenue levels and a control element for the firm's future marketing activities. In addition, it serves as an instrument for checking preliminary costings.

5. Quality: since the domestic textile finishing industry is in competition with cheap labour countries, quality enjoys high status. Basically however, the following rule applies here too: the cost of control must be adapted to the product, its purpose of use, and the price paid. The more stringent the customer's quality requirement, the greater the expense necessary on personnel and processing technology. Costs due to quality requirements are relative to the product and the economic situation. Low value products are subject to less stringent quality requirements than high value products, and it is a fact in economic terms that there are more complaints in bad times. Quality requirement costs include:

a) length compensation, short measure and weight: these cost classes are quite typical in textile finishing. Natural raw material differences, e.g. weight per square metre and shrinkage behaviour, always result in variations. Agreement between finisher and customer on a margin of tolerance is therefore to be recommended.
b) compensation for fabric damaged in finishing.
c) credits/price reductions for faulty finished fabric.
d) return costs: internal works and customer returns, including associated freight costs.
e) compensation: this includes price reductions for non-compliance with delivery dates in accommodation cases.

Costs due to quality requirements amount in total to about 6–10% of turnover. They vary relative to product type; in the case of simple products, they are about 3%, whilst they can be as much as 15% with high quality products. Here, return costs make up the biggest items at approx. 50% . Quality assurance is an instrument for reducing costs due to quality requirements. We can differentiate basically between two types of quality assurance: operational checks (semi-finished and finished inspection) and the work carried out in the laboratory for quality assurance. Operational check costs are difficult to particularise, since operating personnel and supervision, which also check at the same time, are essential in any case. Precise costs are not recorded, but amount to at least 5% of turnover. Quality assurance itself, including the work carried out in the laboratory to that end, represents a cost factor of approx. 1.5% of turnover. As far as the laboratory is concerned, an investigation should be carried out as to whether installing and using an in-house laboratory is more cost effective than engaging the services of an independent institute. In any case, it is sensible for small and medium-sized firms to have special checks made by testing institutes, since it is uneconomic to buy expensive special testing equipment which is seldom needed.

Cost comparisons Not only colour, design and quality, but also price, are decisive in textile finishing for the success or failure of a collection. Particularly important for pricing in the case of a fashion-dependent product are product appraisal by the customer, and the limit of his or her readiness to pay. In pricing, fashion article producers must be oriented to target group purchasing power, and may not exceed the selling price of an upper limit laid down by consumers. The lowest price limit for a product is set by the production piece costs incurred. Piece costs for calculating selling price are determined via cost calculation, which is preceded by cost class calculation and cost centre calculation (in the following weaving/printing comparison).

1. Cost class calculation embraces the itemisation of all costs the company has to bear, and is dependent on company size and structure. These costs comprise:

a) the annual fixed costs (interest, amortisation, maintenance costs, premises etc);
b) material costs;
c) personnel and personnel incidental costs;
d) energy costs (these are considerably higher in printing than in weaving, owing to water and steam costs);
e) other costs occur in printing by way of dyestuffs and chemicals, which occur only indirectly in weaving as warp and weft yarn dyeing costs.

2. Cost centre calculation involves the allocation of total cost to individual production areas. The main cost centres "printing" and "weaving" should be clarified in comparing the cost of printing and jacquard weaving for example. Recording these costs poses a particular problem, since they are affected by different variables within the recording period. For the "printing" cost centre, these are:

- the printing process used,
- the number of designs printed,
- the number of colourways printed,
- the number of colours per design,
- the number of metres printed per design and colourway.

From these, various production times, change-over and machine stopped times, fabric production lengths and fixed cost contents occur for the cost centre, from which the cost per metre of individual products is calculated. For the "weaving" cost centre, the following variable parameters have to be taken into account:

- woven fabric construction (number of warp ends and picks/cm, number of warp and weft systems),
- number of designs woven,
- number of colourways woven,
- number of colours per design,
- running qualities of warp and weft yarns,
- the number of metres woven per design and colourway.

As in printing, and for the same reasons, there are different costs per metre for a product. The cost of producing pattern carriers, jacquard cards and printing screens can be apportioned in different ways:

a) the average screen or card costs are recorded per season, and apportioned as a patterning surcharge on the total patterning cost.
b) screen or card costs are apportioned to the lifetime of the design, it being taken into account that not every design has the same lifetime, while some are not even put into production under certain circumstances.
c) screen or card costs are apportioned over the lifetime of the screen or the card.

As far as the latter are concerned, the cost of printing after-treatment (fixation, washing and drying) and fabric finishing (desizing, washing and drying) have to be calculated for the "printing" and "weaving" cost centres, since they differ in terms of printing process, fabric weave and raw material. In addition to the purely technical costs, the development and patterning costs play an important role. They are to be calculated as special individual costs as a rule, since, independently of the number of metres produced, they represent one-off costs, which may have a different volume depending on type of order (in-house production or production to order).

3. The individual product cost can be calculated from the total cost determined (cost class calculation) and the costs arising in individual production areas (cost centre calculation) with the aid of cost product unit calculation. Short-term cost product unit calculation is indispensable, particularly for the fashion-oriented business with a wide product range, in order to be able to calculate products newly admitted to each collection. In the preliminary calculation, the variable costs and the fixed costs calculated on an assumed production quantity form the calculated unit price (price per metre). The actual unit cost can be determined in costing only if the number of units sold is known. The higher the sales figures for a design, the lower the fixed cost proportions, and the more easily the product can be calculated. Unit cost comparison between a print design and a jacquard design is extremely difficult due to the different production cycles and operational stages in weaving and printing. Nevertheless, identical basic assumptions must be laid down for the calculation example in order to obtain, via the product unit calculation, comparable results for the print design and weaving design product units (Tab. 1).

a) Only the cost of the materials supplied and the technique employed are compared. Design patterning and development costs are not taken into account in the calculation.
b) The cost of the printing forms and jacquard cards are apportioned over the number of metres produced (150 m, 3000 m, 10 000 m).

Cost comparisons

Material/operational stage		150 m	3000 m	10000 m
1. Printed fabric	3 DM/m	450.00	9000.00	30000.00
2. Printing form	600 DM/colour	1200.00	1200.00	1200.00
3. Ground dyeing	0.10 DM/m	15.00	300.00	1000.00
Colourways	7 DM/colour	63.00	63.00	63.00
Printing paste	3.20 DM/kg 0.08 kg/m	38.40	810.00	2700.00
4. Printing	(*1)	631.00	10800.00	17800.00
Fixation	0.23 DM/m	34.50	690.00	2300.00
Washing	0.52 DM/m	78.00	1560.00	5200.00
Drying	0.09 DM/m	13.50	270.00	900.00
Total price of batch		2523.40	24693.00	61163.00
Unit price per metre		16.82	8.23	6.12

Tab. 1: Figures in product unit calculation for producing a printed product on a rotary screen printing machine. (circa 1990) with production lengths of 150 m, 3000 m and 10 000 m per design with 3 colourways.
*(*1) printing cost for 150 m = 4.21 DM/m; for 3000 m = 3.26 DM/m; for 10 000 m = 1.78 DM/m.*

c) The personnel and machine costs per hour for single shift operation form the basis of the cost per metre used for operational stages 3 and 4 of the product unit cost calculation.
d) The products to be produced should be of equal value as regards raw material, colourability, finished width and quality.

The costs used for operational stages 1–4 are average values, which can be changed upwards and downwards in the individual case. The prices for the grey fabric supplied are dependent on fabric quality and country of origin, and also on the expenses necessary for print preparation. The screen costs to be used (Tab. 2) are calculated from screen size, gauze mesh fineness, the transfer process and the time required for producing colour separations and complete films. The price difference for flat printing screens and rotary printing screens is of a ratio of 2 : 1.

Screen type	Printing width (in mm)	Screen fineness (points per inch)	Price (DM)
Rotary screens	641 / 1620	40 - 80 mesh	728.00
	819 / 1620	40 - 80 mesh	785.00
	914 / 1620	40 - 80 mesh	940.00
Flat screens	1250 / 1500	40 - 80 mesh	372.00
	1500 / 1500	40 - 80 mesh	400.00
	1750 / 1500	40 - 80 mesh	438.00

Tab. 2: Cost example (circa 1990) for rotary printing screens and flat printing screens with identical mesh fineness and the indicated printing widths.

The cost of ground dyeing, colourways and printing pastes is dependent on the dyestuff classes employed and the required quantity/kg. In printing paste calculations, account should be taken of the fact that 13 % of the paste does not reach the fabric. The loss is due to residues in containers, pipes, pumps, screens etc. The cost per metre of the printing, fixation, washing and drying operations is calculated from the personnel and machine cost/hour and metres produced/hour ratios, different hourly rates being used for the printing process relative to fabric length.

The unit costs listed in Tab. 3 are incurred for producing the jacquard product in batch sizes of 150 m, 3000 m and 10 000 m:

Material/operational stage	150 m	3000 m	10000 m
1. Material			
Warp 2.18 DM/warp metre	399.00	7980.00	26600.00
Weft 0.48 DM/m weaving length			
2. Jacquard card 1175 DM	1175.00	1175.00	1601.00
3. Weaving 1000 picks à 1, - = 3.60 DM/m	540.00	10800.00	36000.00
4. Washing 0.52 DM/m	78.00	1560.00	5200.00
Drying 0.09 DM/m	13.50	270.00	900.00
Total price of batch	2205.50	21785.00	70301.00
Unit price per metre	14.70	7.26	7.03

Tab. 3: Unit costs (circa 1990) for the production of a jacquard article in various batch sizes.

Here too, the costs used for operational stages 1–4 are average values, which can be changed by different affecting parameters. The warp and weft yarn costs are dependent on raw material prices and dyeing costs, and can reveal big differences. The costs to be used for the jacquard card are oriented to the number of picks in the repeat and the number of controllable warp ends. Depending on repeat dimensions, there are big price differences, which can be illustrated for a 1344 jacquard machine.

The cost of reading in the model, copying in the card via the computer, and card copying for the required card length is calculated. Depending on the mill, the weaving costs lie between 0.08 DM and 2 DM per 1000 picks. The cost of after-treatment (point d of the product unit cost calculation) is calculated from the personnel and machine cost/hour and metres produced/hour. The cost calculation result for both articles points to a different cost degression as product quantity increases. Cost degression comes about because a specific proportion of fixed costs (printing forms and colourways, jacquard cards) are offset by the quantity-proportional costs (material and personnel costs). Comparison of the degression curves shows that, with a production quantity between 4000 m and 5000 m, the unit costs for a comparable jacquard woven article are lower; above this quantity, the prices per metre of the printed article are lower.

The difference in cost degression curves is, among other things, attributable to the fact that jacquard cards have a shorter working life (4000 m to 5000 m) than printing screens (10 000 m to 15 000 m). After 4000 m to 5000 m production length, the cost of a new set of cards (card copying and punching) increases the proportion of fixed costs for the jacquard product, while the fixed costs of the printed article remain the same up to a production length of 10 000 m to 15 000 m. After that, the cost of a new set of screens arises here too. The calculated unit prices of the jacquard article at 14.70 DM, 7.26 DM and 7.03 DM and the printed product at 16.82 DM, 8.23 DM and 6.12 DM are very high, since single-shift production was taken as the basis of calculation. With optimum utilisation of the production capacity in three shift operation, the unit costs of the printed article can be reduced by about 30% because, among other things, the high proportion of setting-up time at the beginning and end of the shift in single shift operation can be used as production time in three-shift operation. In jacquard weaving, a unit cost reduction of approx. 15% is possible in three-shift operation, since here there is no significant setting-up time at the beginning and end of the shift as compared with printing. This means that the degression curve for a printing works producing in three shifts reveals a considerably steeper rise as that in the weaving mill, and the intersecting point of the curves moves in favour of the course of unit costs in the printing works. Nevertheless, unit prices for the jacquard product are lower here too with short fabric lengths.

The unit prices to be calculated by the manufacturer for the individual articles of a collection are not exclusively determined by patterning technique. Depending on plant size, production capacity and production quantity, an article can be produced more cost effectively or at the same cost with one or the other patterning technique. A further decision criterion for using one or the other patterning process is represented by the economic requirements on fashion-dependent production.

Cost structure Reveals a hierarchy in textile finishing. If one looks at the cost of a textile product from the consumer standpoint, the textile pipeline cost structure breaks down into the following areas: commerce, making-up and textile industry. Thus, the cost of a man's cotton/polyester suit for example is illustrated in Fig. 1.

If the selling price is 100%, approx. 15% falls to value added tax, 39% to sales, 29% to making-up, 15% to yarn and woven fabric production and 2% to fibre material (raw material purchase). If we examine the cost structure of a finished woven fabric, we see that the yarn production cost makes up only 20–30% of the cost incurred in spinning, weaving and finishing. Here, the yarn must meet the following requirements:

a) the yarn structure must be suitable for the end-product.
b) running behaviour must be free of problems in weaving and weft and warp knitting, inclusive of all preparation stages. Yarn breakage behaviour in spinning is a determining factor for behaviour in further processing. This also applies to fly, the adhesion of fibre to fibre and work capacity.
c) the raw product must be capable of being used again without difficulty after finishing.

The costs incurred in producing a woven fabric are as follows (Fig. 2):

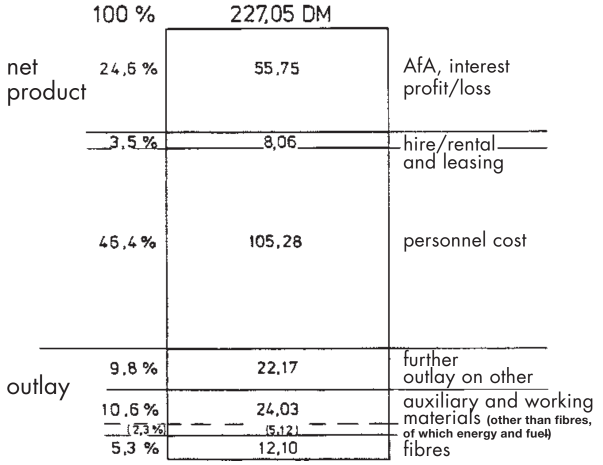


Fig. 1: Possible cost structure in the textile pipeline of a man's suit (wool/polyester).

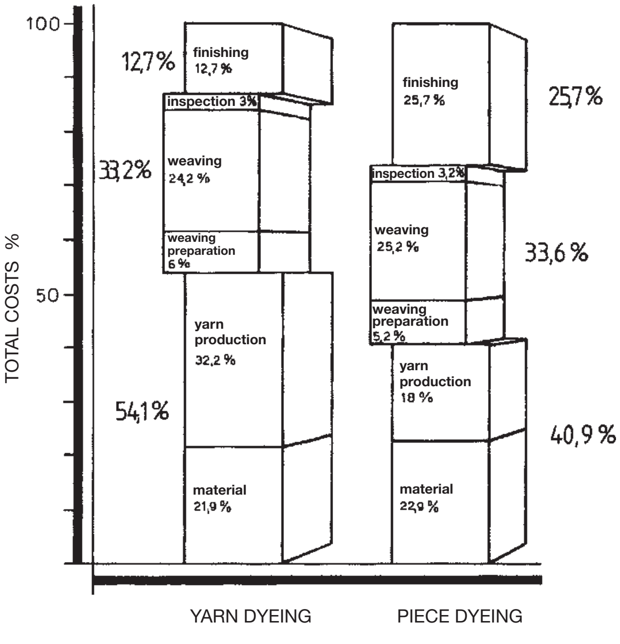


Fig. 2: Cost structure of a woven fabric up to finishing.

Cost structure

	% cost with articles of Cotton	% cost with articles of Wool/polyester
Material	23	34
Spinning	14	38
Weaving preparation	8	
Weaving	35	} 19
Darning	6	
Dyeing and finishing	14	9

Tab.: Cost distribution in woven fabrics of different raw materials.

Production method of course has an effect on this cost structure, depending on the fibre material employed (Tab.).

In a commission finishing mill which turns over DM 50 mill. per year, and brings into circulation a fabric value of approx. 300 mill. DM, the cost structure is composed as follows (with no material cost incurred):

– wages	42%
– energy	18%
– dyestuffs	16%
– effluent	3%
– administration	3%
– repairs	4%
– craftsmen	2%
– returns	6%
– depreciation	6%

Relative to an individual dyeing process, we differentiate between net dyeing cost and added dyeing cost. Net dyeing cost proportions (Fig. 3) can be determined by computer or by programmable examination. Brought together under the added dyeing cost concept are all machine dyeing cost percentages, which also change during net dyeing time specifically to operations and batches, particularly those relative to quality and delivery, and for which calculatory processing and production time reserves are prescribed on the basis of operational experience values. In addition, it is advisable to view the drying and additional cost of part batches, overhead costs and quality assurance and testing costs under the aspect of added dyeing costs, as this contributes considerably to cost transparency between technology-oriented and experience-oriented cost percentages.

In Fig. 3, we have taken the representative net dyeing cost of a machine dyeing example. The percentage net dyeing cost was entered for batch weight $G_T = 200$ kg and $G_T = 500$ kg. In addition, the net dyeing cost of a 200 kg batch was illustrated in column terms, relative to dyeing times of 4, 6 and 8 hours. Under the pump drive aspect, it should be recognised that approx. 10% of net dyeing cost is taken up by the pump drive power cost. The effect of pump drive speed regulation on energy cost can be estimated by examining the fact that the hydraulic output of a centrifugal pump changes approximately as the cube of the pump speed. If pump output is reduced to 80% of nominal speed, the hydraulic output of the pump falls to $(80\%/100\%)^3 = 0.51 \cdot 100\% = 51\%$ of output at 100% nominal speed. Even

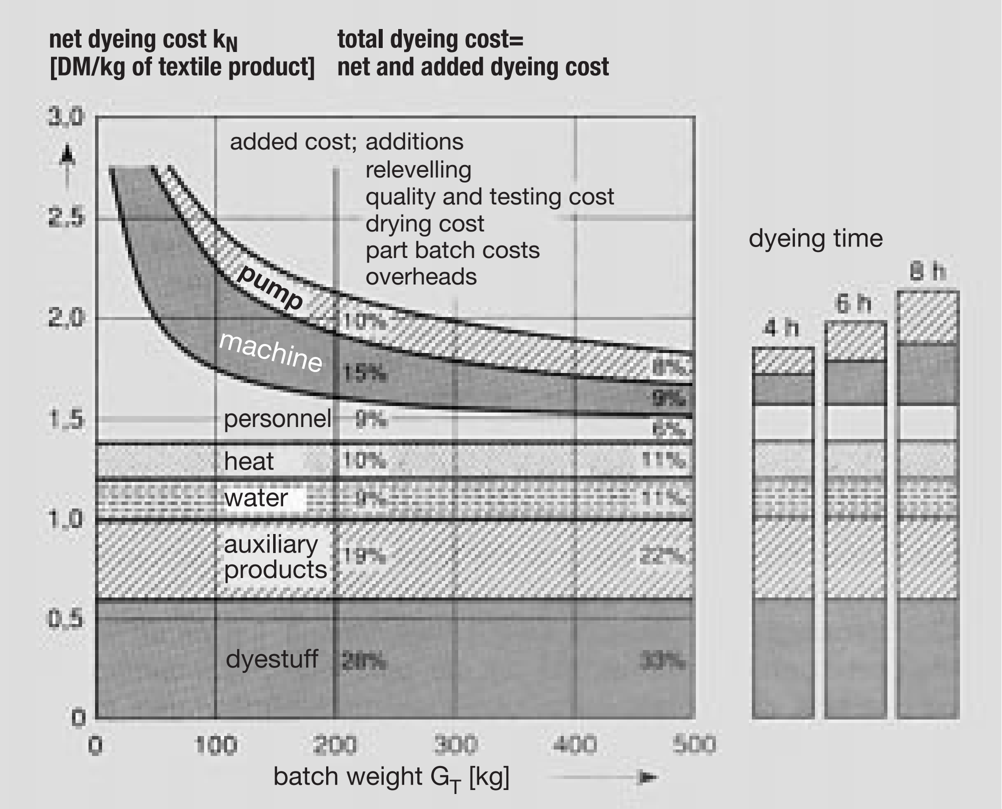


Fig. 3: Spread of representative net dyeing costs over the batch weight of an exemplary machine dyeing (Kretschmer).

taking account of the speed-dependent pump and motor efficiency level, it is permissible to assume that the power cost of the electric motor drive falls approx. quadratically as the speed is reduced. If pump speed for example is reduced to 80% of nominal speed, the energy cost falls approximately to $(80\%/100\%)^2 = 0.64 \cdot 100\% = 64\%$ of the energy cost at 100% nominal speed. In line with trends and practical experience, it is also of advantage in cost terms to operate piece beam and yarn package dyeing machines with speed controlled pump drives, particularly as this is amortised in less than 1 year (partially in accordance with Kretschmer).

Côtelé (Fr.: côte = rib). Worsted and cotton fabric with fine compact warp ribbed or striped textured appearance, sometimes in patterns or checks etc., commonly called bengaline (England and U.S.). French term for corduroy, although in German trade terminology generally used for finely constructed fabrics having cord-like warp-way ribs. End-uses: ladies wear, suits and coats.

Cottage steamer → Steam mansard.

Cotton The seed hair of plants in the Gossypium botanical genus of the mallow family. After flowering the ovary located in the calyx develops into an elongated capsule which bursts open to allow its seed hairs to billow out. A cotton capsule contains about thirty seeds and each seed is host to 2000 to 7000 seed hairs. Depending on cultural strain, climate and cultivation, plants attain a height from 25 cm to over 2 metres. They are cultivated predominantly as shrubby annuals. There are only a few areas (Peru and North Brasil) where cotton is grown as a perennial and here plants may be up to thirty years old. The period from sowing the seed to harvesting the cotton amounts to between 175 and 225 days. At the time of sowing the plant needs moisture and when it is ripe in needs considerable heat. Therefore the zones of cultivation are located in tropical and sub-tropical zones. After harvesting the cotton bolls are allowed to mature and dry for around thirty days and are then ginned in cotton gins which separate the fibres from the seeds. 100 kg cotton bolls will yield about 35 kg fibres, 62 kg seeds and 3 kg trash. The cultivation of one tonne of harvested cotton requires 400 kg fertiliser, 40 kg insecticide and 1.2 kg defoliant (systemic in action). Examples of yields per hectare in 1990 were: Israel up to 1300 kg, USA and China each approx. 650 kg, Uganda approx. 30 kg. For the purpose of transport the cotton fibres are press-packed into heavy bales wrapped in jute and held by steel bands. They are shipped in this form and arrive at European warehouses and spinning mill destinations via transshipment ports such as Bremen, Venice/Trieste, Rotterdam/Antwerp.

Raw cotton in the trade is classified by fibre length (staple), uniformity, fineness, colour, cleanliness, handle, strength and elasticity. Principal defects are impurities, short staple and high content of immature and badly developed or "dead" fibres. Some grades are of harsh rough handle whilst others are silky soft. In terms of colour, raw cotton is graded as "white", "creamy", "light spotted", "spotted" and "light grey". The most important quality attribute is the staple length. This is generally between 18 and 42 mm. The separate grades are divided into the following four classes according to their maximum staple length:

short staple	< 26 mm
medium staple	26–29 mm
long staple	30–38 mm
extra-long staple	> 39 mm

Quality criteria are:

- length and length distribution, including uniformity of length and percentage short fibre (excessively long fibres can also be troublesome)
- strength
- trash content, subdivided as follows:
  - a) Trash: percentage content, particle size and nature of the trash (taking into consideration the propensity for removal, seed hull fragments, particulate matter etc.).
  - b) Dust: percentage content and particle size (distinction is made between micro-dust and inhalable dust).
  - c) Foreign matter and contaminants (e.g. plastics).
- Fineness (micronaire).
- Maturity index and distribution, including "dead" fibres.
- Colour (including dyeing characteristics and colour defects; generally associated with certain fibre dimensions and structures); other colours such as beige, brown or green are genetically possible.
- Neps (size and distribution).
- Fibre convolutions (twists).
- Stickiness (mainly but not solely caused by honeydew).
- Fibre friction (probably mainly associated with surface wax).
- Elasticity, modulus and breaking strength (associated with some of the attributes already listed).
- Bulk and crimp (associated with convolutions and other properties).

A great deal of progress has now been achieved in efforts to characterise objectively, comprehensively and precisely the textile quality and value of cotton. Systems such as the AFIS method of integrated comprehensive lint analysis and the NIR system (e.g. for stickiness, maturity, dyeing propensity, moisture content and nature of the trash content) could be features of the new generation of HVI (= High Volume Instrumentation, comprising at present micronaire index, strength, length, length uniformity index, colour reflectance index, yellowing, colour gradation index and trash content, plus classified grade). It is important for existing HVI tests to be standardized, improved and fully utilised and for the present HVI system to be extended to include other significant fibre properties. It is a challenge for all spinners throughout the world to make effective use of present and future HVI data.

Some possible applications of the HVI system include:

1. Classification, marketing and the use of data telecommunication systems in cotton classing and data processing.
2. Optimum selection of cottons for specific end-products, processing conditions and for intended blend assembly (e.g. the EFS programme).
3. Establishing the price of cotton in relation to its true textile value and its quality.
4. Cotton breeding and cultivation with improved interchange of information between breeders, producers, gin operators and processors, although for example fibre strength should not necessarily be the main criterion in the breeding programme.
5. Ginning trials, estimation of cleaning propensity and fibre damage, although still better SFC and neppiness test methods are needed.
6. Accurate forecasting of processing performance and product quality using empirical regression equations specific to the spinning plant.
7. Computer controlled and computer assisted fibre processing and yarn production.

The fibre presented for processing is often heterogeneous containing a certain proportion of immature and dead fibres. Immature and dead fibres, because of their different nature, do not conform in their dyeing behaviour and require additional processing stages (Tables 1 and 2). “Hard” and “red” cottons are the exception with a high content of calcium and iron compounds respectively. With the former, problems can occur for example with constantly increasing liquor contamination, especially in continuous preliminary processes such as short liquor treatments. In the case of “red” cotton problems in the form of “dirty whites” arise in bleaching and optical brightening.

Cotton, acetylated → Acetylated cotton.

Cotton, aminoethylated → Aminoethylated cotton.

Cotton damask Jacquard-patterned cotton fabric with satin ground, for bed linen and table linen. The clarity of the figurative designs is achieved by the technique of warp and weft satin weave. The silky lustre is intensified by a special finish.

Content of:	Content in:	
	ripe cotton	unripe cotton
Cellulose	90 - 95 %	reduction
Pectins	0.7 - 1.2 %	–
Proteins	1.1 - 1.9 %	increase
Wax, fats	0.4 - 1.0 %	increase
Organic acids	0.5 - 1.0 %	increase
Total sugar	approx. 0.3 %	–
Ash	0.7 - 1.6 %	increase

Tab. 1: Characteristic composition of ripe and unripe cotton (CO).

Impurities	Colouristic effects
With raw fibres	
Seed husks, leaf and stem residues Neps	Impairment of fabric appearance depending on article and dye selection
Residues of: - insecticides - growth regulating agents - defoliants	Staining, possibly resisting
Metal traces	Rust stains, bleach damage
Foreign fibres	Resisting
After spinning, weaving	
Size and spin finish residues	Unlevelness, resisting
Oil and graphite residues	Light/dark stains
Abraded metal	Light stains, possibly holes
Dirt Dust from storage	Unlevelness Resisting

Tab. 2: Impurities in cotton articles from which difficulties frequently arise in textile finishing.

Cotton dust → Byssinosis.

Cotton fibre fine structure The molecular chain of cellulose (Fig. 1), as the basic substance of cotton, is stretched. Stretched conformation of the polymer chains is also present in analogous form in polyamide fibres and polyester fibres, as well as in the crystalline areas in silk. By contrast, the chain molecules in unstretched wool (α-keratin) and in polypropylene fibres are shortened by helix formation (screw formation).

The cellulose molecules stabilise themselves, lying parallel, through inter-molecular and intramolecular hydroxyl bonds (Fig. 2) which, in spatial construction, leads to a unit cell in X-ray terms. In the cellulose grid according to Fengel, the chain pairs run counter to each other.

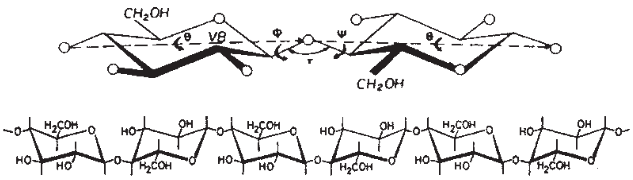


Fig. 1: Steric cellulose formula of the cotton fibre (bottom) with possibilities of free turning capacity in a cellobiose unit (top).
VB = molecule longitudinal axis; Q = rotation of the entire monomer; t = bonding angle with the glycosidic oxygen;
F and y = rotation about the C–O bond with the glycosidic oxygen.

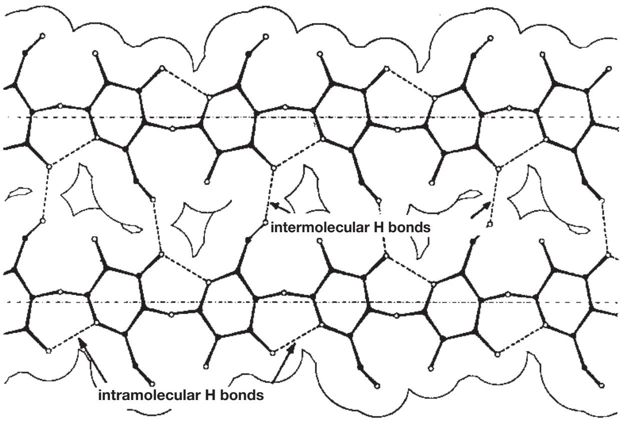


Fig. 2: Intramolecular and intermolecular hydrogen bridge bonding in two adjacent cellulose chains of the cotton fibre.

The internal structure of the fibrils has not yet been fully described, and various models will be discussed. The models are, however, based on 3 basic types:

1. Micelle model, in which the less ordered areas are formed from molecule chains that change over from one fibril to another. With this model, a certain variation in the fibril diameter can be explained (Dolmetsch, 1968).
2. Strand model, which consists of individual fibrils of the same diameter with non-ordered areas or defect points (Mühlethaler, 1969). Particularly in the second case, additional non-ordered cellulose molecules are necessary for the corresponding degree of crystallinity to be achieved.
3. Fold model, in which the non-ordered areas are explained by the reversing points of the molecule chains. An anti-parallel chain course results from the change in direction of the molecules (Marx-Figini, Schulz, 1966; Menley, 1964). However, the physical behaviour of the cellulose contradicts a model of this kind to a certain extent.

In the supra-molecular construction, the elementary fibrils organise themselves into microfibrils. The amorphous area of the cellulose fibre cotton is characterised by its ability to swell in water; during drying, this water is removed with the release of energy (Fig. 3). In contrast to this reversible swelling, the whole fibre structure reacts irreversibly in the case of swelling with soda lye (e.g. in the case of mercerisation), with cellulose I transforming into cellulose II (Fig. 4).

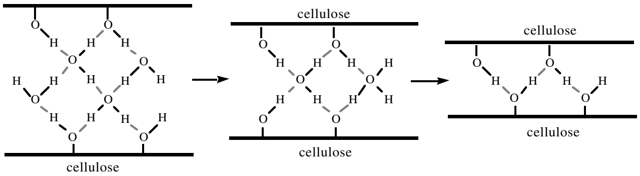


Fig. 3: Drying process between cellulose surfaces of the cotton fibre.

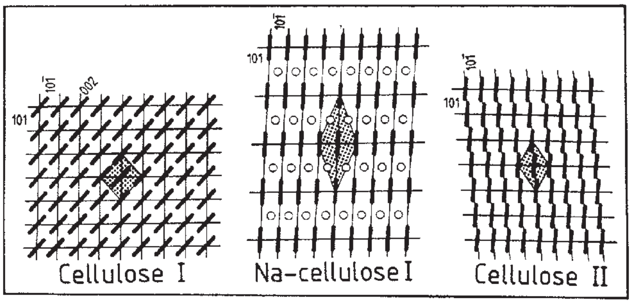


Fig. 4: Grid of cellulose I, sodium cellulose I and Cellulose II. The horizontal mathematical lines connect a "sheet" in each case (a series of imbricated cellulose molecules in the cellulose I) of the cotton fibre.

Whilst the models of Frey-Wyssling and Mühlethaler are still 2-phase models, the alternative concept of the cotton fibre represents a 1-phase model, which assumes homogenous, crystalline cellulose, with certain faults in the crystal structure. This direction has been most emphatically pursued by Statton. However, a super lattice of the cellulose results not only – as for example with synthetic fibres – from the sum of the faults caused by the ends of the molecule chains in a fibre crystal ("kinks", "jogs"). Rather, a certain number of parallel cellulose chains combine to form sub-units, which then cause the typical morphological structure of the cotton.

If one follows the efforts of the structure researchers in the field of cotton to discover the smallest sub-unit of fibre morphology, then one could state that since the use of the electron microscope (around 1953), the diameter of the smallest sub-unit which can still be demonstrated has shrunk to around 30% with the increasing perfection of the techniques applied. The most extreme view represents the claim that the smallest sub-unit, which it will not be possible to demonstrate optically only because of deficiencies of resolution, is the cellulose macro-molecule. On the other side, studies from quite different directions (X-ray, infra-red spectroscopic, electron-microscopic, chemical, physico-chemical) have now condensed the picture of the morphological structure of cotton to such an extent that it is more appropriate to postulate a bio-synthetically-based basic unit, the elementary fibril, than to assume a distribution of all possible fibril diameters which is subject to the laws of probability. This view is also supported by a study by Mühlethaler, which showed that certain amoebae produce polysaccharides in biosynthesis in an extra-cellular manner, in the form of proto-fibrils with a diameter of 3.5 nm.

When the biosynthesis of the cotton fibre in the seed

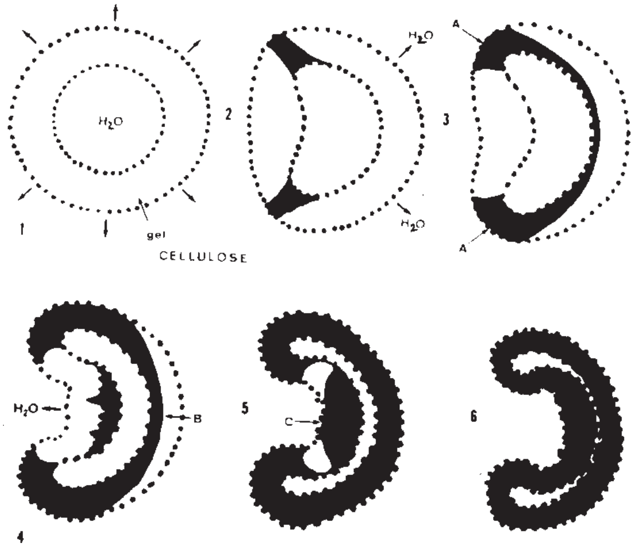


Fig. 5: Kinetics of cotton fibre collapse in original drying (Kassenbeck).

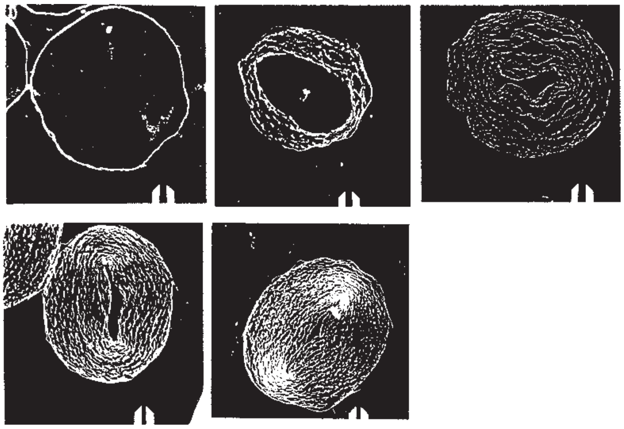


Fig. 6: Cotton fibre growth in the cross-section of a series of electron microscope photographs. After initial formation of the primary wall, which illustrates the "transport line" for conveying the cellulosic building block material, the secondary wall layers appear in concentric rings, growing from outside to inside.

capsule is complete, the product is present as a more or less cylindrical fibre. The capsule bursts open, and the young fibres are subjected to a drying process. Kassenbeck was able to show that the fibre collapses (Fig. 5) depending on origin (degree of maturity, provenance, fineness), resulting in the familiar kidney-shaped fibre cross section. Lately it has been conjectured that the collapsed state grows as such (Fig. 6).

During this collapse (primary drying), asymmetrical, mechanical tensions arise, which cause zones of varying density. Compression forces that act radially lead to an increase in the packing density of the fibrils, and to a parallelisation of the fibril layers in the convex part of the collapsed fibre. The concave fibre wall, lying on the inside, suffers a reduction in the degree of order, due to compression forces that act tangentially. This bilateral structure (Fig. 7) leads, when viewed macroscopically, to differing accessibility of the various areas, so that e.g. in the case of enzymatic hydrolysis of the fibres (a process which – like any finishing operation – is associated with a swelling of the fibre wall), it is predominantly the non-ordered, concave area which is destroyed; the remaining convex part becomes soluble only at an advanced stage of hydrolysis.

Fig. 7: Bilateral structure of cotton according to Kassenbeck.

Kassenbeck showed that this concept also has consequences for the cross-linking of the fibre (with formaldehyde). According to that, due to greater accessibility far more bonds are constructed, but due to the high degree of swelling during cross-linking, the bonds formed are mainly intra-fibril. In contrast to this, the degree of swelling and the accessibility of the convex fibre part is so low that only a few bonds are formed, but these are inter-fibril, and therefore are effective in terms of the desired mechanical stabilisation of the fibre. A disadvantage of this sequence of the cross-linking process is the reduction in the originally good stability of the convex fibre part, which was due to the high degree of order; however, since the stability of the unordered concave fibre part is not changed by the cross-linking, and thus is not improved either, the overall stability of the fibre drops.

Kassenbeck showed that the swelling of the fibre depends, in terms of macroscopic visibility, on the swelling agent used. Thus it has been demonstrated, for example, that caesium hydroxide, in contrast to sodium hydroxide or morpholine, specifically swells the concave part of the fibre. Rolins demonstrated that morpholine separates the crystallites visible by electron microscope from one another, whilst zinc chloride solution swells in an inter-crystalline manner. The crystallites observed here are probably the crystallographically aggregated elementary fibrils demonstrated by Ingram. With the aid of the so-called "dark field image technique", it has been possible to quote the dimension of an elementary fibril as 5.0 nm. These elementary fibrils aggregate to crystallites of varying size, in that their surfaces lie so close to one another that in X-ray terms they form one unit, i.e. they fuse, and therefore together they present a smaller surface when attacked by a medium which swells in an inter-crystalline manner, such as morpholine. Zinc chloride on the other hand cam burst such aggregates of elementary fibrils or crystallite (Fig. 8).

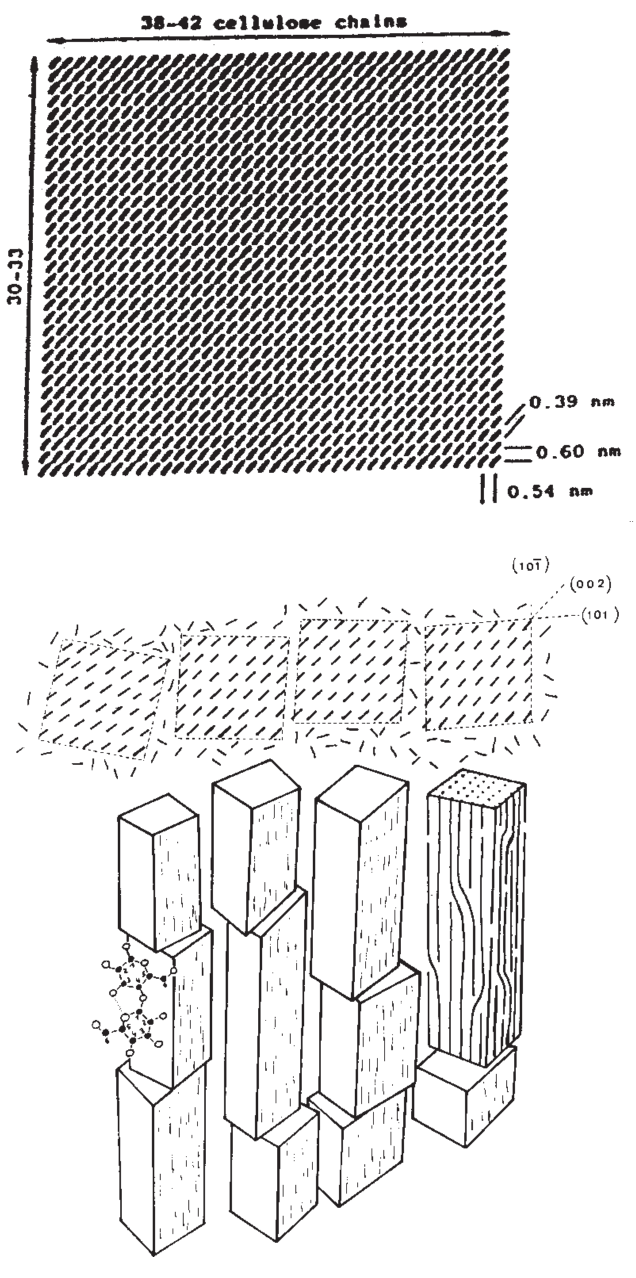


Fig. 8: Difference between models of cotton fibre elementary fibrils which are crystallographically aggregated (Ingram, bottom) and of monocrystals as microfibrils with perfectly arranged cellulose molecules (Sugiyama, top).

Using older terminology, one would probably have described these crystallites as microfibrils of differing diameter. With the aid of repeated methylation operations with diazomethane, Roberts concluded from the accessibility of the cellulose which he had measured, that on average 4 elementary fibrils bundle together, and layer to form higher units. This magnitude accords with electron microscope data from Frey-Wyssling and Mühlethaler concerning the dimension of the microfibrils. Also striking is the agreement between the measurements of an elementary fibril which have been achieved by chemical and optical methods. Mühlethaler established the diameter of an elementary fibril of cellulose as 3.5 nm, which corresponds approximately to an arrangement of 7 x 6 cellulose macromolecules in a rectangular cross section. Roberts determined the dimension of this rectangle as 8 x 12 molecules, of which on the surface of the elementary fibril, during inter-fibril swelling, 36 molecule chains are accessible for chemical reactions.

According to Sugiyama (Fig. 8), however, there are no crystalline sub-structures (elementary fibrils) in the cell wall of Valonia macrophysa, a green algae. Rather, each lamella in the cell wall consists of a flock of microfibrils, the directions of which change by 90° between neighbouring lamellae. The microfibril is a monocrystal with lateral dimensions of 20 x 30 mm, consisting of 1200–1400 perfectly arranged cellulose chain molecules. Sugiyama was also able to isolate amorphous and crystalline substances from cell walls of the green algae, and to distinguish them from one another by means of special staining techniques: here, the crystalline microfibrils of cellulose appear light, and are surrounded by the particles stained by metal salts. The encrusting matrix substances are thus brought into association with the microfibrils, so that on the one hand homogenous, stratified arrangements of micelles are formed, whilst on the other hand the micellar systems of the 2 different substances penetrate in such a way that all surfaces of the one substance are covered by the other. For this reason, the more strongly dispersed phase can develop cohesive bonding features like a type of putty substance.

If one extracts using alkali (e.g. in boiling off), then the encrusting matrix substances are dissolved and what remains is the insoluble crystalline cellulose. After Preston had already questioned the existence of the elementary fibrils as long ago as 1958, he later demonstrated that the microfibril which he favoured is surrounded – as the smallest sub-unit of crystalline cellulose – by a matrix. The matrix contains not only other polysaccharides, but also isolated cellulose chains which, although they are oriented, are not crystallised. These substances which accompany cellulose cannot crystallise at all. Nevertheless, one should not speak of amorphous areas, since this interlaying material is tightly interwoven with the cellulose crystals, whose crystallinity is not necessarily 100% either. Since, on the other hand, surface zones of the microfibrils are para-crystalline or non-crystalline, these days we no longer speak of a 2-phase model of crystalline and amorphous phases, as in the earlier Fransen micelle model. According to Sugiyama, whilst the amorphous material, which can be stained with metal salts, forms a shell around the crystalline microfibrils, so that a network similar to a honeycomb is formed (honeycomb model), this amorphous material is encrusted in such a way that the honeycomb structure of crystallised cellulose microfibrils is probably closer to a 1-phase model, even if gaps are to be observed between the cellulose crystallites and the amorphous polysaccharides. These gaps are enlarged by boiling off with alkali to form pores, so that the dye uptake correlates with the increase in pore diameter. Safaan and Habid define micropores as < 1 nm diameter, transitional pores from 2–6 nm, and macropores > 6 nm. A diameter of 1–3 nm for dye molecules is particularly effective for dye adsorption in equilibrium. This porosity in the water-swollen state has a considerable influence on the speed of chemical reactions and dyeing processes for cotton.

Taking as a basis the unit cell of Marchessault, in particular the anti-parallel arrangement of the macromolecule chains, and taking into account the arrangement – postulated by Hermans – where the anhydroglucose units which follow one after another (with intramolecular hydrogen bonds between the OH group on the C_3 atom and the pyranoside-oxygen of the neighbouring anhydroglucose unit) are slightly rotated against one another, the following sequence results for the chemical reactivity of the OH groups on the surface of the elementary fibrils: $C_6 > C_2 > C_3$.

To sum up, we can state the following:

1 cotton fibre = 15 000 microfibrils
1 microfibril = 400 elementary fibrils (aggregated crystallographically)
1 elementary fibril = 100 cellulose chains arranged in 6–8 packages
Diameter of macrofibril = 400 nm
Diameter of microfibril = 200–300 nm
Diameter of elementary fibrils = 3.5 nm

In the inter-fibrillary spaces of 5–10 width, lignin – amongst other things – fills in as a "cement". The intermicellar spaces of 1 nm located between the elementary fibrils are accessible to H_20, $ZnCl_2$ or I_2, but not for dyes (unless the pores are expanded through boiling off with alkali). Macroscopically, this structure peaks in the texture of the secondary wall, which is surrounded by the thin primary wall (Fig. 9).

The mechanical properties of the cotton fibre depend on this supra-molecular structure; the mechanical stability of the fibre is reduced by chemical cross-linking. The initial stability of the fibre can be increased by more than 10%, so that certain unavoidable losses of stability are of barely any consequence. A corresponding method works as follows:

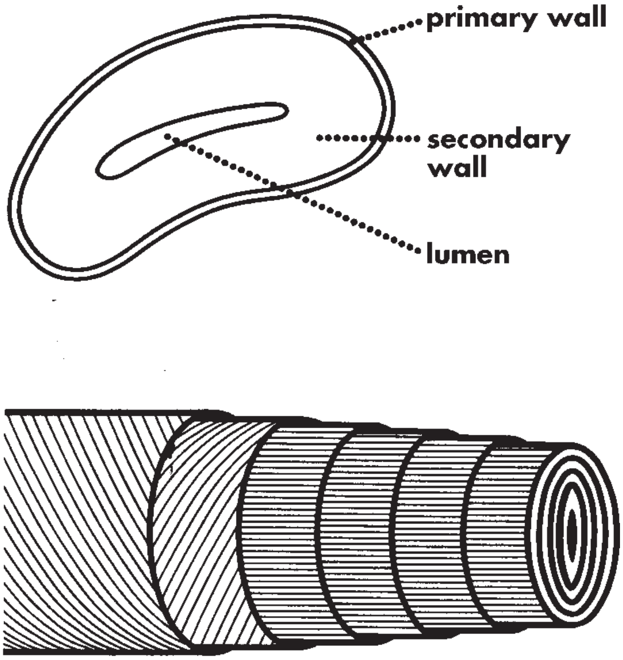


Fig. 9: Model of a convolution-free cotton with its primary wall removed (bottom). The daily secondary wall rings follow on the transition lamella consisting of two opposed layers. Growth in thickness occurs from outside to inside starting from the primary wall (top).

The fibres are treated in mercerisation lye, in the course of which they shrink as usual. Before the fibres are washed out, they are stretched to the original length. The stretched fibre is rinsed, dried and fixed at 120°C. In this way, the typical kidney-shaped cross-sectional shape changes into a round shape, and in stereo-scan electron microscope images, the new fibre is shown to be an even cylinder with a smooth surface. The unwanted bilateral structure is eliminated, and the cross-linking can proceed more smoothly from a macroscopic point of view.

But the fine structure of the fibre has also changed during the treatment, benefiting the stability of the untreated and/or cross-linked fibre. If one takes the 1-phase model of cotton as a basis, the following picture results: The elementary fibrils running parallel in the fibre show differing contact points. Either they are crystallographically aggregated, or they are held together via non-covalent physical interaction (hydrogen bonds, van der Waals forces). The greater the number of these lateral contacts, the lower the possibility of one elementary fibril slipping off from another when subjected to tensile stress or compression load; furthermore, an acting force can be distributed more evenly over the fibre from fibril to fibril. A concentration of

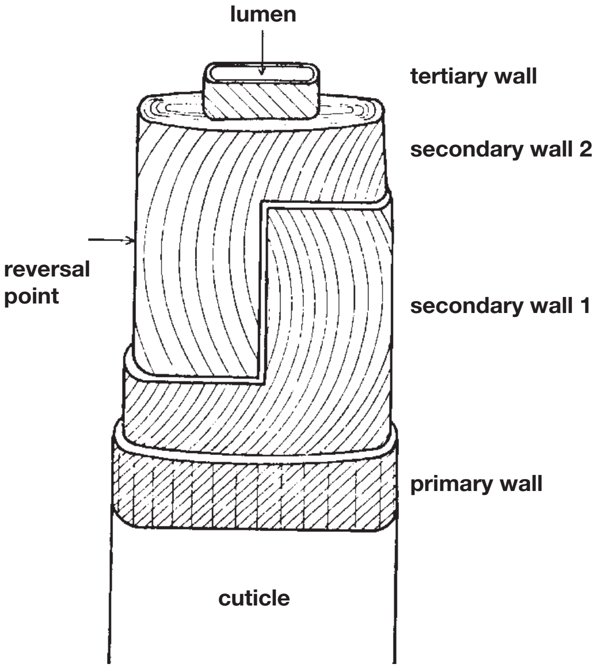


Fig. 10: Sematic model of the cotton fibre with structural reversal points.

the forces will however take place at the point at which a slipping-off of the elementary fibrils is possible due to an insufficient number of contact points between the elementary fibrils. This point (“structural reversal”, in Fig. 10) is the weak point in the system. Here is where the starting point of any tear in the fibre lies, which from this point then progresses fairly regularly along a neighbouring fibril longitudinal axis (Fig. 11).

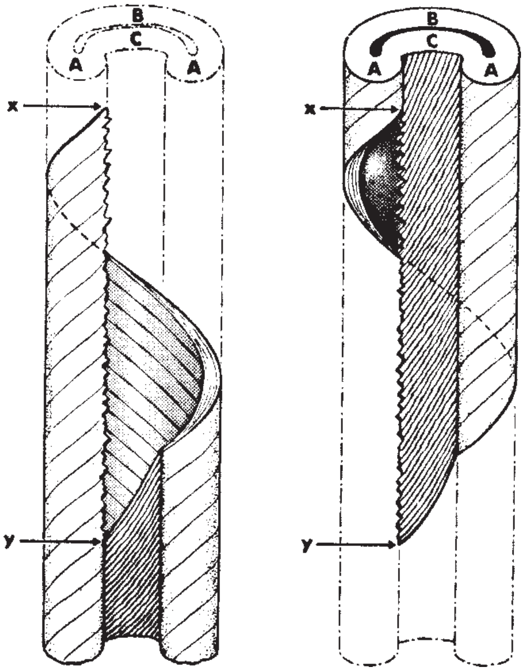


Fig. 11: Fracture along the fiblar longitudinal axis of a cotton fibre (Hearle).

The strength of a fibre thus essentially depends on the regularity (and also of course on the number) of the contacts between the elementary fibrils. The random irregularities that occur during the growth of the fibre would probably be tolerable in this respect if they were not emphasised through the first collapse of the fibre when the seed capsule bursts open, and the associated drying. This can be counteracted either by the production of cotton varieties which have a less pronounced bilateral structure, or by compensating the differences in the packing density of the fibrils which exist in the fibre by means of processes such as mercerisation. Such a homogenisation of the fibre structure prevents the situation where – despite optimum cross-linking in relation to the evenness of the finish -one accentuates those differences which exist in natural untreated cotton, thus causing great losses in stability. For whilst if, in the areas of the firm, untreated cotton, a slippage of the elementary fibrils (even if limited by the unevenness of the fibre) when a force can help to distribute the load a little, by cross-linking the fibres one forces very tightly defined areas to take the entire strain.

The most direct way of achieving a re-packing of the elementary fibrils consists in swelling the fibre up to a cylindrical shape, which was originally set for it during biosynthesis. Through suitable re-crystallisation of the fibre cylinder, this form must then be fixed in order to prevent renewed collapse. There is a pre-treatment process which was developed for yarn by the English firm Coats (Prograde method) and for woven fabric by Norwegian researchers, and which is technically applicable. It involves pre-treating the fibres with liquid ammonia, in which an improvement in the stability of the cotton fibre is likewise achieved (even if not to the extent of mercerisation), so that the subsequently cross-linked woven fabric still demonstrates better stability than the untreated woven fabric. If one treats cotton in this way, a strong swelling occurs, in which H-bonds of the cellulose are split (→ Hierarchical fibre structure).

Cotton fibre tufts Short cotton tufts, coarse, very stiff, more or less coloured. They are found at the pointed narrow end of the cotton seed, and frequently occur in clusters in neps. Cotton fibre tufts can only be separated from the cotton seeds with difficulty and normally require ginning that results in seed shell fragments, in which they are firmly anchored, being found with them. Even after boiling that dissolves the seed shells, the cotton fibre tufts remain spun into the yarns as burls.

Cottonized flax By → Cottonizing of → Bast fibres with a cotton-like short staple is produced with high strength and linen- to silk-like handle. Due to their smoothness, they are usually used in combination with other fibres (cotton, spun viscose, wool etc.), in the cotton spinning system. They are especially suited to fabrics that are very hardwearing and wash-resistant. → Mulberry cottonized bast fibre.

Cottonized mulberry bast fibre → Mullberry cottonized bast fibre.

Cottonizing "To make similar to cotton", i.e. cottoniszing → Bast fibres. Term for chemical retting by alkali scouring for example or acidic chlorine bleaching, the result being the exposure of individual fibre cells cemented and bundled by vegetable glue, which are spun by the 2 or 3-cylinder spinning process into yarns like cotton (→ Cottonized flax).

Cotton maturity index Important factor in evaluating the average stage of development of a cotton quality (→ Green unripe cotton). Due to the use of mechanical pickers, the proportion of immature, abnormal fibres has increased. Determining this proportion is important, since the immature fibres result in a reduction in the quality of the textile goods. The maturity index in accordance with DIN 53 943 indicates the proportion of the number of mature fibres to the total number of fibres in the sample.

Test method:

1. Microscopic procedure, swelling with soda lye: action of 18% NaOH: The assessment is made by assignment to one of the two groups "mature" (cylindrically swollen fibre), or "unripe" (tightly twisted fibre) and/or "dead" (thin-walled, remaining flat) under the microscope.
2. Causticaire method: Determination with the aid of an air flow test device with a causticaire scale. The air flow through it is determined before and after the sample has been treated with NaOH; the so-called causticaire value is calculated in % from the two values.
3. Microscopic method under the polarizing microscope: The interference colours observed on the fibres under the polarizing microscope depend on the specific double refraction of the fibre substance and on the optical thickness of the fibres. With the same fibre substance, the height of the interference colour is a measure of the differing wall thickening. A direct value for the maturity index is obtained.

Cotton Press International Cotton Council International's information office for the processing of cotton; → Technical and professional organizations.

Cotton resist agent →: Retarding agent; Immunization.

Cottonseed oil Density at 15°C = 0.92–0.93. Half-drying oil of shelled and pressed cotton seeds. External features: light yellow, typical odour; raw: reddish brown, odour/taste bitter/rank, saponification number 191–198 (unsaponifiable 1.7%). Without an emulsifier, blown cottonseed oil produces a highly resistant and consistent, slightly soap-like emulsion; reoxidation and rancidification should be excluded. Desize with water at 50°C. Used for oil sizing.

Cotton waste → Linters.

Cotton wax Constituent of raw cotton (→ Raw cotton composition) at 0.4–0.8%. Melting point 70–75°C, saponification number 65. In particular free → Fatty acids of higher molecular weight ([carnuba wax alcohol-] fatty acid ester), 50–55% free, unsaponifiable high molecular alcohol and hydrocarbons. Accordingly around half can be removed by hot alkaline liquors (kier boilings) via saponification. The rest is insoluble and only emulsifiable.

Cotton with natural green colour → Green unripe cotton.

Cotton wool In compliance with DIN 60 000: loose mass of fibres, usually built up in layers (of nonwoven fleece) and condensed, made of fibrous material open to a single fibre, whereby the fibres are held together only by their natural adhesion. Application: upholstery padding; industrial padding (RAL 319 A); glued wadding (glued on one side) for wardrobe inserts; medical padding (DIN 61 640) for bandage and surgical dressings.

Coulomb Physical unit for the quantity of electricity flowing through a conductor in 1 s with a current of 1 ampere. It follows that:

Coulomb = ampere x second

This unit is therefore independent of the electrical potential (volts). The electrochemical equivalent is the amount of electricity required to deposit one (gram) equivalent in electrolysis. According to Faraday, this is 96 500 Coulombs:

1 Faraday (F) = 96 500 Coulombs = 26.81 ampere-hours.

Coulometry allows organic substances to be determined by measurement of the amount of electricity required for their reaction, and so allows Faraday's Law (96 500 coulomb of electricity is needed for the electrolytic deposition of one equivalent) to be applied to analysis. Coulometry used for the determination of organically bound carbon, of adsorbable halogens and of adsorbable, organically bound sulphur depends on the same measuring principles in each case: the gases produced from burning a sample in a stream of oxygen in an infra-red oven are led into an electrolyte. There they react with a part of the electrolyte and so reduce its concentration in the solution. The electrolyte that has been used up is regenerated electrochemically to get back to the original concentration. The amount of current needed for this is proportional to the amount of gas produced and therefore also to the element to be determined in the sample. In coulometry the amount of electricity takes the place of the "titrating agent" . The big advantage of this type of detection is that no calibration is needed.

Counter coat process → transfer coating.

Counter current In drying: the drying medium (hot air, steam, hot gases etc.) flows against the direc-

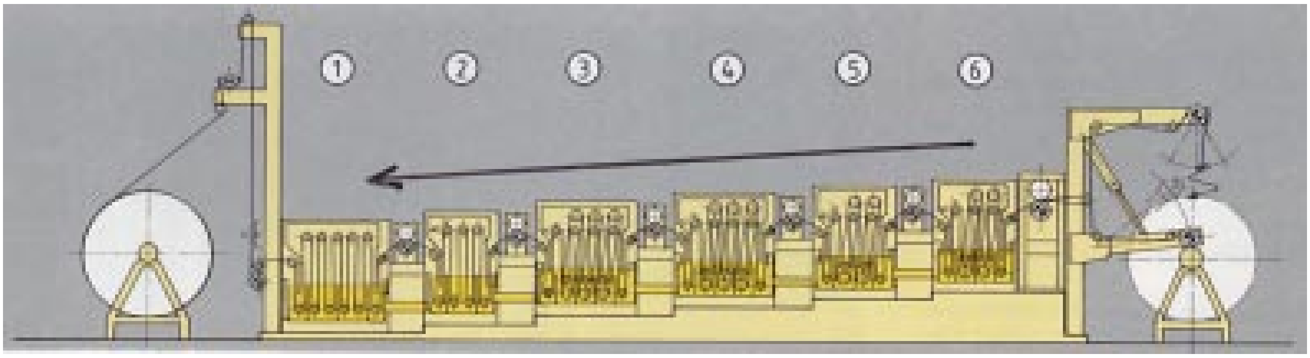


Fig.: Arrangement of 6 roller vats in the counter current principle (fabric flow = left to right; water flow according to the arrow).

tion of the fabric movement (→: Uniflow principle in drying; Circulating air drier). In scouring: the scouring liquor flows against the direction of the fabric movement (→ Counter current washing process).

Counter current principle Diffusion-controlled processes such as scouring are affected both by temperature and an existing concentration gradient. In an open width wash range, it is preferable to bring the clean, fresh detergent solution into contact with the goods being processed at end of their dwell in the range so that the cleanest process liquor meets the cleanest goods in process (see Fig.). By using a counterflow system, the goods first entering the range with the highest level of soiling meet the process liquor with the highest rate of soiling and this soiling is then carried out of the system by the liquor flow. It is necessary to ensure sufficient detergent is used to maintain the efficiency of the scouring process in the first tank. The counter current principle is also used in single-vessel systems (e.g. goods moving from below upwards, solution from the top down) and in the movement of fabric and energy in air currents (when drying).

Counter current washing process Continuous → Flow washing plant with counter-current water supply (bath current) and fabric transport: water supply in the last spray zone and drain-off in the prewash section. Counter current washing processes allow savings in water usage and optimisation of detergent and heating energy. In principle, a series of separate but interlinked machines with phased washing output, either with up to 12 washing units in a double row (individual machines back to back) or in circular layout in series as a carousel (washing machines in the form of frontal washers or Pullman type), on a turntable with localised charging. In the latter case at each phased change all washing units move one stage forward, each washing unit passing through all stations and returning to the start, which is both loading and unloading station. The phase duration depends on the number of machines; in the case of household washing of average soiling 4–8 min. Further developments have led to → Continuous washing plant.

Counterpile rollers The actual raising rollers in the → Raising elements of raising machines.

Counting glass → Piece glass.

Counting tube → Radiation meters.

Couple, to Operation in dyeing: the bottomed naphthol colour is coupled to the dyestuff with diazotised azoic base or the dyeing salt.

Coupling components → Developer.

Coupling of dyeing machines Dyeing machines are coupled in order to extend the capacity of existing dyeing machines, e.g. for large batches. This can be done by parallel coupling or cross-coupling. Existing valves can of course be regulated in such a way that each machine can also operate individually (i.e. uncoupled).

Only machines with identical capacity, identical pump characteristics and identical heating systems should be coupled. Classic cross-coupling (Fig.) is worth while as long as the operation is carried out with a low bath circulation and at low heating-up rates. As we know, bath circulation, heating-up rate and dye exhaustion behaviour have an orderly relationship. When

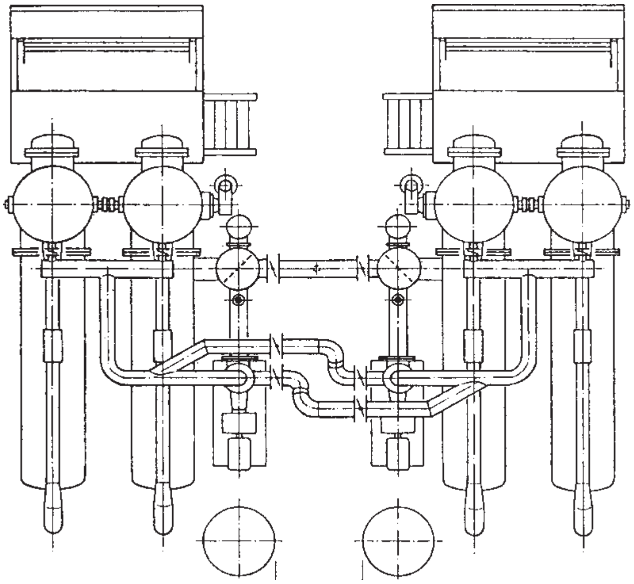


Fig.: Cross-coupling of overflow dyeing machines.

coupling by means of cross-piping, the pumps are located one behind the other, thus halving bath circulation. The consequence of halving batch circulation is that level dyeing can be achieved if the heating-up rate is also halved. If we assume that the heating-up rate is largely utilised up to the maximum possible in individual dyeing operations, the problem of cross-coupling becomes apparent.

If individual and coupled batches are to be treated by the same programme and under identical conditions, the parallel coupling system is offered as an alternative. With this coupling system, the pumps remain in parallel, and the bath circulations are adapted to the size of the batch. Two equal sized machines with identical pumps and heating systems, located close by each other if possible, are linked via a mixing chamber. The liquor of the two machines flows through this mixing chamber relative to bath circulation frequency, and pressure is equalised. Four cut-off units per machine prevent liquor from passing from one machine system to the other in individual dyeing operations. Since the mixing chamber is located between the four cut-off units, this chamber is provided with a drain, which is open for individual dyeing operations, and closed for coupled batches.

Couplings A connection between two coaxial shafts to form one length of shafting and to transmit torque, e.g. from one shaft to another, to gear wheels, pulleys etc. Often also used to transmit power to a machine tool from a motor. They basically consist of two halves connected together by frictional contact or positively (by bolts, claws, springs, teeth). The form of connection depends on what purpose it serves. A bolted coupling is solid and rigid, a claw coupling is positive without being rigid, and flexible couplings are formed by rubber, plastics or sprung steel. Couplings intended for engagement and reengagement during use are termed clutches or release couplings forming a positive connection. These are for use in suituations where a shaft needs to be temporarily stopped or there has to be a change in speed or in direction of rotation.

Course counter For counting the number of courses in → Knitted fabrics.

Because the loops of the courses are aligned three-dimensionally by the hooks in the production of knitted fabrics, the stitch structure can be observed in finishing quality control by optically photocopying these "highlights" by radiating them with light (Fig. 1).

With the Tube Tex "Stitchcounter", an instrument for the quality control of knitted fabrics on running on a shrinkage line, the fabric is illuminated by point light and photographed by a video camera with the aid of a stroboscope (Fig. 2). With the aid of software, the entire background can be filtered out in order to photocopy only the "highlights" – the uppermost tips of the wales and courses of the fabric - on the screen. From this image, the stitch density is calculated in order to obtain a quality standard. "Highlights" are therefore projecting occurrences which it is effective to filter out from the noisy background.

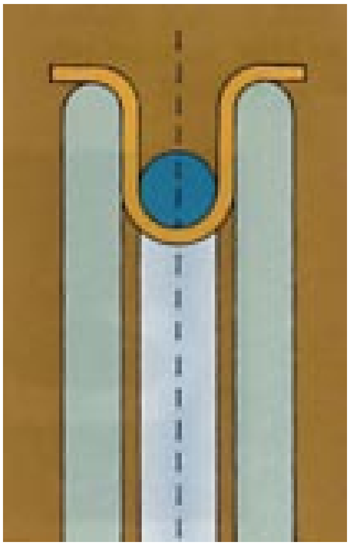


Fig. 1: Interaction between a knitted fabric loop and luminous radiation.

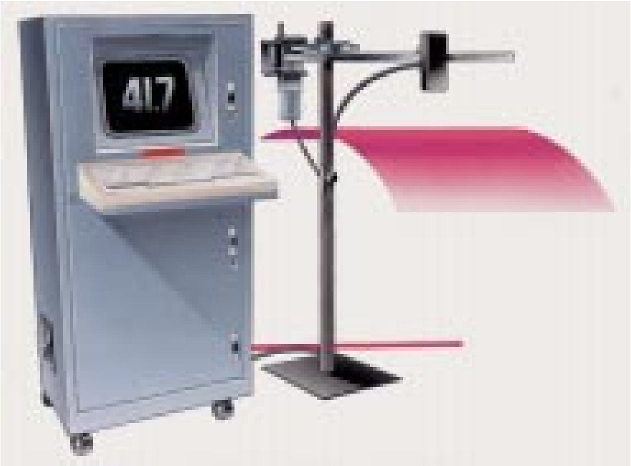


Fig. 2: Tube Tex Stitchcounter (knitted fabric course counter).

Covalent bond → Atomic bond.

Covercoat (Overcoat). Warp generally mouliné twist (which gives a finely mottled appearance) from worsted yarn or carded yarn, weft also made of worsted or carded yarn. In the past, fine covercoats were manufactured from super-fine spun carded yarns with a fine napped finish. By comparison, today's worsted covercoats are generally napless or have a melton finish with a carded yarn weft. Weave: 5-harness reinforced satin. Similar to a gabardine in appearance. Uses: men's coats and rainproof jackets (frequently given a waterproof finish).

Covered yarns Elastomeric yarns covered with continuous filament synthetic yarns or with spun natural fibre yarns of mixtures with synthetic yarns. Not to be confused with (→ Core-spun yarns), in which the elastomeric yarn is spun together with natural or synthetic yarns.

Covered yarns have the following uses:
- hosiery: tights, stockings, socks, men's knee socks;
- clothing: waistbands, gymnastic clothing, ski clothing, underwear, foundation garments, general sportswear;
- technical uses: automobile industry (upholstery); medicine (bandages, surgical stockings); paper industry (reinforcement material for paper felt); protective wear (military uses: nuclear- or gas-protection; special carbon fibre core with sheath made from synthetic or natural fibre), fire brigade, steel industry: as protection from heat; glass with aramide fibre sheath; abattoirs, woodworking: steel core with sheath made of kevlar filaments; space technology, high-temperature protection: quartz or ceramic core with sheath made of synthetic filament yarns.

Yarns for clothing and technical applications (e.g. automobile industry and medicine) usually contain an elastic core. Covered yarns for hosiery and clothing necessitate the production of a dual-component yarn for core and sheath. The core is normally an elastomeric, either a synthetic elasthane or a natural rubber product. The sheath consists of a textile yarn, normally synthetic filament yarns; but there are also products with synthetic and natural fibre spun yarns. The synthetic filament yarn may be either flat or textured and may, depending on its final use, be made with either a single or a double cover.

The most active branch of the covered yarn industry is the market for ladies' hosiery, especially in the USA where it is twice as big as in Europe. Whilst demand in the US was originally for products with fine titres and double sheaths, in the last few years it has developed into a market for practically 100% single-sheath products.

Growth is now in air jet sheathing because of the cost per kg. It is estimated that 50% of the 1500 mill. pairs of ladies' stockings manufactured annually in the USA have an elasthane core:
- 3% with double covering,
- 36% with single covering,
- 10% with air jet covering and
- 1% without covering.

Around two thirds of them have a sheath of textured polyamide 6.6 and the other third of flat filament yarn. The trend is towards flat yarn and away from textured yarns for covering, except for air jet covering, in which textured yarn is currently used. Developments in the field of polyamide 6.6 support this trend. Thus for example DuPont's product with greater strength and lower flexural modulus and other microfilaments are the reason for the trend away from textured yarn for covering in ladies' hosiery; another reason is less twisting (according to I.C. Dupenble).

Cover factor (CF),

I. Knitting. A term used for the comparative assessment of knitted fabric density. The cover factor CF is calculated from the number of knitted courses c, the number of knitted wales w, and the yarn count Nm.

$$CF = \frac{c + w}{\sqrt{Nm}}$$

Alternatively, the density coefficient, D_{coeff}, which is given by the stitch length l (in cm) and the yarn count, can also be used:

$$D_{coeff} = l \cdot \sqrt{Nm}$$

There is a linear correlation between the two. The cover factor is important for the shrinkage behaviour of knitted fabrics during washing. An inverse relationship exists between the CF and the shrinkage in surface area, i.e. the higher the cover factor (knit density) the lower the shrinkage in surface area.

II. Weaving. The cover factor (CF) is a figure indicating the extent to which the area of a woven fabric is covered by either the warp or weft (filling) threads. It is the ratio of fabric surface occupied by yarns to the total fabric surface. Thus for any woven fabric two cover factors are involved, i.e. the warp cover factor and the weft (filling) cover factor.

Covering layer (covering zone, covering effect, skin effect, fibre sheath). A microstructural outer peripheral zone with a physical behaviour differing from that of the fibre core is familiar in various man-made fibres. Differently distributed packing densities in the fibre cross-section entrain far-reaching consequences, particularly in swelling behaviour terms, in dyeing processes (e.g. the retarded dye uptake rate of viscose as against copper fibres) and other intercalation reactions. A denser covering layer, where molecules have preferably to be oriented parallel to the fibre surface, is further demonstrated by polyamide 6.6. for example. In → Silk structure, we also talk of a covering layer in terms of the outer layer zone of degummed fibroin filaments. In the case of viscose fibres, covering layer formation starts as early as in the spinneret (reduced flow rate in consequence of friction at the spinneret rim). In the precipitating bath, during compaction and shrinkage in the fibre core, there follows much quicker coagulation of the outer zone, surface crystallisation being further encouraged, its extent, in the extreme case of stretch spinning, resulting even in a hollow fibre interior. Crystallite orientation in the covering layer begins with the stretching itself.

Cover roller → Blotch roller.

CPB → Cold pad batch dyeing.

CPB (cold pad-batch) liquor stability calculation programme Calculation, developed by Hoechst, of the stability of alkali-reactive dye padding liquors. Following input of the processing parameters and the hydrolysis and temperature constants, the concentration of active vinyl sulphone in the padder trough is calculated by means of a computer programme, preventing any shading occurring due to hydrolysis.

CPB jet dyeing processes Dyeing processes for woven polyester/viscose fabrics, in which a soft, wool-like handle is to be achieved. Cellulose fibres are predyed with vinyl sulphone dyes (reactive dyes) by the PCD process, and the polyester fibres then cross-dyed with disperse dyes in an HT short liquor jet.

Cr, chemical symbol for chromium.

Crabbing Preparatory process for undyed woven fabrics (e.g. ladies and menswear fabrics in worsted, Cheviot and mohair) a) for setting the cloth to restrict excessive creasing and felting in subsequent dyeing, and b) for removing oils and additives. In the case of dyed fabrics, for smoothing and evening out running (rope) marks after dyeing. Undyed fabric after washing is wound under tension onto a roller or in the → Crabbing machine in water at approx. 60–80°C (with the possible incorporation of wetting or cleansing additives). After 10–30 min. dwell in the hot water the cloth is allowed to cool in the roll, or is cooled down rapidly in open-width by cold water, or whilst still warm is immediately rewound onto another roller and allowed to cool. → Wet decatizing.

Crabbing fastness → Fastness to hot water.

Crabbing jack Serves for → Crabbing wool fabrics and mixed fabrics for the purpose of stabilising the dimensions (length and width) as well as immunisation against felting in the subsequent dyeing process. For this, the run of fabric is wound onto a fixed batch roller, which dips into the liquor. Depending on the desired effect, the wound roller rotates for a shorter or longer time in the boiling liquor, and after the process has ended, it is stripped hot or cold (flat-folded or wound up).

Crabbing machine → Crabbing.

Cracking of thickener films If the thickener film placed on the material is not flexible enough it may have a tendency to crack when the dry material is being transported, particularly if hydrophobic fibres are being used. The cracks deposit themselves on the material and lead to dye specks on the material that cannot be removed.

Crackle effects Specific colour effects on woven fabrics, which consist of polygons combined in rows and thin, and from time to time also intersecting, lines, like "splintered" glass or a "broken" glaze in the case of pottery. Produced for example by the → Bubble coloration process.

Craquelé (→ Cloqué). Fabric with relief texture woven with synthetic fibres. Generally produced by mixing high-shrinkage and low-shrinkage synthetic yarns woven in fancy design, the effect being obtained by appropriate finishing. At high temperature (in hot aqueous solution or steam atmosphere) the high-shrinkage yarn contracts and acting in association with the low-shrinkage yarn produces the relief effect. Similar effects can also be obtained by topical application of fibre-swelling or fibre-contracting agents (alkalis, phenols, cresols etc.).

Crayons → Copying ink pencils.

CRB, abbrev. for: Centre de Recherches de la Bonneterie (French Research Centre for Knitwear and Hosiery), Troyes, France; → Technical and professional organizations.

Creaming Term used to describe the upward sedimentation of an oil-in-water emulsion. → Coalescence.

Cream of tartar → Potassium bitartrate.

Crease formation This subject falls within the category of deformations where a distinction has to be made as to whether these are present in a superficial or a substantial form. Whether a permanent distortion forms or not is dependent on the geometry and the friction (superficial form) as well as on the stability of the structural state (substantial form). The entire problem of crease formation is exclusively a question of → Relaxation. Consequently, materials in unstable states are quite easily deformed. Since the relaxation is dependent on time and temperature, process selection and control as well as the correct stabilization of the material are of decisive importance. As soon as a fabric is produced the possibility exists for creases to form: in laying-up, plaiting down and during storage in general, during transportation, and in dyeing and finishing through careless treatment. The fabric is particularly at risk when subjected to wet finishing processes in rope or tubular form. Shrinking can also form creases, which calls for particular attention when developing crimp during the relaxation of textured knitgoods. It should also be mentioned that if dye liquors are cooled down too quickly after dyeing this can also encourage the formation of creases.

A permanent crease in a two-dimensional material is formed by the irreversible shifting of structural elements. The likelihood of the components of a fabric to undergo displacement is encouraged amongst other things by a loosely woven construction, a floating weave and the slight extension of continuous warp and weft threads. Knitgoods exhibit less tendency to form creases than wovens, and is likewise dependent on the structure. Knitgoods are produced from single yarn structures, whereas wovens are built up from two independent yarns. A knitted structure reacts to a deforming influence as a coherent system which can adapt itself and then recover again. This is not generally possible with wovens. On the one hand, there is a lack of extensibility and, on the other hand, the weft and warp behave like two more or less independent systems. Moreover, the thicker the fabric, the greater the deformation into a crease and vice versa, thus creases are more likely to be prevented in a fine fabric than in coarse cloth. Lastly, fibre also plays a role during creasing which is not insignificant. The fibres are subordinate to the weave structure, knit structure and yarn structure and follow the deformation of the fabric, but nevertheless behave in accordance with their physical properties towards mechanical influences. Their behaviour can either be of an elastic or plastic nature and, in borderline cases, destructive phenomena may be involved.

Crease-free dyeing of tubular knitgoods Semi-continuous dyeing process for cotton and cotton/viscose tubular knit goods for crease-free dyeing with reactive dyestuffs according to the pad-roll dyeing process. After the dye liquor application in the pad trough, there follows compressed air injection and inflation of the fabric tube before squeezing and winding onto the perforated cylinder where the fabric will dwell (2–6 hours). Washing then follows on the same perforated beam.

Crease permanence → Pleat resistance.

Crease recovery angle (uncreasing angle). Dimension for determining the effect of non-crease finishing (→ Crease resistance). It is a measure of the recovery power of a fabric. It is the angle which results after a specific time when a straight yarn test specimen, folded through 180°, is released after prior loading. In contrast, the angle achieved in immediate back spring is described as the immediate crease recovery angle. A distinction is drawn between the wet and dry crease recovery angle and the measuring process, depending on test set-up with upright or hanging free end (DIN 53 890 and 53 891).

Crease resistance (fastness to creasing). Resistance of textiles to → Creasing in terms of wet and dry crease resistance. Not only measurement of the wet and dry crease recovery angle, but also the actual wash and wear behaviour of a woven fabric is used for qualitative assessment. Temperature, air humidity, period of loading and recovery time have a great effect.

Crease-resist finishing → Anti-crease finish.

Creasing Sensitivity of individual fibres to continuous flexure, creasing, pressing, squeezing across the fibre direction, in woven fabrics transversely to warp and weft ends. Assessment by the so-called → Crease recovery angle or creasing angle. It is dependent on fibre structure, mechanical fibre properties, fibre water content and swelling, fibre air content, type of yarn and fabric structure (count, twist, torque, yarn density and construction) plus the type of finish.

Creasing angle →: Creasing; Crease recovery angle.

Creasing behaviour of cellulose fibres As with the mechanical characteristics, the tendency to crease also depends on the macromolecular structural features of the fibre. The dimensional stability of a fibre depends on the arrangement of its structural elements and the forces bonding them. In the case of the cellulose chain, the individual glucose components are bonded covalently with each other via a glycosidic oxygen bridge. The bonding of cellulose chains with one another is made possible by van der Waal forces and by the development of hydrogen bridges. The forces acting from outside in system deformation tend to break existing bonds. If the latter resist this influence, full recovery to the initial position occurs when the load is removed. Residual deformation (creases) stems from irreversible bond changes, as may occur in the slipping of fibrils and molecules by hydrogen bridge fracture. Of importance in the crease behaviour of cellulose fibres is the degree of orientation, which describes the proportions of amorphous and crystalline zones. The creasing tendency rises as the polymer degree of orientation increases. The degree of orientation also has an effect on the creasing tendency and strength of polynosics.

Bending a cellulose fibre leads to a change in bonding angle. The material is stretched on the outside, and compressed on the inside. Recovery is a function of the condition of reversible and irreversible deformation, and is dependent on the dimension and duration of the acting force. Deformed fibres return to their initial position with the aid of stored energy; rupture of hydrogen bridges allows the polymer chains to slide. In the deformed state however, newly formed hydrogen bridges oppose recovery when the load is removed. Similar importance is to be attached to the van der Waal forces, which do not withstand a specific tensile load, and which are reoriented following chain slippage. As soon as some irreversible deformation occurs after fibre bending, a new force equilibrium sets in when the load is removed, preventing complete return to the initial position. Crease recovery is therefore incomplete.

Creasing inhibitors Textile auxiliaries for the prevention of → Running creaser, especially when dyeing in rope form.

CRECIT, abbrev. for: Centre de Recherches d’Essai et de Contrôles Scientifiques et Techniques pour l’Industrie Textile (Scientific Technical Research Centre of the Belgian Textile Industry), Tournai, Belgium; → Technical and professional organizations.

Creel system for dyeing machines Device for permitting liquor circulation with reloadable magazines containing the material carriers.

I. For festooned yarn hanks with box magazine, into which rods are placed on which the yarns are suspended. Once the doors are closed, the conveyor unit transports the yarns into the dyeing tank.

II. For cones and cheeses with feed apron or box magazine, which contains vertically fitted, perforated bobbin holders (hollow or channelled spindle) for stacking the material.

III. For cones and cheeses with beam-type magazine, which is a warp beam, into the axially drilled holes of which perforated bobbin holders are screwed.

IV. For cheeses with porcupine-type arrangement of the dye packages on the outer shell of the dyeing cylinder, similarly to III. Alternatively, for cheeses or warp beams combining systems III. + IV.

Crêpe (Lat: crispus = puckered). Textile fabrics with a typically wavy, grained or puckered surface (patterned). A distinction is made between:

I. So-called true crêpe produced by weaving with → Crêpe yarns, where the weave, type of material and finishing effects combine to create the crêpe effect. In this case, the crêpe is formed by crêping, where contraction of the extremely overtwisted crêpe yarn systems takes place as a result of swelling in a hot, moist state. Fabrics produced in this way include numerous types of so-called fashion crêpes (type: bark crêpe and hammerblow) and the woven crêpe constructions (e.g. crêpe jersey or sand crêpe). Typical types of crêpe generally contain, in at least one direction, a crêpe yarn system produced from highly overtwisted yarns in alternate S and Z twist (type: crêpe de chine), preferably in the weft and less frequently in the warp. Fabrics of this type include crêpe chiffon, crêpe chinette, crêpe cloqué, crêpe craquelé, crêpe flamenga, embossed crêpe, crêpe iris, crêpe orientale.

II. So-called false crêpes, including → Woven crêpes and certain smooth fabrics with embossed designs such as embossed crêpe and crepon printed effects produced by localized caustic soda treatment, etc.

Crêpe Charmeuse A fine, soft (as well as stiffer) crêpe in twill or plain weave (one warp and two weft systems, i.e. a crêpe backing weft and a crêpe face weft). The face exhibits a satin crêpe effect, and the reverse a shaded crêpe effect. Use: for elegant womenswear.

Crêpe chiffon A printed, true crêpe with a chiffon character.

Crêpe cloqué → Cloqué.

Crêpe de chine,

I. (Yarn). A silk yarn made from raw silk filaments with a more or less left-handed twist which have been very sharply twisted together to the right.

II. (Material). A soft, supple dress fabric in plain weave with e.g. a raw silk warp and a crêpe weft (produced from two S and Z highly twisted alternating yarns). It is usually either piece-dyed or printed.

Crêpe façonné A crêpe fabric with small woven patterns, → Façonné.

Crêpe Flamisol A so-called matt crêpe fabric made from e.g. a warp delustred in spinning and a crêpe weft.

Crêpe Georgette A fine, matt crêpe fabric, similar to voile (gauze-like). It has a fine irregular surface with a grainy, dry, firm handle. The warp and weft consist of highly overtwisted crêpe yarns (ply yarns), with alternating pairs of S and Z twist yarns in a plain weave construction. The fabric is tightly woven but nevertheless transparent. It is dyed in the piece or printed. Uses: blouses, dresses, skirts, gowns and millinery.

Crêpe Gloria A crêpe fabric having pleat-like lengthwise folds in a plain weave construction.

Crêpe Jersey A crêpe fabric resembling jersey-knit produced in a plain weave construction (with a crêpe weft consisting of 2 Z-twist and 2 S-twist yarns) used for womenswear fabrics.

Crêpe lavable A more tightly woven example of an easily washable crepon or crêpe de Chine with only a slight crêpe effect.

Crêpe Marocain A light, finely ribbed, puckered crêpe (similar to crepon or crêpe de Chine) with a crimped, grainy surface, (slightly wavy weft), in plain weave, also patterned (jacquard fabrics).

Crêpe Marocaise A lustrous crepe comprising a viscose warp and viscose filament or spun yarn or crepe wool crepe yarn weft, lightly crimped appearance in taffeta or rib weave.

Crêpe Mousseline A transparent, light crêpe fabric with a wool-like character produced in a so-called sand crêpe weave.

Crêpe ondé A crêpe with yarns consisting of folded crêpe yarns with chemically spun viscose slub filaments.

Crêpe piqué A matt crêpe fabric with a piqué-like character.

Crêpe prepared by steeping in caustic soda Treatment by local causticisation of mainly woven cotton fabrics with concentrated caustic soda, in which locally shrunk and therefore – on untreated sections – crimped areas produce different types of crêpe effects, which are also described as crimp crêpe. These types of process are technically extraordinarily good value, and make interesting dyeing effects etc. possible.

I. Lye printing process: on cotton muslin (27 warp ends/24 picks), which is well desized and bleached so as to be easily wettable, thickened caustic soda is printed in accordance with the pattern by a roller printing machine. Hot treatment with 0.5–1 g/l of sodium metaphosphate prior to printing has a beneficial effect. The viscosity of the print paste has a marked effect on the crêpe appearance, for excessively thin print paste is squeezed out into unprinted places, while excessively thick print paste produces too narrow stripes. Plaiting down is followed by a maximum dwell time of 30 min. for exothermal swelling and shrinking; here, any temperature increases must be watched for (they can lead to charring of the piece) in order to be able, if possible, to intervene if necessary by ventilating the pieces. Lengthwise contraction should be approx. 15%, and width contraction about 18%. Further treatment must follow with care and without tension or pressure, i.e.

neutralising with diluted hydrochloric or sulphuric acid in rope form in large washing vats, rinsing in running cold water up to neutral reaction, rinsing off with formic acid for a good handle, gently centrifuging, plaiting down and drying in festoon dryers, and then pulling out to the correct finished width on a single level stenter with intensive steaming. The woven fabric to be printed can also be predyed or printed with lye-resistant dyes, or these dyes can be added to the lye print paste.

II. Resist process: a thickener which resists caustic soda is applied by roller printing in accordance with the pattern, a causticising passage following on the padder. The process permits storage of the piece for as long as necessary before the causticising passage, i.e. no synchronisation is necessary between printing and washing off. In addition, operation is more reliable, eliminating rapid and expensive printing machine back grey wear, but against which costs are higher due to the high thickening agent consumption. Predyeing can be effected with lye resistant dyes prior to resist paste application. Indirect heating of the printing trough to 80–90°C by means of a steam coil is recommended for good penetration and bilateral reservation on account of the large quantity of resisting agent dry substance. If dye has been added to the resist paste, the print must be fixated after the printing process, otherwise an open-width passage through 24–35% caustic soda ensues at 18–20°C on a two-roll padder, or slop padding with a picotised roller on the printing machine. Another possibility is to dry rigorously after resist printing, carrying out the lye treatment if necessary. Further treatment is similar to the lye printing process. Used as resisting agents in addition to rubber thickeners are synthetic resin condensates, to which dyestuffs and white and dye pigments etc. can be added. In this case, causticizing is preceded by drying, calendering and curing. One variant is provided by a combination of the above-mentioned mechanical resist with a chemically acting one which prevents the shrinking action of the caustic soda in the sense of a neutralising process; to this end, acid salts or solid organic acids, which require careful selection, can be used in order to prevent granular precipitation in the preparation of an absorbent printing paste.

Crêpe reversible A fine, double-sided, patterned crêpe fabric (produced mainly with jacquard effects); the face is e.g. matt with a crêpe character and the reverse is smooth and lustrous (similar to satin), other variations also exist.

Crêpe Romain The finest crêpe fabric, similar to crêpe Georgette, with a check-like surface, in a panama weave construction (therefore also referred to as panama crêpe), with two alternating warp and weft threads.

Crêpe Satin A generally small-figured crêpe with an ultra-bright face and a low lustre reverse, the latter having a ribbed effect; the ground fabric is in plain weave and the pattern effects in satin weave (2 S-twist and 2 Z-twist threads).

Crêpe yarns These are highly twisted, tightly folded yarns, produced in S or Z twist, used to produce crêpe fabrics in various patterns thereby giving the fabric its characteristic puckered crêpe effect after the so-called → Crêping.

Crêping Development of a special surface effect for → Crêpe products in the chemical finishing stage with completely tension-free treatment. Up to 40% fabric contraction in the crêpe yarn system direction.

I. Woven cellulose fabric: requires great experience. Relevant preliminary trials should be carried out beforehand on each quality in order to achieve the best results. Thus, the embossing roller pattern, the caustic soda concentration, the crêping bath temperature etc. all have an effect. Most qualities must be pre-calendered on the embossing calender to produce uniform contraction. Woven fabrics with no acetate content shrink best in a 1.5–4.5% (2–8°Baumé) cold caustic soda bath. They then go, with or without rinsing, into the scouring or crêping bath, where the fabric can shrink. Fabrics with an acetate content come directly to the hot scouring bath. Only after full shrinkage is further treatment possible in rope form.

II. With wool crêpe too, hot water treatment with soap or detergent takes the place of lye.

III. Polyamide crêpe is embossed under 5 tonnes pressure at a maximum of 70°C, and is crêped, with added detergent, for 1–1.5 hours with 1 g/l of 33% caustic soda (38°Baumé). By processing shrunk and unshrunk polyamide yarns with weaving techniques, the crêpe effect can be produced by heat treatment in water or steam.

Crepon,

I. Yarn: → Crêpe yarns.

II. Material: a crêped material which only has crêpe yarns of one twist direction in the weft or both the warp and weft, or even 3 Z-twist threads alternating with 2 S-twist threads, which gives rise to the typically wavy folds. It is generally produced in plain weave.

Crepon printed effects,

I. On cotton piece goods: crêpe prepared by steeping in caustic soda.

II. On wool piece goods: on the same principle as described under crêpe prepared by steeping in caustic soda, but preferably with calcium rhodanide, which has a very energetic action without affecting wool strength. Up to 15% fibre shortening occurs in the warp and weft on suitable woven wool fabric (e.g. muslin). The required crimp effect is produced with regularity here only under condition that the wool is not chlorinated, since chlorinated wool largely or completely loses its ability to shrink. In contrast to crêpe prepared by steeping in caustic soda, the crêpe effect on wool is completely fast to washing and ironing.

III. Polyamide piece goods: cloqué effects by printing on swelling agents like phenol type substances, organic acids, calcium rhodanide and aliphatic alcohols according to pattern. The shrink effect is 10–15% and more. Considered for machine printing are preferably 20–25% resorcin or phenol solutions (less in screen printing), mainly in Senegal or gum arabic, British gum or modified carob seed grain thickening. Swelling agent combinations with added glycerine are also usual to some extent. Afterwards, tension-free steaming, either on a star ager for 5–10 min. or in a setting unit at a higher temperature for a shorter time, i.e. 2–3 min. at 130°C. The cloqué effect formed in this way withstands subsequent dyeing well, and is also adequately fast to ironing with careful processing. The print pastes can also contain dyestuff. Printing on thickened lactic acid (possibly with urea) or with calcium rhodanide is less established. Tensioning or stretching the fabric is to be avoided as far as possible during any treatment. A short loop dryer for example is suitable for tension-free drying.

IV. Polyester piece goods: by printing on according to pattern print pastes which contain 20–50% carrier-active substances in dispersed form, and subsequent treatment in hot steam (20 min. at 1.5–2 bar).

CREST, abbrev. for: Centre de Recherche et d'Enseignement Supérieur Textile (French Research and Textile Secondary Education Centre), Villeneuve d'Asq, France; → Technical and professional organizations.

Cretonne A rather strong, more or less tightly woven, cellulose fabric or plain weave construction; fine qualities used for washable dress goods, coarser qualities for printed articles. First produced in Créton, a village in Normandy. Cretonne is encountered in the trade in the form of bleached, piece-dyed or printed fabric. Uses: shirts, bed linen, aprons, everyday dress, traditional costumes, upholstery and curtain fabrics.

Crimp Waves and curves exist in virtually all staple fibres and are especially evident under the microscope. The nature of the crimps and their frequency vary widely (→ Crimp, types of). Crimps hold fibres apart thus producing numerous air cavities in the yarn which influence to varying degrees its bulk, softness of handle and insulation properties.

Crimp contraction (or crimp retraction). Defined by the Textile Institute (see also BISFA) as the contraction in length of a previously textured yarn caused by the formation of crimp in individual filaments under specified conditions of crimp development. It is expressed as a percentage of the extended length. It thus represents an index of the elastic recovery of yarns and is generally expressed wet/dry (wet under high loading, dry under low loading) or where required also dry/dry. A high crimp contraction implies high elastic recovery:

non-stretch bulked yarns	< 15 %
low-stretch yarns	20–30%
high-stretch yarns	50%

Crimp crêpe The term is not quite correct. What is meant is fabrics with a crêpe-like effect a) like the crepon printed effect on cotton or wool, or b) with the use of crimp yarn.

Crimp effects → Crepon printed effects.

Crimp elongation Max. stretch or elongation of a crimped yarn/thread (or fibre) under tensile loading up to the neutralisation of crimp or up to the start of effective material elongation. Is expressed as a ratio to original length, and serves as a measure of volume increase due to texturing, i.e. high crimp elongation is equivalent to large volume increase.

Crimped fibres Wool-like crimped man-made fibres after texturing.

Crimp frequency (crimping arc count). Number of crimping arcs/10 cm, independent of count. Controlled by texturing in the case of textured yarns.

Crimp index Synonym for → Crimp contraction.

Crimping of wool hair Lower quality wool can be crimped on special machines by the → Overfeed system (IWS process), "programmed pile".

Crimp modulus Force required to stretch crimped (textured) yarn by 100%: e.g. at its lowest with polyamide 6 (2.1), polyamide 6.6 (2.4), at its highest with polyester (3.5).

Crimp process Designation for the IWS (International Wool Secretariat) process for inducing crimp in smooth wools, especially those of New Zealand origin.

Crimp stability in textured yarns The ability of a textured yarn to retain its crimp, measured before and after mechanical or thermal stress imposed under specified conditions.

Crimp, types of The → Crimp of natural fibres is a natural attribute whilst in man-made fibres it is created in fibre production in apparent or latent form. In man-made fibres distinction is made between the following types:

I. Stuffer-box crimping: Crimp-free filaments in tow form are by mechanical means or fluid-jet forcibly injected into a stuffer-box where they buckle and fold to form crimps (optionally followed by crimp stabilisation by steam/hot air).

II. Bicomponent fibre crimp: Contrived crimp imitating the crimp structure of wool (paracortex/orthocortex) produced with → Bicomponent fibres comprising components of differering shrinkage characteristics. Shrinking treatment then creates a highly stable three-dimensional form of crimp (e.g. Superbulk-PP).

III. Hot-water crimp is created by immersing filaments in a relaxed state in hot water (caused by unequal shrinkage of fibre matrix and sheath) in the form of irregular three-dimensional arcuate crimp.

Crin d'Afrique (crin végétal, African fibre). A coarse variety of → Palm fibres (*Chamaerops humilis*) with a similar texture to horsehair native to North Africa and Southern Spain. Used for upholstery and braids. It is nearly always black, dyed with cationic dyes.

Crinkle Crimp, e.g. the production of crimp yarn by the texturing of yarn hanks made from bicomponent yarns (hot air treatment in a textile tumbler).

Crinkle process Texturing process (knit-set-deknit process) for polyamide and polyester textured yarns. The yarns are used in knitgoods, jerseys and hosiery garter tops.

Crinkle yarns → Crinkle process.

Crinkling In the sense of uneven waves, for example through excessive stretching of seams, edges, folds, pleats during ironing.

Crispy handle → Silk scroop.

Critical add-on value This refers to the amount of finishing liquor which must still be applied with low pick-up systems in order to avoid uneven distribution of the resin finishing agent after drying and curing.

Critical concentration In detergent chemistry, any detergent concentration above or below which washing power declines.

Critical micelle concentration (CMC, c_k). Characteristic concentration of surfactants in solutions, above which the number of micelles increases to the extent where the concentration dependency of specific physical properties is rapidly changed. The critical micelle concentration is determined by the intersection of two extrapolated curves, which describe the property of the solution as a function of concentration (see Fig.).

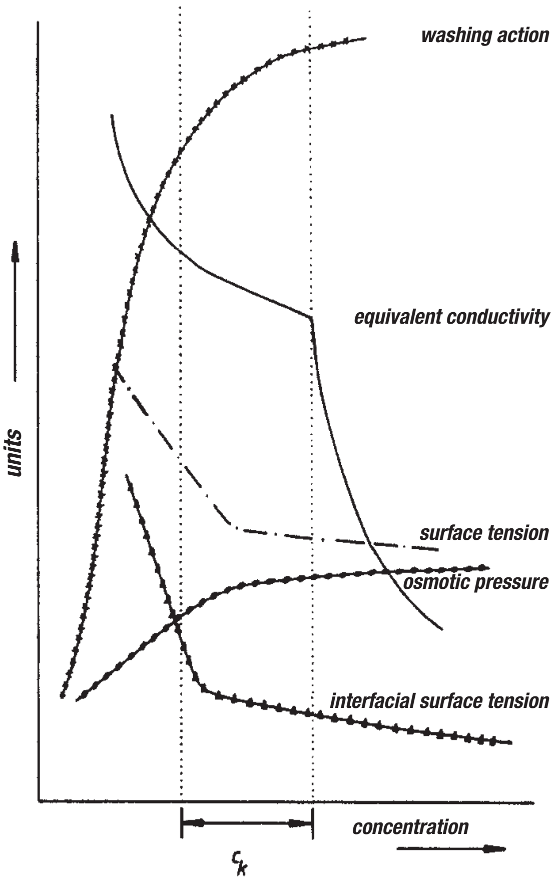


Fig.: Critical micelle concentration c_k relative to various properties (ordinate) and concentrations (abscissa) of a surfactant solution.

Critical path analysis Developed from a planning and control system used primarily for military purposes (Polaris weapons systems), now mainly employed in the fields of development and production. Critical path analysis forms part of operations research and graph theory. Especially suited to complex production processes of which an overview is difficult, the introduction of new operational sequences, maintenance tasks, the introduction of new products, systems and procedures. Critical path analysis ensures that operational sequences are fully thought through and encourages Cupertino. A critical path network plan may, for example, be based on events (for leading departments). The relevant overall project is broken down by specialist employees (start/end of the task) and denoted by numbered circles (intersections) and connecting lines (edges) with directional arrows and time entries. Procedures, the delay of which would endanger the project as a whole, are designated “critical” (see Fig.).

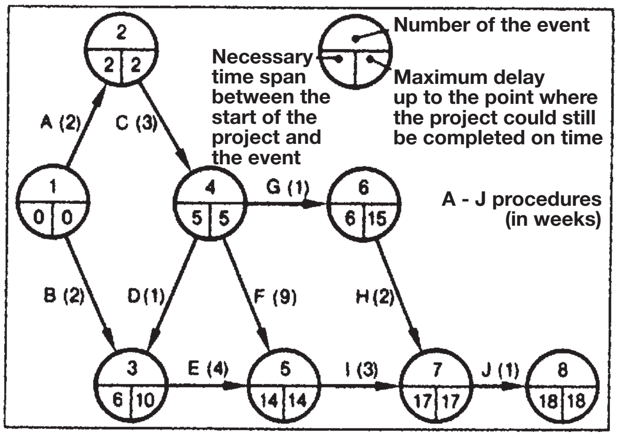


Fig.: Example of a critical path network plan.

Network plans enable improved coordination and constant controls. Any problems arising from new calculations of data can be recognised by their effect on the whole project, thus offering the potential for time or cost savings to be made.

Crocking Detrimental manifestation of indigo, naphthol, vat and pigment dyeing or prints.

Crockmeter Standard test equipment for testing the → Colour fastness to rubbing of dyed or printed textiles. Traditionally hand-operated, electronically-controlled crockmeters have also become available recently.

Croisé (French croisé = twill). A twill weave cotton fabric (generally 2/2), smooth on the face side, and heavily brushed on the reverse to a varying degree. It is generally extremely difficult to differentiate between finette and croisé. The former is generally more finely ribbed, the latter more heavily ribbed. There is, however, an intermediate designation as well (croisé-finette). It is available in the market bleached white, piece-dyed in delicate colours, or printed. Uses: nightwear, skirts and winter wear.

Cropping → Shearing.

Crossbred wool A fairly frequently processed wool variety: it falls between merino and cheviot wool in terms of count, strength, lustre and crimp. The sheep are a cross between the fine-fleeced merino sheep and the coarse-fleeced Lincoln breeding ewes. Crossbred sheep provide strong wools with a high fleece weight, between B and C in count.

Cross-brushing machine for cord finishing Special form of → Brushing machines for cord finishing. Makes possible double fabric contact with each brush. Positive brush control on a bar provides for a reproducible brushing effect.

Cross-dyeing polyamide fibres → Differential-dyeing polyamide fibres.

Cross-laid nonwovens Nonwovens preferably with fibres oriented by web crossing.

Cross linkages,

I. → Hydrogen bonds.

II. Cross linkages in proteins: important features of the fibre protein wool are its insolubility and indigestibility, which has been explained by Zenko Stary by the presence of cross linkages. The sulphur-containing amino acid cystine - incorporated in wool keratin to an approximate level of 12% – the functional groups of which can be components of two adjacent polypeptide chains (inter-chain) and/or of one chain (intra-chain), stabilises the fibre structure in covalent bonding with its disulphide grouping. Disulphide bonding is the most important natural, covalent wool cross linkage, and, as such, is important for the numerous characteristics of the fibre. The frequently expressed formulation of ester bonding from the hydroxyl groups of combined serine/threonine with ω-carboxyl groups is pure speculation. Nor is there any evidence of the presence of ω-amino-peptide bonds in or between the polypeptide chains, as have been found in collagen for example. In 1941, Horn, Johnes and Ringel discovered the thioether amino acid lanthionine in wool treated in alkali, which is not found in natural wool. Its formation is linked with a reduction in disulphide content and decreased solubility of the wool in a urea-bisulphite solution. In this reagent, the thioether bonding of the lanthionine is stable against the sensitive disulphide bonding. Observed in addition to disulphide bond decomposition was a reduction in free lysine-amino groups with weak alkaline fixation. One possible explanation of this discovery by the assumption formulated by Speakman that sulphenamide bonds could have formed, has not been analytically provable. With the discovery of a new amino acid - lysinoalanine – in the hydrolysate of alkaline-treated ribonuclease, the study of the alkali effect on wool has experienced a new impetus.

The first trial was conducted in accordance with the fixation conditions employed by Speakman in his time, in which a bundle of wool fibres, extended by about 40% of its clamped length, was heated up to 100°C for 60 min. in an 0.05 molar borax solution (pH 9.2). Found in the hydrolysate of this test specimen with the aid of the automatic amino acid analyser - in addition to reduced lysine, cystine and serine values - was a compound unknown in wool, which was identical with lysinoalanine. Over and above that, considerable quantities of lanthionine had been formed. On the assumption that the alkali attacks combined cystine first of all, the formula pattern illustrated in Fig. 1 ensues for the formation of lysinoalanine and lanthionine:

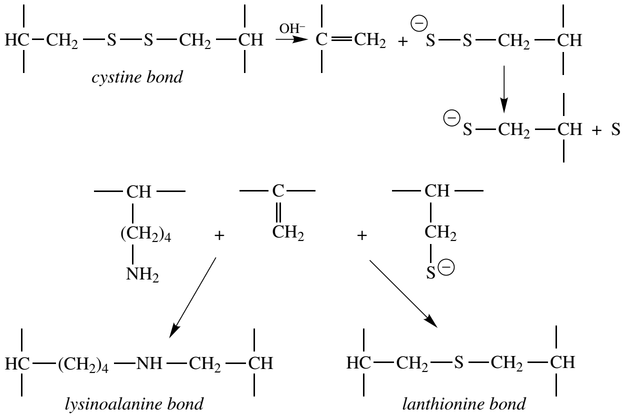


Fig. 1: Cross-linking of wool by lanthionine and lysinoalanine in alkaline treatment.

The bimolecular, nucleophilic, β-eliminating reaction forming the basis of the formation of both amino acids, which results in intermediarily occurring reactive dehydroalanyl residues, appears in fact to be most plausible. Yet other mechanisms were also discussed however as regards lanthionine formation. Since the initial publication of the discovery of lysinoalanine in alkaline treated wool in the autumn of 1964, trials have been conducted on the effect of different alkaline reagents for example on lysinoalanine formation, varying the duration of effect, the temperature, the pH, the ion concentration etc, and the effects in terms of changing physical characteristics studied in connection with the cystine and lanthionine cross-linkages. Some studies have attempted to clarify whether the dehydroalanyl residue necessary as an intermediary product in the formation of lysinoalanine is due to the alkaline decomposition of cystine and/or serine. In addition, a simplified method of simultaneously determining lysinoalanine and lanthionine was worked out. Despite the wealth of knowledge, the question as to whether one of the two new covalent bonds of incorporated lysinoalanine and lanthionine formed in the alkaline medium results in bond formation within or between chains has not been answered with any degree of certainty. The reduced solubility of alkaline treated wool in urea-bisulphite solution can in fact be seen as the resultant cross-linking of the polypeptide chains. However, a disulphide exchange reaction can also take place simultaneously. Both this reaction and the formation of lanthionine and lysinoalanine result in some degree of chemical stabilisation, although wool like this has technologically inconvenient behaviour. In addition to increased solubility, there are yet other observations where weak alkaline treatment of wool results in cross-linking. Thus, the extent of supercontraction decreases after replacing disulphide bonds by thioether bonds, and, especially, by NH bonding. Some of the last mentioned bonds already have a significant effect. If all processes are looked at in terms of their chemical and physical change, to which the wool is exposed in the various stages, raw wool washing already deserves notice. In the washing of greasy wool with synthetic detergents with added sodium carbonate, there are already conditions as regards pH and temperature, which can lead among other things to lysinoalanine and lanthionine formation. This applies moreover to the steaming of worsted yarns, the decatizing of woven fabrics and improper dyeing in the weakly alkaline range. Cross-links can also be incorporated in wool or other proteins by conversion with bifunctional cross-linking agents. Thus, the yellow reactive dye o,o'-difluorodinitrobenzol can cross-link wool in such a way (Fig. 2) that cross-links can be insulated by two formic acids coupled on to it (Ziegler).

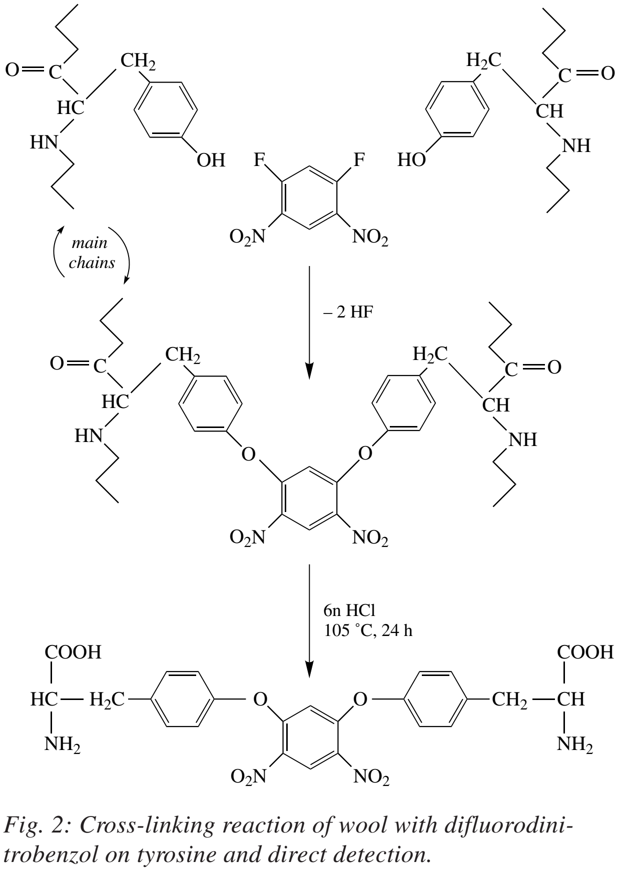


Fig. 2: Cross-linking reaction of wool with difluorodinitrobenzol on tyrosine and direct detection.

Cross-linkers Chemicals which build linear molecules of macromolecular chemicals with reactive sites into networks of three-dimensional structure by forming intermolecular bridges. → Cross-linking.

Cross-linking Connecting of linear molecular chains to form three-dimensional networks, e.g. of synthetic resins in → Resin finishing. A polymer-like reaction of two macromolecules with bifunctional bridge-type cross-links causes covalent bonding of polymers via their side chains. In the process the properties of the polymer materials will change, as seen in the tanning of collagen to leather or the vulcanisation of natural rubber to rubber. In wool there are natural cross-links in the form of cystine bonds, which are formed at the keratinization stage through stretching in the hair follicle during the growth of the fibre. Low-molecular cross-linking agents are applied in the crease-proof finishing of cellulosic fibres; at the same time, as with all cross-linking of fibres, their swelling capacity will decrease or the state at the time of the cross-linking will become fixed. Cross-linking reactions also occur with the use of bifunctional reactive dyestuffs to increase the fixing rate with the reactive dyeing of cellulose fibres; these may react according to the addition or substitution mechanism. The condensation of polymers which function as binding agents for nonwoven fabrics or as binders in pigment printing leads to cross-linking due to the displacement of water after drying when there is no more water present in the system (Fig. 1).

The chemical properties of polymers will change during cross-linking. Hence cotton, which as untreated cellulose has a very definite, so-called critical solution strength in concentrated sulphuric acid, will only dissolve after cross-linking with greater concentrations of sulphuric acid. The principle behind this method should be understood as follows: sulphuric acid works on cotton as a swelling agent for as long as the concentration lies below the critical strength. In the event of swelling the van der Waals bridge-type bonds are pushed apart between the OH groups of cellulose. In the event of cross-linking, i.e. the insertion of a bridge-type link between the OH groups (e.g. N-methylol bonding, ether formation), any dissolving and swelling is only possible for the cross-linked area if the ether formation is split up by the intermediate stage of an oxonium salt formation. This presupposes, however, a greater acidic strength than is given for the critical solution strength of non-cross-linked cellulose (Fig. 2).

Cross-linking

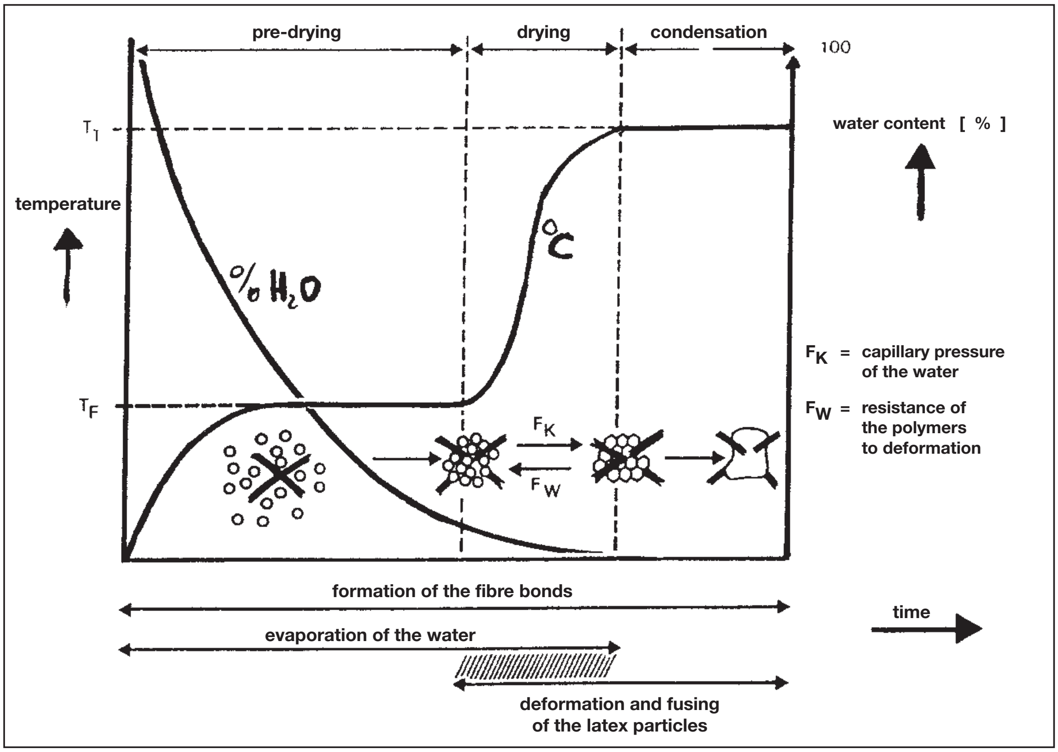


Fig. 1: Temperature development. Reduction in water content and formation of the fibre linkage during the drying process.

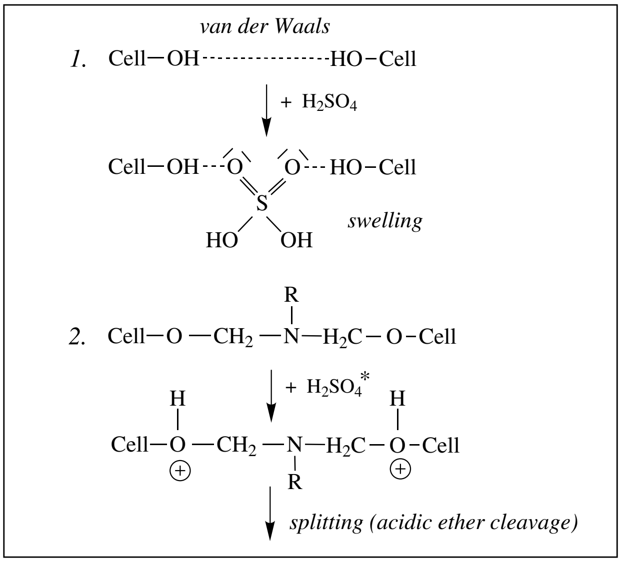


Fig. 2: Swelling of cross-linked cellulose in sulphuric acid (compared with non-cross-linked cellulose).
** more concentrated than with 1.*

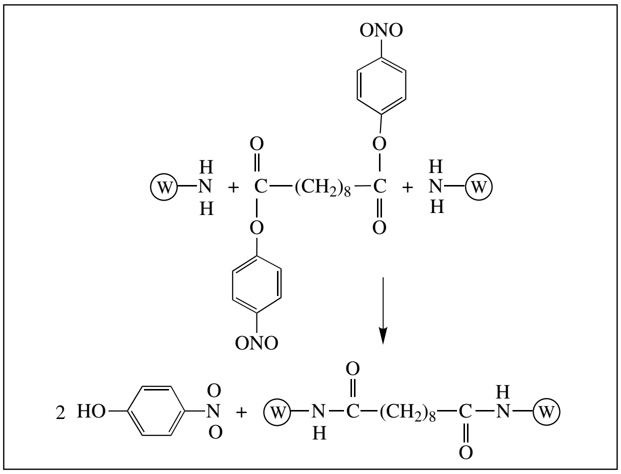


Fig. 3: Cross-linking of wool-linked lysine with p-nitrophenyl ester of sebacic acid.

If wool is cross-linked with bifunctional p-nitrophenyl esters, e.g. sebacic acid, then a severe change in solubility behaviour will occur in ammonium performate (Fig. 3 and Table).

With the self cross-linking of wool with alkali, cystine will be converted into lanthionine so that the urea-bisulphite solubility of wool will fall from approx. 60% to 0% (Fig. 4).

To protect the wool from damage during HT dyeing (separation of keratin material from the non-keratin

	Wool [%]	
fraction	untreated	cross-linked
insoluble	13 β-keratose	69
precipitated at pH 4	53 α-keratose	0,3
soluble	22 γ-keratose	17

Table: Fractionation of untreated wool, cross-linked with di-p-nitrophenyl sebacic acid ester, with ammonium performate.

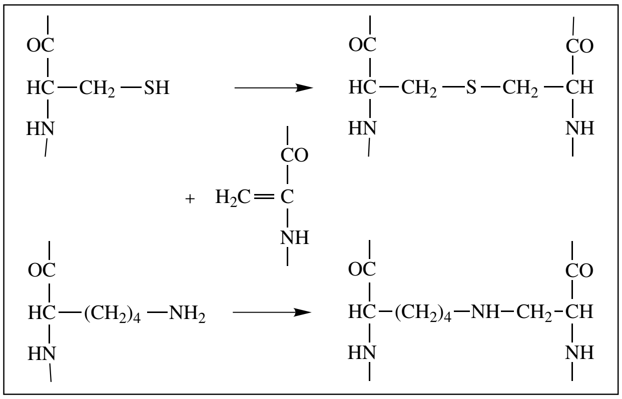


Fig. 4: Formation of lanthionin and lysinoalanine in wool through the addition of an SH group (top) or NH_2 group (bottom) to aminoacrylic acid residue.

proteins) cross-linkers such as formaldehyde are added to the dye bath in order to stabilise the composite structure of the wool.

Cellulosic textiles are resin-finished to improve their properties, such as dimensional stability and crease resistance. This is achieved by cross-linking some hydroxyl groups of cellulose through derivatives of urea or melamine and through cyclic cross-linkers based on ethylene and propylene urea.

Fig. 5 depicts a typical dye curve (Rhodamine B) of cross-linked cotton fabric, as found via extraction of marked patterns. What is noticeable from the curve obtained with the aid of remission readings is that the positive function changes to a negative with a certain cross-linker content. This is an availability phenomenon: in the rising section of the curve the cross-linking agent binds the dye before the availability of cellulose for the dye is reduced due to the high degree of cross-linking. Such availability of the cross-linked cotton very much depends on the cross-linking conditions.

Cross-linking mechanism, chemical In macromolecular chemistry the spatial connecting of polymer chains to form a polymer network. This reaction occurs with the hardening of synthetics, the vulcanisation of rubber, the tanning of leather, the crease resist finishing of cellulosic textiles, etc. With increasing branching of the polymer chains the degree of cross-linking, and hence the hardness of the end product, also increases. The cross-linker is typically a bifunctional, low-molecular weight compound in a suitable medium for the polymer to be cross-linked and must be provided with suitable conditions to allow cross-linking to take place. Much more important for the process are those cross-linkers that are added in the synthesis of polymers from monomers to the parent monomer mix as co-monomers in order to create copolymers, which combine the cross-linkers as side chains.

Textiles are impregnated with such cross-linking copolymers before bringing the cross-linkable groups in this heterogeneous system to a reaction. Where the cross-linking of copolymers with N-methylol groups or N-methylol ethers is concerned, there are two mechanisms to differentiate between:

- a purely thermal mechanism,
- condensation in the presence of acidic hardeners.

Fig. 1 shows the purely thermal condensation (100–200°C). The end result is a methylene bridge. It is supposedly formed in two ways:

- via the cleaving of an intermediate ether bridge (left-hand side of Fig. 1),
- via the cleaving of formaldehyde by the formation

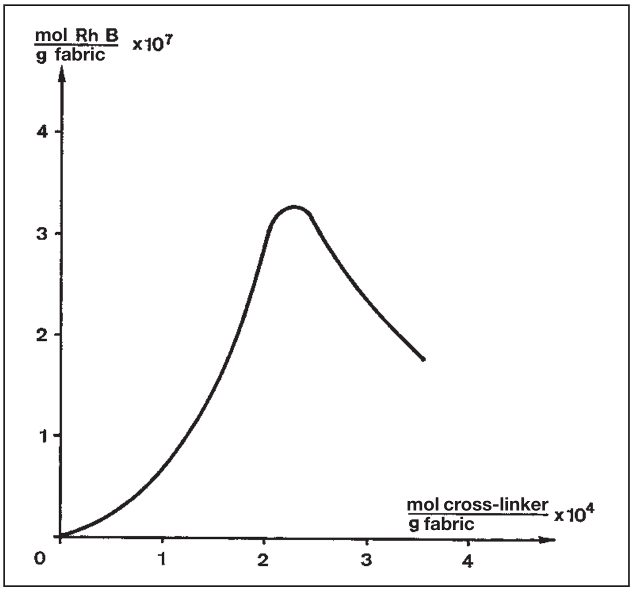


Fig. 5: Rhodamine B uptake as a function of the amount of cross-linking in the fabric.

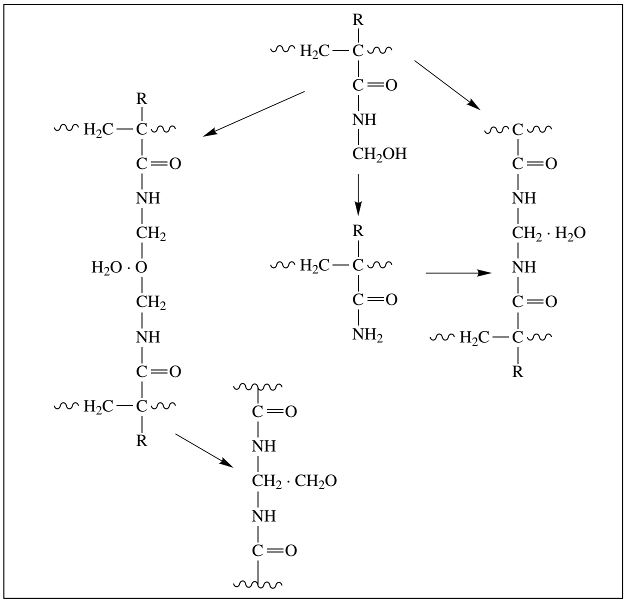
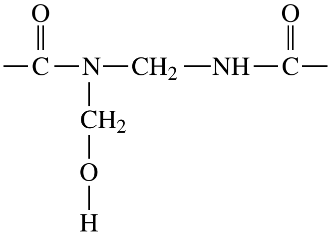


Fig. 1: Thermal condensation of polymers containing N-methylol groups (after Hübner and Kollinsky).

of an amide group and the reaction of this amide group with an N-methylol group (right-hand side of Fig. 1).

According to the findings of Petersen when investigating the reactivity of low-molecular N-methylol and alkoxyl methylol compounds, a mechanism might be probable where the N-methylol groups do not only react to form ether but also via the grouping



$$-C(=O)-N(CH_2-O-H)-CH_2-NH-C(=O)-$$

which because of the weak bonding of a molecule of formaldehyde immediately splits off this formaldehyde. Subsequently thermal condensation of polymers containing N-methylol groups ought to develop in line with Fig. 2.

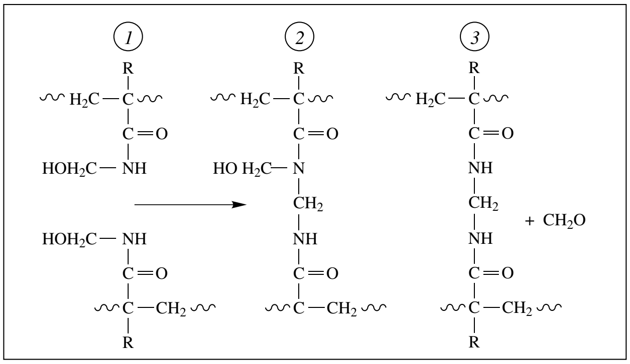
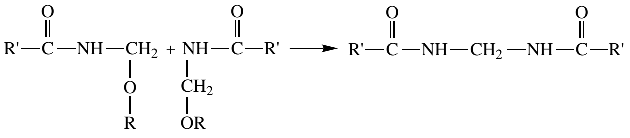


Fig. 2: Thermal condensation of polymers containing N-methylol groups on low-molecular N-methylol compounds (after Petersen).

The purely thermal condensation could also develop, especially with N-alkoxyl methylol compounds, according to a "four-centre mechanism". In a synchronous reaction two molecules of an N-alkoxyl methylol compound can condense under by a rearrangement of bonds to N,N'-methylene bis compound:



$$R'-C(=O)-NH-CH_2(-O-R) + NH(-CH_2-OR)-C(=O)-R' \longrightarrow R'-C(=O)-NH-CH_2-NH-C(=O)-R'$$

As shown in Fig. 3, with hardening in the presence of acidic hardeners, a proton attaches to the amide nitrogen or ether oxygen. A carbamide group and formaldehyde are formed from the N-addition product. The O-addition product forms an immonium ion mesomeric with the carbonium ion. If this carbonium ion combines with an amide group, a methylene group (left) will result; if it joins an N-methylol group, an ether bridge will be the result. The condensation of N-methylol compounds catalysed by acid is not a specific acid catalysis only dependent on the concentration of the protons, but rather a general acid catalysis. The cleaving velocity of the C-O compound is responsible for the reactivity of the N-methylol and N-alkoxyl methylol groups.

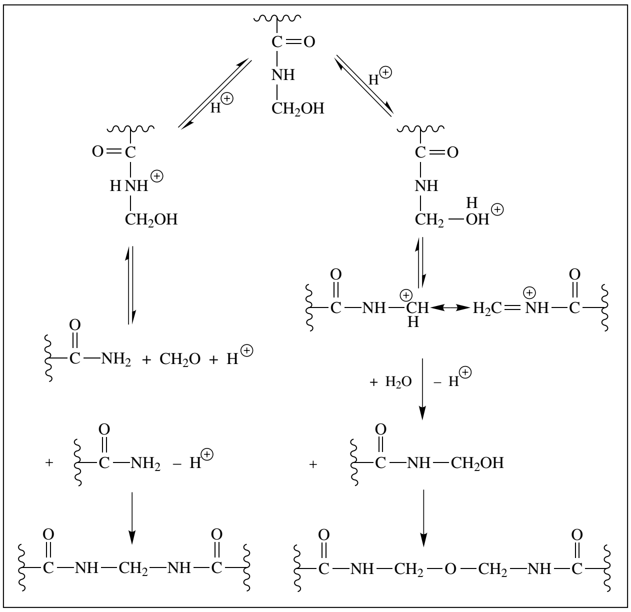


Fig. 3: Condensation of polymers containing N-methylol groups in the presence of acidic hardeners (proton catalysis).

Fig. 4, shows the transfer of these mechanisms to the N-methylol compounds of copolymers. Under the influence of an acid HS mesomerically stabilised carbon amidomethyl (carbonium immonium) ions (3), which can react with NH groups or other nucleophile partners (4). The carbonium ions can react with water to the N-methylol group (5), which in turn can split up into a carbon amide group (6) and formaldehyde (7).

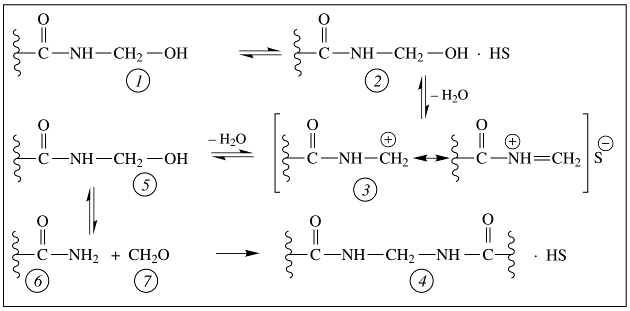


Fig. 4: Condensation of polymers containing N-methylol groups in the presence of acidic hardeners (after Petersen).

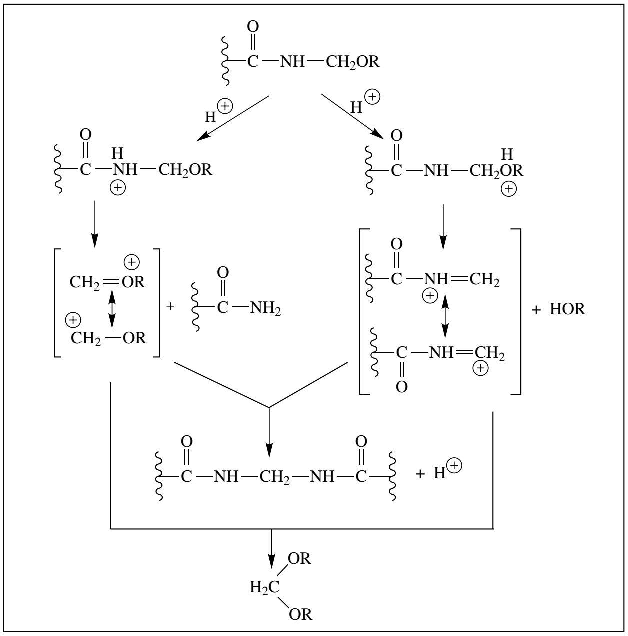


Fig. 5: Thermal cross-linking of copolymers containing N-methylol ether groups in the presence of acidic hardeners.

As a result of the acidic hardening of copolymers with N-methylol ether groups, dialkyl formals are obtained, i.e. cross-linking via methylene bridges. In Fig. 5, a proton attaches to the amide nitrogen (left) or to the ether oxygen (right). A carbamide group and the carbonium ion are formed from the N-addition product. The carbonium ion mesomeric with an immonium ion results from the O-addition product. This can react with the resulting amide group in methylene bridge formation. The carbonium ion takes up the alcohol released in the formation of the carbonium ion by forming dialkyl formal.

If one draws on the work of Petersen on low-molecular alkoxymethylol compounds for the cross-linking mechanism, then a schema can be constructed as in Fig. 6 for the cross-linking of the polymers by cleaving off dialkyl formal. According to this schema, mesomerically stabilised carbon amidomethyl (carbonium immonium) ions (3) are formed under the influence of the acid HS (2) from the N-alkoxyl methylol groups (1) of the polymer by splitting off alcohol. They react with water to the N-methylol group (5), which can split up into the free carbon amide group and formaldehyde. The free carbon amide group (6) reacts as a nucleophile partner with the carbonium immonium ion (3) to the methylene group. The free formaldehyde can react with the displaced alcohol (8) to dialkyl formal (9). The water (10) that is released in the process can attach in turn to the carbonium immonium ion by forming an N-methylol group.

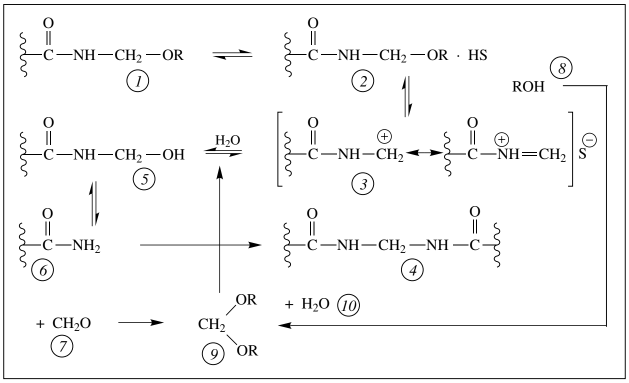


Fig. 6: Thermal cross-linking of copolymers containing N-methylol ether groups in the presence of acidic hardeners (following Petersen).

The overall catalytic effect is composed of several components. When using any acid HS and water as a reaction medium, the following velocity equation would have to be used:

$$v = \left[\wr\!-\overset{\overset{\displaystyle O}{\|}}{C}-NH-CH_2-OR \right] \cdot \left(K_{H_2O}[H_2O] + K_{H_3O^\oplus}[H_3O^\oplus] + K_{HS}[HS] + K_S[S]\right)$$

The greatest catalytic effect indicates the H-ion concentration.

$$K_{H_3O^\oplus}[H_3O^\oplus]$$

Cross-linking resins Amongst the reactive long chain polymers used for textile applications are found acrylamides and methacrylamides with N-methylol or N-methylol ether groups. Acrylamide and its N-methylol compound are easily soluble in water. The somewhat lower solubility of methacrylamide and its methylol compound is of benefit for emulsion polymerisation. Reactive long chain polymers used for textile applications containing carboxyl groups as found in acrylic acid or methacrylic acid. They are used to stabilise dispersion systems, provide adhesion to substrates, change mechanical properties and alter the reaction towards solvents after application. Carboxyl groups are also involved in the cross-linking process. The reaction of mixed polymers having only carboxyl groups with hexamethoxymethylmelamine suggests that the cross-linking here occurs via a methyl ester bridge (Fig. 1).

In practice mixed polymers as aqueous solutions or dispersions with amide groups are found. The aqueous solutions mostly contain polyacrylamide or mixtures of acrylamides with methacrylamide. Methylol groups are unstable in aqueous solution with the result that cross-linking will take place even with short-term storage.

Cross-linking resins

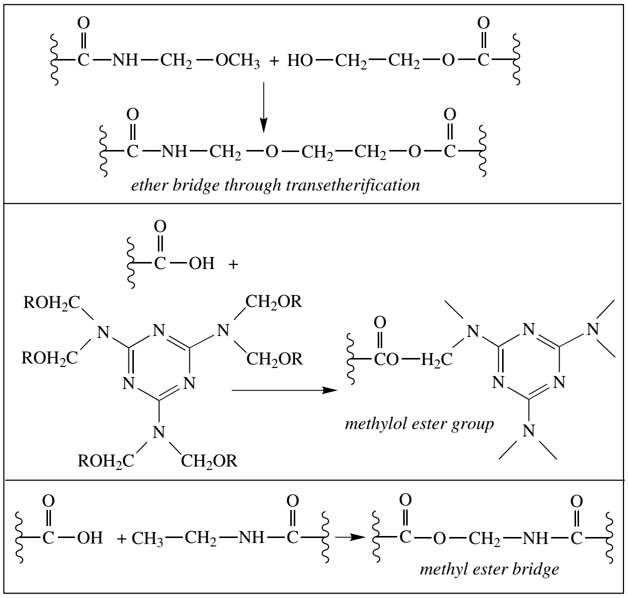


Fig. 1: Cross-linking possibilities between macromolecules.

Carboxyl groups are undesirable because the copolymers can flocculate prematurely in mixture with acidic components in a formulation. The finishes become less durable to washing with increasing carboxyl content.

These products have formed part of the palette of textile finishing agents since 1955 as finishing agents resistant to washing at the boil and wash durable sizing agents for cotton and viscose. As additives for finishing baths, they provide body, handle and stiffness, without affecting the creasing properties. With wool they confer a stretch/recovery effect and a full handle. For cellulosic textiles it is necessary to use formaldehyde condensates as co-reactants for easy-care effects. Co-reactants are the resin hardeners and reactants generally used. For crease resist finishing the resin cross-linkers used are dimethylolurea, partially etherified mixtures of dimethylolurea and monomethylolurea, trimethylol melamine, etc. They become deposited in the capillaries and micelles of the cellulose fibres, forming resins and accumulating as an amorphous filling. If a mixed polymer containing an amide group is used then part of the resin will react with it (Figs. 2–5).

The emulsion polymers, commonly used as print binders, also contain amide groups, these are replaced by the self-crosslinking N-methylol and N-methylol ether groups. With the cross-linking of polymers containing N-methylol groups and with low-molecular N-methylol compounds, formaldehyde and water are displaced and methylene groups will remain. If polymers containing N-methylol ether groups react with low-molecular compounds containing N-methylol ether groups, then methylene groups will form with the separation of dialkylformamide. In this case reactions between polymer-precondensate adduct and precondensate may take place. Quasi-crosslinking is similarly possible through polyvalent metallic ions such as calcium, aluminium or zirconium.

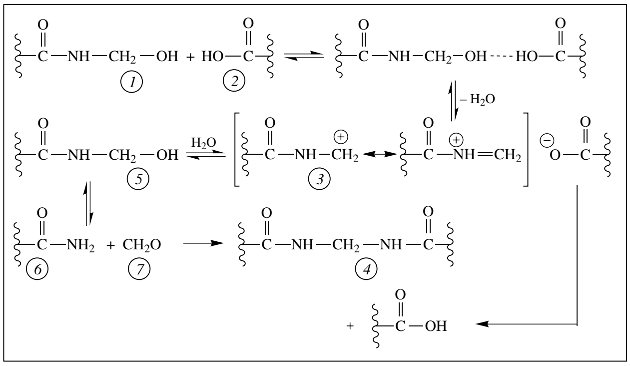


Fig. 2: Carboxyl groups as “ internal” catalysts in the cross-linking of copolymers containing N-methylol groups.

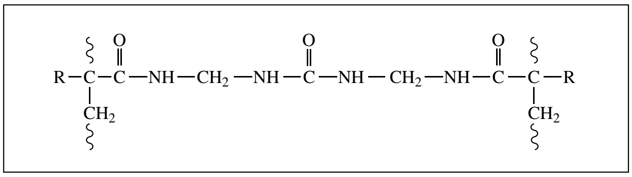


Fig. 3: Dimethylolurea as a linking agent between copolymers and polymers containing amide groups.

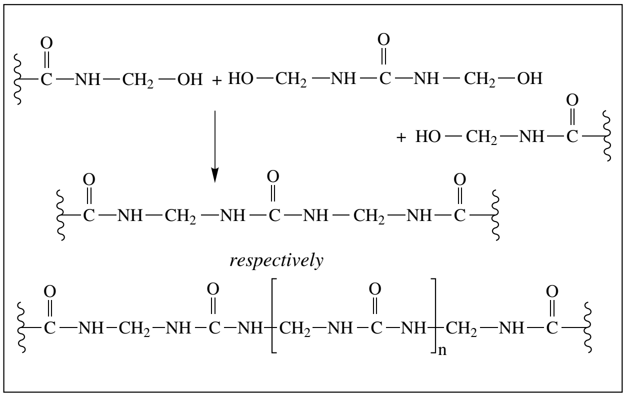


Fig. 4: Reaction between dimethylolurea and copolymer in the presence of acidic substances.

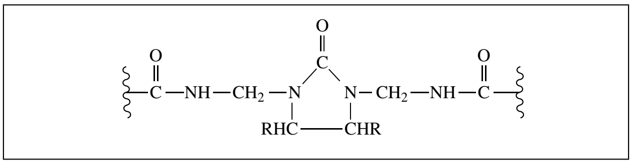
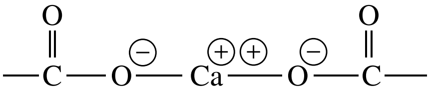


Fig. 5: Cross-linking of copolymers containing N-methylol ether groups with etherified precondensate.



$$-\overset{O}{\overset{\|}{C}}-O^{\ominus}-Ca^{\oplus\oplus}-{}^{\ominus}O-\overset{O}{\overset{\|}{C}}-$$

The cross-linked polymers, however, will swell in the water, while the polyvalent ions may be exchanged, e.g. in the washing process. This reaction was used in the past for the manufacture of non-woven fabric. Nowadays it is mostly used solely in combination with other types of cross-linkage, e.g. with coatings. These additional cross-linkages increase the resilience of textiles. A reaction that also occurs at room temperatures is the cross-linking of the carboxyl groups with di- or polyepoxides (Fig. 6).

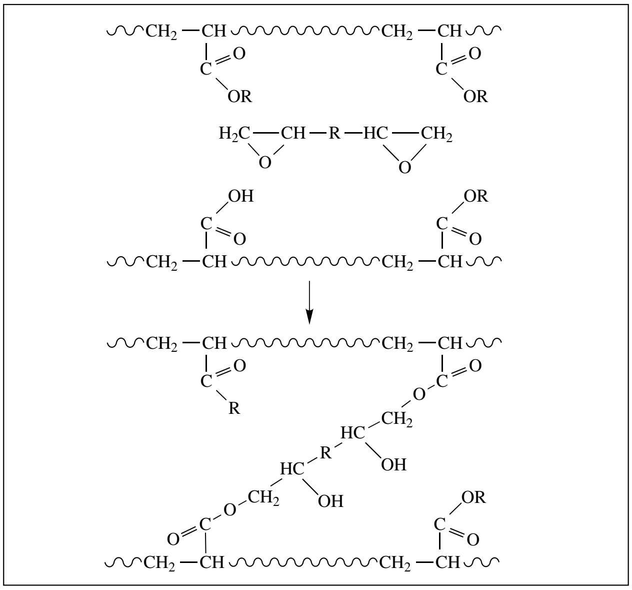
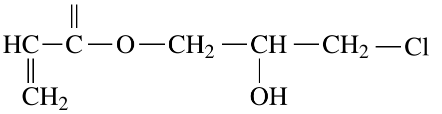


Fig. 6: Cross-linking of copolymer containing a carboxyl group with a diepoxide.

For textile applications, e.g. pigment printing, pigment dyeing, permanent sizing, diglycidethers are especially recommended as epoxy compounds. The chlorohydrin group is so insensitive to water that it can be used in emulsion polymerisation. The allyl ether of 1,2-dioxy-3-chloropropane, for example, is suitable as a monomer. However, the acrylates or methacrylates are also preferable here, e.g. the 2-oxy-3-chloropropylacrylate or the 2-oxy-3-chloropropylmethacrylate,

2-oxy-3-chloropropylacrylate or methacrylate



$$\underset{\underset{CH_2}{\|}}{HC}-\overset{\overset{O}{\|}}{C}-O-CH_2-\underset{\underset{OH}{|}}{CH}-CH_2-Cl$$

which is easily available from acrylic acid or methacrylic acid and epichlorohydrin. In this case it is possible to manufacture a reactive polymer from a copolymer (Fig. 7) since epichlorohydrin reacts fairly quickly with carboxyl groups. The reaction occurs in an aqueous medium at normal temperature and can be used as an aqueous dispersion in emulsion polymerisation.

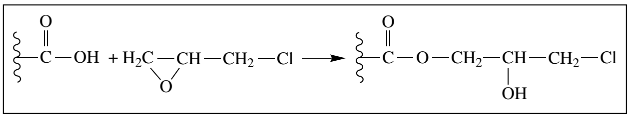


Fig. 7: Reaction of epichlorohydrin with carboxyl group of a polymer.

The condensation conditions of these types of copolymers are suitable for the fibre sector: 0.5–1% sodium hydroxide solution, approx. 5 min. with 100–140°C. For this reason it is recommended wherever acidic hardeners are not useable. For cross-linking the assumption is that chlorine is separated off with the addition of alkaline substances, whereby an intermediate epoxy group is formed. This reacts immediately with carboxyl groups of the copolymer (Fig. 8).

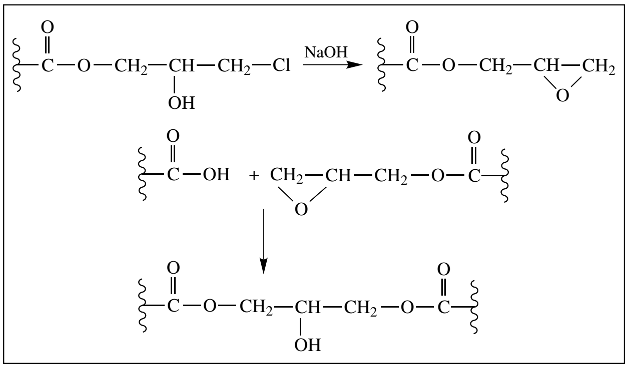


Fig. 8: Cross-linking of copolymers containing chlorohydrin groups.

It is not possible to carry out in an aqueous medium some of the reactions indicated because the reactive groups of the polymer or those of the cross-linker prefer to react with water (hydrolysis). Included here are systems such as

- copolymers containing hydroxyl groups with isocyanate groups,
- self-crosslinking copolymers with glycidyl groups.

Solutions of copolymers with these reactive groups are used for coatings and impregnation. Their films are more water-resistant than dispersion films because they are free from emulsifying agents. Through incorporating the reactive groups they become solvent-resistant after cross-linking. Both the hydroxy isocyanate system and the epoxy system are used as reaction polymers for this. However, the isocyanate groups of the cross-linker prefer to react with water, and epoxide groups do not survive the usual emulsion polymerisation with the result that a copolymer containing a hydroxyl group is formed (Fig. 9). The isocyanate group

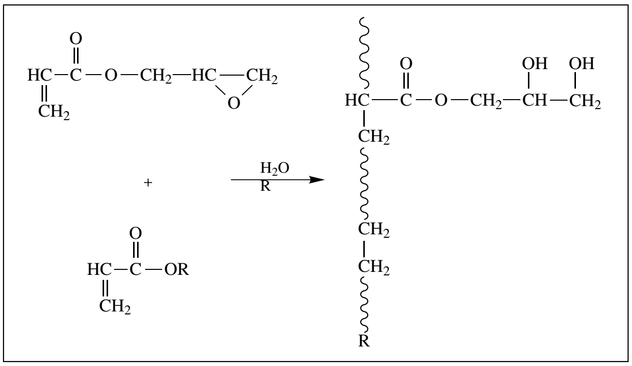


Fig. 9: Formation of copolymers containing hydroxyl groups by the emulsion polymerisation of epoxy group containing monomers.

may be masked, however, e.g. with alcohols, phenols, ketimines, lactams, etc., that it becomes insensitive to water and only reacts at high temperatures under separation of the masking agent. Polyisocyanates containing both free and masked isocyanate groups are able to react with compounds that contain both hydroxyl and epoxide groups. If, on the other hand, the epoxide groups are allowed to react with an amide, products are obtained which contain amino groups, masked epoxy groups and free hydroxyl groups. They will emulsify in water (Fig. 10) following acidification (source: Wilhelm).

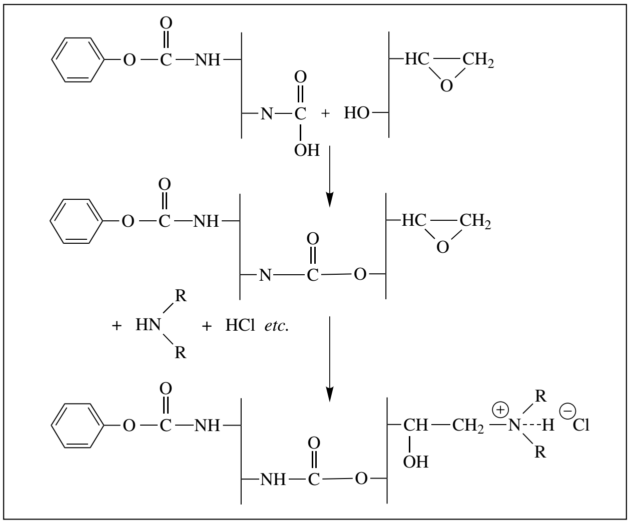


Fig. 10: Reaction of a partly masked polyisocyanate with a secondary amine containing hydroxyl groups.

Cross migration When dyeing blend fabrics containing polyester fibres, the second fibre is often heavily stained by the disperse dyestuffs used for the polyester. It will be necessary to use a two-bath dyeing process or a subsequent clearing bath for a single bath technique (see Fig.).

Even with pre-dyed polyester there remains a danger of dyestuff bleeding off the polyester and cross-staining the second fibre during cross-dyeing e.g. with acid dyestuffs in the dyeing of wool-polyester blends based upon pre-dyed polyester fibre.

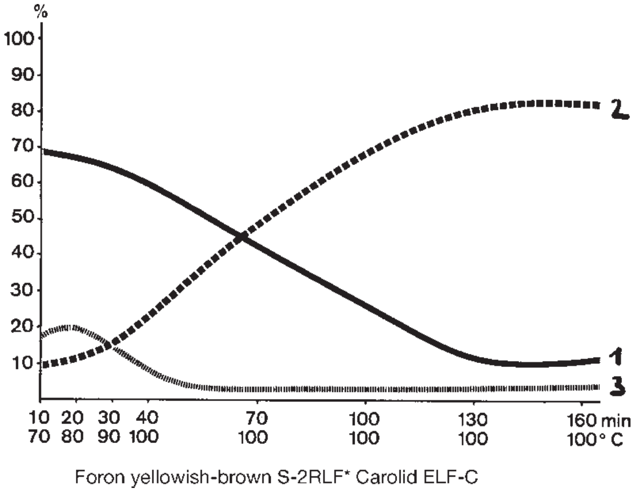
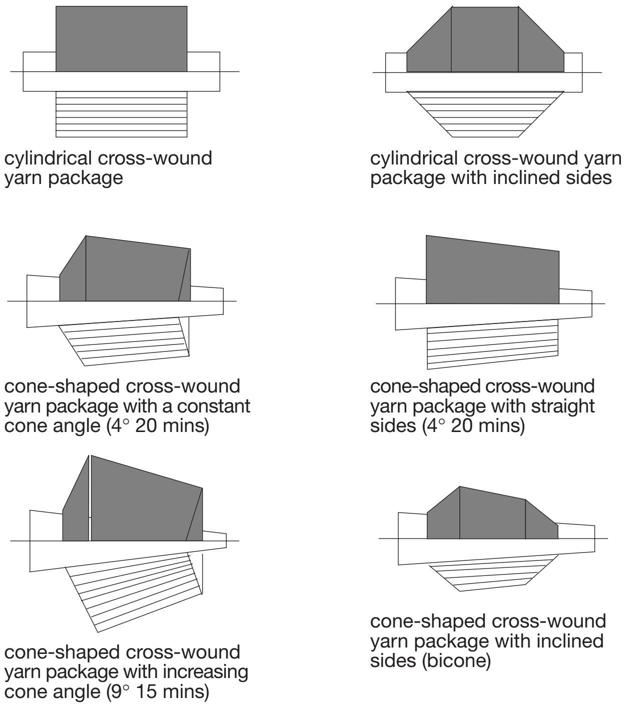


Fig.: Distribution of disperse dye (as a % of the amount of dye used) when dyeing at the boil or during boiling depending on the dyeing time (according to Sandoz).
1 = dye bath; 2 = polyester; 3 = wool.

Crossover point Crossing point between warp and weft yarns in woven fabrics.

Cross-sections of fibres A preponderant number of microscopic studies of the textile fibre cross-section are concluded with a predominantly qualitative report. Longitudinal textile fibre sections on the other hand are largely necessary for quantitative tests in as much as light-optical microscopic orders of size are involved. The production of fibre sections, particularly with the aid of the microtome, is a preparation process for light-optical microscopy. In the electron microscopic testing of textile materials, the ultra-thin section production method is employed in addition to the classic replica technique. Compared with the light-optical microscopic section preparing methods and the operational technology of scanning electron microscopy, which also employs the usual microtome section, ultrasection technology is making slow progress in textile research. Technical sectioning problems are probably largely responsible. The nature of the textile fabric represents the real problem in the production of textile cross-sections. For cutting, all textile materials have to be "stabilised" by embedding, and this represents the biggest difficulty for developing an easily employable method, in that textile fibres cannot be penetrated by the embedding agent. Thus in section testing, other processing questions and effects appear basically as biological histology preparations in sectioning for example.

Crosswound yarn package Package of yarn wound onto cylindrical or conical former characterised by the crossing of the successive helices of yarn. A



cylindrical cross-wound yarn package

cylindrical cross-wound yarn package with inclined sides

cone-shaped cross-wound yarn package with a constant cone angle (4° 20 mins)

cone-shaped cross-wound yarn package with straight sides (4° 20 mins)

cone-shaped cross-wound yarn package with increasing cone angle (9° 15 mins)

cone-shaped cross-wound yarn package with inclined sides (bicone)

Fig.: Types of cross-wound yarn package.

cross-wound package from which the cylindrical former has been removed is termed a muff. The successive coils wound onto the package lie parallel to the surface of the former (both cylindrical and conical). Formers comprise paper or varnished paper tubes or for dye packages perforated tubes (usually in rustproof metal or plastics), whilst muffs are crosswound onto spindles from which they are removed. The principal advantage of crosswound packages and muffs is their stability, with each successive coil retaining its predecessors and overcoming the need for costly flanged formers. Yarn can be unwound from the centre of muffs as from a ball of knitting yarn. Cylindrical and conical packages with parallel or tapering sides are distinguished by their particular forms (see illustration) whilst the most common form for man-made filaments is the tapered pineapple (or biconical) cheese with taper at each end.

Crow's feet Technical term for folds and creases in densely woven piece goods (poplin, gabardine) treated in rope form.

CRSIT, abbrev. for: Centre de Recherches de la Soierie et des Industries Textiles (French Research Centre of the Silk and Textile Industry), Lyon, France; → Technical and professional organizations.

CRTM, abbrev. for: Centre de Recherches Textiles de Mulhouse (French Textile Research Centre of Mulhouse), Mulhouse, France; → Technical and professional organizations.

Crushed Foam Rohm and Haas Company produce a variety of Primax acrylic emulsion polymers designed specifically for crushed foam coatings (Fig.). The acrylic copolymers withstand the high shear encountered in mechanical foaming devices and adhere well to both natural and synthetic fabrics whether woven, non-woven or knit. They provide softly clear or pigmented coatings durable to repeated laundering and dry cleaning and contribute to good low temperature flexibility without the incorporation of external plasticisers (Tab. 1 + 2). Crushed foam systems based on Primax emulsions which can be used for clear or pigmented coatings are also excellent adhesives for producing laminated fabric composites. Properly compounded and applied, acrylic foams exhibit minimal penetration into the base fabric and therefore, desirable aesthetic properties can be achieved with a wide variety of substrates.

The crushed foam coating process is simple and consists of the following sequence of operations:

1. Foaming of the Primax emulsions.
2. Coating of the foam onto the substrate.
3. Drying of the foam.
4. Calendering of the dried foam with or without lamination.
5. Curing of the crushed foam.

Depending on the end-use applications, the curing process can be deleted or the crushed foam coated fabric can be treated (e.g. for soil release or water repellency) prior to the curing operation.

The foamer pump should be adjusted to deliver the amount of compound required for the proposed coating speed and the wet density of the foam for most applications should be set at approx. 0.15 to 0.25 g/cm^3 by regulating the air flow and turbo speed. The consistency of foam is very similar to that of aerosol shaving cream. The gap setting of the metering device should be adjusted over the substrate to give a dry add-on of the desired weight.

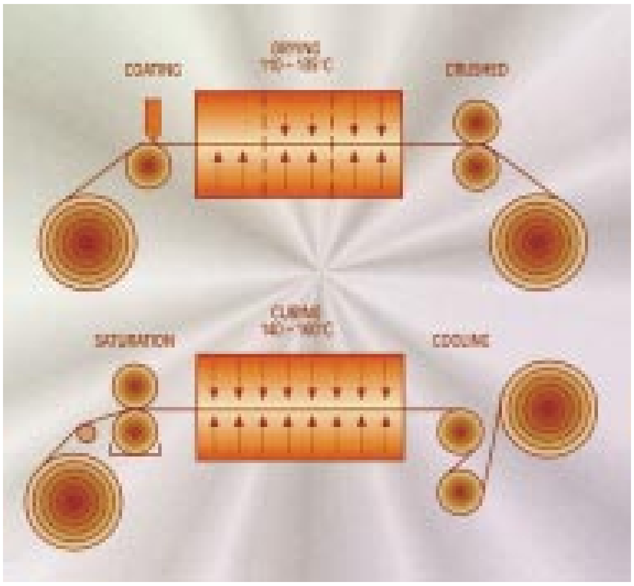
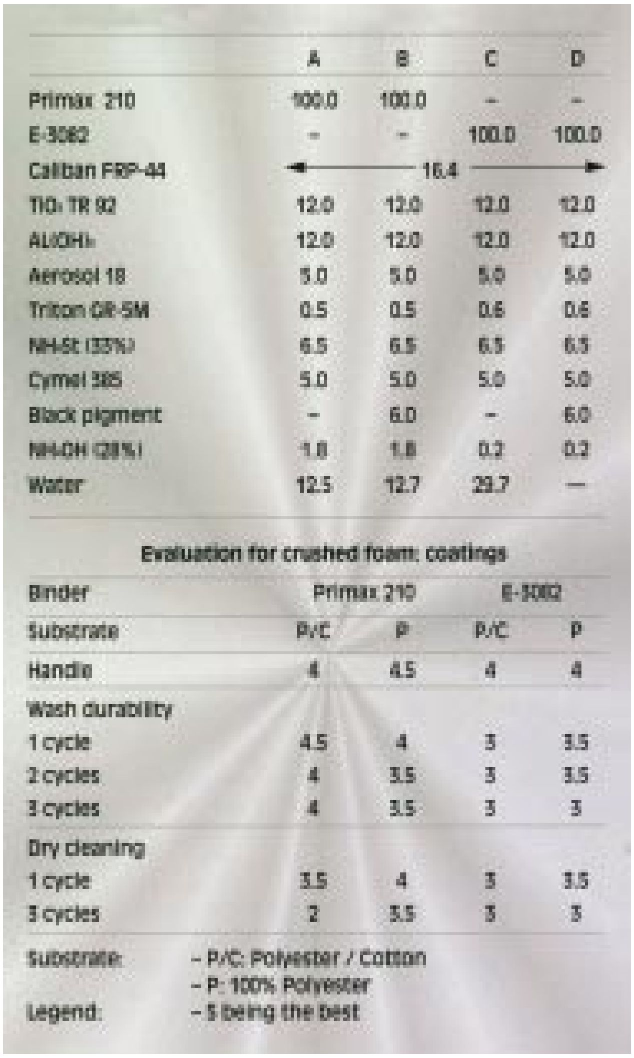


Fig.: Schematic of crushed foam equipment.



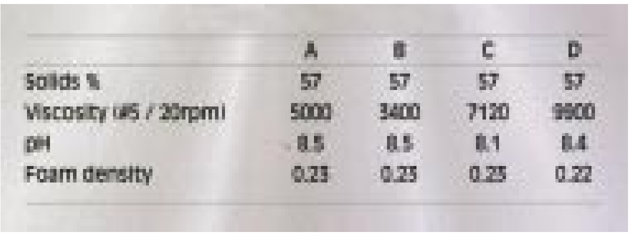
	A	B	C	D
Primax 210	100.0	100.0	–	–
E-3082	–	–	100.0	100.0
Calliban FRP-44	←	16.4		→
TiO_2 TR 92	12.0	12.0	12.0	12.0
$Al(OH)_3$	12.0	12.0	12.0	12.0
Aerosol 18	5.0	5.0	5.0	5.0
Triton GR-5M	0.5	0.5	0.6	0.6
NH_4St (33%)	6.5	6.5	6.5	6.5
Cymel 385	5.0	5.0	5.0	5.0
Black pigment	–	6.0	–	6.0
NH_4OH (28%)	1.8	1.8	0.2	0.2
Water	12.5	12.7	29.7	—

Evaluation for crushed foam: coatings

Binder	Primax 210		E-3082	
Substrate	P/C	P	P/C	P
Handle	4	4.5	4	4
Wash durability				
1 cycle	4.5	4	3	3.5
2 cycles	4	3.5	3	3.5
3 cycles	4	3.5	3	3
Dry cleaning				
1 cycle	3.5	4	3	3.5
3 cycles	2	3.5	3	3

Substrate: – P/C: Polyester / Cotton
– P: 100% Polyester
Legend: – 5 being the best

Tab. 1: Formulation prepared for crushed foam coatings.



	A	B	C	D
Solids %	57	57	57	57
Viscosity (#5 / 20rpm)	5000	3400	7120	9800
pH	8.5	8.5	8.1	8.4
Foam density	0.23	0.23	0.25	0.22

Tab. 2: Physical properties.

Preferably a 3 or 4 section hot air oven (with individual temperature control) with tenter frame should be used. Hot air impingement from both sides is recommended but it is essential to have well functioning baffles in the system so that the air flow can be correctly adjusted. High temperature should be avoided in the initial stages of drying to prevent "mud-cracking". This can also occur if the cup weight has been allowed to climb to a higher level than recommended. The foam should be dried for approx. $1^1/2$ to 2 minutes at a temperature between 110°C and 135°C. The exact time and temperature requirements will vary depending on the efficiency of the oven and the density and thickness of the foam coating. Drying time and temperature are also dependant on the weave of the fabric, an open weave requiring less time and lower temperatures than a close weave. The foam can be tested for degree of drying by using the "thumb test". If the foam is not dry enough, there is only a surface skin and a slippery wetness will be felt. If the foam bounces back the foam has been over-dried (premature curing). The fault can be corrected by either speeding up or slowing down the drier and/or adjusting the temperature.

Most available steel/hard rubber (or paper or cotton) roll calenders can be used for crushing but crushing pressure should preferably be at least 250 N/cm.

The foam can be crushed cold under certain conditions but it is advisable to use a heated calender (50°C or more) to avoid poor crushing and, therefore, loss in abrasion and wash and dry clean resistance. To obtain clear coatings and strong laminates with the Primax 210/Primax 310 emulsions, the foam must be crushed at 150°C minimum.

In addition to waterproof and blackout coatings, a number of speciality crushed foam applications have been successfully developed based on the Primax emulsions mentioned above. Among those are coatings to seal-off porous substrates, conductive coatings for wallcoverings, simulated leather, textile laminations etc.

There are several types of foaming equipment on the market and details on these machines are available from the manufacturers. Most technical foaming devices employ a Mono pump to deliver the compounded emulsion to the mixing head where air is supplied to generate foam. In order to assure adequate and consistent foam generation, the delivery line from the compounded feed tank to the Mono pump should be as short and unrestricted as possible, and a head of at least 30 cm over the pump inlet should be maintained. In addition, care should be taken to avoid air entrapment while compounding and shipping the acrylic latex as the presence of excess air can dramatically reduce pumping rates and cause delivery to be erratic. Pump packings should be carefully maintained to assure that air is not sucked into the pump on the inlet side.

Crushed foam coating A coating process with acrylic foam which, after application, is dried on the underlay, broken between rollers and then hardened.

Crushed patent leather Polyurethane coated → Synthetic leather on a woven, warp knitted or nonwoven substrate, crinkled and calender embossed and lacquered. Can be washed, but cannot always be dry cleaned. Preferred on a polyester, polyamide or polyacrylonitrile base (blends). Use: clothing purposes, upholstery covers, motor car upholstery, decor textiles, wall coverings, covering fabrics and imitation leather.

Terms: antique velvet, crash velour, crushed velour, grained velvet etc.

Crushed styles Fabrics in which irregular folds and creases are set. They are stuffed in rope form into nets, and laid in boiling water, or steamed in a tumbler.

Crush-effect machine For producing crushed crease effects in continuous fabric throughput. A pair of draw rollers conveys the fabric free-running in rope form to the pressing unit, the material is pressed into a perforated stuffer tube where the desired crush structure is obtained, and subsequently steam set over an adequate dwell time. The top roller can be slewed; lateral material feed. The setting tube is a perforated stainless steel tube clad in an insulated stainless steel jacket with steam and condensate connections. Setting temperature thermostatically adjustable between 70 and 150 °C. Crease formation dimensions and setting permanence depend on the intensity of the pressing process, the steam temperature and the dwell time. The draw roller pair feeds in free-running mode only on the operating stroke. Roller speed internally controllable, automatically following machine speed.

Crystall gum,

I. → Dextrines.

II. → Industrial gums.

Crystallinity The level of the crystalline content. Has a considereable effect on the characteristics of fibres and polymer application effects. In the latter case e.g. provides a measure of dry-cleaning fastness of heat-sealable polymers: the more crystalline a polyethlylene type (e.g. high-density polyethylene), the greater its resistance to penetration by solvents, the less crystalline it is (e.g. low-density polyethylene), the lower its resistance.

Crystallites (micelles). Crystal-like, elementary bodies of crystalline construction, i.e. uniform spatial arrangement of a very small cell structural component. So-called chain grate construction for example (pleated sheet structure). In the fibre fine structure, these types of crystallite are well ordered areas of a crystalline structure. They are identified by X-ray observation. To some extent, the densely packed molecule chains overlap from one crystallite to the next (elastic bonding) giving rise to loosened, so-called non-crystalline (amorphous) areas between individual crystallites. The single-phase model (crystallites with faults) is the opposite of the dual phase model with crystalline and non-crystalline areas (“fringe micelles”).

Crystalloid Crystal-forming substance, e.g. sodium chloride, sodium sulphate, copper(II) sulphate, sugar. Antonym → Colloid.

Crystalloidal solution Mainly solutions of low molecular substances in water, like sodium sulphate, sodium carbonate, magnesium sulphate, urea (as softeners and weighting and hygroscopic agents) for example, on the other hand, scarcely or not at all in a form already precondensed with formaldehyde = transition to the → Colloidal solution already.

Crystals (Lat., Gk.). More or less uniformly constructed bodies which occur by the crystallisation during cooling of saturated salt solutions (sodium crystals). There are 32 crystal symmetry classes with 230 space groups. Classification in six crystal systems in accordance with the type and number of symmetry axes and axis intersection:

I. Cubic (regular or isometric): 3 identical vertical axes, as for example in sodium chloride or potassium aluminium sulphate.

II. Hexagonal: 3 axes, two of them equally at a 120° angle, and one vertical to them; also included here is the so-called trigonal system, as in quartz or tourmaline for example.

III. Tetragonal: 3 axes as in I., vertical to each other; 2 identical, the 3rd of a different dimension.

IV. Rhombic: 3 dissimilar axes vertical to each other, as in magnesium sulphate or zinc sulphate for example.

V. Monoclinal: 2 axes of different dimensions at right angles, and one intersecting at an oblique angle, as in sodium tetraborate or sodium carbonate for example.

VI. Triclinal: 3 dissimilar axes at oblique angles to each other, as in copper(II) sulphate for example.

There are also multi-form crystal shapes, so-called dual, triple and quadruple combinations etc.

CS, abbrev. for: Commercial Standard (USA).

Cs, chemical symbol for caesium.

CSIRO, abbrev. for: Commonwealth Scientific and Industrial Research Organization, East Melbourne, Australia; → Technical and professional organizations.

CSN, abbrev. for: Ceskoslovenskych Norem (Czechoslovakian Foreign Standard).

CT,

I. → Triacetate fibres, → Standard abbrev. for textile fibres, according to DIN 60 001 up to 1988, from 1991 → CTA.

II. abbrev. for: Commission Technique = technical committee.

CTA, → Triacetate fibres, → Standard abbrev. for textile fibres, according to DIN 60 001 T4/08.91.

Ct Product, c = concentration in mg/m^3, t = reaction time in min. It is relevant to particularly volatile toxicants which are local irritants when inhaled (e.g. phosgene) where, instead of the dose, information on the effective concentration and duration of exposure (ct) apply. For specific degrees of poisoning, the ct product is constant over a fairly broad concentration range, i.e. at low concentration and with a long reaction time, there is the same effect as at high concentration for a short time.

CTNSS, abbrev. for: Centre for Thai National Standard Specifications, Bangkok, Thailand; → Technical and professional organizations.

CTTN, abbrev. for: Centre Technique de la Teinture et du Nettoyage (French Technical Centre for Dyeing and Drycleaning); → Technical and professional organizations.

CU → Cupro fibres, → Standard abbrev. for textile fibres according to the → EDP fibre identification code; → CUP.

Cu, chemical symbol for copper.

Cubex Wash test machine especially for determining the felting shrinkage of wool fabrics. Temporarily proposed by the IWS as a standard washing machine.

Cudbear, Archil → Natural dyes.

Cuite silk degummed natural silk.

Cumulative effect (Lat.: cumulatio = accumulation). Aggregation, concentration, increased effectiveness, e.g. by different products next to each other in the chemical finishing cycle or by different waste residues next to each other in effluent. "Cumulative effect" is the term employed here.

CUP → Cupro fibres, → Textile fibre symbols according to DIN 60 001 T4/08.91.

Cupra A collective term of the IVC for filaments and textile fibres (cupra fibres) produced by the cuprammonium process in use until mid 1956. Since then (in accordance with the CIRFS ruling) the term "Cupra" may only be used throughout the world, other than in Germany, for customs, statistical purposes and the like, whereas in Germany, the term → "Cupro" is now used.

Cuprammonium → Cuprammonium hydroxide.

Cuprammonium fluidity It is well-known that purified natural cellulose dissolves in cuprammonium hydroxide solution to give a solution that is viscous even at low concentrations. Cellulose that has been partially hydrolyzed or oxidized dissolves to give less viscous (more fluid) solutions at the same concentration; → Damage factor (S).

Cuprammonium hydroxide (cuoxam, Schweizer's reagent), $[Cu(NH_3)_4](OH)_2 \cdot 3H_2O$. Dark blue solution. Production: add a saturated solution of copper(II) sulphate ($\cdot 5H_2O$) in distilled water to 25% ammonia; thoroughly rinse the precipitate with distilled water, and dry. The resultant powder is durable for a long period, and is dissolved for use with 25% ammonia. Use: for the chemical identification of cellulose fibres and silk, and also for the quantitative determination of the degree of polymerisation (DP) of cellulose fibres.

Cuprammonium silk → Cupro fibres.

Cupric, Copper (II) compounds.

Cupric acetate (acetic copper, neutral copper acetate, copper acetate), $Cu(CH_2COO)_2 \cdot H_2O$. Molecular weight 199.67; density 1.88. Easily soluble bluish green crystals. Use: resisting agent for indigo resist products; oxygen carrier with aniline black.

Cupric chloride (hydrochloric copper), $CuCl_2 \cdot 2H_2O$, molecular weight 170.52. Greenish crystals, easily soluble (colour green, blue diluted). Use: highly effective oxygen carrier for aniline oxidation black.

Cupric ethylene diamine (ethylene diamine copper), $Cu(NH_2{-}CH_2{-}CH_2{-}NH_2)_2(OH)_2$. Solution of copper hydroxide (0.5 mol) in ethylene diamine (1 mol). Use: solvent for cellulose (and silk), like cuprammonia, but, in contrast, superior due to greater swelling and solvent capacity (much more rapid and intensive), cellulose solution not so sensitive to light and oxygen.

Cupric sulphate (blue vitriol, bluestone, blue jack, sulphuric copper), $CuSO_4 \cdot 5H_2O$; molecular weight 249.6; density 2.3. As blue crystals containing water of crystallisation (only these are correctly described as "blue jack") and as a white salt free of water of crystallisation. Soluble in water; also soluble in glycerine, but not in alcohol; aqueous solution strongly acid. Use: as an oxygen carrier; for fastness after-treatment of dyed fabrics, antiseptic agent (finishes), only in the presence of rust-resistant steels); for oxycellulose identification etc.

Cupro The term "cupro" has now come into widespread use throughout the world to denote any regenerated cellulose fibre produced by the cuprammonium process.

Cupro fibres A class of → Cellulosic fibres, regenerated, produced by the cuprammonium process from raw materials containing cellulose (predominantly cotton linters, also wood pulp). Principle: mechanical pre-cleaning of the linters, chemical treatment with sodium hydroxide solution (kier boiling), bleaching, expressing to approx. 70% water content, dissolving in ammoniacal copper oxide (cuoxammon cellulose), filtering, deaerating, spinning through multihole spinnerets (as a single filament bundle) into a weak ammoniacal coagulation bath, i.e. the so-called draw spinning process, followed by removal of the copper, washing, softening by adding lubricants, drying, then winding on to bobbins or sectional beams. Chemical properties as for viscose filaments. Due to the higher degree of swelling, cupro fibres possess a greater affinity for dyestuffs than viscose. In contrast to viscose (surface structure with dogbone cross-section), cupro fibres have a circular cross-section and a scale-like torn filament surface structure, which therefore gives a more matt, silk-like lustre. Because of the copper content of the spinning mill effluent, cupro fibres are ecologically problematic.

Cuprous,

I. Chemical: copper (I) compounds.

II. Name for → Cupro fibres.

Cuprous ion dyeing method (cuprous ion process, copper (I) ions dyeing process). A now obsolete method for dyeing acrylic materials. It is a dyebath premordanting dyeing process, in which cuprous ions bind acid wool dyes to the polyacrylonitrile molecule. As mordants, copper salts give the strongest effect on polyacrylonitrile fibres whereby cuprous ions co-ordinate with the nitrile groups and thus produce positively charged sites in the fibre on which adsorption of dye anions can take place.

Curie (Ci) A unit for the measurement of radioactivity. One Curie of any radioactive substance is the matter from which $3.70 \cdot 10^{10}$ atoms decay radioactively per second. The Curie is an extremely large unit. Clothing contaminated with radiation is measured in millicuries (microcuries) = $^{1}/_{1000}$ Curie. From 1965 to the end of 1977 abbreviation Ci. Since 1978, the SI unit is given per second, i.e. the activity of a radioactive nuclide with $3.700 \cdot 10^{10}$ disintegrations/s.

$$Ci = 3.700 \cdot 10^{10} s^{-1}$$

The “new Curie” (Ci) is a useful unit of activity for counting tube measurements and is applicable to all radioactive substances. Now replaced by the becquerel (Bq), $1\ Bq = 2.7 \cdot 10^{-11}$ Ci.

Curing characteristics Temperature and time function of a chemical product (e.g. reagent) which distinguishes the course of the cross-linking process up to the max. cross-linking effect. Particularly important with permanent press processes operating with a number of reagents of different condensation characteristics.

Curing conditions Cross-linking conditions in the → Cross-linking of permanent finishing agents.

Curing curve The graphic representation of the achievable dry crease angle (→ Crease recovery angle) relative to the cross-linking temperature with constant cross-linking times for a specific permanent finish agent.

Curing machine Used for the continuous heat treatment of textiles, particularly for curing (cross-linking) permanent finish agents (→ Dry cross-linking process). Designed on the hot flue principle, with driven rollers, generally stepless speed control, for temperature measuring and regulating systems, various infra-red radiators being located upstream for quicker fabric heating.

Curing machine, festoon type Condensing machine with a large fabric content and tension-free fabric guiding for (benzine-free) pigment printed knitted fabrics. Festoon system with special insulation-covered carrier rods rotating during fabric run.

Curing process Usual term in resin finishing for the dry cross-linking process (→ Cross-linking).

Curl → Snarl.

Current (market) value → Service life of textile plant and equipment.

Current strength, electrical The base measure of the → SI system of units with its basic unit of ampere (abbreviation: A). Defined as the ratio of the current Q flowing through a conductor and the time, t, it takes to do so:

$$I = \frac{Q}{t}$$

Curtain coating process Low add-on application technique for woven and knitted goods based on the Texo-Roll machine, and which avoids the use of the pad mangle.

Curtain materials →: Window curtaining fabrics; Furnishing fabrics; Net curtain fabrics.

Curved blade applicator (CBA). A low pick-up application system. Liquor is applied over the entire width of a stationary curved blade and forms a fine film which is stripped off by the fabric. Unused liquor at the edges is recirculated for reuse. – Manuf.: West Point/USA.

Curved expander rollers The name describes the curved form of these → Expander rollers (Fig. 1). A rubber hose runs on the curved axis, and is held at regular intervals by several ball bearings (Fig. 2). The expansion effect results from the varying distances which the goods have to travel.

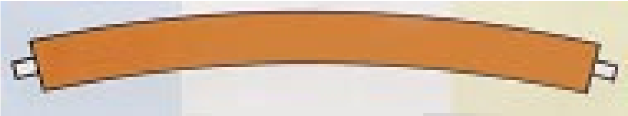


Fig. 1: Curved expander roller (Wittler).

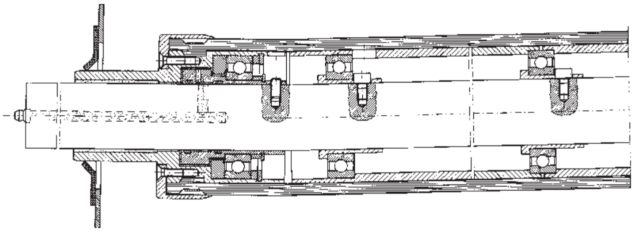


Fig. 2: Rubber hose held by ball bearings of the curved expander roller (Wittler).

Cut (Na Cut). An American yarn numbering system used for woollen yarn measurement. 1 Cut = 1 hank at 300 yards/lb.

$$1\ \text{Cut} = 0.605\ \text{Nm} = \frac{1\,653.5}{x} \cdot \text{tex.}$$

Cut fabric Of tubular knits or → Fents, made up using patterns and sewn together to form garments.

Cut film in screen making When producing hand-painted → Colour separation designs, smooth surfaced patterns may be produced through screens.

Transparent film is used which has a similarly transparent laminate coating and the pattern is traced with a knife on the laminated side. The laminated layer is then removed, without damaging the base film, wherever the pattern should be absent when printing.

Cuticle (Lat. cuticula = skin). In general use a biological term meaning the epidermis or superficial skin. In a textile context the term cuticle is used for the thin surface membrane of the cotton fibre and especially of hair and wool fibres. In the latter case the term is not quite correct as the surface of hair and wool is not a self-enclosed membrane but a series of overlapping keratinized scales enclosing the actual fibre stem, the → Cortex. The literature includes other terms such as epicuticle, endocuticle and exocuticle (components of the cuticle), epidermis and epidermal cells, epithermis and epithermal cells, epithelium, surface membrane etc. The term scale membrane is also sometimes used, referring to the scales of which it is formed. The internationally accepted terms are cuticle or cuticle cells.

Cutin,

I. (Suterin). A component (3.5–4%) in the primary wall of cotton. It is apparently still awaiting elucidation and cannot yet be defined more precisely.

II. (Cutin). A working description in research for a substance enveloping the → Cuticle of the wool hair which apparently consists of chemically highly resistant → Keratin of high density. The terms epicuticle, exocuticle and endocuticle are used as alternatives.

Cutis (Lat. = skin). A rarely used term for → Cuticle in radial fibre structure. In wool structure, it is identical to the scale cell layer beneath which lies the subcutis (intermediate membrane).

Cut length → Staple length.

Cut of garments, style, shape, design, cut, e.g. the cut of a suit.

Cut of spiral shearing cylinder → Shearing machine.

Cut-pile carpets → Tufted carpets, the pile of which consists of loops which have been cut open; in contrast to → Loop pile carpets.

Cut-pile plush A knitted plush fabric produced by cutting the loops of → Circular-knit pile fabrics. The production of this article involves high finishing costs (up to 40% of the final material cost). The following example represents a typical processing route: Slitting of tubular knitgoods – presteaming – pre-cropping – washing – hydro-extraction – drying – heat-setting – dyeing – tumbler drying – cropping – stentering. The total weight loss in pre-cropping and final cropping is 20–25%.

Cut selvedge suction remover For removing selvedge and centre strips by suction; can be used on all reroll cutting, transverse cutting, laminating and coating machines, extruders, stenters, printing machines etc.

Cutting in textile finishing The different types of cut in use are shown in Fig. 1.

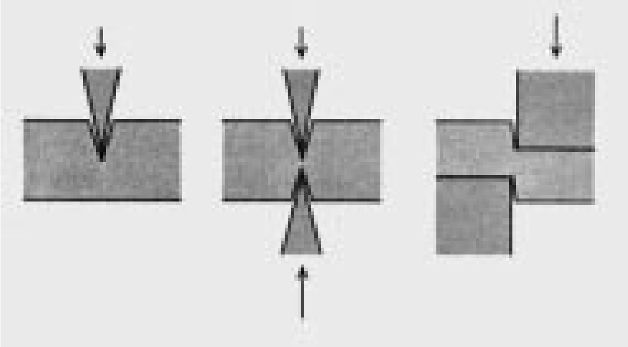


Fig. 1: Diagrammatic section of the different types of cut: cutting – biting in – shearing.

The cutting of fabrics often does not take place as an individual process, but usually directly on exit from a production machine. Conventional procedures include cold cutting with rotating blades or hot cutting with rotating cutting blades for thermoplastic fabrics. Cutting with circular rotating blades is used for the cutting of cloth edges or the length-wise splitting of fabric lengths, two different cutting principles are applied, a) rotary blade cutting and b) rotary blade shearing (Fig. 2).

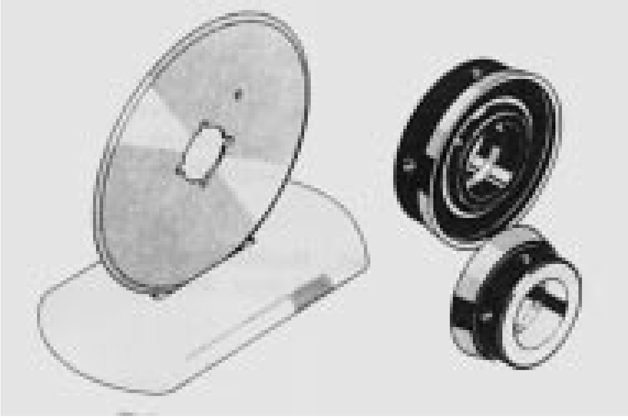


Fig. 2: Principles of rotary blade cutting (left) and rotary blade shearing (right).

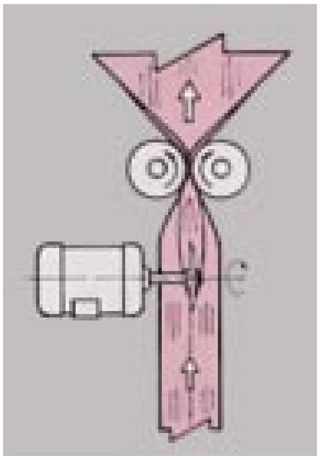


Fig. 3: Tubular fabric slitting machine (Fong's).

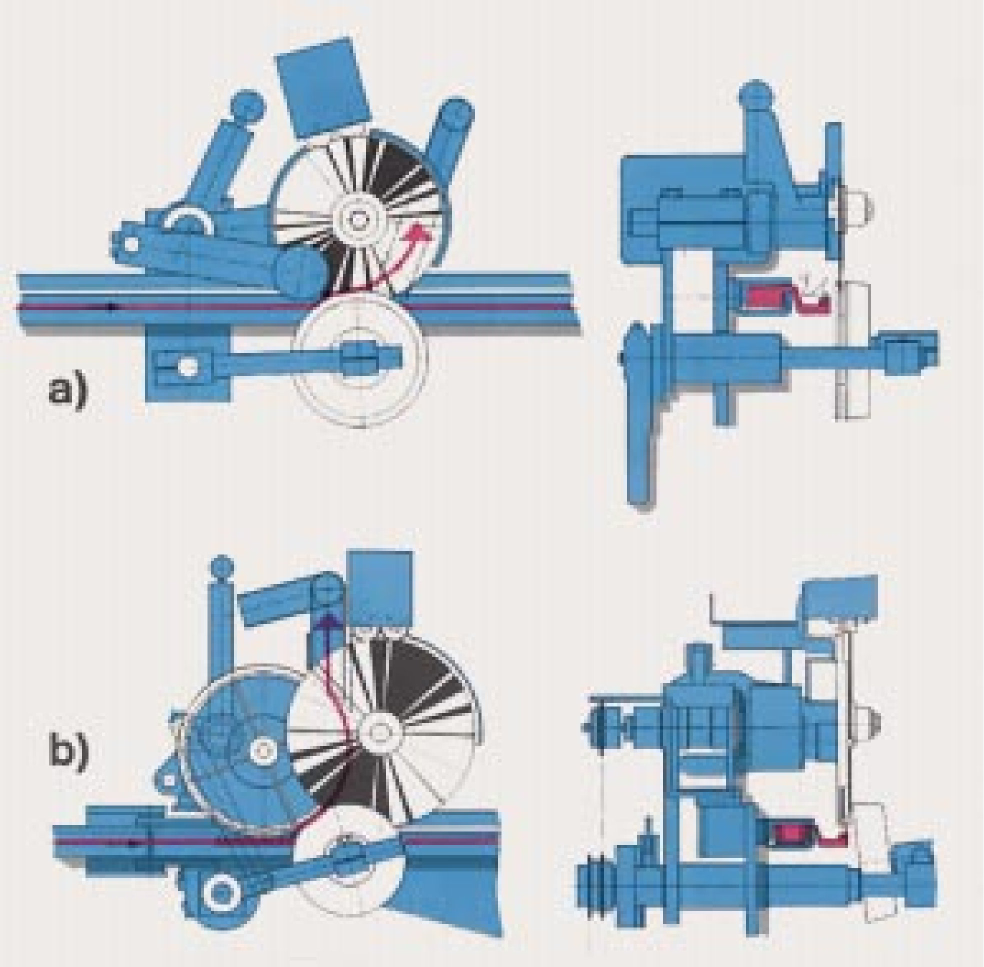


Fig. 4: Selvedge cutting machine with automatic extraction of the cuttings (Krantz).
a) Type LS 11 for cutting close to the warp; b) Type LS 8 for cutting above the warp, reduced clippings.

The rotary cut is only suitable for relatively thin material. A disc blade is used that penetrates only slightly a groove in the cutting table. The disc blade is fixed directly on to a drive shaft. It is sharpened by means of a grinding device during operation. The cutting speed of the blade is unimportant, but should nevertheless be sufficiently in excess of the cloth speed.

In the case of rotary blade shearing two slightly overlapping rotary blades work together, pressing slightly against one another. This method is suitable for cutting thick, thin and relatively hard material, especially for edge cutting and central cutting up to approx. 2 mm material thickness. The cutting speed is approx. 5% higher than the cloth speed. The blade assembly for edge trimmers takes two forms, the disc blade/lower blade for thin material, and the plate upper/lower blade for thicker and stiffer material. Both cutting principles, modified as appropriate, are used for selvedge and central cutting and tubular fabric slitting (Fig. 3). Complete cutting units (cutting machines) use the cutting equipment described, e.g. for the cutting/waste extraction on exit from the machine (Fig. 4) (rotary blade cutting, max. 200 m/min.), for the cutting of foam-bonded fabric lengths and also felt lengths (rotary blade shearing, max. 60 m/min.) and for the cutting of tubular knitted fabrics (rotary blade cutting, max. 60 m/min.); the latter with e.g. photo-electronic split detector and tubular piece guide (→ Tubular fabric slitting machines).

Cutting of textile fabrics A survey of the possible methods of generating heat reveals four principal groups:

– mechanical heat generation,
– numerous methods of generating heat by electricity,
– chemical generation of heat,
– heating by means of radiation.

These methods of generating heat are used for cutting and joining. More important is the question of "active energy" at the actual cutting or joining point. By active energy is meant that which leads directly, i.e. with no change in appearance, to an alteration in energy or a change in the material in the active element, that is the microscopic area surrounding the cutting and joining point. If all types of energy are examined and regarded as possible types of active energy (see fig.), then the thermal processes can be arranged systematically. A great many types of active energy are required; some of the most important for textile processing and the garment industry are listed.

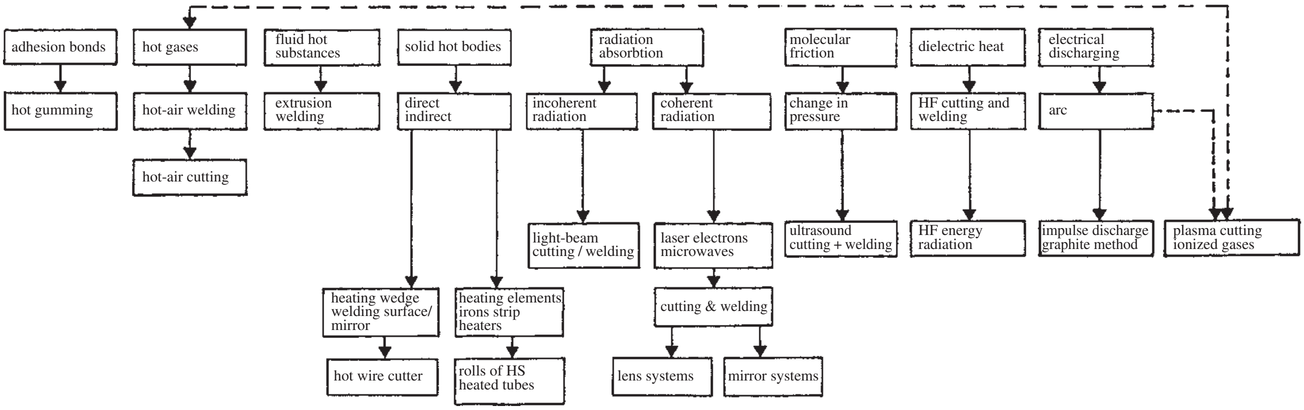


Fig.: Survey of well-known active energies for thermal cutting and joining (welding) (according to Bäckmann).

Cutting	Trend
– Hot cutting with bars	+++
– Hot wire cutting	– –
– Roll hot cutting	+++
– Light-beam cutting	–
– Laser cutting	++
– Electron-beam cutting	– –
– Plasma cutting	–
– Energy beam (HF cutting)	– –
– Ultrasound cutting	+++
– Electroerosion	–
– Hot-air or hot-gas cutting	+

Thermal cutting processes are increasing in importance. Thermal cutting such as hot cutting or ultrasound cutting, thermal pressing such as hot pressing or high-frequency pressing, thermal cutting by laser, light beam or hot air and plasma must be examined (source: Bäckmann).

Cutting oils Facilitates the work of cutting tools by conducting away the heat generated during (metal) cutting processes. Cutting oils are (non-)emulsifiable mineral oil blends.

Cuttle down Generally refers to the cooling down of woollen piece goods by laying up in piles.

Cutts sizing system A minimum application process based on the nip-padding principle. The warp is no longer immersed in the sizing bath. Instead, the sizing agent to be used is applied at higher concentration by means of an engraved roller.

Cuvettes Square, standard glass vessels comprising a centrepiece with plane-parallel window plates fused on, or also as disposable plastic cuvettes, used particularly in liquid colorimetry and spectrophotometry.

CV, → Viscose fibre, → Standard abbrev. for textile fibres, according to DIN 60 001 T4/08.91.

CY, → Modal fibre, → Standard abbrev. for textile fibres, according to DIN 60 001 up to 1988, from 1991 → CMD.

Cyanine dyes → Polymethine dyes.

Cyanoethylation of celluloses Applies particularly to cotton and involves treatment with → Acrylonitrile. Main reactions:

$$\text{Cell–OH} + CH_2{=}CH{-}C{\equiv}N \rightarrow \text{CellOCH}_2\text{CH}_2\text{CN}$$

The reaction is dependent on the following factors:

- Concentration of alkali, max. substitution is 15% NaOH;
- Moisture content of the fabric (50–80%);
- Reaction temperature;
- Reaction time;
- Concentration of acrylonitrile.

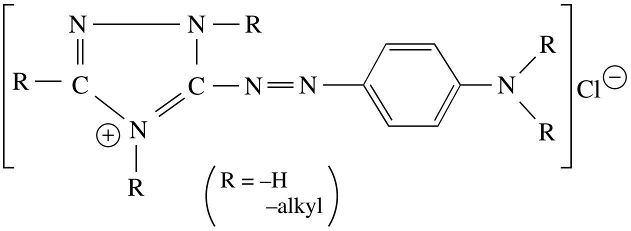
Various processes such as single-bath, two-bath and impregnation processes are known. Properties of cyanoethylated cotton: with an increasing degree of substitution there is a decrease in density and breaking strength; a gradual increase in the elongation at break, the dry abrasion resistance and the resistance to acids. It is highly resistant to rotting and oxidizing agents, saponification in the presence of alkalis, and is not resistant to washing at the boil in alkaline wash liquors. It can be dyed with direct, acid, cationic, vat, sulphur and naphthol dyes. Coloration with disperse dyes in heat transfer printing is possible. The required degree of substitution is at least 0.1.

Cyanurtriamide → Melamine.

Cybernetic Relating to → Cybernetics. In contrast to single track/linear-causal thinking in insulated individual factors (e.g. egocentric profit optimisation) cybernetic thinking is holistically oriented (e.g. sociocentric efficiency optimisation). Cybernetic control circuit: principle of maintaining a specified set value. Taken account of by controller and controlled system by constant adaptation of the control unit also faults (during implementation). When the control unit is adapted to constantly changing conditions, the control unit makes an adjustment and at the moment when information feedback is coupled with the control position in such a way that specific changes in effect ensue "automatically", it is referred to as back-coupling and also as self-regulation and automation.

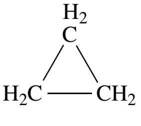
Cybernetics (Gk.: kybernetik = steersman's art). Theory of the behaviour and organisation of target oriented systems. Mechanically imitable path of energy flow (frequently interpreted as information/communication flow), comparative control and regulatory processes, as science of the structure, relations and behaviour of dynamic systems which make automation possible. These systems can organise themselves by internal structural change in the event of significant environmental change, for which reason they are called adaptive systems. They include for example machine systems (electronic computer systems, electronic data processing) and social systems (economics, administration and management functions).

Cyclammonium dyes Cationic dyestuffs of the type:

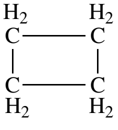


Cyclic (Lat.: *cyclus*; Gk.: *kuklos* = circle, ring). Recurring or revolving in regular cycles, circulating, ring-shaped. → Cyclic compounds.

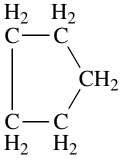
Cyclic compounds Organic compounds whose structure is characterized by one or more closed rings. Single ring compounds may contain ring structures based on 3, 4, 5 and 6 atoms, e.g.:



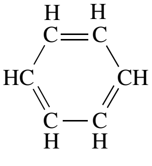
Trimethen
Cyclopropan



Tetramethen
Cyclobutan



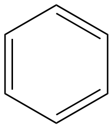
Pentamethen
Cyclopentan

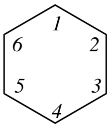


Benzol

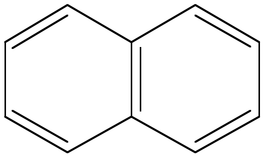
Cyclic compounds can be subdivided into homocyclic compounds, in which the ring is composed only of carbon atoms, e.g. benzene, and → Heterocyclic compounds, in which the ring is composed of atoms of more than one kind, e.g. pyridine. Higher ring compounds are derived from benzene and are described more fully under → Cyclic hydrocarbons.

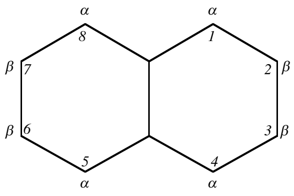
Cyclic hydrocarbons Comprehensive group of aromatic hydrocarbons which form ring systems, and the best known representative of which is → Benzene. → Naphthalene follows with 2 condensed benzene nuclei or benzene rings, whilst → Anthracene consists of 3 condensed benzene nuclei. For identifying complicated systems, the benzene formula is thought of as numbered consecutively, and derivatives are represented in the 1.2 position as ortho-compounds, in the 1.3 position as meta-compounds, and, in the 1.4 position, as para-compounds. The benzene formula is generally written simply as a six-membered ring:



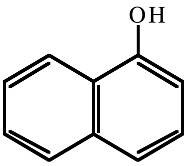


Corresponding also to the naphthalene form simplified:

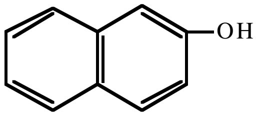




Complicated derivatives are consecutively numbered, and, if necessary, represented by α or β, because isomers can have different characteristics, e.g. α-naphthols and β-naphthols, of which only the latter have affinity for cellulose:

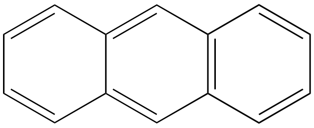


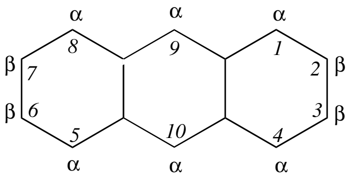
α–naphthol



β–naphthol

A similar procedure is also used with all other ring systems, e.g. with the anthracene formula:



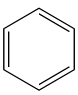


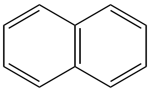
Cyclic hydrocarbon classification into:

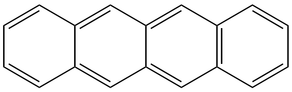
I. (Iso)cyclic or aromatic hydrocarbons with ring members only of carbon atoms, benzene type. Aromatic hydrocarbons (isocyclic, cyclic) have predominantly the common characteristic of easy alkylating and sulphonating ability, from which follow almost incalculable possibilities of building up different types of substitution products. The lower members (benzene and its homologues) are not only outstanding solvents, but the higher members serve also as an extremely important basic substance for many dyestuffs, textile auxiliary products and other products.

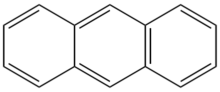
Classification as:

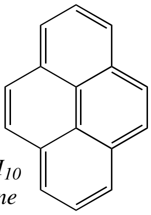
a) single and multinuclear condensed ring systems, consisting of 1–5 benzene rings:

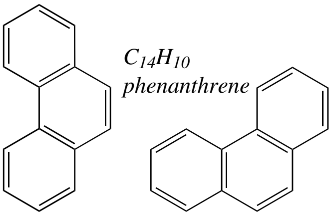

C_6H_6
benzene

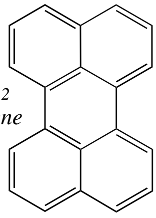

$C_{10}H_8$
naphthalene


$C_{18}H_{12}$
tetracene

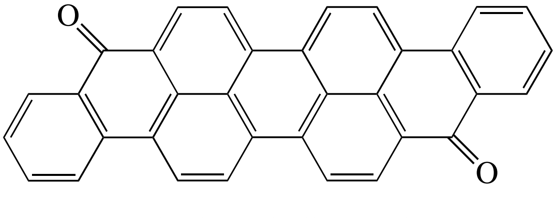

$C_{14}H_{10}$
anthracene


$C_{16}H_{10}$
pyrene


$C_{14}H_{10}$
phenanthrene

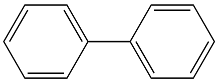

$C_{20}H_{12}$
perylene

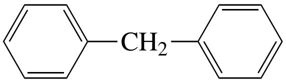
There are however still bigger important ring systems with up to 30 C atoms, which form the basis of a series of indanthrene dyes for example:



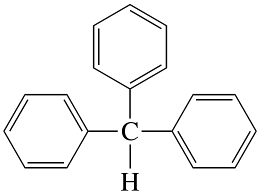
indanthrene brilliant violet 3 B

b) Multinuclear uncondensed rings also play a part as a basic substance for numerous important dyes, like for example:

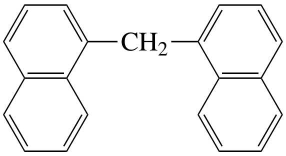

$C_{12}H_{10}$
diphenyl



$(C_6H_5)_2CH_2$
diphenyl methane



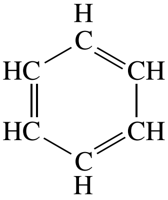
$(C_6H_5)_3CH$
triphenyl methane



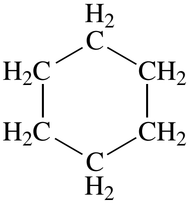
$(C_{10}H_7)_2CH_2$
dinaphthyl methane

II. Alicyclic, cycloaliphatic or hydroaromatic hydrocarbons with, in contrast to I., a higher number of hydrogen atoms, → Cyclohexane type.

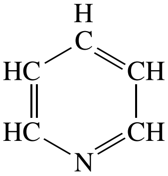
III. Heterocyclic compounds with foreign atoms in the ring system, → Pyridine type. Strictly speaking, this group is no longer included among the hydrocarbons.



benzene
(iso)cyclic



cyclohexane
alicyclic
hydroaromatic



pyridine
heterocyclic

Cyclic polyphosphates → Metaphosphates.

Cyclic sulphonates So-called nuclear sulphonates of aromatic compounds like benzene, napthalene and toluene sulphonate. → Alkyl benzenes.

Cyclo-aliphatic (alicycyclic). Cyclic carbon compounds which do not possess an aromatic ring with its system of conjugated double bonds. They are cyclic compounds with aliphatic characteristics, e.g. cyclopropane and cyclohexane. →: Aliphatic compounds; Alicyclic hydrocarbons.

Cycloalkanes Cyclic → Alkanes. Saturated hydrocarbons also referred to as naphthenes; → Alicyclic hydrocarbons.

Cycloclatrate Technical realisation of the removal of non-exhausted dye molecules from segregated streams could take the following form at the dyeing machine: phase 1 involves the selective filtering out of residual dyes, while regeneration takes place in the side vessel of the machine (see Fig.) in phase 2.

Cyclodextrins Used as textile auxiliaries obtainable from the bacterial degradation of starches. They form inclusion compounds with a wide variety of organic substances, whereby the physico-chemical properties of the included molecules are changed, e.g. in-

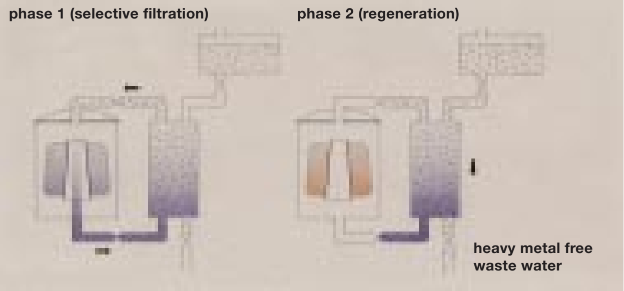


Fig.: Jasper's ideas (according to Schollmeyer) for the selective adsorption of dyes from used dye liquors with regeneration.

creased light stability of sensitive compounds, improved water solubility of sparingly-soluble compounds, reduction in the vapour pressure of highly volatile substances. Cyclodextrins are non-toxic and readily biodegradable. In comparison with other textile auxiliaries, their use brings about a clear reduction in the pollutant load of effluents and improved effluent clarification. → Cycloclatrate.

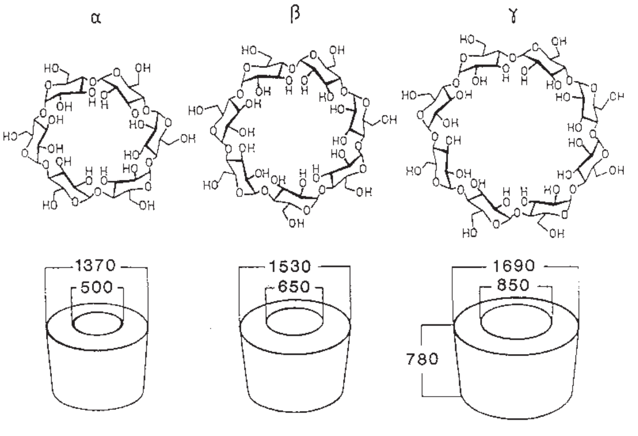


Fig.: Chemical structure and hollow space dimensions (in pm) of cyclodextrines (Buschmann).

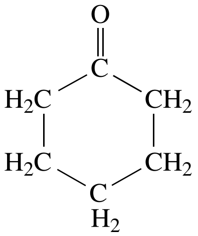
Cyclodextrins (see Fig.) are fixed on the fabric by the condensation reactions of cross-linking agents with the hydroxyl groups of cotton and those of the cyclodextrin structure. This makes it possible to include aromatics (e.g. perfume oils) in the fixed cyclodextrin molecules, so that they are able to volatilize over a fairly long period of time from the textile fabric at low concentration. It is also possible to bind unpleasant substances which are e.g. contained in perspiration, and thus reduce their vapour pressure. The ability of cyclodextrins to bind nonpolar substances prevents the redeposition of oily soils already located in areas close to the surface of such a finished fibre, thereby also achieving better soil removal during washing.

Cyclohexane (hexamethylene, hexahydrobenzene, hexanaphthene), $(CH_2)_6$; → Alicyclic hydrocarbons.

Cyclohexanol (hexahydrophenol). Chemically correct term for → Hexalin.

Cyclohexanol acetate (cyclohexanyl acetate). Solvent for nitrocellulose, cellulose ether, bitumens, metallic soaps, basic dyes, blown oils, crude rubber, many natural and synthetic resins and gums, lacquers, waxes.

Cyclohexanone (pimelic ketone, ketohexamethylene), $C_6H_{10}O$. Water-white to pale yellow liquid with acetone and peppermint-like odour. Immiscible with water, soluble in alcohol and ether. Solvent for nitrocellulose, celluloid, acetate cellulose, cellulose ether, chlorinated rubber, vinyl compounds, fats, oils, resins and cationic dyes. Also used in fat solubilizing soaps.



Cyclohexanyl acetate → Cyclohexanol acetate.

Cyclone An installation for dust extraction, e.g. from raising, emerizing, shearing, singeing and other machines which generate dust. The air to be extracted is pumped into large vertical funnels with the aid of powerful fans where it circulates downwards in the form of a vortex (Fig. 1). The dust is separated from the dust-laden air by centrifugal forces and friction on the walls of the funnel and spins slowly to the mouth of the cyclone at the bottom from where it is collected in bags for subsequent disposal (Fig. 2).

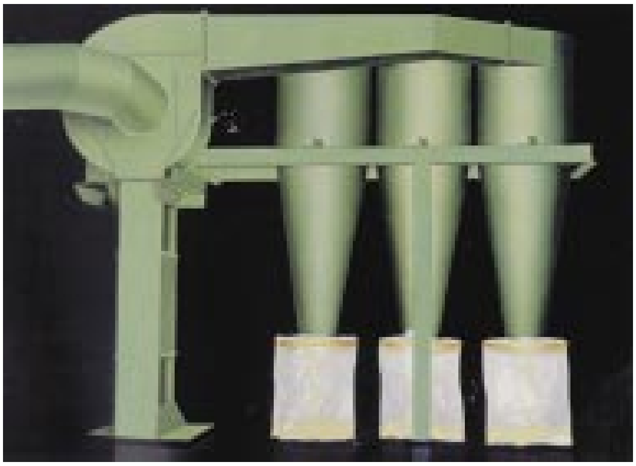


Fig. 1: Cyclone unit (LTG).

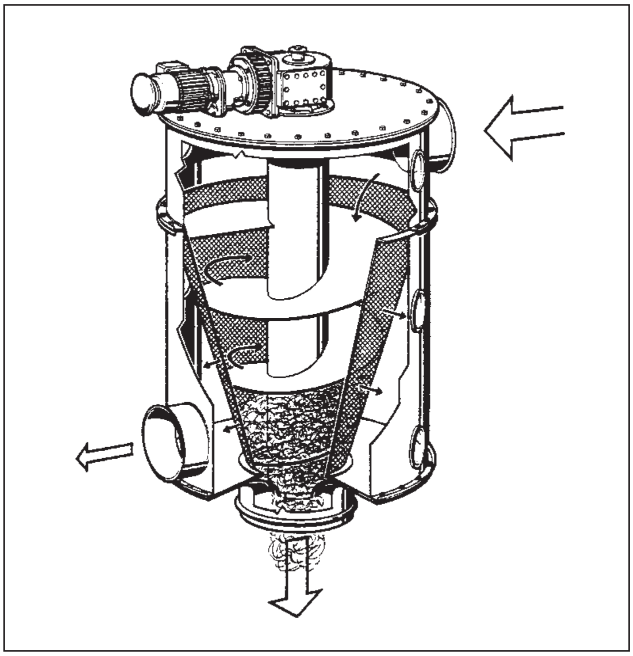


Fig. 2: Fibre compactor model FKA (LTG).

Cycloparaffins Cyclic → Paraffins, alicyclic hydrocarbons.

Cylinder dryer Cross-wound package dryer, in which the packages to be dried are exposed to different drying conditions creeled in segments of a cylinder or lying on perforated bottoms.

Cylinder drying machines In order to increase drying efficiency and improve heat utilization, cylinder drying machines are available in enclosed versions (Fig. 1) with additional ventilation. As a rule, the steam formed during the drying of textile materials on vertical or horizontal stacks of cylinders (Figs. 2 and 3) is ex-

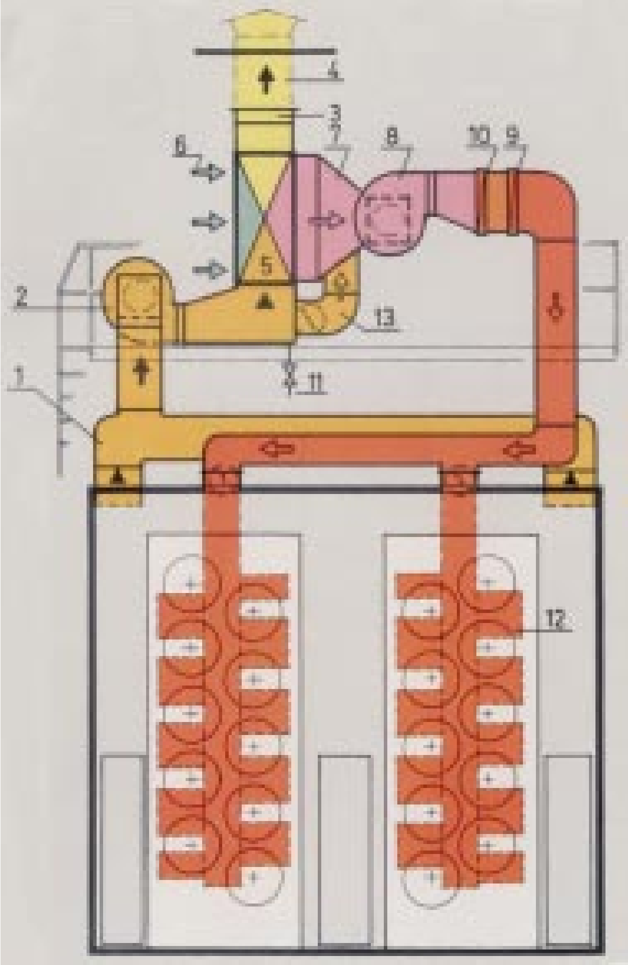


Fig. 1: Schematic diagram of a heat recovery plant for a cylinder drier (Monforts).
1 = exhaust air; 2 = exhaust fan; 3 = exhaust air after heat extraction; 4 = exhaust air vented to atmosphere; 5 = air/air heat exchanger; 6 = incoming fresh air; 7 = incoming heated air; 8 = incoming air fan; 9 + 10 = heating elements; 11 = condensate discharge; 12 = air distribution; 13 = circulating air addition.

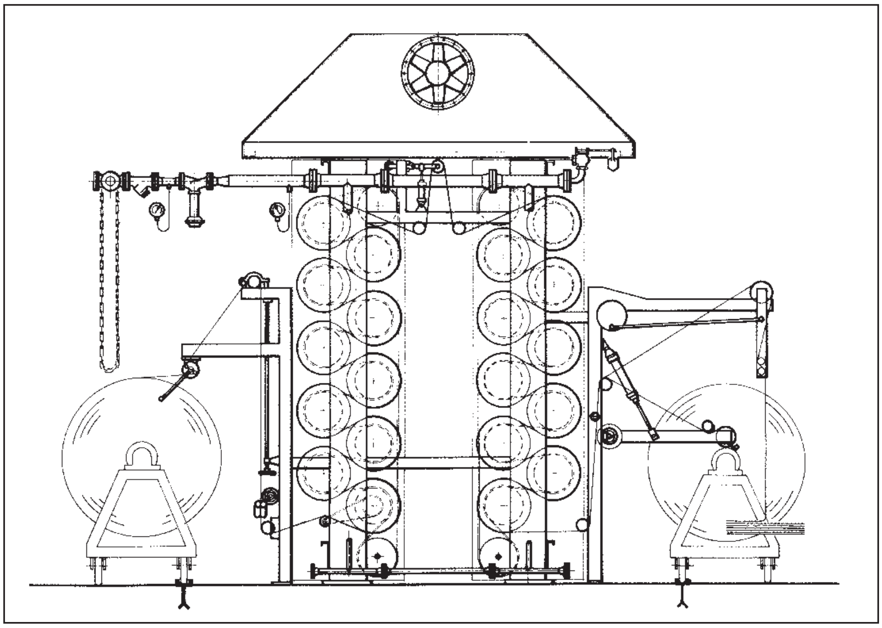


Fig. 2: Vertical cylinder drier with steam exhaust hood.

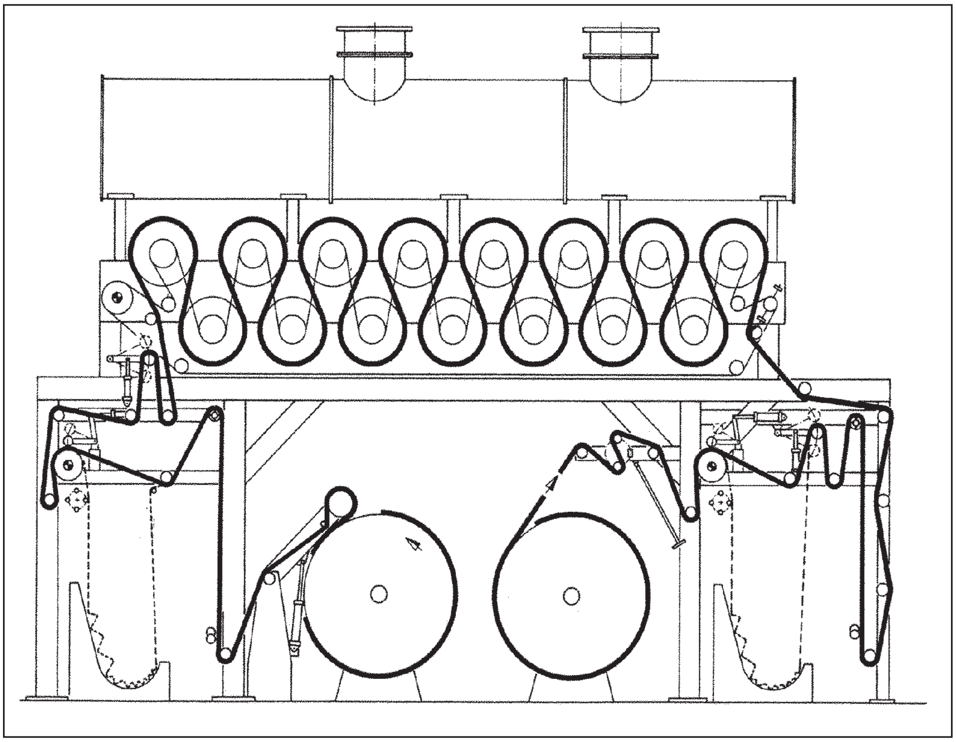


Fig. 3: Horizontal cylinder drier with steam exhaust hood (Wumag).

tracted via a steam exhaust hood above the cylinders. The adhesion of textile auxiliaries, finishes, etc. to cylinder surfaces when drying textile materials can be prevented by applying a surface coating of polytetrafluoroethylene (Teflon) to the first few cylinders. During contact transfer, heat is transferred by contact between the textile material and the heated cylinder surfaces through thermal conduction. The material may be dried by cylinder contact on one or both sides (Fig. 4).

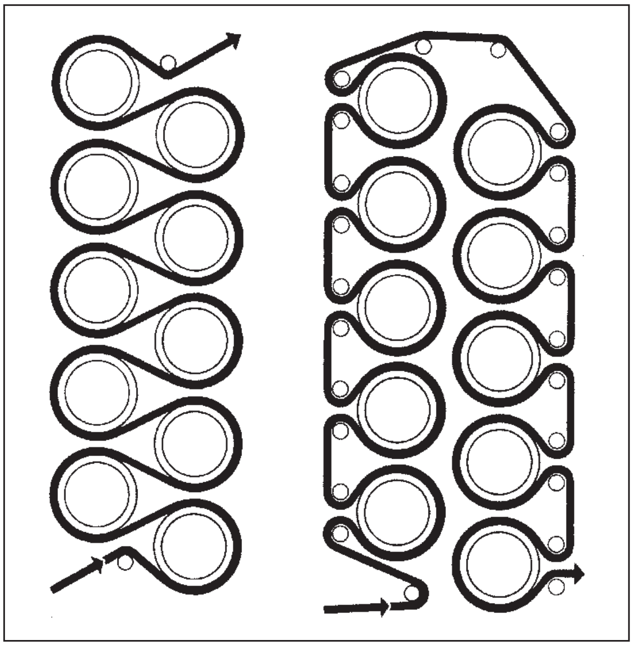


Fig. 4: Drying of material with contact between both sides (left) or one side (right) and the drying cylinders (Monforts).

Fig. 5 shows a closed loop control system for a steam-heated cylinder drier where it is desired to dry lightweight fabrics followed by heavy fabrics. As a control parameter, the moisture content of the material is determined by means of a sensor roller. The steam pressure for heating the cylinders is regulated by means of a central control valve in the centralized steam supply line to all cylinders.

a) Control function for material where the moisture content is too high: for material having too high a moisture content all the cylinders are in operation and the machine is run with maximum possible steam pressure at a manually preselected transport speed. If these heating conditions are still insufficient to dry the material to the desired residual moisture content, the transport speed is reduced by the control system until the set target value for moisture content is achieved.

b) Control function for material where the moisture content is too low: if the actual moisture content value of the dried material is too dry, the steam pressure is reduced first of all at the manually preselected temperature rate to a minimum value consistent with the safe discharge of condensate from the cylinders which must not be exceeded. If this measure is insufficient, and depending on the degree of variation from the target value, the steam supply to individual cylinders is shut off by the diaphragm valves 4–9, beginning with number 9.

Cylinder drying of textiles Contact drying by passing sheets of yarn, tapes and woven fabrics in open-width over heated stainless steel cans or cylin-

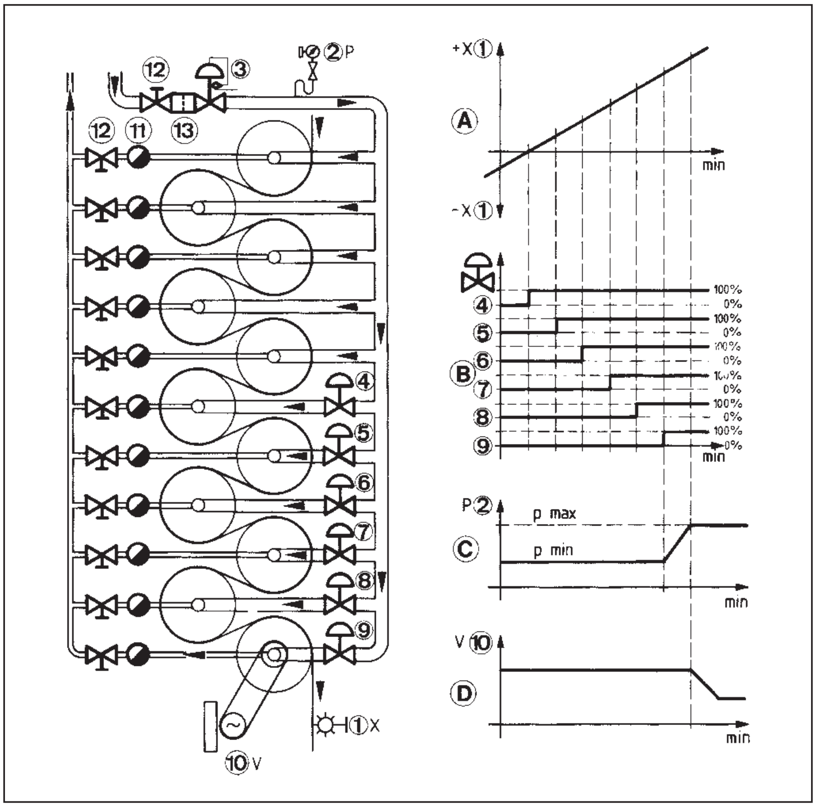


Fig. 5: Closed loop control system for the steam heating of a cylinder drier (Baelz). 1 = sensor roller to determine the moisture content of the material; 2 = steam pressure sensor; 3 = pneumatic control valve with i/p converter; 4-9 = two-way diaphragm steam valve with air control three-way valve; 10 = continuously-controllable drive to all cylinders; 11 = steam trap; 12 = manual valve; 13 = dirt trap; A = moisture content variation curve of the material; B = phase diagram of cylinder valves 4–9; C = steam pressure of cylinders for heating; D = curve of transport speed.

ders. The cylinders are driven by toothed wheels so that the textile material is subjected to lengthwise tension during drying. Cylinder driers with just a few cylinders up to 30 are available. Flat fabrics are threaded through the drier with alternate contact on the face and reverse sides from one cylinder to the next. Structured or figured fabrics, on the other hand, are dried with contact on one side only; i.e. only the flat reverse side is in contact with the cylinders. For improved heat utilization, the stacks of cylinders are enclosed, and air circulation is used for rapid drying. Only → Sieve-drum driers are suitable for elastic knitgoods whilst in the pretreatment of woven cotton fabrics (see Fig.), the material is dried at an undefined width on cylinder driers at the end of a continuous process. This is possible since cotton fabrics are subsequently dyed wet-on-dry before drying to specified width is carried out on the stenter in final finishing. → Drying systems.

Contact drying, like convective drying, proceeds in three drying stages. The heat transfer coefficient α_{contact} is defined by taking the processes of heat conduction from the heated (mainly with saturated steam) rotating contact surfaces (cylinders) into consideration. Heat and mass transport proceed simultaneously and the different kinds of heat and mass transfer (radiation, convection) influence the drying. The water vapour which forms on the contact side flows resp. diffuses through the material being dried and evaporates from its free surface into the boundary layer which forms above it. This can be extremely stable and makes removal of the

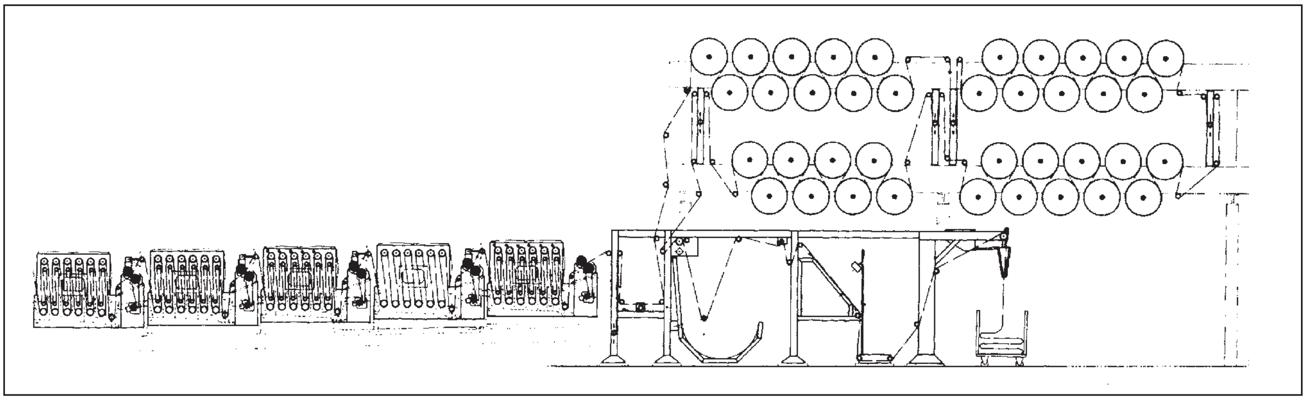


Fig.: Cylinder drying unit at the end of a pretreatment range for the intermediate drying of cotton fabrics.

built-up steam more difficult. Consequently, methods which have been introduced to break down the boundary layer, e.g. by additional forced convection (supplementary ventilation with fresh air) lead to a significant improvement in the performance of cylinder driers (up to 20%).

Another factor can reduce the transferable thermal output in cylinder driers at least in the first stage of drying. If the material being dried meets an excessively high flow resistance to the steam forming between the contact surface and the material, a steam space is created between the contact surface and the material (Leidenfrost phenomenon) which can drastically reduce heat transfer and result in considerable losses of evaporative capacity (1 : 3 to 1 : 4). Good control of the material tension, especially between the individual cylinders, helps to eliminate or reduce these undesired effects.

A third phenomenon, (often not fully appreciated in practice) should also be mentioned here which can occur at high production speeds and lead to a fall-off in cylinder drier performance. As a rule, cylinder driers are heated with saturated steam. The resultant condensate collects in the rotating hollow cylinders from where it is discharged via siphon pipes and steam traps. Normally, the heat transmission coefficients of the saturated steam condensing inside the cylinders are higher by orders of magnitude than those on the outside of the material. However, at high rotational speeds, a so-called ring of condensate can form, i.e. the condensate sump which originally collects at the bottom of the cylinders ascends at high rotational speeds due to viscous forces and inner friction, combined with the influence of centrifugal forces, and a circulating ring of condensate several millimetres thick which presents a high resistance to heat transfer is suddenly formed.

If the negative factors of influence mentioned above are eliminated, drying performance in the first stage of drying can be readily predicted from the following equation:

$$GD = \frac{Q}{r} = \alpha_{contact} \cdot \frac{F\,(T_{temperature\ of\ the\ heating\ surface} - T_{textile\ material})}{r}$$

The order of magnitude of the heat transfer coefficient $\alpha_{contact}$ is approx. 1257 kJ/m^{2}h°C under sufficiently high fabric tension. With saturated steam heating, the temperature of the heating surface ($T_{heatsurf}$) can be obtained from the vapour pressure curve. For the temperature of the material (T_{mat}), the assumption that evaporation takes place at the boil is more or less correct.

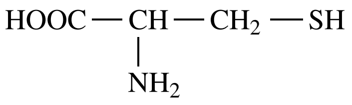
The total heat quantity balance is extremely favourable for (e.g. steam heated) contact driers. It is sufficient, in fact, to provide the process heat (Q_{Pr}) alone. Besides the heat loss (which, however, can be relatively high when the effective drying surfaces of the cylinders in the drier are not fully utilized, e.g. when drying narrow fabrics), as well as condensate losses (through evaporation), only a low proportion of energy is required to drive the machine (source: Pabst).

Cylinder fulling machine (milling stock, bumper). Used for the dry removal of hydrocellulose after → Carbonizing. Similar in design to the → Rotary milling machine.

Cylinder roller milling machines The most popular method of → Milling involves treatment in a rotary milling machine, in which woollen piece goods are processed in rope form and drawn through the machine between two rollers, where considerable pressure may be exerted by the top roller. The material then passes into a trough or spout (stuffing channel) where it is compacted.

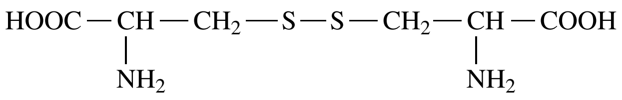
Cylindrical package, cheese A → Yarn package in which the surface of the wound yarn runs parallel to the axis of its supporting package centre or tube (only suitable for cross-wound packages). With single-end conical cylindrical yarn packages, one end of the package is built up conically.

Cysteine A sulphur-containing amino acid, constituent of many proteins where it forms disulphide bonds crosslinking the protein chain. Present in wool up to 0,5%. With oxidizing agents 2 mols of cysteine can combine to form 1 mol of → Cystine.



$$HOOC - \underset{\displaystyle NH_2}{\underset{|}{CH}} - CH_2 - SH$$

Cystine A sulphur-containing (double) amino acid (diaminodicarboxylic acid):



$$HOOC - \underset{\displaystyle NH_2}{\underset{|}{CH}} - CH_2 - S - S - CH_2 - \underset{\displaystyle NH_2}{\underset{|}{CH}} - COOH$$

It is formed in proteins by oxidation of the sulphydryl groups of two cysteine residues to form a disulphide bridge crosslinking the protein chain. It is a substantial constituent of wool keratin (12%) and animal horn, etc. (Burning test gives a typical odour of burnt horn). On reduction it forms 2 mols of → Cysteine.

Cystine bridges (disulphide, sulphur, –S–S– bridges). They form a substantial part of the side chains in wool keratin which is crosslinked by sulphur-sulphur bonds. These bonds are broken down resp. degraded by the action of alkalis, hydrolysis (boiling water), oxidation and reduction. →: Sulphitolysis; Thioglycolic acid.

Cystine oxides Oxidation processes on wool and animal hair fibres are always accompanied by cystine oxidation. The cleavage of cystine bonds involves a loss of tensile strength, however, and is therefore gen-

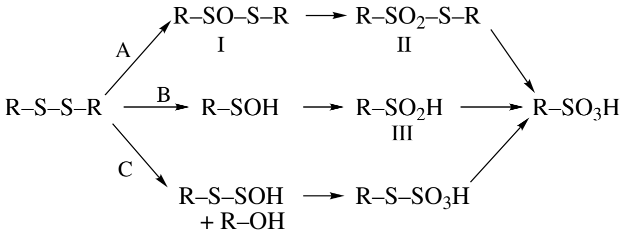


Fig.: Reaction diagram of disulphide oxidation.

erally undesirable. The extent of this oxidative damage is determined by increased solubility in alkali or by cysteic acid analysis. However, these methods are not conclusive, as they do not determine the actual degree of oxidation of sulphur in the oxidised keratin.

Even the free amino acid cystine can form compounds in which the sulphur occupies an intermediate oxidation stage between the disulphide and the sulphonic acid.

The reaction (see Fig.) can either proceed along route A, whereby the disulphide bond remains intact during the first two oxidation stages, or along routes B or C, which means a rupture of the disulphide bonds already at the initial oxidation stage. Under certain conditions, the intermediate stages II as well as I and III of the cystine have been isolated.

Oxides of the non-ionic peptide model are more stable than those of the "free" cystine. The monoxide has an unexpectedly high stability over a wide pH range. This is consistent with the observation that aminothiolsulphinates are hydrolysed considerably more quickly than their aryl and alkyl equivalents. For disulphides in general, it can therefore be deduced that dissociative hydrolysis of their partially oxidised products only takes place to any significant extent if adjacent amino groups are present. As this is only the case with peptides and proteins when amino side chains of neighbouring amino acids are present, relatively stable cystine oxides can exist there.

Cystine sulphur Sulphur bonds of the → Cystine (in wool keratin), which in part is extremely labile under the action of alkali and is converted into hydrogen sulphide, while the other part does not decrease any further even after fairly long treatment with a mild alkali. The "residual sulphur" remaining in the wool is then no longer present as cystine, but exists as → Lanthionine (easily isolated).

Cytoplasm → Protoplasm.

D

D, symbol for:

I. → Debye.

II. → Dielectric constant.

III. → Diffusion coefficient.

IV. deuterium.

d,

I. unit prefix for → Deci- (one tenth), factor 10^{-1}.

II. abbrev. for dextrorotatory (→ Optical activity).

DA, abbrev. for dye accessible. The term is used e.g. in connection with the bilateral structure of the cortex cell layer in wool (paracortex/orthocortex).

da, symbol for deca- (prefix indicating 10, as in decametre), factor 10^1.

Dabbing Faults in silk fabrics with a brushed face (white or mealy marks) are rendered invisible by dabbing with a felt pad lightly impregnated with paraffin oil. Also on → Dabbing machines.

Dabbing machines These are used for → Dabbing. Paraffin oil is applied either continuously using rotating felt discs or intermittently using oiled felt rollers which are traversed by a cam mechanism across the cloth. The cloth advances once an area has been treated.

Dabbing print Surface printing in the form of a stamp for printing industrial textiles using pigment printing, e.g. trademarks on drive belts and carpet backing. If necessary, the substrate to be printed should be pre-treated with primers (adhesion agents) or by corona treatment in order to overcome the polymer incompatibility between the substrate and the pigment printing binder.

Daghestan rugs Provenance: Republic of Daghestan. The country extends into the eastern part of the Caucasus up to the shores of the Caspian Sea. The principle centre for rug making is the town of Derbent. Technical details: Warp and weft in wool. The warp thread, which is often quite thick and brown in colour, can easily be seen on the back of the rug. The medium deep pile is of good quality but lustreless wool. The field is completely divided into fairly narrow diagonal bands (5–10 cm wide) of different alternating colours. The most frequently used colours are blue in various shades, yellow, white, and a faded green. These bands are closely decorated with small squares of different colours. At opposite corners of each square is a hooked motif. The decoration of these bands is completed by stylized roses or eight-pointed stars scattered in haphazard fashion. The ground colours are red and blue. The Turkish knot is used with a density of approx. 150 000 knots per m^2.

Damage factor (S) is used to assess the effects of chemical treatments on cellulosic textile goods. It is calculated from the average → Degree of polymerization (DP) before and after the treatment. Celluloses with different degrees of polymerization can be compared. Chemical damage does reduce the degree of polymerization, even though it cannot be detected from a loss of tensile strength. The reduction is not a direct measure of the damage, as the same damage to celluloses with different degrees of polymerization produces different reductions. The damaging effect of any treatment on celluloses with different degrees of polymerization can be compared through the damage factor, S, which is calculated with the following formula:

$$S = \log\left(\frac{2\,000}{\text{Final-DP}} - \frac{2\,000}{\text{Orig.-DP}} + 1\right) \cdot 3{,}3219$$

Orig. DP = average degree of polymerization of the material being tested before the damaging treatment;
Final DP = average degree of polymerization after the damaging treatment.

A value of the damage factor of DP = 2000 serves as the reference for the damage factor. A graph of the DP values against time for a constant damaging treatment is hyperbolic, (i.e. the same treatment produces a much bigger drop in DP with high mol. wt. cellulose than with low mol. wt.). The damage factor can be read off much more quickly and simply as a nomogram. The test is carried out as follows: the sample is shredded and dissolved in a suitable solvent, e.g. cuprammonium. The time it takes for a definite volume of this solution of the fibre sample and cuoxam to flow through a capillary tube is measured with a suspended level viscometer (see Fig.). The greater the damage, the faster the solution flows through the capillary.

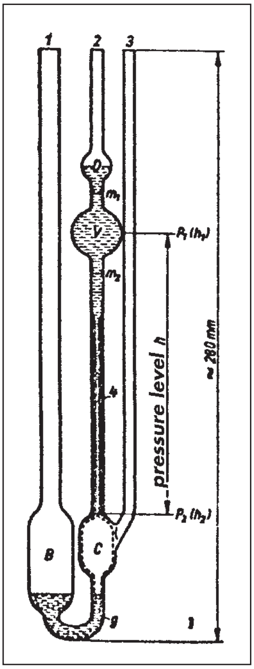


Fig.: Flow viscometer (Ubbelohde) for measuring the average degree of polymerization.

Damage factors in bleaching:
S = 0–0.4 → good process,
S = 0.4–0.7 → the process is still acceptable,
S > 0.7 → the process is not acceptable.

The damage factor should not exceed a maximum value of 1.0 in laundering, if the results are to comply with current regulations.

Damage to fibres → Fibre damage tests.

Damask A compact, figured fabric which takes its name from the city of Damascus from where the original Chinese-made fabrics were introduced into Europe. It is woven with medium to fine count yarns of cotton (often mercerized), linen, linen/cotton union, silk, regenerated cellulose or wool. Both the ground as well as the figured effects are in satin weave (patterns also in twill). Irrespective of its colour (usually a plain shade), damask owes its effect to the contrasting lustre of adjacent areas of warp and weft satin (usually 5 resp. 8-shaft) which reflect light differently. Stripe or check patterned damask is produced by dobby constructions and large patterns by jacquard techniques. It is necessary to distinguish between single and double (true) damask as follows:

1. Single damask: patterning by dobby or jacquard weaving; the borders and outlines of the pattern are smooth and rounded, with each individual thread having its own particular weave and interlacing. The floats of warp and weft threads are of unequal length; the ground is in satin weave whilst the patterning can be produced with various weaves.
2. Double (or true) damask: dobby or jacquard patterning woven on special looms; stepwise rounding of the pattern edges and, depending on whether the steps involve 2, 3 or 4 threads, the effect is referred to as a 2, 3 or 4-thread satin construction; the floats of warp and weft threads are always of the same length; only warp and weft satin weaves are used as a rule, i.e. no other weave constructions.

Depending on their field of use, damask fabrics include the following main types:

- Bed damask: consists always of 100% cotton. In addition to the numerous figured patterns, this damask quality was also referred to particularly as stripe damask in former times and is known today as stripe satin. Various types of stripe patterning are used for bed damask fabrics. Some stripe satin is produced nowadays with coloured yarns, e.g. for coloured satin or “irisette”. Used for bed and duvet covers.
- Table damask: this quality is often made of linen or linen/cotton union; a 5-shaft satin weave is frequently employed as well as 8-shaft for finer qualities; the dobby check pattern damask is typical here as well as some smaller patterns; usually white (for lunchtime and dinner table settings) or soft pastel shades (for coffee or tea table settings); these fabrics often have cross borders as well as the usual side borders thus forming a kind of rectangular frame; as in the case of bed damask, table damask is sold by the metre or in measured lengths.
- Hand towel damask: this is only mentioned here to convey some idea of the versatile applications of damask fabrics. Made from cotton, linen and linen/cotton union. Sold by the metre or measured pieces.
- Quilt damask: used for the face side of eiderdowns and quilts, mainly jacquard patterns woven with viscose or synthetic fibres which are therefore very smooth, so that pure cotton fabric is mostly used for the inner material. Because of the delustring possibilities with man-made fibres, advantage can be taken of special patterning effects here, e.g. with a bright synthetic fibre in the warp and a dull (delustred) type in the weft to achieve particularly attractive light-contrast and lustre effects. This latter variant is frequently used for coffee table damasks. Quilt damasks have lost much of their former importance due to the fact that, nowadays, they have been largely replaced by coloured continental quilts and duvets.
- Upholstery damask: also known under the name lampas. Made from silk, wool and synthetic fibres; in general, these are heavy and richly patterned for use as upholstery fabrics, furnishings and wall coverings. In most cases, these fabrics are woven with several warp and weft systems and various weave constructions as well as broché patterning. Lampa-

sette is an example of such a fabric but with a more simplified weave construction.

Damask effects in printing → Pigment printing.

Damassé,

I. A general term for silk fabrics woven on a jacquard loom (also viscose) used for festive clothing, furnishings, linings and quilt covers. Compared to true → Damask, damassé has floating threads of different length in the pattern areas.

II. A descriptive term for rich woven designs similar to damask, with contrasting lustre in the ground and pattern.

Dammar resin (cat's eye resin). A tree-derived resin of irregular form, often teardrop-shaped, pale yellow, transparent, sprinkled with white and frequently containing turbid patches. It is brittle and breaks down to a white powder on chewing. The resin has a mildly aromatic odour and is somewhat harder than colophony. At 70–90°C it becomes plastic; at 100°C it is thick, and at 150–180°C it is highly liquid and glass clear (not milky or turbid). Adulteration: especially with colophony. Dammar resin is soluble in chloroform, turpentine, chlorinated hydrocarbons. Used for oil sizing applied from a solvent or emulsion with non-drying oils, fats, waxes and solid or liquid fatty acids. When sizing is carried out correctly, viscose yarn is not brittle and not subject to dusting. Desizing: soap with the possible addition of a fat solubilizer.

Damp centrifuged Designation for textile goods which are only hydroextracted/spun dry briefly, which are damp, but no longer dripping wet.

Damping,

I. Dynamic parameter: the extent of reduction of amplitude of oscillation in an oscillatory system, due to energy dissipation, e.g. friction and viscosity in mechanical systems and resistance (ohmic losses) in electrical systems.

II. Static parameter: the ratio of input power to output power. Damping distortions as a result of the dependency of damping on the frequency.

Damping of textiles,

1. The application of moisture to yarns (yarn packages) by means of a) spray nozzles, with water containing additions of hygroscopic agents; or b) application of a vacuum and subsequent suction of moist vapour through the material (Figs. 1 and 2).
2. The application of moisture to piece goods by means of spray nozzles or brush rollers partially immersed in a water bath. Wool and wool-blend fabrics are moistened in a fine mist of water which is sucked through perforated drums (air suction damping). The application of steam on steaming tables is also sufficient in many cases.

The damping of fabrics in the Hygrocor damping machine (Fig. 3) takes place around the circumference of a perforated damping drum (1). This is covered with a

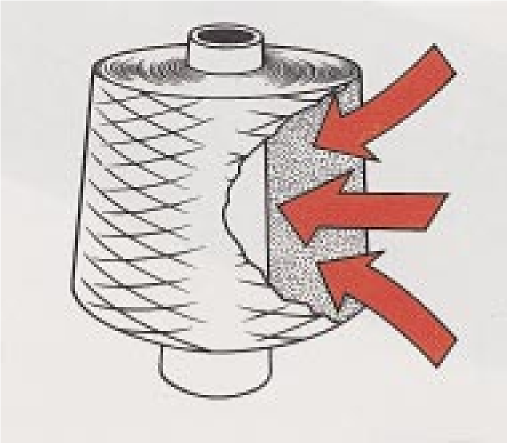


Fig. 1: Due to the extremely deep vacuum in the Welker damping process (over 95%), the steam penetrates to the core of the yarn package.

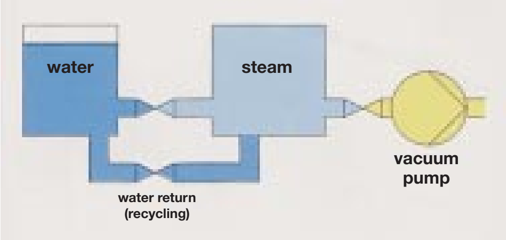


Fig. 2: Simplified processing diagram of vacuum damping.

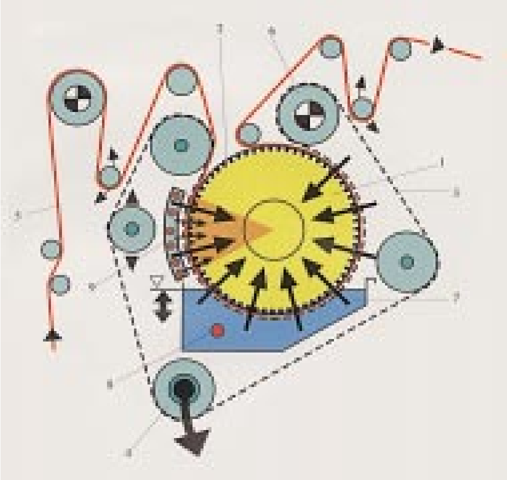


Fig. 3: Menschner Hygrocor intensive damping machine for woven wool fabrics. 1 + 2 = perforated cage; 3 = nonwoven fabric; 4 = tensioning roller; 5 = fabric; 6 = drive; 7 = water; 9 = steam shoe.

non-marking lapping (2). The drum is driven by an endless blanket, permeable to the damping medium (3) which, by means of an adjustable tensioning device (4), presses the fabric radially around the circumference of the drum thereby ensuring intimate contact between the drum and fabric (5). The blanket is driven by the drive rollers (6). As clearly illustrated in Fig. 3, the drum, together with the fabric and blanket, is partially immersed at the bottom of its passage in a trough (7) filled with liquid for damping in which a heating element (8) is installed. The liquor level in the trough as well as the heating temperature can be regulated. A continual damping of the lapping and blanket, and therefore the fabric, is achieved by rotation of the drum, whereby the blanket (3) is moistened from outside and the lapping from inside the drum (wicking system). Steam impinges on the tensioned blanket (3) from a steam box (9) which is drawn through the lapping, blanket and fabric into the drum under partial vacuum. A good contact with moisture is already produced by the steam and the fabric under pressure which is further reinforced by subsequent suction of hot water through the material.

Another well-established damping technique for piece goods is the Weko-Rotor-Damping-System which ensures a contact-free uniform application of moisture. The moisture is applied by means of special spraying discs called rotors. These rotors spin at high speed and are fed with the damping liquid from a separate unit. Centrifugal force causes two very flat fans of spray to form which are then thrown on to the moving web of material. The rotors are installed side by side in a rotor carrier and the number of rotors required depends on the width of the textile material. Typical applications of the Weko rotor damping system include: 1) damping before sanforizing; 2) damping before calendering; 3) reduction of the residual shrinkage in tubular fabrics made of cellulosic fibres; 4) improvement of dye fixation (colour yields) in certain printed fabrics prior to steaming (e.g. reactive dyes printed on viscose, etc.).

Dancer roll → Compensator roll.

DänP Obsolete abbrev. for Danish Patent. Now → DK.

Dark-dyeing polyamide → Differential dyeing polyamide fibres.

Darning (Mending) Correction of defects in wool fabrics carried out manually using needles and thread in the weave itself, either directly, where threads are missing (holes) or, where there are incorrect threads, after these have been removed. Generally carried out after burling on loom-state (grey) or scoured cloth. (→ Invisible mending).

DAS, abbrev. for Deutsche Auslege-Schrift (German Patent Specification), preliminary stage (→ Patent law).

Data logging Data from process measured variables or the signals representing these are taken and subsequently recorded in a storage medium, e.g. in order to process data (→ Process data logging). A distinction is made between absolute data logging, where every item of data can be reproduced, and incremental data logging, where determination of changes in past data takes place. In addition, a distinction is made between analog data logging, where the signals received are recorded by appropriate conversion as a graph on recording strips, and digital data logging, where it occurs using standard steps which can be defined digitally and are stored on optical disk.

Data processing systems Now almost entirely electronic data processing (EDP) systems for the collection, storage and analysis of data and information. The former Hollerith machines and manual punched card systems were also examples of simple data processing systems.

Day-glow colours The intense luminosity of the so-called day-glow paints and dyes is based on their property of reflecting both the light component of a specific colour of sunlight and the ultraviolet which has been changed into the same colour visibly for the eye, whereby the normal luminosity of the colour is increased. Such day-glow colours give → Fluorescent dyes whose shade is to a large extent the same in daylight and UV light, thus e.g. for wool or silk, optimum 0.5% fluorescein (yellow-yellow), on silk, cellulose, acetate optimum 0.5% Rhodamin 6G extra (pink-orange-red) or B extra (bluish red). With these and similar dyes, organic glasses are used as colour carriers and then generally sold as day-glow colours in finely powdered form. Use (textiles): decorative fabrics, swimwear, sunshades, flags and bunting, etc. provided that the light fastness requirements of the dyed products are not too high.

Daylight colour Appearance of a colour in daylight. → Colour matching.

Daylight lamps For constant lighting conditions in colour matching cabinets. W.C. Heraeus Original Hanau developed the Variolux in addition to the D 65 daylight lamp. The Variolux had four types of light for colour matching which is suitable for testing metamerism, where the sample is viewed under two different sources of light. Fluorescence phenomena can be tested with the UV component. A range of equipment is available in the form of test analysis lamps for tests in the short and long-wave UV range. → Colour matching.

DB, abbrev. for Deutsches Bundespatent (German Federal Patent).

dB, abbrev. for decibel; → Sound level.

DBGM, abbrev. for Deutsches Bundes-Gebrauchsmuster (German Federal Registered Design), formerly DRGM.

DC multi-motor drives for textile finishing machines These involve optimum arrangements of motors with power supplies from voltage-regulating transformers and downstream silicon-controlled rectifiers (with additional correction via synchronization field voltages) or with individual thyristor supplies for progressive drives, designed to subject the fabric to minimum tension. Further alternatives are also available:

I. Controller for the synchronization of several drives supplied by voltage-regulating transformers: an oscillation-free synchronization can be achieved by this means which is not influenced by variations caused by the fabric. This system makes it possible to run machines designed for different speeds in continuous synchronized operation as an integrated production line. The continuous control provides problem-free operation up to a max. speed range of 1 : 10.

II. Synchronization field voltage regulators for multi-motor drives: the field voltage to the individual motors is controlled in order to achieve synchronization of the fabric passage. Compensators or dancer rollers are coupled with the synchronization field voltage regulator for this purpose.

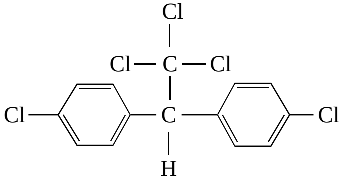
III. Digital difference measuring system for mercerizing plants. Consists of a motor with a pulse generator for the precise adjustment of fabric shrinkage or extension. Variable multipliers are used to balance out differences in fabric synchronization with motor speeds. Individual values are called up via measuring switches and displayed digitally in % with the measuring-indicator unit.

IV. → Technology cards (machine-programmable punched cards for thyristor technology).

DD → Differential dyeing.

D.D. American abbrev. on textile care labels for drip drying (hang only). Applies to garments made from self-smoothing fabrics.

DDT, abbrev. for: dichlorodiphenyltrichloroethane; a synthetic insecticide remarkable for high toxicity to insects at low rates of application. Formerly used as a contact insecticide in moth proofing formulations. DDT is the best known of a number of chlorine-containing pesticides used extensively in agriculture in the 1940s and 50s. The compound is stable, accumulates in the soil, and concentrates in fatty tissue, reaching dangerous levels in carnivores high in the food chain. Because of its high toxicity, DDT has been banned in Europe and many other countries; it can, however, still be found in imported materials.



Deacetylation of acetate In practice, this means the same as → Saponification.

Dead cotton Cotton fibres which have died before maturity, unlike → Immature cotton they do not contain any protoplasm. The fibres are collapsed flat, have broad, more solid and more brittle ends and thin, transparent cell walls. On the whole, they are very brittle and have low elasticity. They have a lower dye affinity than mature cotton, so pale areas occur in dyeing. These can be compensated however, by sodium hydroxide treatment, which also increases strength. → Cotton maturity index.

Dead time Dynamic parameter of transfer elements in automation systems; the time between turning on an input signal in a system at rest before the output signal begins to alter distinctly (for humans: reaction time).

Dead times in dyeing The length of time in which dyes have not yet been absorbed, or have been completely absorbed before reaching final fixation conditions, is referred to as dead time. In batch dyeing processes, these should either be completely avoided or be accomplished quickly. The Fig. shows a temperature-controlled method.

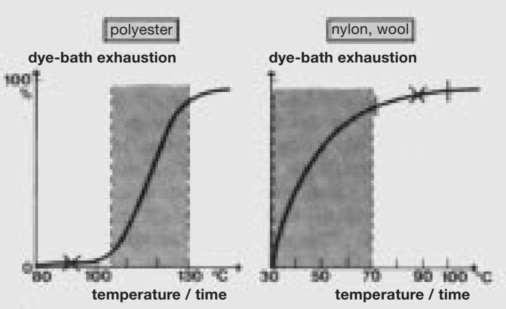


Fig.: Dead times (x) before the critical temperature range is reached in polyester dyeing (left) or after passing through the critical temperature range in nylon or wool dyeing.

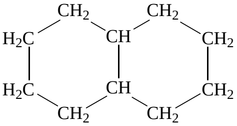
Above or below the dye absorption zone (critical temperature range), rapid heating can be carried out without endangering levelness. The necessary absorption zones, (temperature, pH or salt level zones) of the dyes and fibres should be obtained or determined from recommended dyeing procedures. With high levelness and reproducibility specifications, controlled absorption techniques are used, with absorption and/or fixation being controlled in such a way that dyeing is virtually level from the very beginning and generally more economic. In contrast to this are the migration processes, which require dyestuffs with good migration characteristics to be used, as the greater initial unlevelness must be compensated by migration. In this case the unfavourable dyeing conditions (lower liquor throughput, slower passage of the cloth) can be more economic, as it would be time consuming to achieve virtually level dyeing under these conditions. However, migration processes often cannot be avoided, e.g. with fibre and temperature differences in the machine or with dyes having rapid absorption (e.g. vat dyes). By using controlled absorption, insufficient attention is often paid amongst other things to the following: it is only necessary to control the absorption approximately to avoid absorption which is essentially too fast (lack of levelness) or that which is essentially too slow (time consuming). This is possible by rule of thumb (derived from → Dyeing theory) to control temperature, pH or levels of salt or even with the aid of absorption control instrumentation. Despite this, there is no direct relationship between dye absorption rate and levelness of different shades as the dye absorption rate is always only one of several factors which govern levelness.

Dead wool An inferior wool quality that is insufficiently protected by wool fat (suint) with reduced softness, elasticity and strength. It is not identical with → Fallen wool.

Debye A unit of molecular dipole moment equal to 1 x 10^{-18} electrostatic unit. Named after Peter J.W. Debye (1884–1966). → Dipoles.

deca- (Gk.: *deka* = ten). Unit prefix denoting ten times = 10^1; e.g. 1 daN = 10 N.

Decahydronaphthalene (decalin), $C_{10}H_{18}$.



Colourless, water-clear, liquid with a faint odour (naphthalene-like). Miscible with most organic solvents. It is a solvent for fats, oils, resins, pitch, wax, etc. Uses: component of fat solubilizing soaps, spotting agent (turpentine substitute).

Decalcification of water Softening of water; → Water-softening process.

Decalin → Decahydronaphthalene.

Decationization The removal of cations from water using a hydrogen-ion exchanger. First step in complete desalination. → Ion-exchange processes.

Decatized A German quality label which guarantees a lustre fast to water drops and ironing (→ Decatizing); fabrics bearing this label must be dimensionally stable but should nevertheless permit styling during garment manufacture.

Decatizing (decating). A finishing process mainly used to improve the characteristics of wool and wool-blend piece goods with regard to appearance, shape, handle, lustre and smoothness, thereby producing a fabric in the desired finished state. Decatizing is accomplished by steaming under pressure, i.e. by subjecting the well-packed or firmly wound fabric to a steam treatment. Since this treatment is usually carried out as the final operation after the rotary press, the pressed state of the fabric is retained by the decatizing treatment. The purpose of decatizing is therefore to improve handle by the action of moisture, to moderate and set the lustre imparted by pressing or calendering (lustre effects resistant to steam pressing), to achieve a finish fast to water spotting and to set the fabric in length and width. This process is carried out immediately before final inspection and making-up and is primarily applied to wool fabrics as well as some fabrics composed of man-made fibres. Whilst the → Wet decatizing (wet setting) process carried out in the early stages of finishing is preferably carried out with hot water, final decatizing is a dry setting process which is the reason why the term steam decatizing is often used and, depending on the steam quality, wet steam or dry steam decatizing. Decatizing includes open decatizing as well as kier vacuum decatizing (Figs. 1–5).

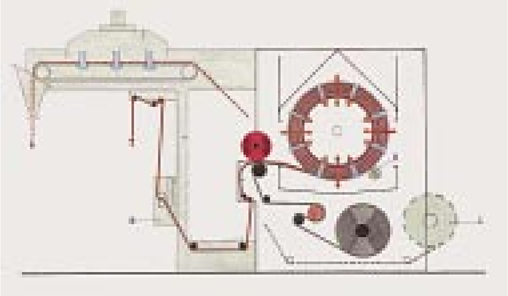


Fig. 1: Finish decatizing as an open decatizing process (Bisio).
B = tension regulator at fabric entry; C = back grey supply; D = pressure roller.

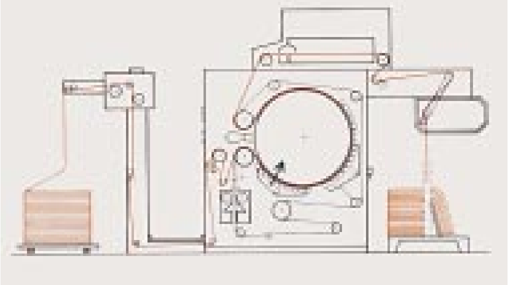


Fig. 2: Continuous decatizing (Sperotto-Rimar) based on the through-flow principle, as an open decatizing process (arrow = steam entry).

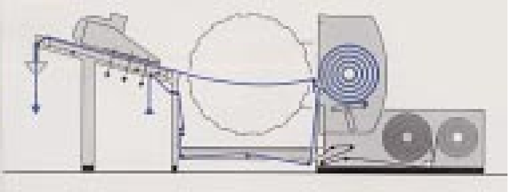


Fig. 3: Kier decatizing (the so-called “frying pan” design of Menschner).

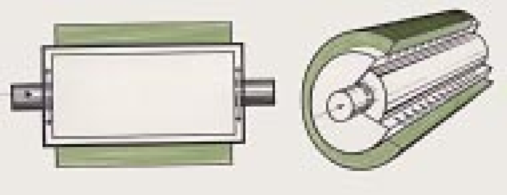


Fig. 4: Batching roller for kier decatizing (Biella Shrunk).

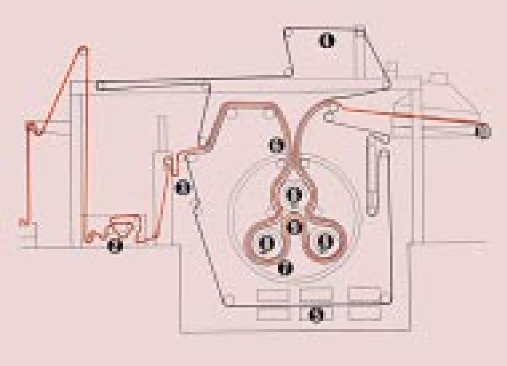


Fig. 5: “Ekofast” continuous kier pressure decatizing machine (Parex-Mather).
1 = fabric entry; 2 = weft straightener; 3 = compensator; 4 = upper conveyor (non-permeable PTFE-coated fabric); 5 = lower conveyor (endless permeable needled felt); 6 = entry and exit seals; 7 = pressurized autoclave; 8 = nip rolls; 9 = centre bowl; 10 = delivery conveyor.

Decatizing, fastness to Resistance of the dye to the effect of steam when → Decatizing wool goods. Wind a sample sandwiched between molleton cotton cloth brushed on both sides around a perforated decatizing cylinder through which dry saturated steam is blown for 15 min.; a) light decatizing factor: steam pressure 147 kPa, temperature 110ºC; b) intense decatizing factor: steam pressure 245 kPa, temperature 127ºC. Dry specimen in warm air (< 60ºC). Simultaneously test dyed reference fabric. When assessing the dyed reference fabric using the grey scale, light decatizing should result in yellowing to grade 4, and intense decatizing yellowing to grade 3, which is more yellow.

Dechema, abbrev. for: Deutsche Gesellschaft für Chemisches Apparatewesen (German Society for Chemical Instrumentation). A technical scientific society concerned with the promotion of chemical instrumentation and equipment. → Technical and professional organizations.

Dechlorinate, to → Antichlor.

deci- (Lat.: *decimus* = tenth). Unit prefix denoting one tenth = 10^{-1}; e.g. 1 decitex = 0,1 tex.

Decibel (dB). One tenth of a bel. A unit for comparing levels of power, often used to express sound intensities. → Sound level.

Decolorization of waste water The indirect release of dye water, from textile mills, for example, often presents the operators of municipal sewage works with insoluble problems. Usually, it is only in exceptional cases that sufficient decolorization can be achieved using mechanical/biological processes and indeed, from time to time, the dye substances impair the biological process. The wavelength (λ) of the dye is measured and reveals whether, for example, it is blue (436 nm), green (525 nm) or red (656 nm) which is present. Thus, in waste waters, the dye is described via the transmittance colour index ((TCI) as described in DIN 5033, Part 1). The whole visible spectrum, from violet to dark red, lies between λ = 390 nm and λ = 760 nm. The colour intensity is given by the absorbance E. The absorbance is the logarithm of the reciprocal of the transmittance T.

$$E(\lambda) = \log \frac{1}{T}$$

In Appendix 38 of “Allgemeinen Rahmen-Verwaltungsvorschrift über Mindestanforderungen an das Einleiten von Abwasser in Gewässer [General Framework Administrative Regulation Covering the Minimum Requirements Concerning the Discharge of Waste Water into Waterways] 25.05.1990, the coloration of waste water is restricted. Thus, for a 2-hour mixed sample, the spectroscopic absorption must not exceed the following values (the absorbance is generally related to a layer thickness of 1 cm). The transmittance colour index listed here is evaluated by eye using a 1 meter long plain cylinder (layer thickness 1 m) according to Streichfuß:

7 m^{-1} at 436 nm
5 m^{-1} at 525 nm
3 m^{-1} at 620 nm

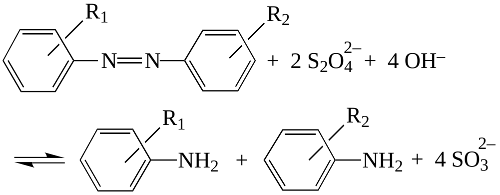
Selective discharge constraints are also confronting the textile industry with new demands in regard to exceeding specified tolerance limits. Because the dyeing process involves establishing a distribution equilibrium between dye exhaustion in the fibre and dye in the liquor, there will always be a certain amount of dye remaining in the liquor – bath exhaustion lies between 85% and 95% depending on the dye. Effluents from textile printing works are particularly damaging to the environment because of their colour and the high levels of organic contaminants which they contain. Their disposal is very problematic and they usually cannot be discharged to municipal sewage works as certain components pass through the biological purification steps unchanged or may even impair them. Even in conventional effluent treatment plants, the dye content is not reduced sufficiently.

There are various processes in waste-water treatment which can reduce the colour to a certain degree. Hydrolysates, produced during dyeing processes using reactive dyes, are hardly degraded at all by biological methods and, for this reason, they must be removed from the effluent using suitable procedures. Their removal is usually accomplished by means of precipitating agents and flocculants although inorganic reagents, such as iron and aluminium salts, are not suitable for their separation, making it necessary to use organic flocculants instead. But this creates new ecological problems as a certain amount of the flocculant remains in the effluent and is itself difficult to degrade biologically. Precipitation produces sludge which must be classified as hazardous waste and this has a detrimental effect on the costs of the process. Furthermore, this sludge contains little dye but a comparatively large amount of water.

The following may be considered for decolorizing effluent:

1. Adsorption (e.g. activated carbon).
2. Oxidation (e.g. ozone).
3. Biological purification.
4. Precipitation/flocculation (iron or aluminium salts).
5. Reduction.

Reductive cleavage of azo dyes (and therefore decolorization) to amines using $Na_2S_2O_4$ is well known in preparative organic chemistry. This takes place according to the following equation:



The standard potential for the system $S_2O_4^{2-}/2\ SO_3^{2-}$ is –1.12 V in alkaline solution and –0.082 V in acid solution ($HS_2O_4^-/H_2SO_3$). From this, it is clear that reductive decolorization must be carried out in an alkaline medium. Electrochemical treatment of effluents can also lead to a reduction in coloration. Using iron electrodes produces iron hydroxide in the solution which precipitates out together with the heavy metals contained in the liquor. Organic substances such as dyes can also be removed in this way. However, this method

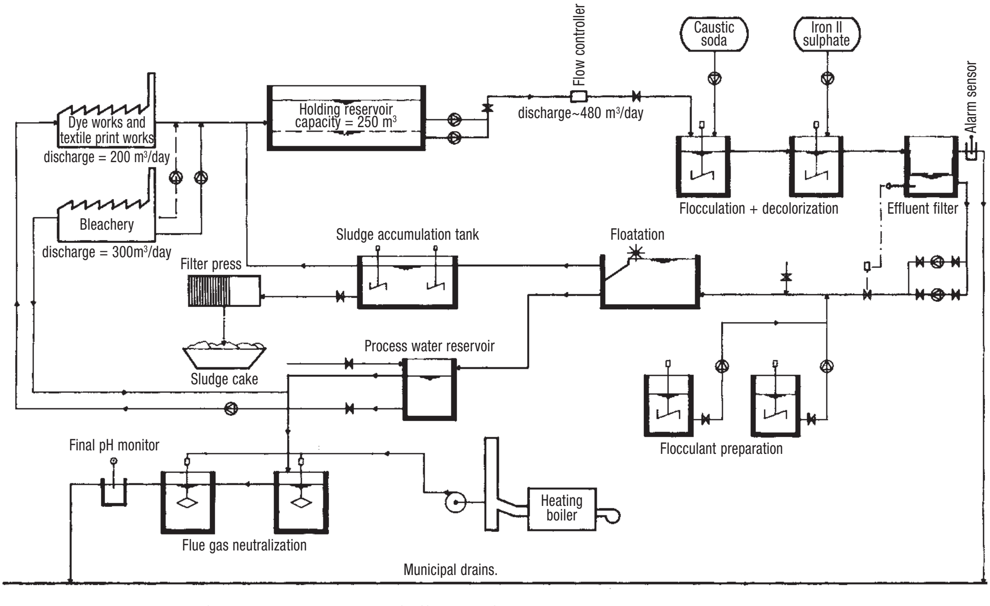


Fig. 1: Treatment plant for the decolorization of effluents (flow diagram).

produces a dye-containing iron-hydroxide sludge which has to be disposed of as hazardous waste. Oxidative cleavage using hydrogen peroxide also produces sludge because iron salts have to be added as activators.

Decolorization by flocculation and floatation can be achieved as follows (Fig. 1): all coloured effluents from the printing works, including those from the floor drains, are collected in a 250 l holding reservoir. Many of the components in the effluents neutralise each other in this pool and the waste water is continually fed throughout the day to an effluent treatment plant and then on to the municipal sewage works. The pH of the effluent is reduced to 10.5 in a 4 l initial neutralisation step using caustic soda and in a second 4 l container, 20% Iron II sulphate solution is added to produce flocs and decolour the effluent. The pH drops to around 9.2 as a result and the flocculation process is complete after a short reaction time. The flocculated effluent is pumped into the floatation plant where the iron hydroxide flocs are made to float by adding more flocculant and injecting air, as the air inflates the flocs. The macro flocs produced separate out on the surface and can then be skimmed off as a sludge.

One possible method for removing dyes from aqueous solutions which has received little attention up until now, consists of forming low solubility dye-inclusion compounds using a macrocyclic complexing agent.

This type of selective decolorization can be achieved by creating occlusion compounds of specific dyes in cyclodextrins. A corresponding process for decolorizing dye-works water has been suggested by Jasper (Figs. 2 and 3): in Phase 1, the extracted dye feed liquor is pumped through a filter cake with cyclodextrins and the individual dyes occluded. Regeneration is carried out during Phase 2 using salt solution, thus producing altogether a colourless effluent.

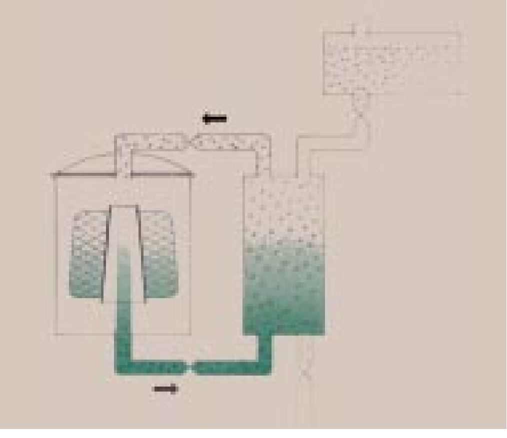


Fig. 2: Phase 1: selective filtering out of dyes in the effluent with cyclodextrins (source: Jasper).

Fig. 3: Phase 1: regeneration (source: Jasper).

Decolorizing carbon → Activated carbon.

Decomposition When sizing or finishing, using standing dye baths etc. and as a result of multiple foreign substances on mainly natural and man-made fibres, numerous degradation phenomena may occur. A distinction is made between → Decay and → Fermentation.

Decontamination A term generally used for the removal of radioactive components. In a wider sense, the elimination of toxic, microbial or radioactive pollutants.

Deconvolution index According to Calvert and Clibbens, this is the criterion for assessing mercerization. It is determined by counting out approximately 800 fibres (0.1–0.2 mm long) under a microscope. The percentage number of fibres with no twist corresponds to the deconvolution index. Assessment: 9–15 = unmercerized cotton, 60–70 = mercerised cotton (for piece goods, 25–40, usually fewer in the weft direction than in the warp direction).

Deep-dyeing polyamide → Differential dyeing polyamide fibres.

Deep Dye process (colourbox process). This unit was developed by Deep Dye Processes, USA, for the printing of tufted carpets. The printing element consists of a plastic block, with which all the colours in a design are applied simultaneously. The individual colours of the pattern are separated by ridges, so that the pattern figures form practically flat “colour troughs”. The print paste is fed into the troughs from below through special feeding channels. During the printing operation, the blocks are pressed mechanically against the material from below, so that the print paste is applied to the carpet pile. This printing process is no longer in use.

Defect According to § 459 BGB, an object displays a defect if it “contains faults which negate or reduce its value or fitness for normal use or use as laid out in the contract”. → Faults in textiles which only “result in an insignificant reduction in value or fitness for purpose" are not classed as grounds for a defect. In the area of textiles, performance defects include incompleteness or deviation from the contract covering properties which have been guaranteed and "permanent defects". A distinction is made between the following (although it is not always possible to make a clear distinction):

1. Visible defects: immediately recognisable according to the state of the art and without costly preliminary examination, possibly preventable by specialist assessment.
2. Latent defects: only avoidable at considerable test expense.
3. Hidden defects.

Defect costs (→ Quality costs), are costs which arise when production or processing does not meet up to specified quality requirements. In contrast to → Defect prevention costs and quality control costs, defect costs may vary substantially from month to month; thus regular evaluation is justified, especially as this facilitates recording/evaluation, e.g. by frequently occurring causes of defects.

Defect elimination during dyeing is the avoidance and removal of factors which cause defects during the dyeing process by the selection of specifically compatible fibre material, auxiliaries, dyestuffs, dyestuff combinations, mechanical settings and process types.

Defective colour vision In Germany, 8% of the male and 0.4% of the female population have defective colour vision. Of these, 60% suffer from → Anomalous colour vision and 30% suffer from → Colour blindness.

Defect prevention costs (→ Quality costs) are the costs of preventive quality assurance for the purposes of defect prevention. Defect prevention costs may arise in practically any cost centre in the form of salaries and similar cost types. Apart from the cost centres directly concerned (quality planning, quality job preparation) these are not readily definable.

Defect rate Ratio of faulty goods to the total number of goods (percentage seconds).

Defects in grey goods For the finisher of textile fabrics, grey goods are the products obtained directly from the respective production machines (e.g. machines for weaving, knitting, warp-knitting, production of nonwovens, etc.) without having been given any aftertreatment. For the dyer of textile fibres (loose stock, tops) or yarns, the material from the corresponding preceding stage of processing represent grey goods. Defects in grey goods are those defects present in a visible or latent form in the goods before they have been given a finishing treatment and which are unacceptable for quality reasons. They may be subdivided into the following groups:

I. Localised defects:

- Defects present in grey goods which are visible to a greater or lesser extent and which cannot be caused in finishing.
- Defects present in grey goods which, from their appearance, could also be caused in finishing.
- Latent defects in grey goods which only become visible during finishing, or give rise to problems in the finishing process.
- Defects in grey goods which can, perhaps, be eliminated during the course of finishing.

II. Variations from agreed standards:

- Grey goods which have been finished according to tried-and-tested recipes as agreed between customer and finisher, but which subsequently no longer give reproducible results.

The possible causes of defects in grey goods should be listed separately according to the process stage, and not by the type of fabric. By classifying the defects according to their source, the process stage (or stages) where most of the defects originate can be clearly identified. Once this has been done, an attempt should be made to eliminate the most costly defects first of all. This type of defect classification system, however, calls for a detailed knowledge of all the various process stages involved in the manufacturing process.

The textile finishing plant receives its grey fabric for finishing from the preliminary manufacturing stages of spinning and weaving. The following process stages stand out as possible sources of defects here:

1. Raw material
1a. Dyeing of the raw material
2. Spinning
3. Winding and twisting
3a. Yarn dyeing
4. Warping and sizing
5. Fabric production
5a. Dyeing the textile fabric

The classification scheme for defects in grey goods may be demonstrated by reference to defects in woven textile fabrics:

Defect type	Source of defect
I. Defects present in grey goods which are visible to a greater or lesser extent and which cannot be caused in finishing:	
– Constructional defects in the yarn (incorrect twist, coarse yarns, irregular yarn, slubs, neppiness, fluffiness, interlacing faults, knots, weft snags, differences in texturing)	1, 2, 3
– Impurities in the yarn (fibre fly, dirt, waste material, husk and leaf residues in cotton, burr residues in wool)	2
– Damaged threads (broken ends, broken picks, chafe	5

Defect type	Source of defect
marks, shuttle smashes, interlacing faults)	
– Constructional defects in the fabric (floats, mispicks, weaving bars, wrong check pattern, double picks, weft defects; Drawing-in defects: reed marks, reed stripes, cracks; Machine defects: stop marks, start-up marks, loose shuttle picks, sloughed-off weft, standing places, taut picks, reed marks, reed stripes, double ends, kinky weft, floating weft, slack threads, shuttle pressure marks, uneven weft density, lashing-in, loom-stained fabric)	5
– Tension differences in the thread systems (tight threads, bright picks, shed changes, baggy fabric)	1, 2, 3, 4, 5
– Impurities in the fabric (fibre fly, soiled yarns)	5
– Damaged fabric caused by improper procedures to eliminate defects (scratch marks, cleaning marks, ripples, pick-out marks)	5
II. Defects present in grey goods which, from their appearance, could also be caused in finishing:	
– Damages in the fabric (holes, tears, damaged selvedges, abrasion marks, cloth expander stripes)	5 + 5a
– Deformations in the fabric (folds, wrinkles, pressed-in folds, creases, moiré)	5 + 5a
– Stains in the fabric (water stains and rings, oil, rust and dirt stains)	5 + 5a
III. Latent defects in grey goods which only become visible during finishing, or give rise to problems in the finishing process:	
– Falsely declared goods and inadvertently mixed up fabric qualities	1, 2, 3, 4, 5
– Constructional defects in the yarn (abnormal fibres, non-uniform filament count)	1, 2
– Impurities which are neutral in colour (fibre fly, foreign fibres, invisible oil stains, small iron particles, uneven size add-on, inadequate fastness properties, non-removable spin finishes)	2, 3, 5
– Structural differences (chemical damage, differences in shrinkage, absorbency and dye uptake)	1, 1a, 2, 3 3a, 4, 5
IV. Defects in grey goods which can, perhaps, be eliminated during the course of finishing:	
– Faulty selvedges (pulled-in, folded, curled, wavy, slack edges)	5
– Distorted goods (skewed weft, bowed weft)	5
– Variations in width	5
– Impurities (dirt, oil, rust, chalk, size residues)	1, 2, 3, 4, 5
– Inadequate fastness properties	2a, 3a
V. Grey goods which have been finished according to tried-and-tested recipes as agreed between customer and finisher, but which subsequently no longer give reproducible results:	
– New production batch (man-made fibres) or different source (natural fibres)	1
– Differences in texturing	1
– Differences in structure	1, 3
– Variations in yarn construction	1, 2, 3

(source: Berndt and Heidemann).

Defects, invisible marking of, using → UV fluorescent dyes or UV marking pens.

Deferred curing (post curing) → Permanent-press process.

Defixation Defixing in the sense of neutralising the effect of fixation. In this way, it is possible, for example, to observe the progressive defixation of a finished textile (e.g. having a non-shrink finish) after repeated washing as a result of the gradually increasing shrinkage.

Deflecting bar,

I. Deflection device inserted at a 45° angle to the passage of the cloth, causing the cloth path to undergo a 90° turn (e.g. in conventional → Spiral steamer). With a cylinder having a double deflecting bar, a double reversal of 2 x 90° occurs (enabling cloth to enter and exit at an adjacent position). In the form of a heatable hollow body, a deflecting bar enables a steam cushion to form which reduces friction, particularly when steaming damp goods (e.g. in two-stage printing with vat dyes).

II. Piece guide in drying lofts, hotflues or steamers which draw the processed goods out of the side of the machine from the centre.

Deflecting roller Smoothing roller to deflect the run of cloth in another direction (Fig.) or onto another level.

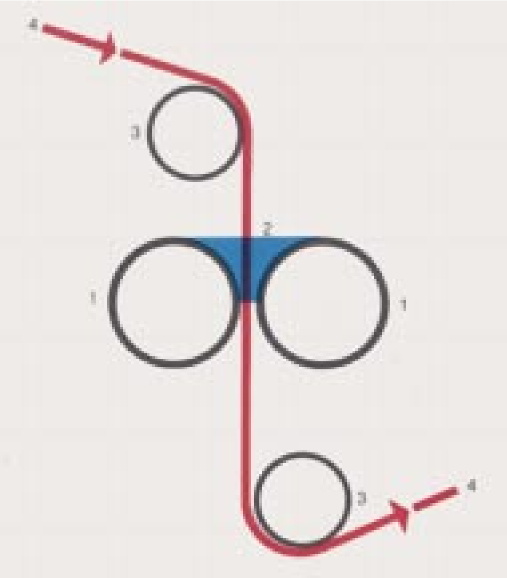


Fig.: Action of deflecting rollers in a padding machine. 1 = horizontal pad; 2 = impregnating liquor; 3 = deflecting or guide roller; 4 = goods.

Defoamers (defoaming agents, foam suppressants). → Antifoams. Products designed to prevent the formation of foam or considerably reduce foam stability in processing liquors, print pastes, etc. The main requirement for an effective defoamer is that the agent should be insoluble in the foaming system in order that, at low concentrations, it can be retained at the phase interface. The entry coefficient must be positive and the agent should form quasi-gaseous boundary layers. These requirements are fulfilled e.g. by the following products: straight or branched-chain and alicyclic alcohols (with 5–18 carbon atoms in the molecule hydrophobe such as isooctanol), pine oil (chief constituent terpineol), insoluble alkyl esters of phosphoric acid (such as tributyl phosphate) as well as lower alcohols. A distinction is made between “defoamers” which are intended to destroy already-existing foam, and „antifoams“ which are designed to prevent the formation of foam.

Deformation damage Defects in textile materials caused by mechanical energy, e.g. impacts in weaving due to shuttle malfunction, etc. The cross-sections of the affected threads/fibres are changed or deformed (detectable microscopically) which then have variable lustre, or they suffer surface damage.

Deformation-free rolls (deformation-free bowls). Used in calenders, padders and squeezing units to ensure an absolutely uniform distribution of pressure across the entire width of the nip.

Deformation of squeeze rollers Rollers are a major component of calenders or padding machines which are used in the textile industry for mangling and pressing goods. These rollers, which should act uniformly across the entire width are elastic bodies which deform slightly under strain. Deformations pose a major problem in use as well as for the technical designer, as they exert direct influence on the quality of the product. The normal design of rollers basically takes into consideration the flexing deformation, as this is the most important, though by no means the only type of deformation. In addition to flexing deformation, shear and contact deformation, as well as the less commonly cited radial deformation are important factors.

The deformation can be “reversed” (Fig. 1a) by exerting pressure on the journals outside the roller covering. This is known as roll-bending. Positioning two rollers so that they intersect slightly (Fig. 1b) also corrects the roller gap in the desired direction.

Both these measures are functions of the 2nd order, while deformation corresponds to the 4th order. Therefore theoretically, congruence between the curves of the corrective measure and the deflection cannot be achieved. A profile in the form of an “ox-yoke” (Fig. 1b, bottom) is formed. With rubberised rollers, rubber helps to solve the problem, as with its elastic deformation, it evens out the negligible differences which are of the order of hundredths. Whilst roll-bending is used in textile squeezing apparatus, oblique adjustment is not suitable here as it would lead to crease formation along the length of cloth.

Another means of correction is the extension to a triple roller system by adding an auxiliary roller (Fig. 1c). With this type of system it is possible to use a roller with a relatively small diameter and consequently a narrow nip, which results in a highly specific surface pressure and consequently a high squeeze action. With this type of system, it is preferable for the central, small roller to be bare metal and to cover the large outer rollers. The fabric is generally fed through the lower opening so that the liquor only takes the shorter route over the large roller. In addition to the triple roller system, a quadruple roller system with two squeeze rollers and two auxiliary rollers is conceivable; for this, the rubber covering must be of suitable type and at least one of the small rollers must be rubber coated.

In order to even out the deformation in a roller system, one or both rollers can be lapped with cloth. However, this correction only applies to one specific load. Different load conditions require different lapping.

One possibility is to lap the core of the roller (Fig. 2a). The most common method is without doubt lap-

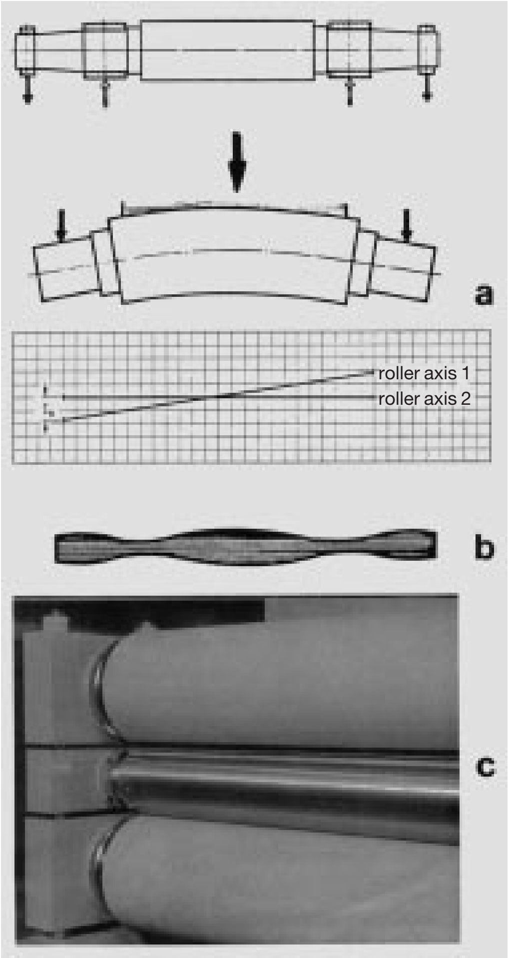


Fig. 1: Correction of deflection of roller – corrective measures in the system:
a) Roll bending; b) Intersection of rolls, below: "yoke";
c) Supporting roller, triple roller system.

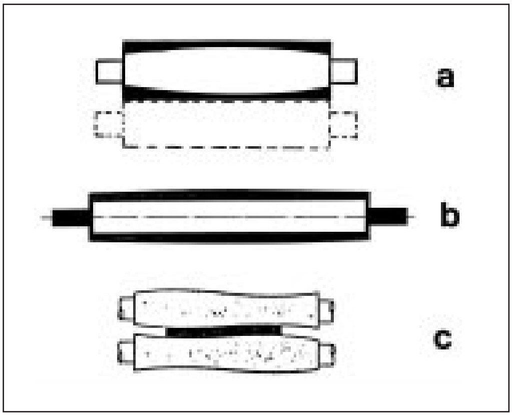


Fig. 2: Correction of deflection of rollers – corrective measures on the roller.
a) Lapping of the core; b) Lapping of the rubber cover;
c) S-lapping, CVC = Continuously Variable Crown.

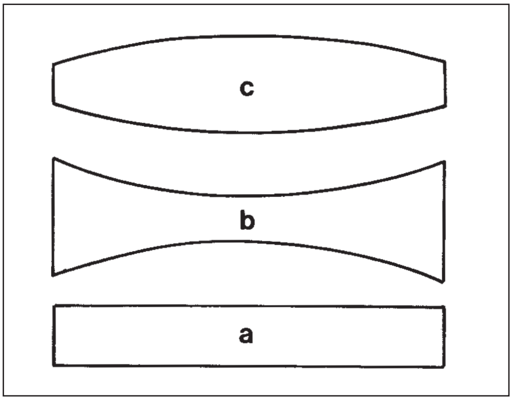


Fig. 3: Lapping of rollers - nip profiles.
a) Correct gap, correct lapping; b) Too little lapping; c) Too much lapping.

ping the rubber covering (Fig. 2b). If the hard roller of a hard/soft combination is lapped, this has the advantage over a lapped soft rubber roller that less damage will occur as a result of wear or edge contraction.

In the event of lapping being incorrectly applied, as shown in Fig. 3b where there is insufficient lapping, or in Fig. 3c where there is too much, then the necessary correction can be calculated using the following formula:

$$b = \frac{(B_M^2 - B_E^2) \cdot (D_o - D_u)}{2 \cdot D_o \cdot D_u}$$

and for rollers with the same diameter:

$$b = \frac{B_M^2 - B_E^2}{D}$$

Nip = width of pressure zone,
B_M = width of nip in the centre,
B_E = width of nip at the end of the roller (measured 50 mm from the [stress-bearing] end of the cover),
D_O = diameter of the upper roller,
D_U = diameter of the lower roller,
b = correction of lapping in mm for the pair of rollers (in relation to the diameter).

Deformation of squeeze rollers

Whilst both these methods were introduced a long time ago, the use of rubber lapping is predominant for cost considerations alone, but this is also easier to produce than core lapping. The third method (Fig. 2c) was only introduced in the past few years, however. With this method, upper and lower rollers are provided with a ground-in section of S-shape which is identical for both rollers. The rollers are simply arranged at 180° to each other, so that when axially displaced in relation to each other, their shapes form a symmetrical contour in the roller gap. The differences in diameter are slight, corresponding to the deflection to be corrected of a few tenths and do not affect the run of the cloth. In 1987 CVC rollers (Continuously Variable Crown) were introduced in Monforts' Matex Color padding machine.

Rollers with central supports are a cost-effective solution for roller deflection problems and are therefore often found in practice, especially with rollers for machines which are not very wide, such as those used in textile finishing. Combinations with normal rollers and solid-cored rollers, whether or not they are lapped, are standard in squeezing apparatus and padding machines, where more costly designs are not used.

Rollers or roller combinations of this kind are often given company-related names: e.g. Stabil rollers (Babcock), Elastoroll rollers (Kleinewefers KTM), Unipad (Brugmann), or Variflex-S-padding machine (Babcock). A similar solution is the Wakoflex roller in which the contact surface of the central support is narrow in order to assist adaptation to the deflection curve of the counter roller.

In the covering of rollers with rubber, three points must be considered for rollers of this type:

- During production of the cover, especially during vulcanizing, the seat of the core and sleeve should be protected from dirt and moisture. In practical use in finishing plant this is achieved by fixing rubber caps.
- During production of the cover (this is not absolutely necessary during grinding) the free ends of the rubber covering must be supported at the core.
- If the rubber covering needs to be renewed, it is important to ensure that the thickness of the roller sleeve is not reduced, otherwise the flexing line will no longer correspond to the calculations.

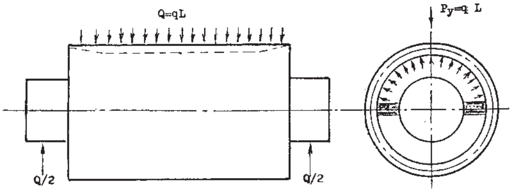


Fig. 4: Sectional view of Küsters' "swimming roll". Arrows: hydraulic pressure in the upper half of the chamber.

Amongst the roller systems in which the roller tube is hydraulically supported (or shaped), Küsters' "swimming roll" or "S-roll" is the oldest and most widely used system throughout the world (Fig. 4).

1. The principle of Küsters' "swimming roll" is that the inner pressure in the upper half of the roller evens out the squeeze pressure applied, i.e.

$$10\ qL = p_b \cdot 2\ rL,\ \text{oder}\ p_b = 5\,\frac{q}{r}$$

q = the linear equalizing pressure (N/cm),
p_b = the equalizing pressure (bar)
L = the inner width of the hydraulic chamber (cm),
r = the inner radius of the hydraulic chamber (cm).

   The eye is not able to perceive any bending moment which affects the normal levels of the centre lines of the rollers. The cylindrical cross-section (Fig. 4, right) shows that the squeeze pressure is concentrated above, whereas the hydraulic pressure extends across the entire upper semicircle. Consequently radial deformation in the upper cylindrical section occurs. This radial deformation is reduced at both ends, as the roller barrel is loaded above the bearings. For this reason, the operating pressure, p, should be slightly higher than the compensating pressure p_b.

2. The Kleinewefers KTM Vari-Flex roller has two roller traversing devices, one acting on the axial shaft, the other acting on the roller barrel by means of pneumatic pressure, so that the flexing resulting from pressure control can be regulated (Fig. 5). This compensation effect is highly effective with low tolerance of the bending on the squeeze roller. However, this design uses two loads which act in opposing

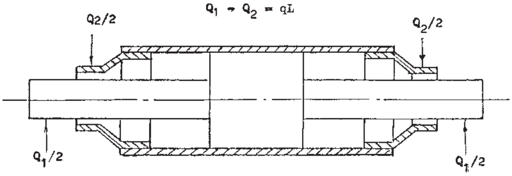


Fig. 5: Diagram of Kleinewefers KTM Vari-Flex roller.

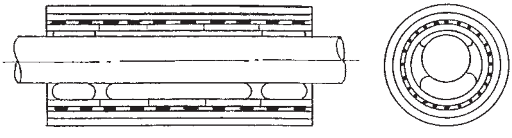


Fig. 6: Side and end views of Kleinewefers KTM Bicoflex roller.

directions. This is a result of the bearings wearing excessively and from high energy consumption.

3. The Kleinewefers KTM Bicoflex roller is equipped with a pneumatic bag which controls the squeeze pressure (in place of the hydraulic pressure of Küsters' "swimming roll", so that no oil seal in the chamber is required. Nor are any external loading devices required (Fig. 6). As the pressure of the rubber bag is kept below 6 bar, the compensation effect is also restricted. This effect can be increased by reducing the roller hardness. Copper and aluminium alloys could be used, copper being preferred to aluminium due to its better anti-friction behaviour, as it can be easily provided with an anti-friction coating.
4. The Kleinewefers KTM Nipco roller is a roller made from the plastics material Racolan, and does not have any kind of rigid roller barrel shell. The roller barrel is not connected to the stationary spigot. The piston mounted on the spigot is used to even out the squeeze pressure. The squeeze pressure is only dependent on the piston loading.

(Source: 1. Wang, 2. Zeppernick).

Deformation of textiles Creases arise when folding or wrinkling textiles as a result of:

1. Alteration of the geometry of the yarn and/or fabric in the peak of the fold (Fig. 1).

   The points of cohesion between the warp and weft when flat are indicated (Fig. 1). On bending, the warp and weft threads push against each other to a certain extent. Whether or not this happens depends on the cohesive force between the yarns and their mobility. Where the cohesive force is strong, these displacements only occur under high deformation forces, and are then partly irreversible or require a high degree of smoothing force in order to remove them (pressing, mangling). If these types of high forces are at work, without it being possible to displace the shifted threads, smoothing is achieved in flat plate screening. This can be seen in the form of visual phenomena which are observed at the site of the original creases (crows feet etc.).

   If the cohesive forces are low, then these creases can be removed using low forces. Low cohesive forces are present in smooth yarns (e.g. filament yarns made from man-made fibres), in textiles of mobile structure (e.g. knits). However these articles have disadvantages in terms of lower shape retention properties or clothing comfort disadvantages (early nylon shirts). High mobility of the yarns also occurs in floating state in the washing liquor, less so when wet. Auxiliaries which reduce non-slip properties (fabric conditioners, crease inhibitors) make it simpler to remove wrinkles caused by displacement of the yarn. Creases are caused in this way with all types of textiles.
2. However, creases are also caused by deformation of fibres in the peak of the fold (Fig. 2). If the fabric is not able to accept the deformation by changing the geometry of the fabric (and this is almost always the case to a certain extent), then the fibres themselves become deformed.

   If a fibre is deformed, internal compression forces and external tensile forces arise in the peak of the fold (Fig. 2). If these forces are so low that they still remain in the elastic region of the stress-strain diagram, then the fibre spontaneously returns to its original form when the load is removed. However, this only applies if the load time is sufficiently short. Fibres are visco-elastic materials: this means that they fatigue under tensile stress or deformation stress; retroactive force diminishes slowly. The fibre then no longer returns completely to the original form (source: Krüßmann, Hloch, Vogel, Ertl and Schultes).

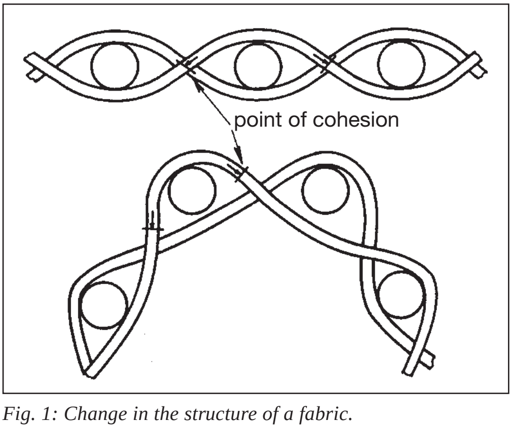


Fig. 1: Change in the structure of a fabric.

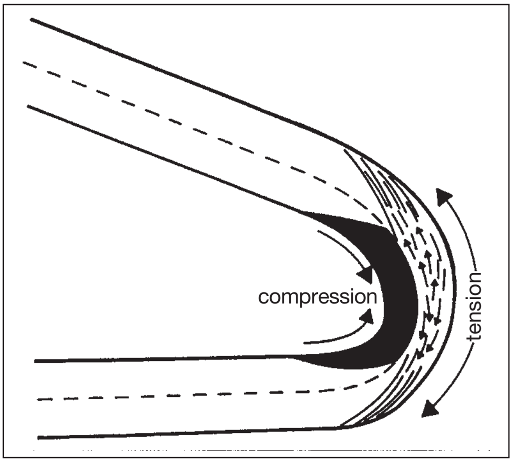


Fig. 2: Deformation of fibres.

Degradation,

I. The stepwise breakdown of high molecular weight compounds to simpler compounds of low molecular weight. Examples: the degradation of cellulose by mineral acids to hydrocellulose; the degradation of starch by diastases to simple soluble sugars; the degradation of proteins by proteases (protein digesters) to amino acids; the degradation of high polymers by ultrasound; the → Biodegradation of surfactants in waste water treatment. Various possibilities for the degradation of wool by acid or alkali during finishing processes exist (this degradation is shown in Fig. 1 as undesirable side reactions).

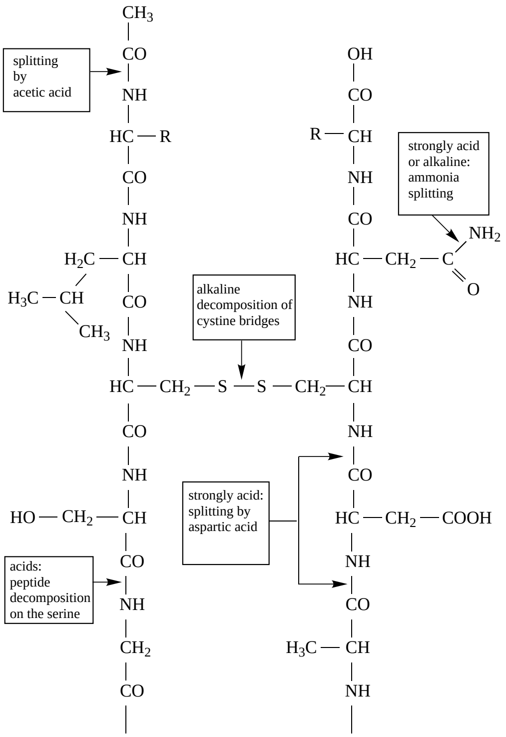


Fig. 1: Decomposition of wool protein by acid or alkali (schematic).

An example of degradation as the desirable main reaction of a textile finishing process is the enzymatic degradation of starch (Figs. 2 and 3): β-amylase “chops off” monomeric glucose from the non-reducing chain ends whilst α-amylase attacks within the polymer chains producing dextrins, i.e. chain scission fractions (R = reducing end at a C atom).

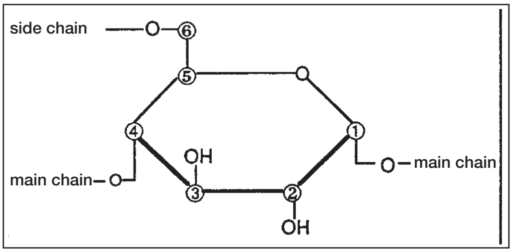


Fig. 2: Starch molecule structure.

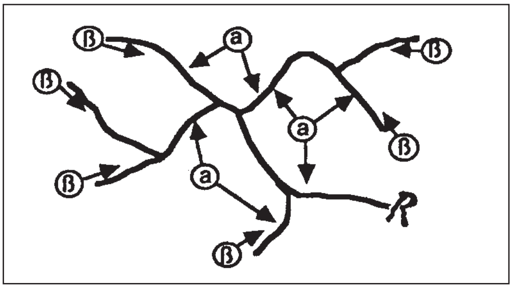


Fig. 3: Enzymatic decomposition of starch with α and β amylase.

II. → Depolymerization.

Dégradé An ombré effect with alternating light/dark zones, where the shade gradually changes in contrast to the uninterrupted dark/light/dark sequence (→ Ombré). Such effects can be achieved by interlacing suitably dyed yarns or alternatively by liquor feed pipes which have holes of varying diameter. These enable dye liquor and water to flow into the trough of the padding machine and create a variable dyestuff concentration in the trough.

Degree of coverage → Print coverage.

Degree of polymerization Average number of → Monomers contained in a → Polymer. As the degree of polymerization always fluctuates to a greater or lesser degree, the so-called → Average degree of polymerization (DP) is often quoted; e.g. for cotton: 2000, i.e. the structure of a cellulose chain consists of on average 2000 chain linked glucose ring molecules.

Degree of transparency → Transparency.

Degree of water hardness → Water hardening salts.

Degumming Boiling of silk to remove natural substances on the fibre. Silk is the fibre extruded by silk worms when they spin their cocoons. It is fine and strong and possesses a natural sheen. Raw silk fibre, however, is not homogeneous, and consists of:

- 70–80% fibroin (the silk fibre itself)
- 19–28% sericin (silk gum, consisting of three layers)
- 0.5–1% fatty substances
- 0.5–1% mineral components

The degumming process is the first and fundamental finishing process for yarns and fabrics made from natural silk and it has a crucial effect on the aesthetic and utility properties of these textiles. The principle is to remove all possible substances, such as sericin, fats, waxes, pigments and mineral salts from the silk fibres. A whole range of parameters of the fibre and its production, such as strength, softness, handle, crease resistance, sheen, smoothness and dyeability depend on this process being carried out correctly. Fibroin and sericin have the same chemical composition. An important difference is found in their reaction to alkali solutions. Fibroin is sensitive to alkalis whereas sericin is soluble in alkalis.

The standard method used for removing sericin consists of → Scouring the silk in a bath containing soap and sodium carbonate. In so doing, the two outer layers of sericin are easily removed through the treatment with hot alkali. The molecular groups of the inner sericin layer, which are intimately bound with the fibroin during silk secretion, are difficult to remove. The choice of correct treatment time, therefore, is a critical factor in the conventional degumming process as excessive degumming can easily cause damage to the fibroin.

Qualitative analyses used for the verification of degumming:

a) Neocarmine W (Merk): stains degummed silk golden-yellow and the gum red.
b) Sirius Red F3B 200% (Bayer): only stains the gum red. The degummed silk remains colourless.
c) Dissolving in Cuoxam: fibroin is soluble but sericin is not.

Silk is degummed using soap in mildly alkaline baths in which the sericin dissolves away. During this process, the pH must not go above 9–10. At higher pH levels, the degumming process is faster but there is the risk of alkali damage to the fibroin. Soft water must be used when degumming with soap to avoid lime-soap deposits which later cause unevenness when the silk is dyed and printed. It is best to use Marseilles soap (olive oil soap). The process is always carried out batchwise in the vat or on a star frame at 98°C in two baths in succession. Before the actual degumming process takes place, if the gum is adhering strongly, the silk pieces are soaked folded in bookform in the vat for 3–4 hours. This swells the gum and the acid components are then neutralised in the soap solution.

Procedure:

I. Steeping vat: 1–2 ml/l concentrated ammonia + 1 g/l nonionic surfactant.

II. Degumming bath (1.5–2 h at 98°C): 8–10 g/l Marseilles soap + 1–3 g/l complexing agent (according to the residual hardness of the plant water) + 1–2 g/l nonionic surfactant.

III. Repeat bath (1.5–2 h at 98°C): 4–5 g/l Marseilles soap + 1–3 g/l complexing agent + 1–2 g/l nonionic surfactant.

If necessary, the pH of the degumming liquors is adjusted to 9–10. When degumming in the vat, the silk pieces in book form are rolled or cuttled with sticks inserted. The degumming bath is brought to the boil and the steam switched off before putting the material in, as the liquor must not be boiling briskly or the silk will float. Even and gentle degumming is achieved by carefully moving the sticks backwards and forwards ("interspersion"). After 20–30 minutes, the sticks are thrown out onto grids and the bath brought to the boil again and the process repeated. After 1.5–2 h, most of the gum (80–85%) is dissolved. To remove the rest of the gum, the fabric pieces are placed in a second, light, repeat bath. There, the silk is treated under the same conditions for another 1.5–2 h. The repeat bath is replenished by adding more soap and then used again as the initial degumming bath. Rinsing is also carried out in a vat of hot soft water. A final rinse is carried out in cold water and acetic acid is used to bring the pH down. Attempts have been made at rationalising the degumming process of silk in book form in the soap vat by installing heating coils in the base as a source of indirect heat and monitoring the temperature electronically. After loading, the vat is covered with foil and the temperature held precisely at 98°C, thus avoiding any risk of the liquor boiling briskly. Because the heating is applied indirectly to the base of the vat, the liquor simmers gently obviating the need for interspersion using sticks.

Dehydration Removal of water. The splitting-off of water from chemical compounds (opposite effect → Hydration). Dehydration is an intramolecular reaction, i.e. the elimination of hydrogen and oxygen in the ratio of 2 : 1 from the same molecule during the course of reaction with the formation of water. Thus, during e.g. the combustion of cellulose, the formation of carbon dioxide, carbon monoxide and water vapour takes first place. The dry distillation of cellulose results in a liquid degradation product in the form of a water-containing tar distillate.

Deionization → Ion-exchanger.

DEK, abbrev. for: Deutsche Echtheitskommission (German Fastness Committee); → Technical and professional organizations.

Delamination The breakdown of lamination in textiles, e.g. as a fabric defect after drycleaning or washing.

Delayed curing (post curing). → Permanent-press process.

Delay factor, washing machine The distance covered by a fixed (imaginary) point on the circumference of the drum when the drum revolves (duration of the drum cycle = effective washing time). Calculation in m delay factor of the goods = 0.4 · m/s circumferen-

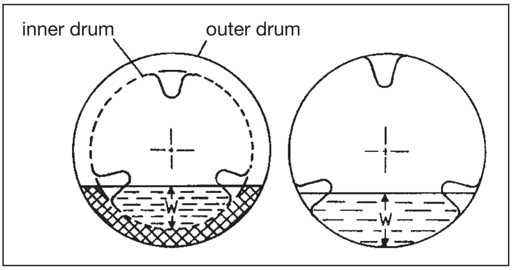


Fig.: Cylinder washing machine with double drum (left) or with single drum (source: Hloch). W = working liquor.

tial velocity · s drum revolution + m height of fall · 1/s number of revolutions · s drum revolution (see Fig.).

The liquor in domestic washing machines is referred to as the working liquor. This is calculated from the difference between the total liquor and the liquor in the inoperative space:

$$V_{\text{work}} = V_{\text{total}} - V_{\text{inoperative space}}$$

One of the factors determining the detergency efficiency is the working liquor. For this reason, attempts are made to construct single or double drum machines with the smallest possible volume between the inner and outer drum.

Delicate articles, in contrast to non-boil → Coloureds, these are delicate articles of wool, silk, viscose (filament and staple fibre) and synthetics (sorted for washing into dark and light colours), which are best washed lukewarm with → Mild washing agents (or possibly weak acetic acid) or high-quality soap. Such items include e.g. fine lingerie (including delicate tops, nightwear, socks), knitwear, needlework, delicate curtains, soft furnishings and drapes, lace, embroidery etc., and all colour sensitive or otherwise delicate items, especially those for which dry cleaning is not suitable.

Delphin rope processing range Brückner's continuous rope processing plant employs an unusual fabric run: i.e. the fabric rope runs into the first fabric chamber via the feed unit. From here, it slides over a Teflon lining to the back side of the machine. From there, the fabric is immediately transferred into the neighbouring chamber by the transport roller and slides in the opposite direction to the front of the machine again. This passage is continued throughout the remaining chambers of the machine. There is a considerable difference here compared to other well-known machines where the fabric passes spirally through the treatment chamber; this involves long distances before immersion in the following bath takes place, which has a negative effect on the lengthwise extension of the fabric. With the Delphin machine on the other hand, the distances are extremely short and the fabric is transported gently with the aid of large diameter transport rollers. The counterflow system is not only used from chamber to chamber (as in conventional machines) but also within each individual chamber itself. This leads to an improvement in the washing effect.

The diagrams shown in Figs. 1 and 2 illustrate the essential elements of fabric transport and liquor flow with a cross-section of a chamber. This shows the fabric passage in the first chamber. The fabric slides over the Teflon-lined bottom and is lifted from the bath by the transport roller. A forced displacement of the fabric by a pair of rollers and intensive spraying is given before and after each transport roller which ensures good fold transfer.

The large diameter of the transport rollers also allows the machine to be operated without squeezing

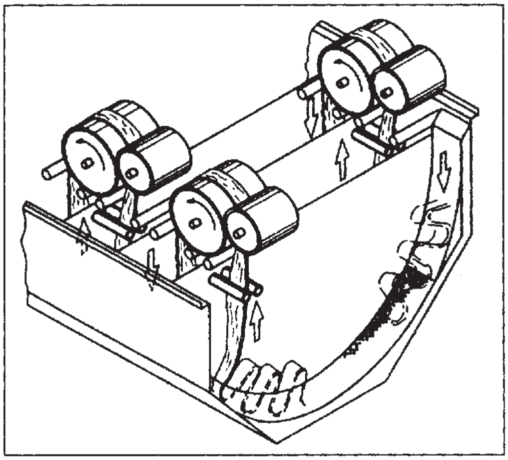


Fig. 1: Perspective diagram of Brückner's "Delphin" rope washing machine.

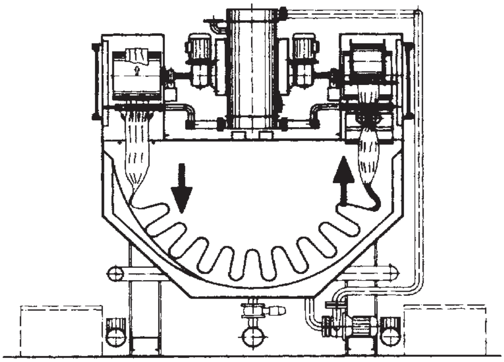


Fig. 2: Section through a fabric chamber of the Delphin plant (Brückner).

rollers, although this is only possible up to certain speed limits within the 40–60 m/min range (depending on the rollers and the chemicals used). The max. production speed is 80–120 m/min with squeezing rollers applied. The transport rollers are driven separately and, together with the stepless fabric loading control ensures precise synchronization of the machine. Switching between light and heavy articles in quick succession is possible due to the individual drives. If e.g. a fabric runs into chamber 1 with double the weight of the fabric already in the machine at that time, the feed is adjusted to half speed for the same hourly production performance. However, the final section of the machine continues to run at double the speed. Main fields of application include prescouring, prebleaching before dyeing, bleaching, washing after mercerizing or causticizing, washing off after dyeing and printing.

Delustring Causing delustring effects required by fashion on woven fabrics and knitwear made from manmade fibres, particularly from regenerated cellulose. A distinction is made between dope delustring and post-delustring.

I. Dope delustring is achieved by adding white pigments, in particular titanium dioxide, from water-insoluble fatty compounds or by the formation of blowholes during the spinning process. The effect is wash-fast and fast to cross-dyeing, but is covered by dyeing with full shades (unattractive greasy shine). With some direct dyes, the light fastness when damp is considerably reduced when titanium dioxide is used. Lustrous acetate fibres can be delustred in boiling soap liquors before dyeing. The effect can be accentuated by adding phenol, pine oil, fenchyl alcohol etc. Triacetate woven or knitted fabrics can be delustred by impregnation with urea, drying and heating to 165°C (Courtaulds method).

II. Post-delustring has lost a great deal of significance in favour of dope delustring. Delustring lustrous synthetic fibres is based on the formation of an optical dull layer on the fibre by pigment deposits. The pigment can be applied as such to the fibre or formed on the fibre itself. If delustring is carried out before dyeing, it must be fast to cross-dyeing; if it is carried out after dyeing, then only light to medium shades are suitable as a whitish layer appears when dark hues are used.

III. A certain reduction of lustre can also be achieved by embossing with a suitable pattern.

Delustring agent These are used to reduce the shine on textiles, predominantly those made from viscose and synthetic fibres. One-bath delustring agents can be divided into three groups:

I. Pigment dispersions: extremely fine pigment suspensions in association with softening agents, e.g. fats. Titanium dioxide, zinc sulphide, aluminium oxide and barium sulphate are predominantly used as pigments. They are generally cation-active and therefore high affinity absorbent products.

II. Hydrolyzable salts: commercial products based on zirconium oxychloride or stannates.

III. Synthetic resins: Non-pigmented products whose effect is based on the fact that finely dispersed synthetic resin particles are deposited on the fibre during condensation following coagulation. This produces wash-fast finishes. The following values result as percentages of delustred fabric after incineration (in a platinum or quartz crucible):

Viscose with barium sulphate	2.02%
Viscose with titanium dioxide	3.4–4.75%
Cupro with titanium dioxide	2.05%
Viscose with tin phosphate	10.3%

Delustring in spinning → Delustring.

Demulsifier A substance which is capable of breaking an emulsion. It functions by changing the state of electrical charges and the surface tension of emulsified sulphonic acids, etc. Opposite → Emulsifier.

Denatured A product that has been made undrinkable, e.g. alcohol (→ Ethanol, denatured) or sodium chloride for exemption of tax and reduced price for industrial purposes.

Denatured alcohol (methylated spirits, industrial methylated spirits = IMS). Alcohol (ethanol) which has been made unfit for human consumption by law with the addition of nauseating or toxic substances, e.g. methanol, pyridine, etc. For household use, it is often coloured with a violet dye.

In Germany, the product consists of 95% alcohol by volume (ethanol, denatured alcohol). As a fuel, 1 kg denatured alcohol produces approx. 31 425 kJ (= 7500 kcal.).

Denep, to → Knops.

Denier A weight-per-unit-length measure of any linear material. Officially, it is the number of unit weights of 0,05 g per 450 m length. This is numerically equal to the weight in g of 9000 m of the material. Denier is a direct numbering system in which the lower numbers represent the finer sizes and the higher numbers the coarser sizes. In the U.S., the denier system is used for numbering filament yarns (except glass), manufactured staple fibre (but not spun yarns), and tow. In most countries outside the U.S., the denier system has been replaced by the tex system. → Linear density of fibres and yarns.

Denim A firm 2/1 or 3/1 cotton twill-weave fabric (workwear twill) with a dyed blue warp and raw white weft. The warp is sometimes dyed during sizing (→ Blue jeans, etc.). Denim represents a further development of “Serge de Nîmes”, a coarse cotton fabric produced during the last century in Provence. After reaching North America, the Bavarian immigrant Levi Strauss realized as early as 1873 that an urgent need could be satisfied with this material. At the time of the California Gold Rush tough, hard-wearing trousers were needed by the hard working gold prospectors.

Denim finishing

Strauss designed a pair of trousers from denim material provided with ample pockets. He achieved rapid success and was soon able to build a factory in San Francisco for their production. These trousers were given the name „jeans“ which was supposedly derived from Gênes = Genoa, since Genoese sailors had already been accustomed to wearing working clothes made from denim material some time previously.

Denim finishing, includes e.g. chemical shrink-resistance, Sanforizing, liquid ammonia treatment and permanent press process. Stone-washed finish refers to indigo-dyed denim with a faded appearance. This is achieved by using stones when washing the articles, so that the dye is washed out partially and unevenly. This effect can also be achieved in the dyehouse by a form of aftertreatment following dyeing (e.g. by enzymes = biowash); it is fashion-dependent and today may also be produced commercially at a subsequent stage. The warp preparation, dyeing and sizing procedures are of great significance in the manufacture of denim. Dyeing with indigo requires a combination of practical experience and precise knowledge of the physical and chemical background. The various dyeing and sizing methods, recipes and concentrations, the reaction and oxidation times not only influence the associated weaving process, but also determine to a substantial extent the appearance, characteristics and quality of the denim. There is a fundamental distinction between the classic indigo rope dyeing method (Fig. 1) and the slasher, sheet dyeing or double sheet dyeing method (Fig. 2), in which the dyeing and sizing processes are carried out in a single cycle or separately. Another variation is the loop dyeing process.

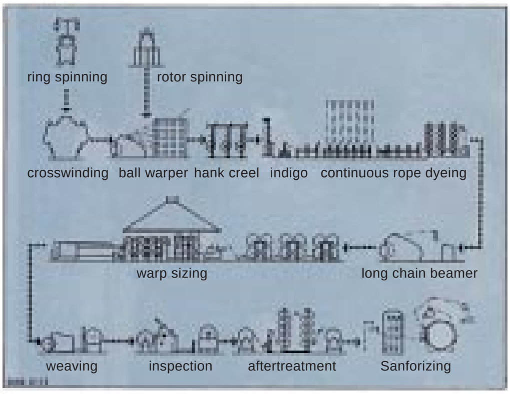


Fig. 1: Rope dyeing method for indigo.

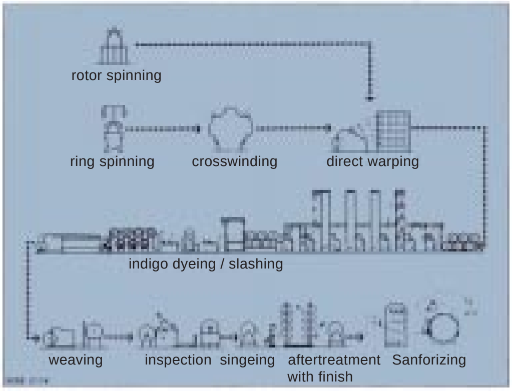


Fig. 2: Slasher or sheet dyeing method for indigo.

I. Rope dyeing method: 350–400 warp threads are combined by the ball warper to form a rope of 10 000–15 000 m in length. 12–36 ropes at a time are conducted through the continuous dyeing plant, dried on cylinders after dyeing, and deposited in cans. The ropes are converted into warps on the long chain beamer. These are introduced to the sizing machine, sized, and assembled to form the weaver's warp with the required number of ends.

II. Slasher or sheet dyeing method: Instead of ropes, warps are fed to the continuous dyeing/sizing machine. The warps are dyed, oxidized, dried, sized and after drying again, assembled to form the warp.

III. Double-sheet dyeing: A further development of the sheet dyeing method, the dyeing and sizing processes are here carried out separately. Double the number of warps are fed to the dyeing machine. The dyed, oxidized and dried warps are wound into two batches according to the total warp thread count, and these feed the sizing machine. Production rates are thus practically doubled.

IV. Loop dyeing method: All the methods described above involve passing the ropes or warps through several successive dye baths until the required depth of colour is achieved. In contrast, the loop dyeing method involves passing the warp threads repeatedly through the same bath until they have attained the required depth of colour.

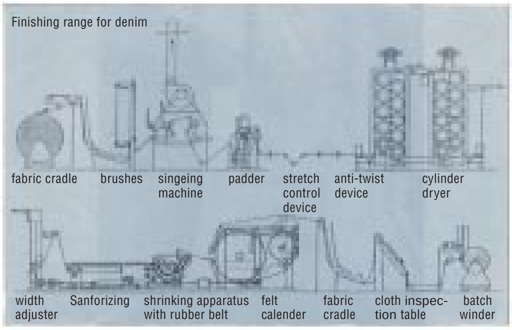


Fig. 3: Finishing range for denim.

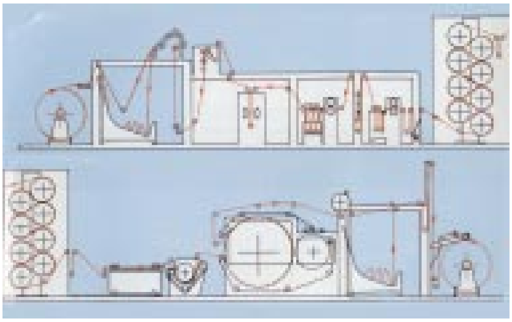


Fig. 4: Cibi finishing range for denim, consisting of feeder with fabric cradle, singeing machine, dust extraction, impregnation troughs, width stabilization unit, weft straightener, cylinder dryer, stenter, shrinking unit with rubber belt, felt calender, cooling roller, fabric cradle at outlet end, large batch winder, various stock reservoirs, shrinkage value display, moisture meter for monitoring optimum cloth shrinkage.

The finishing and Sanforizing of denim ususally takes the form of a continuous (in-line) method, but depending on the plant and machinery may be carried out in several stages (Figs. 3 and 4).

The finshing process is made up of the following stages:

- Brushing (on one or both sides),
- Singeing (on one or both sides),
- Desizing (where necessary),
- Padding (1–2 padding mangles),
- Stretching to the desired cloth width (where necessary), Stretch Meter (compensator),
- Weft skew correction (Anti-Twister) 6–16% excluding 3/1 and 2/1 twill, to prevent twisting of the fabric,
- Drying (12–24 cylinders) to a residual moisture content of 15–20%,
- Stentering (clip or clamp stenter),
- Sanforizing (moistening, shrinking, calendering) with a shrinkage of 11–15% to a residual shrinkage value of 2–2.5%.

(source Kessels).

Denitrifying bacteria Anaerobic bacteria which use cellulose as an oxygen carrier and therefore have a destructive action on cellulose. → Microbial damage to textiles.

Densimeter A → Hydrometer which provides a direct reading of the density of a liquid.

Densitometer An instrument for measuring the optical transmission or reflection of a material.

Density, mass per unit volume, specific gravity:

$$\text{density} = \frac{\text{mass}}{\text{volume}}$$

Relative density is the ratio of a given mass of a substance to the mass of an equivalent volume of water at the same temperature. The basis is the maximum density of the water, i.e. 1 ml water at +4°C = 1 g = relative density 1. It is determined by means of a hydrometer, hydrostatic balance or pycnometer.

The derived SI unit is kilograms per cubic metre (abbreviated to kg/m3).

$$\text{density } 1 = 1\,\frac{\text{kg}}{\text{m}^3}$$

All other ratios of a statutory mass unit and a statutory volume unit may be used for the representation of density, e.g.:

$$1\,\frac{\text{kg}}{\text{dm}^3} \quad \text{or} \quad 1\,\frac{\text{g}}{\text{cm}^3}$$

As the law relating to units of measurement equates the terms for mass and weight, relative density replaces the term specific gravity.

Density balance by de Vries and Weijland, used for the determination of the relative density of e.g. textile fibres. The fibre sample is weighed, attached to a quartz fibre 220 mm in length and 0.4 mm thick, and immersed in a fluid with a density lower than that of the fibre. The downward deflection of the quartz fibre caused by the weight of the fibre is read off microscopically and used to determine the fibre relative density. Reproducibility up to ± 0.002 g/cm^3 (given a fibre sample of approx. 0.5 mg).

Density determination of fibres From the definition of the concept of density it is clear that in order to determine the relative density of fibres two physical parameters must be measured at a constant temperature, mass and volume. Whilst the mass of a fibre may be determined without problem by weighing, the precise determination of the volume of a fibre is dependent on the existence of a defined impermeable periphery. If a solid body has simple, geometrically regular surfaces, the volume can be calculated. If a body has an irregular surface configuration, as is the case with fibres, the volume may be determined by submersion in a wetting fluid or introduction into a known volume of gas and measuring the volume of the gas or fluid displaced. Determination in this way is relatively simple, provided the prerequisite of a defined, impermeable periphery is satisfied.

In the case of fibres this condition is generally not fulfilled. Microscopic or submicroscopic cracks and/or pores of varying shape, location and permeability are often a typical feature of fibres. Thus the volume of a fibre is to a certain extent ambiguous, and from the outset only relative results can be expected from determination by means of fluid or gaseous media. This factor raises the question of whether fibres should be considered "porous bodies". Porosity is typically a macroscopic concept which loses its meaning when applied to intermolecular space. The term packing density is more appropriate. When considering the mass of fibres, account must also be taken of the fact that the solid body of a fibre often does not comprise a single substance, but is to all practical purposes a "hybrid", consisting of the substance of the fibre itself and attendant materials; water and air as atmospherically determined attendant materials are particularly significant in a textile context. The idea of fibre density expressed as a ratio of fibre volume and fibre mass therefore requires a precise explanation, both in terms of the concept itself and of the various means of experimental determination.

When determining density we should really speak of apparent density, giving the conditions (method, medium) which were obtained during the measurement. The apparent density is just as meaningful as the absolute density, as it is relative density which is used to establish structural changes. When studying the structure of cellulose, the following should be required of the immersion fluids:

- The molecules of the immersion fluid must be sufficiently small to be able to penetrate the microcapillary system of the cellulose.
- The fluid must be chemically inert in relation to the material being tested.
- It must not cause the test sample to swell or dissolve.
- It must not form an adsorption layer on the surface of the test sample.
- It must not promote moisture exchange between the test sample and the medium.
- It must not cause decomposition.
- It must show a low surface tension in the fluid/test sample system.
- Should a second medium be added to produce a gradient it must preserve the layered structure and must not cause selective diffusion.

In addition to the importance of temperature, especially when using inhibiting fluids, the time factor is fundamental and must be taken into account when considering the results of the measurements. Fibre density is also dependent on the method of determination and the medium used. Therefore, if unequivocal concepts are to be obtained, account must also be taken of both influencing factors when establishing the concept. The best-known density measurement methods are:

- Pycnometer (density bottle) method,
- Hydrostatic balance method,
- Buoyancy method,
- Suspension flotation method with concentration variation,
- Suspension flotation method with gradient column,
- Electromagnetic float method,
- Gasometric method,
- Radiographic method.

The individual measuring techniques often differ substantially from one another, as do the densities thereby determined. The density values determined by different methods and using different media may therefore only be compared with one another in relative but not absolute terms. Further influences include preparation of the test sample, measuring time, evaluation etc.

Density gradient, linear gradation of density per unit of length within a fluid, with varying densities obtained by the combination of selected fluids. The reference fluids are combined so that the composition of the mixture constantly alters during the mixing process. The constantly changing mixture passes into a graduated glass column. The gradient column thus obtained shows a density gradient reading downwards of, say, 1–0.0001 g/cm^3 per mm column height. In order to determine the density of e.g. a fibre sample, it is introduced to the gradient column whereupon it sinks to the level corresponding to its density. The gradient column is marked beforehand by calibrated glass spheres. The statistical error of the calibrated density gradient, given a statistical significance of 90% , is less than 1%.

Density gradient method, a method for determining the density of e.g. textile fibres using a → Density gradient. Reproducibility: $\pm 2–0.7 \cdot 10^{-4}$ g/cm^3.

Deodorant A substance used to remove or mask an unpleasant odour. Products suitable for use as deodorants include, inter alia, oxidizing agents (products containing chlorine or peroxide), adsorbents, fragrant finishes, chlorophyllin, etc. →: Fragrant finishes; Antiperspirants.

Deodorization refers to the bonding of odourous substances by sealing in the odour-emitting molecules (clathrate), a process which has not yet been fully explained. Odour molecules are bound according to their structure and thus rendered indectectable to the senses. There is a quantitative interrelationship between the odour-emitting substance and the deodorant. Zinc soaps are an example of a group of deodorants.

Deodorizing treatment A procedure for removing substances responsible for generating undesirable odours from textiles.

Deodorizing Making a material odourless by → Odour suppression, masking, destruction (oxidizing agents) or adsorption (adsorbents). In solvent processes (drycleaning, solvent finishing, solvent sizing) deodorizing is carried out at the end of the process, after drying, by subjecting the goods to a current of fresh air in order to ventilate them and make them odourless.

De-oiling

I. → Washing wool fabric.

II. → Desizing (of linseed-oil-based sizes).

Dephlegmator A precondenser (e.g. activated carbon) on the surface of which the material to be adsorbed (e.g. solvent) accumulates.

Depolarization at metal surfaces The process of rust formation. Principle:

1. Iron ions and free atomic hydrogen are initially formed through the action of chemically pure water (e.g. rain water); this produces a complete, unbroken (hydrogen) iron-protective film on the metal surface (polarization).
2. Molecular hydrogen (gas bubbles) are formed in the presence of free, aggressive, carbonic acid. If water containing dissolved atmospheric oxygen is present, reaction takes place between oxygen and hydrogen resulting in the back-formation of water, partial dissociation, formation of new hydrogen ions, and corrosion (rusting).

Depolymerization The opposite of → Polymerization, i.e. the breakdown of polymers into their monomers, dimers, etc.

Depreciation →: Amortisation; Service life of textile plant and equipment.

Depth gauges Mechanical or optical devices which are used e.g. to check the engraving depth when manufacturing printing rollers.

Depth of shade is regarded as the criterion for dyestuff concentration on dyed material, enabling fastness evaluations to be carried out. → Saturation.

Dermatitis → Skin diseases.

Desalination (demineralization) → Ion-exchange process.

Design Generally pattern, model, design, but also in the sense of an illustration, figure. In the textile industry, design is often regarded in the sense of an optical effect, in particular an aesthetic effect of the surface of the textile fabrics.

Every textile fabric has a specific structure, but this cannot be automatically described as design. Important characteristics arise from this structure, which in the simplest case is distributed evenly across the entire fabric. The following are characteristic of the structure:

- Fibres and/or threads with their specific properties.
- The way in which the cohesive assembly of fibres and/or threads is formed.

The interlacings for the most important textile materials are unique structural features for a particular type of thread. The fundamental structures are typical of woven and knitted goods. This principle is also true of other textile fabrics. The basic structures, i.e. the basic weaves, are non-patterned. Altering or changing the fibres and/or threads and the sequence of their interlacing gives rise to other structures, generally with different properties, or other visual effects. These can be added to by further ornamentation, i.e. colour, material or 3-dimensional effects both during fabric production and in subsequent processes (in particular during finishing). This results in patterned textile fabrics.

On the other hand, however, a relatively large number of textile fabrics cannot be described as plain despite their regular appearance. The borders between plain and patterned are fluid. The following conclusions can be drawn from this:

1. The characteristic structure of a textile material, plain weave in the case of fabrics, appears non-patterned when only one fibre or type of thread is used.
2. All variations of the conditions described above under 1 may be regarded as patterned textile fabrics.
3. In the processes which follow fabric production, the non-patterned effect is only retained if the basic structure or the surface remains unmodified.

The following definitions can therefore be made:

- Design is the result of variation being introduced into a fabric in terms of material, colour or structure, or a decoration.
- Patterning is on the one hand the intricate technological means of producing a design and on the other the appearance of a design as a whole.
- Pattern is the individual feature and/or element of a design.

(contributed by Martin, Loler and Mühlmann).

Design digitalization The production of stored design information on data storage systems through scanning. For textile printing applications, the production of colour separation films with the extremely precise utilization of digitalized design information as follows:

- by means of a laser beam directly on to film, e.g. the Scitex Response 200 System;
- by direct engraving on to a printing roller, e.g. with the Helio-Klischograph;
- by direct engraving with a laser beam on to a roller with a plastic skin, e.g. with the Crossfield Laser Engraving System 700;
- by printing without a printing roller or printing element by using a laser beam for ink-jet printing, e.g. the Chromotronic or Millitron process for carpet printing.

Designing Product development and textile designing, e.g. of woven and knitted fabrics. In the production of, e.g. plain-dyed or yarn-dyed woven and knitted fabrics, as well as prints, successful sales of a collection can only be ensured if it meets the requirements of the market and is attractive. The task of producing a collection is the responsibility of the designer and consists of a) a creative element and b) his/her efforts to bring about the realization of creative ideas. Finally, the designer has to follow up „his/her“ product not only during sampling, but also in production throughout the entire season and, possibly, also through garment making to the final consumer. This wide-ranging task must be accompanied by

- increased creative possibilities,
- reduced sampling costs,

- reduction in reaction times in meeting customer demands and trends,
- linking of production methods to CIM concepts in weaving, dyeing (colour measurement) and printing.

This very diverse work can only be accomplished within the time scale of “quick response” with the aid of data processing and CAD systems. Creativity must be supported by possibilities for integrating the design computer into the total information flow of the company. In a CIM concept, product development is of outstanding importance. There are several reasons of decisive significance for this:

1. Considerable master data relating to the article arises during the construction process which is required in the further course of production and organization.
2. A construction which conforms to the production requirements improves the manufacturing possibilities and reduces production costs.
3. Important end-product costs are already determined during construction (yarns, colours, machine types, finishes).

Because of the above reasons, it is important that a CAD system is installed not as an isolated solution for the designer only, but should also be capable of generating production data and production control information. Moreover, quality control results as well as actual production data from previously manufactured products should also be available.

CAD/CAM systems are now available for virtually all types of textile product, with systems for knitting, dobby and jacquard weaving, as well as textile printing being particularly prominent. For dobby weaving applications, two different types of system are currently available:

1. Systems in which the output is in the form of a paper printout and which also incorporate extensive CAM functions, e.g. High-Tex, CIS/Barco (Design 3), IAM (Tweed), Sophis.
2. Systems which are connected to a “semi-mechanical” sample weaving machine whereby the output is in the form of a short length of grey fabric, e.g. Texel-Texy.

Designing techniques in textile printing When printing, a distinction is made between the types of design shown in Fig. 1.

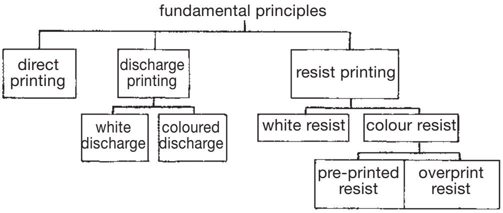


Fig. 1: Classification of printing techniques.

I. In direct printing the dye is applied to the textile surface in accordance with the pattern and dried and fixed as required by its chemical and physical properties (Fig. 2).

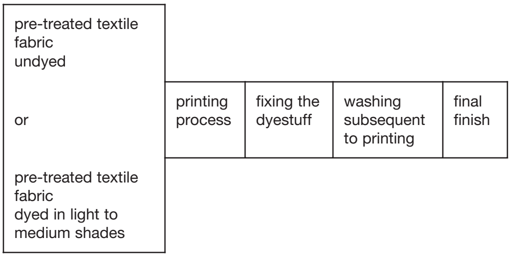


Fig. 2: Direct printing sequence.

II. If an already present dye is locally destroyed by the application of print paste during subsequent fixation, this is referred to as discharge printing (white discharge) (Fig. 3). If a coloured pattern is to be produced on a coloured base, chemicals which break down the base and discharge-resistant dyestuffs are added to the print paste (coloured discharge) (Fig. 4).

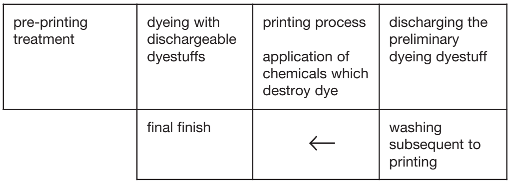


Fig. 3: White discharge printing sequence.

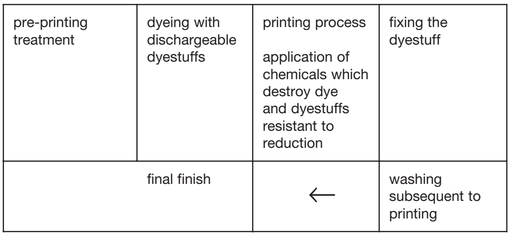


Fig. 4: Colour discharge printing sequence.

III. The resist print is characterized in that suitable thickening agents are printed on an undyed textile material according to the pattern. These prevent penetration or fixation of the dyestuff on subsequent dyeing. Such white resists (Fig. 5) can be achieved either by purely mechanical means or by using agents which have a chemical effect. Using the mechanical resisting

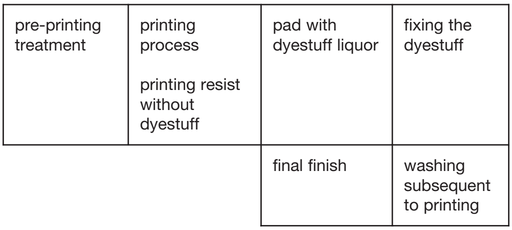


Fig. 5: White resist.

agent, the dyestuff is denied access to the fibre during dyeing, e.g. by using wax. A chemical resist agent prevents the fixation of the dyestuff by a chemical reaction. This is referred to as pre-printed resist, whereas the term overprint resist is used when a previously applied dyestuff component is prevented from subsequent dyestuff formation with a second component by direct printing using predominantly chemical means.

If a dyestuff is applied at the same time as the print paste so the resist printed areas later appear coloured, this is referred to as colour resist (Fig. 6).

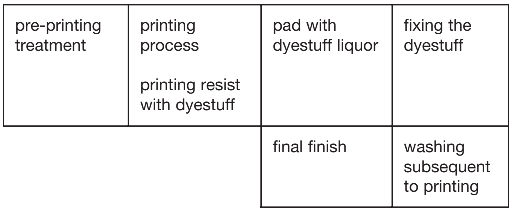


Fig. 6: Colour resist.

Design transfer to printing screens The aim is to close the fine pores of the gauze fabric to the area which is not to be printed using an agent which is impermeable to dye paste, and which cannot be dissolved by dye paste. On the other hand, the areas where printing is to take place should remain open and permeable to dye paste. Various methods are used for this operation. The simplest method in terms of the agents required is manual design transfer. The most widely used method is design transfer by means of photochemical processes, but also with laser technology.

Desize/bleach, single-bath A so-called combination process whereby the oxidising agents used for bleaching will also degrade starch and polyvinyl alcohol under certain circumstances. It is dependent on the type of size used.

Desizing Intended to remove size and finish constituents to ensure even bleaching, level dyeing and soft handle. The process is geared towards the type of size present. These can be as follows:

1. Sizing agents based on natural substances:
   - Starches and starch derivatives: native starch, degradation and chemically modified starch products,
   - Cellulose derivatives: carboxymethylcellulose (CMC), methylcellulose and oxyethylcellulose,
   - Protein-based sizes: glue, gelatine.
2. Fully synthetic sizes:
   - Polyacrylates,
   - Modified polyesters,
   - Polyvinyl alcohols,
   - Styrol/maleic acid copolymers.

The cost of the chemicals and the process used for desizing depends on the type of size. For this reason, the person responsible for desizing will aim for a desizing process that is technically simple and environmentally friendly with regard to effluent. While production speeds are continuously increasing in the textile mill, correspondingly increased demands are being made on the fabric and, therefore, the sizing agents. As a result, significantly more size (up to 30%) is applied. Because of the high water content, heavier size deposits require adjustments to be made to the evaporative capacity. In most cases, this adjustment is not achieved by lengthening the drying zone but by increasing the temperature of the drying cylinders. The formerly gentle drying conditions have now developed into high-speed drying at 150–160°C. In the meantime, sizing has been optimised in such a way that the simple rule of thumb “the more the better” is no longer valid with regard to the efficacy of size in the weaving process.

The different desizing processes are as follows:

- Thermal desizing of starches on glass-fibre fabrics (corona discharge),
- Enzymatic desizing of starches on cotton fabrics,
- Oxidative desizing using peroxymonosulphuric acid or sodium bromite,
- Desizing of water-soluble sizes using a washing procedure.

I. The corona discharge of starches on glass fabrics (0.8–1.2% binder and 1% size in the form of starch derivative and polyvinyl alcohol) is carried out in a stationary bath with the fabric wound on perforated beams in order to avoid breaking the glass fibres. The beams stay in an oven for 72 h at 365°C before they are unwound. The glass fabric is then fed through an IR tower ager at 450°C to burn off residual size.

II. The classical desizing process consists of removing the starch from cotton fabrics using enzymes. This desizing process simply involves liquefying the film of size on the product. The size kitchen of a warping plant has equipment for dissolving the conventionally powder-form size products. The amounts incorporated may be selected so that the desired sizing objective can be achieved, compatible with temperature, viscosity, operating speed and liquor uptake. For the desizing process, the situation appears to be significantly less favourable. The concentration of size on the product is predetermined and, in most cases, the amount of desizing liquor which would produce ideal liquidity cannot be absorbed by material which has invariably been overdried on the singeing machine.

The causes of desizing problems are as follows:

Group 1 (problems arising from pre-treatment):

- Over-drying the sized warp,
- High content of fats with poor emulsion properties or waxes subsequently applied to the warp,
- High content of finishing auxiliaries released from the synthetic component during sizing of polyester/cotton products,
- High copper content from the size-hydrolization plant and size trough,
- High content of preservatives.

Group 2 (problems arising from the process itself):

- Liquor uptake too low, because the impregnation box is too small or too little surfactant has been added.
- The swelling time (dwell time) is too short.
- Enzyme-toxic surfactant has been used.
- The wash power is too small for removing the hydrolized size.

Unlike other types of size, starch can be easily identified. A drop of brown iodine solution will colour a fabric violet-blue which has been sized with starch. The depth of coloration corresponds to the amount of starch on the fabric. A violet scale (TEGEWA) calibrated from 1–9 serves as a reference. When carrying out the comparison test, the ranking is used to evaluate the degree of desizing. Non-damaging treatment of material and environment calls for the use of enzymes which decompose the starch without attacking the cellulose. In this method, diastases are used including pancreas and malt extracts. Enzymes may be defined as organic, soluble bio-catalysts, formed by living organisms and quite specific in their action on a particular substrate. A small quantity of enzyme is able to decompose a large quantity of substrate. In chemical terms, an enzyme may be defined as a molecular protein complex with a very specific number of amino acids. It reacts to all chemically active substances (including water) and requires precisely determined conditions to produce the optimum effect.

Strict control of pH, temperature, water hardness, electrolyte addition and choice of surfactant are vital for effective desizing. Otherwise, desizing cannot be guaranteed and problems can arise, especially during dyeing and printing.

The possible consequences of inadequate desizing are as follows:

- Irregular dyeing,
- The presence of (undesirable) reserve sites in the dyed or printed materials,
- Weaker colour depth,
- Increased tendency towards moiré phenomena,
- Increased tendency to crease because of the harder handle,
- Reduced absorbency,
- Lower whiteness.

In general, insufficient desizing impairs all subsequent finishing processes. The reasons for poor results may be as follows: unsuitable choice of enzyme, reduced enzyme activity due to incorrect storage or unfavourable working conditions, outdated or crystallised sizes and insufficient wetting giving rise to insufficient uptake of liquor etc. In practice, the combination singeing/sizing pad-batch system is used most often. Approximately 2000–5000 m textile fabric passes through a desizing bath at 70°C containing amylase directly after singeing. After squeezing, the fabric is batched, wrapped in plastic film and held for 4–6 h at room temperature. After this, the fabric is washed out. For successful desizing, the washing stage is as critical as the desizing process itself, as all size residues must be loosened from the fibre and removed. For this reason, it is advisable to heat the wash liquor to 95°C, to use counter-current washing machines and to squeeze out the fabric several times. At the end of the washing process, the iodine test should give a yellow coloration. Apart from these, there are other desizing processes which are used in practice, such as continuous processes using J-Box and pad-steam equipment, the Enzyme shock process or batch processes using jiggers, winch vats, jet machines and autoclaves.

III. The oxidative desizing methods are relatively unimportant and when using them, damage to fibre can never be completely avoided. The power of oxidizing agents to break down starch has always given occasion to use this method for desizing. Perborate or sodium toluenesulphochloramine have been tried as additives to the kier liquor. Later, sodium or potassium persulphate have been recommended as oxidizing agents and have been used to some degree (Fig.). In both cases, intensive alkaline after-treatment is necessary to achieve complete desizing.

IV. When water-soluble sizing films, such as polyacrylates, polyvinyl alcohol or sulphonated polyesters, are to be removed from the fibre, then the swelling and dissolving processes overlap. This form of desizing does not follow simple first-order kinetics as one would

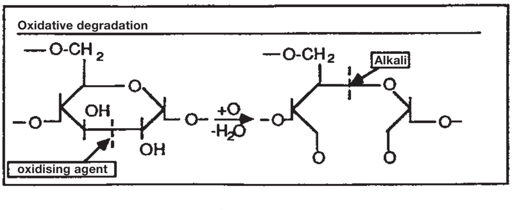


Fig.: Oxidative desizing of starch.

expect. Apart from the delay during the swelling phase, it is more the case that two first-order partial-processes take place concurrently: a) release of the enveloping size-film mantle from the yarn surface and b) leaching out of the size from the core of the yarn as the rate-determining step (as accessibility to the textile matrix is so low). Raised temperatures and turbulent flow increase accessibility by improving the extraction of domains of higher viscosity out of the fibre assembly.

Desizing agent Desizing agents are used for → Desizing and removing water-insoluble printing thickeners from printed fabric. The different desizing agents are distinguished as follows:

I. Those for starch-based sizes, in the form of starch-splitting → Diastases (bacterial, malt and pancreas amylases).

II. Those for protein-based sizes, in the form of proteolytic enzymes (→ Proteases).

III. Those for oil-based sizes, in the form of surface-active substances in combination with solvents (fat-dissolving soaps) or oxidising agents.

Desizing auxiliary Products which accelerate the desizing process and removal of printing thickeners (when there are starch-containing products present). Suitable surface-active substances, such as wetting agents or detergents, can also be used in conjunction with enzyme products.

Desmo- (desmos = bond, band), relating to bonding.

Desmolases A small sub-group of → Enzymes which are capable of rupturing C–C- or C–H-bonds generally preceded by or accompanied by simultaneous oxidation.

Desmotrope This term applies to tautomers which can be separated from each other.

Desorption The process of removing an adsorbed material from the solid on which it is adsorbed. The opposite of → Sorption.

Detection limit This is the smallest quantity of a substance by weight which is still capable of giving an identification reaction (analysis). Expressed in mg or µg.

Detergency The cleansing power of surface-active compounds (surfactants) or detergents in developing a washing or cleansing effect often associated with the emulsification of fatty soils and the prevention of soil redeposition. →: Washing; Washing efficiency.

Detergency efficiency Problems of cost reduction, water resources and effluent treatment and disposal force finishers to study wash processes in depth and to learn as much as possible about performance when buying new machines. Detergency efficiency is a measure of the extent to which chemicals and foreign substances can be removed from the goods in a specific situation. However, this parameter is not representative of the overall efficiency of a machine.

$$\mathrm{WWGRD} = \frac{C_A - C_E}{C_A} \cdot 100\ \%$$

WWGRD = detergency efficiency,
C_A = initial load of foreign matter on the textile,
C_E = final or residual load on the textile after laundering.

With a given washing plant the detergency efficiency of solvent scouring is dependent on the following factors:

- Type of fabric circulation,
- Type of liquor circulation,
- Temperature,
- Dwell time,
- Liquor supply,
- Type of bath separation,
- Flow conditions.

When discussing the washing process in terms of detergency efficiency several influencing variables should be considered:

- The equilibrium of the wash, i.e. the limit value in a bath or liquor exchange,
- The rate of adjusting the equilibrium of the wash in a closed system,
- The rate of adjusting a stationary process in an open system,
- The combination of individual washing elements.

Every textile and liquor system reaches equilibrium after an infinite length of time, in which the concentration of the contaminant in the textile and liquor no longer changes. This condition can also be achieved after a shorter period of time under practical conditions. Equilibrium should be aimed for as close to the beginning of the wash as possible in order to achieve uniform treatment.

Calculation of the equilibrium concentration is possible using the mass conservation law:

$$m_{S0} + m_{F0} = m_{S\infty} + m_{F\infty}$$

m_{S0} = mass of the substrate at time moment zero,
m_{F0} = mass of the liquor as make-up water at time moment zero,
$m_{S\infty}$ = mass of the substrate after adjusting the equilibrium,
$m_{F\infty}$ = mass of the liquor after adjusting the equilibrium

When introducing make-up water, $m_{F0} = 0$ and with $m = V \cdot c$, this equation follows:

$$V_S \cdot c_{S0} = V_S \cdot c_{S\infty} + V_F c_{F\infty}$$

V_S = substrate volume,
c_{S0} = concentration of contaminant contained in the substrate at time moment zero,

$c_{S\infty}$ = concentration of contaminant contained in the substrate after adjusting the equilibrium,
V_F = liquor volume,
$c_{F\infty}$ = concentration of contaminant in the liquor after adjusting the equilibrium.

In equilibrium, $c_{F\infty} = c_{S\infty}$ and therefore

$$c_{S\infty} = c_{S0} \frac{V_S}{V_F + V_S}$$

If the volume ratio from the liquor and the substrate is introduced using

$$F \equiv \frac{V_F}{V_S}$$

then

$$c_{S\infty} = c_{S0} \frac{1}{1 + F}$$

and the detergency efficiency is

$$WWGRD = 1 - \frac{c_{S\infty}}{c_{S0}} = 1 - \frac{1}{1 + F}$$

If the substrate has a particular retentivity for the contaminant, this is often described using the Nernstsch distribution isotherm

$$\frac{c_{S\infty}}{c_{F\infty}} = k > 1$$

The mass flow of the substance to be scoured out via the interface between substrate and liquor is proportional to the magnitude of this interface A_s and to the difference in concentration of the substance to be scoured out between substrate and liquor.

The proportionality factor is known as the mass transfer coefficient β. The diffusion coefficient D of the substance to be scoured out in the liquor, the viscosity η in the liquor and the thickness δ of the flow interface are contained in the thickness factor β:

$$\beta \equiv \frac{D}{\eta \cdot \delta}$$

The mass transfer is therefore dependent on temperature and flow. It is assumed that the diffusion rate in the substrate is high compared to the rate of mass transfer. This is the case with contaminants e.g. on the surface of the substrate. Consequently, when calculating the concentrations in the substrate c_s, only those masses of the substance to be scoured out which have correspondingly high mobility are to be taken into consideration (source: Heidemann and Dugal).

Detergency power Detergency power is calculated using the formula:

$$\% \, WK = \frac{\%WG_{gew.} - \%WG_{ung.}}{\%WG_{unb.} - \%WG_{ung.}} \cdot 100$$

gew. = laundered,
ung. = unlaundered,
WK = detergency power,
WG = white content, laundered, unlaundered or unsoiled.

This is based on the term “one hundred percent detergency power”, which corresponds to the → White content of the textile before soiling.

Detergent and Cleaning Agent Law The German Detergent and Cleaning Agent Law (Waschmittelgesetz) is concerned with the environmental compatibility of detergents and cleaning agents and was originally a reaction to the → Eutrophication of rivers and lakes by phosphates from household detergents. This law was promulgated on 20.08.1975 and published in the Federal Law Gazette No. 100 of 23.08.1975, page 2255 et seq. The law came into force on 01.09.1975.

According to official objectives, this law was intended to further develop the provisions of the former Detergent Law (1961) and conform to the relevant EC guidelines. In addition, it also provides a legal framework to take action against the pollution of water courses by detergents and cleaning agents through comprehensive legally-enforceable measures. The scope given in § 2 is more extensive than the range of application of the former Detergent Law and also covers detergents and cleaning agents used in the industrial sector. § 3 provides the statutory orders relating to biodegradability requirements for surface-active and other organic substances. § 4 provides the statutory authority to fix the maximum permissible quantities of phosphates. Provisions for legal hearings concerning affected parties are embodied in § 6. Specific directions for package labelling are contained in § 7 and the statutory obligations of manufacturers to notify the Federal Department of the Environment of their generic product formulations are given in § 9. →: Water Resources Law; Washing agent additives.

Detergent base materials To manufacture detergents, cleaning agents and rinsing agents for industrial, commercial and domestic use. Detergent base materials are not textile auxiliaries. Product basis: surface-active substances (→ WAS) or preparations resulting from these.

Detergent booster An additive to improve the performance of → Detergents. Usually based on fatty acid (mono) ethanolamides R–CO–HN–C_2H_4OH. These products improve foam stability (foam control) and detergency properties, and also protect the skin. → Heavy duty detergent booster

Detergents The meaning of this term has changed during the course of time and even today a clear definition has still not proved possible. As defined during the 1960s (German Detergents Law of 1962, Regulations on Detergent Degradability 1962, European Convention 1968) detergents were primarily understood to be surfactants, i.e. synthetic surface-active substances. After the so-called 1973 European Community Guidelines, a more comprehensive definition was further extended to include additional components as well (such as additives, diluents, extenders and other secondary constituents). The still further extended Washing Agents Law of 1975 also defined products containing no surfactants as washing and cleaning agents. For the purposes of this law, washing and cleaning agents are understood to be products which, in mixtures with surface-active substances, as well as phosphates, perborates or their substitutes, as well as supplementary additives, have a cleaning action together with water, or which are formulated for cleaning purposes and which can enter a water course after use.

Detergents Law (Germany) → Water Resources Law.

Detinning of weighted silk Pretreatment with a liquor containing 1–1.5% hydrochloric acid or salts of oxalic acid. Processes with a preliminary step using mineral acid produce the greatest possible activity while allowing significant savings to be made in concentration in the detinning bath.

Deuteranomalous So-called “green deficiency”; → Anomalous colour vision.

Deutsche Forschungsgemeinschaft e.V. (DFG), an organisation which supports research in Germany. Provides financial assistance for technical, scientific or research projects etc. Work includes the provision of a senate commission for the control of substances hazardous to health (dangerous substances) in the workplace. → Technical and professional organizations.

Deutsche Industrie-Norm → DIN.

Deutscher Färberkalender (FärKal). International finishers’ yearbook, Deutscher Fachverlag, Frankfurt (formerly Lorch-Verlag, Frankfurt). An annual technical publication containing articles of topical interest for the dyeing and finishing industry, published since 1875.

Deutscher Normenausschuß (DNA), in mid-1975 the name was changed to “Deutsches Institut für Normung”, → DIN.

Deutscher Textilreinigungs-Verband (DTV) → Technical and professional organizations.

Deutsches Institut für Normung → DIN.

Deutsches Teppich-Forschungsinstitut (TFI) → Technical and professional organizations.

Deutsches Textilforschungszentrum Nord-West (DTNW) → Technical and professional organizations.

Deutsches Wollforschungsinstitut (DFI) → Technical and professional organizations.

Developer (coupling components for diazo dyes) are usually phenols, naphthols and amines which couple with previously diazotised dyes. This process leads to an increase in the size of the molecule and this significantly improves the wet fastness properties of the dye. There are numerous developers available, some of which are very diversely constituted, depending on the existing diazo dye, intended colour tone and desired fastness. Their solubility can be extremely variable and their range of application in each case is very limited.

Developing dyestuff All dyes consisting of a pair of components such as → Naphthols in dyeing and printing. → Dyestuffs for coupling are seldom used.

Deviation In statistics, deviation is the difference between an observed value in a series of such values and their arithmetic mean. It is also the difference between an observation and a fixed (target) value.

Devoré style → Burn out style.

Dew point The dew point is defined as the temperature at which water vapour present in the air saturates the air and begins to condense, i.e. dew begins to form. The relative humidity of air with a constant water vapour content increases on cooling and dew (condensed water) forms as the temperature falls below the saturation line. A particular temperature (the dew point) can thus be assigned to this point at which the saturation line is crossed. In other words, the dew point is the temperature at which an initially unsaturated mixture of air and water vapour has to be cooled in order to reach saturation.

Dextran ($C_6H_{10}O_5$). A storage polysaccharide polymer synthesized by bacteria (Leuconostoc mesenteroides resp. Leuconostoc dextranicum) consisting of macromolecules with chain-like structures made of glucose residues joined by α-1,6 linkages with an average molecular weight of 100 000–200 000. Fibres can be spun from hardened dextran (60% aqueous solution with acetone or alcohol acidified with hydrochloric acid) or it can be used as a lacquer on paper or fabric with the addition of glycol as a plasticizer and ammonium chloride. Clinical dextran is used as a blood plasma substitute.

Dextrin Heat-treated starch used as a size ingredient for finishing and printing purposes. Colour varies according to the degree of heat applied.

Dextrines Degradation products of starch, yellowish to white friable granules or powders (crystal gum, British gum, roasted starch, burnt farina). They are further broken down (liquefied) to maltose or glucose by the action of diastases. In finishing they produce a starch-like crispy handle. They have a sweetish and slightly harsh taste. Water solubility: cold (depending on quality) extremely variable (25–98%); most are soluble in hot water. Iodine reaction: blue-violet to red-violet, red-brown to colourless (depending on extent of degradation). Stiffening power approx. 5–6 times lower than starch. Adhesive power considerably greater than starch. Uses: important finishing agent (stiffening, non-dulling, non-chalking, cheaper substitute for gum arabic), textile printing thickeners.

Dextrins Intermediate products obtained in the transformation of → Starch with the following properties: a) external characteristics: progressively low viscosity; b) iodine reaction: blue-violet, red-violet, red, reddish brown (achromatic); c) solubility: cold water soluble; d) Sizing mechanism: hardens, strongly conglutinated dextrin films (size, proofing) are transparent and decrease rapidly in strength and elasticity with progressive decomposition.

Dextrorotatory → Optical activity.

Dextrose → Glucose.

DFE, abbrev. for: directional frictional effect. The term is used in connection with the wool fibre and means that the friction in the tip-root direction is greater than vice versa. It contributes largely to the → Felting propensity of wool.

DFG, abbrev. for: Deutsche Forschungsgemeinschaft; → Technical and professional organizations.

D-form, an abbreviation used in chemistry to describe that form of a compound which is dextrorotatory in polarized light (opposite = laevorotatory → L-form). → Optical activity.

DGN, abbrev. for: Dirección General de Normas (General Office for Standards, including textiles); → Technical and professional organizations.

DGQ, abbrev. for: Deutsche Gesellschaft für Qualität (German Association for Quality, with textile division), Frankfurt, Germany. Until the end of 1972 known as ASQ. It collaborates, as the DGQ technical group on textiles with the → Gesamttextil organization in Germany. → Technical and professional organizations.

dH Obsolete abbrev. for: German Hardness Degree for water. → Water hardness units.

di-, prefix meaning two, twice, double, e.g. disodium phosphate (Na_2HPO_4).

Diagonal register in roller printing Achieved by altering the horizontal position of the printing roller. This is accomplished by a device which raises or lowers the bearing on one side. This means that the roller can be positioned slightly diagonal to the passage of the cloth. The type of repeat is seldom used as it results in increased wear of the bearing shell.

Diagonals Textile fabrics characterized by (often fairly wide) stripes running in a diagonal direction. The term refers only to the pattern effect and not to any particular fabric quality. Mainly described as broad twill or stitched twill fabrics.

Dialog system A unit in electronic data processing systems which permits a two-way information exchange between an operator and a computer based on question and answer interplay.

Dialysis → Osmotic pressure.

Diamine → Hydrazine.

Diamines Diamino compounds, i.e. containing two –NH2 groups as represented in numerous → Direct dyes. → Amino group.

Diaminocarboxylic acids → Amino acids.

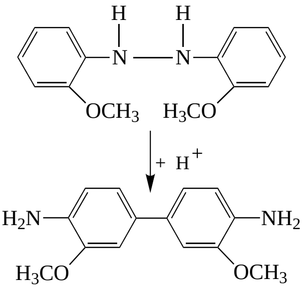
Diammonium phosphate (DAP) → Ammonium phosphates.

Diamond finish → Embossing.

Diamond point graver Engraving tool used in pantograph engraving to scratch the engraved design into the varnish coated surface of a copper printing roller.

Diamond-wound package → Crosswound package.

Dianisidine base MW 244,24. Obtained by the rearrangement of benzidine:



Dianisidine blue A vivid blue shade produced on cotton fabrics prepared with beta-naphthol, especially for blue/red styles. Unsatisfactory colour fastness to light and acids.

Diaphragm porous dividing wall which a) is water and ion permeable; b) impedes diffusion from one side to the other (clarification); c) renders impossible a mechanical combination of the liquids separated by the diaphragm. An example of a diaphragm is a plate of Portland cement with occlusion of sodium chloride solids (which dissolve away in water giving the necessary porosity). Application: for osmosis (diluting or increasing concentration), dialysis (principle: the separation of colloids and crystalloids), electrolysis. Diaphragm process principle: the separation of the anode and cathode areas, e.g. of sodium chloride solution, to produce caustic soda and chlorine (production of sodium hypochlorite).

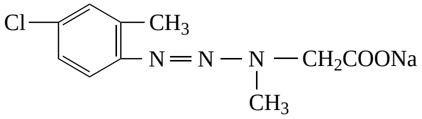
Diastases (Gr.: *diastasis* = a separation). Available for practical use as technical (impure, diluted) enzyme products, i.e. starch-degrading products of three types →: Bacterial diastases, Malt diastases and Pancreatic diastases. As active degradation constituent they contain a more or less temperature-sensitive enzyme (→ Amylases) which converts insoluble carbohydrates (starch) via dextrines into soluble sugars (maltose, glucose). Malt diastase has a strong liquefying and saccharifying action. Bacterial diastase hydrolyzes the glucoside bonds in starch and has a strong liquefying and weak saccharifying action. Pancreatic diastases have a strong saccharifying action. The degradation of starch by diastases is always accompanied by various stages of degradation at the same time proceeding via dextrine to maltose resp. glucose.

Diatomaceous earth → Kieselguhr.

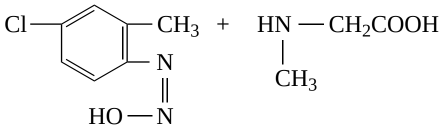
diazo-, an atomic grouping of the type –N=N– in → Aryl compounds

diazoamino- The atom grouping: –N=N–NH–. → Diazoamino compounds.

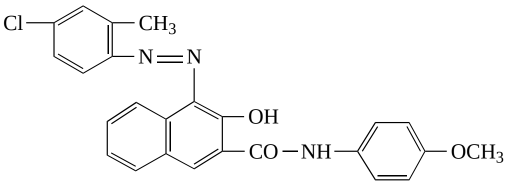
Diazoamino compounds participate e.g. as important components in dye synthesis. For example, a mixture consisting of equivalent amounts of a naphthol and a diazoamino compound with a stabilizer is allowed to react. At this stage, the stabilized diazoamino compound is not yet able to couple with the naphthol present.



Coupling only occurs after an acid treatment (acid steam). This breaks down the stabilizer with the formation of a diazonium compounds which is capable of coupling:



Coupling now takes place with the naphthol to give an insoluble azo dye:



Diazo compounds are characterized by the presence of the azo group (–N=N–). Isomeric diazo compounds are represented by the mostly unstable syndiazo compounds and the stable antidiazo compounds (both in the cis-form). They are subdivided into two structurally different types:

1. Diazonium compounds: Ar–N≡N–X.
2. Diazotates resp. diazohydrates: Ar–N=N–X.

Diazo fast salts → Fast colour salts.

Diazonium compounds Diazotized bases having a salt-like character (from hydrochloric, sulphuric or nitric acids) with the formula $(Ar–N^+≡N)X^–$, where Ar represents an aryl group and X a negatively charged ion (e.g. $Cl^–$). Diazonium compounds dissolve in water like ammonium compounds with a neutral or alkaline reaction. They are formed, e.g. as unstable intermediate compounds by diazotization of an amino group in a direct dye:

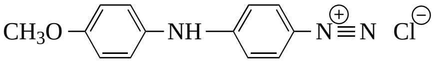
$$R-NH_2\cdot HCl + HNO_2 \longrightarrow R-\overset{\oplus}{N}\equiv N-\overset{\ominus}{Cl}$$

$$\left[R-\overset{\oplus}{N}\equiv N\right] + Cl^{\ominus}$$

The dye-diazonium compound formed in this way is then coupled with a developer, as a result of which a henceforth stable azo group is formed as a new bridge in an enlarged dye molecule:

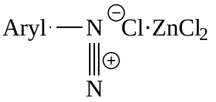
$$R-N=N-C_{10}H_6-OH.$$

Similar diazonium compounds are formed by Fast Colour Salts, e.g. the well-known Variamin Blue Salt B (Fast Blue Salt NBL):



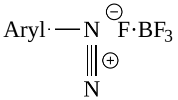
Whilst this product, because of its low solubility in aqueous salt solutions may, by way of exception, be readily isolated as the dry salt form, the majority of other diazonium compounds are more difficult to separate and readily decompose in the dry state.

Diazonium compounds in stabilized form are complex → Diazonium compounds. Thus, the extremely stable tetrachlorozincates of diazonium salts are produced with the following typical formula:



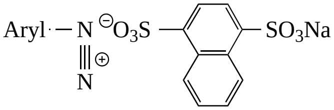
$$Aryl-\underset{\overset{|||\oplus}{N}}{N}\overset{\ominus}{Cl}\cdot ZnCl_2$$

or the very stable tetrafluoroborates can be produced with the typical formula:



$$\text{Aryl}-\overset{\ominus}{\underset{\underset{\text{N}}{|||\oplus}}{\text{N}}}\ \text{F}\cdot\text{BF}_3$$

Another approach is the introduction of naphthalene disulphonate:



Fast Colour Salts produced by the above means are so stable that no stabilizer addition to solutions prepared for practical use is necessary. They mostly contain suitable standardizing agents in the form of, e.g. acidic salts (sulphates of aluminium, sodium, magnesium and zinc, or sodium chloride) etc., so that the commercial forms often have only a 20% content of stabilized diazonium compounds. Uses: Fast Colour Salts and coupling components for substantive dyes.

Diazo reaction for wool damage (according to Pauly-Binz, Eppendahl). A well-known macroscopic and, particularly, microscopic rapid test for the detection of mechanical, bacteriological and chemical damage to wool. It is based on the red resp. orange staining produced by a soda-alkaline diazo solution with the amino acids tyrosine, tryptophan and histidine which are only encountered beneath the scale layer. Ice-cooled diazobenzene sulphonic acid (decomposes readily; must always be freshly prepared) readily stains even healthy wool quite markedly at elevated temperatures. A test solution with longer keeping properties (to be used with care) has been developed by Reumuth and Köhler. An even more trouble-free method is that of Eppendahl using Fast Yellow Salt GC which is dissolved in cold water and conc. sodium carbonate solution added until a weakly alkaline reaction is obtained; the pre-wetted wool specimen is immediately added, treated for a few minutes, then rinsed in cold water. Evaluation: undamaged wool = beige (turning red at the cut edges); damaged wool is stained red to a greater or lesser degree depending on the type of damage; alkali damage = orange.

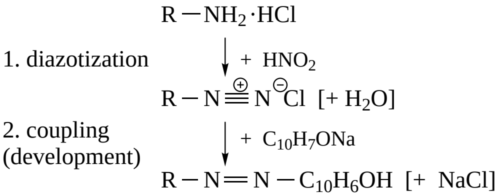
Diazo single bath chrome dyeing process, a combined dyeing process for wool-cotton mixtures with diazotizable direct and single bath chrome wool dyes. The process is complicated and very time-consuming due to the various operations; it is only employed relatively infrequently.

Diazo solution An aqueous solution of a diazonium salt (capable of forming an azo linkage).

Diazotizable dyes Includes direct dyes for cellulosic fibres containing one or several diazotizable amino groups. Limited shade gamut. Good wet colour fastness but only poor to moderate light fastness. Used for cheap washable articles, corduroy, hosiery, umbrella fabrics. Principle: → Diazotization. Analogous to diazotizable disperse dyes for acetate, triacetate, polyester; mostly deep shades.

Diazotization and development of dyeings Aftertreatment for dyeings produced with diazotizable direct dyes (development, coupling). The treatment involves the following stages after dyeing: a) rinse thoroughly; b) depending on depth of shade diazotize cold (15–20 min) with 1,5–2,5% sodium nitrite and 5–7,5% hydrochloric acid (20°Bé) or 3–5,5% sulphuric acid (6°Bé); c) rinse (if possible, continue treatment immediately, avoid long standing, protect from alkali, light and, especially, direct sunlight, avoid local drying out to prevent the formation of stains; d) develop cold over 20–30 min with 0,3–1,75% developer; e) rinse; f) soap (to improve colour fastness to washing).

During diazotization, the nitrogen atom resulting from the formation of nitrous acid (HNO_2) combines with the nitrogen atom contained in the amino groups (NH_2) of the diazo dye to form a new compound which forms a new dye with higher fastness properties on the fibre after coupling or developing with a dye developer. Principle (direct dye-hydrochloride):



$$\begin{array}{ll} & R-NH_2\cdot HCl \\ \text{1. diazotization} & \quad\downarrow +\ HNO_2 \\ & R-\overset{\oplus}{N}\equiv N\,\overset{\ominus}{Cl}\ \ [+\ H_2O] \\ \text{2. coupling (development)} & \quad\downarrow +\ C_{10}H_7ONa \\ & R-N=N-C_{10}H_6OH\ \ [+\ NaCl] \end{array}$$

Completely diazotized dyeings on the fibre. Diazotizable acetate dyes on polyamide are treated as follows after dyeing: a) rinse thoroughly; b) diazotize cold; c) short rinse; d) develop with β-oxynaphthoic acid at 70°C; e) soap. Diazotizable disperse dyes and a coupling component are applied to polyester in a single bath, followed by rinsing, diazotizing hot at 70–80°C and soaping.

Dibasic Term used to describe acids with two active acid hydrogen atoms which can be ionized and replaced by metals, e.g. sulphuric acid H_2SO_4 (sodium sulphate Na_2SO_4), phosphorous acid H_3PO_3 (sodium hydrophosphate Na_2HPO_3).

Dibutyl phthalate (DBP) (phthalic acid dibutyl ester), $C_6H_4(COOC_4H_9)_2$. Density 1,045–1,055, b.p.

205–210°C, flashpoint 160–170°C. Miscible with common organic solvents; insoluble in water. Compatible with most binders (except acetate cellulose) and resins with very good stabilty to light and resistance to frost. It is the most used plasticizer for nitrocellulose lacquers, resins, chlorinated rubber, polyvinyl chloride, etc.

Dicarboxylic acids Carboxylic acids containing two COOH groups, such as:

oxalic acid	HOOC–COOH
adipic acid	$HOOC–(CH_2)_4–COOH$
sebacic acid	$HOOC–(CH_2)_8–COOH$
terephthalic acid	$HOOC–C_6H_4–COOH$

The last mentioned is an important raw material for the manufacture of polycondensation fibres (polyester).

Dichlorobenzenes ($C_6H_4Cl_2$). The most important are:

a) Ortho-dichlorobenzene (1,2-dichlorobenzene), colourless liquid, density 1,328, b.p. 179°C; highly toxic (all contact with the skin must be avoided).

b) Para-dichlorobenzene (1,4-dichlorobenzene), white crystals, volatile (sublimes readily) with a penetrating odour, density 1,458, b.p. 173°C, insoluble in water, soluble in ether and benzene. Toxic by ingestion, irritant to eyes. Uses: formerly used as a moth repellent by spreading the crystals between the material or by dispersing the vapour in closed rooms from above (vapour is heavier than air), using approx. 100 g per 1 m^3 of enclosed space.

Dichlorodiethyl sulphide (2,2´-dichlorodiethyl sulphide, mustard gas). Can be formed e.g. as a result of contact between thio(di)ethylene glycol and hot hydrochloric acid. Colourless oily liquid with a faint garlic or mustard-like odour. It a powerful vesicant and poison, and can penetrate clothing and leather, etc., where it is absorbed by the skin causing the cells to blister and die.

Dichlorodifluoromethane (difluorodichloromethane, fluorocarbon-12). → Chlorofluorocarbons.

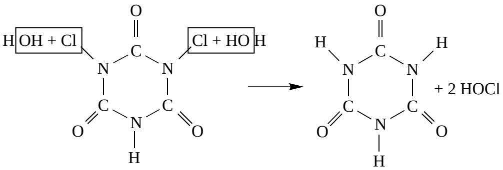
Dichlorodiphenyltrichloroethane → DDT.

Dichloroethylene (1,2-dichloroethylene, dichloroethene, acetylene dichloride, dichloracetylene). $C_2H_2Cl_2$ or CHCl=CHCl. Colourless, low-boiling liquid, similar to chloroform, low flammability (flashpoint +11°C). Slightly soluble in water up to 0,1%. Miscible with practically all organic solvents. Does not corrode metals even in water under the influence of heat). It must not be mixed with solutions diluted with alcohol or water due to the formation of acetylene chlorides which are subject to spontaneous combustion. Dichloroethylene is an excellent solvent and spotting agent (substitute for chloroform and ether). It is a solvent for fats, oils, varnish, waxes, resins, rubber, lacquers, oil colours, tar, etc. Often used in mixtures with 25% carbon tetrachloride. Also used in combinations as a non-toxic respiratory poison in moth repellents. Symmetric dichloroethylene referred to here must not be confused with asymmetric dichloroethylene ($CH_2=CCl_2$), which is used in the production of polymerization products.

Dichlorohydrin (1,3-dichloro-2-propanol). → Chlorohydrins are toxic compounds. Formerly used as a resin finishing agent.

Dichloroisocyanurates → Dichloroisocyanuric acid salts.

Dichloroisocyanuric acid (→ Chloroisocyanuric acids). DCCA solutions and DCCA processes are used as antifelting finishes for wool. Besides dichloroisocyanuric acid, the salts (dichloroisocyanurates) are also used. The special importance of products based on these chemicals is based on the formation of hypochlorous acid (HOCl) through hydrolytic breakdown:



Aqueous solutions of dichloroisocyanuric acid lie within the range of pH 6–7 (stable for several days).

Dichloroisocyanuric acid salts The sodium and potassium salts of → Dichloroisocyanuric acid have an intense bleaching action on secondary acetate, triacetate, cotton and polyester between pH 3–11. To some extent, a simultaneous crosslinking action has been established in the case of cotton.

Dichloromethane (methylene chloride, methylene dichloride), CH_2Cl_2. Colourless liquid, slightly soluble in water (1:40), readily soluble in alcohol and ether. Nonflammable. Vapours are narcotic. Dichloromethane is a good solvent for fats, oils, resins, rubber, chlorinated rubber, cellulose acetate, cellulose ethers, polyvinyl chloride, polystyrenes. It is used in the manufacture of lacquers and adhesives as well as the production of cellulose triacetate fibres. It is also used as a spotting agent and for solvent extraction in the determination of residual fat content, etc.

Dichlorotetrafluorethane (fluorocarbon 114) → Chlorofluorocarbons.

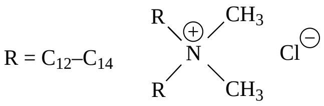
Dichroism, the characteristic of birefringent crystals to appear as different colours when viewed from two different directions. Thus for example the absorption maximum of a dye may extend on the one hand to infrared and on the other to ultraviolet. The dichroism of applied dyestuffs indicates the orientation of the absorption of the longitudinal axis of the dye molecules parallel to the fibre axis, as is the case (according to Morton) with direct dyes on wool and disperse dyes on polyamide, but not on acetate, as longitudinal orientation of disperse dye absorption is not possible here.

Conversely (according to Evans) dichroism showing the orientation of the fibre structure again occurs in the case of direct dyes on deacetylized acetate. As demonstrated by Morey and Morton, the dichroitic behaviour is more prevalent in disperse dyes of elongated, symmetrical shape, although the dyeing conditions also have an effect (fibre swelling, degree of dispersion of dyestuff, dye/fibre bonding, liquor composition etc.). Under certain conditions, dye molecules are primarily bonded to micelle surfaces, and secondarily in the amorphous region. Generally, in the above cases, a stronger dichroitic effect is obtained from dyeing with an aqueous alcohol solution than from dyeing with an aqueous dyebath.

Dichromatic Having, or consisting of, only two colours.

Dichromatism → Colour blindness.

Dicoconutalkyldimethylammonium chloride,



Reviving agent, which, because of its short-chain dicoconutalkyl residue fatty substituent, is used to ease manufacture.

Dicyandiamide is formed by dimerization from cyanamide $N{\equiv}C{-}NH_2$ and is used in the manufacture of → Melamine. Colourless, easily water-soluble, melting point 209°C, stable up to approx. 80°C in neutral and acidic solution. Stable to a certain extent in neutral and alkaline solution. Strong alkalis cause transformation to urea (is then hydrolysed). Possesses hydrotropic qualities (removes e.g. cloudiness or flocculent precipitation in aqueous solutions of surface-active substances). Dicyandiamide-formaldehyde and urea-dicyandiamide-formaldehyde synthetic resin (precondensate) are used as crease-resist finishes. Dicyandiamide is used e.g. under thermosol conditions as a substitute for urea in the fixation of reactive dyes. It has greater thermal stability in comparison with urea, along with other process technology advantages. Its solubility in cold water is low (22 g/l), but good in hot water. At higher concentrations crystallization is impeded by the dye, so that the pad liquors may be augmented up to 35 g/l. In the presence of dicyandiamide certain reactive dyes react with wool without the need for alkali; the slightly alkaline character of these compounds has the effect of promoting reaction, which has led to the development of the thermosol/thermofixation dyeing process for the continuous dyeing of polyester/cotton blends (AT process).

Dielectric Electrical non-conductor (insulator) which receives an "induced dipole moment" by displacement polarization when subjected to friction, pressure or tension or when it is in the vicinity of dipole molecules. Examples of dielectrics are: amber, ebonite, quartz and electrostatically charged textiles. A well-known "dielectric crystal" is piezoelectric quartz which when subjected to pressure or tensile force, responds by changing polarity, i.e. it produces piezoelectricity. It is used conversely for producing ultrasound (electrostriction). Non-polar liquids may also be polarised but, in this case, polarizability decreases with increasing temperature, as the thermal molecular movement makes dipole orientation more difficult. The dielectric constant, one of a number of material constants for the dielectric, also decreases; its value is always greater than 1 (1 = vacuum, the absolute non-conductor) and, in the case of most solid materials, lies between 2 and 5 or at most 25. For ceramic materials, this value can be as much as 100.

Dielectric constant (D) → Dielectric.

Dielectric drying → High frequency drying.

Dielectric heating In drying and heating processes, the thermal energy required is usually applied to the surface of the material from where it reaches the interior through heat conduction. For materials having a low thermal conductivity in particular, this results in long drying times and non-uniform temperature and moisture distributions. In the case of dielectric drying or heating with radio waves (RF-drying and heating), the material represents part of a "lossy" capacitor. Thermal energy is generated directly in the interior of the material by the displacement of electrical charges in an alternating electrical field. If a body composed of electrically non-conducting, or poorly conducting, material is exposed to the action of an alternating electrical field, then that body will be heated up (Fig. 1). The material occupying the space between the electrodes (e.g. the plates of a capacitor) is described as the dielectric. The electrical power absorbed by the treated material generates heat within that material.

The power P which is converted into heat in the dielectric of a capacitor for RF treatment is given by:

$$P = 2\,\pi\,F\,\varepsilon_0\varepsilon_r\,\tan\delta\,E^2\,\Lambda\,h\ [W]$$

F = operating frequency [Hz]
ε_0 = electrical field constant
= $8.85 \cdot 10^{-12}$ [As/Vm],
ε_r = relative dielectric constant,
$\tan\delta$ = loss factor,
E = electrical field strength [V/m]

$$= \frac{\text{voltage}}{\text{plate separation distance}}$$

Λ = surface area of capacitor plate [m^2],
h = capacitor plate gap [m].

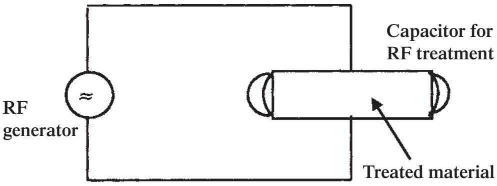


Fig. 1: Principle of dielectric heating.

By introducing a material with a sufficiently high loss factor $\varepsilon_r \cdot \tan\delta$ into an alternating electrical field with a high frequency and high field strength, it will be heated rapidly. The required field strengths are obtained by applying high voltages to the electrodes. The power achieved is limited by the permissible field strength E. As long as the system works without an air gap and no locally limited field concentrations arise, this is dependent on the electrical breakdown strength of the material. In practice, however, the permissible field strength is lower as a rule, due to the occurrence of field concentrations, entrapment of air in the material, and the process-dependent necessity for an air gap between the electrodes and the material. Moreover, high energy densities are not always desirable, since they can damage the material. In virtually all drying and heating investigations, it has been found that, as a rule, the material being treated sets the upper limit for the energy density.

The heat is generated in the body of the material itself. If the material is homogeneous, a uniform generation of heat takes place, so that the temperature is the same throughout the material. Since direct contact with the electrodes is not necessary, the possibility exists for the heating to be carried out in special atmospheres. As a rule, the required frequencies are so high that electronic generators (vacuum tube oscillators) must be used. The frequency range lies between 3–50 MHz. Since dielectric heating equipment must not create any stray interference radiation, appropriate shielding precautions must be adopted. The standard frequencies are:

13.560 MHz ± 0.06%
27.120 MHz ± 0.60%
40.680 MHz ± 0.05%

The most commonly used frequency in high-frequency ovens is 27.120 MHz, which also has the widest tolerance limits.

In the microwave oven (Fig. 2), microwaves are radiated within the metallic cladding of the oven interior and a more or less uniform microwave field is created by reflection from the walls of the oven. Microwave generators (magnetrons) are usually of low power (a few kW), which is why provision must be made for a large number of magnetrons to achieve a high power output. A high-frequency (RF) installation consists essentially of an electrode system and a generator. By this means, generator power outputs of a few hundred kilowatts can be realized. The price : performance ratio of installations with high power outputs (from approx. 60 kW) is therefore much more favourable. With suitable electrode design, the electric field can be controlled in a way that is most appropriate for the actual application. The lower frequency, compared to microwaves, permits a high degree of penetration so that even those materials having a large volume can be uniformly irradiated with energy. The efficiency for part loads is better with RF installations than microwave equipment since the transfer of power is “demand-oriented” in the former case, i.e. the power to be transmitted by the electrode is determined by the material itself. There is also a considerable difference in the shielding precautions required between the two systems. Due to the large wavelength of the high frequency used, relatively short decoupling zones are sufficient for large free incoming and outgoing cross-sections. The execution of comparable free cross-sections is not possible for microwave installations.

In HF (RF) installations, the electric power from the mains supply is conducted to a high voltage transform-

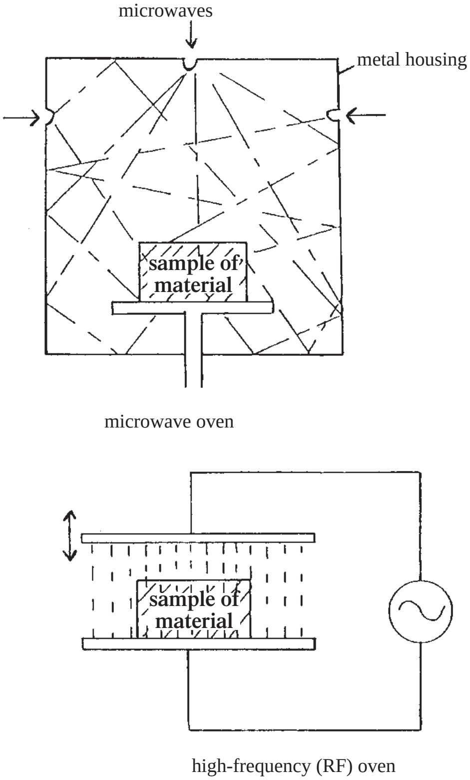


Fig. 2: Principle of microwave and high-frequency technology (source: Böhnke).

er via an electrical regulator (thyristor regulator). The task of the regulator is to limit the grid current of the transmitter tube under no load conditions, to start up the high voltage transformer via a “ramp” and ensure a quick disconnection in the event of an overload or high voltage flashovers. The high voltage transformer converts the mains voltage to a voltage of approx. 10 kV. This “3-phase high voltage” is rectified by means of a 3-way rectifier after which the voltage is approx. 14 kV.

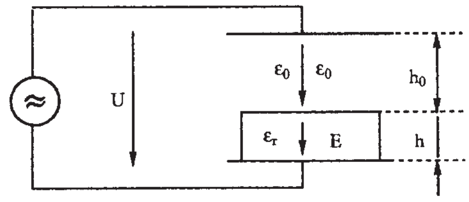
By means of an oscillator and downstream oscillation circuits and HF filters, the DC voltage is converted into a high-frequency AC voltage. This HF voltage is then supplied to an electrode system. The power transferred to the material can be measured directly in the intermediate DC circuit since no idle power is transferred there. Approx. 10% no-load power as well as the heat losses of the generator must also be taken into account here.

In principle, electrodes of various designs are possible. When deciding on the configuration of an electrode layout, attention has to be given to the following points:

- it must be capable of achieving the required or permissible energy density,
- the energy density should be distributed as uniformly as possible in the material,
- it must be capable of transferring the full power of the HF generator used,
- some possibility to adjust or regulate the power output should be provided,
- local field strength concentrations as well as the associated risks of overheating and flashover must be prevented as far as possible.

Among the many possible systems, the 4 most commonly used in practice have been selected here:

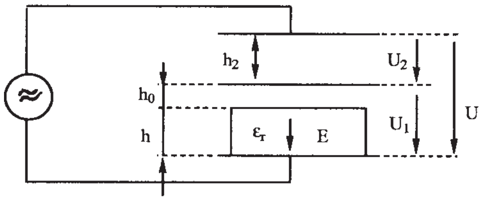
1. Parallel-plate electrodes:
   a) Direct coupling, without intermediate electrode (Fig. 3).
   When drying individual objects which are narrower than the width of the electrode, energy density concentrations occur, which results in non-uniform heating and rates of drying. Layer thickness up to approx. 500 mm.



$$E = \frac{U}{h + \varepsilon_r h_0} = \frac{\varepsilon_0}{\varepsilon_r}$$

Fig. 3: Direct coupling without intermediate electrode with parallel plate electrodes in an RF drier (source: Böhnke).

   b) Capacitive coupling into an intermediate electrode (Fig. 4).



$$E = \frac{U_1}{h + \varepsilon_r h_0} \qquad U_1 = \frac{U}{\frac{h_2}{h \cdot h_0} \cdot \varepsilon_r + 1}$$

Fig. 4: Capacitive coupling with parallel plate electrodes in an RF drier (source: Böhnke)

   This involves a series connection of 2 capacities. Consequently, no voltage division takes place. E_1 is the dielectric index of the air gap h_0 + material h combined. The advantage of this arrangement is that h_0 can be made very small, so that the field distribution in the material is very uniform. Layer thicknesses up to approx. 200 mm.

2. Stray field electrode (Fig. 5).

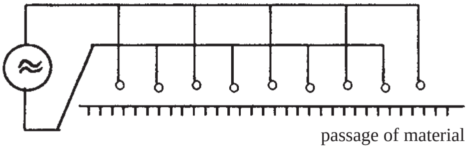


Fig. 5: Stray field electrodes in an RF drier (source: Böhnke).

The power which is converted into heat is dependent almost exclusively on the field components in the direction of movement. Its value depends on the distance x_W. Layer thickness ≤ 1 mm. Plot: $K = F(x_W)$. x_W = distance between material and electrodes.

3. Z-Z field (Fig. 6).

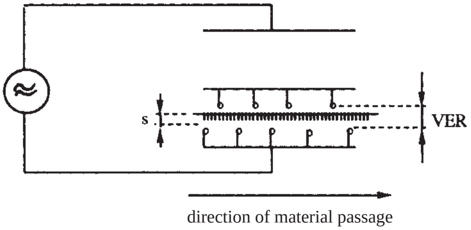


Fig. 6: Z-Z field electrodes in an RF drier (source: Böhnke).

Capacitive coupling into an intermediate electrode; the field is generated between the upper and lower rods. Layer thickness up to approx. 100 mm. Plot: the power is dependent on the distance from the vertical rod. u = a constant (source: Böhnke).

Dienes (diolefins). Unsaturated aliphatic hydrocarbons (olefins) with 2 conjugated double bonds (diene) of the → Butadiene and → Isoprene type. The position of the double bond in the molecule is designated by the respective number of the C atom at which the double bond begins, e.g.:

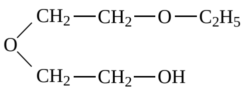
1 2 3 4
$CH_2{=}CH{-}CH{=}CH_2$ 1,3-butadiene or butadiene (1,3)

Compounds of this type have a particularly high reactivity and are readily polymerized (polyenes) to give technically important end-products such as, e.g. synthetic rubbers.

Diethylene glycol (DEG, diglycol, dihydroxydiethyl ether), $CH_2OHCH_2OCH_2CH_2OH$. Density 1,121, b.p. 245°C. Colourless, practically odourless, viscous liquid; extremely hygroscopic. Soluble in water, alcohol, acetone, chloroform. Solvent for oils, resins, nitrocellulose, etc. Uses: substitute for glycerol in finishes, stabilizer for emulsions, auxiliary in discharges on acetate fabrics, solvent for vat leuco ester dyes, improves the homogeneity of Marseilles soap, increases the solubility of benzine soaps in special boiling point spirits, etc.

Diethylene glycol esters These are encountered especially as → Synthetic waxes under various trade names.

Diethylene glycol ethers The most important are diethylene glycol diethyl ether (diethyl “Carbitol”) and diethylene glycol dibutyl ether (dibutyl “Carbitol”):



They are excellent solvents for cationic dyes as well as vat leuco ester dyes; pasting auxiliaries for vat dyes, print pastes, etc. Good solvents for fats, oils, waxes, synthetic resins, etc., b.p. 180–200°C.

Diethylenetriaminepentaacetic acid (DTPA), $(HOOC{-}CH_2)_2N{-}C_2H_4{-}N(CH_2{-}COOH){-}C_2H_4{-}N(CH_2{-}COOH)_2$. White crystalline solid. The sodium salt is readily soluble in water. Chelating agent used for complexing iron, alkaline earth metals, etc. in water softening. Additive in washing agents and detergents.

Differential dyeing Differential dyeing technology for synthetic fibre mixtures composed of normal and/or chemically modified polyacrylonitrile, polyester or polyamide fibres. Single bath piece dyeing is employed to produce solid shades, similar shades but in different depths, as well as multicolour and contrast effects. Advantages include the avoidance of stockholding of dyed yarn, easier adaptation to changes in fashion and more rapid delivery of finished orders. Applications: predominantly in the carpet sector (tufted carpets), and also for woven and knitted fabrics (shirts, blouses, hosiery, beachwear, nightwear, sweaters).

Differential dyeing fibres in carpet printing In carpet printing the possibility exists to produce multicolour effects (analogous to dyeing) by employing polyamide fibres with different dye affinities. As a rule, Low and Deep dyeing fibres are used for tone-in-tone effects or Deep dyeing and Basic types for contrast effects. Differential effects are, however, more difficult to control in printing since the dyes are applied from a thickened paste in this case. For this reason, fibres with only slight differences in amino end-groups give very little colour differentiation or none at all, and dyes must be carefully selected with regard to their resist properties. In addition, a precipitation inhibitor must be used in order to avoid the possibility of precipitation when acid and cationic dyes are present in the same print paste.

Differential dyeing polyamide fibres The following types are available:

a) Dyeable with anionic dyes:	
R – Regular type	normal dyeing
D – Deep type	dyes more deeply than regular polyamide
L – Low type	very low dye uptake
b) Dyeable with cationic dyes:	
B – Basic type	dyeable with cationic (basic) dyes.

Polyamide types with different affinities for anionic dyes are used for the production of tone-in-tone dyeings or (including the Basic type) for the production of multicolour effects in single bath dyeing. The technology is based on the different number of amino end-groups in fibre types dyeable with acid dyes, whilst in fibre types dyeable with cationic dyes the amino end-groups are saturated and no longer capable of protonization. By combining different fibre types and dyestuffs, tone-in-tone and contrast effects may be obtained. Fields of application: floorcoverings, textile fabrics.

Differential reading, a display which indicates by how much the actual value differs from the specified set-point value.

Differential Thermal Analysis (DTA), is used for the analysis of:

1. Glass-transition temperature of polymers.
2. Burning processes of fibres.
3. Synthetic fibres which have been pre-treated in various different ways.

Differential Thermal Analysis

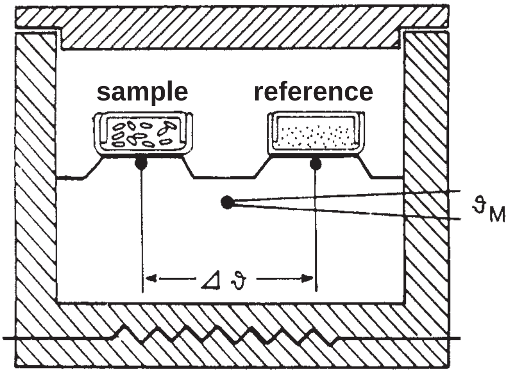


Fig. 1: DTA measurement principle (source: Berndt).

I. Principle (Fig. 1): Two measuring chambers, each provided with a thermal element, are placed in a metal furnace (approx. 1 cm x 1 cm x 1 cm). Measurement Chamber I contains an inert reference substance such as pre-heat-treated (burnt-out) sand. Measurement Chamber II contains the film obtained from a dispersion (approx. 1 g) fused compactly into the measurement chamber by heating it for a short time to determine the approximate glass-transition temperature for the polymer. Both chambers are cooled externally using liquid nitrogen to a temperature at least 50°C below the temperature at which glass transition is expected. When the cooling process has been completed, heat is applied steadily (3–5°C/min. – time required: approx. 1 hour). Plots of the temperature difference between the two measurement chambers and the temperature inside Measurement Chamber II are recorded. Two curves are produced from which the temperature of the glass-transition point is determined (Fig. 2). When the temperature curves have been determined for the two measurement cells, in the ideal case, these will appear as two typical plots. The temperature rise of the inert material will be constant throughout the measurement period. The temperature curve for the polymer, on the other hand, will reach a plateau, giving the temperature at which the polymer heat demand is greater because of an increase in specific heat caused by the greater mobility of the molecules. The increase in temperature is delayed. The temperature at which the heat demand is greater is the glass-transition temperature (glass-transition point) (Fig. 3).

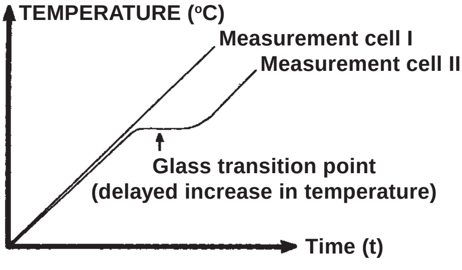


Fig. 2: DTA: Time/Temperature curve.

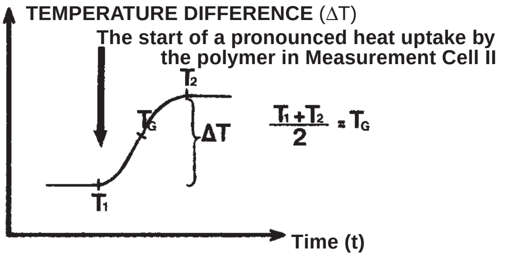


Fig. 3: DTA: Determination of glass temperature.

From T_1, the temperature difference between the two measurement cells increases until T_2, due to the increased heat demand caused by the polymer becoming more mobile. From this, we have:

$$\frac{T_1 + T_2}{2} = T_G$$

Temperature differences between T_1 and T_2 of 8–10°C suggest a uniform homopolymer. Temperature differences > 10°C indicate increased chemical impurities or copolymers.

Fig. 4 shows the curves of different pre-treated polymer-fibre materials. The arrows on the endothermic

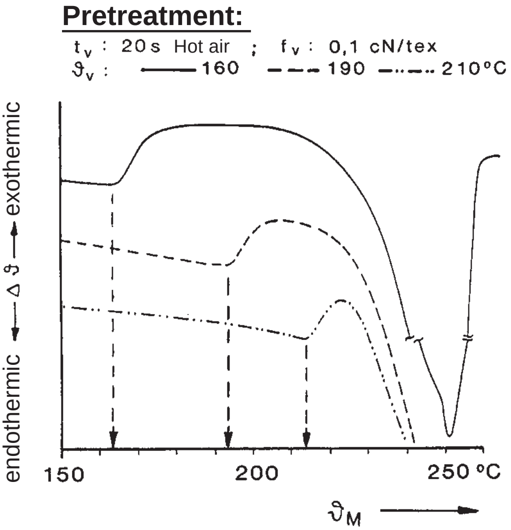


Fig. 4: DTA diagram of a heat-set polyester fibre (Arrows: effective temperatures of pre-treatment) source: Berndt.

shoulders of the curves indicate the temperature at which the partial fusion of the crystallites, formed during fixing (or during cooling) in the non-crystalline areas, takes place. This is defined as the effective temperature of thermal pre-treatment. The main fusion peak at approx. 255°C represents the endothermic fusion of the crystalline areas. Crystallisation of polyesters in the non-crystalline areas (and therefore the effective temperature) increases linearly with the pre-treatment temperature (around 7 K per time decade with increasing periods of delay and in swelling media between 35 K and 60 K). The effective temperature decreases with increasing heat-setting tension. The crystallite-size distribution increases with increased cooling rate.

II. Volatile thermal breakdown products are produced during the different phases of decomposition throughout the burning process of fibres. The burning process can be analysed using DTA to reveal the following phases: a) pyrolysis, b) carbonisation and c) combustion. Pyrolysis precedes ignition and ignition precedes the thermal combustion process. Pyrolysis refers to the thermal decomposition or dry distillation of a substance. In inert atmospheres, this type of decomposition is predominantly endothermic. Because of the exclusion of oxidation reactions, it is possible to obtain reproducible, discrete determinations of the temperature and time-dependent de-polymerisation behaviour of high polymers, thus yielding important information about the course of pyrolysis in air. Distinct exothermic decomposition reactions which take place during pyrolysis may also occur in atmospheres such as those which contain oxygen. Temperature and time-dependent data in relation to the type and quantity of gases which are produced are particularly important when examining the combustion processes. These have a significant effect on ignition and combustion behaviour and therefore on the possible toxic effects.

As far as the course of pyrolysis is concerned, washed cotton can be regarded as pure cellulose. In inert atmospheres, the endothermic maxima of depolymerization are found at 125°C and 375°C (Fig. 5). In the case of cotton, within a temperature range of about 280°C–360°C and under conditions of air exclusion, the easily combustible decomposition products, hydrogen, methanol, methane, ethanol, ethylene, furfural, low molecular weight organic acids , low molecular weight aldehydes and ketones as well as phenolic compounds and levoglucosan are produced in addition to carbon monoxide, carbon dioxide and water. In oxygen atmospheres, the depolymerization of cotton starts at around 200°C. Exothermic decomposition reactions clearly start at 275°C and rapid carbonization takes place above 350°C. At temperatures a little above the carbonization temperature, the cotton can easily ignite. The exothermic course of the depolymerization of polyacrylonitrile suggests a smaller heat capacity in comparison to other thermoplastics. This, together with the relatively high heat of combustion of polyacrylonitrile (approx. 30 kJ/g) may possibly explain why combustion is comparatively easy.

III. In transfer printing, DTA provides heat-effect prognoses for dispersed dyes, i.e. it clarifies the relationship between the behaviour of the dye at increased temperatures and the transfer properties, thus providing information for the selection of dyes for transfer printing.

Diffusion Molecular movement of a substance due to its natural intrinsic mobility, i.e. without the participation of external forces. A substance in solution will migrate at constant temperature from zones of higher to lower concentration until a concentration equilibrium is established within the entire system. Diffusion is thus a general characteristic of the dilution tendency of a solution which is accelerated by elevation of temperature.

Diffusion coefficient A proportionality factor which gives the number of moles of a dissolved substance diffusing through a cross-sectional area of 1 cm^2 per unit time for a given temperature and solvent when the concentration gradient is –1 (Fig.):

$$D = \frac{\text{Depth of penetration}^2\ (\text{cm}^2)}{\text{Time (s)}}$$

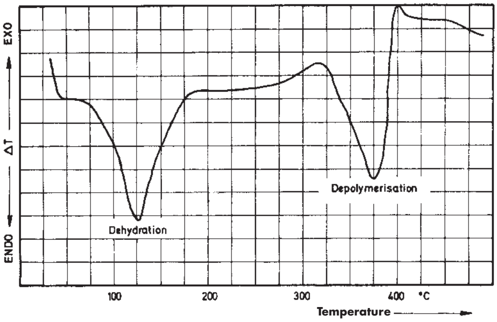


Fig. 5: Thermogram of the pyrolysis of cotton in an inert atmosphere (DTA).

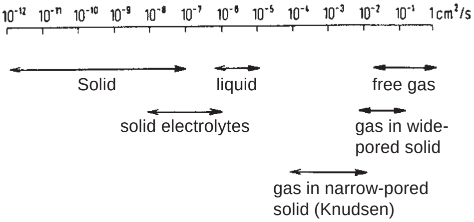


Fig.: Orders of magnitude of real diffusion coefficients (D_{real}) (source: Rys).

In a concentrated solution, the diffusion coefficient is dependent on the concentration. Basically, it is much smaller in solids than it is in solutions and gases and in solids it is more strongly dependent on temperature. From an exact scientific point of view, it is only constant where dilution is significant. Depending on the case, the differences in the packing density of the fibre molecules presupposes an average value composed of the component values over the whole fibre cross section. In the case of acid dyes, for example, the diffusion coefficient is much smaller than it is for dispersion dyes depending on the constitution. Generally speaking, the diffusion coefficient decreases more or less strongly as the number of atoms in the dye molecule increases. The value decreases according to the following sequence: dispersion dyes, acid levelling dyes, milling dyes and metal complex dyes. With regard to the receptivity of dyes against fibre-molecule packing densities, the relationship is exactly the reverse. The diffusion coefficient is well suited to characterising the properties of dyes by number values for assessing the dyeing behaviour of the dyes, because these values characterise the diffusion of the dye in the fibres. In combination dyeing using dispersion dyes, differences in the dye penetration come about when the ratio of diffusion coefficients for the dyes used exceeds 1 : 1.3. The result is unevenness in tone or faded dyeing. Similar diffusion coefficients for the component dyes, on the other hand, guarantee even extraction of all dyes from the bath. After the fibre surface has been fully covered, further dye pick-up takes place in relation to the coefficients of the components. Before this, it takes place in relation to the affinities. When the fibre surface is covered with dye, further dye pick-up only takes place in proportion to the way in which dye diffuses from the outer areas into the interior of the fibre. This happens more quickly for dyes with large diffusion coefficients than it does for those with small diffusion coefficients. Where dye affinity is low, dye penetration is good for dyes with large diffusion coefficients and poor for dyes with small diffusion coefficients. High-affinity dyes with large diffusion coefficients penetrate evenly and well and those with small diffusion coefficients penetrate unevenly and badly. The ability of the dye to even out differences in concentration inside the fibre, therefore, depends on the diffusion coefficient of the dye and this property depends on the dye. (→ Levelling capacity of dyes).

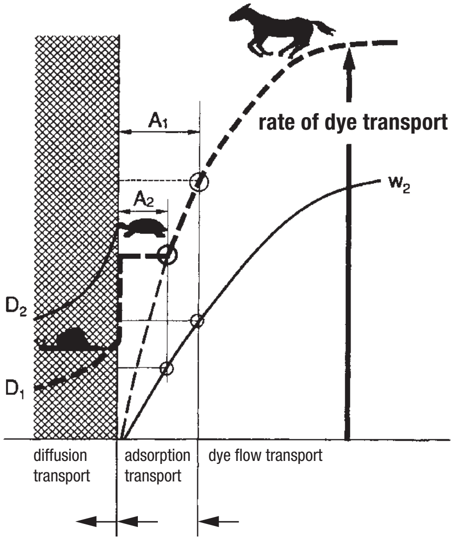
During washing, dye is first released from the surface. More dye follows in relation to the way in which the dye diffuses from the interior of the fibre to the fibre surface. The loss of dye from the surface during washing increases with the size of the diffusion coefficient. Small diffusion coefficients are required for good wash fastness. In general, the diffusion coefficient increases with temperature.

Diffusion constants Various laboratory methods are available for determining the rate of diffusion of dyes in textiles of a certain configuration during dyeing. Two procedures have been found to be worthwhile:

1. 130 circular fabric platforms are placed in a cylinder and subjected to flow under defined conditions to simulate a beam-dyeing section of approximately 8000 m of cloth. The coloration of the 1st and 130th platform is compared colorimetrically.
2. A defined, yarn cross-wound bobbin is dyed for twenty minutes at setting temperature and the maximum and minimum dye concentrations in the winding compared to obtain the Ku_{20} value (contributed by Hoechst).

Diffusion mechanisms in dyeing Dyeing processes are very dynamic as they involve the transport of diverse products from the dyeing medium into the fibres. Because dyeing processes seldom reach a genuine state of thermodynamic equilibrium, analysis of the "end product" usually only gives a transient picture of the distribution of dye between the medium and the fibre after a certain dyeing time, long before the state of equilibrium would be reached.

Three transport zones which depend on three different transport carriers and transport effects have been defined (Fig. 1):



dye flow transport primarily determined by the dyeing **machine** resp. the **liquor circulation pump**,

adsorption transport primarily determined by the chemistry of the **dye and auxiliaries**

diffusion transport primarily determined by the chemistry of the **substrate** and the **dye**.

Fig. 1: Schematic presentation of the dye transport mechanism and the spheres of influence in a random fibre mass subjected to through flow (source: Kretschmer, simplified for purpose of illustration).

1. The zone of transport due to flow, which is mainly determined by the machine or flow pump.
2. The zone of transport due to absorption, which is mainly dependent on the chemistry of the dye and the ancillary agents on the liquid side.
3. The zone of transport due to diffusion, which is mainly dependent on the chemistry of the dye and the substrate.

The combined effects of the three transport zones in the random fibre mass is expressed quantitatively in Fig. 1, starting with a simple example dye which is easy to understand. The insight gained from the dye example, which involves the transport of dye to the surface of the fibre mass, also applies, of course, to the transport of substances away from the surface of the random fibre mass during other processes such as washing.

If the dye is delivered at a sufficiently high rate through the laminar boundary layer on the surface of the fibre, then it will get into the fibre by a process of absorption and slow diffusion. As the dyeing time progresses, it is only when the flow towards the fibre is strong that deterioration of flow in the immediate vicinity of the fibre surface will be avoided. The knowledge that a dye accesses the fibre via a transition interface is the key to understanding the dye interactions in the area of dye kinetics. That is to say, if a dye exists on its own, then the rate of diffusion of the dye into the fibre interior is controlled by its concentration at the fibre surface. If the dye is present in combination with another, then not all of the surface is available to this dye for bonding. The dye kinetics and resulting concentration profile are determined by the rates of the following component processes: diffusion, adsorption and immobilisation. In the case of reactive dyes, for example, the process of immobilisation is a chemical reaction. Adsorption of the dye molecules on the fibre surface is characterised by a decrease in the number of degrees of freedom in thermal molecular movement. Within the flow, a dye molecule has at least six degrees of freedom. In the adsorbed state, on the other hand, only slight translation movements are possible. Rotation appears to be inconceivable. It is very probable that even the number of degrees of freedom associated with oscillation is reduced.

There are many reports on the relationship between the fibre titre and dyeability. When considering the effect of the titre, we start from the external geometry of the fibre, i.e. the size of the surface through which the dye penetrates to the fibre interior. The specific surface of the fibre appears in the simplified Crank solution to Fick's second law of diffusion:

$$\frac{(c_F)_t}{(c_F)_\infty} = 2\frac{F}{V}\sqrt{\frac{Dt}{\pi}} = \frac{4}{r}\sqrt{\frac{Dt}{\pi}}$$

Strictly speaking, this only applies to fibres with a circular cross section and fully homogeneous structure. Porous fibres cannot be clearly described by their external dimensions or radii. F and V are not exactly accessible. However, it is possible to replace the specific surface in relation to volume F/V by the value F' which relates to mass:

$$F' = \frac{F}{m} = \frac{F}{V \cdot \rho}$$

thus yielding the following equation:

$$\frac{(c_F)_t}{(c_F)_\infty} = 2\ F'\rho\sqrt{\frac{Dt}{\pi}}$$

The mass-specific surface area F' can be calculated from the fibre titre in tex and the cross-sectional area in cm^2 taken from the microscope picture:

$$F' = \frac{20\sqrt{Q}\cdot\pi}{\text{tex}\cdot f}$$

$(c_F)_t$ = Dye concentration in the fibres at time t
$(c_F)_\infty$ = Dye concentration in the fibres after equilibrium has been established
F = Area in cm^2
F' = Mass-specific surface area in cm^2/g
V = Volume in cm^3
D = Average apparent diffusion coefficient in cm^2/min
ρ = Fibre density in g/cm^3
t = Dyeing time in minutes
r = Fibre radius in cm
Q = Cross-sectional area in microscopic picture in cm^2
f = Enlargement ratio

This equation gives a linear relationship between the mass-specific surface area of the fibre and the dye pick-up. The dyeing speed, therefore, increases with increasing fibre fineness. If ring dyeing is not the aim, the even distribution of the dye over the fibre cross section among other things may be regarded as a measurement standard for successful dyeing. After adsorption onto the fibre surface, the dye must migrate into the interior through the fibre mass or through existing channels and distribute itself there in the optimum manner. At the same time, the diffusion medium has a vital influence on the rate of diffusion. This becomes evident in the variable order of magnitude of the true diffusion coefficient D_0. The diffusion coefficient is significantly greater in the gas phase than in liquid or solid phases. The main driving force behind diffusion is the difference in concentrations. The diffusion coefficient is also dependent on temperature. If the concentration in a stationary system remains constant, the number of dye molecules diffusing through a membrane (Fig. 2) is constant and Fick's first law of diffusion applies:

$$\frac{\Delta n}{\Delta t} = - D \cdot F \frac{c_1 - c_2}{\Delta x}$$

The minus sign on the right of the equation indicates that the particles flow from the high concentration to the low concentration. If the (thin) layer is replaced by a uniform porous plate of greater thickness, there will be a concentration distribution in the stationary case.

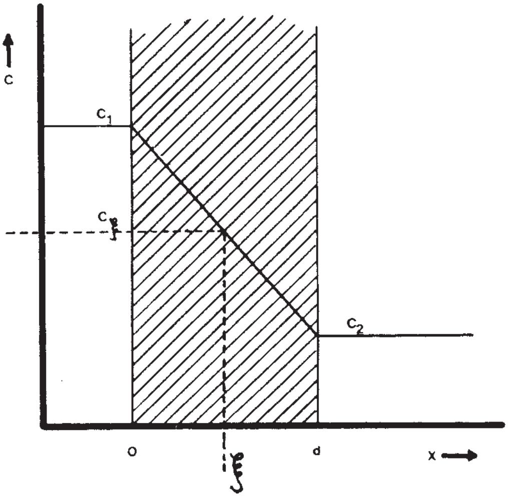


Fig. 2: Diffusion through a porous plate: the concentration c_x at at x is $c_\xi = c_1 - \frac{\xi}{d} \cdot (c_1 - c_2)$.

So-called "non-stationary diffusion" is what is found in practice and characterises the variation in flow according to the periodic assembling of diffusing dye molecules at a particular location on the fibre. In this case, Fick's second law of diffusion applies to the porous plate just described. The left side of the equation describes the change in concentration at any one location in relation to time:

$$\frac{\partial c}{\partial t} = D \frac{\partial^2 c}{\partial x^2}$$

If interactions are taking place between the diffusing dye molecules and the medium, then the following equation applies:

$$D_{exp} = D_0 \cdot e^{(-E_a/RT)}$$

D_{exp} = experimental diffusion coefficient
D_0 = true diffusion coefficient

E_a is a kind of activation energy and remains constant within a range of temperatures for the same diffusion mechanism. In the case of the so-called Free-Volume or Mobile-Segment model, the diffusion coefficient is quite different to that for the so-called Pore model (Fig. 3).

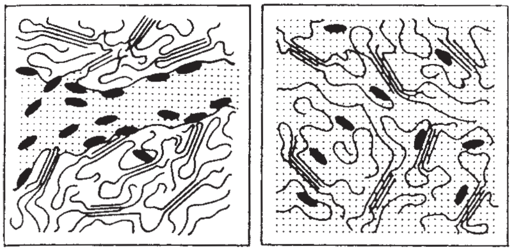


Fig. 3: A comparison between the Pore model (left) and the Free-Volume model (right) (source Hori and Meyer et al.).

It is mainly the rate of diffusion and not, as is often maintained, the affinity of a dye which is the decisive factor in regard to the rate of leaching. The affinity is only one of many parameters which influence the rate of diffusion. The phase during which the dye can diffuse freely (until it is stopped by reacting with the fibre or by the textile drying out), and the rate of diffusion have a significant effect on the levelness of dyeing, on the efficiency of the fixation phase and on fastness to certain agencies.

If cellulose fibres are dyed using reactive dyes, then in this particular case and under certain conditions, chemical reactions take place between the end groups or side chains and the reactive dye. Providing the reaction conditions are favourable for reactive dyeing, the affinity of the non-reactive reactive dye (in weakly acid media) is manifestly increased by the addition of sodium carbonate. In addition to the diffusion and setting processes, the most important processes which must be taken into consideration here are the competition reactions (substrate – water), competition adsorptions (reactive and hydrolysed dye), changes in the charge density of the substrate (which, among other things, is determined by the setting process) and the effect of established association and tautomeric equilibria on the setting rate and the selectivity of competition reactions (source: Gerber). →: Kinetics in heterogeneous systems; Kinetics in homogeneous systems; Weisz pore model.

Difluorochloropyrimidine (bis-FCP). Water soluble bifunctional crosslinking agent containing sulphonic acid groups based on difluoropyrimidine. Used on wool.

Digest (Lat.: *digerere* = to divide, separate). Process of digestion, e.g. the action of an enzymatic solution on a solid material (protein-stained textile) in a vessel (digester) at elevated temperature.

Digester Water, oil or salt bath for heating suspended containers (slub dye beakers) for laboratory-scale experiments.

Digital (Lat.: digitus = finger). Using figures or numbers; e.g. data and information represented by numbers.

Digital control A control system in which the signals along the control loop are in → Digital form and the control deviations are also processed digitally. Direct digital control = DDC.

Digital measurement technology Electrical measurement technology in which instrument pointer movements are translated into numbers. Control technology in which control values are resolved by individual steps.

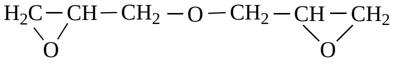
Digital output unit Functional unit of an input and output system of a process computer. It fulfils the task of transmitting control commands in digitally coded form or binary signals to a technical process.

Digital printing → Ink-jet-printing.

Digital readout Measurement values or signals are converted directly into numbers and transmitted.

Digitizer Electronic pen for design processing in electronic equipment for the production of colour separations.

Diglycidyl ether (DGE, di(2,3-epoxypropyl) ether). Colourless liquid with a strong, irritating odour. Used *inter alia* as a resin finishing agent (→ Epoxides).



Diglycol → Diethylene glycol.

Dihydroxydiethylsulphone → Bis(β-hydroxyethyl) sulphone.

Diisocyanates Organic compounds with 2 isocyanic acid groups $(–N=C=O)_2$. They have a wide textile importance as reaction products of diisocyanates with, e.g. glycols for the production of polyurethanes used in fibre manufacture, etc. Also used with ethylene glycol and adipic acid in coating, in reaction with diamines to give polyureas, with ethylene imines for water-repellent and swelling-resistant finishes, and with diphenylmethane for the production of adhesive binders and lacquers. Diisocyanates also react with alginic acid and can be used to produce alginate filaments with increased resistance to alkalis and soap.

Dilatancy A system is said to be dilatant if its rate of increase of strain decreases with increased shear. Dilatancy is usually associated with suspensions, especially those containing high concentrations of suspended matter often of colloidal dimensions. → Rheopexy induced by rapidly changing mechanical shear forces.

Diluent Diluting agent added to adjust commercial dyestuffs or textile auxiliaries.

Dimensa mercerizing range This plant is a combination of the classic chain mercerizing machine and a modern chainless mercerizing machine (see Fig.). This mercerizing plant was introduced to the market by Benninger in 1987 and enables a two-stage mercerizing treatment to be carried out (i.e. stage 1: hot mercerization for better penetration; stage 2: cooling to increase the exothermic swelling effect). The stabilizing zone incorporates a stenter passage.

Dimensional change Dimensional change is the change in length of a test specimen in the lengthwise and/or widthwise direction (→ Dimensional stability). The distance measured between two marks made on the test specimen before and after it has been subjected to a particular treatment is used as a measure of the change in length induced by that treatment. Dimensional change is expressed as the ratio (in percentage) of the change in length induced by the treatment compared to the original (untreated) length and is given a negative prefix when the distance between the measurement marks is shorter (due to shrinkage) and a positive prefix when it is longer (due to extension). In principle,

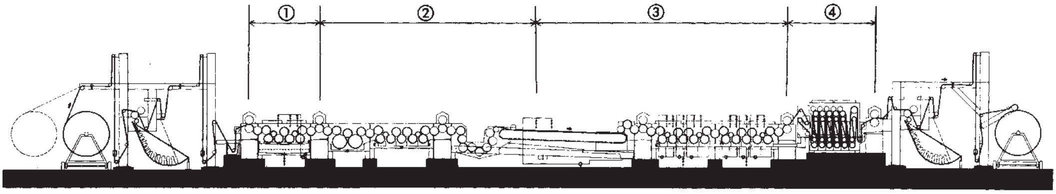


Fig.: "Dimensa" fabric path diagram (Benninger). 1 = impregnating zone; 2 = cooling and dwell zone; 3 = stabilising zone (in the form of a stenter); 4 = neutralising and washing zone.

shrinkage and contraction signify a negative dimensional change in manufactured textile products. The total shrinkage potential of a textile fabric involves several shrinkage mechanisms:

1. Residual shrinkage: this is generally understood to be the dimensional change which takes place in textile fabrics after the first wash. With a low washing machine load, i.e. in the largely relaxed state, tensions introduced during the manufacturing processes are released and the knitted loops (in the case of knitgoods) are able to assume their energetically more favourable round form. Depending on the direction of distortion, a knitted fabric can therefore become shorter or longer in the width or length direction. A change in shape without any change in the size of the surface area is described as affinitive deformation. Due to swelling of the cotton fibre, the yarns become more compact which increases the shrinkage of the textile. The result is an opening up of the yarn systems.
2. Progressive shrinkage (consolidation shrinkage): This phenomenon occurs gradually (successively) after several washing or drycleaning treatments. Progressive shrinkage is not attributable to fibre shrinkage but, rather, to the crimped fibres interlocking and slipping against each other. Progressive shrinkage ends as soon as the adjacent thread systems are able to support each other.
3. Tumbler shrinkage occurs when a fabric has not had sufficient opportunity for the inherent tensions to be released during washing. Moreover, when a cotton garment is dried to an absolutely dry state, the yarns become shorter, i.e. overdrying in a tumbler can cause a microscopic bending of the fibre. This kind of shrinkage has the same effect on the shape of a garment as shrinkage in washing and is particularly striking in heavy materials. With excess moisture of 30% and more, the cotton fibre is fully swollen. During extraction of this moisture the diameter of the fibre decreases which causes an increase in the free space surrounding the fibre. Through the mechanics of tumbler drying, and the possible addition of a lubricant (softener), the frictional forces between the fibres and yarns are further reduced and, as a consequence, the knitted loop structure becomes more compact.
4. Affinitive deformation of a geometrical figure exists then if an affinity axis of the figure remains unchanged in length, and all perpendiculars to this axis change by the same factor. In affinitive deformation, knitgoods usually exhibit two affinity axes where one axis is affected by contraction and the other by extension. Affinitive deformation and shrinkage represent the sum total of dimensional change in knitgoods. The affinitive deformation of knitgoods is attributable to a return of the distorted loop structure to the energetically more favourable form, i.e. into the largely rounded form of a knitted loop with bending tensions in balance with the circumference of the knitted loops.

Dimensionally stabilizing processes are intended to ensure minimum residual shrinkage in woven and knitted fabrics both during use as well as in washing. Such processes include: form retention finishes (wool); permanent-press treatments (cellulose); sanforizing (cotton); heat setting (synthetic fibres).

Dimensional stability This concerns the stability of a textile in terms of its dimensions and shape and is of particular importance for apparel fabrics. Steam pressing, either with direct steam or with a wet cloth and a hot iron, is the method employed to give a garment its required shape and final appearance. During this process, however, the material can shrink and problems relating to shape, size integrity, crimp and waviness may arise as well as some loss of appearance. It is for this reason that an upper limit of dimensional change during pressing is generally demanded by garment manufacturers. The procedures used to determine dimensional change in textile fabrics are typically based on in-house or national standard test methods in which steam is used.

The shrinkage value obtained on steam pressing a textile fabric is, however, not a single phenomenon. When a fabric is steamed on or in a press, a dimensional change occurs due to the release of relaxation shrinkage. At the same time, the fabric also shrinks to a certain extent depending on its properties of extensibility and contraction in the damp state. The dimensional change of a fabric in pressing is therefore the result of a combination of two properties which, together, are responsible for the dimensional stability characteristics of that particular fabric. These two properties are defined as follows:

1. Relaxation shrinkage is the irreversible dimensional change caused by the release of tensions in the fabric.
2. The extensibility in the damp state (hygral expansion) is the reversible dimensional change which occurs when the material absorbs or desorbs moisture.

In a test using a closed ironing press, it has been demonstrated empirically that the following relationship exists between shrinkage in pressing and the relaxation shrinkage (RS) and hygral expansion (HE):

$$\text{Shrinkage in pressing} = 0.3\ (\text{HE} + \text{RS}).$$

This relationship also demonstrates that for any material, a given shrinkage in the closed press can be due to a large number of combinations of damp shrinkage and relaxation shrinkage values. Furthermore, it is generally known that a great variation in the temperature and moisture content of the fabric exists depending on the pressing conditions.

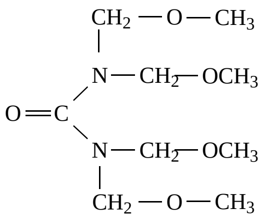
Dimensional stability-carpet test, a supplementary test for the dimensional change of carpet tiles and needlefelts to determine their suitability for use in humid environments. A customary accelerated test is used which involves 2 h dry heat at 60°C followed by a 2 h wetting treatment, drying at 60°C for 24 h and final connditioning for 48 h in a standard test atmosphere at 20°C/65% relative humidity. For special cases, more elaborate testing in climatic chambers is employed. The results are expressed as the percentage change in relation to the initial measurement made before the test.

Dimensional stability requirements for textile goods According to a draft proposal of the RAL (Reichausschuß für Lieferbedingungen, or the German Committee for Terms of Delivery and Quality Protection), easy-care or non-iron textiles should, in principle, not undergo a dimensional change in excess of –2% after 5 drycleaning cycles. After 5 wash cycles, however, the required limits are somewhat more discriminating: i.e. for shirts/blouses, –2% for woven and –4% for knitted fabrics. For the outerwear sector as well as for home textiles the required limits are –3% for woven and –5% to –6% for knitted fabrics. Control tests for machine washing are carried out in a standard reference washing machine according to DIN 53 920, drycleaning according to DIN 54 303 and dimensional change according to DIN 53 892, Part 1.

Dimensions are measurements, e.g. of the size of machinery, apparatus or plant in particular directions such as length, width, height or diameter and are useful in ascertaining the spatial requirements, e.g. floor space, etc., needed to accomodate such equipment.

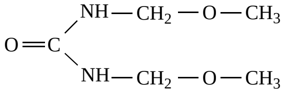
Dimer A compound formed by the polymerization of 2 molecules of a → Monomer.

Dimethoxymethyl-4,5-dimethoxyimidazolidone,



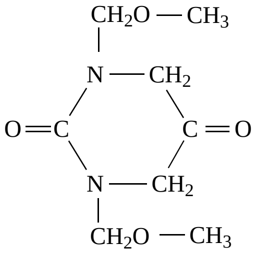
A resin finishing agent used *inter alia* for low-formaldehyde finishes.

Dimethoxymethylurea,



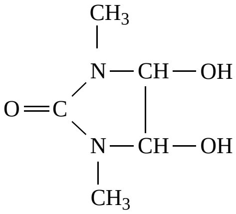
Resin finishing agent with better storage life than the free methylol compound. Finishes are less stiff but otherwise similar to → Dimethylolurea.

Dimethoxymethyluron,



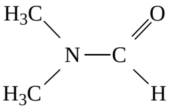
N,N´-bis(methoxymethyl)uron. It is produced from urea, formaldehyde and methanol. Because of their good stability, methoxymethyl compounds are used as reactant resins. Chlorine retention is dependent the purity. Co-application with buffered → Methoxymethylmelamine.

Dimethyl-4,5-dihydroxyethyleneurea (N,N´-dimethyl-4,5-dihydroxyethyleneurea),



Formaldehyde-free resin finishing agent for → Formaldehyde-free finishes.

Dimethyl formamide (DMF), $HCON(CH_3)_2$, colourless, mobile, liquid. Density 0,952, b.p. 153°C. Solvent for high polymers, natural and synthetic resins. Also used as a selective solvent.



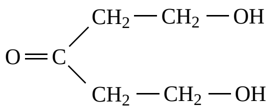
Reagent for some man-made fibres:

- Cold soluble: acetate, certain modacrylic copolymers, polyvinylidene dicyanide, polyvinyl chloride.
- Soluble at the boil: some polyacrylonitrile and modacrylic copolymers, copolyamides, polyacrylonitrile, polyamide 6 and 11, polyester, polyurethane, polyvinylidene chloride, triacetate.
- Insoluble, no change: polyamide 6.6, fluorofibres.
- Insoluble, changed (swells, agglomerates or disinte-

grates): polyethylene, polypropylene, polyvinyl chloride.

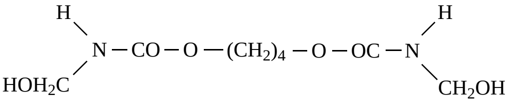
Dimethyl glycol phthalate, $C_6H_4(COOCH_2CH_2OCH_3)_2$, plasticizer (gelatinizing) for cellulose esters. Resistant to benzine and oils, very good stability to light and ageing, slightly sensitive to water. Density 1,160, b.p. 228–238°C, flashpoint +174°C.

Dimethylolacetone Acetone-formaldehyde. Reactant resin with no chlorine retention.



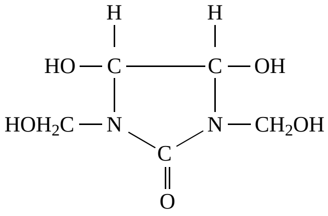
Dimethylolalkane diols Nitrogen-free reactant resins with the general formula: $HO–CH_2–O–(CH_2)_n–O–CH_2OH$, → O-methylol compounds.

Dimethylolbutane-diol-diurethane,



Resin finishing agent for self-crosslinking, non-chlorine-resistant finishes on cellulose with good wet crease recovery but only moderate dry crease recovery. Full handle.

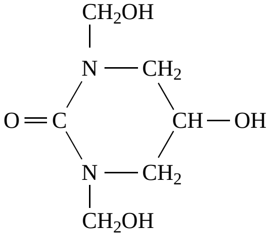
Dimethyloldihydroxyethyleneurea (DMDHEU), dimethylolglyoxalmonourein or N,N´-dimethylol-4,5-dihydroxy-2-imidazolidone. Produced mainly by reaction of urea, glyoxal and formaldehyde.



DMDHEU is the most important reactant resin. Universal application by dry, wet and moist cure methods. It is important for permanent-press and post-cure processes especially on coloured fabrics. Does not impair the light fastness of textiles dyed with substantive or reactive dyes. Very stable to hydrolysis, slight chlorine retention. The finished effects are fast to boiling wash treatments. Detection is possible by chromatographic analysis of the hydrolysate from textile fabrics.

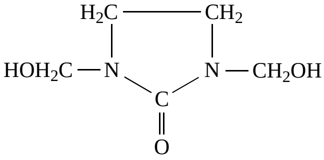
Dimethylol-4,5-dihydroxy-2-imidazolidone → Dimethyloldihydroxyethyleneurea (DMDHEU).

Dimethylol-5-dihydroxypropyleneurea (N,N´-dimethylol-5-hydroxy-hexahydro-2-pyrimidone),



Produced mainly by reaction of urea, 1,3-diamino-2-propanol and formaldehyde. Important reactant resin. The finishing effects are roughly similar to those obtained with the unsubstituted → Dimethylolpropyleneurea (DMPU) but more reactive and somewhat more stable to hydrolysis.

Dimethylolethyleneurea (DMEU), N,N´-dimethylol-2-imidazolidone,



DMEU is produced mostly by the reaction of urea, ethylene diamine and formaldehyde. It is a → Reactive resin of high reactivity. It finds particular application in dry crosslinking processes, and is also suitable for shock curing. Used for the production of finished effects on white and coloured goods which are fast to boiling wash treatments. Disadvantages: DMEU can impair the light fastness of textiles dyed with substantive or reactive dyes. DMEU finishes have inadequate fastness to chlorine (chlorine retention). For this reason, various co-applications with buffered → Methoxymethylmelamine are often employed.

Dimethylolethyltriazone → Dimethyloltriazone.

Dimethylolglyoxalmonourein → Dimethyloldihydroxyethyleneurea (DMDHEU).

Dimethylolhexahydro-2-pyrimidone → Dimethylolpropyleneurea (DMPU).

Dimethylolhexahydrotriazone → Dimethyloltriazone.

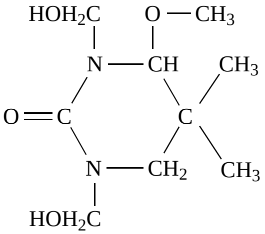
Dimethylolhydroxyethylenecarbamate → Dimethylol(mono)carbamate.

Dimethylolhydroxyethyltriazone → Dimethyloltriazone.

Dimethylol-5-hydroxy-hexahydro-2-pyrimidone → Dimethylol-5-dihydroxypropyleneurea.

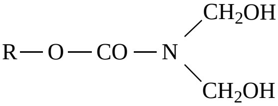
Dimethylol-2-imidazoline → Dimethylolethyleneurea (DMEU).

Dimethylol-4-methoxy-5,5-dimethylpropyleneurea N,N´-dimethylol-4-methoxy-5,5-dimethylhexahydro-2-pyrimidone.



Dimethylolmethoxyethylenecarbamate → Dimethylol(mono)carbamate.

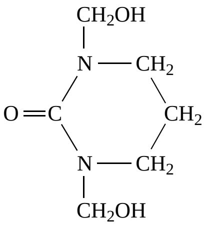
Dimethylolmonocarbamate (DMC),



R = alkyl residue
hydroxyalkyl residue
alkoxyalkyl residue

For application as resin finishing agents the toxicologically harmless dimethylol compounds of hydroxy and alkoxyalkylcarbamates are preferred. Strong curing conditions are required. DMC is particularly suitable for the production of resin finishes on polyester/cotton blends. The finishes are resistant to chlorine and hydrolysis and are fast to washing at the boil. The hydroxy and alkoxyalkylcarbamates do not impair the light fastness of dyeings. A disadvantage is the high content of free formaldehyde.

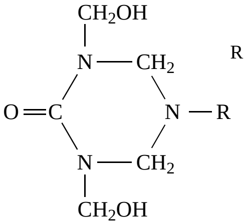
Dimethylolpropyleneurea (DMPU), N,N´-dimethylolhexahydro-2-pyrimidone.



DMPU is produced mainly by reaction of urea, propylene diamine and formaldehyde. It is an important reactant resin for finishes with very good resistance to chlorine and fastness to washing at the boil, especially on white goods. Disadvantages: impairs the light fastness of textiles dyed with reactive or substantive dyes, DMPU finishes are sensitive to hydrolysis.

Dimethyloltriazone Dimethylolhexahydrotriazone. Also known as a triazone resin.

It is produced inter alia by reaction of urea, formaldehyde and a primary amine. Important reactant resins (dimethylolethyltriazone, dimethylolhydroxyethyltriazone). Finishes produced with dimethyloltriazones have low chlorine retention and tend to have a fishy odour which makes an afterwash usually necessary.

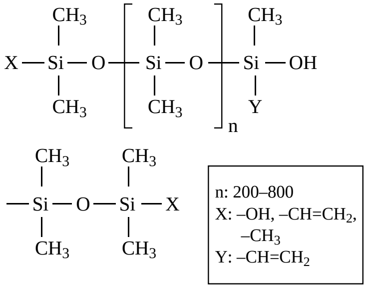


R = alkyl residue
alkylol residue

Reactant resin with good resistance to chlorine and hydrolysis. Does not impair the light fastness of dyed or printed fabrics. Particularly suitable for resin finishes on cotton. On polyester/cotton blends the finishes have a firm handle.

Dimethylolurea (DMU). Condensation product of urea and formaldehyde. A preferred resin finishing agent, available commercially in powder or paste form, very reactive. It is used to produce finishes with good crease resistance, non-shrink properties and high elastic resilience, especially on viscose. The finishes have only moderate fastness to washing at the boil and are not chlorine resistant. DMU has limited storage life.

Dimethylpolysiloxanes with reactive groups Linear dimethylpolysiloxanes containing various end groups, possibly with additional isolated reactive side groups:



n: 200–800
X: –OH, –CH=CH$_2$,
–CH$_3$
Y: –CH=CH$_2$

As silicone crosslinking agents, polymers are obtained which are capable of producing finishes on textiles with high resistance to solvents, temperature, washing, good extensibility, high tensile strength and resistance to rubbing as well as a soft and elastic handle. Uses: for coatings, as silicone elastomers for finishes on wovens and knits produced from fully synthetic fibres and synthetic fibre/cotton blends. Also used for low-shrink finishes on wool.

Dimethyl sulphoxide (DMSO, methyl sulphoxide), $(CH_3)_2SO$. Colourless, odourless, hygroscopic liquid. Density 1,1, flashpoint 95°C; soluble in water, alcohol, benzene, acetone, chloroform. Extremely powerful aprotic solvent. Solvent for hydrocarbons and numerous man-made fibres (cold = acetate, triacetate. modified polyacrylonitrile and some modacrylic fibres). Also used for the preservation of cells at low temperatures, e.g. hemicellulose. → Methylsulphinyl carbanions.

Dimethyl terephthalate (DMT, terephthalic acid dimethyl ester), $C_6H_4(COOCH_3)_2$. Starting material for the manufacture of polyester fibres (polyethylene glycol terephthalate) by condensation with glycol.

DIN DIN is an acronym for the Deutsches Institut für Normung e.V. (German Standards Institution) which succeeded the former DNA (Deutscher Normenausschuß, i.e. German Standards Committee) in 1975. As a member organization of ISO and CEN, the DIN is the official German institute with responsibility for standardization work. Purpose: to establish and publish standards through the combined efforts of all those involved as well as to represent standardization in Germany and abroad.

Organs: General Assembly, Presidium, President, Director General with Secretariats. The technical standards committees (Fachnormenausschüsse, FNA) and working committees (Arbeitsausschüsse, A) with their own departments are each responsible for a large technical field with special working groups for subfields if required. Independent working committees are maintained directly by DIN.

A prerequisite for use of the DIN mark is that manufactured products bearing this mark must meet the appropriate DIN standard and satisfy other authorized requirements of use. All the standards published by DIN carry the DIN mark together with the number group for particular fields of technology, e.g. textile standards are mainly grouped within the 60 000 series. The latest date of issue is decisive for the validity of a particular standard edition. The DIN “Normblatt-Verzeichnis” (index of standards) provides an overview of all published DIN standards (Beuth-Vertrieb). New and revised standards are reported monthly in the “DIN Mitteilungen, Zentralorgan der Deutschen Normung” (official gazette of the central organ for German standardization). Published DIN standards are sold exclusively by Beuth-Verlag GmbH, Burggrafenstraße 6, 10787 Berlin, Germany. → Technical and professional organizations.

DIN colour chart A system of colour filters (hues) which may be used for the determination of colours under standard illuminant C in terms of their appearance and characteristics (hue, chroma and lightness). Used for the systematic arrangement of colour collections (colour atlases), for the determination of colour tolerances, the evaluation of redyeings, and price calculations.

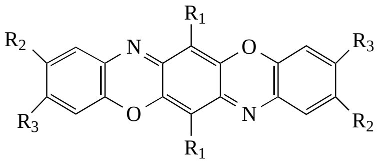
Dinitrile fibres → Polyvinylidene dinitrile fibres.

Diolefins → Dienes.

Diols (dihydric alcohols) → Alcohols containing two hydroxyl groups per molecule.

Dioxan (1,4-diethylene dioxide), $C_4H_8O_2$. A colourless, oily, neutral liquid with a faint and not unpleasant odour. Very toxic (suspected carcinogen). Miscible with water and virtually all organic solvents for printing thickeners. Solvent for cellulose acetate, nitrocellulose, cellulose ethers, chlorinated rubber, resins (mostly acrylate and methacrylate polymers), oils, fats, waxes.

Dioxazines,



Compounds with this general structure form the basis of a small, but not unimportant, group of metal-free violet pigment colorants.

Dioxins Dioxin is the commonly accepted, though chemically imprecise, name for the compound 2,3,7,8-tetrachlorodibenzo-p-dioxin, TCDD (see Fig.) which is the most well-known example of 75 chemically related chlorinated dioxins that differ greatly in their toxicity. They are generally considered together with the dibenzofurans, a further group of 135 substances

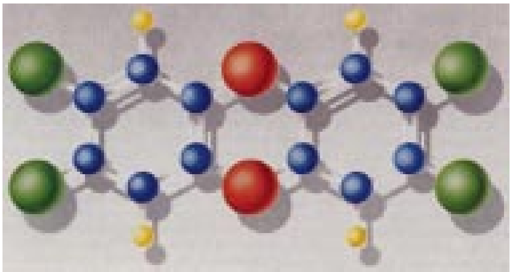


Fig.: Dioxin (TCDD).

which are actually closely related to the dioxins by reason of their chemical structure. All 210 substances have one thing in common, i.e. they are based on a skeletal structure composed of carbon, hydrogen, oxygen and chlorine atoms.

Chemists first became alarmed about these substances during the 1950s. After accidents in two German chemical factories where certain chlorinated hydrocarbons were manufactured, the same sickness symptoms were found in more than 200 workers, i.e. chloracne, besides headaches, indigestion and, in some cases, pain in the muscles and joints. The cause was first identified in 1956 as being due to 2,3,7,8-TCDD which was formed as a contaminant during production of the defoliant 2,4,5-trichlorophenoxyacetic acid (2,4,5-T). The explosive nature of this problem was, however, still not recognized at that time and it was considered sufficient to introduce additional safety measures in chemical factories producing such substances. At the end of the 1960s, extensive research on dioxins began, triggered by American use of the defoliant „agent orange“ during the Vietnam war. One of the components of this herbicide is 2,4,5-T. Public awareness of the problem was aroused following a parliamentary hearing in the USA in 1970 on the subject “effects of 2,4,5-T on humans and the environment”. For the first time, people became aware of the possible dangers to health and the environment posed by TCDD. Shortly afterwards the defoliation program in Vietnam ended. Since the 1980s, the manufacture of substances such as 2,4,5-T and others, which can be obtained in the production of TCDD, is no longer allowed in Germany and many other countries.

Dip/extract method To dye hank yarns and cheeses with reactive dyes by the cold pad-batch method. Cheeses are impregnated with the dye bath on a centrifuge. Interest is restricted to → Space dyeing.

Diphenyl (biphenyl, phenyl benzene), $C_{12}H_{10}$, or $(C_6H_5)_2$, cyclic hydrocarbon containing two benzene rings. Starting material for the manufacture of benzidine.

Diphenylacetamidine (N,N´-diphenylacetamidine). Gas fume fading inhibitor to improve the colour fastness of disperse dyes to burnt gas fumes. It is fibre-substantive and can be applied to acetate fibres simultaneously during dyeing. It exhibits optimum substantivity at 65°C.

Diphenylamine (DPA), $(C_6H_5)_2NH$. A weak base, colourless crystals, virtually insoluble in water, readily soluble in alcohol, ether or conc. sulphuric acid. Uses: redox indicator.

$$\begin{array}{c}\text{diphenylamine}\\\text{(colourless)}\end{array} \xrightleftharpoons[\text{reduction}]{\text{oxidation}} \begin{array}{c}\text{diphenyl benzedine}\\\text{violet}\\\text{(deep blue)}\end{array}$$

For this purpose it is either dissolved at 0,2–1,0 g in 100 ml conc. sulphuric acid, or made up as a 0,2% solution of diphenylamine-p-sulphonic acid (or the sodium salt) which gives an even sharper colour change. It is also used for the detection of oxidizing agents and nitrate fibres (→ Diphenylamine sulphuric acid) as well as the detection of polyacrylonitrile (→ Diphenylamine copper sulphate test).

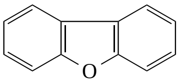
Diphenylamine copper sulphate test Confirmatory test for polyacrylonitrile and polyacrylonitrile copolymer fibres and analogous finishes. Procedure: A few grains of → Diphenylamine are dissolved in 1–2 ml conc. sulphuric acid followed by the addition of a few drops of copper sulphate solution and the test specimen. Positive reaction: the production of an immediate intense dark blue colour (also valid for finishes on fabrics etc., provided they are not too darkly coloured) which during fibre tests disappears after some time and then turns brown.

Diphenylamine sulphuric acid,

I. Specific reaction for nitrate fibres: the fibre specimen is placed in a solution consisting of → Diphenylamine in conc. sulphuric acid (1% solution). After a few seconds an intense blue colour develops, then a deep blue solution. On acetate a yellow, and on cupro or viscose, a weak brown coloration is obtained. With all other fibres the colour remains unchanged.

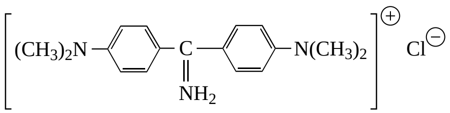
II. Sensitive confirmatory test for oxidizing agents (nitrates, chromates, nitric and nitrous acids, etc.) with which a blue colour is produced. Qualitative test in water: a little diphenylamine dissolved in some conc. sulphuric acid is added to 1 ml of the water to be tested plus 3 ml conc. sulphuric acid. Positive reaction: immediate deep blue colour.

Diphenylene oxide (dibenzofuran). Starting material for the production of carriers, mp 80°C, b.p. 287°C.



Diphenylmethane (benzyl benzene), $(C_6H_5)_2CH_2$, cyclic hydrocarbon composed of two benzene rings linked by a methane residue. Uses: organic synthesis, dyes, etc.

Diphenylmethane dyes A few basic dyes which are now of little practical interest belong to this group, e.g. auramine (C.I. Basic Yellow 2):



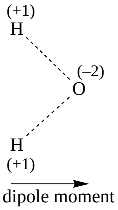
Diphenylthiocarbazone (dithizone), $C_{13}H_{12}N_4S$. A blue-black solid. Prepared from phenylhydrazine and CS2. Dissolves with a green colour in alcohol, chloroform and carbon tetrachloride. Decomposes at 100°C. Gives a characteristic coloration with heavy metals (Ag, Cu, Hg, Pb, Zn, etc.). Used as a specific confirmatory (colorimetric) test for metals.

Diphosphates → Pyrophosphates.

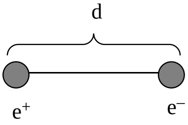
Dipole forces (orientation forces) → Secondary valency forces.

Dipole moment → Dipoles.

Dipoles These are best described by using water as an example. Water shows quasi-ionic character because of its weakly charged negative oxygen atom and two weakly charged positive hydrogen atoms. The result is a molecule with positive and negative "ends" or two permanent opposite poles forming the dipole. This is true for all polar molecules in which the centres of the two electrical charges do not coincide.



The deviation from symmetrical charge distribution, or "Dipole moment", has been chosen as a comparative measure of the degree of polarization of molecules.



The product of charge, e, times the distance, d, = μ, giving the dipole moment unit, $\mu = 1 \times 10^{-18}$, also called 1 Debye or 1 D, after Debye who discovered the dipole phenomenon. Using this value, which is known for many individual bonds, it is possible to estimate dipole moments (see Table where the valency angle and corresponding force parallelograms are taken into account in each case).

It is known that the dipole moment of a disperse dye has a significant effect on its dyeing properties. This is especially pertinent in regard to the suitability of strongly polar dye molecules for spreading the polymer chains and thus acting as carriers. The dissolving power of substances also commonly relies on the interactions between two individual molecules with distinct dipole moments (while non-polar liquids are good solvents for non-polar substances). In this connection, complexes with double dipole moments caused by partial polymerization, for example, are increasingly important because of their increased tendency to form hydrogen bonds.

H_2	0	C=O	2,3
O_2	0	C=O	0,7
Cl_2	0	C—Cl	1,5
CO_2	0	C—OH	1,6
CS_2	0	C—COOH	1,0
CH_4	0	C—NO_2	3,7
CCl_4	0		
NO	0,1	CH_3OH	1,67
HCl	1,05	C_2H_5OH	1,7
H_2O	**1,84**	CH_3COOCH_3	1,47
SO_2	1,61	$C_2H_5COOCH_3$	1,81
NH_3	1,47	CH_3COCH_3	2,75
C—H	0,4	C_2HCl_3	0,9
O—H	1,6	C_2Cl_4	0
		C_6H_6	0
		C_6H_5Cl	1,69
		C_6H_5OH	1,56
		$C_6H_5NH_2$	1,54
		$C_6H_5NO_2$	3,95

Tab.: Dipole moments of different compounds in Debyes.

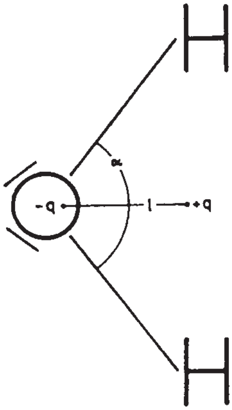


Fig.: Dipole in water molecule.
α = valency angle;
q = negative and positive centres of charge;
l = spatial distance.

Water is an insulator with a total charge of zero. The valency angle, formed by the bonds between the oxygen and the two hydrogen atoms, has been determined experimentally as 104° 27'. The centres of positive and negative charge are spatially separated (see Fig.). This permanent electrical dipole moment gives rise to microwave absorption as a result of dielectric losses. The valency angle α depends on the configuration of the whole molecular environment of the water molecule. As this angle changes, so does the spatial separation, l, of the centres of charge and, therefore, the permanent dipole moment. The more strongly bound the water molecule, the smaller the dipole moment and, therefore, the microwave absorption. In wet textile fabrics, the water has several bonding states with different proportions side by side, for example, the bonds between the OH groups of cellulose and neighbouring water molecules or the physical adsorption forces in the boundary layer between water and synthetic fibres.

Dipping vat Used very rarely nowadays and only for indigo, preferably for fabrics printed with reserving agents. Fabrics are hung up on hooks in a dipping frame so that they can be immersed in a vat and be held there. After the dipping frame is removed, air oxidation takes place and the goods are then immersed in the vat once again (one pass). Full-shade indigo requires several passes.

DIP process The abbrev. “DIP” stands for diazotization in the paste (→ Naphthols in direct printing). It represents a variation of base printing: for preference liquid bases are stirred into a thickener together with sodium nitrite. A second thickener contains a medium strength acid, e.g. phosphoric acid. By gradually mixing the two stock thickeners together, the fast colour base is diazotized without the otherwise usual addition of ice (for cooling). Due to metered addition, no nitrous gases are released by this method. The print paste with the diazotized fast colour base must not be neutralized, and is immediately ready for printing.

Dip treating The process of passing fibre, cord, or fabric through an adhesive bath, followed by drying and heat-treating of the adhesive-coated fibre to obtain better adhesion.

Direct coating The application directly on to the web of moderate and high viscosity polymers, both in the form of solutions, concentrated dispersions and in fused, thermoplastic state. This mainly applies to coating processes, as used in the manufacture of textile/plastics composites. Following this process, material can be added indirectly using another web (textile, foam or film). The Fig. shows a plant by Brückner for the direct coating of carpet backing.

The doctor blade (squeegee) process is also a direct-coating process. The polymer-based coating agent is applied directly to the coating base and adjusted to the required thickness over the entire width of the cloth by means of a doctor blade. The air knife (squeegee), knife-on-blanket and knife-on-roll processes are adjusted according to how the material is mechanically applied to the base at the doctor blade.

Unlike the direct coating process, indirect coating processes, such as roller-application methods, involve the indirect application of the product. The film of coating material is first applied to the roller and then transferred to the textile web.

Direct discharge of waste water The direct discharge of waste water into a main outfall (e.g. a stream) without prior treatment in a municipal waste water treatment plant.

Direct dyes Also known as direct cotton, substantive, benzidine or salt dyes. Group classification for dyes which exhaust substantively on cellulosic fibres, cotton, viscose, cupro and high wet modulus fibres, especially in the presence of salt. They are mainly sulphonated disazo or polyazo dyes. The sulphonic acid groups are responsible for good solubility in water. The high light fastness types already contain a complex-bound metal atom in the molecule. The colour fastness of various direct dyes can be improved by aftertreatment with metal salts (→ Aftercoppering dyes). Specially selected direct dyes are available for streaky-dyeing viscose qualities. Direct dyes represent the main class of dyes for cellulosic fibres in terms of usage: they are simple to apply, economical, have generally good levelling properties, a wide shade gamut and a wide range of colour fastness. Special types can be diazotized and developed on the fibre (→ Diazotizable dyes) for better wet fastness or may be coupled with readily soluble diazo compounds. Direct dyeings on cellulosic fibres exhibit considerable differences in colour fastness to light which ranges between 1 and 7–8. Different direct dyes can therefore be used for articles which are only required to have low light fastness as

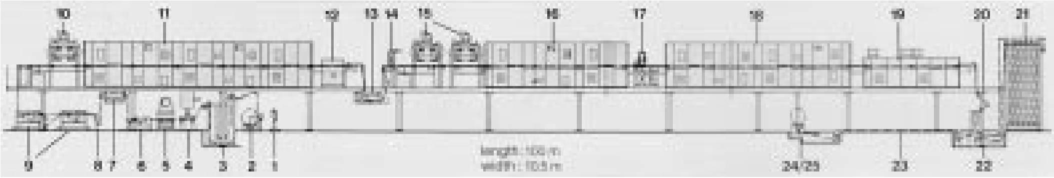


Fig.: The largest known plant for coating the back of tufted carpet with a primary coat for tuft anchorage and a finishing coat of latex foam (source Brückner).
1 = Sew end-to-end∞ 2 = Unwind∞ 3 = Accumulator∞ 4 = Brush/Suction extract; 5 = Steam; 6 = Straighten; 7 = Control; 8 = Tension; 9 = Lick applicator; 10 = Dry on; 11 = Pre-gel; 12 = Cool; 13 = Singe back; 14 = Coat; 15 = Dry on; 16 = Pre-vulcanize; 17 = Emboss; 18 = Vulcanize; 19 = Cool; 20 = Trim edge; 21 = Accumulator; 22 = Control; 23 = Monitor; 24 = Wind; 25 = Cut across.

well as goods with high light fastness. In general, direct dyes have poor wet fastness properties and dyeings must be aftertreated to improve their serviceability.

Direct dyes, dyeing mechanism As distinct from the concept of → Substantivity, frequently quoted in the field of cotton dyeing, the affinity of a dyestuff is determined as a measure of the distribution between fibre and dye bath under standardized dyeing conditions in equilibrium, and represents the difference between the dye affinity to water (hydrophilicity) and to cellulose.

According to Vickerstaff and others, the cause of the affinity of a dye molecule to cellulose is to be sought in the formation of hydrogen bonds between cellulosic hydroxyl groups and proton donors of the dye substituents such as e.g. amino groups (Figs. 1–3). According to Ciba-Geigy, the affinity of direct dyes to cotton cellulose results from hydrogen bond-like linkages of the cellulosic hydroxyl groups (as proton donors) with the de-localizable π electron system of the dye (as proton acceptor). All substances with substantial affinity to cellulose nevertheless have a large planar chromophore (Fig. 4) with a large number of conjugated double bonds. Any interruption of this planarity of the chromophore, i.e. any reduction in the extension of the de-localizable π electron system, reduces affinity. Besides such “Yoshida” forces, other interactions also play a part, such as van der Waals forces and hydrophobic interactions; thus the introduction of an increasing number of water-solubilizing (hydrophilic) sulpho groups into the chromophore of a direct dye causes a significant decrease in the affinity of the dye to cellulose fibres.

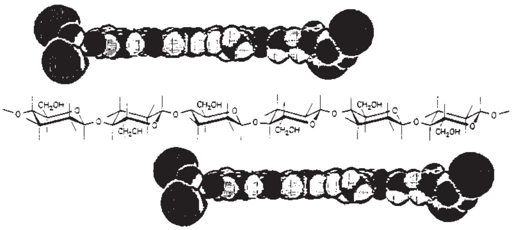


Fig. 1: Schematic representation of co-planar dye adsorption on cellulose (source: Flath).

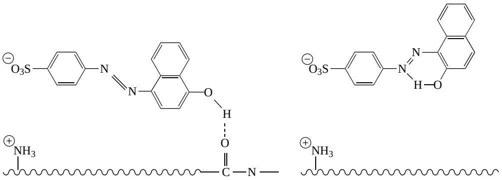


Fig. 2: Inter- and intra-molecular hydrogen bonds in the sorption of Napthalin Orange I (left) and Napthalin Orange II (right) in wool.

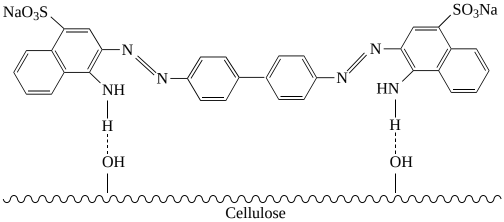


Fig. 3: Model of hydrogen bond formation between substantive dye and cellulose fibre (source: Vickerstaff).

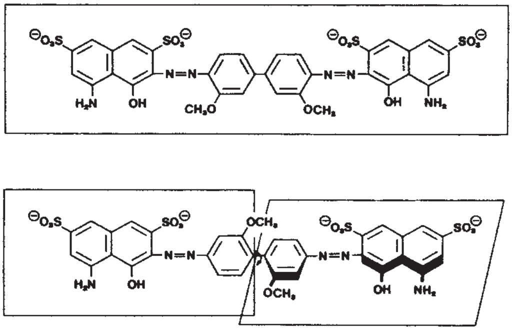
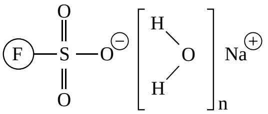


Fig. 4: Importance of the planarity of the dye molecule for the affinity to cellulose. Top: high affinity (direct dye); below: low affinity (acid dye).

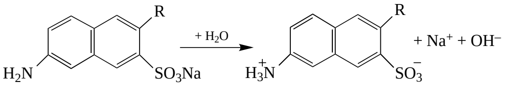
In pure water, cellulose carries negative charges, which with the negative charges of the sulpho groups cause electrostatic repulsion (electrostatic barrier or “Donnan potential”). Through the addition of electrolytes, such as e.g. sodium sulphate, to the dye bath, this electrostatic repulsion is suppressed, which causes a better interplay of the “Yoshida” forces and of the van der Waals interactions, and thus greater affinity. Higher concentrations of salt (which in low-affinity reactive dyestuffs is still 40–70 g/l sodium sulphate) cause an aggregation of the dye molecules in the solution (in effect, a salting-out action); however, these associates degrade with increasing dyeing temperature, so that the dyes diffuse in a monomolecular manner as dye ions into the fibre pores. In the fibre, the solubility of the direct dyes could be reduced through coagulation of several molecules. The dye aggregates in the solution could thus serve as a reserve supply from which, as a result of the association equilibrium, the individual dye ions are constantly supplied after they have been taken up by the fibre.

For the addition of salt, from the point of view of the process technology, there are basically two options: before or after adding the dye. The fixation yield of reactive dyes increases with increasing concentrations of salt; above 50 g/l, the influence of salt concentration in the dye bath declines, however. The trend towards shorter liquor ratios provides the option of reducing the salt content. The salt-saving potential is greater, the lighter the dyeing. Working with low amounts of salt aids the solubility of the dye; so one can use sodium chloride (corrosive to metal!) in place of sodium sulphate, without increasing the dye particle size or precipitation taking place. Besides this empirically obtained information, it still seems sensible to define the type of salt dosing (as a sol or solid) in terms of time, so that one can follow the influence of the salt on the state of the dye molecules in the dye bath and in the fibre kinetically.

Dyes with anionic groups have to be of substantially planar structure if they are to aggregate in the liquor; bulky molecule parts impede aggregation. The less the solubilising sulpho groups with their hydrate shells are mutually repellent, the better the dyestuff molecules are able to aggregate. The addition of salt to anionic dye solutions causes not only a suppression of dissociation, but also leads to the formation of ion pairs (hydratised counterions united via water molecules):



This “kinetic entity”, which is stable for a certain time, is electrically neutral. The same applies to zwitterions in the case of dyestuffs with the same number of amino groups and sulpho groups at a certain pH:



Levelling agents which have an affinity to dyestuffs, and which interact both with the polar groups, displacing water, as well as with the hydrophobic groups of the dye molecule, in each case incorporate a dye molecule into a micelle, and thus reduce the dye aggregation in the solution. The dye aggregation in solutions can be demonstrated photometrically. The interaction of the π-electron systems of aggregated dye molecules causes a splitting open of the excited π-states into two adsorption maxima in the transmission spectrum of a dyestuff solution with a higher and a lower energy. During the transition from the excited to the “normal” state of the aggregated molecules, short-wave radiation is emitted.

Although previously the view was held that anionic, planar dyes adhere in cellulose because they form aggregates there, it was later shown through transmission measurement – with transparent cellophane films dyed with Indanthren Dark Blue BOA – that anionic dyes bond to cellulose in a mono-molecular manner. It must be emphasized above all here that the dye which has been taken up in a mono-molecular manner is 200 times more concentrated in the film than in the liquor, where it is present as dimer. More recent work too assumes the mono-molecular adsorption of direct dyes in cellulose; postulating that the pores of cotton are only of such a size that the inward diffusion of dye monomers (at best with hydrate shell) is solely possible, but not that of dimers.

The salt content at the start of dyeing should be kept low, in order – with high dyestuff concentration – to control dyeing in such a way that initial dye monomers are “dissolved” out of dye aggregates with poor diffusion properties, due to the aggregate ↔ monomer balance, as these tend to form ion pairs with suppressed dissociation when salt is present. These ion pairs have affinity to cellulose, because their solubility in water is lower than their “solubility” (adsorption) in cellulose. With increasing temperature, more monomers emerge from the aggregate. The addition of salt also increases the tendency towards aggregation, but necessitates further addition of salt as dyestuff concentration declines during the dyeing process, to displace the equilibrium.

The substantivity of a cotton dyeing with direct dyes also increases depending on typical dyeing parameters, as follows:

- when the pH of the dyebath decreases,
- when the dye concentration in the dyebath decreases,
- when the dyeing temperature decreases,
- when the liquor ratio decreases.

That the hydroxyl groups of cellulose are somehow responsible for dye bonding is apparent from, amongst other things, the fact that when these groups are esterified, the dye-fibre affinity ceases to exist.

Direct dyes, dyeing methods,

I. Batch method: With batch dyeing, the dyeing method to be selected in each case depends on the type of dyeing equipment (loading system, winch vat, jig, paddle or jet), the nature of the material to be dyed, as well as the solubility and the affinity of the dye. Before the actual dyeing process, the material is pre-treated with a wetting agent. The dye is mixed into a paste with some warm water, and is then diluted with more water, boiled up, filtered, and then added to the dyebath. Whilst the bath, with the fabric, heats up to the optimum temperature (usually 80–90°C), the electrolyte is added, gradually if necessary. Dyeing takes 30–60 minutes. After the dyebath has been run off, the dyed material is briefly rinsed with cold water and, in general, subjected to after-treatment. The dyeing process is divided into 3 phases: a) uptake (adsorption) through substantivity; b) penetration of the dye into the fibre (diffusion); c) bonding to the fibre (immobilisation) through van der Waals interactions. Assurance of level take-up through progessive addition of salt, temperature control, sufficiently long dyeing time, and use of levelling agents.

II. High-temperature dyeing method: With suitable dyes, one can work in a closed system at temperatures over 100°C (up to approx. 130°). Due to the rapid diffusion rate, particularly level dyeings are achieved with short dyeing times, even with fabric with difficult dye penetration. After the high-temperature phase, the dyebath is cooled down to 80–90°C, with dye pick-up continuing, and the result is the same depth of colour as in the normal dyeing method at 80–90°C.

III. Continuous and semi-continuous method: With these so-called pad methods, the dyeing material, mostly in the form of woven fabric, is first of all steeped in a concentrated dye solution, passed full-width through a trough filled with the dye solution, and subsequently the excess liquor is removed between the rubber rollers. With high fabric speed, temperatures as low as possible (30–40°C for light shades, 60–80°C for medium to dark shades), and with the minimum amount of pad liquor, the situation can be avoided where the dye already picks up substantively in the padding process. Distinction may be made between the following methods:

1. Pad-jig method: Pad, salt bath develop on jig or winch vat.
2. Pad-roll method: Pad, heat up in an IR zone, roll up and rotate in a dwell chamber for a considerable time under fixation temperature/moisture conditions.
3. Pad-salt method: Pad, pass through salt solution at boil in continuous piece-dyeing machine (light shades only; for darker shades an intermediate steam process is necessary).
4. Pad-steam method: Pad, continuous steam, optional final salt bath.
5. HT-steam method: Pad, HT-steam.

IV. After-treatment: The wetfastness properties of direct dyeings are not adequate for the demands of everyday use, particularly in medium and deep shades. However, by means of suitable after-treatments, products can be obtained having good water and perspiration resistance, and which are washable at 40°C. Distinction may be made between the following:

1. After-treatment with cationic compounds: With anionic direct dye applied to the fibre, cationic after-treatment agents of relatively high molecular weight form water-insoluble salt-like compounds with good wetfastness properties. Possibly simultaneous shade alteration or reduction of the light fastness.
2. Metal complex formation: Some azo dyes can form 1 : 1 copper complexes. If such dyes are after-treated with aqueous metallic salt solutions (e.g. copper sulphate), then considerable improvements in lightfastness and, to some extent, also in wet fastness, are obtained since molecule enlargements reduce solubility and diffusion speed is considerably reduced. After-metallizing to improve wet fastness by means of copper sulphate/acetic acid, potassium dichromate/copper sulphate/acetic acid, potassium dichromate/copper sulphate. Metallizing can cause severe shade changes.
3. Diazotization and coupling.

Direct engraving process In contrast to the classical method of → Engraved printing rollers from individual colour separations produced by the engraving designer, in direct engraving the actual engraving is carried out directly from the multicoloured design by means of optoelectronic scanning.

Direction-dependent coefficient of friction → DFE, friction.

Directive for use of dangerous substances → Legislation on environmental protection.

Direct printing The most frequently employed method of textile printing in which print pastes are applied to white or dyed fabrics without destroying the ground colour, e.g. as in → Resist printing and → Discharge printing.

Direct steam as a liquor heating medium → Steam as a liquor heating medium.

Dis → Bis.

Dischargeability of dyes Dischargeability is mainly dependent on the chemical constitution of the dye. The presence of an azo group is the most important requirement. This is why, in principle, azo derivatives are used as dischargeable dyes since they can be destroyed by cleavage of the azo groups.

Dischargeable dyes are to be found in various dye classes:

- disperse dyes,
- vat dyes,
- cationic dyes,
- pigment colorants,
- direct dyes,
- acid dyes,
- metal-complex dyes,
- reactive dyes,
- naphthol dyes.

In the dye maker’s pattern cards, the dischargeability of each dye is rated on a scale from 1–5 (1 = virtually undischargeable, 5 = easily dischargeable). Many azo types are not readily dischargeable because the cleavage products formed during the discharge process have an affinity for the fibre. Moreover, small amounts of impurities or side products in the original dye can also impair dischargeability. Since these contaminants often only give rise to problems above a certain concentration of use, dischargeability is frequently concentration-dependent. Moreover, the same dye (i.e. with the same CI number) from different manufacturers can also exhibit different dischargeability properties. Colourless cleavage products can likewise have a negative influence on the discharge effect which usually becomes apparent only during storage of the discharge printed fabrics. Some white discharges are subject to yellowing due to the action of light or oxidation. Dyes which react typically in this manner, e.g. CI Acid Blue 116, are referred to as "reversionary" dyes. The state of fixation of a dye also has a considerable influence on its dischargeability. For this reason, dyes which adhere to the surface of the fibre after padding or printing are easier to discharge than those which have already been fixed on the fibre in a dyeing process. The nature of the fibre itself also plays an important role in dischargeability. Since the common reducing agents are all hydrophilic and, in some cases, readily water-soluble, it is obvious that water-soluble dyes on hydrophilic fibres (e.g. wool or cotton, are more easily discharged than hydrophobic dyes on hydrophobic fibres (e.g. disperse dyes on polyester fibres). Furthermore, the type and concentration of reducing agent and auxiliaries, as well as the drying and steaming conditions are of decisive importance here.

In the production of coloured discharges, a new dye (illuminating dye) is applied to the discharged areas of the design at the same time. This new dye is added to the liquor or print paste containing the reducing agent and must therefore be resistant to reducing agents. Discharge-resistant or coloured discharge dyes are mainly anthraquinonoid, phthalocyanine, triphenylmethane, methine or oxazine types. Whilst numerous discharge-resistant dyes were recommended by various dye makers in the past, the number of suitable dyes has been reduced to a minimum today because of their generally poor colour fastness properties. It is therefore almost impossible to cover all the desired shades for coloured discharges with one dye class due to the relatively limited selection now available. For this reason, up to 4 different dye classes can be combined alongside each other to produce one coloured discharge design. Acid and direct dyes are the most widely used among the following types:

- cationic dyes,
- pigment colorants,
- vat dyes,
- acid dyes,
- direct dyes,
- mordant dyes.

Although only azo groups are dischargeable with reducing agents, an alkaline discharge can also be used to bring about cleavage between the former vinylsulphone group and the –OH groups of cellulose in dyeings produced with vinylsulphone (VS) reactive dyes (see Fig.).

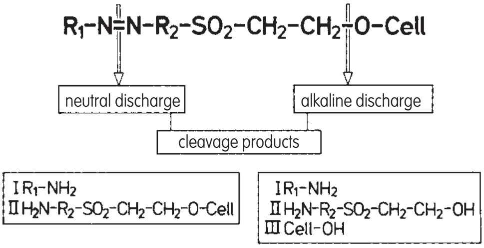


Fig.: Dischargeability of vinylsulphone ground dyeings (source: Hoechst).

Polyester fabrics are only dischargeable if the ground shade produced by continuous dyeing has not yet been fixed in the thermosol process. A classic discharge print on lightweight polyester fabric is produced as follows:

1. Dyeing: exhaust dyeing in conventional jet or beam dyeing machines.
2. Wash off: short rinse (a reductive afterclear is not necessary at this stage).
3. Drying: stenter dry at low temperatures to remove creases only.
4. Printing.
5. Fixation: HT steaming at 175–185°C, 6–8 mins.
6. Wash off: cold water rinse; hot alkaline reductive afterclear, followed by hot and cold rinses.
7. Drying.

Dischargeable grounds Dyeings made with dyes suitable for the production of white or coloured discharges. Direct, reactive and naphthol dyes are mainly used on cellulosic fibres; acid, metal-complex, disperse and cationic dyes are used on the appropriate synthetic fibres. An essential prerequisite is good dischargeability of the ground dyeing. Since there is a direct relationship between dischargeability and depth of shade, dye selection must be made by reference to recommendations given in the dye pattern card relative to the 1/1 standard depth. There is often no single dischargeable dye capable of producing the desired shade so that combinations of different dyes resp. dye classes have to be used. In many cases preliminary trials are essential in order to determine to what extent the inclusion of small proportions of a difficult to discharge dye may impair the discharge effect, or to establish the higher proportions of a readily dischargeable dye necessary to achieve a satisfactory discharge effect. The dischargeable ground dyeing is, in any case, dyed in the same manner as a normal dyeing.

Discharge print halo → Halo in discharge printing.

Discharge printing A style of printing in which predyed or prepadded fabric is printed with a paste containing chemicals capable of destroying the ground colour to produce white effects (white discharges) in the printed areas, or coloured effects (coloured discharges) with the addition of a discharge-resistant dye (see Fig.). The discharge print paste consists of a thickened discharging agent which may contain further additives, e.g. white pigments, discharge-resistant dyes if required, and other necessary chemicals, auxiliaries, etc. Well-bleached material is a prerequisite for white discharges. As dischargeable grounds, either normal plain dyed fabric or, more frequently, prepadded grounds are employed. Discharging agents consist mainly of reducing agents based on sulphinic acid derivatives and tin salts. The advantages of discharge printing, i.e. flexibility and great variety of design possibilities are offset by the more complicated and costly production process which generally involves the following stages: dyeing, intermediate drying, application of discharge print pastes, intermediate drying, steaming (reaction medium), washing-off and drying. The development of alternative processes is of great interest from the ecological point of view since, on the one hand, the classical discharge printing process is associated with a high energy consumption and a high water consumption on the other hand, in order to remove the thickener which is often difficult to wash out in the print afterwash stage. Moreover, the waste water is contaminated with *inter alia* sulphur-containing reducing agents and large quantities of high molecular weight thickeners which results in a drastic increase in the COD values (→: Acetate, Triacetate, Polyester, Polyacrylonitrile, Polyamide, Silk, Wool in discharge printing; Cationic, Mordant, Direct, Vat, Vat leuco ester, Naphthol and Reactive dyes in discharge printing).

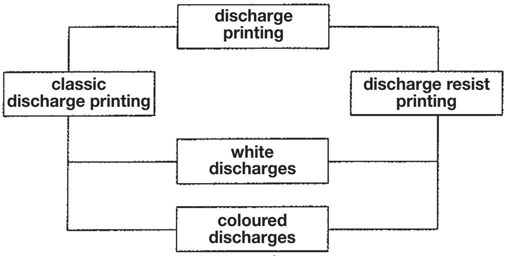
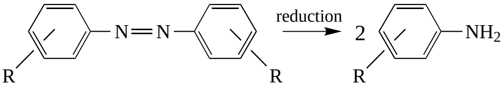


Fig.: Basic concepts of discharge printing (BASF).

Depending on the class of dye to be discharged, 3 different types of chemical reaction are employed:

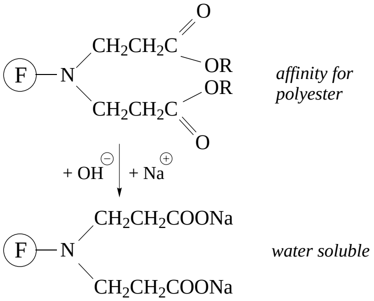
1. Cleavage of azo groups by reduction:



2. Alkaline cleavage of ether linkages in vinylsulphone reactive dyeings:

$$\text{Cell}-O-CH_2CH_2SO_2-\text{Ⓕ} \xrightarrow{OH^{\ominus}} \text{Cell}-OH + HOCH_2CH_2SO_2-\text{Ⓕ}$$

3. Alkaline cleavage of ester groups in disperse dyes (before thermosol treatment):



Discharge printing assistants These include products capable of making otherwise difficult to discharge dyeings (e.g. vat dyes) dischargeable, and which assist the discharging action and fixation of the coloured discharge illuminating dyes. In the main, these are products based on quaternary ammonium compounds. Hydrotropic auxiliaries accelerate or make possible the discharge process during dye fixation and also dissolve cleavage products thereby facilitating their removal in subsequent afterwashing. Hydrotropic auxiliaries also ensure the presence of a certain quantity of water on the fabric during steaming thereby increasing the efficiency of the reducing agent. Urea, which is the most frequently used hydrotropic auxiliary, performs the following functions:

- increases dye solubility in the discharge print paste or pad liquor,
- accelerates dye fixation during steaming,
- improves dye colour yield,
- prevents the fibre drying out during steaming.

Wetting agents are also employed in discharge print pastes or pad liquors to reduce the surface tension between water and air so that the aqueous medium can penetrate air-filled capillary spaces in the fibres more easily. White effects produced by white discharges can also be improved by additions of zinc oxide and titanium dioxide (often as mixtures of both), as well as fluorescent brightening agents, to the discharge print paste. Thiodiglycol is also used as a dye solvent and hydrotropic agent, whilst glycerol is used as a hygroscopic agent and solvent.

Discharge print pastes → Discharge printing.

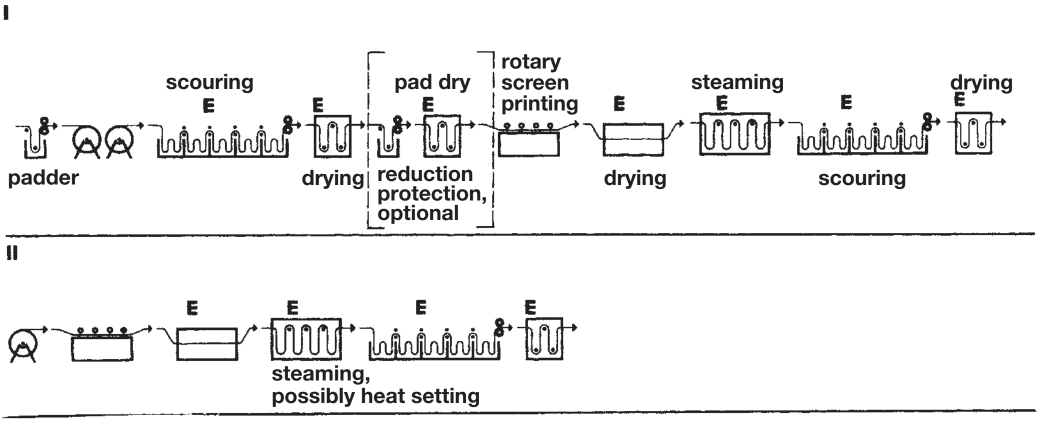


Fig. 1: 2 possibilities of discharge resist printing on cellulose fibres with indication of high energy cost processing stages. I = cold batching with reactive dyes, then coloured discharge with vat dyes or pigments as decorative dyes; II = wet on wet process, reactive under reactive or pigment reactive dye.

Discharge resist printing In contrast to normal resist printing, fixation of the dye to be resisted is not only prevented but also simultaneously destroyed by the discharging agent (Figs. 1 and 2).

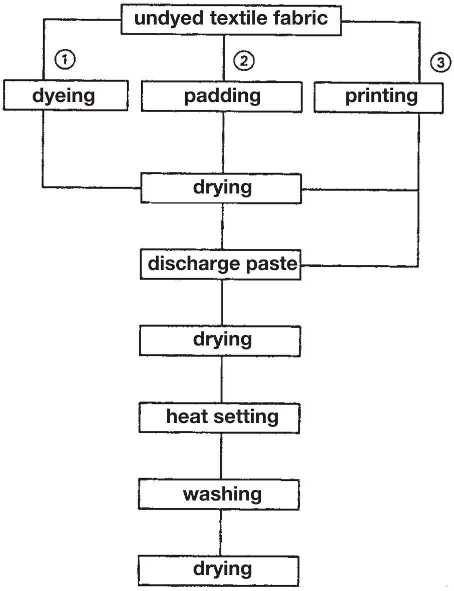


Fig. 2: Processing cycle in discharge and discharge resist printing.

Discharge resist printing on polyester Because of the difficulty of discharging polyester dyeings, the → Discharge resist printing technique is preferred. Either stannous chloride or sodium, calcium or zinc formaldehyde sulphoxylates are used to destroy the dyed grounds. An alternative is the use of alkali discharge resists without reducing agent.

The following method is used to produce discharge resists on polyester with stannous chloride:

1. Padding:

thickener (to prevent migration)	100 g/l
citric acid (adjustment to pH 5)	2 g/l
monosodium phosphate	10 g/l
dischargeable disperse dye (azo type)	x g/l

2. Drying:
   the drying temperature must not exceed 100°C
3. Printing:

thickener	500 g/l
urea	80 g/l
carrier (HT fixation accelerator)	10 g/l
stannous chloride	100–200 g/l
disperse dye for coloured effects (anthraquinone type)	x g/l

4. Drying.
5. Development:
   HT steaming or pressure steaming.
6. Afterwash:
   cold rinsing, followed by an alkaline reductive clear, hot and finally cold rinsing.
7. Drying.

Discharging agents in printing The application of a → Reducing agent is necessary for discharge printing. In practice, the formaldehyde sulphoxylates, thiourea dioxide (formamidine sulphinic acid) and, in certain cases, tin (II) chloride are the preferred reducing agents. The latter is unsuitable for wool since brown tin sulphate can be formed with the reduced cystine groups in the fibre resulting in unsightly effects. The most important reducing agents are:

– sodium formaldehyde sulphoxylate,
– zinc formaldehyde sulphoxylate,

– calcium formaldehyde sulphoxylate,
– thiourea dioxide.

The individual products are applied under different pH conditions. Tin (II) chloride is applied under strongly acidic, and zinc formaldehyde sulphoxylate under mildly acidic conditions. Thiourea is used under both mildly acidic as well as alkaline conditions. All other products are used in the weakly alkaline range. Discharging agents also differ in their solubility. Calcium formaldehyde sulphoxylate and thiourea dioxide are only sparingly soluble in water which also makes it possible for the former to be applied at higher concentrations without problem. All the other products have good to very good solubility in water.

Strongly alkaline sulphoxylate discharges are not particularly suitable for the production of discharge effects on alkali-sensitive fibres, e.g. wool, silk, acetate. Since thiourea dioxide is effective under neutral or mildly acidic conditions, it does not cause any damage to alkali-sensitive fibres. Choice of the optimum discharging agent for a particular application is based on the product which is capable of giving the best effects with appropriate additives under the given conditions of fibre type, dye class and processing technique. The selected product must not cause damage to the fibre nor influence the colour fastness of the dyes used. A prerequisite for the reaction is a sufficiently high reactivity of the discharging agent. This is characterized by the redox potential, i.e. the more negative the redox potential, the more reactive the discharging agent (dependent on temperature, pH and concentration).

Disinfectant cleaning → Sanitized chemical cleaning.

Disinfectants chemicals suitable for disinfecting, e.g. in particular oxidizing agents in the form of chlorine carriers (thermochemical disinfection of textiles), phenol derivatives, bactericidal finishes. It is probable that these agents mainly work by destroying the cytoplasm membrane of the bacteria.

Disinfectant washing agents, a product which combines detergents with → Disinfectant in the form of phenol derivatives or stabilized chlorine carriers. Typical disinfection system for thermochemical disinfection of textiles. Increasing interest in combining disinfectants with other agents to produce bactericidal, fungicidal, anti-tubercular bactericidal, antiviral etc. effects.

Disinfectant washing process →: Disinfection washing of textiles; Thermal disinfection.

Disinfection, destruction of microorganisms that cause disease (bacteria).

Disinfection in the laundry, is carried out in hospitals and similar institutions in pressure vessels using superheated steam and hot air, or in a washing machine using a disinfectant washing process.

Disinfection washing of textile Disinfection by adding disinfectant detergents at a time-dependent minimum temperature (40–60ºC, 10–15 min.) in the presence of a disinfectant. This is currently the predominant working method in hospital laundries. A list issued by the Federal Health Office taken from the federal law relating to the control of contagious diseases (§ 41) contains appropriate, i.e. officially tested, production and process procedures for the disinfection washing of textiles. Disinfectants often used are stabilised → Chlorine carriers, which can separate active chlorine and/or hypochlorite in washing liquors, although this does not necessarily have to occur. Risk of chlorine separation in the wash bath: → Active chlorine losses.

Disinfestation The destruction of harmful insects (clothes lice, bugs, moths, etc.) and their larvae or eggs.

Dislocation Term used to describe a change in position or place of dye during dyeing as in → Migration.

Disodium hydrogen phosphate Acid sodium pyrophosphate, $Na_2H_2P_2O_7$, fine powder, non-hygroscopic. Density 1,848. Solubility in water at 20°C up to 120/140 g/l. The solution has an acidic reaction at pH 4,2. Gives clear acidic solutions even in hard water. As a builder it improves the washing and foaming efficiency of detergents. Removes undesirable iron and manganese compounds in washing, dyeing, etc. (especially in iron dyeing vessels). Other uses include bleaching stabilizers and flame-retardant finishes. → Sodium phosphates.

Disodium phosphate Sodium phosphate, dibasic (DSP, sodium orthophosphate, secondary), Na_2HPO_4. Colourless translucent crystals or white powder with a saline taste. Soluble in water, very soluble in alcohol. Hygroscopic, converted to sodium pyrophosphate at 240°C. Textile applications include weighting of silk, dyeing and printing, flame-retardant finishes.

Disodium pyrophosphate → Disodium hydrogen phosphate.

Disodium salt → Triethylsulphateamine.

Dispersants Dispersing agents which are effective e.g. in aqueous treatment baths. Dispersants prevent the redeposition of largely insoluble substances (e.g. soil particles). They are mainly → Surface active compounds. Dispersants reduce the surface tension of water and accumulate on the fibre surface. They are used in virtually all wet processing and finishing treatments.

Disperse dyeing systems For dyeing polyester fibres, in practical terms only disperse dyes are suitable. Through their hydrophobic properties, these dyes are capable of penetrating into the similarly hydrophobic polyester fibre. This class of dyes has only extremely poor solubility in water; for this reason, conventional aqueous dye liquors, e.g. tensides, have to be added as levelling agents. Since it is only such dye that has been dissolved to a molecularly dispersed state which is capable of diffusing into the fibre, only poor levelness can be achieved without levelling agents.

The model of an aqueous disperse dye system is shown in the figure. Through the dispersant, stabilisation of the dispersion is achieved (prevention of crystallite enlargement etc.); by adding tenside, a reservoir for dispersed-molecule dye is created via the solubilisation of dye molecules into micelles. The actual dyeing process is initiated through the adsorption of the dispersed-molecule dyes on the fibre surface. A boundary layer forms on the fibre surface, through which the dye molecule must diffuse. The rate of the dye transfer through the boundary layer depends on the diffusion coefficient, the fibre surface, and the change in the chemical potential in this process. The same applies analogously for diffusion of dye in the interior of the fibre.

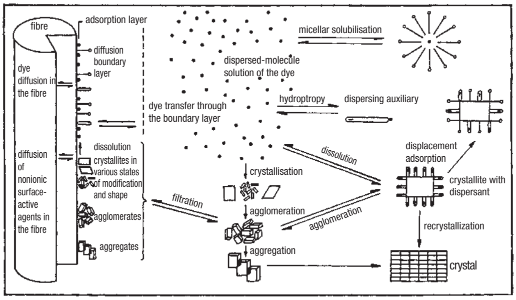


Fig.: Model of a disperse dyeing system (source: Schollmeyer).

Assuming that the transfer of the dye molecules through the solution itself is not the step which determines the speed, the diffusion of the dye into the fibre shows itself to be the slowest sub-process. In the polymer/water/disperse dye system, there must be a sufficiently large free volume present. For this reason, the mobility of the polymer chains determines the rate of the diffusion. To increase the diffusion rate, carriers are often added to the aqueous dyeing liquor. They act as plasticizers in a similar way to solvent molecules, i.e. they increase the free volume of the system. Both the solubility of the dye and the kinetics of the dyeing process are increased by higher temperatures. However, problems arise with the dispersion stability. Thus for example recrystallization processes become more likely, and above the cloud temperature characteristic of a particular tenside, an additional tenside phase forms besides the aqueous phase.

In order to achieve high bath exhaustion, the distribution of the dye between fibre and bath must be in favour of the fibre. In equilibrium, the distribution coefficient $K = c_F/c_L$, where c_F is the concentration of the dye in the fibre, and c_L is the concentration in the solution. Since the solubility of disperse dye in aqueous solution is very low, one thus obtains a suitable equilibrium. Other known dyeing systems have used organic solvents instead of water. This causes considerable acceleration of the dyeing process. As a solvent, predominantly tetrachloroethene has been used, in which dispersion dyes have good solubility. Moreover, its evaporation enthalpy is considerably lower than that of water, which is of economic significance for the drying process after dyeing. However, the bath exhaustion when using tetrachloroethene is unsatisfactory (source: Schollmeyer).

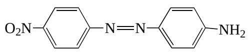
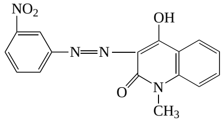
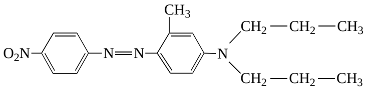
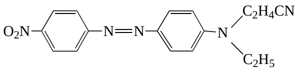
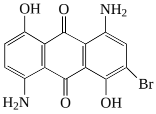
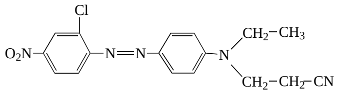
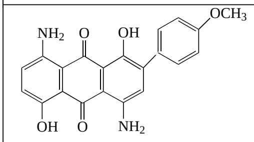
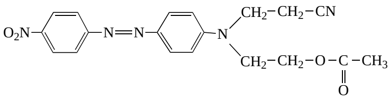
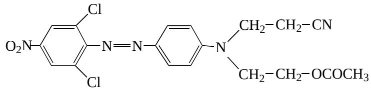
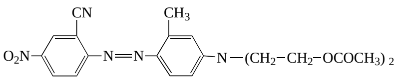
Disperse dye parameters for suitability in heat transfer printing These parameters are used to characterize disperse dyes under standard conditions for their suitability in heat transfer printing. The parameters for this purpose are →: Equilibrium yield; Standard time t_{70}.

Disperse dyes Dyes with extremely low solubility in water which, in a finely dispersed state, are used for dyeing polyester, acetate, triacetate, polyamide, polyacrylonitrile, modacrylic and polyvinyl chloride fibres. Both azo and anthraquinone disperse dyes can differ considerably in molecular weight (see Table).

Since the majority of synthetic fibres do not possess any ionic groups, they cannot be dyed by an ionic mechanism as is the case with e.g. acid, metal-complex or cationic dyes. These synthetic fibres can only be dyed with non-ionic dyes (= disperse dyes) which are practically insoluble in cold water due to the absence of any solubilizing groups in the molecule. Disperse dyes are applied in the form of fine aqueous → Dispersions (→ disperse dyeing systems). The size of the dispersed dye particles is in the region of approx. 0,5–1 µm. Because of their hydrophobic character, disperse dyes have an affinity for the likewise hydrophobic synthetic fibres. The dye particles are able to penetrate the fibre during dyeing in a molecularly dispersed state and are held in the fibre in this form. Disperse dyes are produced with various chemical structures. The two main classes are the azo and anthraquinone dyes. Azo disperse dyes contain relatively unstable azo linkages in the molecule so that the sensitivity to reduction of these dyes must be taken into consideration. Anthraquinone disperse dyes have more stable structures and a smaller molecular size which gives them greater mobility. The solubility of disperse dyes in cold water is very limited (only a few mg/l). Solubility rises rapidly with increasing temperature, however, and some dyes can achieve a solubility of 100 mg/l at dyeing temperature. As alternatives to the azo or anthraquinone disperse dyes, a small number of dyes with very different chemical structures exist which, in most cases, produce more brilliant shades.

Important parameters for disperse dyes are:

1. Sublimation fastness: a property specific to this class of dyes which is evaluated by the behaviour of

dye structural formula	relative molecular weight
	242
	324
	344
	347
	349
	358
	376
	416
	451
	453

Tab.: Summary of various disperse dyes (azo and anthraquinone forms), arranged according to molecular weight.

the dye on transition from the solid to the gaseous state. Sublimation problems can arise during dye fixation (thermosol process, steaming) or during thermal treatments of the dyed material.

2. Thermomigration: the fastness properties of a disperse dyeing can be impaired by certain finishes or preparations applied to the fibre. The effect of heat as well as prolonged storage of dyed goods can cause thermomigration.

The dyeing process between dye and synthetic fibre can be described as a process of solution whereby the dye dissolves in the fibre. The fibre therefore acts as a solid solvent for the dye (solid solution). However, in order for the dye to migrate more easily into the fibre interior it must be present in a monomolecular form; → Dispersing agents are employed in practice to assist this process.

Disperse dyes, diazo → Disperse dyes.

Disperse dyes, diazotizable Disperse dyes which can be diazotized and developed on the fibre. → Disperse dyes.

Disperse dyes, dyeing methods Synthetic fibres (especially polyester, which is the most important fibre for disperse dyes) are difficult to dye because of their high cohesion forces and high degree of orientation. For this reason, dyeing conditions must be selected which promote a loosening of the fibre structure in order to allow easier uptake of dye. The dyeing methods are subdivided into:

I. Exhaust methods: these involve exhaustion of the dispersed dye from the dyebath on to the fibre.

II. Continuous methods: in this case, the dye is applied to the fibre mechanically after which it diffuses into the fibre during a thermal treatment.

Continuous methods are subdivided into:

1. Thermosol process: the dye is applied to the fibre mechanically with water acting as a transport medium. The water is then removed by drying (approx. 1 min. at 200–220°C). The fibre becomes thermoplastic in this temperature range which facilitates diffusion of dye into the fibre.
2. Steam fixation: satisfactory results are not achieved by steaming in saturated steam at 100°C. Pressure steaming at 130°C gives relatively good fixation whilst superheated steam, which finds wide application in the fixation of printed disperse dyes, is only used on a small scale in continuous dyeing.

Examples of dyeing methods:

a) Dyeing at the boil: this dyeing method should be avoided whenever possible as it suffers from many disadvantages. In some cases, e.g. deep shades, very high carrier additions are used to obtain good results (problems of waste water and exhaust air pollution). The process also has disadvantages with regard to costs and the levelling of fibres which exhibit inherent differences in affinity compared to dyeing under HT conditions. Dyeing at the boil is carried out on atmospheric winch dyeing machines, atmospheric overflow machines or jets, and jig dyeing machines.

b) Dyeing under HT conditions (130°C): polyester piece goods are mostly dyed by this method. Suitable dyeing machines include: HT winches, HT jiggers, HT beam dyeing machines, jets and overflow machines. Additions of appropriate auxiliaries for the prevention of running creases as well as the dyeing of material that has already been heat-set are recommended measures.

c) Aftertreatment: After dyeing, the dyed fabric is subjected to an aftertreatment (in some cases a reductive clear aftertreatment is necessary) to improve colour fastness properties.

Exhaust dyeing with disperse dyes proceeds through the following stages: Stage A: movement of individual dye molecules at the molecular level due to thermal influences; Stage B: dye molecules are captured in the adsorption zone of the polyester fibre surface; Stage C: transport or migration of adsorbed dye molecules into the fibre interior. Stages A and C represent the bottlenecks of the dyeing process. Dye solubility plays a decisive role here and can be improved by chemical additions and rising temperature (see Fig.). Suitable chemicals for this purpose are, e.g. carriers.

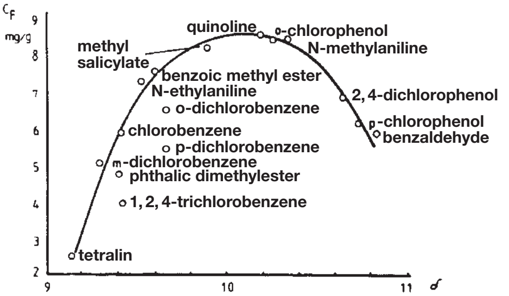


Fig: Disperse dye take-up (ordinate) relative to the solubility parameter (abscissa) of the added dye accelerator (Flath).

Disperse dye sensitivity Certain disperse dyes contain substituent groups in the molecule that are sensitive to hydrolysis. These substituents can be split off from the dye molecule by changes in pH of the dye liquor (Fig. 1). In general, marked deviations in the shade, exhaustion and fastness properties of the hydrolyzed dye in comparison with the original dye are observed.

Other disperse dyes can form metal-complex compounds with heavy metal ions, e.g. iron or copper ions, which again exhibit deviations in shade and dyeing properties. Calcium or magnesium ions can cause colour changes in the dyeings of numerous anthraquinone red dyes towards violet on drying.

Finally, changes can also occur in azo disperse dyes during dyeing due to substances with reducing properties. Under unfavourable conditions, azo disperse dyes can be broken down in the dyebath to yellow or colourless amines. Reducing agents responsible for such effects are size residues, cellulosic fibres, cysteine in wool, or certain dispersing agents (e.g. pyrocatechol groups in lignin sulphonates and sulphite-containing naphthalene sulphonic acid condensation products), see Fig. 2.

Sensitivity to pH, heavy metals, and reducing agents can seriously impair the reproducibility of HT-

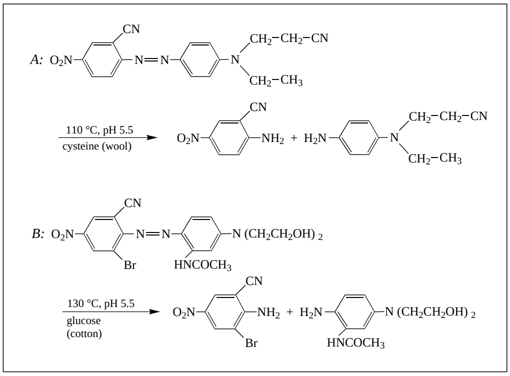


Fig. 2: Disperse dye reduction in the dyebath: the amines resulting from A and B do not dye polyester, or only dye it a weak yellowish shade.

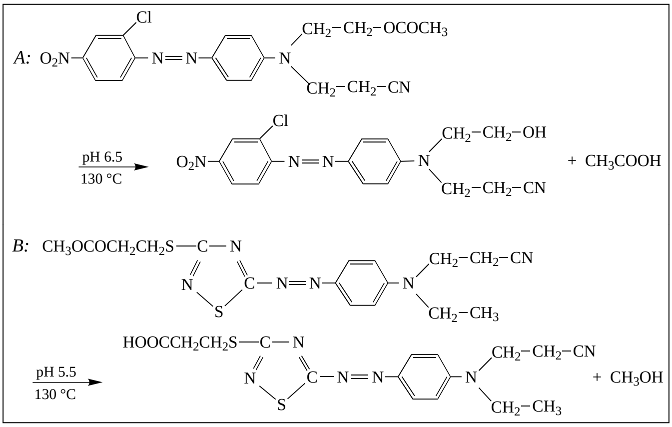


Fig. 1: Disperse dye hydrolysis in the dyebath.
A: The hydrolysed dye gives bluer red dyeings than the esterified on polyester.
B: The hydrolized dye dyes polyester only a little.

dyeings. In the optimization of HT-dyeing programs, therefore, highly sensitive disperse dyes should be avoided from the outset.

Disperse dyes in textile printing,

I. Printing on polyester: suitable thickeners include locust bean gum derivatives, guar derivatives and alginates or half-emulsions. Since a number of disperse dyes are sensitive to alkalis, the pH of the print pastes must be adjusted on the weakly acidic side by the addition of a non-volatile acid such as tartaric, citric, lactic or glycollic acid. The addition of a fixation accelerator is beneficial for the achievement of good colour yields if fixation of the prints is carried out by the thermosol or HT-steam process. In the case of half-emulsion thickeners, no addition of fixation accelerator is necessary. Print pastes are prepared by the stock paste method (strewing-in method) so that disperse dyes in powder or liquid form may be used as desired. After printing and drying, colour fixation can be achieved in 3 ways: a) by pressure steaming (20–30 min at 1,5–2,0 bar); b) by thermosol treatment (45–60 sec. at 190–200°C) or; c) by HT-steam (6–8 min at 160–180°C). Careful selection must be paid to dye selection (sublimation fastness) and thickener selection (hardening problems) when fixation is carried out by the thermosol and HT-steam methods. After fixation, the prints are first given a cold reduction clear treatment in a bath containing sodium dithionite, caustic soda and washing agent, which is repeated again at 60–70°C, followed by rinsing, neutralizing if necessary, and drying.

II. Printing on triacetate: print paste composition and choice of thickener as for polyester. However, unlike polyester printing, the print pastes must contain an addition of fixation accelerator, even in the case of half-emulsion thickeners if fixation is carried out with HT-steam.

After printing and drying, two methods can be used for colour fixation: a) by pressure steaming (20–30 min at 1,0–1,5 bar); b) by HT-steam (8 min at 180°C). After fixation, the prints are first given a cold reduction clear treatment in a bath containing sodium dithionite, caustic soda and washing agent, which is repeated again at 50–60°C, followed by rinsing, neutralizing if necessary and drying.

III. Printing on acetate: print paste composition and choice of thickener as for polyester. An addition of 50 g/kg urea can also be made to the print pastes. After printing and drying, colour fixation is achieved by steaming in the star steamer for 20–30 min at 0,2 bar, after which the prints are given a thorough cold rinse and dried.

IV. Printing on polyamide: seldom used due to inadequate colour fastness in most cases.

V. Printing on polyacrylonitrile: disperse dyes are generally only used for areas of large coverage where levelling problems may otherwise be encountered, or to obtain sharp outlines. They are also used for the production of light beige or olive shades which are difficult to obtain with good reproducibility if cationic dyes are used. Print pastes contain thickener, water, glycerol, tartaric acid and dyestuff. The prints are fixed by steaming in the star steamer for 20–30 min at 0,3–0,5 bar, after which they are rinsed, soaped or given a reduction clear treatment, rinsed and dried.

VI. Printing on polyester/cellulose blends: combinations of disperse and reactive dyes are used; the print pastes contain thickener (alginate or half-emulsion), urea, solubilizing agent, sodium bicarbonate and dyestuffs. Colour fixation is achieved either by a thermosol treatment (1 min at 200 C) or by HT-steam (8 min at 170°C), followed by afterwashing and drying.

VII. Printing on polyester/wool blends: combinations of disperse and acid or metal-complex dyes are used. The print pastes contain thickener, glycerol, water, acetic acid, carrier and dyestuffs. Colour fixation is achieved by steaming for 30 min at 1 bar, followed by thorough cold rinsing, soaping at 50–55°C, rinsing and drying.

Disperse dye solubility The solubility of disperse dyes in water is low at room temperature but there are two explanations for this in the case of azo dyes:

1. The azo group forms hydrogen bonds with water clusters (Fig.)
2. Entropy is achieved when parts of the water's iceberg structure are broken down; however, larger cluster areas can develop hydrophobic reactions with the benzene rings in the disperse dyes and dissolve them in this way. This effect is counteracted by the hydrophobic reactions between the dyes themselves (agglomeration), which can be reduced by adding urea, which is the reason why urea increases the solubility of dispersion dyes in water.

In order to understand how a → Disperse dyeing system model consisting of fibre, water and dye works in different states, with different emulsifying agents and level agents and with differing amounts of acetic acid for

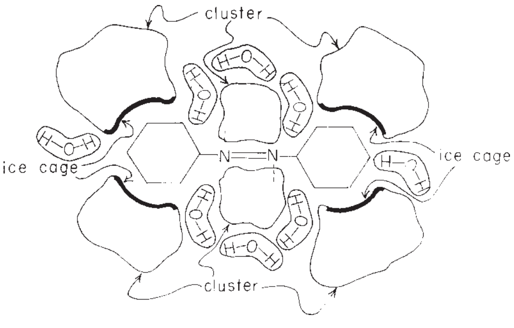


Fig.: Model representation of the solubility of dispersion dyes in water (contributed by Kimura).

adjusting the pH, it is important to provide evidence concerning the state of the disperse dye in the solution. In the dispersion phase the dye is added to the dye bath, which produces a low concentration dispersed molecule dye solution by means of a dissolving process. The stability of the crystallite is caused by adsorption of the dispersing agent, whereby the proportion of dispersed molecules is increased in the presence of anionic dispersing agents by the hydrotropic change effect. Levelling agents (usually non-ionogenic tensides) lead to increased dye solubility, which can be explained by the concept of micellar solubilisation: because of the differing solubility, dispersed molecule disperse dye is dissolved in the hydrophobic part of the micelle below the clouding temperature, whereas phase separation occurs above it. Displacement adsorption of the tensides on the crystal surface must also be taken into consideration, which usually reduces dispersion stability. Due to recrystallisation, either the larger crystallite will grow to the detriment of the smaller one, or crystal growth will occur in the oversaturated dispersed molecule master phase. Furthermore, agglomerates and aggregates occur, which can cake into a low-defect crystal.

Solubility is low, being between 2 and 100 mg/l at 130°C for pure dyes and increasing when dispersing agent is added. The dispersing agent molecules (condensation products or lignine sulphonates) are deposited on the dye particles because of π electron reactions, dispersion force and hydrophobic reactions. Anionic dispersing agents create a negative potential which leads to mutual repulsion of particles. Solvate coatings may be regarded as an effective stabilisation factor for non-ionogenic dispersing agents. The following mechanisms may become effective:

a) Increased osmotic pressure because of the local concentration increase occurring because of the convergence of two particles;
b) Volume limitation, i.e. the number of sorbed dispersing agent chain conformations is restricted because of reciprocal penetration of the solvate coatings.

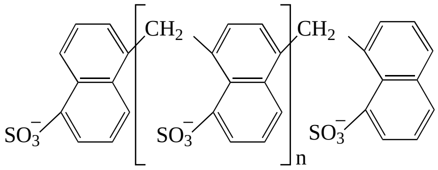
The dispersing agent molecules are approximately the same size as the dye molecules. If we assume that deposition does not just take place on the dye aggregates but (as shown by the increased solubility) also on the individual molecules, we can imagine how the intermolecular reactions work: the aromatic rings of dye and dispersing agent arrange themselves plane-parallel on top of each other, meaning that there is space for a dispersing agent molecule above and below the dye molecule, which is held by the strong π electron reactions and polar forces. It is understandable that dispersing agent molecules are displaced during sorption to the polymer, since the dispersing agent is more soluble in water.

Disperse phase The discontinuous phase of a → Dispersion.

Dispersing agents are products which promote the formation of a → Dispersion (→ Dispersants). Textile auxiliaries used as dispersing agents serve the purpose of bringing insoluble or virtually insoluble dyes into a form which makes them readily dispersible in water and keeping the dispersion stable throughout the entire application process. Dye dispersions can therefore be considered as examples of colloidal dispersions.

Typical dispersing agents include:

1. Lignin sulphonates (can have a reducing action).
2. Modified caseins (readily biodegradable, but expensive).
3. Formaldehyde-naphthalene sulphonic acid condensates (cresol is often co-condensed in such products which leads to the presence of phenol in waste waters).



Dispersing agents traditionally contain proportions of reducing agents as constituents which can have an adverse effect on disperse dyes that are sensitive to reduction.

Dispersing power The efficacy of a product's capacity to form a → dispersion.

Dispersion,

I. (suspension). A two-phase system where one phase consists of finely divided particles (often in the colloidal size range) distributed throughout a bulk substance, the particles being the → Disperse phase (internal phase) and the bulk substance the continuous phase (external phase or → Dispersion medium). In general, the finely divided distribution of a substance (e.g. dye) in an aqueous medium. → Dispersion, degree of.

II. Collective term for the variability characteristics of a feature. Measures are e.g. → Variance, → Standard deviation and range.

Dispersion colloids → Colloids.

Dispersion, degree of → Dispersivity.

Dispersion forces → Secondary valency forces.

Dispersion medium, continuous → Phase of a → Dispersion.

Dispersions for coating Considerable demands are made of the stability of the plastic dispersions used for coating the backs of carpets, which essentially relate to shear and storage stability (Fig. 1). A considerable amount of shearing force occurs when filler materials are mixed in, and also occurs beneath the doctor

Dispersions for coating

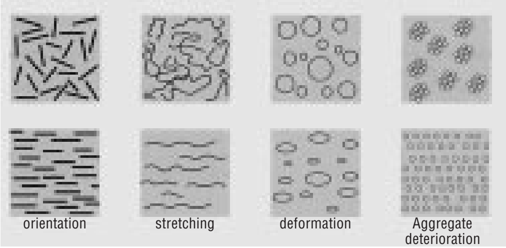


Fig. 1: Structural relationships in a dispersion in a quiescent state (top) and under shearing stress (bottom).

blade. The storage stability of plastic dispersions depends on the thickness of the particles. Sedimentation and creaming can occur after a long standing period. This does not indicate that a dispersion is unstable, provided that the particles can be redispersed. Electrolyte additives and lowering the pH considerably reduce the stability of the dispersion. Behaviour in the presence of fillers and pigments depends on their surface structure. A plastic dispersion can coagulate slowly or immediately by adsorbing the emulsifying agent on the surface of the fillers. Emulsifying agent migration ceases to occur if enough emulsifying agent is present. Dispersions often tend to coagulate when dry pigments or fillers are added. Help can be obtained by using appropriate polyphospates, ionogenic or non-ionogenic wetting agents or protective colloids. The pigment compatibility of plastics dispersions is improved by polymerising monomers with hydrophilic groups.

Perfect tuft anchorage is also dependent on the film-forming characteristics of the polymer dispersions when coating the backs of carpets. When dispersions are being processed the film formation temperature must be maintained, otherwise no film will form but a brittle, inconsistent layer. Too much humidity also prevents film formation when drying. Air bubbles, which can occur when the dispersions are applied, are undesirable. If they cannot escape during the drying phase they either cause large cavities in the surface or remain in the film as bubbles. The defective areas reduce both the mechanical strength and the extensibility of the material. Consistent pigment distribution is extremely important when processing dispersions, since it determines the evenness of the film coating and therefore affects the strength thereof.

The adhesive strength of the films differs on the various substrates. It can be improved (e.g. on leather, wood, textiles, paper) by using hydrophilic groups (–COOH; –C≡N; –COH; –CONH$_2$) incorporated by polymerization.

Surface tension is low in most dispersions because of the presence of emulsifying agent. However, if there are problems with the wetting capability of a substrate, the addition of more surface-active substances will reduce the surface tension even more. Unfortunately, dispersions with a high proportion of wetting agent tend to foam. In primary coating this would result in too little base coating being applied during slop padding, which means that the film would be extremely defective and the carpet yarn would not be correctly bedded in because of the increased viscosity.

Natural latex (Fig. 2) from the hevea rubber tree is a colloid system that has water as the liquid phase, which has organic and inorganic substances dissolved in it. The solid phase is rubber with a particle size of 0.5 µm. The rubber absorbs the anionic substances on the surface, which are in equal proportion to the positively loaded ions and represent an electrically neutral colloid system to the outside. The iso-electric range of this system lies at a pH of 4.8 to 5.1. For this reason, natural latex is preserved using ammonia in order to prevent coagulation. Protein in the latex acts as a natural stabiliser. Natural latex is concentrated by means of condensation, centrifuging, creaming or electrodecantation. During purification rubber approaches the element composition of $(C_5H_8)_n$, which represents cis-1.4 polyisoprene. Natural rubber has many applications.

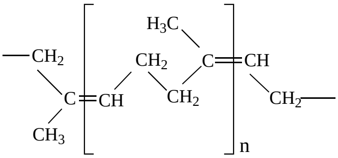


Fig. 2: Natural latex.

Most synthetic latices (Figs. 3–5) are manufactured using emulsion polymerisation. Their particle size is relatively constant for the individual products. Depending on the type, it varies between 0.03 and 2.0 µm. The application area of synthetic latices cannot be called universal. The product is often one which has been designed for a special purpose.

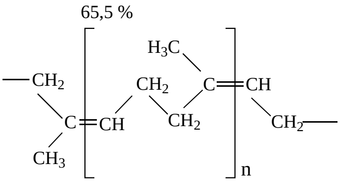


Fig. 3: Polyisoprene latex with fatty acid emulsifying agent. Solid content 65.5%. Application: oil-resistant submersible articles.

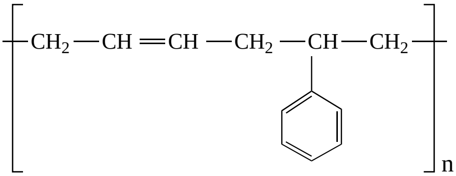


Fig. 4: Polybutadene styrol latex with fatty acid emulsifying agent, solid content 66–68%. Application: carpet foam application.

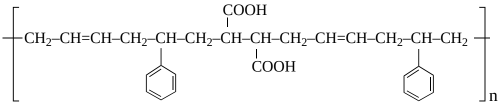


Fig. 5: Polybutadene styrol latex with fatty acid emulsifying agent, solid content 66–68%. Application: carpet foam application.

Dispersions in finishing The use of polymer "liquid plastics" offers considerable advantages. The production process using monomer building blocks leads to environmentally friendly products for which textile applications are found. Application areas are to be found in all areas of the textiles, non-wovens, carpet, wallpaper and textile glass fibre industries. Technical textiles in particular have attained growing importance from the point of view of textile finishing. These are woven materials, pile textiles, knit fabrics, non-woven fabrics, textile laminates, the use of which extends beyond the classic application areas of clothing, household, linen, furnishing fabrics, upholstery fabrics, carpets. The fundamental principle of the application of dispersions is: a) Apply dispersions to substrate (by dipping, kiss rolling, spraying, foaming, doctor coating, coating/spreading, bonding, laminating, printing; b) Drying/condensing. Dispersions can be used with other dispersions (latices), resins, pigment dyes, filling substances, water repellents, antistatic agents, foaming agents, thickeners, stabilisers, defoaming agents etc.

Textile use of dispersions:

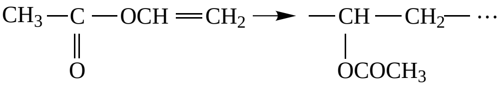
- Clothing: a) finishing of woven fabrics and knit fabrics, corduroy, velvet, Wildman plush, sports shoe uppers; b) modification of handle, proofing; as additive in resin finishing; c) non-woven: quilting in anoraks, coats, interlining materials, shoe inners, synthetic leather for clothing; d) coated textiles, rain wear.
- Hygiene, medicine, foodstuffs (non-wovens): quilting, tampons, nappies, incontinence pads, sanitary towels, milk filters, surgical products.
- Household, leisure, sport: a) modification of handle, proofing, down-proof finish; b) bed linen, table linen, curtains; c) non-wovens: cleaning cloths, table cloths, quilting in bedclothes; d) textile floor coverings: woven and tufted carpets (backings), needlefelts, sports mats, tennis mats, outdoor mattings; adhesive bonded structures; e) coated textiles: roller blinds, vertical blinds, table cloths, tent fabrics, sails, upholstery cover fabrics, flocked materials, textile wall coverings.
- Cars, aviation, railway: a) moulded textiles: carpets, needlefelts, bonded non-woven fabric waste; b) coated textiles: seat covers.
- Technical textiles: a) slick finish: glass fibre facing; b) non-wovens: non-woven filter fabrics, roof liners (polyester spun-bonded, glass fibres), soundproofing mats, non-woven coverings for cracked walls, polyester non-wovens, electrical insulations; c) finishing: glass fibre scrim interlinings, fishing nets, sailcloth; d) coated textiles: tarpaulins, canvas; e) laminates: non-woven/films etc.; f) geo-textiles.

Special finishes, such as e.g. antistatic, oil repellent, water repellent, gloss, play an important role in technical textiles too. They are also included in coloration (printing, dyeing). Dyeing auxiliaries are thus used. Frequently, an external textile finish and a textile handle are required. Since the method for producing technical textiles depends on special additives such as foamers, de-foamers, catalysts, stabilisers (additives), corresponding processing expertise is necessary. The quality control of technical textiles too is predominantly oriented on textile test methods.

For the sake of clarity, one can classify textile dispersions not only according to application areas, but one must also do so according to chemical composition and according to physical features or performance properties. Hoechst plastics dispersions, for example, are classified by chemical composition and glass transition temperature. At the same time, associated with this is an empirical classification of the dispersions according to their hydrophobic or hydrophilic actions. For orientation purposes evaluation is carried out after application and drying/condensation of the dispersions on viscose fibre non-woven fabric, with the capillary rise of water and the spread of a drop of water serving as a measure. A low capillary rise and a drop of water remaining for over 1 minute results in classification as "hydrophobic", whilst rapid wetting results in classification as "hydrophilic".

The glass transition temperature (T_G) is the temperature of the transition range of a polymer from hard glass state into the elastic state. A flexible film of a polymer dispersion becomes hard at the glass transition temperature, and breaks. T_G relates to a polymer or to the film of a dispersion, and not to the dispersion itself, which is a system of polymer, water and emulsifier/protective colloid; for example, films of pure polyvinyl acetate dispersions lie at T_G = 29°C/30°C; such a film breaks at room temperature; very soft films lie at T_G = < –0°C; in this range also are non-woven bonding agents for the impregnation process; contact adhesive laminating bonding agents lie at –30°C. In comparison with that: polyvinyl alcohol approx. 70°C, standard polyesters approx. 80°C, without fracture being observed in the stretched filament form. T_G is lowered by plasticizers; in the case of polyvinyl acetate from 29°C to –3°C with approx. 25% dibutyl phthalate, and to –21°C with 50%, in both cases related to the polyvinyl acetate content of the dispersion. Also through the co-polymerisation of vinyl acetate with maleic acid di-n-butyl ester or with butyl acrylate, dispersions are produced which form films with lower glass transition temperatures than those of the base-monomer vinyl acetate.

Textile dispersions are produced in water through polymerisation of monomers, polymerisable chemical compounds, such as e.g. vinyl acetate.



$$CH_3-\underset{\underset{O}{\|}}{C}-OCH=CH_2 \longrightarrow -\underset{\underset{OCOCH_3}{|}}{CH}-CH_2-\cdots$$

Without additions of emulsifiers or protective colloids, most monomers would dissolve in water only with difficulty. A polymerisation process can, however, take place; the polymer would be omitted and no viable dispersion would be produced. By adding selected emulsifiers or protective colloids, a viable dispersion can be produced. Thus the polymerisable substance is mixed by stirring with emulsifiers and/or protective colloids to form an emulsion, is dispersed and polymerised in emulsified form to fine solid particles or to aqueous solution. The type and amount of emulsifiers and protective colloids and the combination of various polymerisable substances mean that there is a wide variety of dispersions with different performance. Fine dispersion of the polymer particles, and the resultant high light scatter impart to the dispersion a milky-white appearance. Despite the emulsifiers and protective colloids, a dispersion remains an unstable structure. There is limited thermal stability anyway. Dispersions are not stable above 75°C. They coagulate by that point at the latest. Many dispersions are not compatible with salts, acids or lyes. Paraffin-based cationic water repellents often cause precipitation; albeit not in the case of certain non-ionic dispersions containing protective colloids. But the non-ionic character does not in every case mean stability to cationic products. Other stability factors such as emulsifier content and combination of emulsifiers play a part. Suitable protective colloids in textile dispersions include e.g. polyvinyl alcohol or cellulose ether.

An index less suitable for the systematic characterisation of polymer dispersions for the textile sector is the minimum film formation temperature (MFT). At a

Dispersion/ polymer of	Ionic character	Degree of dispersion	Film at room temperature	Glass transition temperature (T_G) °C	Min. film formation temperature, °C
vinyl acetate	n	coarse	hard, fractures easily	+ 29	15
	a	fine	hard, fractures easily	+ 29	15
	n	medium	hard, fractures easily	+ 29	17
vinyl acetate/	n	coarse	soft	- 3	0
ext. plasticizer	n	coarse	very soft, flexible	- 21	0
vinyl acetate/	n	medium	firm, elastic	+ 16	12
dibutyl maleinate	n	medium	viscoplastic	+ 10	5
	n	medium	soft	+ 3	0
vinyl acetate/	n	fine	soft, flexible	+ 7	10
ethylene	n	medium	soft, flexible	- 5	0
	a	fine	very soft, flexible	- 20	2
	n	medium	very soft, strongly adhesive	- 30	0
vinyl acetate/	a	fine	hard, fractures easily	30	11
acrylic ester	a	fine	soft, very tough	15	8
	a	fine	soft, flexible	- 9	9
	a	fine	very soft, flexible	- 18	9
acrylic ester	a	fine	soft, tough	13	10
	a	fine	soft, tough	4	9
	a	fine	soft, flexible	- 15	8
	a	fine	very soft, flexible	- 25	8
acrylic ester/	a	fine	hard, fractures easily	+ 45	approx. 70*
styrene	a	fine	soft, flexible	- 12	0

* A film, also clear and transparent at room temperature, is produced after temperature treatment above 70°C.

Tab. 1: Characteristics of dispersions.
(Particle size: fine = 0.07–0.5 μm; medium = 0.07–5 μm; coarse = 0.5–5 μm, mostly 1–3 μm) (source: Fischer).

particular temperature, a polymer dispersion dries to a transparent or translucent continuous film. Below this temperature, a white membrane forms (white point). If for example a white point temperature of approx. 15°C is quoted for a dispersion, then this dispersion, if spread and allowed to dry on a glass plate at ≥ 16°C, will form a clear, continuous film. If drying on occurs at ≤ 15°C, on the other hand, a white inhomogeneous membrane forms. The softer the film of a dispersion is, the lower the white point temperature or the MFT. Through additions of plasticizers, solvents, as well as acetic acid etc., the MFT is lowered, thus e.g. in the case of a vinyl acetate/homopolymer dispersion from +15°C via 23% glycol acid butyl ester to +3°C. Dispersions containing protective colloids are medium or coarsely disperse, and those produced with tensides are mostly finely disperse. Particle size and particle distribution critically determine, together with the emulsifier system, the performance characteristics of a dispersion, such as e.g. the viscosity. Coarsely disperse dispersions sediment when diluted liquors are left to stand (source: Fischer).

In terms of their properties (Tab. 1), high-polymers are characterised by their primary components (monomers) and the type and course of the polyreactions. One characteristic is the degree of polymerisation, or the average degree of polymerisation (DP). In the case of high-polymers, the mean molecular weight is quoted as a rule for the sake of better comparability; generally it lies at 20 000–200 000. Also important for the properties of the high-polymers are reactivity and particle size, insofar as dispersions are involved. In the case of reactivity, as a rule one is dealing with one or more of the 5 reactive groups shown in Fig. 1.

These reactive groups enable high-polymers to react with the fibre, and/or to react on the fibre (with itself or with other compounds). The particle size is naturally only important in the case of dispersions (whether they are emulsions or suspensions) although, influenced by drying and other thermal processes, it is to a large extent responsible for the distribution of the high-polymer on the fibre surface. This distribution has a strong influence on the physical or physico-chemical binding forces, and thus on the permanence of the bond. The physical influence on the permanence is, as a rule, even more important than the influence which derives from the usually somewhat limited chemical reactivity.

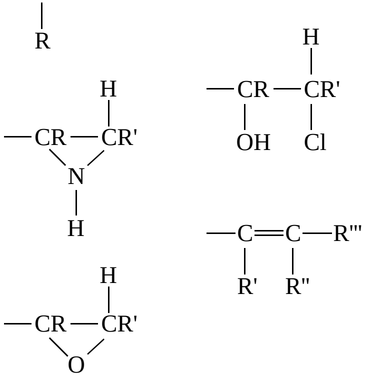


Fig. 1: Reactive groups in the case of additives.

The following polymers are important in resin finishing (source: Schlüter):

I. Polyacrylates: The versatility of acrylate chemistry is mainly provided by a broad spectrum of monomer primary products. Beyond that, the technical variation possibilities in the polymerisation have a decisive influence on the characteristics of high-polymers, their specific attributes in processing, and their quality on the textile goods. Film hardness or film softness show a clear dependence on the glass transition point of the respective homopolymer. The hydrophobic or hydrophilic character of the selected monomers is reflected, in equivalent amounts, in the high-polymer.

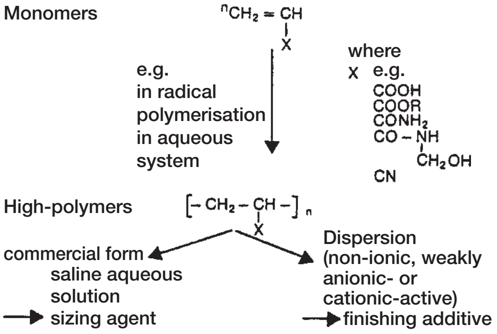


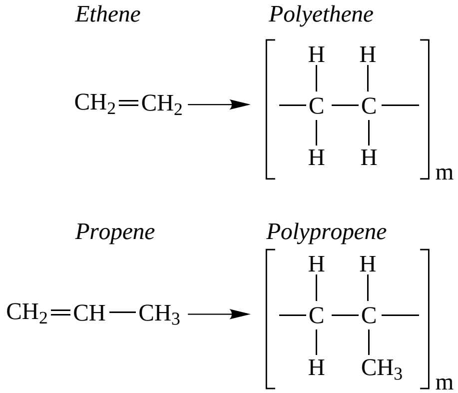
Fig. 2: Composition of polyacrylates.

Fig. 2 shows the schematic sequence of the polymerisation process which, using monomers containing double bonds, produces polyacrylates. Here, the selection of monomers and control of the reaction are of vital importance to the “make-up” of the polyacrylate. Saline aqueous solution is chosen, for example, for use as sizing agent. When used as a resin finishing additive, for processing reasons (higher concentration, lower viscosity), dispersions are usually preferred. Of course dispersions can display sensitivity to shearing forces (hardness of the padding rollers, goods running speed). However, there are also auxiliaries which ensure perfect processing even under extreme operational conditions.

II. Polyolefins:

Polyolefins derived from (α) olefin

$C_n H_{2n} \longrightarrow [C_n H_{2n}]_m$



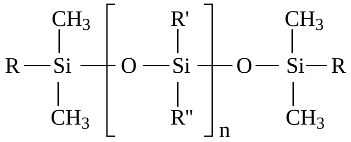
Polyolefins are obtained through the polymerisation of unsaturated hydrocarbons. To date, it has not yet been possible to achieve, with technically assured reproducibility, the manufacture of polypropene dispersions (neither primary nor secondary dispersions) with such qualities as would be suitable for the requirements of the textile industry. In the case of polyethene too, a distinction is made between primary and secondary dispersions (Tab. 2). Polyethene primary dispersions occur at high temperatures (> 200°C) and under high pressure (300 bar), in that ethene is caused to react in an aqueous solution containing catalysts and emulsifiers. The polymer results directly in emulsion form. In the case of polyethene secondary dispersions, one starts from a block polymer which has been rendered into a wax form through oxidation and hydration. The melted wax is stirred into a concentrated emulsifier solution, through which the secondary dispersion occurs.

	Primary disp.	Secondary dispersions	
Solids content [%]	40	35	25 - 40
Emulsifier content rel. to solids in %	7,5	25	25
Softening range [° C]	109 - 112	130 - 135	< 90
Mean molar weight	30 000	100 - 150 000	3500 - 4000
Preferred application area	Standard additive; sewability, bulk, good permanence	Speciality product for highest standards of sewability, handle, permanence	Economical products for good sewability and smoothness

Tab. 2: Properties of primary and secondary dispersions of polyethene.

An improvement in the sewing characteristics is apparent in all fibre types. Besides that, material containing cellulose fibre is noted as having fibre-protecting effects, e.g. improvement in the tearing resistance and abrasion resistance, shown to best advantage in easy-care polyethene products.

III. Polysiloxanes: For some considerable time now, silicon dispersions have been enjoying a special importance in the field of high-grade water-repellent finish. With siloxane chemistry, quite different opportunities are opening up (Fig. 3). It has revitalized and updated resin finishing of all types of woven fabrics and knit fabrics.



R = $-CH_3$, $-OH$

R' = $-CH_3$, $-H$, $-OH$

R'' = $-NH_2$, $-CH_3$, $-H$, $-OH$

Fig. 3: Diversity of polysiloxane structures.

The versatility is characterised by the diversity of the available options. Products with ethoxylated or oxpropylated substituents, which are water soluble, are suggested current options. Polysiloxanes have many functions:

- soft, lively handle,
- positive influence on the abrasion and tearing resistance,
- improvement in the crease recovery in woven fabrics,
- improvement in the bursting strength in knits,
- improvement in sewing properties,
- favourable behaviour in relation to dyeing and printing.

Polysiloxane dispersions are not without problems with respect to shear stability; however, this can be improved by technological measures.

IV. Polyurethanes: The well-known classic primary monomers are cross-linked in a polyaddition reaction. One thus produces polyether urethanes. If one first converts the diols with dicarboxylic acids (e.g. adipic acid), and allows these polyesters to react with isocyanates, then one produces polyester urethanes. There is

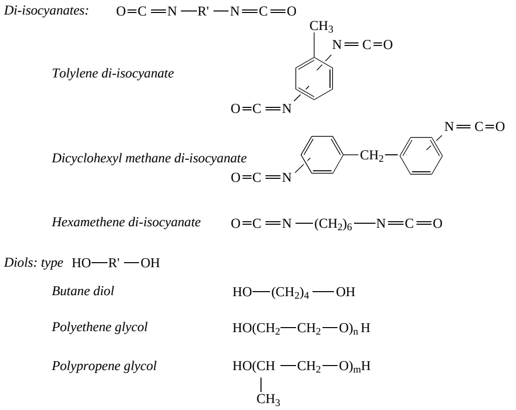


Fig. 4: Monomers for polyurethane formation.

a great variety of chemical variation options (Fig. 5): aromatic isocyanates yield cheap but light-sensitive products. Hydroaromatic or aliphatic isocyanates are more expensive, but provide a good and permanent whiteness. In simple reaction, diols yield soft, sometimes slightly tacky products. Polyalcohols lead, through spatial cross-linking, to permanent, usually somewhat harder films. Polyester types are susceptible to microbial attack, whilst polyether types are resistant to microbial attack. In resin finishing, the textile functions of polyurethanes are similar to those of the polyacrylates.

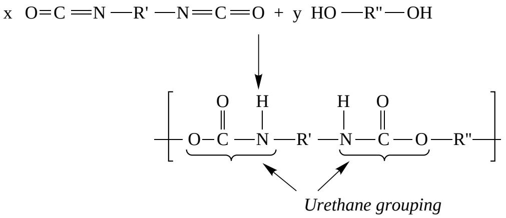


Fig. 5: Standard reaction of polyurethane formation.

Selected areas of process technology with high-polymers also include pigment dyeing, i.e. simultaneous pigment dyeing and proofing (Fig. 6). One advantage is not just the clear savings in terms of cost, but also the low effluent pollution. However, the process has limitations with regard to the depth of colour. The fastnesses depend on the quality of the high-polymer dye bonding agent and the ratio of pigment dye, bonding agent and cross-linking agent (n-methylol compound).

Dispersion stability of disperse dyes Generally applicable to the behaviour of dye dispersions in dyeing (of polyester) under dyeing conditions. Absolute dispersion stability in aqueous systems does not exist and, with regard to the dyeing mechanism, is not even desirable. However, in cases where dyeing problems arise (particularly in rapid dyeing processes and circulating liquor machines) due to filtering out, dye stains on the textile material or precipitations in dyeing vessels, the cause is often attributed to poor or inadequate

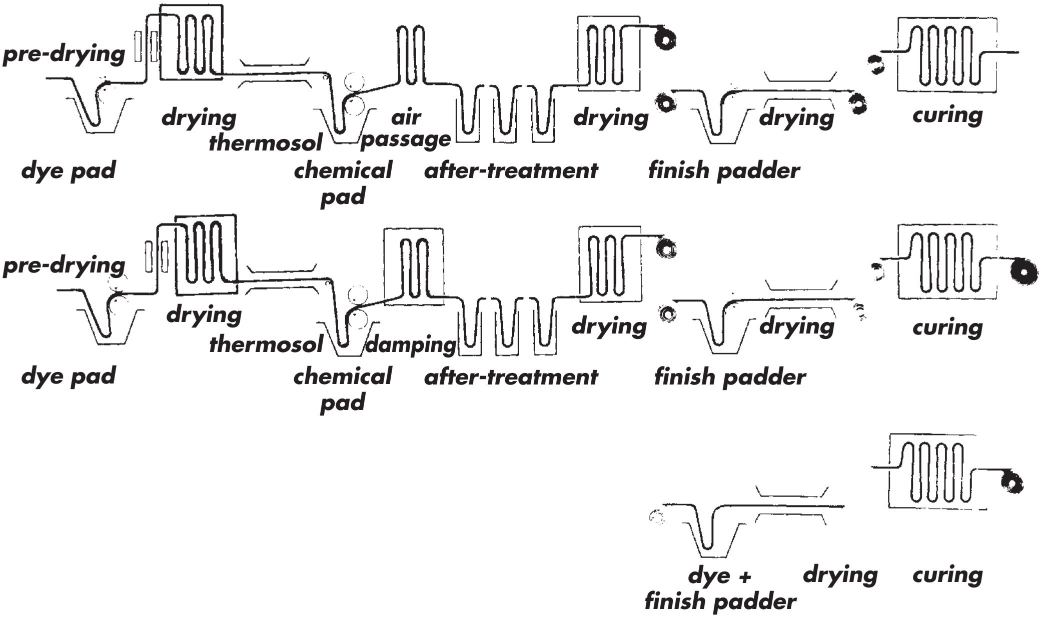


Fig. 6: Variants of simultaneous pigment dyeing and proofing.

dispersion stability. According to Ostwald's rule, dispersions are subject to continuous changes especially the tendency to change into coarser and more stable dispersions.

Dispersion instability can be due to a variety of causes: a) dyeing conditions (e.g. dispersing problems, effects of temperature); b) dyeing machinery (e.g. shear forces in pumps or jets, dye filtration problems in textile materials, liquor overheating in heat exchangers); c) liquor-dependent factors (e.g. dye concentration, non-removable preparations, carriers, levelling agents, electrolyte additions, pH variations).

Important criteria for dispersion stability: the temperature range from 60–80°C is often a critical one for disperse dyes. With additions of non-ionic products this temperature range should be passed through as quickly as possible, or the dye only added at temperatures > 80°C. Changes in the liquor flow rate can be directly related to dye levelling. For this reason, great attention should be paid to the liquor flow rate indicator/recorder during dyeing. In the case of an anomalous decrease in flow rate, an efficient levelling agent and extended final dyeing time is often beneficial.

Dispersive interaction → Adhesion.

Dispersivity (lat.: dispersio = spread), degree of dispersion of a (colloidal) substance in an aqueous solution. Dispersed phase: the dissolved or distributed substance (also known as adispersoid). Dispersion medium (also known as a dispersing agent or dispersant): the dispersant or solvent substance. Disperse system: combination of a dispersion medium and a disperse phase. The degree of dispersion can fluctuate considerably, depending on the particle size of the dispersed substance (see Table). The respective solution status is also evaluated according to the degree of dispersion: e.g. molecular solution, colloidal solution or macrodispersions (emulsions, suspensions).

In the individual disperse systems there are no strict particle size boundaries (grain or droplet sizes), but a continuous transition from macrodispersion to a colloidal solution to a dispersed molecular (crystalline) solution. It is similar to the size distribution of starch grains between approx. 0.2 and 10 nm, and differences of between 0.02 and 0.6 nm are not unusual, even in the submicron pigments in vat dyes. However, the maximum and minimum values can be shifted in one direction or the other using suitable means:

macrodispersion colloidal dispersion molecular dispersion

————> (Dispersion) ————> (Dissolution)
(Coagulation) <———— (Condensation) <————-

	→ Disperse systems Increase in degree of dispersal →			
	Macrodispersal		Colloidal dispersal	Highly dispersed
	Macroscopically disperse	Microscopically disperse	(fine dispersal)	(molecular dispersion)
Particle size µm	> 100	100–0.5	1–0.001	> 0.001
Number of atoms per particle	More than a billion		1000–100 000	1–1000
External signs	Mechanical division		Colloids	Molecularly dispersed (cristalloidal) solution
Particle nature	Most individual particles dissimilar			Molecules and ions have the same structure and same size in the same substances
Visibility	Some macroscopic, otherwise microscopic	Light microscope	Electron microscope	Hardly or not at all in the electron microscope
Filtering capability	Through filter paper (average pore diameter $5 \cdot 10^{-4}$ cm)		Only through parchment and organic membranes (these and ultrafilters with Ø-pore diameters of 10^{-5} to 10^{-6} cm)	Nor through parchment and organic membranes (e.g. sodium chloride solution)
Dialysis capability	no	no	no	diffuse and dialyse
Other means of detection			→ Increasing Brownian (colloidal) movement →	

Tab.: Distribution principle of dispersed systems according to average size of dispersed particles.

Important factors affecting the degree of dispersion are: particle size, molecule size, chemical constitution, concentration ratio, thermal influence, pH influence, influence of the addition of foreign materials (electrolyte, chemical reactions, physical processes etc.).

Displacement resist Displacement effect. A ground dye initially applied to a textile substrate is removed (displaced) by subsequent local application of chemicals, thickener and/or dye (or their combinations).

Display (VDU, monitor screen). Used in EDP and e.g. machine control/monitoring systems for the visual representation of information in the form of numbers, letters, symbols or other graphic elements (see Fig.).

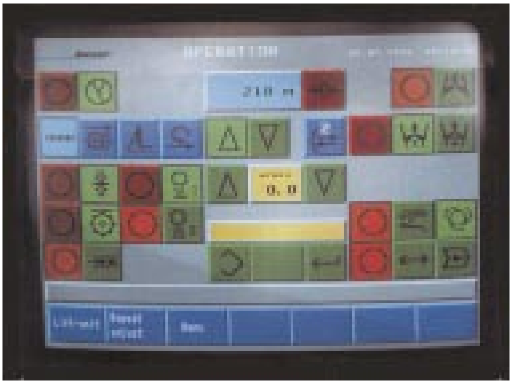


Fig.: Monitor screen display with direct touch basic control panels (masks) on a Buser rotary screen printing machine.

Disposable dye tubes (perforated). These are subdivided into rigid, axial-flexible and radial-flexible dye tubes. Radial-flexible disposable dye tubes are used in package dyeing for high shrinkage yarns (e.g. polyacrylonitrile, regenerated cellulose, polyester/cellulose blends, etc.). During dyeing, the tube remains soft and gives the yarn more room to shrink. In this way, hardness of the package centre (as a cause of unlevel dyeing and fibre damage on rigid plastic tubes) is avoided. When using soft paper tubes, the counter pressure of an interposed spring sleeve provides the necessary stability; their corresponding lengths must therefore match each other exactly. After drying, the spring sleeve is ejected, the yarn wound off, and the paper tube discarded.

In the dyeing of press-packed yarn packages, axial-flexible plastic disposable dye tubes are irreversibly deformed axially by up to 40% (see Fig.) in order to prevent leakages between the packages (without spacers) and achieve a uniform package density in the package column (almost like dyeing a yarn beam).

Fig.: Eisbär C disposable core before pressing (right) and after dyeing of the compressed core (left).

From the ecological standpoint the use of all types of disposable dye tubes raises the question of recycling. In the case of plastic tubes a possible solution would be to collect the deformed tubes after use, grind them into granulate form, and convert them into dye tubes again (injection moulding).

Disposable laundry Typical → Disposable textiles made of paper nonwovens. Used in hospitals (e.g. diapers, pads, drawsheets, bed linen). The use of such materials is questionable because of relatively high costs and problematic disposal/destruction.

Disposable textiles Articles of a more or less textile-like character intended for once-only or short-life usage such as → Disposable laundry (e.g. bed linen, table linen, hand towels, underwear, diapers); disposable garments (e.g. coloured or printed holiday and party garments); disposable workwear (e.g. hospital gowns, painters' overalls); disposable sanitary goods, etc. Short-term serviceability ranges from "disposal after use" to "multiwash/dryclean" goods. Disposables are made from tailored/shaped pieces (sewn, glued) of reinforced nonwovens (cellulose, textile fibres or fibrids). Binders used to achieve the necessary resistance to drycleaning, washing and wet treatments include, e.g. cellulose derivatives, plastics, reactant resins, etc. The competitiveness of such materials is subject to problems of price structure and especially environmental pollution (also procurement, pay-back and transport in the case of hospitals).

Dissimilation (Lat.: *dissimilis* = not alike). The breakdown and consumption of nutrients to provide energy and simple compounds for intermediary metabolism. It is the opposite of assimilation. Also a term used in waste water technology to describe the conversion of materials whereby energy is provided by the oxidation of organic compounds for the formation of new organic matter.

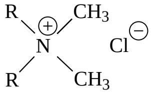
Dissociation (ionization). The electrolytic breakdown of acids, bases and salts on solution in water. This process involves the formation of ions, i.e. electrically charged particles: anions (–) and cations (+) from electrically neutral molecules. In practice, therefore, acidic reaction is due to electropositively charged cations (H^+ ions) and alkaline reaction is due to electronegatively charged anions (OH^- ions).

Dissociation, degree of Numerical expression for the state of dissociation (see Table). It corresponds to the respective (actual) strength of reaction (e.g. of acids, bases and salts). The degree of dissociation is of great practical importance since it is a term which denotes the strength and not the content of e.g. an acid. The degree of dissociation can be used to determine the equilibrium constant for dissociation, an important factor in ascertaining the extent of a chemical process.

hydrochloric acid	90 %	strong acids
nitric acid	90 %	
sulphuric acid	60 %	
oxalic acid	31 %	medium strength acids
phosphoric acid	12 %	
formic acid	5 %	
acetic acid	1,3 %	weak acids
carbonic acid	0,12 %	
boric acid	0,007 %	
salicylic acid, benzoic acid		

Tab.: Comparative examples of 0.1n acids with identical acid content at 18 °C (degree of association as a %).

Distearyldimethylammonium chloride (DSDMAC), $((C_{18}H_{17})_2(CH_3)_2N)Cl^-$; laundry softener,



R = (hydr.) stearic alkyl

Adsorption properties: better for natural fibres (cotton, wool) than synthetic fibres. Adsorption on synthetic fibres is increased in hard water. Uniform exhaustion is achieved in the neutral to mildly acidic range at an average liquor temperature of 30–40°C over at least 10 min. The optimum softening effect is obtained with 1–1,5 g/kg of material. The product is manufactured from fatty acids or fatty alcohols. As a classical laundry softener (paste form containing 75% active substance) it is used in a concentrated mixture with imidazolinium compounds or in combination with selected emulsifiers.

Distillation, comprising the constituent processes of evaporation and condensation. The term fractional distillation is applied to the separation of liquid mixtures (fractions) on the basis of their different boiling points. Distillation as a process for the separation of substances is classified according to the delivery of the liquid mixture. Thus distinction is made between distillation carried out intermittently and continuous distillation. In the first case the mixture to be separated is collected and then evaporated as a whole. In the second case the liquid mixture is fed continuously in a controlled flow. The processes are further classified according to the flow pattern of the distillation liquid. If there is only one phase of motion, i.e. the vapour phase, it is known as simple distillation. If, on the other hand, part of the condensed vapour (the return flow) moves in the opposite direction to the rising vapour, this is known as counter-flow distillation or fractionation.

The separation procedure is based on Raoult's Law which when derived leads to the following essential basic value:

$$\frac{y}{1-y} = \alpha \frac{x}{1-x} \quad \text{with} \quad \frac{p_a}{p_B} = \alpha$$

α = ratio of vapour pressure of the pure constituents,
x = mol fraction of the liquid,
y = mol fraction of the vapour.

x and y apply to the more volatile constituents. α is designated relative volatility and where the Pictet-Trouton rule applies, i.e. ideal behaviour, may also be calculated from the absolute boiling point. The above relationship shows that separation by distillation only occurs when $\alpha > 1$. Only in this case may a difference in the composition of vapour phase and liquid be achieved. The concentration of the more volatile constituents of the vapour on the other hand increases as α increases, i.e. the greater the difference between the vapour pressure of the pure constituents. The equation only represents a single evaporation, however. If the difference in the volatility is insufficient, the process must be repeated, or fractionation selected as the method to be used.

Representation of the phase equilibrium: three diagrams are significant for the graphic illustration of the phase equilibrium between vapour and liquid: the diagrams for pressure, temperature (= boiling point diagram) and composition (= state of equilibrium diagram).

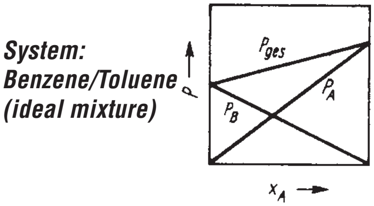


Fig. 1: Diagram of equilibrium in two-component mixtures. Dependency of pressure p on the composition of the system.

The pressure diagram (Fig. 1) shows the partial pressures p_1, p_2 and the total pressure dependent on the composition of the liquid (x_1 and x_2) and the vapour. Fig. 1 is intended to exemplify this. A characteristic feature of evaporation is that the two-phase region is exceeded (an increase in pressure would conversely lead to condensation). On the basis of Raoult's Law under isothermal conditions, linear curves are obtained when plotting p_1 against x_1 and p_2 against x_2. Further more, according to Dalton, the total pressure p is obtained from the sum of the partial pressures.

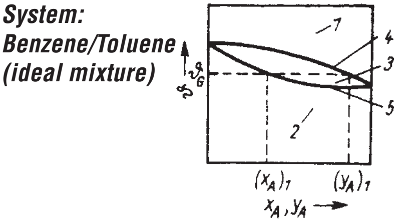


Fig. 2: Diagram of equilibrium. Dependency of boiling point on the composition of the system.
1 = vapour; 2 = liquid; 3 = saturated steam; 4 = dew point curve; 5 = boiling point curve.

In the temperature diagram the boiling point is plotted against the composition of the system under constant pressure (Fig. 2). This type of representation is important, as in practice constant pressure is generally employed. Two curves are obtained from the T-x-diagram, the boiling point curve and the dew point curve. The boiling point curve connects the temperature values at which the first liquid particles evaporate or starting from the vapour condition, the last vapour particles condense. Below this curve there is only liquid, above the dew point curve there is only vapour. In the boiling point region liquid and vapour exist in equilibrium. This area is known as the saturated steam region.

The composition diagram which represents the equilibrium curves shows the composition of the vapour phase dependent on the liquid under constant pressure conditions. The more volatile constituents of the vapour phase are plotted against the proportion of more volatile constituents of the liquid phase. The arc of the resultant curve is sharper, as the relative volatility increases (Fig. 3).

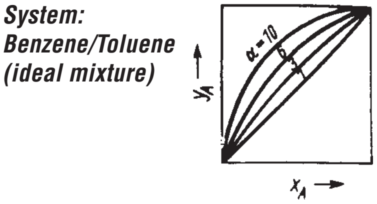


Fig. 3: Diagram of equilibrium in two-component mixes. Dependency of mole fraction of the more volatile constituent of the vapour y_A on the mole fraction of the more volatile constituent of the liquid x_A.

Types of mixture systems: mixtures exhibit ideal behaviour if the individual constituents in any proportion are soluble in one another and the interaction forces between different molecules are equal to those between ones of the same kind. Raoult's Law applies to ideal mixes, and in accordance with this law there is no heat of mixing. If a mix is characterized by real behaviour, the interactions therein are not equal, as there are deviations from Raoult's Law. These deviations may be of a positive kind. A further special case is represented by substances which have miscibility gaps. Azeotropic behaviour is distinguished by vaporization curves showing either a maximum or a minimum (the opposite phenomenon applies to their boiling behaviour). This is explained by the fact that above a certain temperature or a certain pressure, vapour and liquid have the same composition. The heat of mixing at the point where the total pressure reaches a maximum or minimum is equal to zero.

$$\frac{dp_{tot}}{dx} = 0$$

p_{tot} = total pressure

Azeotropic mixes cannot be separated by simple distillation or fractionation. It is therefore necessary to control the point of inflection in order to permit mixture reduction down to the point of disappearance. For this reason azeotropes may only be separated by means of a specific type of distillation, such as two-stage fractionation, heteroazeotropic fractionation, or fractionation with azeotrope converters such as azeotropic and extractive distillation. In the case of a positive azeotrope there are stronger interactions within the individual constituents than between the different constituents. In contrast to a fictive ideal solution, a non-linear vapour pressure curve is observed. The vapour pressure curve is at a maximum, the boiling point curve at a minmum. This phenomenon is the most common. It arises firstly if a liquid liable to association and forming a dipole is mixed with a liquid which destroys this association; secondly in the case of hydrocarbons with similar boiling points. In the case of negative azeotropes the interactions in the pure constituents are less than those between the different constituents. As against an assumed ideal solution this leads to a minimum in the vapour pressure curve and a maximum in the boiling point curve. This type is rarer and arises when both constituents have a certain affinity to one another.

If the volatility α = 1, the equation

$$\frac{p_a}{p_B} = \alpha$$

represents a straight-line equation, which runs through the coordinate origin and possesses the gradient 1. If α > 1, then curves are generated which have a greater arc as α increases. In the case of azeotropes these S-shaped curves intersect the linear curve, for which α = 1, and a separation by distillation is not possible. The course of the equilibrium curves of positive and negative azeotropes is shown in Figs. 4 + 5.

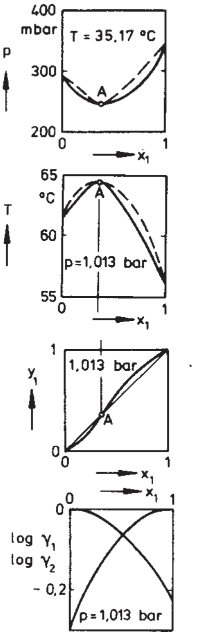


Fig. 4: Phase equilibrium diagram for the system of acetone (1)/chloroform (2) (negative deviation from Raoult's Law).

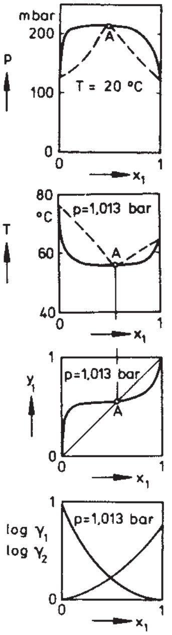


Fig. 5: Phase equilibrium diagram for the system of methanol (1)/carbon tetrachloride (2) (positive deviation from Raoult's Law).

The solubility is influenced by additives. This is used in the recovery of materials, e.g. the crystallization of organic substances from aqueous solutions. This problem also applies to the recovery of materials from textile processing effluent; to the recovery of surfactants from laundry effluent, and to the recovery of salts (Fig. 6) and dyestuffs from dyeing effluents. The solubility of the substances contained in the aqueous medium affects the separation obtained. This is also dependent on the volatility. It may be deduced that the

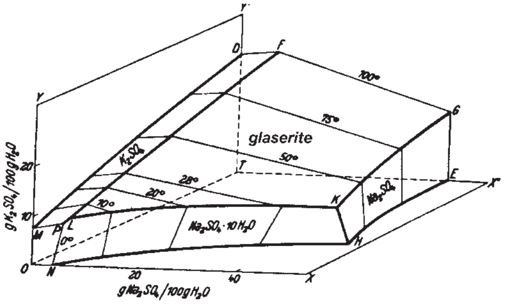


Fig. 6: Crystal composition of the mixed salt $Na_2SO_4 \cdot K_2SO_4 \cdot H_2O$ (perspective diagram). The isotherms for 0, 10, 20°C etc. have been plotted on the areas representing the equilibrium between saturated solution and the various crystal types.

greater the solubility and the boiling point, the greater the energy expenditure.

Distillation residues from dry cleaning plants (tetrachloroethylene sludge) must be classified as hazardous waste due to their high toxicity, regardless of the level of the residual solvent content. Even traces of solvents can cause considerable pollution to the ground water and drainage systems. Disposal may only be carried out at hazardous waste disposal sites or incineration plants, or alternatively the waste material should be handed in for solvent recycling at reclamation centres with suitable equipment; these will also undertake the disposal of any remaining residues.

Distribution coefficient (Partition coefficient). If a substance is introduced to a system of two immiscible solvents and the mixture is shaken vigorously, the substance will separate into the two phases. A distribution equilibrium occurs according to the law first formulated in 1891 by Nernst: the ratio of a soluble substance between two solvent phases is constant.

$$K = \frac{c_{\text{substance}} \text{ in phase 2}}{c_{\text{substance}} \text{ in phase 1}}$$

K = Nernst distribution coefficient.

On the surface of a solid body, the forces of attraction which the atoms or ions exert on one another, are not fully assimilated. External molecules which occur can therefore be added and bonded firmly to a greater or lesser extent. This interfacial concentration is described as adsorption, or chemisorption, when the bonding forces are chemical. The quantity of adsorbed substance (the adsorbate) per m^2 of the surface of the solid substance (the adsorbent) is defined as the interfacial concentration. As this is not known precisely, however, the quantity adsorbed is generally rounded up to 1 g of adsorbent and called “specific packing density” or “loading”. It is quoted in mol (or also in g) of adsorbate per g of adsorbent and depends on the temperature and, when a gas is adsorbed, on the pressure of the gas, or when a dissolved substance is adsorbed from a solution, on its concentration. A bivariant equilibrium thus occurs:

$$\text{Load} = f(p, T) \text{ or } f(c, T)$$

If a cationic surfactant for example is permitted to flow through a column under controlled flow conditions, with the column packed with cellulose, then one can deduce the surfactant mass adsorbed by the cellulose powder in relation to the initial concentration of the surfactant solution added c_0, and the concentration of the eluate. An adsorption process of this type is a reaction of the first order due to the distribution of the surfactant between cellulose and liquor, so both the equilibrium concentration c_∞ and thus the distribution isotherm as well as the material exchange constant β can be ascertained from such experiments (Fig. 1). A relevant adsorption isotherm is shown in Fig. 2.

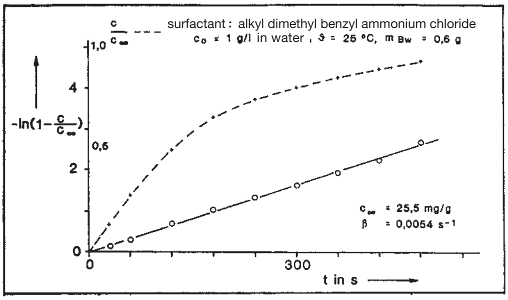


Fig. 1: Adsorption of the cationic surfactant alkyl dimethyl benzyl ammonium chloride on cotton (source: Schollmeyer).

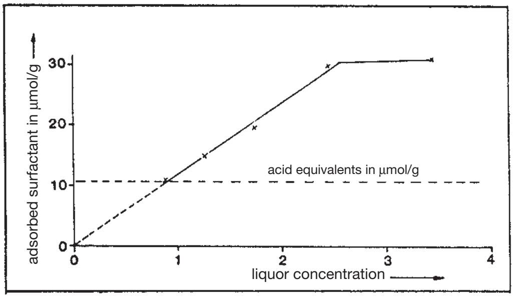


Fig. 2: Adsorption isotherm of DSDMAC (distearyl dimethyl ammonium chloride ammonium chloride) on cotton. Water, 25°C (source: Schollmeyer).

If the acid equivalents which can be compensated by cationic surfactants can be defined, it may be seen

- that more surfactant is adsorbed than appropriate for the acid groups present,
- that with a liquor concentration of up to 2.5 µmol/g (+ 1.5 g/l distearyl dimethyl ammonium chloride), there is a proportionality between the concentration on the fibre and in the liquor with a distribution coefficient of

$$k = \frac{c\infty}{c_{B\infty}}$$

From this distribution coefficient, it is possible to calculate the liquor exhaustion under the conditions of equilibrium when exhausting from a finite bath with the liquor ratio FV:

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$$BE = \frac{c_\infty}{c_{0T}}$$

c_{0T} is the initial concentration of the surfactant in the liquor in relation to the textile mass and is therefore dependent on the liquor ratio FV:

$$FV = \frac{\text{mass of textile goods}}{\text{liquor volume}}$$

In addition the mass equilibrium gives

$$c_{0T} = c_{BT\infty} + c_\infty$$

where $c_{BT\infty}$ is the equilibrium liquor concentration in relation to the textile goods.

$$c_{BT\infty} = \frac{c_{B\infty}}{FV}$$

With the distribution coefficient

$$k = \frac{c_\infty}{c_{B\infty}} \left(\frac{\text{liquor mass}}{\text{textile mass}} \right)$$

the bath exhaustion is therefore

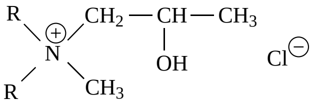
$$BE = \frac{k \cdot FV}{1 + k \cdot FV}$$

and amounts to only 50% with a distribution coefficient of k = 10 and a liquor ratio of 1 : 10. A systematic investigation into the influencing variables on the distribution coefficients is consequently of high practical relevance (source: Schollmeyer).

Disulphide bridges Crosslinkages between wool protein chains via two mutually bound sulphur atoms, W–S–S–W. → Cystine bridges.

Disulphonated acid dyes → Acid dyes.

Ditallow-alkyl-hydroxy-propyl-methyl ammonium chloride



$$\left[R_2\overset{\oplus}{N}(CH_3)-CH_2-\underset{OH}{CH}-CH_3 \right] Cl^{\ominus}$$

R = C_{16} or C_{18} (non-sat.)

Avivage substance (as ditalg imazolinium derivate with 70/75% active substance) for fabric softener. A similar effect can be obtained using coconutalkyl residue with shorter chains as fat substitutes (→ Dicoconutalkyldimethylammonium chloride).

Dithio compounds Compounds with 2 sulphur atoms in the molecule, e.g. dithionous acid (sulphinic acid) $H_2S_2O_4$, known in the form of its salts, e.g. sodium dithionite $Na_2S_2O_4$ (incorrectly described as sodium hydrosulphite).

Dithizone → Diphenylthiocarbazone.

Diversification (Lat.: *diversus* = turned in different directions) Sustained company adaptation to new markets through entry into markets not previously exploited by varying products, operations, etc., in order to spread risk, expand, exploit spare capacity, etc. In many cases these changes or extensions to the manufacturing program, although fundamentally new to the company, nevertheless often have some connection with former business activities. Diversification is a policy for long-term growth and the spreading of risks. There are 3 possible routes, i.e.:

1. In-house development of new products.
2. Acquisition of licences to manufacture/distribute products for which the company has had no former experience.
3. Amalgamation (merging) with other companies which offer alternative products/customer services.

Divided screens in screen printing Design interrupted several times across the width of the screen. Predominantly used when producing new collections (patterning) as several colours can be printed at the same time with one screen.

Divider Used in liquor compartments to decrease the liquor ratio, e.g. in padding machines incl. full-width treatment machines and cheese dyeing machines (Fig.).

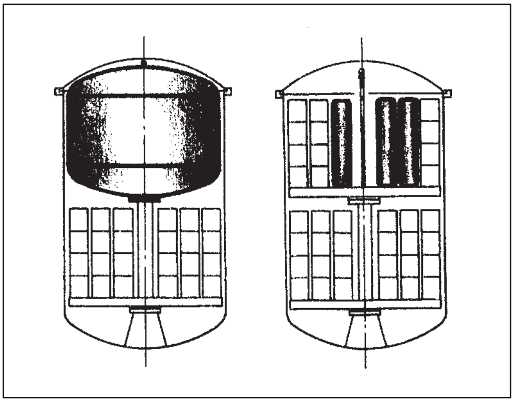


Fig.: Use of divider inserts to decrease the liquor ratio with circulating-liquor machines which are not fully loaded.

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Divinylsulphone compounds are derived from divinylsulphone $CH_2=CH–SO_2–CH=CH_2$, mainly with masked vinylsulphone groups, e.g. $R–O–CH_2–CH_2–SO_2–CH_2–CH_2–O–R$, where R = e.g. $–SO_3Na$, $–CH_3$, –H; symmetrical and asymmetrical divinylsulphone compounds. Used as resin finishing agents, e.g. →: Bis (β-hydroxyethyl) sulphone; Disodium salt of tris-(β-sulphoethyl) sulphonium.

DK, abbrev. for: Danish Patent.

DMC → Dimethylol (mono) carbamate.

DMDHEU → Dimethyloldihydroxyethyleneurea.

DMEU → Dimethylolethyleneurea.

DMF → Dimethyl formamide.

DMI, abbrev. for: Deutscher Medizinischer Informationsdienst e.V. (German Medical Information Service). An independent nonprofit-making association for general health information, considerations of industrial and public medicine, promotion of industrial hygiene and protection against infection hazards in the workplace environment, and the control of readily combustible textiles. → Technical and professional organizations.

DMPU → Dimethylolpropyleneurea.

DMT,

I. → Dimethyl terephthalate.

II. → Dimethyloltriazinone.

DMU → Dimethylolurea.

DNP, abbrev. for: dinitrophenyl, e.g. DNP-formic acid.

DNS → Sodium sulphate.

DOB, (Ger.) abbrev. for: Damenoberbekleidung (women's outerwear).

Dobby mechanism, a shedding mechanism on looms or weaving machines (→ Weaving). The harness motion can be either negative or positive by means of a controlled lifting gear. In negative-dobby shedding, the shafts are raised by the dobby and lowered by some form of spring undermotion. In positive-dobby shedding, the dobby machine both raises and lowers the shafts. A distinction is made between single and double lift, as well as between closed and open shed dobby machines.

DOC, abbrev. for: dissolved organic carbon. → Summation parameter.

Doctor bars in roller printing These arise due to the doctor blade lying unevenly on the roller. This gives rise to oscillations which can be seen in the form of horizontal stripes on the goods and which are generally repeated 3–6 times. In order to rectify the fault, the doctor blade must be readjusted.

Doctor bed-plate Scraper device in flat screen printing where the fabric passes between a stationary padded table and the → Doctor blade positioned on this.

Doctor blade Stripping device in the form of a fixed blade which extends across the entire treatment width in steel, as a wedge-shaped, tapered vulcanite strip or as a roller squeegee (→ Squeegee systems in printing). It is used to form an angle of incidence on a moving substrate by means of an incline. When moving, this then enables a highly viscous paste (for printing or coating) to become fluid briefly as a result of its intrinsic viscosity due to the shear forces which arise,

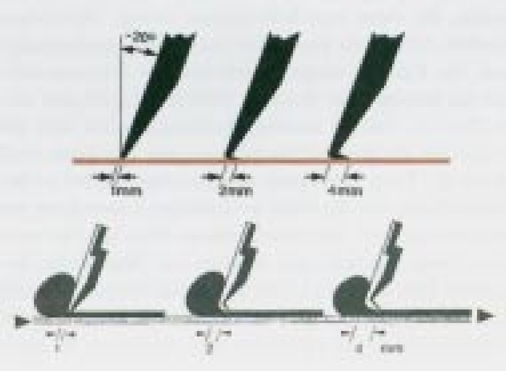


Fig. 1: Illustration of the bevel (in mm) in three different widths at the same angle of incidence, with and without paste in front of the doctor blade (doctor blade is stationary; fabric in motion).

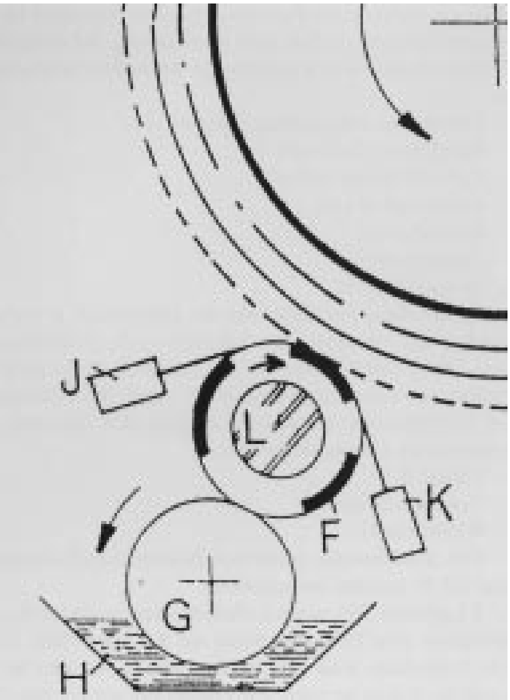


Fig. 2: Position of the doctor blade in classic roller printing. F = engraved zone in roller printing; G = dye paste feed roller; H = trough; J = tractive doctor blade; K = counter doctor blade applying pressure.

and this can therefore be applied. The passage of the paste under a rubber doctor blade is controlled by the angle of incidence and the bevel (Fig. 1). A doctor blade pushes the paste and a squeegee pulls the paste (Fig. 2). Double bladed doctors also move the printing paste back and forth (Fig. 3). Doctors and roller squeegees can be used in both flat screen and rotary printing (Fig. 4).

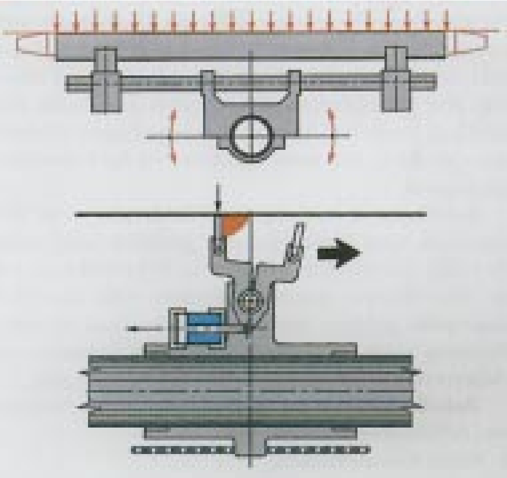


Fig. 3: Reggiani double bladed doctor for flat screen printing (doctors applied weftway on a stationary fabric).

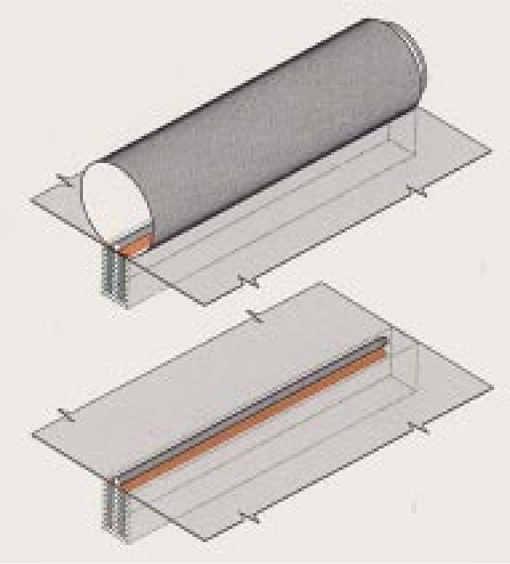


Fig. 4: Magnet roller squeegee technique in rotary printing (above) and flat screen printing (below).

Doctor blade grinding machine Precision machine to grind all types of doctor blades up to 300 cm in length. Operation with rotating continuous abrasive disc, with a universal rapid fixing device for every type of doctor blade, continuously adjustable for any angle in the swivelling range of 0–90°.

Doctor blade holder The doctor blade in roller printing consists of a doctor blade holder and a doctor blade plus possibly an auxiliary doctor. The doctor blade holder consists of a steel protector bar with axle bearings, two load-bearing arms, spigots for the thrust rods and a brass drip bar over which the squeegeed printing paste runs back to the trough. The protector bar and drip bar are bolted together and the doctor blade is clamped between the two.

Doctor blade sharpening in roller printing Three operations are carried out:

1. Filing (straightening).
2. Filing the “crown”.
3. Sharpening (grinding).

Filing takes place initially with a file of coarse cut and is intended to make the blade of the doctor even. In this procedure, the doctor blade is generally filed into a moderate concave curve, the slope of which measures approx. 3–5 mm from the end of the doctor blade to the centre with a blade length of approx. 100 cm. This shaping ensures that the doctor blade fits more evenly on the printing roller. The file is then held against the doctor blade at an angle of 20–45° depending on the slope of the covering in order to “file down” the “crown”. The crown is sharpened on the side of the blade which is opposite the roller surface. Finally sharpening or grinding of the blade imparts strength and smoothness. A special grade of grinding stone is used for this purpose. Two surfaces need to be ground. Then the entire blade area on the side facing the roller is sharpened and the stone is then placed in such a position that it acts on the upper quarter in particular. Next the crown is ground. During this process, the blade and the crown are ground alternately until the burr which has formed on the cutting edge during filing has worn away.

Doctor edge → Doctor blade sharpening in roller printing.

Doctor roller as opposed to the conventional blade used in rouleaux printing (stripping knife) and flatbed and rotary screen printing (doctor knife, roll doctor), which usually have a straight edge or surface, the doctor roller takes the form of a roller with surface engraving, fluting or helical grooving of varying depth. However, because of the contact pressure on the padding roller, only a minor quantity of the liquor that is originally taken out of the trough remains on this doctor roller. Other forms include the → Comb doctor → Squeegee blade system in printing.

Doctor roll padder Padder which has a → Doctor roller attached to its application roller for minimising the amount of liquor that is collected from the trough, after which the retained liquor is evenly distributed on the lick roller.

Doctor roll washing machine With automatic drive system for printing. This cleans soiled doctor blades without wasting water and prevents damage to the doctor blades. Water-efficient valve system adjustable to the number of doctor blades. Doctor blades are transported in the trolley into a lockable washing cabinet. Vertical brushes move over the exterior of the doctor blade, with simultaneous traversing water injection.

Doctor sharpening stone → Levantine squeegee oil stone.

Doctor streaks Incorrect stripes which become visible on roller printed fabrics as fine streaks following damage to the sharpness of the doctor blade.

Doctor traverse in roller printing The doctor blade moves back and forth with an eccentrically mounted doctor blade traverse device. The printing paste is stripped as thoroughly as possible on the smooth roller surface as the blade moves in one direction and as it moves in the other, the doctor blade is prevented from cutting into the engraved roller.

Dodecylbenzene sulphonates → Alkyl aryl sulphonates.

Doeskin Two different types:

1. A fine quality, close, compact, all-wool fabric of five or eight-shaft satin weave with a lightly napped dress-face finish. Used for suits, coats, uniforms.
2. Rayon twill or small satin with face nap. Used for suits, coats, sportswear.

Dog hair Once a valuable commercial ware (hat felt). Nowadays only of limited regional significance, e.g. for arts and crafts. Productive breeds include St Bernard, Newfoundland, chow-chow, poodle, spitz. Is spun alone or with wool.

Dolly A term used for various types of faller washing machines consisting of rectangular troughs in which the goods to be treated in a detergent solution are placed. Rotating beaters or fallers are lifted by cams and allowed to fall into the trough. At the same time, the trough moves backwards and forwards. The machine is also known as a tom-tom and is used by finishers of knitwear, hosiery and lace.

Domestic washing (household laundering) The washing of domestic household → Laundry. Over the last two decades there has been a dramatic change in domestic washing practices due largely to requirements for protecting the environment with regard to the conservation of resources and the minimisation of environmental pollution caused by waste waters. The liquor levels and washing temperatures in domestic washing machines have been significantly reduced and solutions for multiple water usage, especially in commercial laundries, are being adopted on an increasing scale. The standard test methods (e.g. colour fastness to washing) have not kept pace with these changes which, to a large extent, have been introduced as a result of legislation. As a consequence, considerable discrepancies exist in some cases between these test methods and the procedures now used in practice. The adoption of reduced wash temperatures is, on the face of it, an advantage but energy-saving wash programs can also subject textile materials to higher mechanical stresses since the wash times in these programs have been extended to the same duration as high temperature programs. Of particular significance are the changes in detergent formulations to include bleach activators in order to meet the trend of consumers to use low-temperature wash programs. As a result, dyeings on textiles which will only be washed at low temperatures must also possess adequate colour fastness to bleaching. The adoption of lower liquor levels in washing machines to reduce energy consumption is accompanied by a more intensive textile/textile contact. At the same time, the concentration of detergent is increased which leads to a greater interaction with dyeings and prints. This tendency has been further reinforced by the use of dosing systems. In exceptional cases, this can cause the stripping of prints due to the high surfactant concentration used as well as bleaching damage. This practice runs counter to current efforts aimed at reducing the quantities of detergents used in household laundering.

At present, environmentally-compatible washing is frustrated due, especially, to the problem of colour transfer (bleeding, staining) which prevents washing machines being used to their maximum capacity. Each part load involves higher specific consumption rates. The tendency for dyed or printed textiles not be washed off adequately after coloration and for consumers to be compelled to wash coloured articles separately must be regarded as particularly questionable in this context. Similar tendencies aimed at conserving resources are to be found in commercial laundries which likewise widen the discrepancies between the requirements to be met in practice and the test methods. The abandonment of chlorine as a bleaching and disinfecting agent, which has been largely realized in the meantime, and its substitution by peracetic acid which is less aggressive towards dyeings, is a definite advantage. The obligation stipulated in the appendix relating to “laundries” contained in the General Administrative Regulation for the reuse of wash and rinse liquors has given further scope to acidification as a means of achieving a satisfactory rinsing effect. The resultant concentration of the acetic or formic acid which takes place during drying must be taken into consideration in the selection of dyeings, finishes, sewing threads, etc. Colour fastness, as well as the problem of optical brighteners, also present difficulties here. As a result of the compulsory ban on the use of powerful sequestrants, the need for textile materials to be free of catalysts (inclusions or iron pigment in yarns, etc.) is of increasing importance (source: Krüßmann and Hloch).

Domestic washing practices The dictates of fashion determine the use of particular fibres, certain textile constructions which go beyond standard woven and knitted fabrics and, in addition to dyeings and prints with high colour fastness, even some colorations with poor wash fastness. Whilst dyeings and prints are expected to meet the requirements of, e.g. the Marks & Spencer "multifibre strip" wash test on the one hand, the detergents must still be capable of adapting to extreme fashion-related trends on the other. Based on the wash and care requirements of textile materials, the term "fast to domestic washing" needs to be defined. This is to be understood as the sum of the desired colour fastness requirements together with appropriate requirements concerning easy-care properties in relation to the washing operations in modern washing machines with modern detergents. From the standpoint of wash fastness, these requirements mean perfect wet fastness ratings after repeated wash cycles (at least 5 wash cycles) within a temperature range of 40–60°C with the main emphasis on 60°C. The chief requirements to be placed on the detergent system are, of course, selected on the basis of the particular textile material being washed (see Table).

Lower washing temperatures are preferred in order to save energy (Fig. 1). Most of the energy consumed in washing is used to heat the water. For this reason, washing is mainly carried out at 60°C nowadays whilst in former times washing at the boil was predominant. The energy consumption for heating and running a washing machine at 40°C, 60°C and 95°C is given in Fig. 2.

The good washing performance and the low energy and water consumption of the automatic drum-type washing machine will ensure its continued usage in the European market for many years to come. Where the

Type of fibre:			
Textile material	Desired detergent action	Achieved by	Particular requirements of the detergent system
wool	reduced mechanical washing action no felting	fine suds	foam-specific surfactant combination
silk	no colour bleeding	neutral to weakly acidic conditions	surfactant combination, pH control
PES/PAC/PA/PP	improvement of handle	softener in the wash bath	non-ionic and cationic surfactants
PES/PAC/PA/PP	antistatic preparation	cationic surfactants in the wash bath	non-ionic and cationic surfactants
Textile construction:			
down	no adhesion during drying	softener in the wash bath	non-ionic and cationic surfactants
fleece fillings	no drying stiffness after drying antistatic effect	softener in the wash bath	non-ionic and cationic surfactants
membrane textiles	retention of proofing	cationic surfactants in the wash bath or neutral wash liquor	non-ionic and cationic surfactants non-ionic surfactant combination
suede leather panels	no stiffening of the leather	cationic surfactants in the wash bath	non-ionic and cationic surfactants
Dyeings and prints:			
dyeings and prints with poor fastness to washing	no colour bleeding	absence of salts which promote dye staining ≃ pH 7	non-ionic surfactant combination / low electrolyte content
	no dye migration; dye stabilizing effect	dye-stabilizing additives	non-ionic and ionic surfactants
pastel dyeings	no change in colour	washing without optical brighteners	no optical brightener in the product
bleach-sensitive dyeings and prints	no change in colour due to bleaching agents	washing without bleaches	no bleaching agent in the product

Table: Particular requirements placed on special detergents on a textile-specific basis.

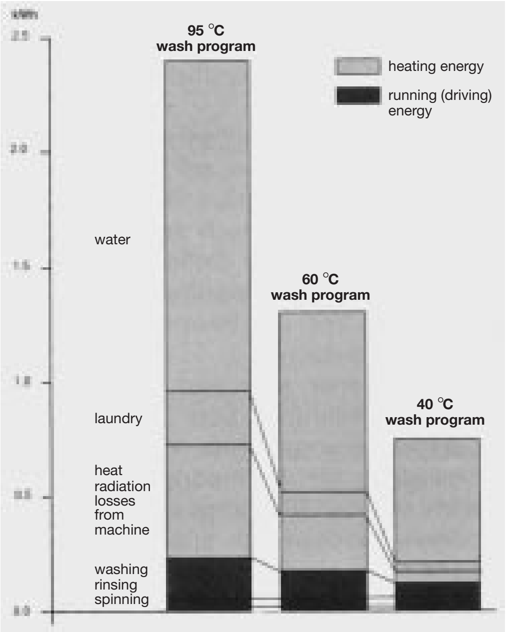


Fig. 1: Comparison of the kWh consumption of a washing machine (3–4 kg load) for washing energy and driving energy.

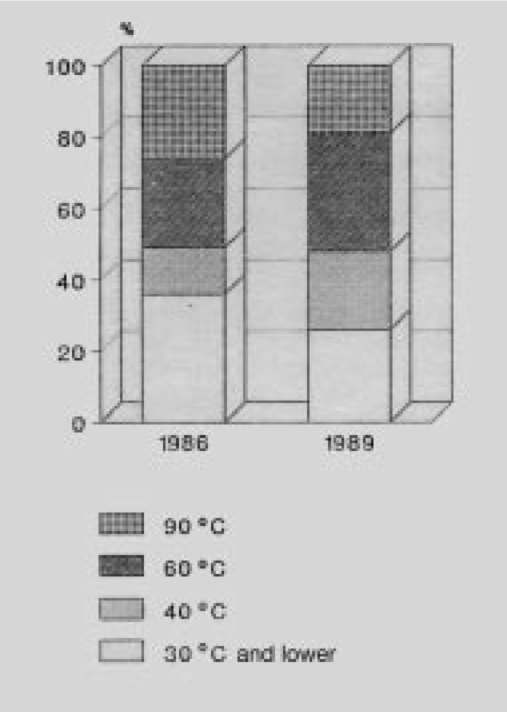


Fig. 2: Comparison of temperature selection in machine washing.

top-loading agitator type of machine is still in use, gradual replacement by the front-loader drum machine is to be expected. In recent years, new developments in washing machines have led to considerable savings in energy and water consumption. Formerly, the energy consumption of a washing machine with a nominal capacity of 4.5 kg was 3 kWh. Currently, the energy consumption for the same type of machine is below 2.1 kWh, i.e. almost 30% less. Water consumption has followed a similar trend: consumption has been reduced from the former 120 l to well below 100 l (usually 60–70 l) per wash cycle. Moreover, the utilization of detergents has also improved. Formerly, complaints of substantial detergent losses in the wash liquor sump were not uncommon. Losses of this kind have been overcome through technical modifications in the construction of the draining system, e.g. bypass conduits, “eco-locks” or spherical closures. Currently, the most up-to-date drum-type washing machines, which are gaining an ever-increasing share of the market, circulate extremely small volumes of water which results in the laundry being cleaned largely by “showering” with wash liquor.

Although the principle of the drum-type washing machine will not change, developments in this area will be concerned with the automatic dosing of detergents and the composition of the wash load. The success of liquid detergents has prompted the washing machine industry to develop automatic dosing systems for these products. A new development in this field is represented by the so-called “multi-component washing machine” in which the products required by the particular wash process are supplied by automatic dosing. Washing is carried out with liquid products which include a universal liquid detergent, a special detergent without optical brightener, a bleaching agent containing optical brightener and a concentrated fabric conditioner. As an alternative, a conventional powder detergent can be used with the usual drawer-type flushing dispenser. It remains to be seen whether such complicated and expensive machines will succeed in the market.

The increasing number of tumble driers, which is certainly expected to rise in future, raises questions as to the advantages of this type of drying for easy-care textiles. In principle, textiles made of synthetic fibres, or their blends with cellulosic fibres, may be dried quite successfully in such machines.

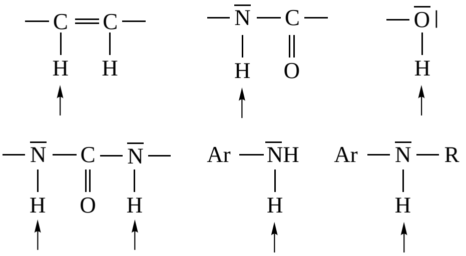
The undesirable build-up of electrostatic charges on synthetic fibres can be reduced or largely suppressed through the use of fabric conditioners (softeners) in the final rinse. The antistatic effects achieved by this means are dependent on the concentration of softener used. Cotton and resin-finished cotton textiles do not suffer from the build-up of electrostatic charges.

A fabric conditioning pad can also be used during drying in the tumble drier instead of a conventional fabric softener in the final rinse. These pads facilitate the transfer of softening and antistatic substances to the laundry during drying and an improvement in odour is also achieved. Moreover, textiles made of synthetic fibres which may have become creased due to inappropriate washing conditions, are smoothed out again in tumble drying. The influence of temperature on the thermoplastic fibres during constant movement of the laundry in the water vapour atmosphere of the drier is crucial in this respect (source: Robinson and Egger, Weber, Krings and Hoffmeister, as well as Brüschweiler, Felber and Schwuger).

Donegal A plain-weave tweed fabric made of wool and characterized by brightly-coloured randomly distributed slubs or flecks introduced at intervals into the weft yarn before spinning. The touches of colour are scattered throughout the cloth and show up usually against a light grey or natural coloured ground. Donegal is named after the county where it was first produced as a coarse woollen suiting in northwest Ireland. Originally, it was woven entirely by hand but today power looms are used for its manufacture. There are many imitations of Donegal on the market today, executed in a wide variety of qualities and weaves mostly consisting of relatively coarse, strong plain-weave all-wool fabrics with white or coloured slubs; very often the warp is lighter and more uniform than the weft which is darker and has more slubs.

Donnan membrane equilibrium The distribution of ions on each side of a membrane separating two portions of a solution of an electrolyte, e.g. NaCl in water. A polyelectrolyte, e.g. a protein, the molecules and ions of which cannot pass through the membrane is introduced on one side of the membrane. The distribution of NaCl on the two sides of the membrane will be unequal and a membrane potential is established.

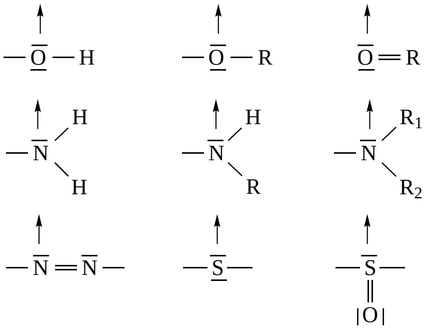
Donor (Lat.: *donare* = to give). A term used in chemistry when the supply of certain functional groups is necessary for the initiation of a reaction, i.e. an atom, ion, or molecule that provides a pair of electrons in forming a coordinate bond. Example: A proton donor is a compound which donates a proton for the initiation of a reaction (e.g. transesterification). In the case of hydrogen bonds, the water donor donates hydrogen ions, and is therefore known as a proton donor. Such functional groups include, e.g.:



In the same process, hydrogen ions are accepted by the hydrogen acceptor:

H_2-donor + acceptor → donor + H_2-acceptor.

Since, in the case of hydrogen bonds, the coordinate bond of hydrogen ions is formed by an electron pair from an atom of the functional groups, the hydrogen acceptor is also described as an electron donor. Examples:



Dosacid system A process developed by Ciba-Geigy for dyeing polyamide carpets in winch dyeing machines with liquor circulation. Principle: pH control during the course of dyeing by means of a metering system consisting of a sensor and a programmmable metering unit.

Dosimetry, method of studying colouring processes in molecular dye solutions, whereby a dye concentration that is constant over time is achieved using automatically-operating burettes, the replenishment from which over time provides the desired dye absorption curve. This makes it possible to perform a single dyeing test (without the need for analysis of the dyed material). Dosimetry is therefore regarded as a rational, fast and precise method (approx. 1% statistical error compared to conventional analysis). Principle: concentration loss in a dye bath caused by dye absorption causes a potential change in a colorimeter, which activates the automatic burette via a controller, i.e. injects concentrated dye solution into the dye bath until the original bath concentration is restored.

Dot coating Process to produce → Hot melt adhesive materials using dot/pattern type paste coating of the non-woven fabric base by printing silk screen printing screens in the rotary screen printing method. In the dot process polyamide dots, for example, are “printed” onto the length of fabric (Fig. 1) in a wet-on-wet process. This process is particularly suited to non-woven bonded or siliconized fabrics. The moisture is removed from the dot in the drying chamber; it is baked at the same time.

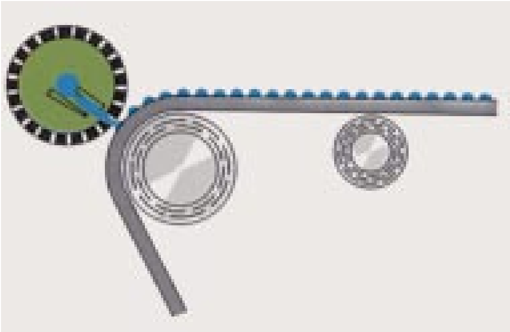


Fig. 1: Caratsch dot process.

Fig. 2 shows the principle for → Direct coating with separate laminating in the form of a diagram. The main part is the applicator head which is in the form of a “two lip” applicator. A closed system should be used for application from the melt. This is the only way to ensure uninterrupted deposition of material on the film screen and to prevent reticulation in the applicator

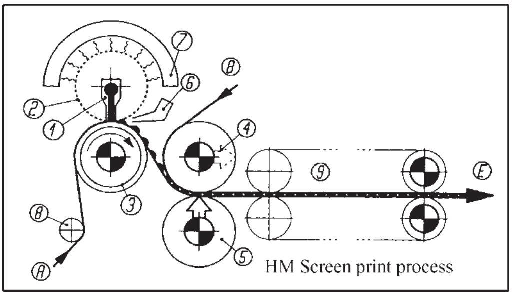


Fig. 2: Direct paste dot coating with separate lamination (Villars).
1 = applicator head; 2 = screen stencil; 3 = counter roller; 4 = laminating station; 5 = calendar roller; 6 = hot air jet; 7 = IR-emitter; 8 = guide roller; 9 = twin-belt laminating and cooling press; A = substrate 1; B = substrate 2; E = end point.

head. Equipment of this type is particularly suitable for applying low viscosity melts, preferably those with a viscosity of below 20 000 mPa/sec. Reactive single-component systems which reticulate at standard atmospheric humidity are able to be processed in the same way if the viscosity remains within the indicated range.

The “print” element is the critical factor in this process. This is known to be minimal in silk screen printing. Pressure-sensitive substrates are able to take advantage of this. Materials which are less pressure-sensitive can also coated directly from granulate using a heated engraved roller. In detail, the granulate comes from its reservoir into a melt unit or an extruder (Fig. 3). Filling the cup cleanly with the melt poses a problem. A special doctor blade system ensures a clearly defined pattern of deposition. The counter roller presses the textile fabric against the engraved roller and in doing so this removes the coating material from the cup of the engraved roller, as it adheres to the textile more readily than to the steel of the engraved roller. The web coated in this way then passes into the laminating station into which the second web is fed and lamination takes place between the transfer and calendar rollers.

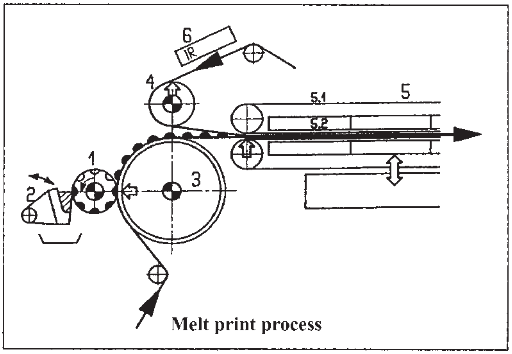


Fig. 3: Paste dot coating with engraved roller instead of a screen stencil (Villars).
1 = engraved roller; 2 = applicator head; 3 = counter roller/ transfer roller; 4 = laminating station; 5 = cooling zone; 5.1 = cooling belt; 5.2 = cooling plate; 6 = IR-emitter.

Double backing (double back). A → Secondary backing glued or laminated to the back of a carpet, usually to increase dimensional stability.

Double bonds →: Atomic bonds (unsaturated); Conjugated double bonds.

Double cloths Compound fabrics consisting of two component fabrics with two warp and two weft systems woven at the same time in a single operation. They are bound together by interchanging warp and weft threads between the face and back fabrics, or by using a special binder thread (e.g. ulster). The weave of the two fabrics can be different.They are produced in order to give the material greater weight or to achieve differently coloured face and back sides (e.g. double face or ulster fabrics).

Double crabbing jack Used to accelerate the crabbing process by winding the fabric from one crabbing jack to another.

Double cure process A two-stage → Permanent press process. Stage 1: pre-cure in the presence of swelling agents; Stage 2: post-cure after garment making.

Double drum machine Double drum machine concept for the washing, dyeing and drycleaning of ready-made garments with an inner and outer drum (see Fig.). The so-called “free liquor space” available for liquor uptake by the garments is held between both drums.

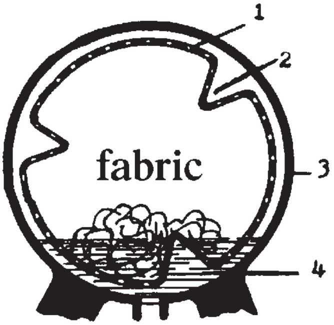


Fig.: Conception of a double drum machine for washing, dyeing or dry-cleaning finished fabric.
1 = perforated inner drum; 2 = driver rib; 3 = outer drum; 4 = liquor.

Double-faced carpet → Treeply carpet.

Double face fabrics In general, these are textile fabrics having two different sides, i.e. with a different colour, design (printed or otherwise) or material on each side.

Double mercerization Double mercerization of yarn (only applicable to high quality yarns). By double mercerization any variations in the mercerizing effect on the yarn which may occur in single mercerization are avoided. The process is nevertheless very expensive.

Double plush (double velvet, double plush carpets) Produced by the double velvet technique to obtain two completely identical fabrics in design and colour which are bound to each other by shared pile yarns. These pile yarns are finally separated in the weaving machine by a knife giving two identical plush, velvet or carpet materials.

Double shed In carpet weaving machines two sheds are formed from the pile and binder warps, i.e. an upper and a lower shed, through which the weft is inserted.

Double-sided transfer paper is a → Transfer printing paper which has been printed on both sides to enable the simultaneous transfer printing of two fabric webs by using the sandwich principle (fabric/paper/fabric).

Double spot coating A dot coating process in which each dot consists of a lower melting core and a higher melting outer shell. The advantage is that, in pressing, the adhesive is prevented from sinking into the fabric thereby achieving a stronger bond.

Double squeegee A squeegee system for wide printing widths in which the print paste is applied between two squeegee blades. Used in screen printing and screen printing machines.

Double stitch (double loop) Combination of stitch and loop.

Double weft carpets → Woven carpets where each row of tufts is tied up by 2 wefts.

Double worsted cloth Given this name because of the double-faced weave. A type of compound warp fabric consisting of two warp thread systems but only one weft thread system. The warp and the weft are usually fine twofold yarns in the case of worsted fabrics. Fine, dense fabrics, sometimes worsted, usually in muted shades with discreet weave, yarn and silk effects; with a deliberately smooth finish. Dyed in loose stock, yarn and piece. Used in classic suits and formal wear.

Doubling machines (folding machines) During the lengthwise passage of a fabric through such a machine it is folded in the centre to half its width and either batched on rolls (doubling and batching machine) or plaited down (doubling and plaiting machine) as desired.

Douppioni (doupion, dupion) Silk fabric with a characteristic irregular slubby texture. The effect is obtained by the use of irregular, raw, rough silk, reeled from double cocoons, in the weft. The double cocoons are the result of two cocoons having been spun by two silkworms too close together. Nowadays schappe silk slub ply yarns or raw tussah silk is often used in the weft. A schappe silk ply yarn is used in the warp.

Dowlas Originally a plain-weave coarse linen fabric. Now often used for a cotton fabric produced from coarse yarns and finished to imitate linen in handle and lustre.

Down the soft fine feathers that grow under the contour feathers of ducks, geese and other waterfowl to prevent loss of heat. The eider duck has been the principle source for textiles as a filling material. The German RAL-RG 094 specification distinguishes between the following qualities:

(1) pure down (also known as “feather-free original duck or goose down”) which is the softest quill-free plumage consisting of core down without any feather content, (2) down, similar to pure down, but with a permissible content of 10% small feathers by weight, (3) feathery down, like pure down, but with a permissible content of max. 50% small feathers by weight, and (4) half down, which consists of feathers with at least 50% down content and occupies approx. half the volume of pure down since the latter is considerably lighter than feathers. Uses: filling material for pillows, quilts, eiderdowns, etc. (approx. 30 geese produce 1 kg of down).

Down mixture 50%/50% small feather → Down.

Downproof batiste (maco downproof), a fine, tightly woven, fabric made from particularly fine and uniform long-staple cotton (maco). Combed yarns are mainly used. Special finish: feather and down proof. Qualities: grey fabric and dyed. Used for tickings.

Downproof fabric, a woven cotton fabric of approx. 120 g/m^2 made from very fine yarns (usually of maco cotton) and extremely tightly woven. It is used for pillows, quilts, etc. filled with down. Downproof fabric is very prone to creasing and the crease marks are highly visible after subsequent dyeing; it is also difficult to wash off because of the tightly woven construction. As a rule, it is only produced in plain weave and supplied in its natural colour for this reason. These fabrics are generally given a wax finish to make them downproof.

Down time, operationally dependent component of → Operating time.

DP, abbrev. for: → Degree of polymerization.

DPB, abbrev. for:

I. Deutsches Bundespatent (German Federal Patent), now → DB.

II. → Dibutyl phthalate.

Drafting zone, a section in many spinning machines which reduces the cross-section of a fibrous strand (sliver, slubbing or roving) by drawing in order to decrease the linear density and bring the fibres into parallel alignment at the same time.

Draining of steam chests This is carried out in such a way as to remove condensate from the heat exchanger as quickly as possible using a → Steam trap and condensate pipe.

Drape, serviceability parameter of woven and knitted textile fabrics.

Drawing (drawstretching) of synthetic fibres A process applied in the spinning of thermoplastic man-made fibres to achieve optimum performance characteristics. Drawing involves a post-stretching of the freshly spun filaments (by 400–1200% depending on the type of synthetic fibre). The process brings about a deformation of the polymer structure and, at the same time, an increased orientation of the chain molecules in the direction of the fibre's longitudinal axis (→ Texture). The long-chain molecules are pulled into alignment so that they become more closely packed alongside one another (chain packing) thereby forming crystalline regions (crystallites) which increase the fibre's tenacity through secondary valency forces (dye affinity is reduced in highly oriented fibres). The degree of "orientation" achieved can be determined by means of X-ray diffraction, infra-red spectroscopy, ultrasonic or double refraction measurements. The high strength of synthetic fibres is founded on the link between drawing and the degree of crystallization. →: Drawing variations in synthetic fibres; Melt-spinning process

The drawing of a non-oriented polyester fibre can proceed across the entire test sample if sufficient heat is provided. In cold drawing, however, orientation of the chain molecules occurs at a contraction point or flow zone which moves along the length of the test sample at a certain speed (known as neck formation). A schematic representation of the stress-strain curve and corresponding flow zone is given in the Fig. As can be seen from this stress-strain curve, a small, reversible, Hooke's deformation zone (3% extension) is followed by a plastic, irreversible, deformation zone after a minimum resp. flow stress σ_M is exceeded, at which point a flow zone creeps along the test sample. The minimum applied tension σ_M is constant here. The fibre is fully drawn after passing through this plastic deformation zone. Further extension leads to a reversible deformation of the fibre which can lead to rupture at very high extensions.

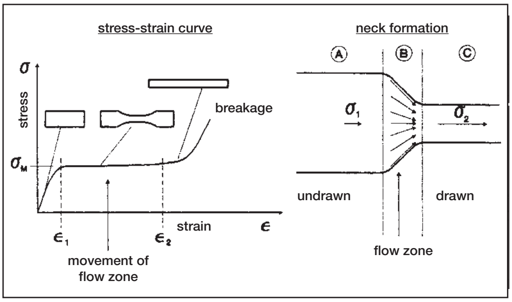


Fig.: Schematic representation of the stress-strain curve and the flow zone during the cold drawing of a synthetic filament fibre.

The important transformation of the amorphous polymer from the undrawn to the drawn, oriented, state occurs in the flow zone (see Fig.). The heat liberated in the flow zone is transferred to neighbouring molecules in the undrawn region which, through the combined effects of thermal mobility and external stress, easily overcomes the secondary valency forces and a parallel arrangement of the chain molecules results. The flow effects proceeding in region B are largely triggered by shear forces and are maintained. Because of the reduced cross-section in the drawn part of the fibre C, the external stresses summoned up here are greater than in the undrawn region A.

The energy balance of the work done in external deformation is essential for the observation of neck formation. A part of the work done is irreversibly dissipated as heat due to internal frictions. A further, reversible, part of the heat here is based on the decreased entropy of the material. The temperatures generated in this way are just sufficient to maintain adequate flowability in the moving flow zone. A further part of the mechanically performed deformation work is, on the other hand, not necessarily dissipated as heat, but is stored resp. frozen as increased internal energy in the drawn material. The material sustains internal stresses during the course of drawing. This part of the work done in deformation, and the resultant internal stress field, is the source of the shrinkage effects which occur in this material during thermal treatment. Moreover, these frozen, internal stress fields are considered to be the driving forces for shaping the structure.

In contrast to highly drawn fibres, in which the stress field is internally frozen and blocked by a network of crystallites, the stress field required for shaping the structure of undrawn fibres can be generated through subsequent external stretching (source: Schollmeyer).

Drawing in spinning → Melt-spinning process.

Drawing variations in synthetic fibres These are caused by differences in → Drawing (drawstretching) of synthetic fibres. They become manifest in fibre production as local differences in the radial structure of the filaments (telescopic effect). Such variations can give rise to difficulties in dyeing (it is particularly problematic with polyamide and other articles dyed in solid shades) since the more highly stretched finer sections of the filaments require more dye for a specific depth of shade. For the same volume, the surface area of a fibre inversely proportional to the radius (→ Microfibres). Corresponding changes in surface effects are predictable. Dyeing variations due to differences in drawing can occasionally be levelled out within certain limits (e.g. by appropriate dye selection, dyeing process and the use of specific levelling agents).

Draw out, to → Water extraction.

Draw roller, cloth handling roller driven by cogs; → Rollers.

Draw texturing → False twist yarn (textured).

DRE, directional (or differential) friction effect, German form of DFE.

DREF, false twisting method In this system a sliver, preferably produced by a drawframe, is drafted on a high draft drawing system. The drawn sliver is aerodynamically split on leaving the drawing system by being separated by force lateral to the roving axis. The slivers obtained in this way are combined by conventional means and twist is imparted by a twisting unit. A heavier feed sliver can be produced by drafting just one intermediate sliver instead of both. This practice further improves the economic viability of the false twisting method by reducing preparation costs and provides considerably better drawing from a technological point of view. The increased number of fibres in the cross-section of the sliver to be drawn and less twist compared to the conventional roving produced by the speed frame guarantees more even drafting in the high draft drawing system. The aerodynamic splitting of the drawn sliver which follows mechanical high draft drawing is less precise than in ring spinning. The in-phase combination of the two rovings whilst being twisted together immediately following the splitting process compensates any irregularities of fibre mass distribution in the two slivers. The character of the false twisting method is ultimately governed by the relatively easily controlled high drawing process, whereas splitting problems are of secondary significance.

Dried gypsum Calcium sulphate (anhydrous or with $^1/_2$ molecule crystal water), solidified when mixed with water (with heat generation), is able to hold large volumes of water. Produced by heating to 150–180°C = plaster of Paris for modelling and rendering purposes, for plaster casts, for fixing iron objects to stone walls (should harden in 10 min with one part water), or to over 1000°C = anhydrous flooring plaster (as accelerated setting agent, mortar admix). In the region 400–600°C "dead-burnt gypsum" is produced (only combines with water slowly).

Driers for textile materials A drier for textile materials has the following functions:

- Removal of the surface water (e.g. expression of water by pressure) (Fig. 1);
- Evaporation of the capillary water (Fig. 2);
- Achievement of an equilibrium moisture content with the chemically-sorbed water which is characteristic for the type of fibre being dried (conditioning) (Fig. 3).

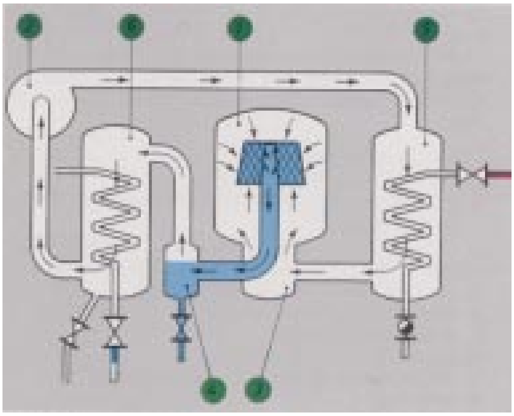


Fig. 1: Expression of surface water from a yarn package by pressure in the drier.

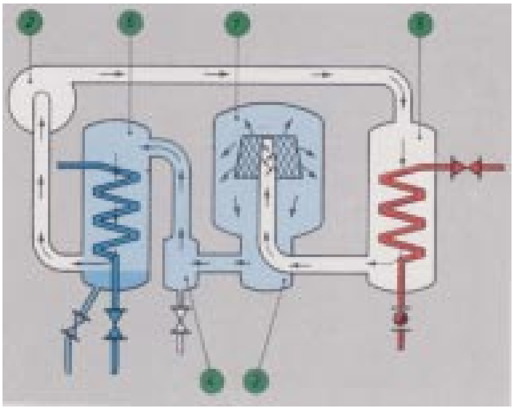


Fig. 2: Removal of capillary water in the drier.

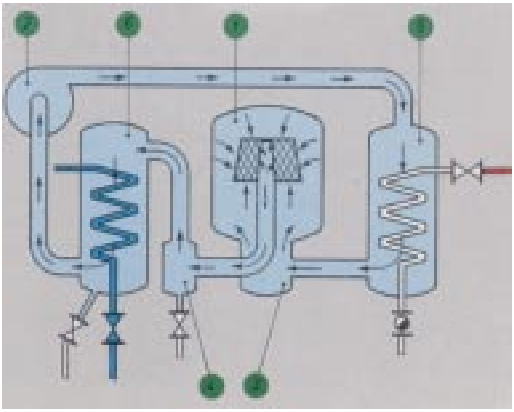


Fig. 3: Conditioning of chemically bound water in the drier.

Moreover, the drier must be designed specifically for the particular form of textile material being processed:

- Loose fibres (loose stock),
- Yarn in package or hank form,
- Woven or knitted fabrics (Fig. 4),
- Open-width or tubular fabric (Fig. 5),
- Made-up garments.

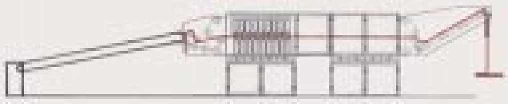


Fig. 4: Santex drier for knitted fabrics with feed zone.

Fig. 5: Henriksen drier for tubular knitgoods.
1 = fabric feed; 2 = reel; 3 = drying tube outlet; 4 = jet; 5 = jet compartment; 6 = fabric basket; 7 = fabric chamber with Teflon coating.

Finally, there are drying processes which represent part of a 2 or multi-stage treatment and must therefore take into account the preceding and subsequent stages:

- Drying after printing (Fig. 6),
- Drying and thermofixation (thermosol) treatment (Fig. 7),
- Drying after application of resin finishes,
- Drying with simultaneous relaxation of the tensions previously built up in the textile material.

Moreover, energy in a wide variety of forms can be supplied to the textile material, depending on the drying method, in order to achieve the evaporation of water:

- Contact heat (Fig. 8),
- Convective heat (Fig. 9),
- Electrical energy (high frequency energy),
- Chemical combustion energy.

Fig. 7 illustrates the drying zone of a conventional drying machine with infrared radiators and heat exchangers. In conventional drying processes, heat energy is supplied to the material as a drying medium from the outside. Steam, gas, oil and electricity are the energy carriers used. Evaporation is achieved through heat radiation and hot air currents. A pad liquor with 100% water requires large amounts of energy for evaporation.

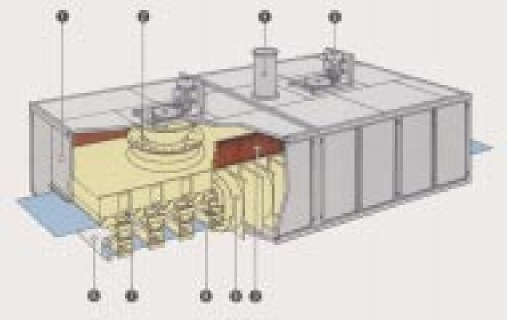


Fig. 6: Construction of a drier for printed fabrics (Stork).
1 = insulation; 2 = axial fan for air circulation; 3 = heater; 4 = exhaust fan; 5 = motor for air circulation; 6 = one or three passages; 7 = air nozzles; 8 = slit nozzles; 9 = air distribution system.

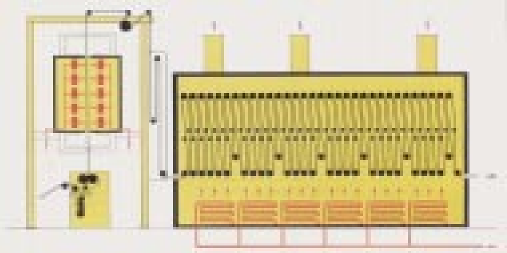


Fig. 7: Brückner pad-dry-thermosol unit with IR pre-drier and thermosol dye fixation chamber.

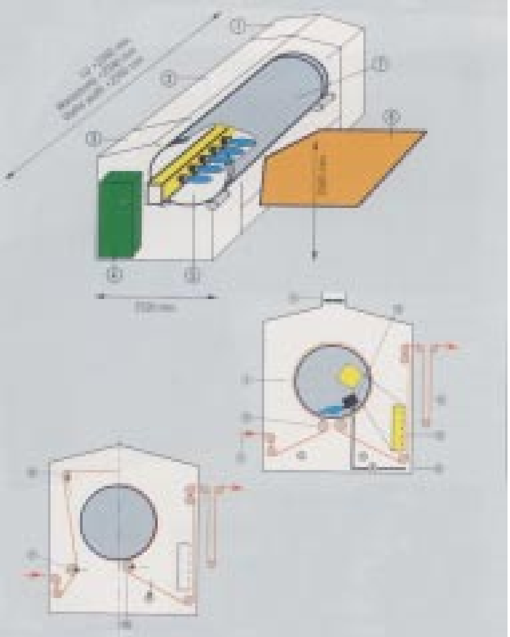


Fig. 8: AGI cylinder drier with gas heating.

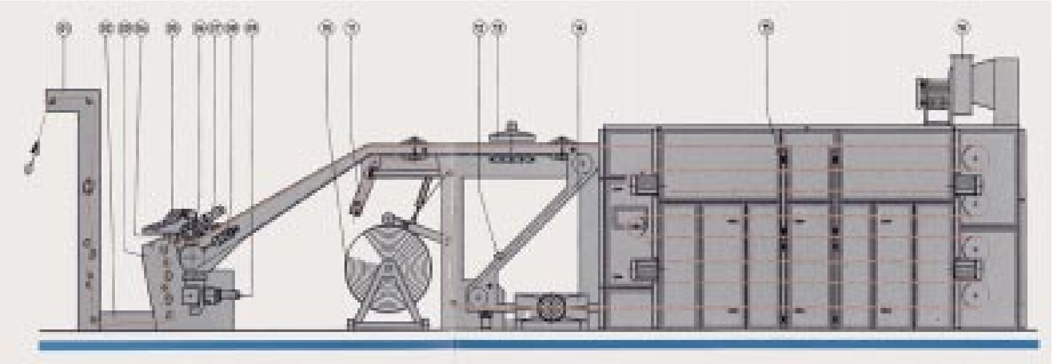


Fig. 9: Santalucia multi-layer stenter based on the convective drying principle.

Long fabric passages are necessary for the achievement of uniform temperatures on the fabric. The addition of expensive wetting agents and migration inhibitors are essential for uniform results.

Through-flow driers (e.g. sieve-drum driers) achieve a very good utilization of heat energy (Fig. 10).

If it is intended to bring the shrinkage which takes place through de-swelling of the fibres under control during drying, the textile fabric has to be dried in special machines. An important example of this type of drier is the → Stenters (Fig. 11).

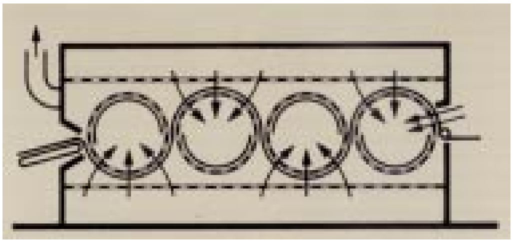


Fig. 10: Through-flow drier based on the sieve-drum principle (Fleissner).

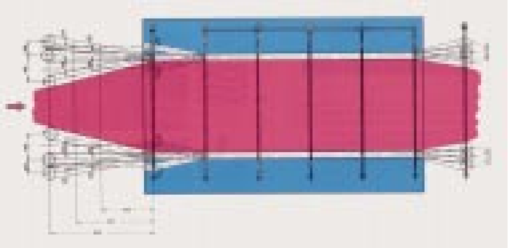


Fig. 11: View of fabric passage through the stenter with entry zone (left), drying tunnel and exit.

Driers, heat recovery systems → Exhaust air heat recovery.

Drill A general term for a strong, medium to heavy weight, densely woven fabric (linen, linen/cotton union and cotton) produced mainly in twill weave and occasionally satin weave (satin drill, mattress drill), also with herringbone stripe or check patterns, etc. Drills with a twill weave construction resemble denim except that the latter has a warp-faced right-hand twill and the former a warp-faced left-hand twill. Various terms are used according to the nature of the fibre used and the field of application (e.g. bed drill, table drill, trousering drill, sacking drill, cotton drill, etc.). It finds use in the grey, bleached, dyed or printed state for a variety of applications including workwear, pocketings, shoe linings, uniforms, bookbinding, coated fabrics, industrial fabrics, ticking, etc.

Drive belts →: Belt drives; Transmission belts.

Drives → Electric motors.

Drop printer Jet printing system for manufacturing sharp-edged prints (100 lines/inch). When leaving the end of the nozzle, the dye solution droplet is given a defined electrical charge (16 possible charge levels). Depending on the charge level, the droplet is either withdrawn, in which case no dye is applied, or electrostatically deposited over a width of 4 mm in a certain position (nozzles arranged at 4 mm intervals across the width of the material).

Drum cleaning machine, for batch dry cleaning of finished goods using tetrachloroethylene (perchloroethylene). Two parallel processes take place, cleaning and liquor recirculation (Figs. 1 and 2).

Drum drying machine →: Drying systems, Sieve-drum drier, Cylinder drying machines, Tumbler drier.

Drum dyeing machines consist of a perforated, reversible rotating drum, sometimes consisting of several compartments. Liquor ratio 1 : 8–1 : 10. Finished items, such as hosiery and fully-fashioned garments, and piece goods, such as uncut and cut plush fabrics,

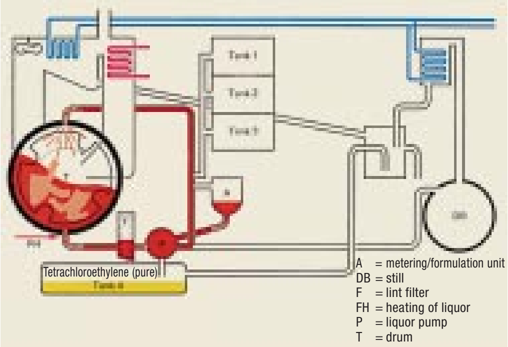


Fig. 1: Drum machine; basic diagram showing the liquor circulation during processing (for colour legend see Fig. 2).

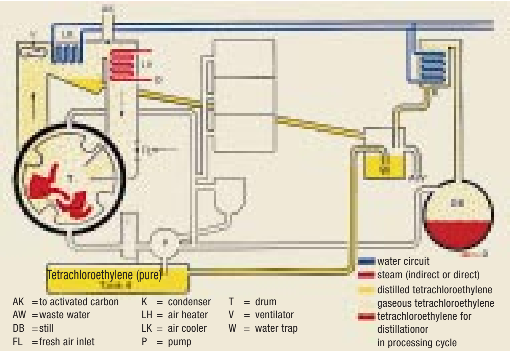


Fig. 2: Drum machine; basic diagram showing the liquor regeneration and drying of the goods.

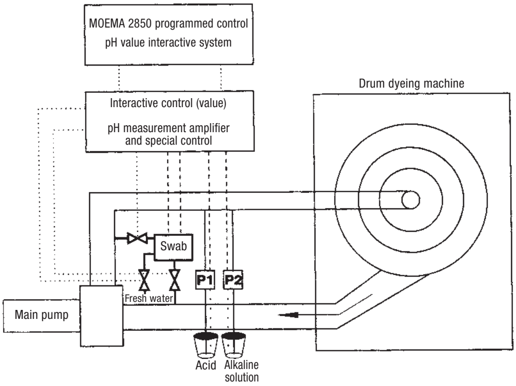


Fig.: Proposal for retrofitting of pH control equipment in a drum dyeing machine (Pardes Speciality Hosiery)

towelling and raised goods, can be dyed or finished. Drum dyeing machines are practically indispensable for the finishing of double plush goods. After tumbling or spongeing, and following shearing, the drum is loaded and the goods are washed, rinsed, spun, bleached, rinsed and spun again, dyed, rinsed, washed and hydroextracted. Processing times, e.g. for bleaching and dyeing, are often substantially shorter than those using other machinery, as the contact between liquor and goods is more intensive, and the direction of flow of the liquor is constantly changing as the rotation of the drum changes direction. A pH control system (see Fig.) is recommended for hosiery drum dyeing machines.

Drum partitions There are several different types of partition of inner drums, as shown in the Fig.:

O-partition = open, undivided circular drum;
D-partition = 2 sections, 2 inner chambers to the drum;
Y-partition = 3 sections, 3 inner chambers to the drum;
Star partition = 4 sections, 4 inner chambers to the drum;
Vertical partition = possible additional subdivision.

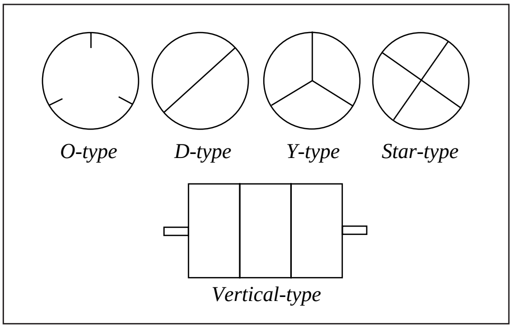


Fig.: Drum partition types.

Drum partitions and their effect on the washing mechanics are judged as follows: O-type: → Fall height across full drum diameter, items allowed to fall individually with good penetration, fast drum rotation = high fall frequency. D-type: items fall with “slippage brake”, tendency to bunch together with moderate penetration of inner sections, slower drum rotation = lower fall frequency. Y-type: fall height practically as low as half drum diameter, tendency to bunch together and fall outside liquor level. Slow drum rotation = low fall frequency.

Drum perforations, perforations in the surface of inner drums of → Drum washing machines, to allow the penetration of liquor.

I. Simple perforation (round holes) e.g. in the case of washer-driers.

II. Funnel-type holes, used in the majority of washing machine drums (= more efficient flow conditions, low mechanical loading).

III. Beaded holes (= more favourable flow conditions, high mechanical loading).

The perforation area usually represents 20–40% of the total area of the drum in washing machines. Sometimes additional perforations are found in the end or partitions of the drum (= additional penetration).

Drum pumps (barrel pumps) Purpose-built pumps for drawing liquids from drum containers, etc. Depending on chemical resistance requirements, constructed from polypropylene, aluminium, stainless steel, etc.

Drum washing machine In a high-speed washer (see Fig.) with special drum, the goods are advanced without conveyor belt, air cushion or pressure belt and the kinetic energy transformed into impact or compression forces. The washing and relaxing effects on fabrics and blends with wool content are therefore achieved with short processing times, thus eliminating the undesirable running creases which often result from wet finishing of textile substrates in rope form.

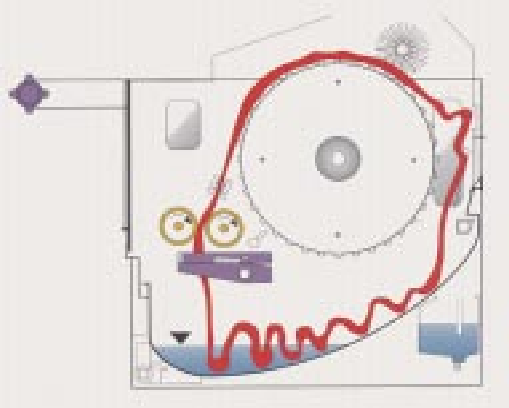


Fig.: Drum washing machine for wool cloth in rope form (Hemmer-Menschner).

Dry bonding → Bonding on textiles.

Dry chlorination, oxidative → Antifelting finish for wool with chlorine gas.

Dry clean, basic Cleaning and drying only in dry cleaning plants, i.e. without any special stain removal (spot removal) treatments.

Dry-cleaning Dry-cleaning involves 4 stages: 1) presorting of articles for dry-cleaning, 2) a basic dry clean in special machines with suitable solvents in combination with dry-cleaning detergents at a liquor ratio appropriate for the type of articles being cleaned, 3) stain removal with spotting agents and 4) finishing to shape by Hoffman pressing or ironing by hand.

Soil adheres to the surfaces of fibres to a varying extent. This attachment mechanism, referred to as adhesion, exists between a solid boundary layer and a second phase which is composed of individual particles (dust particles, gas molecules) or a continuous solid film. This adhesion may be due to electrostatic forces, van der Waal's forces, adsorption or an actual chemical bond. According to DIN 50 900, the energy of adhesion is defined as follows:

"The work expended in the isothermal and reversible separation of two phases carried out at their interface brings about an increase in the free energy of the system. This energy is described as the free energy of adhesion. It is equal to the sum of the free energy of wetting and the free surface energy (surface tension)."

The majority of surface contaminations are of an oily nature; they are therefore hydrophobic and consequently insoluble in water. Water is a polar compound; a water molecule is a dipole with a positive partial charge at the side of both H atoms and a negative partial charge at the side of the O atom due to the high electronegativity of the oxygen atoms and the geometry of the molecule (both H atoms are positioned at an angle of < 180° to each other). By contrast, a hydrocarbon molecule is non-polar since carbon is less electronegative and the chain-shaped molecule is completely enveloped by the hydrogen atoms.

The bond strength between a molecule in a contamination layer and the surface of the substrate is dependent on the potential energy of the particle. The dependence of this potential on the distance of the particle from the surface is shown in the Fig. Depending on the magnitude of the binding energy E_B, a distinction is made between the physisorption ($E_B < 40$ kJ/mol) and the chemisorption ($E_B > 40$ kJ/mol); as far as the bond strength is concerned, this latter represents the transition to an actual chemical bond. Whilst the bonding energy (resp. the amount of adsorption enthalpy) increases from the physisorbed through the chemisorbed

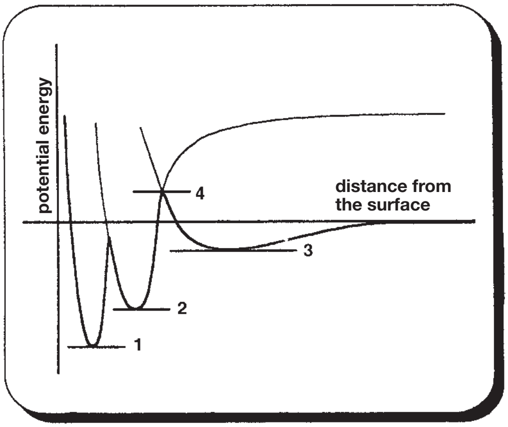


Fig.: Dependence of bonding energy on the distance of a particle from the substrate surface.
(1 = chemical bond; 2 = chemisorption; 3 = physisorption; 4 = activation energy).

	Vapour pressure at 20/50 °C	Solubility in water at 20 °C in mg/l	Boiling range in °C	Flash point in °C	Autoignition temperature in °C	Lower/upper explosion limit in g/m^3	German Water endangering class	TLV in ppm
Trichloroethylene (“Tri”)	**77/-**	**1. 100**	**87**	**-**	**410**	**7.9/90 (vol. %)**	**3**	**50**
Tetrachloroethylene (“Per”)	**18.6/-**	**150**	**121**	**-**	**-**	**-**	**3**	**50**
Trichlorotrifluoroethane (R 113)	**294.4/-**	**-**	**48**	**-**	**-**	**-**	**2**	**1 000**
Shell A 151	**0.85/4.9**	**-**	**185-330**	**> 65**	**230**	**26/467**	**-**	**none**
Shellsol D7	**0.5/2**	**15**	**220-330**	**99**	**220**	**84/500**	**-**	**none**
Shellsol C 153	**< 1**	**-**	**180-195**	**> 61**	**260**	**37/460**	**-**	**none**
Shellsol Degreaser 105	**1/6**	**6**	**182-212**	**60**	**375**	**37/460**	**-**	**none**

Table: Product and safety data for halogenated hydrocarbon and halogen-free hydrocarbon cleaning solvents (“Tri” and “R 113” are now prohibited).

state to the reaction layer, the distance between the sorbed particles and the surface of the substrate decreases. The minimum of the potential energy shows that a sorbed particle on the substrate surface is in an energetically-favourable state. The desorption of contamination layers requires the introduction of energy which corresponds at least to the amount of the bonding or sorption enthalpy.

In a dry-cleaning machine, this energy is introduced by means of chemical engineering. The energy required is provided in the form of mechanical, thermal and chemical energy. A comparison of the amounts of energy has revealed that it is not possible to desorb the adsorbed contaminations in a dry-cleaning machine with mechanical energy alone. Moreover, in order to remove adsorbed contaminations with thermal energy alone, temperatures significantly higher than 100°C must be realized in the dry-cleaning bath. In this regard, an increase in the bath temperature, which is limited by the boiling point of the dry-cleaning solvent, can only serve to shift the physical characteristics and interfacial properties of the contaminations in a favourable direction. As a consequence, the kinetics of dry-cleaning are influenced in the sense of a process acceleration.

In a dry-cleaning machine, the energy necessary for the desorption of contaminations is provided in the form of chemical energy. This is achieved by the selection of a cleaning solvent with suitable physico-chemical properties. In the simplest case, this requires that the contaminations should be soluble in the selected solvent. The cleaning action of halogenated hydrocarbons and halogen-free non-aromatic hydrocarbons for fat-based and oily contaminations is based on this principle. The energy required for desorption is provided by the enthalpy of solution, i.e. the energy gained in dissolving the contamination.

The advantages of oil and fat-based soil removal with halogenated hydrocarbons together with those of cleaning with surfactants can be combined by using a hydrocarbon/water dispersion. Because of the cleaning mechanism, which is based essentially on the solubility of contaminations in both phases, similarly uncomplicated types of dry-cleaning plant to those used for cleaning with halogenated hydrocarbons have been realized. As an alternative to the use of halogenated hydrocarbons, cold dry-cleaning agents based on hydrocarbons are available. These products contain neither chlorine, fluorine nor aromatic compounds, but have comparable cleaning properties to the halogenated hydrocarbons. Product and safety data for a number of solvents are compared in the table accompanying this article.

The advantages of the halogenated hydrocarbon solvents are due to their very low flammability at low boiling points and high vapour pressures. Comparable halogen-free hydrocarbons with similar boiling points would be extremely flammable. For dry-cleaning purposes, only those solvents with flash points above + 55°C are acceptable. The low volatility of such solvents reveals itself in their relatively high boiling points and low vapour pressures. The flammability of non-halogenated hydrocarbons involves a higher outlay on adequate safety precautions for dry-cleaning plants. Under no circumstances must the flash point, or lower explosion limit, be exceeded. The solubility of non-halogenated hydrocarbons in water is extremely low and, for this reason, a water endangering classification has not yet been allocated to these solvents (source: Haase).

Dry-cleaning antifoams (→ Antifoams in dry-cleaning) prevent and destroy the build-up of foam in solvent distillation liquor by means of e.g. saturant containing silicon in combined action with residues of finishing agents and dry cleaning detergents, and prevent the contents of the distilling kettle from boiling over, which would otherwise often be inevitable. Usually flammable liquids.

Dry-cleaning detergent (dry-cleaning intensifier). These are used in → Dry-cleaning in normal organic solvents to considerably increase the cleaning action with maximum removal including water-soluble impurities. New concept introduced in 1953, replacing → Benzine soap in terms of composition, efficiency and economic viability.

Composed from synthetic active detergents with low salt content + dissolving agents (low molecular alcohols) + possibly activation additives (surface active agents, emulsifiers, organic phosphates etc.) + (water 5–20 %) + (organic solvent) + possibly special additives (anti-static agents, optical brighteners, bleach (hydrogen peroxide), disinfectants, fabric conditioners, proofing agents, leather oils, corrosion inhibitors etc.). Non-ionics are preferred as they can be used as dissolving agents for solvents in addition to their active detergent properties. Commercial forms as clear solution, water-in-oil emulsion, dispersion and also as powder.

Attributes: Increases the solvent conductibility (prevention of electrostatic charges on the fibre or redeposits of previously removed soil which promotes greying; intrinsic detergent action even without the addition of water (N.B. necessary for light, loose woollen goods); can be easily filtered, even when water has been added (no increase in the filtration pressure); repeatedly capable of absorbing water in the solvent liquor (high charged system) for enhanced removal of water-soluble impurities; promotes high water retention in the solvent; does not impair any subsequent wet or dry impregnation; inert to fibres, dyestuffs and finishes; promotes pleasant fabric handle; inert to metal parts of the machine and in closed circuit systems.

Dry-cleaning detergent concentration test → Methylene blue method.

Dry-cleaning effects The effects of appropriate dry cleaning extend beyond the cleaning effect itself, as they are also accompanied by extensive quality characteristics of various kinds which are altogether typical of the advantages to be gained from cleaning by means of a solvent treatment, e.g.:

- a clearer, cleaner, odour-free result is achieved;
- the colours, effects and printed designs are maintained and appear clearer and brighter;
- the finish effects are also maintained (provided they are not soluble in the dry cleaning solvent), restored and improved;
- the fibre properties are protected;
- the original made-up dimensions remain unchanged;
- parasites are destroyed;
- germs are completely destroyed through the use of special additives.

Dry-cleaning effluents According to scientific investigations, the presence of tetrachloroethylene (perchloroethylene) in quantities of less than 10 mg/kg in effluents does not impair aerobic degradation in biological waste water treatment plants. In 1975, the Hohenstein Institute was able to establish that the tetrachloroethylene content in water from water separators was usually below 200 ppm (= 200 mg/kg), i.e. only slightly above the natural solubility of tetrachloroethylene in water at 20°C which is 160 ppm. In order to assess possible effluent contamination by tetrachloroethylene, the quantity of effluent outflow must be taken into consideration: only 0.10–0.15% of the total water leaving the drycleaning machine flows from the water separator. Consequently, the concentration of tetrachloroethylene in the total water is reduced to below 0.5 mg/kg. Although the dilution ratio is, in fact, reduced to 1 : 30 by steam distillation, there is still no danger for the effluent at this phase of the operation. In order to take advantage of all possible precautionary measures, the effluent (together with other waste process water = dilution effect) can be diverted into a separating pond with an upper outlet for water and a possibility for draining off tetrachloroethylene at the bottom (with a bypass line in order to break-up any emulsions, if necessary, by high additions of salt and thus separate off the tetrachloroethylene); regular inspection and maintenance are necessary here. Effluents from collection sumps and extracts from stain removing tables contain, in addition to predominantly surface-active compounds (harmless in effluents), numerous chemicals and many different solvents which should not be discharged into the effluent. These wastes must be disposed of, together with distillation residues, as special sludge wastes.

Dry-cleaning fastness, determination of the capability of dyed textiles to withstand → Dry-cleaning. A bag of cotton twill containing 12 steel discs and the test sample is treated for 30 min in the appropriate machine at 30°C in 200 ml tetrachloroethylene (or other solvents) without added reagent, then spun and dried at max. 65°C. In commercial dry cleaning consideration is also given to the following fastnesses: →: Fastness to: Stain removing, Organic solvents, Water spotting, Ironing, etc.

Dry-cleaning machines, various models in long drum (industrial scale) or high drum (cabinet) design. Dry-cleaning machines consist of:

1. Cleaning system (perforated cylindrical cleaning drum with paddles, cleaning cycle (partially reversible), spin cycle, pump cycle via needle traps and filters, with solvent tank).
2. Drying system (air is drawn through the outer drum via heating/cooling radiators for the evaporation and recovery of the solvent contained in the hydroextracted dry-cleaning load).
3. Distillation system (distillation apparatus, condens-

er, water separator, distilled solvent tank) for the regeneration of the soiled solvent. Different designs for chlorinated hydrocarbons, fluorinated hydrocarbons and petroleum hydrocarbons. So-called cold units (cleaning and fresh air drying in separate systems, manual unloading-reloading) are used for petroleum hydrocarbons. So-called hot units are used for chlorinated hydrocarbon and fluorinated hydrocarbon solvents. In these, the goods for dry-cleaning are automatically passed through the entire working process including drying. Drying method: for chlorinated hydrocarbon machines, circulatory flow drying with partial fresh air drying. For fluorinated hydrocarbon machines only circulatory flow drying in closed machine systems due to the high volatility of the solvents. The operating cycle is always controlled by an automatic programme; duration: 20–30 min., cleaning incl. drying (hot units). Use of activated carbon devices to recover the solvent in the adsorption process serves a) to remove exhaust air which is free of solvents, (statutory directive for air pollution control) and to reduce solvent loss; b) particularly with fluorinated hydrocarbon installations to maintain a closed drying and recovery cycle, where work does not occur in a vacuum.

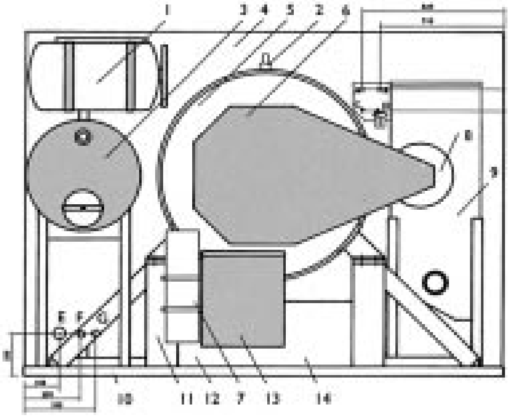


Fig. 2: Rear view of the HC-sol.
1 = rotating filter; 2 = door lock; 3 = distillation apparatus; 4 = front wall; 5 = drum; 6 = V-belt guard; 7 = collecting bin; 8 = drive motor; 9 = settling tank; 10 = collecting basin; 11 = machine stands; 12 = distilled solvent tank; 13 = needle trap; 14 = operating tank; A = compressed air; B + C = water supplies; D = maintenance unit; E = water run-off; F = condensate run-off; G = steam supply.

The use of petroleum fractions in new-style machines is experiencing a revival, e.g. MSG HC-sol with Shell hydrocarbons (Shellsol D60 S or T) or Exxon (Actrel Dryclean 56 or Isopar H). The principle problem when using pure hydrocarbons as textile drycleaning agents is their flammability and therefore the risk of explosion, which led people to switch to halogenated hydrocarbons at one point. The HC-sol machine (see Figs. 1 and 2) has the following three advantages in relation to this:

- Operating temperature is below the flash point (71°C);
- Operating mode at low pressure, i.e. pressure is less than 1 bar (e.g. 300 mbar) in the cylindrical cleaning drum during the drying process;
- Air-tight drum.

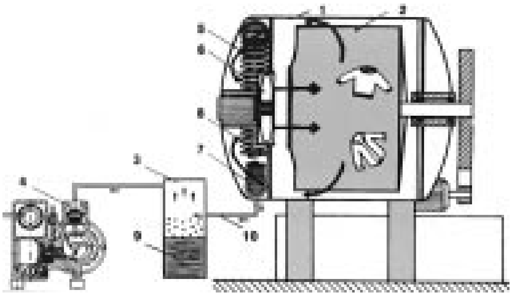


Fig. 1: Design of the HC-sol (MSG).
1 = outer drum; 2 = inner drum; 3 = collecting bin; 4 = vacuum pump; 5 = heating coil; 6 = exhaust fan; 7 = cooling coil; 8 = lint trap; 9 = solvent; 10 = condensate run-off.

After the loading door has been pneumatically sealed, the drum is evacuated. If a leak or defect prevents the necessary vacuum forming, this is indicated and the programme is interrupted. Filling the machine with solvent, cleaning, solvent discharge etc. takes place at temperatures well below the flash point. During the final stage of the hydroextraction, evacuation of the drum begins and the radiator is heated up. In the evacuated drum, the remaining air is now circulated and heated. The solvent expelled from the clothing condenses on the walls of the tank and on the cooling coil and is continually extracted. Drying can take place above the flash point without posing a risk in the evacuated drum. The vacuum also reduces the boiling temperature of the solvent by approx. 50°C, enabling gentle drying. The radiator is switched to cold water throughput for cooling, the ventilation cools down the goods being treated. The drum can be unloaded after airing.

Dry-cleaning – organisational procedure,

1. Receipt of goods and tagging with identification marks.
2. Textiles, leather and fur goods, as well as details concerning their resistance to dry cleaning are checked, and the appropriate treatment method is allocated.
3. Brushing.
4. Sorting according to type of material (quality, colour).

5. Preliminary treatment with spotting agents for stain removal.
6. Machine dry cleaning (basic treatment).
7. Appearance and shape of cleaned goods is restored by e.g. ironing, steaming.
8. Final inspection.
9. Collation of orders and preparation of bills/invoices.
10. Despatch.

Dry-cleaning problems Of the approximately 8000 dry-cleaning companies in the Federal Republic of Germany, in 1990, 1500 of those companies made up 80% of the turnover, while a further 4000 companies accounted for only 10% of the turnover. Of the 100 000 tonnes per annum of tetrachloroethylene used in Germany, only 15 000 tonnes per annum were used by the dry-cleaning companies for clothing. Tetrachloroethylene (perchloroethylene) may cause cancer in rats, however it is not the tetrachloroethylene, but the epoxide formation in the rat's metabolism which can be carcinogenic if the oxygen metabolism is exhausted. The question as to whether this metabolism is specific to rats and to what extent it may be applicable to humans still remains unanswered.

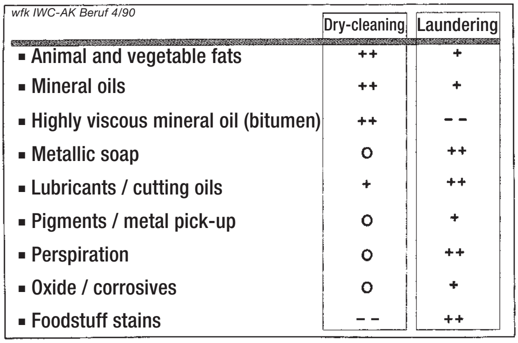
In laundries, alternatives to dry-cleaning in aqueous systems are being looked into. When clothing is used, foreign substances present in the environment inevitably come into contact with the textile. The longer the garment is used, the more the protective effect in particular is lost. The textiles are able to be permeated by those substances against which they are intended to provide protection. They become increasingly impermeable to water vapour, i.e. perspiration. Body temperature, well-being and performance become impaired. Cleaning processes ensure that such deposits are removed again. Cleaning processes involve aqueous treatment methods (laundering) or solvent treatment (dry-cleaning). This results in emissions. In laundering, this means predominantly pollution of the washing water as a result of the cleaning chemicals and soiling which has been removed; in dry-cleaning, these are solvent emissions in the air and accumulation of distillation sludge which needs to be disposed of as special category waste. Laundering and dry-cleaning are therefore being put increasingly under pressure from requirements by the laws and regulations governing environmental protection. Extra costs are also incurred in fulfilling these requirements. The main concern in laundering is the Water Resources Act (WHG) and the appendices based on § 7 for framework regulatory provisions, and for dry-cleaning, in addition to this regulation, the Federal Clean Air Act (BImSchV) and the 2nd ordinance relating to this (2nd BImSchV). Environmental liability and environmental penal law must also be taken into consideration. The polluter-pays principle in environmental law is significant here, i.e. the person causing damage to the environment must make good the damage regardless of blame. Procedures therefore have to be assessed as regards their potential to cause damage and any resulting charges.

Fundamental requirements of that cleaning process, which is in actual fact a recycling process for a textile which can be reused rather than scrapped, are that a garment is produced which is completely hygienic, free from harmful substances, clean and able to be completely used again. Cleaning technology is faced with a conflict of aims between the fulfilment of the environmental directives and the maximisation of cleaning results in order to be profitable. One factor which is a decisive element in achieving profitability is the retention of fibrous substances, as in addition to ensuring that there is sufficient removal of dirt, this also determines the life-span of the recyclable textile.

These cleaning processes are particularly significant if industrial or commercial processes are used where hazardous substances are involved. Penetrative hazardous substances can pose a risk to health. In order to avoid risks of this type to the workers, e.g. in the form of dermatitis and allergies, it is not only important to make a suitable choice of textile, but more importantly to remove these substances as far as possible, to avoid re-deposits on other textiles which are washed together and to achieve this under conditions which pose the minimum risk to the environment. An essential prerequisite for this in addition to optimising cleaning technology is an optimal adaptation of the textile to use in the trade concerned and the necessary care treatment. The correct care treatment is determined by the properties of the textile goods, such as fastness and cleanability, the nature and severity of the soiling compared with how successfully it can be removed, the requirements of the cleaned textile (flame resistance, permeability to water and dust) and in recent years increasingly by the nature and severity of the soiling with respect to environmental impact.

When deciding between laundering or dry-cleaning a garment, a whole range of issues need to be considered: the cleaning process is determined in the first instance by the properties of the textile (is wet treatment possible or not?), and secondly by the nature of the soiling (is the soil water or solvent soluble?). It is only possible to remove a large proportion of water-soluble soils sufficiently by laundering, whereas bitumen or similar highly viscous mineral oil products can only be sufficiently removed using a solvent treatment.

The Table gives a list of selected soils and whether they can be removed by cleaning or laundering. If a type of soil is poorly removed by one process, this is also true of any hazardous substances present in this type of soil. Although laundering chemicals contain substances which pollute effluent waste, they can later be safely removed by a communal clarification plant. Laundering can therefore be regarded as a polluting



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	Dry-cleaning	Laundering
▪ Animal and vegetable fats	++	+
▪ Mineral oils	++	+
▪ Highly viscous mineral oil (bitumen)	++	– –
▪ Metallic soap	o	++
▪ Lubricants / cutting oils	+	++
▪ Pigments / metal pick-up	o	+
▪ Perspiration	o	++
▪ Oxide / corrosives	o	+
▪ Foodstuff stains	– –	++

Tab.: The table gives a list of selected stains and whether they can be removed by cleaning or laundering.

process, but which does not affect the quality of the surface water or groundwater. It is therefore not usually necessary to treat the effluent or exhaust air, or if it is necessary, then only in ways which are simple to implement (pH, temperature). Mineral oils and fats in the form of restricted pollutants according to local authority regulations and “hazardous substances” according to § 7a come almost exclusively from soiling, with the exception of AOX compounds (chlorine compounds) which may also arise as a result of the technical procedures (chlorine bleaching).

Dry-cleaning with chlorinated solvents basically requires emissions to be minimised due to toxic properties which pollute the air and water. The high risk of endangering groundwater together with the high density and low water-solubility result in considerable risks in the event of an accident. In contrast to laundering, dry-cleaning chemicals and soil have to be extracted in concentrated form through the distillation sludge as special category waste and are not passed into municipal sewage. The 2nd BImSchV, which has already been referred to, or the amended version and the appendices to the “Dry-cleaning” and “Laundries” framework regulations specify the necessary work involved.

a) In the amendment to the 2nd BImSchV, a ban on tetrachloroethylene was originally envisaged for 2002. In the new edition of April 1990 this ban was withdrawn, but the limitations on levels of emissions in adjacent rooms of 0.1 mg/m^3 has been retained. It is of no importance here whether the source of the emission is the cleaning process itself or subsequent procedures (e.g. discharge from the textile).

b) “Hazardous substances” are to be minimised in accordance with § 7a WHG in line with the state of the art before introducing the effluent into the sewerage system. This state of the art is stipulated by standard limits and discharge pollution maxima in the appendices to the framework regulations.

Dry-cleaning processes These are subdivided according to the amount of dry-cleaning detergents applied:

I. Low-charged process: dry-cleaning detergent concentration 1–10 g/l liquor, rinsing bath necessary in exceptional circumstances.

II. Medium-charged process: dry-cleaning detergent concentration 10–20 g/l liquor, rinsing bath necessary for mercery and aftertreatments.

III. Super-charged process: dry-cleaning detergent concentration 20–40 g/l liquor, rinsing bath necessary.

Distinction is made according to the technical processes required:

- one-dip process,
- two-dip process,
- three-dip process,
- multiple dip process,

which generally need to be further subdivided into stage processes. A stage refers to a process phase in which the composition and/or circulation of the liquor is altered. The “no-dip process” is unique; this is carried out with a cylindrical cleaning drum which operates without dipping and continually applies filtered solvent to the goods before immediately draining this away (generally used for badly soiled, hard-wearing goods). Other processes include emulsifier processes, steam spray processes etc. which use a large proportion of free water which continues to be evaporated and discharged during the cleaning process via a blower (only for hard-wearing goods). These processes take approx. 20–30 min. in general for 1 to 2-dip processes.

New processes are developed by replacing halogenated hydrocarbons with those which are non-halogenated (→ Dry-cleaning solvents). In the cleaning process, the use of non-halogenated hydrocarbons creates more problems than tetrachloroethylene, for example. Due to the lower steam pressure, drying processes are more costly and due to the flammability of the products, each thermal treatment must take place in inert gas or in a vacuum for safety reasons. Regenerating the solvent in the dry-cleaning machine is more difficult with high boiling-point products, as pollutants from textiles and flammable substances such as ethanol from auxiliaries with boiling points below that of hydrocarbon solvents have to be separated in the same way as pollutants with boiling points higher than those of the solvents. With tetrachloroethylene, it can be assumed that, with the exception of water, the pollutants which have entered the solvent from the textiles and auxiliaries have a higher boiling point than the solvent itself and therefore it is possible to separate them off in a simple batch distillation as residue. Substances separated off by distillation must be disposed of as hazardous waste in the case of both tetrachloroethylene and hydrocarbon solvents. However, disposal by incineration of hazardous waste is simpler with halogen-free residues as it is possible to avoid flue gas being produced chemically.

Hydrocarbon machines dry the dry-cleaned textiles in a closed cycle, similar to tetrachloroethylene machines. Exhaust air drying systems are standard in some countries, although not in Germany. As the drying process is more difficult when using hydrocarbons (which have a high boiling point), the drying system needs to be designed differently from that of tetrachloroethylene machines in terms of heating capacity and air circulation. To achieve a drying time which is technically feasible, drying must take place at a temperature of above 60°C, as steam pressure is too low below this temperature. The drying temperature is therefore well above the flash point. In order to avoid the formation of explosive air/solvent mixes, work therefore takes place either in a vacuum or with nitrogen.

With a Transferon system, the interior of the machine is rinsed with nitrogen after loading. This comes from a separating plant which by means of an adsorption process produces nitrogen from air with a residual content of 2% O_2 which is used for making the system inert. The oxygen content in the machine is continually monitored. As an explosive mixture is no longer possible at an oxygen content of less than approx. 12% with hydrocarbon vapour with a lower flash point of approx. 0.6% and with an upper flash point of approx. 6%, the machine is operated at approx. 6%, i.e. half the limit value. The machine cleans after the air-nitrogen exchange in a cold state due to the nitrogen and automatically activates the drying process. The inert gas in the machine is heated by a steam-heated gas heater to approx. 90–95°C, passes through the drum with the textiles and takes the solvent vapour with it. This is condensed on the refrigerant vaporizer of a heat pump and removed from the cycle. The circulating gas then flows through the condenser, i.e. the warm side of the heat pump, and thus ensures effective heat exchange. The drying time is approx. 30–40 min.

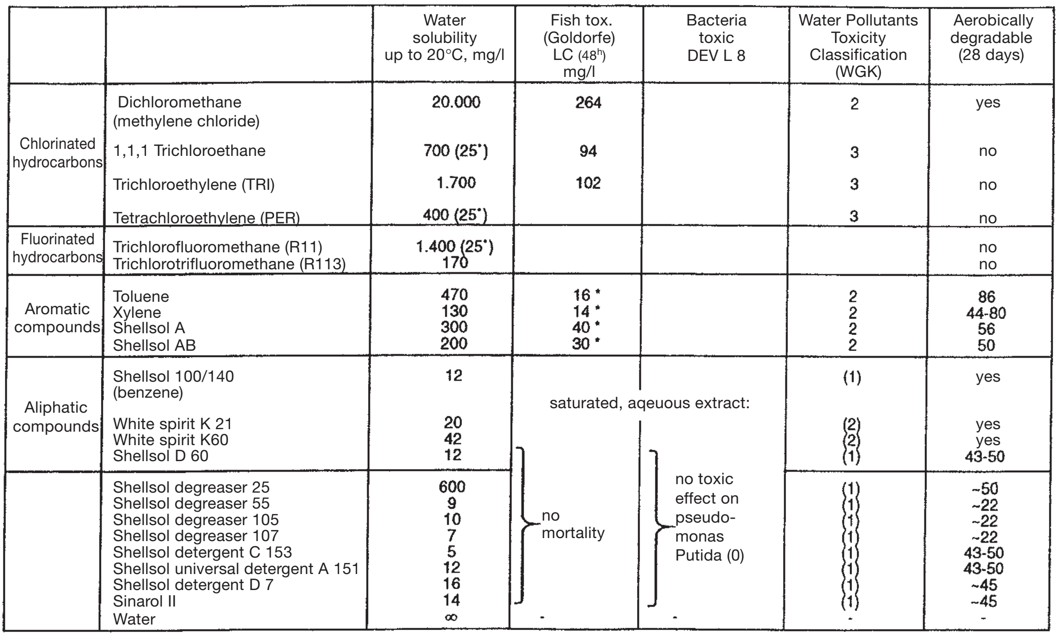
Rewatex uses vacuum technology in its hydrocarbon machine. After loading the machine, the door is pneumatically sealed. Before the program begins, a leak test is performed (brief evacuation of the drum followed by reventilation). The following steps – filling with solution, cleaning, solvent run-off, pre-heating the heating radiator, hydroextraction, take place below the solvent's flash point. In the final stage of hydroextraction, evacuation of the drum begins, the heating radiator is heated up. When an absolute pressure of 500 mbar is reached, hydroextraction is interrupted, the drum is bled until the correct operating pressure is reached. During the drying process, the solvent expelled from the clothing condenses on the walls of the tank and the cooling coil and is continually extracted. The boiling temperature of the solvent is reduced by approx. 50°C as a result of the vacuum, and this enables a gentle drying to take place. For cooling, the heating radiator is switched to cold water throughput and a fan cools the goods down. The drum can be unloaded after airing.

Dry-cleaning regulations The fundamental legal points concerning operation of dry-cleaning equipment are protection of labour (e.g. Technical Regulations for Hazardous Substances, TRGS) and protection of the environment (e.g. the Federal Clean Air Act, BImSchG). Permission, licence, or authorization to operate hydrocarbon solvent dry-cleaning equipment is not necessary. The machines must meet the generally accepted engineering standards (a.a.R.d.T.), e.g. the regulations guiding protection of the environment and the regulations for the prevention of accidents in line with the employer's liability insurance association, DIN and other standards applicable in Germany. "Approved safety" labels are available, but are not compulsory. Authorization in accordance with the Federal Clean Air Act under the 4th BImSchG is only compulsory for emissions above 25 kg/h during the drying stage. According to the state of the art, limit values of the technical directive on air must be complied with. Appendix 40 of the regulatory provisions concerning effluent must be complied with due to the Fundamental Principles of the Laws Relating to Water Resources. For environmentally problematic substances such as hydrocarbons, only the generally accepted engineering standards are applicable. Hydrocarbon cleaning equipment should be placed in a collecting basin. The "Order governing Flammable Fluids" (VbF) is applicable to the reservoir function of the dry-cleaning equipment not to its operation. Basically, the numbers present in a plant are not storage containers in this sense and are therefore not subject to the regulations for public permits.

The situation for de-aromatized hydrocarbons (→ Dry-cleaning solvents) is detailed below.

I. Industrial health: according to TRGS 420, a so-called tolerance level is determined from the saturation concentration divided by the max. work place concentration (MAK = threshold limit value). For hydrocarbon compounds, working standard values (ARW) are given as a basis in accordance with TRGS 404. For de-aromatized hydrocarbons, this value is 350 ppm. De-aromatized hydrocarbons do not irritate the skin according to the OECD test procedure (4 h semi-occlusive). However, nitrosamines which have conclusively been classified as carcinogenic in tests on animals can form in an oxidizing atmosphere. A particularly oxidizing atmosphere arises in the atmospheric drying working area, for example.

II. Industrial safety: The primary danger when dealing with hydrocarbons is the risk of explosion and fire. As long as the working temperature is 10–15°C below the flash point, there is no risk of explosion from steeping baths. The same applies to spray applications with pressure of up to 2 bar at the nozzle exit with diameters > 2 mm (current safety level). Products with a flash



		Water solubility up to 20°C, mg/l	Fish tox. (Goldorfe) LC (48^h) mg/l	Bacteria toxic DEV L 8	Water Pollutants Toxicity Classification (WGK)	Aerobically degradable (28 days)
Chlorinated hydrocarbons	Dichloromethane (methylene chloride)	20.000	264		2	yes
	1,1,1 Trichloroethane	700 (25°)	94		3	no
	Trichloroethylene (TRI)	1.700	102		3	no
	Tetrachloroethylene (PER)	400 (25°)			3	no
Fluorinated hydrocarbons	Trichlorofluoromethane (R11)	1.400 (25°)				no
	Trichlorotrifluoromethane (R113)	170				no
Aromatic compounds	Toluene	470	16 *		2	86
	Xylene	130	14 *		2	44-80
	Shellsol A	300	40 *		2	56
	Shellsol AB	200	30 *		2	50
Aliphatic compounds	Shellsol 100/140 (benzene)	12			(1)	yes
			saturated, aqeuous extract:			
	White spirit K 21	20			(2)	yes
	White spirit K60	42			(2)	yes
	Shellsol D 60	12	no mortality	no toxic effect on pseudomonas Putida (0)	(1)	43-50
	Shellsol degreaser 25	600			(1)	~50
	Shellsol degreaser 55	9			(1)	~22
	Shellsol degreaser 105	10			(1)	~22
	Shellsol degreaser 107	7			(1)	~22
	Shellsol detergent C 153	5			(1)	43-50
	Shellsol universal detergent A 151	12			(1)	43-50
	Shellsol detergent D 7	16			(1)	~45
	Sinarol II	14			(1)	~45
	Water	∞	-	-	-	-

() Values in brackets = classification based on fulfilmet of the criteria
* Rainbow trout 96 ^{h}, LC_{50}

Tab.: Effluent parameters for solvents.

point of approx. 99°C and working temperatures of over 80–85°C which are watered down by more than 10% in the fluid phase are rendered sufficiently inert. When drying garments which have been cleaned and rinsed, it is compulsory and sufficient to comply with the regulations for the prevention of accidents (VGB 24) and the “Regulations concerning calculation of necessary ventilation for cabinet and continuous flow dryers”. Exhaust fans should be designed in accordance with VDMA 24 619.

III. Air emission: The quantity discharged into the atmosphere per unit of time is significant in the reduction of exhaust air. When comparing the evaporation losses from open baths, all substances with low vapour pressure must naturally separate off sufficiently. A comparison between hydrocarbons and chlorinated hydrocarbons at working temperature indicates lower emissions by a factor of 100.

IV. Effluent: Effluent parameters for solvents are given in the table. Compliance with appendix 40 of the framework regulatory provision governing the effluent when using de-aromatized hydrocarbons is unproblematic. These substances are subject to microbial decomposition, although this is not significant at operating temperatures above 45–50°C (water solubility of hydrocarbon compound 180–210°C with 20% aromatic compounds = 42 mg/l, with 0.1% aromatic compounds = 5 mg/l). The concentrated aqueous extract from hydrocarbon dry-cleaner agents is neither toxic to fish nor bacteria toxic, and the products have therefore been assigned 0 on the water pollutants toxicity scale (WGK). As isoparaffin is less biodegradable, it is classed as WGK 1; white spirits containing aromatic compounds come under WGK 2. When cleaning using hydrocarbons, it is advantageous not to use surfactants and dissolving agents especially oil separation in a gravitational separator in accordance with DIN 1999, which means that pre-dilution and separation plants at the end of the process (coalescence filters, flocculation plants, membrane filters etc.) are not generally necessary. Tried and tested three phase decanters (centrifuges) are suitable for recycling (longer serviceable life).

V. Waste management and recycling: Hydrocarbons obtained from mineral oils are waste oils according to § 5 a of the Refuse Disposal Act. They cannot therefore be disposed of as industrial refuse. The assignment to recyclings bowls depends to a large extent on whether the re-processor has suitable equipment and operating permits. Hydrocarbon dry-cleaning agents can be used in association with the “contaminated oils” as category 2 waste oil. As, in dry-cleaning, dispersed water contents of 10–12 % are generally sufficient to remove water-soluble stains and to achieve surface activity but also by making inert by steam it is possible to economically dispose of all the fluid in the cleaning bath (hydrocarbon solvent + water) without the need for any in-house effluent treatment/processing. With quantities below 500 kg/year, it is not necessary to provide regular proof on the waste disposal site in accordance with the "specimen regulatory provision for the implementation of §§ 11 and 12 of the "Waste Disposal Act" and the "Regulations for monitoring wastes and refuse" of 3.4.90. Hydrocarbons, including the "contaminated oils" or their distillation residues, can be physically recycled if they occur in a sufficiently large quantity in a carbon or oil residue hydrogenation plant as long as they are pumpable. Mineral oil products containing chlorinated paraffin in particular can be disposed of in this way. For thermal recycling, authorisation in accordance with the Federal Clean Air Act and separation treatment in the context of mineral oil excise duty is necessary (source: Hertlein).

Dry-cleaning solvents These are generally classified into two groups:

1. Flammable solvents: light petroleum distillates, white spirit, Stoddard solvent, and heavy petroleum spirit.
2. Non-flammable solvents: chlorinated hydrocarbons such as trichloroethylene, tetrachloroethylene (perchloroethylene), 1,1,1-trichloroethane and trichlorotrifluoroethanes (solvents R11 and R113).

The general properties of halogenated hydrocarbons have been responsible for their wide application in commercial dry cleaning. They offer the following advantages:

- non-flammable;
- superior cleaning power compared to petroleum distillates;
- better solvents for fats (animal, vegetable, mineral);
- good solvent action towards asphalt, resins, oil paints, paraffin, pitch, tar, waxes, etc.;
- no fibre damage (exception: polyvinyl chloride = PVC).

Their disadvantages are:

- various synthetic resins (e.g. in zip fasteners, buttons, finishes, etc.) are partially soluble;
- in the presence of aqueous moisture, they promote the corrosion of certain metals;
- trichloroethylene has a certain solvent action towards cationic (basic) dyes as well as some disperse dyes;
- they have properties which are injurious to health: suspected carcinogens.

In the draft of the German 2nd Federal Emissions Protection Law, which has been in force since 01.03.1991, the use of tetrachloroethylene for textile dry cleaning has been permitted without any time limit (→ Dry-cleaning problems) and the chlorofluorocarbons (e.g. R11, R113) were banned. On the other hand, the Federal Government has been directed by parliament to seek suitable alternatives in order to reduce as far as possible the usage of organohalogen compounds. As more acceptable substitutes, especially for cleaning delicate textiles which were formerly cleaned with chlorofluorocarbons (CFC's), higher boiling point hydrocarbons offer a possible alternative. Other possible products are currently not available for large-scale industrial use. In the search for alternative solvents, it must be assumed, in principle, that all organic products which have not been fully halogenated are flammable. An important criterion for the suitability of alternative solvents in dry cleaning is the possibility for hazard-free handling outside the machine. This provides a good indication as to whether the solvent is compatible for use by operatives employed in the dry cleaning industry under acceptable circumstances and that, in the case of flammable products, the flash point is so high that the product can be handled safely at ambient temperatures. Moreover, if the product leaks or spills into the environment, in the event of accidents, it should be less harmful than tetrachloroethylene which is highly persistent. Adequate protection against the risk of fire or explosion is provided if the flash point of the product lies above 55°C and it can therefore be classified under Class A3 for flammable liquids. This flash point requires that the product has a boiling point of approx. 180°C.

Dry crease recovery angle → Crease recovery angle; a measure of the tendency of a fabric to crease when dry.

Dry cross-linking → Cross-linking of cellulose in a de-swollen, i.e. dry, state with resin-finishing agents in the presence of resin-finishing catalysts at elevated temperatures (120–190°C) within a few minutes or seconds (→Resin finishing). Practical significance as dry cross-linking process with methylol compounds in the presence of acid-active catalysts, such as the classic curing process, the →: shock-cure process and the permanent press process. Alkaline dry crosslinking processes are rarely used. The most important is the classic curing process with co-application of latent acid catalysts such as ammonium salts (e.g. ammonium nitrate) or metal salts (e.g. zinc nitrate, magnesium chloride). Procedure: impregnate (pad), dry at 110–130°C (stenter), cure 140–160°C, 5–2 min in curing machine, where necessary wash off/apply softener. Finishes obtained: high dry crease recovery angle, good wet crease recovery angle, excellent shape retention and dimensional stability, reduction in tear and abrasion resistance commensurate with the dry crease recovery angle improvement.

Dry distillation → Fibre identification by dry distillation.

Dry finish,

I. Gen.: → Final finishing.

II. Specifically relates to a dry finish applied to garments following dry cleaning; it is used as a final finish for suits, wool garments, overcoats, skirts, which have become limp through wear and from the effects of dry cleaning, especially those items which have been finished with solvent-soluble finish (softener). Application of a dry finish has the effect of enabling garments to stay clean for longer.

III. Term used for the mechanical processing of textile fabrics (→ Dry finishing of fabrics), e.g. opening, brushing, decatizing, embossing, calendering, polishing, pressing, pleating, raising, shearing etc.

Dry finishing of fabrics The fundamental modification of handle and quality of fabrics is carried out using → Wet finishing procedures appropriate for each type of goods. The processes of dry finishing, on the other hand, have the task of further developing and refining the effects achieved by wet finishing. The appearance and handle of the finished goods can only be fully achieved by a combination of wet and dry finishing. Although the sequence of operations in dry finishing to achieve a finish ready for make-up is to some extent a standard one, involving the standard processes of shearing, pressing, shrinking, decatizing, at least in the case of high-volume smooth finish worsteds, which are compatible with continuous processing systems (Fig. 1). The stages in the dry finishing process or the sequence of operations require constant review, due to factors such as fashion trends. Dry finishing not only touches on the latter stages of the fabric finishing routine; specific surface finishing measures such as singeing, emerizing, brushing or raising for quality enhancement may also be applied to cloth in the dry state during pretreatment.

Apart from singeing, all visual effects forming part of the surface finishing of fabrics are achieved by mechanical action on the fibre. While the results of shearing and raising are mainly tactile, the characteristics achieved by lustre or glazed finishes (e.g. by Polrotor machine) or raising are largely of a visual nature. Whilst the skin provides sensory perception of the complexities of the handle of the fabric, the eye when examining a surface perceives a specific area by means of its two-dimensional matrix of light-sensitive elements. By irregular displacement of this area across the whole surface in rapid succession the optic nerve uses comparison to form an overall image of the evenness or unevenness of the textile surface of the cloth. The optic nerve is working in the same way as a very complex computer, which can take in certain physical characteristics at high speed and relay to the consciousness highly condensed data such as matt, lustrous, silky, sandy, granular, rough, level, unlevel, patchy, etc. as visual references. Such perceptions of the eye are augmented by the tactile aspects experienced through the skin (and possibly also acoustic perceptions of the ear), such as hard, soft, full, lean, limp, crisp, etc., to form impressions of the material which predominantly derive from surface finishing.

The fact that no unified sequence of operations is found in finishing machines or processes is linked with the fact that individual stages (dry and wet treatment) often overlap. The fabric, which itself is often used as the guide for the sequence of the treatment stages, can often pass through the same machine several times in different stages of its production (e.g. surface finishing in the form of wet and dry raising). The DIN 61 704 standard is suggested as a basis for sequential arrangement. In the case of appearance-related processes, which also include finishes such as wet brushing, the

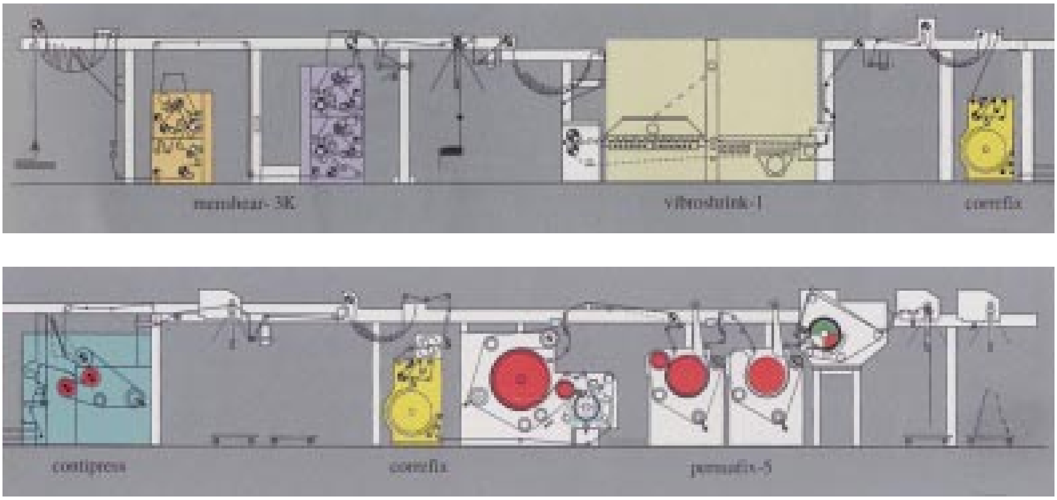


Fig. 1: Sequence of operations in a worsted smooth-finish range for wool fabrics (Menschner).

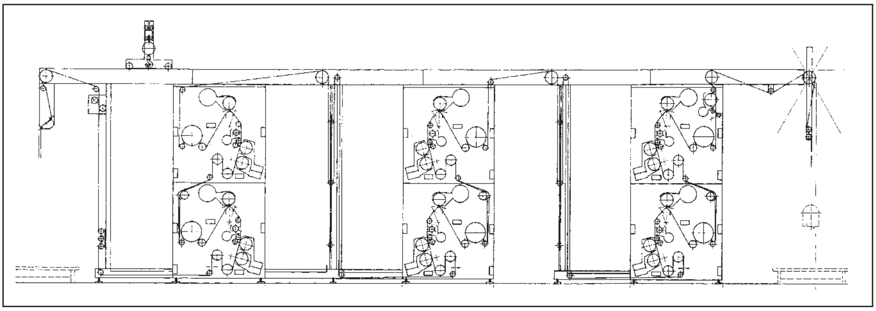


Fig. 2: Shearing machine by Sperotto-Rimar.

sequence suggested here could cause problems. Thus in the systematic arrangement of wool fabric finishing processes, the concept of surface finishing by mechanical means is only applied to the processing of dry goods (singeing, shearing, brushing, raising, emerizing, lustre finishing, raising), while wet raising and wet brushing are regarded as stabilizing processes, as drying is essential to this stabilizing process in order to achieve the texture retention (permanence) of the finish.

The sequence of operations for individual articles determines their passage through the dry finishing processes. The finishing manager coordinates and simplifies the flow of goods; this pre-planned flow should if possible not be interrupted, even if certain qualities are only required by parts of the production chain.

In this case it makes more sense simply to cancel (set to zero) the parameters relating to the processes which are not required, e.g. shrinkage without steam or low-pressure press. Any interruption requires stoppage and thus a reduction in efficiency. Interruptions also cause impairment of the finish, such as stop marks and similar. They also take up storage space and time and incur transport costs. Only an interrupted cycle through the whole range can ensure success. The machine line shown in Fig. 1 incorporates precautionary measures which ensure non-stop operation. Thus, for example, special fabric trucks and mobile cuttling units capable of setting down goods at several points contribute to uninterrupted operation. Stoppages are no longer required even for changing fabric rolls or trucks. Monitoring elements ensure the movement of the goods through all processing stations with the minimum of tension, and readjust the synchronization of travel.

As can be seen from Fig. 1 automatic weft straightening equipment (Correfix) is installed at various intervals, always before setting operations, e.g. before pressing, before permanent decatizing and/or before the final decatizing. Also of particular importance are the control and measuring stations, which monitor the moisture content of the goods. The fabric is dampened at certain points and a constant humidity is ensured through closed-loop control systems.

Machine lines such as this provide an additional advantage: the reject level in a continuous plant is re-

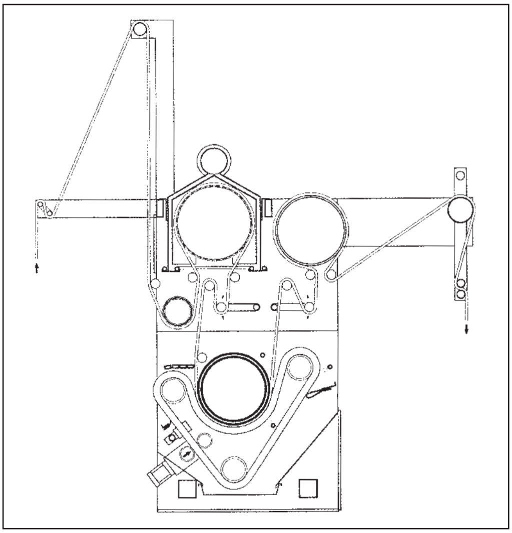


Fig. 3: Machine for the shrinking of fabrics (Sperotto-Rimar).

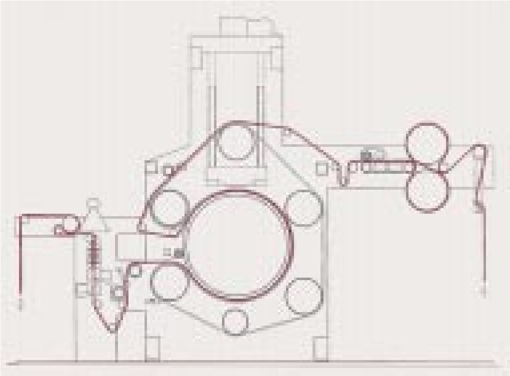


Fig. 4: Multiset decatizing plant by Sperotto-Rimar with finish similar to that achieved by batch decatizing.

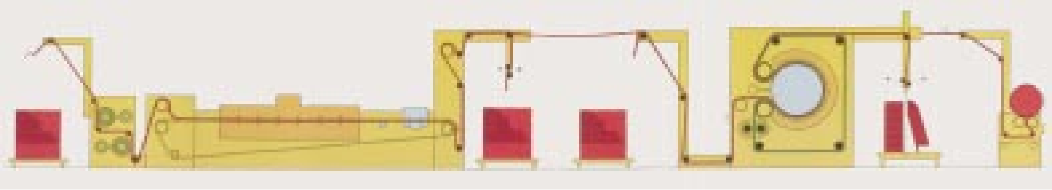


Fig. 5: Shrinking and continuous finish decatizing for wool fabrics (Sperotto-Rimar).

duced, as the functioning of a dry finishing range is more reproducible, whilst in a finishing plant with batch operation at all stages and which is subject to frequent human intervention, there are plenty of opportunities for faults to arise.

A classic dry finishing sequence for wool fabrics (continuous) could, for instance, be made up of the following processes:

- Shearing section (Fig. 2): for example, the back of the fabric is sheared once and the face twice to min. 0.1 mm shearing height.
- Pressing (Fig. 3), corresponding to the rotary press: sandwich systems are used here, in which the thickness of the fabric is reversibly established; subsequent batch decatizing stabilizes the thickness.
- Batch decatizing or equivalent continuous decatizing (Fig. 4) at 140°C using the parameters of moisture content and time.
- Shrinking on a perforated belt steam shrinking unit (with vibration) for relaxation of the fabric (Fig. 5).
- Finish decatizing (Fig. 5) for the removal of all finish characteristics not properly stabilized.

Dry heat fixation → Heat setting.

Dry heat setting and pleating fastness, resistance to dry heat, as is usually found with → Heat setting and dry pleating. → Sublimation fastness during heat treatment. The test sample is heated on both sides by contact heat for 30 s at 150°C, 180°C, 210°C or other temperatures, in a precision ironing press or Fixotest apparatus (Heraeus). Experience has shown that this test corresponds to hot-air treatment on a hot-air stenter at a temperature around 20°C higher. Unlike the DIN standards, the AATCC standards differentiate between the behaviour of dyed goods and prints under the effect of heat during finishing operations (In-Plant Test), AATCC 117-1974 and those during pressing (End-Use Test), AATCC 133-1973/74 in course of making-up or use. Three temperatures, 110, 150, 220°C are used for the End-Use Test. The temperatures for the In-Plant Test are in the region 163–218 ± 2°C.

Dry ice, carbon dioxide snow pressed into blocks (evaporation temperature –76°C), evaporates without melting, thus does not generate water when used. Cooling effect per kg double the strength of conventional ice (152 kcal).

Drying A process to free a textile material of moisture, thermal hydro-extraction. → Drying systems for textiles are based on, e.g. convection, contact heat, radiation, through-flow or combustion drying. In choosing the most suitable machine, consideration has to be given as to whether it will be used for the final drying stage only, or for the intermediate drying of material impregnated with dye liquors as well. The use of appropriate monitoring instrumentation and control systems is essential for the achievement of uniform drying and energy savings without overdrying and its negative effects on quality. More and more driers are now being provided with heat recovery systems for optimum economy.

Drying carriage in screen printing When working on a short printing table, using a drying carriage enables the printed pattern to be dried, avoids smearing of the underside of the stencil and produces sharper prints.

Drying chamber, (→ Hot air drying chamber, jet-drying chamber), drying chamber system in which the cloth is carried in a spiral path, print side upward, via guide rollers, used especially for the drying of printed piece goods. Operated by means of warm or hot air (60–110°C) or by means of jet drying.

Drying loft, hot-air chamber for printed fabrics. A distinction is made between airing lofts with drying temperatures of approx. 60–70°C and jet-heated drying chambers (see the following Fig.) which operate at higher temperatures (100–140°C) and which therefore enable shorter drying time.

Drying of textiles The aim here is to achieve preferential evaporation of the surface water and the water bound by fibre swelling (→ Swelling, water of) whilst still retaining the natural moisture content of the fibre. The loss of normal moisture content is due to the use of excessive heat and overdrying which generally has negative consequences for the quality of the material. For this reason, efforts have been made to achieve a more gentle drying technology, i.e. by giving consideration to the control of air movement and the control of heated air supply. Each intensification of these conditions (drier heat, shorter drying times) is made at the expense of the → Capillary water (i.e. the fibre's natural moisture content) and leads to brittleness, hardness and

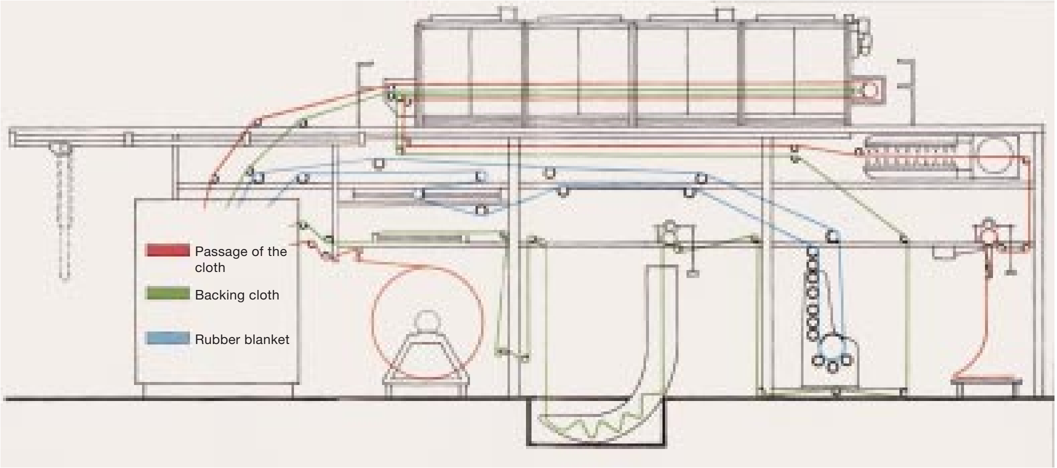


Fig.: An overhead drying loft to dry printed goods (red) and laundered backing cloth (green).

fibre degradation (losses in strength and extensibility). Drying performance may be increased through the use of higher air speeds, lower air humidity or more turbulent air movement in the drier. Drying is an increasingly important cost factor in textile finishing. Reductions in drying costs are possible by avoiding intermediate drying stages, by wet-on-wet application techniques, by giving a maximum mechanical → Water extraction treatment before thermal drying and by the avoidance of overdrying, i.e. drying only until the fibre's normal residual moisture content has been reached (use of appropriate measuring and control systems). →: Drying systems; Drying technology.

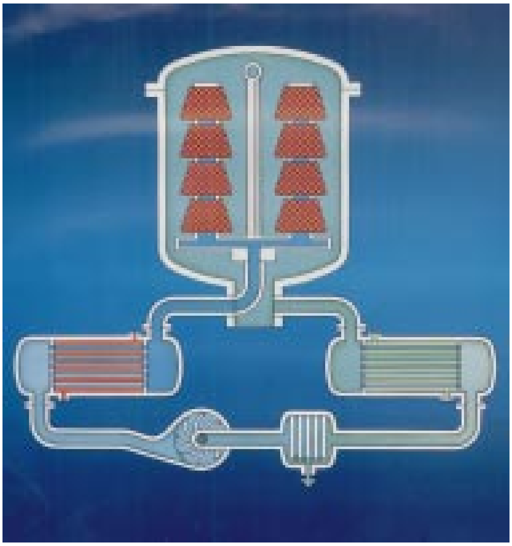


Fig.: Then yarn package drier.

Drying of yarn packages A mechanical → Water extraction (centrifuge, suction or pressure extraction) must be given before thermal drying. For hydro-extraction in the centrifuge, the yarn packages have to be taken off the material carrier and packed into a centrifuge basket (protection of rigid centres from distortion due to high G forces necessary). Alternatives: centrifuging of single packages with automatic loading. Suction and pressure extraction takes place on the material carriers (without repacking). Suction extraction is carried out in a vacuum extractor whilst pressure extraction is carried out in a closed vessel (e.g. in the dyeing machine itself). In rapid driers, warm air is blown through the packages on the material carrier after pressure extraction. The drying time may be reduced still further if drying is carried out in high pressure driers with overpressure (see Fig.). Vacuum drying offers a further possibility (two-phase drier), by alternately blowing partially saturated hot air through the packages and applying vacuum extraction to achieve a uniform residual moisture content (no risk of overdrying in this case, but the drying times are somewhat longer than in the high pressure drier). Another option is the use of RF driers after mechanical hydro-extraction.

Drying oils, e.g. linseed, wood, poppyseed, nut, sunflower oils. Consist to a large extent of linoleic and linolenic acids and to a lesser extent oleic acid. Due to the presence of predominantly unsaturated fatty acids with several double bonds,

$$CH_3–CH_2–HC=CH–CH_2–HC=CH–CH_2–HC=CH–(CH_2)_7–COOH$$

Linolenic acid

the drying power is at its most pronounced in comparison to ➝: Non-drying and Semi-drying oils. Of importance for oil sizing. (➝: Oxidation of oils; Oils).

Drying power A measure of the water absorbency of hand towels for surfaces to be dried (e.g. the body, crockery, glassware). The more quickly and completely the water is removed from surfaces to be dried, the greater the drying power. It is dependent on time (e.g. approx. 10 s for the drying of hands), pressure (approx. 3–6 kg pressure applied for drying), and the quantity of water (e.g. 30–50 g of hand towel fabric per g of body surface).

Drying reel in screen printing, obsolete drying device in screen printing, whereby the goods were hung from bars in loops to dry; slow air circulation from top to bottom.

Drying rigidity ➝ Drying stiffness.

Drying/setting stenter, for woven and knitted fabrics (especially with selvedge spreaders and expander rollers with adjustable angle of wrap) in nominal widths of 1200–1300 mm with 2–8 sections, speed range 1.6–160 m/min; special jet design (with two axial fans) with air circulation sections arranged in interchangeable design. Special evaporative capacity/section/h under normal conditions is 45 kg H_2O/m^2 with a nominal width of 1600 mm. Vertical warp run. Overfeed of the order of –15 to +50%. Total air volume may be controlled by adjusting the rotational speed of the exhaust fan depending on the goods to be dried. High jet exit velocity of max. 33 m/s, short heating-up times, short setting times.

Drying stiffness (Drying rigidity). The stiff handle of a textile caused by a phenomenon arising from the combined effects of a wet treatment involving movement of the material (e.g. washing in drum-type washing machines) and drying without movement. The disordered state of the textile surface produced by intensive mechanical action during washing becomes fixed when the material is dried without movement. This problem is particularly noticeable in textiles where softness and fluffiness are usually expected, i.e. textiles worn close to the body such as underwear, terry materials, diapers, nappies, etc. The problem can be avoided by drying in a ➝ Tumbler drier (movement of material) or by using ➝ Fabric softeners.

Drying systems Ever since textile fabrics, either as wovens or knits, have been cleaned and consolidated (relaxed) in pretreatment and coloured in dyeing and printing, they have been required to undergo subsequent finishing after such wet processing treatments. Drying is the stage between wet processing and dry finishing. The drying process has to be carried out in such a way that the consolidated state of the textile is maintained and set. Tension-free drying is therefore indicated when the textile fabric is required to withstand subsequent steaming treatments (pressing in garment manufacture) and washing processes (e.g. domestic laundering) without shrinkage. Drying may be regarded as a setting process to the extent that after removal of the surface and capillary water (de-swelling), the “enemy of hydrogen bonds”, i.e. water, is withdrawn during further application of energy so that the secondary valency bonds are locked into the polymer network in the state in which the textile material finds itself after drying.

Correct drying makes a significant contribution towards maintaining the quality of the material during finishing. It is not only the regenerated cellulosic fibres, but also the natural fibres, that exhibit reduced water inhibition values after e.g. repeated drying, which can be attributed to a change in the fibre structure. Drying is also one of the energy-intensive processes of textile finishing so that overdrying (during the drying operation) should, if possible, be avoided for this reason. Overdrying can be avoided through contact-free measurement of the residual moisture content of the textile as it leaves the drying machine.

Each type of fibre has its own natural moisture content, unique to that particular fibre, which must be maintained. If the moisture content falls below this limit during drying, then overdrying is said to occur. The residual moisture content of the material being dried is therefore used as a measurement parameter for the control of drying machines.

The various alternatives illustrated in Table 1 are available for heating textile driers. Direct heating with natural gas has become more and more widespread, even in textile finishing plants, as it is quick to reach operating temperatures, environmentally-friendly and adaptable. Gas jet burners represent a modern form of gas heating. For cost reasons, electrical heating on its own is only used in exceptional cases. Electrical heating does, however, find application in supplementary heating, e.g. for infra-red radiation. Two types of IR radiators are encountered in textile plants, bright radiators at a wavelength of approx. 1.3 µm and dark radia-

	% efficiency
superheated steam up to 180°C	**70**
hot water up to 180°C	**80**
oil circulation up to 270°C	**80**
oil burner - direct heating	**85**
oil burner - indirect heating	**60**
gas - direct heating	**85**
hot air generators	**75**
electrical heating	**98**

Tab. 1: Efficiency (in relation to energy utilization).

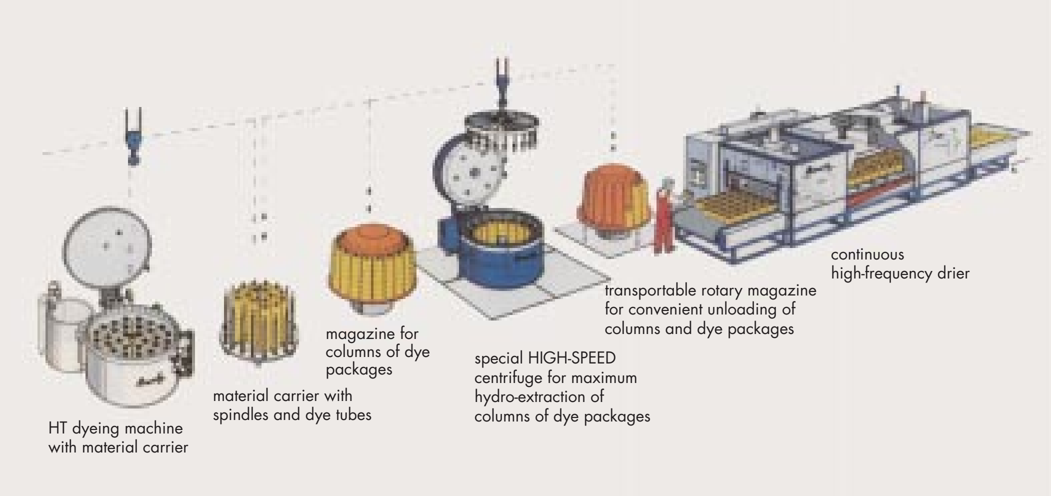


Fig. 1: Operating procedure of the Krantz-HF drying system for yarn packages.

tors at a wavelength of approx. 3.6 µm. The surface temperature of 750°C is high, with a correspondingly high risk of overdrying which is why IR-radiators are used for pre-drying in conjunction with conventional thermal drying systems. High-frequency driers (radio frequency, microwave and dielectric driers), see Fig. 1, are used for drying loose fibres (loose stock), tow, muffs, yarn packages, etc. The advantage of high-frequency drying is the short drying time and the environmentally-friendly process. The material being dried is transported continuously between condenser plates and subjected to a high-frequency alternating electrical field. The interior of the material is heated up rapidly to the evaporation temperature of water irrespective of the thickness of the layer. Driers of this type with wattages up to approx. 140 kW are available from several manufacturers. For knitted and woven fabrics, however, high-frequency drying is still uneconomic. An unconventional drying technique is the Remaflam process of Hoechst in which the material to be dried is passed through a mixture of methanol/water. After squeezing to remove excess, the evaporating methanol is ignited which results in subsequent evaporation of the water. A suitable machine for the Remaflam process is manufactured by Brückner.

Drying with hot air (convection drying) and contact heat are examples of conventional drying processes. Drying in hot air involves the following stages:

1st stage: heating of the material with temperature rising to the wet bulb temperature.

2nd stage: establishment of constant temperature conditions until all the water has been transported to the surface of the material. This wet bulb temperature is independent of the temperature and moisture content of the air used for drying. A high evaporative capacity is achieved with high temperature air circulation.

3rd stage: a further increase in temperature occurs when all the water has evaporated; at this point the material assumes the same temperature as the drying air.

In contact drying, e.g. on the cylinder drier, the fabric assumes the same temperature as the evaporating water

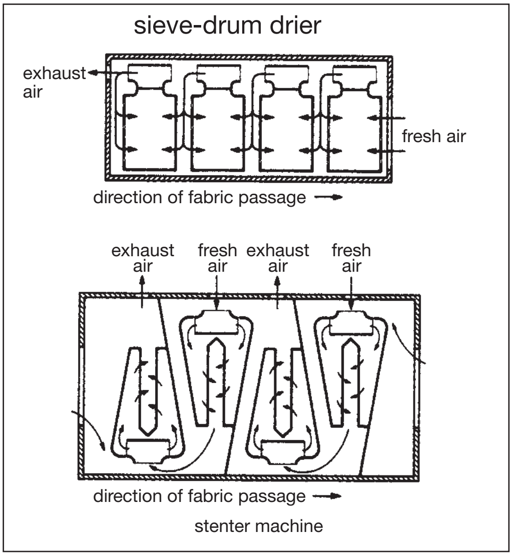


Fig. 2: Comparison between the air passage, based on the counter-current principle, in the sieve-drum drier and in the stenter machine.

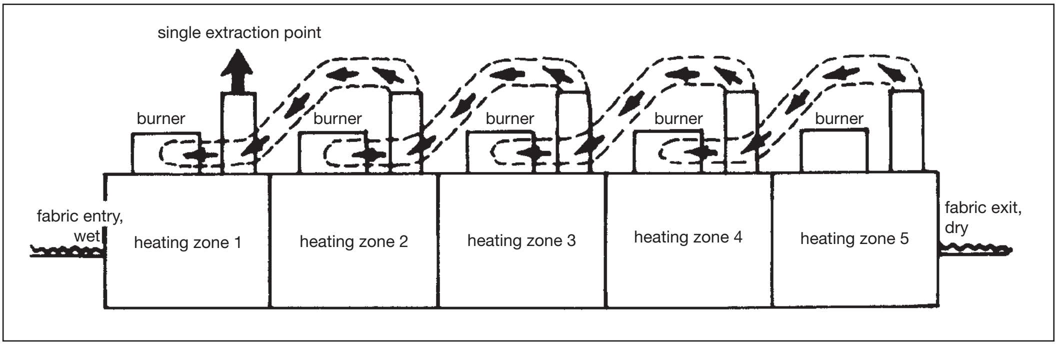


Fig. 3: Counter-flow principle in convective drying based on the “Rickbourg Wilson Flow-Through Progressive Recycling” method with only one exhaust air extraction point – material flow from left to right; energy and air flow from right to left.

in the second phase no matter how hot the cylinders are. As soon as the water has evaporated, a further rise in temperature takes place.

To achieve better heat utilization and more gentle drying of the material, some convective drying machines work on the multi-stage (Fig. 3) or the countercurrent principle (Fig. 2). In the first zone, the material is heated as quickly as possible; in the middle zones this temperature is maintained and in the last zone the temperature is lower. Moisture-laden air is extracted at the entry of the drier and fresh air enters at the exit end of the drier. This is not the case with the stenter, however, where several exhaust air extraction points (for the various drying sections) are provided.

The main focus of development in recent years has been directed towards achieving better insulation of driers, control of exhaust air moisture content and heat recovery from the exhaust air, in order to gain the most positive energy balance possible (Fig. 4). Exhaust air cleaning systems are based on adsorption, condensation or combustion of the pollutants present in the water vapour of the exhaust air.

Installations for drying loose fibres (loose stock) are designed as follows: the block of fibres from the packing press are torn apart from each other in an opener and the loose material is fed into the driers via a hopper feeder. Cabinet and chamber driers are batchwise systems with air flow from top to bottom or vice versa. The material lies on trays. Continuous drying is carried out in conveyor driers in which the fibres are transported through the drying chamber on an endless conveyor belt. In the sieve-drum drier (Fig. 5), the fibres are transported as a fibrous web over perforated drums through which hot air flows from outside to inside. Installations for drying card slivers, tops and tow: in contact driers the card slivers are transported over heated drums and in cabinet driers the sliver runs through the hot air on skeleton drums. Sieve-drum driers and contact driers (Fig. 6) are used for combed slivers. Installations for drying hanks of yarn must be fed by hand. For higher performance, continuous driers are available in which the hanks are passed slowly through a heated channel. Other systems use support rods, which are capable of rotating to some extent, attached to endless chains. In another model, the hanks are suspended individually on clamps and are transported through the drier on a chain. The point where the hanks are supported changes several times during their passage through the drier (Fig. 7).

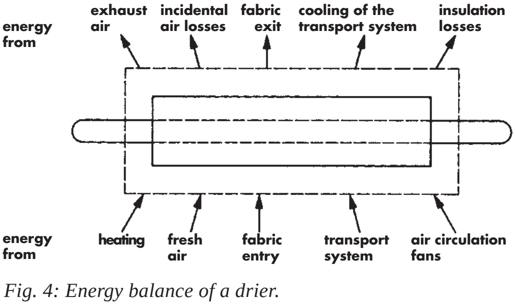


Fig. 4: Energy balance of a drier.

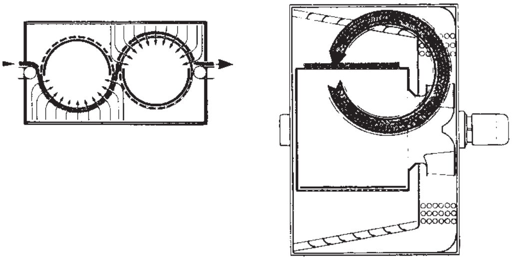


Fig. 5: Sieve-drum drier (Fleissner). Longitudinal (left) and cross sectional view (right).

Drying systems

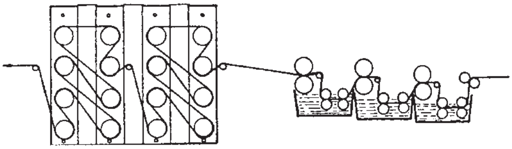


Fig. 6: Backwashing machine for undyed wool sliver with contact drier.

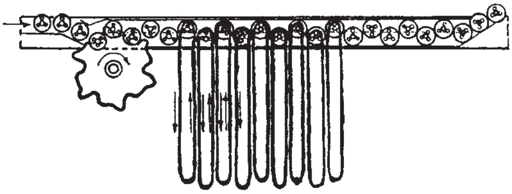


Fig. 7: Drier with rotating rods for drying hanks (Fleissner).

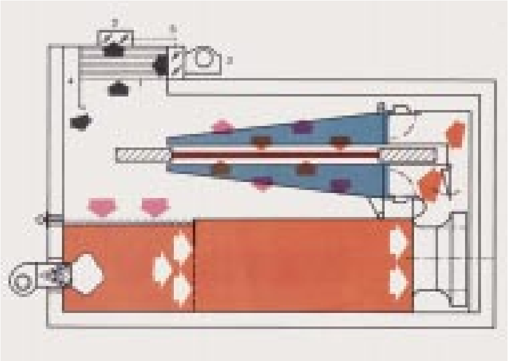


Fig. 8: Air passage in a Monforts single-layer stenter with heat recovery in the exhaust air ducting (Montex system). 1 = hot exhaust air; 2 = exhaust air ducting with flow control; 3 = fresh air intake with flow control (5); 4 = pre-heated fresh air flows to the gas heaters and is forced into the nozzles by the fans.

Installations for drying yarn packages (cheeses, cones, spinning cakes, muffs) are based on thermal or electrical systems. Tunnel driers are continuous machines: the packages run through the drying zone on a conveyor. For large packages, the yarn to be dried is wound off the packages and laid spirally on the endless conveyor of the drier. Rapid driers include various systems for drying yarn packages. A common feature of all these driers is the circulation of hot air through the yarn package from inside to outside by means of fans. In the so-called “half rapid drier” machines, the hydro-extracted yarn packages or insert-free packages are placed on perforated spindles. Depending on the model, these spindles are mounted on a carousel or a wagon. The spindles are connected to a hot air blower which causes the carousel to rotate; the transportable wagons with the wet material are wheeled into closed containers. The hot air now circulates through the packages from inside to outside. The flows of exhaust air and fresh air can be regulated. In addition to this air circulation, a further separate ventilation of the packages can take place from outside.

For yarn packages, replacing the dye tubes on to the drying spindles is too labour intensive. In rapid driers, the dye tube is therefore placed in the drying machine together with the yarn package. In basic rapid driers, the exhaust air is vented directly into the atmosphere which results in significant losses of heat. The other two systems are air-recirculation or air circulation systems. Even with air circulation driers, part of the air must be vented into the atmosphere after reaching a certain moisture content and has to be replaced with fresh air. In the pressure drier, the system is completely enclosed and under pressure (up to 8 bar). The moisture is extracted from the circulating air through a condenser and returned to the drying vessel again after reheating, whilst the condensed water is discharged to the drain through a separator.

The drying of woven and knitted fabrics is mainly carried out on stenters or tumblers. The means of heating such driers is, in each case, adapted to local requirements. Many driers are not only designed for drying but also for carrying out hot air treatments (heat setting, thermofixation of dyes, etc.). For stenters which, in addition to special driers, are often used for intermediate drying, the introduction of hot air (Fig. 8) is supplied in such a way that uniform drying across the entire width of the fabric is ensured. For extensible fabric qualities, stenters with “carrier nozzles” are used in which the fabric is supported on an air cushion. The stenter chains are individually adjustable in width throughout the length of the fabric passage.

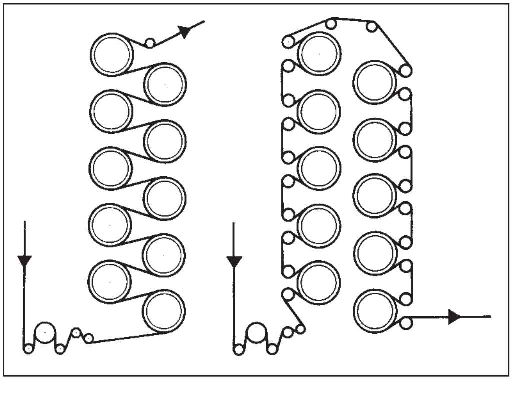


Fig. 9: Monforts cylinder drier with fabric contact on one or both sides.

Drum or cylinder driers are available in all sizes from units with just a few cylinders to driers with 40 or more. The latter can be divided into groups thereby allowing a stepwise increase in the degree of heating. With such driers, intermediate drying of fabric padded with dye liquor is possible without migration. Cylinder driers are less suitable for structured fabrics due to the flattening effect under tension. The cylinders are made of stainless steel and, under certain circumstances, may be coated with Teflon (e.g. for sizing machines, etc.). The fabric passage can be arranged so that either one or both sides are in contact with the cylinders (Fig. 9). In order to reduce the lengthwise tension on the fabric in cylinder drying, special cylinder drives have been developed, e.g. electrically controlled multi-plate clutches where the driving force can be predetermined, and slipping clutches or spring clutches instead of gears. When cylinder driers are used to pre-dry fabrics for subsequent dyeing, consideration must be given to the fact that, under certain circumstances, excessive temperatures can have a negative influence on the levelness and colour yield of the dyeing. The efficiency of cylinder driers can be considerably increased by installing the cylinders in enclosed housings and blowing hot air on to the fabric. An IR-preheater is often retrofitted to existing hot air driers when the performance is unsatisfactory.

For the intermediate drying of fabrics padded with dye liquors, only those systems with absolutely uniform air circulation both above and below the fabric are suitable. A selective change of the upper and lower air flow is a prerequisite for the gentle drying of sensitive fabrics. This applies particularly to knitted fabrics. These textiles are usually highly elastic and must therefore be dried without tension. For this purpose, either festoon driers or, for preference, short loop driers, horizontal driers or the efficient sieve-drum drier are used.

For tubular knitgoods, special driers which extend the fabric to the desired width and bring the knitted courses into parallel alignment are available. Warp-knit fabrics, or opened tubular knits, are often dried on the pin stenter which can also be used for heat-setting.

Drying principle	Advantages	Disadvantages	Comments
Contact drying (cylinder drier)	– Good heat transfer – Relatively low power consumption – Low consumption of heat energy – Low investment costs	– Losses in width due to lengthwise tension – Not a universal machine (rarely used for knits, unsuitable for pile fabrics) – Marking off with dyed fabrics – Smooth ironed effect occurs when fabric is almost dry – Creases are “ironed in”	– Used almost exclusively for intermediate drying – Only suitable for final drying of lower quality or non-sensitive fabrics
Convection drying	– Versatile application – With direct heating, some of the evaporated organic substances are burned off – No creasing problems – Problem-free shrinkage – Fabric width can be set in the stenter – Uniform and gentle drying especially with festoon driers	– High heat transfer losses with indirect heating – High energy consumption – Relatively large floor space requirements	– The stenter is the most frequently used machine of this type (fabric is set to the required weight during drying) – Energy consumption is highly dependent on machine design (e.g. counter-current passage of fabric and air, effective sealing). Float-on-air type driers rel. energy-efficient, tumblers are the least efficient
Combination of contact and convection drying	– Less floor space requirements compared to stenters – Relatively gentle and uniform drying	– Setting of fabric width more difficult than on the stenter – Relatively high investment costs – Unsuitable for pile fabrics – Marking off with dyed fabrics	– The most frequently used type of drier after the stenter
High-frequency drying (RF drying)	– Compact machine with high drying performance – Uniform drying even for material with a non-uniform moisture content – Gentle drying conditions – Energy requirement is precisely adjusted to the particular material	– High investment and running costs – For microwave systems, regulations for the protection of personnel have to be observed	– Particularly suitable for very sensitive thick materials
Infra-red drying	– Rapid heating of the material – low space requirement	– Surface drying – Higher energy consumption	– Used as a pre-drier for textile prints and some continuous dyeing processes

Tab. 2: Advantages and disadvantages of various drying systems.

Stenters with carrier nozzles are particularly suitable for such fabrics. Continuous tumblers are also used for knitted fabrics. For tubular knitted fabrics in particular, a tension-free drying process plays a decisive role in achieving shrinkage values below 2% in the finished fabric. Tumblers attempt to achieve shrinkage values below 5% with vibration and a convenient supply of air. When tubular knits are dried in the open-width, particular care must be taken to ensure that the paths from the feed roller to the chain are short. Clip stenters have proved unsuitable for knitted fabrics since they do not provide much overfeed and produce clip marks in elastic materials. By contrast, clips have proved more gentle to the selvedges of very wide woven fabrics. With knitgoods the edges must be bonded with a suitable adhesive and cut away again on exit from the stenter. The bonded edges are cut either beyond the pins (at the chain side when viewed from the pins) or, more generally, on the inside of the pins (i.e. towards the body of the fabric when viewed from the pins). It is helpful to equip the pin stenter with an additional open-mesh conveyor (e.g. composed of aramid fibres) which assists the fabric to pass through the drying zone without tension but at a specified width. The tumbler drier is used for drying individual knitted garments. The advantages and disadvantages of the most popular drying systems for textiles are summarized in Table 2.

Drying technology Textile materials are dried after each wet processing stage when further wet treatments have to be carried out on dry material. The fixation of dyes by dry heat (e.g. thermofixation) can also be carried out in suitable driers. The drying of textiles is to be regarded as a process of heat and mass transfer in which a quantity of heat Q is transferred from the drying medium (air) to the wet material. This state is characterized by the air-jet temperature t_{jet} and the prevailing partial vapour pressure of the air. This partial vapour pressure again determines the temperature t_{fabric} established on the fabric surface F during the free evaporation stage. The transfer coefficient α is a drier constant and is determined by the intensity of the air-jet flow, the air-jet geometry and the air-jet/fabric separation distance. The temperature difference

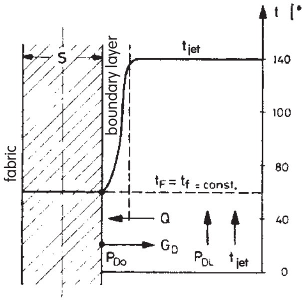
$$t_{jet} - t_{fabric}$$

determines the quantity of heat transferred. A mass transfer also takes place in parallel with the heat transfer which is due, of course, to the diffusion of evaporated water from the fabric into the drying medium (air). Like the temperature gradient during heat transfer, it has been recognized that the decrease in vapour pressure here

$$p_{DO} - p_{DL}$$

(together with specific constants) is decisive for the quantity of water evaporated G_D in unit time (p_{DO} = vapour pressure at the fabric surface; p_{DL} = partial vapour pressure in the drying stage).

In the stationary state, a corresponding quantity of water G_D is evaporated by the quantity of heat Q so that, by including the heat of evaporation r of the water, the heat and mass transfer can be compared (Fig. 1). (Strictly speaking, these mathematical relationships only apply to the so-called first drying section).



(1) Heat transfer : $Q = F\alpha\,[t_{jet} - t_f]$

$$\parallel$$

(2) Mass transfer : $[r]\,G_D = F\frac{\beta}{R\,T}\left[P_{Do} - P_{DL}\right][r]$

(3) $G_D = \frac{Q}{r} = \frac{F\alpha}{r}\left[t_{jet} - t_f\right]$

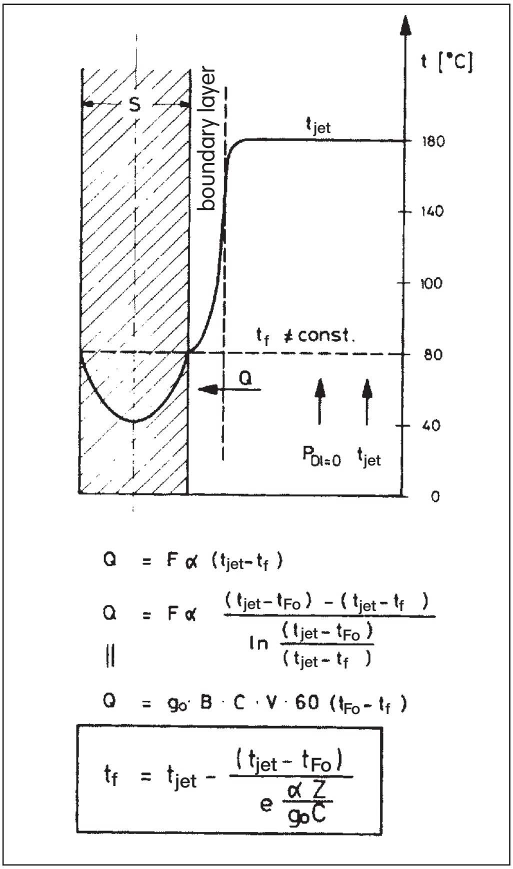
Fig. 1: Heat and mass transfer during drying. The fall in temperature of the circulating air in the laminar boundary layer region to the wet-bulb temperature should be noted here (source: Monforts).

During the thermofixation of dyes, the drier constant α is also significant for the heat transfer (Fig. 2). An important criterion here is the heating of the fabric to the thermofixation temperature and to know the point in the hotflue at which the fabric has reached its target temperature = air-jet temperature. After reaching this point, the fabric must remain at this temperature for a certain period of time in order to allow the dye to diffuse into the (polyester) fibre.

Two process variants are used in practice for the thermofixation of dyes:

1. Drying of the padded fabric (1st passage) followed by thermofixation of the dried fabric (2nd passage).
2. Drying and thermofixation in a single stage.

The heat energy required for drying and heating up the textile fabric is transported by the air. The impinging air is cooled through the evaporation and heating of water and leaves the surface of the textile at a lower temperature. The difference in temperature (Fig. 3) between the incoming and outgoing air flows is therefore directly



$$Q = F\alpha\,(t_{jet} - t_f)$$

$$Q = F\alpha\,\frac{(t_{jet} - t_{Fo}) - (t_{jet} - t_f)}{\ln\dfrac{(t_{jet} - t_{Fo})}{(t_{jet} - t_f)}}$$

$$\|$$

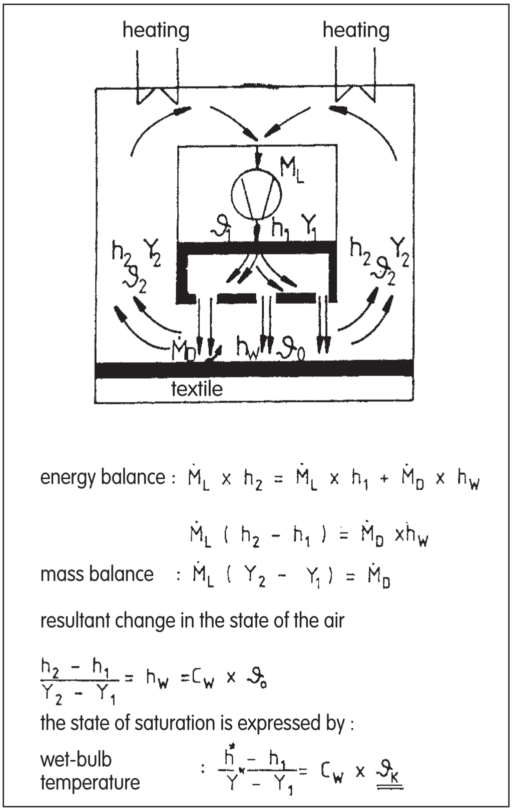
$$Q = g_0 \cdot B \cdot C \cdot V \cdot 60\,(t_{Fo} - t_f)$$

$$\boxed{t_f = t_{jet} - \frac{(t_{jet} - t_{Fo})}{e^{\frac{\alpha Z}{g_0 C}}}}$$

Fig. 2: Heat transfer during thermofixation (source: Monforts).

t_f = temperature of fabric at a certain point in time Z (°C),
t_{jet} = air-jet temperature (°C),
t_{Fo} = temperature of fabric before thermofixation (°C),
a = drier constant (kJ/m^2h °C),
Z = thermofixation time (s),
g_0 = weight of fabric per square metre (g/m^2),
C = mean specific heat capacity of the fabric (kJ/kg °C).

dependent on the quantity of evaporated water, the change in the temperature of the textile and the residual moisture content still present in the textile material. When the difference in temperature is zero, the textile is dry and already heated up. Unfortunately, however, there are a number of other factors which greatly reduce the accuracy of this procedure. Errors arise, for example, as a result of variations in the quantities of circulating air, poor air flow across the temperature sensors and malfunctioning or incorrectly set temperature regulators. These effects are easily transferred to the running fabric. Whilst the drying of a stationary textile material yields time-dependent temperatures, the temperatures of a running fabric are location-dependent (Fig. 4). The



energy balance : $\dot{M}_L \times h_2 = \dot{M}_L \times h_1 + \dot{M}_D \times h_W$

$$\dot{M}_L\,(h_2 - h_1) = \dot{M}_D \times h_W$$

mass balance : $\dot{M}_L\,(Y_2 - Y_1) = \dot{M}_D$

resultant change in the state of the air

$$\frac{h_2 - h_1}{Y_2 - Y_1} = h_W = C_W \times \vartheta_0$$

the state of saturation is expressed by :

wet-bulb temperature : $\frac{h^* - h_1}{Y^* - Y_1} = C_W \times \underline{\underline{\vartheta_K}}$

Fig. 3: Basis for determining the fabric surface temperature by the creation of a heat balance (Krantz).

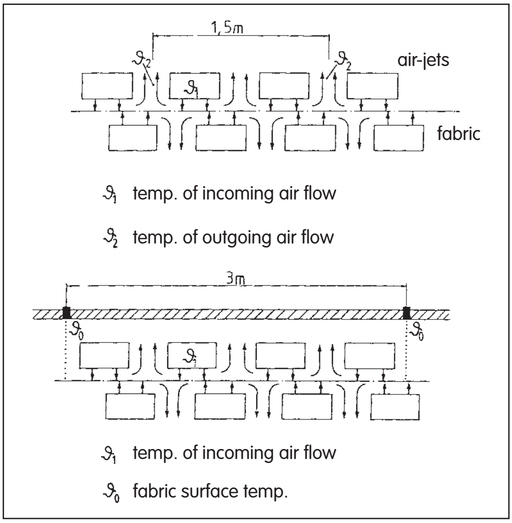


Fig. 4: Location-dependent siting of temperature measuring sensors to establish a heat balance in a short resp. long drier section.

temperature difference progression must therefore be determined from numerous measuring points along the direction of fabric passage through the machine. By this means, for example, a typical temperature difference progression may appear as the one shown in Fig. 5.

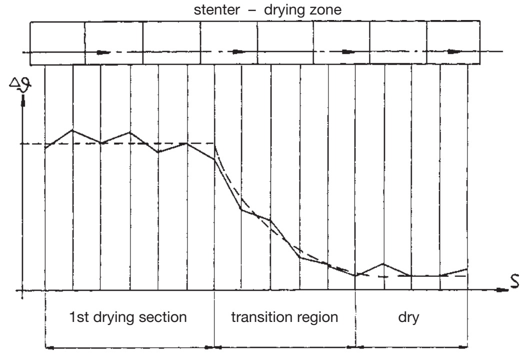


Fig. 5: Typical temperature difference progression during drying; curve adapted by software.

Establishing a constant small temperature difference to define the point of drying can lead to highly variable data for the actual values and result in a discontinuous control response. In the so-called 1st drying section, the temperature difference progression has been adapted to give a straight line. The wet/dry transition region has been brought more into line by means of an exponential function. The dry region has been represented as a straight line. Depending on the position of the wet/dry transition point, three curve adaptations have been carried out. A temperature difference is then defined as the point of drying on the exponential function of the transition region.

In a drier, water is evaporated from a textile material into the air flowing over it in the 1st drying section. The energy required for evaporation is supplied only by the air itself. Under such circumstances, the textile material acquires an almost constant temperature. The air becomes saturated with moisture on the surface of the textile material, and the temperatures of the air and the surface of the textile in the boundary layer are the same. The temperature achieved at this point is known as the → Wet-bulb temperature and represents the state of equilibrium between the air and the moist material. As drying progresses, the moisture level in the interior of the fibre recedes; the surface dries out and the surface temperature rises. The completely dried textile material finally acquires the same temperature as the air flowing over it.

The surface temperature of the textile material can be measured accurately and without contact with radiation pyrometers. As a rule, there is far less deviation in these measurements than in the measurement of temperature differences. This more precise measuring technology suffers, however, from the disadvantage that far fewer measurements are normally available. The measuring distance is increased, and it is seldom the case with long single-layer stenters that the entire length of the drying zone is monitored with pyrometers.

The progression of drying may be represented (see Fig. 6) by

- the effective temperature of the fabric at each point in time or at each point of drying and
- the drying progression curve.

In this process, the differences between convection drying and radiation are to be noted (Fig. 7).

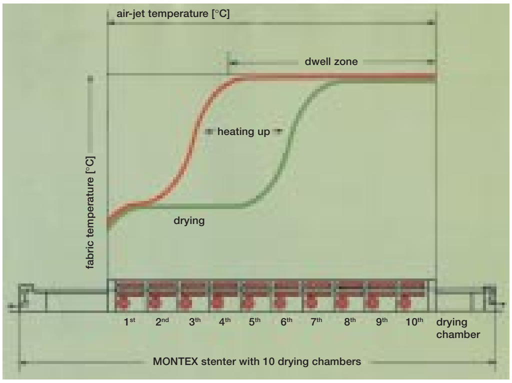


Fig. 6: Progression of fabric temperature during the drying and heat-setting of blend fabrics (source: Monforts).

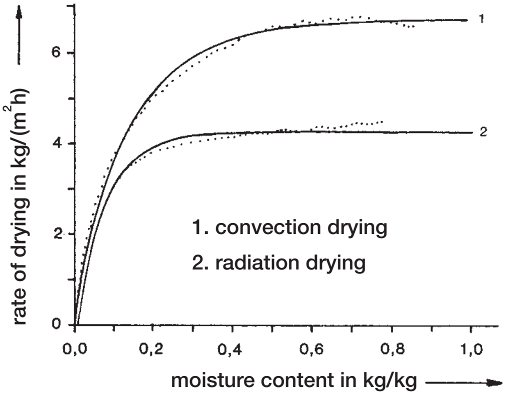


Fig. 7: Drying progression curves with adaptation functions for different drying techniques (source: Heidemann).

An important opportunity to increase the speed of drying would be to increase the heat transfer coefficient α. With air-jet application, for example, in the form of fan nozzles to achieve increased turbulence in the vicin-

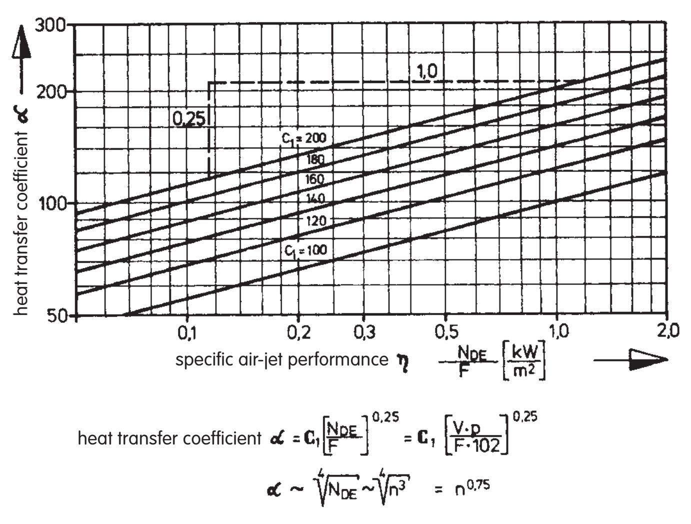


Fig. 8: Dependence of the heat transfer coefficient on the air-jet or air flow performance.

ity of the textile material, a corresponding increase in the heat transfer coefficient α results from an increase in the performance of the air flow rate to the 4th root.

By taking a close look at the formula for the transferable flow of heat resp. the transferable quantity of heat,

$$N \approx Q = \alpha \cdot F \cdot \Delta T \text{ [kJ/h]},$$

the dependence on the heat transfer coefficient, the surface area and the temperature difference between the impinging air flow and the fabric can be seen. In this relationship, the effective drying surface is defined as the length multiplied by the working width, i.e. this value is fixed before purchasing a particular drier. In the end, only the heat transfer coefficient and the temperature difference are available for effecting changes to increase the heat flow. To increase the heat transfer coefficient by increasing the performance of the air flow would be no problem. In most cases, however, this is not possible due to the fabric requirements. For good fabric quality, however, the finisher desires a uniform mild air flow. Moreover, the guiding principle of achieving "increased evaporation performance without additional expenditure of energy" runs counter to this solution. Other ways of approaching the problem must be pursued by taking into consideration the three basic conditions for optimum geometry of the air-jet systems (Fig. 9). These are:

$$a)\ (H/D)_{\text{opt.}} = 5.$$

$$b)\ \left(\frac{F_{\text{air-jet}}}{F_{\text{subjected to air impingement}}}\right)_{\text{opt.}} = 2\%.$$

c) optimum separation = 1.4 H.

H = air-jet/fabric surface separation;
D = air-jet diameter;
F = surface area.

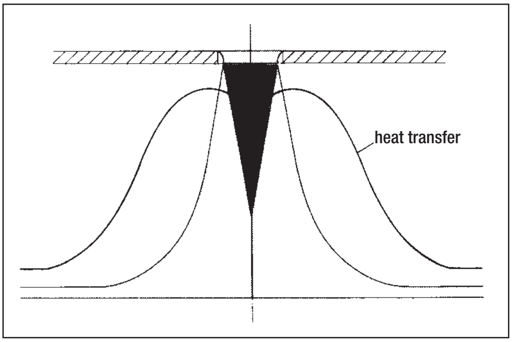


Fig. 9: Schematic representation of the heat transfer of an individual air-jet (source: Babcock).

A high heat transfer is observed in the region of an impinging air stream. The heat transfer is correspondingly reduced if the impinging air jet changes to a tangential flow. This observation applies to a fan jet as well as to a round air-jet.

In the first driers used for textile finishing applications, the air flow was blown parallel to the fabric from the front to the back of the drier. A considerable in-

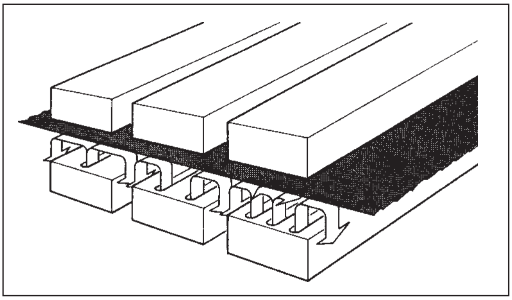


Fig. 10: A standard nozzle finger with different numbers of fan jets (Babcock).

crease in performance was achieved after the introduction of air-jet systems. Fan jets were used initially (Fig. 10). One air-jet was installed on each nozzle finger. However, this arrangement in no way provided an optimum separation. Wide stretches of the running fabric were still receiving only a tangential impingement of the air flow. The introduction of two air-jets per nozzle finger improved the optimum separation. This modification also resulted in a higher heat transfer.

With fan jets, a further increase in performance was not possible. A third row of fan jets on one nozzle finger only resulted in a tendency for a tangential flow to develop since the air-jet in the centre caused the two outer air streams to break up due to its outflowing air stream, thereby rendering them virtually ineffective.

The next stage in air-jet development led to the adoption of round nozzles distributed throughout a single nozzle finger. In this way, several rows can be accommodated within the surface area of a single nozzle finger. This arrangement also presented a certain obstruction to the individual air jets although, in the case of round nozzles, the exhaust outflowing air can find a path between the individual air jets which keeps the degree of obstruction within acceptable limits. The increase in heat transfer between the fan jet and round jet system is approx. 15%.

Drying with infra-red radiation Principle: heat transfer by radiation and absorption of the radiation by the textile material. The depth of penetration of IR radiation in textile materials is dependent on the wavelength of the radiation and the degree of absorption of the textile material itself. → Infra-red drying.

Drying zone part of the → Heat treatment zone in drying and stentering machines.

Dry lamination The dry laminating process (Fig.) enables two, three or more substrates to be laminated under the actions of temperature, pressure and treatment time, each factor being capable of individual regulation. The necessary adhesion between the substrates is achieved by the use of film, powder or fusible fibres.

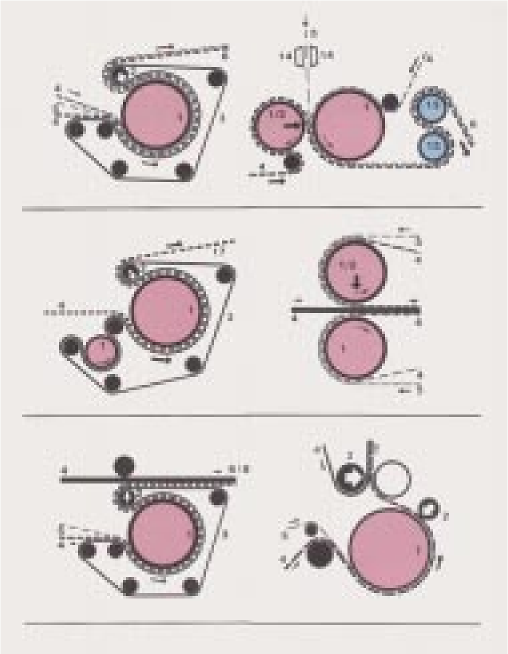


Fig.: Stork dry lamination options.
1 = (teflonized) heating element; 2 = press roller;
3 = (silicon-coated) belt; 4 = substrate; 5 = heat-activated film; 6 = laminate; 8 = coated end product; 13 = cooling; 14 = heating zone; 17 = double-heat-treated end product.

Dry mercerizing → Mercerizing of dry cotton or cotton/viscose fabrics. Mostly carried out on grey goods (→ Mercerizing of grey goods). Disadvantges: the finish is not as good as on scoured fabrics; heavy contamination of the caustic soda solution (size, lignin, etc.), addition of expensive wetting agent necessary (effluent problems). The advantage, however, lies in the mercerizing of blended fabrics with regenerated cellulose, as with dry mercerizing the swelling and dissolving range of 12–13°Bé caustic soda where these fibres are particularly at risk is not undergone twice, as happens in the mercerizing of wet goods. The → Mercerizing of grey yarns and fabrics is what is usually understood by dry mercerizing.

Dry setting → Heat setting.

Dry spinning A spinning process for man-made fibres in which the polymer, dissolved in an organic solvent, is converted into filaments by extrusion through spinnerets and subsequent evaporation of the solvent in warm air which allows the bundle of spun filaments to harden. The dry spinning principle is used for the production of acetate, triacetate, acrylic and polyvinyl chloride (PVC) fibres.

Dry steam → Steam without water droplets. Contrast → Wet steam.

Dry strength → Tensile strength.

DS process A direct stabilizing process for textile fabrics developed by Kannegiesser and Stockhausen. Instead of using adhesive interlinings the outer material is coated in stripe form.

DTA → Differential thermal analysis.

DTNW, abbrev. for: Deutsches Textilforschungszentrum Nord-West e.V., Krefeld (German Textile Research Centre North West); → Technical and professional organizations.

DTV, abbrev. for: Deutscher Textilreinigungs-Verband e.V., Bonn (German Textile Cleaning Association); → Technical and professional organizations.

D-type drum division (Pullman division), a “D”-shaped division of the inner drum cross-section into two chambers of equal size.

DU (Delft unit). An arbitrary unit for the proteolytic activity of enzymes and biologically active washing agents: e.g. the enzyme preparation has a protease activity of 1000 DU/g if 1 ml of a 2% solution of the enzyme preparation gives an extinction difference of 0,400 under experimental conditions.

Dual-action (Flip-flop mechanism). This is the oloephobic-hydrophilic behaviour of certain fluorine compounds, as opposed to oleophobic hydrophobic systems of known oleophobic finishes. Dual action compounds contain both hydrophilic segments and oleophobic-hydrophobic fluoric traces. The fluoric trace in the film coating the fibre has an oleophobic and hydrophobic action when it comes into contact with air, and when transferred into water the entire polymer is rearranged with hydrophilic groups projecting outwards and available for the dispersal and removal of soil in the washing solution (Fig.)

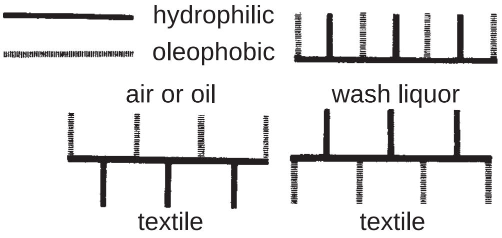


Fig.: Dual action.

Dual anchor Name for → Reactive dyes which have two or more reactive groups in the dye molecule. These kinds of dual anchor reactive dyes can have two “anchors” to the OH groups of cellulose molecules, e.g., i.e. enter into a dual reactive bond (→ Bifunctional).

From an ecological point of view there are two problems with reactive cold pad-batch dyeing, which are its cumulative AOX parameter and its colour persistence. The AOX parameter means the chlorine, bromide and iodine halogens that are contained within organic compounds and adsorbed by active charcoal, and is also an indicator of “hazardous substances” in industrial effluents as defined by § 74 para. 1 sentence 1 of the Federal Water Resources Management Act. The reactive group of the majority of conventional monofunctional reactive dyes has more than one halogen atom and varying degrees of reactivity, which also gives the hydrolysate a considerable AOX content, which can exceed the discharge threshold value of 3 mg/l suggested in appendix 38. Colour persistence is due to the dye hydrolysate, which is extremely soluble in water. Only a small amount of this dye is absorbed in activated sludge, meaning that the rest enters the sewage system. Colour persistence is therefore always an aesthetic topic of discussion between the processor and the authorities, particularly when an unacceptable proportion of reactive dye effluent is discharged to municipal sewage. In a meaningful comparison between cold pad-batch dyes and conventional monofunctional reactive dyes or dual anchor dyes, both systems would have a high AOX value in the original dyebath. Whereas only about a third of the AOX load in previously-used reactive dyes has disappeared after 24 hrs. of hydrolysis conditions, the AOX value of dual-anchored dyes is only slightly above the threshold value suggested in appendix 38, which determines whether or not a discharge requires treatment. In practice it would be feasible for the dye padder residue after completion of the padding process containing a mixture of dye and alkali, to be transferred to a secondary vessel to allow time for full hydrolysis, and then sent for biological treatment as industrial effluent.

Dual process (Dual technique, dual phase), cleaning method for use on industrial clothing which uses successive solutions in the same washing machine, mainly consisting of either water or solvent (tetrachloroethane, white spirit). Particularly used for industrial clothing that cannot be adequately cleaned in water or solvent, depending on the type of material. Although it was already known that dual processes could improve dirt removal using relatively little power and water compared to wet washing, greying of whites is still a problem.

Duchese satin, a heavy satin fabric woven on an 8-end or 12-end repeat, formerly with a grey warp and a tram weft. Now produced from acetate or viscose filaments, also with a fine cotton weft for dress fabrics and blouses.

Duffel (duffle), a heavy, low quality woollen cloth, napped on both faces. Napped duffel is similar to eskimo and is mainly woven in a 4-end warp cross twill construction. Other duffel qualities are given a melton finish. Used for short coats and certain types of military or contract cloths.

Duhamel wool washing process, circulating process possibly including wool fat recovery. The process uses potassium carbonate to remove the suint in several becks with increasing washing activity until an optimum is reached. The wool is treated with lukewarm water without additions, the bath is dropped, and the liquor centrifuged to separate undissolved matter (possibly multistage), and the liquor pumped back for reuse in washing.

Dull colour, consists of grey elements, i.e. white and black, in addition to colour. The opposite is → Clear colour.

Dummies,

I. → Steam ironing dummy.

II. Dummies are used for simulation of those processes which cannot be carried out on humans. Protective clothing must, for example, be designed in such a way that it protects the wearer from burning in the event of fire. With this aim in mind, safety clothing materials are to be developed and the necessary test methods to achieve this performed on dummies. The dummy test (Fig.) helps provide solutions. Numerous sensors are attached in and on the body of the burning dummy, enabling measurements of the degree of burning and therefore giving information about the performance properties of a protective garment on the human body. Similarly, clothing physiological tests are developed on test dummies (→ Copper man).

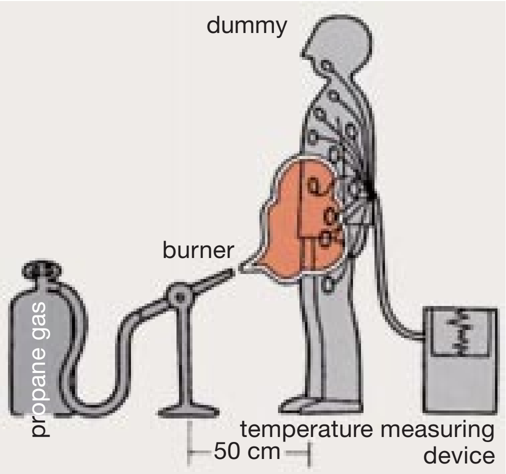


Fig.: Test dummy for flame test: a gas flame (1200 °C) is directed at the clothes for 10 s.

Duotuft, special tufting technique in which some of the pile loop that has already been tufted is re-engaged. This part of the pile loop is then pulled into the next pile loop. This improves cover whilst being relatively economic in pile yarn consumption.

Duplex machines,

I. In general, two machines running in tandem.

II. Special Sanforizing or Montforts compressive shrinkage machines with two felt calenders.

III. Special roller printing machines for printing both sides of a textile fabric.

Duplex printing process Double sided patterning is possible using the duplex printing process, which can be carried out in both screen and roller printing. There are 2 screens and/or rollers per pattern and these print the pattern identically on both sides of the fabric. This is predominantly used for blankets and towels.

Duplosolv process A continuous 2-stage process for desizing fabrics which have been sized with polymer sizes. In the first stage, the size is swollen with water (80–150% based on weight of fabric) and brought into solution. In the second stage, this solution is displaced by tetrachloroethylene. The size can be regenerated from the aqueous solution. Manuf.: Brückner.

Dupont bleaching system Cotton and cotton/synthetic fibre blends are bleached with hydrogen peroxide using J-boxes as reaction dwell chambers. After impregnation with bleach liquor, the goods are heated to the bleaching temperature by steam in a steam chamber immediately prior to entry to each J-box.

Dupont Minute Bleach process A 2-stage continuous scouring and bleaching process: 1. alkali scour stage; 2. peroxide bleach stage. Each stage involves a 2 min. steaming treatment in a normal Mather-Platt continuous steamer.

Dupont shrinkage test (boiling test). A test method for determining the dimensional stability of textiles made from synthetic fibres to treatment in boiling wash liquors or for determining the efficiency of heat setting. A square of specific dimensions is drawn on the material, after which it is boiled for 30 min. in soft water in a washing machine, hydro-extracted, allowed to dry in air, and the square measured again. The difference in the dimensions of the square before and after the wash test provide a measure of the dimensional stability of the material.

Duralized A commercial term for the effect produced on a fabric, preferably of pure cotton, by treatment in liquid ammonia (Duralized process). Manuf.: Cluett, Peabody + Co. (licensor).

Duromers → Duroplastics.

Duroplastics (Duromers), plastics (synthetic resins) made from three-dimensionally cross-linked macromolecules that can be thermally hardened by means of cross-linkage. The thermal hardening process is irreversible (compared to → Thermoplastics). These materials cannot be melted and are insoluble in organic solvents, e.g. phenol-formaldehyde resins of the Bakelite type. Also logically includes rubber vulcanisation.

Dust Suspended particulate matter in gases or in the air which are able to remain in suspension for a relatively long time due to their low particle size. In respect to the effect of dust on human respiratory organs, it is not dust in general, but fine dust which is significant. But dust is also unwelcome in the product and on/ in the machine. Lower dust content gives improved product quality. Dust can be released on the machine in a large variety of places, and consequently there are considerable problems to solve in textile machinery design in order to achieve the required levels. Suitable finishing agents (anti-dust compounds) are available with which in many cases, a reduction in fine dust emissions and fibre abrasive wear with both cotton and blends with synthetic fibres can be achieved without other accompanying negative phenomena.

Dust extraction units for printing machines In order to remove lint, loose fibres and other loosely adhering matter from the surface of textile fabrics to be printed (which could impair printing quality, e.g., local resists and screen blocking problems, etc.) a dust extraction unit is installed, e.g. immediately before the printing zone (see Fig.)

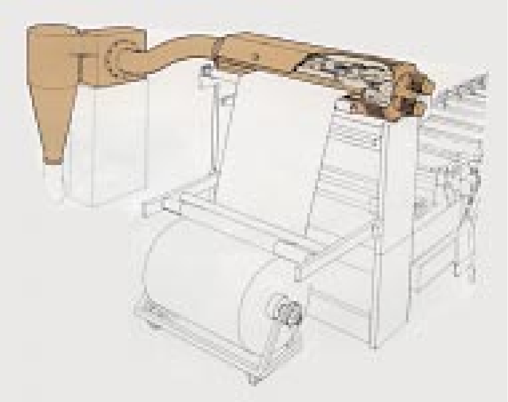


Fig.: VIP heating, brushing and suction extraction machine with cyclone unit and rotary screen printing machine ionisation.

Dust filtration In the textile industry, dust filtration entails the removal of dust particles of various sizes from the discharge (air extracted from the working environment) of air-conditioning units. Other extraction systems of various types deal with the extraction of dust from the actual textile machine. Air from all these sources is recirculated to provide uniform air engineering and energy saving in production premises. Exhaust filters must be used to keep the dust content of the air in the production environment within the permitted limits. Both the air from the production environment and the machine exhaust contain dusts and fibres in various forms. The filtering of exhaust air can, therefore, be divided into two tasks:

1. Filtering out the fibres and fibre accumulations.
2. Fine filtering the exhaust air so that it can be recirculated back to the production environment without exceeding the maximum permitted levels of respirable dust in the air.

There are no filter media available which can be used for all situations to optimum effect. The difference in composition of discharged air which contains dusts of many different types and long and short fibres is too great. In some cases, these discharges may contain sticky components as well. Problems of this nature can be solved by experience or trial and error with different filter media. With its various surface or fibre treatments, needlefelt in particular offers possibilities where the cleaning of the filter medium can also be improved. What is important, is that the low limits of the OSHA guidelines can also be maintained using state-of-the-art filtration technology. Equally important is the knowledge that the production machines themselves produce dust directly. This problem must also be borne in mind especially in view of the constant increase in throughput per m^2 production area with the same or slightly greater generation of waste.

Dust in cotton spinning Dust in cotton spinning may be roughly divided into the following categories:

1. Mixed dusts of inorganic/organic components consisting of natural dusts or impurities from leaves, seed capsules, harvesting methods, etc., adhering to the fibres.
2. Technical dusts mainly arising from fibre debris and fragments of various sizes which are added to the naturally occurring dusts during mechanical processing. The composition of these dusts extends over a broad spectrum with particle sizes ranging from < 1 μm up to fibre fragments of several mm in length.

The yarn quality is primarily influenced by coarse to medium-sized dust particles whereby impurities adhering to the fibres become separated by mechanical cleaning processes during fibre preparation. Lubricants and spin finishes would more likely lead to undesirable effects on fibres which have not undergone a preliminary cleaning stage. By contrast, fine dusts are usually only released in the actual spinning process (abraded fibres, fly) and can be positively influenced by the presence of spin finishes especially with regard to expectations of higher productivity performance. The fine dust remaining in the material should be a “spinnable dust” (i.e. dust which does not adversely affect the spinning process) and which can be removed in subsequent finishing processes.

Dust/lint eliminator (for printing). There must be no dust particles on the print ground as it passes into the printing zone, as these would act as resist agents.

Dust/lind removal

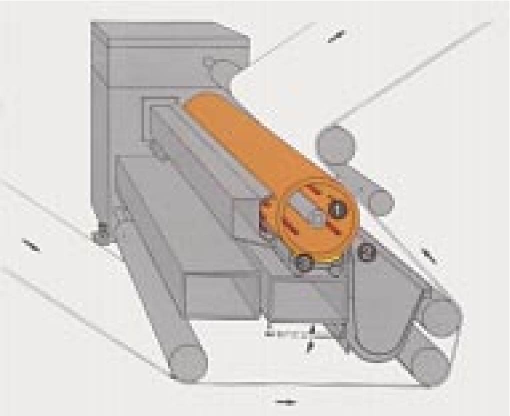


Fig.: Stork dust eliminator with application of adhesive in the adhesive trough (3); transfer of lint from the fabric passing tangentially to the adhesive cylinder (1) and stripping off the adhesive/lint mix with the doctor blade (2).

The ground is therefore cleared of dust by suction or adhesive techniques (Fig.).

Dust/lint removal This takes place on the finished fabric by beating or brushing or a combination of the two processes. Dust which has accumulated from fibres and finishing agents is extracted through extraction slots. The removal of dust from printed fabric takes place immediately before the fabric enters the printing zone (Fig. 1). Distinction is made between dust removal using a dust extractor and dust removal using a dust-removal unit with adhesive-coated rollers.

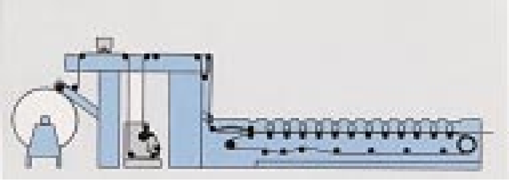


Fig. 1: Dust extraction unit before entry into the printing zone.

Extraction units are available in three different designs: a simple extraction unit for one side of the material, two extraction units attached to a single fan for one or both sides of the material and two extraction units each attached to its own separate fan for removing dust from one or both sides of the material. Extraction is carried out as follows (Fig. 2): the contaminated material is transported by the extraction unit itself. A specially designed nozzle guarantees high extraction efficiency and uniform extraction over the full width of the material. Fans and noise insulators ensure a powerful but almost noiseless extraction of lint and threads. Lint and dust are finally collected in a filter plant.

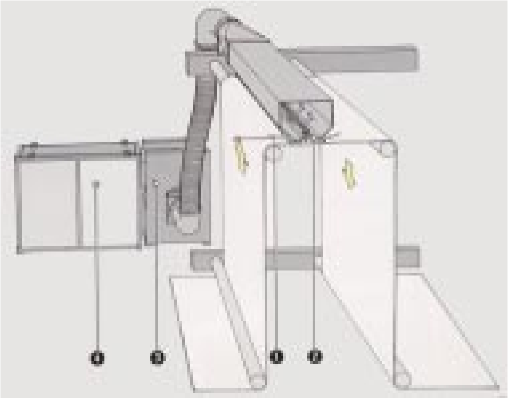


Fig. 2: Dust extraction on a web (contributed by Stork). 1 = fabric; 2 = extraction slot; 3 = dust extraction unit; 4 = electrical installation.

The adhesive-roller device (Fig. 3) operates as follows: fabric is transported to the adhesive roller before entering the printing or finishing machine to ensure the complete removal of microscopic dust particles. The adhesive applicator roller rotates slowly in the opposite direction to that of the fabric. The lower part of the roller is immersed in a trough of adhesive where a thin layer of adhesive is applied to the roller. The roller is

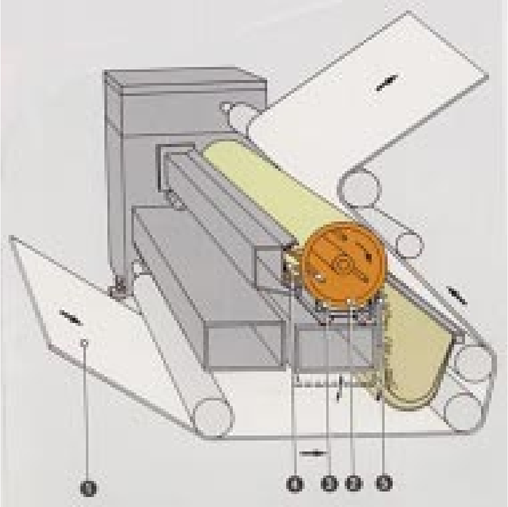


Fig. 3: Dust extraction unit with adhesive roller (source: Stork).
1 = fabric; 2 = rotating screen for adhesive coating;
3 = doctor blades; 4 = adhesive coating.

heated internally and externally, thus drying the adhesive. As the material runs past, the dust and lint particles adhere to the adhesive roller running in the opposite direction. A doctor blade removes the spent adhesive and adhering dust and lint particles and fresh adhesive is automatically taken up from the sizing pan.

Dust measurement Dust contamination can have a negative influence on production processes and also represents a source of nuisance and risk to the health of operatives exposed to dust-laden environments. For the industrial monitoring of dust pollution levels, a distinction is made between total dust and fine dust pollution. For health risk assessment, the particle size range of fine dusts is of particular interest whereby textile dusts, with their diverse particle forms and compositions, pose additional problems for dust measurement technology.

One way of determining dust concentrations involves collection of the airborne dust. In this method, a specific air flow is drawn by suction through a fine pore filter on which the dust particles are filtered out. From the known air flow and prescribed period of time, the dust concentration may then be determined by subjecting the filter element to gravimetric analysis.

For many investigations, it is necessary to obtain information relating to the particle size distribution of the dust particles. This applies particularly to tests for determining the efficiency of filter media and filtration plants. An important characteristic of a filter is the so-called "separation curve" T(d) which, in contrast to the total degree of separation, is expressed in the form of a function of the degree of separation for each particle size d (Fig. 1). The separation curve therefore provides much more comprehensive information on filtration properties than the total degree of separation. In order to determine T(d), it is necessary to measure the particle size distribution in dust-laden air H_s(d) and in the filtered air H_r(d) with two separate measuring instruments as simultaneously as possible. The distributions H_s(d) and H_r(d) indicate the proportion of a specific particle size d, either in number or mass-related terms, or a size group (d_1 to d_2) present in the total dust; they are correspondingly identified by means of a supplementary index letter "m" for mass and "n" for number-related values. If number-related particle size distributions are measured, the separation curve is calculated from the formula

$$T\,(d) = \frac{N_S \cdot H_{S,n}\,(d)}{N_r \cdot H_{r,n}\,(d)}$$

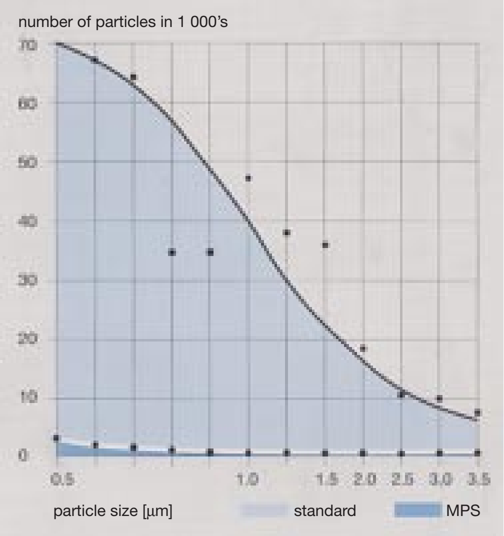


Fig. 1: Separation curve for dust separation on standard filters or on micropore filters (BWF).

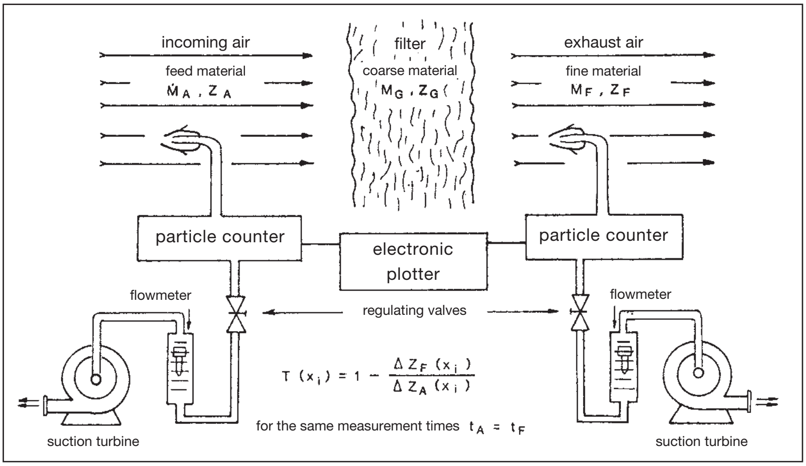


Fig. 2: Schematic representation of the measuring procedure to determine the separation curve of a filtration plant (source: Bahners).

with the total particle counts N_s and N_r recorded within the measurement time t_m. The measurement procedure is represented schematically in Fig. 2. For an appropriate test on industrial filtration plants, a small partial stream is therefore withdrawn before and after passing through the filter and is led to the respective measuring system. In order to meet the requirements for rapid measurement, optical particle counters are suitable which utilize the scattered light or even the diffraction effects produced by the dust particles in order to obtain size-dependent signals.

The instrument consists essentially of a filter housing with a membrane filter disc and an impeller type centrifugal fan mounted behind it to produce a specified air flow volume. The dust filtered out onto the filter disc as well as the fibrous components caught in the fibre catcher pan are usually determined gravimetrically.

The Andersen sampler is used primarily for the fractional collection of fine dust for particle size analysis. The dust particles are filtered out in the measuring instrument, according to size, into 8 separate fractions on the impaction principle. A corresponding mass-related particle size distribution is obtained by weighing the fractions. By adding up the collected dust quantities, the total dust quantity and, consequently, the fine dust concentration can be calculated as well.

Samples collected in industrial plants can, amongst other things, be further classified in the laboratory with a so-called Coulter counter. With this instrument, volume-related particle size distributions of collected dusts can be determined on the basis of conductimetry (source: Bahners).

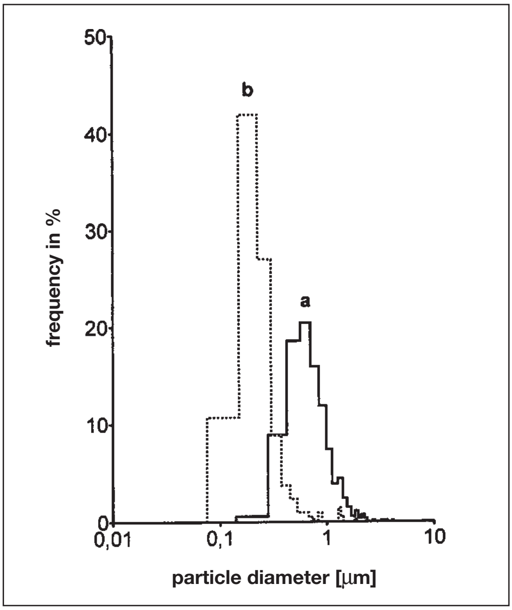


Fig.: Number-related frequency distributions of the smallest particle projection diameters $d_{Fe, min}$ of a cotton dust in weaving (distribution a: sample taken from an air-jet weaving machine processing unsized rotor-spun yarn) and a mixed dust present in the aerial environment of a surface treatment on fabrics made from PES resp. PA microfibre yarns (distribution b: single roller emerizing machine (according to Bahners and Schollmeyer).

Dust problems → Dusts are solid particulates dispersed in a gaseous medium (usually air). Dusts from dyes are generated during handling, e.g. dispensing, transfer to other containers, "strewing-in" when preparing print pastes, etc. The particle size distribution is largely independent of the form of the dye itself. Depending on the severity of the mechanical stresses imposed, large quantities of dust are also dispersed into the surrounding air during processing of textile fibres in the spinning, throwing, weaving and dry finishing stages of manufacture. The dusts involved here are either mixed dusts composed of particles of fibres and fibre impurities adhering to the raw material which are simply set free during mechanical processing, or fibre fragments of various sizes that are only formed as a result of the action of the processing machinery itself. These waste products of transition and attrition which, in the form of finely dispersed particles having a wide particle size distribution (see Fig.), are carried along in gaseous (air) currents. For technical, economic and/or work hygiene resp. health reasons, these dusts must be removed from the air environment as close as possible to the source of generation in order to prevent quality deficiencies due to inclusions of dust particles in textile structures and unnecessary wear and tear to machine elements due to dust accumulations, as well as to avoid health risks to the operatives. For this reason, very high demands are placed on effective cleaning and → Dust filtration in the production of rotor yarns from low-grade cotton.

The air in a textile manufacturing plant is in continual circulation. It is extracted at appropriate locations, e.g. at the machines, and treated for dust removal. In addition, dust extraction plants of various types are used which are based on different physical principles. The treated air is then returned to the production departments as "clean air". After a certain period of time (corresponding to the effective range of the dust extraction plant) a stationary state for the individual particle fractions is established in this cycle. Since very fine dusts (< 5 μm particle size) are only filtered out inadequately by this means, dusts in this size range accumulate. Filtration separators are usually employed for dust removal in spinning plants which filter out, in successive stages, the coarse contaminants including long fibres and fine dusts contained in the air extracted from the machines and the production departments. Wire gauze is mainly used as a prefilter, the mechanical blocking action of which filters out the coarse dust particles whereas a variety of textile materials including woven fabrics, nonwovens, pile fabrics and felts are used to filter out fine dusts. Virtually all the processing operations in a spinning plant right up to the spinning machines themselves participate in dust removal from fibrous materials. For this reason, dusts should be filtered out as early and as completely as possible. The problem therefore lies in the requirement to significantly improve the removal of fine dusts by filtration effectively and in an economically viable manner.

In the processing of raw cotton, the amenability of the fibrous material for effective cleaning is an important quality criterion. To determine cleaning efficiency the raw fibrous material is subjected to a dust and trash test. The percentage of dust and trash is determined which:

– can be released in fibre-to-fibre and metal-to-fibre friction during processing into yarns;
– constitutes fibre fly (short fibres < 5 mm);
– constitutes trash (particles ≥ 500 µm).

Wool yarns which have been dyed with chrome dyes can generate dust during the rewinding process and impair the running properties if excess chromium is adsorbed on to the surface of the fibres during treatment with dichromate.

Dyestuffs in solid form are available in various physical forms (e.g. powders, granules). The particle size distribution of commercial dyes varies to a great extent. The average particle diameter may be less than 50 µm but can also be as much as a few millimetres. Moreover, the particle size distribution may be narrow or wide. In all handling operations with solid dyes, the formation of dust is to be expected and the amount of generated dust is dependent on the handling operation as well as the particular product. In order to prevent the exposure of operatives handling dyestuffs in colour kitchens (and laboratories) for textile dyeing and printing, special downdraught dust control booths are now available for weighing and dispensing operations, etc. The quantity of dust generated by products from the same manufacturer is a quality characteristic of the product (source: Schollmeyer and Bahners).

Dustprone fabrics, goods which are prone to dust due to the fact that quantities of non-bound finishing agents (kaolin, delustring agents etc.) are too high.

Dust removal plants There are two stages in removing dust from environmental air or exhaust air from machines (Fig. 1). The core of a plant such as this is the drum filter with prefiltration discs built into the entry. The exhaust air to be filtered passes through the circular prefiltration discs into the filter drum. From here, the air passes outwards through a filtration medium which covers the circumference of the drum.

Fibres are filtered out by the prefiltration discs and removed from this by a suction slot. The dust passes through and is first deposited inside the filter drum which acts as a fine filter. The stationary, non-rotating drum made from filtration fabric has a forced outward air flow so that the contamination remains inside the filter drum and the environment in which the drum filter is situated stays clean (Fig. 2).

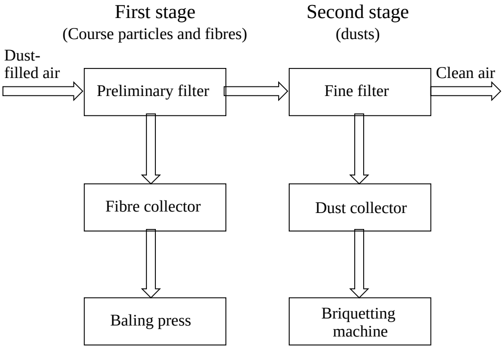


Fig. 1: System for exhaust-air dust filtration.

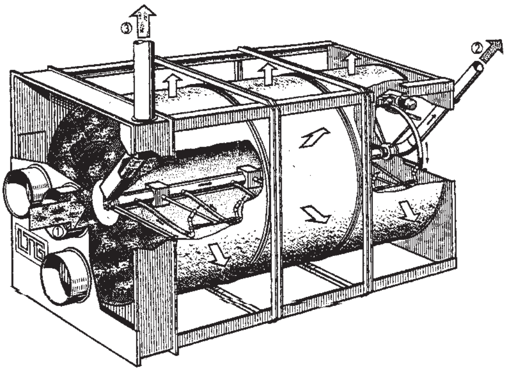


Fig. 2: Drum filter with prefiltration discs fitted to the entry (source: LTG).

The filtration fabric is cleaned by moving suction nozzles which rest on the filter fabric under spring loading. The nozzles are moved by means of a hollow shaft to which the nozzles are attached and which takes away the contaminated air stream. A second cross-recess shaft superimposes rotational and reciprocating movements so that the extraction nozzles cover the entire surface of the filter.

The fibres extracted from the prefiltration disc by the suction slot are collected internally on a perforated sheet-steel cone in the fibre compactor (Fig. 3). The fibre web which forms on the cone is stripped in a downward direction by a rotating worm screw, precompressed and pushed out through a spring-loaded panel. Dust which still remains in the air stream is fed

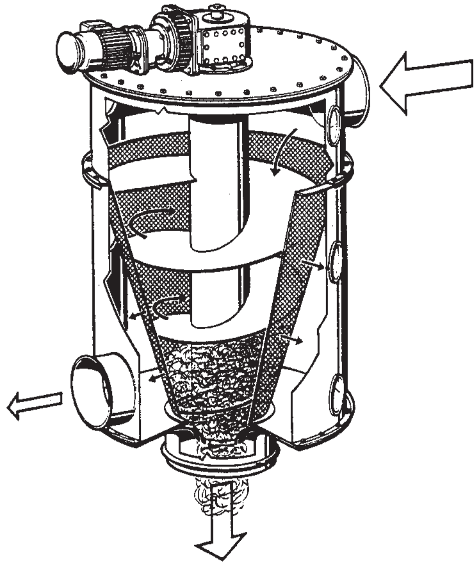


Fig. 3: Fibre compactor with perforated sheet-steel cone (contributed by LTG).

back to the drum filter for fine filtration. If the precompressed fibre is of uniform composition, this is fed directly to a baling press. If there are several types of fibre present, a silo collector is used. The collected fibrous dust is compacted and made into briquettes (Fig. 4).

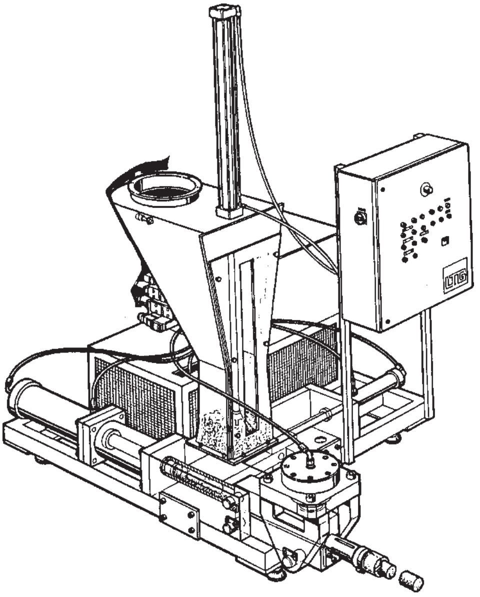


Fig. 4: Briquetting machine for collected dust (source: LTG).

Duty free tax import for finishing Customs authorities of many states grant customs facilities for temporary import and/or export of goods as a result of applications. This system is also significant for the textiles industry to a certain extent, depending on the economic situation. Duty is deferred for goods which are imported from abroad for finishing and goods are exempted from customs duties on proof that the goods have been exported. This is commonly referred to as duty free tax import. Commission processing transactions occur almost exclusively between neighbouring states. A distinction is made between active and passive tax import. It is passive if finishing takes place abroad, and active if foreign goods are imported for finishing. Reasons for recourse to duty-free tax imports can be economic (lower prices) or qualitative (special finishes). It is also used by companies whose operations are situated in different countries and who wish to take advantage of the favourable cost structures in these countries. In addition to known finishing operations, the following are also examples of processes included in duty free processing: embroidering fabrics, cutting of pile fabrics and also redyeing materials which have already been dyed. In order to guarantee the identity of textiles sent for finishing, the customs authorities make appropriate regulations, taking finishing requirements into account.

Duvetine (duvetyn, duvetyne) from Fr. *duvet* = down. Originally of cotton warp and spun silk weft. Sometimes made of fine woollen yarns. Constructed of six-, seven-, or eight-shaft satin weave and face finished to give a smooth, plush texture. The down-like surface, produced by several napping, shearing and brushing operations is characteristic of duvetine fabrics. In comparison to velours, the surface pile is shorter and less pressure-sensitive. Duvetine is mainly dyed in the piece. Soft handle and appearance similar to suède, drapes well, wears well, but spots easily. Used for ladies' outerwear, costumes and coats.

DVM abbrev. for: Deutscher Verband für Materialprüfung e.V. (German Association for Material Testing).

DVM softness, a specialized system of notation mainly used only in laboratories in Germany for measuring the softness of rubber and synthetic rollers and suchlike. The softness corresponds to the respective depth of impression in 0.01 mm increments produced by a steel ball of 10 mm diameter with a test load of 1 kg.

Dwell chambers In order to complete the process, in many finishing stages it is necessary to batch the fabric or knitwear impregnated with chemicals for a period of time. This can take place in air, steam or gas. Two transport systems are used for this: conveyor belts and roller conveyors. The conveyor belts can be arranged in one or several levels above one another (see Fig.). This is the most common design. In addition,

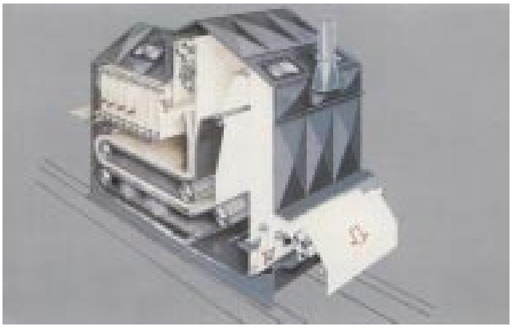


Fig.: Dwell chamber in a Küsters' steaming machine.

there are carousel type devices and towers, in which the conveyor belt is arranged in the form of a spiral.

Dwell process, bleaching and dyeing process for fabrics and knitwear, whereby goods impregnated with chemicals or dyestuffs are rolled up in open width and are stored for the necessary length of time at room temperature or in heated chambers (e.g. pad roll chamber).

Dwell time, phase of the processing cycle during which the actual reaction takes place, e.g. at the final temperature reached. Finishing processes where fibres, finishes or coatings undergo heat treatment generally do not achieve optimal finish as neither the period of time nor the result is continuously monitored. There is no direct method of measuring which can define the set in a length of cloth which is in motion, and it difficult to check objectively the degree of vulcanizing, e.g. of carpet backing which is still in the coating unit. Therefore in practice, all of these processes are carried out empirically using formulae as far as possible, and these often take into account a considerable safety factor in terms of dwell time. Naturally it is not possible to speak of optimisation in terms of economy and technique given these conditions; many products are also unable to withstand a process time which is either too long or too short, which means that the increased safety factor is no guarantee that the final finish of the goods will be correct. During curing and pre-setting for example the temperature of the goods and length of time the goods should dwell at process temperature are prescribed. Heating up to this temperature takes varying lengths of time depending on the goods; the heating time is especially variable if drying needs to be carried out immediately before heating. The heating process also generally requires more time and greater energy consumption than the actual fixing or curing. Conditions for producing coatings are similar. Depending on the type and weight of the application, drying and heating take different lengths of time, while dwell times which must be strictly adhered to are prescribed for the actual development process (vulcanizing, polymerisation).

Dwell units (cloth accumulators). Machines which subject the textile goods to a finishing process for a period of time (of up to 24 hours) in order to expose them to the effects of chemicals or dyestuffs. For shorter periods of time, guide roller systems are used for this purpose in the continuous method, inclined accumulator chutes, J-tubes (J-boxes) or → Rebatching chambers. For longer periods of time, i.e. in batch processing, frames or trolleys are used. The goods are laid down or rolled up in open width in these for the dwell period. Rolls are generally rotated slowly in order to avoid the fluid settling. →: Mobile dwell chambers; Circular accumulators. Rope-dyeing machines also have a dwell unit (Fig. 1).

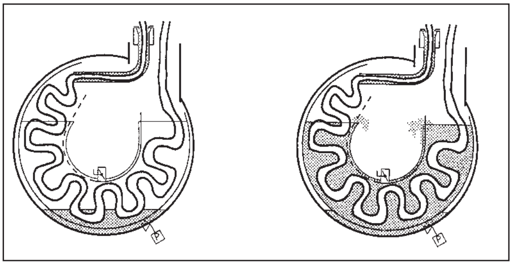


Fig. 1: Diagram of the full-flooding device: left short liquor operation; right full flooding in the dwell unit of a rope-dyeing machine (Scholl).

There are different designs depending on use (see Fig. 2):

I. Conveyor dwell unit: Also to be retrofitted into existing plants. Goods are transported by means of traction via the wetting-out trough into the bath and deposited evenly in the liquor between two driven conveyor belts by reciprocating bars. Spray pipes are used to spray the relatively loose cloth assembly upwards whilst in the liquor, (= even distribution of chemicals and temperature, liquor exchange/movement of goods). Options: above/below liquor, cold/hot, at boil, tight/loose assembly (depending on proneness of goods to creasing).

II. Dwell unit for steaming processes:

a) Perforated belt steamer: operated with saturated steam, proved to bleach delicate fabrics. Fabrics after impregnation are inverted between belts via intake conveyor. They are heated rapidly in extended state, then flat folded for the lengthy process taking 20–40 min.
b) Roller steamers (→ Roller conveyor steamers): Also operated at saturated steam temperatures, particularly used for goods which are subject to creasing which require controlled fabric transport.
c) Universal combination steamer (see Fig. 3): Fills

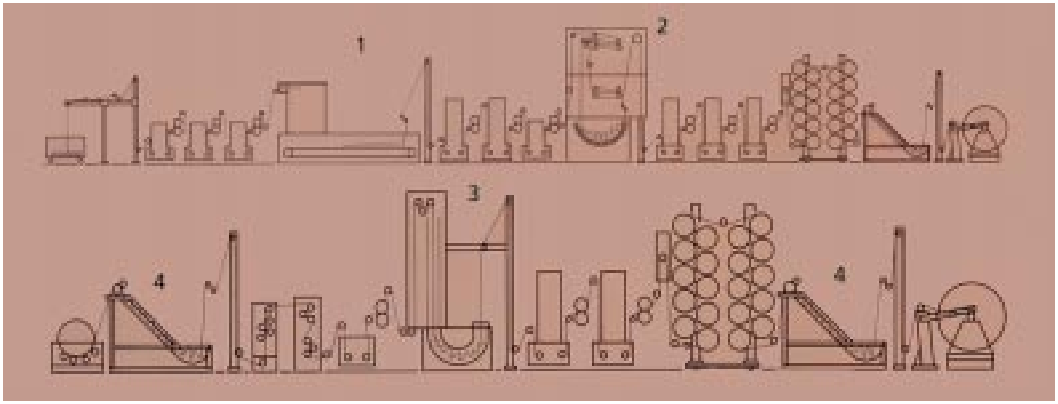


Fig. 2: Various dwell units in pre-treatment lines (Morrison).
1 = perforated-belt dwell; 2 = U-box; 3 = J-box; 4 = trough dwells.

the gap in dwell time between perforated steamers (20–40 min) and roller steamers (1–2 min). Consists of a roller section for controlled transport of cloth. Improves trash elimination in cotton goods with a slightly longer dwell time of approx. 7 min in both alkali and peroxide stages, making better use of the bleaching chemicals employed, i.e. lays down folded goods without risk and without disturbing marks as long as they are not assembled too densely and if possible there is no compressive load on the assembly. Fabric feed via air locks until the swelling process is completed, depending on the capacity of the steamer and the speed of travel with controlled transport 0.5–1 min treatment time, then laid down via reciprocating roller in loose folds. Remove goods at the end of the conveyor and exit via the water lock. Inflow and outflow locks and production of steam in the sump ensure air-free steam atmosphere and even temperature distribution. "One-stage bleaching line" comprising the following components – perforated drum washing unit, impregnation conveyor and combination steamer – are particularly useful for printing plants, as optimum pre-treatment can be carried out on cotton, cotton/polyester and knitted goods.

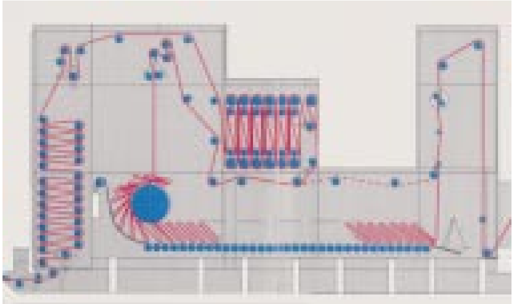


Fig. 3: Combination steamer (Küsters).

III. J-tube: J-box for 80–200 m cloth capacity with direct/indirect heating, with/without circulation of liquor, max. temperature 98°C.

DWF, (Ger.) abbrev. for: Deutsche Wäschereiforschung (German Laundry Research Organization); → Technical and professional organizations.

DWI, (Ger.) abbrev. for: Deutsches Wollforschungsinstitut, Aachen (German Wool Research Institute); → Technical and professional organizations.

DWV, (Ger.) abbrev. for: Deutscher Wäscherei-Verband (German Laundry Association); → Technical and professional organizations.

Dy, chemical symbol for Dysprosium (66).

Dye → Dyestuff.

Dyeability As a prerequisite for the use of textile fibres, one of their most important properties is dyeability. Consequently, the range of application of some synthetic fibres has been, and still is, limited either because they have poor dyeability or the problem of dyeing these fibres has not yet been satisfactorily solved. For example, when $2^1/2$ acetate fibres were first introduced, they were not successful for a long time because they could not be dyed with the known dye classes at that time. Indeed, it was only after the discovery of disperse dyes that acetate fibres gained wide acceptance. The same problem applies to polypropylene fibres although, in this case, appropriate modifications have provided a partial solution. Comparable examples are the attempts to develop polyester fibres with a higher dye uptake as well as the efforts to produce a polyamide fibre with differential dyeing characteristics (→ Differential dyeing) which has had a favourable influence on their range of application. Some textile fibres may be dyed with several technologically different dye classes capable of achieving relatively good colour fastness; others, however, can be dyed with one particular dye class only (and, even then, not without difficulty in some cases).

In practice, the dyeability of a textile fibre is determined by the rate of dyeing and the degree of saturation which can be achieved. For example, the different dyeing properties of mercerized cotton compared to non-mercerized cotton can be characterized by results from the time of half dyeing (i.e. the reciprocal of the rate of dyeing) and the saturation concentration of the substantive dye.

Dyeability is dependent on the following factors:

a) Chemical composition of the fibre: fibres of native and regenerated cellulose differ from each other, for example, in their physico-mechanical structure but, despite this, they can be dyed with the same classes of dye. The same situation applies to protein fibres (a gram equivalent of wool is 1200 g and that of silk is 4200 g for reactions as bases) as well as for polyamide and polyester fibres.

b) The coloristic dye class resp. the entire dyeing system including additions to the dyebath: certain dye classes are only suitable for one particular type of fibre, i.e. either the dye is not capable of dyeing certain fibres, or can only dye them very slightly resp. stain the fibre; this can, however, be caused by unsuitable dyeing conditions, e.g. by using an inappropriate dyebath pH.

c) The geometrical form of the fibre, the fibre dimensions as well as the morphological and histological structure of the fibre (the cuticle in cotton, the scale layer of wool and the skin effect in viscose fibres) and the fine, or supramolecular, structure of the fibre, whereby each change in fine structure results in a change in dye uptake: e.g. mercerized or non-mercerized cotton, different regenerated cellulose fibres, drawn or heat-set synthetic fibres.

Those changes which, for example, involve changes in the ratios of crystalline, oriented and amorphous regions due to the ageing of cotton or changes in the pore size, can be attributed to changes in the accessibility of the fibre to certain reagents. The relationship between fibre accessibility A% and the degree of crystallinity K% can be derived as follows:

$$A = (100 - K) + \alpha K$$

α is a constant which is related to the crystalline part of the fibre. It can have values from 0–1. An ideal substance with hundred percent accessibility would be represented by $\alpha = 1$. The first part of the formula represents the amorphous part of the fibre φ, and the second part represents the accessible surface of the crystallites (if $\alpha = 0$, this surface would be inaccessible):

$$A = \varphi + \alpha K$$

In the case of high tenacity viscose fibres K can vary, for example, between the limits of 33–49%, $\alpha = 0.09–0.67$. The accessibility A represents an appropriate numerical criterion of dyeability. It is an absolute parameter which represents a previously given property of the fibre and, in general, gives expression to the requirement for its dyeability in achieving dark shades or black within an acceptable dyeing time provided the dye has adequately high build up properties. The fact that, in isothermal dyeing, dyeability decreases with the time of dyeing and that a fibre has a greater affinity for the dye at the beginning of the dyeing process than at the end, is well known to every dyer. It is also possible to assess dyeability from the standpoint of the momentary quantity and rate of dye uptake by the fibre at a given time. The relative dyeability is always a kinetic parameter which is related to a specific dyeing system. If it is assumed that at time t, a dye concentration c_t exists in the fibre, then the reciprocal of this parameter c_t^{-1} is the dilution of the dye in the fibre at time t. At the start of dyeing, the dilution reaches a value which increases beyond all limits (apart from the dye adsorption on the fibre surface at time t = 0; the dilution has a value of $c\infty^{-1}$).

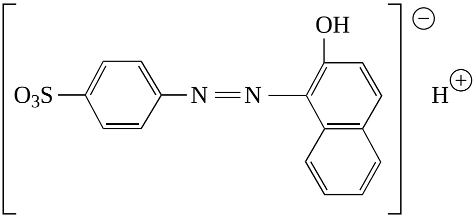
The dilution of solutions behave in an analogous manner: before a substance dissolves in a solvent, the dilution is infinite (since the reciprocal value, i.e. the concentration, is equal to 0); with increasing concentration the dilution decreases (not, however, to 0 but to a certain value which corresponds to the dilution of the substance in a saturated solution). The rate of dyeing at any time of dyeing t is proportional to this dye dilution:

$$\frac{dc}{dt} = \frac{K}{c_t}$$

The dyeability of the fibre at time t is the dye dilution related to a unit of time, i.e. $(c_t \cdot t)^{-1}$. It is infinite at the beginning (if the dye adsorption at time t = 0 is disregarded) and decreases with the time of dyeing (usually very quickly) and is equal to 0 at equilibrium. According to experience, the fibre is now no longer capable of absorbing any dye from the dyebath (only an interchange of dye particles between the fibre and the dyebath takes place as a result of the dynamic equilibrium which exists in reversible processes).

Dye absorption index (fibre affinity index SF), fibre characteristic which gives information on the max. dyestuff affinity of an acrylic fibre for cationic dyestuffs.

Dye acids These are organic acids consisting of the hydrophobic dye residue and the hydrophilic auxochrome groups. The latter are mainly sulphonic acid ($-SO_3H$) and/or carboxyl ($-COOH$) or hydroxyl groups ($-OH$) which, with their acid character and negative charge, make the dye residue function as a dye acid and become a dye ion. Free dye acids exist, for example, in the acid dye range, either in the commercial form itself or they are formed by the addition of acid in an acidic dyebath:



The dye acids formed during the vatting of vat dyes are known as → Vat acids. Due to their ionic behaviour in aqueous solution, formation of the dye acids and their alkali salts (→ Dye salts) occurs in contrast to → Colour bases, i.e. the main group contained in cationic dyes (→ Dye ions).

Dye affinity In simple terms, dye affinity (also neutral affinity) is the dye absorbing capacity (of textile fibres). It varies between wide limits depending on the state of equilibrium between the fibre and the dye in solution. A number of factors play an important role in this process, e.g. liquor ratio, dye characteristics, additions to the dyebath (such as acids, salts and dyeing auxiliaries), dyeing time, dyeing temperature, and the degree of purity, extent of drawing and degree of crystallinity of the fibre being dyed, as well as the number of dye bonding groups available in the fibre. For affinity-controlled dyeing processes, a temperature is selected at which diffusion proceeds at a relatively fast rate. If it is assumed, as a model, that a bath exhaustion equilibrium is established momentarily at any one time, then the kinetics of exhaustion are given by the change in equilibrium. For polyamide fibres and wool, the equilibrium between the dye in the fibre (concentration C_F) and the dye in the liquor (C_L) can be approached by a superimposed Langmuir and Nernst distribution:

$$C_F\,(pH) = \frac{k_L\,(pH) \cdot S_L\,(pH) \cdot C_L}{1 + k_L\,(pH) \cdot C_L} + k_N\,(pH) \cdot C_L$$

with the pH-dependent distribution coefficients k_L and k_N, and the saturation value S_L. The pH dependencies are both dye and fibre-specific.

Dye affinity of wool, treatments to improve,

a) Pretreat for 1 h at the boil in a 5% potassium thiocyanate solution, rinse, dye in the presence of 20% sodium sulphate and 5% acetic acid 30%;
b) Bring the yarn to the boil in a solution of 2,5–4% solution of sodium thiosulphate or neutral sodium sulphite or sodium tetraborate, boil for 1 h, hydroextract and dry;
c) Treat the wool for 20–30 min. in a liquor containing 1–1,5% active chlorine under weakly acidic conditions, treat in a fresh bath with 1–2 g/l sodium dithionite as an antichlor and bleach.

Dye ager A horizontal continuous-dyeing machine for all conventional textile fabrics (including difficult qualities such as cotton velvet and lining fabrics) with all classes of dye, by the pad-steam process and the wet-in-wet process of vat dyeing voluminous fabrics in which dye is applied on a preceding padder and the reducing agent padded on directly before the ager entry using a special applicator unit. A high degree of reproducibility is achieved by the ager.

Dye analysis → Dye tests.

Dye anions → Dye ions.

Dye application – control methods in continuous dyeing In continuous dyeing, the quantity of dye applied to the textile fabric can be measured indirectly from the amount of moisture (liquor) applied by the padder (e.g. by means of microwaves). It would be even better, however, to measure the quantity of dye applied to the running fabric by taking reflection measurements on the wet fabric shortly after it leaves the padder nip since, in this case, it would be possible to make any necessary corrections from direct readings and the short control loop. Other control possibilities opened up by reflection measurements on the wet fabric include:

1. Concentration distribution of dyes and auxiliaries applied from the pad liquor (side, centre, side).
2. Localized pick-up of liquor by the fabric (in relation to its dry weight before padding).
3. Localized residual moisture content of the fabric entering the liquor and the exchange coefficient between water and product.

It is to be understood in this case that the directly measurable dye pick-up parameter desired (Fig.) does not have to be replaced by a group of measurement parameters which can, in principle, be handled but which require very involved measurements (the exchange coefficient is likewise not amenable to direct measurement. However, since it is only used as a correction parameter, it can be applied as a value capable of interpolation from a series of trials).

Before a decision is made to invest in an elaborate measuring system of this kind for a particular process stage, it is of course necessary to establish first of all whether or not sufficient control would be achieved by measuring the dyed result at the end of the dyeing process and only then make any necessary corrections to the two factors exercising the greatest influence on the process, i.e. the dye liquor itself and the dye liquor pick-up. Colour measurement on fabrics at the point of delivery from a continuous dyeing plant with a drier is

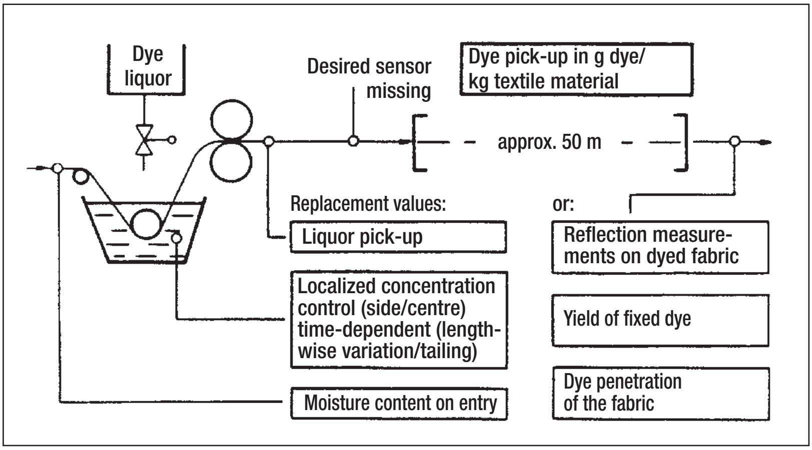


Fig.: Sensors for the measurement of dye pick-up in continuous dyeing.

state-of-the-art technology. Measuring sensors are already available which can take reflection measurements across the full width of dyed fabrics (by means of a single traversing measuring head or 3–5 dixed measuring heads) and display from the standard. The main problem here lies in the time response of the control system rather than in the measuring sensors.

Measurements are carried out approx. 30–100 m after the point of dye application. There is consequently a long time lag, i.e. under these conditions, many metres of fabric have to pass through the dyeing plant after a correction has been made to the dye pick-up before the point of change in the fabric reaches the measuring head.

Dye batch A → Batch of textile material dyed in a single process cycle (→ Charge).

Dyebath exhaustion, difference in concentration, measured by colorimetry, in the dyebath before and after dyeing. It is quoted as a percentage of the original dye concentration. The colour of the exhausted dyebath is measured against the full colour. Dye exhaustion is of course also dependent on the composition of the dye concerned.

Dyebath finish application → Softening of textiles.

Dyebath preparation is the preparation of a dyebath incorporating additives and chemicals or dyeing assistants using dispersing agents, sometimes solvent accelerators, and in the case of disperse dyestuffs also carriers, ethoxylates etc., usually in pourable form as dye pastes of varying viscosity. Weighing apparatus may be connected to the dissolving plant (Fig. 1). The transfer of the weighed-out dyestuff to the dissolving plant is improved in health and saefty respects by the use of robots (Fig. 2).

Dye beam A perforated cylinder (usually of stainless steel) on which woven or knitted textile fabric to be dyed in a → Beam dyeing machine is wound.

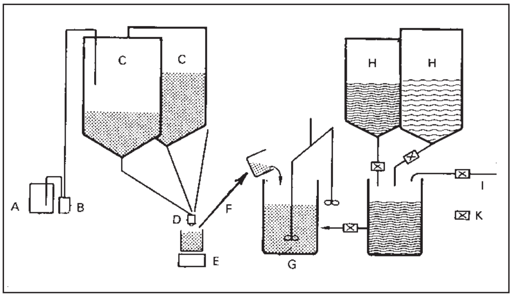


Fig. 1: Dyestuff weighing/dissolving plant.
A = dye container; B = pump; C = dyestuff reservoir; D = metering device; E = automatic balance; F = robot; G = formulating vessel and agitator; H = chemical solutions; I = water; K = flow meter.

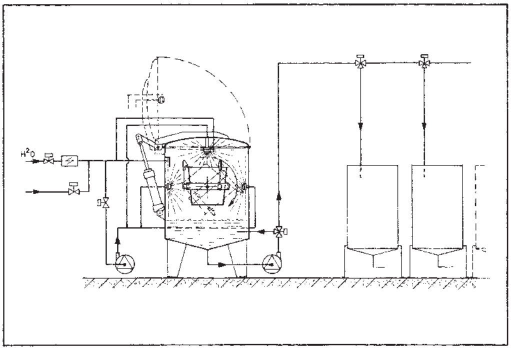


Fig. 2: Lawer robotic dyestuff dissolving plant.

Dye beam batcher Special batching unit for batching textile fabrics on to dye beams before dyeing and debatching after dyeing. The debatching operation takes place in the wet state.

Dye carrier → Carrier.

Dye cations → Dye ions.

Dye/chemical dispensing Weighing dyestuffs and textile auxiliaries in the → Colour kitchen.

Dye class identification on fibres, if the fibre material is unknown, → Fibre identification should be carried out first.

test	cellulose	protein fibres	acetate	polyamide	polyacrylonitrile	polyester
boiling water-	–	–	x	x	x	–
ammonia-	()	()	–	x	x	–
wash-	x	x	x	x	x	–
paraffin-	x	x	x	x	x	–
sodium hydrosulphite-	x	x	–	x	x	–
sublimation-	x	x	–	–	–	–
chlorine-	x	–	–	x	x	–
hydrochloric acid-	x	–	–	–	–	–
activated carbon-	–	–	x	–	–	–
benzene-	x	x	x	x	x	x

Tab.: Dye class identification for various fibres.

The most well-known dye class identification systems on fibres are:

I. Krefeld method:

a) For cellulose fibres: dissolve sample in suitable solvent, sulphur test (for sulphur-based dyes), blind vat (oxidation and cationic dyes), stripping and staining reactions (for mordant, acid, direct and diazo dyes), dimethyl formamide test (for reactive dyes), glacial acetic acid test (for vat, naphthol and phthalocyanine dyes).

b) For animal fibres: paraffin test, blind vat and reoxidation (for vat and naphthol dyes), detection of metals (metal complex and chrome dyes), cold glacial acetic acid (cationic dyes), suitable solvent (reactive, acid and direct dyes).

c) For synthetic fibres: a caprolactam melt is prepared or stripping by means of glacial acetic acid carried out. The melt and the solution are mixed with ether and processed further. Dye classes which can be identified are disperse, metal complex, chrome, acid, cationic and naphthol dyes.

II. Reutlinger method:

a) For cellulosic fibres: water, wash, paraffin, pyridine, glacial acetic acid, hydrogen sulphide, chlorine, benzene tests and blind vat.

b) For animal fibres: water, wash, paraffin, glacial acetic acid, ammonia, pyridine, benzene tests and blind vat.

c) For synthetic fibres: →: Acetate, Polyamide and Acrylic dyes.

III. In accordance with the AATCC guidelines for cellulosic, animal and synthetic fibres.

Dye classification A distinction is made between the following methods of classification:

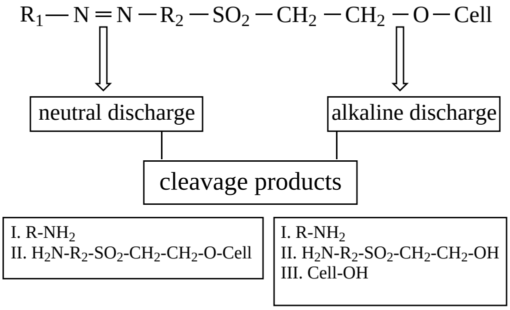
I. Scientific classification of dyes based on their chemical structure, e.g. anthraquinone, azo dyes, etc.

II. Technical classification of dyes based on their dyeing properties, e.g. direct, acid, wool dyes, etc.

III. Commercial classification of dyes based on various aspects according to the manufacturer, e.g. according to fastness properties such as Sirius Light, Indanthren, etc. or according to the method of dyeing under collective names, e.g. Remazol = reactive dyes (Dystar), Palanil = disperse dyes (BASF), etc.

Dye cleavage → Cleavage of dyes.

Dye cleavage product → Cleavage of dyes. When discharging a reactive ground with vinyl sulphone dyestuffs, the dye cleavage product which contains the reactive group remains in the neutral region, as is the case with a dyestuff with other reactive groups bonded with cellulose. In contrast to the latter, the vinyl sulphone group is split off from the cellulose in the alkaline region, this being the basis for the good dischargeability of these dyestuffs:



Dye concentration – colorimetric evaluation, is carried out after measuring the → Reflectance using the Kubelka-Munk function and Lambert-Beersch's Law. The reflectance R is measured close to the absorption maximum. The following formula applies when calculating the concentration C:

$$A \cdot C = \frac{(1-R)^2}{2R}$$

where the factor A must be found for the dyestuff on the basis of calibration dyeing with known concentrations.

Dye, definition of Dyes are coloured compounds which are absorbed or adsorbed by the fibre from a solution or suspension where they are subsequently fixed and are thus used for the coloration of textiles. The term also applies to certain colourless compounds (optical brighteners) and those which only form an insoluble dye through combination on or in the fibre (e.g. naphthols and Turkey Red). Between these groups are the mordant dyes. The final colour obtained on the fibre with these dyes is formed by applying the dye to a textile previously treated with a metal salt (mordant) or vice versa (colour lakes). Pigments do not fit this definition since they are water-insoluble colorants having no affinity for textile fibres and, for this reason, have to be applied with a binder capable of bonding to the fibre. Consequently, pigments must be regarded as a special case in textile coloration

Dye developer → Developer.

Dye diffusion (→ Diffusion mechanisms in dyeing). Two mechanisms are compared below:

1. The pore mechanism: in this case, dyes dissolved in the aqueous liquor diffuse through the water-filled pores in the fibres and are adsorbed on to the walls of the pores at the same time. This case applies particularly to cellulosic fibres and porous acrylic fibres. According to Valko, the dye molecule is dissolved in the aqueous liquor first and subsequently becomes attached to a cellulose crytallite within the pore.
2. The mobile-segment or free-volume mechanism describes the dyeing process as diffusion through the less ordered, amorphous regions of a polymer substance. The rate of diffusion of the dye molecule is determined in this case by the mobility of the segments in the polymer chain molecules. The segment mobility starts at the glass transition temperature at which point the non-crystalline regions of the fibres or polymers are transformed from a glass-like into a viscoelastic state. Free-volume diffusion is particularly dominant in the case of polyamide.

Dye dispersing agents → Dye solubilizing and dispersing agents.

Dye exhaustion rate → Exhaustion rate of dyes.

Dye extraction from dye liquors in dyeing The difference in concentration, determined colorimetrically between the dye liquor before and after dyeing; it is expressed as a percentage of the original liquor concentration. The coloration of the extracted liquor is determined by measurement of the full colour. The extraction of dye from the dye liquor is, of course, also dependent on the respective dye structure.

Dye fastness Although colour fastness ratings are given by the dye manufacturers for each of the dyes they produce, it is the colour fastness of dyeings or prints (→ Fastness testing) which have been dyed or printed on a given material under normal production conditions that is important in practice and for which standard fastness test methods are used.

Dye/fibre bonds These are the bonds formed between dyes and the fibre through surface energy and intermolecular forces, covalent and/or ionic bonds or dipole forces, hydrogen bonds or Van der Waals forces.

Dye finish is dye supplied in a form which in addition to the dyestuff itself also contains → Extenders. Both consitutents are ground in a mill into a powdered, liquid or pasty end product (→ Dyestuff formulations).

Dye fixation efficiency in exhaust dyeing An estimate of the average proportion of dye actually fixed on a textile substrate carried out by the OECD in 1975 revealed very wide variations which, on the one hand, can be attributed to different products within any particular dye class and, without doubt, to the different methods of application used in practice (which could be further improved in many cases) as well. The results of one study to investigate the proportion of unfixed dye remaining after the completion of dyeing, i.e. the proportion of dye lost in spent dyebaths and rinse water are given below:

– sulphur dyes	30–40%
– reactive dyes	20–50%
– vat dyes	5–20%
– direct dyes	5–30%
– naphthol dyes	5–10%
– disperse dyes	8–20%
– metal-complex dyes	2–5%
– cationic dyes	2–3%
– acid dyes	7–20%

Dye formulation, instrumental → Computer colour matching.

Dye formulations → Dyestuff formulations.

Dyehouse An industrial (→ Textile dyehouse) or commercial plant (→ Garment dyeing) for the dyeing of textiles (Fig.).

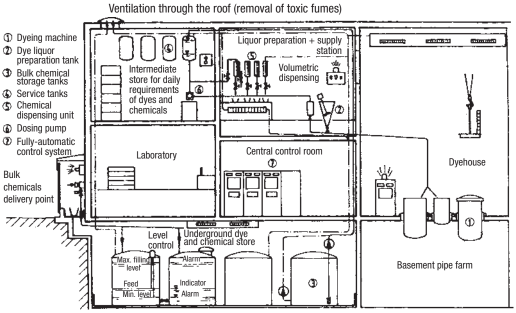


Fig.: Dyehouse plant.

Dyehouse communication (for fully automated dyehouse). Manual interventions to control a dyeing machine must be reduced in order to allow the operators sufficient time to be able to respond appropriately to system reports and messages. With the aid of an operator control panel in the form of a visual display unit (monitor screen) and a data printer, it must be possible to obtain an overview of the process status at all times and deal with any malfunctions that may arise. Moreover, it must be possible to present the process objectives in simplified form, i.e. with dying-specific data resp. parameters. In addition to possible malfunction reports, the daily progress of various batches as well as the consumption of chemicals, dyes and energy involved can be printed out on a daily, weekly or monthly basis, or as required.

Dyehouse installations and equipment These include, e.g. fog dispersal systems, dyeing machines, dye vessels, colour kitchen, computer colour measurement systems as well as the dyehouse laboratory.

Dyehouse laboratory A laboratory under the control of the dyehouse mainly intended for carrying out laboratory dyeings and tests in addition to dyeing-related analytical procedures in many cases.

Dyeing Dyeing is carried out in a dyehouse with dyestuffs and is used in (textile) finishing. The process depends on the type of fibre and form of the material in dyeing vessels, dyeing apparatus or machines. The dye is applied to a given substrate by a technological process, mainly consisting of deposition or adsorption and fixation (both processes being carried out simultaneously or in succession). If necessary the process is preceded by pre-treatment and followed by post-treatment of the substrate.

Dyeing accelerator → Carriers.

Dyeing and finishing combination processes Combination processes for dyeing and finishing in a single operation: Delaware Process; Procion-Resin process.

Dyeing auxiliary products →: Stripping auxiliary, Stripping agent, Mordanting, Fastness improving agents, Levelling agent, Dyeing Oils, Wetting agents for dyeing and dyeing oils, Dye solubilizing and dispersing agents, Fibre protections agents, Wetting agent, Retarding agent, Overboiling inhibitor.

Dyeing centrifuge for yarn dyeing In order to achieve a more intensive liquor exchange during the rinsing of dyeings, and consequently reduce the consumption of rinse water, it is recommended to centrifuge the batch in the dyeing machine after each rinse cycle (Fig.). A suitable system was introduced by Flainox in 1991.

A yarn dyeing carrier divided in two halves is placed in the dyeing cylinder to prevent deformation of the yarn packages before the large drum rotates on its axis during centrifuging. Dyeing is carried out by circulating the liquor as usual through the yarn packages supported on dye spindles.

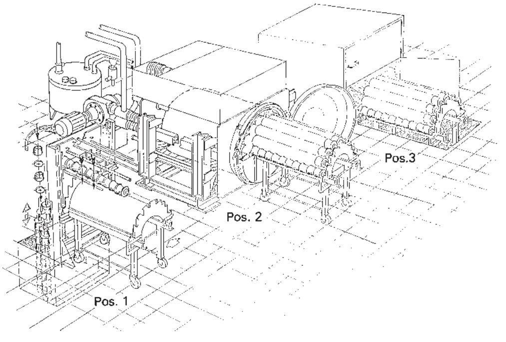


Fig.: Position 1: loading the yarn dyeing carrier, Position 2: dyeing centrifuge, Position 3: drying.

Dyeing curves → Reflectance.

Dyeing equilibrium A concentration equilibrium between the amount of dye on the fibre and the amount of dye in the dyebath which becomes established by the end of every dyeing process.

Dyeing faults, all causes which result in defective dyeing or unacceptable dye batches.

Dyeing in standing bath → Standing bath dyeing.

Dyeing kettle, hemispherical or cylindrical vessel (copper, stainless steel or ceramic) for dyeing material in hank or rope form, garments, etc. Usually having double (part-removable) perforated floors under which are steam tubes for heating the liquor; may incorporate a winch.

Dyeing kinetics, physico-chemical processes during the dyeing process which, for the main part, are characterised in mathematical terms (→ Kinetic equation in fibre loading). Three kinetic steps are involved:

1. transfer of dye from the dyebath to the fibre surface,
2. adsorption of dye onto the fibre surface,
3. diffusion of dye into the fibre.

Dyeing laboratory → Laboratory.

Dyeing machine for garment panels Finished garments or panels can be dyed in special machines. Paddle machines were used formerly, whilst more modern machines seek to reduce the liquor ratio.

Dyeing machines Devices in which the material which is to be dyed (as distinct from → Dyeing machine, circulating) is agitated in more-or-less stationary liquor – for example: padder, rope-winch vat, jigger, continuous dyeing machine, paddle dyeing machine, star frame and, among others, modern processors such as the pad-jigger, pad-roll, pad-steam, pad-wet and pad-winch processes. The dyeing machines which are in use today for batch dyeing consist of the following basic elements:

- the vat as the stationary zone,
- the pump for circulating the liquor,

- the mechanical elements for controlling the liquor (pipes and valves),
- the heat exchanger (heating unit),
- the mechanical elements for transporting the material and circulating the liquor, such as guide bars, reversing winches, transporter winches, material carriers and immersion wetting-out apparatus.

Dye movement in the solution is brought about by convection whilst liquor movement is brought about by agitation or circulation pumps. High temperatures and liquor exchange accelerate this process so that the overall dyeing speed is not adversely affected by diffusion. Diffusion is the dynamic dispersion of dye particles caused by the system's tendency towards a state of equal concentration of particles throughout the liquor irrespective of the liquor movement. Optimum flow at the interface and through the textile material to produce the highest possible degree of levellness depends on the liquor-exchange system of the dyeing machine in question. High flow rates accelerate the dye absorption, the various machine designs produce different types of flow (Fig. 1).

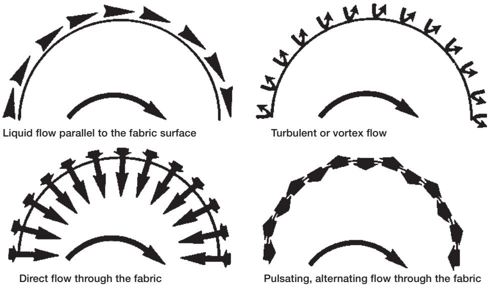


Fig. 1: Types of flow between fabric and liquor.

Different machines or apparatus are used according to the material being dyed. There are dyeing machines in which the liquor is stationary and the material is moving and dyeing machines in which the liquor is moving and the material is stationary (Fig. 2).

Dyeing is carried out according to the makeup of the material to be dyed:

I. Dope-dyed synthetic fibres: In synthetic fibre production the dye pigment (insoluble but finely divided dyestuff) is added to the spinning solution so that a coloured fibre is produced when extruded through the spinneret.

II. Loose stock dyeing: Loose stocks can be dyed by batch (non-continuous or continuous methods). In the case of batch dyeing, the fibre material is packed in a perforated vessel through which the dye liquor is forced. Coloration is not always evenly distributed but this is immaterial as the loose fibres are subsequently dispersed in the spinning mill and evenly mixed so that the colour ultimately appears to be uniform. In the case of continuous dyeing, dye solution is continuously applied to the stock on a padder and the dye fixed in a steam ager. The material is then washed and dried. Stock of different colours can be used for colour blending.

III. Sliver dyeing (slubbing dyeing): top or combed sliver consists of a continuous sliver from which the short fibres have been combed out on a combing machine. This sliver can be, for example, dyed in ball form. There are several areas where slubbing dyed material can be used in coloured wool yarn production.

a) Sold shade yarn: the essential advantage of dyeing combed sliver is the high fastness achieved. However, it is only economically viable where large batches are involved.

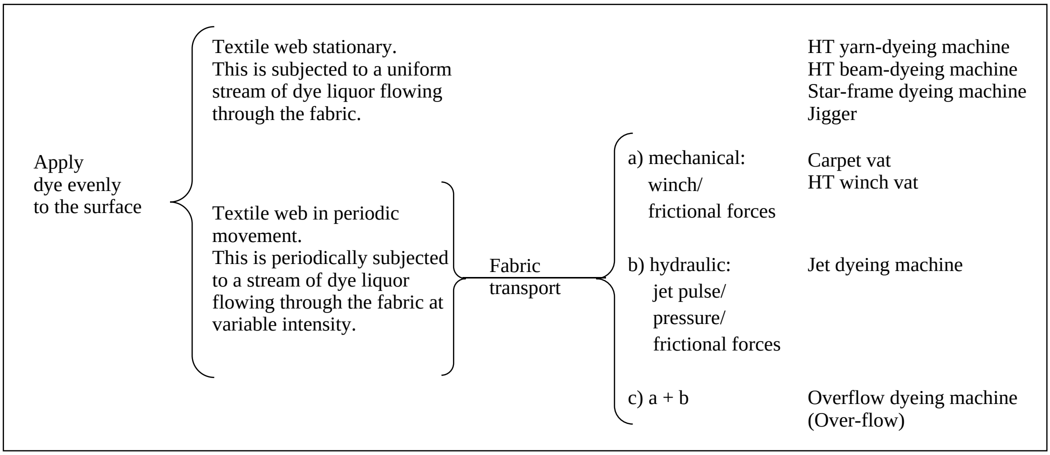


Fig. 2: Characteristics of dye units in relation to fabric transport.

b) Melange yarn: in a melange yarn specified percentages of combed slivers are dyed in different colours. These different-coloured slivers are then mixed together at the drawing stage and spun.
c) Vigoureux yarns: In this case, printing paste is applied at different intervals by means of a printing roller and fixed.

When the combed sliver is drafted during the spinning cycle, the coloured and non-coloured areas intermix so as to create the characteristic melange yarn. In the vigoureux printing process, the individual fibres are striped zebra fashion. The patterning in the finished product resulting from this process is so small that the eye can only perceive a mixed colour. For example, from a mixture of black and white stripes the resulting colour is grey. In melange products, on the other hand, the eye is still able to identify the individual black and white fibres.

IV. Yarn dyeing: The following different machines are used for dyeing yarns:

a) Hank dyeing machines: the yarn is wound into hanks, the individual hanks laid on a roller conveyor and the hanks passed through the dyebath on the rollers.
b) Spray-dyeing: in this case, hanks are laid over a perforated tube out of which the dye liquor flows. The hanks are placed at regular intervals so that dyeing is uniform. The amount of dye liquor required for this machine is significantly less than for a).
c) Pack cage: the hanks are placed in a cage and dyed in a similar way to the loose stock dyeing process.
d) Assembling columns of cross-wound packages and subjecting these to a stream of dye liquor in an autoclave.

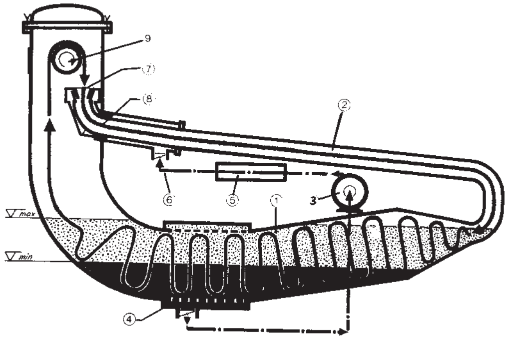


Fig. 4: "Krantz" overflow machine for fabrics in rope form. 1 = dwell chamber; 2 = liquor-exchange pipe; 4 = circulation pump; 5 = liquor extraction; 6 = heat exchanger; 7 = liquor injection; 8 = wetting-out device; 9 = wetted-out fabric; 10 = return winch.

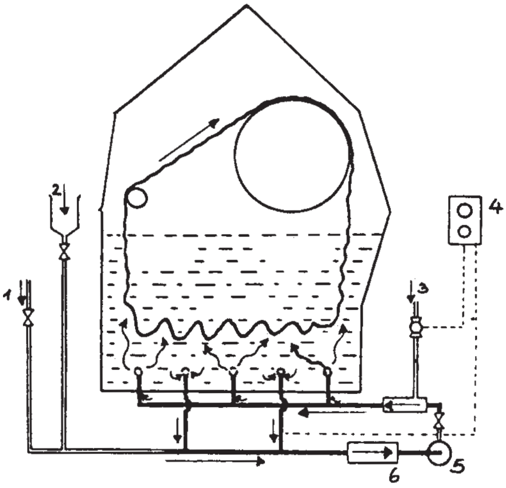


Fig. 3: Classical winch vat (IWS model). 1 = water supply; 2 = dye metering; 3 = steam supply; 4 = controller; 5 = pump; 6 = filter. Fabric throughput 20–40 m/min, liquor temperature 96–98°C.

V. Piece dyeing: there is a whole series of machines which can be used for dyeing fabrics. Modern dyeing machines operate via mechanical systems using program controllers or microprocessors, the whole dyeing process being controlled by a program.

a) Winch vat: these machines are suitable for qualities which are not subject to running cracks. The cloth is passed through the dye liquor at boiling point as a continuous rope with a rotating winch providing the traction. Temperatures can be as high as 100°C (Fig. 3).
b) Jet dyeing machine or Overflow machine: the overflow machine has been especially designed for dyeing fabric which is sensitive to tensile stress. These fabrics can be dyed using this apparatus with the minimum possible tensile loading. In this type of machine (Fig. 4), both the fabric and the liquor are in motion. The construction can be either vertical or horizontal. In jet dyeing machines, the liquor is caused to move by jets from nozzles, thus causing the fabric to move at the same time. In most cases, the fabric is also driven by means of a winch.

Dyeing machines, circulating liquor type These are differentiated into package systems, Hussong-type systems and spindle-and-separator systems. The principles differ according to working methods: stationary liquor - moving material (dye machines: padder, winch vat, jigger, roller box and hank-dyeing machine); stationary material - moving liquor (less significance, particularly common for loose stock and bulk dyeing in, for example, garment dyeing and hat dyeing; garment-dyeing machines and paddle-dyeing machines). Examples of these are:

a) Cheese dyeing machine: the packages are on perfo-

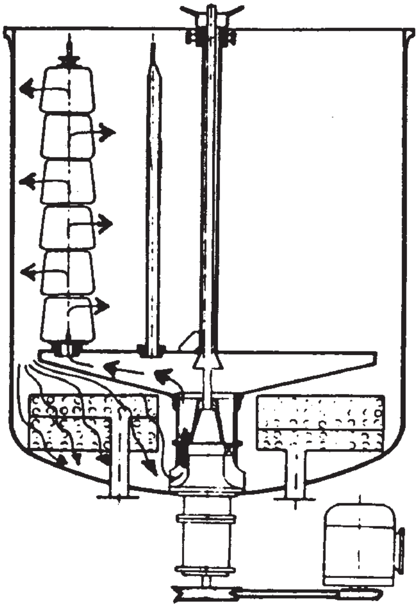


Fig. 1: Cross-wound package yarn dyeing machine.

rated plastic tubes which are stacked on perforated spindles and then put into a sealed vessel (Fig. 1). In this vessel the dye liquor can be forced through the packages under pressure. Dyeing temperatures > 100°C are possible.

b) HT Beam dyeing machine: In this case, dyeing is carried out at temperatures above 100°C. The fabric is wound on to a perforated cylinder and inserted into a sealed vessel (Fig. 2). The dye liquor can be pumped in an inward or outward direction through the rolled fabric.

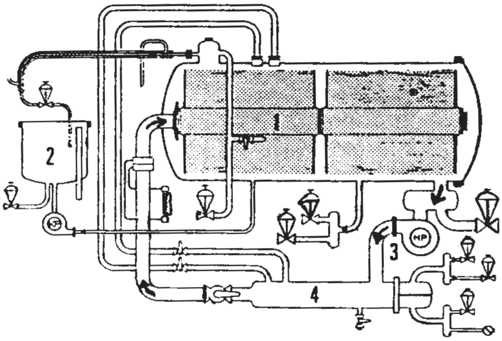


Fig. 2: Operational cross-section of a dyeing machine for open-width piece dyeing.
1 = coupled dye beams with outward circulation; 2 = stock reservoirs with separate pump; 3 = main pump; 4 = heat exchanger.

Dyeing methods These have been the subject of continual development over the years especially because of the need to rationalize or for reasons related to colour levellness and dye compatibility or because of new problems appearing with new substrates. Thus, there is a whole series of possibilities for variation such as short-liquor dyeing, foam applications, thermosol processes, jet dyeing (jet-dye machines), overflow dyeing, (overflow dyeing machines), HT dyeing processes, pad-steam dyeing processes and continuous wet-steam processes among others. In order to optimise the dyeing-process, the dyeing procedure is controlled according to a program and process control systems are used to control the operations. This means that a set of measurement instruments of maximum reliability continually records certain parameters and issues appropriate commands to the valves etc. Actuators, for example, are used for speed/time control and other operational control aspects for individual forms of apparatus, machine or automatic process management and control systems. Development in the area of textile dyeing and dyestuffs and in relation to technical applications is very dynamic.

Dyeing of acetate fibres (→ Dyeing of triacetate fibres). Disperse dyes are predominantly used both for acetate and triacetate fibres and are mainly used in exhaustion processes. As is the case for polyesters, triacetate must be dyed either with the addition of carriers or under HT conditions. In the case of acetate, selected cationic and naphthol-based dyestuffs can also be considered. There are only limited possibilities for using the padding process as the thermosol dyeing process cannot be used for acetate fibres and can only be used for triacetate fibres when lighter shades are being applied.

Dyeing of acetate/wool cotton unions,

I. Acetate white, union coloured: single-bath dyeing with suitable neutral-dyeing acid, direct or union (mixed fibre) dyes. Two-bath method, this is possible by pre-dyeing the cellulosic fibres with direct dyes at approx. 70°C, rinsing and filling in the wool with acid dyes from an acidic bath.

II. Acetate coloured, union white: it is questionable whether a satisfactory union reserve is possible as even the most suitable acetate dyes cause staining of the wool.

III. Acetate and union in two colours: single-bath method using a combination of dyes according to I. + II. (if necessary II. + union dyes) in a neutral sodium sulphate bath (Glauber's salt). Two-bath method by pre-dyeing the acetate, filling in the union and rinsing.

IV. Acetate, union in three colours: single-bath method using dyes which reserve the other fibres completely by dyeing according to dyeing methods I.–II. in a neutral bath. Two-bath method as single-bath with filling in of the vegetable fibre.

V. All fibres dyed the same colour: dye with a combination of direct-dyeing union dyes and acetate dyes.

Dyeing of acrylic fibres These fibres can exhibit very different dye affinities. Acrylic staple fibres are more easily dyed and in greater depths than filaments. The dyeing of acrylic fibres has proved difficult to the extent that whilst polyacrylonitrile fibres only begin to exhibit adequate affinity at relatively high temperatures of 70–85°C (depending on origin), the rate of dyeing is virtually doubled with an increase in temperature of around 3–4°C. Moreover, only a very low degree of migration takes place at the usual dyeing temperatures, i.e. as a rule, uneven dyeings cannot be levelled out adequately.

I. Cationic dyes: suitable for pale to dark shades; pale to medium depth shades are usually dyed using cationic or anionic retarders at the boil. The HT process is only suitable for acrylic filaments and fibres of low affinity. Continuous methods are used for loose stock, tow and combed sliver as well as, to some extent, acrylic/cellulosic blends (fixation medium = saturated steam). The thermosol process is of practically no significance (levelling problems, unsatisfactory reproducibility and effect on handle).

II. Disperse dyes: the material is introduced into the dye bath at 70°C, brought to the boil quickly and dyed at the boil for 1 h. The thermosol and pad-steam processes are of secondary importance.

Dyeing of acrylic/wool blends Dyeing methods: single-bath single-stage, single-bath two-stage or a two-bath process. Cationic dyes are used to dye the acrylic component and acid, 1 : 2 metal-complex and reactive dyes are used to dye the wool component. When dyeing acrylic fibres and wool, the cationic dyes stain the wool component first. As the boil is approached during dyeing, they transfer slowly from the wool on to the acrylic fibre and if the proportion of wool is at least 30%, retarders are not necessary. The transfer of cationic dyes from the wool is dependent on the quantity of dye, dyeing time, dyeing temperature and the pH. In the case of deep shades, a dyeing time of 45–60 min. at the boil is necessary to achieve a good wool reserve. With falling pH, the wool reserve increases. A good wool reserve is a prerequisite for the achievement of optimum wet and light fastness properties.

Dyeing of cellulose fibres ➝: Dyeing of cotton, Dyeing of linen, Dyeing of jute, Dyeing of regenerated cellulose.

Dyeing of coir Method as for jute – dyeing is usually carried out using direct or acid dyes under mildly acidic conditions (cationic dyes have inadequate light fastness). Coir is also dyed before spinning using oil-soluble dyes in the spinning oil.

Dyeing of cotton The affinity of cotton for dye varies according to its history. The adsorption capabilities of cotton are increased by caustic solutions or mercerization. There is a huge selection of dyestuffs available for cotton: substantive dyes, vat dyes, sulphur dyes, leuco-ester vat dyes, reactive dyes, naphthol dyes and phthalocyanine dyes. Of less importance are pigment dyes and chrome dyes. Cationic, aniline black and mineral khaki dyes do not have any significant application. There is a clear trend towards dye groups with high fastness properties. A continual problem for the finisher is the proportion of immature or dead fibres (dead cotton) which give rise to the appearance of bright spots in coloured fabrics. These faults are significantly reduced by treating the fibre with caustic solution or by mercerization.

Dyeing of cotton/acetate or cotton/triacetate blends,

I. Acetate or triacetate white, cotton coloured: dyeing is usually carried out with selected substantive dyes which reserve the acetate and triacetate. The dyeing temperature must not exceed a maximum of 80°C with acetate since staining of the fibre occurs at the boil. Acetate which has been scoured at too high a temperature and which is partially saponified will no longer be reserved. Even for acetate and triacetate which have been delustered in spinning a good reserve is more difficult to obtain.

II. Cotton white, acetate or triacetate coloured: this is a considerably less favourable combination as disperse dyes stain the cotton to a greater or lesser extent. An afterclear treatment is necessary with sodium dithionite, sodium hypochlorite or potassium permanganate.

III. Cotton/acetate or triacetate dyed tone-in-tone: usually carried out by single-bath dyeing with substantive and disperse dyes. Two-bath method : a) the acetate or triacetate is dyed with diazotizable disperse dyes; b) then using a fresh bath for the acetate or triacetate, the cotton is filled in with substantive dyes.

All the above variants are carried out by exhaust dyeing; pad dyeing is only used in exceptional cases.

Dyeing of cotton and wool ➝ Dyeing of wool/cotton unions.

Dyeing of cotton/regenerated cellulose blends Cotton/regenerated cellulose blends are dyed using the same classes of dyes as for cotton. The achievement of tone-in-tone uniformity between cotton and regenerated fibres is problematic due to the greater dye affinity of the latter (greatest with cupro fibres and weakest with high-wet-modulus fibres). The dyeing method, especially for substantive dyes, must be appropriately adapted with regard to salt additions and temperature, i.e. dyeing must be carried out with less salt or no salt at all and at lower temperatures. If necessary, dyeing is started at the boil with a portion of the dye, and the rest is added to the bath after cooling down. Padding methods are more suitable than exhaust methods for vat, leuco-vat ester and naphthol dyes. Causticizing before dyeing improves the affinity of the cotton. However, despite all these measures, tone-in-tone dyeing is not achievable with dark shades.

Dyeing of cotton/regenerated cellulose with polyamide blends Tone-in tone dyeings with a single class of dyes are only achieved with great difficulty. In most cases, one or other of the fibre components will have to be filled in with specifically appropriate dyes. Exhaust methods: selected substantive and vat dyes (for which the semi-pigmentation process is particularly suitable) are capable of producing tone-in-tone dyeings in pale shades by using appropriate dyeing methods. A single-bath method with substantive and metal-containing disperse dyes can be used here. For dark shades, the polyamide must be dyed first with metal-containing disperse dyes followed by the cellulose in the same bath with substantive dyes. A single-bath two-stage method may also be used with selected reactive dyes. In this case, either the cellulose is dyed first under alkaline conditions followed, after acidifying the bath, by the polyamide or, the polyamide is dyed first at pH 5 and followed, after neutralization, by the cellulose. Two-bath two-stage method: metal-containing disperse or 1 : 2 metal complex and reactive or vat dyes. Pad dyeing: pigments may be used for pastel shades. Where high fastness is required, each fibre component must be dyed separately by the methods customarily used for it. For the polyamide component, metal-containing disperse dyes are by far the most important, and vat, sulphur or reactive dyes for the cellulosic components. Selected acid dyes may be applied together with vat dyes by a single-stage method, e.g.: both classes of dye are padded together, followed by acid steaming, drying, thermofixation, padding with caustic/sodium dithionite, then steaming, oxidizing and washing. Phthalocyanine dyes may be employed for turquoise shades.

Dyeing of flammé effects This process is mainly carried out on hank yarns. This is effectively done by tying off the hanks individually at the sites where they are to be dyed in one particular colour first. Dyeing is then carried out in the customary way with the liquor just reaching the ties. The hanks are withdrawn and thoroughly rinsed by immediately spraying them with cold water in an upward direction. The ties are undone (after an intermediate drying step if necessary), rehung and tied again for the next dyeing with another dye, as already described, and rinsed down again etc. until the whole hank is dyed in the various colours desired. Two, three, four or more different colours may be involved and these may be interspersed with non-dyed areas or the colours may be adjacent to each other or even overlapping. Instead of obtaining flame effects on non-dyed yarn, hanks can be pre-dyed in a certain shade and then dyed in certain places as described above. Instead of using the technique described above, dyeing is also carried out using a pulley lifting system without tying off the hanks. → Dyeing of ombré or shaded effects.

Dyeing of garments → Garment dyeing.

Dyeing of glass filaments, fabrics In this case, it must be taken into consideration that, under normal circumstances, there is no affinity between fibre and dye and that no penetration of the dye into the fibre is possible, only surface coloration. The following overview includes patented processes which must be regarded as being legally protected:

I. Fused mass coloration: using coloured metal oxides yielding weak colours only as the colour intensity inevitably decreases with the cross section of the filament.

II. Dyeing of activated surfaces: predominantly older processes of relatively little practical importance and usually yielding weak coloration, deficient in crocking fastness and, almost without exception, having a tendency to damage the fibres.

III. Direct dyeing methods: without pre-treatment, using conventional dyeing techniques and, in this case, yielding surface coloration which is barely acceptable. Methods involving the deposition of water-insoluble dyes are exceptions to this but usually only weak coloration can be achieved, e.g., when using sulphur or vat dyes.

IV. Pre-mordanting dyeing methods: a) metal-salt process gives strong colours in some cases but almost always with insufficient crocking fastness, b) cation-active process gives very strong colorations which, with the right choice of dye, can have good fastness properties against water and light but only moderate crocking fastness.

V. Bonding-agent dyeing methods: coating with dyeable or dyed films: a) pigment dyeing methods are the most elegant and simplest to use. Pale to medium shades are possible with maximum light, water and crocking fastness (with the right choice of dye) while the properties of the dark colours (marine and black) are frequently much worse. The principle consists of fixing the pigment using synthetic resins. b) Other bonding-agent dyeing methods are to some extent still very inconvenient and unsatisfactory (especially with regard to crocking fastness). Exception: → Corona discharge process with good overall fastness but crocking fastness and grease resistance are not completely satisfactory. No dark full shades obtainable.

Dyeing of hat bodies → Hat dyeing.

Dyeing of hats → Hat dyeing.

Dyeing of hemp (→ Dyeing of linen), this is of no significance as the products manufactured from hemp are almost exclusively used for technical purposes (fire-engine hoses and belts, etc.).

Dyeing of hat trimmings of straw, panama and sisal,

1. For dyeing straw: acid and 1 : 1 metal-complex dyes
2. For dyeing panama: disperse and cationic dyes
3. For dyeing sisal: direct, acid, and 1 : 1 and 1 : 2 metal-complex dyes.

Dyeing of iridescent effects by piece-dyeing A prerequisite is that the warp and the weft have different affinities – usually acetate/triacetate or triacetate mixtures. Single-bath dyeing can be carried out with direct and disperse dyes, usually giving contrasting shades.

Dyeing of jute (→ Dyeing of cotton), the high proportion of non-cellulosic material gives jute an affinity for cationic dyes (mordant unnecessary) and acid dyes. Unlike cotton, jute is sensitive to alkalis. The light fastness of jute dyeings is poorer than on cotton.

Dyeing of leather(goods) Because of the wool-like chemical nature of leather, appropriately modified dyeing methods are used depending on the type of tanning process. The usual treatment with aqueous dye solutions given to new articles (by brushing on or dipping) has only a limited application for second-hand goods (garment dyeing). For expediency, dyeing is carried out using tried and tested commercially available → Leather dyes. → Leather dyeing.

Dyeing of linen (flax). In principle, dyeing is carried out using all the dye classes that are suitable for cotton (→ Dyeing of cotton). Dye penetration is generally more difficult, especially in the case of vat dyes. The best penetration and levelness is achieved with reactive dyes.

Dyeing of loose material (loose stock, loose fibre), advantages: any unlevelness in dyeing is evened out during the subsequent spinning process, large quantities can be produced to one shade by blending several batches and a low liquor ratio is possible in dyeing. Disadvantages: satisfactory processing in spinning is usually only achieved through the application of spinning oils and dressings. The spinning of coloured yarns demands total separation of different shades in spinning and laborious cleaning is necessary when changing colours. Unavoidable co-processing of short fibres and dyeable impurities. Continuous dyeing can be carried out by a pad steam process (e.g. the Smith Piston Pad Dyeing Machine).

Dyeing of modacrylic (acid dyeable)/wool blends This blend can only be dyed in solid shades with difficulty because of the considerably higher affinity of the acid dyes for the wool component. The best possible solid shade dyeings are achieved with the Chem-Acryl process and other process variants (manufacturer: Chemstrand Corp., Decatur, Alabama/USA). An addition of the following auxiliaries is necessary: cationic and non-ionic dyeing assistants which retard the exhaustion of selected acid dyes and bring about a satisfactory balance between the dye on both fibre components in the sulphuric acid bath.

Dyeing of modacrylic fibres → Modacrylic fibres.

Dyeing of ombré or shadow effects, shadow dyeing on one and the same hank, e.g. by hand using square or U-section rods. Firstly, the palest colour is dyed from a full vat then, after dropping a little of the bath, a dye addition is made and a somewhat darker shade is dyed – this procedure is repeated with the increase in depth of shade becoming less and less as ever smaller additions of dye are made. In this way, light to dark shadow effects of the same colour, i.e. so-called tonal gradations, are obtained. Ombré variations are produced by using different dyes. Excellent ombré dyeings are obtained on thoroughly pretreated dry goods by employing a material-specific dye selection (hot and cold dyeing types and no pre-mixed dyes if possible) as well as the absence of wetting agent (undesired upward migration of dye) with, if necessary, controlled additions of salt and temperature regulation. The most efficient results are obtained on the hank dyeing machine where good dye penetration is achieved by raising and lowering the entire yarn carrier assembly. With increasing depth of shade, the hanks are lowered to a lesser and lesser extent into the dye liquor which is correspondingly increased in strength with additions of dye. By dropping the liquor level approx. 5 cm for each individual shade a reduced depth of immersion is achieved. After reaching half the original bath volume, the yarn carrier assembly is lowered to a reduced depth. For piece goods, dyeing on the star frame is very practical (star dyeing machine) by continually raising and lowering the frame with the aid of a beam assembly (a cable running over a boom-arm); this method has proved particularly suitable for sensitive qualities (e.g. pure silk).

Dyeing of polyamide fibres Various dye classes of dye are suitable for dyeing polyamide fibres, and dye selection is based on the form of the material, the fastness requirements and the dyeing properties.

I. Disperse dyes: these dyes have good affinity and levelling properties. Affinity differences in the fibre are easily levelled out. The wet fastness properties of medium to deep dyeings are unsatisfactory.

II. Acid dyes: the most widely used class of dyes for dyeing polyamide fibres. They offer a wide colour gamut and good fastness properties, especially following an aftertreatment with products to improve the wet fastness. For combination dyeings it is essential to use dyes with similar rates of exhaustion. The selected dyes must not exhibit any blocking action. In order to cover up affinity differences in the material, anionic levelling agents, which possess an affinity for the fibre, are used in the dyebath.

III. Metal-complex dyes: these dyes have good light and wet fastness properties. Their use is limited (except for black) since differences in the polyamide material cannot be levelled out in most cases. Fastness properties can be improved with a tannin/tartar emetic (potassium antimony(III) tartrate) aftertreatment.

IV. Metal-containing disperse dyes: the fastnesses properties are the same as those of the metal-complex dyes. Material-dependent affinity differences are largely covered in dark shades. Improved fastness properties are possible with a tannin/(tartar emetic) (potassium antimony(III) tartrate) aftertreatment.

V. Reactive disperse dyes: dyeable as disperse dyes; chemical bonding with the fibre takes place following an alkaline aftertreatment thereby giving good wet fastness properties.

VI. Direct dyes: the selection is limited: used chiefly for reasons of shade and price.

VII. Naphthol dyes: of no importance.

VIII. Chrome dyes: of interest only for black shades (applied by the so-called Metachrome process in which dye and mordant are applied simultaneously from a single bath).

IX. Reactive dyes: the light fastness of these dyes varies appreciably on polyamide. Wet fastness properties are good. Any affinity differences that may arise are not covered in all cases. Combination dyeings are only possible to a limited extent. The build-up is also limited.

X. Logwood black: This dye is of interest for reasons of shade and fastness but, the method of dyeing is very involved.

Dyeing of polyester/acrylic blends Single-bath and two-bath exhaust processes are used with disperse dyes for the polyester and cationic dyes for the acrylic fibres.

Dyeing of polyester/cotton or polyester/regenerated cellulose blends These mixtures occupy a very large share of the market, and the blend ratio is nearly always 67% polyester and 33% cotton; with regenerated cellulose, the ratio is often 70 : 30 in many cases. Disperse dyes are almost exclusively used for the polyester component and reactive, vat, vat leuco ester or sulphur dyes for the cellulosic component. Direct dyes are used only occasionally. In most cases, a tone-in-tone dyeing of both types of fibre is required, for which special ranges of pre-mixed dyes are available from different manufacturers. The formulation of these mixed dyes has been fine-tuned so that both fibre components can be dyed to the same shade by exhaust as well as continuous dyeing methods.

I. Exhaust method: for the dyeing of yarns this process is only of secondary importance. Dyeing is carried out on cross-wound yarn packages or warp beams by the single-bath single-stage or single-bath two-stage process. Direct dyes can be used for cotton in the single-bath single-stage process provided they have sufficient resistance to carriers. With the single-bath two-stage process, the cellulosic component is dyed first in the case of reactive dyes whereas the polyester component is dyed first in the case of vat dyes. In two-bath processes, the polyester is likewise dyed first followed by the cellulose with appropriate dyes for each fibre. Where the cellulosic fibres are too heavily stained with the disperse dyes, an intermediate reduction clear with dithionite must be given (as well as for processes involving the use of carriers in order to remove carrier residues). The exhaust method is also used for lightweight woven fabrics as well as knitgoods. Dyeing equipment as for 100% polyester fabrics.

II. Continuous method: this process is used for all other qualities and offers numerous possibilities. Intermediate drying is critical as a certain amount of dye migration can take place at this stage. Most of the disperse dye on the cellulose is transferred by diffusion on to the polyester component during thermofixation.

Dyeing of polyester fibres Polyester fibres are hydrophobic, have a very low swelling capacity and, with the exception of copolymer fibres, have no reactive groups and no affinity for water-soluble dyes. Dye accessibility must be achieved by the addition of carriers or the use of high temperatures (→ High-temperature dyeing). The heat-setting of polyester before dyeing has a considerable influence on dye affinity, especially in exhaust dyeing with carriers. Oligomers also have an effect on the dyeing results. Exhaust processes are of importance for disperse dyes and naphthol-based diazo combinations. In continuous dyeing processes, pigments are used for pastel shades whilst vat and vat leuco ester dyes are likewise only used for pale shades. In general, disperse dyes are applied by the heat-set thermofixation process. For dyeing polyester loose fibre and card sliver, HT circulating liquor dyeing machines with the material press-packed into cages are used; card sliver can also be dyed by continuous methods. Smooth yarns in the form of cross-wound packages and textured yarns in the form of cross-wound muffs loaded on to spindles are likewise dyed in HT circulating liquor dyeing machines. For woven and knitted fabrics, HT winches or HT jet and HT beam dyeing machines are available. Thermosol plants are used for the continuous dyeing of woven fabrics. Polyester copolymer fibres (modified polyester) contain anionic groups and can therefore be dyed with cationic dyes as well. Optimal batchwise polyester dyeing processes are characterised by coordinated temperature control and liquor circulation. In this connection, it should be noted that an increased rate of liquor circulation leads to improved levelness. As a result, the critical rate of dyeing increases in proprtion to the rate of liquor circulation. However, an increased rate of liquor circulation through the textile material only leads to optimum levelness up to a certain limit. Moreover, with increased liquor throughput, increasingly unlevel results are observed. The conditions for this minimum unlevelness are to a large extent independent of the rate of heating.

Dyeing of polyester/natural silk blends The polyester component is dyed first with disperse dyes in a single-bath two-stage or two-bath process, followed by an intermediate reduction clear if necessary. Finally, the silk is dyed with acid dyes.

Dyeing of polyester/polyester copolymer (cationic dyeable) This mixture is only seldom encountered. Disperse dyes are used for the polyester and cationic dyes for the modified polyester fibres in a single-bath two-stage or a two-bath process. For continuous dyeings, the modified polyester fibres are pre-dyed with cationic dyes on the pad-steam range, then disperse and vat dyes are applied on the padder followed by thermofixation and development on the pad-steam range. In the knitgoods sector, two-colour effects are produced as well as solid shades. Acid-modified polyester with a high rate of dyeing: carrier-free dyeing at the boil with suitable disperse and cationic dyes.

Dyeing of polyester/wool blends The blend ratio is mainly 55% polyester and 45% wool. For the highest quality it is recommended to dye each fibre separately. Optimum fibre protection is not possible. As there is nothing to be gained by two-bath dyeing, it has been substituted by single-bath processes. A major disadvantage in dyeing this fibre blend is the fact that disperse dyes result in a more or less pronounced staining of the wool component and this staining has no colour fastness to speak of. A strict selection of those dyes which exhibit the least possible staining on wool is therefore necessary. Dyeing is carried out by the exhaust process at 105–107°C if possible, and with reduced amounts of carrier. Disperse dyes are used for the polyester and 1 : 2 metal-complex dyes for the wool. Pre-mixed dyes are also available from a few manufacturers.

Dyeing of polynosic fibres → Dyeing of regenerated cellulose fibres.

Dyeing of polyvinylchloride (PVC) fibres Polyvinylchlorid fibres are mainly dyed with disperse dyes. Cationic or metal-complex dyes are also frequently used. Pigments are seldom and naphthol dyes only occasionally used. The dyes must be carefully selected and, depending on the type of fibre, are dyed with or without the addition of a swelling agent (carrier) or dyeing is carried out under HT conditions, whereby polyvinylchloride filament yarns have a considerably lower dye affinity than polyvinylchloride staple fibres.

Dyeing of regenerated cellulose fibres (Viscose, cupro fibres, high wet modulus /polynosic fibres). In principle, all dyes used for dyeing cotton are suitable for dyeing regenerated cellulose fibres (→ Dyeing of cotton). The most important dyes are substantive and reactive dyes, with preference being given to hot dyeing types. The affinities of fibres produced by various manufacturers differ and can even vary from batch to batch from the same manufacturer. Textiles made from these materials are sensitive to pressure, friction and tension and this must be taken into account during the dyeing process. A well-known fault is the streaky appearance of woven or knitted fabrics due to slight variations in fibre manufacture. This streakiness can be avoided to some extent by selection of suitable dyes. The pronounced swelling properties of these fibres must be taken into account from the dyeing kinetics point of view (exothermic swelling) so that a fibre-specific processing sequence is necessary.

Dyeing of silk Like wool, silk is a protein fibre and can therefore be dyed using the same methods as for wool dyeing (→ Dyeing of wool). As silk is considerably more resistant to alkali than wool, dyeing processes which are carried out under weakly alkaline conditions are also used. In this regard, it must also be borne in mind that under alkaline conditions, high temperatures and conditions of high mechanical stress at the same time, individual fibres (fibrils) can split away from the silk filaments giving the material a fluffy and rough appearance. Compared to wool, silk also has a distinctly lower affinity because of its weaker acid binding capacity. Additional factors influencing the affinity of silk are its origin, extent of degumming, the yarn quality (tram silk, organzine) and whether the silk has been weighted or not. In general, it can be said that, under the same dyeing machine conditions, level dyeings are less problematic to produce on silk than on wool. The dyeing temperature should not exceed a maximum of 80°C since temperatures at the boil have a negative influence on the lustre and handle of silk.

Silk is dyed in all its commercial forms but is best dyed in the form of hanks (yarn) and piece goods. In principle, all the well-known types of dyeing machine can be used if they have been suitably modified to take into account the sensitivity of silk to tension and mechanical stress. The most important types of dyeing machine include:

a) Hank dyeing machines: no hank deformation (with double stick systems), no filament splitting, level dyeings obtainable provided the rate of liquor circulation is adequate;
b) Spray type dyeing machines for hank yarn: good liquor circulation and therefore hardly any levelling problems, hank deformation and filament splitting is possible; particularly suitable for high-twist and folded yarns;
c) Package dyeing machines for cross-wound packages: short liquor ratio, no levelling problems with adequate liquor circulation, no filament splitting, uniform winding of packages important because of the risk of channeling;
d) Star frame: suitable for all types of woven silk fabrics, no chafe marks, low productivity, high energy and water consumption (liquor ratio 100–300 : 1);
e) Winch: good levelness is possible, high productivity, average liquor ratio, high risk of chafe marks,
f) Jigger: high productivity possible, extremely short

liquor ratio, risk of moiré formation, good levelling resp. slow-exhausting dyes are an advantage here;

g) Jet-dyeing machines: good levelness, high productivity, short to medium liquor ratio, especially suitable for jersey and crêpe fabrics (due to the virtual absence of fabric tension), possibility of chafe marks;
h) Beam dyeing machines: good to excellent levelness, short liquor ratio 10–20 : 1, no chafe marks, especially suitable for heavy and smooth silk qualities, risk of moiré formation.

Dye class	Field of application	Advantages and disadvantages	Fastness ratings at 1/1 standard depth (Average ratings)		
			Xenon light	Bleeds on to silk	
				Water severe	Perspiration alkaline
Direct	Piece	Simple dyeing method Good light fastness in some cases Low wet fastness	4–6	3–4	2–3
Acid	Yarn and piece	Simple dyeing method Good light fastness in some cases Brilliant shades in some cases Low wet fastness	2–5/6	2–4	1–4
1:2 metal-complex	Yarn and piece	Simple dyeing method Good light fastness High degree of exhaustion Dull shades Moderate wet fastness	6	3–4	3–4
Reactive for CO	Yarn and piece	Suitable for cold-pad-batch methods High wet fastness Moderate to good light fastness	3–6	4–5	4–5
Reactive for WO	Yarn and piece	Brilliant shades in some cases Good light fastness High wet fastness High degree of fixation	6	5	4–5

Tab.: Fields of application, advantages and disadvantages and fastness properties of various dye classes suitable for dyeing silk.

Practically all classes of dye can be used for colouring silk (see Table). There is hardly any other textile fibre for which this is possible. Nowadays, silk is mainly dyed with direct, acid, metal-complex or reactive dyes.

a) Metal-complex and acid dyes: from the dye classes listed in the Table the 1 : 2 metal-complex and acid dyes are the most important in practice. Apart from a few exceptions in the acid dye range, they can all be applied from a weakly acidic bath (Fig. 1) and exhibit good levelling properties. By careful selection, all fashion shades, including those specific to silk, can be dyed although, from time to time, the colour fastness has to take second place. Thus, for the brilliant shades, red, blue, turquoise and green, often only moderate light fastness ratings and, in deep shades, only moderate wet fastness ratings are achieved (e.g. colour fastness to water severe, alkaline perspiration and washing at 40°C).

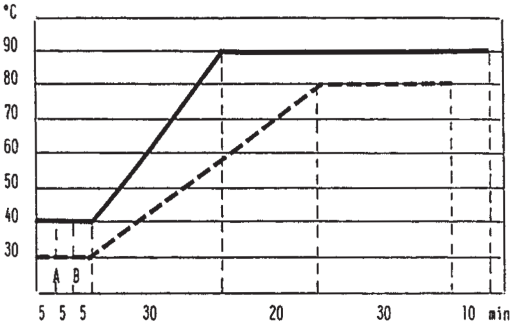


Fig. 1: Method and dyeing recipes for dyeing silk with metal-complex and acid dyes (Ciba-Geigy).
- - pale shades; — dark shades.

b) Reactive dyes: These are being used to an increasing extent (Fig. 2). They are characterised by their brilliance, high degree of fixation, high light fastness and outstanding wet fastness properties. In general, they are not very substantive although differences exist between the individual types. Consequently, the aim should be to use the shortest possible liquor ratios for these dyes. Dyeing is carried out first of all in a neutral bath with the addition of sodium sulphate at temperatures of 60–70°C, with the exception of black dyeings which are dyed at 90°C. Only in the last 15–20 min. at the end temperature is an addition of sodium carbonate made to adjust the pH of the dyebath to 8–8.5 for dye fixation. After rinsing, the dyeing must still be soaped in order to remove the unfixed dye which is not covalently bound to the substrate (source: Flensberg and Hammers).

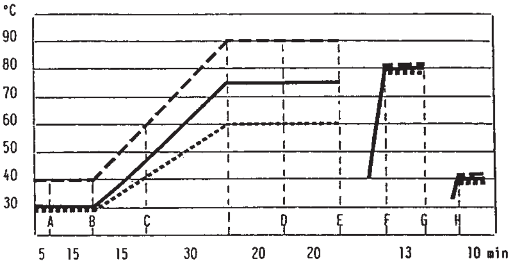


Fig. 2: Method and dyeing recipes for dyeing silk with reactive dyes (the dyeing time can be reduced for pale shades).
.... Cibacron F dyes; — Lanasol dyes; - - Lanasol Black B and Cibacron dyes (Ciba-Geigy).

Dyeing of silk/wool/polyamide blends In general, these fibres have (in some cases very) different dye affinities which must be taken into account.

I. Silk/wool: a) solid shades: dyed with acid dyes. A low temperature, and high quantities of acid, promotes a deeper dyeing of the silk whereas intense boiling and low quantities of acid promotes a deeper dyeing of the wool. b) two colours: the wool is pre-dyed with acid or chrome (mordant) dyes and the silk is cross-dyed with suitable cationic (low rub fastness) acid or direct dyes. c) white silk: dyed mainly with selected acid dyes (womenswear) or mordant dyes (menswear).

II. Wool/polyamide: (solid shades) usually dyed with carefully selected acid or mordant dyes and the controlled addition of acid for pale to medium shades accompanied by the addition of polyamide-retarding auxiliaries. In cases where the dyeing on the polyamide component is too light, shading additions with disperse or acid dyes must be made in order to dye the polyamide to a deeper colour.

Dyeing of textured polyester goods Woven and knitted fabrics of textured polyester occupy a large market share of polyester products. In general, disperse dyes are used for dyeing by both the carrier as well as the HT process. A strict dye selection is necessary since there are some products among the disperse dyes which react strongly to differences in texturing and others which are hardly affected so that, in the latter case, streakiness is avoided. The addition of carriers and use of high temperatures reduce the incidence of streakiness. Yarns are dyed either as press-packed muffs or on elastic tubes in liquor circulating machines. Flat woven fabrics are dyed on HT winches, HT jet dyeing machines or beam dyeing machines depending on the weave construction and weight. Knitgoods are mainly dyed in tubular form. Only unsatisfactory results are obtained if dyeing is carried out in open winches. The thermosol process is also used for dyeing woven and knitted fabrics made from textured polyester.

Dyeing of tow (card sliver, sliver, roving), advantages: any unlevelness is corrected by the subsequent blending of several dyed lots into large batches. Low liquor ratios are possible; short fibres and impurities are removed (e.g. comber waste for carded wool spinning). Semi-continuous and continuous dyeings produced by the pad-steam process are usual here. Disadvantages: The spinning of coloured yarns demands a thorough cleaning of the spinning machines when a change of colour is made but no cleaning of the carding machines (a particularly lengthy procedure).

Dyeing of triacetate fibres The affinity of triacetate fibres lies somewhere between that of acetate fibres and that of polyester fibres. The rate of saponification at the boil and pH 9–9.5 is insignificant. Only disperse and disperse diazo dyes are of interest on triacetate. The former is the most important dye class but careful selection is nevertheless important. The liquor ratio should be as short as possible and the dyeing temperature must be at least 95°C or higher. For dark shades produced with 2–4% of dye, there is a tendency for surface saturation to occur as well as streakiness so that the addition of a carrier here offers significant advantages. Full depth fast black shades are almost impossible to achieve with direct-dyeing disperse black brands which is why a diazo black, applied by the process normally used for polyester fibres, should be employed for deep black shades. In principle, it is recommended to heat-set triacetate fibres after dyeing since, if carried out beforehand, the reduced dye affinity can sometimes give very variable results and the colour fastness is also poorer in most cases.

Dyeing of wool Dye selection is dependent on the colour fastness required, the brilliance of the shades and the form in which the wool material is to be dyed. The most important classes of dye are as follows:

I. Acid dyes, for brilliant and well covered shades with average to good colour fastness and very good application properties in general.

II. Chrome dyes, for very good wet fastness, average to good light fastness but mainly dull shades (especially black, dark brown, navy blue; mainly used for loose fibres, combed sliver and Vigoureux printing). The use of these dyes can give rise to problems with chromium in the effluent.

III. 1 : 2 and 1 : 1 metal-complex dyes, with good to very good colour fastness to light and good wet fastness but mostly dull shades (especially black, dark blue, navy blue; used mainly for loose fibres, combed sliver and Vigoureux printing).

IV. Reactive dyes, for very good wet fastness and good to very good light fastness, and brilliant shades. In general, dyeing is carried out at 80–90°C (fibre protection, savings in energy and water consumption); dyeing is mainly by the exhaust process.

Dyeing of wool/cotton unions,

I. Neutral dyeing process: this method has proved itself in practice over many years and the dyeing results are good, although there is little fibre protection and the quality of the wool fibres is consequently impaired.

II. Acid dyeing process: in practice this method is used particularly for wool and mohair plush, since it offers a large degree of protection to the wool and mohair fibres and allows a good degree of process control. Suitable levelling agents are available for wool dyes as well as retarding agents for substantive wool dyes. Union dyes are suitable for solid shades and mixtures of wool and direct dyes are suitable for solid shades as well as the achievement of two-colour effects.

Dyeing of woven and knitted fabrics Compared to dyeings on yarn, the dyeing of woven and knitted fabrics in the piece offers the manufacturer a cheaper production route and a more flexible response to changing fashion trends. A wide selection of batchwise methods (winches, beam dyeing and HT jet dyeing machines, jiggers and star frames), semi-continuous methods (pad-jig, pad-roll, pad-batch) and fully-continuous methods (pad-steam, pad-dry-bake, thermosol) is available to the dyer. The last-mentioned processes are only used for long runs because of the high investment costs for the necessary plant and machinery as well as the need for laborious and intensive cleaning when a colour change is made.

Dyeing of yarn in hank form, advantages: good dye penetration, levelness and handle. Disadvantages: costly process due to a high liquor ratio (low capacity of the dyeing machines), re-reeling in hank form and subsequent rewinding on to cross-wound packages or weft cops. Automatic hank-yarn dyeing machines have not been a success. More economical variants in common use are, e.g. jumbo hanks from rocket muffs as well as high bulk yarns and soft muffs especially in the case of acrylics.

Dyeing oils, a now largely obsolete term for → Wetting agents used in dyeing which confer additional softening effects on the textile material.

Dyeing parameters These include all the factors exercising an influence on the dyeing process.

Dyeing processes Dyeing processes can be carried out by the direct application method or the exhaust method (Figs. 1 and 2). In the exhaust process, the dyebath is set with the necessary chemicals and then adjusted to a pH appropriate for the actual dyes/s being used. The textile material is then entered into the bath, during the course of which, a good wetting-out of the material as well as a uniform distribution of chemicals in the dyebath are important objectives. The establishment of a pH equilibrium between the material and the liquor is necessary before dyes are added in the exhaust process and the dyebath starts to be heated up. The well-dissolved dye, together with other chemicals and auxiliaries, depending on the particular dyeing process, is metered into the dyeing machine at 30–50°C (Fig. 3). Then the temperature is slowly raised up to the boil (depending on the required heat-up rate) and dyeing allowed to proceed at the boil for the specified time until a sample is taken for colour matching and before the dyed material is thoroughly rinsed after completion of dyeing.

Levelling is to be understood as the most uniform possible distribution of dye both on and within the fibre during the dyeing process. In the case of a uniform (level) dyeing, different parts of the same dyed fabric,

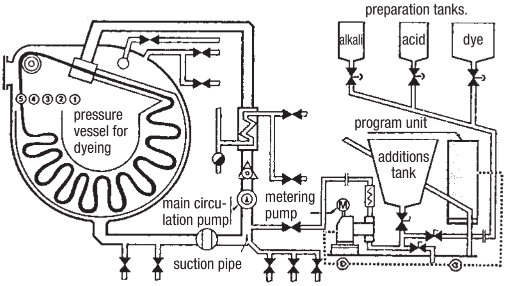


Fig. 2: Microprocessor-controlled machine for the dyeing of cellulosic/synthetic blends by the exhaust process involving movement of fabric.

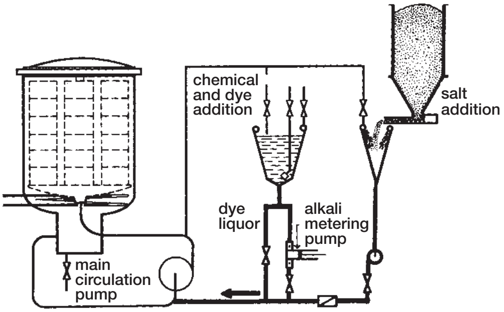


Fig. 3: Metering system for chemicals, dyes and electrolytes in package dyeing with stationary material and movement of liquor by the exhaust process.

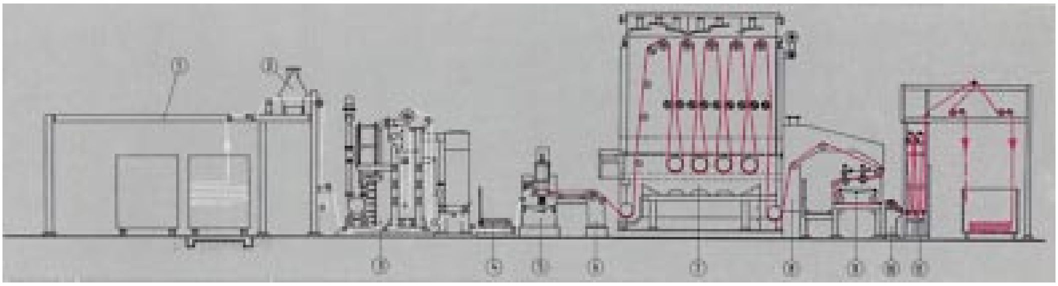


Fig. 1: Design of a typical carpet-dyeing plant for the direct application of dyes (source: Küsters).
1 = fabric infeed; 2 = presteamer; 3 = jet bulker; 4 = working platform; 5 = fluid dyer; 6 = draw rollers; 7 = loop steamer; 8 = steam hood; 9 = vacuum extraction washer; 10 = draw rollers; 11 = plaiter with fabric accumulator.

when placed side by side, should exhibit no perceptible difference in depth or tone. To achieve level dyeings, a distinction is made between two dyeing techniques (Fig. 4):

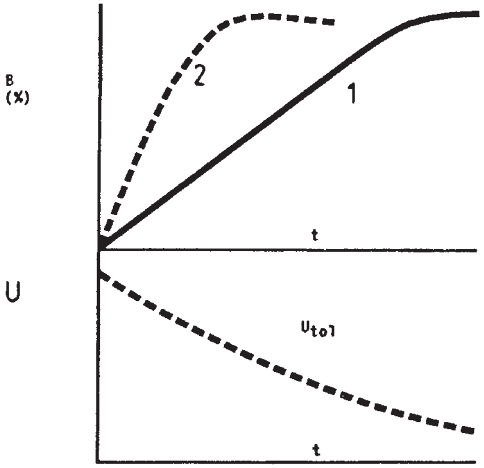


Fig. 4: A comparison of dyeing according to the principle of controlled sorption (1) and the migration principle (2) in exhaust dyeing.
B = bath exhaustion; U = degree of unlevelness; U_{tol} *= acceptable unlevelness (tolerance limit); t = time.*

1. The migration process: in this process unlevelness occurs during the short heating-up phase which is subsequently evened out (levelled) during the course of the long migration and fixation phase at the boil.
2. The controlled exhaustion process: in this case the dye is allowed to exhaust uniformly on to the fibre during a long heating-up phase. After this, a short fixation phase at, or above, the boil is given to complete the dyeing process.

$$t = \frac{100}{C \cdot E}$$

E = relative bath exhaustion/contact, in order to stay below the unlevelness tolerance limit U_{tol};
C = number of contacts per unit time, e.g.:

$$C = \frac{\text{liquor circulation (l/min)}}{\text{liquor content (l)}} \text{ for package dyeing machines}$$

$$C = \frac{\text{liquor circulation}}{\text{liquor content}} + \frac{\text{fabric speed (m/min)}}{\text{fabric length (m)}}$$

for jet dyeing machines.

The danger of the migration process lies in the fact that not all dyes level out at the boil. The rate of dyeing is dependent on the diffusion properties and, above all therefore, on the size of the dye molecule. Dyes with large molecules have a relatively low rate of exhaustion because their mobility in the liquor and, especially in the fibre, is limited. Besides the size of the dye molecule, interactions between the fibre and the dye also influence the rate of dyeing. The so-called “critical rate of dyeing” describes the heating-up curve which is just still capable of giving level dyeings. After the dye has penetrated the fibre from the liquor, it is bound to sites capable of bonding within the fibre. As a result, a typical ratio between the quantity of dye in the fibre and in the liquor is established on completion of dyeing (bath exhaustion or degree of exhaustion). This dyeing equilibrium is dynamic, i.e. dyes which have already become bound to the fibre can, depending on the class of dye, be easily detached again to a greater or lesser extent. These dye molecules are thus able to diffuse again and this occurs, in fact, from regions of high to regions of low concentration (migration). Levelling dyes with small molecules migrate well due to the low degree of bonding with the fibre through forces other than electrostatic bonds and because of their high diffusion properties which therefore compensates for the main disadvantage of these dyes, i.e. a high rate of exhaustion. Dyes with large molecules, on the other hand, exhibit a high affinity for the fibre with a low diffusion capacity and therefore have poor migration properties but, precisely because of their large molecular size, these dyes have high wet (wash) fastness properties.

Dyeing/sizing combined process → Warp sizing and dyeing.

Dyeing skeleton This involves selectively dissolving out (destroying) one fibre component of a fibre blend as an aid in the colour matching of fibre blends (e.g. in order to visually establish whether both components of a fibre blend have been dyed to the same tone and depth). For the production of dyeing skeletons, only those solvents and compounds with a hydrolizing action are suitable which have the least possible effect on the remaining fibre component and which have no influence on the shade of the remaining dyeing.

Dyeing stick (dye stick). Dyeing sticks are used for the following purposes:

I. In yarn-dyeing for suspending the hanks (hardwood dyeing sticks made from hazelnut, hickory etc., with a synthetic resin/ebonite coating as well as aluminium or toughened glass, bent into a U-shape).

II. In garment dyeing for moving/turning the goods during dyeing.

Dyeing time The dyeing time is the speed at which dyebath exhaustion is accomplished (it is temperature-dependent). Because of the need for level dyeing, the temperature of the dyebath cannot be raised at just any speed. The quantity of liquor in relation to the quantity of textile material and the rate of liquor circulation are also important. After reaching the dyeing temperature, the dyeing time is dependent on dye diffusion. The term “dyeing time” must include the entire treatment time required for the batch, i.e. the times required for the pretreatment, clearing, rinsing and aftertreatment stages in addition to the actual dyeing time. As far as the entire dyeing process is concerned, the dyeing time is further extended by the → Setting-up time.

Dyeing time controller → Passage counter.

Dyeing theory,

I. Cellulose dyeing: the relationships involved during the course of dyeing with substantive dyes are explained under → Substantivity. They may be subdivided into the following processes: a) fibre swelling in the liquor; b) (→ Adsorption) accumulation of dye at the fibre surface (salt addition); c) → Diffusion of dye molecules into the interior of the fibre.

II. Wool dyeing: the individual processes which take place in the dyeing of wool are as follows : a) adsorption of dye molecules at the fibre surface; b) diffusion of dye molecules through the fibre surface into the interior of the fibre to sites containing basic groups capable of reaction; c) formation of linkages with the colourless acid (e.g. sulphuric acid) in the interior of the fibre; d) displacement of the colourless acid ions by dye-acid ions in the fibre interior and e) the formation of salt linkages between the dye-acid ions and the basic groups of the wool protein.

III. Acetate dyeing: the uptake of dye in this case may be described as follows: the acetate fibre behaves as a solvent for disperse dyes so that, during dyeing, the dyes are adsorbed preferentially by the fibre to form a solid solution (solution mechanism).

IV. Polyester and triacetate dyeing: during the first stage of dyeing these fibres, the disperse dye accumulates at the fibre surface (adsorption) before subsequently diffusing through pores between the fibre molecules into the interior of the fibre. The rate of diffusion increases by raising the temperature (high temperature process) or through the use of carriers.

V. Polyamide dyeing: in the case of disperse dyes, the process is similar to triacetate. With acid dyes, the adsorption and fixation of dyes occurs through interactions between polar groups on the fibre and those on the dye (salt linkage mechanism). With metal-complex dyes, the salt linkage mechanism and the solution mechanism are superimposed.

VI. Acrylic dyeing: with disperse dyes a solution mechanism is involved. In the case of cationic dyes, on the other hand, a salt linkage mechanism between the polar groups of the fibre and those of the dye is mainly responsible.

There is no generally applicable theory of dyeing capable of explaining all dyeing phenomena satisfactorily. However, various models are available which provide a basis for the study of dyeing systems. Already around the middle of the 19th century, Fick had discovered that the rate of particle diffusion through a section of unit area (ds/dx) is proportional to the concentration gradient of particles measured in the direction of diffusion.

$$\frac{ds}{dt} = D\frac{dc}{dx}$$

This so-called first → Fick’s law of diffusion contains the diffusion coefficient D as a proportionality factor and characteristic system constant for the particular system involved. It represents, first of all, nothing more than a definition of the diffusion coefficient in a steady state.

$$D\frac{d^2c}{dx^2} = \frac{dc}{dt}$$

Fick’s second law of diffusion refers to non-steady state conditions, i.e. under conditions where the concentration gradient changes over time. The left-hand side of the equation corresponds to the quantity of dye which diffuses into or out of two adjoining boundary surfaces of a volume element per unit time. The right-hand side of the equation corresponds to the quantity of dye which accumulates in this volume element. Fick’s second law is therefore nothing more than a mass transfer balance. With D, a constant is obtained for a particular diffusion process.

Theories of dye kinetics are concerned with the nature of dye diffusion in solid polymers. Essentially, they are based on two important fundamentally different models for dye diffusion in fibres, namely the pore-diffusion model (Fig. 1) and the free-volume or mobile segment model (Fig. 2) (→ Diffusion mechanisms in dyeing).

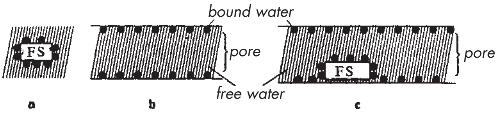


Fig. 1: Schematic representation of the change in hydration due to the attachment of dye molecules (FS) to the fibre (pores).
a) a dye molecule enveloped by hydration water in the solution; b) longitudinal section through an intercrystalline channel (pore) in the swollen fibre; c) longitudinal section through an intercrystalline channel (pore) in the swollen fibre with dye molecule attached.

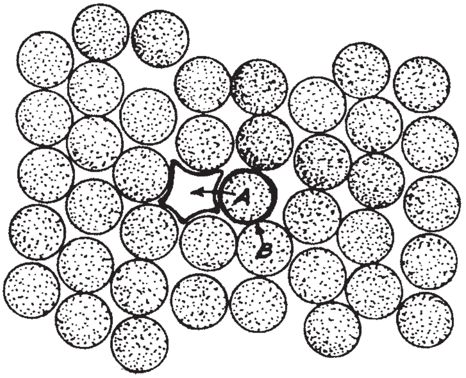


Fig. 2: Displacement of a molecule or chain segment A, the original position of which is now occupied by B, in a schematic cross-section through spherical molecules or a segment of parallel-oriented cylindrical polymer molecules.

The pore model represents the fibre as a solid structure with a network of interconnected channels or pores which are filled with the dyeing liquid, which is normally water. The dissolved dye diffuses through these pores, where it can be simultaneously adsorbed on the walls of the pores. For quantitative expressions of the rate of diffusion, the porosity P, i.e. the proportion of pores in relation to the total volume of the fibre available under the conditions of dyeing is of primary importance as well as the adsorption equilibrium. In 1966, Weisz developed a mathematical model for diffusion processes which is overlaid by an adsorption/desorption equilibrium of the dye liquor at the external and internal boundary layers of the fibre. The pore model presupposes, of course, that the pores are connected to each other as well as to the external dyebath and that their diameter is sufficiently large for the dye molecules to find room in them. Model concepts for dye uptake on cellulosic fibres are generally based on the pore model. According to this, a network of pores swollen and filled with water is present in the fibres within which dye diffusion and sorption takes place followed, if applicable, by chemical reactions as in the case of reactive dyes.

The first mechanistic hypotheses on the uptake of anionic direct dyes soon after their discovery were based on the assumption that these dyes form colloidal particles in the fibre voids. Later, these views were expressed more precisely and, on the strength of various experimental findings, it was concluded that substantivity is largely based on the fact that the dye molecules which have diffused into the fibre form aggregates in the cellulose pores. Likewise assisted by experimental findings, the mechanism of monomolecular adsorption in the pores has found support for low to medium depth dyeings at least. It is well-known that the dyeing results on cellulosic fibres are greatly influenced by the fibre's physical structure. This explains the different dyeability of various types of regenerated cellulosic fibres; in this case it is known that differences exist between the regenerated cellulosic fibres and cotton, and that the country of origin, maturity and pretreatment can influence the results of dyeing on cotton fibres.

Fig. 3: A longitudinal view of the Rosenbaum model. A bundle of chain molecules in the non-crystalline region of a fibre lies above the glass transition temperature and has a fraction of free volume. Dye molecules enter the free volume through a series of location-changing leaps.

In contrast to the pore mechanism, the free volume model describes the dyeing process as diffusion of the dye through the less ordered ("amorphous") regions of the polymer matrix (Fig. 3). The rate of diffusion is therefore determined by the mobility of the polymer chain segments. The most important support for this theory comes from the observation that the temperature dependence of the rates of dyeing for a particular type of fibre is less above a certain temperature. The resistance of the solid structure of the fibre to the penetration of dye is much lower above this temperature. This is referred to as the glass transition temperature of the fibre in question (T_G), or more precisely, the glass transition temperature under dyeing conditions or the dyeing transition point (T_D), since the classical glass transition temperature is a parameter which is measured in the dry state. Both parameters, T_G and T_D, correspond to those temperatures at which, from a microscopic perspective, the less ordered component of the polymer is converted from a glass-like state into the viscoelastic state, or, at a molecular level, at which the less ordered segments of the macromolecule move against each other, i.e., become, in effect, like "micro fluids". This model does not come from dye research but from the physical properties of the macromolecules. The glass transition temperature plays an important role here. It corresponds, at a molecular level, to the temperature at which the amorphous regions of a polymer are converted from a glass-like state to a gummy (i.e., viscoelastic) state. Above this temperature, parts of the polymer chain (thread) molecule become mobile. This segment mobility (Fig. 2) causes an uninterrupted change in the spatial arrangement of the chain molecules in these regions. "Holes" are formed above T_G and disappear again or occur at neighbouring sites of the polymer segment involved. In the viscoelastic state, therefore, the polymer structure cannot be conceived in static terms; the structure changes constantly. The possibility for the diffusion of relatively small molecules through such a

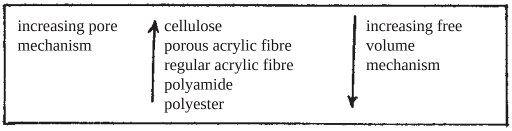


Fig. 4: Relationship of the pore mechanism and free volume mechanism for dye diffusion in different substrates (source: Zollinger).

structure is a problem of probability (or expressed in physical terms, it is a question of entropy) as to whether "holes", "channels" and adsorption sites for small molecules are formed by segment mobility.

With the majority of dyeing systems there are fluid transitions between the pore model and the free volume model (Fig. 4).

The cuticle of wool represents a hydrophobic, highly crosslinked barrier to the penetration of chemicals. During the dyeing process, the dye diffuses from the liquor to the fibre surface (Fig. 5) where it is then adsorbed. After this, the dye must diffuse from the surface of the fibre into the fibre interior. This last-mentioned step is the slowest and determines the rate of dyeing. Under normal circumstances, this penetration only takes place at temperatures above approx. 70°C. This is associated, on the one hand, with the degree of dispersion of the dye since only individual dye molecules can normally diffuse into the fibre. Dye aggregation decreases with increasing temperature. On the other hand, the wool only appears to be accessible to the dye at high temperatures.

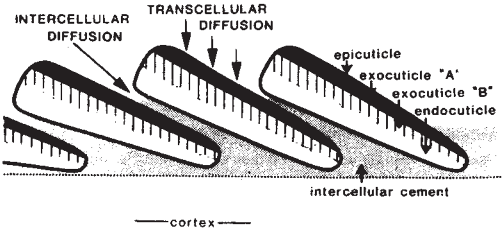


Fig. 5: Schematic representation of the cuticle cells with intercellular cement (source: Leeder).

At the start of dyeing, the dye migrates preferentially through the intercellular cement, i.e. it penetrates into the putty-like substance between the cuticle cells. From there, it enters the other non-keratin regions of the fibre. After this, the dye migrates through the endocuticle (low sulphur content) into the sulphur-rich exocuticle. The dye enters the matrix at the end of the dyeing time. The route, therefore, passes through the "soft", highly swollen regions into the less polar regions which have a high affinity for the dye (source: Zollinger).

Dyeing tube changing device, for the stripping of stiff package tubes and the introduction of dyeing tubes which are usually flexible.

Dyeing tube paper, filter paper for use in dyeing crosswound packages. Used to filter impurities from contact with the goods and prevents yellowing when drying bleached packages in the rapid drier. Crocking fastness is improved when dyeing darker shades (specifically vat dyestuffs).

Dyeing tubes for yarn dyeing Substantial changes have taken place in the field of yarn dyeing. To summarize, the following developments can be stated:

- Winding technology: introduction of progressive precision winding, which is especially suited to compression systems.
- Tube systems: polypropylene tubes with secure thread reserve. The dyeing packages can be transferred on for use in weaving without the need for rewinding.
- Stacking systems: stable, leakproof dyeing columns with special seals to prevent leakage by "sagging" of the columns of packages.
- Instrumentation: comprehensive automation of all functions including metering systems. Installation of frequency controlled motors for optimum adjustment of the flow rate at each stage of the process. Turbulence-free flow at low speeds with minimal loss of pressure in the pipework.
- Drying systems: high-frequency drying.
- Laboratory engineering: dyeing of "mini-packages" in realistic liquor ratios with fully automatic control of all procedures.

The most important ways of assembling dry packages are:

- Self-supporting systems: usually conical dyeing tubes of V4A steel or polypropylene (4° 20' taper) with spacers.
- Stack system: rigid cylindrical reusable polypropylene dyeing tubes which are stacked together without spacers.
- Compression system: cylindrical, axially flexible disposable polypropylene dyeing tubes, which are pushed together to form a column.

In practice, 54 mm cylindrical compression tubes have proved best for the dyeing of yarns. To achieve optimum liquor flow in a package the ratio spindle diameter : outer package diameter should not exceed 1 : 3.5–4. Modern automatic winders can easily produce dyeing packages of 300 mm diameter and 8-inch traverse. This enables weights of over 3 kg per package to be achieved on compression tubes with a 69 mm diameter. This is not however done in practice, not only because of the limitations of process technology, but also because of the problems associated with the unwinding qualities of such packages or potential difficulties encountered in circulatory flow drying (but not with HF drying). When compressing the columns of dye packages the stroke should be such that the column is compressed evenly from edge to edge. The usual compression, depending on tube length, is 13–30%, with a package density before compression of 330–380 g/dm^3, depending on yarn quality and winding system. In order to ensure even compression throughout the column the number of packages per column is limited according to the stacking system. For this reason, double spindles are often used. Package density and degree of compression must be set precisely for each yarn quality. In the case of liquor flow from outside inwards, the columns sometimes tend to sag, which can give rise to leakages at the package interfaces. In order to prevent this, they are connected either by sprung snap-fasteners or auto-locking slide fasteners. The latter do have the disadvantage that the package column may become locked, and when dyeing with outward-flow the mass of yarn material is made more dense.

Axially flexible, cylindrical plastics tubes are manufactured by injection moulding. The principle functions of an injection moulding machine are shown in Fig. 1. The rotation of the feed screw delivers the granules of plastic to the cylinder where they are plasticized. The feed screw then sprays the moulding material into the mould cavity with the two halves of the tool together. After hardening the two halves are separated and the piece is removed from the mould. The pressures generated during the filling of the mould are so great that forces of several hundred tonnes are needed to keep the two halves together, dependent on the diameter of the tube and the number of cavities operated in parallel in the machine.

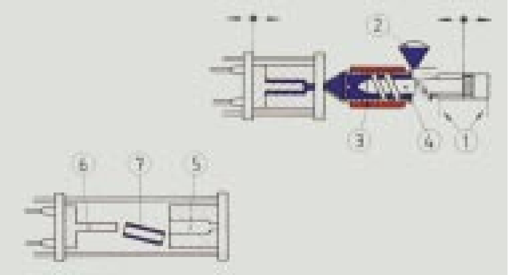


Fig. 1: Injection moulding machine.
1 = connections to hydraulic system; 2 = feed funnel;
3 = cylinder heating; 4 = feed screw; 5 = die; 6 = mandrel;
7 = plastics tube.

The desired qualities of the injection-moulded articles, such as the avoidance of burrs, the extrusion quality and the colour consistency are ensured throughout the production cycle by optimum machine adjustment and its reproducibility. These requirements are fulfilled by computer-controlled injection moulding machines, which, subject to certain tolerance limits, are capable of adjusting the machine to deal with differences in operating conditions, such as stock feed variations, ambient temperature and humidity. The use of state-of-the-art technology for the development, design and production of plastic package tubes contributes to the level of quality assurance available to the end user in the textile trades.

Fig. 2: Flexible disposable dyeing tubes for compression systems (for key to numbers see Table).

For package dyeing there are various types; cylindrical or conical tubes form corresponding package builds. Sun-spools or Barber-Coleman packages are a special type of cylindrical package where the traverse is less than the diameter. Another type is the rocket (bottle) package, where the diameter does not increase as yarn is added, but the winding increases in height. Packages are often supplied for dyeing with cardboard tubes, which then have to be rewound onto stainless steel or plastics tubes. Automatic tube changing machines are available for this purpose. Rigid or flexible tubes are used dependent on yarn type (see Table):

1. Rigid tubes: the tendency here is to use → Disposable dyeing tubes of polypropylene. In this case there is no need for rewinding back on to cardboard tubes. Polypropylene tubes may also be re-used, but are usually crushed after use and recycled in granular form for the manufacture of tubes or other articles. Triangular or rhombic shapes are sometimes used instead of round holes. This is an attempt to prevent the yarn from being forced into the perforations at high flow rates.
2. Flexible centres (dye-springs, Fig. 2): these can be compressed axially and are thus suited to shrinkable yarns arranged radially. A knitted sleeve separates tube and yarn packages, not only for the purpose of filtering out impurities, but also to spread the pressure distribution evenly. The yarn must be wound under constant pressure, and the wound package

No.	Manufacturer	Type	Additional radial shrinkage acceptance	Yarn reserve	Remarks
1	*Engel*	Multiflex	approx. 12% by 130° C	yes	uncompressed
1a	*Engel*	Multiflex	approx. 12% by 130° C	yes	compressed
1b	*Engel*	Multiflex			examples from colour range
1c	*Geidner*	Article number 40 600			spacer for Engel system
3	*Zimmermann*	AC II	no	yes	non-rotating version with spacer, uncompressed
3a	*Zimmermann*	AC II	no	yes	as above, compressed
3b	*Zimmermann*				range of colours
4	*Zimmermann*	Combiflex	up to approx. 15%	yes	polygonal surface
6	*Zimmermann*	AC I	no	yes	version with spacer uncompressed
6a	*Zimmermann*	AC I	no	yes	as above, compressed
2	*Zapf*	ZET Flex	no	yes	uncompressed
5	*Crellin*	Dye Spring	no	no	uncompressed
7	*Karo*	Compression tube	no	yes	new, not illustrated

Tab.: Flexible disposable dyeing tubes for compression systems.

should not be too hard. The evenness of the dyeing depends on the evenness of the winding. All packages in a batch must be equally dense.

A disadvantage of conical packages lies in the differences in pressure distribution within a package and the package column during dyeing. With cylindrical tubes, random wind is distinct from precision wind. Random wind is carried out on a helically grooved drum consisting of winding element and yarn guide element, in such a way that the traverse tapers from the small to the large diameter while the angle of winding remains constant (e.g. 30°), e.g. the Autoconer by Schlafhorst. Precision wind is carried out initially at 45°, subsequently changing to 18°. Yarn guide and drive are separate functions, thus generating by mechanical means pattern-free winding (e.g. by Schärer). An ideal system somewhere between random and precision wind is provided by the Digicon winder (Schweiter). Digicon packages are random wound via variable speed gears; they have straight end surfaces and are pattern-free; they do not tend to swell as is the case with precision wind. Practical dyeing results will show whether the precision-wound package with its wind angle narrowing as the diameter increases will ensure better liquor distribution at the edges of the package during the dyeing process, due to the liquor flow from inside outwards. The tighter structure towards the top of the package could create a form of backward pressure in the liquor, which would provide a more effective penetration of the package. This would make it possible to make the package more dense than is possible in the case of random wind. It has been shown that a precision-wound package can be fully penetrated by the dye at a density of 0.43 g/cm^3; random-wound packages also allow densities of up to 0.45 g/cm^3.

Dyeing tube stripping machine, used in wound package dyeing for stripping the cardboard tubes before dyeing or the steel tubes after dyeing.

Dyeing vat (beck, tub), four-sided vessels for dyeing, bleaching etc. made of wood, metal, earthenware, tiled or similar for hank yarn and loose stock; may be fitted with two squeeze rollers or with winch for piece dyeing. Heated by means of open (and/) or closed steam pipe.

Dye ions Dye ions, which represent by far the greatest proportion of the dye molecule, and which are responsible for the dyeing properties at the same time, dissociate in aqueous solution. The resultant dissociated ions of the considerably smaller fraction of the molecule, which have opposite charges, are referred to as counter ions. All dyes which form dye salts or dye acids contain both types of ion together. The respective charge of the dye ions allows the following distinctions to be made:

I. Dye anions, which are formed from anionic dyes, include acid, most direct dyes, wool/cotton union, vat, sulphur, naphthol and vat leuco ester dyes. The acidic auxochrome groups (→ Dye acids), which are built into the dye molecule to confer solubility in water, are responsible for its anionic character and that part of the dye molecule containing these groups dissociates as the so-called dye acid residue.

II. Dye cations are formed from basic (cationic) dyes which contain cationic nitrogen groups (→ Colour bases) as auxochromes. Their properties are the opposite of I above.

III. Dye anions and dye cations are contained in zwitterionic dyes. These include, e.g. direct dyes which, besides anionic acid groups, also contain cationic basic amino groups (NH_2), which may also be capable of dissociation depending on their position in the dye molecule. Such dyes are representative of the diazo dyes. Depending on the proportion of acid or basic groups capable of becoming charged which predominate in the system, more or less anionic or cationic zwitterions are formed or, when the charges are equal, isoelectric zwitterions.

Dye jigger → Jigger.

Dye kitchen → Colour kitchen.

Dye liquor, also called dyebath. The dye liquor consists of liquid medium (usually soft water), the dye and the additives necessary for the dyeing process in question such as levelling agents, retarding agents, padding auxiliaries and dispersants etc. Concentrated liquor is used for padding textile fabrics. Dilute liquor is used for exhaust dyeing.

Dye-liquor colorimetry Ongoing analytical monitoring of a dye liquor in a continuous process is important both from an economic and ecological point of view. The dyeing process can be monitored and optimised by checking the individual agents in a sample extracted from the bath. Individual components which become prematurely exhausted can be objectively replenished. This minimises both chemicals consumption and the associated chemical loading in the effluent. One measurement technique uses a form of absorption spectroscopy. An aliquot of the liquor flows continuously through a measurement cell. However, the volume of liquid flowing through the cell is so small in comparison to the total cell volume that the system can almost be regarded as closed. The cell stands in the light path of a broad-band light source and a monochromator which scans the entire spectrum. The individual substances absorb light at characteristic wavelengths and the energy absorbed by the solution causes the temperature to rise. This increase in temperature, which is recorded using sensitive sensors with a rapid response time, is proportional to the concentration of the substances in the solution (source: Schollmeyer).

Dye liquor volume calculation → Liquor calculation.

Dye loading of fibres The supply of dye to the fibre is an "active" step in the dyeing process whereby the dye is transported to the surface of the randomly oriented mass of the textile material and is held in the interstices of the fibre mass (e.g. as in dyeing on the padder or jigger), or the dye is transported to the surface of the fibre mass from the continuously circulating dye liquor throughout the entire time of dyeing (e.g. as in the beam dyeing of piece goods and hank dyeing). During this process, water is indispensable as a solvent and transport medium for the dye. As shown in the Fig., where the weights of dye in the ratio G_{PT}/G_P [kg of dye on the textile material/(kg of dye in the textile material and in the liquor)] are applied in accordance with the liquor ratio $e_F = G_F/G_T$ [kg of liquor/kg of textile material], the weight of dye actually used to dye the fibre is dependent on the distribution coefficient K [–] of the dye and the liquor ratio e_F [–] of the dyeing machine. Experience has shown that practically no savings in water are to be achieved for the supply of dye to textile fabrics if part batches, reliability of dyeing and uniformity of handle are taken into account. An interesting alternative in this regard, which offers the possibility to work with shorter liquor ratios, e.g. where $e_F = 2–4$, is provided by the Then-Airflow machine in which the fabric rope is transported by a stream of gas instead of the dye liquor.

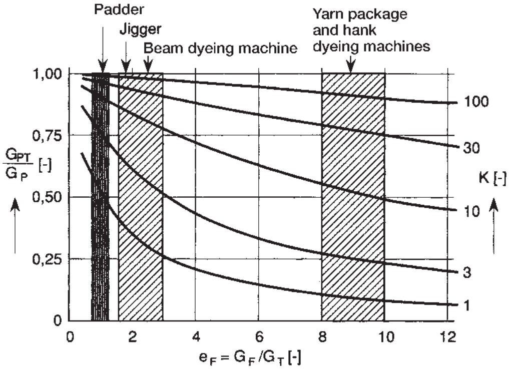


Fig.: Dye loading of different types of textile materials in various dyeing machines dependent on the liquor ratio e_F and the distribution coefficient K (source: Kretschmer).

The loading of a textile material with dye is also an "active" step in the dyeing process, in which more dye than that actually used to dye the fibre is continually being supplied to the material during dyeing. The resultant loss of dye makes the costs of dyeing more expensive and increases the pollutant load of the effluent and its cost of treatment. The ratio of the weights of dye G_{PT}/G_P is characteristic for the loss of dye resp. the pollutant load of the effluent, i.e. the higher the ratio G_{PT}/G_P, the lower the loss of dye or the pollutant load of the effluent. According to the Fig., the highest G_{PT}/G_P value is achieved with the short liquor ratio dye loading on the padder whilst the G_{PT}/G_P value obtained with the long liquor ratio of the hank dyeing machine is appreciably lower. From this it follows that, in principle, a realistic reduction in the quantity of water or effluent cannot be achieved in the "active" step of loading a textile material with dye. It also follows that the losses of dye, which increase the pollutant load of the effluent as well, are determined exclusively by the type of machine used to load the textile material with dye and the distribution coefficient of the dye itself since the coloristic and article-dependent requirements of the customer limit or reduce the choice of suitable dyes and consequently the pollutant load of the effluent (source: Kretschmer).

Dye : metal ratio, the ratio of dye molecules: met-

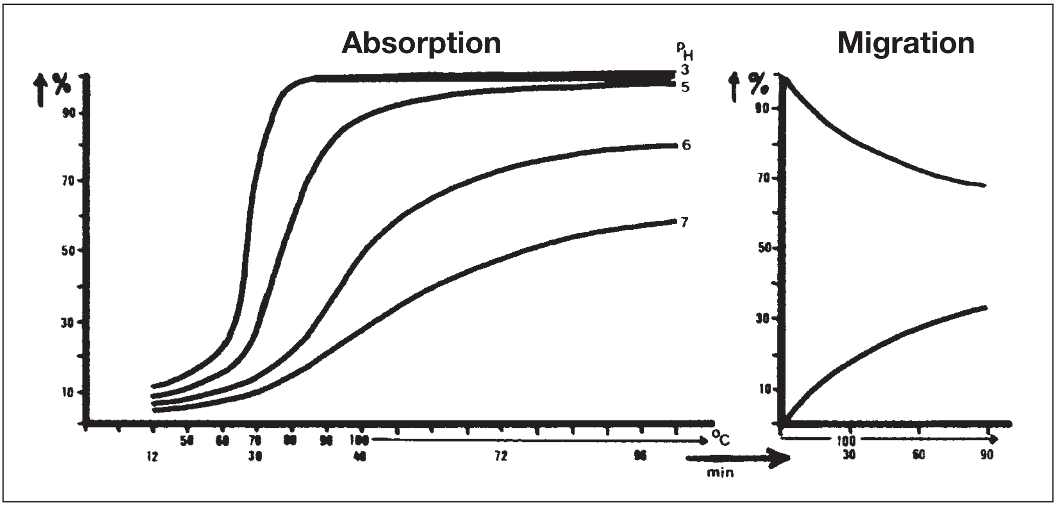


Fig.: Migration test of a wool cloth (right) which has been dyed at pH 3 with 2% Supramin Yellow RN (Bayer).

al atoms in metal complex dyestuffs. Opposite notation principle to that shown in → Complex formation.

Dye migration,

I. Reduction of depth of colour in wool dyeings. Dyestuff migrates across to adjacent undyed wools. Migration test: test for migration propensity of a dye (see Fig.).

II. In union dyeing, the migration of individual dyes to specific fibres, e.g. acrylic/wool mixes: cationic dyestuffs to acrylic, anionic dyestuffs to wool.

Dye migration in drying This undesirable phenomenon causes previously level dyeing to become uneven due to incorrect drying. This migration phenomenon (→ Migration during intermediate drying) mainly arises when dyeing with dyestuffs with low or no fibre affinity (but also in the case of proofing, synthetic resin finishes or similar). Typical dyeing processes include in particular undeveloped pigment padding and leuco vat ester dyeings, non-coupled naphthols, and also disperse and similar direct dyeings. The dyestuffs (dyestuff pigments) affected are always those which are intercalated to a greater or lesser extent mechanically; since they do not display fibre affinity, they have a tendency to migrate as the water evaporates. Thus the dye is concentrated around the hotter sites in the fabric, producing an uneven, cloudy final colour. There is a critical water content level, above which migration may occur. This is 36% for wool, 40% for viscose, 21% for cotton, and approx. 10% for polyamide 6.6. Dye distribution also causes migration. For this reason when dyeing using the pigment padding process, a padding additive such as sodium alginate or a specific textile auxiliary is recommended. When cylinder drying, where the contact principle leads to a tendency towards temporarily intensive surface drying, especially at the start, a compensatory effect can be achieved by constantly alternating the upper face of the fabric from cylinder to cylinder. In the case of the air-drying process a medium air speed is recommended. The drying temperature also has a significant effect on dye migration. Preliminary drying at a relatively low temperature can limit dye migration at higher temperatures. Dye migration (areas of lighter colour) may also be observed if stain removal is incorrectly performed, with the steam gun placed directly on the surface of the fabric (temporary predominance of internal drying).

Dye mist, a dye liquor which has been atomised by passing it through fine jets.

Dye mixtures, dyestuff formulations preconstituted by the dyestuff manufacturer for various fibre blends e.g. for

I. Wool/cellulose: mixtures of acid dyes and direct dyes with neutral or weakly acid affinity.

II. Wool/polyester: mixtures of acid dyes and/or 1 : 2 metal-complex dyestuffs and/or reactive and disperse dyes.

III. Cellulose/polyester: mixtures of vat and/or leuco vat ester dyes and/or reactive and/or sulphur dyes and disperse dyes.

Use: mainly to achieve solid-shade dyeing on fibre blends. As the dyes are adjusted to certain types of fibres in a specific mixture and liquor ratio, in some cases it is necessary to tint one fibre or another. Dye mixtures are used to dye yarn and pieces, including reclaimed fibres and rags or in garment dyeing where necessary.

Guidelines for solid-shade dyeing:

I. Half-wool (wool/cotton, wool/viscose): a) neutral dyeing method b) weakly acid dyeing method. At boiling point, a deeper dyeing of the wool generally occurs, when the dyeing temperature is falling (bath exhaustion) and if salt is added, a deeper dyeing of the cotton or viscose is achieved.

II. Wool/polyester blends: dye mixtures of selected polyester disperse dyes, which stain the wool component as little as possible, with wool dyes with weakly acid to neutral affinity: a) dyeing at the boil and addition of carrier; b) dyeing at approx. 105°C with added carrier.

III. Cellulose/polyester blends: dye mixtures are principally used a) in high temperature exhaust dyeing (120–130°C); b) in thermosol dyeing (continuous method).

IV. Polyamide/wool blends: use of wool dyes which dye both fibres equally deeply as far as possible. For light and medium depths of shade polyamide is generally coloured more deeply. By choosing suitable dyes and blocking agents, it is possible to achieve solid-shade dyeings.

V. Acrylic/wool and/or acrylic/polyamide: ready-made dye mixtures are not available for these fibre blends. Dyeing is generally carried out as a one-bath process using cationic and wool dyes (reactive, 1:1 metal complex and acid dyes) in association with appropriate dyeing auxiliaries.

Dye mixtures, fastness properties The dye mixtures available provide dyes with good to very good fastness. A dyeing after-treatment is generally necessary when dye mixtures are used for wool/cellulose fibres with higher fastness requirements.

Dye mordants → Mordanting.

Dye package, shrink, cross-wound bobbins with flexible → Dye tube which permit shrinkage of the yarn by radial elasticity.

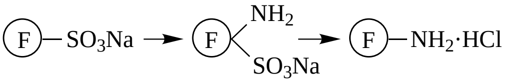
Dye pasting and dissolving agents → Dye dissolving and dispersing agents.

Dye preparation, a dyestuff within a combination of substances designed to facilitate application or subsequent use. → Yarn preparations.

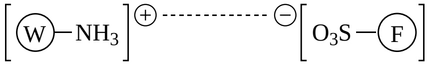
Dye recipe formulation Before dyeing, the most cost-effective recipe must be established, i.e. with the fewest possible or least expensive dyes and the shortest possible dyeing time. Thus, a dyeing process must be found which minimises the recipe costs (dyes and auxiliaries) and the dyeing time for the particular dyeing machines available. The selected dye recipe must also be capable of achieving the desired requirements profile in terms of colour match and fastness properties against the approved sample. A record is kept of the established recipes for each article number and the quantities are "scaled up" appropriately for a specific order.

Dye resisting agent → Retarding agent.

Dye salts, salts of → Dye acids or → Colour bases.



Examples of this type include, e.g. some commercial dyestuffs (substantive dyes, vat leuco ester dyes, etc.) or they may be formed temporarily during dyeing, as in the case of vat and sulphur dyes, which are present in the alkaline dyebath as the sodium salts of the corresponding leuco compound (vat acid). Dyeings produced on wool with acid dyes, in particular, are also representative of typical dye salts.



Dye-selection criteria, the criteria for selecting, for example, the dyestuff group or the dyeing process etc. to obtain a certain → Requirement profile. When dyeing using disperse dyestuffs, for example, the dye-selection criteria determine whether preference is given to azo or anthraquinone dyes. For example:

1. Azo dye applications:
   - where high wet-fastness is a requirement
   - cellulose resists
   - in rapid dyeing
   - in yarn dyeing
   - in the thermosol process
   - under difficult dyeing machine conditions such as HT beam or high-density packages
   - for acetate, triacetate/polyester mixtures and acetate/ polyamide mixtures
   - for economy dyeing.

The azo dyestuffs are more economic and satisfy the technical application requirements and specified fastness requirements in the dyeing of outer wear. Plus factors: wet-fastness properties, level dyeing characteristics and fastness to sublimation.

2. Anthraquinone dye applications:
   - where high light-fastness is required
   - for polyester/wool mixtures
   - where there is a risk of cloth streakiness
   - for neutral to weakly alkaline dyeing conditions
   - where there are reduction problems.

Anthraquinone dyes are used in large quantities in polyester dyeing. They will also be in demand in the future for certain fibres, fastness requirements and applications. Their strengths are light fastness, level dyeing and reproducibility and they can be used at boiling point or high temperatures.

Dyes of vegetable origin, the (historically) most significant → Natural dyes of vegetable origin are →: Indigo, Madder, Woad and Logwood.

Dye sensitivity to metals, property of numerous dyestuffs during the dyeing or printing process or on completion of dyeing or printing to produce dull or different coloured tints in the presence of metal ions or on contact with metal surfaces. The following are particularly dangerous: copper, nickel, manganese, iron, chromium. Remedy: addition of ammonium rhodanide, polyphosphates, EDTA.

Dyes for summer or winter clothing → Infra-red reflecting dyeings.

Dyes of animal origin → Cochineal, Kermes, Purple.

Dye solubility in water is determined by the presence of solubilizing groups in the dyestuff molecule. These are usually sulpho groups, carboxyl groups and hydroxyl groups. In the case of the last named the result may often be dyestuffs of only extremely low solubility, depending on the constitution of the dyestuff.

Dye solubilizing and dispersing agents are used in dyeing and printing for paste preparation, dissolving and dispersing of the dye, thus satisfying the prerequisites for a perfect dyeing or printing operation (yield, penetration, evenness). These are surface-active organic products (→ Solvents for dyeing and printing), such as fatty acid esters and fatty acid amides, fatty acid condensates, alkylaryl sulphonates, hydroxyalklylation products and derivatives of aliphatic amines.

Dyes on textiles, quantitative determination of,

I. Extraction method: the dye is detached from the fibre by extraction with a suitable solvent or an azeotropic mixture. The concentration is determined through photometric evaluation of the extract by comparison with known extinction coefficients. With this method there is a risk of the dye undergoing irreversible change due to the long extraction time at high temperatures. Furthermore, only a limited number of suitable solvents and azeotropic mixtures are available. For small samples of material this method is less efficient.

II. Solution method: by dissolving the fibre and dye in an appropriate solvent (e.g. polyamide in 85% formic acid and in m-cresol or cellulose in 80% sulphuric acid). This method is quick to carry out but does not have universal application. There is a risk of clouding due to the delustrant, discoloration of the dye due to substrate decomposition and poor substrate solubility after cooling down.

III. Residual dyebath method: this method is based on determining the non-exhausted dye. The method is somewhat involved since dye, which is still removed in subsequent washing, off must also be taken into account.

IV. Repeated boiling in solvents or solvent mixtures. The fibre material is heated repeatedly with fresh solvent. This procedure is very versatile, and protects the dye. There is also a greater choice of solvents capable of swelling the fibre or even causing it to lose its form.

V. Specific methods of detection for a few characteristic elements, e.g. the colorimetric determination of copper, nickel, iron, cobalt, etc.

VI. → X-ray fluorescence.

Dye springs, dye centres which intermesh elastically and can be compressed slightly. Often used in the place of perforated tubes for dye packages in order to achieve better dye penetration.

Dye stability to diazotize, the behaviour of dyes on the fibre in the presence of nitric acid in aqueous liquors.

Dye structure and formation The specific properties of a dye, such as its colour and dyeing properties, are given by its molecular structure or chemical structural formula. The elements which participate in dye structure are mainly those derived from coal and tar starting products such as carbon, hydrogen, oxygen, nitrogen, sulphur (hence the now obsolete term “coal tar dyes” from the early days of the synthetic dyestuffs industry) and to a lesser degree, also chlorine, sodium and bromine, etc. Since only relatively few elements are contained in the great majority of different dyes, their ability to form bonds with chemical groups, complexes, molecular chains and nuclei plays a very important rôle. → Coloured compounds.

Dyestuff (dye). Of several tens of thousands of chemically different dyestuffs known, approximately 3000 are used industrially and a few hundred of these in large quantities. The remaining multitude has arisen as a result of the need to dye the various fibres in the greatest possible number of different shades as well as to dye them with the desired fastness properties in each case.

Classification: dyestuffs may be classified according to the fibres on which they are used (see Fig. 1).

1. For cotton, viscose, modal fibres and linen:
   - Direct (substantive) dyes: anionic dyes which exhaust directly on to the fibre, i.e. without premordanting. They have only moderate wash fastness and some have very high light fastness.
   - Reactive dyes: anionic dyes which exhaust directly and react chemically with the fibre. Consequently, they are very fast to washing and offer a brilliant range of shades.
   - Vat dyes: These are water-insoluble pigments which are dissolved (vatted) by reduction and dye the fibre in the reduced form. After subsequent oxidation, the original pigment is restored on the fibre. Vat dyes are very fast to washing and light (Indanthren) but there are no brilliant shades.
   - Sulphur dyes: some sulphur dyes are available as unmodified pigments which are dissolved by reduction during dyeing, others are available in a pre-reduced form. Subsequent oxidation restores the original pigment on the fibre (analogous to

Dyestuff

	CO	WO	PES	PA	PAC	CA	leather	paper
azo dyes								
water soluble	●	●	–	●	●	–	●	●
water insoluble	●	–	●	◗	◗	●	–	–
with reactive group	●	◗	–	–	–	–	–	–
metal-complex dyes	◗	●	–	●	–	–	●	–
anthraquinone dyes								
water soluble	–	●	–	●	●	–	–	–
water insoluble	–	–	●	–	–	●	–	–
vat dyes	●	–	–	–	–	–	–	–
with reactive group	●	◗	–	–	–	–	–	–
indigoid dyes	●	◗	–	–	–	–	–	–
sulphur dyes	●	–	–	–	–	–	–	–
triphenylmethane dyes	–	–	–	–	●	–	–	●

● = very important application, ◗ = of less important use, – = not used

Fig. 1: Main fields of application for dyestuffs.
CO = cotton; WO = wool; PES = polyester; PA = polyamide; PAC = acrylic; CA = acetate.

1. cellulosic fibres		
reactive dyes	**no** extraction with DMF, DMF/H_2O (1:1) or pyridine/H_2O (1:1)	acid or alkaline decomposition on boiling chromatography
vat dyes	bleeds heavily with DMF	redox reaction with an alkaline/acidic vat
naphthol AS dyes	bleeds heavily with DMF	reductive decomposition chromatography
direct dyes	bleeds heavily with DMF/H_2O (1:1) or pyridine/H_2O (1:1)	re-dye on to cotton chromatography
sulphur dyes	virtually no bleeding with DMF	change of colour on reduction test for sulphur
2. synthetic fibres/wool		
disperse dyes	the dye is stripped with pyridine or glacial acetic acid	re-dye on to acetate fibre chromatography
cationic dyes	more easily extracted with glacial acetic acid than with pyridine	re-dye on to PAN chromatography
acid dyes	bleeds heavily with pyridine/H_2O (1:1) or ammonia/H_2O (1:1)	re-dye on to wool test for metals chromatography
metal-complex dyes	slight to heavy bleeding with pyridine/H_2O (1:1)	test for metals chromatography
afterchrome dyes	slight to heavy bleeding with pyridine/H_2O (1:1)	test for metals chromatography
reactive dyes	no bleeding	strip with alkali chromatography

Tab. 1: Application-related analysis of textile dyestuffs: extraction of dyestuffs from the fibre.

  vat dyes). Economical, but the shade gamut is restricted to browns, olives, dark blues and blacks.
  - Azoic colorants: the dye is formed on the fibre in two stages, i.e. by pretreatment with a naphthol followed by a second treatment with a diazonium salt. High fastness properties.
  - Pigments: these are deposited on the fibre and fixed mechanically with binders. They have low rub fastness but are very fast to light. They are used for dyeing pale shades and for printing all depths of shades
2. For wool, silk and polyamide fibres:
   - Acid dyes: anionic dyes. These include acid levelling dyes with moderate wash but high light fastness and milling dyes with high wash fastness.
   - Chrome dyes: anionic dyes which are bound to the fibre in the form of chromium complexes by means of an aftertreatment with chromium salts. Very high wash fastness.
   - Metal-complex dyes: anionic 1 : 1 or 1 : 2 metal-dye complexes. They are characterized by high wash fastness and very high light fastness but include no brilliant shades.
   - Reactive dyes: see 1, used especially for machine-washable wool.
3. Dyes for acetate, triacetate and polyester fibres:
   - Disperse dyes: these are non-ionic dyes which are only sparingly soluble in water and are therefore applied as dispersions.
4. For acrylic fibres:
   - Cationic dyes: these are characterized by high wash and light fastness.

Another classification system for dyestuffs is based on their chemical structure.

Among the chemical test methods for dyestuffs, the extraction of dyes from the fibre occupies a very important position (see Tab. 1). For tests on dyed textiles, extraction is a preliminary requirement for subsequent dye analysis. The behaviour of a dye bound to a textile substrate in different solvents permits a rapid but nevertheless reliable determination of the dye class. Since the trend in analysis is towards short tests and rapid methods of detection, a scheme is presented here with the aid of which conclusions concerning the presence of certain important dye classes, depending on the type of fibre, can be drawn. The important dye classes and their ease of extraction in different solvents as well as any further necessary analytical steps are given separately for the different groups of fibres. However, this scheme represents a very idealized form of analysis. In reality, each dye class contains examples, the behaviour of which may deviate to a greater or lesser extent from the scheme. In order to be able to recognize such dyes with confidence, considerable experience in the behaviour of dye classes is necessary.

Since a dyestuff was first characterized by a few properties and its colour fastness (50 years ago, for example, by its fastness to water and washing and today by its resistance to "chlorinated city water", its dispersion stability or its hygienically problem-free handling), the catalogue of requirements has changed and continued to grow in size (Tab. 2). New properties such as these, play a far more important role in modern finishing technology than those few characteristics which confronted the finisher at that time. The finished material has become more expensive and, with the high degree of rationalization in dyehouses and printing establishments, sources of potential problems can no longer be afforded. The quality and quality assurance of dyestuffs are now indispensable requirements and are indeed demanded by the purchaser; the consequences of product shortcomings have now become more far-reaching, more expensive and more irksome during the production process than hitherto.

Commercial forms: dyestuffs have a diverse requirements profile. The commercial form of the various dyes classes has long been recognized as one of the

property	effect on
solubility/ solution stability	liquor preparation, depth of shade, colour yield, appearance of the goods
dispersion stability	state of the liquor and appearance of the goods, depth of shade, soiling of machinery
commercial form	transport, shelf-life, handling
metal content/ type of metal-complex bonding	effluent
colour yield	value for money, competitiveness
degree of purity	shade, solubility, dischargeability, colour fastness
gelatinization	handling, colour yield
washing off properties	colour fastness, effluent
degree of hydrolysis	shade, colour yield, colour fastness, effluent
staining of other fibres	resist or multicolour effects, processability in garment manufacture
dyeing behaviour (e.g. migration) compatibility with dispersing agents, thickeners and auxiliaries resp. finishing chemicals	Applicability in well-established processes, combinability with other dyestuffs, ecology, economy, behaviour in garment manufacture, storage life

Tab. 2: A selection of dyestuff properties and some of their (negative) consequences.

auxiliaries	chemical name
dispersing agents surfactants	ligninsulphonates, naphthalenesulphonate and formaldehyde adducts, ethylene oxide propylene oxide copolymers
salts	sodium sulphate, chloride
antidusting agents	mineral oils, paraffin oils (+additives)
defoamers	ditertiary acetyleneglycols
antifreezing agents	glycerine, glycols
thickeners	carboxymethylcellulose polyacrylates
buffer systems	phosphate, acetate

Tab. 3: Commercial forms-additives.

most important quality characteristics (Tab. 3). With disperse dyes in particular, the physical properties have a crucial influence on dyeing behaviour. Thus, for example, the behaviour of the dispersion in the dyebath, the rate of diffusion into the fibre as well as undesirable and inappropriate behaviour (such as the formation of specky dyeings) are all properties influenced by the particle size. Similar direct effects on the results of dyeing may also be encountered with vat dyes and pigments. However, for dyestuffs which participate in the dyeing process in the dissolved state, among which the reactive dyes are a typical example, the commercial form was still of secondary importance until a few years ago. The main requirement was ease of removal from the supplier's drums without excessive dusting. For as long as it remained usual practice to heat up the dye solutions by inserting a steam pipe into the dissolving vessel, solubility behaviour was determined almost exclusively by the solubility of the molecule. The only recently specified new requirements placed on the commercial form of reactive dyes are based on various developments especially with regard to their handling and application:

- automated metering systems which are intended to simplify work in colour kitchens,
- cold-water dispersibility is desired in order to make the preparation of dye liquors easier,
- the scaling up of dyeing machine capacities has placed new demands on the removal of dyes from their containers,
- occasional cases of sensitization after inhalation have led to far-reaching requirements with regard to dusting properties,
- the increasing problems of drum disposal calls for high dye concentrations and high powder density.

The profile of requirements for the commercial form of reactive dyestuffs has now become firmly established even though the priority attached to the individual properties varies to a considerable extent geographically throughout the world. Several of the individual and important requirements mentioned above could certainly be fulfilled in a liquid form but unfortunately reactive dyes are subject to serious limitations in this respect, i.e.:

- liquid formulations with good physical stability can only be produced with dyes having outstanding water solubility;
- highly reactive dyes in particular (e.g. dichloroquinoxaline, difluorochloropyrimidine, fluorotriazine or vinylsulphone) tend to hydrolyze to a greater or lesser extent in the dissolved state, which can result in a chemically limited shelf life and, on prolonged storage, to reduced colour yields and problems in washing off;
- in conventional colour kitchens, the handling of liquid forms is somewhat more complicated than is the case with commercial dyes in solid form;
- the, in most cases, relatively low-percentage formulations calls for large-volume deliveries with their associated costs and problems, including, among other things, the disposal of empty containers;
- as far as the physiological effects are concerned, it should be mentioned that sensitizations and allergic reactions can also be caused by sprays or by the formation of aerosols.

New → Formulations of textile dyestuffs have been especially geared towards easier handling by the customer. Dyestuffs should therefore be:

- clean and dust-free,
- easy to dispense, even with automated metering systems,
- easy to prepare in solution (i.e. without boiling), readily soluble and, in stock dye liquor preparations, there should be no limitations on mixing with other dye liquors.

In addition, much effort is being directed towards the achievement of more simplified manufacture and advantages in ecological aspects as well as in the transport and storage of large quantities. These objectives should be achieved without incurring any severe penalties and justify the generally somewhat higher production costs. Examples recently introduced on to the market include new liquid formulations and various granular formulations, especially for reactive and disperse dyes as well as for acid and cationic dyes. In addition to the general requirements already mentioned expected of modern formulations, still further requirements are also placed on liquid dyes:

- high stability during storage, transport and dispensing, no precipitation, no changes in particle-size distribution and crystal structure, the least possible sedimentation, no phase separation, and no chemical changes (hydrolysis in the case of reactive dyes);
- high concentration in order to keep transport costs, storage space and bath volumes low;
- constant flow properties;

- no drying out or encrustation;
- easy homogenization in the event of freezing and thawing out;
- high miscibility with water and, if possible, with other dyes;
- no promotion of corrosion;
- dyeing properties to be as close as possible to, or better than, those of the standard brands [up to same depth of shade (concentration)].

Not all of these requirements and expectations have to be fulfilled in every case. Depending on the type of dye (reactive, disperse, vat or direct dye) and the specific method of application (exhaust process, textile printing, continuous dyeing), the dye formulations contain special additives which confer optimum properties on the commercial form with regard to shelf life, handling, dyeing results, etc. Because these substances do not exhaust on to the fibre, they pass into the effluent after completion of the dyeing process. Some of the larger dye manufacturers with a few hundred dyestuffs in their product range will often produce several commercial forms of these (tailor-made for different applications). In their formulation, hundreds of different products and product qualities find application in the case of surfactants and dispersing agents alone which may be further combined with each other and with other auxiliaries.

Since there is usually a considerable amount of know-how involved in dye formulations, no dye maker is interested in disclosing his recipes. A technician working on the development of commercial forms of dyes is therefore quite happy to know just a part of the product range of his own company. The composition of commercial forms produced by other dye makers can only be determined with the aid of complicated analytical procedures, so that any knowledge gained is, of necessity, selective and only fragmentary. However, some general information on this topic can be given. As this is not possible for all classes of dyes two important ranges, i.e. disperse and reactive dyes, have been selected as examples here.

From the point of view of technical application, the quality of the finish for disperse dyes must take into account the following aspects:

- particle size distribution in the stock liquor dispersion and at the start of dyeing,
- dispersion stability under dyeing conditions,
- redispersibility resp. the redispersion of agglomerates.

Disperse dyes in the form in which they are produced by dye synthesis are usually obtained in a more or less coarse crystalline state. The coarser the dye crystals obtained in synthesis, the easier it is to separate them from the reaction solution, but the greater is the effort required to finish the dye in order to achieve a uniform fine dispersion. The main task of the finish, in the case of disperse dyestuffs, is, therefore, to break down the crystals formed during synthesis into sufficiently fine particles. This comminution is achieved by kneading or milling. Finally, a dispersant is added to the dye, the purpose of which is to ensure that the dye disperses easily and completely in water at a later stage. The maximum size of the dispersed dye particles requires that approx. 100 billion particles are formed from 1 g of the coarse crystalline dye. The size of the dispersed particles is, as a rule, not uniform. This gives rise to the following problem: any dispersion consisting of more or less sparingly soluble particles of different sizes is thermodynamically unstable, since a solution in which the smallest particles are in equilibrium is oversaturated as far as the larger particles are concerned. The result of this is that, at a sufficiently high temperature and especially during intermediate cooling, a continual growth of large particles takes place at the expense of the smaller particles. This process is often referred to as Ostwald ripening and has been frequently discussed. The system is only stable when all the particles are of the same size. From a practical dyeing standpoint therefore, a disperse dye consisting of uniform, medium-sized particles, e.g. around 0.5 mm, is regarded more favourably than a dye of identical chemical constitution, the particle size of which varies between 0.1 and 0.5 mm since, in this case, the larger particles will continue to grow in size under favourable conditions. As far as dyeing behaviour is concerned therefore, dyes with a different particle size composition but the same chemical constitution cannot be described as identical.

Toxicology: the ecological and toxicological testing of intermediates, dyestuffs, dyeing processes and effluents is now of paramount importance. Through the foundation of ETAD (Ecological and Toxicological Association of the Dyestuffs Manufacturing Industry) all large dyestuff manufacturers throughout the world (with the exception of East European dye makers) have demonstrated that they can deal with these problems successfully on their own initiative.

As far as the carcinogenic effects of colorants on humans are concerned, no conclusive evidence can be drawn from available epidemiological data and studies. However, a few dyestuffs have produced such effects in long-term tests on animals. After a painstaking evaluation of the available test results from long-term animal tests according to the criteria used e.g. by the IARC (International Agency for Research on Cancer), sufficient experimental evidence of a conclusive carcinogenic activity exists at present for only seven dyestuffs (Fig. 2). However, the fact that a whole series of dyes are strongly suspected of being carcinogenic is justified on the basis of certain indications. For example, the metabolism of benzidine dyes in animal and human organisms results in the formation of the carcinogenic benzidine through reductive cleavage of the azo group

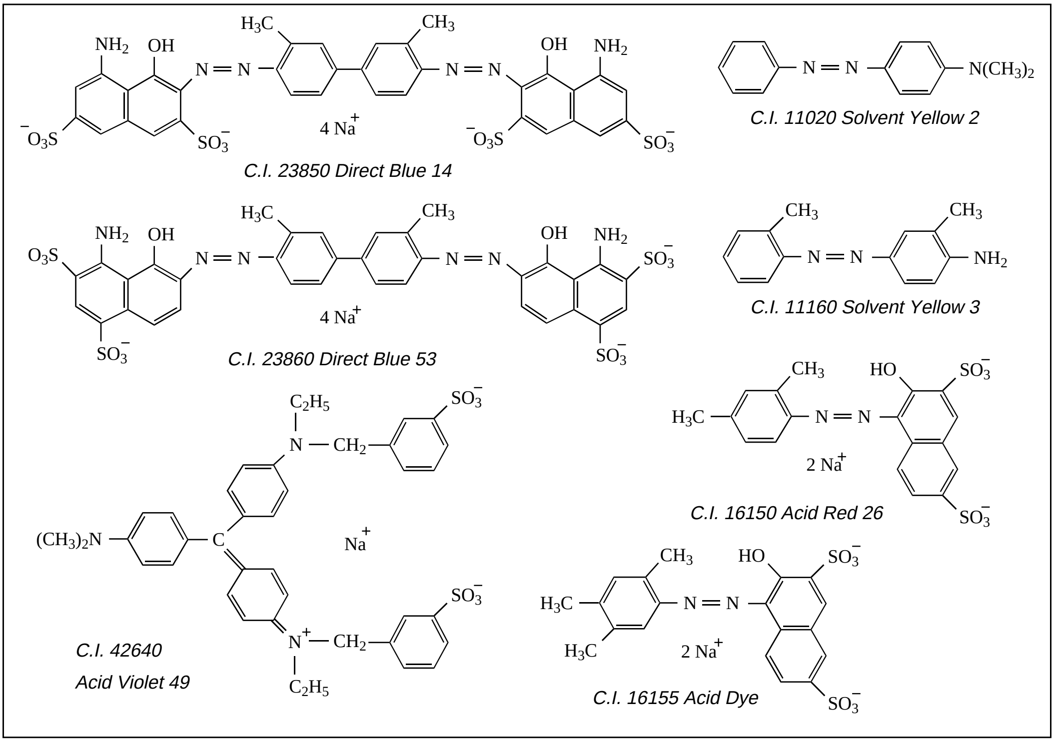


Fig. 2: Dyestuffs found to have a conclusive carcinogenic activity in animal tests.

(Fig. 3). With the ingestion of large quantities of such dyes, an increased risk of bladder cancer can no longer be ruled out.

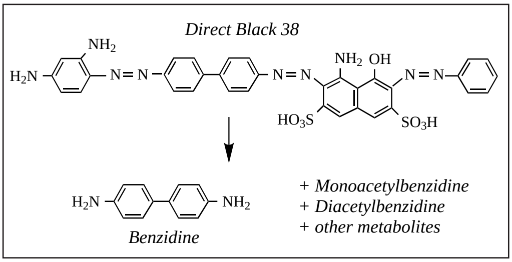


Fig. 3: Metabolism of Direct Black 38 (a benzidine type) in the hamster.

The general reaction which proceeds at azo groups has been known for a long time. Only the red dye Prontosil will be referred to here which was first synthesized by Mietsch and Klarer in 1932. Its antibacterial properties, discovered by Domagk, ushered in the era of sulphonamides. The active principle, p-aminobenzosulphonamide, is formed by a similar primary metabolism (Fig. 4).

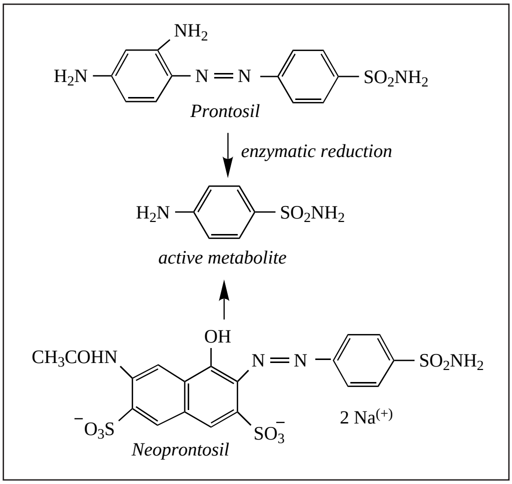
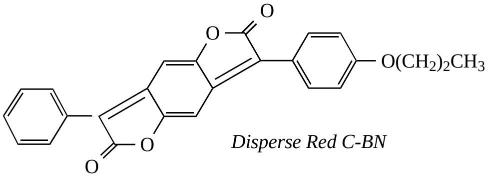


Fig. 4: Enzymatic reduction of azo dyes. (Both have found application as sulpha drugs; the metabolite has an antibacterial effect in the blood).

In recognition of the above-mentioned facts, a significant proportion of the efforts of the ETAD Committee on Toxicology is devoted to the ongoing evaluation of new data from tests on carcinogenic as well as mutagenic effects in relation to possible cancer risks, the realistic assessment of which is not without problems. It is precisely in this field that the dyestuff manufacturing industry sees itself as being confronted with controversial interpretations of data, with effects which are the result of absurd levels of overdosing, with opinions that are not based on scientific facts and questionable conclusions relating to structure/effect analogies. Because of the relatively low general toxicity of colorants, the administration of very high doses is possible. The toxicological effects, which are usually only produced by high doses, must be extrapolated to the trace exposure level which is lower by many orders of magnitude. The relevance of the findings from tests such as these is also uncertain. However, it is known that in many cases where excessive doses are administered, a carcinogenic effect is only triggered by overtaxing the deactivated metabolism and/or by severe primary damage to organs or tissues (e.g. a hepatoxic condition or tissue damage caused by repeated subcutaneous injections).

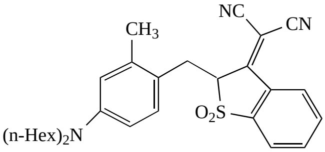
Development: the dyestuff's industry is sometimes accused of neglecting "textile engineering" considerations by giving priority to marketing concerns. It invests, for example, hardly any effort in traditional dye research because the costs involved in the development and introduction of new dyes are too high. Under these circumstances, how can the development of new chromophores be expected? Electronic data processing is also important in the development of new chromophore systems. This began in the 1950's with Kuhn's electron gas model. Thanks to the computer, very reliable predictions concerning the absorption spectra of new dyes which have not yet been synthesized can be made. However, this does not mean that traditional organic dye chemistry has become in any way superfluous. In the 1980's, at least three new chromophore systems were discovered and realized on a commercial scale. There are no grounds to assume that this will not continue to be the case in future. These three systems are summarized in the formulae given below:

– Disperse Red C-BN (C.I.Disperse Red 356) of ICI has probably the best thermomigration properties of all red disperse dyes known up to now.



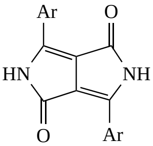
Disperse Red C-BN

– Foron Brilliant Blue S-R (C.I. Disperse Blue 354) of Sandoz is at present the most brilliant disperse blue ever produced.



Foron Brilliant Blue S-R

– Irgazine pigments of the 1,4-diketopyrrolo-(3,4-C)-pyrrole type of Ciba-Geigy (C.I. Pigment Red 254 and 255) have, up to now, been mainly used for the coloration of plastics and, only to a lesser degree, for textile applications.



Irgazine pigments

Dyestuff commercial forms Dyes are available commercially in powder form or, for improved metering, as liquid dyes in easy-pour paste form (e.g. vat or disperse dyes) or as dustless granules for easier weighing. Dyes in paste form are usually used in printing to ensure improved distribution during inspissation. As well as the standard types, most dyes are also available as concentrates. These are designated by percentage (e.g. 150%, 200%) and are then reduced to a lesser extent or possibly used as straight dyes (→ Dyes without extender). The purpose of reduction is to ensure accurate repetition of the dyeing recipe, whereby any manufacturing fluctuations are balanced out. The diluent, extender and reducing agent take the form of neutral additives, dependent on dye type, such as sodium sulphate, sodium carbonate, starch, sodium chloride etc.

Dyestuff for coupling, specifically diazo dyestuffs where the developer is coupled with the dyestuff by diazotization (usually diazotized p-nitraniline).

Dyestuff formulations, form of supply as → Commercial forms of dyestuff (including all additives, e.g. extenders etc.). Depending on dyestuff type (reactive, disperse, vat, direct dyestuff) and application type (exhaust dyeing, printing, continuous), dyestuff formulations contain specific additives which give the commercial form the best possible properties in respect of storage stability, handling, results etc. As these substances are not absorbed by the fibre, they are discharged with the effluent on completion of the dyeing process. As a considerable degree of specialist knowledge is required for dyestuff formulation, manufacturers do not readily allow their recipes to be revealed. The composition of the commercial forms can therefore only be discovered by means of complicated analysis, so that the knowledge is of necessity selective and patchy. Some general observations, however, may be made on the basis of the patent literature.

Auxiliary	Chemical designation
Dispersants Surfactants	lignin sulphonates, naphthalene sulphonate, formaldehyde addition compounds, ethylene oxide-propene oxide-copolymers
Salts	sodium sulphate, sodium chloride
Dust-bonding agents	mineral oils, paraffin oils (+additives)
Antifoams	ditertiary acetylene glycols
Antifreezes	glycerine, glycols
Thickeners	carboxymethyl-cellulose polyacrylates
Buffer systems	phosphate, acetate

Tab. 1: Principal additives used in dyestuff formulations.

A quantitative evaluation of the environmental safety of the additives shown in Tab. 1 is difficult, as there is a great number of testing methods making it a difficult matter to collect comparable data. In addition, the test methods used often show considerable variation, and finally different countries attach different weight to various parameters, thus for example the COD which is significant in Germany is not relevant in Switzerland.

From industrial health and ecological aspects, dyestuff formulations should ensure that the following requirements are satisfied:

- capable of being cleanly removed leaving the minimum possible residue,
- do not generate dust,
- easily metered (including by automatic systems),
- easy to set (soluble without boiling),
- can be mixed with stock solutions,
- manufactured without potentially toxic additives.

In general it may be stated that the dispersants and surfactants shown in Tab. 1 are not toxic to fish. Thus in all cases the LD_{50} values are above 1000 mg/l. Bioaccumulation and heavy metal activation are also unknown. Other investigations do however lead to the suspicion that in a few cases products are still being used which are potentially harmful. Reference must be made here to e.g. condensation products of formaldehyde with phenol or cresol, which always contain small amounts of the primary substances toxic to fish. Furthermore, alkyl phenol ethoxylates should also no longer be used, as they generate metabolites toxic to fish on decomposition. The salts, buffer systems, thickeners and antifreezes shown in Tab. 1 do not present a problem in respect of toxicity to fish. It may therefore be generally said that dyestuff formulations must not contain any auxiliaries toxic to fish. If this is the case in individual products they should immediately be replaced, as there is a sufficient range of alternative products available.

The situation is different regarding biodegradability (Tab. 2), which is of great significance in effluent treatment. Some of the products used as antifreeze agents are compounds which are to an extent degradable, but at least capable of elimination. The thickeners most frequently used (especially the polyacrylates) are at least largely capable of elimination. Dispersants and surfactants, on the other hand, only decompose slowly. This is due on the one hand to their polymer structure, on the other to their aromatic components. The products identified are partially eliminated by adsorption on digester sludge, but the adsorption rate is not high. In general, such elimination is welcome in terms of effluent pollution but only represents the second-best solution. The main objective must be to achieve complete decomposition at the biological treatment stage. Salts and buffer systems are usually not retained by an effluent treatment plant, with the exception of phosphates, which can be removed by precipitation. As the usual dust-bonding agents all contain oils, they too are only minimally degraded.

Auxiliary	COD	BOD_5	TOC
lignin sulphonates	approx. 1200	approx. 50	approx. 15%
naphthalene sulphonate formaldehyde addition compounds	approx. 650	approx. 50	approx. 15%
propene glycol		approx. 10	approx. 95%
glycerine		approx. 780	approx. 90%
carboxymethyl-cellulose		approx. 0	approx. 30%

Tab. 2: Biodegradability of certain additives in dyestuff formulations.

Among the thickeners there are numerous degradable alternatives (e.g. based on biopolymers) which are capable of use in the majority of formulations. The agents currently used as antifoams have no easily degradable replacements with a broad spectrum of activity. As antifoams are only present in the formulations in small quantities, this is not an urgent problem. The same can be said of the dust-bonding agents, although here new, environmentally-friendly solutions are expected to be available soon. A more important development, however, would be degradable dispersants and surfactants, as these constitute the main volume of auxiliaries contained in dyestuff formulations. Among these are e.g. fatty alcohol ethoxylates, alkyl benzene sulphonates or alkyl polyglycosides. These products were formulated above all for use in washing and dry cleaning agents, which is where their strengths lie. In most cases they are poorly suited to use in dyestuff formulations, for instance as dispersants for HT exhaust dyeing on polyester. Formulations based on this auxiliary would cause serious loss of quality (e.g. poorer levelness). However, use could be considered in such cases where surfactants are used to improve the wettability and as an extender. Even here, there is the problem of the tendency of the products indicated to generate substantial volumes of foam which then necessitate extensive use of antifoams either in the formulation itself or by the dyer. Overall, at the present time, there are no real alternatives to the surfactants or dispersants at present used in dyestuff formulations. On the other hand, it is certain that such alternatives are possible and that they are also under development.

Solid and liquid commercial types are distinguished by their water content (Tab. 3). Thus the ratio of dyestuff to auxiliaries in the case of powders and granules is max. 2 : 1, in the case of liquid types 3 : 1. On average it may be assumed that the liquid form at similar concentration contains around half, in better cases only around 25–35% of the auxiliaries of the solid type. This should mean a substantial reduction in effluent pollution. The reason for these huge differences lies in the fact that the small dyestuff particles obtained by wet grinding must be prevented from agglomerating during drying, and this is only achieved using a substantial dispersant content. Even if the volume of auxiliaries does not vary so substantially, liquid formulations are often more ecologically advantageous, as the antifreeze agents they contain are either degradable or at least capable of easy removal.

Formulation component	Powder form	Liquid form
Dyestuff	30-50 %	20-40 %
Dispersants	40-60 %	10-20 %
Salts	0-20%	–
Dust-bonding agents	0-5 %	–
Antifoams	0-5 %	0-5 %
Antifreezes	–	10-15 %
Thickeners	–	0-5 %
Water	5-10 %	40-60 %

Tab. 3: Components of solid and liquid dyestuff formulations.

In the case of reactive dyestuff formulations (Tab. 4) the liquid forms are clearly lower in auxiliaries. For powders in favourable cases a dyestuff/auxiliary ratio of 5 : 1 is achievable, in the case of 15 : 1 solutions. As less additive is needed, however, for reactive dyestuff formulations, and in the case of the powders high concentrations of dyestuff can be achieved, the absolute differences between solid and liquid forms is lower than is the case with disperse and vat dyestuffs (Tab. 5). In addition to the differences described between solid and liquid commercial forms, in individual cases there are also differences between different solid commercial forms of the same dyestuff. For example if a dyestuff exists in commercial forms of 100% and 200% high-concentration, the latter will with certainty be the more environmentally friendly.

Formulation component	Powder form	Liquid form
Dyestuff	50-80 %	15-30 %
Salts	0-10 %	–
Surfactants	10-40%	0-15 %
Dust-bonding agents	0-5 %	–
Buffer	5-10 %	1-5 %
Water	3-10 %	65-80 %

Tab. 4: Components of reactive dyestuffs in liquid and solid formulation.

When considering the environmental impact of commercial forms, the packaging should also be taken into account. Solid forms are usually supplied in drums, liquid forms in canisters or disposable containers. All these containers are usually retained by the purchaser and require disposal. Although polyethylene is used as the material, this can be a problem, especially if the packaging drums still contain traces of the product. This is where the type of commercial form is again of significance: good granular types are removed from their packaging leaving practically no residues; this is not the case to a sufficient extent with powders or liquids, so that they must be rinsed out. Regardless of this aspect, endeavours are being made to design drums which are themselves more environmentally friendly. For example, in the place of barrels, cardboard containers with polyethylene liners could be used, with a resultant 90% reduction in the amount of plastic used. In addition the paper and polyethylene constituents of the packaging can easily be separated, thus facilitating separate dumping or recycling. A shift towards such drums can be regarded as a contribution towards more environmentally-friendly commercial forms of dyestuffs. Similar developments also exist for liquid forms. Consideration is also being given to the feasibility of reusable drums. This is probably only suitable for large-capacity vessels, and careful evaluation must be made to ascertain whether this option is really ecologically and economically the best option. Separating and recycling the compacted or shredded materials of the drums

	Powder, 100% (standard) concentration	Powder, 200% concentration	Liquid, 100% concentration
Percentage of crude dyestuff in commercial dyestuff	25%	50%	25%
Percentage of dispersant in commercial dyestuff	30%	47%	12,5%
Dispersant concentration in the liquor from the dyestuff	0,9 g/l	0,7 g/l	0,38 g/l
Dispersant addition when dyeing	1,0 g/l	1,0 g/l	1,0 g/l
Total dispersant concentration	1,9 g/l	1,7 g/l	1,4 g/l

Tab. 5: Contamination of effluent by dispersants when dyeing with disperse dyestuffs in powder and liquid formulation (calculation for typical dyestuff composition, liquor ratio 1:10, 1 g/l dispersant addition, depth of colour equivalent to 3% of fabric weight, powder dyestuff 100% concentration).

could well be more beneficial than the traffic generated by transportation of empty drums. A further alternative, suitable for and already being practised by large users of liquid commercial forms, is delivery by tankers (according to Möckel and Beckmann); there is also the possibility of the supply of dyestuff powder in water-soluble foil packaging.

Dyestuff identification (by chromatography). Dyestuff mixtures are extracted from the textile with the following solutions:

I. General and for almost all anionic dyes: ammonia/water 1 : 10, 100°C, water bath.

II. General and very good for dyes plus optical brightening agents on cellulosic and polyamide fibres: dimethyl formamide/water 2 : 1, 100°C, water bath.

III. For disperse dyestuffs and optical brightening agents on polyester: dimethyl formamide, boiling (153°C), 1–2 min.

IV. For disperse and cationic dyestuffs on acrylic fibres: dimethyl formamide/water 3 : 1, 100°C, water bath, or nitromethane-methyl-n-propyl-ketone, 90–100°C.

V. For disperse dyestuffs on acetate: dichloromethane, room temperature.

VI. For disperse dyestuffs on triacetate: acetone/water 4 : 1, room temperature.

VII. For optical brightening agents on cellulosic fibres: methanol, Soxhlet extractor.

The dyestuff mixture extracted is broken down into its constituents using paper or thin-layer chromatography or paper or thin-layer electrophoresis. These constituents then undergo the following tests for definitive identifcation:

1. Minidyeing: various fibre types are dyed in solutions of the individual dye constituents and chemically tested or compared with sample cards.
2. Comparative tests and matching with chromatograms of known dyestuffs or dye classes.
3. Comparative fluorescence spectra of dyestuff constituents and standard substances.
4. UV and IR spectrophotometric reflectance curves are compared with the equivalent curves of known dyestuffs.
5. Finally, chromatograms of the tested dyestuffs are compared with those of the known dyestuffs. Before chromatographic analysis, preliminary tests are carried out to determine the dye class (microscopic tests and solution tests).

Dyestuff origin → Natural dyes, mineral dyes, pigment colorants.

Dye tests,

I. In substance: a) for uniformity →: Chromatography, Capillary analysis, Fractional dyeing, Fractional solution of dyes, Blow test; b) to identify dye class; c) for constitution; d) for competitiveness by means of comparative dyeing.

II. On the fibre → Dye class identification.

Dye toxicity → Dyes are included in the legal regulations governing toxic substances. Dye manufacturers avoid the benzidine dyestuffs and developers for diazo dyes which are considered carcinogenic. The degradability of dyes in waste water should also be considered (→ Waste water evaluation). Even if a dye is non-toxic, the question still remains of the degradability of any residues (metabolites) in the waste water which may result from its degradation. → Fish toxicity of waste water.

Dye-tube changer (for tube changing machine), automatic device for replacing paper tubes, etc. with rigid or flexible dye tubes or springs in cross-wound packages.

Dye tubes, tubes on which yarn is spooled for dyeing in the form of yarn packages (→ Dyeing tubes for yarn dyeing), → Disposable dye tubes made of plastic, flexible tubes (flexible either axially or radially) for yarn with pronounced shrinking properties, non-disposable dye tubes made of plastic such as Biko dye tubes (which can also be made from stainless steel) and dyesprings.

Dye tube, split → Flexible dye tube made from perforated stainless steel, slit open in order to make it radially flexible.

Dye uptake,

I. The dye uptake is the quantity of dye absorbed by the fibre.

II. → Substantivity, exhaustion (diffusion) model.

Dye-weave process, polychromatic dyeing process in which the dye is supplied by moving nozzles. The jets of dye solution are directed onto the surface of an angled plate, from where they impinge upon the substrate and are then squeezed out on a vertical two-bowl padder.

Dye winch (Paddle-dyeing machine, Paddle vat), dye vat of hemispherical or $^3/_4$-spherical form made of wood, copper or stainless steel with a rotatable hank winch or paddle as a "moving device" sitting horizontally and to one side on the top. The ends of the winch or paddles extend down into the top of the liquor and when put into operation, they provide continuous movement to the liquor and material. It is sometimes possible to sit the paddle up, thus converting the apparatus into a → Winch vat for piece dyeing. Also made with a hood, which can be fully closed, or with hinged or sliding glazed hatch. Application: widely used for dyeing cloths in general and also much used for stockings packed in small sacks. Advantages: universal application, very efficient use of dye, economic use of steam as liquor bath ratio, 1 : 20–25, can be shorter than for paddle. Rapid rinsing (half the time and quantity of water), gentle handling of material (minimum abrasion against the vat walls).

Dyewoods → Natural dyes.

Dye works, dye manufacturing plant (dye factory).

Dynamic viscosity → Rheology.

E

EA → Elastane fibres, → Standard abbrev. for textile fibres, according to the → EDP Code; DIN standard abbrev. → EL.

Easy-care finishes In order to eliminate creasing (wrinkling) of cotton fabrics during wear and service (washing, drying, ironing) as far as possible, i.e. to make ironing or pressing superfluous if possible, cotton materials are treated with crosslinking agents (→ Wash and wear finishing). The effect of an easy-care finish is influenced by different fabric pretreatments (Fig. 1).

a) Pretreatments: causticizing, mercerization, hot mercerization, stenter causticizing with caustic soda or caustic potash liquor, Sanfor-Set process with liquid ammonia. The increased fibre strength which results from such mercerization processes compensates for the inevitable strength losses in easy-care finishing.

b) Bleaching: peroxide bleaching, in particular, has a positive influence on creasing propensity (Monsanto ratings 1–5) and, in combination with an easy-care finish, causes the least loss in strength.

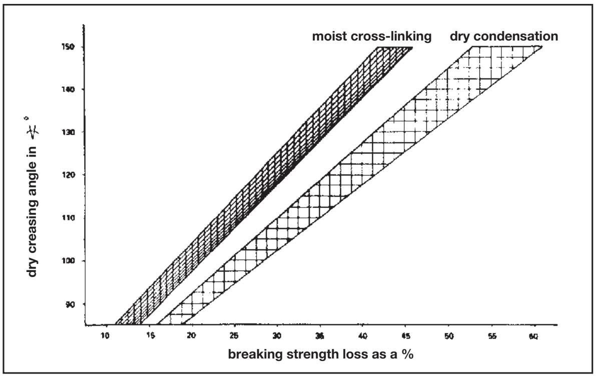


Fig. 2: Dry-crease angle/breaking strength ratio in dry (right) and moist cross-linking (left).

Fabric moisture during crosslinking has a positive effect on the unavoidable losses in strength (Fig. 2). For the same crease recovery angle (e.g. dry crease recovery angle 150°) the strength loss is approx. 40% under moist crosslinking conditions and 55% under dry

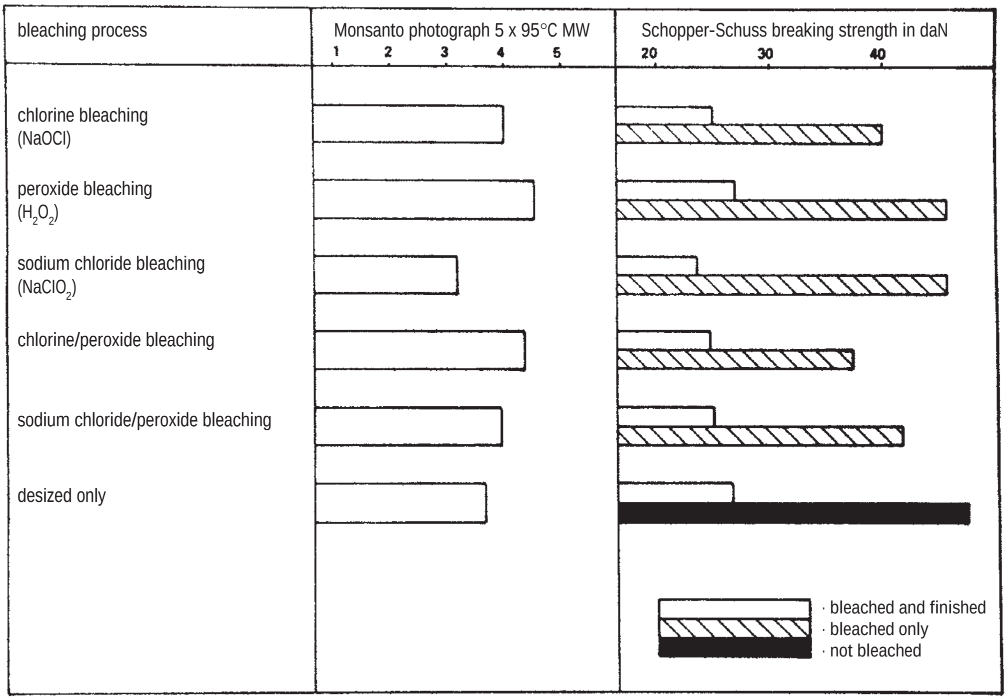


Fig. 1: Monsanto photograph and breaking strength after different bleaching processes.

cross-linking process	woven fabric moisture content %	liquor pH value	cross linking temperature (°C)	cross-linking duration	fibre condition	effect/strength ratio
classic dry condensation	0– 2	4–7	150–160	5– 4 min	unswollen	good
rapid curing	0– 1	4–7	140–220	10–10 s	completely unswollen	good
low curing	0– 3	3–5	130–180	50–30 s	unswollen	varying moderately good
moist	5– 7	0.5–1.8	25– 35	16–24 h	partly swollen	very good
wet	50–80	< 1	15– 25	20 h	swollen	optimal but no dry creasing angle
wet/dry	50–80	< 1	15– 25	20 h	swollen	good/very good
	0– 2	5–7	140–160	30 s–5 min	unswollen	moderate dry creasing angle

Tab.: Cross-linking process, application conditions and effect/strength ratio.

crosslinking conditions. The various crosslinking conditions used in easy-care finishing are compared in the table.

Easy foaming quality Ability to generate considerable quantities of → Foam, mainly very aerated, at low temperature, low concentration and with minimal labour consumption, e.g. using the coconut oil soap type. In general, this foam is neither stable nor achievable at high temperature.

Eau de Javelle (eau de Javel). Named after the district of Javel in Paris. Originally a clear aqueous solution of potassium hypochlorite also containing potassium chloride. Used for bleaching cellulosic fibres. Potassium hypochlorite solution has now been largely substituted by a cheaper but similar sodium hypochlorite solution under the same name.

Eau de Labarraque Sodium hypochlorite solution named after its French discoverer. Also commercially available as → Eau de Javelle.

Ebonit → Hard rubber.

Ebrú process The precursor to → Aquagraphics. This is an 800 year old Turkish printing method which uses animal waste products including ox bile and boiled papyrus. Method as for aquagraphics.

ECE (Ger.), abbrev. for: Europäische Convention für Echtheitsprüfung (European Convention on Fastness Testing); → Technical and professional organizations.

Ecobalance Comprises the description and listing of the primary effects of specific processes on the environment, i.e. on air, water and soil, taking additional account of energy and raw material requirements. The balancing of all environmental effects and loads, which can occur in the production, use and disposal of no longer usable products, also raises the question of how protractedly the environment will be polluted in future by production, consumption and disposal. Ecobalances are first of all emission balances, i.e. all outflowing substances from basic commodity raw material production and product use and disposal are collected and compared with each other, along with noise pollution, for the products and application processes to be tested. An ecobalance includes the various costs and environmental loadings which ensue in the production of textiles and in the subsequent disposal of by-products: substance emissions, including airborne pollutants, effluent, waste and residual matter together with heat emission, raw and auxiliary material requirements, water and energy plus space requirements, and also the effects on the function and use of ecosystems, including the recording of the external cost of treating pollutants in outside plants. The ecobalance is a comparison of input and output, quantitatively recording as emissions and immissions the sum of all bulk flows such as air, water, waste and energy flows, and all products and raw materials used. Classification of the pollutants and their quantities, determined in accordance with environment endangering criteria, is followed by ecological assessment of the item under examination.

An ecobalance should express by means of objectively produced figures the effects on humans, animals, plants and their environment occurring over the entire life cycle of a product. To this end, the life cycle of the product to be tested is first of all subdivided into self-contained part processes. All statistically ascertainable effects on the environment will then be determined for

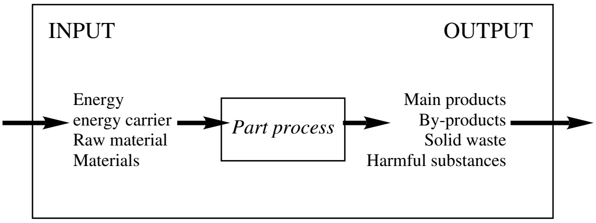


Fig.: Input/output analysis in producing ecobalances.

each part process in an input/output analysis in accordance with the illustration.

The following factors are determined in input/output examination:

1. Input:

a) Raw materials: each stage of the total incoming material, in the form of raw materials and semi-finished or finished products, is recorded in units of weight. In the case of materials which are themselves the result of preliminary stages or recycling processes, the cost of energy and environmental pollution resulting from preliminary production processes must be taken into account in the process.

b) Energy and energy media costs: the consumption of energy in the form of process heat or electrical power, plus the quantity of energy media not used for energy purposes, is determined. In the case of fossil fuels, the entire route from deposits through to utilisation is taken into account. The fact that energy also has to be used to produce energy (e.g. power) is taken into account by calculating back to the so-called primary energy with the degree of efficiency of the energy supply. In the energy medium balance, the quantities of energy contained in the product (e.g. wood or polyvinyl chloride in window frames) are determined by their net calorific value. In the case of subsequent energy utilisation, this can flow back into the system.

2. Output:

a) Main/by-products: first of all, main and by-product quantities are obtained as the result of each production process. They are not emitted into the environment in the sense of an environmental balance, but are prepared for use and application processes. At the end of a life cycle, the products are either re-used from the material or thermal standpoint, or disposed of in dumps.

b) Environmental pollution: whilst energy and material flow analysis is comparatively unproblematic (the distribution key to the proper allocation of pollution to those causing it should be produced analogous to weight, volume or price relationships), pollutant recording presents bigger problems. The decision as to which substance emissions in general, and from what threshold, are damaging or environment endangering is alone difficult to make. The national regulations for maintaining the cleanliness of air, water and soil contain lists of many hundreds of pollutants and their limit values. The fact that, in the case of many pollutants, their limit values are indicated very differently in different regulations, reveals the continuing uncertainty of toxicologists, ecologists and politicians in this area. This can only be resolved by additional experience. Furthermore, international conventions are required in this respect to decide which pollutants should basically be included for comparison. In addition to the generally measurable ecobalance dimensions described to date, there are additional environmentally relevant criteria, which are sometimes difficult to evaluate statistically, and cannot therefore be represented in ecobalances. These include the quality of the workplace directly associated with production, the susceptibility of processes to problems and accidents, the general availability of raw materials (how long will fossil raw material supplies last, and at what extra cost can residual stocks be exploited?) and also the assessment of risks (assessing environmental catastrophies, e.g. tanker accidents, nuclear power plant problems etc.). To begin with, these factors should not be directly included in the ecobalance, but should not – particularly if they are very important – be ignored, and therefore should at least be qualitatively described.

In order to make clear and comprehensible environmental assessments, and to enable comparisons to be made with other product balances, all assumptions made in the course of an operation must be documented. These include primarily the so-called balance and system limit data (which processes have been recorded by what means and with what target parameters?). As a rule, these boundary conditions are selected in such a way that all important pollutants can be recorded at reasonable expense. Whilst on the energy side for example the immediate production energy must be directly determined, secondary energy consumption (for lighting, heating and air-conditioning the production and administration buildings for example) is ignored in many balances. In addition, the question as to whether the so-called grey energy used in producing the production premises, production machinery and vehicles should be included must be laid down in the system limits. In most of the ecobalances produced to date, this energy figure is still not included for reasons of simplification, although its proportion can lie between 5 and 100%. Of significant importance for an ecobalance is the assumption of the degree of efficiency for energy utilisation and supply. Different energy media can be used in various proportions in producing power and heat. This must be represented and taken into account by a specific split, expressing the proportions in which power is produced, e.g. thermal, nuclear, hydraulic or others. Depending on circumstances, it is possible to undertake the division purely in plant terms (in-house energy supply), or regionally, nationally or internationally. The data can be had from national and supranational energy supply statistics. In any case, the division, which concerns not only the primary energy cost but also the energy-dependent emissions, must be indicated in the marginal balance conditions. The same applies to the basic data listed below, which can be of importance to the correct interpretation of an ecobalance:

- basic transport data (e.g. energy cost and emission factors per unit of weight and length of journey),
- assumed average transport distances,
- maintenance expenditure,
- average length of service life of products and buildings,
- assumed recycling figures and disposal splits.

The quantitative recording and listing of the energy and pollutant flows in an ecobalance make the ecological classification of different products possible only to a limited extent. Whilst the consumption of fossil raw materials and primary energy for two products of identical economic value is directly comparable one with the other, a clear ranking order of the numerically listed pollutant emissions into the above-mentioned environmental areas can only be established within each environmental factor if the same product (or process) comes off better. As this is seldom the case, the individual material flow data must be transformed via evaluation models in a second environmental evaluation stage in such a way that its environmental effects are more comparable. In consequence of the complexity of the subject, there is no universal evaluation method for this. The most frequently used model to date transforms the pollutant emissions within the individual component areas by weighting with the immission limit values. If, in a production cycle for example, 5 g of dust, 3 g of nitrogen oxide and 2 g of sulphur dioxide are emitted, and assuming the immission limit values of the TA_{air}, the volumes are loaded up to the legal limits. This does not take account of possible decomposition and synthesis effects between different pollutants. It is also assumed that the same environment area reference unit, e.g. 1 m^3 of air, may be charged by only one pollutant in each case. As long as identical immission limit values have been used in different ecobalances, the critical volumes produced with this model can be directly compared with each other.

With ecobalances, important decision bases can be provided, enabling

- ecologically damaging processing stages to be recognised within existing production and processing operations, and their improvement immediately to be checked statistically in terms of the evaluation criteria provided;
- different products and materials with the same performance characteristics to be compared directly with one another in order to recognise the most environment-friendly variants.

The complex ecobalance production procedure necessitates making a multitude of assumptions and decisions which have a very pronounced effect on trial results, and must be absolutely understood in order to be evaluated and interpreted. Since there are as yet no international conventions on ecobalance production, the results of different studies should not be compared without detailed checking of the system and the boundary conditions.

Ecolabelling of textiles For identifying the

- physiological and toxicological properties of the product in wear,
- disposal or recycling of “used” articles of clothing,
- ecology and human ecology of the production process.

The problems lie in environmental pollution during cultivation and production as uncontrollable preliminary stages, i.e. as early as fibre cultivation and preparation up to spinning, be it wool, cotton, silk, ramie, linen or regenerated fibres like viscose. Whether the natural resources are carefully treated here, defoliants, fungicides etc. are dispensed with, harmful substance emissions minimised, and the workplace polluted as little as possible with noise, dust, heat and toxic substances, is as a rule still beyond the knowledge of the buyer. Then there are other environmental problems associated with yarn and piece dyeing, printing and finishing, processes which are often carried out in suppliers’ works.

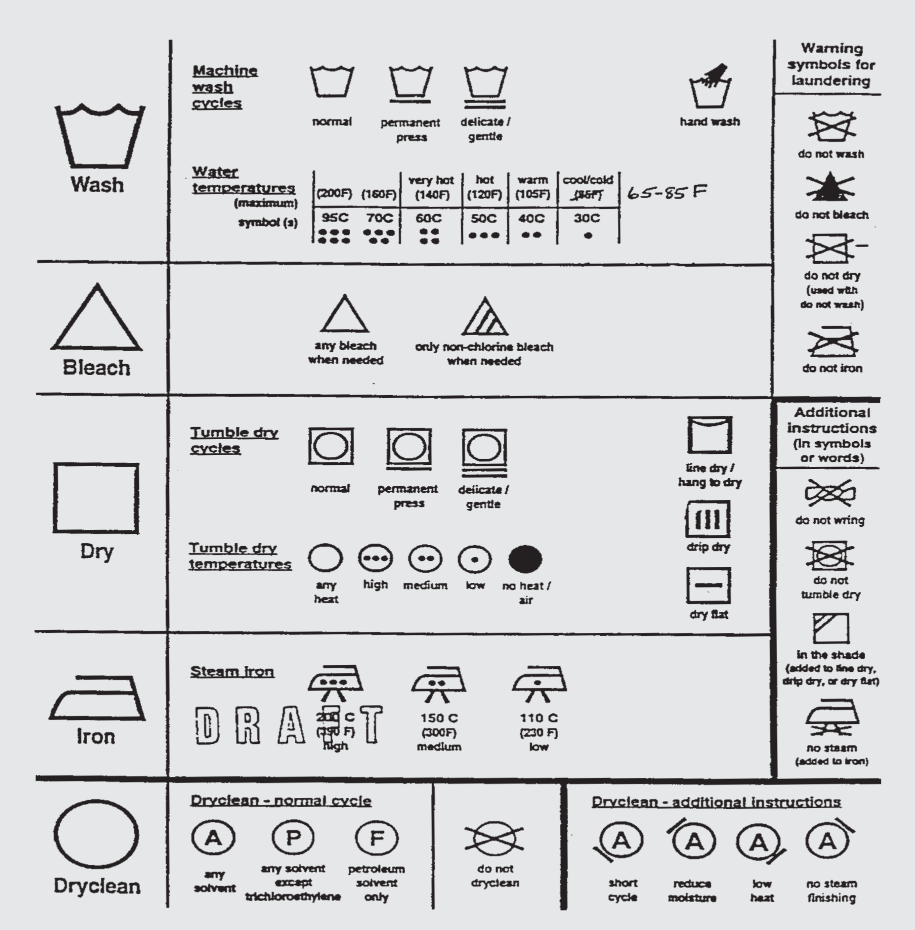
The natural fibre cotton, with over 40% representation in clothing and household textiles, reveals on the one hand severe chemical contamination due to growth, cultivation and harvesting through the individual stages, and, on the other, the need to apply carefully selected chemical finishing processes in order to be able to produce clean, wearable, functional and skin-friendly textiles from this fibre.

In earlier times, textiles were predominantly looked at from the economic, functional (Tab. 1) and clothing fashion standpoints. For some time, end-users and their initiatives have imposed extensive requirements which involve the health safety factor of textiles and also to some extent the ecology of textile production.

Against this background, different textile manufacturers, makers-up and merchants throughout the world have taken care to ensure that textiles meet specific criteria. Thus, some firms have stopped using

- chlorine bleaches,
- azo dyestuffs, which can split off during decomposition into carcinogenic amines according to MAK lists III A or III A 2,
- washing and cleaning agents containing APEO.

Furthermore, there is a prescription to keep below specific limits for a series of parameters, although no criteria of any kind are defined in the case of some collection specifications. The specifications serve only as a marketing instruments.



Tab. 1: ASTM Guide to care symbols (labels for function of textiles).

There are some very diverse initiatives:

- producers and chemical finishers who put ecological collections onto the market (Tab. 3),
- makers-up and merchants with their own ecological collections (Tab. 2),
- trade associations (e.g. Textile Clothing Dialogue, Tab. 4),
- associations, institutes and firms which have laid down the test criteria as a basis for brand names, ecolabels, seals etc. The tests are mainly conducted by independent institutes. Some firms also test in their own laboratories.
- European syndicates (e.g. Textile Clothing Dialogue, EPG, GUT, eco-tex).

I. The “Dialog Textil-Bekleidung” (DTB) (The Textile Clothing Dialogue) has produced for its over 100 member firms from 7 European countries with an approximate total turnover of 10 billion DM an Eco-Info as a complement to the Product-Info already in existence for quite some time. From the ecological standpoint, product requirements should be the determining factors in intercourse between the partners of different production stages. Indicated in it are limits for specific criteria relative to purpose of use, together with the relevant test criteria (Tab. 4 + Tab. 5).

II. The OTTO mail order company in Hamburg, in which environmental protection is an acknowledged company aim, specifies ecological textile material requirements for natural fibre textiles, and also includes them for synthetic fibre textiles. The different limits for content substances and properties such as natural fibre textile pH and colour fastness are listed in Table 6, a distinction being drawn between clothing worn next to and away from the skin and also baby clothing.

In addition to the requirements of individual textile firms, there is also quite a number of brand names, ecolabels and seals for textiles offered by associations, societies, institutions and also service firms (Fig.). Most initiatives start in fact from the Federal Republic of Germany, but claim to be valid throughout Europe (sometimes throughout the world).

Examples are:

- eco-tex (eco-audits of the eco-tex consortium),
- EPG (The European Project Guarantee of ELTAC = Europe’s Largest Textile and Apparel Companies),

Company	Collection	Testing in accordance with	Testing station*	Comments
C & A, Düsseldorf		Minimum in-house requirements	in-house	no company label, generally strict ecological requirement
Esprit, Düsseldorf	»ecollection«	no in-house testing		highest standards condition: non-contaminated condition »What isn`t in there can`t come out« 12 stores
Hess, Bad Homburg	»Hess-Natur«	in-house quality guidelines	in-house laboratories Bremen Institute for the Environment	
Lucia, Lüneburg	none	M.S.T. Eco-Tex	Zugel, laboratories Hohenstein	all collections must comply with eco-standards
Neckermann, Frankfurt	»Neckermann« Eco-quality	No in-house testing		purchases only from firms with Neckermann certificate award
OTTO, Frankfurt	environment-friendly textiles	Hansa-Control Hamburg		OTTO-Requirement profile
Quelle, Fürth			in-house laboratories External laboratories	purchases from firms with eco-collections
Rödel, Freiberg	R-line	Eco-Tex	Hohenstein Zürich (testex)	
Steilmann, Bochum- Wattenscheid	»Britta Steilmann«	Klaus Steilmann Innovation (KSI) EPG/ELTAC=M.S.T.	EPEA-Umweltinstitut, Hamburg	undyed, unbleached cotton
Triumph, Heubach	Slip-Programme	Eco-Tex		planned: eco-Programme
Tumlin, Stockach		Testing for: • Heavy metals • Pesticides	GFIT, Bernstadt	

Tab. 2: Ecotextile makers-up and traders, Germany (according to BASF).

- GuT (Signet der Gemeinschaft umweltfreundlicher Teppichboden = Seal of the Environmentally Friendly Carpeting Association), founded by well-known European carpet firms),
- GuW (Signet der Gemeinschaft umweltfreundlicher Wohntextilien = Seal of the Environmentally-friendly Domestic Textiles Association),
- M.S.T. [Markenzeichen schadstoffgeprüfte Textilien des Vereins für verbraucher- und umweltfreundliche Textilien e.V. (VvuT) = Harmful Substance Tested Textiles Trademark of the Consumer and Environment-friendly Textiles Association],
- M.U.T. (Markenzeichen umweltschonend hergestellte Textilien des VvuT = VvuT Trademark of Textiles Produced by Environmentally-friendly Means),
- Eco-Tex (a label of the International Association for Research and Testing in the Field of Textile Technology Eco-Tex),
- TOX-PROOF (a German Control International criterion catalogue).

The above-mentioned trademarks, eco-labels and seals extensively comply with the following requirements for textiles so distinguished:

- They contain no dyestuffs which can be regarded as cancer inducing, or can split off into cancer inducing products.
- Products for infants or small children below two years of age may not release dyes in contact with saliva or perspiration.
- The concentration of heavy metals released when affected by perspiration may not exceed the limits for drinking water.
- Pesticide residues may not exceed the limits admissible for foodstuffs.
- They contain less free formaldehyde than prescribed by law.
- The pH should be equivalent to that of human skin.

In addition to the above-mentioned labels, the following initiatives are important:

- AKN (Arbeitskreis Naturtextilien e.V. = The Natural Textiles Association, with approximately 20 members).
- EU ecobabel and eco-audit.

III. The eco-tex label of the eco-tex consortium, founded by Scotdic, Textile Farben GmbH, Cologne, and tdg,

Fig.: Ecolabels: the new Eco-Tex label: Confidence in textiles – textiles tested for harmful substances in accordance with eco-Tex standard 100 (top); three water droplets in a circle as the symbol for 92% water recovery in the Brinkhaus textile finishing works (centre); the vauDe symbol (bottom) for 100% single component material sportswear.

Company	Collection	Comments
Belgium		
UCO, Gent	Eco-Denim	
Italy		
Legler, Ponte San Pietro	Eco-Denim	
Kunert, Milano		s. Kunert, Kulmbach
Austria		
Getzner, Bludenz		
Blaas, Feldkirch		
Kunert, Wolfurt		s. Kunert, Kulmbach
Switzerland		
Kunert, St. Margarethen		s. Kunert, Kulmbach
Pflanzenfärberei Bollhalder, Dornach		AKN
Natura, Sidema, Barbegro		AKN

Tab. 3: Eco-textiles, foreign (according to BASF).

Features	Supplier details specification*	Production note	Test specification a) obligatory b) recommended
1. Formaldehyde	( ) < 1000 ppm ( ) < 300 ppm ( ) < 75 ppm	Recommended among other things for: • outerwear, lining fabrics, clothing not in contact with the skin • shirts, blouses, knitwear, clothing worn next to the skin • underwear, nightwear	a) Acetyl acetone method in accordance with Japanese Act 112
2. Pesticides	( ) pentachlorophenol (PCP) max. 0.5 ppm ( ) total pesticides max. 1 ppm ( ) (DDT, HCH, lindane, aldrin, dieldrin, 2,4-ditoxaphene and 2, 4, 5-tritoxaphene) ( ) ensure that fabric has been scoured or washed (80°C)	1. generally relevant only for natural fibre products which have not been subjected to wet pretreatment (e.g. scouring, washing) 2. from experience, leather contains higher proportions of PCP/pesticides, recommended limit: 5 ppm	a) extraction in accordance with eco-tex standard 200 b) subsequently GC, HPLC, DC
3. Azo dyes which can split off amines on MAK lists III A 1 and A 2	benzidene-based dyes 3,3-dimethylbenzidene 3,3-dimethoxybenzidene 3,3-dichlorobenzidene o-toluidine ( ) not used ( ) used ( ) check, as not known		b) DC, HPLC
4. Skin neutrality (pH value)	( ) pH 4.5 – 7.5		a) DIN 54 276 DIN 54 275

* In each case, the specification indicates various limits/content substances which are to be marked with a cross by the supplier.

Tab. 4: DTB eco-info (1) (according to BASF).

Textile Design Group, Milan. The consortium is a consultancy and service organisation which offers its services for all textile stages from the fibre to the market for developing "ecologically optimised" textiles. The label comes in three different categories, the awarding criteria for which are listed in Tab. 7 and Tab. 8. 0.5% of turnover must be earned from ecological products in order to be able to use this registered trade-mark. The RAL seal has been awarded for this label in order to make eco-tex an ecolabel.

IV. By producer request in accordance with an idea of July 1992, the ELTAC EPG European Product Guarantee is to be awarded via ELTAC by way of international criteria catalogues and test procedures, taking special account of ecological and physiological clothing aspects.

The limit values resemble those of M.S.T. (Tab. 9 + 10). Quality requirements such as technical data (e.g. tear strength) are additionally required. In addition, four of the following seven production stages

- spinning,
- weaving, knitting,
- pretreatment,
- dyeing, printing,
- finishing,
- cutting,
- sewing

should be carried out in Europe. EPG can be traced back to activities on the part of the Steilmann company in Bochum (Germany).

V. Die Gemeinschaft umweltfreundlicher Teppichboden, GuT (The Association of Environmentally-friendly Carpeting) was founded in 1990 by well-known firms in the European carpet industry, and currently has approx. 80 members. GuT awards the "Teppichboden schadstoffgeprüft" seal ("Harmful substance tested carpeting" seal) if a carpet fulfils the criteria listed in Tab. 11 which are tested by institutes in the Federal Republic (TFI), Belgium, Denmark, and, in the future, Austria. GuT members undertake moreover to maintain their production machinery to a high technical level so as to pollute the environment as little as possible. The GuT seal is recognised in the sector and in the market, and is accepted by the consumer.

VI. As with the carpet sector, household textile producers also want to set up a Gemeinschaft umweltfreundlicher Wohntextilien GuW (Association of Environmentally-friendly Household Textiles), and award a seal.

VII. At the suggestion of Gesamttextil, the "Association for Consumers and Environmentally-friendly Textiles" was set up in July 1992 as a sponsor company for awarding the M.U.T and M.S.T. manufacturers' labels. All producers of textile products in the EU and EFTA, together with textile and clothing industry associations, can become full members of the association. Merchant houses, trade representatives, textile and clothing industry suppliers, associations from these fields and testing institutes can become support members. The association currently has approx. 60 members. First of all, manufacturers' labels are awarded only for products sold in the Federal Republic; full European introduction has been postponed. The guaranty seals can be applied for irrespective of association membership; for members however the associated cost is small. According to association rules, guaranty seals can also be awarded for foreign products irrespective of production location as long as they fulfil the criteria laid down. The label erects no trade barriers in this respect.

The M.S.T. differentiates between six product groups:

1. Clothing textiles:
   - outerwear, lining fabrics, industrial protective clothing
   - shirts, blouses, sportswear
   - nightwear, underwear, stockings
   - baby clothing and small children's wear.
2. Home and household textiles:
   - table linen, decor fabrics, curtains, furnishing fabrics
   - bed linen, blankets, bath textiles.

The criteria are grouped in Tabs. 12–14.

Features	**Supplier details specification***	**Production note**	**Test specification** **a) obligatory** **b) recommended**
5. Heavy metals	( ) Cr (total) ≤ 20 ( ) Cr (VI) = undetectable ( ) Cu ≤ 100 ppm ( ) Ni ≤ 10 ppm ( ) Co ≤ 10 ppm ( ) Other...		a) extraction with perspiration solution in accordance with DIN 54 020 (test solution 2) b) AAS
6. Nickel content in accessory components, extractable proportion	( ) Ni ≤ 10 ppm		a) extraction with perspiration solution in accordance with DIN 54 020 (test solution 2) b) AAS
7. Dyeing auxiliary agents use of carriers	Carrier based on aromatic compounds derived from • chlorine ( ) used ( ) not used • biphenyl ( ) used ( ) not used		
8. Fastness to perspiration recommended Note 3 – 4	( ) acidic/score… ( ) alkaline/score…		a) DIN 54 020
9. Fastness to water recommended Note 3	( ) strict standards/score…		a) DIN 54 006
10. Fastness to saliva	( ) yes ( ) no	with children's wear	a) DIN 53 160
Was an eco-certificate (e.g. eco-tex, M.S.T.) issued/requested? ( ) no ( ) yes, which:			

Tab. 5: DTB eco-info (2) (according to BASF).

Product group	**A** **away from the skin**	**B** **next to the skin**	**C** **baby clothing**
pH value DIN 54 276	4.8 – 7.5	like A	like A
DIN 54 275	4.0 – 7.5 (Wo)		
Formaldehyde Law 112 [ppm]	300	75	20
Heavy metals [ppm]			
Mercury	0.1 (cotton)		0.02 (cotton)
Copper	50		10
Chromium (total)	20		1
Chromium (VI)	undetectable		like A
Cobalt	20		1
Nickel	10		1
Pesticides (total) [ppm]	1	like A	like A
Azo dyes			
Reductive splitting MAK List III A 1 and A 2	undetectable	like A	like A
Colour fastness	(pigment)		
heavy water	3	like A	like A
wash 40°C	3 – 4	"	"
acid perspiration	3 – 4	"	"
alkaline perspiration	3 – 4	"	"
fastness to dry rubbing	4 (3)	"	"
fastness to wet rubbing	2 – 3 (2)	"	"
fastness to saliva	–	–	yes
PCB	undetectable	like A	like A
PCP [ppm]	0.5	like A	like A
Odour testing	textiles may not reveal an odour foreign to the product		

Tab. 6: OTTO, Hamburg, ecotextile material requirements (according to BASF).

As a manufacturers' label, M.U.T. guarantees very far-reaching requirements as regards environmentally compatible production processes in addition to the product-related criteria of M.S.T., e.g. in effluent purification, clean air maintenance and waste disposal. In addition, specific substances must not be employed in production (Tabs. 15–18). This manufacturers' label is to be provisionally awarded for preliminary stage products, but not for finished products. The seal was introduced to the market after overcoming objections by the federal environment authority and consumer organisations, that "only" the legal regulations in the Federal Republic are stipulated here. New criteria (e.g. specific loadings in regard to effluent, exhaust air etc. relative to the finished material) are also under consideration.

VIII. The foundation of the International Association for Research and Testing in the field of textile technology (Eco-Tex) with various standards was announced at Interstoff 1993 in Frankfurt by the Vienna and Hohenstein textile research institutes. The association is now active in over 10 countries. With the label "Tested for harmful substances in accordance with eco-tex standard 100", the eco-tex standard includes general conditions for labelling entitlement. The eco-tex standard differentiates between 12 different product groups:

- general award conditions – 100
- textile fabrics (woven and knitted fabrics and nonwovens) for clothing, excluding baby clothing – 101
- clothing accessories, excluding baby clothing (e.g. zip fasteners, buttons, fasteners, shoulder pads, nontextile applications) – 102
- clothing, excluding baby clothing – 103
- textile fabrics (woven and knitted fabrics and nonwovens) for baby clothing – 104

- baby clothing accessories (e.g. zip fasteners, buttons, fasteners, shoulder pads, non-textile applications) – 105
- baby clothing – 106
- textile floor coverings – 107
- textile wall coverings – 108
- decor fabrics and curtains – 109
- furnishing fabrics – 110
- blankets and pillows – 111
- bed linen – 112
- test procedures – 200.

Tab. 19 shows the human ecological limit values suggested for the individual product groups. The eco-tex standard is to be flexible; accordingly the limits are therefore to be adapted to the latest information. It is understood to be a scientifically based list of criteria for the human ecological properties of textile products with their associated testing and control system, which represents the basis of label entitlement.

IX. TOX-PROOF: German Control International, a subsidiary of the TÜV Rheinland, has designed a criteria catalogue with three different requirement profiles which are listed in Tabs. 20–22. The tests are implemented by the Textil-Express-Service of German Control International, which guarantees a laboratory and analysis service with certificate within 5 working days at a fixed price per test sample and test type.

The requirements laid down for awarding the labels discussed above

- eco-tex,
- EPG,
- M.S.T.,
- TOX-PROOF

are similar in many cases; there are differences however. The criteria for the various labels plus requirements by Eco-Info for better comparability are compared in Tabs. 23–25.

X. Der Arbeitskreis Naturtextilien e.V. (AKN) (The Natural Textiles Association) has been in existence since 1991, and includes approx. 20 home and foreign textile firms. The purpose of the association is

- to promote the production and use of natural fibres,
- to dispense with chemical finishing processes,
- to dye only with vegetable or harmless synthetic dyestuffs,
- to allow independent institutes to conduct regular tests on any residues (pesticides, herbicides, formaldehyde, heavy metals).

XI. EU environment trade-marks and eco-audit are not exclusively relevant to textiles. They can however be used for textile products and processes too.

1. EU ecolabels: on 23.3.1992, the EU Commission laid down Regulation No. 880/92 of the Council in which a system valid within the EU for awarding an ecolabel was established. The aim of the Commission is to promote the development, production, sale and use of products which have a negligible effect on the environment throughout their service life.

The ecolabel can be awarded for products which comply with the above-mentioned aims and the health, safety and environmental requirements of the Union. The conditions for awarding the ecolabel are deter-

Parameter	eco-tex **(Traditional)** **February 1993 status**	eco-tex **(Human)** **February 1993 status**	eco-tex **(Natural)** **February 1993 status**
1. Dyestuffs, which can split off amines on MAK lists III A 1 und A 2 Other dyestuffs which are classed as cancer-inducing	undetectable	undetectable	undetectable
2. Organic chlorine carriers	undetectable	undetectable	undetectable
3. Flame retardant finishing	undetectable	undetectable	undetectable
4. Biocide finishing	undetectable	undetectable	undetectable
5. Fastness to persipiration	acidic 3 – 4 alkaline 3 – 4	acidic 3 – 4 alkaline 3 – 4	acidic 3 – 4 alkaline 3 – 4
6. Fastness to water	3	3	3
7. Fastness to saliva and persipiration	yes	yes	yes

Tab. 7: eco-tex award criteria (1) (according to BASF).

Parameter	eco-tex (Traditional) February 1993 status	eco-tex (Human) February 1993 status	eco-tex (Natural) February 1993 status
8. Heavy metals	[mg/l]	[mg/l]	[mg/l]
As	0.01	0.01	0.01
Pb	0.04	0.04	0.04
Cd	0.005	0.005	0.005
Hg	0.001	0.001	0.001
Ni	0.2	0.2	0.2
Cu	3.0	0.2	0.2
Cr (VI) as total chromium	–	–	–
Cr (III)	0.1	0.1	0.1
Co	0.2	0.2	0.2
Zn	5.0	5.0	5.0
9. Pesticides	[mg/kg]	[mg/kg]	[mg/kg]
DDT	1.0	0.5	0.05
HCH (α and β–hexachlorocyclohexane)	0.5	0.2	0.05
lindane (γ–hexachlorocyclohexane)	1.0	0.5	0.05
aldrin	0.2	0.2	0.05
dieldrin	0.2	0.2	0.05
2,4-dichlorophenoxyacetic acid	0.1	0.05	0.05
2,4,5-trichlorophenoxyacetic acid	0.05	0.05	0.05
toxaphene	0.1	0.05	0.05
Pentachlorophenol (PCP)	0.5	0.2	0.05
Total limit:	**1.0**	**1.0**	**1.0**
10. Free formaldehyde	[ppm]	[ppm]	[ppm]
Clothing textiles:			
outerwear, industrial protective clothing	600	500	500
lining fabrics	600	300	300
shirts, blouses, sports textiles	300	300	300
nightwear, underwear, stockings	75	75	75
textiles for babies and small children	20	20	20
Household and domestic textiles: table linen, decor fabrics, curtains, furnishing fabrics, bed linen, blankets, bathing textiles	no known data	no known data	no known data
11. pH value of the aqueous extract	4.5 – 7.5	4.5 – 7.5	4.5 – 7.5
award conditions: award of the eco-tex seal on the basis of advisory services (car certification) with random sample type testing. Neither the test institutions nor the random sample test plan are known.			

Tab. 8: eco-tex award criteria (2) (according to BASF).

Parameter	Requirements 2/93 status
1. Dyestuffs, which can split off amines on MAK lists III A 1 und A 2 **Other dyestuffs which are classed as cancer-inducing**	Undetectable
2. Organic chlorine carriers	Undetectable
3. Flame retardant finishing	No requirements
4. Biocide finishing	No requirements
5. Fastness to persipiration	Staining of attendant fabrics is no criterion for harmful substance availability (results of the Federal Health Authority working group are awaited).
6. Fastness to water	Staining of attendant fabrics is no criterion for harmful substance availability (results of the Federal Health Authority working group are awaited).
7. Fastness to saliva and persipiration	Textiles for babies and small children
8. Heavy metals	[mg/l]
As	0.01
Pb	0.04
Cd	0.005
Hg	0.001
Ni	0.2
Cu	3.0
Cr (VI)	–
Cr (III) as total chromium	0.1
Co	0.2
Zn	5.0

Tab. 9: EPG award criteria (1) (according to BASF).

Parameter	Requirements 2/93 status
9. Pesticides	[mg/kg]
DDT	1.0
HCH	0.5
(α and β–hexachloro-cyclohexane)	
lindane (γ–hexachloro-cyclohexane)	1.0
aldrin	0.2
dieldrin	0.2
2,4-dichlorophenoxyacetic acid	0.1
2,4,5-trichlorophenoxy-acetic acid	0.05
toxaphene	0.1
pentachlorophenol (PCP)	0.5
Total limit:	**1.0**
10. Free formaldehyde	[wt. %]
Clothing textiles:	
outerwear, industrial protective clothing	0.06
lining fabrics	0.06
shirts, blouses, sports textiles	0.03
nightwear, underwear, stockings,	0.075
Textiles for babies and small children	0.002
Household and domestic textiles:	
table linen, decor fabrics,	0.06
curtains, furnishing fabrics,	0.06
bed linen, blankets,	0.03
bathing textiles	0.03
11. pH value of the aqueous extract	4.5 – 7.5
Other requirements:	Quality criteria not broken down into greater detail. Basis ISO 9000 – 9004, 4 out of 7 production stages are to be processed in the European economic theatre
award conditions	not known

Tab. 10: EPG award criteria (2) (according to BASF).

Ecolabelling of textiles

mined by product group. The EU Commission has already formulated an initial list of product groups, for which however award criteria still have to be drawn up. Denmark is currently empowered to clarify whether an EU label is appropriate for T shirts and bed linen.

The award system is based on voluntary participation. Currently existent national ecolabels can be retained. In the longer term however, the EU will be introducing a standard ecolabel. After being awarded, the ecolabel may be used in advertising the specific product. Producers and importers in the EU can submit applications for the award of an ecolabel only to an authorised office. This is named by the member state in which the product is marketed for the first time.

2. EU Eco-Audit: EU Ministers for the Environment have formally passed the EU Eco-Audit guidelines in Luxembourg. In accordance with this regulation, No. 1836/93 of the EU Council/Commission of 29.6.1993, industrial firms in the EU have the possibility of participating in periodic voluntary tests designed to record the constant improvement of industrial environmental protection. The EU has created an association system for environmental management and environmental plant testing, and will select and accredit testers in the member states.

Test for freedom from harmful substances
- Pentachlorophenol
- Formaldehyde
- Pesticides
- Butadiene
- Vinyl chloride

Excluded from use
- Asbestos
- Highly volatile chlorofluorocarbons
- Dye carriers
- Azo dyestuffs, the amine components of which are grouped in MAK III A 1

Emission, limit for individual components [mg/m^3]

• Toluene	0.2
• Styrene	0.01
• Vinylcyclohexane	0.002
• 4-Phenylcyclohexen	0.03

Emission, limit for individual Total parameters [mg/m^3]

• Aromatic hydrocarbons	0.5
• Volatile organic substances	1

Odour test*: < 4

*score1 – 5	1 odourless
	2 light odour
	3 tolerable
	4 disturbing
	5 intolerable

Tab. 11: GuT award conditions (according to BASF).

Parameter	Testing method	Requirement
No use of dyes which can split off amines on MAK lists III A 1 and III A 2. No use of other dyes which are classed as cancer-inducing	Extraction, reductive splitting off, identification of cleavage products by DC or spectroscopic methods	Undetectable
No use of dyes which give rise to the "leggings" allergy with acetate (C.I. Disperse Blue 106 and 124)	Extraction, identification with DC or spectroscopic methods	Undetectable
No use of organic chlorine carriers in the dyeing process	Extraction/GC	Undetectable
No flame retardant finishing		Excludes award
No biocide finishing		Excludes award
Attendant fabric staining in accordance with	DIN 54 020	Attendant fabric staining is no criterion for harmful substance availability. From the ecotoxicological standpoint, textile working group results are awaited by the Federal Health Authority.
Attendant fabric staining in accordance with	DIN 54 006	

Tab. 12: M.S.T. criteria catalogue for clothing, household and domestic textiles, 8/93 status (1) (according to BASF).

Parameter	**Testing method**	**Requirement**
Heavy metals: dependence on drinking water directive	From the eluate in accordance with eco-tex standard 200, item 3.1.1 Cr(VI) DPC process, otherwise AAS	[mg/l]
As		0.01
Pb		0.04
CD		0.005
Hg		0.001
Ni, Co		0.2
Cu		3.0
CR (VI)		-
Cr (III)		0.1
Zn		5.0
pH value of the aqueous extract	DIN 54 276, 54 275	4.5 – 7.5
Pesticide and plant protective agent maximum quantities directive	Extraction, Gas chromatography	
		[mg/kg]
2.4.5-T*		0.05
aldrin		0.2
dieldrin		0.2
HCH, with no lindane		0.5
DDT, lindane, 2.4-D**, toxaphene		1.0
Total limit:		1.0
PCP		0.5

* T = trichlorophenoxyacetic acid
** D = dichlorophenoxyacetic acid

Tab. 13: M.S.T. criteria catalogue for clothing, household and domestic textiles, 8/93 status (2) (according to BASF).

0.06%	outerwear, lining fabrics, industrial protective clothing, table linen, decor fabrics, curtains, furnishing fabrics
0.03%	shirts, blouses, sports textiles, bed linen, blankets, bathing textiles
0.0075%	nightwear, underwear, stockings
0.002%	textiles for babies and small children

* The figure 0.002% is equivalent to the analytic method detection limit, and means that no formaldehyde was used.

Fastness to saliva and persipiration (DIN 53 160)

yes	textiles for babies and small children

Tab. 14: M.S.T. criteria catalogue for clothing, household and domestic textiles, 8/93 status (3) (according to BASF).

1. Effluent discharge	Compliance with the following limits* must be ensured in the case of discharge into a **water course**		Comments
		[mg/l]	
	COD	160	Detection by suitable equipment or individual detection
	BOD_6	25	
	N total	20	
	P total	2	
	Hydrocarbons	10	
	AOX	0.5	
	Free chlorine	0.3	
	Sulphide	1.0	
	Chromium VI	0.1	
	Chromium total	0.5	
	Copper, Nickel each	0.5	
	Zinc, Tin each	2.0	

* The limits comply with appendix 38 of the framework effluent management regulation for direct dischargers

Tab. 15: M.U.T production condition requirements, 2/93 status (1) (according to BASF).

2. Dry cleaning **effluent discharge**	Compliance with the following limits must be ensured in the case of discharge:		Comments
	AOX	0.5 mg/l with a filling quantity > 50 kg of pollution product	Detection by suitable equipment or individual detection
	AOX	0.25 mg/kg 1 hour's pollution with a filling quantity > 50 kg of pollution product	

Tab. 16: M.U.T production condition requirements, 2/93 status (2) (according to BASF).

3. Clean air maintenance	In accordance with the current state of the art	Criteria are laid down depending on the development of exhaust air treatment in accordance with the current state of the art
4. Exhaust air treatment when operating dry cleaning plant	a) Plants with no suction exhaustion LHKW < 25 g/m^3 drum zone temp. > 30°C b) Plants with suction exhaustion LHKW < 200 g/m^3 filling quantity capacity < 30 kg/m^3 LHKW < 100 mg/m^3 filling quantity capacity > 30 kg/m^3	Detection by suitable equipment
5. Waste disposal	Single component collection of waste/residual substances; controlled disposal	Official disposal verification

Tab. 17: M.U.T production condition requirements, 2/93 status (3) (according to BASF).

6. Material use		
6.1 Pretreatment	Bleaching	Dispensing with the use of • Sodium hypochlorite • APEO-based washing and dry cleaning agents
	Mercerising	Caustic soda recovery on continuous mercerising machines
6.2 Dyeing		Dispensing with the use of • Potassium bichromate as oxidising agent • Copper sulphate for improving fastness • Organic chlorine carriers

Tab. 18: M.U.T. exclusion catalogue (4) (according to BASF).

Eco-tex standard	101		102	103	104	105	106	107	108	109	110	111	112
pH value DIN 54276	4.8 – 7.5		–	=101	=101	–	=101	=101	–	=101	=101	=101	=101
DIN 54275 (Wo)	4.0 – 7.5												
Formaldehyde													
Law 112 away from the skin	300 (75*)		=101	=101	20	20	20	800		800	75	75	75
[ppm] emission								0.1	0.1	0.1			
Heavy metals [ppm]													
Mercury	0.1**				0.02**		=104				=101	=101	=104
Copper	100			=101	30		"						
Chromium (total)	20				1		"						
Chromium (VI)	undetectable						"						
Cobalt	20		undetectable		1		"						
Nickel	10				1	=102	=102			=101			
Pesticides (total) [ppm]	5		=101	=101	1	=101	=101	=101	=101		=101	=101	=101
Azo dyes													
Reductive splitting MAK List III A 1 and III A 2	undetectable		=101	=101	=101	=101	=101	=101	=101	=101	=101	=101	=101
Colour fastness		(Pig.)											
Heavy water	3		=101	=101	=101	=101	=101	=101		=101	=101	=101	=101
Wash according to care labelling	3 – 4		"	"	"	"	"	"		"	"	"	"
acid perspiration	3 – 4		"	"	"	"	"	"		"	"	"	"
alkaline perspiration	3 – 4		"	"	"	"	"	"		"	"	"	"
fastness to dry rubbing	4	(3)	"	"	"	"	"	"		"	"	"	"
fastness to wet rubbing	2 – 3	(2)	"	"	"	"	"	"		"	"	"	"
fastness to saliva		–	–	–	yes	yes	yes	–		–	–	–	–
Highly volatile and odour-forming components													
total parameter [mg/m^3]								Δ					
Aromatic hydrocarbons "								1					
Volatile organic substances "								5					
Odour test, Note								3					

* next to skin
** only cotton

Δ Butadiene and vinyl chloride emission is still established

Tab. 19: Eco-tex standard criteria catalogue (according to BASF) (in German Ökotex 100).

Parameter	100	500	1 000
1. Dyestuffs, which can split off amines on MAK lists III A 1 and A 2. Other dyestuffs which are classed as cancer-inducing	benzidine permitted up to 100 mg/kg, no information on other MAK amines	undetectable	undetectable
2. Organic chlorine carriers	Δ	Δ	Δ
3. Flame retardant finishing	Δ	Δ	Δ
4. Biocide finishing	Δ	Δ	Δ
5. Fastness to persipiration	Δ	outerwear: fastness score 3 – 4 textiles for babies: fastness score 3 – 4	outerwear: fastness score 3 – 4 textiles for babies: fastness score 3 – 4
6. Fastness to water	Δ	outerwear: fastness score 3 textiles for babies: fastness score 3	outerwear: fastness score 3 textiles for babies: fastness score 3
7. Fastness to saliva and persipiration	Δ	textiles for babies: fast to saliva	textiles for babies: fast to saliva

Δ = no requirements

Tab. 20: TOX-PROOF criteria (1) (according to BASF)

Parameter	100	500		1 000	
8. Heavy metals		[mg/kg] outerwear:	Textiles for babies:	mg/kg] outerwear:	Textiles for babies:
As				0.1	0.01
Pb				20	1
Cd				20	1
Hg		0,1	0.02	0.1	0.02
Ni		10	1	10	1
Cu		50	10	50	10
Cr (VI)		undetectable			
Cr (III) as total chromium		20	1	20	1
Co		20	1	20	1
Zn				100	30
9. Pesticides	[mg/kg]	[mg/kg]		[mg/kg]	
DDT					
HCH (α and β–hexachloro-cyclohexane)					
lindane (γ–hexachloro-cyclohexane)					
aldrin					
dieldrin					
2,4-dichlorophenoxyacetic acid					
2,4,5-trichlorophenoxyacetic acid					
toxaphene					
pentachlorophenol (PCP)	5	0.5		0.5	
Total limit:		**1.0**		**1.0**	
10. Free formaldehyde	[mg/kg]	[mg/kg]		[mg/kg]	
Clothing textiles:					
outerwear, industrial protective clothing lining fabrics shirts, blouses, sports textiles nightwear, underwear, stockings textiles for babies and small children **Household and domestic textiles:** table linen, decor fabrics, curtains, furnishing fabrics, bed linen, blankets, bathing textiles	1500 valid for all products to be tested	outerwear • away from the skin 300 • next to skin 75 textiles for babies 20		outerwear • away from the skin 300 • next to skin 75 textiles for babies 20	

Tab. 21: TOX-PROOF criteria (2) (according to BASF).

Parameter	100	500	1 000	
11. pH value of the aqueous extract	4.5 – 7.5	4.8 – 7.5 4.0 – 7.5 (wool)	4.8 – 7.5 4.0 – 7.5 (wool)	
12. Other requirements				
fastness to wash at 40°C	3 – 4	3 – 4	3 – 4	
fastness to dry rubbing	4	4	4	
fastness to wet rubbing	2 – 3	2 – 3	2 – 3	
PCB	May not be detectable	May not be detectable	May not be detectable	
nickel	0.5 µg/cm²/week (in the accessories)	0.5 µg/cm²/week (in the accessories)	0.5 µg/cm²/week (in the accessories)	
Pesticides:		Methoxychlor, DDD, DDE, heptachlor, malathion, mirex, heptachloroepoxide, parathion, sevin	Methoxychlor, DDD, DDE, heptachlor, malathion, mirex, heptachloroepoxide, parathion, sevin	
Sensory odour test:		2 – 3	2 – 3	
Metals:			Outerwear [mg/kg]	Textiles for babies [mg/kg]
Sb			20.0	1.0
Ba			100.0	30.0
Se			100.0	30.0

Tab. 22: TOX-PROOF criteria (3) (according to BASF).

Parameter	Accordance	Variation	Institution
1. Dyestuffs, which can split off amines on MAK lists III A 1 und A 2. Other dyestuffs which are classed as cancer-inducing	undetectable	Benzidine permitted up to 100 mg/kg, no information on other MAK amines ( ) not used ( ) used ( ) check, as not known	TOX-PROOF 100 eco-info
2. Organic chlorine carriers	undetectable	no requirements ( ) used ( ) not used	M.S.T., eco-tex eco-info
3. Flame retardant finishing	no requirements	undetectable excludes award	eco-tex M.S.T.
4. Biocide finishing	no requirements	undetectable excludes award	eco-tex M.S.T.
5. Fastness to persipiration	acidic 3 – 4 alkaline 3 – 4	no requirements required, no ratings attendant fabric staining is no criterion for harmful substance availability	TOX-PROOF 100 eco-info M.S.T.
6. Fastness to water (strict standards)	3	attendant fabric staining is no criterion for harmful substance availability required, no ratings no requirements	M.S.T., EPG eco-info TOX-PROOF 100
7. Fastness to saliva and persipiration	Textiles for babies and small children	no requirements no information	TOX-PROOF 100 eco-tex

Tab. 23: Criteria comparison (1) (according to BASF).

Parameter	Accordance		Variation	Institution
8. Heavy metals	[mg/l]	[mg/kg]		
As	0.01	0.2		
Pb	0.04	0.8	depending on product group	Eco-tex
Cd	0.005	0.01		
Hg	0.001	0.02	no values	TOX-PROOF 100
Ni	0.2	4	other values	TOX-PROOF 500
Cu	3	60	"	TOX-PROOF 1000
Cr (VI)	–	–	"	Eco-info
Cr (III) as total chromium	0.1	2		
Co	0.2	4		
Zn	5	100		
9. Pesticides	[mg/kg]			
DDT	1.0		no individual limit values	Eco-tex
HCH (α and β–hexachlorocyclohexane)	0.5		"	Eco-info
lindane (γ–hexachloro-cyclohexane)	1.0		no information	TOX-PROOF 100, 500, 1000
aldrin	0.2			
dieldrin	0.2			
2,4-dichlorophenoxyacetic acid	0.1			
2,4,5-trichlorophenoxyacetic acid	0.05			
toxaphene	0.1			
pentachlorophenol (PCP)	0.5		5.0	TOX-PROOF 100
Total limit:	**1.0**			
10. Free formaldehyde	[wt. %]	[ppm]		
Clothing textiles:				
outerwear, industrial protective	0.06	600	other limit values	Eco-tex
clothing	0.06	600	1000 ppm	Eco-info
lining fabrics	0.06	600	500, 300 ppm	Eco-tex
shirts, blouses, sports textiles	0.03	300	1500 mg/kg	TOX-PROOF 100
nightwear, underwear, stockings	0.0075	75		
textiles for babies and small children	0.002	20		
Household and domestic				
textiles: table linen, decor	0.06	600	other limit values	Eco-tex
fabrics, curtains,			no known data	Eco-tex
furnishing fabrics	0.06	600	no information	TOX-PROOF 100, 500, 1000
bed linen, blankets, bathing textiles	0.03	300		Eco-info
11. pH value of the aqueous extract	4.5 – 7.5		4.8 – 7.5	Eco-tex
			4.0 – 7.5 (wool)	TOX-PROOF 500, 1000

Tab. 24: Criteria comparison (2) (according to BASF).

Parameter	eco-tex	EPG	TOX-PROOF 100	TOX-PROOF 500	TOX-PROOF 1 000	Eco-Info
Other requirements which are not contained in M.S.T.	fastness to washing, fastness to rubbing, dry/wet	quality criteria no longer classified	fastness to washing at 40°C 3 – 4	fastness to washing at 40°C 3 – 4	fastness to washing at 40°C 3 – 4	
	accessory products: limits for Cu, Cr, Co, Ni	basis: ISO 9000 – 9004	fastness to rubbing dry: 4 wet: 2 – 3 PCB may not be detectable	fastness to rubbing dry: 4 wet: 2 – 3 PCB may not be detectable	fastness to rubbing dry: 4 wet: 2 – 3 PCB may not be detectable	Eco-Info is replaced by awarding M.S.T or Eco-Tex
	formaldehyde emission (textile wall coverings, decor fabrics, curtains) max. 0.1 mg/kg		nickel: 0.5 µg/cm²/ week (in the accessories)	nickel: 0.5 µg/cm²/ week (in the accessories)	nickel: 0.5 µg/cm²/ week (in the accessories)	extractable nickel content in accessory products max. 10 ppm
	sensor odour testing					
	Eco-tex			other pesticides: methoxychlor, DDD, DDE, heptachlor, malathion, mirex, heptachloro-epoxide, parathion, sevin	other pesticides: methoxychlor, DDD, DDE, heptachlor, malathion, mirex, heptachloro-epoxide, parathion, sevin	
	none					
				sensor odour testing: 2 – 3	sensor odour testing: 2 – 3	
					other metals [mg/kg] outerwear: Sb 20 Ba 100 Se 100 textiles for babies: Sb 1 Ba 30 Se 30	

Tab. 25: Criteria comparison (3) (according to BASF).

Ecolabels

Ecolabels An ecolabel with well-founded, verifiable criteria provides the industry with the motivation for ecologically optimising textile products, security for the trade and confidence for the consumer in the textile product purchased. In this way, it fulfils the producer's obligations as to information on the one hand, and the buyer's safety requirements on the other. The textile chain should really be in a position to solve the problem of textile ecology itself, yet the German parliament had already set up a commission of enquiry in April 1992 into "Protection of mankind and the environment", involving itself in the "Textiles and clothing" study field for weighing the commercial benefit from clothing against the risks to mankind and environmental pollution, with the ultimate aim of "ecologically transforming" the industrial firm. Furthermore, in 1992, the Federal Health Authority set up a "textile" study group to determine the type and quantity of auxiliary textile products and dyestuffs remaining on textiles, and to evaluate their relevance to health. The most important instrument of a credible product seal is the basic criteria catalogue and the exact verifiability of all quoted data, for nothing would damage the standing of the textile sector more than disillusioned confidence in tested products as a result of the consumer's discovery of the contrary. An ecolabel based on this level can have a positive effect on ecology-oriented industrial standards as regards the product and its manufacture if it achieves a high requirement level, e.g. with the quality and reputation of the IWS virgin wool label. In this way, it largely ensures harmonisation of the ecolabel requirement profiles in the industrial sectors concerned. The specification of high but justifiable test criteria ensures confidence in the label, and, despite the cost, ultimately offers unequivocal market advantages for participating firms. On 3.6.1992, the "Consumer and Environment-Friendly Textile Association e. V." was founded. Since January 1993, it has awarded the "Harmful substance tested textiles label" and the "Environmentally friendly textiles label". One of this association's technical committees has laid down the product and production-related award conditions in accordance with joint suggestions on the part of the partners involved, and has formulated well-founded criteria catalogues for both labels, which have been available since January 1993 for the following collections. On acceptance of the design, the labels will comprise an uncomplicated logo with a "T" and a test number which can be followed up if need be. Notwithstanding, there are other ecolabels with high requirements too. The first to mention is the EU environmental label designed to inform the consumer before his or her decision to buy that the greatest possible level of environmental compatibility has been observed in every case at all stations of the life cycle of the product distinguished in this way (Fig. 1). A jury will decide whether to award the environmental label or not. This label does not however make a statement about the human ecological nature of the product, but it is well suited to enlighten the end-user on textiles.

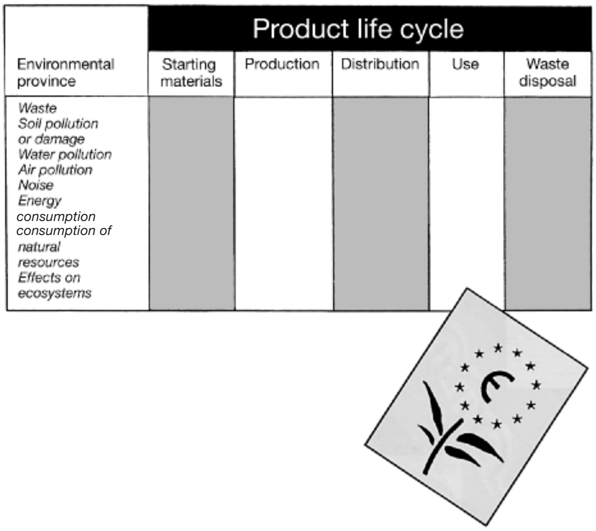


Fig. 1: Sketch of the EU eco-oriented quality label which covers the entire life cycle of a product.

The "Textiles tested for harmful substances in accordance with → Eco-Tex Standard 100 label of the International Association for Research and Testing in the field of textile ecology (supported by the Hohenstein Research Institute and 15 other European institutions) can already look back on international experience and a lengthy market presence (Fig. 2). Depending on end-

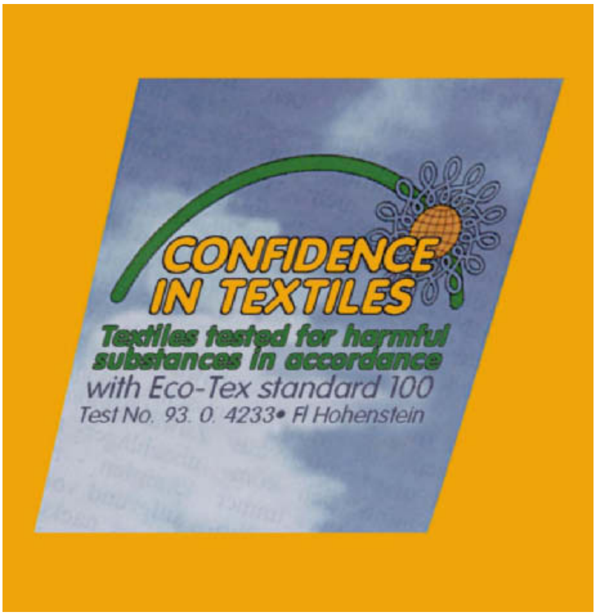


Fig. 2: Eco-Tex label of the International Association for Research and Testing in the textile technology field as an institutional initiative in cooperation with M.S.T. (Translation)

use, there are standards specific to product groups, and in eco-tex standard 200, a comprehensive, well-founded compendium of suitable test processes for granting entitlement to the eco-tex label, which others, be it by way of guidance or as a test institution to be brought in, make use of. This therefore involves an institute label which is available to anyone for his collection in availing himself of the test institution and complying with the product-related specifications for product labelling (also with a test number). Consequently, despite the same background, there is a definite difference to be seen in label entitlement by a national brand label sponsors' association.

A third initiative was also presented to technical circles on the occasion of the autumn Interstoff 1992 as a company-oriented industrial consortium eco-quality label, also based on a well-founded criteria catalogue. Under the "eco-tex" brand label (Fig. 3), this industrial consortium can, to its advantage, quickly react, stand by as a partner in an advisory capacity in fibre procurement, recipe and process creation, can arrange tests, and more quickly achieve success in the market from the advertising standpoint, particularly since the parties interested in this system, based on a legal guarantee of test results produced, exist on a wider basis.

Fig. 3: "eco-tex" label of an international consortium as a company initiative.

The "Eco-Info" of the "Textile Clothing Dialogue" is in fact also based on the test criteria of the ecolabels quoted, though no additional competitive label is to be created here. The initiators rather have in mind the rapid realisation within the member firms of the basic ecological requirements relative to the textile product in order to arrive quickly at clothing which is exemplary from the human ecological standpoint, and guarantee it accordingly. The Eco-Info therefore becomes a component of supply agreements between producer and customer. Target orientation is ultimately the same in this respect however (according to Hemmpel).

Ecological problems in textile dyeing, printing and finishing Textile problems form part of the overriding aspects of environmental protection, and are consequently stamped by the laws of growth, intensification and problem postponement. Evidence for this statement can be furnished by world textile consumption. If e.g. 30% of the cotton were to be replaced by synthetic fibres, approx. 200 g of bread could be produced per person per day by the increased foodstuff production made possible by that. Quantitative growth must of course be taken into account in the case of world textile consumption. The problems associated with this are revealed by the life cycle of a textile product. The associated field of requirements on "production, utilisation and disposal" life cycles must always be regarded as a complete package (Fig. 1).

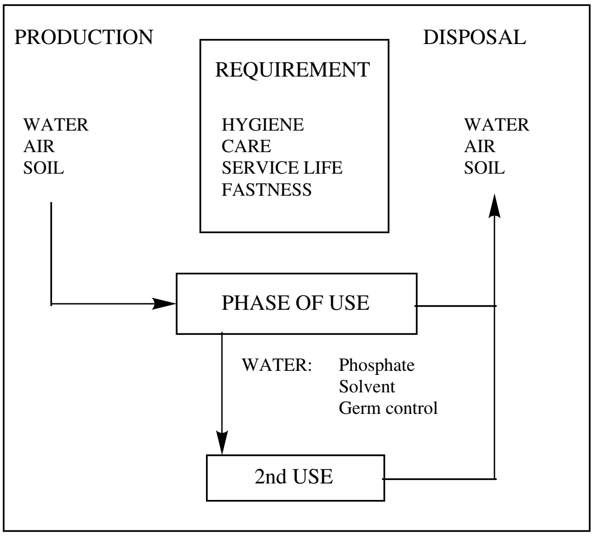


Fig. 1: Problem water, soil and air cycle in textile production.

A certain amount has already been achieved in the soil/water/air fields, but despite all these measures, consumer consciousness ultimately plays the decisive role, yet how is the consumer to decide whether he or she should buy wool, cotton or synthetic trousers (presuming identical shape and colour)? An integral way of looking at this is fundamentally necessary in the future. Environmental problems are of course evaluated differently depending on one's view of things. Objective discussion from the entrepreneur's standpoint appears to be a good prerequisite for influencing the bureaucratic handling of environmental regulations by the authorities. Difficulties with public sewage treatment plants understandably lead to requirements by textile finishers on their suppliers for dyestuffs and auxiliary products and also to doubts by entrepreneurs about their location in the Central European environment. The dyestuff and auxiliary product manufacturers rightly refer in this connection to the high cost of their environmental research, and make their advice available. The problem of the existence of textile finishing agents has received further publicity from an accident which happened at Sandoz in Basel on 1.11.1986, giving rise to significant warehousing changes after the nearby Rhine was contaminated by large quantities of water used for fighting a fire in a large dyestuff store.

The material classification situation as regards storage risks is not very clear at the national and interna-

Category	Characteristics	Danger symbol CEA/BVD	Examples
1.	Explosion hazardous/especially easily combustible substances	Ex	Picramic acid Sodium azide
2.	Spontaneously reacting, self-igniting substances	Fa	Acrylate Catalysts
3.	Combustible with water or developing combustible gases	Fh	Alkali metals Metal hydrides
4.	Developing toxic gases with water	Gh	Acid chlorides Fuming sulphuric acid
5.	Combustion-promoting, highly oxidating substances and peroxides	Ox	Nitrate of ammonium Hydrogen peroxide
6.	Combustible liquid substances with a flash point below 55°C	Fe	Acetone Toluene
7.	Combustible solids/combustion number 4+5	Fe	Activated charcoal Gamma acid
8.	Toxic, malodorous, water-endangering substances	Tx Yl Zl	Formaldehyde Thiourea Chloroform
9.	High pressure gases or liquefied gases in mobile pressure containers Spray cans, aerosol packs	Gp	Chlorine Ammonia Crop protection spray
10.	Not very critical solids/combustion number 1-3 Not very critical liquid substances with a flash point above 55°C	Fe Xn Nn	Maize starch Magnesium hydroxide Benzaldehyde Polyethylene glycol

Fig. 2: Storage categories.

tional levels (Fig. 2). The trend is towards detailed, danger-specific classification. In 1987, Sandoz was faced with the problem of undertaking a more sophisticated classification of its materials into storage categories. 10 categories were defined, and all materials handled by Sandoz (approx. 8000) classified accordingly. A specific order of danger in the event of fire can be deduced from the class sequence, class 1 being rated as the most dangerous, class 10 the least dangerous, though not rated as safe. The new danger symbols suggested by the European Insurance Board are included in Fig. 2. Danger-specific requirements for storage premises are laid down with this storage classification. The prerequisite for material classification in accordance with an improved system is however the availability of relevant analytical data. Unequivocal criteria are being produced for defining the danger to the atmosphere for example. The large majority of dyestuffs can be classed in category 10. There are however those dyestuffs in categories 6, 7 and 8, which, depending on whether they contain solvents (6), are more flammable (powder form) (7) or may have a toxic effect on human beings and the environment (8), i.e. nitrogen, sulphur, phosphorous or halogens are present.

Commercial forms of dyestuffs are not chemically homogeneous products. In order always to guarantee the same colour intensity, they are mixed during production with “standardising agents” (adjusting agents) such as different types of salt, complex formers, buffer substances, dedusting agents (mineral oil, phthalic ester), dispersing agents, emulsifiers and other substances which subsequently contaminate the effluent. For the purpose of better applicability, dyestuffs are marketed in different commercial forms: powder, granulate, paste and liquid dyes; the latter are relatively new, and have specific advantages. Initially, sulphur, vat and disperse dyes were offered in liquid form, followed by cationic and direct dyes, and, recently, reactive and acid dyes too. Liquid dyestuffs have the following advantages:

- they are dust-free;
- they need neither pasting nor dissolving, boiling nor cooling;
- they can easily be automatically metered.

Synthetic dyestuffs are dyed at temperatures between room temperature and 130°C; thermosol processing temperatures up to 200°C are also usual with polyester fibres. Selected auxiliary products are used for dyeing in order to achieve optimum results in terms of dyeing quality and the quality of the textile material produced in this way. Dyeing conditions depend on fibre material and class of dyestuff. Conversely, both dyestuffs and auxiliary products have been adapted to the constant development of textile fibres, dyeing machinery and processes and to ecological and economic requirements, or have been newly developed to that end. Current dyestuffs achieve bath exhaustion levels as high as 99%. On economic grounds, attempts are being made to improve yields in so far as levelness permits, as every kilogram of unused dyestuff which runs into the effluent has been paid for in vain.

Dyes which reach the sewage treatment plants are not usually decomposed during their dwell-time in aerobic biological sewage plants, but are largely adsorbed on to the sewage sludge, and consequently eliminated from the effluent. This also applies to many textile auxiliary products. One exception is reactive dyes which are only 80–85% fixed on the fibre at the maximum, and are not adsorbed on to the biological sludge to the same extent as other dyestuff classes either. Of the heavy metals which should be regarded as critical from the ecological standpoint, and the introduction of which into surface water courses and public sewage plants is strictly limited, only copper, chromium, nickel and cobalt occur in any quantity worth mentioning in premetallised dyestuff form. Here, the metal is coordinatively bonded as a central atom, and is adsorbed on the fibre with the entire molecule, depending on the degree of exhaustion in each case. Tetrachlorozincate is contained as a counter-ion in some cationic dyestuffs. Effluent contamination by heavy metals also occurs in textile finishing during the following processes: for wool dyeing, dyes which have to be after-treated with potassium dichromate in order to form a complex which is difficult to dissolve can be used for achieving particularly high fastness levels. The appearance of chromate and chromium(III) in the effluent is therefore inescapable, but is very limited legally.

Following the undisputed successes in the water protection field, interest is becoming increasingly concentrated on sanitary measures in regard to residual pollution flows from sewage plants, which are quantitatively small but difficult to combat. This largely involves organic chemical compounds from households, trade and industry which are difficult to break down. The textile industry, in which numerous chemicals are used in wet processing, is no exception here, often leaving a number of these "refractory" substances detectable in its effluent even after biological purification. DOC (dissolved organic carbon as an overall parameter for organic compounds as a whole) is also almost always increased; specific analysis, e.g. gas chromatography, may additionally indicate in detail the chemicals which are involved, yet the decisive question as to the effect on the environment of such small concentrations of residual impurities can hardly be answered: ecotoxicology is in fact under lively discussion internationally, but will be able to put forward better founded results only after intensive basic research. In the meantime, residual organic pollution must on the whole be regarded as a serious source of danger, and reduced if possible within the meaning of the legal definitions. To be handled with particular caution in this respect are substances, as listed in the table, which time and again, on the basis of long-standing observation and the interchange of experience with industrial specialists, continually give rise to effluent problems.

The degree of danger of processing materials, i.e. "classification" in terms of toxicity, is weighted with the main emphasis on acute oral toxicity and on the basis of the primary caustic or irritant effects. In each case therefore, testing is carried out first of all by means of basic tests. The results are communicated on safety data sheets. Acute oral toxicity is quantified by measuring LD_{50} values. According to German chemicals legislation, the LD_{50} (lethal dose) is the quantity of the product in mg/kg of body weight at which (with a single oral feed) 50% of the experimental animals die within 14 days. The following classifications are applied on the basis of the test results:

– very toxic	<25 mg/kg
– toxic	25 – 200 mg/kg
– negligibly toxic	200 – 2000 mg/kg
– unclassified	>2000 mg/kg

According to an ETAD study, the LD_{50} values of approx. 4500 commercial dyestuffs are

82%	>5000 mg/kg
10%	2000 – 5000 mg/kg
7%	250 – 2000 mg/kg
1%	<250 mg/kg
0%	<100 mg/kg

According to this, less than 10% of dyestuffs are in the health-endangering or toxic product group, the harmful effect in some cases possibly being due not to the actual dyestuff but to the auxiliary substances. To an increasing extent however, the potential long-term effects play a role in evaluating danger. In the sense of lasting environmental compatibility, this involves the so-called

Ecological problems in textile dyeing, printing and finishing

Substance group	Danger to water courses or sewage treatment plant	Necessary measures
Detergents (washing powders, wetting agents, auxiliary dyeing products etc)	Biologically difficult to break down products still on the market with consequently high residual ARA let-down pollution, particularly as dissolved organic carbon (DOC)	Change over to easily degradable products. Declaration of composition and biological degradation required
Organic complex formers	Difficult to break down types (particularly EDTA) can bring toxic heavy metals into solution (danger to water courses)	Water hardness agents (Ca, Mg) should be precipitated by inorganic softening agents, dissolved by degradable organic complex formers (e.g. NTA) or dumped.
Dyestuffs	Difficult to break down. Legal requirement (no receiving water discolouration) can often fail to be complied with. Ecotoxicological effects cannot be excluded in every case	Where necessary, dyestuffs should be precipitated from concentrated residual liquors in the works
Organic chlorine compounds (chlorinated solvents, rot resistant agents, specific carriers)	Environmentally dangerous substances which are generally difficult to break down. Water soluble compounds endanger water courses, while those which are not easily water soluble endanger the sewage sludge	Change over to products with no organically bonded halogen. Example: chlorine-free phenol derivatives as carriers are the lesser evil in comparison with chlorobenzenes! Pentachlorophenol (PCP) should be avoided as a rot-proofing agent
Sulphites, hydrosulphite, thiosulphate (stripping dyes, generally as reducing agents, e.g. “antichlor”)	Disruption of the biological stages of the sewage treatment plant by oxygen supply. Possible reduction to sulphide (toxic effect on microorganisms)	Limitation of use to the absolutely necessary. In use as “antichlor”, safety reserves are to be avoided. Special metering equipment has proved good in practice
Heavy metals (Cu, Cr, Zn, Cd and others)	Heavy metal compounds are mainly concentrated in the sewage sludge, endangering the soil in agricultural usage.	Use auxiliary products which are most free of heavy metals

Tab.: Water course endangering content substances of textile effluent.

“CMT effects”, i.e. carcinogenic = cancer-inducing, mutagenic = genotype-changing, and teratogenic = deformity-inducing effects.

The MAK commission has decided to insert a paragraph on “azo dyestuffs” in the section on cancer-inducing processing materials in the annually published MAK list. In this respect, the impression has been given by the media that all azo dyes are cancer-suspect, representing a health risk to processors and consumers alike. This kind of all-embracing statement is untrue however, because there are many substances in this class which have revealed no evidence of cancer-inducing potential in relevant animal experiments. Only a few azo dyestuffs used in practice, like benzidine dyes for example, have up to now provided any evidence of carcinogenicity in animal experiments. So-called azo splitting plays a part in evaluating the toxicity of azo dyes. Azo splitting means that azo dyes are reductively split under quite specific conditions, and aromatic amines (R-NH_2 and R’–NH_2) can form in consequence.

This process can be triggered both by reducing agents and in the organism, as long as the compounds are "bioavailable", and are evaluated under the effect of enzyme systems. With each substance of this class therefore a check should be made as to whether azo splitting can actually occur, and whether the potential occurrence of aromatic amines can be a health risk. In total, azo dyestuffs are a substance group embracing several thousand products. Health risks to the user can be suspected in only the small number of those azo dyes which contain carcinogenic aromatic amine components. Dyestuffs based on human carcinogenic amines, like benzidine dyes for example, have not been produced or marketed in many countries for a long time.

In the textile dyestuff field however, there are still amine-based dyes on the market which were carcinogenic in animal experiments. Further processors of the producing firms amalgamated with the ETAD have been voluntarily informed since the beginning of 1987 by means of customer circulars, safety datasheets and appropriate Xn and R 40 labelling (= possible irreversible damage) of the possibility of reductive splitting and the consequently conceivable potential dangers in the handling of these products. Use of these dyes for textile dyeing also appears quite safe for the future, as long as it can be ensured by appropriate work hygiene measures that exposure can be kept low enough virtually to exclude health risks. It can be said in terms of potential risk to the end user that the American Consumer Protection Safety Commission (CPSC) has carried out a series of trials on the extent to which this kind of dyestuff can be absorbed through the skin. No measurable skin penetration has been established in these trials, i.e. there is no danger to the end user from these types of textile dyes as far as is currently known, and textiles dyed with these azo dyestuffs can be worn quite safely. A series of screening tests, which are carried out with bacteria or on isolated cells for example, is available for testing for mutagenicity. Among the most well known is the Ames test, the value of which in terms of evidence is however disputed. Its importance lies particularly in the fact that further tests should be conducted in the event of a positive Ames test. Mutagenic (changing genetic make-up) and teratogenic (causing malformation in unborn children) effects due to the practical handling of textile dyestuffs and auxiliary products have not been noted to date. In addition to the CMT effects, potential sensitising effects also merit particular attention. Allergies cause irksome skin reactions (e.g. itching or weeping eczema or pustule formation) and also, in rare cases, dangerous respiratory disorders, which, beginning with sneezing and running eyes, can extend to asthmatic attacks. By far the largest number of allergies are triggered by natural products like plants or plant particles (hay fever), flour or fish and other food proteins. Of the products used in the textile industry, auxiliary products which split off formaldehyde, and some reactive dyestuffs, have triggered allergies during processing in a few cases.

Environmental protection regulations require the responsible use and management of solvents in textile cleaning with the aim of preventing solvent loss. Waste resulting from blowing and filtering is registered as special refuse, because it contains residual matter. This type of waste is therefore removed by special firms, and environmentally responsibly processed. The American Environmental Protection Authority (EPA) has developed a special refuse model which can be used in graphic combination on cartridge and filter powder residues. Source reduction and prevention have priority, followed by re-utilisation, combustion (heating value) and dumping.

The variety of environmental protection problems faced by the textile sector is evident. All environmental protection regulations related to material have their origin in good analysis. This complicated field of activity is called "environmental analysis". It is understandable that, with this variety of materials and the constantly changing concentrations and mixtures of substances in effluent, complete logging and control of all substances must remain impossible. Environmental analysis presupposes a great deal of well-founded knowledge, and requires a good deal of understanding of the interrelationships. In addition to well-founded textile chemical knowledge of the substances employed in textile finishing, the analyst has to be familiar with the typical chemical functions of all product groups such as textile auxiliary products and finishing agents for example.

a) Chemically unchanged oils and fats:
- lubricants, flushing oils, sizing agents, auxiliary chemical finishing agents.

b) Surfactants:
- wetting, scouring and fulling agent,
- boiling off, kiering, bleaching and mercerising auxiliary products,
- dyeing and printing auxiliary products,
- levelling and brightening agents and emulsifiers.

c) Polysaccharides:
- sizing agents,
- finishing agents,
- thickeners.

d) Enzymes:
- desizing agents.

e) Synthetic polymers:
- permanent finishing, anti-felt finishing,
- water repellence, oil repellence,
- antistatics, flame retardant finishing.

Without environmental protection analysis,
- the extent of the presence of substance pollution cannot be established,

- no targeted measures can be initiated for preventing environmental pollution,
- the success of such measures cannot be established,
- pollution limits cannot be defined and established,
- no legal requirements can be laid down for eliminating existing pollution and preventing fresh pollution.

Consumer protection, legal liability, quality awareness, and price-oriented and above all cost-conscious purchasing behaviour have encouraged complaints, for the frequency of claims on the part of the consumer has increased. The textile industry sees itself facing a changed situation. It is no longer possible for producers to exclude or limit their responsibility by their own general trading conditions, and consequently liability claims are on the increase, and additional costs for new liability insurance are also in store for textile mills. The end-user expects high-quality characteristics in accordance with the promises made in advertising and product labelling, for quality textiles are not cheap. The textile finisher has to guarantee this property profile, which is based on promises and expectations. To this end is a wealth of national statutory regulations covering garanties in respect of product deficiency and also in the case of damage which a product causes to people or other material goods (standard EU product liability for so-called damage due to defects). A range of important focal points in regard to quality assurance, planning, control and testing stems from the standpoint of this liability on the part of the textile finisher, and therefore of all producers of consumer goods. Safety data sheets are important in considering a situation, as the textile finisher can easily be the cause of environmental damage. Numerous environmental regulations control textile chemical finishing processes in the Federal Republic of Germany. On this point, the European Common Market will encroach on states not yet affected, and will not make textile finishing any easier. This concerns not only the handling of chemicals, but also the danger to effluent, the pollution of exhaust air and the production environment, the disposal of residual liquors, waste and sewage sludge and also the physiological effect of "chemistry" on the consumer by way of textile products. Concepts such as environmental liability legislation and environmental criminal law underline the entire problem.

In the future, textile chemistry, and consequently textile finishing too, can no longer be divorced from environmental requirements. Problems like reducing the quantities used, optimum utilisation of liquor baths, residual liquor disposal, effluent disposal in chemical finishing, after-burning or cleaning stenter exhaust air etc. raise questions which affect the textile finisher more than ever. Legal requirements on water treatment and exhaust air emission are already in existence. Legal measures like environmental liability legislation and environmental criminal law are already in place in many European countries. Few fundamentally new finishing agent or dyestuff discoveries are to be expected in the future, particularly as there is hardly any profit in announcing completely new chemical compounds. There will however be continuous product optimisation and also the creation of new ready-for-use preparations which will enable the textile finisher to optimise application and effects, and to gain quick access to market requirements, creating new requirement profiles for textile products. This however is the textile finisher's great opportunity for innovation.

Future developments are currently aimed for example at micro-encapsulating the widest variety of active substances, at seamless sewing techniques, textile auxiliary products which destroy themselves at the end of the process for ecological reasons, and also, for example, structuring smooth fibres by laser beams, a process which can produce interesting effects. However, future activities not only involve the diverse technical developments. For the future, the "province of the textile finisher" will rather set the dominant tasks, such as quick adaptation to market requirements, reducing energy and water requirements, improving effluent treatment, eliminating exhaust air problems, reducing handling, automating production technology, measures for quality assurance and attention to product liability questions. This includes moreover improving measuring and testing methods, guaranteeing physiologically safe textiles, and all this in collaboration with the upstream and downstream links of the textile production and sales chain (according to Brune, Dierkes, Rosenthal, Wentz, Loss, Widmer, Schefer and Hemmpel).

Ecology (Greek: oikos = dwelling; logos = science). Concept of the science of relationships in the living organism/environment system introduced in 1866 by Ernst Hackel. Ecological equilibrium is based on the natural capacity for self regulation between different links of a long-term relationship (xenobiosis). This equilibrium is affected, disrupted or even broken up by massive environmental pollution. Ecological problems upset nature's equilibrium. This happens to some extent in the textile industry due to textile finishing. All resources are ultimately converted into waste by human activity. Positively expressed, waste is therefore resources in the wrong form, in the wrong place or wrongly distributed, being found, in thermodynamic terms, in a condition of increased entropy, mainly in mixed or diluted forms. Generally speaking, with all energy conversion, i.e. with all civilising activities like industrial production or motoring, entropy is produced in the form of heat emission to the environment, pollution emission into the air, on to the ground or into the water. Due to the constantly increasing quantities required by the earth's increasing population therefore, human/environment relationships are characterized by increasing utilisation

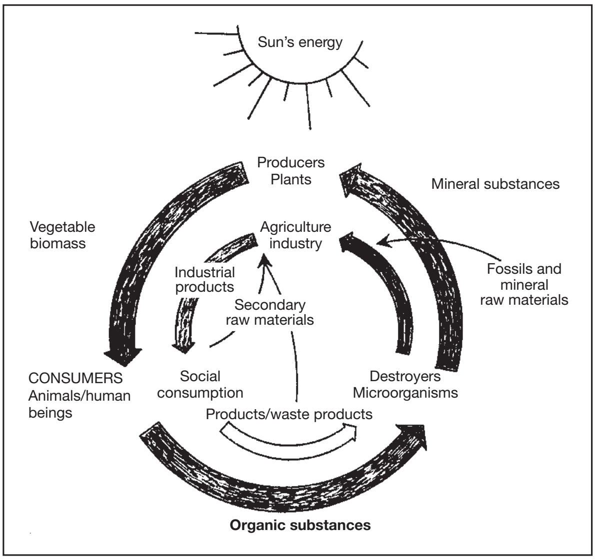


Fig. 1: Metabolism between mankind and nature: outer, natural cycle with the synthesis and break-down of substances of an organic nature, to which many products of the inner, industrial product cycle can be transferred only with great energy expenditure (according to DTNW).

of and changes in the natural environment. The resultant intensified metabolism between mankind and nature (Fig. 1) gives rise on the one hand to decreased dependency on the natural environment, and also a weakened relationship with the environment in the sense of the physiocentric concept of "the age we live in". The build-up and extension of the self-created environment creates fresh dependencies on the other hand due to the extent and the intensification of natural resource utilisation. Awareness of the need for protective measures for maintaining the natural equilibrium of the ecosystem, and therefore for the basis of existence of mankind and nature, is becoming increasingly commonplace. Here, comprehensive technical information for the general public on scientific and technical relationships, ecotoxicological substance properties and basic concepts of risk and danger evaluation are of particular importance. It is never in fact possible to exclude all dangers to the environment, but the aim must be to reduce the risk, i.e. the probability of the occurrence of damage, to a reasonable dimension. The necessary measures do not however concern the natural environment alone. In a technical and industrial society, environmental protection embraces three protective aims, i.e. worker, environment and consumer protection. If one becomes involved in the subject of environmental research, and comes to the conclusion that more has to be done in this field, one quickly concludes that environmental research also represents a sub-system with many complex interrelationships in the overall "earth" system. We must particularly learn how to understand the relationships reproduced in Fig. 2.

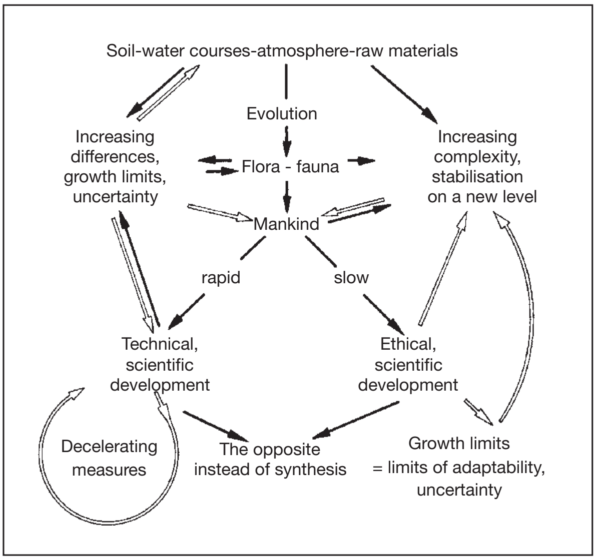


Fig. 2: Effects of time on the earth's ecosystem.

Here, the effects over time of the developments taking place in the "earth's ecosystem" are summarily reproduced, the processes exerting a braking effect being illustrated in broken lines. It is particularly important that the increasingly short-term thinking phase aimed at countering momentary difficulties makes room for longer-term thinking (lastingly environmentally friendly!) in all decision stages. This change is difficult to realise of course in a period of increasingly quickly changing situations, but does nevertheless require constant encouragement. In this sense, basic research in relevant areas, in addition to applied research, is hugely justified, particularly when we try to understand interrelationships by interdisciplinary means, and to work out from them the important targets which should be set (Fig. 3).

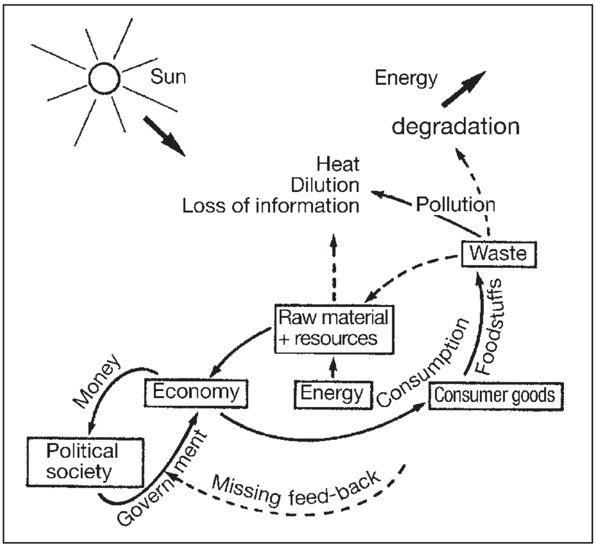


Fig. 3: System earth.

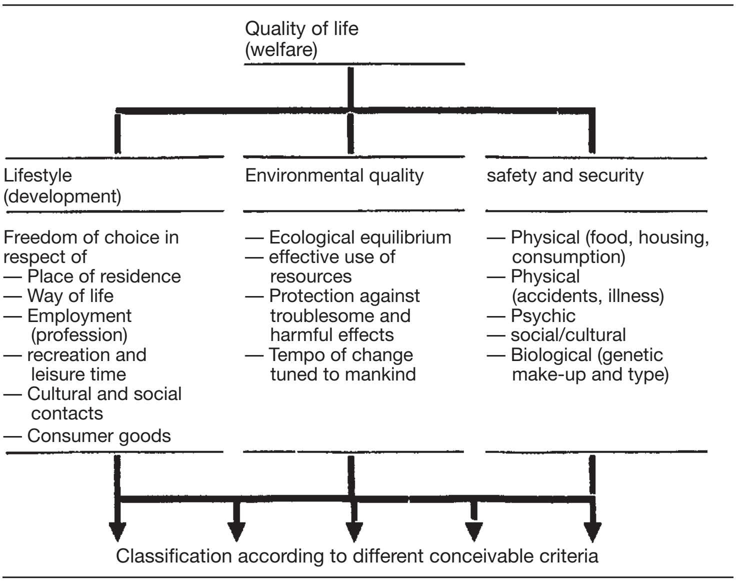


Fig. 4: Ecological target hierarchy.

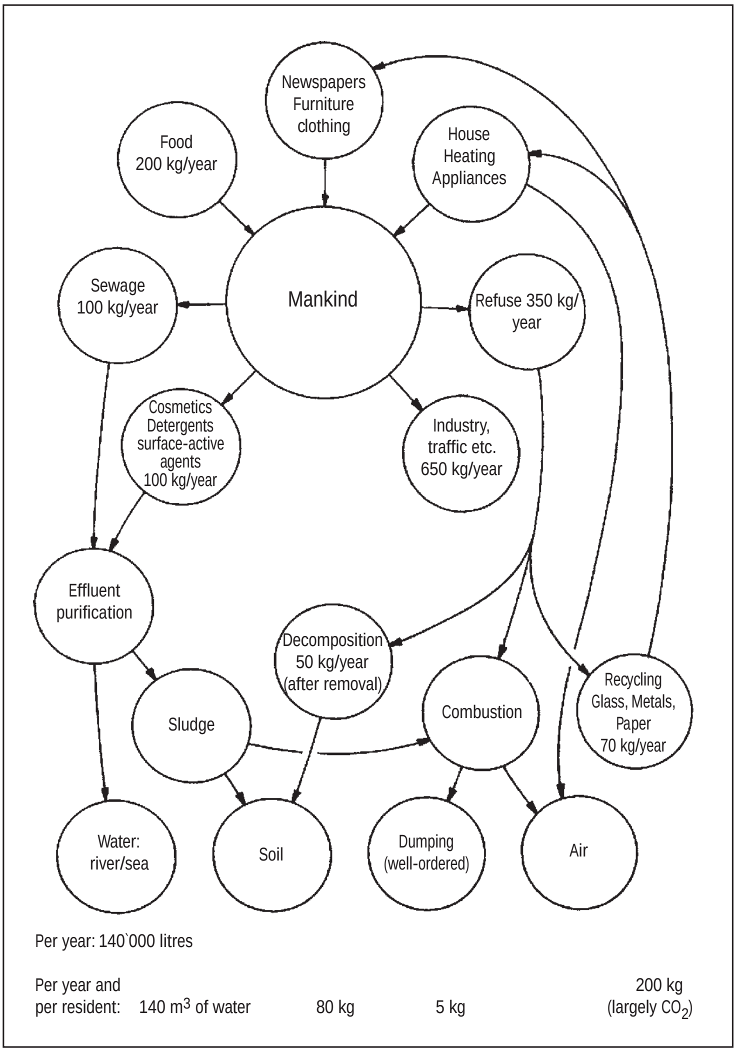


Fig. 5: Mankind's ecological environment (excluding traffic, industry).

Life means: converting energy from the directed state (low entropy) at a high level (thermodynamic) into final states at a low energy level with high entropy (i.e. massive uniform distribution of energy in the cosmos). This process is described as "heat death": all movement comes to a stop, and all heat differences are equalised; no further energy conversion takes place.

Life consists of organic processes obtaining their energy ultimately from the sun, and excessive energy being radiated out into space (Fig. 4). From the sociopolitical standpoint, optimum quality of life is to be aimed for in a form which produces a balanced relationship between "lifestyle" and "security", partial aims of these competing with each other in evenly matched stages. Environmental protection is concerned with maintaining environmental quality, involving keeping water courses and air clean, and also involving noise pollution plus waste disposal and energy recovery together with the product-related concept of environmental protection. If the economic effects of environmental quality assurance are balanced, positive and negative effects for the individual plant and for society are qualitatively opposed to one another with no possibility of quantitative evaluation.

There is a tendency to consider only partial aspects of ecology as a whole (Fig. 5). The problem area of water, soil, air, waste and disposal are focal points. →: Ecobalance; Ecological problems of textile finishing.

Economy trough Padding trough normally supplied with high performance padders. Low liquor content to prevent tailing problems, etc. The fabric immersion path is designed to be as long as possible and the trough liquor volume is reduced by means of a → Divider.

Econ-Tex This Babcock scouring machine looks like a roller vat at first glance (Fig. 1). It has actually taken over the roller vat's vertical fabric guiding system in single and double loop feed, with the possibility of scouring sections with different fabric contents, which can be adapted to different function definitions. The Econ-Tex however eliminates a roller vat disadvantage: the bath in a large liquor

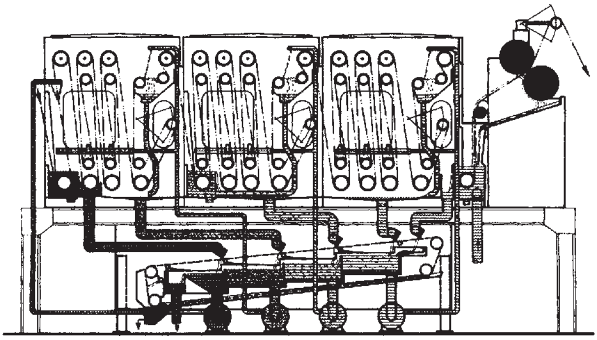


Fig. 1: Babcock Econ-Tex.

trough. The large bath content is only incompletely renewed by the liquor contraflow, because back currents and dead corners and angles are unavoidable, and therefore only part of the bath content takes part in the actual scouring process at any one time. The Econ-Tex has no liquor trough; all sections have a common, steamproof housing. Water seals are located at fabric entry and exit. During the scouring process, the fabric remains in the steam chamber, providing excellent prerequisites for the scouring process.

The total contraflow liquor circulation, which runs through a band-pass filter located near the machine, is superimposed by liquor circulation in the scouring sections. The scouring liquor is therefore brought into contact with the fabric a number of times, and is consequently continuously filtered. In the first section, the fabric is sprayed on both sides with the most heavily contaminated liquor (Fig. 2), the fabric being wetted out and surface impurities removed. In each section, part of the circulated liquor is fed via distributor pipes directly into the fabric/roller nip. Intensive fabric perfusion due to the hydrodynamic nip pressure and additionally to the centrifugal force on each deflecting roller, reinforced by the lack of liquor counter-pressure on the bottom rollers (no bath), produces an excellent scouring effect. The other part of the circulated liquor is used in each standard Econ-Tex section for spraying the fabric with penetrating flat jets shortly before it leaves the section. This spraying effects liquor exchange in the fabric. Kinetic energy improves the scouring effect, particularly when washing out gels or highly viscous substances. Integral intermediate squeeze units can be used for precise liquor separation instead of the spray line. As a rule, an Econ-Tex scouring machine has only one final squeeze unit. The liquor dripping from the fabric is caught on the bottom plate in each section, and fed to the band-pass filter battery, which has a collecting dish and a circulating pump (Tischbein) for each section and for the entry spray unit.

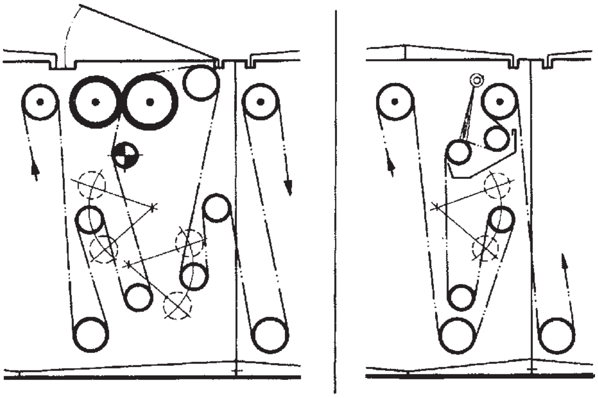


Fig. 2: The internal squeeze unit (left) as an alternative to the spray line (right) in the Babcock Econ-Tex open-width scouring machine.

Econtrol reactive dyeing The Econtrol concept has been developed jointly by Monforts and Zeneca Colours to provide a simple, rapid and economical continuous coloration process with minimum chemical usage (Fig. 1). Econtrol brings together the innovation of the Thermex Hot Flue from Monforts with Procion reactive dye technology from Zeneca.

The innovation utilises the physical laws of water evaporation from cellulose to provide the optimum temperature and moisture conditions within the Thermex Hot Flue drier, ideal for the efficient fixation of the specially selected Procion dyes. The control (Fig. 2) and maintenance of the humidity level in the drying process avoids the use of large quantities of chemicals such as urea and sodium chloride (salt).

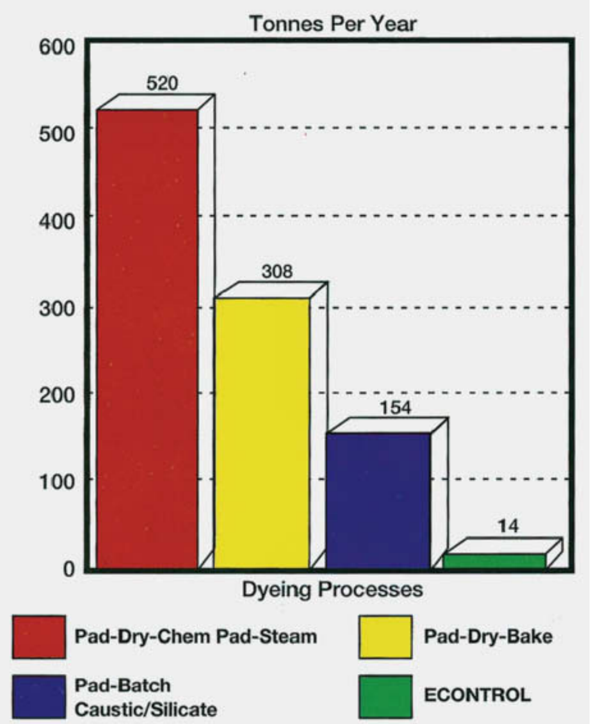


Fig. 1: Chemical consumption per 10 mill. metres.

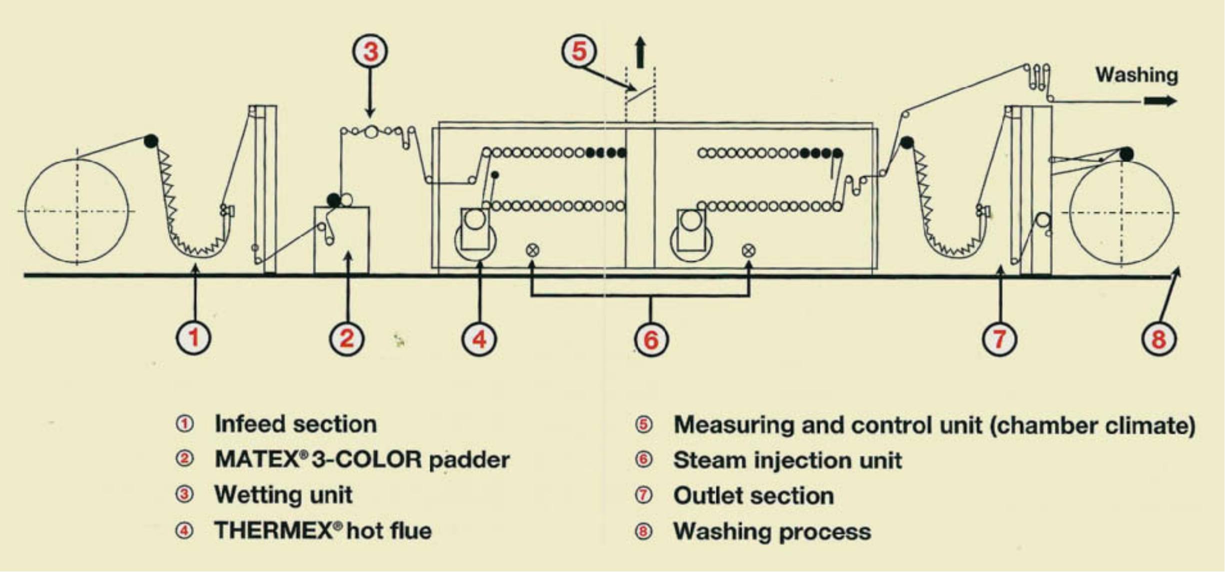


Fig. 2: Econtrol reactive dyeing.

The relative humidity in the hot flue dictates the cloth temperature when wet, with the actual temperature controlling the time spent on the fixation plateau before drying takes place. The Procion reactive dye reacts with the cellulose rapidly under these conditions.

The Thermex Hot Flue (Fig. 2), under normal running conditions, utilises the evaporating moisture from the fabric and injected steam at start-up, to achieve the required degree of humidity by use of moisture meter and control of the exhaust fan. The Monforts innovation involves the special steam injection technique to give the optimum conditions of temperature and humidity.

The corresponding recipe contains only:

x g/l Procion MX dye
2 g/l wetting agent
10 g/l sodium bicarbonate

Ecosystem → Ecology.

Eco-Tex Standard 100 An ecological quality mark should embrace the following ideas:

- a textile product the nature of which is free of harmful substances and is skin-compatible,
- a method of production (fibre cultivation, fabric production, finishing and making-up) which is perfectly ecologically harmless and environmentally compatible,
- easy to dispose of in order to get rid of the used textile product by recycling, decomposition or combustion.

Important, and at the same time achievable, is at least the pragmatic implementation of point 1. The heart of the Eco-Tex Standard is the testing of fabrics and clothing in human ecological terms (Fig.); this relates to the effect of textiles on human beings, i.e. on their immediate environment.

Here, specific substances ecologically harmful to human beings are analysed, and compared with scientifically based limits. Production and disposal ecology are not taken into account in this process. The clothing textile, accessory, household textile and baby clothing sectors have laid down their own standards and test processes. Standardisation of values makes possible a high degree of flexibility in adapting to new information, which would not be possible in DIN standardisation. Tests are conducted in accordance with the current standard in terms of:

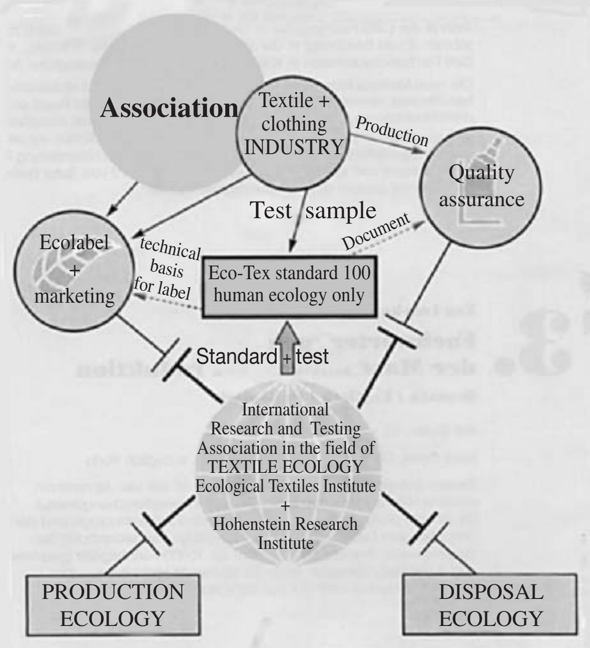


Fig.: Tying the Eco-Tex Standard 100 into the whole environment of ecological endeavours in the textile sector.

- pH (pH 5–7);
- the formaldehyde component which is free and can be split off, particularly with cotton and pigment dyestuffs (here, there is already a DIN labelling obligation at values exceeding 1500 ppm, which is not met in textiles as a rule); baby clothing: 20 ppm, underwear: 75 ppm, other articles of clothing: 300 ppm;
- heavy metals;
- pesticides in natural fibre textiles (e.g. PCB);
- indication as to whether fission products, which can be carcinogenic under certain circumstances, occur in the case of dyestuffs;
- colour fastness (fastness to rubbing, perspiration, water and washing).

Research institutes test the textiles presented singly, using a comprehensive questionnaire for obtaining a maximum of preliminary information. Depending on the number of tests carried out, the current cost lies between 1000 and 3000 DM. In theory, each product colourway must be tested separately; in practice, many articles can be combined according to the dyestuffs employed for example. Guarantees to the effect that the production quantities conform to the tested sample must be given by individual firms. In Eco-Tex Standard 100, the concept of harmful substances is defined as follows: “harmful substances in the sense of this guideline are substances which are contained in a finished textile product in excess of a laid down measure, or occur in excess of a laid down measure in normally expected use, and can in some way have an effect when normally worn by people, and can be a danger to peoples’ health according to the current level of scientific knowledge”. It is improbable that harmful substances can occur “in normal, prescribed use”, but it is incorporated as a precautionary measure in the definition here. The limitation that a substance is a harmful substance only when it has some effect on people in normal, prescribed use excludes substances which are chemically bonded in the textile product in such a way that they cannot migrate either due to inhaled air or to water, perspiration (in the case of clothing), saliva (children’s clothing) and skin contact. Important too is the limitation “normal, prescribed use”. This does not of course include burning and the combustion gases CO and CO_2 which occur, as with any organic material, during the combustion process. The list of substances which can be regarded as harmful is reproduced in product-specific Eco-Tex Standards 100/1 to 100/7. These lay down the limit concentrations above which a substance is harmful in the sense of these standards. These standards also lay down the test procedures as to how these harmful substances and their emission into the atmosphere are determined by aqueous extraction etc. These tests are conducted, targeted towards harmful substances laid down in the standards. The conditions and procedural method for awarding the “Free from harmful substances in accordance with Eco-Tex Standard 100” are laid in Eco-Tex Standard 100. This begins with a precisely laid down request for the sample material to be presented, the submission of a statement of responsibility, and ends with the test. The statement of responsibility contains:

- liability for the statements made,
- responsibility for immediately informing the awarding authority of any change in the technical data,
- agreement that authorised people can at any time inspect product manufacture without notice, and can take away samples of all kinds,
- responsibility for doing everything to prevent misuse of the label,
- responsibility, following expiry or cancellation of labelling entitlement, for ensuring that further product labelling will not take place.

Finally, Eco-Tex Standard 100 also contains the definitions for granting entitlement, entitlement period and cancellation, and type of label. It would be nonsensical and economically unrealistic, if the award of entitlement to label a product with the seal of quality were to be limited to only one random sample which is tested for every only possible harmful substance. One must proceed from the fact that a firm which wishes to distinguish its products with “Free from harmful substances in accordance with Eco-Tex Standard 100” applies no harmful substance to its products deliberately and intentionally. → Ecolabelling.

Ecotoxicology A term which combines → Ecology and → Toxicology. By ecotoxicology is meant the effect of a substance on biological species (plants and animals) or an entire biocoenosis. The simulation of natural conditions is laborious and complicated and can only be carried out for individual model substances. Safety data sheets contain information concerning acute ecotoxicological effects on individual organisms (fish, daphnia, algae, bacteria) which have been determined in short-time tests of approx. 1–96 h duration. These values are useful in comparison with short-term shock loads in waste waters. The chronic effects must be related to a substance concentration determined in a specific catchment area. Such tests are only possible in individual cases and are not, as a rule, contained in safety data sheets. Important parameters for acute ecotoxicity are the so-called EC_0 and LC_0 values which correspond to test concentrations with no toxic effect, resp. the EC_{100} or LC_{100} values which represent a 100% effect on the test organism. For comparison purposes, the EC_{50} or LC_{50} values are the most commonly used for statistical reasons.

Ecru (Fr.). In general, the colour of fibres, yarns, or fabrics that have not been subjected to processes affecting their natural colour, i.e. untreated, unbleached, undyed. Specifically: (1) ecru linen → Unbleached linen;

(2) ecru silk (bast silk) is barely degummed silk (maximum 4% loss) – only grease, wax and resinous substances removed.

ED, → Elastodiene fibres, → Standard abbrev. for textile fibres, according to DIN 60 001 T4/08.91.

EDANA, abbrev. for: European Disposables and Nonwovens Association, Brussels; → Technical and professional organizations.

EDCO, abbrev. for: Editing Committee. Special committee responsible for the editing of ISO recommendations; → Technical and professional organizations.

Edge abrasion resistance → Flexing abrasion resistance.

Edge/centre evenness testing (printing) → Formatted piece method.

Edge crease offsetting device Attachment for device with tricot padding machine to avoid edge creases with tricot pads.

Edge curling A fabric defect which arises in the processing and finishing of woven and knitted fabrics due to faulty construction. In woven fabrics it is due to excessive tension of warp threads in the selvedges (tight selvedges) or an unsuitable woven construction. Knitgoods, in general, are particularly prone to edge curling. In the case of fabrics composed of synthetic fibres, the problem is prevented by heat setting. On entry to processing machines, edge curling is prevented by appropriate → Expander.

Edge curling of knitgoods Problem encountered in processing knitgoods in the open width state. The cause is mainly due to tightness of the fabric edges and is largely prevented by → Edge gumming.

Edge cutting and sealing machine Tubular knitgoods are cut lengthwise in this machine to produce open-width fabric and both cut edges are glued at the same time. A chemical auxiliary is applied as an adhesive to prevent → Edge curling.

Edge glueing device Device for glueing the edges of open-width knitted fabrics.

Edge guider (→ Expander). Selvedge guiding device →: Edge uncurling device; Edge guiding sensors; Overfeed devices; Selvedge monitor, device to remove the fabric using clip openers or to lift the fabric from stenter pins and fabric take-off mechanism.

Edge guiding sensors Sensors used for fabric edge detection in the entry zone of stenters and drying machines. Function: mechanical (mechanical feeler lever control), electrical (electrical feeler lever control), photoelectric (with light beam and photocell) or pneumatic (with air supply).

Edge gumming A necessary measure to prevent the → Edge curling of knitgoods. The edge adhesive is applied from a special edge glueing device by spraying and drying, or by roller application from the edge glueing units on a stenter.

Edge roll → Edge curling.

Edge stitching (French: piquer = to quilt), lockstitch-type sewing of → Padding and its permanently elastic binding with the outer fabric (by means of an edge stitching machine).

Edge-to-centre levelness Side-to-centre levelness of shade across the width of a textile fabric. An important quality parameter in continuous dyeing which can only be ensured by completely uniform dye uptake across the entire fabric width in pad dyeing.

Edge-to-edge unevenness → Listing.

Edge trimmers With suction device. Used to trim the needled edges of the run of cloth and to simultaneously aspirate the trimmed selvedges on exit from stentering and drying machines. The run of cloth is transferred from the needles on the unneedling wheel with the aid of the supporting roller from the needles on the flange of the chain guide and fed to the cutting apparatus. The unneedling wheel can also be fitted with a second row of needles to adapt to different types of goods. The height of both the unneedling wheel and cutting apparatus can be continuously adjusted, enabling adjustment of the edge stress at the point of intersection. It is therefore possible to adapt the cutting capacity of the goods precisely. The insertion depth of the revolving blade in the unneedling wheel can also be continuously adjusted. The lateral adjustment of the revolving blade to the unneedling edge depends on the type of goods and can be carried out in accordance with arrangements I–III (see Fig.).

- Arrangement I: Only suitable for types of goods where the selvedge can be stretched in such a way through the suction current of the strip suction device that it is possible to make a cut. Minimum sel-

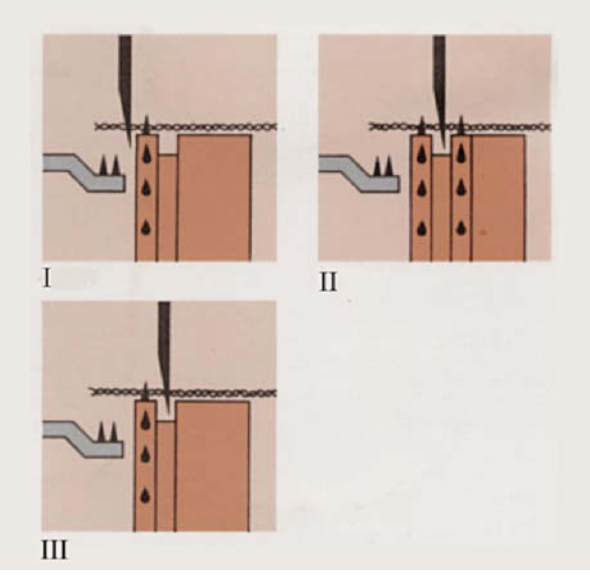


Fig.: Three possibilities of edge trimming: arrangement I–III.

vedge trim 3.5 mm from the raw edge up to the first needle row of the stentering machine.

- Arrangement II: This is the most common arrangement. The trimmed goods do not have needle impingement. Minimum selvedge trim 9 mm from the raw edge up to the first needle row of the stentering machine.
- Arrangement III: During the cutting process, the goods are held by an additional needle row on the unneedling wheel. This prevents breakage or further tearing when the goods are stretched laterally. Minimal selvedge trim 9 mm as with arrangement II.

Edge uncurling device Device used to remove the curl from selvedges that have a tendency to roll and make processing difficult.

Edging (Fr.), → Binding, edge binding, border on woven textiles and knitwear.

EDIFACT, abbrev. for: Electronic Data Interchange for Administration, Commerce and Transport. → EDITEX.

EDITEX A project group, founded by the European technical clothing organisation AEIH in coordination with the textile clothing discussion group. The governing body of the AEIH Commission decided in agreement with Comitextil to give the EDITEX group active support from all countries. The objective of the EDITEX group is to develop a set of standards specific to the field of textiles, EDIFACT, taking account of the various specialisms such as the cataloguing of data on sizes and colours. The swift exchange of information should in future produce a quicker reaction time, living up to the slogan "Quick response". In order to facilitate a cost-efficient transfer of data, the Datenzentrum Einzelhandel (DZE; = retail trade data centre) was established as a clearing centre for the textile industry in Germany. The transfer of data takes place via the worldwide IBM telecommunications network. → Technical and professional organizations.

EDP Code → EDP key system.

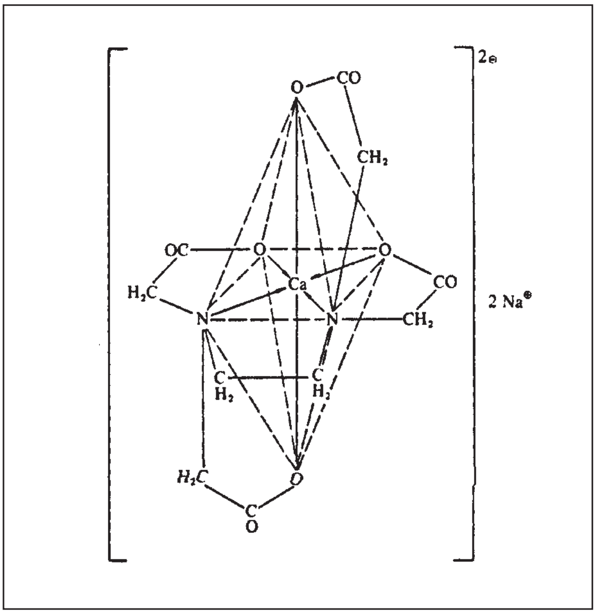


Fig.: Ca-EDTA-complex.

EDP fibre identification code → EDP Code.

EDP key system A system of abbreviations for fibres agreed at the beginning of the 1970s between the EEC member states according to EDP guidelines (→ Textile fibre symbols).

EDPM, abbrev. for: electronic data processing machine.

EDTA, abbrev. for: → Ethylenediaminetetraacetic acid. Complexing agent which can be used as a water softening agent by direct addition to hard water (see Fig.).

eee pretreatment system (eee = efficiency, economy, ecology), Sandoz, Basle, Switzerland, offers the eee system, a series of tried and tested process combinations for all pretreatment requirements, which comply with strict quality control measures (see Tab.). The term for this complete system of recommended proc-

	Desizing	Alkaline treatment	Boiling off	Bleaching	for
Proc. 1				Pad batch (room temp.)	Dyeing
Proc. 2		CRC process		as required	Dyeing, printing, deep shades,
Proc. 3	Pad batch with enzymes	Mercerization	Pad steam or U-box	Pad steam or U-box	Dyeing, printing, quality goods
Proc. 4		Sandoflex		Under-liquor	Dyeing, white goods, knitted goods,
Proc. 5				Pad batch/ pad steam combined	Ultra-white
Proc. 6	Pad batch with enzymes			Pad steam or U-box	Dyeing, printing
Proc. 7	with enzymes		Pad steam or U-box		dark dyeing

Tab.: Possible processes for the pretreatment of cotton fabrics to achieve certain effects (eee pretreatment system/Sandoz)

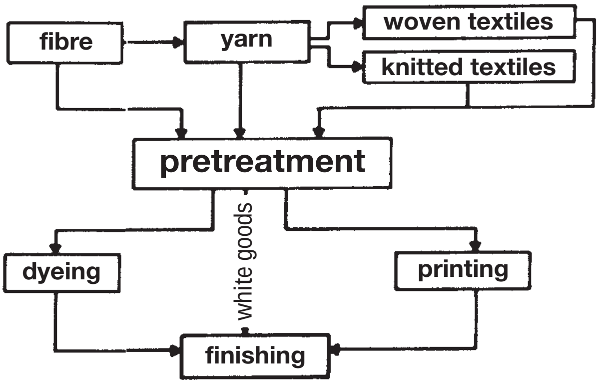


Fig.: Sequence of pretreatment operations in textile finishing.

esses and special products for pretreatment stands for efficiency, economy and ecology, and all processes and products covered by the system must fulfil all three criteria. The eee system therefore corresponds mathematically to the average of all three criteria:

$$I = e_1 + e_2 + e_3$$

The factor e = efficiency, for example, comprises all those active qualities which fulfil the following criteria:

- activity (ability to achieve an effect),
- efficiency (maximum efficiency),
- selectivity (effect relates to the desired function).

The term “pretreatment of textiles” (see Fig.) covers a range of cleaning operations on a fibre, starting from the grey state.

The aim is to prepare the goods for the subsequent finishing processes (dyeing, printing, finishing). The different operations include desizing, boiling off, alkaline treatment (mercerizing, caustic treatment) and bleaching. The resultant loss of weight is a clear indication of the success of the cleaning. The grey goods contain natural impurities such as fats, pigments or mineral substances, and artificially or accidentally introduced substances such as sizings, traces of mineral oil introduced during weaving and similar (e.g. fungal traces, water, rust). Everything has to be removed, as it is detrimental to subsequent finishing. Precise analysis determines the various criteria of a given pretreatment effect. Special machines, processes and products are required in order to remove impurities from the fibre without causing actual damage to the fibre:

- mineral oil stains are difficult to remove;
- unless the fabrics are cleaned sufficiently, it is impossible to achieve perfect dyeing or printing;
- imperfections in pretreatment (e.g. silicate stains on cotton goods) can adversely affect the goods; for this reason silicate-free peroxide bleach treatments are recommended;
- traces of iron can lead to catalytic damage, thus chelating agents should be used to mask the harmful element.

A variety of machines can be used. For continuous processes the main types are the pad-steam, J-box, U-box and under-liquor systems. An essential factor is the speed of throughput of the goods. Below 50 m/min is considered low speed and above 100 m/min high. Pretreatment is also carried out discontinuously, using a winch beck, jig, jet or autoclave. The liquor ratio is of essential importance here. Liquors are classified as short (<1:5) and long (>1:10). The individual stages of the process (desizing, boiling off, bleaching) are sequential. With semi-continuous processes around 2,000–5,000 metres are impregnated and left to dwell for 12–24 h at room temperature (pad batch) or 1–3 h in saturated steam (pad roll). The pretreatment is therefore dependent on the substrate (natural or manmade fibre), the make-up (woven goods, knitted goods, yarn etc.), the machinery (continuous, discontinuous, semi-continuous) and the chemicals (enzymes, wetting agents, detergents, chelating agents, stabilizers, reduction or oxidation agents, antifoams, etc.) (source: Fornelli).

Effective temperature of synthetic fibres Thermal analysis is used to measure the stability of reciprocal intermolecular action or the stability of frozen-in crystalline systems in thermoplastic fibres. This is done, for example, using → Differential Thermal Analysis. In a differential thermogram, in addition to the main melting (e.g. polyester at approx. 256°C), a characteristic subsidiary melting is observed at each preceding fixed temperature point. This is the melting of crystallites, which have been formed under the set conditions of previous treatments. The melting temperature of these crystallites, defined as the peak maximum, is a measure of the thermal stability of the physical network of the synthetic material. It is described as the effective temperature of the thermal treatment.

Effectivity factor (EF), the effectivity factor is extremely useful for the (relative) evaluation of the finish effect of various resin treatments:

$$EF = \frac{\text{TKW (resin finished)} - \text{TKW (non-resin finished)}}{\text{RFV (warp) \%}}$$

TKW = dry crease recovery angle
RFV = loss of breaking strength

Optimum values lie between 2.5 and 3.5. EF values >4 indicate under-cured goods; values <2 indicate overcuring.

Efficiency rate Ratio of actual to possible production performance.

Efflorescence Problem of finishing agents crystallizing out as powdery grey deposits on textile surfaces.

Effluent fining pond Naturally situated water reservoir at the end of an industrial effluent treatment cycle, used to make a final adjustment of the water to the natural balance - in a stretch of water (biozonosis pond) - before the water reaches the receiving stream.

Ehrlich's reaction Test reaction for the detection of urea, amines, imidazolidones and triazones in resin finishes. Reagent: 1 g p-dimethylaminobenzaldehyde in 100 ml 2n hydrochloric acid. Reactions:

1. Immediate formation of brilliant yellow stains = imidazolidone.

2. Formation of pale yellow stains after a few minutes = urea.

3. Gradual development of weaker stains = amines, triazones and other heterocyclic substances with primary amino groups.

Ejector Pneumatic device for mock cake for connection to a compressed air supply.

EL

I. → Char length

II. → Elastodiene fibres, standard abbrev. according to the → EDP Code; → ED.

III. → Elastane fibres, → Textile fibre symbols according to DIN 60 000 T4/08.91.

Elastane fibres Manufactured fibres composed of at least 85% segmented polyurethane (→ Polyurethane elastomer fibres). Elastane fibres can be extended reversibly up to 500–700%. Compared to natural rubber fibres, they have the following advantages: almost white in colour (even transparent elastane fibres are commercially available), higher strength, good resistance to oils and cosmetics, more easily dyed.

Structure: the macromolecules of elastane fibres contain hard (highly inextensible) segments alternating with soft (highly extensible) segments. The hard segments can form quasi-crystalline structures. Physical interactions between the hard segments of different molecules provide the necessary mechanical stability for a textile fibre. The hard segment structure is also responsible for the behaviour of elastane fibres at high temperatures as well as their setting characteristics. The soft segments are formed from special polyethers or polyesters and exist in a quasi-liquid state at room temperature. This physical state ensures high mobility of the soft segments and is the basis of the high extensibility of elastane fibres (see Fig.). The soft segments are also responsible for the thermal behaviour of these fibres.

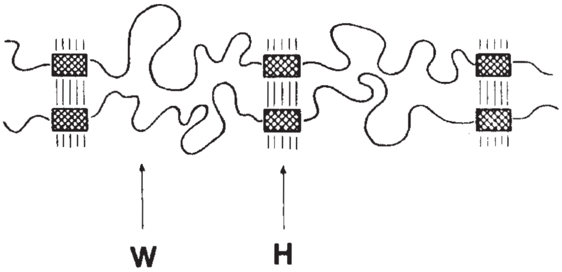


Fig.: Structure of elastane-polymers.
W = soft segments; H = hard segments.

Fibre production: the technique used in spinning elastane fibres depends upon the type of polymer that is spun. Some segmented polyurethanes, for example, are essentially linear molecules, and are soluble in solvents. Other segmented polyurethanes may be branched or crosslinked structures which are insoluble. The dry spinning process, in which the prepared elastane solution is spun through spinnerets into heated spinning cabinets, is preferred by the majority of elastane fibre manufacturers. The drawing tension of the take-up winders forms individual fibres of specified strength. In practice, filament fineness usually lies between 4–20 dtex. The individual filaments are brought into contact with each other by false twist whilst still in the viscous state in the heated spinning cabinets, resulting in their adhesion to one another.

Elastic band consists of textile warp threads and elastic threads, which are generally not covered by spinning, positioned between these at specific intervals.

Elastic calender bowls (elastic calender rolls). These are made from paper, cotton, jute, plastic, etc. The elastic material is pushed on to a steel axle in the form of individual slices (e.g. approx. 20 000 per metre width), pressed hydraulically under high pressure (up to 1000 t), and held together at both ends by iron flanges. The steel axle must be of a suitable diameter to prevent distortion of the elastic calender bowl under load. The surface of an elastic calender bowl produced in this way is extremely hard and can only be turned down to the desired final diameter with a diamond tool.

Elastic extensibility → Tensile elasticity.

Elasticity As in the case of strength, a distinction is made between the various types of elastic stress →: Tensile elasticity; Bending elasticity; Torsional elasticity. In each case, the elasticity may be permanent or temporary. Inferences can be drawn from these parameters concerning dimensional changes in textiles which are of practical value with regard to their serviceability.

Elastic recovery → Recovery capacity of fibres.

Elasticum According to Allwörden, a putty-like substance made up of carbohydrates in → Wool structure.

Elasticum reaction (Allwörden's reaction), a microscopic test for the detection of chemically damaged wool. Method: degrease the wool with ether, and spot with chlorine water under the microscope. Undamaged wool: strings of semi-circular pearl bead-like blisters over the entire fibre surface (→ Elasticum, swollen out of the fibre). In the case of alkali damage as well as chlorinated wool, the reaction is either negative (due to removal of the epicuticle) or only very weak.

Elastified or modified resins → Alkyd resins.

Elastin Connective tissue protein, major component of elastic fibres as in blood vessels, ligaments, etc.

Elastodiene fibres Generic name for man-made fibres based on polyisoprene, or polymerized dienes (polybutadiene), with or without vinyl polymers. Extensibility characteristics similar to → Elastane fibres.

Elastomer fibres →: Elastane fibres; Elastodiene fibres.

Elastomer filaments → Polyurethane elastomer fibres.

Elastomers Elastic polymers. As originally defined, this term refers to a group of synthetic thermosetting high polymers (such as polyisobutylene and its copolymers, polyurethane, "Thiokol", etc.) having properties similar to those of vulcanized natural rubber, namely the ability to be stretched to at least twice their original length and to retract very rapidly to approximately their original length when released. The term was later extended to include uncrosslinked polyolefins that are thermoplastic; these are generally known as TPO rubbers.

Electrical attraction → Fibre attraction.

Electrical conductance (G) is the reciprocal of electrical resistance R. The derived unit is the Siemens (unit symbol: S). 1 Siemens is equal to the electrical conductance of a 1 Ω (ohm) resistance conductor:

$$1\,\mathrm{S} = \frac{1}{1\,\Omega} = 1\,\Omega^{-1}$$

Electrical → Conductivity K is the reciprocal of specific resistance.

Electrical double layer Occurs in dyeing from aqueous electrolytic solutions at the liquor/substrate interphase. Electric charges can be present at the interphase, i.e. the substrate surface, building up an electric field out into the liquor. This can be a question of ionic groups, adsorbed ions etc.

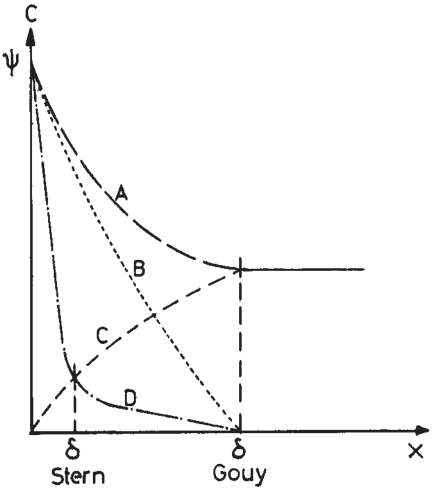


Fig.: Stern and Gouy model.
Ψ = electrical potential; c = concentration in mol/l (ordinate); δ Stern = Stern layer thickness; δ Gouy = Gouy layer thickness; A = counterion concentration curve; C = equally loaded ion concentration curve (as surface loading); B = Potential curve according to Gouy; D = potential curve in Stern layer; x = distance from surface.

Ion distribution and the electric field can be quantitatively described with the aid of Poisson's electrostatic differential equation and Boltzmann's distribution. Gouy's simple model was extended by Stern by the inclusion of a linear voltage drop in the immediate vicinity of the interphase (illustration). The following electrostatic relationships apply to this layer.

$$\frac{\partial^2\psi}{\partial x^2} = -\frac{4\pi}{D'}\sigma$$

$$\frac{\partial\psi}{\partial x} = \frac{\psi_0 - \psi_{St}}{\delta_{St}}$$

$$\rho = -\int_0^{\delta St}\sigma\,dx = \frac{D'}{4\pi}\int_0^{\delta St}\frac{\partial^2\psi}{\partial x^2}\,dx$$

$$\rho = \frac{D'(\psi_0 - \psi_{St})}{4\pi\,\delta\,St}$$

Electrical heating, of textile finishing machines. In comparison to the heating of machines involving thermal treatments with other energy carriers (steam, gas, hot water, hot oil circulation) electrical heating is, in certain cases, simpler to install from the machine construction point of view, e.g. for revolving calender bowls (see Fig. 1 and 2).

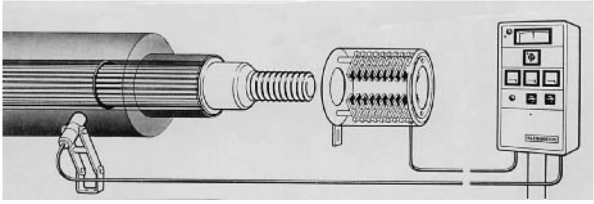


Fig. 1: Electrical heating for calender bowls.

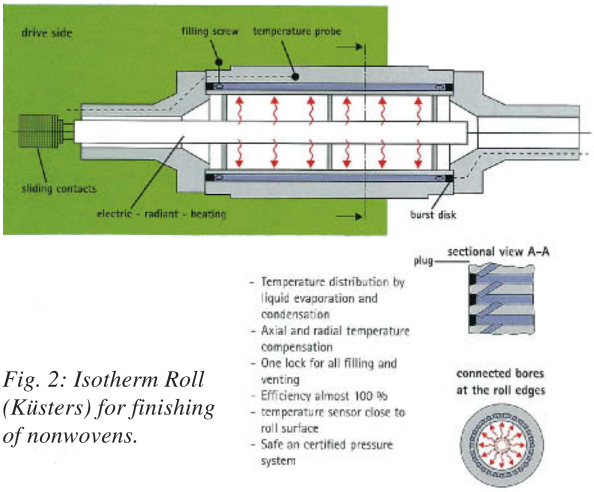


Fig. 2: Isotherm Roll (Küsters) for finishing of nonwovens.

Electrically heated pressboards → Pressboard.

Electric motors Electrical machines for transforming electrical energy into mechanical energy. Motors run hot during operation, part of the electrical energy being transformed into heat energy. If the electrical energy cannot be converted into mechanical energy because of motor stoppage due to overloading for example, the whole of the electrical energy is transformed into heat energy, and the motor "burns out". In the case of electric motors where electrical power is taken from the mains, and is transmitted to the drive shaft as mechanical energy, eddy current, frictional and air vortex losses occur due to the Joule effect. Here too, part of the energy supplied is lost; this is referred to as power loss.

When operating in humid premises or where other dangers do not permit high voltage connection (380 V for example), safety transformers reduce the voltage down to 42 V or 24 V. Machines are often switched on and off via contactors with the aid of lower control voltages (Fig. 1). New developments in drive technology – brushless electric motors – are in the offing.

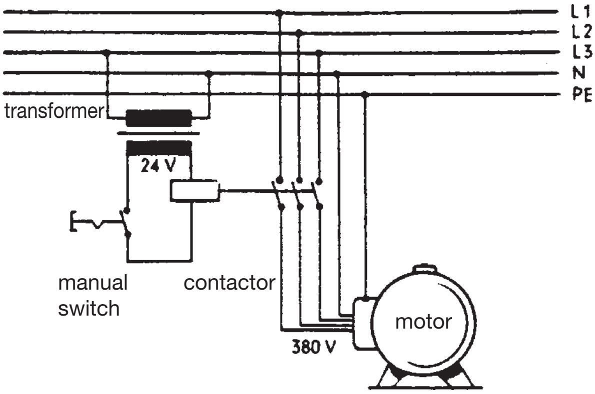


Fig. 1: Switching on a high voltage motor via a low voltage contactor.

On finishing equipment, electric motors are used for driving pumps or rollers. Normally, liquor pumps in dyeing machines are equipped with constant speed drives. This solution is useful in max. pressure and flow operating conditions. In many cases of application however, different flow quantities are required during the dyeing process, this being made possible either by means of a by-pass control unit, a differential pressure valve, or by speed control (Fig. 2), alternating current or three-phase motors etc. being controlled in terms of required power by means of current frequency, while direct current motors can be steplessly controlled via resistors. Currently, control via direct current motor is the most cost-effective solution, while the frequency solution requires a 30% higher investment. Speed reduction means reduced pump motor power input, because performance is reduced by the power of three.

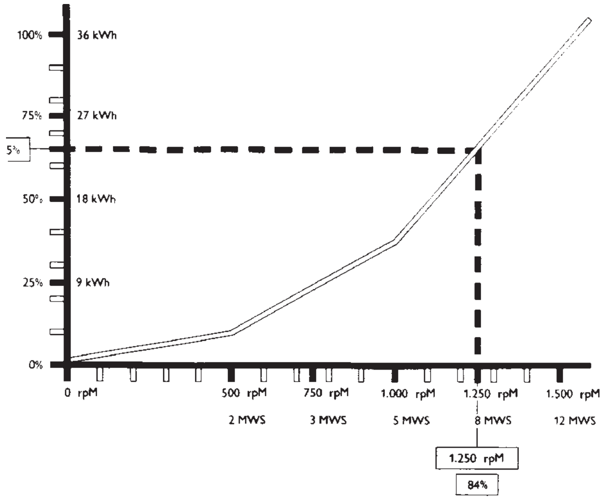


Fig. 2: Current consumption of an electric motor relative to speed and pump capacity (contributed by Thies).

The output of a centrifugal pump can be adapted to the textile material to be dyed relative to the pump's characteristic curve. A slower reduction in differential pressure and an adapted number of jet passages in jet bleaching can reduce power consumption by almost half, while the Thies SDC-System (Synchronous Dyeing Control System) reduces power consumption during dyeing by one third.

If, with the use of direct current motors, a large tractive effort is necessary on machine start, a so-called series wound motor is used. It is externally recognizable by the thickness and low number of field coil windings. The direct current shunt wound motor keeps its speed constant within specific load limits, which makes it suitable for precision instruments. It is externally recognizable by the large number of field coil windings. Speed requirements can be set by connecting resistors into the shunt circuit. The compound motor with combined series and shunt wound circuitry combines high tractive force with approximately constant, easily controlled rpm.

With alternating current motors, a distinction is drawn between synchronous and asynchronous motors. In the case of synchronous motors, the stationary component receives single or multiphase alternating current, and the rotor separate direct current. For running up to synchronous speed, the motor requires an auxiliary unit. With the asynchronous motor, the stator receives alternating or three-phase current, while the rotor current is generated by induction. Rotor speed maintains a specific slip behind that of the rotating field. Asynchronous motors have either short circuited (squirrel cage) or slip ring rotors. Asynchronous motors are self-starting; their tractive effort depends on rotating field strength and armature current intensity. High speed and starting under load require slip ring rotor motors with rheostatic starters. In the case of commutator motors, alternating current is fed not only to the stator but also to the rotor via a commutator (as in the case of direct current motors). Their speed can be constantly controlled within wide limits.

Due to progressive automation and rationalisation in the textile finishing industry, there is a demand for a) integrating as many machines as possible into machine combinations, and b) fewer restrictions on production changes by means of wide variation potential within the existing machine park in order to be able to adapt to the relevant market and fashion conditions. Both measures place new requirements on production machine drives. The combination of individual drive motors into a motor system goes hand in hand with the combination of machines into machine systems. This results so to speak in a new configuration, the multimotor drive. One frequently encountered multimotor drive variant is the use of direct current motors within the framework of Ward-Leonard control, e.g. for synchronized open-width scouring machines (Fig. 3). The basic speed of all component motors is set by the Ward-Leonard voltage. Speed differences between the motors due to fabric length change or load variation are compensated in the motor fields via dancing rollers. In a manner of speaking therefore, this can be regarded as coarse basic speed setting and fine motor speed control for synchronization. One of the motors has a fixed set field, and consequently indicates the control speed to which the subsequent component motor has to be adjusted. This again determines the control and slave speed for the subsequent component motor.

The much used dancing roller (Fig. 4) is a roller suspended in a fabric loop and free to rotate around its axis. A fabric length change produces vertical displacement, which is converted via deflector rollers into a rotary motion, and is used for potentiometer actuation. The advantage of the dancing roller is that, independently of the actual position, constant fabric tension is maintained by loading or counter weights. Other synchronizing devices are rocking roller arrangements with fewer bearing points.

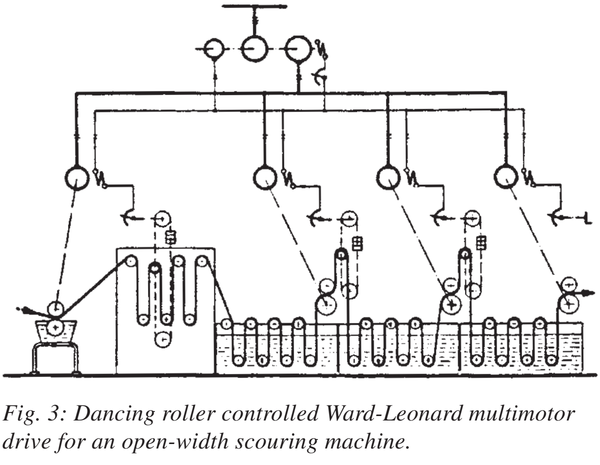


Fig. 3: Dancing roller controlled Ward-Leonard multimotor drive for an open-width scouring machine.

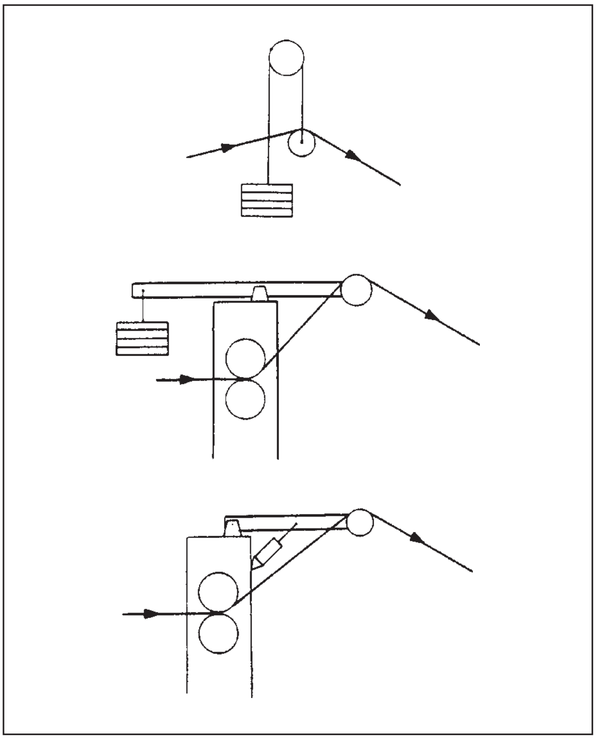


Fig. 4: Various roller layout possibilities for transposing fabric shortening or lengthening on a potentiometer (for controlling the subsequent machine's direct current motor); top dancing roller, centre and bottom rocking rollers.

Fabric take-up varies relative to the position of the rocking roller, and the short fabric feed between top and bottom rocking roller positions can also be a disadvantage. Today, synchronisation is controlled to a large degree by photoelectric sensors, a method which is particularly useful with especially tension-free fabric runs via a festoon control system.

Textile machinery drive technology requirements have also become more stringent due to increasingly better processes for producing and further processing textile raw materials and intermediate and end products. In the first place, variable drive motor speeds are required in order to enable production processes to operate at the technical optimum for specific products, and consequently to achieve high quality standards. Until a few years ago, these applications could only be realized by means of controlled direct current motors, the machines' disadvantages, such as wearing parts (brushes and commutators), the low degree of protection against fly and humidity, and also the relinquishing of high primary speeds all having to be taken into account. There remains no doubt that the speed controlled direct current machine has complete supremacy in some applications. Extruder drives may be an example of this. In the case of the majority of industrial textile drives however, the brushless three-phase motor has predominated. Examination of the marginal drive conditions in the textile industry reveals that a drive unit has to meet the most varied requirements. In addition to wear-free construction designed for a long service life in continuous operation, a high degree of protection against humidity, fly and dust should be provided together with compact and standardized structures. Of all electrical machines, these requirements are best met by the three-phase motor. There are also both diverse and quite specific application possibilities for the different asynchronous, reluctance and permanent synchronous motor versions. However, the three-phase motor also has disadvantages. Due to the machine's winding configuration, only speeds which correspond to an integral feeder mains frequency number can be attained. The formula:

$$n = \frac{f \cdot 60}{p}$$

n = synchronous speed in rpm,
f = feed frequency,
p = number of pairs of poles.

applies.

Thus, synchronous operating speeds of 3000 rpm, 1500 rpm or 1000 rpm are obtained from a mains feeder frequency of 50 Hz and 1, 2 or 3 pairs of poles. Adaptation to the actually required machine speeds can be effected via fixed or variable transmission ratio gears. A further disadvantage is that, due to its physical structure, the three-phase asynchronous motor, when under load, varies its speed in terms of the load. This divergence from synchronous speed is described as slip. In the case of three-phase motors, allowance has been made for variable speed requirements with the development of static frequency converters. These electronic instruments supply the motor with a variable frequency three-phase alternating current. The motor terminal voltage also varies simultaneously with the rotating field frequency variation so that the motor can operate with almost constant magnetic excitation, enabling it to deliver constant torque over a wide speed control range. In contrast to the direct current machine, actual shaft speed feedback is as a rule unnecessary. With the asynchronous motor, the stator is connected to the mains with three-phase current winding, producing a field rotating at synchronous speed (3000 rpm at 50 Hz and with a 2-pole motor). The rotor has transformer stampings with short circuit winding. This is a cast aluminium squirrel cage for example, and the motor itself is consequently simply and robustly built. The motor takes blind current from the mains in all operating circumstances. Torque is produced by relative movement of the rotor to the stator field which runs at a fixed speed. At synchronous speed torque is zero, because there is no relative movement between rotor and stator field. The characteristic torque curve then rises steeply to breakdown torque. It can be seen from this characteristic curve that the motor is not very easy to control in speed terms, as it has a rigid speed/torque curve in the usable range. When the motor is running at a speed/torque point determined by the load, the following formulae apply if stator losses are ignored:

mechanically delivered power: $P_{mech} = M \cdot \omega_R$

electrical power: $P_{el} = M \cdot \omega_S$

rotor losses: $P_R = M \cdot (\omega_S - \omega_R)$

with angular velocity $= \frac{2\pi \cdot n}{60}$

n = speed,
R = rotor,
S = synchronous.

The frequency converter operates with pulse-width modulated (PWM) high pulse frequency output voltage which is substantially close on average to the ideal sinus form. The additional losses in the motor due to the frequency converter feed are therefore negligible. The three-phase asynchronous motor connected must not be overdimensioned. These characteristics should be taken into account in comparison with other frequency converter systems which operate for example with impressed intermediate current circuits, with square wave voltage blocks or at a lower pulse frequency. The 3-phase mains voltage is rectified by 6 input diodes (active power drawing only). On the intermediate circuit condenser therefore, there is a direct current voltage which is equivalent to that of the peak value of the linked mains voltage. The intermediate circuit capacity charging current is limited at switch-on in order not to load the mains and the circuit fuses with maximum current. In order to prevent unnecessary conduction losses, the charging current limit is bridged by a relay point after capacitor charging. A pulsed mains supply circuit (SMPS), which operates with a high efficiency factor on the blocking oscillator principle, produces from the intermediate circuit voltage the potential-free supply voltage for the electronics and for power semiconductor control. The control electronics are therefore independent of the mains frequency. Even short-term mains voltage drops have no effect on reliable frequency converter operation. Depending on dimensions, the inverter component consists of power field effect transistors or of high-speed frequency thyristors. In the output phases, these power semiconductors control varyingly wide voltage zones, the mean

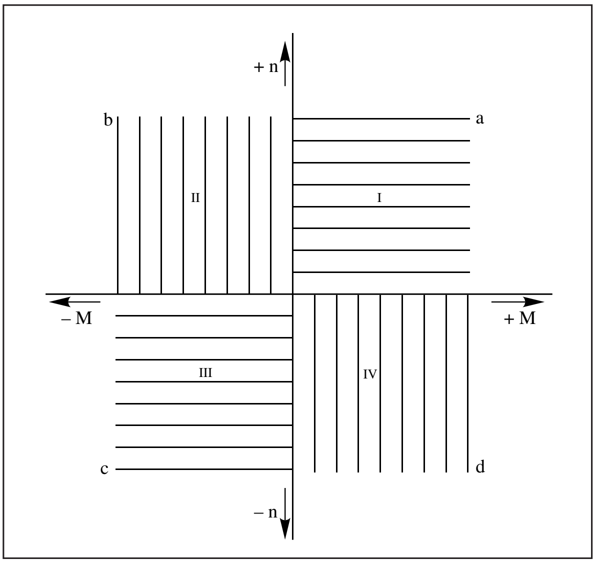


Fig. 5: Representation in quadrant form of drive operating methods (I, II, III, IV quadrants).
a= motor operation, clockwise; b = generator operation, clockwise; c = motor operation, anticlockwise;
d = generator operation, anticlockwise.

values of which approximate substantially to the ideal sinus form.

Electric motors should not cover more functions than the purpose requires. In specific cases, they must also be able to run in 2 directions, or also be able to brake. Clockwise and anticlockwise operation is possible with all three-phase current drives. With mechanically stepless transmission with torque-dependent contact pressure on the other hand, driving and braking require appropriate pressure curve configuration. With these drives, energy feed back into the mains is always possible during braking. With purely electric drives, energy feedback requires appropriate frequency converter design. With the use of a brake chopper this does in fact permit braking, but no energy feedback. The quadrantal form is usual in cartesian coordinates for representing operational methods (Fig. 5).

Electrochemical displacement series (electrochemical series, electromotive series) → Standard electrode potential.

Electrochemical series → Standard electrode potential.

Electrochemical techniques Widely used in the textile industry for analytical and measurement applications as well as in the supply industries for the manufacture of basic chemicals. Up to now, only a few of the great number of electrochemical processing techniques have found a direct application in the textile finishing industry (see Table). The main emphasis of development in the textile industry so far has been particularly concerned with measuring sensors for the monitoring and control of different processing parameters.

Electrochemistry in vat dyeing Comprehensive tests using electrolytic processes have shown that a direct cathodic reaction of dye pigments under usual application conditions is not possible. An electrochemical reduction may, however, be achieved by indirect electrolysis, by the selection of appropriate systems. During indirect electrolysis the reduction/oxidation of substances takes place through mediators or electron transfer substances. These renewable redox systems (mediators) are reduced/oxidised at the electrode and with appropriate orientation of their potential in the solution can reduce any substances present. The

Measuring principle	Sensor	Application
Analytical techniques		
Potentiometry	Glass electrodes Solid state electrodes ion-selective electrodes	pH measurement Redox systems Salt contents
Conductivity measurement	Pt electrodes	Electrolyte contents
Amperometry	Solid state electrodes	Bleaching/reducing agents
Polarography	Hg electrodes	Trace analysis organic compounds
Voltammetry	Metal electrodes	Redox systems Ultra-trace analysis
Chemical process technology		
Electrolytic processes	Chlor-alkali electrolysis, aluminium production, hydrogen peroxide, hydrogen production	
Galvanotechnology	Metal deposition, surface technology, anodizing	
Electrodialysis	Water demineralisation	
Galvanic elements	Current generation, corrosion protection	
Fuel cells	Current generation	
Electro-organic synthesis	Primary industry - raw materials	

Tab.: Survey of electrochemical measuring and process technologies.

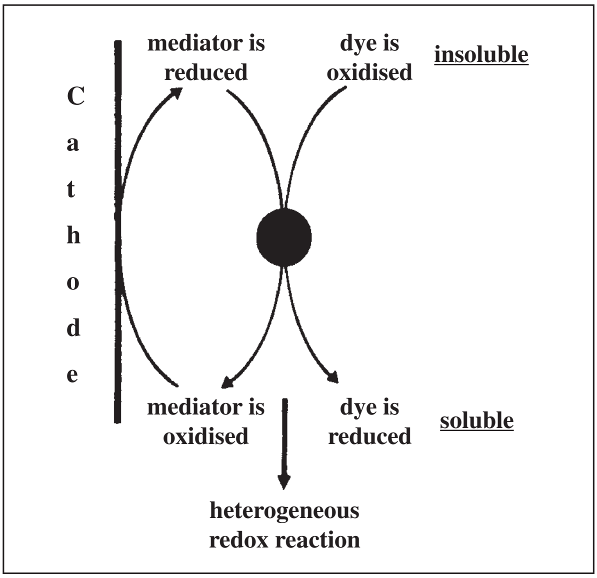


Fig. 1: Principle of indirect electrolysis showing the example of reduction.

mediator system is thus oxidised and in the next stage of the reaction renewed at the cathode (Fig. 1).

Fig. 2 shows the basic layout of laboratory apparatus for the indirect eletro-chemical reduction of sulphide and vat dyes. In this method, direct-voltage electrolysis areas enable the reduction effect at the cathode to be used for indirect reduction of the dye. The reoxidation of the reduced molecules at the anode, causing the release of oxygen, is prevented by a diaphragm (according to Bechthold).

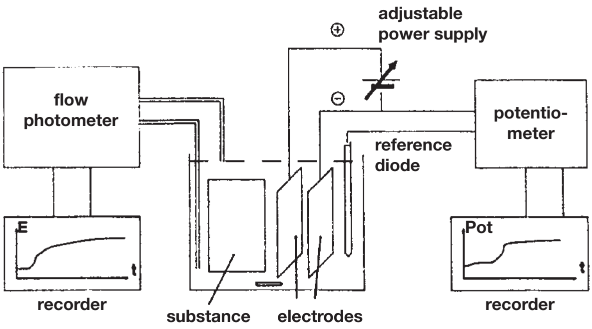


Fig. 2: Trial apparatus for the electro-chemical reduction of dyes (principle according to Bechthold).

Electrodes Electrical conductors (plates, sieves) as used, e.g. in electrolysis (electroplating, electro-deposition, etc.). Positive pole = anode, negative pole = cathode.

Electrokinetic interfacial potential (EP → Zeta potential), electrical charging and voltage ratios at so-called interfaces (fibre/water, fibre/dirt, dirt/scouring liquor) in aqueous solutions. EP is determined by the inherent charge (fibre/dirt) and foreign matter charge, which can be like or opposite (repulsion or attraction/affinity). It is therefore dependent among other things on solution pH and the adsorption of ions on the way from the treatment liquor to the fibre interior. Cellulose fibres for example always have a negative charge, as do protein fibres above pH 3–5. Below this value however (i.e. even more acidic), protein fibres are positively charged. The maximum EP of the fibre in alkaline solutions (negative charge) is at approx. pH 11; in addition, protein fibres have a lower maximum in highly acidic solution (positive charge) below pH 3–4. Between pH 3 and 5, both fibre types have practically no significant electrokinetic potential against the aqueous environment. In practice, the EP maximum coincides with the optimum values: a) of fibre swelling, which is at its maximum at pH 10–11 (minimal at pH 4–6); b) of the scouring power (scouring process) of anionic products (soap etc.), which is at its maximum in alkaline solutions at pH (9.5–) 10.7 (at its lowest at pH 4–6), or of cationic products with scouring power below pH 3. The fact that emulsified dirt particles for example exhibit the smallest charge in aqueous solution complements in practice the importance of EP explained above. The practical inference: textile fibres have a negative charge in pure water:

wool	– 48 mV
cotton	– 38 mV
acetate	– 36 mV
cupro	– 5 mV
viscose	– 4 mV
silk, degummed	– 1 mV

Impurities of all kinds are also negatively charged by contact with water, and this can be significantly increased by soap or other anionic scouring media (Table).

dispersed »dirt particles«	ζ in mV, in water	in soap solution
liquid paraffin	—86	—151
cotton seed oil	—74	—140
dyestuff	—62	— 79
carbon	—60	— 71
bacteria	—34	— 49
iron oxide	—28	— 78

Tab.: Zeta potential of dispersed dirt particles in water and soap solution.

The negative charging of fibre and dirt is explained by the preferred adsorption of hydroxyl ions from the water which is to a degree continuously dissociated. If the charge of the same polarity between dirt and water does not make sufficient electrostatic forces effective in repelling dirt from fibres, it is a consequence of the still too low EP. For this reason, the negative charges are increased vis-à-vis the fibre, achieving an effective potential difference by adding hydroxyl ions to the water in the form of scouring alkalis on the one hand, which already loosen and partly repel dirt, and, on the other, surface active scouring agent anions. A combination of electrokinetic tests with solvent extractions enables theoretically based zeta potential values to be obtained, and consequently to reach definite conclusions on the ionogenic nature of extraneous fibre substances.

Electrokinetic potential (→ Electrokinetic interfacial potential; Zeta potential). The adsorption of surfactants also affects the electrical charge of solid surfaces, which come into contact with the surfactant solution. When e.g. an anionic surfactant is adsorbed, the dissociated anions form a diffuse layer close to the surface so that the adsorbed long-chains form an excess negative charge at the surface. This is expressed in the so-called electrokinetic or zeta potential. Solid surfaces which come into contact with pure water or surfactant-free aqueous solutions also almost always have a surface charge which is predominantly dependent upon the adsorption of ions or the dissociation of surface groups. The polarity of this surface charge frequently depends on the pH. The addition of ionic surfactants therefore causes an increase in the surface charge where the polarity is the same and reverses the charge where the polarity is different. For example, negatively charged carbon black in pure water undergoes a charge reversal when the cationic surfactant dodecyl pyridimine chloride is added at a concentration of less than $1 \cdot 10^{-4}$ mol/l.

Electroluminescence → Luminescence.

Electrolyser Apparatus for the automatic production of sodium hypochlorite from sodium chloride (5–25 wt. %) for bleaching. Principle: an ordinary solution of sodium chloride is allowed to flow through the Electrolyser (see Fig.) where, under the influence of an electric current, a ready-to-use sodium hypochlorite solution is formed without any evolution of chlorine gas. After dissolving the required amount of salt and switching on the current, the electrolysis proceeds automatically without maintenance or supervision. Operating data for the smallest unit: current rating at 110 volts = 5 amps, at 220 volts = 2,5 amps, power consumption = 0,55 kWh, salt consumption = 1,3 kg/h, output (at 3 g/l active chlorine) = 90 g in 1 h, active chlorine in 24 h = 2160 g.

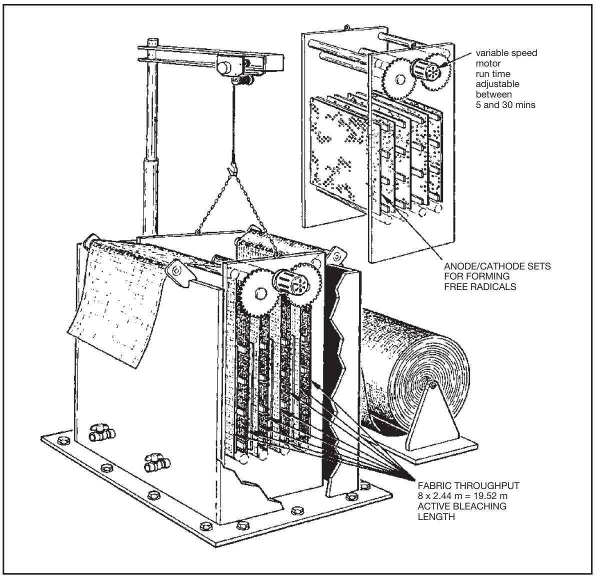


Fig.: Electrolyser-based (Ster-O-Lizer Manf. Corp.) woven fabric bleaching.

Electrolysis Decomposition of chemical compounds dissolved in water (→ Electrolytes) by the application of an electric current in which the (positive) cations migrate to the cathode (negative pole) and the (negative) anions migrate to the anode (positive pole), e.g. sodium chloride (NaCl): Na = cation, Cl = anion.

Electrolyte addition in dyeing In certain dyeing processes, dye exhaustion is not controlled by diffusion. Rather, levelness of the dyeing is controlled by addition of an electrolyte (in the form of metered salt additions). Such processes may be described as "affinity-controlled". A temperature is selected at which diffusion proceeds rapidly. At the point when the equilibrium bath exhaustion momentarily ceases, the kinetics of dye exhaustion are due to the change in equilibrium. For cellulosic fibres the equilibrium distribution of direct dyes can only be represented approximately by a Freundlich or Langmuir isotherm because, e.g. strong associations of large planar dye molecules can be present in the bath. It is exactly these associate equilibriums that are influenced, both within and outside the fibre, by the addition of electrolyte (e.g. salting out of dyes). Thus, in the case of linear salt dosing in a cellulose-direct dye-water system, dye uptake by the fibre rises more strongly at first and then becomes less (see Table). Salt should therefore be added at an increasing dosage rate in order to provoke a linear exhaustion of dye.

The amount of salt should be measured in such a way that a high colour yield is achieved which is insen-

Shade depth (% of fabric weight)	**Salt quantity (% of fabric weight) with**					
	Liquor 10:1 dye salt requirement			**Liquor (20:1) dye salt requirement**		
	low	medium	high	low	medium	high
up to 0,2	1	1,5	2	3	5	7,5
0,5	2	2,5	3	5	7,5	10
1	2,5	3	5	7,5	10	15
2	5	7,5	10	15	20	30
from 4	10	15	20	30	40	60

Tab.: Salt quantities for substantive dyes for cotton dyeing.

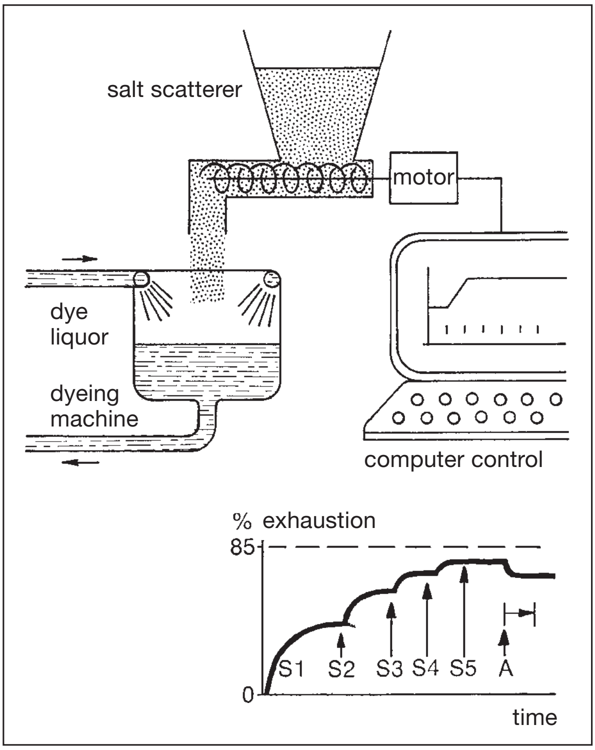


Fig.: Control of electrolyte admixture in the reactive dyeing of cellulose by the exhaustion method by means of so-called "poly product injection" – Thies in cooperation with BASF. S1–S5 = salt dosing; A = alkali addition.

sitive to slight variations in the electrolyte content of the liquor. The amount depends on the type of steel from which the dyeing machine is constructed, as well as the depth of shade, the liquor ratio, and the fibre. A few details for direct dyes are given in the table where the dyes have been subdivided into three groups depending on their salt requirement (this subdivision is somewhat different from the usual SDC classification; these figures also relate to migration properties). Reactive dyes need higher amounts of salt which makes metering more difficult. Since reactive dyes migrate well in the substantive phase, salt should be added from the beginning provided this does not have an adverse effect on levelness (salt dosing is controlled by conductivity measurements or a computer control system) (see Fig.).

Electrolytes Substances which undergo partial or complete dissociation into → Ions in solution (in water or other solvent). The solution then acts as a conductor of electricity. The most important groups of electrolytes are acids, bases and salts. Colloids with electrical properties are known as → Colloidal electrolytes. Electrolytes are frequently employed as diluents for dyes and textile auxiliaries (sodium chloride, sodium sulphate) and to promote exhaustion in dyeing (e.g. salt addition in dyeing with direct or reactive dyes).

Electrolyte sensitivity A characteristic property of synthetic thickeners based on acrylic acid and maleic anhydride: the electrolyte sensitivity manifests itself as a sharp to total loss of viscosity with negative charges on the thickener molecule. It can be prevented, where permissible, by mixing with high-viscosity grades of modified natural thickeners, e.g. carboxymethylcellulose.

Electrolytic bleaching Vegetable or animal fibres are either immersed in a bleach bath, or saturated with bleach liquor, and subjected to the action of a medium to high frequency alternating current.

Electrolytic corrosion plays an extensive role in the → Corrosion of metals. Principle: formation of galvanic elements or electrical currents between metals of different electrode potentials in the presence of low amounts of moisture (as an electrical conductor). It is dependent on local structural differences of the metals (composition, welded areas, etc.). "Anodic sites" are the metals themselves (the more negative ones being placed below each other) and "cathodic sites" are formed by oxide or surface skins, metal additives (carbon) as well as more noble (less negative) metals. In the condensing kettle for recovery of chlorinated hydrocarbons in drycleaning the following course of action takes place:

1. Localized electrolytic corrosion: Acid-containing condensate droplets are formed in the air space of the distillation apparatus and recovery tank after cooling on the metal surfaces. Anodic dissolution of metal takes place in the middle of the droplets (selective corrosion, pitting) and corrosion begins.

2. → Pitting corrosion: further condensate is deposited in the now porous areas of the metal; pitting continues to eat through the metal to the outside until complete perforation occurs.

Electrolytic water purification Processes based on electro-osmosis for the softening of boiler feed water and removal of salts.

Electro-m-process An electro-chemical process for → Waste water treatment. It involves breaking down water by electrolysis. Impurities are oxidised or reduced by the resultant oxygen and hydrogen at the nascent stage. May be supplemented by the perco-filter process (a series of multi-layer adsorption and filtration processes operated under 5 bar pressure), giving water practically of drinking quality.

Electron acceptor/electron donator One way of categorizing the wide variety of reaction types in organic chemistry is into electron or ion reactions. Thus in the case of substitution reactions (e.g. at the benzene nucleus), the controlled effects of existing substituents arise as a consequence of their electron-attracting or electron-repelling (electron transfer) characteristics, and also dipole elements of organic compounds result from electron displacements within the molecule.

There is a difference in terminology depending on whether the reaction is a result of electron migration or whether an electron pair is "borrowed". It thus follows that an electron acceptor is an oxidation agent, the electron donator a reducing agent. Thus, for example, the weak dyeing (λ 330 nm) of azobenzene (azo dye) can be traced back to the migration of one of the two lone electrons to the azoic nitrogen. By introducing an electron acceptor group, e.g. $-NO_2$, in the 4 position, a clear bathochrome migration (λ_{max} = 478 nm) takes place, with visible bands which analytical findings have found to correspond above all to the electron migration of the azobenzene.

Electron donor → Electron acceptor/electron donator.

Electroneutral compounds arise from the conversion of aqueous solutions of cation-active and anion-active compounds of sufficient molecular size. Electroneutral compounds are used as antistats, lubricating agents, etc.

Electron formulae → Atomic bond.

Electronic engraving An electronic scanning and engraving system which converts the reflected light from a design sketch by means of an optical sensor into electrical signals which are transmitted to the engraving system via a computer.

Electronics A branch of electrical technology concerned with electrical circuits developed from electrical or magnetic fields, electrical currents, heat, light or other radiation sources in which the motion of → Electrons is controlled for technical applications in communications, control systems, or computing.

Electron microscope A microscope which uses electrons for imaging instead of light. Quantitative and qualitative application. Principle: a directed electron beam, which impinges on the examined test specimen in a vacuum, brings about the emission of an X-ray spectrum which is characteristic of the elements contained in the specimen. From this spectrum, conclusions can be drawn as to element type and concentration. Either a point on the test specimen (point analysis) or an area (scanning) can be sensed with the electron beam. Construction: consists mainly of electron sources and three vertical coil or electron systems (in an approx. 1 m high vacuum tube), which act as lens sets (from top to bottom): 1. condenser for condensing the electron beam on to the object, 2. objectively, and 3. projectively. These current traversed coils act on the directed electron beam passing parallel to their axis relative to current strength (adjustable focal depth) as so-called magnetic lenses. Electric lenses also have the same action (charged pin diaphragm). The magnified object appears as an image on a fluorescent screen or photographic plate. Direct magnification up to x 150 000. Total magnification with optical after-magnification (light-optical microscope) up to 1 million. The resolving power depends on the electron beam wavelength, i.e. its speed (at 10 000 volts, approx. 60 000 km/s wavelength approx. 12 billionth of a mm), and the spherical error of the electron lens. Achievable resolution up to approx. 1 millionth of a mm. Used for research purposes (also on textile fibres). → Scanning electron microscope.

Electron number → Atomic number.

Electron pair bond → Atomic bond.

Electron polarization → Polarization.

Electrons (Greek), electronegatively charged particles of an → Atom, the unit charge of which (in contrast to the positive electricity of positrons) can exist (cathode and X-rays) dissociated from the material, i.e. in the "flying off" of an electron from an (electrically neutral) atom, a positive charge is produced in the nucleus, and consequently a monovalent positive ion. With the expulsion of two, three etc. electrons therefore, bivalent, trivalent, tetravalent and multivalent positive ions (cations) are formed. Conversely, a monovalent, bivalent, trivalent etc. negative ion (anion) is formed with the joining of one, two, three etc. electrons with a neutral atom. If numerous electrons are involved in these processes, "electrical phenomena" occur. The speed of an electron is 2000 km/s. The "mass" of an electron is approximately $^{1}/_{1800}$ of the atomic weight of hydrogen. An electron should therefore be regarded as the smallest quantity of electricity capable of existence.

Electron shift → Standard electrode potential.

Electrophoretic coagulation A process for bonding fibrous webs with acrylic and polyurethane binders.

Electrophoretic mobility describes the velocity of migration under direct current influence of colloidal particles in an aqueous medium to the plus or minus pole. It is of a similar order of size as with conventional ions, which is perhaps due to an increase in electrical charge with increasing particle size. Electrophoretic mobility represents for example an electrical component phenomenon of the scouring process, involving detached pigment particles in the liquor, in which an increase in electrophoretic mobility makes itself apparent by increasingly affecting the fibre/dirt system. →:

salts		EB 10^{-4} cm/s
neutral and weakly acid salts	WITH NO ADDITION	4.6
	sodium chloride	5.4
	sodium sulphate	
	disodium orthophosphate	
	acidic pyrophosphate	5.9
	sodium metaphosphate	5.8
alkalies	sodium hydroxide	4.8
	sodium carbonate	5.7
	trisodium orthophosphate	4.9
	tetrasodium pyrophosphate	5.2
	sodium metaphosphate	5.5
	magnesium chloride	3.9

Tab.: Electrophoretic mobility (EM) of soot particles with the addition of inorganic electrolytes.

Zeta potential and suspending power are closely associated with electrophoretic mobility. In an approx. 2.9 g/l fatty alcohol sulphate (sodium dodecyl sulphate) solution, the electrophoretic mobility of soot particles for example changes with the addition of inorganic electrolytes in equivalent concentration (Table).

Electrophoretic mobility is accordingly slightly increased by monovalent cation salts (sodium example above), but reduced by the magnesium salt. Reduced electrophoretic mobility also produces higher scouring substance concentration.

Electroplating (electrodeposition). The deposition of a layer of metal (typically silver, nickel, zinc and chromium, etc.) by electrolysis. The object to be plated forms the cathode in an electrolytic tank or bath containing a solution of a salt of the metal to be deposited.

Electropolishing Surface treatment of rollers to prevent the build-up of deposits and stains.

Electrospray process (→ Spray printing). This process is more rapid than mechanical spray printing methods and allows the production of finer details. Not yet applied in textile printing except, to some extent, carpet printing, because of high investment costs and the lack of genuine textile printing effects. On the other hand, it has found wide application in coding systems and the production of printed letters and policies, etc.

Electrostatic bond → Ionic bond.

Electrostatic charge Electrical surface effect on textiles, machines, fluids etc. Actually "at rest" electricity (static), but which moves anywhere with extreme rapidity at the moment of perception, only then being observed as attraction or repulsion. The occurrence of electrostatic charges is almost always accompanied by unwelcome difficulties in processing operations and in use. They are particularly production disrupting and quality impairing phenomena, such as the splaying out of electrically charged fibres, yarns (fly and tangle formation) and the bellying of charged fabrics (difficulties with plaiting, folding, cutting etc.), the unwanted "clinging" together of oppositely charged clothing during wear, the "sticking" of textiles to oppositely charged machine components, tenaciously adhesive light-coloured fly, yarn waste etc. on other, dark-coloured, types of textile material, the difficult to remove soiling of machinery by dust etc. from the atmosphere, the not infrequent electric shocks to personnel (assisted by rubber shoes) through to open sparking, fire and the danger of explosion (e.g. in dry cleaning plants). The causes are due to surface contact, especially in association with rapidly interrupted contact (e.g. high fabric speed), mainly during or after mutual contact and friction (e.g. textile/textile, textile/machine component, textile/hot air in drying processes, water/air in the case of nozzles), by distortion pressure (e.g. on calenders and printing bowls) and due to temperature change (variously on drying units, tumblers etc.). Familiar causes are often simultaneously involved too. The electrostatic fibre charging process is essentially explained as the effect of a charge transfer on the surface due to (the above-mentioned) mechanical causes.

In this connection, any tendency to electrostatic charging (coulomb forces) is generally more pronounced with higher electrical resistance, i.e. lower electrical conductivity (affinity), which again mostly equates with lower (fibre and air) humidity (wool is a particular exception) and vice versa. The electrostatic range illustrated in Tab. 1 has been compiled in accordance with these standpoints. Broadly speaking, it can be said that the upper list of fibres is positively charged by the effect of friction for example, i.e. chiefly by other, lower list fibre types or yarns. Conversely, the lowermost fibres are negatively charged by friction on other fibres listed above them. As charge polarity can sometimes also be markedly overridden by impurities, the presence of residual charges and so on, relationships in the middle of the list are less pronounced and increasingly uncertain.

In addition to a glimpse of quite normal charge levels, it can be seen from Tab. 2, in this case at two different

charge	material range	specific electrical resistance (ohm x cm) §	% approx. water content mean value
		at 20 °C and 65 % r. h.	
+ ↑ increase	glass	↑ increase $10^{11} \dots 10^{15}$	0 increase ↓
	polyamide	$10^{9} \dots 10^{12}$	4
	wool	$10^{7} \dots 10^{10}$	13
	silk	10^{9} (degummed)	10
	viscose	$10^{6} \dots 10^{7}$	12
	cotton	$10^{6} \dots 10^{7}$	9
	ramie	10^{5} (estimation)	7
	(steel)	$(10^{6} \dots 10^{7})$	
	(ebonite)	(10^{18})	
	acetate-artificial silk	$10^{9} \dots 90^{11}$	6
	(synthetic rubber)	$10^{6} \dots 10^{16}$	
	polyacrylic	$10^{8} \dots 10^{14}$	1
	polyester	$10^{8} \dots 10^{14}$	0,5
	polyvinylchloride	10^{12} (estimation)	0
− ↓ increase	polyethylene	10^{12} increase ↓	0 increase ↑

(§ = rough limiting dimensions according to various authors)

Tab. 1: Electrostatic charge on various materials.

material	take-up speed	50 m/min		400 m/min	
	relative humidity	50%	80%	50%	80%
cotton		8	0	500	0
viscose-filament		870	0	8 700	4 200
wool		1 700	250	7 300	3 200
acetate-filament		8 700	1 800	4 900	2 900
polyamide		9 300	3 000	13 500	4 900

Tab. 2: Electrostatic charge depending on relative humidity and different take-up speeds.

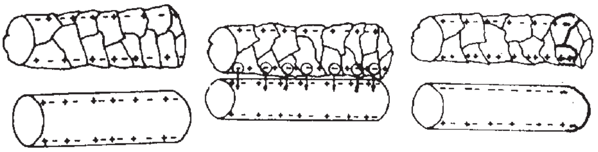


Fig. 1: Electrostatic charge reversal of polyester fibres and wool.

ent processing speeds, that higher humidity alone creates a tendency to reduced electrostatic charging and consequently to better behaviour.

Accordingly, where it is important in practice to prevent difficulties with complete reliability, care should be taken to ensure rapid discharge of the electrostatic charge produced, for which the numerous possibilities with suitable → Antistatic agents (with dry cleaning → Antistatics in drycleaning) are of great importance.

In the initial state (Fig. 1, left), both fibres wool/synthetic are electrically neutral (as many positive as negative charges). With mutual friction (Fig. 1, centre), electrons are transferred from wool to synthetic, resulting in uneven charge distribution: wool now has fewer electrons than in the initial state, while synthetic has more. This fact is visible in the electrostatic charge effect (Fig. 1 right).

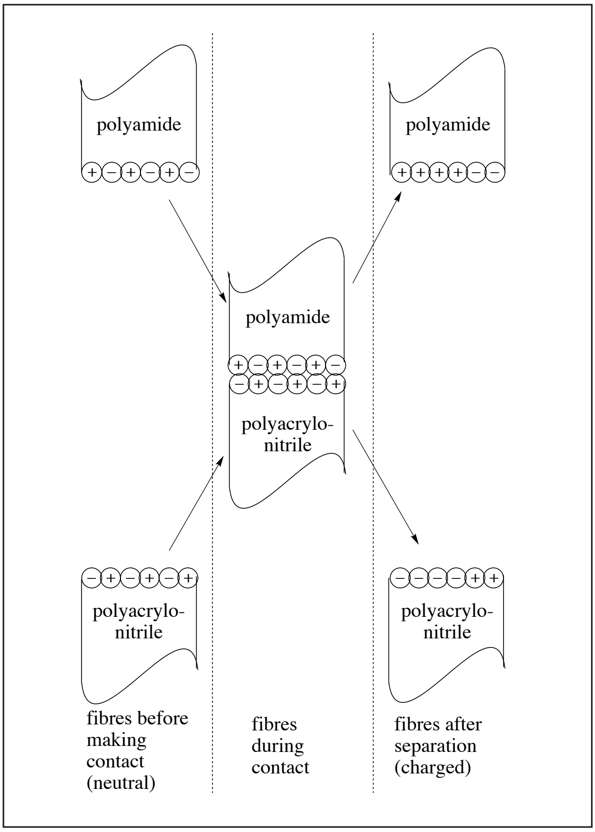


Fig. 2: Electrostatic charge separation.

On the surface of a body the molecular charge distribution is no longer in equilibrium. The mutual interplay between nucleus and electron sheath is disturbed at the boundary layer, resulting in a specific surface potential which is dependent on various factors, e.g. on the polarisation potential of the molecules, i.e. on the mutual transferability of the positive and negative charge focal point, on the orientation of the molecules to the surface, and their packing density. If now the surfaces of two different bodies come into mutual contact, the two electrical field margins overlap. A double electric layer forms, corresponding to the difference between the two surface potentials, the distance apart of the opposing surface points and the size of the area in contact. After subsequent separation, the body with the higher permittivity carries the positive charge. This can be simply illustrated if two materials of polyamide and polyacrylonitrile are rubbed together (Fig. 2). The electrostatic charge is a surface effect, permittivity on the other hand is a dimension which comprises the total volume of the body. Deposits on the surface of the fibre material, which need only be present in a molecular layer, such as humidity, impurities, surfactants etc. for example, can significantly affect the charge polarity sign and level, while the electrical characteristics of the material are hardly affected by it.

Electrostatic charge elimination Can be achieved by:

I. The deposition of chemical substances which increase the conductivity of the substrate to which they are applied, thereby increasing the mobility of ions through the material. Such substances include: polyhydric alcohols, polyethylene glycol derivatives, organic nitrogen compounds such as amines, ammonium salts, amides, etc., as well as derivatives of phosphoric and sulphuric acids.

II. The topical application of → Antistatic agents: in general, cationic and amphoteric antistatics are more effective than anionic and non-ionic types. The presence of an antistatic causes the formation of a thin but uniform film of moisture on the fibre surface which consequently increases its conductivity.

III. Metallic needles and brushes are brought into close proximity to the surface to be neutralized without actual contact. Provided the electrostatic charge is sufficiently high, it will be discharged discontinuously.

IV. → Ionizers.

Electrostatic charge, measurement of Electrostatic charges disrupt both the production and use of textile products. Utilisation problems frequently involve safety interests, e.g. in flameproof zones, in computer areas, in handling fine-grain solids. When these utilisation dangers have to be evaluated, they are assessed on the basis of appropriate specifications regarding surface and volume resistance (DIN 54 345 T1; and, in accordance with DIN 54 345 T5, in the presence of conductive fibres), raising the question of the charge level at the centre point, which can be answered with adequate accuracy by means of resistance measurement. Electrostatic behaviour is not just a safety-relevant characteristic, but is also of importance as a material property, i.e. as a functional characteristic (similar to strength or air permeability) or as a product distinguishing feature. This can be the case for example in flocking, filtration (gas dedusting), in special (electrostatic) spinning processes, in the development and production of antistatic equipment, electrically conductive fibres and yarns, and also soiling process evaluation. From experience, the differentiability of surface resistance and penetration resistance characteristics is insufficient to allow electrostatic behaviour to be described as a material property with adequate precision. In the case of textiles containing conductive yarns or fibres, resistance measurements in accordance with DIN 54 345 T1 can produce physically absurd results. It should also be remembered that the local charge density on an electrically charged fabric surface can not only be inhomogeneous but that the character of the charge also varies locally (negative and positive charge islands).

Electrostatic behaviour is a typical product characteristic because of its distinct dependency on the textile make-up form. Its peculiarity consists of it being equally

- a material property,
- a surface property,
- a property markedly dependent on environmental conditions.

In describing electrostatic behaviour as a product characteristic, both charge capability and discharge behaviour have to be taken into account. Charge state and discharge behaviour can be described by known dimensions like charge and field strength and also by change relative to time, e.g. in half-life form. The charge on the sample to be tested can be the result of

- sliding friction and charge separation,
- charged particles deposited on the test specimen surface,
- a charge character suitable for ions (produced with the aid of corona electrodes, i.e. spray electrodes),
- by direct current voltage above 1 kV.

2 mechanisms play an important role in discharging:

- charge leakage conductance,
- charge decay (on the spot).

In this respect, half-life as a feature of discharge rate varies within extremely wide limits; it is approx. 0.1 s at the minimum, and weeks at the maximum. This data should be taken into account if the "electrostatic behaviour" product characteristic is to be reproducible and quantitatively characterized. If electrostatic behaviour is regarded as a product characteristic, the test component should obviously be charged under conditions close to the practical, friction being a possibility in many cases. Numerous test processes are open to choice if the resultant electrostatic behaviour, i.e. the effective triboelectric behaviour in a simulated wear test, is to be characterized, the test specimen surface being subjected once or a number of times to frictional stress, producing charges the number of which depends among other things on friction duration and discharge rate (Fig. 1). Some triboelectric behaviour characterizing processes have been standardized, including for example:

- DIN 53 486 for laminates, e.g. conveyor belts;
- DIN 54 345 T2 for textile floor coverings;
- DIN 54 345 T4 for textiles in general.

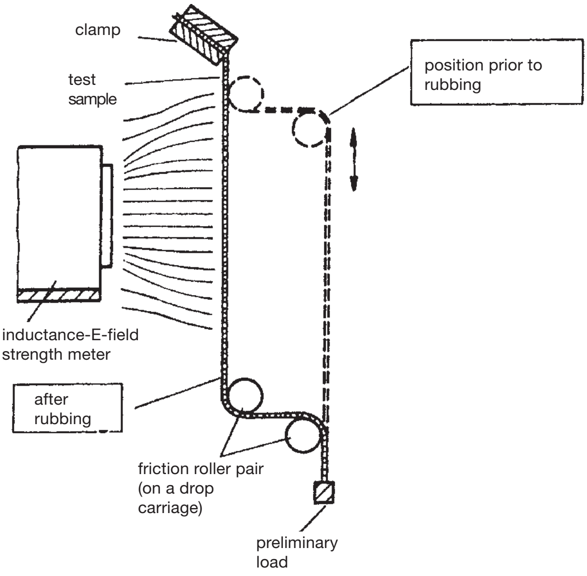


Fig. 1: Schematic diagram of the test set-up in the triboelectric behaviour determining process.

The principle of throwing charged test samples quickly into a Faraday beaker after a friction process, and measuring their voltage is not only described in DIN 54 345 T4 but also by two Japanese standards particularly specified for clean room textiles: JIS L 1094-1980 and JIS T 8818-1983.

In the so-called "Cling test" (AATCC Method No. 115) too, the test sample is charged by friction. It is not of course the field strength or the charge which is used as the criterion but the adhesive tendency of the test sample to a standardized surface. Another charging principle is discussed as an alternative to friction stressing: the "corona" effect, where a test sample, first of all discharged, is charged with spray electrode ions and its discharge behaviour evaluated.

In addition to the above-mentioned standardized processes, there are other methods: in measuring triboelectric behaviour, the experiments concentrated on a single friction process of short duration. Considerable information loss is feared with multiple rubbing or longer duration rubbing of a test sample unit: with multiple rubbing and with longer-term rubbing of the same test sample unit, charging and discharging processes overlie each other in a way which is impossible to monitor. The disadvantageous effect of this overlapping is expressed for example with conveyor belts when testing is effected in accordance with DIN 53 486. These overlapping influences are again reflected in the considerable effect of a walk test in accordance with DIN 54 345 T2.

The following needs go beyond the obligatory requirements for reproducibility, comparability and calibration facility:

- single rubbing process;
- short-term contact between frictional body and test sample;
- short total rubbing process period in order to be able to keep the overlap of charging and the onset of discharging at a minimum;
- rubbing speed: depending on the sliding friction level of the sample to be tested in each case;
- recording both charge and discharge behaviour.

The last-named requirement is essential, because electrostatic behaviour can only be meaningfully recorded in terms of both values. With regard to normal wear factors, a low discharge rate always conceals the danger that the charge level will be disturbingly high. Independently of the charge level, a low discharge rate is therefore regarded as particularly critical.

The following process has been developed with regard to these requirements (Fig. 1): the test sample, one end clamped in an earthed clamping unit, is subjected to a single frictional stress process with the aid of a controlled low-friction drop carriage. Field strength relative to time is measured by an electrostatic induction field meter positioned near the test sample (Fig. 2). The following parameters are used:

1. the field strength level E_0 (maximum field strength) attained at the end of the rubbing process as a measure of charging capability.

2. the discharge rate characterized by the half-life or by the residual field strength (E_{30}) attained after 0.5 min.

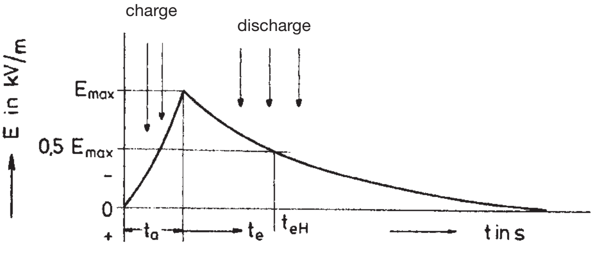


Fig. 2: Typical measurement graph for evaluating the charge and discharge capability of a test sample in the triboelectric behaviour determining process.
t_a = charge period; t_e = discharge period; t_{eH} = discharge half-life; E = electric field strength (kV/m); E_{max} = maximum charge.

In this type of test, numerous influencing factors play an important role. They are controlled as far as possible: distance apart of test sample plane and field strength meter: adjustable; standard 55 mm. An "electrostatic induction E field strength meter" (Eltex-Elektrostatik GmbH) is used. Drop carriage mass: 1 kg. friction roller: as required; standard: 2 x 15 mm diameter cylindrical polyethylene rollers (HDPE = low friction level and low charge capability). Effective test sample length: 150 mm. Test sample width: 50 mm. Preliminary test sample load: depending on fabric: woven fabric 1.3 N/50 mm. Test sample discharge before testing with the aid of a spray electrode. Despite these measures, different friction levels cannot be prevented from occurring in the test (depending on the fabric to be tested in each case). Whether this difference in level has an effect on the maximum field strength depends again on triboelectric behaviour: fabrics with a high charge tendency vary their field strength maximum relative to the friction level (this maximum increases as the friction level rises). This factor is not process-determined, but is a result of electrostatic behaviour mechanisms and of the requirement for simulating frictional conditions closely similar to those in use. As we know, ambient conditions have a considerable effect on electrostatic behaviour, and are also adapted to the conditions of use in each case (standard test atmosphere 22°C and 50% relative humidity). Although this air humidity level is comparatively high (DIN 54 345 T1: 25% relative air humidity), the test process is capable of a high degree of differentiation even under those conditions (contributed by Ehrler and Schmeer-Lioe).

Electrostatic filters The separation of exhaust air pollutants can be intensified by means of electrostatically charged filtration media. Since the discovery of the „Hansen filter“ in 1930 it has been known that, be-

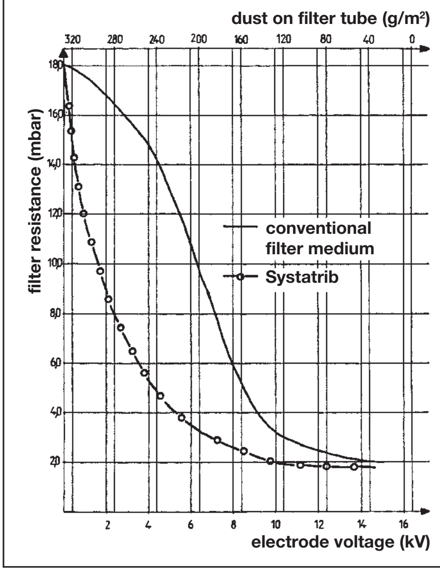


Fig. 1: Effect of electrode voltage on filter resistance.

sides other separation mechanisms such as diffusion, inertia, gravitational force and blocking effects, electrostatic forces have a great influence on the separation performance of fibre filters (Fig.1). Synthetic fibres, in particular, are susceptible to electrostatic charges. Despite having been known for a long time, the exploitation of electrostatic forces in fibre filters only achieved significance in the middle of the 1970s. However, in electrostatic fibre filters the charges on the electrostatically-charged fibres are of a semi-permanent nature only.

Despite the significant structural surface of synthetic fibres in the fine and very fine titre range, actual test bed investigations have revealed that the natural, i.e. production-determined morphology of synthetic fibres used in modern filter media is insufficient by itself to fulfil the requirements relating to separation efficiency and filter resistance. It is only possible to meet these requirements if a sufficiently large filtration surface is available together with an appropriate cleaning system for regeneration of the filter. Even the naturally available and detectable electrostatic influencing variable normally present in all synthetic fibres and dusts is incapable of meeting all the requirements on its own, although it is known that

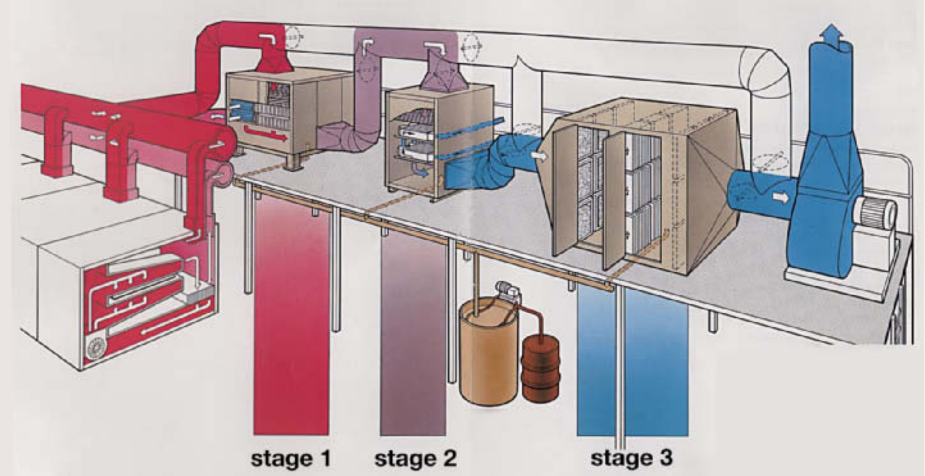


Fig. 2: Electrofilter as stage 3 in a Behr stenter exhaust air cleaning plant.

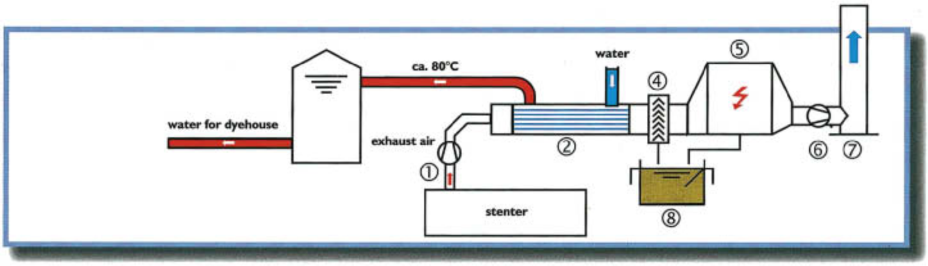


Fig. 3: Condenser air/water with mist collector and electrostatic precipitator (e.g. water heating for dyehouse).

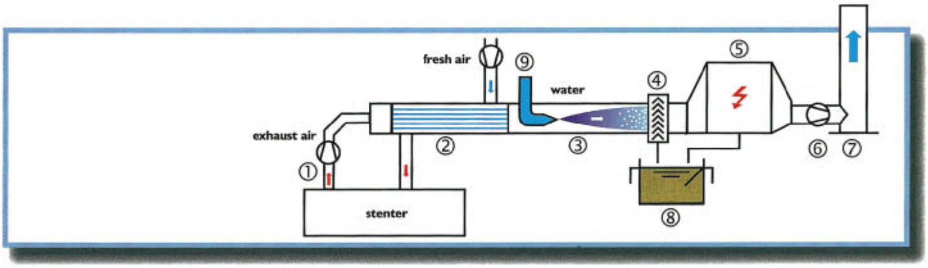
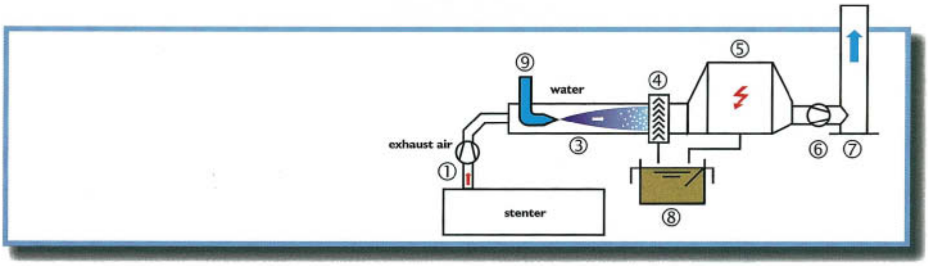


Fig. 4: Condenser air/air with injection condenser, mist collector and electrostatic precipitator (fresh air heating for stenter).



① Exhaust air duct
② Condenser
③ Injection condenser
④ Mist collector
⑤ Electrostatic precipitator ESP
⑥ Ventilator
⑦ Stack
⑧ Oil-/water seperator
⑨ Injection nozzle

Fig. 5: Injection condenser with mist collector and electrostatic precipitator.

the exploitation of electrical or electrostatic forces improves separation as well as the storage capacity and regeneration properties. It is for this reason that the combined application of an electrostatic filter with other methods of exhaust air cleaning is recommended for optimum performance (Figs. 2–5).

Electrostatic generator Device used as a source of high tension for electrostatic flocking and flock printing. When connected to an alternating current supply (100–250 V) it delivers a high tension direct current (approx. 20–100 kV) which, depending on the equipment, can be regulated steplessly. Energy consumption is generally low and less than 200 W/h. Various models are available commercially, either as single units or integrated units in complete plants. Electrostatic generators are now supplied with a safety relay which provides protection against short stoppages, accidental contact, and overloads by means of an automatic circuit breaker.

Electrostatic series → Electrostatic charge.

Electrovalency → Ionic bond.

Electroviscous liquids (EVF), liquids based on silicone oils which contain a suspension of fine, non-metallic hydrophilic particles with a low proportion of adsorbed water. These suspensions have the quality of changing their viscosity within milliseconds. Depending on the strength of the electrical field applied, the viscosity can be modified from free-flowing to a congealed, plastic state. In order to congeal an EVF, relatively high field strengths of several kV/mm are needed, but the currents are very low, so that the electrical output (several watts) of a standard commercial high-voltage module is usually adequate.

To explain the electroviscous effect, the particles in suspension should be envisaged with an electrical charge and surrounded by a diffuse cloud of counterion. By applying an electrical field the clouds of ions are distorted to such an extent that they overlap. Thus the particles restrict each other's movement, manifested as an increase in viscosity. The effect may also, however, be explained by the solid particles assuming an ordered arrangement in the electrical field (formation of chains).

Because of this property, the EVFs have numerous applications in industry and engineering, especially in situations where mechanical forces are transferred hydraulically and need to be controlled by electronic switching with low electrical rating. A particular feature of EVFs is that they are particularly compatible with and stable in the presence of elastomer materials, have a high flash point (>250°C, DIN 51376), are physiologically safe and environmentaly friendly. In addition, they are resistant to cold and heat across a wide temperature range, and their electroviscous property is only dependent on temperature to a relatively slight extent.

Elementary fibrils → Fibrils.

Elementary filament (Filament, single fibre, filament fibre, capillary filament). A virtually continuous structural component of the → Filament yarn, i.e. in the case of silk, the fibroin thread, in the case of man-made filaments, the continuous filament formed by extrusion through the individual spinneret holes.

Elements Chemical "raw materials" consisting entirely of → Atom of the same → Atomic number, and which cannot be decomposed into simpler substances by normal chemical methods. At present, 104 elements are known of which 92 occur in nature. The → Periodic system of the elements begins with the lightest, hydrogen, and ends with the heaviest, Kurtschatow. Elements are the building blocks of all chemical compounds and are subdivided into → Non-metals and → Metals.

Elevated temperature dyeing machine A description for low pressure dyeing machines (winches, yarn dyeing machines) which, in contrast to HT-dyeing machines, only permit dyeing temperatures up to a maximum of 106/108°C.

Elimination potential (Lat.: eliminare = remove, leach). Elimination is used, for example, to describe the removal of the impurity content of effluents in treatment plant (see Fig.). The term does not imply whether the substances removed are biologically degraded or adsorbed on to sludge. Even in the case of elimination by biodegradation, polluting metabolites could arise from the original substances.

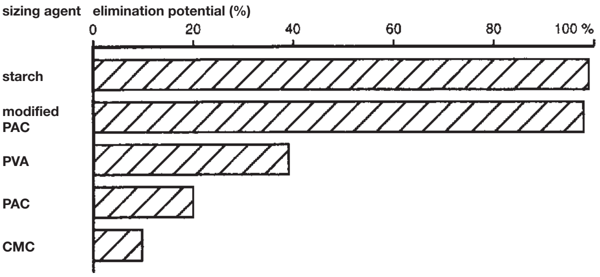


Fig.: Biological elimination potential of sizing agents (source: Sandoz).

Starch, alone or in combination with other products, is still the preferred sizing agent. It is clear from the Fig. that certain sizing agents are only eliminated, and should therefore be replaced by other, more degradable products. Polysaccharides, which include starch, will be of growing significance in future due to their good biodegradability.

Elmendorf tear strength tester A test apparatus originally designed to determine the tearing strength of paper, but which is now specified as a standard test (BS 4253:1967 (1986); ASTM D 1424-83; M & S P-29) to measure the tearing strength of very lightweight fabrics and resin-finished apparel fabrics. A trapezoidal fabric test specimen is employed.

ELMO, abbrev. for: European Laundry and Drycleaning Machinery Manufacturers Organization, Brussels.

Elongation Simultaneous extension which arises during the → Tensile strength test and leads to a break. The elongation at break is expressed as a percentage. It is derived from the (reversible) elastic elongation and the (irreversible) permanent stretch (→ Elasticity of elongation). →: Tensile strength; Fibre strength.

Clothing restricts the freedom of movement of the wearer. According to the activities carried out, certain elongation demands are made at particular points of the garment (Fig. 1). The cut of a garment, especially whether it is close-fitting or loose-fitting, is of essential importance in determining the type and extent of the elastic elongation properties. In principle, close-fitting garments require two-way stretch, whilst elasticity in one direction only is better suited to a more loose-fitting garment.

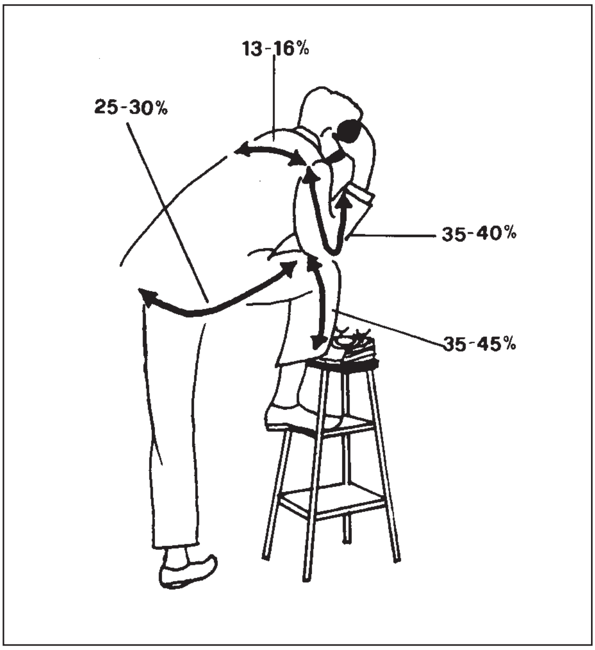


Fig. 1: Example of posture showing the relevant elongation behaviour of clothing.

The drape of the fabric, the factor which determines the aesthetic appearance of the garment, is only sufficiently evident in the case of unidirectional elasticity. Two-way stretch fabrics are more comparable in character to knitted goods.

The elasticity of fabrics made from polyester/elastomer blends is developed by a hot wet finishing treatment. The fabric thereby contracts until all the picks are close together (Fig. 2). If the fibre density now needs to be opened out, thus making the fabric lighter, or the width increased in the case of a filling sateen, the fabric can be heat set under tension. Consideration must, however, be given to the fact that during heat setting a degree of strength, specifically of the elastomer fibres, is permanently lost, thus having a considerable effect on the properties of elastic recovery. It is therefore important to adjust the composition of the fabric accordingly.

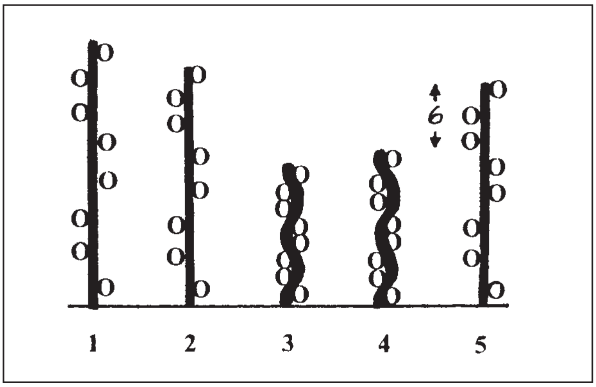


Fig. 2: Changes to the warp length and position of the weft following finishing processes.
1 = as on loom; 2 = off the loom; 3 = boiled; 4 = finished, relaxed; 5 = finished, stretched; 6 = elasticity.

In addition to heat setting temperature and duration, the degree of elongation of a textile fabric during heat treatment is essentially influenced by the later service properties. The elongation or a certain elongation property during processing is also determined indirectly by testing using the usual methods. A change in length is marked on an external device (e.g. stenter frame, elongation testing equipment) and is applied as actual elongation of the test subject along its full length. It is at the stage of correcting the width of the goods when the edge – middle – edge elongation profiles arise, which can have a negative effect on the properties of the textile.

It may be that case that a fibre is required to contribute to the stability of form of a fabric. It is then recommended that fibres are used with a higher modulus of elasticity. For example, fibre type A (Fig. 3) is more

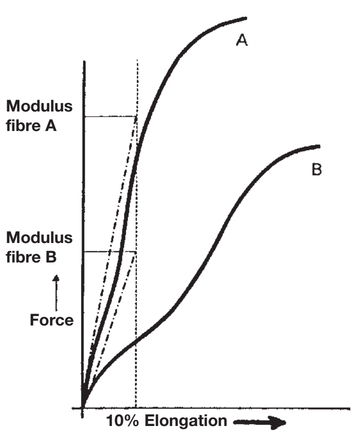


Fig. 3: Two fabrics with varying elongation properties (moduli).

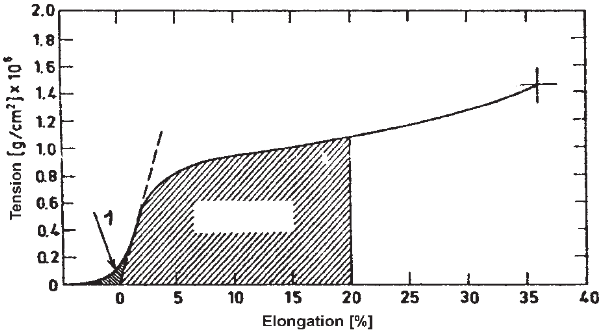


Fig. 4: A typical stress-strain curve for wool with de-crimping region (1), Hooke's area, yield and post-yield region. Hatched area: Stretch recovery at 20% elongation.

stable than B under the application of lower deformation forces. Whether this advantage has an effect depends to a great extent on the design of the goods, i.e. in particular the type and number of the crossing points.

Of course, the change in fibre microstructure is reflected in the elongation of the modulus (mechanochemistry). Thus wool has a greater tendency towards attaining its elongated condition the damper it is. If a wool fibre, having passed through the de-crimping region, is stretched in cold water, it will follow Hooke's Law of linear stretch, up to a change in length of 2%. At this point it enters the yield region, which extends to a change in length up to 30% (Fig. 4). During this elongation process the radiogram of the wool changes critically: within the microfibrils the α-keratin in the form of the α helical structure is reversibly transformed into β-keratin in a folded structure (Fig. 5).

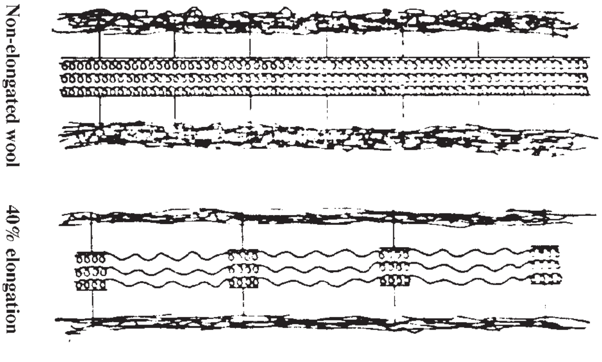


Fig. 5: Two-phase model of the polypeptide chain molecules in wool which is not elongated and wool elongated by 40%. The partially crystalline microfibrils contain helical chains (a-helices). The amorphous regions (matrix) consist of partially oriented chain bundles.

Elongation at break The quotient of the change in length (→ Elongation) and the original length obtained in a → Tensile strength test. In practical tests it is the increase in length when the last component of the specimen breaks.

Eluent (eluting agent). An auxiliary consisting of pure solvent or a multicomponent solvent mixture used in → Chromatography. The glass separation vessels used in chromatography (normally circular for paper chromatography and of square section for thin layer chromatography) are filled with 50–100 ml (approx. 5–10 mm height). All tests should be conducted at a constant room temperature. Depending on carrier and eluent, the running time is variable.

Embossed transfer printing paper Transfer printing paper with an embossed effect which is "permanently" fixed in the textile material after transfer printing.

Embossing (Embossed finish, goffering, gauffering, fluting, schreiner finish, silk finish, high-lustre finish), impressing of patterns on normally smooth textile surfaces, produced under high pressure and at high temperature on the →: Embossing calender (Fig. 1); Schreiner calender, etc., between a heated embossing cylinder and a mating or elastic counter roll. Distinction is made between embossing of unfinished fabric (fast to washing and ironing) for special crepe fabric (→ Creping) and embossing of finished fabric. The latter applies chiefly to cellulosic fabrics. It is only through resin finishing agents (preferably melamine formaldehyde compounds, reactant resins) that a permanent embossed finish (e.g. Everglaze™) is produced. This provides a good opportunity for dimensionally stable finishes, which can be just as resistant to laundering and dry-cleaning as they are remarkably creaseproof and shrinkproof at the same time. Typical embossed finishes include:

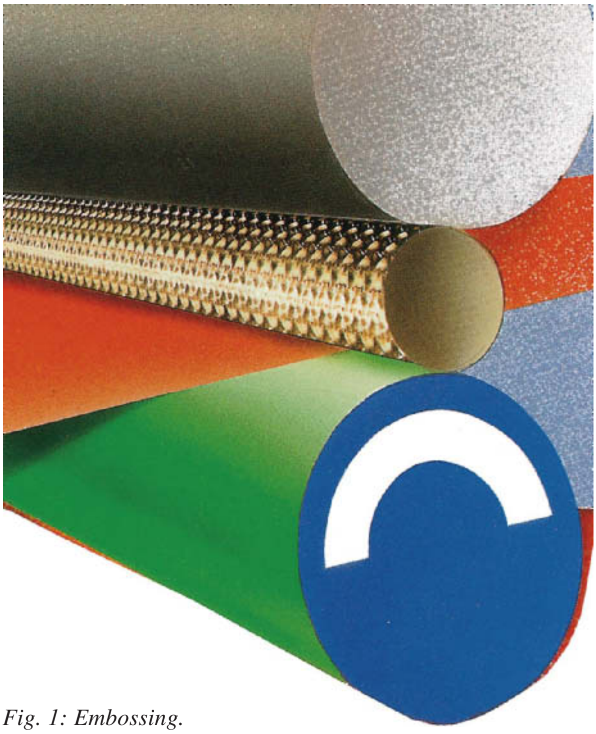


Fig. 1: Embossing.

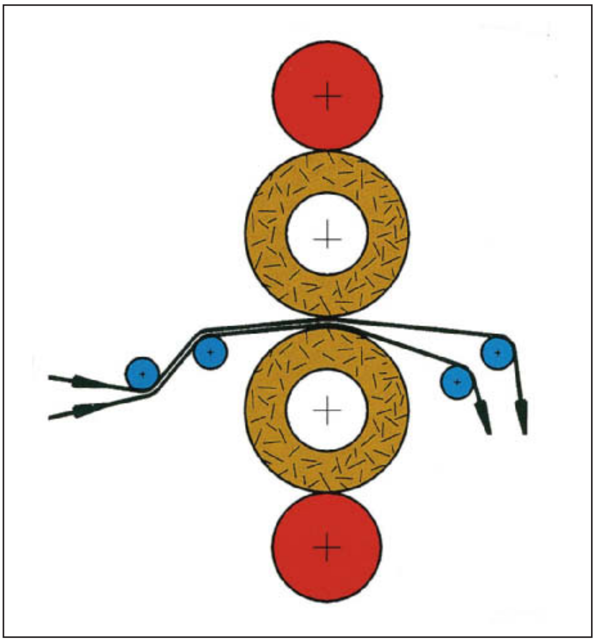


Fig. 2: Embossing with smooth paper-rolls.

I. Deep embossed finishes: Simulated weave designs produced by relief engraving (e.g. honeycomb piqué), geometric motifs, figured designs and the like (Figs. 3 + 4).

II. Silk finish: Not produced by the fabric design but rather light reflectances resulting from imprinting fine ripple lines ranging from a soft, silky matt shimmer to a high lustre, associated with virtually all possible handle variations (via the schreiner calender).

III. "Echolux" finishes: A type of silk finish involving light-and-shadow effects created by the diverse directions of the ripple lines defined by the design.

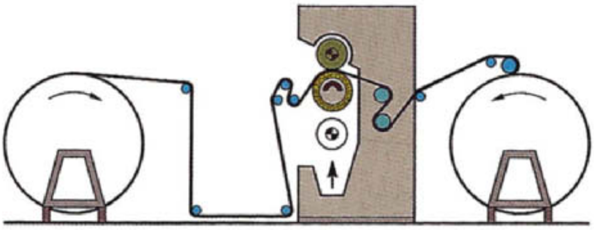


Fig. 3: 3-Roll Calender, Schreinerfinish or other embossing effects.

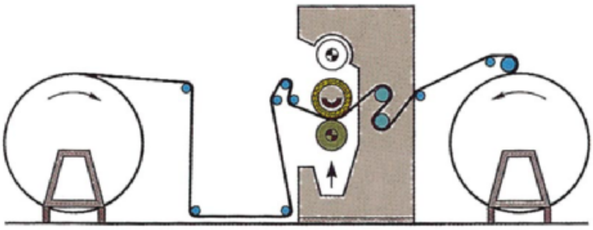


Fig. 4: 3-Roll Calender, mat-, rolling-, smoothing-, glazing-, Chintz or a further embossing effect.

IV. Embossed moiré finish: Varied matt-lustre patterned finishes created by fluted embossing (→ Moiring) (Fig. 5).

V. Lustre finishes: Vary in extent and definition, ripple lines follow the design or fill out the design areas framed by contours.

VI. Ciré finishes: Produced (in contrast to II.–IV.) not by fluted engraving, but by relief engraving with a smooth surface, which involves operating against smooth, relatively hard mating rolls (ciré calender with a heated engraved steel roll, a cotton roll and, to retain the smooth finish, a heated plain steel roll), in other words without forming a reverse image. The design is "fused in" between the smooth faces of the embossing cylinder and the cotton roll (e.g. into acetate fabric). With moiré relief engraving: ciré moiré finish.

VII. Embossed finishes: Simulated lace and embroidery and burnt-out patterns (finely perforated contours and burnt-out designs), also delightful combination effects (burning-out and embossing, or printing and burning-out and embossing) on, acetate and synthetic textiles, produced on the same calender with steel roll relief engraving and at high temperatures (electric heating).

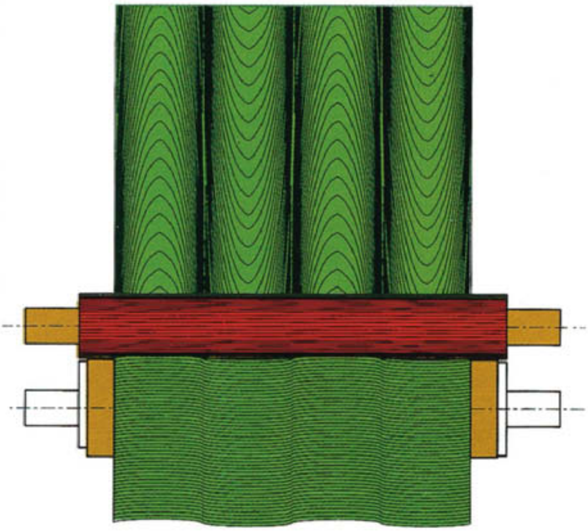


Fig. 5: Genuine Moiré Effects with corrugated roll.

VIII. Colour embossed finishes, etc. (→ Emboss printing) also represent a valuable option for creating sophisticated designs.

Suitable fabrics: Generally bleached, dyed or printed fabric of even wetting capacity, singed, possibly with preliminary finish but chemically unmodified. Loss in tensile strength: min. 10–30% (weft normally more at risk), largely dependent on and controllable via suitable fibre quality (long-staple cotton, fine yarn), weave density (not too loose) and, above all, residual moisture prior to embossing (observe guide values).

Delustring impairs the embossing efficiency on viscose fabric; wash resistance of the finishes generally inferior to cotton.

For embossing in particular a variable adjustment of the working pressure is necessary. The working pressure is dependent upon the quality of the fabric and also the embossing design because of the different pressing areas given by each design. Moreover the requirement of even pressure across the full width should not be neglected.

Embossing calender (goffering calender, crêping calender), is used for → Embossing pattern designs on woven fabric surfaces. It consists in principle (similar to → Schreiner calender) of two rollers: heated top steel roller (pattern engraving mainly in relief, more rarely indented) and elastic cotton or paper counter roller below (both linked by 2:1 gearing). The negative pattern is impressed into the paper roller against the steel roller by → Conditioning of calender bowls. For colour embossing, additional equipment with colour unit, as may be required, at the fabric entry end (colour embossing unit, dyes deeper places during embossing, i.e. embossed ground; colour paste drying by the heated steel roller during embossing) and at the fabric exit end (cross-dyeing unit, dyes high spots immediately after embossing; additional infra-red drying for example before fabric batching). On its way to the batcher, the hot fabric runs over a driven chromed cooling roller on leaving the embossing nip. A double let-off and batching system is provided for the back paper which is additionally necessary for colour embossing and overdyeing.

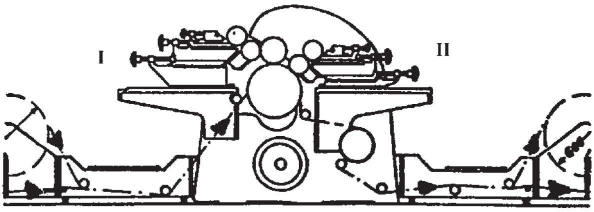


Fig.: Kleinewefers KTM pneumatic embossing calender. I = colour embossing unit, II = over-dyeing unit.

Multipurpose embossing calenders (Fig.) are commonly used for preference, practically every type of embossing and every fabric being possible with the aid of accelerated top engraved roller changing (less than 30 min.) (eccentric snap lock), e.g. the following combinations (figures denote max. pressure):

- 10 tonnes for viscose crêpe, burnt out and ciré effects (three rollers),
- 20 tonnes for additional moiré effects and permanent embossing,
- 30 tonnes (50 tonnes) for additional schreiner finish (special requirements).

Heaviest models (30 tonnes, 50 tonnes) should be equipped for chintz effects with additional bottom roller drive (0–200% or 1:1–3:1 stepless degree of friction control. Colour units can be fitted to all models, (with eccentric quick lift unit, steplessly controlled). Hydraulic-pneumatic pressure control (quick pressure relief potentiality for seams, also automatic). Operating speed can be controlled between 6 and 30 m/min. Heating by steam, gas or electricity.

Embossing felt Usually tubular wool felt, 7–9 mm thick multiple fabric, for heated cylinders, ironing presses, etc. → Tubular felt.

Embossing foil To produce shadow effects, transparent embossing foils with a granular surface are used for colour separations. They are laid on the design and the drawing is transferred with a suitable chalk. The shadow effects are created by applying heavy and light pressure when tracing.

Emboss printing (Relief or surface printing), offers various application options for producing single- or multi-coloured print designs alongside or combined with permanent embossed finishes, for example:

I. Localized emboss (colour) printing: Principle of a local synthetic resin application (by means of roller or screen printing), which is embossed in the customary way on the → Embossing calender and then cured. This produces a washproof design fixed on the synthetic resin sites, similar to → Chintz printing, and is a coloration process provided that the synthetic-resin precondensate printing paste contains suitable colorants. Printing is followed by predry, emboss, dwell, cure, etc.

II. Tip printing: Only the surface of the embossed sites of the fabric is dyed on the embossing calender directly after embossing, namely by means of an overdyeing unit situated on the cloth delivery end. An intensified relief effect is relatively easily obtained by this process. Localized tip-dyed effects can also be produced with suitably engraved rollers.

III. Deep emboss printing: Coloured embossed finishes in which the embossing roller on the embossing calender operates simultaneously as a printing roller. Immediately before embossing, the upper areas of the heated relief roller are supplied with dye paste by means of a colour embosser situated at the cloth entry end and this paste then spreads straightaway into the embossed, deep parts of the fabric. Only suitably heat-resistant emboss printing pastes can be used for this purpose. To prevent any soiling of the paper roller serving as a matrix, a paper backing sheet or similar is used in the embossing process.

Unlike I.–III. the combination of first print and subsequent embossing over the entire fabric surface should not be regarded as genuine emboss printing technique.

Emerizing Surface character processing of woven or knitted fabric. Through emerizing, the fabric structure is masked by a fine pile without destroying the knitted or woven construction. The effect is dependent on yarn and fabric structure. The shorter and finer the fibres in the yarn, the easier it is to produce a better pile. The finishing stages preceding emerizing also have an effect.

Two different machine types are available in practice for surface changing mechanical finishing: multi-roller machines for surface emerizing or single-roller machines for → Sanding. In the first case, the tensioned fabric is drawn over four to seven emery paper covered rollers which rotate with or against the fabric run, the fabric rubbing against the emery surface under more or less adjustable contact pressure. Through emerizing, projecting fibres are split open, producing a velvet-like but very low fibre pile. The effect is also finer or coarser relative to emery grain size. Many products are emerized first of all on relatively coarse and then on fine emery rollers. In the case of woven microfibre fabrics however, the reverse sequence is more successful. In practice, multi-roller machines offer significant advantages over single-roller machines:

- yarn knots can avoid contact, and, at a relevant setting, are not emerized and opened up.
- the emerizing rollers are hardly heated. This makes for a longer emery paper service life.
- the mechanical energy is distributed over the number of emerizing points, and is therefore lower.

In the case of single roller machines, the sanding depth can be precisely adjusted, although all thickness differences are ground down. This means that yarn knots are opened up, and proud selvedges and fabric edges can be ground off and destroyed. Natural thickness differences in the material (e.g. tight warp ends and shrinkage differences) are increased, limiting the application potential of this machine. The multi-roller machine offers greater potential for variation. Only part of the total emerizing energy required is transmitted to each roller. Individual roller coverings can differ in grain size, and a choice of different running directions is possible. Finishing works with a constantly changing product range and special customer requirements should therefore operate predominantly with multi-roller machines.

Emerizing technology has learnt and adopted a great deal from raising. The illustration (Fig. 1) shows how to achieve optimum emerizing effects, and indicates the direction of rotation of the emerizing rollers relative to the fabric direction. With the majority of products, the first roller is allowed to run counter to the fabric direction, raising the weft ends. The second roller then runs in the fabric direction, emerizing the raised weft. The third roller again runs counter in order to intensify the process. Rollers four and five again turn in the fabric direction in order to subject the emerized pile to a light brushing process. Uniformly higher fabric tension is employed with microfibres and fine-fibril yarns, allowing them to make only light contact with the emerizing rollers (tangential contact).

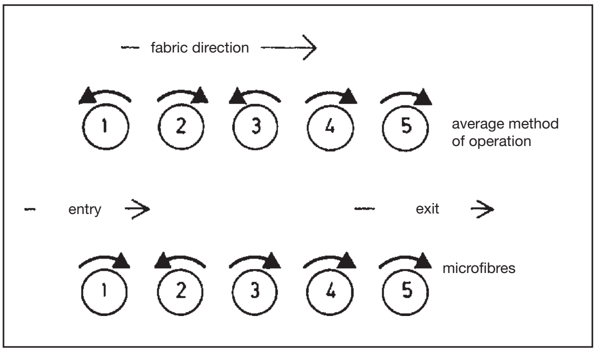


Fig. 1: Optimum emerizing effects, direction of emerizing roller rotation relative to fabric direction (Menschner).

The individual emerizing rollers can be obtained in two versions – cylindrical and lattice rollers. Lattice rollers raise, emerize and brush the weft with an intensive mechanical action. Suitable paper granulation for this purpose is within the 80 to 120 range. This intensive mechanical action is not recommended for women's outerwear fashion fabric. The zone between "too weak" and "good tear strength" is then so narrow that it can no longer be controlled with certainty.

Lattice rollers are of advantage when plain cotton, viscose or woollen piece goods are to be emerized for a "woollier" effect. Cylinder rollers are preferred for microfibre qualities, as the mechanical action on the fabric is not so intensive. Silk or high/low jacquard woven fabrics can only be emerized with solid rollers. Cylinder roller emerizing machines are so silent that only the noise level of the extractor is of any consequence. In practice, the possibility of changing individual emerizing rollers is regarded as a great advantage. The table summarizes and compares operating data.

The emerizing machine is a "shredding" tool. With a coarse tool (80–120 granulation), the floating weft ends can be picked up and raised. The end is subsequently pulled open, and then brushed in the required direction.

	cylinder roller	lattice roller
fields of application	silk, low-high jaquard woven fabric lightweight women's outerwear products (100–180 g/m^2)	plain cotton/viscose or wool piece goods over 200 g/m^2 (mainly coarse graining: 80–120)
noise	very low level	high level
grain size	280/320 with lightweight women's outerwear qualities, 400/500/600 with fine-fibril polyester yarns and microfibres	80–120

Tab.: Comparison of cylindrical and lattice emerizing roller operating data.

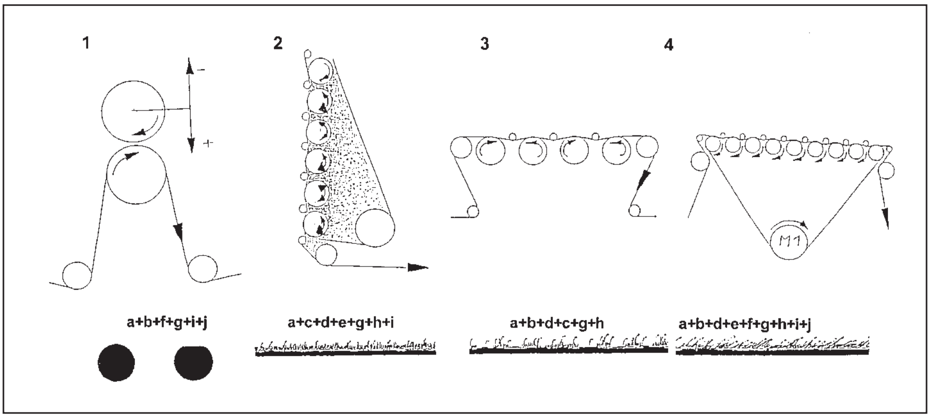


Fig. 2: Various systems of Emerizing/Sueding involving following problems. a = tension problems; b = fabric strength; c = dust back to the fabric; d = high temperature (pilling); e = only long pile; f = one way emerizing only; g = emery paper only short time; h = difficult for micro fibre; i = not for elastic fabrics; j = stripes and marks (no oscillation).

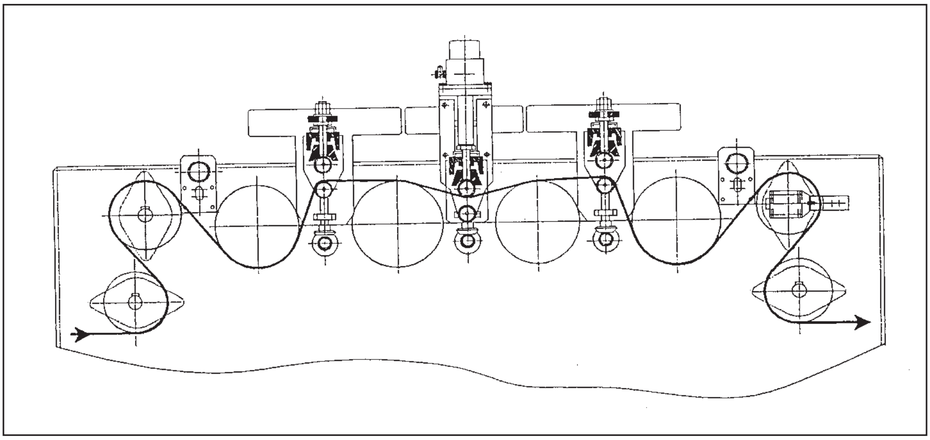


Fig. 3: Fabric feed for knitted goods.

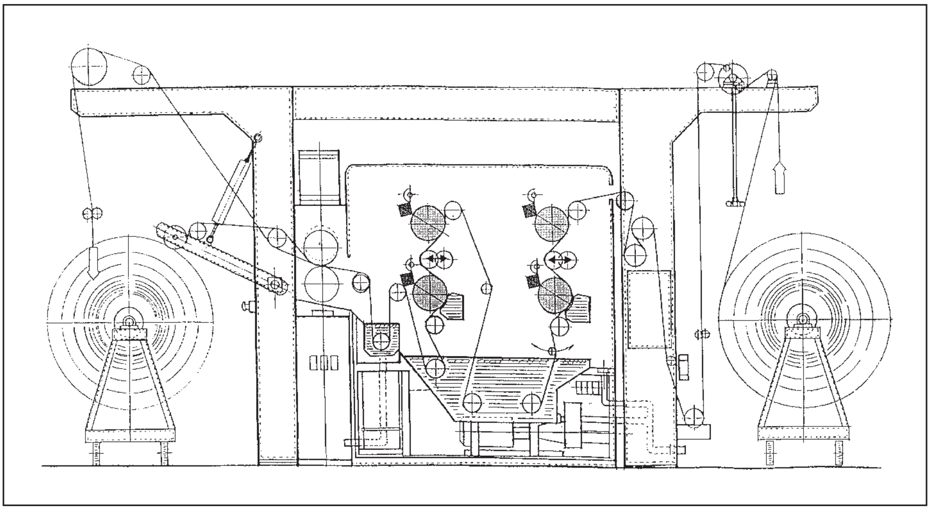


Fig. 4: Wet sueding unit (BM 4 from Naigai/Japan).

The result of this coarse grain processing is a denser, longer pile. If woven cotton or wool fabrics come out too boardy, while a “woolly surface” is required, a grain size between 80 and 120 should be used. Lattice rollers produce the best effects here, and they are therefore mostly covered with coarse paper. Lightweight women’s outerwear products weighing between 100 and 180 g/m^2 should be given a short, dense pile. Grain sizes between 280 and 320 have proved effective with these types of fabric. Fine-fibril polyester yarns and microfibres are emerized with 400/500/600 grain sizes. Still finer grain sizes, around 600–800, are not normally used because they really “polish” rather than emerize.

Fabric tension in the actual emerizing zone is of decisive importance for a good emerizing effect (Fig. 2). It must be adjustable relative to the product and easily readable. Set tension values must be kept constant, and automatic readjustments made if the material stretches. It is particularly important that tension units, which may be located at the machine entry or exit, do not influence the emerizing effect (contributed by Riedel).

Emerizing can be carried out after bleaching and before dyeing. This has the advantage that the colour is not changed by subsequent emerizing (shade change). One disadvantage could be dyeing machine contamination by emery dust, or different fabric dyeing behaviour. Other users carry out this dry finishing as the final processing operation on the finished fabric, shade changes sometimes being targeted effects. With patterned woven fabric, e.g. shirtings, there is no shade change effect. It should be noted here though that the emerizing effect is reduced by subsequent permanent finishing. This has to be compensated for during emerizing by correspondingly more intensive processing.

On jeans fabric, the emerizing process should be carried out prior to sanforizing in order to guarantee the required residual shrinkage value of <1%. The sanforizing effect would be impaired by the fabric tension within the machine. Another emerizing application is the preparation of fabric for a subsequent raising process, in which the fibre capillaries pulled out of the spun yarn during processing can be more easily caught up by the raising fillet card wire points and further processed. This reduces the number of raising passages required. A classic example of this case is warp knitted interlinings (Fig. 3). From the textile technological standpoint, the application of a finish is necessary for both raising and emerizing. These softeners can be applied during the spinning process etc.

Different stages in which emerizing can be effected:

1. After bleaching, before dyeing, e.g. woven polyester microfilament fabrics.
2. After bleaching, before dyeing or in the finished product, e.g. the finish emerizing of outerwear fabrics, depending on the works' organisational structure and the type of effect aimed for.
3. Emerizing only on the finished product, e.g. scoured silk.
4. Emerizing as a preparatory process for raising, e.g. interlinings.
5. Wet emerizing (Fig. 4).

Emission (Latin: emissio = let out),

I. Radiation of electromagnetic waves by atoms or molecules. Antonym → Absorption. The radiation emission of all bodies has a fixed relationship for every wavelength, dependent only on wavelength and temperature to its absorption capacity for the same wavelength. By the total emission capacity of a radiator, we understand the relationship between the total radiation emitted and that of a black body at the same temperature. The spectral emission capacity of a body has the same value as the spectral absorption capacity. Emission bands (emission spectra) are so-called band spectra of coloured lines or bands or from a continuous coloured spectrum, as occur for example in fluorescence and luminescence. →: Reflectance; Optical brighteners.

II. Air impurities, noise, vibration, radiation and other phenomena coming from a plant (emitter). Typical example: tetrachloroethane in the exhaust air of a dry cleaning plant. In the case of chlorinated hydrocarbons, emission forms by far the largest proportion of solvent losses. Technical measures for preventing these losses are contained in VDI guideline 2280. In accordance with dry cleaning plant regulations (amendment to the 2nd BImSchG of 1990), these types of plant should not emit more than 30 ppm, and from 1993, 20 ppm of tetrachloroethane. Exhaust air emissions from stenters are another typical example. Emission measurement as vapour and gas concentrations in exhaust airflows (mg/m^3 or ppm) or as a pollution quantity in kg of solvent/hr or kg of solvent/tonne of fabric treated.

Emission register Expresses integrally (e.g. from the manufacture of a dye through its application to its behaviour on disposal) information on the emissions of a textile finishing agent (see Fig.).

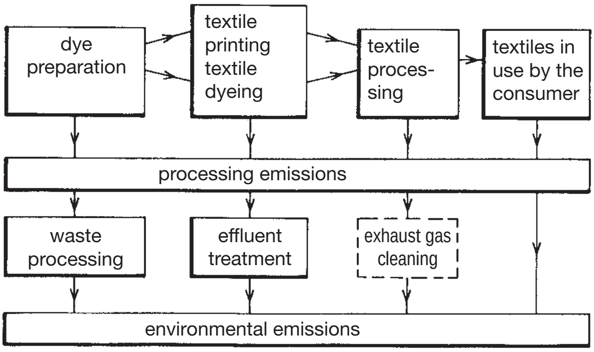


Fig.: Example of an emission register for a dye.

As a consequence of the tightening-up of environmental protection laws and the increasing awareness of the general public, the industry is obliged to undertake comprehensive ecological studies. The full analytical understanding of the present situation which is necessary to ensure compliance with the legal requirements is very difficult to achieve in the field of textile finishing because of the wide variation in substances and application methods used. For this reason, efforts are currently being made to establish time-saving yet meaningful emissions prognoses using theoretical estimates and simulation trials.

Emissions, measurement of in effluent or exhaust air. Precise exhaust air and exhaust gas measurements are used for example for establishing whether limits are exceeded. A variety of measurements are necessary of course for assessing plant effectiveness.

Emissions potential

Exhaust air emissions can be measured by various processes:

- exhaust air and gas quantity flow: Prandtl's pitot tube with bent tube manometer, revolving vane speedometer;
- temperature: thermocouples, resistance thermometer;
- pressure: box barometer;
- moisture: aspiration psychrometer, silica gel tube;
- oxygen: paramagnetic O_2 analysis;
- carbon monoxide: infra-red absorption;
- nitrogen oxides: chemiluminescence analysis;
- aldehydes (e.g. formaldehyde): test tube method, DNPH process, HPLC method;
- hydrochloric acid: wet chemically with NaOH;
- dust: gravimetric dust measurement;
- organic carbon: flame ionisation detector, silica gel adsorption;
- odour: sensory odour determination (olfactometry);
- individual organic components: gas chromatographic method, possibly with selective detectors;
- total harmful substance in the exhaust air (gases, vapours, aerosols, solid particles): cooling and condensation or admixture of dry, oil-free air to reduce moisture, heated filter and adsorption to silica gel.

One important measurement function is determining the concentration of organic components. In many cases, the substitute dimension of the "total quantity of organically bonded carbons" (total C) suffices instead of measuring the individual components. Special problems are still currently posed in measuring the hydrocarbon content in unpurified exhaust air, for here all kinds of unknown compounds (aerosols, solid particles, vapours etc.) can occur. The illustration shows by way of example emission and immission measurement on stenters.

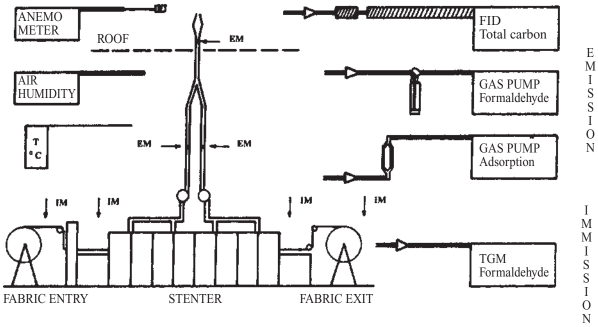


Fig.: Emission (EM) and immission (IM) measuring positions on stenters.

Emissions potential In the Federal Republic of Germany, the exhaust air situation is legally regulated by federal immission protection legislation (BImSchG). In the case of air emissions, specific mass flow and concentration limits are to be complied with irrespective of the legal emission protection status of the plant in question. The practical interpretation of these regulations is effected by the Technical Air Instructions. When the 4th Federal Immission Protection Directive (BImSchV) comes into use, it will be designed from experience, in that in the case of an industrial plant not only will the individual emission point in isolation form the basis of evaluation, but in all cases a combination of equipment with all its associated emission points, which can be based on a technical process. For the chemical finishing industry for example, this means that total organic mass flow limitation is effected not for a particular stenter but rather for the sum of all technical operation related exhaust air producing heat treatment machines. The most elegant possibility of reaching this situation would be a purely theoretical estimate of the emission potential of textile product and chemicals during a heat treatment process. With precise knowledge of the chemical product composition, and taking account of all parameters of a technical process nature, the potential emissions would have to be precisely projected. Such a plan runs aground first of all in that the finisher does not have precise information on the chemical formulae and product composition of textile auxiliary products and dyestuffs. The data relevant to this on the safety data sheets is inadequate for estimating emission potential (in effluent, exhaust air and waste).

A simpler equivalent is to outline the emission potential within a definite framework, e.g. in a low volume car interior. 80% of the heat in the car comes through the windows to produce a greenhouse effect by which endogenous emissions are increased. Individual temperature measurements revealed for example:

Air in the interior at head height	70°C
Instrument panel surface	105°C
Inside roof surface	67°C
Upholstery surface	48°C
Hat rack surface	108°C

Endogenous pollution sources are dyestuffs, paints, adhesives, sealing compounds, fuel evaporation from the tank and jerry can, fuel lines, anti-drumming materials, waxes, packing materials, and plastic and textile car furnishing materials; nor should those which are due to smoking (CO, NO_2, aldehydes, nitrosamines, smoke particles, polycyclic and aromatic hydrocarbons) remain unmentioned. Exogenous pollution sources are due to nature, occurring through human civilising practices, particularly road traffic itself. The outside air is of considerable secondary importance for the emission potential of interior fitting materials. The following applies to the chemistry in the passenger seats: the air in the interior can be no better than the outside air (despite the fact that forced ventilation produces six changes of air per minute).

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In this case, distinctions are to be drawn between air impurities according to their origin in car production, interior fittings (→ Fogging) and driving. Interior fittings represent an emission potential in two respects: on the one hand from the material standpoint and, on the other, as temporary emission and immission material media. Fitting materials consist of a variety of substances and 3-dimensional forms, e.g. injection moulded parts or textile coverings. These are based on plastics, elastomers and natural materials, as alloys and mixtures. They always contain additives. Corresponding to this width of variation, the emissions are also multilateral, particularly in terms of type and quantity; the number of product types could be well over 1000.

Discovery of the emission potential of a material, and consequently the strategies for preventing emission from interior fitting materials, necessitates a special type of analysis (FMEA = Failure Mode and Effectiveness Analysis). It has a reference to simultaneous engineering, and must be continual because there may be interference. Chemical technology identifies those effects and possibilities of intervention relating to the raw materials which have to be taken into account in processing the material components, and can ultimately be relevant in use, i.e. in material ageing. A simple FMEA for plastics runs from the monomers through the polymers and also additives up to processing. Once again, additions can be made here too. In the end, the actual usage requirements become significant (according to Eisele).

E modulus Modulus of elasticity; → Tensile elasticity.

EMPA, abbrev. for: Eidgenössische Materialprüfungs- und Versuchsanstalt, Zürich and St. Gallen (Swiss Institute for Material Testing and Research Centre); → Technical and professional organizations.

Empirical formula (molecular formula, total molecular formula, total formula) → Formula, chemical.

Empirical formula, total molecular formula Modulus of elasticity; → Tensile elasticity.

Empirical test for water repellency (Non standardised test). A rapid and demanding assessment for water repellency often used by garment manufacturers. Literally, a handful of water is thrown against a hanging fabric sample. There must be no water penetration or wetting out of the fabric surface. Few fabrics are considered likely to pass this test.

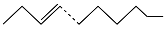
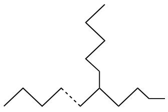
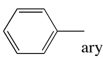
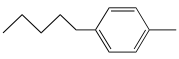
Emulsification The preparation of a finely distributed suspension or emulsion of mutually immiscible liquids.

Emulsified oil sizes → Oil size.

Emulsified textile lubricants → Textile lubricants.

Emulsifier A product which makes the formation of an → Emulsion possible or easier; e.g. in the production of emulsified textile lubricants, finishes and preparations, etc., to achieve specific effects. Emulsifiers are surface-active substances with an ambiphilic character, or preparations containing such substances. The lipophilic part of the molecule is formed from straight, branched, or cyclic hydrocarbons. In contrast, a considerably greater variety of structures for the hydrophilic part of the molecule are possible (see Table).

The basic building blocks include: soaps, alkyl sulphates, alkyl sulphonates, fatty acid condensation products, polyglycol esters and ethers, besides fatty acid esters of polyhydroxy compounds.

lipophil end groups	hydrophil intermediate groups		hydrophil end groups		class
 alkyl residue  alkyl residue, unsaturated  alkyl residue, branched  aryl residue  alkyl aryl residue	$\overset{\text{OH}}{\overset{\vert}{—}}$ —COO— —SO$_2$NH— —CONH— $\left[\text{CONH}\right]_n$ $\left[\text{NH}\right]_n$ —N═ —O— $\left[\text{O}\right]_n$	hydroxyl group ester group sulphamide group amide group polyamide group polyamine group amine group ether group polyether group glycerine group sorbite group pentaerythrite group saccharose group	$—COO^{\ominus}$ $—SO_3^{\ominus}$ $—OSO_3^{\ominus}$ $—OPO_3^{\ominus\ominus}$	carboxylate sulphonate sulphate phosphate polyphosphate lactate citrate tartrate	anionic emulsifiers
			$—\overset{\oplus}{N}H_3$ $—\overset{\vert}{\underset{\vert}{N}}{}^{\oplus}—$	amine salt QAV	cationic emulsifiers
			$<^{COO^{\ominus}}_{\overset{\oplus}{N}H_3}$ $<^{COO^{\ominus}}_{\underset{\vert}{N}^{\oplus}}$	ampholyte betaine	amphoteric emulsifiers
			—OH $\left[\text{O}\right]_n\text{H}$	alcohol residue polyether residue glycerine residue sorbite residue pentaerythrite residue saccharose residue acetic acid residue lactic acid residue	nonionic emulsifiers

Tab.: Structure of various emulsifiers.

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Emulsifying liquid A liquid which is capable of forming the discontinuous phase of an → Emulsion.

Emulsifying power The capacity of a product to facilitate the formation of an → Emulsion.

Emulsion An emulsion is a disperse system of two immiscible liquids in which one of the liquids (disperse phase) is distributed in the form of fine droplets in the other liquid (continuous phase or dispersion medium). The most well-known example of an emulsion is milk. Emulsions in which an oil is dispersed in water are described as oil-in-water (O/W) emulsions whilst those in which the water forms the disperse phase are water-in-oil (W/O) emulsions. Washing is an example of an emulsifying process in which fats and soil are emulsified in water by the washing agent so that they may be easily rinsed out. The particle size of an emulsion is greater than 0.1 µm since otherwise a colloidal or true solution would exist. A distinction is made between macro and micro-emulsions which differ mainly in their particle size and optical appearance. Macro-emulsions have a particle size of 100–0.5 µm and appear milky-white to bluish milky-white due to light scattering. Micro-emulsions with particle sizes of 0.5–0.1 µm have an almost transparent appearance with a bluish sheen.

Emulsion breaking After the washing stages of textile finishing the washing water contains, in addition to tensides and emulsified oils, solid particles and possibly coarse impurities such as fibres etc. These are removed by a suitable coarse separator. The o/w emulsions formed during washing are broken down using organic cleavage products. The action is shown in the Fig.

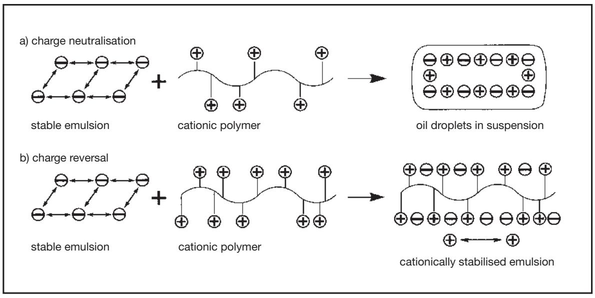


Fig.: Action of organic cleavage products.

Generally speaking, this mechanism is also used for the destabilization of fine-particle suspensions. In this case the negative surface charging of the particles is neutralized, enabling them to coagulate into larger agglomerates. The oil or sludge phases thus formed are separated from the washing water by flotation or sedimentation. Flocculants are often required in order to accelerate the solid/liquid separation. Both weakly and strongly anionic products have proved useful.

Chemical emulsion breaking, combined with membrane filtration, is the most reliable method for the disposal of highly stable effluent emulsions. Various water-soluble chemicals can be used for chemical emulsion breaking according to the stability of the emulsion, their effectiveness depending on the charge neutralisation of the tensides contained in the emulsion. The chemicals neutralise the tenside groups so that the new cleavage chemical/tenside/oil compound no longer floats. The stable emulsion is separated from coarse impurities, and an initial cleavage according to charge takes place in a reactor vessel; the metered, volume-related addition of the chemicals is carried out as the reactor vessel is filled. After a timed reaction and separation phase, the cleavage oil and water are removed separately from the reactor vessel. The oil phase includes the emulsifier, oil sludge, free oil and the chemicals. The residual water content of the oil phase should, however, be less than 10%, so that combustion is possible. Membrane ultrafiltration is used to filter the cleavage water from the preliminary separation; the residual oil content of the permeate is reduced to 5 mg/l. A subsequent neutralization process is not usually necessary in the majority of applications. The concentrated residue is returned to the emulsion reservoir and undergoes a repeat of the cleavage process. The permeate from the ultrafiltration plant may be released indirectly to the main outfall, following any necessary neutralization.

Emulsion lubricant → Textile lubricants.

Emulsion pad process A pad-dyeing process in which low solids water-in-oil emulsions are used as thickeners for the pad liquor. Disperse, acid and metal-complex dyes are applied to synthetic fibres, and vat dyes to cellulosic fibres. The process has not found wide application in practice.

Emulsion polymerization The main textile application of emulsion polymerization is the production of latex emulsions, e.g. for carpet backcoating. In contrast to polymerization processes in the mass (in which the polymer being formed remains for a certain time dissolved in the monomer during radical polymerization) or polymerization in solvents, emulsion polymerization is a multiphase (often three-phase) reaction system (see Fig.) including additions of appropriate emulsifiers which later remain in the latex emulsion after polymerization.

Emulsion printing Textile printing in which emulsion or half-emulsion thickeners are used in the preparation of print pastes.

Emulsions on acrylic basis for coating Among the many uses for acrylic emulsions is the backcoating of fabrics. Fabrics are coated for many reasons: to obtain dimensional stability, to prevent ravelling, to modify hand, to add scale weight, to provide opacity, to permit easier handling when cutting and sewing, to pre-

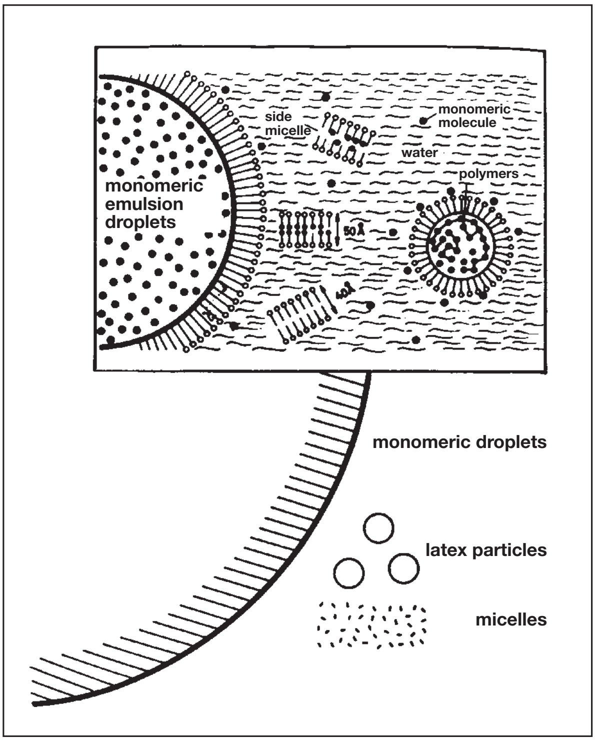


Fig.: Dimensional comparison of the participants of emulsion polymerization.

vent distortion of patterns and to minimise seam slippage. While many different effects are required to satisfy particular end-users, the versatility and diversity of the Primal range of acrylic emulsions qualify them for practically all of these uses.

Films of these acrylic emulsions are colourless and odourless while exhibiting good adhesion to a variety of substrates, both natural and synthetic. If any one characteristic were to be singled out which makes these products so useful for fabric coating, it would be their outstanding resistance to the degrading effects of ultraviolet light, heat and ozone. Unlike conventional latices, Primal acrylic emulsions will not yellow and stiffen with age or heat as they retain their clarity and flexibilty over an extended period of time and wear. This factor is of prime importance in quality fabrics.

The internally plasticised Primal acrylic polymers offer an additional advantage, in that the desired degree of flexibility results from the composition of the polymer and not from the separate addition of a plasticiser. Therefore, no plasticiser migration can rob the backing of its particular degree of softness or stiffness. These acrylic emulsions, supplied as milky-white liquids, are also stable over a wide pH range. Their ease of compounding, coupled with their ability to be applied on conventional coating equipment, demonstrates that their superior properties can be obtained at little or no added cost when compared to conventional coating materials.

Emulsions on acrylic basis for coating

One of the most common methods of coating is kiss roll application. The fabric passes over a roller partially immersed in the thickened mix, or over a roller in contact with a transfer roller which is immersed in the mix. The acrylic mix is usually thickened to a viscosity of about 3000 to 5000 mPa for this particular mode of application. There are many variations of this type of equipment, some of which are:

a. A second roll situated directly above the kiss roll applicator which can be pressed against the face side of the fabric to push the fabric backing firmly against the kiss roll applicator. The purpose of this second roll would be to obtain maximum penetration of the coating into the fabric.

b. In addition to doctor blades used to remove any excess acrylic resin from the fabric, doctor blades can be placed in contact with the kiss roll applicator to control the amount of resin picked up by the roll before it makes contact with the fabric, thus controlling the amount of coating applied.

The rheology, viscosity and solids of the mix, as well as the speed, direction and contact pressure of the roll and fabric, are variables which determine the amount, uniformity and penetration of the backing.

A single doctor blade or floating knife is another means of coating fabric. The coating mix, thickened to the desired viscosity, is poured directly onto the fabric and spread across the fabric by the forward motion of the fabric as it passes under the knife. A movable dam at each selvage prevents spillage sideways off the fabric. The backing material must be properly metered by the knife to avoid uneven results. Strike-through, a disadvantage of this method of application, can be minimised or eliminated by proper thickening. Strike-through can be caused by the mix being poured onto the fabric and allowed to remain in one place for some time, such as during machine shutdown. In addition, the pressure of the coating blade can also cause penetration of the backing material into the fabric. The knife coating technique is also used with plastisols, organosols and solvent-based resins.

The frothing method simply dilutes and thickens the binder with air rather than water and thickener. When compared to other processes, froth coating reduces energy costs and lowers drying requirements, as from 50 to 75 percent less water is used. Froth coating also provides a softer hand and equal strength at equal or lower binder add-on. Froth coating can be used on any type of fabric. It is particularly useful on loose weave, nubby polypropylene fabrics. Primal acrylic emulsions can be frothed straight out of the drum without adding stabilisers or foaming aids. When curing conditions are less than optimum and durability is required, catalysts can be added. These emulsions can also be formulated with fillers and pigments to obtain the desired effect.

Foam coatings are recommended for hard-to-coat, porous, ribbed fabrics. The foam back-coating not only imparts opacity but also provides good thermal insulation. As with froth coating, energy costs are reduced, a softer hand and equal strength at equal or lower binder add-on can be achieved. Durability can be maximised by selecting the right Primal acrylic emulsion. Pigments and fillers can be used to obtain opacity. Foam is a very aesthetic coating that is widely used on draperies and mattress tickings.

Coating automotive upholstery fabrics will usually extend their wear life. The backing prevents distortion of the fabric not only when in use but also when being cut and sewn. The backing also prevents ravelling, improves abrasion resistance, aids in ease of cutting, and helps the fabric to lie flat when being handled. With proper formulation, it can also impart low flame response properties. The backing also provides a further benefit, in that it reduces seam slippage. The repeated stresses to which automotive seat fabrics are subjected puts a tremendous strain on the seams of the fabric. The pull of the threads used to sew the seams can cause them to work through the fabric. If the fabrics are properly backcoated, the seam slippage is virtually eliminated. Primal acrylic emulsions excel in this application because they impart the necessary stabilisation and tensile strength without objectionable build up of hand. Because upholstery in cars is constantly subjected to extremes in heat and cold as well as prolonged exposure to direct sunlight and high humidity, the resistance of the acrylic emulsions to heat and ultra-violet light makes them outstanding for this application. Acrylic emulsions also have excellent adhesion to both natural and synthetic fibres used in automotive upholstery. The minimal temperatures needed to dry and cure the polymers also permits the use of heat-sensitive yarns such as polypropylene in the construction of the fabric. From 12 to 100 g/m^2 of fabric are usually applied. If the fabric is yarn-dyed and not post-dyed, and does not require durability to wet processing, the Primal polymer does not have to be crosslinked.

Like automotive fabrics, the design and construction of furniture upholstery fabrics ususally necessitates a backing material to impart dimensional stability and to prevent seam slippage. Some furniture upholstery fabrics are post-dyed, and a complaint often raised is that the backing dyes off-tone compared to the face of the fabric. This becomes a serious problem with fabrics having open weaves because objectionable “grin-through” is further amplified by the colour difference. Conventional SBR latices tend to resist dyeing or can preferentially absorb one of the dyes in the colour formulation with a resultant change in case. The dyeing characteristics of the Primal acrylic resins closely resemble those of cellulose acetate and nylon fibres, so that dyes used to colour these fabrics also colour the acrylic backing. Any grin-through can be effectively camouflaged by the addition of disperse or nylon dyes to the dye bath if they are not already included in the dyeing formulation. Most backings used for furniture upholstery are loaded with clay or whiting. A filler can be used for one or any combination of the following reasons: to reduce tack; to add weight; to extend and thus reduce the cost of the formulation; to colour the backing. Usually, from 80 to 120 g/m^2 of fabric are applied.

Certain furniture fabrics are post-dyed rather than yarn-dyed and therefore must be able to withstand the severity of a dyeing cycle. These dyeing cycles can be anywhere from 6 to 8 hours in length at 170°C to boiling. When matching a difficult shade, fabrics can stay much longer in the hot dyeing water; thus, water-soluble antioxidants and other components in conventional SBR backings can be extracted, resulting in greatly reduced resistance to ageing and dusting. Primal acrylic backings are not so effected because they contain no antioxidants. With the wide range of upholstery fabrics used in the industry today, various backcoating methods are used to achieve different effects. Frothed backcoating methods are easily applied to bulky, loose weave polypropylene fabrics, whereas plush fabrics can be coated using standard clear or filled formulations.

Rohm and Haas has developed a processing method that imparts an ignition resistance to all classes of upholstery fabric. It incorporates a protective aluminium barrier which transfers heat from a cigarette, thereby preventing combustion of fillers or padding. It is used on fabrics that have had a conventional backcoating previously applied.

Curtains are lined to give them opacity to light and to prevent colours from fading. Lining not only takes time but also involves costly and detailed work. In addition, it is usually recommended that curtains that are lined should be drycleaned. Although drycleaning is expensive, if the curtains are washed, the lining can shrink more or less than the curtains themselves. The opacity achieved by lining can be more easily obtained by backcoating the curtains with a filled/pigmented Primal polymer formulation. This type of backcoating not only imparts opacity but also thermal insulation. The desired durability of the backing to laundering and drycleaning can be obtained by the proper selection of Primal emulsion and proper formulation. Usually from 45 to 70 g/m^2 of fabric are applied. While these backcoatings can be applied by several methods, they frequently are applied by crushed foam coating to produce a uniform coating on textured curtain fabrics.

Emulsions (O/W) type, determination of water content This involves ascertainment of the maximum solubility of electroytes: approx. 5 g of the emulsion is precisely weighed and approx. 1 g of dried electrolyte (preferably sodium chloride) is added. The emulsion is then heated and allowed to cool back to room temperature. The electrolyte precipitated out from the saturated aqueous solution is filtered off, washed, and determined analytically.

Emulsion stability The capacity of an → Emulsion to remain stable, i.e. not to “break” or separate into its component phases.

Emulsion thickener A thickener for textile printing consisting of → Emulsifier, water and a water-immiscible liquid (chiefly kerosene or white spirit). Depending on the type of emulsifier, either a water-in-oil or, as generally preferred in practice, an oil-in-water emulsion is formed. Emulsion thickeners have found the widest application in pigment printing. For other classes of colorants, particularly reactive dyes, half-emulsions are generally used, i.e. emulsions to which conventional thickeners have been added (e.g. alginates) in order to achieve improved stability.

Enamel (vitreous enamel). Protective glazed coating applied to metal surfaces. It is produced by the application of finely powdered glass containing lead or boric acid in an aqueous paste followed by fusion in an oven.

Encapsulated dyes Dyestuffs of various classes (cationic, acid, reactive, disperse, and vat dyes) which have been encapsulated in fine granular form with hydrophilic film-forming substances of high molecular weight (e.g. gelatine, pectin, agar agar, methylcellulose or polyacrylic acid) by the microcapsule technique. The microcapsule diameter lies within the range of 10–200 µm. Dyes in this form can be applied together with reactive compounds without any initial reaction; reaction eventually takes place during a subsequent steaming or other thermal treatment. Special effects, e.g. in → Speck printing.

End

I. An individual warp thread (weaving).

II. Each passage of a length of fabric through a machine as, e.g. in jig-dyeing.

Ending A dyeing fault consisting of a change in colour from one end of a length of fabric to the other, or a difference in colour between the bulk and the end of a length of fabric.

Endless belt batcher → Paternoster batcher.

Endless conveyor Continuous conveyor for piece goods. An enclosed track (rail) consisting of an electrically driven endless chain or endless rope. Goods are carried mounted on hangers. Possible configurations include horizontal, inclined, vertical running, also for horizontal and vertical bends. Max. single load 1 t, up to 6000 m, velocity of up to 0.4 m/s; so-called light circular conveyors for up to 30 kg/hanger, up to approx. 40 m, velocity from 0.1 m/s; gradients also possible to a limited extent.

Endless felt → Tubular felt.

Endless screen Further development of the large-repeat rotary screen, whose scope is restricted for reasons of stability. With the endless screen, an endless loop runs across three rollers which are arranged in the form of a triangle. This makes it possible to achieve very large repeats at high printing speeds even when using narrow print widths in screen printing.

Endocuticle → Intermediate membrane.

Endocuticula The innermost cuticle layer. In → Wool structure it is the so-called inner scale-cell layer.

Endophilic (Greek), turned inwards, e.g. tendency of a hydrophilic molecular group to enter into or remain in the aqueous phase, or of a lipophilic group towards the organic phase (solution). Characterized by the reduction in chemical potential as a function of concentration and temperature. Opposite → Exophilic.

Endosperm (Gk. *endo* = inner, within; *sperma* = seed). The nutritive tissue surrounding embryo in most seeds.

Endothermic An adjectival term used, e.g. to describe a chemical reaction which is accompanied by the absorption of heat. Compare → Exothermic.

Endotoxins Toxins contained within the protoplasm of an organism, especially a bacterium, and liberated only at death. (Opposite term: exotoxins which are produced by living bacteria and secreted into the surrounding medium). An endotoxin is a bacterial toxin that is an integral component of the cell. → Byssinosis.

End ring Metal ring introduced into each end of a rotary printing screen to obtain a stable cylinder. End rings are bonded to the screen with a special adhesive.

End ring glueing device A vertical or horizontal unit designed for the glueing of → End ring to rotary printing screens (see Fig.).

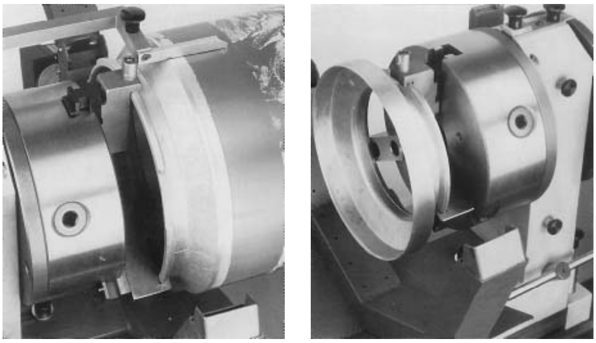


Fig.: Harlacher end ring glueing device for rotary printing screens.

End-to-end uniformity A term used for piece-dyed goods which exhibit the same shade throughout the entire length of the batch, in contrast to defective dyed goods where ending or tailing problems have occurred during dyeing .

Energy Available power. The capacity of a body or system to do work. The first law of thermodynamics states that energy can be neither created nor destroyed but can be converted from one form into another. Energy is available in various forms which, apart from two exceptions (electromagnetic waves and heat radiation), is always associated with matter. Energy exists as mechanical, thermal, electrical, magnetic, chemical and nuclear energy.

Energy carriers Raw materials from which energy can be released, e.g. coal, gas, oil, nuclear fuels, and the potential energy from hydroelectric sources. Primary energy carriers supply existing energy in its original form (solar power, wind power).

Energy consumption It is recognised that the treatment temperatures for pretreatment, dyeing and finishing of the same article can vary widely and depend above all on the following conditions:

- quality or fastness requirements of the consumer;
- cost and profit considerations of the dyeing process;
- available machinery and capacity.

There is a great number and variety of pretreatment, dyeing, printing and finishing machinery types, whose energy consumption can vary widely for the same production purposes. An additional factor is that numerous fibre types are processed, singly and in blends, which also give rise to substantial differences in energy consumption for similar articles. In order to remain in control of the present and future energy supply situation, the energy supply must be analysed accurately and energy-saving measures implemented wherever weaknesses are discovered.

Energy consumption, optimisation of The textile finishing industry uses optimising systems in the case of the energy media electricity and gas. Energy cost optimisation means limiting energy procurement within a unit of time to a specified maximum value; i.e. in the case of electricity, not to exceed an average power consumption figure in kW over a measuring period of 15 or 30 min, during which short-term peak values are quite possible, as only the mean value within the measurement period will be taken into account in calculation. This power consumption limit is the main concern of optimising systems. If production machines are exclusively connected to an optimising system, power purchases can be transferred only to other measuring periods which are not normally so high. Within the daily load curve then, this means transferring to the trough periods. In this case, there is no work saving (kWh). If however peripheral production plant and machinery (e.g. heating, air conditioning, ventilation, lighting) are connected to the system, the number of kilowatt hours consumed is additionally reduced.

Gas presents a similar picture. The quantity consumed per unit of time (1 hour or 1 day depending on contract) is limited. Here too, peaks may be recorded within a measuring period; the aim should be not to exceed the purchase quantity agreed in the contract. The optimising system prevents exceeding the limit by reducing the quantities consumed by individual consumers together with total consumption projection to the end of the period. Here too, quantity limitation acts as a cost reducer. If quantities cannot be varied, one must consider substitution with the aid of other suitable energy media, the utilisation period of which is computer monitored and controlled. An optimising system economises on cost, nevertheless it is generally called a "savings system", since the false conclusion that something must be dispensed with could easily be drawn. This is not the case however when using an optimising system. Power supply companies generally divide the daily supply period into high tariff and low tariff periods. Up to the limits imposed by technical plant layout, there are normally scarcely any limits in the low tariff period as regards the energy quantity which may be drawn over a 15 or 30 min. measuring period. It is a different matter in the case of the high tariff period, where stipulated agreements are to be found.

Energy recovery → Heat recovery.

Energy use, efficiency of Ratio of obtained, released energy to energy used, expressed as a percentage.

English black A term used to describe a black dyed with → Logwood.

English blue A collective term used in the 18th century for processes involving the local application of indigo directly in the vatted form (→ Orpiment).

English print A French method similar to Orbis printing using polychromatic rollers which have the required design on the surface made up of a pattern of dye platelets (number of colours optional). Printing (depending on colour layer thickness, 3,000–25,000 m of cloth, 20–40 m/min) is carried out on damp cloth (prewet, with additional additives after dyeing) with simultaneous steam injection, followed by usual fixing.

English tulle → Bobbinet.

Engraved printing roller, production of → Engraving.

Engraved roller printing → Gravure printing.

Engraving There are three classical options available for the engraving of rollers for textile printing:

1. Mill engraving: This can be described as a predominantly mechanical process. The pattern is firstly engraved manually onto soft metal rollers/plates. The design will be transferred onto hardened steel rollers, the circumference of which corresponds to the repeat of the design. The steel rollers are given a light electroplating of copper. The design is traced onto the soft plates using a sulphur-containing colour paste. The design is then laid over the steel rollers and gently heated. This causes the sulphur to combine with the copper. On those places where the design has been attached, the copper becomes black, rendering the design visible on the steel roller.

The outlines and the edges of the surfaces are then chiselled out manually. The roller is then coated with an acid-resistant lacquer and the engraving is made onto the coat of lacquer using a scutcher or stamping machine. An etching process etches the hatchings imprinted even more deeply. The master roller produced in this way is hardened. In use it is pressed against a second soft steel roller on the relief engraving machine. This has an integrally larger circumference, whereby the engraved areas of the master roller impress onto the so-called relief roller. This relief roller is used to produce the printing roller. The relief roller is pressed against the copper roller of the printing roller on the so-called mill engraving machine. This imprints the embossed pattern deep into the roller. With this type of milling, the pressure must always be uniform and the distance between the milling cycles must be accurate to a fraction of a millimeter. If this is not the case, gaps will become visible. Mill engraving is used for small patterns such as needlepoint and dog's-tooth checks etc.

2. Pantograph engraving is suitable for larger area patterns. After being enlarged several times, the pattern is transferred onto zinc plates. Depending on the size of the repeat, several plates are laid next to each other. The edges are manually chiselled as an outline on these plates and the surfaces relating to the various colours in the pattern are labelled according to each colour. The pattern is transferred to the printing roller using a special machine, the so-called pantograph. The engraved plates are used as a model. Several engraving levers corresponding to the number of repeats are actuated across the width of the roller using a pantograph. A diamond is inserted into the tip of each of these levers. Using these diamonds the pattern is engraved into a coat of lacquer with which the roller is evenly coated. The outlines are then retraced. The hatchings are later added using a hatching plate. The roller scored in this way is etched more deeply in a nitric acid bath. A further development of this is the photoelectronic pantograph, which consists of two separate units. In the first unit, there is a roller to which the design is attached. The roller to be engraved in stored in the second unit. The design is in black/white and is scanned using a photoelectric cell. The light impulses obtained are converted into electric impulses. These are then chiselled relative to their intensity. The chisel impressions are made onto a roller, which has been coated in lacquer and their close location forms into lines. Up to three rollers can be engraved at one time using this method.

3. Photo-engraving enables smooth surfaces and short runs to be printed. Firstly, colour separations are prepared from the design; i.e. each colour is transferred separately onto a film with an opaque colour. A reproduction camera is then used to copy the appropriate screen or hatching into the design by means of a screen plate or hatching plate. In the meantime, the printing roller (copper roller) is given a light-sensitive chrome gelatine coating. The design is presented to the prepared roller and the whole assembly is exposed to light. The non-engraved areas are covered during this process. The exposure causes the chrome gelatine areas to be hardened. The areas that are not exposed remain water-soluble. When the process is complete, the entire roller is rinsed off. The remaining chrome gelatine is hardened by heating and the roller is placed in an etching solution (iron chloride) which slowly etches away the copper from the non-exposed areas. In addition to the chemical etching process, electrolytic etching also takes place. Using the principle of electrolysis, the roller to be etched becomes the anode and the positive copper ions migrate to the cathode. The ions are prevented from migrating to the areas covered in hardened gelatine, with the result that the copper coating may only be corroded in the free areas.

Manufacturing of flat screen and screens for rotary film screen printing takes place in special companies or in separate departments at the printers. After a repeat design drawing and a resulting colour separation have been drawn up, either the flat screen is manufactured using the photochemical method or the rotary screen is manufactured using the galvano-plastic method (or less frequently using the photo resist method). Where screen meshes are made by specialist companies, the fabric is dyed in specific colours in order to eliminate the effect of underexposure (reduction of areas to be printed). During copying, the light falls through the negative onto the fibres of the screen gauze, and is reflected in the case of white fabric and underexposes the positive in the covered areas. With dyed fabrics, part of the light is absorbed by the dyeing; only the remaining part of the spectrum is reflected and underexposes the positive to a significantly lesser degree, with the result that sharper outlines arise. The carrier layer is produced by coating with gelatine. The gelatine contains ammonia and potassium dichromate. After exposure, those layers which are not exposed continue to be soluble and may subsequently be rinsed out. Water-insoluble chrome gelatine forms after the photochemical reaction (Fig. 1):

$$Cr_2O_7^{2-} + 2\,HO^- \rightleftharpoons 2\,CrO_4^{2-} + H_2O$$

$$3\,e^- + CrO_4^{2-} + 6\,H^+ \rightleftharpoons CrO^+ + 3\,H_2O$$

$$CrO^+ + \text{Gelatine} \rightleftharpoons \text{insoluble chrome gelatine}$$

Fig. 1: Photochemical formation of chrome gelatine.

The galvano-plastic method to produce rotary screens uses more seamless, thinner nickel foil rollers. These are perforated and must have uniform thickness. The fineness of the perforations is selected depending on the print. 25 holes/cm (approx. 60 mesh) are chosen for blotch prints, 30 holes/cm (approx. 80 mesh) for small

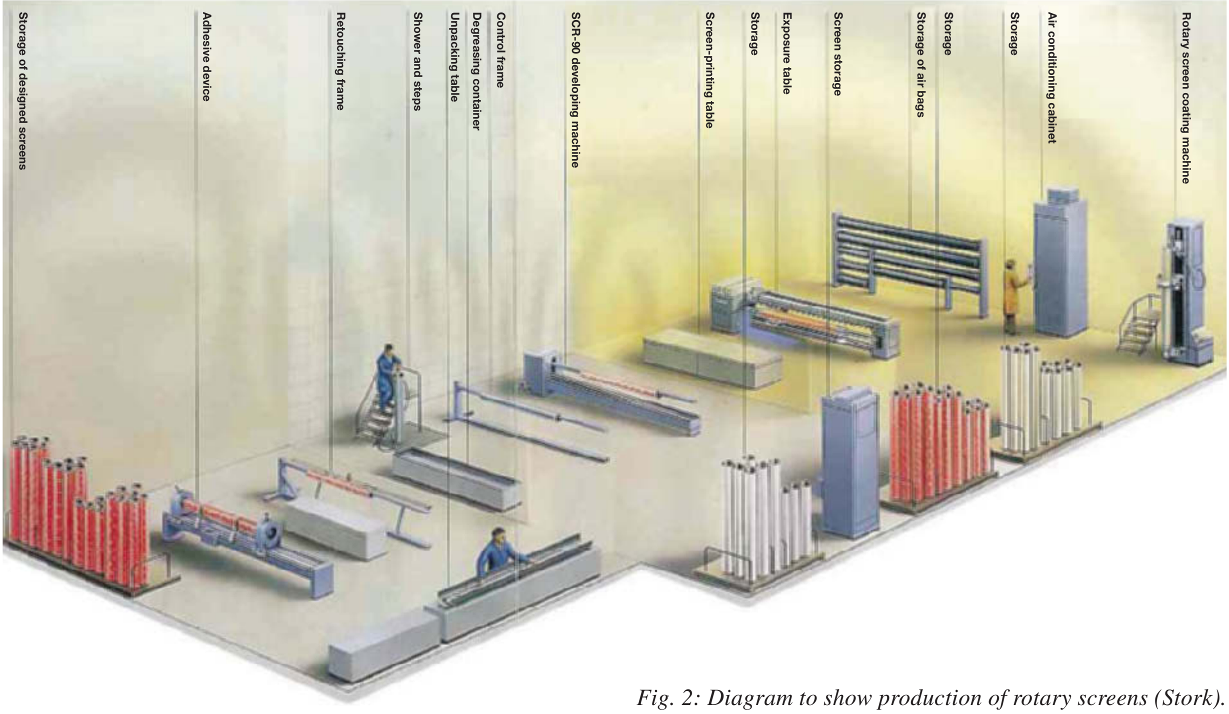


Fig. 2: Diagram to show production of rotary screens (Stork).

figures and edges, and for very slight application of print paste, 40 and more holes/cm (corresponding to 100 mesh and more). With the galvano-plastic designed screen, the sealed nickel coating is still in place on the areas which have not been printed, whereas the screen is located on the areas which have a pattern. The work processes in the galvano-plastic process are as follows: a light-sensitive layer is applied to the carrier roller. A negative film with delayed solubility is then copied onto the carrier roller. The photo layer must be developed and hardened on this before a separating layer is applied to the carrier roller. The nickel sulphate roller is nickel-plated in the galvanising process before the nickel screen is separated from the carrier roller. The mesh count gives the number of openings per linear inch (corresponding to 2.54 cm).

In principle, a total engraving system comprises the following finishing equipment:

- Unpacking table,
- Degreasing container,
- Coating machine,
- Air conditioning cabinet,
- Exposure machine,
- Developing equipment,
- Retouching frame,
- Polymeriser,
- Shrinkfit frame,
- Stripping tank.

Auxiliaries such as films, lacquers, retouching lacquers incl. chemicals, supporting hooks, various auxiliary rings etc. are also required. The engraving department is made up of the rational arrangement of all machines in the space available. Fig. 2 shows an example of how to set up and divide the department. The division into three functional areas should be noted:

- A preparation area for unpacking, milling and hardening the screens;
- An area for wet processes such as degreasing, rinsing and developing;
- An area for drying and exposure.

When planning an engraving department, requirements such as specific light sources, temperature control, power supply, transport and floor coverings must all be taken into consideration. The screens are particularly sensitive due to the extreme thinness of the nickel. They are therefore packed with extreme care to avoid damage. The screens are stacked in long cartons. There is a risk of bending the screens when unpacking or pulling them apart. This can be avoided by using the special unpacking table, which is twice the length of the actual screen. Slight pressure is applied to the reel of screens using a travelling roller. This enables the screens to be easily removed individually from the reel from the inside.

Laser engraving essentially enables the significant acceleration of preparatory work (transfer without film) up to the production of the ready-for-press rotary film printing screens. Stork (STK) and Zedco (Piolat) demonstrated the direction in which colouring and screen manufacturing are heading. In rotary screen production, higher precision is achieved by the use of laser engraving, whilst the automatic combination of CAD and engraving is becoming increasingly widespread. The use of laser engraving does away with lighting, development and polymerisation in comparison with conventional processes. Engraving takes only approx. 15–20 min.

Engraving chisel Tool used in the repair of damaged gravure printing rollers. Also used in pantograph engraving to engrave the zinc or aluminium plates.

Engraving company A company specialising in the production of gravure rollers for printing. The machinery and methods used for the manufacture of Gravure rollers is varied and expensive and for this reason, it is normally only feasible for a textile printer to commission the production of new rollers or the machining, re-coppering and re-engraving of old rollers with new designs. The staff must be especially skilled to carry out this work. Smaller printers therefore often send this work to specialised engraving companies.

Engraving depth In gravure printing the engraving depth is dependent on the number of → Hatching per cm, which in turn is dependent on the fabric to be printed. The larger the number of hatchings, the lower the engraving depth. → Engraving.

Engraving designer The engraving designer produces colour drawings according to a design in the relevant individual colours.

Engraving die This is used for engraving. The finish hardened relief cylinder is pressed against the copper roller of the printing roller in a special machine, the so-called mill engraving machine. The raised pattern is then engraved/ indented into the cylinder. The roller undergoes a special treatment before this. The necessary capacity is then established by allowing the engraving machine to “run over”. The necessary copper layer is then wrung off. Rod steel which has been diagonally ground is used for this, in order to achieve machining which is as even as possible. In order to achieve total smoothness of the surface, an “engraving planer” is passed over, the machining being “smoothed down”. The engraving planer is also referred to as an engraving die.

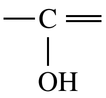
Engraving hammer One of a number of special tools required when repairing damaged gravure printing rollers.

Engraving of embossing rollers Engraving of steel rollers for → Embossing calender.

Engraving quarter tones The printing roller is initially pre-etched and the areas of the pattern, which need to be engraved less deeply, are coated with lacquer. The free areas can then be subsequently etched at the desired depth.

Enol form →: Enols, Ketones.

Enols Organic compounds characterized by the presence of a double bond and neighbouring hydroxyl group, i.e. containing the group –CH=C(OH)– in their molecules, e.g.



$$-\underset{\mathrm{OH}}{\underset{|}{\mathrm{C}}}=$$

The term “enol” is a compound of “en” (double bond) and “ol” (from alcohols). → Ketones are practical examples of the enol form.

Enthalpy Thermodynamic variable (H), defined as the sum of the internal energy and the displacement energy (pV) of a system, being the product of the volume under constant external pressure (p): H = E + pV. The enthalpy is equal to the heat content under constant pressure. Chemical reactions in a system at constant temperature and constant pressure only take place spontaneously towards a reduction in the free enthalpy G ($\Delta G < 0$). The relationship shown in the Fig. applies to the system.

free enthalpy (tendency to react) = tendency to minimum enthalpy - tendency to maximum entropy

$\Delta G_{\text{system}} = \Delta H_{\text{system}} - T \cdot \Delta S_{\text{system}}$

free enthalpy = maximum amount of work the system can support

Fig.: Statements on enthalpy changes ΔH in systems: the enthalpy itself cannot be measured.

Entropy (Greek entropein = turn), thermodynamic measure of order or disorder. The second law of thermodynamics states that in a closed system, the entropy cannot decrease. When the original energy of a reaction is present at a high level, the entropy amount is low, in the opposite case it is correspondingly high. In other words, the deeper the quality of the energy form, the greater is the entropy amount arising from the conversion of a unit of energy. If energy conversions are also accompanied by material conversions and blending effects, these are also contained in the definition of entropy. The entropy of a system is a measure of a lack of information or, simply, a measure of disorder. For calculation purposes the entropy is subdivided into separate amounts capable of addition. The two most important are the thermal and configurational amounts. As a rule of thumb the following can be observed: the thermal entropy proportion increases as the temperature of a system increases, that is as the movement of the smallest particles (molecules, ions, atoms) increases and the average space between particles widens.The information on the resting place and direction of travel of the individual particles is reduced as the temperature increases, and the disorder is increased. The configurational entropy proportion, that is, the entropy of the arrangement of the atoms in a molecule, a lattice or a system, increases the more a system is blended, and the less precisely the location of the individual particles

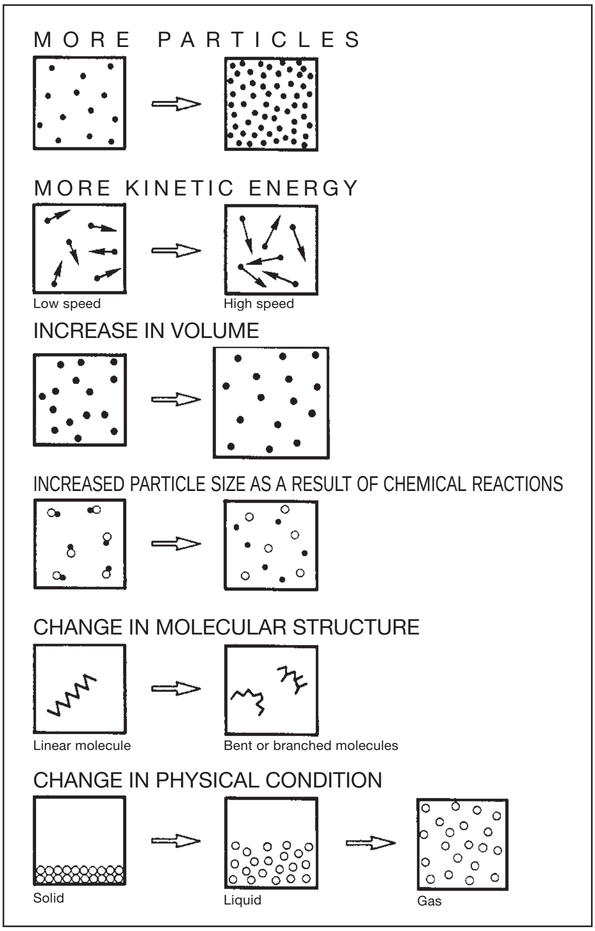


Fig.: Possible causes of increases in entropy (source: Tyler Miller).

can be described. The total entropy of a system is therefore the sum of all the entropy parts. For simple ecological considerations it therefore applies that during warming and/or blending or thinning of a substance the entropy of the system increases (see Fig.).

Entropy is therefore used in defining the second law of thermodynamics: in irreversible (i.e. self-contained) processes in an isolated system the entropy always increases. Put another way: a process in which a transfer of energy takes place can only continue spontaneously if the entropy of the system and the surroundings increases overall. The entropy of the system alone may decrease, but then the entropy of the surroundings must increase by a corresponding amount. Given this aspect, the second law of thermodynamics limits all efforts towards environmental balance to a finite degree. Every resource is ultimately converted to waste by human activity. Waste is therefore, put positively, a resource in the wrong form, the wrong place or the wrong distribution. From the point of view of thermodynamics, waste is therefore in a state of high entropy, usually resulting from blending or thinning. Generally, every instance of energy conversion, therefore also every case of civilizatory activity, e.g. industrial production or car usage, produces entropy in the form of heat emissions into the environment or pollutant emissions into the earth's atmosphere, ground or water (source: Kummert and Strumm).

Entry zone of a stenter or drying machine is the area in which the edges of a textile fabric are taken up on pins or held by clips.

Environment The surroundings of a living creature, the milieu. The study of environmental interrelations is referred to as → Ecology.

Environmental compatibility assessment Biological degradation represents both in the aqueous environment (sewage treatment, surface water) and in the soil the main mechanism of natural processes that cause compounds introduced into the environment to be dissipated. It therefore has a crucial influence on the environmental concentration of substances and is a key factor in environmental compatibility assessment, where the environmental concentration and the active ecotoxicological concentration of a substance are compared. The speed and completeness of biological degradation determine whether and to what extent the ecotoxicological potential of a substance comes to bear on the environment; hence environmental compatibility assessment will frequently refer to "biological degradation priority".

Environmental compatibility assessments are officially demanded whenever large-scale projects (e.g. of an industrial nature) threaten to fundamentally alter an environment (residential area, natural environment) if brought to fruition.

In textile finishing aspects of environmental compatibility and the efficiency of materials used, together with the demand to save on energy and labour costs, are acquiring major significance. Some of the tenside classes developed in recent years go a considerable way towards satisfying these requirements. To be able to assess the environmental impact of any organic substance, however, those properties that are especially important ecologically first need to be clarified. There is a definite ranking order to these:

- quick and complete degradability,
- elimination in treatment plant or by special procedures,
- exclusion of any accumulation in the food chain,
- zero or low ecotoxicity.

This ranking order may be described as follows: if a higher placed criterion is met, then the one below it is of lesser importance. Thus, for example, high fish toxicity is of major significance for a substance of low degradability and one that cannot be eliminated since it could cause the destruction of fish stocks if it should enter the waterways in a high concentration via the sewage system and sewage works. A degradable or eliminable substance, on the other hand, cannot possi-

Tab.: Test methods for determining biodegradability.

Test Method	Dwell Time	Test Concentration [mg/l]	Principle	Analysis	Advantages/ Disadvantages
OECD 301 D – Closed Bottle Test (GF)-Test	30 d	2–10	static, test substance is sole carbon source	BOD	+ proof of biological degradation - extremely severe
OECD 302 B – Zahn-Wellens test	28 d	200–500	static, test substance is sole carbon source	COD carbon decrease	+ indication of fundamental degradability - elimination may simulate degradability - not severe enough
Coupled Units Test	3h or 6h	10–20	continuous, organic base substrate	carbon decrease	+ simulation test - quantification - elimination may simulate degradability

BOD = Biological Oxygen Demand
COD = Chemical Oxygen Demand

bly enter the water since it is already eliminated in the sewage treatment plant.

There are several methods available (see Table) for testing the most important parameter, biodegradability (→ Surfactant biodegradability).

They are all suitable for evaluating the degradability of water-soluble organic substances, by testing their complete degradation, i.e. their mineralization to carbon dioxide and water. Methods do not only differ considerably in terms of test procedures, but also in the transferability of their findings to actual circumstances in a surface waterway or in a water treatment plant (source: Schlüter).

Environmental ethics It is important for the textile industry to understand the technical and legal dimensions of environmental problems and that the concept of the environment and environment law has moved further away from the anthropocentric approach, centred around human beings, towards a central nature conservation law under the motto “Nature doesn’t use people, but people use nature”. In this respect, human activity must be regarded as fundamentally disruptive, something which should be legally limited as far as possible. These activities should at the very least be in harmony with nature, working with the environment, rather than against it (physiocentric philosophy of Meyer-Abisch).

The German Water Resources Act (WHG) has accordingly developed away from a prescriptive law into a water conservation law. The Federal Pollution Control Act has less to do with health and safety, in contrast to the trade law on which it is based; the Waste Avoidance and Waste Management Act is increasingly both directly and indirectly concerned less with the removal of refuse than with its prevention. The Soil Conservation Law has developed similarly into an independent area as a third central issue.

Environmental impact Increasingly, integrated methods have gained in significance in recent years in the study of the environmental impact of products or systems. All developmental stages of a product from acquiring the raw materials through manufacture and end-use right down to disposal at the end of its useful life are included in this process. A characteristic variable is the “cumulative energy expenditure” – the sum of all energy expended during the life cycle of a product. The ecobalance, a new instrument still in the process of perfecting, goes a stage further in additionally examining the effects on the natural environment of, for example, emissions or the consumption of resources.

Environmental legislation Environmental legislation has developed exponentially since 1970. Textile finishing is affected by this in the following areas:

I. Handling of chemicals:

1. (German) Federal legislation on chemicals:
   a) Hazardous Substances Regulation (Ger.: Gefahrstoffverordnung, GefStoffV) with Annexes I–VI;
   b) classification and identification of hazardous substances and formulations;
   c) dangerous substances which are carcinogenic, genetically damaging and cause infertility;
   d) toxic, caustic, irritating and chronically harmful substances;
   e) medical check-ups;
   f) classified hazardous substances and formulations.
2. MAK list (workplace threshold limits).
3. BAT list (biological materials tolerances).
4. TRK list (technical standard concentration)
5. Legislation on combustible liquids (VbF).
6. Storage of chemicals and technical materials.

II. Waste water pollution: Water Management Act (WHG), regional regulations, Schedule of Water Pollutants, Laundering and Cleaning Agents Act, Tenside Regulation, Effluent Discharge Levy.

III. Emissions and atmospheric pollution: Federal Immission Protection Act and its legal regulations.

- TA (technical) guideline on air,
- TA guideline on noise.

IV. Disposal of residual liquor, effluent and clarification sludge: waste legislation, implementation regulations, clarification sludge regulation.

V. Physiological effects of textile material: Hazardous Substances Regulation with Annexes I–VI, allergic effect, odour, skin tolerance, prevention of domestic toxins (home textiles).

VI. Environmental liability legislation (risk liability): legislation governing liability for environmental damage and for amending the Water Resources Law and the Federal Immission Protection Act (Ger.: Bundesimmissionsschutzgesetz, BImSchG, 1990/91).

VII. Environmental criminal law: 2nd Act for Combating Environmental Crime (1991/92).

VIII. Heat Utilization Regulation, Draft 5.9.1991: decision-making criteria and operators' obligations.

At the same time, the Self-Monitoring Regulation envisages for the future in-house supervision of all potential causes of environmental pollution.

Through the environmental provisions that have been made particularly in recent times, a new action requirement has been placed on many companies (Table 1). The need to examine existing waste disposal arrangements in regard to current regulations, for instance, is always paramount. At the same time, trends need to be recognised and addressed, which is only possible as a rule through knowing the relevant legislation. While the content of the major environmental legislation is generally familiar to the planning engineers, technicians are not usually up to date in following the ongoing legal judgements. Hence collaboration with suitably experienced legal experts is proving to be very useful in many cases today.

To achieve a certain security in dealing with the regulations, it is sensible to first familiarise oneself with the basic system of environmental legislation, which is divided into four major areas:

- the law governing prevention of water pollution with its "guiding act" WHG (Ger.: Wasserhaushaltsgesetz = Water Resources Law),
- the law governing clean air with its "guiding act" BImSchG (Ger.: Bundesimmissionsschutzgesetz = Federal Immission Protection Act),
- the law governing waste disposal with its "guiding act" AbfG (Ger.: Abfallgesetz = Waste Act),
- the law governing nuclear energy with its "guiding act" AtomG (Ger.: Atomgesetz = Atomic Act).

Fig. 1 provides an overview of the provisions regulating prevention of water pollution, clean air, waste disposal and nuclear energy.

In all areas two legal policy principles are applied as the basis of all provisions, namely the principles of precautionary measures and the polluter and cause. A further principle that needs to be observed consists in ensuring that technical progress is put to use in the field of environmental protection. The relevant state-of-the-art technology should be made use of. This has even found legal expression to a certain extent. Laws which directly impinge on future measures are the Waste Disposal Act and the Hazardous Substances Regulation, which provides, among other things, for a reduction of emissions in the handling of dangerous substances in line with the technological state of the art.

With the Industrial Effluent Discharge Levy (Ger.: Abwasserabgabengesetz, AbwAG) the classic regulatory instrument of the Water Management Act has found a legal counterpart in fiscal terms. The amending law of the AbwAG extends the liability to levy payment to the group of organic halogen compounds, such as the heavy metals chromium, nickel, lead and copper. The amount of administration required for implementing

Regulation	Action (examples)
Water Resources Law	Monitoring, updating of sewage plants taking into account the state of the art or the a.a.R.d.T. Monitoring of production plant in regard to the handling of water pollutant substances Water economy measures
Effluent Discharge Levy	Pollutant reduction measures
Hazardous Substances Regulation; Regulation Governing the Storage of Water Pollutant Substances	Inventory of stored chemicals (stock list) Fire prevention provisions (collection of water for fire fighting)
Federal Immission Protection Act	Monitoring of the certification compliance of existing equipment Monitoring of the certification status of modified equipment
Technical Guideline on Air Quality	Refurbishing of old equipment to comply with new requirements
Emergencies Order	Monitoring of the need for emergency analysis Action planning to avoid emergencies
Waste Act	Monitoring of waste disposal for recycling opportunities

Tab. 1: Operational consequences arising from the changing environmental legislation.

the act is visibly reduced. Anyone failing to observe the discharge levels, will be liable to pay a higher effluent discharge levy. Whoever employs state-of-the-art effluent treatment will receive a sizeable effluent discharge levy reduction; while anyone who, provided that no hazardous substances are present, makes even more strenuous efforts that go beyond the treatment techniques usually employed can expect even greater levy concessions. Further investment incentives are offered through the possibility of offsetting the effluent discharge levy against the costs incurred for investing in progressive cleaning technology.

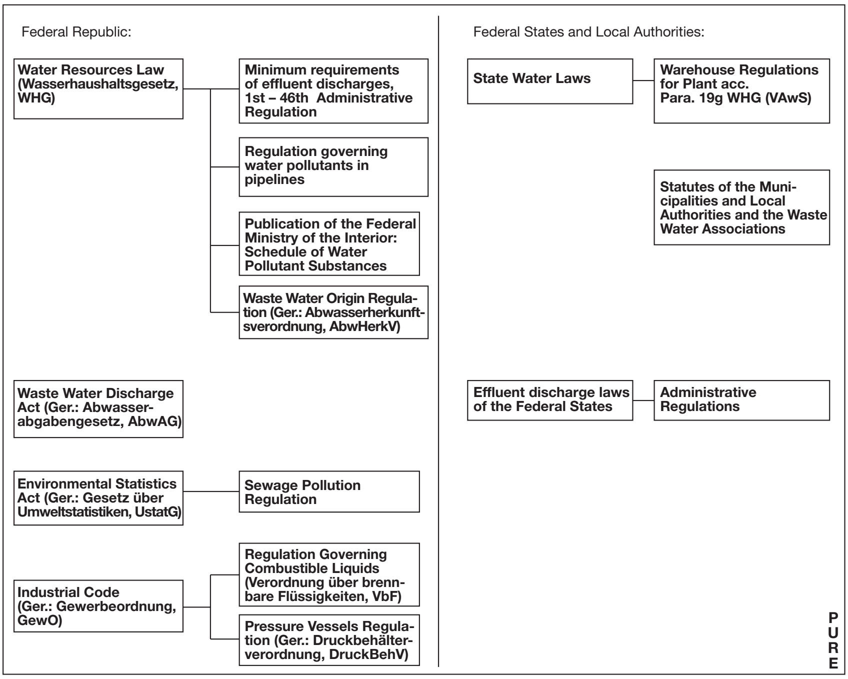


Fig. 1: Important legal provisions in the area of water pollution control.

With the revision of the Washing and Cleaning Agents Act (Ger.: Wasch- und Reinigungsmittelgesetz, WRMG) the aim is to reduce the pollution of water and effluents by washing agents and detergents. The environmental compatibility of these products should be continually improved in accordance with technical progress and consumption limited to the quantities sufficient for cleaning. The scope of the act has been extended to include, for example, anhydrous detergents (solvents, certain paint thinners, etc.) and a series of textile finishing agents that are mainly released in cleaning. The subsequent introduction of requirements affecting industrial laundering and cleaning equipment is aimed at optimizing the overall system of machine/chemical product in regard to water pollution control.

The Water Resources Law (WHG) makes the following provisions: effluents containing hazardous substances must be treated in future by processes that conform to the state of the art. These new, stricter requirements will also apply in future to the public sewerage system. Hazardous substances, as a matter of priority, should be reduced as far as possible at source or preferably avoided altogether. Another priority is the reinforcing of ground water protection. Systems which handle water pollutant substances are subjected to the strictest protective measures of the WHG.

Fig. 2 depicts the statutory instruments for improving water quality. It is the aim of the WHG to keep hazardous substances away from water resources. A further objective is the safeguarding of ground water so that, ultimately, effluent discharge pipes that might or actually contain water pollutant substances must be enclosed in walled conduits. This applies to virtually all effluents from laundries and dry cleaners.

There is also an obligation to obtain authorization for discharging effluents into the public sewer system, which includes the class of “hazardous substances”. Should there be any suspicion of substances of this kind being discharged into the public sewers in high concentrations or loads above a certain threshold value, then informal approval must be sought. Non-action can lead to considerable penalties being imposed.

Permission to discharge effluents may be refused under certain conditions relating to the pollutant level of the effluent or may be linked to the imposition of tertiary treatment. Numerous heavy metals, such as arsenic, lead, cadmium, chromium, copper, nickel and mercury are included here, as well as halogenated hydrocarbons or halogenorganic compounds (AOX) and free active chlorine. All these substances can in principle end up in the detergent solution and hence the effluent from soiled materials or through corrosion

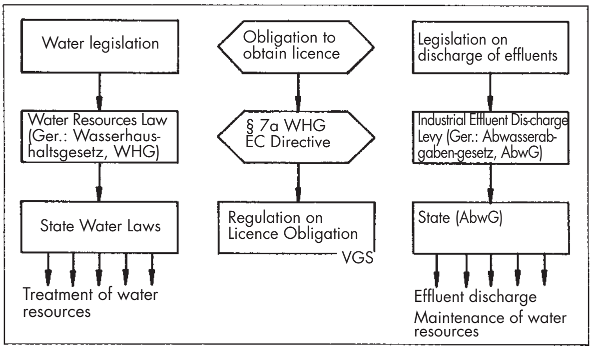


Fig. 2: Statutory instruments for water protection.

(of copper, zincification) or through the process itself (halogenated hydrocarbons in dry cleaning, AOX and free chlorine due to the use of active chlorine with bleaches and disinfectants in laundering).

§ 19g of the Water Resources Law stipulates that for equipment used in the storage, filling, handling, production, treatment and use of water pollutant substances certain precautions are necessary. Water pollutant substances are solids, liquids and gases that are capable of adversely affecting the physical, chemical and biological properties of water. Equipment must be designed in such a way that "there must be no risk of any contamination of water or any other adverse change to its properties." Likewise, water pollution is an important criterion in the classification prescribed in the safety guidelines of the Association of the Chemical Industry for cooling water and fire protection resources in chemical stores.

Water Pollutant Classes (WGK):

WGK 0: generally not pollutant,
WGK 1: slightly pollutant,
WGK 2: pollutant,
WGK 3: severely pollutant.

Criteria behind the water pollutant classification:

- acute oral mammal toxicity LD_{50}
- acute bacterial toxicity EC_0
- acute fish toxicity LC_0
- merit rating due to
  - biological degradability
  - solubility
  - carcinogenicity
  - mutagenicity
  - bioaccumulation
  - photolysis, etc.

Many plant operators erroneously hold the view that producing a licence for their system protects them from further action on the part of the authorities and they therefore try to claim rights of protection. In fact, the holder of a licence is permitted to operate a system in the manner specified. A licence, however, only states that a system complies with the law in force at the time of issue. It does not represent a "privilege" for all time. This is due to the fact that environmental technology is developing rapidly and that, in the interest of environmental conservation, both legislation and legal judgements need to be able to respond to new technologies. The legislator has therefore made provision for various ways of responding, even in retrospect, to material changes that occur. Hence, § 17 BImSchG (Ger.: Bundesimmissionsschutzgesetz = Federal Immission Protection Act) allows for authorities to issue supplementary directives and § 5 BImSchG subjects the operator of any system in need of a licence to a variety of obligations: he must set up his system in such a way that adverse environmental factors, hazards and nuisances to others are avoided, residual substances are either eliminated or recycled, and heat emissions are put to optimum use. This means, first and foremost, for operators of systems requiring a licence that they are required without official notification to observe and implement the statutory requirements. Likewise, operators of systems which do not require a licence should also endeavour to behave appropriately and adapt to the changed legal position, because it is quite likely that given continued technological developments the legal provisions will become more strict.

Which regulations should be complied with in each case is determined by the activity carried out by the plant operator. First and foremost the operator should follow the official advice. This makes clear the main requirements, though it will frequently contain references to other mandatory regulations, directives and legal provisions, too, the requirements of which are not specifically related to the addressee in the order notice, however.

Plant operators who work with chemicals are urgently advised to produce and continually update detailed storage lists. For systems requiring a licence there is a statutory duty to do this (§ 6 Incident Regulation, Ger.: Störfallverordnung). Lists of this kind do not merely provide an up-to-date overview of the quantities stored, but also, given proper design and detail, allow quick and deliberate accessing of all the relevant data on handling the substances, be it for example on the measures needed to be taken in the event of unforeseen emergencies or if a competent member of staff should wish to find out the type of storage most suited to a particular substance, or whether or not only trained personnel are permitted to handle the substances (Fig. 3).

A stock list like this should be subdivided into different categories:

1. Stock data:
- Inventory/material number
- Stored quantity
- Size of container
- Consumption/rate of throughput.

2. Safety data:
- Special storage requirements,
- Special knowledge requirement,
- Risk class VbF,
- Ignition point, flash point,
- EU classification codes for handling and using hazardous substances

3. Environmental data:
- Workplace threshold limits,
- Water pollutant class,
- Concentration and mass flow rates as per Technical Guideline on air quality and Part 2 of BImschV.

Environmental monitoring Temporal and quantitative monitoring of water, air or waste pollution in a particular ecosystem. Phosphates have been used for a long time in detergents, for instance, to absorb water hardness; these contribute significantly to phosphate pollution of waterways (see Fig.).

From 1980 onwards reduced phosphate detergents were introduced, and by 1989 all detergents in Germany had switched to phosphate-free formulas. These measures, along with the introduction of tertiary treatment in sewage plants, have considerably reduced phosphate pollution in waterways. Boron is also found in detergents in the form of sodium perborate. Through the use of bleaching activators it has been possible to improve the effectiveness of sodium perborate and reduce the quantity used.

Environmental pollution Physics tells us that material objects change in time and space under energy defined conditions. Environmental problems arise because man exploits nature to satisfy his own needs. All interventions in the eco-system affect the ecological balance. Safe and environmentally correct production alone is not enough. It is necessary to reduce the potential for risk by technical control, monitoring impact and using effective waste disposal techniques. More importantly, it requires reduction in potential risks and minimising the quantity of waste produced. The key to this is in the development of integrated environmental control procedures that take into account the aspects of safety, environmental protection, energy consumption and the efficient use of resources, without compromising product cost or quality.

When the extent of environmental impact is considered, three areas can be distinguished. According to Cmelka, these areas can be separated by the following boundaries: be-

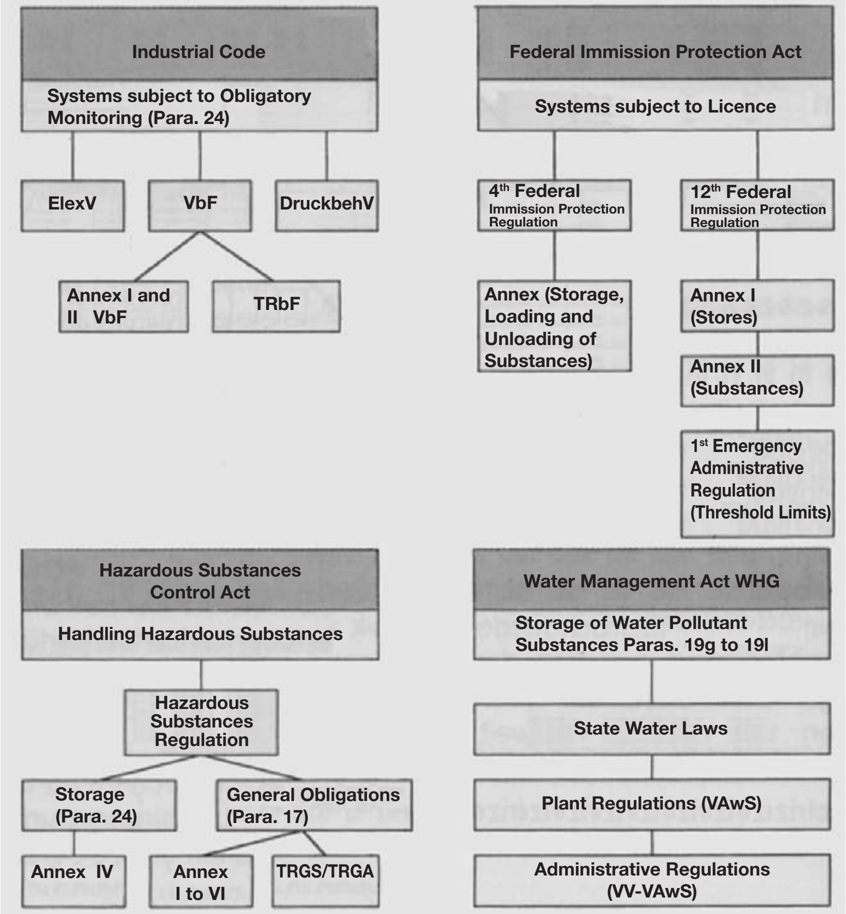


Fig. 3: Overview of the major regulations governing chemical storage.

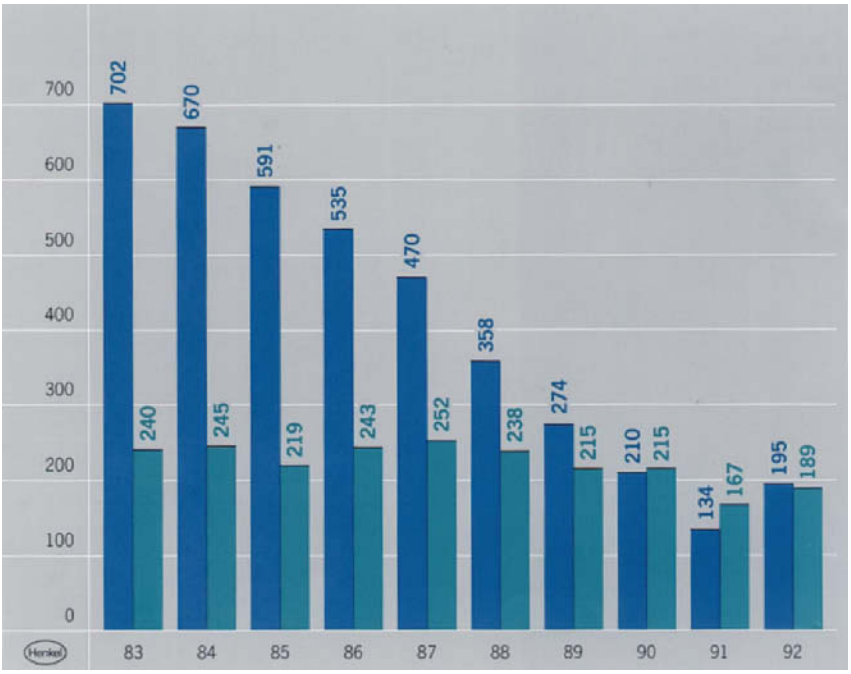


Fig.: Environmental monitoring – boron and phosphate (annual mean values in g/s) in the Rhine (control point: Düsseldorf-Himmelgeist). Blue = phosphate (phosphorus); green = boron.

tween environmental compatibility and environmental impact is the start of statutory regulation, between environmental impact and environmental damage is the start of environmental loading. Environmental compatibility is distinguished by the perceptibility threshold. The size of the individual areas can be quantified for the individual eco-systems, e.g. how high the limit for introducing statutory regulations has been set in relation to the overall magnitude of the potential effect of the environmental factors. Scientific or medical phenomena may be related to the recommended concepts, and these can be traced back to interventions in the eco-system in question. Although this scheme is simple, the limits of its application can be seen if we consider the global eco-system, the biosphere: other factors, such as susceptibility, adaptation, accumulation and synergies also come into play.

Definitions:

- Neutral effect: no measurable difference to the eco-system, any changes remain within the range for these parameters in an undisturbed system.
- Environmental compatibility: measurable change of one component of the eco-system, any effects remain within the range of the range of fluctuation for these components in an undisturbed system.
- Environmental nuisance: subjective influence on the well-being without effects that can be detected objectively. These must be kept to a minimum, taking into consideration both economic aspects and whether it is technically possible to avoid the nuisance.
- Environmental pollution: in the short term, no significant effects, although these do occur in the long term. The effect is reversible, and returns to the original state after the factor is removed.
- Environmental threat: Significant, but reversible effects, even after a short period of exposure. Effects are irreversible after a longer period of exposure.
- Environmental impact: Irreversible effects even after a short period of exposure.
- Detection threshold: This must be stipulated on the basis of scientific data concerning significant affects on eco-systems as a result of environmental factors (noise, contaminants, etc.).
- The introduction of statutory requirements must be stipulated on the basis of environmental quality standards. Although the process of marking out the boundaries includes scientific data, and takes into consideration the regional situation, it is eclipsed by political decisions.
- The limit of load capacity refers to the eco-system in question. It must be stipulated again using environmental quality standards, but this time including a risk factor as regards possible environmental threat. The stipulation of the risk factor is again a political decision.

In textile finishing, environmental pollution can be caused by:

- Effluent,
- Air exhaust,
- Waste,

or by consuming resources:

- Finishing agents,
- Energy.

The Table summarises by way of example the material parameters used to assess effluent from textile finishing, which may involve critical values and require measures to be taken to avoid pollution or to treat the effluent before discharge to the municipal sewage system.

Environmental profile of polymers More environmentally-friendly products are being developed for the application of polymers. Table 1 depicts an environmental profile for dispersed polymers. From the packaging through to the properties of the dispersed poly-

● Systems comprising polymers, water, dispersants, additives (solvent free)

Packaging: type, storage, shelf-life, return, reuse, disposal

Disposal of product residue

Handling: protective measures, pourability, mechanical safety, risk in fire, means of disposal (odour, emissions, effluent, burial), toxicology, physiological characteristics

● Application: from water, pH-values above 2 and below 11

Disposal of residual liquor: recycling, incineration, dumping

Waste water from production:
- reclamation
- receiving stream
- clarification sludge → disposal

Emissions from textile production:
odour
- cleaning → disposal

● Characteristics on the product: health and safety, food legislation, allergies, odour, fogging, poluting, burning

Packaging: type, storage, shelf-like, return, reuse, disposal

Handling: mechanical equipment

Disposal of the textile and industrial product: recycling, incineration, dumping

Disposal of a complex system comprising textile, metal, plastic, glass, e.g. motor vehicle: recycling, incineration, dumping

Tab. 1: Environmental profile of dispersed polymers for textile and industrial applications (source: Fischer).

Parameters	Baden-Württemberg regulations (1978)	ATV worksheet A 115 “Gelbdruck” (April 1981)	Principal source of pollution in the finishing process
1. Heavy metals			
Chromium VI Chrome total +	0.5 mg/l 2 mg/l	0.5 mg/l 3 mg/l *	Chrome dyeing (wool), dyestuff oxidation with vat and sulphur dyeing
Copper ++	2 mg/l additional limit on heavy metal fractions required	2 mg/l *	Coppering dyes, poss. certain reactive dyes
Zinc +	5 mg/l	5 mg/l *	Cross-linking catalysts (resin finishing), stripping faulty dyeing
2. Anions (non-metallic)			
Sulphide +	10 mg/l	2 mg/l	Sulphur dyeing (cotton)
Sulphite	50 mg/l	only in such a low concentration to give no anaerobic effects in the public sewers	Vat dyeing, reductive aftertreatment of disperse dyes on polyester
Nitrite	10 mg/l	20 mg/l (possibly higher fractions)	Various dyeing processes
3. Organic parameters			
Hydrocarbons +++ (especially Baden-Württemberg)	20 mg/l pretreatment plant required	20 mg/l where separation of volatiles includes the removal of hydrocarbons (Hydrocarbon controls as per DIN 38 409 T 18)	Fibre lubricants (synthetic fibres), spin finish, white spirit and mineral oils (pigment printing)
Chlorinated solvent or	5 mg/l as Cl at the point of discharge		Tetrachloroethane,spotting agent, poss. chlorobenzene carrier
halogenated hydrocarbons		10 mg/l as organic bound halogen	
4. General requirements			
Colour +++	Effluent may only be discharged in so far as any colour it may contain can be removed by the Municipal Sewage Treatment Plant	Dyestuffs may only be discharged at concentrations that do not appear coloured after mixing in the entry to a mechanical-biological effluent treatment plant	Total elimination of colour and Reactive dyestuffs in particular is not possible in a mechanical-biological effluent treatment plant
Toxicity	Effluent may only be discharged as long as it does not carry the potential to impair the biological processes in the sludge treatment plant nor impairs the effectiveness of the sludge	Effluent may be discharged only when: – it will not affect the health of staff working in the municipal effluent treatment plant – it will not affect the continuing operation of municipal effluent treatment plants – ground water is not polluted above permitted levels nor adversely changed – no effluent smells are given off in the municipal effluent treatment plant Otherwise the effluent must be treated before discharge or other suitable measures taken.	Potential pollutants in textile effluent: Chrome VI Conc. alkaline solution Sulphide Hydrocarbons Carriers Cationic auxiliaries (when they are not balanced with sufficient anionic auxiliary discharge) etc.

Tab.: Earlier example (circa 1980) of material parameters to assess effluent from the textile finishing industry.
** Where sewage sludge is used in agriculture, the best method of sludge disposal in terms of recycling where there is a well-situated area for the sludge to be deposited, the relevant explanatory documents must be noted and if necessary, the heavy-metal fractions from the waste must be controlled.*
+,++, +++ Relevant to effluent discharge from the textile finishing industry according to actual experience of the water regulatory authorities.

	EVA dispersion 50% T_G – 18°C	dispersed polyacrylic 50% T_G – 40°C
chemical oxygen demand (COD), determined by dichromate oxidation (DIN 38 409, Part 41)	1000 mg O_2/g	940 mg O_2/g
organic carbon, determined by combustion and CO_2 test (DIN 38 409, Part 3)	300 mg C/g	330 mg C/g
eliminability through activated sludge (biodegradability as per OECD Test 302 B)	>80%	>80%
precipitability	with aluminium sulphate	with aluminium sulphate
bactericidal action (fermentation tube test)	>1000 mg/l	>1000 mg/l
water-pollutant class (1 = substances of low pollutant potential)	1	1
acute, oral toxicity (LD50, rat)	>2000 mg/kg	>2000 mg/kg
skin irritation (rabbit)	non-irritant	non-irritant
mucous membrane irritation (rabbit‘s eye)	non-irritant	non-irritant
European Standard EN 71, Part 3, Safety of toys: chemical properties	heavy metals Sb, As, Ba, Cd, Cr, Hg, Pb are not present	
Disposal as per TA technical guidelines for waste/types of waste schedule of the German Federal Environmental Protection Agency	hazardous waste incineration, for polymer dispersions or, if need be, physico-chemical treatment also, e.g. filtration Waste schedule: 57303 (dispersed synthetic), 57702 (latex)	

Tab. 2: Environmental data for dispersed polymers (source: Fischer).

mers and those of the finished textile, from the system of fibre plus polymer with dispersant right down to disposal, the environmental profile of polymers can be characterized in such a comprehensive manner that many technical properties are comparatively overlooked.

The environmental details in Table 2 provide information about aqueous dispersions composed of polymer, dispersant and processing aid. Only when applied on the textile material, dried and cured can the total system, consisting of fibre, additive, dispersion with polymer and processing aids, be ecologically and toxicologically evaluated. Both dispersions (which are free from plasticizers) conform to the recommendation of the Federal Health Ministry, Berlin, for dispersed synthetic substances as defined by the Foodstuffs and Commodities Act (Germany). According to this act, plasticizer-free dispersions of synthetic substances may be used if certain conditions are met, i.e. if the chemical substances specified in the recommendation, certain polymer components (monomers), certain processing aids used in specified small quantities, e.g. certain catalysts, stabilizers, protective colloids, thickeners, emulsifiers, defoaming agents, are components of each of the dispersions being evaluated. “Commodities as defined by the Act are: items designed to be used in the manufacture, treatment, marketing or consumption of foodstuffs and therefore come into contact with these foodstuffs or have an effect upon them.”

Recommendation XIV of the German Federal Health Office on dispersed polymers corresponds to the draft of the new EC Directive No. 128/90 on “Materials and objects made of synthetics designed to come into contact with foodstuffs.” In this EC Directive, the substances also recorded in the dispersion recommendation are divided into two groups:

Group A: The permitted monomers and other parent substances, e.g. acrylic ester, vinyl ester, styrene, acrylic nitrile, butadiene, vinyl chloride, ethene, known monomers and maleic acid, melamine, ethene oxide.

Group B: Monomers and other parent substances where no decision has been made about incorporating them into Group A, e.g. acrylamide, N-methylol acrylamide, reactive monomers capable of being incorporated in the dispersed polymers.

The subject of emissions specified in the environmental profile (Table 1) needs to be examined more closely in regard to C-emissions. The debate on emissions has focused on two particular aspects:

- the concept of “synthetic resins” in the 4th Regulation in the Protection Against Harmful Effects on the Environment Act for machinery, including stenter frames, requiring certification,
- the Technical Guideline on air quality.

The “synthetic resin” concept should initially include various substances used in textile finishing, dressing, easy-care finishing, proofing, etc. It is sensible to understand it in terms of the familiar chemical concept for synthetic resin, which includes the actual synthetic resins alkyd, phenol, epoxy and melamine resins, i.e. three-dimensional cross-linkable products. What should not be included, however, are cross-linking agents that used to be described as easy-care finishing resins, which exist and are used in monomolecular form (as monomers) or are not self-crosslinking dispersed polymers.

In future the OECD definition (Tables 3 and 4) as found in the 7th revision of the Directive on hazardous substances should apply to the concept of a polymer (source: Fischer).

- Molecules comprising a series of one or more monomeric units
- Molecules with > 50% by weight having at least three covalently bonded monomeric units
- Molecules with < 50% by weight having the same molecular weight
- Such molecules must show a molecular weight distribution

Monomeric unit: Reacted form of a monomer to polymer

Tab. 3: OECD polymer definition (for 7th Amending Directive for Dangerous Substances).

M – M – M	S – M – M		
M – M – M – M	S – M – M – M	< 50%	> 50%
M – M – M – M – M	S – M – M – M – M	< 50%	
M – M – M ... M – M	S – M – M ... M – M	< 50%	

M = Monomeric unit (also of varying type)
S = Starter molecule

Tab. 4: A polymer according to the OECD definition.

Environmental protection regulations In order to decrease risks when handling environmentally hazardous substances, regulations for equipment using water polluting toxic substances are established in the Water Resources Act (WHG) in accordance with the precautionary principle. The regulations stipulate that leakages from engineering equipment, official procedures and recurring tests must be excluded and work on equipment should basically only be carried out by specialist companies authorised by the water authorities. The scope of these regulations has been extended to cover equipment used in manufacturing, treating and using water toxic substances in the interests of an improvement of water protection in the WHG which is a necessary precaution. The state regulations fulfilling federal law are contained in the "Ordinance on equipment for storage, drainage and transforming water toxic substances".

In the meantime, operational regulations have been drawn up concerning storage and drainage and conversion of water toxic fluids. These describe safety systems in the form of technical directions (TA) which will have to be adhered in future due to a danger analysis which is to be undertaken in individual cases. It is therefore possible

- to demonstrate to plant operators which requirements the plants must fulfil,
- to give experts a framework for suggestions concerning additional requirements on existing plants,
- to simplify the task of the authorities to ascertain whether existing plants are suitable as well as their assessment.

Environmental reporting The results of a survey of a company's environmental actions. May be used as the first steps leading to an → Ecobalance.

Environment problems in pigment printing Compared with other textile printing processes pigment printing is of major importance. Today pigment printing is the most important printing technique worldwide having a market share of more than 50%. Its advantages are as follows:

1. simple technical application: the application consisting of printing, drying and fixing is basically very simple. Due to this short process pigment printing is quite cheap and one of the most ecologically favourable textile printing processes;

2. applicability to all kinds of fibres: pigment printing can be applied to all kinds of fibres which have sufficient thermostability;

3. wide range of colours, high fastness to light: in pigment printing we have at our disposal a wide range of colours with a high fastness to light;

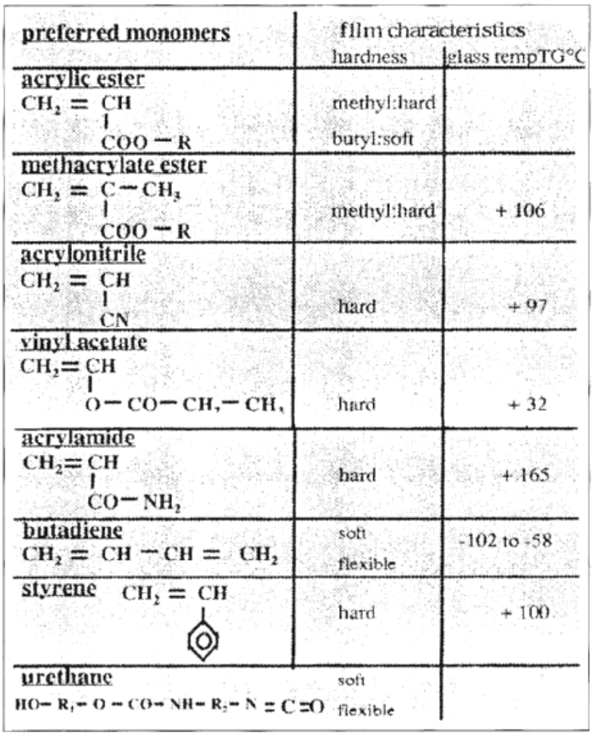
4. special printing processes: a range of special printing processes such as white, bronze and pearl prints can be carried out with pigment systems.

A pigment printing paste consists of the following ingredients:

- water
- antifoaming agent
- emulsifier
- binding agent
- softening agent
- agent improving the running properties
- thickener
- pigment dye
- cross-linking agent
- acid donor

1. Antifoaming agents: One generally recommends adding an antifoaming agent to prevent foaming during the production of printing pastes or during printing.

2. Emulsifiers: Apart from their emulsifying effect these products aim at stabilizing the whole pigment printing system, i.e. preventing dyestuff agglomerations, reemulsifying dried particles of the binding agent



preferred monomers	film characteristics hardness	glass temp TG°C
acrylic ester $\begin{array}{l}CH_2 = CH\\ \quad\;\, \mid\\ \quad COO - R\end{array}$	methyl:hard butyl:soft	
methacrylate ester $\begin{array}{l}CH_2 = C - CH_3\\ \quad\;\, \mid\\ \quad COO - R\end{array}$	methyl:hard	+ 106
acrylonitrile $\begin{array}{l}CH_2 = CH\\ \quad\;\, \mid\\ \quad CN\end{array}$	hard	+ 97
vinyl acetate $\begin{array}{l}CH_2 = CH\\ \quad\;\, \mid\\ \quad O - CO - CH_2 - CH_3\end{array}$	hard	+ 32
acrylamide $\begin{array}{l}CH_2 = CH\\ \quad\;\, \mid\\ \quad CO - NH_2\end{array}$	hard	+ 165
butadiene $CH_2 = CH - CH = CH_2$	soft flexible	-102 to -58
styrene $CH_2 = CH$	hard	+ 100
urethane $HO - R_1 - O - CO - NH - R_2 - N = C = O$	soft flexible	

Fig. 1: Binding monomers and their impact on their films.

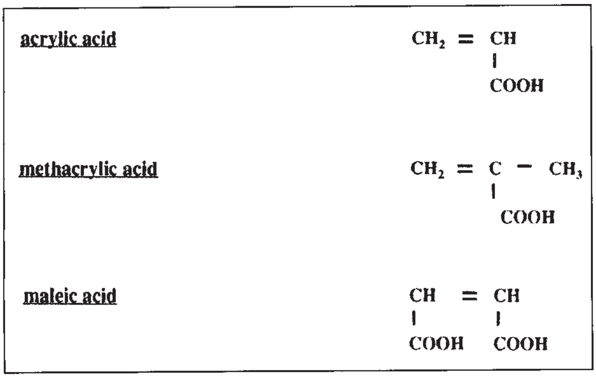
and improving the running properties of the printing paste.

3. Binding agents: Three groups of binding agents are essentially of importance for the fixation of the dye pigments on textile surfaces (see Fig.1). Binding agents based on acrylate stand out due to their good fastness to light and heat. Depending on the polymer structure the films they produce range from being hard to soft and very soft. The polymer structure also influences the fastness levels to dry cleaning and washing. Binding agents based on butadiene are very sensitive to temperature and light, i.e. the films turn yellow and embrittle. On the other hand, they produce soft printing paste films with good binding strength on natural and synthetic fibres with good to excellent fastness levels to washing and dry cleaning. In pigment printing butadiene binding agents are mainly used as a mix with acrylate binding agents. The aqueous dispersions of binding agents based on polyurethane physically form the binder films. The printing paste films are very flexible and can also be fixed at low temperatures above 110°C for 8–10 min. Their fastness to light as well as their fastness levels to washing and dry cleaning on heat-sensitive textiles are good. It is possible to offer a binding agent which meets all requirements of textile printing. Thus, the printer can choose from several types of binding agents to be able to meet the customers' demands in terms of fastness levels and handle.

4. Softening agents: It may be necessary to add a softening agent for the individual modification of the handle depending on the customer's demand. Due to the use of binding and wetting agents and of synthetic thickeners pigment printing has the disadvantage of producing a stiff handle. Thus it works with selected softening agents which have a perfect softening effect without impairing the fastness levels of the prints to a high extent. Non-volatile fatty acid esters, mineral and silicone oils serve as softening agents.

5. Agents improving the running properties: Specific climatic conditions and the use of highly pigmented printing pastes necessitate the addition of so-called moisture regulators or evaporation retardants to the printing pastes in order to avoid screen blockage. Glycols, glycerine and urea are used.

6. Thickeners: Those based on white spirit are not common any more in pigment printing mainly due to ecological requirements. Today the salts of the polyacrylic acid and its copolymers are almost exclusively used (see Fig. 2). For pigment printing mainly ammonium salts are used since during drying and heat-setting of the prints ammonia can escape leaving only the polyacrylic acid. These acids are hardly water-soluble so they have the effect of a catalyst. The rheological properties of the synthetic thickeners are similar to those of thickeners based on white spirit. They can also be used in low amounts to achieve printing pastes with an acceptable viscosity. The effect of synthetic thickeners highly depends on the pH value and they are also sensitive to electrolytes. Thus the necessary application amount of a synthetic thickener depends on the quality of the plant water, the dyestuffs used and the amount of electrolytes of the auxiliaries.



acrylic acid $\begin{array}{l}CH_2 = CH\\ \quad\;\;\, \mid\\ \quad\;\; COOH\end{array}$

methacrylic acid $\begin{array}{l}CH_2 = C - CH_3\\ \quad\;\;\, \mid\\ \quad\;\; COOH\end{array}$

maleic acid $\begin{array}{ll}CH = & CH\\ \mid & \mid\\ COOH & COOH\end{array}$

Fig. 2: Examples of thickening monomers.

7. Cross-linking agents (Fig. 3): Usually these are modified urea and melamine formaldehyde resins with as low as possible an amount of free formaldehyde. They are added to the printing pastes as crosslinking agents to improve the general fastness levels and particularly the abrasion and wet scrubbing fastness levels on synthetic fibres.

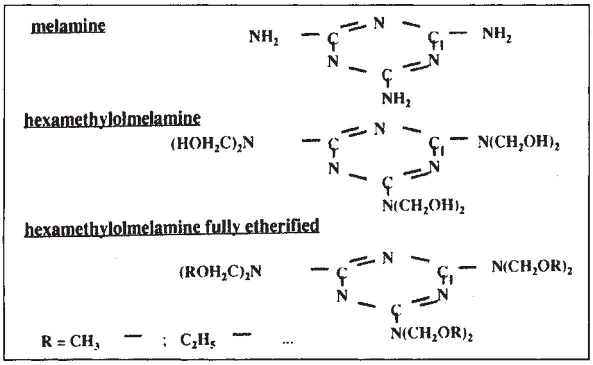


Fig. 3: Examples of crosslinking agents.

8. Acid donors: Binding agents and crosslinking agents require an acid pH value for their fixation. Additional acid donors such as diammonium phosphate are included in the printing paste to guarantee optimum fixation even if the conditions are unfavourable.

Terms such as ecology, environmental protection, ecological textiles, biodegradable products are increasingly used in our daily language. Depending on the test institute various criteria are to be tested. Thus, the recipes in pigment printing have to be adapted to the relevant requirements. Ecological pigment printing means that the environment is less damaged than with a system working with conventional auxiliaries. Different aims are to be achieved, e.g. low formaldehyde content, low APEO content, low hydrocarbon content or formaldehyde-free, APEO-free and hydrocarbon-free. The necessary recipe can be formulated with the individual products (see Fig. 4 and 5). As early as three years ago the first factory trials in formaldehyde-free pigment printing were carried out. Due to the technical problems and high costs formaldehyde-free acrylate binding agents were not taken into consideration.

water	X	g
CHT-ANTIFOAM	2	g
urea	10	g
TUBIGAT A 60	5	g
TUBIFAST AN 15	100	g
TUBIVIS DRL 300	32	g
TUBIFIX ML 50	3	g
	1000	g

formaldehyde content < 50 ppm, measured Jap. Law 112

Fig. 4: Low formaldehyde content, low APEO content and low hydrocarbon content.

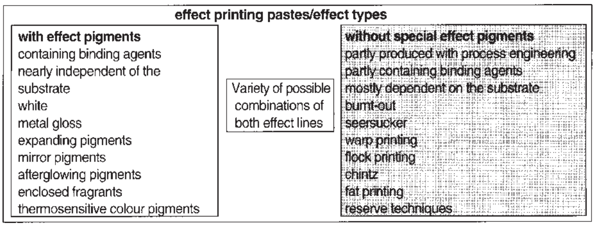
water	X	g	
CHT-ANTIFOAM BS	2	g	(silicone antifoaming agent)
TUBIGAT O 20	5	g	(APEO-free emulsifier)
TUBIFAST BN 35	100	g	(butadiene binding agent)
TUBIVIS SNP 110 S	10	g	(powder synth. thickener)
TUBISOFT PS	5	g	(silicone softening agent)
TUBIFIX P 150	3	g	(based on isocyanate)
	1000	g	

formaldehyde content < 10 ppm, measured Jap. Law 112

Fig. 5: Formaldehyde-free, APEO-free and hydrocarbon-free.

Ready-made pastes are pigment printing systems which can be directly applied. Depending on the effect desired they already contain the necessary auxiliaries to enable continuous working. The effect can be divided into two groups (Fig. 6 and 7):

- producing effects with effect pigments (containing binding agents, nearly independent of the substrate);
- Producing effects without effect pigments (partially containing binding agents; produced by means of process engineering).



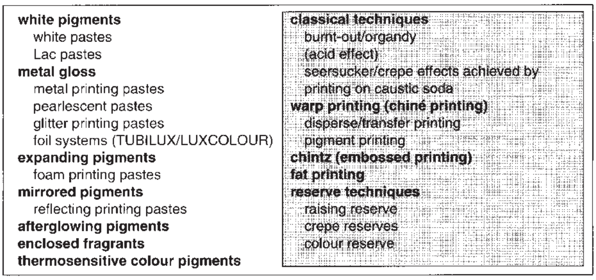
effect printing pastes/effect types

with effect pigments
containing binding agents
nearly independent of the substrate
white
metal gloss
expanding pigments
mirror pigments
afterglowing pigments
enclosed fragrants
thermosensitive colour pigments

Variety of possible combinations of both effect lines

without special effect pigments
partly produced with process engineering
partly containing binding agents
mostly dependent on the substrate
burnt-out
seersucker
warp printing
flock printing
chintz
fat printing
reserve techniques

Fig. 6: Possible effects with/without effect pigments in continuous printing.



white pigments
white pastes
Lac pastes
metal gloss
metal printing pastes
pearlescent pastes
glitter printing pastes
foil systems (TUBILUX/LUXCOLOUR)
expanding pigments
foam printing pastes
mirrored pigments
reflecting printing pastes
afterglowing pigments
enclosed fragrants
thermosensitive colour pigments

classical techniques
burnt-out/organdy
(acid effect)
seersucker/crepe effects achieved by printing on caustic soda
warp printing (chiné printing)
disperse/transfer printing
pigment printing
chintz (embossed printing)
fat printing
reserve techniques
raising reserve
crepe reserves
colour reserve

Fig. 7: Possible effects with effect pastes in continuous printing.

High quality pigment printing is the ecologically cheapest textile printing process which will be suitable to successfully meet the future requirements with its developments.

After several years of development ink-jet technology is still mainly used for sampling, quite rarely for production. This technology stands out due to its flexibility and fastness compared with common printing systems. Moreover there are no screen costs for sampling. The use of different substrates impairs its applicability because every substrate requires its own dye (dyestuff class) and a corresponding fixation process for the fixation of the dyestuffs. Pigment dyes which can be applied to nearly all substrates could solve this problem. However, they cannot be incorporated into the fibre to react with it so they have to be heat-set using suitable binding agents. Up to now this process has not caused any problems with the common printing machines. If ink-jet technology is used for pigment printing, binding agents which are to produce maximum fastness levels on the fabric may clog the jets or block them. In classical printing processes as well as in pigment printing highly fashionable designs are sometimes combined with effect pigments. These coarse-grained pigments (white/pearl/metal, etc.) produce a special effect on the fabric. Ink-jet processes are not yet considered to be suitable for the application of these pigments. (according to G. Schneider).

Environment protection in finishing (European Regulatory Requirements) Pollution from a textile finishing house can be of two main types; water-borne (effluent) and air emissions. Water-borne pollutants can be divided into three classes; firstly, toxic chemicals, which may be present in quite low concentrations; secondly, organic impurities which in large amounts can take much of the oxygen out of the water, so that it can no longer support aquatic life; and thirdly, colour, which, despite protests from technical experts that the low concentrations of dyestuffs which escape into the effluent are not a health hazard, is classed by environmental regulators as an aesthetic pollutant.

Possible solutions which the textile finishers in general will have to consider should include:

1. source reduction;
2. extraction of the pollutant;
3. treatment of the effluent to destroy the pollutant;
4. substitution with a less harmful alternative.

Source reduction is the place to start any environmental program. A complete listing should be prepared from purchasing records for all facilities, including all chemicals for production, maintenance and janitorial supplies. Minimising the variety of chemicals and dyestuffs that are purchased will take time and commitment from top management but can pay big dividends from both the environmental analysis and actual production cost standpoints.

Extraction of the pollutant, by sedimentation or filtration, for example, can lead to another challenge: how to dispose of the extract. In Europe, this is usually by landfill or incineration, as long as this does not produce further pollution hazards. Destruction, for example by bacteria or oxidation, must not result in the formation of hazardous products in the treated effluent, a theoretically possible consequence, for example, of decolorisation of dye liquors with ozone. However, another alternative, re-cycling or re-use of the offending chemical, may be available. Often the least expensive and most reliable answer is to replace the harmful substance with a less dangerous and commercially available alternative, a solution which is frequently overlooked.

Regular environmental audits are essential to ensure that the situation is kept under control, that improvements are being made wherever possible, and that changes in processing operations do not introduce new hazards. ISO-14 000 environmental management standards being developed include guidelines for carrying out such audits.

Environmental terminology and regulations affecting the textile finisher: EC Directive 76/464 covers pollution caused by certain dangerous substances discharged into the aquatic environment. List I, the “Black List”, includes pentachlorophenol (PCP), certain pesticides and organo-halogens which are regarded as so harmful that steps should be taken to eliminate pollution by them. List II, the “Grey List”, covers less harmful substances but recommends that they should be controlled and eventually reduced by environmental quality standards (EQS), and includes heavy metals such as copper, zinc and chromium.

AOX (Adsorbable organo-halogen compounds): German law limits the AOX content of effluent to not more than 0.5 mg/l, with not more than 3mg/l from a component stream (production unit). Belgium imposes a limit of 0.8 mg/l of AOX in waste water. Sweden and Finland have also enacted legislation and regulations are being prepared in the Netherlands. Although not currently an issue in the UK, this situation is expected to change in the near future.

BOD (Biochemical oxygen demand): This measures the amount of oxygen absorbed under defined biological conditions.

COD (Chemical oxygen demand): A measure of the oxygen required to oxidise organic pollutants completely to carbon dioxide and water.

VOC (Volatile organic compounds): The UK Environmental Protection Act 1990 introduced new controls on air emissions, waste and waste disposal and nuisance. Air emissions from textile processes are covered in Section 6.5B defined as coating processes. The definition of coating is not that traditionally used in the textile sector but appears to cover surface application to any substrate. (see Tab.1 for set emission limits to be met by October

Total VOC (as total C, excluding particulate matter)	50 mg/m^3
Total particulate matter (including emissions from material handling)	50 mg/m^3
Carbon monoxide (from incinerators)	100 mg/m^3
Isocyanates (as NCO group)	0.1 mg/m^3
Formaldehyde	20 mg/m^3
Dilution and odor masking specifically forbidden.	

Tab. 1: Emission limits.

1997). Similar regulation on air emissions are being, or have been introduced in other European countries.

Packaging legislation: The EC is developing a regulation on packaging and packaging waste which has now reached a fourth draft stage. This states that ten years after it comes into force 90% by weight of packaging waste must be recovered, 60% to be recycled, the remainder used for energy production or composting. Five years after the regulation comes into force no packaging can be used for which there are no established channels for its return and subsequent re-use or recovery. Germany has already a regulation of this type, Verpak VO, and France introduced a similar system in January 1993.

Environmental aspects of wet processing: The cotton fibre is one of the purest natural forms of cellulose, of which it contains between 88 and 96%. Non-cellulosic impurities will include naturally occurring organic compounds such as wax, pectins, proteins and colouring matter and minerals essential for plant development. Metal contents vary significantly between years and between growth areas; potassium is the most abundant metal followed by magnesium, calcium, sodium, iron, zinc, manganese and copper. Depending on the quality of the fibre, some non-fibrous material, for example seed-coat particles, may also be present in the spun yarn. Finally, in addition to natural impurities, grey cloth arriving from the weaver will contain warp size, and knitted fabric will contain lubricants which have been applied to the yarn to assist in the knitting operation. All these impurities must be removed before the fabric is dyed or printed. For effective and satisfactory dyeing, the material must be absorbent, reasonably and uniformly white in colour and free from non-fibrous material. This is accomplished by desizing, scouring, bleaching and sometimes mercerising. These treatments, and the subsequent dyeing or printing, may require the presence of auxiliaries such as alkalis or surface active agents, which must also be removed from the fabric after processing.

Desizing: Cotton yarns are normally sized with native starch or modified starches. Native starches consist of two components, amylose (linear chain polymer) and amylopectin (branched chain polymer). Native starches vary in their amylose content; the higher the amylose content, the easier the size is to remove in desizing. Typical amylose contents are shown in Table 2.

Sago	26%
Wheat	25%
Maize (Corn)	24%
Potato (Farina)	20%
Rice	19%
Tapioca	16%

Tab. 2: Typical amylose contents.

Native starches may be chemically treated (modified) for improved sizing properties, and these are sometimes, but not always, easier to remove than natural starch. The typical add-on for starch sizes is around 8–15% on the weight of the fibre depending upon the yarn count and the number of threads per cm. Starch and modified starch sizes must be degraded in order to effect desizing, and hence cannot be recovered and recycled. Enzyme desizing is widely practised for the removal of starch sizes, but oxidative desizing is said to be growing in importance. The preferred oxidant is hydrogen peroxide, and this has encouraged the development of combined sizing, scouring and bleaching techniques, in either continuous pad-steam or cold pad-batch processes. The effectiveness of these processes is limited by the seed fragment content of the cotton.

Synthetic sizes: Water-soluble polymers such as polyvinyl alcohol and carboxymethyl cellulose may be used for sizing cotton yarns. These are readily removed in a normal scouring process.

Size re-cycling: In vertical companies which carry out sizing, weaving and desizing operations, it is possible to recover, concentrate and re-use synthetic sizes like polyvinyl alcohol, carboxymethylcellulose and polyacrylates by swelling/removal methods, or by ultrafiltration. Size recovery systems suitable for cotton have been developed by DuPont and BASF.

Effluent from sizing materials: Size removal processes may contribute up to 60% of the total COD value in wet processing.

	COD
Starch	900–1000 mg oxygen per gm
CMC	700–800
Polyvinyl alcohol	1500–1700
Polyacrylates	1000–1200

Tab. 3: COD value in wet processing.

Starch produces higher levels of effluent CODs than synthetic sizes because of the much higher levels of application (Tab. 3). Solid add-on of starch is normally two to three times that of a synthetic size. The effluent from starch desizing is normally easily treatable by conventional means. However, starch-based baths often contain preservatives to extend the life of the bath, which incidentally can also act as anti-mildew agents on the grey cloth during transport and storage. Such substances include chlorinated phenols, sodium silicofluoride, zinc salts, salicylanilide and other. Some of these are prescribed substances under UK legislation, and finishers have experienced severe effluent treatment problems with high levels of the fungicide pentachlorophenol (PCP), for example, in imported greycloth from parts of Asia and the Far East. In countries such as the United States, PCP is not used and has never been registered for use on cotton. The practice in some countries of requiring suppliers to provide a complete listing of all chemicals and materials used in manufacturing can eliminate these problems. Much research is focusing on the need to eliminate the desizing process entirely.

Scouring: This is normally carried out by means of an alkali treatment at high temperature. Sodium hydroxide or sodium carbonate may be used; the former resulting in more complete removal of impurities. The higher the temperature, the shorter the processing time may be; for the high-speed scouring required in continuous processing the treatment may be carried out under pressure. Sometimes the alkali treatment is preceded by an acid scour, to ensure removal of the mineral content, which may otherwise interfere with subsequent bleaching and dyeing processes. Most of the effluent load in cotton wet processing comes from the desizing and scouring operations. However, these effluents are normally easily treated by standard methods. The omission of a scouring process prior to bleaching or dyeing is not to be recommended, as it can only result in low colour yields and wasted dye, with increased cost of dyehouse effluent treatment, uneven dyeing and probable rejection by the customer.

Bleaching: This is normally carried out by using alkaline hydrogen peroxide, or alkaline sodium hypochlorite, or sodium chlorite under acid conditions. Two-stage bleaching with hypochlorite followed by peroxide is also carried out. Hydrogen peroxide is very safe for the environment and decomposes into water and oxygen. It is estimated that more than 95% of cotton textiles are bleached with hydrogen peroxide. The main environmental challenges in textile bleaching in the immediate future are likely to arise with the possibility of AOX formation when using a hypochlorite or chlorite based bleach.

AOX in bleaching: All chlorine-based bleaches can give rise to AOX (adsorbable organo-halogen compounds) in the waste water. Much of the concern over AOX compounds in bleaching arises from the presence of dioxins in the effluent from chlorine bleaching of wood pulp. Dioxins, a particularly toxic group of AOX compounds, are formed by the action of chlorine on lignin, a binding agent between the cells of multicellular cellulosic materials. The cotton fibre is a single cell; and contains no lignin, so dioxins are not formed in bleaching cotton with hypochlorite. In addition, actual studies have confirmed that dioxin is not formed by chlorine bleaching of cotton. However, it is possible that hypochlorite bleaching will be phased out over the next few years in favour of peroxide, mainly for psychological rather than scientific reasons.

Sodium hypochlorite: Sodium hypochlorite (NaOCl) bleaching leaves a residue of chlorine on the fabric which must be removed by an antichlor process. This is ususally accomplished by a sulphur-based reducing agent such as sodium sulphite or bisulphite which must be washed out. Sodium hypochlorite can be given a more environmentally-friendly antichlor treatment with alkaline H_2O_2, and this is accomplished in two-stage bleaching. The concentration of AOX in waste water from sodium hypochlorite bleaching has been reported to be 10–80 mg/l. The AOX loading in the bleach discharge is much reduced when the material has been prescoured with alkali, and this is normally done.

Sodium chlorite: This produces much less AOX (about one-tenth) of that from hypochlorite bleaching. Optimum bleaching takes place under acidic conditions ($pH<4$), but the process is highly corrosive to metals and requires the use of machinery fabricated from acid-resistant stainless steel and the use of anticorrodants such as sodium nitrate in the bleach liquor. An unpleasant gas, chlorine dioxide, can be generated. Engineering controls are readily available, however, to maintain a safe workplace.

Hydrogen peroxide: Hydrogen peroxide, used under alkaline conditions, is usually preferred for bleaching cotton. The decomposition of hydrogen peroxide is environmentally-friendly, producing only oxygen and water. A peroxide stabiliser is necessary to control the rate of decomposition of the bleach bath. Sodium silicate is an effective stabiliser, but can produce a deposit of silica in the fabric under certain circumstances, and is often replaced by proprietary organic stabilisers. These are generally effective in controlling the decomposition of the peroxide, thereby ensuring economic processing, but may contribute to some degree to the BOD of the effluent. The time required to produce a good white depends on the temperature at which the process is carried out. For continuous processing at or near the boil, the time is usually 15–30 minutes, while for energy conservation batchwise bleaching can be carried out at room temperature, in which case the minimum time would be twenty hours. Peroxide bleaching is normally carried out under alkaline conditions, but in certain circumstances, for example, when processing coloured goods, a neutral or weakly acid bath may be preferred. This, of course, reduces the alkali load in the effluent, but increases the time required for bleaching, due to the increased stability of peroxide under these conditions. All traces of peroxide must be removed from the goods prior to dyeing, especially when reactive dyes are to be used. To reduce rinsing time and costs, a peroxide scavenger may be used. A single stage combined scour and bleach using alkaline peroxide can be recommended in some situations to save water, energy, floor space and equipment needs. A single stage scour/bleach can be recommended when: 1. the goods do not have excessive plant/seed coat fragments; 2. this follows an oxidative desize step; 3. the subsequent dye shade is of sufficient depth and colour as not to require a full bleach (i.e. burgundy, black, brown etc.). It has been said that AOX may be generated in peroxide bleaching of cotton due to the presence in the fibre of organochlorine-based impurities e.g. pesticides, defoliants etc., but studies reported by the Bremen Cotton Exchange repudiate these claims. Any traces of contaminants found were well below the maximum permitted levels which apply in Germany to vegetable foodstuffs.

Mercerising: Mercerisation, the treatment of cotton with concentrated caustic soda solution, causes the fibres to swell and become more circular in cross-section. The molecular and morphological changes brought about by the process lead to an apparent increase in the visual depth of colour when the fibres are dyed or printed. This effect can give an important cost saving and an environmental benefit whereby less dyestuff is required for a given depth of colour. A reduction of 20–50% may be achieved in the amount of reactive dye required, depending on the particular dye used. Recovery of caustic soda is normally by evaporation of the dilute waste liquor. The process consumes energy but minimises environmental pollution from alkali or salt. Recovery is not usually carried out during the mercerisation of grey cloth, due to the heavy load of impurities such as starch and cotton waxes in the waste liquor. To obtain maximum benefit from a caustic recovery installation, fabric finishers can carry out mercerisation after scouring or bleaching; and to avoid an extra drying stage, may elect for a wet-on-wet application of the caustic soda. Fabric moisture content and caustic soda concentration must be very carefully controlled to ensure a uniform effect.

Dyeing: The main classes of dye for the coloration of cotton are direct, vat, sulphur and reactive. Opportunities to improve the effluent centre around the use of reducing and oxidising agents in vat and sulphur dyeing, and the high concentrations of common salt often required in dyeing with reactive and direct dyes. Removal of colour from waste water is necessary with all classes of dye, but is especially difficult for reactive dye effluents. Some dyes contain heavy metals, e.g. turquoise shades, but there have been substantial reductions on average over the past two decades. Some manufacturers are now producing whole dyestuff product lines which contain practically no heavy metals (i.e. the amounts are well below the strict ETAD limits). The major dyestuff companies have invested heavily in environmental improvements. The investments have resulted in higher fixation levels and lower salt requirements, most notably for reactives. Also, effluent treatment research targeted for textile mills, has been done by dyestuff companies and equipment manufacturers. Complete environmental solutions to improve textile effluent quality are emerging, but will require additional engineering and capital expenditures. However, in some situations reasonable return on investments should be possible due to recycling of chemicals, reduced treatment costs and surcharges and energy savings. Cotton Incorporated has done substantial research in the area of colour removal using commercially available ultra and nano filtration techniques. This allows dyers to re-use spent dyebaths.

Dyeing machinery and methods: Padding application methods are more environmentally-friendly than exhaust dyeing techniques. In knitgoods dyeing it has been shown that pad-batch application consumes significantly less water than exhaust methods using winches or jet machines. Tab. 4 gives data obtained in dyehouses in Denmark.

	1	2	3
Water	87 l/kg	95 l/kg	29 l/kg
Energy (wet proc.)	13 900 kJ/kg	14 200 kJ/kg	6100 kJ/kg
Energy (drying)	8400 kJ/kg	10 000 kJ/kg	8400 kJ/kg

Tab. 4: Water and energy consumption in comparison. 1 = jet-dyeing cotton knitgoods; 2 = jet-dyeing polyester/cotton knitgoods; 3 = continuous pad-batch dyeing cotton knitgoods.

The figures also showed that the high salt content of the waste water from jet-dyeing, which makes water recycling difficult, could be eliminated by pad-batch processing. Comparing winch and jet machines, the environmental arguments are in favour of the jet machine. Lower liquor ratios mean lower energy costs and less hydrolysed dye, less salt consumption and therefore less in the effluent. For all machines, the installation of automatic controls optimises the use of energy, dyestuffs and auxiliaries, and may reduce the need for corrections.

Reduction of sulphur dyes: The traditional reducing agent for sulphur dyes, sodium sulphide, has largely been phased out, due to the limitations on the presence of sulphide in waste water. There are new sulphur dyes on the market that are pre-reduced and contain much less sulphides as compared to a few years ago. Sodium hydrosulphite (hydros) can be used for blacks and navy, although not for red-brown due to over-reduction. It is relatively expensive, but the effluent is easy to treat. Borohydride is expensive and can produce hydrogen. It is sometimes used to avoid the effect known as “bronzing”. Thiourea dioxide is another option. With current technology it is easier to control than in the past, has good stability, is economical, biodegradable and nonflammable. Proprietary reducing agents for sulphur dyes are available, for example, from BASF and Sandoz. These are claimed to be environmentally safe.

Reduction of vat dyes: The term “vatting” is used to describe the procedure in which vat dyes are transformed from an insoluble form to the sodium salt of the leuco compound which is water soluble. This is normally accomplished using caustic soda and a reducing agent such as sodium hydrosulphite. Other reducing agents have been used including sodium borohydride, thiourea dioxide and reducing sugars. The leuco compound has a higher affinity for cellulose. Subsequently, the leuco dye is converted to the original insoluble form by oxidation. The comments under “Reduction of sulphur dyes” regarding sodium hydrosulphite, sodium borohydride and thiourea dioxide generally also apply to reduction of vat dyes.

Oxidation of vat and sulphur dyes: Bichromates are not permitted in effluents; peroxy compounds are generally regarded as the most environmentally-friendly alternatives. These include sodium perborate, sodium percarbonate and hydrogen peroxide. Potassium iodate, sodium bromate (Diresul Oxidant BRI [Sandoz]) and alkaline sodium chlorate are also acceptable.

Substitution: Sometimes substitution of one dyestuff by another can be a simple alternative to the installation of expensive effluent treatment plant. For example, Sulphur Black may be an acceptable alternative to Reactive Black 5, which can be difficult to remove from effluent.

Toxicity of dyes: The ecotoxicology of dyes has been discussed in relation to carcinogenicity and the impact of dyestuffs on the environment. The manufacture of azo dyes from benzidine was stopped in 1971 by the most important dye producers. Apart from colour, dyestuffs contribute to the BOD and COD of the waste water from dyeing, although not, it is believed, the toxicity.

Heavy metal contents: For non-metallised dyes and fluorescent brightening agents ETAD (Ecological and Toxicological Association of Dyes and Organic Pigments Manufacturers) has recommended the limits for heavy metals in dyebaths which are shown in Tab. 5.

Much useful consolidated information on colorants and the environment has been published by ETAD. The values in the column labelled ETAD limits in Tab. 5 are construed as the values that meet the legal requirements and relate to a 2% dyeing and total dilution of the dye used to a ratio of 1:2500.

AOX from dyestuffs: Dyestuffs and other products that contain organically-bound chlorine, bromine and iodine may contribute to adsorbable organo-halogen. Some dyes and fluorescent brightening agents contain halogen groups. However, a halogen atom split off from a halogenated heterocyclic reactive dye is not considered to be an AOX-active halogen. Halogen-containing solvents or auxiliaries (e.g. halogen-containing carriers for disperse dyeing of polyester fibres) are other sources of AOX.

Element	ETAD Limits	Maximum content in dyebath
Ag	100 ppm	0.2 ppm
As	50	0.1
Ba	100	0.2
Cd	20	0.04
Co	500	1.0
Cr	100	0.2
Cu	250	0.5
Fe	2500	5.0
Hg	4	0.008
Mn	1000	2.0
Ni	200	0.4
Pb	100	0.2
Sb	50	0.1
Se	20	0.04
Sn	250	0.5
Zn	1500	3.0

Tab. 5: Limits for heavy metals in dyebaths.

Dyeing with indigo: The amount of unfixed indigo removed from denim yarn in the wash-off boxes on a continuous dyeing range is influenced to a marked extent by the application method. pH control is an essential factor in indigo dyeing, and products such as a buffered alkali in liquid form have been developed, which will ensure that the optimum pH range of 10.8–11.2 can be safely maintained. Attention is being paid by machinery builders to the environmental requirements of the indigo dyer. For example, a recent machinery development pays attention to the economical use, de-colorisation and recovery of water. Consumption of water in washing is said to be about 3 litres/kg of warp, while recovery of the indigo dyestuff using an ultra-filtration unit means that about 80% of the washing water can be re-used.

Natural dyes: Many old recipes using naturally occurring colouring matters, such as logwood, cutch, madder etc., have been recorded. In dyeing with most natural dyes pre-mordanting is necessary so that they will exhaust and fix on the fibre substrate, develop the desired shades, and attain the – mostly rather poor – fastness properties. As mordants, metal salts are used which, when regarded from today’s standpoint, are applied in very large amounts. Partridge gives a recipe for a “fine and permanent” madder red in which for one pound of cotton, $^{1}/_{2}$ lb. of alum is used. Other recipes require significant quantities of iron or copper salts, or the use of bichromates and arsenates, which today are unacceptable for the commercial dyer. Only cutch and indigo can be dyed on cotton without mordanting, and cutch is usually applied with the addition of copper sulphate. There are many other potential problems to consider when contemplating the use of natural dyes. With the inherent variability of natural products, they lack the high degree of standardisation necessary for batch-to-batch reproducibility and today's "right-first-time" demands in dyeing economics. Fastness tests indicate that, in general, natural dyes possess poor light and wash-fastness.

Natural dyes, except those allowed in foodstuffs and cosmetics, have been subjected to far less examination and toxicological scrutiny than synthetic dyes. Some vegetable dyes are known to have harmful toxicological effect. For example, cutch has long been known to be an effective fungicide, at one time widely used for dyeing sails and fishing nets, for which it acted as a preservative. It may also be of interest to note that to dye one kilo of cotton fibre to a 5% shade with natural indigo would require the extract of no less than 15 kilos of indigo plants. Worldwide consumption of pure indigo is estimated at 14 000 metric tons. Indigo plants are said to contain about 0.5–2.0% of pure indigo with a reported yield of about 20 kilos of pure indigo per acre. It becomes apparent that a very large area would be required to provide the world's indigo needs, using natural indigo.

Safe handling of dyestuffs: Dyestuffs, especially in fine powder form, may be inhaled, ingested or absorbed through dermal contact. Although dyes have generally low toxicity there is always the possibilty of harmful effects. Codes of practice for the safe handling of dyestuffs in colour stores are now in general use, which are designed to minimise the exposure of dyehouse workers who weigh and mix dyestuffs. Respiratory protection equipment can help to minimise inhalation, together with other measures such as the use of weighing booths with dust extraction. Dyestuff manufacturers have also minimised dusting through reformulation, the sale of liquids and non-dusting granulars. Controls to limit skin contact during weighing include personal protective equipment: gloves, aprons or smocks, and eye protection. Controls to limit ingestion include the enforcement of no smoking, eating or drinking in the colour store and dye kitchen areas.

Printing: Reactive dyes account for almost half of printed cellulosic fabrics; the remainder is dominated by pigment printing. Some printing is carried out with vat dyes; the opportunites for improvement are similar to those for reactive dyes, although the insolubility of vat dyes means that they are easier to remove from the effluent. The waste water from printed fabric washing and screen washing contains colour (reactive dye, hydrolysed reactive dye or disperse dye) and the other components (thickener, urea, auxiliaries etc.) will give rise to significant levels of BOD and COD. Most pollution from the textile printing process arises as waste print paste from cleaning the machine, squeegees, pipes and mixing tubs, etc., rather than in washing-off of the print itself. Modern machines, for example the Stork RD Direct Drive, are designed to work with a very low content of print paste in the system.

Thickeners for reactive dyes: Sodium alginate is the preferred thickener for reactive dye printing due to its lack of reaction with the dyes in the presence of alkali. Synthetic thickeners for reactive dye printing have been developed, based on polyacrylates and polyacrylamide chemistry, but their deficiences in terms of electrolyte sensitivity, leading to viscosity fluctuations, and inferior runnung properties compared with conventional alginate pastes, have limited their use. Alginate is the major contributor to BOD and COD in the effluent from a print works and at present no recovery system is available which would permit its reuse. BOD and COD are readily treated before discharge to the environment however.

Urea: Due to limitations placed on the nitrogen content of aqueous effluents in areas sensitive to eutrophication, the use of urea is a particular concern for printers in Western Europe, the USA and Japan. Urea reduction is now one of the major discussion areas with reactive dye printers in these areas. In printing with reactive dyes urea acts as a swelling agent for cellulose. It disaggregates and solubilises dyestuffs, retards evaporation of water during drying, and increases condensation of water during steaming. The benefits for the printer are an increased solubility of the reactive dye in the print paste, improved colour yield, and better levelness and smoothness of the print. With all these benefits, and the low price of urea, it is difficult to find a technically acceptable and cost-effective replacement.

Currently printers are looking at three approaches to eliminate or partially substitute urea in textile printing. These are either: a switch to two stage printing (flash age fixation), complete or partial replacement with alternative chemicals, or the mechanical application of moisture with steaming. There is at least one new system on the market from a major dyestuff company which eliminates urea completely for printing with reactive dyes. Zeneca Colours has undertaken process optimisation studies and recommends the partial substitution of urea by dicyandiamide which reduces the total nitrogen load to the effluent. This system is operating in bulk but requires careful control of the drying and steaming operations in order to achieve good results. Another system used commercially involves printing the fabric with reactive dyes (no alkali or urea) and then dry only. Next, sodium silicate is applied to the face by kiss-roll pad. Steaming follows in a special loop steamer for fixation and the process completed by afterwashing and soaping.

Pigment printing: Possible toxicological concerns from the presence of traces of impurities in the organic pigments are likely to be small because of the very low levels left in the finished pigment. Aromatic amines may be present but only in small amount. Pigments in the form of barium and manganese salts require special attention because these are subject to threshold limits (0.5 mg/m^3 for Ba, 5 mg/m^3 for Mn). Other metals are claimed to be of little concern in pigment printing. Polychlorinated biphenyls (PCBs) may be present from the manufacture of certain organic pigments such as phthalocyanines, but much work has been carried out by pigment manufacturers to decrease PCB contents to below 50 ppm. Drying and curing releases volatile components into the hot exhaust air which may include ammonia, from the print thickener, formaldehyde from the fixing agent, and volatile organic compounds from the organic solvents used for maintaining dispersion stability or from white spirit (kerosene) used in part emulsion or from water-in-oil emulsion thickenings. There are “fume oxidisers” on the market today which claim to totally eliminate Volatile Organic Compounds (VOCs). These devices simply raise the temperature of the contaminated air exhaust to totally oxidise the unwanted organic compounds to water and carbon dioxide.

Waste disposal in pigment printing: Because all of the pigment print paste formulation printed on to the fabric is retained after curing, the waste print paste formulation for each colour can be collected in concentrated form into a tank for disposal to landfill or for incineration. However the rotary screen printing machine must be cleaned and each screen must be washed, which gives rise to some waste water pollution. Some companies may be able to release all of the unused print paste formulation into their waste water. The possibility of storing and reusing any unused print paste is not usually feasible. Automated dispensing systems and modern printing systems decrease the amount of unused print paste to a minimum on each colour in the design.

Chemical finishes: For cotton fabrics the objectives of chemical finishing are generally stabilisation and appearance retention. For these purposes a crosslinking agent is commonly used. A popular product is dimethylol dihydroxyethylene urea (DMDHEU). Other cross-linking resins used to a lesser extent include urea formaldehyde and melamine. The control of free formaldehyde has been a growing concern in recent years. The level of free formaldehyde on resin-treated fabrics in the early 1960’s was several thousand parts per million as measured by the AATCC Jar Test. Today the level of free formaldehyde on fabrics is less than 300 parts per million, and formaldehyde in the workplace is controlled at extremely low levels in many countries by regulation. In the United States for example, the Federal standard is now 0.75 ppm for the workplace on an eight hour time weighted average basis. Effluent considerations in the chemical finishing of cotton will be mainly as a result of the discharge of residual liquor from mangle-boxes, make-up tanks and pipework. This can be minimised by recycling wherever possible and if necessary modifying equipment and procedures. Strict limits on air emissions from drying machines are being introduced, and the control, abatement and monitoring equipment required will increase the price of a stenter on which it is installed. Emissions from the stenter may contain formaldehyde and other volatile organic compounds released from machine lubricants or from finishes applied to the fabric. Scrubbing or thermal incineration systems may be used to remove these impurities and heat recovery systems may be installed, with hot air recirculation. Other environmental factors are the removal of lint (using wire mesh filters) from the hot air circulating in the stenter, and noise and odour if the stenter compartment doors are not adequately sealed.

Easy-care finishes: The main implications for the cotton finisher will be in the application of crease-resistant finishes based on formaldehyde-containing crosslinking agents. Afterwashing is not normally carried out, so the environmental upgrades are mainly concerned with volatile emissions from the stenter and disposal of waste liquor. Afterwashing may however be necessary if very low levels of free formaldehyde, e.g. 30 ppm, are required by the customer. This will remove most of the free formaldehyde, releasing it into the waste water, together with uncured resin and the acid catalyst as well as some of the other chemical finishes applied to the fabric if these are not durable. Some catalysts may contain metals or organic acids which could require attention in effluent treatment. Although non-formaldehyde crosslinking agents have been proposed, most of these suffer from disadvantages of toxicity, adverse effect on desirable fabric properties, low performance and high cost. One which is available commercially is dimethyldihydroxyethylene urea, produced for example by BASF as Fixapret NF. Improved technology has resulted in the development of products containing ultra-low levels of free formaldehyde, such as Fixapret CL (BASF). Wesh of SRRC shows the use of BTCA as an effective non-formaldehyde crosslinking agent.

Flame Retardants: The main durable flame retardant chemicals available for cotton are Proban CC (Albright and Wilson), Pyvrovatex CP New (Ciba) and Aflammit KWB and Aflammit P (Thor Chamicals). During application formaldehyde release may occur in drying and curing. Fume oxidising equipment can be added to the stacks of the drying and curing ovens which will eliminate formaldehyde emissions. Non-durable finishes are mainly based on inorganic compounds such as borax, boric acid and ammonium sulphate. Less soluble systems, based for example on antimony trioxide, may be termed semidurable. Care must be taken when disposing of some of these products.

Waterproofing and Showerproofing; Fungicides and Bactericides: Most waterproofing finishes are based on organic waxes which will produce VOC in the stenter. Some contain metals (aluminium, zirconium or titanium). In the treatment of shower curtains, for example, showerproofing products could be combined with fungicides which may contain prescribed substances such as PCP and organo-tin compounds. As a group these products must be disposed of with great care.

Surfactants: These are used at all stages of textile processing. They can be either anionic or nonionic, and selection will depend on compatability with other auxiliaries in the liquor. Some auxiliaries may contain small amounts of organic solvents, or may be cationic in nature. Selection must also take into account foaming characteristics, biodegradability, stability to alkalis and electrolytes, compatability with water hardness salts, wetting and detergency power and ease of washing-off. APEO-free (alkyl phenol ethylene oxide-free) surfactants are now widely used within the European Union because these biodegrade without producing metabolites toxic to aquatic life. Linear chain fatty alcohol ethoxylates, sulphosuccinates and other anionic and nonionic products have been suggested, altough the straight-chain products exhibit a moderate to high BOD.

Enzyme-based processing: Treatment with cellulose under suitable conditions weakens the surface fibres in a cotton fabric, so that they break off leaving a smoother, lustrous appearance and a softer hand. Fabrics processed in this way are described as “bio-finished” or “bio-polished”. Some loss of fabric weight and strength occurs, but these effects can be minimal when the conditions of treatment are kept under careful control. Biofinishing has been applied to both woven fabrics and knitgoods to simulate a mercerised appearance, but probably the main application to date is in the production of “stone-washed” or faded denim. This effect was originally obtained by tumbling denim jeans with lumps of pumice in industrial washing machines. It was then found that the addition of cellulose could produce the desired “wash-down” effect with less abrasion damage to the fabric. Traces of peroxide in fabric after bleaching can be destroyed with a newly-developed enzyme product, solving a long-standing problem for dyers using reactive dyes which are sensitive to peroxide, reducing rinsing times and saving water. Enzymes are completely bio-degradable, and offer the textile finisher opportunities to reduce energy consumption and effluent treatment costs. There are expectations that specific enzymes will be of value in the scouring of cotton and other cellulosic fibres, to remove natural protein material, fats and waxes gently, without need for strong alkali and high temperature. (according to Cotton Incorporated).

Enzymatic biofinish → Enzymes.

Enzymatic stonewashing → Enzymes.

Enzyme activity Enzymes are biological catalysts with a protein structure. In this role they are not subject to the stoichiometric regularity of the other reaction partner. As a result, the evaluation criterion for enzymes is not an absolute variable, such as the enzyme mass, but rather the effect of a known enzyme dose on the progression of the reaction. This characteristic variable is the enzyme activity. It tells us how much substrate is converted into product in a reaction [S (substrate) → P (product)] in a defined time period with the aid of a certain enzyme dose. A more commonly used variable is the specific activity, the increase in the product per time period and enzyme quantity, which describes the efficiency of an enzyme in relation to the dose. A well established theory on enzyme catalysed reaction originates from Michaelis and Menten: A substrate S to be converted, for example contained in waste water, forms a complex with the enzyme E, thus entering a reactive state. This makes it possible for the substrate to break down. As a typical catalyst, the enzyme is not consumed during the reaction. We can therefore formulate:

$$S + E \underset{k_2}{\overset{k_1}{\rightleftharpoons}} ES \overset{k_3}{\rightleftharpoons} E + P$$

P is the product; k_1, k_2, k_3 are the associated speed constants. The change over time of the substrate concentration can be written as the familiar Michaelis-Menten equation in the form

$$v = \frac{dS}{dt} = V_{max} \frac{[S]}{K_m + [S]}$$

K_m = Michaelis-Menten constant
t = reaction time
V_{max} = theoretical max. decomposition speed

V_{max} is reached when all the enzyme quantity present is saturated with substrate and thus exists as ES. K_m and V_{max} characterize the substrate. It is clear that a high S leads to a high decomposition speed of the substrate. We can therefore kinetically quantitatively formulate the biological breakdown of substances contained in waste water. Of particular interest is the kinetics of the substrate breakdown characterized by the BOD. The basic equation of the BOD curve is familiar as the Henri equation. We can write:

Enzyme activity

$$S(t, y) = \frac{K_m}{V_{max}} \cdot \ln \frac{L}{L - y} + \frac{y}{V_{max}} - t = 0$$

L = BOD final value related to the zero point of the reaction

y = oxygen consumption, related to the zero point of the reaction

It is important to ensure that the pH remains within the range 5–9 during biological waste water cleaning. It is interesting that the temperature dependency of the kinetics of biological waste water cleaning is low, which means that there are no major differences in the decomposition rate between Summer and Winter. The task of enzyme analysis is to quantitatively describe the influence of an enzyme on a reaction S → P. Therefore an appropriate reaction is conducted under standardized conditions and the composition of the reaction mixture compared with the state before the addition of the enzyme (Fig. 1).

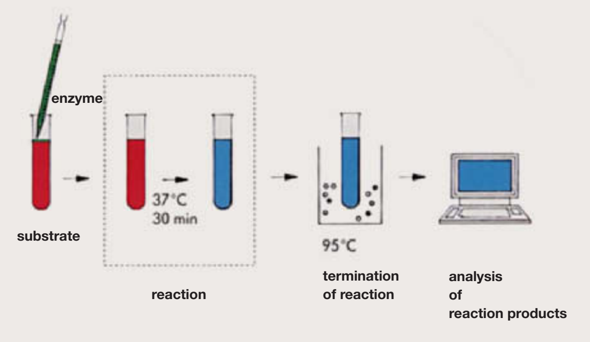


Fig. 1: Enzyme analysis.

The conditions of the experiment should naturally be selected such that the reaction result can be attributed exclusively to the added quantity of enzyme; this allows the enzyme activity to be determined. There are a few peculiarities and basic rules that should be taken into account: Almost 2000 different enzymes have as yet been identified; each is characterized by a specific catalytic activity and therefore there is at least one specific test procedure for each of these enzymes. For example: A Kilo-Novo-Alpha-Amylase unit (1 KNU) is the enzyme quantity which according to the standard method of Novo Nordisk for the determination of alpha amylases breaks down 5.26 g/h starch (Amylum Solubile) under the conditions given below:

Substrate	soluble starch
Calcium content in the liquid	0.0043 M
Reaction time	7–20 min
Temperature	37°C
pH	5.6

It is possible to derive the specificity of an enzyme, which is normally a substrate specificity, from its systematic name. A 1.4–α–D–glucosidase only releases glucose made up of 1.4–α–D–glucane (e.g. starch). Therefore a suitable substrate (starch or maltose) is also used in the analysis of this enzyme. The use of a synthetic substrate is simpler, in this case, p-nitrophenyl–α–D–glucoside, whose hydrolysis (glucose and p-nitrophenol are created) can be demonstrated by an easily measurable colour production (p-nitrophenol).

Enzymes only function when the right external conditions are in place. Normally they are a small part of more highly organised units, from micro-organisms to humans. The enzymes are suited to the conditions, to which they are exposed in their natural environment; e.g. temperature (Fig. 2). The enzymes of the human organism function optimally (not max.) at 37°C. It is a well known fact that a slight rise in body temperature is a signal of a short term increase in metabolic activity. However, temperature fluctuations are only harmless within a small range. Outside this tolerance range they can be dangerous. Enzymes can "coagulate", they lose their enzyme function and turn into "dead" protein. Enzymes also show this temperature dependency "in vitro": A higher reaction temperature normally leads to a higher substrate turnover, like in normal "life" but this effect is not unlimited. Rule of thumb: 10°C temperature increase effects approximately a doubling of the reaction speed. At higher temperatures this effect is overshadowed by the thermal inactivation of the enzyme. The reactivity of the enzyme decreases markedly. From a certain temperature enzyme catalysis is no longer possible. The temperature dependency is a characteristic variable for each enzyme and must be taken into account in analysis. The temperature range for an enzyme analysis normally lies between 25–37°C. An inactivation of the enzyme cannot be expected in this range. The prime necessity under such conditions is

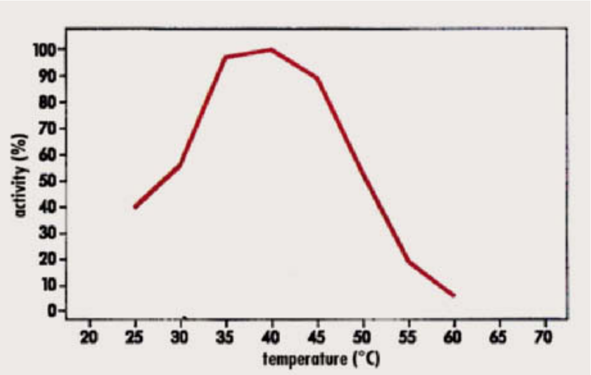


Fig. 2: Pancreas amylase and its temperature dependency when acting on starch.

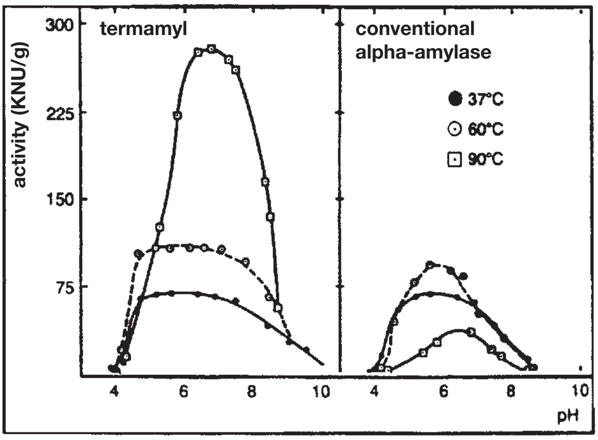


Fig. 3: Influence of the pH on the activity of Termamyl and alpha-amylase at different temperatures (substrate: soluble starch; stabiliser: 30–60 ppm calcium).

naturally a constant reaction temperature. Even temperature fluctuations of 1°C can cause a measuring error of 10%. The same applies for pH influences, which can influence an enzyme analysis in the same way (Fig. 3).

The active centre of an enzyme molecule is always located in cavities in the globular structure. In metalloenzymes the metal atom sits in the inside of a deep pocket, where there is a further cavity made of hydrophobic bits of protein, which accepts the substrate. The metal ion works electrophilically as a cofactor (coenzyme) and supports the catalyst (Figs. 4 + 5).

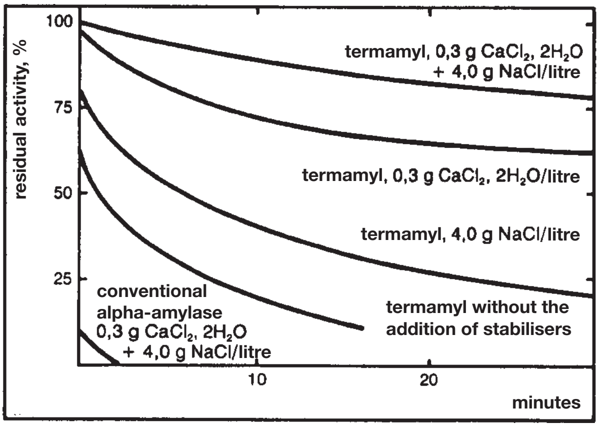


Fig. 4: Stability at 90°C and pH 6.5–7.0 of termamyl and conventional alpha amylase, in the presence of certain stabilisers.

We can see helical domains and β domains (pleated sheet conformation) in the carboxypeptidase (Fig. 6). The splitting into hydrophic, hydrophilic and ionic domains also determines the Amphilie in enzyme activity.

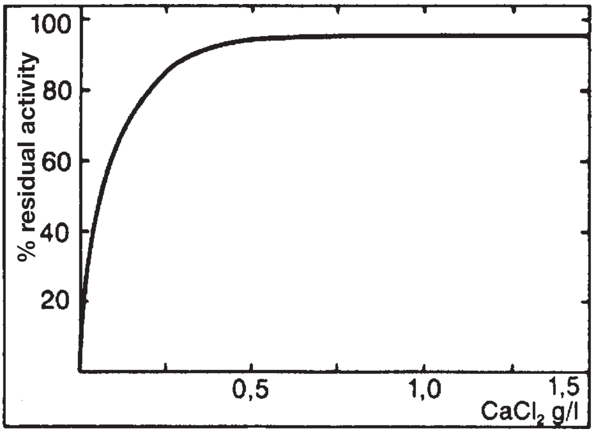


Fig. 5: Influence of the calcium concentration on the stability of Aquazym.

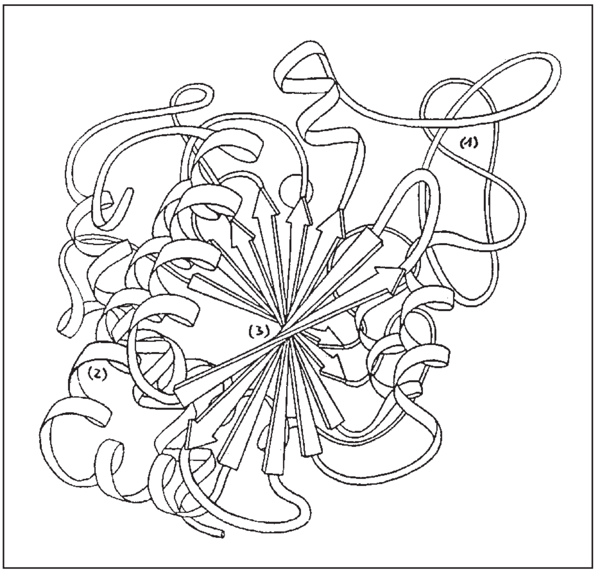


Fig. 6: Typical spatial layout of a macromolecular enzyme molecule with secondary area (1), a-helices (2) and domains (3).

Enzyme analysis Some enzymes, mainly so-called hydrolases, are used on a large scale. They are used to break down starch to sugar or to remove protein and fat spots from fabric during the washing process. Most of these “technical substrates” are high-molecular and offer access points for various enzymes. Therefore technical enzyme preparations often contain a range of different activities, that act at on this type of substrate simultaneously and can supplement each other. The enzymatic total hydrolysis of starch, for example, is normally performed using a combination of α–amylase and glucosidases. α–amylase splits the macromolecule into fragments of varying size, which can then be effectively broken down sugar for sugar by glucosidases.

There are also advantages to using this substrate in enzyme analysis: It is the best way to see the complex effect of a preparation and the synergistic effect of the

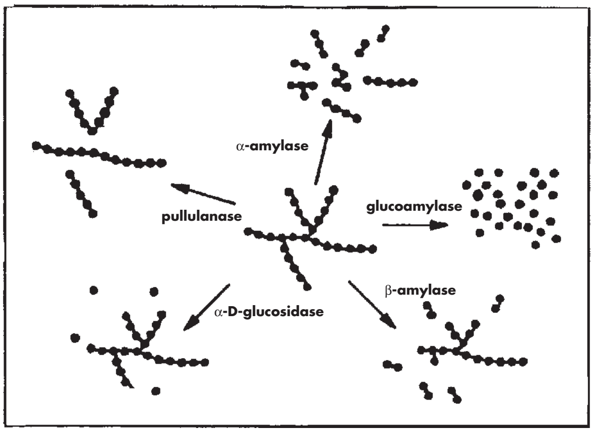


Fig. 1: Starch hydrolysis.

individual enzymes associated with it, for example those that can occur in starch hydrolysis (Fig. 1). But it can also be appropriate to test individual enzymes on these substrates. It makes a difference whether a glucosidase sugar splits from starch or a synthetic substrate (p-nitrophenyl-glucoside). It has a different affinity to the two potential substrates. A simple example should clarify the main procedure of enzyme analysis: Protein splitting enzymes (proteasen) can be simply detected in a spot test. An illuminated black and white film is used as the substrate for this: The film is coated with gelatine. Drops of the protease solution are applied to the film. This starts the enzyme reaction. Because the reaction speed is to be measured, a stop watch is a vital prerequisite. The reaction is finally completed by the enzyme that has been applied being washed off the film. Concentric spots can be seen at the points where the protease was applied; the water soluble hydrolysis products of the gelatine were washed off the carrier with the enzyme. The result can be viewed simply with the eye (Fig. 2).

This test is suitable for the rough estimation of a protease activity. The test described here is a so-called end point determination. At the moment at which the hydrolysed substrate (gelatine) is washed off, the reaction is halted. The enzyme effect between the start and end of the reaction is determined by a measured value.

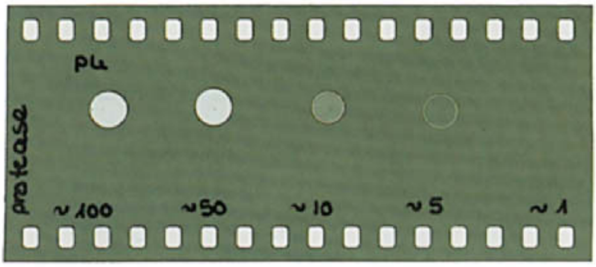


Fig. 2: Gelatine coated film on which protease has been dripped at different times.

The methods used in “professional” enzyme analysis are naturally more demanding. It mainly differs from the above-mentioned test in the minimizing of errors in performance and evaluation, and that can only be achieved at a high cost in terms of methodology and equipment. Enzyme analyses are time consuming and, if carried out manually, labour intensive. The individual work stages must be strictly timed. If several samples are processed at the same time the interconnection of the individual work sequences is unavoidable. The use of analysis machines is therefore appropriate. These machines can be classified into two different systems according to their working method.

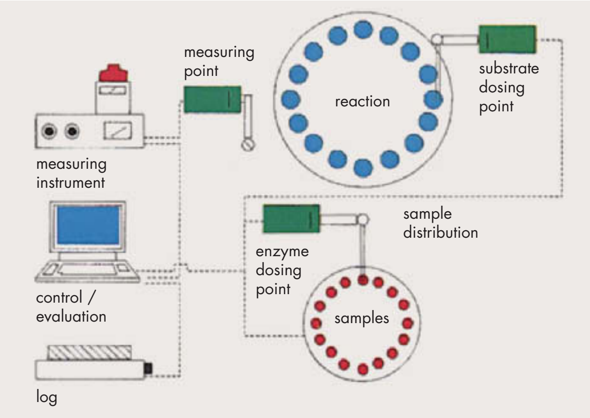


Fig. 3: Fixed volume analyser for enzymes.

Fixed volume analysers (Fig. 3), as their name suggests, operate with fixed, controllable volumes of the individual partners involved in the reaction. This working method is comparable to the work sequence that would be practised manually, but of course with the difference, that more samples can be processed in the same time, because different work processes can be carried out at different positions in the machine simultaneously. A thermostat controllable reaction room is available for the enzyme reaction. Sample, substrate and any reagents for the wet-chemical detection of reaction products are added via dosing stations. The samples pass the individual stations according to a predetermined timing sequence. An appropriate detector at the end of the reaction chain transmits measuring signals directly to the central control unit, which calculates and records the data.

The alternatives are continuous analysis systems (autoanalyser principle or flow injection procedure, Fig. 4). The characteristic feature of these analysis systems is a continuous flow of liquid. This flow is made up of several small secondary flows (= the individual reaction partners) entering a central pipe system. The individual partial reactions take place in the prescribed sequence in this large, connected, reaction area. The

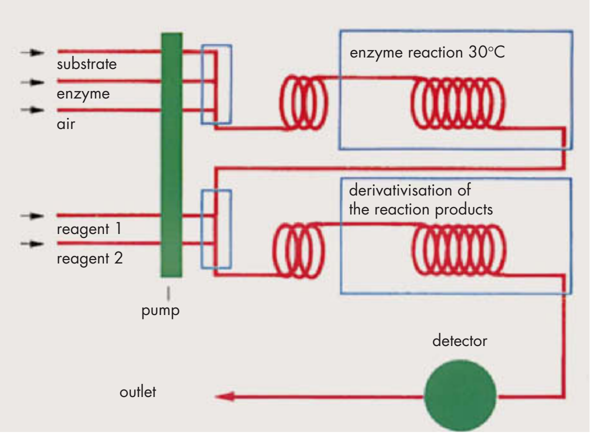


Fig. 4: Flow analysis for enzymes.

flow of liquid is only segmented by air bubbles, which prevent the diffusion of the sample segments. The length of the total system and the selected flow rate determine the dwell time of the samples in the system and thus the reaction time available to the enzyme. The sample segments pass a detector at the end of the analysis system, normally a photometer. Other possibilities are also realisable, such as, for example, an electrochemical detector or viscosity measurement (according to Gottmann).

Enzyme and hydrogen peroxide treatment → Papain.

Enzyme production Enzymes have been used for textile desizing since the beginning of the present century. The first amylases originated from malt extract. Later, pancreatic extracts were also used. The company Swiss Ferment, a forerunner of Novo Nordisk Ferment, started the production of malt extract in Switzerland in 1915 for use in desizing. The future development of enzymes for desizing had already been determined at that time. In 1917, Boidin and Effront used bacterial amylases for the first time. However, the mass production of these enzymes on a practical scale only began after the Second World War. It was found that bacteria could be cultivated under submersed conditions in fermentation tanks to produce large quantities of the desired amylases. Since that time, bacterial amylases have been used instead of the primitive enzyme preparations from malt and pancreatic extracts. These bacterial enzymes are cheaper, more effective, and less sensitive to other chemicals in the desizing liquor. Apart from the development of less temperature-sensitive bacterial amylases, enzymes for desizing have not changed much over the last 40 years. In order to improve the quality of bacterial amylases, however, Novo Nordisk has made use of the most modern tool of microbiology, namely gene technology. With this technology, microorganisms can be modified in such a way that the enzyme yield is increased. In comparison to conventional impure amylases, solutions of enzymes produced by gene technology are virtually colourless and odourless. Moreover, such enzymes also offer the advantage that no addition of stabilizing calcium salts is necessary when they are applied in soft water.

Enzymes (Greek from zymae: leaven/sour dough) Enzymes similar to the inorganic catalysts (Fig. 1) so-called biocatalysts. Technically impure enzyme products are → Diastases for example. All enzyme names end in -ase (amylase, cellulase, maltase, protease); enzyme decomposition products have the -ose ending (dextrose, maltose, glucose). Classification of the degrading enzymes in accordance with their method of reaction in the main hydrolase group (split –C–O– and –C–N– bonds) and desmolases (split –C–C– and –C–H– bonds). There are also holoenzymes (coenzymes and apoenzymes).

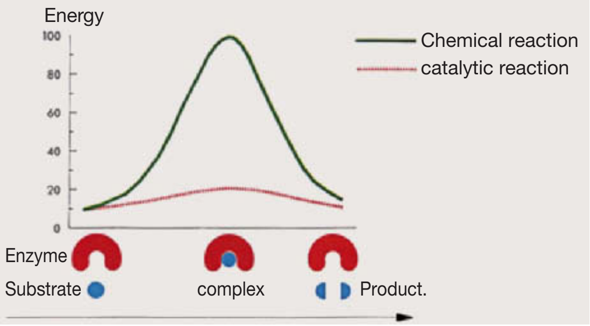


Fig. 1: Graph of a chemical reaction with and without a catalyst: the activating energy is reduced by the formation of a new transition state as a complex of substrate and enzyme to such an extent that the reaction takes place much more quickly.
Abscissa: reaction curve; ordinate: energy content.

Biochemical processes, whether hydrolyses or syntheses, are accelerated by enzymes. Organic nature can only exist at all because natural processes are catalysed by very specifically tailored enzymes. Intracellular enzymes are therefore bonded to cell membranes, while extracellular enzymes are excreted by cells and can be isolated. Enzymes are classified according to effect:

1. oxidoreductases: require oxidation-reduction processes.
2. transferases: transfer chemical groups.
3. hydrolases: split chemical bonds by taking up water.
4. lyases: remove groups.
5. isomerases: catalyse rearrangements.
6. ligases (synthetases): combine molecules.

An international numbering system identifies enzymes: each individual enzyme is allocated four numbers which are separated by full stops. The first number (1–6) indicates the class, the second figure the subclass, and the third the sub-sub-class etc.

Enzymes

Enzymes are proteins, the spatial arrangement of which is typical, and occurs through helical segments, folding leaf structures, intramolecular associations, and, particularly, by the targeted incorporation of prolin as an amino acid, which disturbs arrangement. Each enzyme has a specific amino acid sequence. Approx. 25% of all amino acid residues are found in helices of 12 amino acids in each case. The helices lie mainly on the surface of the enzyme macromolecule, which is hydrophilic for the purpose of better interaction with the medium water. In contrast, the active centre of the enzyme is mostly a hydrophobic pocket which is responsible for enzyme specificity. Emil Fischer minted the expression “key-lock principle”, by which he means: the biocatalytic process takes place in such a way that the substrate on which a reaction is to be implemented, is the key. The lock enzyme then very specifically controls the process on the key only when the two fit each other.

In the case of the enzyme chymotrypsin, for example the active centre is formed from one serine and two histidine residues. The interlaced chains of the enzyme allow the three side chains of these amino acids to protrude into a pocket in such a way that only quite specific steric residues of the substrate can make contact with the three side chains in this gap via (mostly) hydrogen bridges, which also have contact with each other via hydrogen bridges. The absolute prerequisite for these contacts is the close spatial proximity to each other, for which reason the actual biochemical reaction precedes characteristic kinetics, a pre-established equilibrium (diffusion to each other, and adsorption on each other). Michaelis-Menten’s definition runs: enzyme E and substrate S are in equilibrium with the enzyme-substrate complex ES. This complex reacts with its formation only in the speed-determining reaction in enzyme reformation (therefore catalysis) to product P. Substrate bonding to the enzyme in fact means increased order, i.e. decreased entropy; this energy requirement is overcompensated however by a change in enthalpy in bonding (adsorption). The change in enthalpy occurs through the formation of hydrogen bridges and hydrophobic interaction. The bonding energy produced by these non-covalent interactions is responsible for the sharp reduction in the activating energy of the actual reaction by the enzyme.

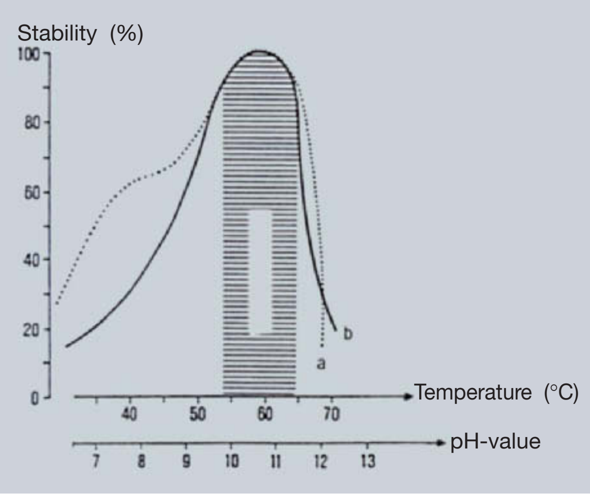


Fig. 2: Effect of pH (a) and temperature (b) on protease stability.

Enzyme action is pH specific. While the formation of the enzyme-substrate complex is implemented via hydrogen bridges, the addition or withdrawal of protons upsets this process (Fig. 2). With increased temperature, the diffusion of the partners to each other is accelerated; with a further increase in temperature however, the entire three-dimensional structure of the protein breaks down (irreversible denaturation) because the numerous hydrogen bridges in the helices and in the folding leaf structures are split. All the more astonishing is the effectiveness of new types of desizing enzymes in the pad-steam process at 100°C (in contrast to the cold-dwell process).

In the textile finishing industry or the detergent industry, enzymes are used mainly for decomposition reactions:

- proteases: splitting of albuminous proteins (into amino acids) during degumming and felt-free finishing.
- amylases: splitting of starches (into saccharides) in desizing.
- cellulases: splitting of cellulose (into saccharides) in cotton softening and in the biological degradation of cotton and also in carbonation
- ligninases: (pectinases for soaping, galacturonases): splitting of lignin during carbonisation and scouring.

Looked at from the enzyme standpoint, the following application possibilities arise:

Enzyme	Origin	Specific effect
α-amylases	Bacillus subtilis/ licheniformis	Starch desizing
Cellulases	Trichoderma reesei, Humicola insolens	Non-stone treatment of jeans, fashionable effects, CMC desizing
Pectinases	Aspergillus niger	Stripping vegetable fibres
Proteases	Bac. subtilis/oryzae	Stripping animal fibres, wool property changes
Lipases	Aspergillus niger, Muco javanicus	Removing fats and waxes
Peroxidases	Horse radish	Oxidising natural pigments

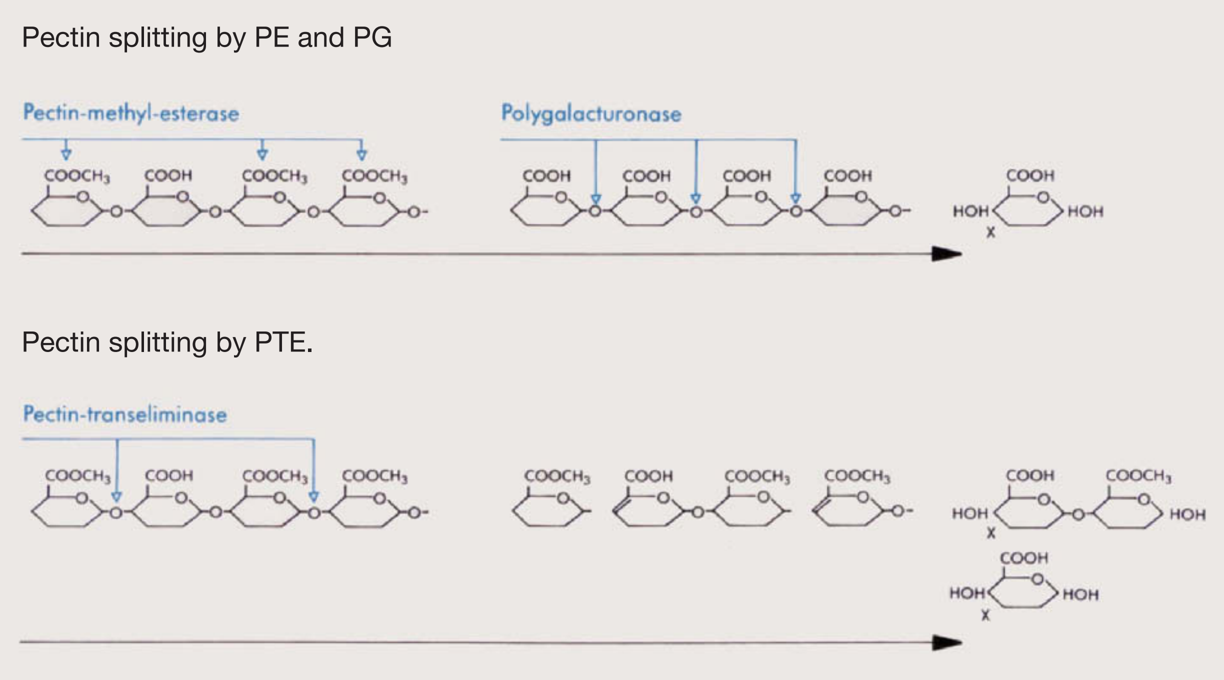


Fig. 3: Enzyme substrate specificity.

Sandoz has put forward the use of cellulases for the "non-stone" technique, jeans being first of all desized with liquid Bactosol MTN, and then treated with liquid Bactosol CE (cellulase). Thanks to the specific effect of liquid Bactosol CE, oxidative bleaches and the use of pumice stone can be dispensed with. The effects obtained are quite comparable with the stone-wash process.

Enzymes are therefore principally capable of very specifically degrading natural substances (Fig. 3). The following holds good in this respect: the more the natural substance is chemically modified, the more difficult it is to be enzymatically degraded. There are of course adaptation stages, in accordance with which degradation is possible. The enzymatic degradation of cellulose largely takes place in different processes, for example the feed-back of dead plants into nature's carbon cycle and the production of glucose and ethanol from wood in industrial biotechnology. The analysis of reactively dyed cotton has already been tried in this way too.

Two basically different test techniques are available for enzyme-catalysed reactions: initial attempts with live cultures of microorganisms and trials with enzymes extracted from them and possibly cleaned. Both have advantages and disadvantages, and are used on an industrial scale. The disadvantage of the first variant is the formation of large quantities of biomasses which make analytical recording of the products of degradation difficult. In addition, the conditions for the decomposing enzymes formed to develop their activity on the substrate to the best effect are poor (concentration, accessibility). Equivalent systems operate very slowly (e.g. the rotting of plants in nature), and are hardly suitable for the efficient decomposition of dyed cellulose. In contrast to that, pure enzymes produce highly active solutions, the action of which can be additionally intensified by the admixture of suitable components.

The cellulase-enzyme complexes are the essential part of cellulose decomposition. The complete degradation of natural cellulose is an extremely complicated process. For various reasons on the one hand, radical changes continually take place during splitting (e.g. inhibition by cellobiose, the product of degradation, or by non-degradable impurities), while, on the other, various routes lead to cellobiose or also directly to glucose. In the case of dyed starting material, cellobiose and glucose derivatives suitably modified by dyestuffs are to be expected. The most active enzyme complexes are produced from fungi of the Trichoderma viride and Trichoderma reesei varieties. Degradation complications arise from the fact that cotton consists not just of pure cellulose, but that there is foreign matter present, particularly in the outermost areas of the fibre (primary wall). One obstacle arising out of this has to be excluded by the addition of other enzymes: hemicellulases for breaking down hemicelluloses and pectinases for decomposing pectins. In this way, optimised decomposing solutions, the exact composition of which depends also on the purity and origin of the main enzyme (cellulases) are produced. One of the main problems in breaking down natural cellulose is the difficulty of access to the substance: as solids, cotton fibres are very unsuitable for enzyme penetration. The partially crystalline areas of the polymer in particular make it more difficult. The result is that chemical changes following the reaction of the more accessible amorphous areas take place only very slowly. It is necessary therefore to break up the solid, and prepare a large surface for enzyme attack. The best known method of comminution in textile analysis is cutting in a knife mill. With this technique however, the fibre interior is inadequately bared for the necessary surface increase. Additional crushing of the fragments and milling to a fine powder is required. Ball mills for example are used to this end. One interesting variant is the planet mill (planet motion of the ball container), the use of which produces fine powder within a reasonable time. The milling process has hardly any effect on the relevant chemical bonds.

Keratin fibres can be quickly broken down by proteolytic enzymes after the disulphide bonds have been split by chemical methods. Enzymatic attack on untreated keratin fibres, e.g. wool, takes place much more slowly, and appears to be limited only to the wool fibre areas which have few or no disulphide bridges, the so-called non-keratin material. This comprises the endocuticula, the cell membrane complex and the cell nucleus residues plus the intermacrofibrillar material of the cortex. In treating wool with pancreatin, 14% of the wool is decomposed after 11 days; in digestion with trypsin, a maximum of 17% is reached depending on the pretreatment conditions and the decomposition time. With the enzyme pronase, 10–20% of the wool is digested, 12% of it after 3 weeks' treatment. At the beginning of 1984, Schoeller Hardturm AG began a development programme for the enzymatic treatment of wool, setting up a development target and product arguments for enzymatic, felt-free finishing. Aims: no synthetic resin, gentle chemistry, ecological safety. Arguments: natural wool, (handle, bulk), no synthetic resin coat (for use next to the skin), natural blended fibre products (cotton, silk). Old processes with this aim have worked with the enzyme papain; sodium disulphite was used to loosen the cystine bridges. The chlorzyme process ran in two stages. The first treatment was with chlorine gas, the wool was felt-free, and then the scales were removed with papain. The process was very expensive, the wool of course had excellent lustre but a poor handle. The perzyme process is also a two-stage process: first, treatment with hydrogen peroxide, then with papain and disulphite. It is not possible however to obtain a good felt-free effect without an extreme change in handle. Weight losses of up to 3% must also be expected during the process. These types of enzyme process have been used industrially only to a limited extent and for a short time. The problem with these processes must be summarised as follows: it is difficult to limit the enzymatic breakdown process to the scales and to avoid enzyme diffusion into the cortex.

Proteases are also effective in the Mazamet wool fell-mongering process. If proteases are used for degumming silk, they break down the hydrophilic sericin component, but also attack the more hydrophobic fibroin component. In the enzymatic removal of the primary wall of cotton (scouring), the main component pectin, which is partially esterified, has first of all to be soaped by pectinases before exo- (monomer for monomer step by step) and endo- (statistically) galacturonases break down the polymer. Cotton can also be bleached with glucose-oxidase, peroxidase and catalase. Finally, the enzymatic desizing process is a breaking down of amylose and amylopectin with amylases.

Denim jeans manufacturers for many years have washed their garments with pumice stones to achieve a soft-hand as well as a desirable look. While a variety of treatments have been used in the past, the use of stones yielding "stonewashed" jeans has increased recently both in Europe and North-America. Jeans processors typically have found that they can achieve this stonewashed look by using cellulase enzyme instead of stones. Enzymatic stonewashing has thus become more widespread over the last two years. As the name indicates, cellulases hydrolyse cellulose, partly yielding soluble products such as short-chain polysaccharides and glucose.

Investigation of the mode of action on cellulose fibres has shown that cellulase attacks primarily the surface of the fibre but leaves its interior intact. This mode of action makes cellulose especially suitable for stonewashing of denim garments dyed with indigo-blue, since this dye stays on the surface of the fibre. Washing the garments with stones removes this surface dye by abrasion. Cellulases remove it by partially hydrolysing the surface of the fibre that includes the dye. Use of cellulase overcomes most of these disadvantages, while yielding the desired softening and "worn" look.

Cellulases for stonewashing are available from several major suppliers to the textile industry. They fall into one of two categories – acid or neutral. Each enzyme is produced by fermentation of a unique mould strain. The two enzymes differ in a number of ways, with the differences in pH optima being the most important for this application. In order to achieve the desired colour contrast during stonewashing it is important to minimise the re-disposition of the blue dye on the garment (backstaining). Fig. 4 shows colour-removal from denim by each type of cellulase as a function of pH. For the neutral cellulase, maximum colour-removal occurs at pH 6.0, but at pH 7.0 to 7.5 this enzyme still has above 90% of the colour-removing activity. Acid cellulase gives maximal colour-removal effect at pH 5.0, but at pH 6.0 the colour-removal effect is reduced to less than 40%. Backstaining also turns out to be very dependent on pH. It is increased by a factor

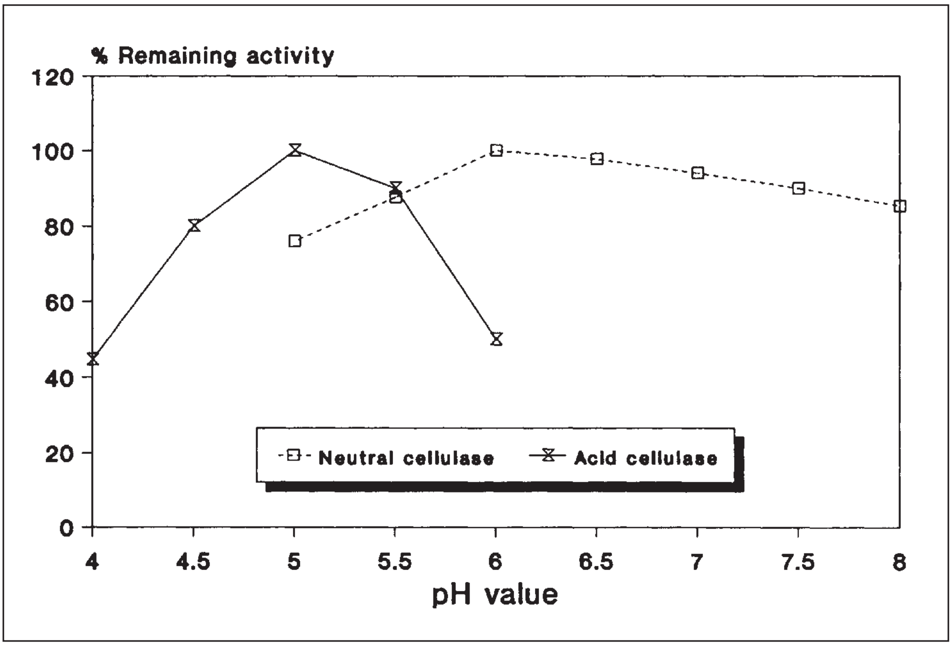


Fig. 4: Effect of pH on colour-removal activity of cellulases.

of 20 or more at pH 6.0 or less compared to the minimum value obtained at pH 7. This comparison of the pH dependence of the acid and neutral cellulases and backstaining points out that the neutral enzyme is the one of choice to minimise backstaining. As Fig. 4 shows, the pH profile for the neutral cellulase is much broader than that of acid cellulase. This results in much better reproducibility of the finished look, since the pH increase during stoning will have little effect on the activity of the neutral enzyme. Because of its much narrower pH profile, acid cellulases will require much tighter control of pH during stonewashing to achieve a high level of reproducibility. Using cellulases as a substitute for stones prevents the damages to wash-machines and the garments, eliminates the need for disposal of the used stones, improves the quality of the waste-water and eliminates the need for labour-intensive removal of dust from the finished garments. Because stones are no longer added, the garment load can be increased by as much as 50%. Some highly-abraded finishes cannot be achieved by using cellulase alone. In such cases partial substitution of stones with the enzyme can achieve the desired look.

The hard core of Sirrix Luna consists of two natural components: metamorphic microlites and microencapsulated enzymes for bringing about a controlled biomechanical erosion of textile surfaces in order to produce novel looks and sophisticated handles. Under the mechanical action of the Combisoft Jumbo, the extra-spherical geodesic dome of Sirrix Lune breaks open, liberating the enzyme which only needs to be activated. The combined physical action of the microlite and biological action of the enzyme bring about a spectacular metamorphosis of the textile substrate into an article with high value added. The physical characteristics of the microlite (very similar to the lunar stone regolite) and the biochemical properties of the enzyme have been specially studied for the purpose of obtaining shimmers, opalescences, iridescences, sheens and moonlight effects on textiles.

The Combisoft Jumbo (Fig. 5)is a versatile discontinuous machine permitting dry or wet as well as cold or hot (110°C) treatments. The tumbler is designed to soften (by breaking), dry or finish textiles through spectacular modifications of their surfaces by mechanical (tumbling), physical (microlite), chemical (pretreatment, causticization, softening) or biological (enzyme) means. It permits a wide range of uses, for small batches as well as large ones (1 to 6 pipes). Its exceptional capacity has no equal: 400–450 kg. The main characteristic of the machine is its system of transporting the fabric, which is original and patented: the fabric is conveyed on a supple elastomer belt and by air cushion at a speed of over 800 metres a minute. The kinetic energy acquired by the fabric is directed at a grill situated at the rear of the machine, after which it falls down into the main compartment, from where it enters the front of the machine, where a system of Turbo air expands and re-heats it in drying. Fabric weights ranging from 50 to 800 g/linear metre can be handled. The machine is suitable for all types of natural, man-made or synthetic fibres such as cotton, linen, viscose, cupro, Tencel, Lyocell, silk, wool, etc., as well as coated fabrics (imitation leather, etc.). The trick is to modify the substrate's reflection of light and extinguish its brilliance by means of a microabrasion of the surface of the textile substrate. These modifications are either of the microfibrillation type (visible under a microscope),

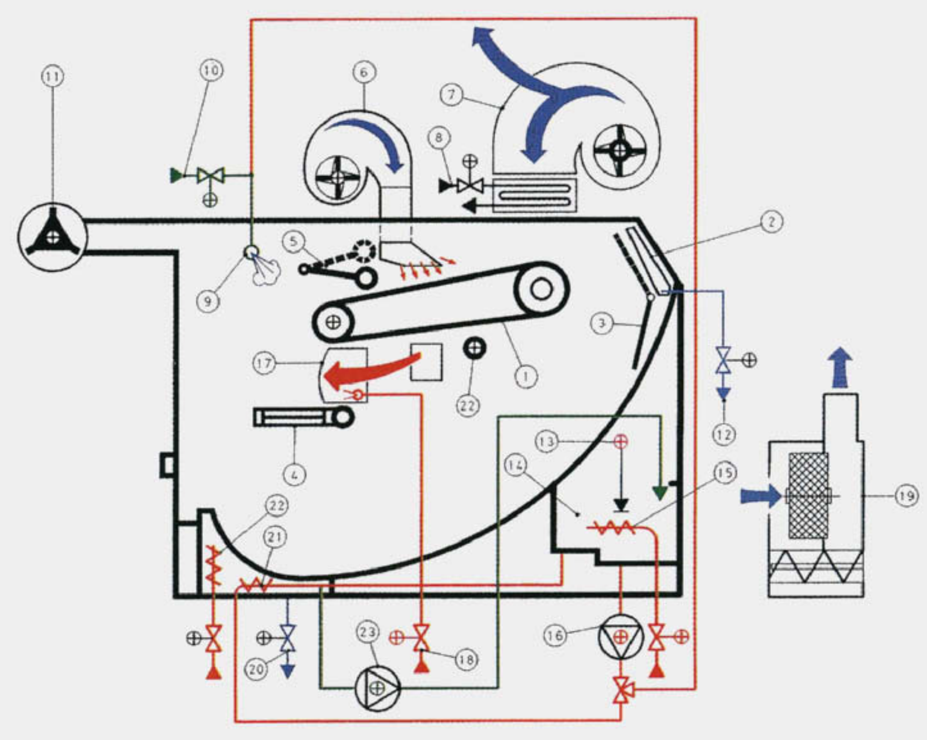


Fig. 5: MAT Combisoft Jumbo.
1 = conveyor belt;
2 = softening plate;
3 = milling plate; 4 = draft gate; 5 = pressure roller on conveyor belt;
6 = pressure fan on conveyor belt; 7 = unit heater fan; 8 = unit heater steam inlet; 9 = sprayers;
10 = water inlet;
11 = drawing-off reel;
12 = pressure lid discharge; 13 = level switch; 14 = tank;
15 = steam back worm pipe; 16 = circulation pump; 17 = diffuser;
18 = steam in the diffuser;
19 = filter for flock;
20 = rear outlet;
21 = enzymes worm pipe;
22 = steam front worm pipe; 23 = circulation pump.

macrofibrillations (visible to the naked eye), defibrillations or destructurizations of the fabric. The nature of the dye can also intervene in order to produce worn out, “used”, washed down or distressed effects. All fibres can be treated: cotton can be transformed into microvelvet, viscose into silk, wool into cashmere and silk into angel skin, and the handle can be varied “a la carte”.

Enzyme structure Depending on the conditions of their environment (pH, temperature, solvent, coenzyme) enzymes arrange their protein chains in a three-dimensional form, or tertiary structure (Fig. 1). Ellipsoids are widely represented in such enzyme structures (Fig. 2).

Certain peptide sequences of the long α-amino acid chains (–NH–CHR–CO–) of these proteins have an inclination to form helix structures whilst others assume less ordered (“coil-shaped”) conformations. Depending on the type and sequence of the peptide groups, therefore, both helical and non-helical sequences occur in a single molecule. Under the influence of hydrophobic bonds, salt linkages, hydrogen bonds, etc., these sequences fold up in such a way that the molecule assumes the external form of a spheroid. However, these spheroids are not homogeneously filled with the building blocks of the macromolecule. Rather, the spheroids also contain pockets and canals filled with solvent. Parts of the spheroid interior are consequently relatively easily accessible for low molecular weight species. Nature exploits such structures, on the one hand, as vehicles for other substances (e.g. haemoglobin for the transport of oxygen to tissues), and as effective catalysts (enzymes) on the other. Spheres and spheroids that are not too assymetrical have low viscosities in dilute solutions. They offer only a low resistance to flow and are therefore easily transported from one place to another.

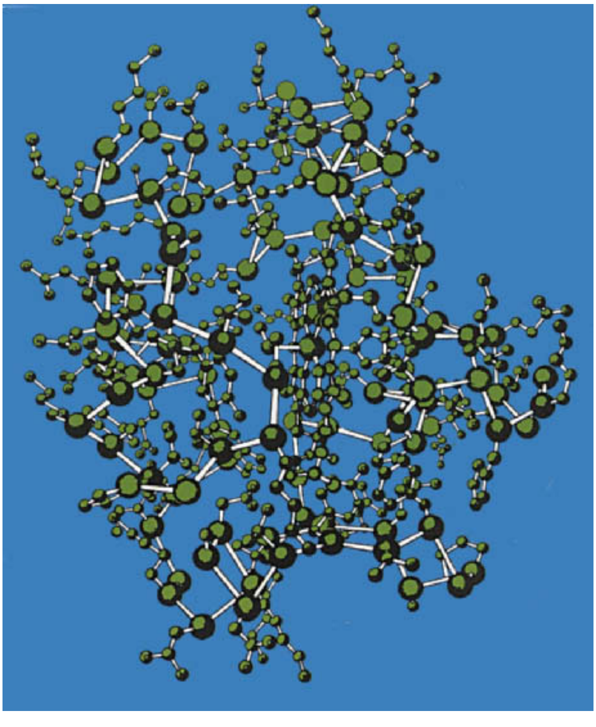


Fig. 1: Typical entwisted enzyme polymer structure.

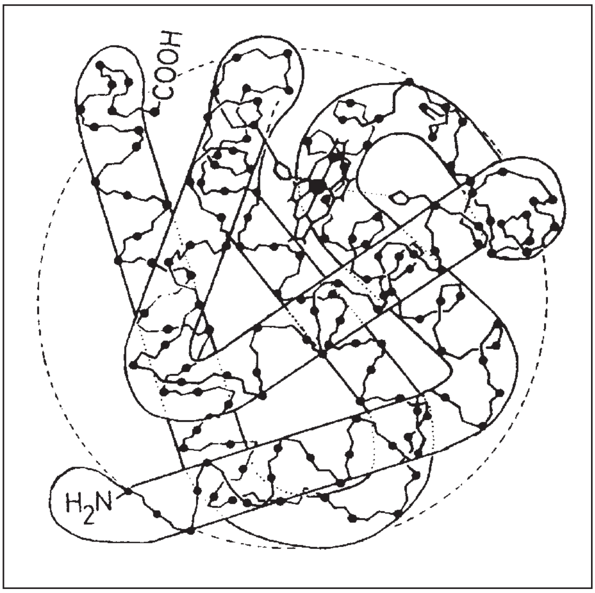


Fig. 2: Schematic diagram of the protein myoglobin. The molecule consists of rod-shaped, helical segments, which are linked by non-helical ("ball-shaped") areas. The inscribed circle shows that the molecule is not spherical but rather ellipsoid. The dots represent central carbon atoms of each peptide residue.

Enzyme wool →: Skin wool and Fleece wool obtained by enzyme treatment.

Eolienne Named from the Greek *Æolus*, the god of the winds. Originally a soft weft-ribbed dress fabric with a silk (or more seldom, cotton) weft and a worsted warp in a plain-weave construction. The cloth is a lightweight zephyr fabric and may be classed as a very fine poplin. Now also produced from man-made fibres, e.g. acetate, rayon.

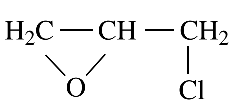
EPA

I. (Ger.), abbrev. for: Europäisches Patentamt (European Patent Office), Munich.

II. abbrev. for: Environmental Protection Agency (USA).

EPDM, abbrev. for: ethylene-propylene diene monomer. A terpolymer elastomer derived from this monomer.

Epichlorohydrin (3-chloropropylene oxide, 3-chloro-1,2-epoxypropane), C_3H_5ClO. Colourless liquid with an odour resembling that of chloroform. A toxic and carcinogenic compound used in the manufacture of epoxides and resin finishing agents for alkaline wet crosslinking. It is formed as an intermediate product in organic synthesis.



Epichlorohydrin rubber Synthetic rubber elastomer based on → Epichlorohydrin. Properties: shore hardness 40–90, moderate to good adhesion strength and abrasion resistance, moderate to good resistance to dil. acids (moderate to conc. acids), resistance to aliphatic hydrocarbon solvents is excellent and good to aromatic hydrocarbon solvents, resistant to oxidation and sunlight, excellent resistance to ozone. Epichlorohydrin rubber has only poor to moderate fire resistance.

Epicuticle The fine outer sheath of the wool fibre which covers the scale-cell layer in the form of a thin water-repellent membrane. It is the only non-protein part of the fibre, and protects the fibre like a covering of wax. → Wool structure.

Epidermal membrane A so-called intermediate membrane in → Wool structure.

Epidermicula The fine outer skin over the scale layer in the → Wool structure.

Epidermis (Gk. *epi* = outer, *derma* = skin). In → Wool structure the term is used in the widest sense to mean the scale cell covering of the fibre comprising the scale-cell double layer together with the epicuticle. In → Flax stem structure, the epidermis is regarded as the external peripheral layer consisting of an outermost thin skin which covers the → Cuticle.

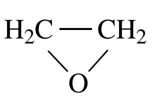
Epinglé A smooth ladies' dress fabric (silk, cotton) with a pattern of alternating delicate and heavy weft ribs.

Epithelium The outermost cell layer of the skin. In a figurative sense, the term "scale epithelium" is used in wool morphology.

Epitropic fibres (epitropics, antistatic epitropic fibres). Polyamide or polyester fibres containing embedded particles of carbon to make them electrically conductive. They are used as permanent antistatic fibres in 2–5% blends with other fibres for floorcoverings, home textiles, protective clothing and technical fabrics.

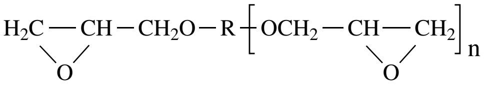
Epoxi → Epoxides.

Epoxides Organic compounds (cyclic ethers) containing one or more epoxide groups:



The epoxide group is a reactive group for crosslinking reactions, e.g. with cellulose in the presence of acidic (zinc fluoroborate) or alkaline (caustic soda liquor) catalysts. The application as resin finishing agents (e.g. diglycidyl ether, ethylene glycol derivatives, butanediol ether, glycerol diglycidyl ether) is problematic due to the toxicity of these compounds.

Epoxy resins (polyepoxides). Thermosetting resins based on the reactivity of the → Epoxides:



Epoxy resins are polyaddition products formed as epoxides with polyhydric alcohols, hexahydrophthalic acids, hydantoin, cyanuric acid, but mainly (up to 90%) from → Epichlorohydrin and Bisphenol. Depending on the number of repeating units available in the molecule, liquid (n = 0) to solid products are obtained. Numerous aliphatic and aromatic compounds may be converted to epoxides which, due to their solubility in water and aqueous alcohol, can form aqueous emulsions. Crosslinking occurs by reaction of the epoxide group with polyamines, anhydrides, polybasic acids, etc. Contraction during hardening is low and therefore the products harden without tension, do not crack, and possess high impact and abrasion resistance. They bond well to most materials, do not attack metals and are resistant to atmospheric influences, water, acids, lyes, oils, kerosene and benzene. They find application *inter alia* as adhesives and binders.

Epsom salt → Magnesium sulphate.

Equal spaced colour depth series, production of Dyeings arranged in arithmetical order, as opposed to geometric order, are not perceived by the human eye to be equally spaced. There is a logarithmic relationship between the quantity of dyestuff applied and the colour perceived (Weber-Fechner law). If three colour depths, perceived to be equally spaced, are placed between dyeings of 1.5% and 0.2%, then where

F = deepest dyeing (1.5% in this instance),
F_0 = lightest dyeing (0.2% in this instance),
n = number of dyeings (5 in this instance),
f = multiplication factor,

the following formula applies:

$$F = F_0 \cdot f^{(n-1)}; \text{ Therefore here } 1.5 = 0.2 \cdot f^4$$

$$f = \sqrt[4]{\frac{F}{F_0}}\ ; \frac{F}{F_0} = 7.5;\ \sqrt[4]{7.5} = 1.655$$

The desired order can be calculated:

		% dyeing
$1 = F_0$	$= 0.2$ (given)	0.20
$2 = F_0f$	$= 0.2 \cdot 1.655$	0.33
$3 = F_0f^2$	$= 0.2 \cdot (1.655)^2$	0.55
$4 = F_0f^3$	$= 0.2 \cdot (1.655)^3$	0.91
$5 = F_0f^4$	$= 0.2 \cdot (1.655)^4$	1.50

This applies to fully exhausted dyeings. In the case of the partial exhaustion of dyestuffs, allowance must be made in the calculation for the dyestuff remaining in the dyebath.

Equilibrium liquid One of the phases formed during → Coacervation in the Two Phase (Cibaphasol) System.

Equilibrium water Water, involved predominantly in organo-chemical reactions, which can change the direction of reaction in a reversible process. When the amount water produced in a reaction exceeds a certain concentration it will reverse the direction of the reaction. A typical example is the reaction of the pair: Esterification ↔ Saponification; e.g.

$$\mathrm{R{-}CO}\boxed{\mathrm{OH + H}}\mathrm{O{-}R'} \rightleftharpoons \mathrm{RCO{-}OR' + H_2O}$$

Equilibrium yield Classification factor for Transfer Print Dyestuffs. Describes the maximum yield obtained for each dyestuff in heat transfer printing after an excessive time (approx. 100 s) under standard conditions.

Equivalent (Lat.: *aequivalens* = equal worth). Equal or interchangeable in value, quantity, significance, etc. Balanced.

Equivalent weight The mass of an element which can substitute 1 g of hydrogen in a chemical compound. It may be calculated from the → Atomic weight divided by the → Valency.

Er, chemical symbol for erbium (68).

erg (Gk.: *ergon* = work). The use of this CGS physical unit of energy is now discouraged, and has now been replaced in the SI system by the joule (1 erg = 10–7 joules).

Ergonomics (Gk.: *ergon* = work). The study of the relationship between workers and their environment.

Ergonomics concerns the → Physiology of the worker, the resilience and reactions of the human organism during the work process, performance conditions with their (mainly emotional) accompanying phenomena, human work place layout (as opposed to technical work place layout) and environmental influences such as climate (temperature, air quality), acoustics (noise, silence), optics (light, colour) and space (area, structural layout). Ergonomics are influenced considerably e.g. by modern transport systems, and this can be either negative or positive.

Eri silk A high quality wild silk produced by the *Phylosamia ricini* larva which is found principally in East Asia. The larva feeds on the castor oil plant. This silk is highly regarded in schappe spinning.

Error limit In measuring technology, the error limit is the agreed or permitted maximum deviation above or below the desired reading or a prescribed value of the measurable variable. It must not be exceeded, irrespective of the measuring uncertainty. It comprises the systematic errors recorded as well as the fluctuations determined by technical possibilities and unavoidable variations in production and wear phenomena.

Manufacturers guarantee specific guaranteed error limits for measuring devices. These are referred to as intrinsic error limits in measuring and control technology.

Es, chemical symbol for einsteinium (99).

ESI, abbrev. for: Ethiopian Standards Institution, Addis Ababa.

Eskimo An all-wool, relatively heavyweight (approx. 800–1000 g) double-faced fabric (with 2 warp and 2 weft systems) mainly in cross-twill construction. Named after the inhabitants of Greenland. The face side is constructed mainly from fine count woollen yarns and the back side from coarser woollen yarns containing a proportion of reclaimed wool.The face side has a finely napped surface. Chiefly dyed in dark shades (black, navy blue). Used for winter coats.

Esparto Grass leaf: *Stipa tenacissima.* → Alfa grass.

Ester amides → Urethanes.

Esterases Hydrolytic → Enzymes belonging to the main group of hydrolases, which attack esters with the uptake of water, splitting off the acid (cleavage of C–O bonds). In the closest sense, esterases react specifically only with water-soluble esters. In the widest sense, they may also be classified together with the lipases (hydrolysis of fats), cerases (cleavage of waxes), lecithases (cleavage of the phosphoric acid esters of alcohols and phenols), sulphatases (cleavage of sulphuric acid esters).

Esterification Chemical reaction between an acid and an alcohol, enol or phenol, resulting in the formation of → Esters and Water.

Ester naphthol Highly-soluble → Naphthols.

Ester number → Saponification value.

Ester oils → Fatty acid condensation products.

Esters Organic compounds, comparable to inorganic salts, which are formed by the condensation of alcohols and organic acids. The following functional group is characteristic of these important compounds: R'–CO–OR–R''. Esters are frequently encountered in nature in the form of fats and fatty oils, waxes, etc. Fats are formed, e.g. from glycerol, a trihydric alcohol and fatty acids.

Ester saponification The basic saponification of an ester takes place in accordance with the reaction equation

$$R_1COOR_2 + OH^- \rightarrow R_1COO^- + R_2OH$$

practically completely from left to right. The reaction is bimolecular and of the second order. The reaction speed equation for the saponification of the ester (E) is then

$$-\frac{d\,c_E\,(t)}{dt} = k \cdot c_E\,(t) \cdot c_{OH^-}\,(t)\,,$$

where k is the velocity constant.

As in this equation two parameters, c_E (t) and c_{OH^-} (t), arise which alter with time, the reaction variable x (t) is defined using the following definition equation with concentrations c_i (t) of the reactants:

$$c_i\,(t) \int c_i\,(0) + \nu_i\,x\,(t).$$

c_i (0) is the concentration of the reactant i with time t = 0, and ν_i is the corresponding stoichiometric number.

Given initial concentrations of the esters and the hydroxyl ions a and b, this gives:

$$c_E\,(t) = a - x\,(t) \text{ and } c_{OH^-}\,(t) = b - x\,(t).$$

It follows:

$$\frac{d\,c_E}{dt} = -\frac{dx}{dt}.$$

If the above relationship is inserted, this gives for the reaction speed equation:

$$\frac{dx}{dt} = k \cdot (a - x)\;(b - x)\,.$$

By integration (initial conditions: t = 0, x = 0), the following is obtained where a ≠ b:

$$\frac{1}{a-b} \cdot \ln \frac{(a-x)\,b}{(b-x)\,a} = k \cdot t\,.$$

Estimated exhaust evaporation → Evaporation losses.

ETAD, abbrev. for: Ecological and Toxicological Association of the Dyestuffs Manufacturing Industries. As in all sectors of industry, manufacturers of dyestuffs are confronted with questions relating to work safety and environmental safety. However, safety can only be achieved through the common efforts of all participating companies. Public concern about the possible dangers posed by chemicals, on which the high living standards of industrial nations as well as the survival of developing countries depend, has in no way decreased. The various government authorities responsible for health and environmental protection have reacted to these fears and anxieties by imposing increasingly complex laws and regulations. The response of industry, i.e. the manufacturers and processors, has been to guarantee an adequate level of safety in the production and use of their products. ETAD regards this as an ongoing task.

Étamine

I. Yarn: a term used mainly for multiple, soft, gassed ply-yarns (produced from cotton).

II. Fabric: a lightweight, open, thin gauze plain-weave fabric usually with a leno or mock leno construction. Used for net-curtaining, dress goods, etc., produced from cotton, viscose, wool (combed yarns) and silk. (The name is derived from the French *étamine* = muslin, cheesecloth).

Etching Diamond slivers are used to etch (scratch) the pattern into the lacquered roll on the pantograph. → Engraving.

Etching cavities Etching cavities occur when etching printing rollers and the lacquer coating shows signs of damage or is not correctly applied.

Etching machine In pantograph engraving, a machine for etching copper printing rollers in an acid bath. In photo-engraving, a machine in which the unexposed lacquer is dissolved out of the printing roller surface.

Etching plant for copper printing rollers An etching plant in which printing rollers for roller printing, produced by pantograph, mill and photoengraving methods, are etched to deepen the engraved areas.

Etching varnish (etching lacquer). Applied to polished printing rollers for pantograph engraving. After this application, engraving and ruling lines are cut into the varnished surface by diamond points to facilitate subsequent etching.

Ethane, C_2H_6, → Saturated hydrocarbons.

Ethanedioic acid → Oxalic acid.

Ethanoic acid → Acetic acid.

Ethanol (ethyl alcohol, alcohol, spirits of wine), C_2H_5OH. Mol. wt. 46. Colourless, readily mobile, flammable and hygroscopic liquid, b.p. 78°C, f.p. –117°C, flash point +11°C. Mixtures of air and ethanol vapour containing 3,1–12,45 vol.% are explosive in the presence of fire.

Miscible with water (evolution of heat and contraction in volume), ammonia, acetic acid, glycerol, ether, acetone, benzine, benzene and organic solvents (cloudiness only in the presence of water). Uses (mostly in the form of denatured alcohol): multi-purpose solvent and wetting agent, especially in dyeing (cationic and vat dyes; naphthols by the cold-dissolving method); spotting agent for textile cleaning, solvent soaps, etc.; fuel for illumination and heating; additive in polishing, cleaning and washing agents, disinfectants, etc. Often substituted by the cheaper but toxic → Methanol.

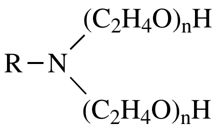
Ethanol, denatured (methylated spirit, industrial spirit). Denatured alcohol is generally composed of 95 vol.% ethanol which has been denatured with various additives depending on its field of application. For some applications, denatured ethanol can have entirely different properties compared to the pure alcohol.

Ethene (ethylene), $CH_2{=}CH_2$. A colourless gaseous hydrocarbon. Ethene is an unsaturated compound (contains a double bond) and is easily polymerized. Used as a starting product in the manufacture of synthetic fibres (polyethylene fibres).

Ethereal oils In contrast to fatty oils, ethereal oils are volatile vegetable oils with characteristic odours. (On paper they produce a volatile "grease stain" which gradually disappears whereas fatty oils leave stains which do not disappear). Used for deodorizing textiles. Terpene hydrocarbons are also used for cleaning purposes.

Ethers (Gk.: *aither* = the sky or upper atmosphere). Ethers can be understood to be the anhydrides of alcohols. They are formed from a) 2 molecules of the same and b) 2 molecules of different alcohols, with the elimination of water, e.g. by dehydrating alcohols with sulphuric acid. In case a) a simple ether (e.g. methyl, or dimethyl ether, CH_3OCH_3) and in case b) a mixed ether (e.g. ethyl methyl ether, $C_2H_5OCH_3$) is obtained.

Ethoxylated fatty amines Compounds with the general structure:



$$R-N\begin{cases}(C_2H_4O)_nH\\(C_2H_4O)_nH\end{cases}$$

These compounds are regarded as non-ionic but exhibit weakly cationic behaviour in acidic liquors. Since the non-ionic character is predominant, they can also be applied together with anionic compounds. Properties: excellent levelling action with all types of dyes.

Ethoxylated or monoacetic converted meal Ethoxylated or monochloroacetic acid substituted gum, e.g. → Carob or Guar gum. It is used as a cold water soluble coagulating thickener, especially in two-phase printing.

Ethoxylene resins → Epoxy resins.

Ethyl The group $CH_3 \cdot CH_2$, often written as C_2H_5 or in abbrev. form as Et. → Alkyls.

Ethyl acetate (acetic ether, acetic ester, ethyl ethanoate), $CH_3COOC_2H_5$, MW 88, density 0,9, b.p. 77°C. A colourless, readily flammable liquid with a pleasant fruity odour; less volatile than ethyl ether; water soluble up to 8,6%. Miscible with water (poor stability), alcohol, ether, chloroform, white spirit, etc. Uses: spotting agent for oil, grease, resin, fruit, and grass stains in particular.

Ethyl alcohol → Ethanol.

Ethylenediamine (1,2-diaminoethane), $NH_2{-}CH_2{-}CH_2{-}NH_2$, MW 60,1, density 0,9, b.p. 116°C. A colourless, alkaline liquid with an ammoniacal odour, soluble in water and alcohol. Uses: with copper salts a good solvent for cellulose (ethylenediamine copper solution); production of wash-resistant finishes with low wet crease resistance on regenerated cellulose fibres (60–90% solution); production of crease-resistant finishes, chelating agents, cationic textile auxiliaries, etc.

Ethylenediaminetetraacetic acid (EDTA; ethylenebisiminodiacetic acid; ethylenedinitrilo- tetraacetic acid), $(CH_2COOH)_2NCH_2CH_2N(CH_2COOH)_2$. An organic complexing or chelating agent of the aminopolycarboxylic acid type. As an ion exchanger, it completely eliminates water hardness salts and heavy metals in water. More expensive than polyphosphates, but more effective and more stable than the latter; EDTA is effective at all temperatures, and is resistant to alkalis and boiling temperatures. It can even bind magnesium in caustic alkali solutions, and dissolves rust and corrosion residues as well as already-formed lime soaps, but does not bind metallic iron.

Ethylene dichloride → 1,2-dichloroethane.

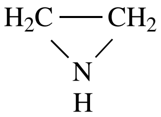
Ethylene glycol (ethylene alcohol; glycol; 1,2-ethanediol; 1,2-dihydroxyethane), $HO–CH_2–CH_2–OH$. Density 1,11–1,14, b.p. 197,5°C. A clear, colourless, syrupy liquid. Sweet taste, very hygroscopic. Soluble in water and alcohol, poor solubility in ether (in contrast to → Glycerol). Uses: solvent for cationic, acid, chrome and vat (including vat leuco ester) dyes; silk printing; finishing softener with fatty alcohol sulphates. Also used as an antifreeze.

Ethylene glycol monobutyl ether (2-butoxyethanol; butyl Cellosolve), $C_4H_9OCH_2–CH_2OH$.

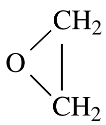
Density 0,905–0,909, boiling limits 164–176°C, flashpoint 65°C. Miscible with water in a 1:1 ratio. Uses: solvent for lacquers, chlorinated rubber, colophony, nitrocellulose, polyvinyl acetate, drying oils, vegetable and mineral oils as numerous synthetic resins.

Ethylene glycol monoethyl ether (2-ethoxyethanol; Cellosolve), $C_2H_5O(CH_2)_2OH$. MW 90, density 0,93, b.p. 130–138°C, flashpoint 40°C, evaporation number 43. Water soluble liquid, miscible with organic solvents. Does not dissolve acetate fibres. Uses: solvent in dyeing and printing for cationic, acid and indigo dyes; solvent for nitrocellulose, etc.

Ethyleneimine (aziridine, dihydroazirine) A compound very similar to ethylene oxide in many respects. A colourless, toxic liquid with a strong ammoniacal odour. Corrosive, absorbed by the skin, causes tumours. Ethyleneimine is very reactive and polymerizes readily (ethylenediamine, diethylenetriamine, polyethyleneimine; the latter corresponds to the polyethylene glycols).



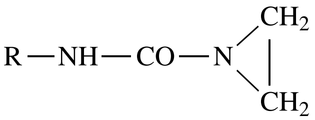
Ethylene oxide (1,2-epoxyethane, oxirane),



Colourless gas at room temperature, liquid at approx. 12°C, soluble in organic solvents, miscible with water. Extremely reactive with mobile H atoms in hydroxyl and amino groups to form numerous technically valuable products used in textile finishing, such as ethylene glycol and ethylene glycol derivatives of all types. Its principal use is for polymerization to 1,2-epoxide polymers.

Ethylene oxide adducts Addition product of ethylene oxide in fatty alcohols, fatty acids and amines. Used alone or in combination as a detergent, fabric conditioner, anti-static agent, emulsifying agent etc.

Ethylene urea (cyclic ethylene urea). Trivial name for imidazolidone-2 and derivatives, ethylene urea resins. As dimethylol compounds, ethylene ureas are important reactant resins, e.g. DMEU, DMDHEU. Linear ethylene ureas are reaction products derived from alkyl isocyanates and ethylene imine, e.g. octadecylethylene urea.

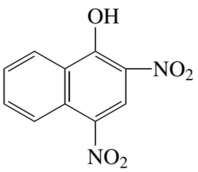


Ethyl ether (ether, diethyl ether, ethyl oxide, diethyl oxide, sulphuric ether, ethoxyethane), $C_2H_5OC_2H_5$, MW 74, density 0,72, b.p. 35°C. A colourless, extremely volatile and mobile liquid. Very flammable (vapours form highly explosive mixtures with air). Characteristic aromatic (narcotic) odour, burning and sweet taste. Slightly soluble in water up to approx. 7%. Miscible with alcohol, chloroform, benzene and other solvents, as well as in conc. hydrochloric acid. Uses: highly effective spotting agent (for oils, fats, resins, fruit and grass stains); does not affect the colour of dyed goods (provided it is not heated).

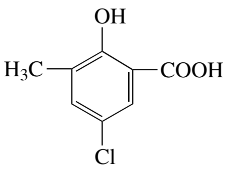
Ethyne → Acetylene.

Eu, chemical symbol for europium (63).

Eulan mothproofing treatment The development of mothproofing and beetle-protection agents for wool is relatively old and has its origins in the coincidental observation that wool dyed with Martius Yellow became resistant to moth attack, i.e. mothproof. The first commercial product of Bayer's Eulan range (chlorocresotic acid) came into being as a modification of Martius Yellow.



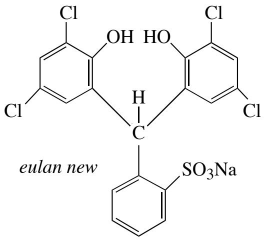
martius Yellow

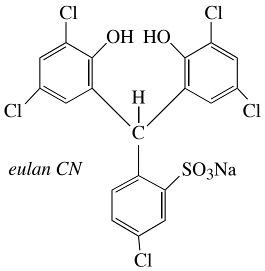


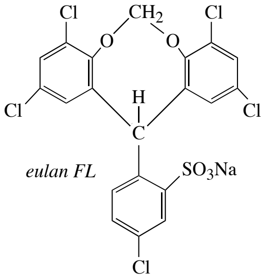
chlorocresotic acid

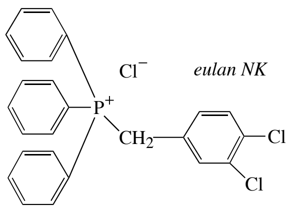
Eulan RHF could indeed be absorbed by wool from an acid liquor but was not resistant to washing. From

1927, therefore, a range of products based on triphenylmethane which could be applied to wool with better wet fastness properties and, through further modification, also without yellowing, were introduced to the market.

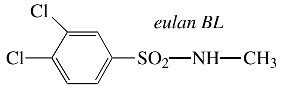

eulan new

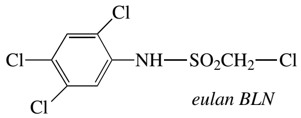

eulan CN

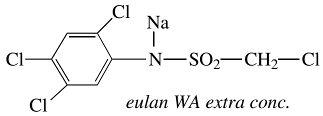

eulan FL


eulan NK

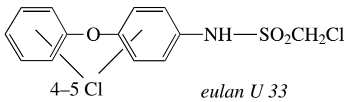
Finally, Eulan brands based on sulphonamides (also suitable for application from organic solvents) superseded triphenylmethane and triphenyl phosphonium compounds. Eulan BL, introduced in 1934, Eulan BLN in 1951, and Eulan WA extra conc. in 1952, are examples of sulphonamide derivatives.


eulan BL

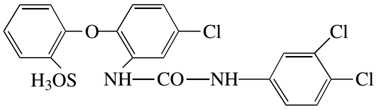

eulan BLN


eulan WA extra conc.

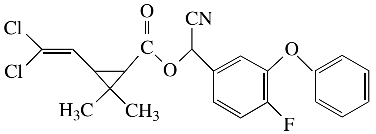
The development of Eulan brands based on sulphonamides was continued, and resulted in products suitable for universal application, thereby allowing the finisher free reign to select the most appropriate stage of wet processing from which to apply the mothproofing finish. In 1957, alkyl-sulphonamidohalogen-diphenylether, as the active constituent of Eulan U 33 was launched on to the market.

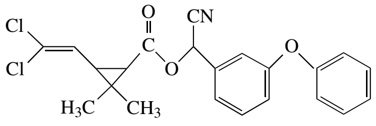

eulan U 33

Finishes produced with this mothproofing agent are characterized by very high fastness properties. For materials that are seldom washed, the cheaper brand, Eulan WA, can be used. At the beginning of the 1930s, the Swiss company J. R. Geigy began the development of mothproofing agents based on substituted ureas which led to the marketing of the product, “Mitin FF”, in 1939. This mothproofing agent could also be absorbed by wool from aqueous solutions like a dye, together with corresponding fastness properties.

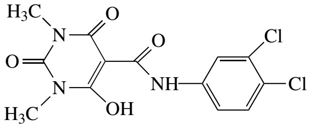

mitin FF

Agents of this type are not insecticides but have the effect of making wool inedible to parasites. They are applied in the final wet process. Individual products can also be applied in the dyebath. Commercial products of different chemical basis include: “Gardone” (Shell) and “Dicaphton” (AMCY), both of which are organophosphorus compounds. “Todmac” is an organic tin compound. The “Sylgard” finish (Dow Corning) which was introduced in the USA, contained the active substance, 3-trimethoxysilylpropyldimethyloctadecylammonium chloride. Practical experience of recommended antimetabolic agents capable of interfering with insect metabolism is not available. An agent with permanent activity is a zinc peroxide complex which relies on the continual release of oxygen. The synthetic pyrethroids also appear promising substances. A commercial product of this type is “Perigen” (Wellcome). Common to all the pyrethroids tested up to now, however, is the fact that although they are indeed highly effective against all moth larvae, moths tend to develop a pyrethroid-resistance, and these substances also offer poor protection against the Anthrenus species of carpet beetle (carpet beetle holes when applied at usual concentrations); often referred to as the “Anthrenus loophole”. Cypermethrin, an agrochemical, provides a slightly higher protection against Anthrenus species but cannot be successfully applied besides permethrin; moreover, pyrethroids have recently come under attack because of their toxicity.


cyfluthrin


cypermethrin

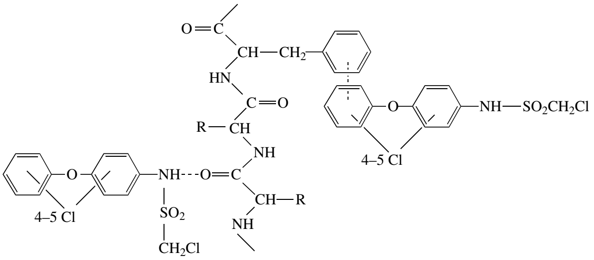
Both Bayer and Ciba-Geigy offer their own products based on pyrethroids. Eulan SP (Bayer) contains trans/cis-cyfluthrin. Mitin AL resp. Mitin BC (Ciba-Geigy) contain *inter alia* permethrin as active component in combination with hexahydropyrimidine derivatives (HHP) for protection against carpet beetles.



HHP

A comparison of the advantages and disadvantages of synthetic pyrethroids in relation to conventional mothproofing and beetle-protective agents shows that the pyrethroids offer the following properties: lower application quantities, a certain toxicity to warm-blooded species, good adsorption and degradability, control of moth larvae, and equal distribution between wool and polyamide.

The high affinity of Eulan brands, based on sulphonamides, for keratin fibres is considerable. The baths, at pH 5, are almost completely exhausted when applied either at the boil or at 40°C. Even in neutral baths the affinity is still high. Since such products exist as free sulphonamides at pH <7, and not as salts, the reason for their affinity cannot be due to a salt-forming mechanism with the wool; rather, the formation of hydrogen bonds can be regarded as the driving force here.



The finishing of wool carpet yarns, as produced in many developing countries, is a particularly interesting application. → Mothproofing and beetle protection.

Eumycetes Hyphomycetes → Moulds.

European Convention for Fastness Testing (ECE). European Colour Fastness Establishment founded in 1952. The leading European study group of dyestuff manufacturers, textile dyers and printers, textile testing institutes, research organizations, as well as fastness testing commissions, in collaboration with → ISO. → Technical and professional organizations.

European legislation relating to machinery safety Within the European Community and E.F.T.A. changes are occurring rapidly as mandatory safety requirements are introduced with the aim of providing a 'level playing field' for competition in the supply of industrial machines throughout these areas. The following Directives provide the driving force for change, the structure and content of the new standards (which are the primary means for manufacturers to ensure that they are complying with the Directives), the particular implications for the coating and laminating sector, and overall progress towards implementation.

1. The Directives: Following the Treaty of Rome, it became increasingly clear that the E.C. would need to take measures to ensure that trade within the community was not subject to national barriers which would impede free competition. Previous attempts to provide a Europe-wide framework for technical standardisation such as the Low Voltage Directive of 1973 had only been moderately successful. This was felt to be a result of two factors – firstly, the Directive was not an enforceable mandatory requirement throughout the community – and secondly, the Directive sought to provide all the technical detail within a single document produced by politicians/civil servants. It was therefore decided that the new Directives would correct these faults. There is a mandatory requirement in each Directive (subject to appropriate transition periods) that they be transposed into national law in every member country and that any conflicting legislation is removed from the statute book. In order to address the second problem, the Directives contain only principles relating to the technical performance and these are normally held in an Annex (for example Annex 2 of the Machine Directive contains the essential safety requirements or ESRs). International standards organisations (originally CEN and CENELEC, but now also including ISO and IEC) are contracted to write full standards in each area which indicate how a manufacturer may comply with the Directive.

It is still technically the legal responsibility of the manufacturer to comply with the ESRs, but compliance with the ESRs by compliance with the standards derived from them is accepted as a de facto compliance, whilst direct compliance will be much more difficult to demonstrate in a court of law because of the nature of the ESRs. Manufacturers are, except in the case of particularly dangerous or critical machines, free to self-certify compliance. However this should not be viewed as an easy option because a wide range of interests are free to challenge the compliance either through the 'Trading Standards' officers in the country concerned or through the courts of law both nationally and internationally. Interests free to do this include aggrieved customers or competitors, local workers or union representatives, and local 'Trading Standards' officers. Complying with the Directives involves generating and maintaining a Technical File for each machine type which documents all the design decisions and associated risk analysis, demonstrates that the machine complies with all the appropriate standards (by external certification where appropriate), and records all the drawings, schematics and instructions supplied with the machine. It is the manufacturers' responsibilty to determine which Directives apply to a particular machine (and it must be admitted that there is still some uncertainty about the dividing lines). The list of Directives below is not claimed to be exhaustive, and in any event the subject is undergoing a phase of rapid evolution, but most manufacturers will be covered by at least one of them.

The Machine Directive: This covers virtually every machine with moving parts and includes sections on design, materials, control (starting, stopping, mode selection), software, stability, guarding, electrical wiring, temperature, fire, explosion, noise, vibration, radiation, emissions, indicators, warnings, instructions and maintenance. It came into force on 1st. January 1993 with a two year transition period.

The Electro-Magnetic Compatibility (E.M.C.) Directive: This establishes the principles of maxima for radiated and conducted emissions, and of minima for immunity from radiated and conducted emissions. It came into force on 1st. January 1992 with a four year transition period.

The Simple Pressure Vessels Directive: This establishes performance criteria, tests and an external certification procedure for pressure vessels. It came into force on 1st. July 1990.

There are also a series of other directives which are associated with items peripheral to the core of machine design. These include:

- The Use of Personal Protective Equipment Directive
- The Use of Work Equipment Directive
- The Display Screen Equipment Directive
- The Manual Handling of Loads Directive
- The Workplace Directive

and the following proposed items:

- The proposed General Product Safety Directive
- The proposed Services Liability Directive
- The proposed Used Machinery Directive.

If a machine complies with the new regulations it is automatically exempt from the old national regulations during the transition period. This is demonstrated by placing a 'CE' mark (see inset) and the year of manufacture on the machine. Care has to be taken in using this mark because it is making a legal claim about the machine, and it implies compliance with all the applicable Directives in force at the time it is placed on the machine.

II. The Standards: Supporting the Directives the standards are structured in a three tier arrangement which provides a simple means of categorising and inter-relating them. This is particularly true of the Machine Directive, and the following examples all relate to that Directive. The uppermost layer (A-type) contains standards which delineate general principles of operation or which describe essential functions which are required throughout the design process. They apply to all machines within the scope of the Directive and include:

- General Principles for Design
- Risk Assessment
- Requirements for the Instruction Handbook.

The next layer contains most of the standards which the designer will use in his day-to-day work and is split into two sub-groups. The first (B1-type) deals with general requirements in specific areas or functions and applies to all relevant machines, whilst the second (B2-type) deals with general requirements for specific devices and applies whenever one of the devices is used. The following examples in the left-hand column are B1-type whilst those in the right-hand column are B2-type.

Safety Distances
Visual Danger Signal
Indicating, Marking and Actuating Principles
Human Body Dimensions
Ergonomic Design Principles
Electrical Equipment of Machines
Principles for design of safety-related Control Systems

Two-hand Control
Emergency Stop Equipment
Guards
Electro-sensitive safety devices
Pressure-sensitive safety devices
Prevention of unexpected start-up
Interlocking devices with and without guard locking

The final level (C-type) is machine specific and is important because these standards not only deal with particularly dangerous aspects of certain machines in detail, but may also provide alternate techniques for achieving the required level of safety in those unusual cases where the requirements of B-type standards make the machine inoperable. A few examples of these standards follow, but the most important are to be found in the standard on the safety of textile machines (prEN31111):

- Textile machinery
- Printing machinery
- Woodwork machines
- Rubber and plastics processing machines.

It is not possible here to deal in detail with the contents of each of these standards, but a few comments are necessary on some of those with a greater impact:

EN292 (Parts 1 and 2) – Basic Concepts, General Principles for Design

This standard sets out the design philosophy and process which should be formally documented and supported within the Technical File. In particular it defines all the relevant terms, deals with safety integration and with additional precautions required in unusual circumstances.

EN294 – Safety Distances to prevent danger zones being reached by Upper Limbs
prEN811 – Safety Distances to prevent danger zones being reached by Lower Limbs
prEN349 – Minimum Distances to avoid crushing of parts of the Human Body

These standards define the safe ways in which access may be achieved to a machine either for running or during regular maintenance. The distances are established using European norms for body dimensions (these distributions are defined elsewhere in the anthropomorphic standards). Care should be taken by manufacturers supplying to regions where these norms do not apply to make the appropriate modifications to distances (each change being carefully documented and justified in the Technical File).

prEN50099 (Parts 1, 2 & 3) – Indicating, Marking and Actuating Principles
EN457 – Auditory danger signals
prEN… – Visual danger signals

These standards give clear guidance on the layout and functional interaction of controls on machines, and on how to implement danger/warning signals. There are a series of associated standards which define the ergonomic needs in a range of environments and the positioning requirements to suit European characteristics.

prEN… – Principles for the design of Safety-related control systems

This is one of the most important standards mandated under the Machine Directive. It describes five categories of control system with increasingly complex protection for more serious hazards. One of the important functions of C-type standards is to define which of these categories applies to each of the machines within its scope. The standard also deals with the important issues of validation of control system function and formal verification.

prEN50100 (Parts 1 & 2) – Electro-sensitive Safety-Devices
prEN574 – Two Hand Control
EN418 – Emergency Stop Equipment

These standards deal with the devices which must be used in the control systems discussed in the previous standard. Particular importance is again attached to validation and verification and, in the case of individual devices, to testing.

EN60204.1 (1992) – Electrical Equipment of Machines
This is a major revision (in fact virtually a rewriting) of IEC204.1. The scope has been dramatically extended and now includes EMC, electronic control systems and PLCs as well as significant changes to all existing wiring and panelling requirements. This additional work has effectively doubled the size of the standard. It is absolute requirement for any machine using electricity as a source of power or control because as well as being mandated under the Low Voltage Directive, it is also mandated under the Machine Directive (according to M.G.B. Mahboubian-Jones).

European regulatory requirements concerning environment protection in finishing → Environment protection in finishing (European Regulatory Requirements).

Eutrophication (Gk.: *eutrophos* = well-fed). A process by which pollution from such sources as waste waters or leachates from fertilized fields causes stagnant or slow flowing surface water to become overrich in organic and mineral nutrients, so that algae grow rapidly and deplete the oxygen supply. The problem is particularly relevant to phosphates in washing detergents which specifically promote the growth of small algae which can result in the feared over-fertilization of surface waters with increased oxygen depletion. A monoculture of algae in a polluted (eutrophic) lake in which other forms of life can no longer exist, is the end-result of this process.

Evaporation losses (Discharge evaporation losses) include (for calculating the water consumption index) all process water losses that do not return as waste water, in particular boiler feed water, all quantities of water evaporated in drying processes, all moisture remaining in the textile substrate, etc. For the reasons specified, the amount of waste water is not identical with the process water supplied and/or extracted. In the absence of suitable water gauges and where calculating industrial effluent discharge levies is cost-prohibitive, a deductible wastage of min. 17% applies (accepted "commercial custom and practice") as a probability criterion and a basis for costings.

Evaporation number (evaporation rate). Comparative evaporation rate in relation to ethyl ether (=1).

Evaporation plant Effluent can be purified by distillation if a solution (power-heat coupling) is available from the energy standpoint. Sludges occurring during evaporation in thin-layer evaporators can be dried and dumped or incinerated in furnaces (licensing).

Wool scouring water enters the evaporation plant with a dry substance content of up to 5% for example. This is thickened to a dry substance content of 55% in 7 evaporation stages, so that approx. 2500 kg of concentrate is produced per hour. The exhaust vapour conden-

Evaporation plant

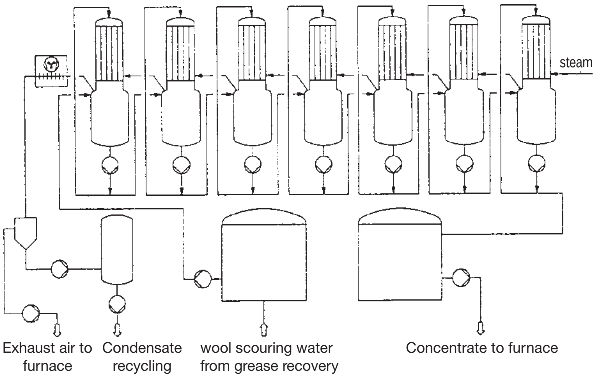


Fig. 1: Bremer Wollkämmerei evaporation plant.

sate from the evaporation plant, which is tainted with a powerful odour, can be re-used as processing water by special after-treatment in a biofiltration plant. The energy-rich concentrate from the evaporation plant has a calorific value (H_u) of approx. 8500 kJ/kg, and is fed to the furnace (Fig. 1).

Evaporation plants are classified as thin-layer evaporators, drop film evaporators and circulatory evaporators, (natural circulation evaporators, forced circulation evaporators).

I. Thin-layer distillation: the principle of thin-layer distillation (Fig. 2) is film evaporation, which represents a gentle form of evaporation. It involves single stage co-current flow distillation, the separating effect of which is equivalent to a max. of one theoretical partition stage. Partition intensity can be increased by serial installation. Trials have shown that the most important advantages of thin-layer distillation can be exploited at normal pressure and in the approximate 5 to 1 x 10^{-1} Torr range; this is because a high fluid layer is heated up, and the dwell time in the heating zone is significantly shorter. In the case of film distillation, a fine film is produced, which generates virtually no pressure increase, and runs off with a short dwell time. This type of heat protection should be used with temperature-sensitive substances. First of all, preliminary separation is effected in a narrow temperature range. If a mixture boiling at high temperature contains small proportions of low-boiling components, it is often impossible, despite increased heating, to recover all fore-running components by piston distillation. If a vacuum is used in order to prevent the high-boiling components from disintegrating, there is a danger that the fore-running components will escape uncondensed. These difficulties can be eliminated by thin-layer distillation at normal pressure.

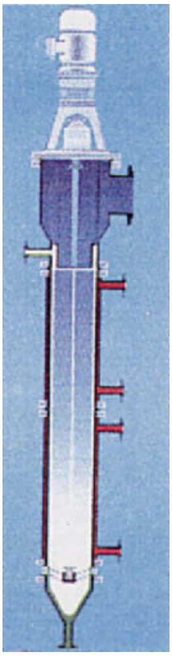


Fig. 2: Canzler thin-layer evaporator.

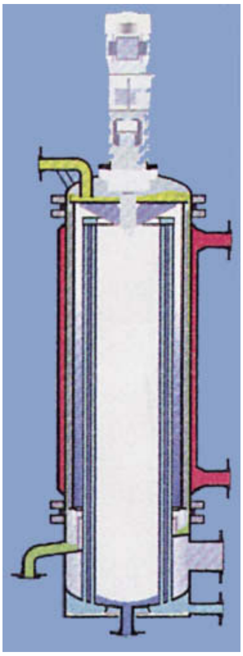


Fig. 3: Cross-section of a Canzler flash evaporator.

A frequently used type of thin-layer evaporator consists of a fairly large diameter vertical tube which can be externally heated. The bottom part forms the boiling zone, while the top part houses the exhaust vapour separator. Inside, the product to be evaporated is moved by a high-speed rotor, which both distributes the liquid entering the top part via the heating surface and prevents heating surface encrustation by means of a special wiper system. Fluids can be evaporated to a powdery consistency in a thin-layer evaporator. The dwell time in this type of plant is only a few seconds. Effluent with a tendency to foam also causes fewer difficulties in a thin-layer evaporator. For this reason, thin-layer evaporators are used mainly as the last stage of multi-stage evaporation plants. The pressure range runs up to approx. 5 mbar; evaporation temperatures are correspondingly low.

The flash evaporator (Fig. 3) finds use in distillation in the 1–0.001 mbar fine vacuum range. In the case of this type of evaporator, the condenser is built into the evaporator, with the evaporation surface directly opposite, which means that there is virtually no pressure loss between heating and condensation surfaces. Extremely sensitive products can be optimally distilled in this way. The product is fed in at the evaporator head, and distributed over the heating area by the rotor. The wiper system produces a turbulent fluid film, the product vapours being precipitated on the condenser located below in the evaporator. The distillate flows down to the condenser tubes, and then drains on to the ground. The sediment is collected, and removed via a lateral connecting stub. In the case of the thin-layer rectifier, the run-back liquid runs down against the flow of the rising vapour as a thin film. In this way, the basic rectification processes are spatially separated by being distributed over an evaporation surface and a condensation surface. One special design comprises a wave of fixed agitator blades (Sambay evaporator), making it possible to adjust the liquid film thickness automatically, depending on the viscosity of the boiling liquid and on the blade contact pressure.

II. Circulatory evaporators are built with natural circulation (automatic circulation) and forced circulation of the product to be evaporated. The operating force is the temperature difference on the liquid side of an evaporation tube. With viscous solutions, this critical temperature difference is higher than with low-viscosity ones. Circulation can come to a standstill if the temperature difference between heating and boiling sides, reduced in raising the boiling point, is small. Due to buoyancy, the liquid in the evaporation tubes rises on account of the vapour bubbles occurring during boiling and the associated reduction in density. The effect is the more intensive the higher the temperature difference between boiling and heating chambers, i.e. the larger the number of vapour bubbles formed. The higher the flow rate in the tube, the better the heat transfer, and the smaller the heating area can therefore be kept. The maintenance of high flow rates is particularly important for effluent containing substances with a tendency to encrustation.

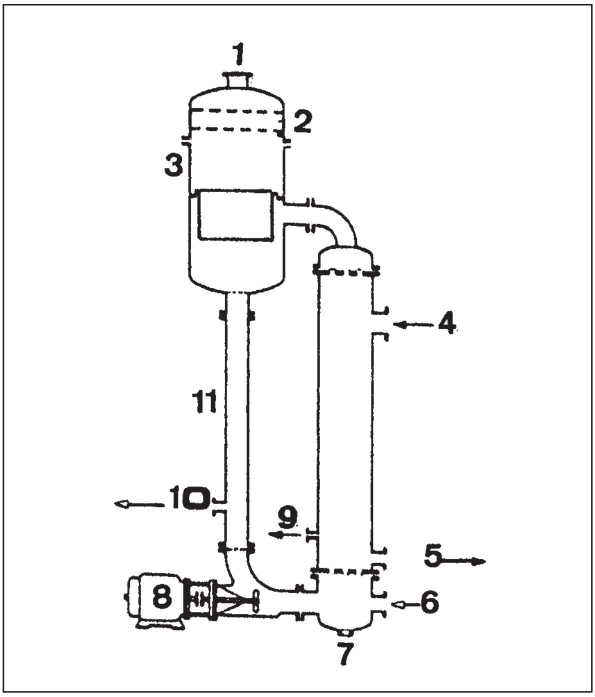


Fig. 4: Forced circulation evaporator with external heater. 1 = Exhaust vapours; 2 = Liquid separator; 3 = Vapour chamber; 4 = heating steam; 5 = Condensate; 6 = Fresh solution; 7 = Drain; 8 = Circulation pump; 9 = Gases; 10 = Lye; 11 = Downpipe.

Use of a forced circulation evaporator (Fig. 4) instead of a natural circulation evaporator can be recommended, and is essential if the danger of content disintegration is greater due to high heating surface loading. Heat transfer is improved with this evaporator. The liquid is circulated by a pump so that the flow rate can be selected independently of heating surface loading. The tendency to encrustation can be countered if boiling is prevented in the tubes. In this event, the solution must be subject to a correspondingly high static pressure ("flooding"), and then boiling begins only outside the tube after pressure release. Centrifugal separators with tangential boiling solution entry are employed for separating vapours and solution, which, if correctly designed, largely prevent solution foaming.

Technical methods of reducing power consumption: good design should take account of the operational behaviour of the solution to be evaporated (encrustation, foaming), its physical properties (temperature and viscosity dependency on concentration, solubility dependency on temperature) and its dwell times (dependent on thermal instability). Only then can power consumption be meaningfully structured. A quantity of heat q = approx. 2800 kJ/kg, taking account of the efficiency of the heat technology, is used for evaporating water up to 100°C. It is possible to reduce energy and steam consumption by multi-stage evaporation. Thus, with 5-stage evaporation, the specific steam consumption of 1 kg of steam can be reduced to 0.2 kg of steam/kg of water as compared with single-stage evaporation. A number of evaporation stages are linked together in such a way that the vapours of one stage form the heating medium for the next. The boiling temperature must be sought by reducing the pressure from stage to stage, as a temperature difference between the stages is a prerequisite. Cooling water consumption is also lower, as only the vapours of the last evaporation stage have to be condensed. The steam consumptions are 1 : 0.5 : 0.33 etc.

The following staging methods are basically available: the variant used in processing technology is cocurrent flow feeding. Liquid is first of all pumped into the stage with the highest pressure, leaving the plant in the stage with the lowest pressure. In the case of counter-flow staging, the solution enters the last stage (lowest pressure), and is pumped from stage to stage against the direction of flow of the exhaust vapour. The concentrate leaves the evaporator at the highest pressure. This possibility is of advantage for highly concentrated solutions, as they evaporate in the stage with the highest temperature, where viscosity is lower and heat transfer is better. The third version is used where the solubility limit is not reached, i.e. the solid substance crystallizes out during evaporation.

Optimum energy utilisation is guaranteed when product flow and temperature and or pressure drop are staged with or against the flow. Combinations of the

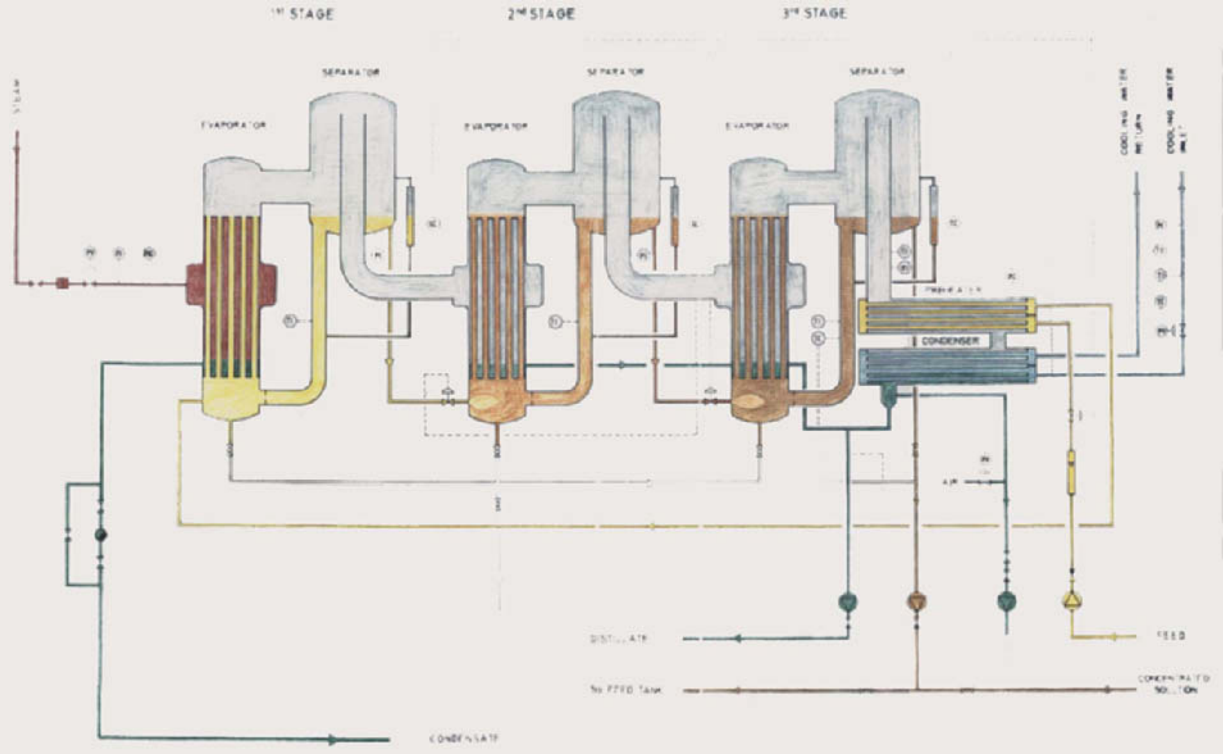


Fig.: Evaporator plant (Kasag).

two are possible. It is important to use energy by combining different evaporator models so as to adapt to changing product characteristics. Effluent evaporation and distillation should not be regarded as the exclusive method of effluent treatment. These methods should be regarded as a feasible separating process in an integral concept. In any case, suitability for problems arising should be examined for industrial scale evaporation, together with the efficiency of other effluent treatment methods if necessary. Before considering effluent incineration, it is essential to check whether advantages are offered by effluent recovery by adsorption, ion exchange, distillation, evaporation, stripping, extraction and crystallisation as alternatives.

Evaporator plant Is multistage and produces distillate and concentrate (see Fig.), with the separation efficiency being dependent on the solution concerned.

Evergreen cut pile carpet → Simulated grass matting.

Evidence reaction (chem.) → Analysis.

Excess pressure valve (safety valve). → Valves designed to open under conditions of undesired excess pressure.

Exchange factor for continuous dyeing The ideal continuous dyeing method consists of applying the dyestuff with no affinity of any kind mechanically on the fibre and then of fixing it in situ as quickly as possible. With direct dyestuffs and leuco vat dyestuffs however, padding is characterised by a larger dye uptake than would correspond to the quantities of dyestuff effectively absorbed. This can be traced back to an affinity of the dyestuff for the fibre. During padding, the fibre undergoes a dyeing process which is more or less pronounced. The degree of affinity can be considerable (the half-life period of dyes for a range of direct dyestuffs lies between 5–25 s at low liquor ratios). As a result of the influence of this affinity, the concentration of the padding liquor diminishes from the point in time when the material begins to flow through until an equilibrium is reached (Fig. 1). The fabric undergoes a process similar to a change of shade (tailing).

In practice, the success of the pad dyeing process depends on the skill of the dyer in controlling his dyeing conditions in such a way that there is minimum

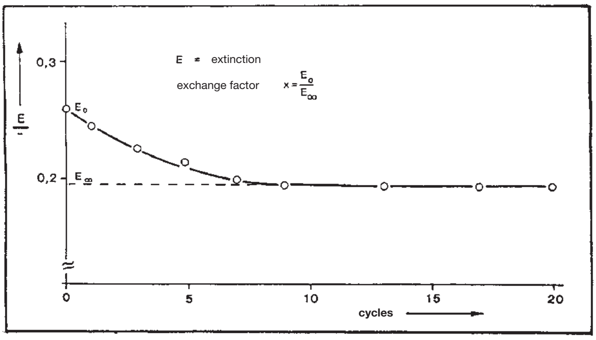


Fig. 1: Liquor concentration after simulated water extraction by squeezing.

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change in concentration. The dyer attempts to avoid a change in concentration from the outset by using a suitable balanced padding liquor. The amount of dyestuff introduced should be equal to the total amount of dyestuff absorbed by the fabric.

As the dyeing process (i.e. the interaction of dyestuff/fibre) is generally an exothermic process, attempts are made to reduce any available affinity of the substantive dyestuffs in the padding machine as the padding liquor is heated. Systematic tests attempt to clarify the fact that the quantity of padding liquor in the trough should be kept constant by adding fresh dye solution, but should differ until the amount of dyestuff taken up by the fabric corresponds to that flowing into the feed liquor.

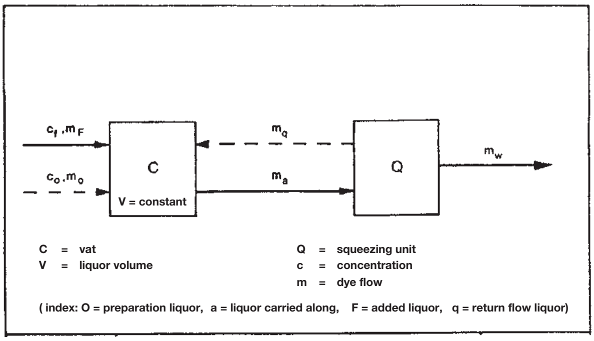

Fig. 2: Mass (dye) transport in a padder.

The temporary alteration to the concentration of the padding liquor in the trough (Fig. 2) can be calculated as follows:

$$V_B \cdot \frac{dc_B}{dt} = V^* \cdot c_0 - V^* \cdot x \cdot c_B$$

V_B = trough volume,
c_B = present concentration in the trough,
c_0 = concentration of the initial liquor and feed liquor,
V^* = liquor volume taken up by the fabric per unit of time,
x = exchange factor.

In order to solve the differential equation for $c_B = c_0$; $t = 0$ and $c_B = c$; $t = t$ an expression for the concentration in the padding trough at time t follows at constant volume flow V* of the liquor introduced to or with the textile and at a constant bath volume V_B:

$$c_t = \frac{c_0}{x}\left(1 + (x-1)^{\frac{-V^* \cdot x \cdot t}{V_B}}\right)$$

An exchange factor

$$x = \frac{E_0}{E_\infty},$$

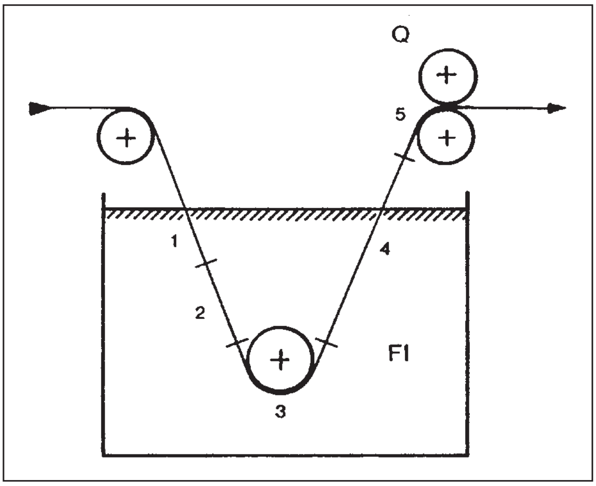

Fig. 3: Schematic diagram of padding.
1 = wetting; 2 = 1st immersion stage; 3 = passage round the deflection roller; 4 = 2nd immersion stage; 5 = squeezing.

is formulated. This can be determined by a specific liquor passage device, and gives information about the interaction in the system. The stationary condition is reached when the concentration (measured by expiry E) of the liquor collected no longer changes after various cycles (E_∞). The adjustment of this balance can be localized by appropriate presharpened and regenerated liquors. The larger the interactions in the system, the more quickly an equilibrium occurs. The exchange of liquor in the pad dyeing machine should be as large as possible and the trough volume as small as possible (Fig. 3).

Execution time Portion of → Order processing time (relating to → Setting up time) for operational outlay in time per unit as →: Basic time and allowance.

Exhaust air In textile finishing plants most of the exhaust air is produced from stenters, curing machines, hot flues, drying chambers, etc. It generally has a high moisture content and contains certain pollutants as well as energy in the form of heat. The pollutants are either removed in scrubber columns or destroyed by combustion; in the latter case exhaust heat is recovered in suitable heat recovery plants.

Exhaust air analysis Quantitative analysis of exhaust air together with analysis of the qualitative and quantitative composition of exhaust gases must be carried out in order to establish whether exhaust air quality is suitable for TA air. Quantity measurement is effected in a straight section of exhaust air ducting as a measurement of flow in accordance with VDI 2066 using a Prandtl pitot tube in combination with an inclined tube manometer. This gives an exhaust air quantity of 20 000 m^3/hr (drying 3000 m/hr of woven wool fabric) for a 9-chamber horizontal stenter.

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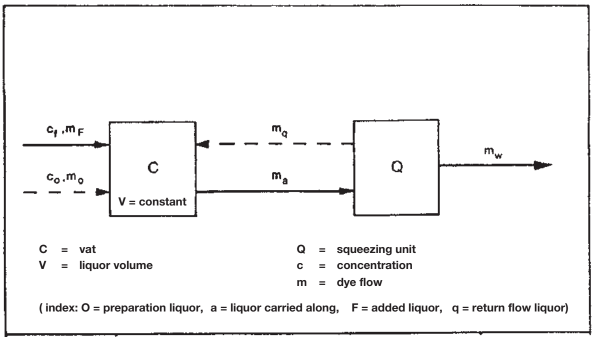

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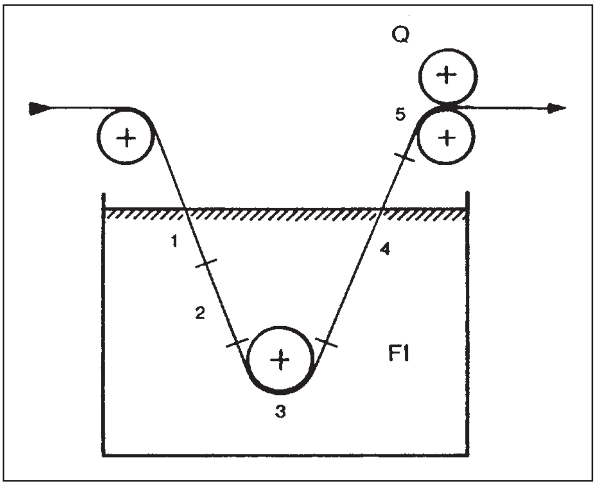

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Generally, stenters produce approximately 10 m^3 of air/kg of fabric, and curing machines only 1 m^3 of air/

kg of fabric. Qualitative exhaust air measurements determine the total carbon content of the exhaust gases by the following methods:

– flame ionisation detector,
– silicagel process,
– combined gas chromatography and mass spectrometry.

Quantitative analysis of all exhaust air content substances is possible by the following method: over a 1 hr period, a defined partial quantity is taken from the works exhaust airstream by means of a vacuum pump in accordance with VDI 2457, the partial flow being passed through condensation traps (0°C) in order to remove any moisture which might impair measurement. The exhaust air content substances are then absorbed in an activated charcoal tube. This activated charcoal collection stage is replaced by carbon disulphide for organic content substance desorption in the laboratory. Any condensate collected is extracted with dichloromethane. The substance mixtures are separated by the gas chromatographic method by means of fused silica capillary columns with methyl-silicon coating, and then detected by computer-aided mass spectrometry, and identified with an electronic data processing library. After that, quantitative calibration is effected with comparative substances as external standards.

Because aromatics are relatively difficult to desorb by activated charcoal, the recovery rate is below 50%. The gas chromatographic response factors are favourable in that the substance to be quantified is used as far as possible as a standard.

Exhaust air, cleaning of Reference to: oxidation, condensation and adsorption processes.

I. Oxidation process: functions of oxidation: combustible atmospheric pollutants in exhaust air can be converted by combustion into harmless substances. In the case of complete oxidation, chemically bonded hydrocarbon compounds are converted into the products of combustion - carbon dioxide (CO_2) and water (H_2O). If the oxidation process is incomplete, carbon monoxide (CO) and formaldehyde are formed. If there are inorganic substances from oxidation processes in the exhaust air, like sulphur, nitrogen or halogen compounds perhaps, a further cleaning process, with washers for example, must follow. For these reasons, combustion is preferred for substances which are largely composed of carbon and hydrogen. A distinction is drawn between thermal combustion and catalytic combustion.

Cleaning exhaust gas by thermal reheating (Fig. 1): thermal reheating is carried out at temperatures between 750 and 1100°C. This process is readily used for exhaust gases with organic compounds such as solvent vapours and highly odorous substances and for impurities like halogen and phosphorous compounds which would destroy a catalyst. A thermal reheating plant consists essentially of the following components: blower, perhaps a heat exchanger, auxiliary heating, exhaust gas feed ducting to the combustion chamber, burner, combustion chamber, measuring and control equipment and safety equipment. The crude gas passes through a blower to a heat exchanger. In this case, the heat content of the cleansed exhaust gas is transferred to the crude gas via a heat exchanger. The crude gas air preheated in this way is brought to the required temperature in an auxiliary heater in order to attain ignition temperature in the combustion chamber. The structural shape of a combustion chamber can vary considerably in design, differing mainly in size, flow behaviour and material. The temperature distribution in the combustion chamber and the exhaust gas dwell time are changed in this way. The function of the burner is to bring the exhaust gas up to the reaction temperature. It can be a point burner for liquid and gaseous fuels or a bottle burner for gaseous fuels alone.

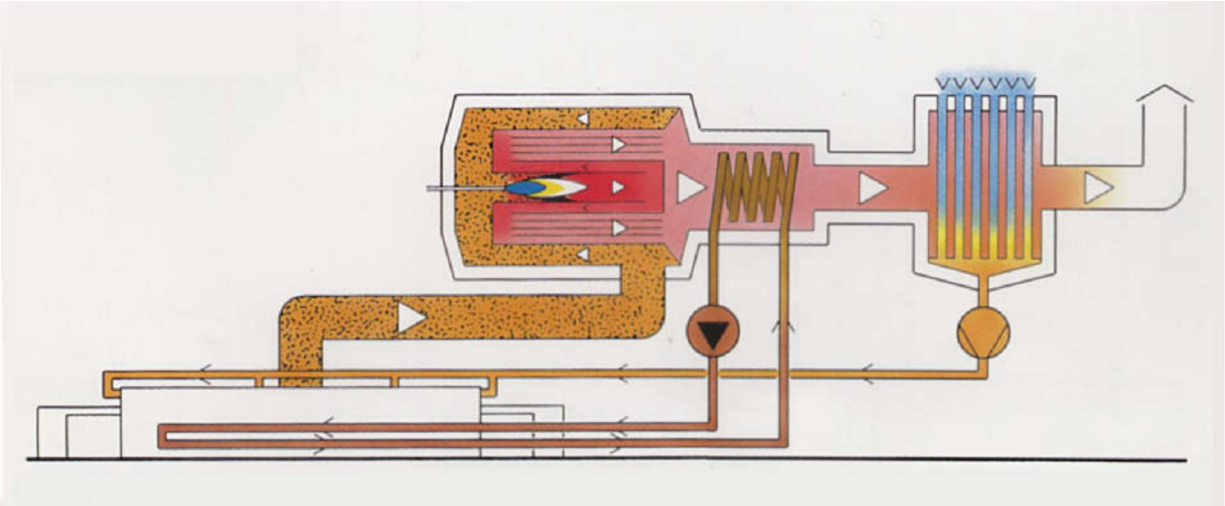


Fig. 1: Thermal reheating principle.

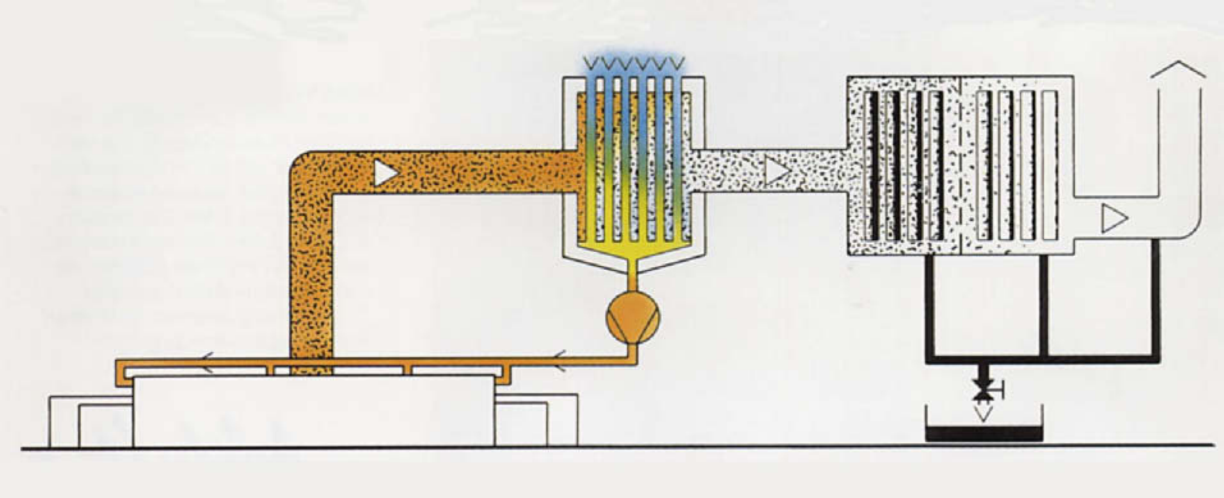


Fig. 2: Cleaning exhaust air by cooling and filtering.

A correct mixture of air and fuel guarantees complete combustion. If air is lacking, gases like CO, CH_4 or H_2 which are still combustible, escape into the flue gas; if there is an excess of air, the combustion temperature is reduced. The consequence of a temperature reduction is that ignition temperature would not be reached. Ignition temperature does however occasion rapid gas combustion. The heat generated by combustion is sufficient to keep subsequently flowing substances at ignition temperature. A measuring and control unit ensures that constant combustion is maintained.

Exhaust gas cleaning by catalytic combustion: the advantage over thermal reheating lies in the decidedly lower activation temperature of 300–450°C. This is explained by the use of suitable catalysts, which hold down the ignition temperature on the one hand, and accelerate the speed of reaction between pollutant and atmospheric oxygen on the other. They are also able to start a reaction, or guide it in a specific direction, without being consumed. Combustion equilibrium can be affected by the pressure, temperature and concentration of the reacting elements. The difference between this and thermal reheating is obvious: the exhaust gases are oxidised in the combustion chamber with the aid of an incorporated catalyst without producing flames. The heat of catalytic combustion released is used for preheating the crude gas flow. If the crude gas contains incombustible dusts, they must be removed in an upstream dust separator, as they are otherwise deposited on the surface of the catalyst, reducing effectiveness over a period. Large quantities of phosphorous compounds, halogens, silicones and heavy metal compounds should not be oxidised either, since they act as catalytic poisons.

A catalytic reaction comprises 4 stages in the heterogeneous system (heterogeneous catalysis):

- pollutant substance conveyance by convection and diffusion from the free gas chamber to the surface of the catalyst,
- adsorption on the surface (chemical sorption),
- combustion product desorption,
- combustion product conveyance by diffusion and convection from the surface of the catalyst into the free gas chamber.

II. Condensation: functions of condensation: vapours of a pure substance, mixed vapours or gas/vapour mixtures are cooled in condensers (Fig. 2), the vapour liquefying (gas/vapour mixtures consist of a condensable vapour and a non-condensable gas). The non-condensable gas is mainly air, depending on the refrigerating temperature. In order for vapour to condense on a wall, its surface temperature must be below the vapour saturation temperature. The condensate is then deposited in individual droplet form (droplet condensation) or as a coherent film (film condensation). Droplet condensation occurs only when the condensate wets the wall, but since practically all liquids properly wet out the materials used for the condensers, beneficial droplet condensation is rarely encountered. Condensation has the great advantage of valuable substance recovery.

Condensation processes and equipment: a process very frequently encountered is the cooling of exhaust gases on the external surfaces of finned evaporators. The equipment, which consists of a succession of finned tubes arranged in parallel, is constructed in the widest variety of performance ratings, materials, and tube and fin dimensions, depending on application. The gas is generally sucked or pushed through the fin system by a fan connected to the vaporiser. Frequently, water or other constituents are condensed out or frozen out during gas cooling. If solid ice forms on the tubes and fins, a second unit must be provided as an alternative for continuous operation. Hot gas from the pres-

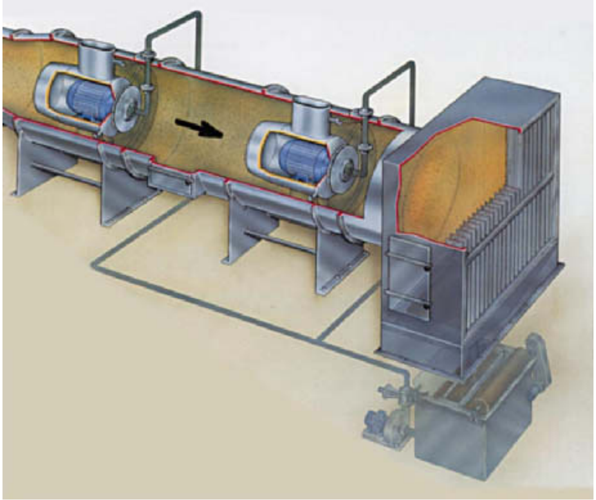


Fig. 3: Prött exhaust air cleaning washer. Arrow = Exhaust air flow direction

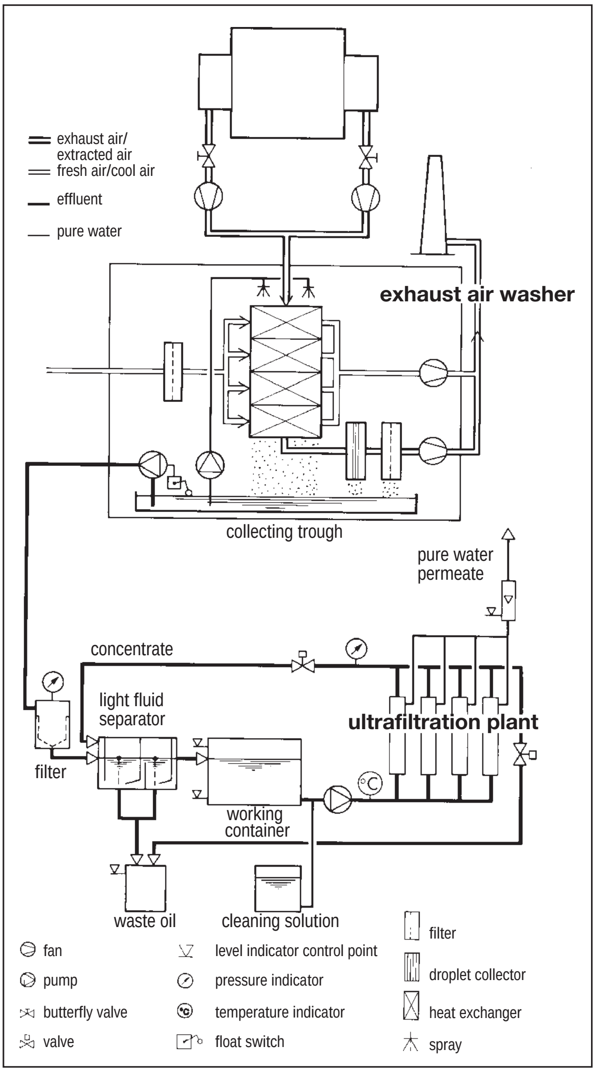


Fig. 4: Function diagram of a Behr washer with effluent preparation.

sure side of the compressor, which gives up its condensation heat to the cold surfaces of the equipment to be defrosted, is employed for defrosting. Another possibility would be to incorporate electric heating elements in the vaporising system. A cooling agent is sprayed into the fin system; the coolant is completely vaporised, and passes through the fin system. In the case of large fin network ramifications, low surface tension liquid coolant is passed through the entire system by means of coolant pumps, part of the coolant being vaporised, and the resultant vapour-liquid mixture returning to a receptacle which simultaneously serves as a coolant separator. A refrigerating agent can also be pumped through the cooler instead of vaporised coolant.

III. Washers: with the use of exhaust gas washers, there are two possibilities of separating exhaust gas content substances by the washing medium (mostly water):

1. Cooling the gases and removing a water-insoluble aerosol which has to be deposited in a sump (Fig. 3).
2. Dissolving the gases in a solvent which is sprayed.

The exhaust air problem is of course transferred to the effluent when washers are used, an integral concept therefore requiring appropriate effluent preparation (Fig. 4).

The principle of the Behr washer: the exhaust air passes through a distributor box into the washing plant, where it is fed via a spray system fed by circulating water, over heat exchangers which act as a packed column. In this way, the exhaust air is brought into intensive contact with the washing water. At the same time, the exhaust air temperature is reduced by the air-to-air heat exchanger, and the washing water kept at low temperature. After leaving the heat exchanger, the exhaust air is turned through 90°, passing into the atmosphere via droplet separators, via stainless steel filters and exhaust fans. Condensate and washing water are collected in the sump, and conveyed from there via a pump to the spray system. Due to condensation of the water-vapour-containing exhaust air in the washer and the heat exchanger, approx. 150 kg/hr of condensate passes into the plant collection container. A second pump pumps the excess wash liquor into an emulsion separator for further disposal. Cooling air is sucked in through dust filters. The cooling air then passes into air-to-air type nozzle mixing plate heat exchangers, where it is heated up by exhaust air and washing water, and finally blown into the atmosphere by means of a radial fan. Depending on the plant housing, the heated cooling air and the exhaust air coming from the washer can be combined and passed into the atmosphere via a collecting duct.

Since, in the stentering process, exhaust air and residual liquors together with dirty water occur simultaneously (Fig. 5), the obvious idea is to combine and couple exhaust air and effluent purification. This trig-

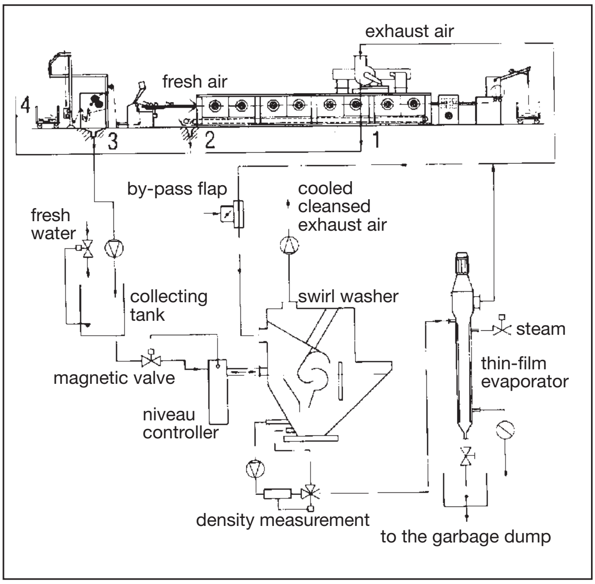


Fig. 5: Exhaust air cleaning system with concentration of residual liquors and effluent by evaporation in the swirl washer (Babcock).
1 = water from the automatic heat wheel or other recovery system cleaning unit; 2 = water from the automatic brattice cleaner; 3 = residual liquor and pad mangle cleaning water; 4 = other dirty water produced, e.g. from scouring or dyeing.

gered the idea of a swirl washer, the basic concept of which is to condense the dirty water and clean the exhaust air by washing in one operation. Processing cycle: the stenter exhaust air is fed into a swirl washer, where it is cleaned in a rotating air-water vortex and its resultant water screens (Fig. 6). Particles, fly and aerosols are enveloped by water droplets, and fall out because of their greater weight. Water-soluble gases and vapours are brought into solution by absorption. Most of the vapours are condensed into fine droplets by cooling the exhaust air to cooling limit temperature (50–65°C).

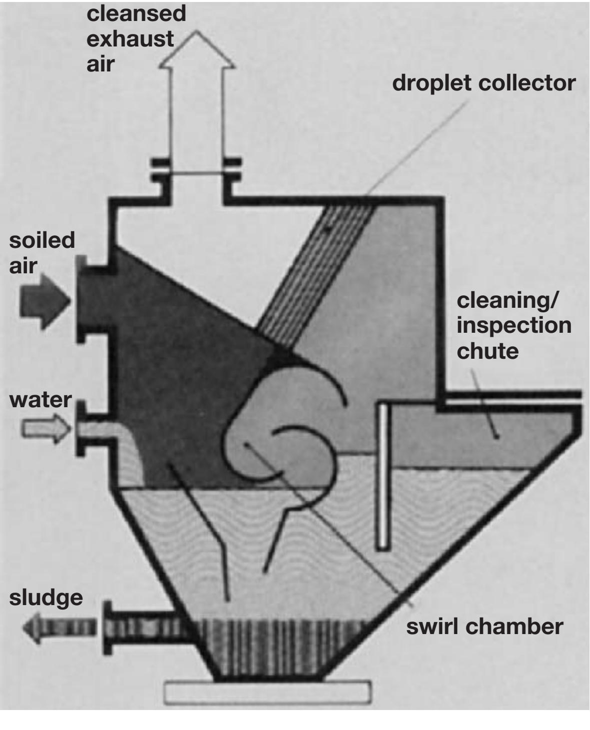


Fig. 6: Swirl washer for exhaust air cleaning (Babcock).

Droplet separators are located downstream of the swirl chamber so that no water is entrained by the airflow. The energy removed from the exhaust air during cooling becomes available for evaporating the washing water. Here are two examples for illustrating the order of magnitude:

a) Drying process:
   Hypotheses:
   – exhaust air temperature 130°C
   – exhaust air humidity 100 g/kg
   – exhaust air quantity 10 000 m^3/hr = 8759 kg/hr

This produces a cooling limit temperature of 57°C in the washer, and an exhaust air humidity level of 132 g/kg. Thus, 32 g of water/kg of air, and therefore 280 kg of water/hr are evaporated.

b) Heat setting process:
   Hypotheses:
   – exhaust air temperature 160°C
   – exhaust air humidity 30 g/kg
   – exhaust air quantity 7000 m^3/hr = 5706 kg/hr

This produces a cooling limit temperature of 48°C, and therefore an exhaust air humidity level of 75 g/kg. Thus, 47.5 g of water/kg of air, and therefore 271 kg of water/hr are evaporated.

The swirl washer liquor level is sensed via a level controller, and the evaporated water quantity supplemented from the supply tank. It is basically possible to utilise all the dirty water produced on the stenter and also other dirty water produced in the works for operating the swirl washer. Fresh make-up water must be fed to the supply tank in case of need, but in fact only when there is either insufficient dirty water available or when concentrations of slightly volatile organic substances are present in the washer.

Approx. 75% of the water content is gradually evaporated in the swirl washer, the pollutants being concentrated in the washer sump. As soon as a specifically set density is reached, the concentrated washing water is automatically conveyed into a steam-heated thin film evaporator (Fig. 7), in which the residual water is largely evaporated to a pollutant-saturated sludge. The heated washing water is distributed in a thin film on the inner wall by means of rotor blades, the water evaporating and the solid matter being scraped off. The vapours are again passed through the swirl washer in order to exclude troublesome odours during evaporation. The remaining residual sludge (max. 10% of the residual liquor content) should be dumped.

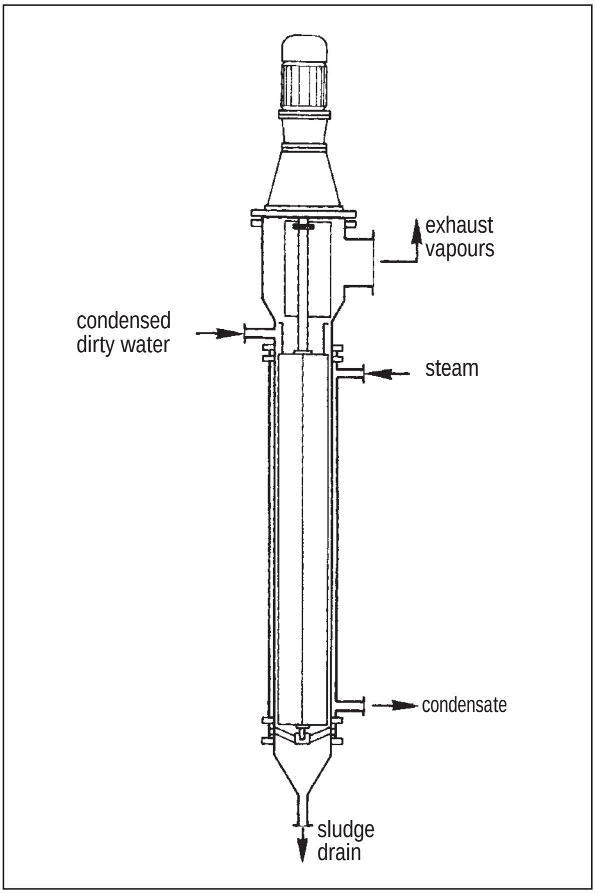


Fig. 7: Babcock thin layer evaporator.

The energy expenditure necessary for operating this combined system (necessary electrical energy relative to the above-mentioned drying process example with an exhaust air quantity of 10 000 m^3/hr) is: for the blowing operation, approx. 15 kW for overcoming the heat exchanger air resistance of approx. 200 water column, approx. 0.5 kW for the circulating pump, and approx. 1.5 kW for the thin film evaporator stirring unit. Steam is also used for operating the thin film evaporator. This requires approx. 125 000 kJ for evaporating approx. 50 kg of water/hr, i.e. 55 kg of steam/hr.

IV. Adsorption: adsorbents are substances which are capable, due to their pore volume and pore structure, of selectively bonding gases, vapours or liquids. On efficiency grounds, they should have specific properties:

- large specific surface, high porosity,
- a high degree of selectivity for the specific substances to be adsorbed,
- a high adsorption capacity for the substances to be adsorbed
- good regenerative capacity,
- resistance to chemical and physical effects (temperature and acid resistance, ignition point),
- good mechanical strength and hardness (important with moving bed adsorbers).

Adsorbents generally differ as regards pore volume and the nature of their chemical surface. Activated charcoal has a much higher pore volume than other adsorbents, and consequently has the largest specific surface. This active charcoal advantage also explains the high adsorption capacity which applies generally to organic substances. Another reason why activated charcoal is used for preference in exhaust gas cleaning is its versatility. This versatile use of activated charcoal as compared with other adsorbents clearly reveals the importance of this substance. Activated charcoal is produced (dry distillation) by heating prepared carbon-containing substances (wood, bones etc.) in the absence of air. Aluminium oxide, silicagel and molecular sieves can be used only in specific cases, and have the disadvantage of readily absorbing a great deal of moisture. In exhaust gas cleaning, granular adsorbents with a grain diameter of 1–8 mm are used exclusively. Once used adsorbents can be used again for adsorption (recovery of the adsorptive as a valuable material if need be) by regenerating the adsorption medium. Two processes determine regeneration:

- desorption,
- downstream reactivation if necessary.

As the adsorbed quantity is favoured by rising partial pressure and low temperatures, desorption should be effected as far as possible by pressure reduction (relaxation) and heating, and also by means of displacement by a slightly adsorbent substance (frequently steam). The various regeneration methods can be used in combination. The method of bonding the adsorptive to the adsorbent generally determines the following desorption methods:

a) Temperature change process: the adsorbents can be regenerated by adding hot steam or hot gas, the steam or hot gas acting as auxiliary media for absorbing and removing the released adsorptive. The disadvantage of this equipment is that long cycle times occur due to the long heating and cooling periods. This can be a matter of hours.

b) Pressure change process: the increased pressure in the adsorber is sharply reduced by pressure reduction or evacuation. The released adsorptive is carried away by a scavenging gas, or is suction extracted. This process is used when there is a high concentration of impurities, as the temperature change process would require a much longer time. An order of size of minutes is involved here.

c) Extraction with solvents: the adsorptive is brought into solution with a suitable solvent, and removed from the adsorbent surface. When extraction is complete, the adsorbent must be removed from the extracting medium. This is effected by thermal desorption.

d) Reactivation: reactivation means reproducing the adsorption capacity of damaged adsorption media, i.e. of those, the adsorptives of which cannot be separated (or can only be incompletely separated) by desorption owing to their low volatility or solubility. This applies for example to granular activated charcoal which has been damaged by organic substances because the organic impurities carbonise inside the pore space.

In addition to electrostatic particle separation (1913), the adsorptive removal of organic components (1917) is one of the oldest basic operations to have been put into effect technically in the "clean air" sense. It means in principle that adsorbents are suitable in this application range only for separating gas and vapour-state pollutant components (adsorptives) from exhaust air/exhaust gas. For separating aerosols, airborne particulates and mists, systems which are located upstream of the adsorption process itself, and are based on other processing principles, should be brought into use. The selection of adsorbents utilised for a specific purpose presupposes knowledge of their properties and of the components to be adsorbed. Influencing factors like temperature, concentration, relative humidity etc. are parameters which are of great importance as regards design. Suitable interrelationships are being worked out in laboratory or semi-industrial trials.

The effect of concentration and temperature on the load capacity of (in this case) single-pore activated charcoal can clearly be seen in the equilibrium isotherms of dichloromethane (Fig. 8). These and a range of other characteristics require thorough examination, including estimation of the serviceability limits of adsorption. Examples in this direction are available where the cleansing of large quantities of air with low pollutant concentrations are concerned, where components present in the exhaust air block the activated charcoal pore system, where reprocessing after regeneration necessitates disproportionately high expense, or where problems lately linked with odour emission crop up by way of solution. Occasionally, it has also required the conducting of semi-industrial trials, as directly as possible at the source of emission, or consideration of possible alternative solutions.

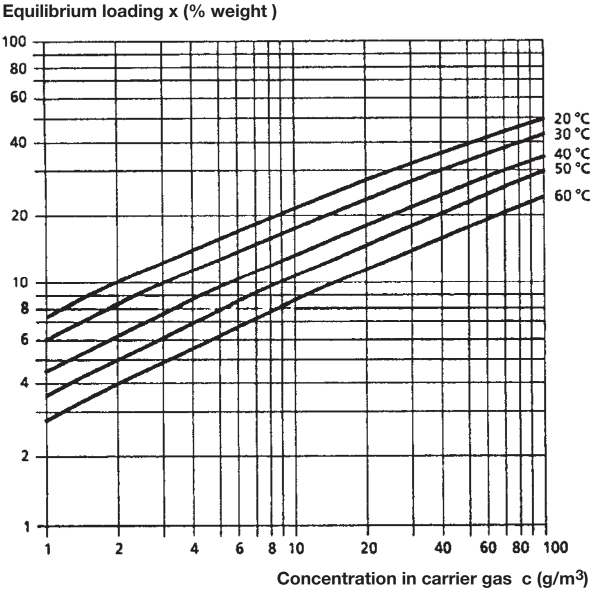


Fig. 8: Adsorption isotherms of dichloromethane on to activated charcoal with dry air.

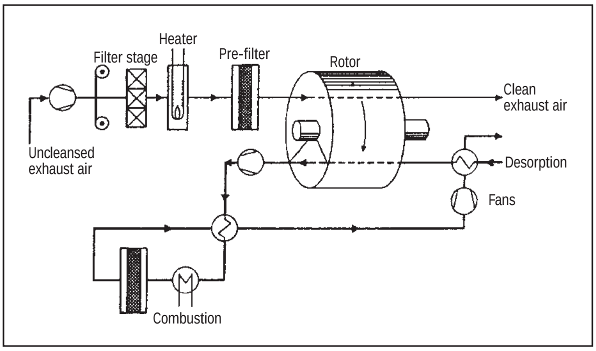


Fig. 9: Flow diagram of an exhaust air cleaning process based on the rotation principle.

In a packed bed adsorption process, at least two adsorbers should be installed in order to create a quasi-continuous method of operation. Here, the packing consists of granular carbon, normally with a diameter of 2.5–4 mm. Ball carbon (0.7 mm), with its specific properties as regards moulding, hardness, particle size, kinetic behaviour on loading and regeneration, makes use of the fluidised bed technique possible. Whilst steam regeneration is pre-eminently state of the art with the packed bed, solvent is extracted by direct heating with circulated nitrogen as the carrier medium in the case of the fluidised bed process. This dry method is indicated when recovery of water-soluble and/or easily decomposable solvents is involved.

The activated carbon fibres are bonded in different types of matrix for mechanical stability, and can be made technically applicable in the form of mats, webs, felts and fabrics. In the case of ball carbon and fine-grained activated carbon, application on ceramic material has gained acceptance. Rotors (Fig. 9) have become accepted as a constructive solution for the use of these commercial forms. These types of system are used pre-eminently for concentrating the organic components, i.e. the main fields of application will be large quantities of air with a low pollutant concentration, and other exhaust air cleaning concepts (such as thermal combustion) will be excluded for various reasons. Regeneration is mainly effected with hot air. The so-called secondary air occurring here is highly enriched with organics, and can be fed either to a small combustion unit or to an additionally installed recovery plant.

Exhaust air dampers, regulation of Drying refers to evaporation of water. The resultant water vapour must be discharged from the dryer so that new water can be continually evaporated. A mixture of hot air and water vapour leaves the dryer via the exhaust air duct. The energy required to heat the air makes up a significant proportion of the overall costs involved in operating the machine. The hot air/steam ratio is therefore a contributory factor in determining the economic efficiency of the entire drying process and must be considered more closely as the energy costs rise. The quantity of water evaporated per unit of time varies continually depending on the fabric weight, infeed and residual moisture, width of fabric and speed. It is not possible to achieve the most efficient use of hot air by constantly adjusting the exhaust air damper. Instead, the moisture content of the exhaust air must be constantly measured and the air dampers and extractor fans must be adjusted in line with the drying conditions or be automatically regulated.

Fig. 1 shows the extent to which the costs of heating a dryer are dependent on the required volume of fresh air and consequently on the steam content in the exhaust air. Whereas the evaporative capacity (A) is relatively flat, the cost index (B) rises steeply, especially where the exhaust air damper is wide open, i.e. the steam content is low. It is therefore recommendable to adjust the exhaust air damper so that there is maximum possible moisture in the exhaust air without the output being noticeably reduced. Exhaust air dampers and fans are controlled via servometers by the electronic control unit. If there are several exhaust air ducts, the various throttle valves can be tracked individually via the servo governor of a co-ordination centre. This makes it simple to take into account the different evaporative capacities within the individual drying chambers.

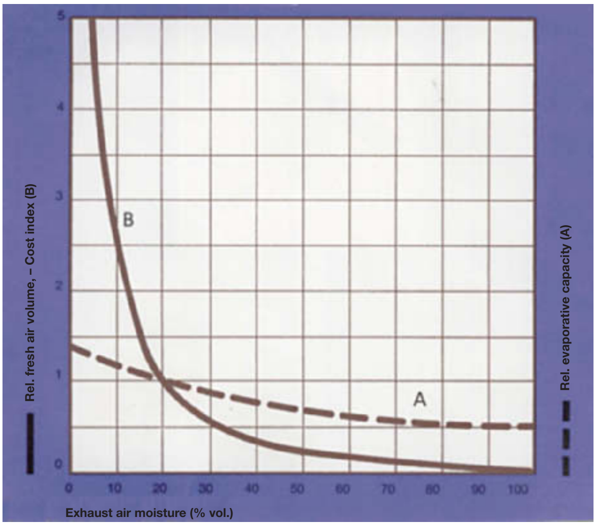


Fig. 1: Evaporative capacity and cost index during the operation of a stenter frame with different exhaust air moisture (Mahlo).

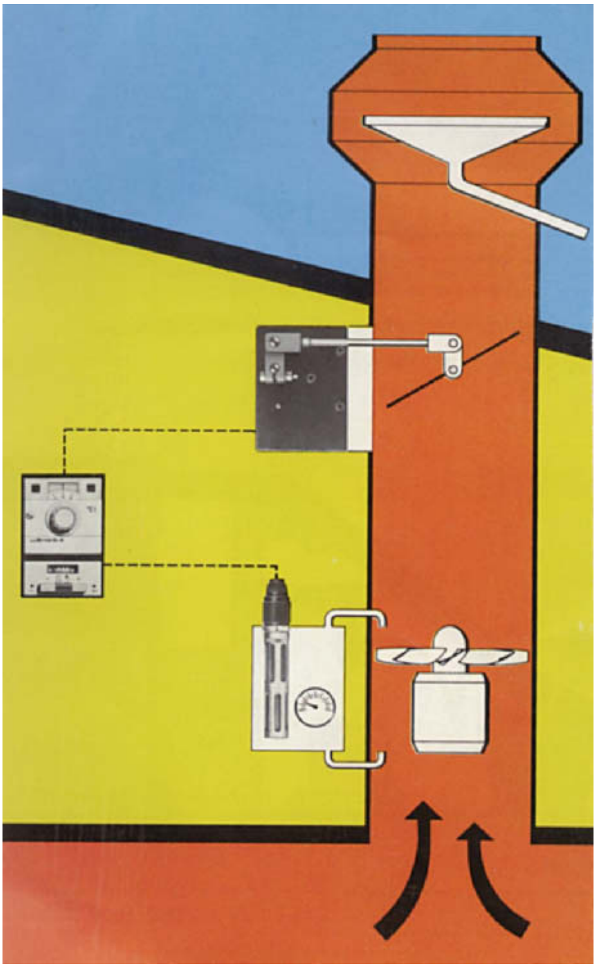


Fig. 2: Measuring the exhaust air moisture using sound in the Mahlo fluidic oscillator.

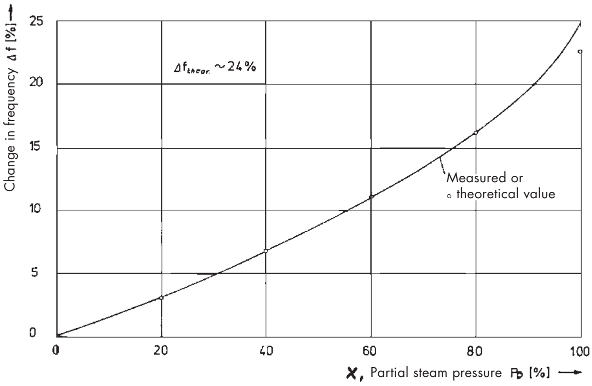


Fig. 3: Change in frequency (in %) of a fluidic oscillator in relation to the exhaust air moisture.

The measurement of exhaust air moisture is based on e.g. the different spread speeds of sound in air and water vapour (Fig. 2). A sound is produced in a source of sound (fluidic oscillator) which is directly exposed to the exhaust air stream. The pitch of this tone is dependent on the ratio of water vapour/air (Fig. 3). The frequency of the sound can be measured extremely precisely using heat-insensitive means. The influence of temperature on the pitch of the sound is compensated electronically.

The exhaust air moisture measuring systems consist of the measuring head with suction pump, oscillator, temperature compensation, sound pick-up and evaluation electronics with a display and operating elements. The measuring head can be introduced into the air evacuation duct or directly into the drying chamber as preferred (Fig. 4). An easily replaceable microfilter prevents the oscillator being contaminated.

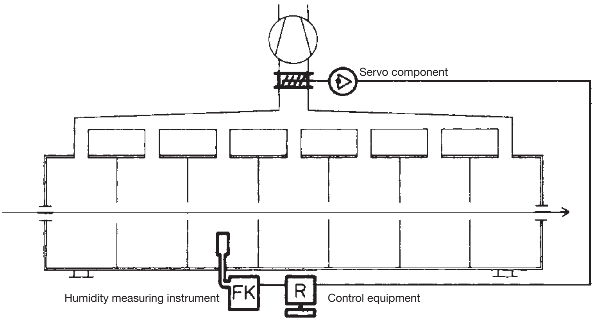


Fig. 4: Adjusting the exhaust air damper by measuring the moisture in the surrounding air in the seven-compartment drying stenter.

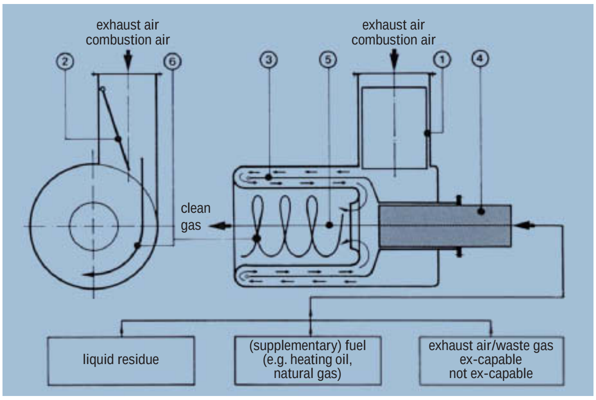


Fig. 2: Illustration of the two-stage burner principle.
1 = tangential entry; 2 = rotary valve; 3 = annular passage; 4 = organset; 5 = combustion chamber; 6 = rotary flow produced.

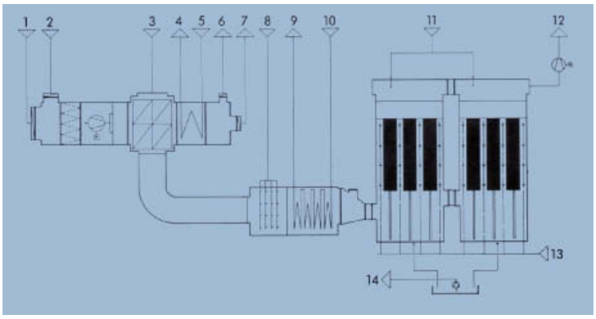


Fig. 3: Filter plant.
1 = external air; 2 + 7 = room air; 3 = crude gas; 4 + 9 = hot water; 5 + 10 = water at 20°C; 6 = exhaust air; 8 = saturated steam for cleaning; 11 = water just for initial filling; 12 = clean gas; 13 = steam; 14 = softener.

Exhaust air disposal Various processes are available for the disposal of exhaust air arising in textile finishing plants depending on the nature of the particular pollutants present:

I. Thermal combustion plants (Figs. 1 + 2) are recommended for the disposal of solvents and softeners. The solvents/softeners contained in the exhaust air are fed into a burner or combustion chamber where the exhaust air is mixed with additional fuel in order to reach the required reaction temperature of approx. 800°C for efficient combustion. Gas or heating oil can be used as the supplementary fuel.

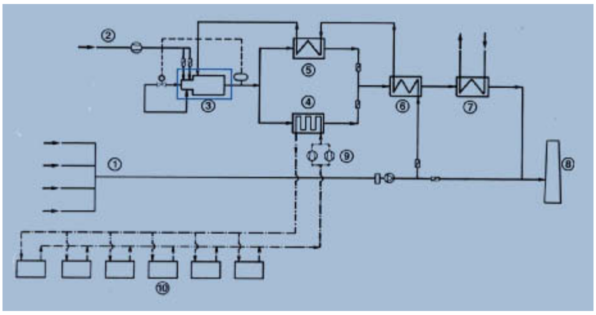


Fig. 1: Thermal exhaust air cleaning plant.
1 = exhaust air entry; 2 = supplementary fuel; 3 = two-stage burner; 4 = heating oil heat exchanger; 5, 6 + 7 = heat exchangers; 8 = chimney; 9 = thermal oil circulation; 10 = consumer.

The energy produced can be used for:

- heating thermal oil systems via a heat deflection chamber,
- preheating of incoming exhaust air via a heat exchanger,
- hot water heating systems.

Filtration plants are particularly suitable for exhaust air containing soft water vapours with aggressive pollutants (Fig. 3). The exhaust gases are cooled down to a temperature of approx. 40°C in a heat exchanger combination. The vapours are extracted through filter candles on the suction side of a high capacity medium-pressure fan which is designed as a diffusion separator. In this way, the softener aerosols which are separated off on layers of fibreglass within the filter candles agglomerate, and are drawn off as softener condensate from below. Energy liberated during the cooling process can be used for space heating or to produce hot water.

II. Adsorption and condensation plants: used in the solvent processing sector and manufactured to individual specifications.

Exhaust air, driers Drying processes produce water vapour as exhaust air (air saturated with water). This may contain pollutants. Before we consider exhaust methods for cleaning, the options to reduce emissions by using chemicals and processes which are low in emissions should be fully exploited. There is a wide range of physical, chemical and thermal methods available to clean exhaust air (→ Exhaust air, cleaning of). It has only been possible to establish a few options within the European textile finishing sector (see Tab.):

- Adsorbing substances (e.g. activated carbon),
- Exhaust air washers,
- Combustion of the exhaust air.

Process	Examples for application
Absorption	Washing columns
Adsorption	Activated carbon filter
Combustion	Introduce exhaust air into the boiler as combustion air
Condensation	Condense off exhaust vapours using condensers
Filtration	Fibrous matting
Biofilter	Conduct through special earths

Tab.: Basic options to reduce emissions in exhaust air.

The simplest and most cost-effective way to ensure low emissions from chemicals and processes is to prevent emissions occurring by selecting appropriate chemicals and processes. This avoids making repeated expensive investments and maintains operative flexibility. Unfortunately at present there are still no recognised methods and assessment criteria for testing and comparing chemicals and processes used in finishing. It is the task of the Chemical Industry and the Textile Processing Industry, the associations and authorities to complete the safety data sheets with meaningful information concerning the behaviour of exhaust air. One option is the thermogravimetric analysis (TGA) of products. With this method, a sample of the substance is exposed to a defined air stream at a prescribed temperature and the reduction in weight is recorded and assessed in relation to time. The figure shows the evaporation and sublimation losses of two fabric softeners. Substance B displays a considerably higher volatility than substance A. It is therefore to be expected that substance A results in lower exhaust air pollution.

The use of activated carbon adsorbing substances is state-of-the-art with processes using organic solvents. A whole range of plants are available in dry-cleaning and textile finishing works. If exhaust air merely contains water and solvent vapours, then adsorption and subsequent thermal desorption is in principle unproblematic. Unfortunately, exhaust air from drying machines and stenters contains emitters (e.g. lints, softeners, resin components and their cleavage/reaction products) which form greasy deposits on the activated carbon and therefore reduce the adsorption capacity. In addition to the considerable reduction in serviceable life, regeneration becomes a problem.

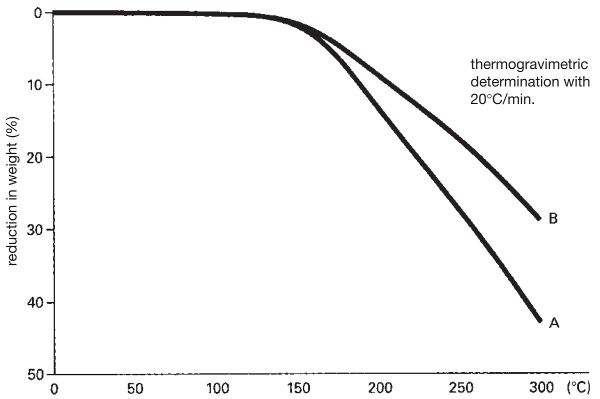


Fig.: Evaporation/sublimation of chemicals (source: Ciba-Geigy).

Exhaust air washers consist of a container in which the aqueous washing liquor (e.g. water possibly with acids, leaching solution, oxidation agents etc.) is sprayed from top to bottom. Waste air is exhausted counter to the current. Exhaust air emitters which are easily water soluble, or substances which react with the chemicals in the washing liquor are eliminated from the exhaust air. The evaporation of the water causes the air flow to cool and water-insoluble vaporous compounds are condensed out depending on the boiling point or the vapour pressure. A wide range of organic compounds remain in the exhaust air, with the remainder passing into the atmosphere as aerosol. The waste air from resin finishing processes only retains 40–60% of the carbon pollutant after being treated in the exhaust air washer. It is not possible to eliminate the remaining exhaust air pollutant using washers.

In recent years, the incineration of exhaust air as air for combustion in the boiler room has become established as an alternative. A number of textile companies have such plants. Several important prerequisites are necessary to ensure safe and economic operation:

- The resultant exhaust air should not exceed the amount of air required for combustion.
- It must be ensured that the occurrence of exhaust air coincides simultaneously with the operation of the boiler or burner.
- The introduction of the exhaust air into the boiler room represents the largest proportion of investment costs. Large distances result in disproportionately high costs.

In many cases, the amount of exhaust air is too large for the boiler room or the gas or oil fired stenters run even when the boiler room is not in operation. Under these circumstances, it can be useful to operate a spec. burner with a large air surplus as an exhaust air combustion plant. Using an economiser and warm water generation, the energy requirement for the combustion of exhaust air can be kept to a minimum. This solution would only be economically viable if there was a need for the warm water produced.

Exhaust air filter In the case of air-conditioned textile finishing departments, both the circulating air as well as the exhaust air must be filtered. Because of the high throughput volumes, large rotating drum filters are used for this purpose (see Fig.).

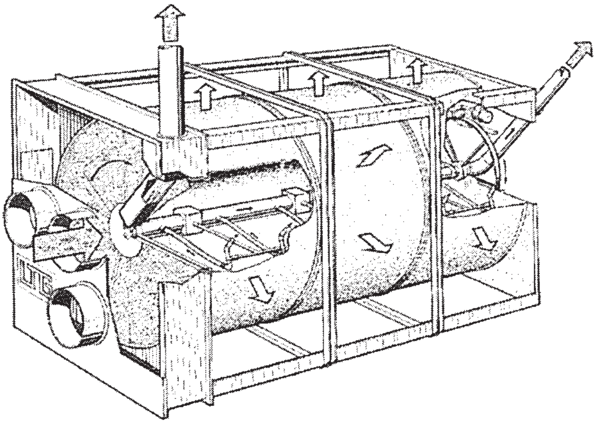


Fig.: LTG exhaust air filter with long nonwovens drum.

Exhaust air heat recovery Exhaust air from stenters, condensation equipment etc, contains a high quantity of energy in the form of heat in addition to moisture and impurities. Relative to m^3/hr of air throughput, there is, with an assumed exhaust air temperature of 80°C and 10°C outside air temperature (yearly average), a Q/m^3 air content energy loss of: Q = 1 m^3/hr, 80–10°C; 1.256 kJ/m^3 x °C = 87.9228 kJ/hr. At 3000 operating hours/year, this is equivalent to a figure of 263 768.4 kJ. Approx. 9 kg of fuel oil was required for producing this energy. A range of manufacturers offers tried and tested equipment for recovering heat from dryer exhaust air, based on the most usual air exchange. Secondary measures, which postulate the first stage of exhaust air optimisation as an effective primary measure, are involved. Heat recovery efficiency may not apparently be improved by processing with an increased exhaust air quantity, i.e. with a smaller vapour content in the exhaust air.

Heat recovery from effluent is feasible only if the temperature gradient between hot effluent and cold fresh water is big enough, and extensive quantities of fresh water and effluent can be exchanged (e.g. 6000 l/hr at any one time). The temperature of finishing effluent in wool textile finishing, especially from scouring, is only about 30°C, for which reason heat recovery in this wet finishing sector alone is not feasible. Recovery is offered in the case of exhaust air with a high energy content (on stenters).

From the processing technique standpoint, a distinction is drawn between regenerative and recuperative processes. The nozzle mixing plate heat exchanger is typical of recuperative processes. Recuperative processes are classified as follows:

- heat pumps,
- plate exchangers,
- circulation-linked ribbed pipe systems,
- tubular exchangers.

If one wishes to use the exhaust air from dryers in order to preheat fresh air in suitable heat exchangers, a number of basic prerequisites must be met: a) the energy-containing exhaust air must be available in ducted form and b) the energy content of the exhaust air must meet the specific requirements for energy recovery in both quantitative and qualitative terms in that the temperature and the quantity of air removed per hour are high enough to obtain economic recovery.

Quite the most important requirement is that energy recovery is possible only when energy is actually required at the same time and in a convenient location, to which the energy contained in the exhaust air can be returned (in fact in the linked system for example). For a stenter heat exchanger this means in concrete terms: the heat is taken from the contaminated exhaust air in order to preheat the fresh air without the two airstreams coming into contact with each other. The reheating required needs much less energy than the full heating required without energy recovery. The biggest problem is keeping clean the exhaust-side surfaces of the heat exchangers, as the exhaust air from stenters, used for example for drying wool fabrics, contains a great deal of fly and wool grease. A distinction is drawn between integrated heat exchangers per chamber of a single-pass stenter, which are easily cleaned by changing drawers, and external heat exchangers on multi-pass stenters.

Heat can be recovered via:

1. Direct air to air heat exchange (Fig. 1):

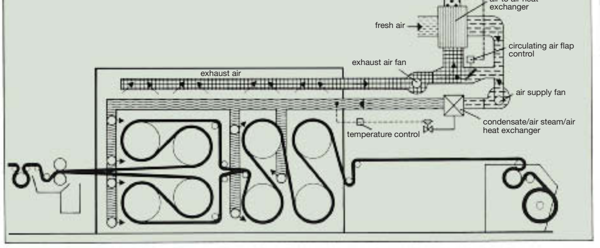


Fig. 1: Sizing machine with Wiessner heat recovery equipment (air to air).

2: Indirect air to air heat exchange via a heat transfer medium (Fig. 2):

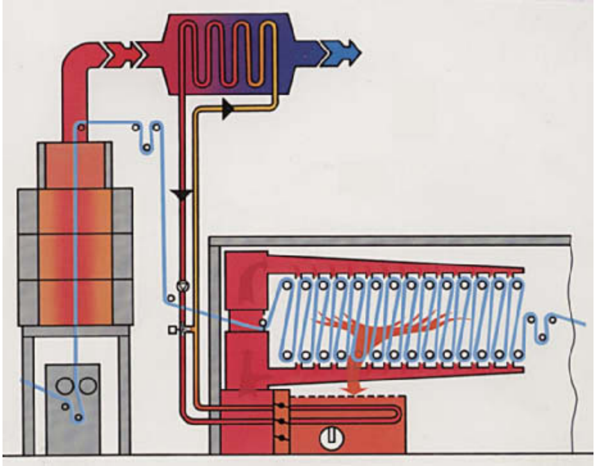


Fig. 2: Infra-red tower waste heat utilisation for heating a Hotflue in a continuous dyeing machine (Monforts).

3. Direct air to water heat exchange (Fig. 3):

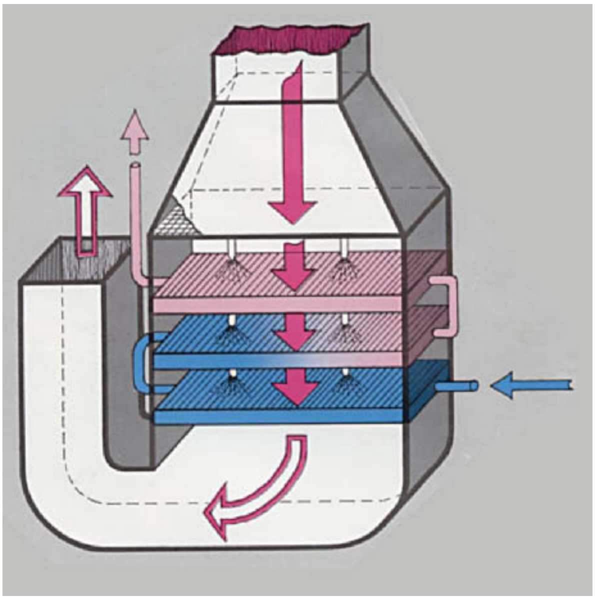


Fig. 3: Heating cold water with hot exhaust air for producing hot water (Krantz).

4. Combined air to air and air to water heat exchange (Fig. 4):

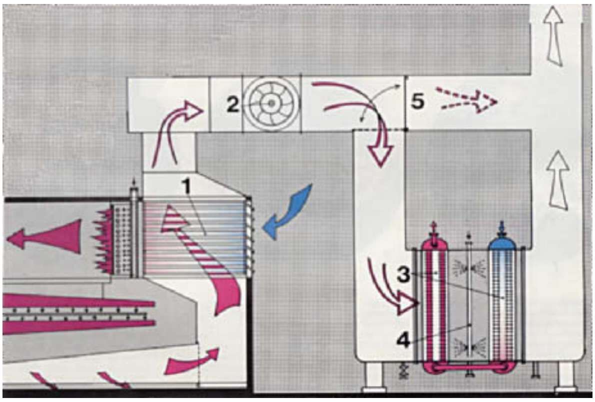


Fig. 4: Preheating stenter fresh air in a glass tube heat exchanger and producing hot water with hot air (Krantz). 1 = heat recovery; 2 = exhaust air fan, 3 = gilled pipe heat exchanger; 4 = cleaning jets; 5 = bypass flap.

Exhaust air moisture measuring systems These systems are used to measure the moisture of exhaust air in the exhaust air duct (driers) and to adjust the exhaust air dampers and fans accordingly using servomotors. This helps to prevent heat losses due to the exhaust air being too dry. Pleva FM 32 (developed by Pleva and Babcock) is almost maintenance-free and may even be used where the exhaust air is polluted. Principle: A small partial gas stream is passed through the measuring device. The actual measuring cell consists of a bare, straight stainless steel pipe in which gas is cooled below the dew point. The input and output temperature of the gas and the heat being discharged on the stainless steel pipe are measured. The gas moisture is then calculated in the computer. Measuring range: Moisture of 20–500 g/kg or from 10–250 g/m^3, at overpressures of 100–1000 Pa (0.001–0.01 bar) and temperatures between 70–250°C. The FM 915 (Pleva) operates with a lithium chloride measuring chamber.

The Mahlo AML operates on the principle of varying spread speeds of sound in air and water vapour: a sound is produced by a source of sound directly exposed to the exhaust air stream. The pitch of this sound is dependent on the ratio of air/water vapour. The frequency of the sound can be measured precisely using heat-insensitive means. The direct temperature influence is compensated electronically (→ Fluidic oscillator). Measuring range is normal up to 30% volume water vapour, and can be extended to 100% volume.

Exhaust air pollution measurement To record the emission in mass per unit of time, it is necessary to determine the concentration of the pollutant emissions in the exhaust gas and the volume flow. The following measuring systems are used exclusively to determine concentration. They are suggestions of how to record substances containing hydrocarbons and substances with intense odours.

I. Gas analysis using gas chromatography: With this method, selective adsorption is used in a column filled with an adsorbent. A small quantity of carrier gas (air, $H_2N_2CO_2$ or noble gas) is added to the vapour or gas mixture and compressed by an effective separating material (e.g. charcoal in the separation column). Pressure, time and volume remain constant. The components come together at different times and therefore reach the end of the tube separately. They can be recorded and measured or registered consecutively. The comparison of thermal conductivity between the carrier gas and the carrier gas measuring components provides a measuring voltage proportional to the gas concentration in question, which then converts an electrical potentiometric recorder into a “gas-phase chromotograph”. This method represents a quantitative analysis of gas mixtures, for the purpose of flue gas analysis, from hydrocarbon mixes and inorganic substances. A major disadvantage of this method is that continuous measurement is not possible. The equipment is both expensive to buy and to maintain. The detection limits are approx. 1–10 g/m^3 for organic carbon.

II. Olfactometer: Odour-intensive air pollutants can be recorded above the olfactory threshold value of the human nose. If the olfactory threshold of the nose is exceeded by a specific concentration, a sensation is triggered which can be divided into 3 dimensional categories:

a) The olfactory sensation can denote a specific quality. This represents the type of odour, e.g. bad eggs, released by H_2S, or fruity, released by specific esters etc.
b) The nose is capable of perceiving the specific intensity of the odour. There are several methods of scaling, the most common being the so-called category scaling.
c) The hedonistic effect of odorous substances describes the degree of acceptance between what is considered unpleasant and pleasant. It is recommended that a 9-level category scale is used to determine the hedonistic effect.

An olfactometer is a device used to dilute air samples. It can be used to dilute the odour samples to a specific concentration. Testers (known as jurors) compare the concentrations of the odour with pure air. The test is positive if the odour is detected, and negative if it is no longer possible to detect an odour. To determine the intensity of an odour, the perception is categorised into various response categories:

0 = no smell,
1 = very weak,
2 = weak,
3 = clear,
4 = strong,
5 = very strong.

The evaluation of the intensity measurements can give the olfactory threshold level. The measuring results of the various jurors are evaluated statistically; a Gaussian distribution curve is drawn up and the average value is calculated. To determine the olfactory threshold or the concentration of the odour, the unit GE/m^3 has been input with the olfactometer. With this method, continuous measurement is not possible.

III. Radiation absorption (infrared gas analyser): Gases made up of different types of atoms absorb certain areas of the spectrum from transmitted light in the ultrared and infrared areas (thermal radiation), giving rise to either spectral or absorption lines. The energy absorbed during this process causes an increase in pressure and temperature which is measured and recorded using resistance thermometers. This method also has the disadvantage that continuous measurement is not possible.

IV. Flame ionization detector (FID): This uses the ionisation of organically bound carbon atoms in a hydrogen flame as a reading. The ion current arising as a result in an electric field is strengthened and displayed electrically. The intensity of the ion current is dependent on the number of organic carbon atoms in the exhaust gas being analysed, both in terms of the form of bonding and the bonding partners and on the type of equipment and its use. The switching principle of a FID shows clearly that an electric field is connected across a pure hydrogen flame which burns when it comes into contact with air free from hydrocarbons. As soon as a measuring gas with organic bonds is introduced to this flame, a measurable ion current arises. The measuring signal is proportional to the number of hydrocarbons added which are not oxidised. In order to be able to determine the concentration of the gas to be measured, the measuring range of the device must be calibrated. In order to achieve this, a zero gas (e.g. pure N_2), which has a zero concentration of hydrocarbon atoms and corresponds to the neutral point electronically, is added to the measuring gas stream. The device is consequently set at zero. Secondly, a specific concentration of organic compounds is introduced into the device via the measuring gas stream. This is either a test gas or a calibration gas, which may be propane in synthetic air. As the proportion of carbon is known, it is possible to adjust the sensitivity of the device to the electrical value. After calibration has taken place, measuring can begin on the gas to be tested. The gas analyser requires 0.5 h before it is ready for use. A constant heating temperature is reached after this time which prevents any incorrect measuring results occurring. The sample gas pipe should also reach a temperature of up to 200°C. At this temperature, it is impossible for the exhaust gas to condense in the pipe. The sample gas pipe should also not be too long as this could cause a perceptible time delay in the measuring result. To guarantee the measurements, it is recommended that the pipes are rinsed with hydrocarbon-free gases every hour and that recalibration is carried out. The use of measuring devices with FIDs is suitable to measure the total of hydrocarbons present in the exhaust gases. Continuous measurement is possible using this method.

V. Qualitative and quantitative data (taking the recovery rate into account) is achieved by the combination of gas chromatography with mass spectrometry (GCMS) if the constituents of the exhaust air can be assigned using a computer library.

VI. Dioxin analyses are very expensive and can only be carried out by special institutes.

Exhaust air problems in textile finishing The discharge of airborne foreign matter into the atmosphere is referred to as emission, whilst the distribution, transport, and dilution of pollutants concentrated over the earth's surface is understood as immission. The pollutant concentration in a specific volume of exhaust air or exhaust gas can be measured. It is determined either as the mass concentration in mg/m^3 (generally based on standard volume, 0°C and 1013 mbar) or as the volume concentration in cm^3/m^3 = ppm (parts per million). Also expressed in emissions as the pollutant mass flow rate in kg/h.

In order to protect humans, animals, plants and material goods from harmful environmental effects, the Federal Immission Protection Law (BImSchG) came into force in Germany in 1974. The general administrative regulation contains the "Technical Instruction on Clean Air" (TA-Luft). This describes the state-of-the-art for reduction of emissions from specific types of industrial plant; dusts and gaseous pollutants are subdivided into three classes depending on the degree of environmental risk, and class-dependent maximum permissible exhaust air concentrations, so-called emission limits, have been laid down. In addition, limit concentrations for the most important air-polluting substances such as, e.g. chlorine and fluorine compounds have also been specified. The draft agreement of the German parliament of 21 February 1986 on revised limits for pollutants lays down the following emission limits for compounds in vapour or gaseous form:

1. Organic substances must not exceed the following mass concentrations even when several substances of the same class are present:

- in Class I: 20 mg/m3 at a mass flow rate of 0,1 kg/h or above;
- in Class II: 100 mg/m3 at a mass flow rate of 0,3 kg/h or above;
- in Class III: 150 mg/m3 at a mass flow rate of 3 kg/h or above.

2. Specific limit concentrations for enclosed working areas have also been drawn up. The so-called MAK limit (maximum workplace concentration) is defined as the maximum workplace concentration limit of an immission measured at breathing height.

3. The MIK limit (maximum immission concentration) of air-polluting substances is defined in VDI Guideline 2306 as "those concentrations present in layers of the free atmosphere near to the ground or, in the case of dusts, those quantities precipitated on to open ground which can, in general, and in the present state of knowledge, be regarded as harmless to humans, animals and plants after exposure for a specific period of time and frequency." (MIKD limits for continuous exposure, and MIK limits for short-term exposure).

4. Dust is understood to be the sum of all solid particulate matter in the air which is apparently held in suspension due to its high resistance. This phenomenon is based on the premise that the settling rate of particles is of the same order as the ascending thermal force or other air movement. Dusts are subdivided into 3 groups depending on their particle size:

- aerosols (<0,001 mm),
- fine dust (0,001–0,02 mm),
- coarse dust (0,01–0,2 mm).

5. The most important chemical pollutants in air are:

a) carbon monoxide,
b) nitrogen oxides,
c) sulphur compounds.
d) ozone,
e) halogen compounds: especially chlorine, bromine and fluorine compounds,
f) volatile hydrocarbons (aliphatic and aromatic) and their oxidation products (e.g. aldehydes and ketones),
g) products of incomplete combustion containing polycyclic aromatic hydrocarbons (e.g. 3,4-benzopyrene),
h) substances with foul-smelling and aggravating odours.

The polluting constituents of exhaust air from stenters in textile finishing plants include a wide range of different chemicals such as, e.g.:

- aldehydes as crack products of coning and spinning oils,
- formaldehyde from resin finishes,
- organic acids from reactive prints,
- solvents,
- carriers.

Textile fabrics can also be a source of air pollution problems (e.g. in the finished goods store of a textile finishing plant or at the consumer). The action of NO_x gases on the yellowing of white goods due to reaction with fluorescent brightening agents can also be regarded as an air pollution problem. Even the destruction of dyes on the fibre due to NO_x gases has also been observed.

Exhaust air segregation in stenters If the temperature of textile fabric being dried in a horizontal stenter is measured (see Fig.), cool zone temperatures (approx. 50–60°C) are encountered in the first sections

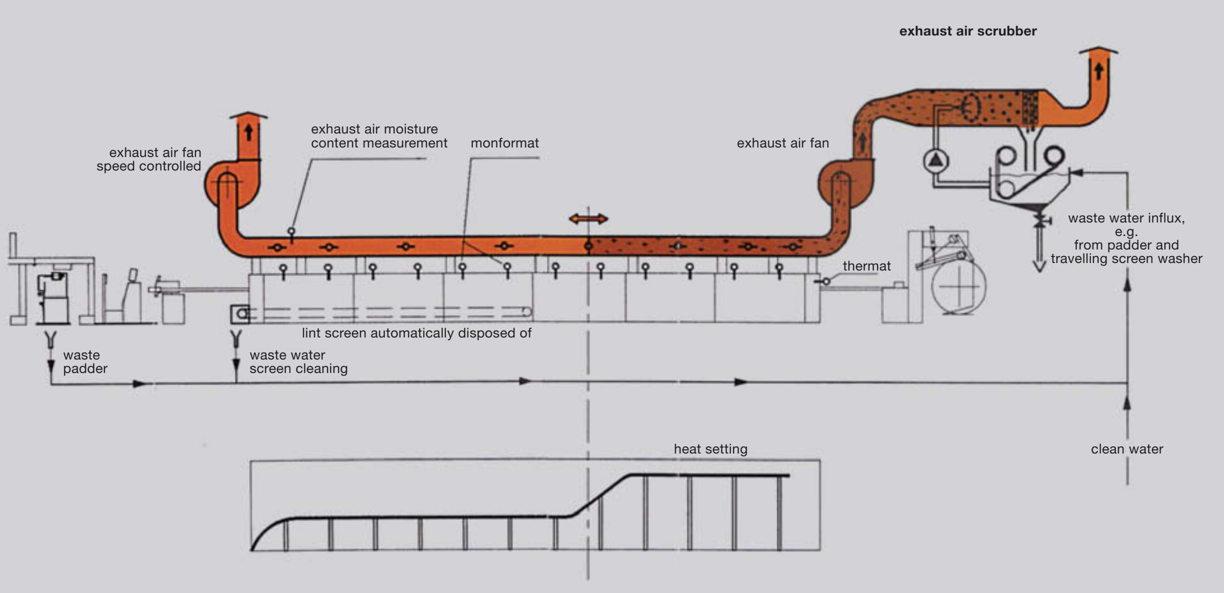


Fig.: Control of exhaust air pollution in the front and rear sections of a horizontal stenter with the Monforts Monformatic process control (cooling limit temperature measurement).

of the drier. At these temperatures, the water which evaporates from the fabric is not accompanied by large quantities of potential exhaust air pollutants which could be carried over by steam distillation or evaporation. This part of the exhaust air stream therefore only has a low level of pollution and can probably be discharged without cleaning. By contrast, the exhaust air stream from the last sections of the stenter, where the fabric temperature reaches that of the circulating air, is more highly polluted and must be cleaned before discharge.

Exhaust curves for dyes (Affinity curves, migration curves). These make it possible to take a direct reading of the quantity of dyestuff which has been absorbed by the fibre in a given dyeing time and temperature. In reactive dyeing, a distinction is to be made between the exhaust curve and the fixing curve. If the latter is subtracted from the former, the portion of non-fixed dyestuff is obtained (Fig. 1).

There are many values which can influence a dyeing process. The most significant are: temperature, pH, dyestuff concentration, liquor circulation, liquor ratio, auxiliaries, quality of the substrate etc. If a dyeing process is observed under these conditions, this can be depicted as a line (integral curve) in a three-dimensional space with the dimensions, time, temperature and absorption level (dyestuff concentration). The projection of this integral curve on the temperature/time (T/t) plane then gives the temperature programme of the dyeing process. The projection on the A/t plane (A = absorption level) is a common exhaust curve (Fig. 2).

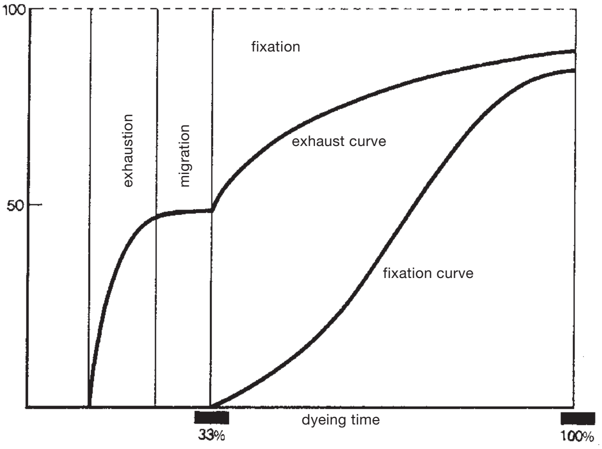


Fig. 1: Substantive adsorption and fixation of a reactive dye as a % of dye supplied.

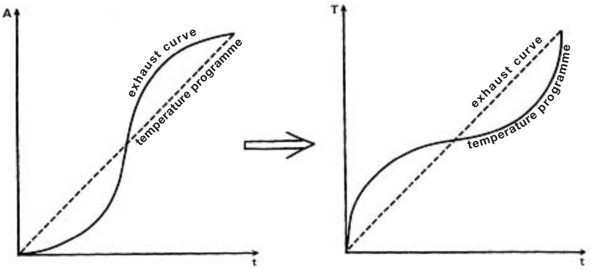


Fig. 2: Determining the temperature programme for linear exhaustion.

The temperature programme for a dyeing process with linear exhaust curve can be ascertained using rule of thumb, with the exhaust curve of a corresponding dye with a linear heating programme being reflected in this

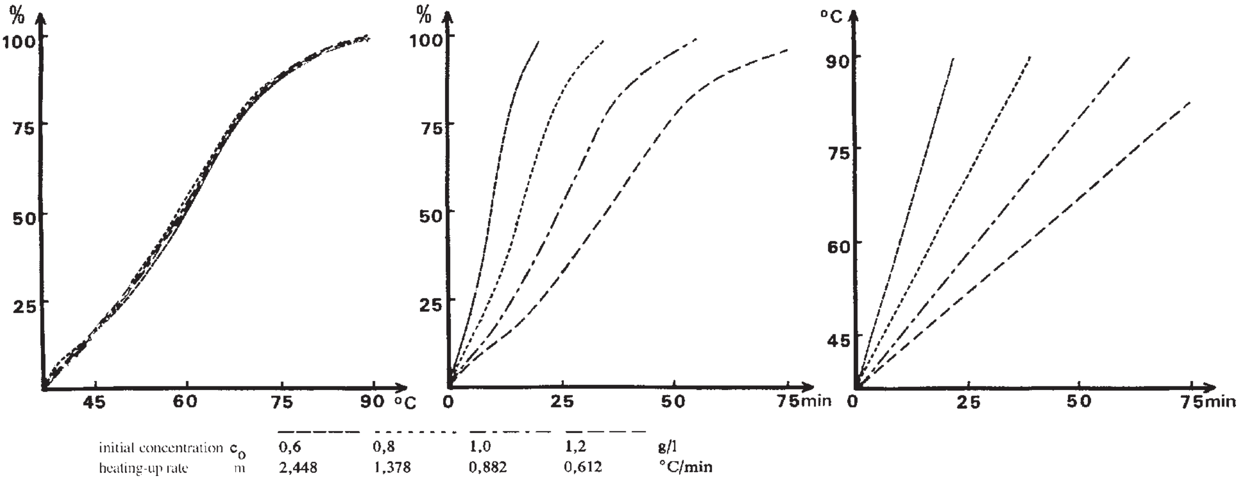


Fig. 3: Dyeing C.I. Acid Yellow 110 on Helanca polyamide 6.6 trico.
pH 5.5; auxiliary agent: 0.5 % Tinovetin JU (Ciba Geigy); liquor ratio 25 : 1.

(45° straight line). If this rule of thumb applies, then it follows that the projections on the A/T level of the integral curves of a linear heated and a corresponding linear absorbing dyeing process are the same.

Figure 3 shows the projection on the 3 co-ordinate planes of 4 different experimental dyes with linear temperature programme. It is obvious from the projection on the A/T plane that these 4 dyes have something in common other than a linear heating programme. This is not obvious from the exhaust curves and temperature programmes. The following relationship applies to the 4 dyes:

$$c_0 \sqrt{m} = 0{,}939 \text{ g/l} \cdot \frac{^\circ\text{C/min}}{2}$$

c_0 = initial concentration,
m = gradient of the temperature programme.

The initial temperature c_0 and the liquor ratio of all dyes is also the same. If the square root – time law (a law for isothermal dyeing) is fulfilled to a certain extent at every point in time and for each temperature reached, then it follows that the projections of the integral curves for these 4 dyes must be the same on the A/T plane.

Exhaust dyeing (diffusion) model The kinetics of dyestuff absorption (with no chemical reaction) by the fibre from the dyebath are described as exhaustion. After equilibrium has been reached, there is no further bath exhaustion, and the exhaustion process is terminated. The following approximate processes take place in exhaustion:

1. The dyestuff undergoes a phase change from the dye liquor in which it is dissolved by adsorption to the fibre surface, equilibrium occurring between the solid and liquid phases. The process is rapid.

2. This is followed by slow diffusion into the interior of the fibre, which is represented as a diverse consequence of desorption, diffusion and adsorption processes. Bath exhaustion is the relationship between the exhausted dyestuff quantity and the available dyestuff quantity as a function of time (t):

$$BE(t) = MF(t) / A$$

Under constant dyeing conditions, exhaustion curves show that the rate of exhaustion is initially high, but soon falls sharply. In the initial phase, BE ≅ Vt (Vt law), which approximates to Fick's diffusion with constant coefficient of diffusion D. The solution to this diffusion equation depends on the type of adsorption equilibrium: the Vt law applies both with constant surface concentration C_{ob} = saturation value S as also with Nernst distribution $C_{ob}(t) = k \times C_L(t)$ (k = constant partition coefficient; $C_L(t)$ = dyestuff concentration in the dye liquor), while an exponential law applies in the final stage of exhaustion. Complicated interrelationships apply for the radial concentration distribution of the dyestuff in the fibre, i.e. for the dye penetration time. The rate of diffusion is oriented to the dyeing temperature and the liquor/fibre concentration gradient, and therefore changes continuously during the exhaustion process in practical dyeing conditions. Diffusion models therefore describe only theoretical types of conditions.

Exhaust dyeing processes (→ Exhaustion processes).

1. Discontinuous, i.e. long reaction time: the necessary time must be allowed for dyes to exhaust from a dyebath on to a textile substrate (see Fig.)

2. Higher liquor ratios are used compared to continuous dyeing.

3. Dye concentration in the dyebath is considerably lower than in continuous dyeing.

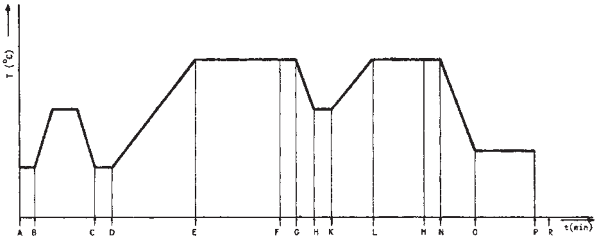


Fig.: Diagram of an exhaust dyeing process.
A = loading and filling; B = pretreating; C = dye; D = heating; E = maintaining temperature; F = sampling; G = cooling; H = adding; K = heating; L = maintaining temperature; M = sampling; N = cooling; O = after-treating; P = unloading; R = end.

Continuous exhaust dyeing is understood to take place when a textile material is run through a dyebath, and the amount of dye continuously added to the bath corresponds to the amount of dye which exhausts on to the substrate in the same time period. The term "exhaustion principle" refers to a process in which a dye previously dissolved or dispersed in a dye liquor exhausts on to a textile substrate. The process involves bringing a dye into contact with a textile substrate, its adsorption on the fibre surface, diffusion into the fibre and, finally, the physical or chemical bonding of dye to the fibre. In simplified form, this can be written as:

Textile substrate (undyed) + Dye ↔ Textile substrate (dyed).

Both the state of equilibrium itself as well as the rate of dyeing at which it is established are (together with the substrate and the dye) dependent on the following factors in the dyeing system,

- the temperature,
- the pH,
- the type of dyeing auxiliaries and their concentration, and dyeing can therefore be controlled with the aid of these parameters.

Development trends: more knowledge gained from measurements made in package dyeing should result in optimum sizes and forms of package; standardization of sizes and package density could lead to further rationalization in package dyeing. Control of dyeing processes by means of colorimetric measuring systems are already being applied to some extent. The development of new control possibilities utilizing → Exhaustion curve is proceeding apace. The standardization of programming systems for dyeing machine automation is recommended. Rapid dyeing and short-liquor dyeing technology now appears to have caught up with the advantages formerly associated with solvent dyeing. New systems must now be developed especially since dyeing from organic solvents can no longer be justified on ecological grounds. Foam and spray dyeing techniques are currently under development and, although these processes offer little chance for package dyeing, they offer greater potential in the piece dyeing sector. A certain development trend towards continuous exhaust dyeing is still at an early stage.

Exhaust gases (waste gases). Combustion gases from (coal, wood, oil, gas) fired systems, heating systems (flue gases) and internal combustion engines (engine and automobile exhaust fumes). In addition to oxides of carbon they also contain *inter alia* → Nitrogen oxide gases, traces of which can affect the → Colour fastness to burnt gas fumes of textiles dyed or printed with certain → Disperse dyes.

Exhaustion → Bath exhaustion.

Exhaustion constant SR The establishment of equilibrium is continually changed by reactive binding of dyestuff on the fibre under dyeing conditions (in the alkali area of → Exhaust dyeing processes). The exhaustion constant SR should be the ratio of fixed and adsorbed dyestuff and residual liquor in the bath:

$$SR = \frac{C_{\text{fixed}} + C_{\text{adsorbed}}}{C_{\text{residual liquor}}}$$

or

$$SR = \frac{\text{dyestuff exhausted}_{\text{(fixed + adsorbed)}}\ (\%)}{\text{residual dyestuff in the bath}\ (\%)} \cdot \text{reciprocal liquor ratio}$$

Exhaustion curve A graphical representation of the progressive exhaustion of a dyebath (bath exhaustion). It corresponds to the quantity of dye taken up by the fibre.

The distribution of dye between a textile substrate and a dyebath during the dyeing process is best illustrated by means of exhaustion curves. For practical purposes, bath exhaustion is represented as a function of time against linear increase in dyeing temperature. By comparing a number of exhaustion curves with different temperature gradients, it can be seen to what extent t the time necessary for bath exhaustion changes in relation to the temperature gradient selected (Fig.1).

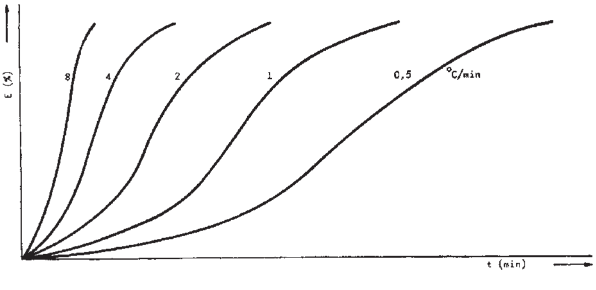


Fig. 1: Exhaustion curves at various heating rates; E = bath exhaustion.

If considerations of dye levelling were to be excluded, the conclusion that a maximum temperature gradient should be aimed at in order to shorten the process time must be reached. However, if a dyeing is to be commercially acceptable, it must possess a satisfactory degree of levelness appropriate to its end-use in addition to the desired shade and brightness which are dependent on uptake of the necessary quantities of dye. It is for this reason that there are clear limits to the max. temperature gradient which can be used in practice.

A significant rate of dyeing determined by a weighting of the exhaustion curves (integration) is responsible for dye levelling, and a critical rate of dyeing, at which the necessary degree of levelling is still assured, exists for each dyeing system (Fig. 2).

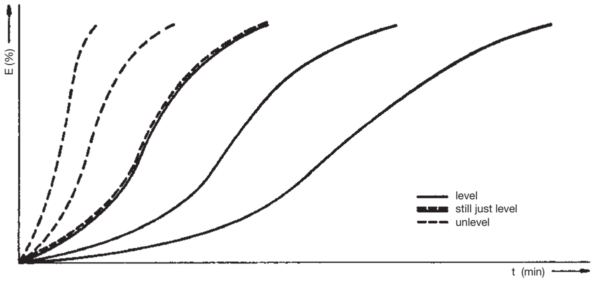


Fig. 2: Critical dyeing rate in exhaustion curves with a constant heating gradient; E = bath exhaustion.

The shortest time of dyeing can be achieved by linear dye exhaustion with the same critical rate of dyeing, although this would call for a complicated non-linear temperature progression (Fig. 3).

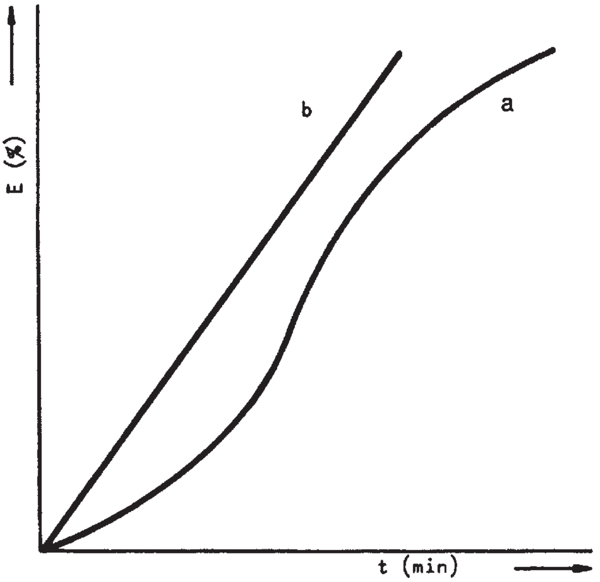


Fig. 3: Time required for heating phase at critical dyeing rate relative to the heating programme.
a = linear heating rate; b = linear dye exhaustion.

Although it has been known for a long time that the chances of obtaining a level dyeing rise with increasing liquor throughput, a connection with the dyeing machine only became possible after relating dye exhaustion to the number of liquor cycles according to the equation

$$F = \frac{100}{C \cdot D}$$

where F = minimum adsorption time,
C = liquor cycles per min,
D = relative percentual bath exhaustion per liquor cycle.

This equation does not, however, take into account the spatial characteristics of the textile material in the form of, e.g. yarn packages, as well as their likely consequences. The maximum allowed percentual bath exhaustion per liquor cycle, and therefore the shortest time of adsorption are dependent on

- the desired degree of levelling,
- the use of appropriate levelling agents,
- reversal of liquor flow,
- the homogeneity resp. non-homogeneity of the substrate being dyed.

In conclusion, it is conceivable for the heat up time to be reduced with the aid of frequent liquor reversal. On consideration of the fact that the heat up process must be able to accomodate the weakest areas of liquor penetration it is clear that, up to now, enough attention is still not being paid to the homogeneity of the textile substrate. In addition to the well-known problems caused by hard packages, variable winding densities within individual packages, non-uniform packing density of loose fibres etc., it needs to be emphasized that liquor circulation losses, in particular, can also arise e.g. as a result of incomplete sealing between yarn packages on dye columns, or incomplete coverage of dye beam perforations in beam dyeing.

Exhaustion processes (→ Exhaust dyeing methods). Processes which involve the desorption and absorption of dyes and textile auxiliaries from dyebaths due to → Substantivity (→ Affinity) for a textile substrate. The process lends itself to computer control (see Fig.). Opposite principle to → Pad process.

I. Fabric in rope form:

1. Principle: both liquor and fabric movement take place simultaneously: woven or knitted fabrics are sewn together lengthwise to form a single rope and stored randomly in the dyeing vessel in rope piece-dyeing machines (including HT versions); for small batch lots the fabric is sewn together to form an endless loop for continuous circulation with a dwell phase.

2. Continuous operation is also possible (e.g. afterwashing of prints).

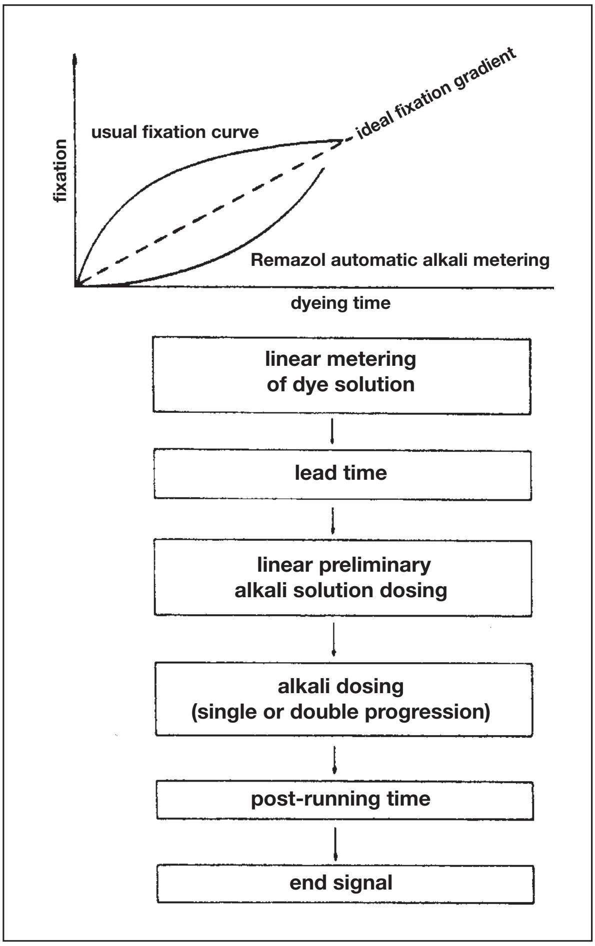


Fig.: Programming the entire exhaustion process with the Remazolautomat, ADC 200.

II. Fabric in open-width:

1. Principle: stationary fabric with liquor movement (circulating liquor): Woven or knitted fabrics are batched in a crease-free open-width state on a perforated beam for beam dyeing. Suitable for small batch lots.

2. Principle: stationary liquor with fabric movement. The fabric is batched in a crease-free open-width state and passes alternately from one batch roll to another through the dye liquor in a jigger. Suitable for small batch lots.

3. Principle: simultaneous movement of liquor and fabric: the fabric is treated in open-width and stored in widthwise folds. Suitable for small batch lots, sewn together to form an endless loop for continuous circulation with a dwell phase.

III. Textiles other than flat fabrics (loose stock, tops, yarn packages, warp beams).

IV. Made-up garment pieces (clothing, hosiery).

Exhaustion rate of dyes The time-dependent shift in the relationship between “dye in the bath” to “dye on the fibre” is dependent on the type of fibre, the condition of the fibre (pretreatment, fibre affinity towards the dye), dyeing method (liquor ratio, dyebath composition, dyeing temperature, pH), dye properties (solubility, fibre affinity, build-up properties, temperature-dependence, behaviour in combinations), and the dyeing equipment (temperature control, liquor circulation, packing of textile substrate in the case of loose fibre or yarn, movement of liquor and/or textile substrate). The exhaustion rate is also dependent on the → Levelling behaviour.

Exhaust rope piece dyeing machines The machine design trends for processing fabric in rope format focus on customising machine configuration to improve fabric appearance, reduce running costs and maximise productivity. Productivity gains are achieved by increasing machine loading and by reducing the production cycle times. These machine design trends can be summarised as follows:

- Classic woven and knitted cellulosic fabrics: low liquor ratio “Apple” configuration machines with hydraulic and/or mechanic fabric drive.
- Classic woven and knitted synthetic fabrics: “Banana” configuration machines operating at high running speeds, up to 600m/min, and in the range of 8–14:1 liquor ratio.
- Value added viscose, cupro rayon, polynosic, lyocell, polyester and polyamide microfibre and elastane containing fabrics: low liquor air configuration machines with special lifter reel and nozzle design employing hydraulic and/or pneumatic fabric drive.
- Tubular knitted cotton fabrics, perhaps containing 2–8% elastane: long liquor ratio wind-like atmospheric machines which are able to blow up the tubes thus preventing creases during mechanical drive (Krantz Blow Dye and Fong’s Dynawin).

In contrary to rope dyeing, open-width dyeing is performed on jigs or beam dyeing machines. The market trend towards short production runs has revitalised the long-established technology of → Jig dyeing for the coloration of woven fabrics. Developments in design that provide much improved wash-off performance and offer advanced levels of process control are offered. Beam dyeing, again a long-established technology is prominent. Focusing on the production of delicate and elastane containing fabrics, new designs that operate at lower liquor ratio are produced.

“Apple” Machine Configuration: The clear aim of all “Apple” machine designs is to offer the highest level of flexibility so that the widest possible range of fabrics can be processed. Common features of machine designs are nozzles to open and reconfigure the fabric rope to prevent running creases, plaiting mechanisms to prevent snagging and tangling of the rope and Teflon coated glide rods and chambers to assist the transportation of the fabric. The machine operates at low jet pressure to preserve the surface of the fabric and provide pristine fabric appearance, a key measure of fabric quality. Brazzoli and Thies offer programmable adjustment of nozzle dimensions to optimise the running properties of the fabric so that surface distortion is minimised for the full range of fabrics processed. The MCS Multiflow machine with its innovative design is unique. Its novel single rope, figure of eight, fabric transport system overcomes variations in liquor circulation that may exist in machines of generic design. By the increased number of liquor interchanges, the new liquor circulation system and the control of the liquor flow rate, it is now possible to process the entire production batch uniformly. Analogue level indicators with a memory function are an important development that allows control of fabric to liquor ratio throughout the process and will result in improved process reproducibility. Machines with the "Apple" configuration operate in the liquor ratio range of 4:1–8:1 for cellulose fabrics and 3:1–5:1 for synthetics and their blends. The design of the machines focus on a step change improvement in productivity. To achieve this step change, machine loading has been increased up to 250 kg/chamber, whilst process cycle times have been significantly reduced by the refinement of new application technology and modified operating procedures. Increased loading has been achieved by redesigning the geometry of the chamber and, in some cases, by running two ropes in each chamber. To optimise machine performance, allow a wide range of fabrics to be processed and allow smooth running of the fabric, Scholl and Thies have introduced machines with adjustable chamber size.

Progress has been made with "Smart Rinsing" technology. This option to continuously rinse with programmed volumes of hot water over a prescribed number of rope cycles and simultaneously raise temperature, inject chemical auxiliaries and cool is offered by Then. Thies offer the patented "CCR Superwash" system, Sclavos the "AquaChron" technology, Gaston County a revised "Low Wash" process and Scholl the "Pulsating Rinse". All these systems are controlled as pre-programmed functions in the machine microprocessor. These processes offer the potential to reduce the wash-off cycle time to 45–60 minutes; a saving of 60–120 minutes compared to conventional drain and fill techniques. There is scope for further productivity gains by the introduction of a simple colorimeter into the liquor circulation system. It would then be possible to wash-off to a defined endpoint and conserve water and time.

Salt injection systems have been introduced to further simplify operating procedures and reduce manual intervention. These systems can be integrated into the addition side tank (Sklavos, Thies) or can operate from a central dispensing system (ColorService, Lawer). Practical experience has shown that it is possible to make addition of chemical auxiliaries, dyes and chemicals in a very short time without disturbing level dyeing performance. The ability to add dyes in 1 minute and fixation alkali in 2–6 minutes provides new process design options and challenges the basic dyeing theory that led to the development of processes based on metered addition. Metering options for chemicals, chemical auxiliaries and dyes are standard on all machines. They offer linear, progressive and degressive addition profiles. Accuracy of dosing is enhanced when a reciprocating pump is used to continuously meter the liquor. These advances in the design of machines with "Apple" configuration complement BASF technology. The combination of BASF's drive for "Right-First-Time Through Control", the "eXceL – Controlled Coloration" concept (Fig.1) and leading edge dyestuff technology from the novel range of Procion XL+ dyes, fully exploits the best available machine designs and challenges traditional application methods. "Load to Unload" production cycle times can be slashed to ~ 180 minutes.

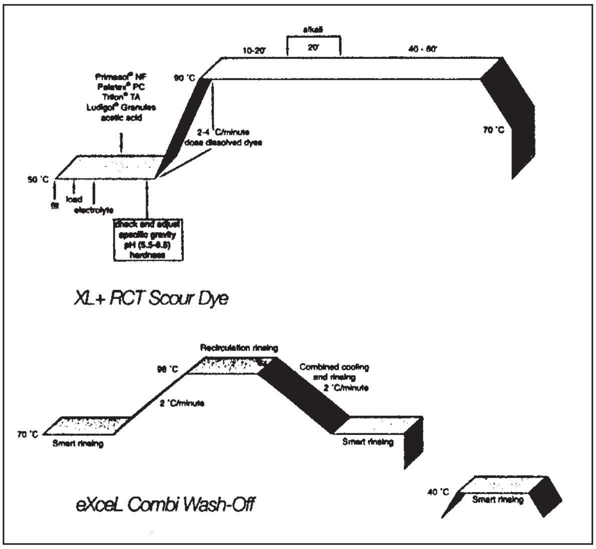


Fig. 1: XL+ RCT Scour Dye and eXceL Combi Wash-Off.

To this class of "Apple" type configuration belong also the "Aquadye" from Krantz, the corresponding Fong's machine and a Cabertex machine.

For classic fabric constructions Thies has introduced the compact eco-flow atmospheric dyeing machine with soft flow nozzle. A ballooning mechanism (air injection) provides crease free processing of tubular knitted fabrics. A feature exhibited on the eco-flow is the proVat plus system that has been jointly developed by BASF and Thies for the control of Indanthren dyeings. The system automatically monitors the redox potential of the rinsing bath. As the redox potential falls and reaches a predetermined level, rinsing is automatically stopped. This novel approach provides improved level dyeing performance, improved shade reproducibility and improved productivity. The Brazzoli Satumo HTFV 150 Superlux, a machine with Turbo-Vario nozzle design, focuses on production of Indanthren dyed fabric. The machine features ancillary equipment to maintain an atmosphere of nitrogen in the dyeing machine to reduce the concentration of hydrosulphite used in the process.

The development of upgraded, multitasking microprocessor machine controllers (Arel, Barco, Becatron, Setex, Termoelettronica) and the introduction into the basic machine format of full size stock tanks and dual-function addition side tanks, that are designed to service both the dyeing machine and the stock tank, mean that operating procedures can be carried out in parallel. By filling the machine from the stock tank the machine fill function is reduced to one minute, eliminating approx. 30–40 minutes from a traditional processing cycle for cotton. The full size stock tank can also be used to prepare the pre-treatment bath and dye bath in advance, utilising either the dual function addition side tanks to prepare the bath or by dispensing chemical auxiliaries, electrolyte and dye direct to the stock tank from the colour kitchen. These features of new operating procedures can reduce the processing time by 45–60 minutes.

Dyehouse management, who fully exploit the technical advances exhibited, have the potential to achieve a fully integrated, semi-automated piece dyehouse. This offers improved productivity without threatening Right-First-Time production rates, improved fabric appearance, reduced environmental impact of wet processing and drives down the unit cost of production. These developments in dyeing machine design and ancillary equipment complement quality and performance values set by the dyestuff and chemical auxiliary innovation programme.

“Banana” Machine Configuration: This long chamber type of jet or over-flow machine differs in downstream or up-stream flow of fabric and liquor. Developments of this machine design are aimed at improving fabric running characteristics, allowing higher productivity and greater versatility for fabrics with surface-sensitive construction or crease-sensitive synthetic fabrics. As well as dyeing set or unset polyester fabrics and polyester blends, these machines are generally also recommended for other difficult synthetics, such as lightweight woven acetates and polyamides. “Banana” machines operate between 8:1 and 14:1 liquor ratio, at maximum speeds of around 600 m/min. The latest machines from Hisaka, the Cut-SR (down-stream) and the Cut-MJ (upstream), feature a dual inner case along the dyeing tube, allowing uniform liquor drainage through a perforated plate, a wider angle of fabric over the reel and a new nozzle position, all resulting in a smoother running of the fabric and increased fabric loading. Increased productivity of 25% is said to have been achieved in practice with the new design, at speeds up to 700 m/min. together with higher product quality through reduced abrasion. Thies have improved their well-established Soft TRD machine by offering the Vario-nozzle option for greater fabric versatility. As with the “Apple” machines, a further option of a hot water tank is offered to reduce process cycles. Sample TRD machines for processing up to 50 kg fabric are now available. Brazzoli now offer a new “Banana-style” machine, the Sirio, featuring a Turbo-Vario nozzle to reach high production speeds at low pump pressure, synchronising liquor flow rate with fabric type. A bath distribution device in the top wall of the machine improves fabric/liquor interchange in weight-reduction, dyeing or rinsing cycles. The latest Rapid Suau machine from ATYC has metered liquor addition for greater accuracy in bath preparation and improved batch to batch reproducibility. To this “Banana-style” machine belongs also the Thenjet II, a configuration which is well established in wool fabric dyehouses.

Low Liquor Ratio “Airflow” Machine Configuration: Variants on the basic “Apple” design are offered by several manufacturers to deal with sensitive, high added value synthetic and cellulose-based fabrics, with and without elastane yarns, using either pneumatic and/or hydraulic fabric transport systems. Then, the originators of air-jet technology, have lowered the lifter reel and nozzle height in the Then-Airflow Aft machine. This reduces fabric tension and therefore improves fabric quality, especially in elastane-containing and lyocell fabrics. Scholl’s new Intensity machine, an evolution of their Softglider concept, is aimed at both sensitive woven and knitted fabrics. After passing through the jet nozzle the fabric accelerates down through the narrow intensive zone, before passing into the hydraulic upglide zone. Here, in the words of Scholl, “like the sky diver who opens his parachute and glides to a soft landing”, rope reorientation and efficient liquor interchange occur under tensionless conditions, minimising bruising and distortion of the surface of sensitive fabrics. Gaston County’s Millennium piece dyeing machine (Fig. 2) offers several new features designed to reduce fabric tension. A lower, high-traction lifter reel transports fabrics to the jet nozzle, from where they pass into a rectangular inclined tube. Here, cloth reorientation occurs under low-tension, “swimming” conditions.

The Thies air-stream has been designed to process modern fabrics such as lyocell, cupro, polynosic and micro-fibres. The machine operates at ultra low liquor ratio and utilises pneumatic fabric drive. MCS offers the “Air jet HT”. For dyers who find it difficult to decide between “Apple” and “Banana” configurations, Tong Geng of Taiwan presents a machine which claims to offer the best of both worlds, with their Model-ROL

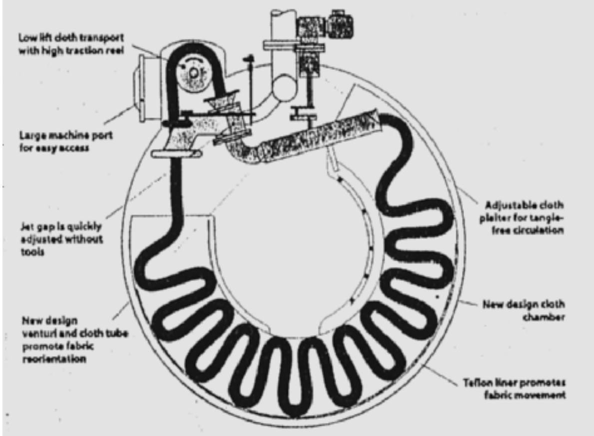


Fig. 2: Gaston County's Millennium piece dyeing machine.

machine, which combines a circular chamber with a long tube section. An air-based machine which is well established in the field of Tencel/lyocell fibrillation to obtain the so-called "peach skin effect" is the "Aero-dye from Krantz. Fig. 3 gives an overview of the process. After desizing, which is preferably carried out on the wide form, the next technical process is fibrillation inside the piece-dyeing machine. This primary fibrillation results in a very uneven, hairy look to the textile. After the primary fibrillation, a defibrillation process removes the fibrils from the surface of the cloth. During the next wet-finishing stage, for example dyeing, the so-called secondary fibrillation takes place, which produces the desired peach skin effect. The intensity of the fibrillation is affected by the following factors: 1. temperature; 2. time; 3. mechanical intensity of finishing process; 4. pH value. The sequence of these factors is not a statement as to their order of importance.

The following mechanical engineering requirements can be derived from the characteristics of the fibre which is to be fibrillated.

1. correct temperature and time control.

2. secure run of fabric throughout processing period.

3. high mechanical intensity of cloth propulsion method from high running speeds and impact zone.

4. minimal friction between textile surface and machine parts, especially where the cloth is moving at high speed.

5. good fabric transfer within the jet.

6. protective liquor feed which avoids faults in the appearance of the fabric at high liquor speeds.

7. good elimination of fluff after enzymatic defibrillation.

8. possibility of cleaning filter during operation.

Technical implementation in the Aero-dye: As to 1: Temperature and time control: Nowadays it is assumed that a machine will have a proper temperature and time control system, and there is no need to mention this as a requisite. There is a difference in the Krantz-Aero-dye

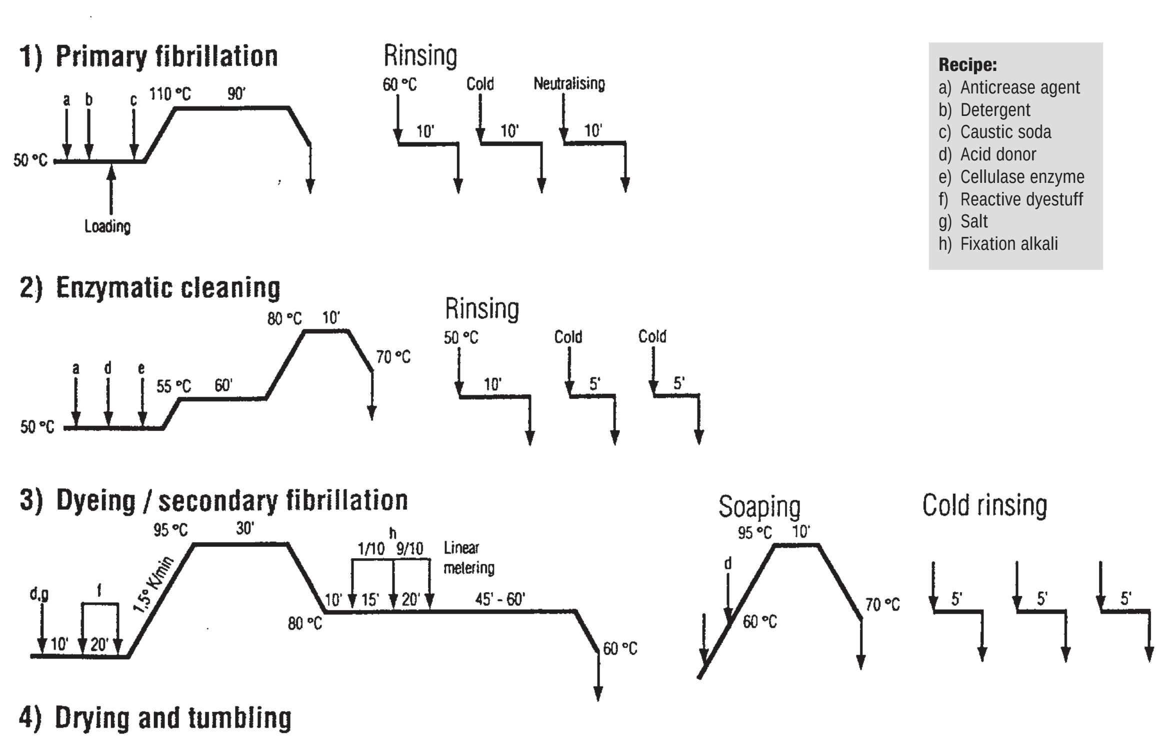


Fig. 3: Fibrillation process of Lyocell in "Aero-dye".

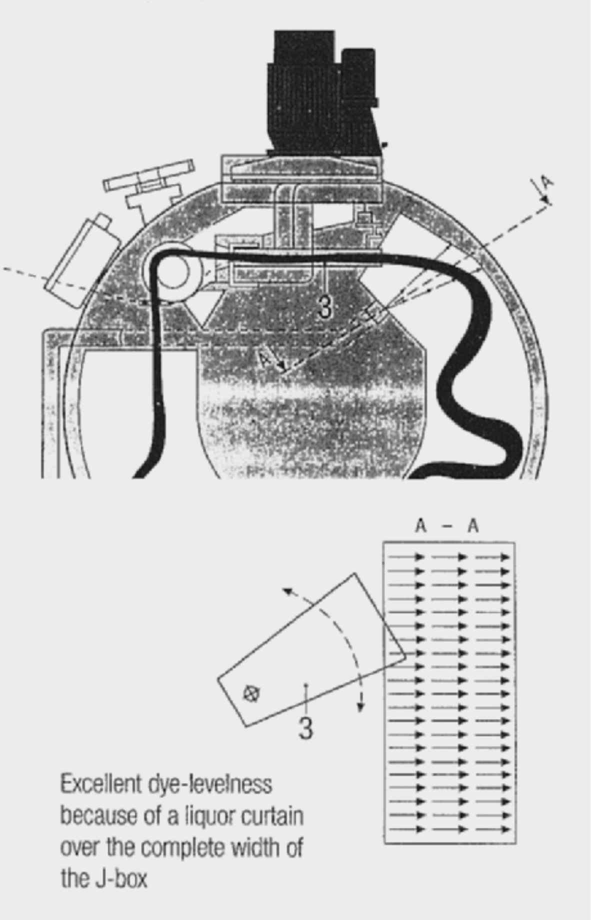


Fig. 4: Aero-dye (Krantz).

from other piece-dyeing machines with air propulsion (see Fig. 4).

In the Aero-dye the treatment liquor is fed completely separately from the propulsion system over a spray bar connected to the inner chamber. This makes it possible to circulate a large quantity of liquor without the need for high flow speeds (i.e. at low pump power). The result is an even liquor temperature in all areas of the dyeing machine. In other machines which are only circulating a small quantity of liquor due to their air drive, the liquor cools off on the way from the fabric to the pump inlet side, so that the exact liquor temperature is present only in the jet area. As to 2 to 5: Requirements numbers 2 to 5 are specifically affected by the cloth propulsion method. The Krantz Aero-dye is equipped with a special, purely aerodynamic propulsion system. For this reason no auxiliary propulsion system is used (Fig. 5).

The following arguments were decisive when selecting this propulsion method:

1. At high cloth speeds the winder drive no longer gives support. The risk of slippage points is minimised. It is interesting to consider the ratios of a combined jet/winder propulsion system in a machine with a propelled winder which is required to advance a fabric weighing 1000 g/m (wet) at 400 m/min. 60 N of force is required to propel this cloth. So the winder only supplies about 20% of the necessary propulsion. Since, in this system, the aerodynamic drive is clearly dominant, it is difficult to achieve synchronisation of the two drive systems in order to minimise the relative movements between winder and cloth. Particularly when friction impacts are used to increase the effectiveness of the winder, the danger of producing slippage points increases greatly.

2. The purely aerodynamic propulsion system is able to perform the complete propulsion power required. The mechanism of the aerodynamic drive of a rope can be described by the well-known equation for friction in pipes (Fig. 6). It is understood that the propulsion force is produced by the propelling air flowing parallel with the surface of the cloth. This model is validated by practice.

It is therefore not necessary to target the propellant air onto the rope at a greater or at a lesser angle. Rather, attempts should be made as far as possible to achieve a parallel flow. This not only allows the cloth to be propelled gently, but also achieves a jet flow that is turbulence free, and this has a positive effect on the propulsion blower capacity. This calculation model (Fig. 7)

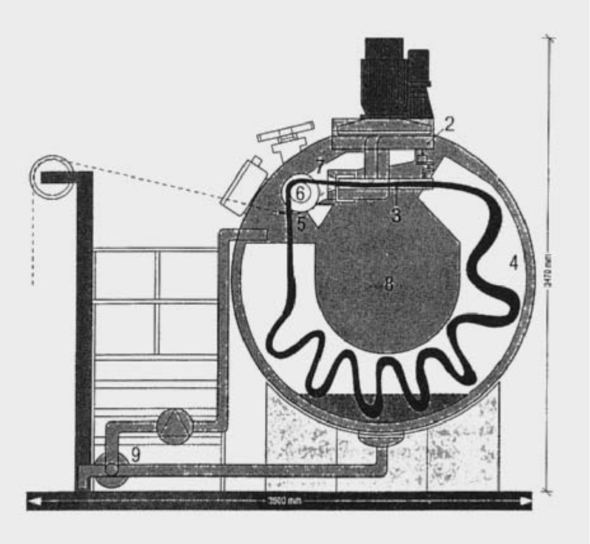
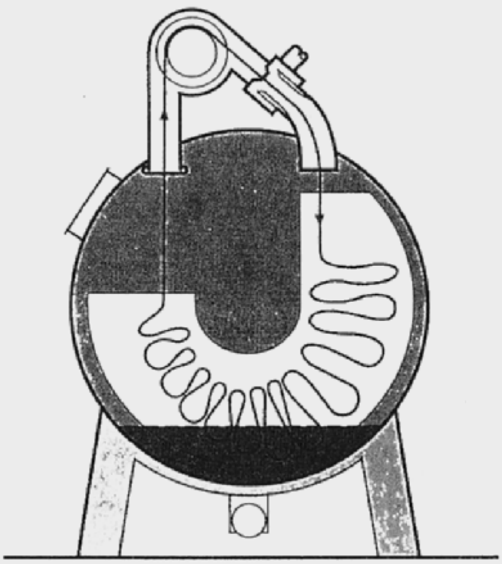


Fig. 5: Aero-dye cross-section.
1 = One blower per rope (chamber): rope speeds separately controlled (up to 1000 m/min). 2 = Built-in blower: no external pipes, extremely low-noise operation. 3 = Energy-saving nozzle with directly connected plaiter. 4 = Teflon coated inner chamber with width graduation for trouble-free fabric run. 5 = Disentangling and fabric stop system. 6 = Fabric run monitoring and rope speed measurement. 7 = Seam seeker. 8 = Cleaning system for fully automatic internal cleaning of machine. 9 = Pipes, filters, heat exchanger below liquor level to reduce liquor ratio.

Exhaust rope piece dyeing machines



From the rope friction formula

(1) $F_{s\text{-}s} = F_{s1} \cdot e^{\mu \cdot \alpha}$

you can calculate the force F_{s1} necessary for the nozzle

(2) $F_{s1} = F_{s\text{-}s} / e^{\mu \cdot \alpha}$

With a coefficient of sliding friction $\mu = 0.12$
and an angle of wrap $\alpha = 100°$ you get

(3) $F_{s1} = 49\ \text{N}$

Fig. 6: Mechanism of the aerodynamic drive of a rope.

The following holds for the propulsion (air friction) F_r:

(1) $F_r = w_r^2 \cdot (l \cdot \rho \cdot \pi \cdot D_w) / (8 \cdot (2 \cdot \lg (D_w / k) + 1.138)^2)$

where
F_r = friction [N]
r = density [kg/m³]
D_w = rope diameter [m]
l = effective length [m]
F_r = frictional force [N]
w_r = relative speed fabric-air [m/s]
k = roughness (also known as sand roughness)

For non-round cross-sections, such as the orifice of the Aero-Dye, D_w must be replaced by the hydraulic diameter d_{hydr}, which for rectangular cross-sections is calculated as follows:

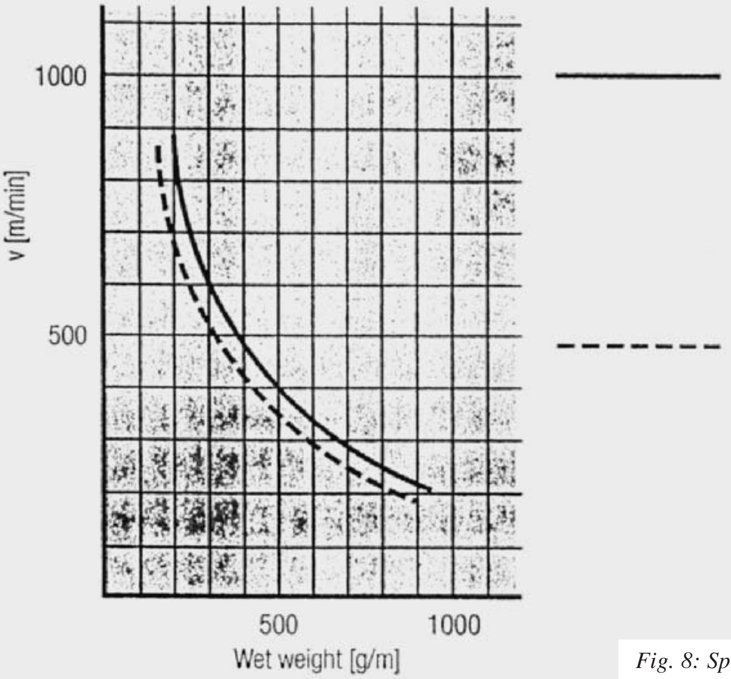
(2) $d_{hydr} = 2 \cdot b / (b/h + 1)$

where
b = width of nozzle
c = height of nozzle

Fig. 7: Diagram of flow of cloth in the Aero-dye jet and air force calculation.

describes the propulsion conditions that are in practice. It also demonstrates that, contrary to other assertions, the pure air propulsion system is also able to propel heavy fabrics.

3. Constant tension even at fluctuating speeds (Fig. 8). The relative speed is basically limited by the sonic speed, within further limits this is dependent only on



Speed attainable at constant fan speed and atmospheric pressure. At higher internal machine pressures the speeds attainable are up to twice as high.

Necessary speed for constant circulation time.

The characteristics of the purely aerodynamic transport system make it possible to dye the entire fabric weight spectrum.

Fig. 8: Speed diagram.

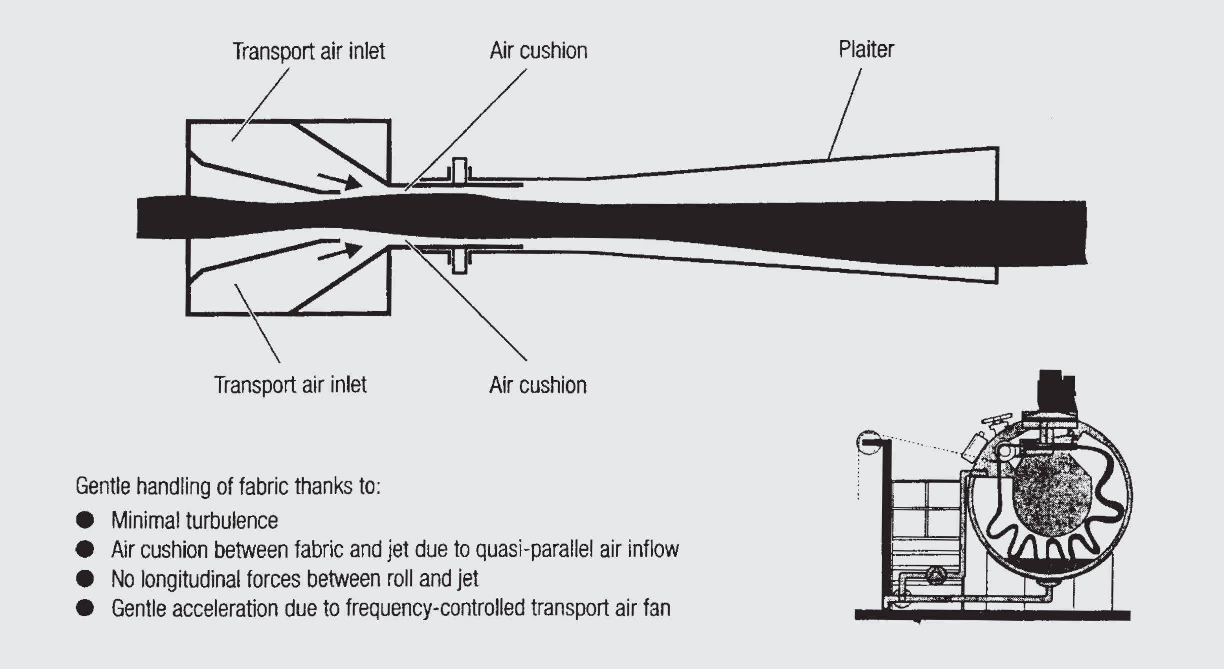


Fig. 9: Jet system.

temperature, but not on pressure. For air at 0° the acoustic velocity is 331 m/s. At higher temperatures the sonic speed increases. However, the required propulsion force is already achieved at lower speeds than “c”. The Aero-dye is therefore designed at 2/3. As the calculations show, the required air speeds are much higher than the cloth speed. Consequently, fluctuating cloth speeds have practically no effect on the propulsion. Thus, an important advantage of propulsion by air alone can be seen. The cloth is not subjected to changing forces. This applies even if the cloth stops suddenly because of a breakdown. Propulsion from aerodynamics alone is therefore particularly advantageous for cloth that is susceptible to tension.

4. Auto adjustment of air gap and excellent wrinkle offset. Propulsion is proportional to the working surface offered by the textile to the air (see air friction calculation). The larger the surface, the lower the relative air/textile speed can be, which can reduce the blower power on a cross-section of stream of flow which stays the same. The Aero-dye is therefore equipped with specially wide rectangular jets in relation to its gap height. The cloth generally fills the entire width of the jet, and therefore it adapts to the elongated shape. In doing so it offers a large working surface to the propellant air on the upper and the lower side, i.e., where the propellant air is flowing almost parallel (Fig. 9).

The gap height first of all only effects the necessary quantity of air. In the interests of reducing drive blower power, a setting that is as low as possible should be selected for this. On the other hand the aperture should be suuficiently high to allow even heavy cloth to pass through reliably. As the development work on the jet proceeds it is evident that these two facts are not self-contradictory. The high air speeds required create an under-pressure at the jet aperture which results in expansion of the rectangular rope. This results in auto-adjustment of the air aperture with the result that all qualities and weights of cloth can be processed with one jet. Furthermore, the expansion of the cloth due to the under-pressure causes excellent rope reorientation (Fig. 10).

The impact zone in the Aero-dye: For good and rapid fibrillation, the fabric must be given intensive mechanical treatment. In the Aero-dye the fabric is transported horizontally through the jet in the inner chamber. While this is happening it is advanced against the rear wall of the inner chamber and thus receives the

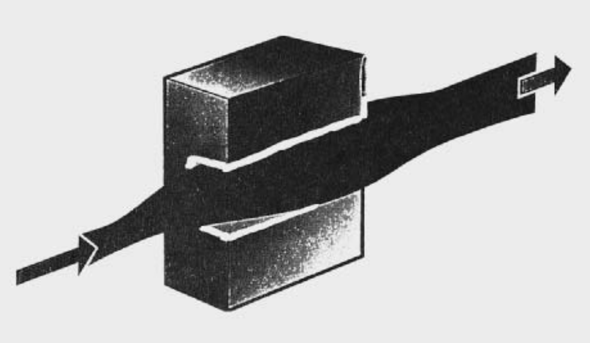


Fig. 10: The expansion of the cloth due to the under-pressure.

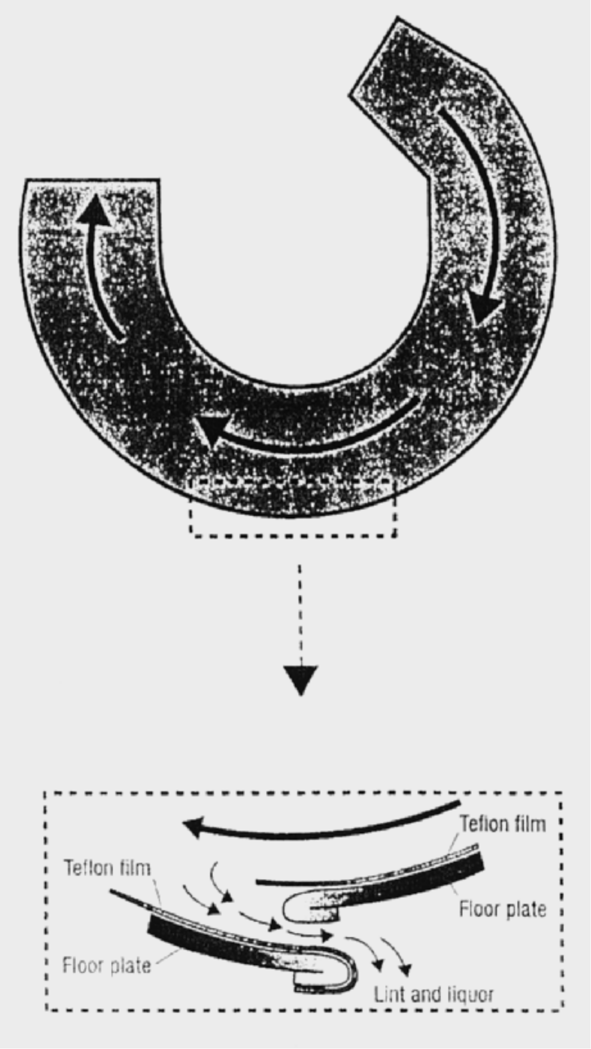


Fig. 11: Lint-intensive process.

required mechanical stress. The rear wall of the inner chamber is not perforated. So no “snags” can occur at this point. Even for very light and delicate articles there is no disadvantage by the fabric being impacted onto the rear wall of the chamber. As a result of the fact that the liquor is fed into the impact zone, and because of the high liquor circulation rate, an excellent colour evenness is achieved (Fig. 4).

As to 6: Protecting liquor feed: As already stated, the liquor is fed into the inlet side of the tank behind the plaiter. This produces a closed curtain of liquor over the entire width of the chamber. The fabric passes through the curtain and is thus thoroughly wetted. The speed of the liquor is only about 3–5 m/s. With respect to the application of the liquor the Aero-dye thus takes on a soft-flow character. Damage to the surface of the textile, which can occur in machines with liquor injection into the air flow, caused by the high kinetic energy liquor particles, is thus avoided. (Fig. 4).

As to 7 and 8: Fibre removal/cleaning: The large amount of fibres that fall during the enzymatic defibrillation process gives rise to two problems:

1. The problem of cleaning the machine.
2. The problem of removing the fibres from the surface of the cloth.

The following measures should be taken to clean the machine:

1. Inner chamber: The lower part of the chamber is equipped with a lint removal slot which makes it easier to clean the inner chamber following lint-intensive processes (Fig. 11).
2. Automatic cleaning device: The Aero-dye is equipped with an automatic cleaning system (Fig. 12). It has a fully automatic control system which provides optimum composition of the cleaning processes. At temperatures below 85°C cleaning takes place in open circuit via the attached tank. The auxiliary pump takes the cleaning liquor from the attached tank and feeds it to the jet system in the pressure container, through which the liquor is fed to the internal surfaces of the machine. The attached tank is continuously filled from the liquor circulation by means of valve (3). If the safe-

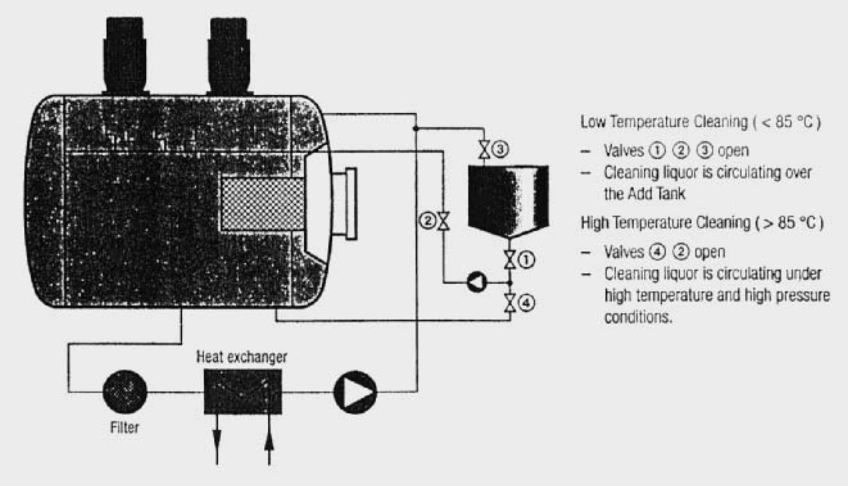


Fig. 12: Aero-dye equipped with an automatic cleaning system.

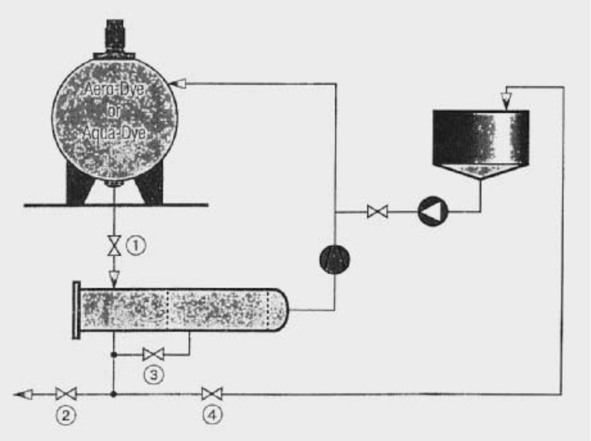


Fig. 13: Cleaning the filter during operation.

ty temperature is exceeded, the system automatically switches to internal circulation. The auxiliary pump drives the liquor through valves (4) and (2) into the cleaning nozzles.

3. Cleaning the filter during operation: If it becomes necessary to change the filter during operation, this can be done without losing any liquor (Fig. 13). The main pump is stopped while the fabric is running through, and valve no.1 is closed. Using air pressure it is now possible to push the contents of the heat exchanger and the filter into the auxiliary container. It is then possible to change the filter. Once the filter has been replaced, liquor circulation is restarted and the liquor is pumped back from the attached tank into the dye tank.

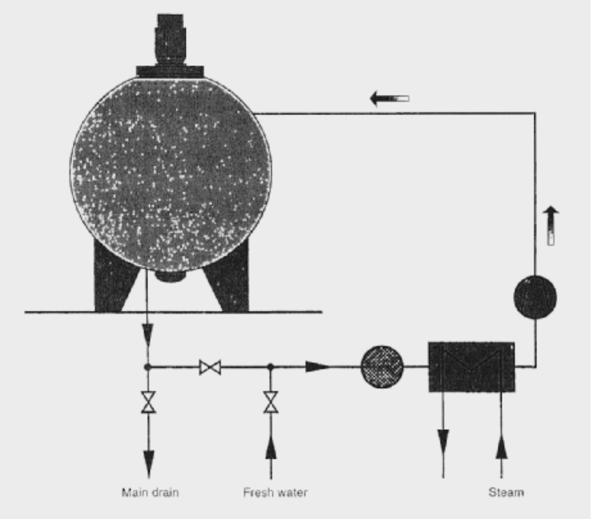


Fig. 14: The rinsing process.

The rinsing process is the principal method of removing fibres from the surface of the textile. The machine offers facilities for the standard bath change rinse method, overflow rinsing and also direct rinsing (Fig. 14). With the latter method, liquor circulation is shut off and fresh water pumped directly onto the fabric over the heat exchanger. The water can run off directly through the main outlet valve. Both, overflow rinsing and direct rinsing, are excellent methods of removing fluff from the surface of fibres.

Besides fibrillation, the powerful swelling of Tencel/Lyocell fibre impairs the wet finishing process. The swelling of the fibres causes a Tencel/Lyocell fabric when it is wet to become very stiff and hard. In this condition, the risk of causing permanent damage to the surface is very high. In addition, the ability of the machine to grasp the cloth is restricted, due to its wet rigidity. Only correct handling of the machine and cloth during the loading process can help here. The wet rigidity of the cloth needs to be moderated as far as possible during the loading process. This is possible on the Aero-dye as follows:

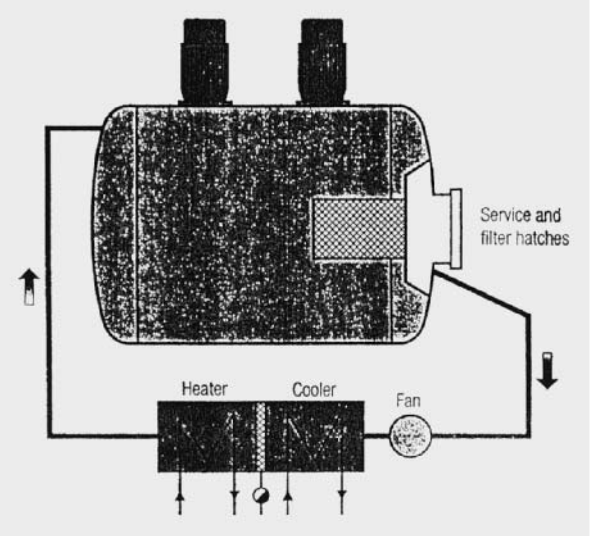


Fig. 15: Tumbler.

1. Heat the liquor to 50°C or 60°C before loading the machine.

2. Add emollient and slip additive before loading the machine.

3. Slowly feed the dry cloth at full blower power.

A slow feed at full blower power is only possible if the hank of cloth is braked outside the machine. This gives the cloth enough time to “flutter” inside the jet and in the liquor application area in order to lose most of the wet rigidity. This achieves a much greater loading capacity and greatly reduces the risk of creating slippage points.

The Krantz Aero-dye can be supplied with a tumbler or drying facility.

A special liquor pump provides the means for a temperature-controlled tumbling facility in the Aero-dye.

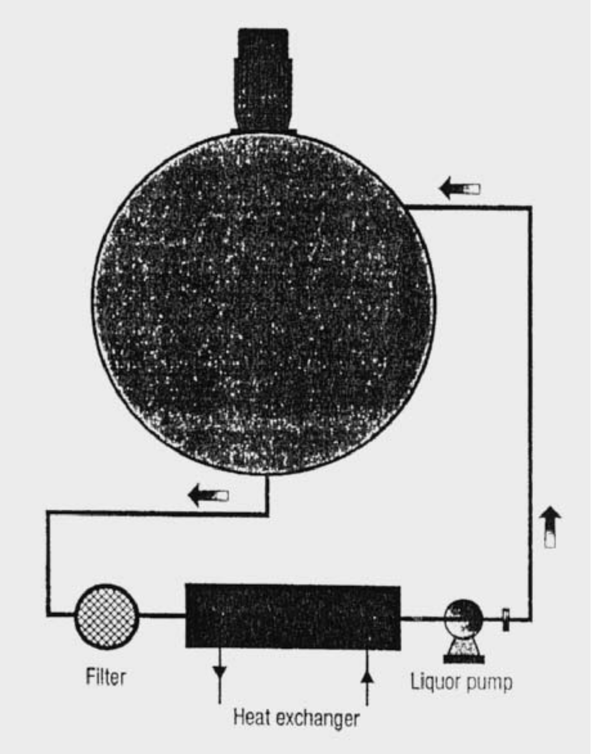


Fig. 16: Tumble and drying facility.

The pump at double speed can act as a blower, and can drive the machine's internal air over the liquor heat exchanger (Fig. 15). If a drying facility is also required for the Aero-dye, a dryer module is necessary (Fig. 16). Similar to a pressure dryer for yarn, the moist internal air in the machine is pumped into a condenser by an external blower. A separator behind the condenser removes the condensation from the air. In a subsequent damper register, the circulating air is heated to a drying temperature and fed to the inlet side of the driving blowers.

During tumbling the liquor pump (special version) functions as a blower and circulates the air in the machine via the heat exchanger. This permits temperature control during tumbling. (According to B. Böhnke and M. J. Bradbury and J. A. Bone)

Exhaust thermosol process Continuous process for (bleaching and) optical brightening of synthetic fibres (also in mixtures with cotton): exhaust treatment 2–5 min in hot optical brightener bath in dwell chamber (submerged open-width dwe ll system), finally squeeze off, dry, thermofix. In thermofixation, nonbound or diffused optical brightener is thermosoled.

Exocuticle Term given to the → Intermediate membrane of the wool fibre situated between the epicuticle and endocuticle.

Exophilic (Greek), directed outwards, e.g. the tendency of a hydrophobic molecular group not to enter into the homogeneous aqueous phase. Characterized by an increased alteration in the chemical potential on penetration of the molecular group. Opposite → Endophilic.

Exothermic An adjectival term used, e.g. to describe a chemical reaction which is accompanied by the evolution of heat. Compare → Endothermic.

Exotics Braided hats or hat bodies produced from various leaf fibres of the bast fibre group from East Asia, Africa, and Central and South America.

Exotic wools Wools from North Africa, Iran and Asiatic countries (China, India, Mongolia).

Expanded foam (Expanded plastics, cellular plastics), porous moulded materials produced from plastics with numerous gas or air-filled cells; 1 cm^3 of expanded foam contains between 10 000 and 1 million such cells with a diameter of 0.1–0.5 mm and a wall thickness of approx. 0.001 mm. Since the cells are enclosed, expanded foams have virtually the same heat insulation characteristics as static air. In flexible expanded foams, the gas or air cells compress to some extent under pressure but expand again when pressure is released. Expanded foams of this type have enormous elasticity and exhibit excellent dimensional stability even under high stress. Expanded foams are derived from ethers and esters. Flexible foams with pronounced elastic padding properties are made from (natural and synthetic) rubber (→ Foam rubber), polyvinyl chloride or polyurethane, and non-elastic foams from viscose or polyurethane; solid foams which have both supporting and insulating properties are made from rubber, ebonite, polyvinyl chloride, polyurethane and polystyrene. Rigid foams for insulation purposes, on the other hand, are based on e.g. aminoplasts or phenolic resins. Manufacture: the above-mentioned plastics are mixed with blowing agents (e.g. ammonium or sodium bicarbonate, ammonium chloride and sodium nitrite or organic nitrogen-releasing compounds such as hydrazine) or with gas-releasing plastic components and/or beaten to a foam with the inclusion of air. The mixture is then poured into moulds and polymerized (rubber is vulcanized). Uses: various heat and sound insulation applications (technical purposes, interior decoration, building insulation), upholstery (foam rubber), linings or padding for winter coats and dressing gowns; cut into strips for filling continental quilts and travel rugs; processed with other fibres for menswear and outerwear.

Expanded plastics → Plastic foam.

Expander Cloth guiders as attachments on equipment and machines which feed with the grain. Serves to reduce the shrinkage in width, to form good selvedges and to prevent formation of lengthwise creases. Simple expanders are stays produced from smooth tubes. A common expander device is the → Variable-tension rolls. (→: Expander, bowed; Slatted expander). This is suitable for processing different widths of fabric tube immediately after each other. Cutting principle controlled by helical tension springs, whereby the two expander guide rollers must simply be adjusted for each width of fabric tube (e.g. in the range of 31–45 or 33–73 cm); Adjustment using self-locking threaded spindles.

Expander, bowed Bowed, stationary rod which stretches the goods widthways depending on the curve of the rod's setting angle.

Expander filter An automatic, self-cleaning single-batch/multi-batch filter for solutions in dry cleaning. Based on stainless steel wire elements, spiral-canted, tightly coiled, extendible. → Filters.

Expander rollers Rollers made from any material which, from the centre, has grooves or threads which run opposite to each other, and which have progressive/constant gradient, to stretch piece goods to their full width on stentering and drying machines (expanders). A bowed roller with roller bodies and a closed, elastic cover to stretch goods is referred to as a so-called "banana roller". The setting angle of the curve of the roller axis is decisive here (Fig. 1).

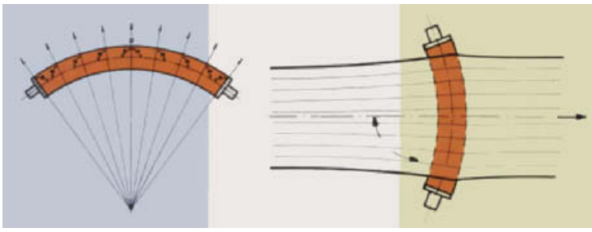


Fig. 1: Operation of a "banana" expander roller (contributed by Wittler).

The roller body which rotates around the radially bowed axis has a different angle of inclination to the adjacent run of cloth, from 0° at the crown of the roller, continually increasing to the roller ends. As a result, the cloth has the tendency to run off at right angles to the roller axis under the looping angle which is adjusted to the particular cloth structure. The resulting deviation of the cloth from the centre progressively to either side causes optimal transverse tension in this area of the roller, thus resulting in the avoidance of lengthwise creases in the cloth. The loose edges or centres of cloth and centre or edge feeds can also be positively influenced (Fig. 2).

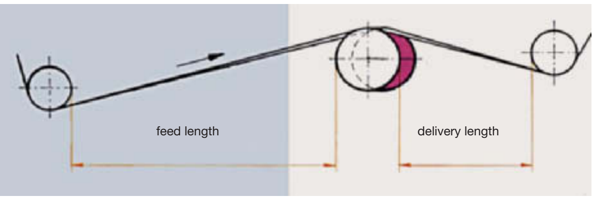


Fig. 2: Arrangement of run of cloth and expander roller.

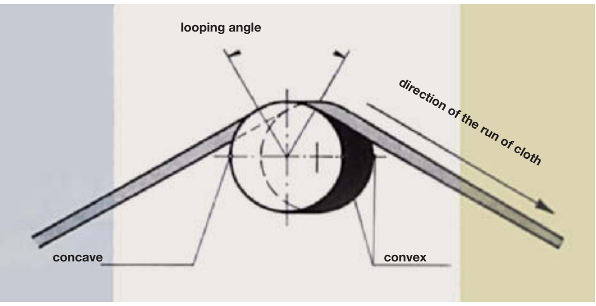


Fig. 3: Looping angle required on an expander roller.

The slats forming the cylinder jacket are moved outwards from the centre of the roller through 180° rotation by means of cam plates, by 180° rotation inwards. A mark on the cam plate indicates the end of the stretch zone or beginning of the compressing zone. The optimum stretch effect is achieved if the cloth feed length in front of the expander roller is sufficiently long and the run off to the subsequent guide roller is as short as possible. Standard values: feed length at least 3 x run off length, larger if possible. Final stretch length maximum 2 x roller diameter. Observe safety margins.

The correct looping angle (Fig. 3) is an important prerequisite for the expansion process. Standard values for bowed expander rollers: in general 40–60°, special cases 60–100°, for slatted expanders 30–180° (Fig. 4).

The same basic principles apply as for the installation of guide rollers. It is particularly important that installation is at right angles and horizontal to the run of cloth in order to achieve perfect effect and to avoid wear of the rubber sheath.

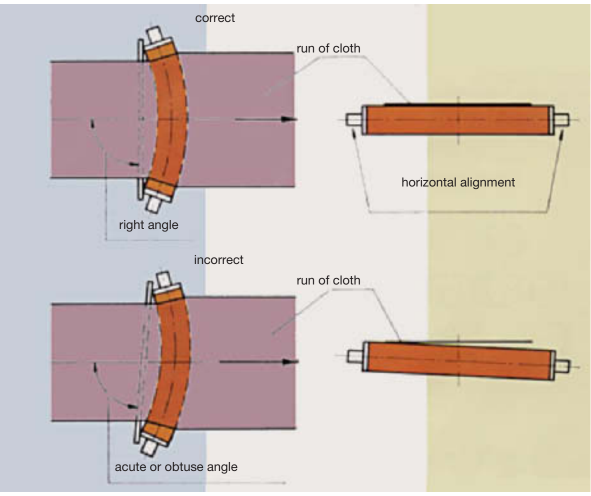


Fig. 4: Correct and incorrect arrangement of an expander roller.

Expanding device for fabric (stretcher, width expander). Device to stretch the material, to avoid crease formation and/or to roll out the selvedges during the passage of the cloth: → Expander rollers (bowed), expander, bowed, slatted expander, selvedge unroller.

Expansion tank Tank on high-temperature equipment used to equalize pressure and absorb fluids at temperatures above 100°C.

Expansion vessel Expansion tank for HT equipment.

Expert system Four complementary components combine their resources here in terms of data processing and provide information on the user interface for the user submitting the query:

1. The problem solving component processes the query submitted and expands the function of the query interpretation to enable results to be processed.

2. The explanation component records the problem solving process so that solutions which have been found can be reproduced.

3. The knowledge acquisition component is used to expand and modify the knowledge basis.

4. The dialogue component carries out both the analysis and transformation of the natural language query and also the dialogue with the user.

Documentation science, communication science, IT and specialist scientific knowledge therefore work together.

An expert system is the combination of a computer with a spec. program which consists of an intelligent shell and a specialist knowledge basis. It differs fundamentally from the previous program in that it contains a very large amount of specialist knowledge, predominantly in text form (control systems). The user no longer has to use their imagination to think up the correct question, as is the case with a database. The expert system only applies the questions relating to the problem and immediately excludes answers concerning irrelevant areas. It adheres strictly to the topic. It then tries other questions and answers to find the solution in the core area; it is not necessary to deal with noise. The so-called shell of the expert system is loaded in the computer: this shell calls a knowledge basis which has been produced with the aid of experts in the field of textiles. A knowledge engineer questions the specialist, structures the specialist knowledge and then helps to formulate the rules and questions for the screen output.

Explosion of hydrogen peroxide Bleaching with hydrogen peroxide may lead to the explosion of the bleaching apparatus. Although the cause of the accident is difficult to determine, investigations have yielded tips for avoiding such explosions. The bleaching process takes place in apparatus which is similar in design and operation to that of HT dyeing equipment. For example they have a capacity of 4500 l and are designed for a maximum operating pressure of 4 bar. They are subject to the pressure vessel act and should be equipped, set up, operated and tested according to the associated technical rules.

A bleaching process may take place as follows: The bleaching liquor, which consists primarily of water plus caustic soda liquor, wetting agents and stabilisers, is added to the fibres in the container. A pressure of 3 bar is generated in the sealed container. Then the contents of the container are heated to approximately 45°C. The hydrogen peroxide is added at this temperature. This is then heated to higher temperatures. After this temperature has been maintained for the time stipulated by the formula, the contents of the container are cooled. The bleaching process is concluded by the discharge of the bleaching liquor and several rinsing cycles. The material can then be removed from the apparatus.

Explosions generally occur before the maximum temperature has been reached. A common cause is the safety valve becoming blocked by lint. This danger is particularly prevalent if the safety valve operates frequently. The following measures can be taken to prevent the pipes to the safety valve becoming blocked:

- Adequate dimensioning of the safety valve (possibly increasing the nominal size);
- Control of the bleaching process such that the safety valve does not operate in normal operation;
- Frequent cleaning of the container and the pipes to the safety valve;
- Checking the safety valve before each new batch;
- In older apparatus the use of a pressure sensor, which opens the discharge valve when a predetermined pressure is exceeded.

The explosions are probably caused by the rapid decomposition of the hydrogen peroxide that is added. It decomposes in an exothermic reaction. The speed of the decomposition reaction sharply increases the rise in temperature. If certain catalysts are present the breakdown leads to an explosion even at low temperatures in a weak solution. Possible catalysts are a range of metals, particularly copper, but also iron(rust) and alkalis. Industry standard hydrogen peroxide contains stabilisers, which are added to hinder the decomposition process, e.g. during storage. Further stabilisers are added during bleaching. However, despite the addition of stabilisers a catalytic decomposition of the hydrogen peroxide cannot be ruled out. → Hydrogen peroxide bleaching regulators.

Explosion risk areas Areas in which the risk of explosion exists are those in which gases, vapours, mists or dusts, capable of forming explosive mixtures in air, can develop, accumulate or spread. Such areas include: enclosed rooms or parts thereof, the insides of machines (e.g. curing and drying machines), containers, channels, shafts, pits and similar cavities, entire buildings, sections of factories, workshops, warehouses and offices or any other locations where explosive mixtures can arise or be penetrated by.

Explosive limits The lower and upper concentration limits of flammable gases and vapours, or dust in mixtures with air, between which gas or vapour mixture with air can explode on ignition in a confined area. Explosive limits are usually expressed as a concentration in vol.% or g/m^3 at an initial state of 1,0133 bar and 20°C. Below the lower explosive limit the concentration is too small to cause combustion or explosion. Above the upper explosive limit the mixture is too rich in combustible component for an explosion to occur.

Exposure to dyes, auxiliaries and chemicals Exposure to certain dyestuffs, auxiliaries or chemicals during their production or use. Leading European dyestuff manufacturers have assumed an important pioneering role in ensuring and increasing safety with the foundation of the → ETAD in 1974:

1. Continual reduction of exposure by:

- Improved production technology,
- Good levels of industrial hygiene and appropriate devices,
- Personal hygiene and sufficient washing facilities,
- Good information and staff training,
- Improved physical properties of the products (e.g. non dustprone forms),
- Reduction of dyestuffs in the effluent,
- Improved applications facilities and technology,
- Use of the best applications technology available,
- Use of products with optimum fastness,
- Product innovation.

2. Constant monitoring by industry, authorities and the public:

- Monitoring the environment,
- Medical supervision,
- Epidermology,
- Exchange of scientific and technical information,
- General vigilance of workers, employers, scientists.

3. Ongoing tests:

- Tests for those substances representing an unacceptable risk which cannot be controlled,
- Development of new, shorter, economical toxicological and ecotoxicological test methods, espec. short-time tests for chronic effects,
- Basic research into the relationship between structure and effect and into metabolism (pharmacokinetics).

When assessing a risk, it must be taken into account that this is a function of a) the potential harmful effects, based on the inherent toxicological properties of a product and the extent of its bioavailability in the organism, and b) the exposure and probability of occurrence. Risk is generally quantified as the statistical probability of a particular harmful effect arising under specific exposure conditions, e.g. the amount and frequency of exposure during a specific period of time. (E.g. a risk of cancer of 10^{-6} indicates that out of every 1 mill. people exposed under clearly defined conditions, 1 of these will develop cancer). It is clear that the risk of harmful effects occurring can be decreased by reducing exposure. This is clearly the simplest means of increasing safety.

The probability that a substance will represents a hazard, i.e. the risk of using this substance, is given by the equation

$$R = G \cdot E$$

R = Risk,
G = Hazard potential of the substance,
E = Exposure.

In other words: it is possible to handle hazardous substances without this constituting a risk if exposure to the products is avoided. Potassium cyanide is a dangerous chemical even when stored in a sealed bottle, but handling it does not represent a risk if there is no possibility of exposure to the substance (e.g. by using unbreakable, sealed receptacles). It can be deduced from the equation that the risk to the consumer when using textiles which have been dyed is determined not only by the hazard potential of the dyeing agent, but also by exposure to it. The exposure of the consumer to the dyeing agent presupposes migration of the dyestuff from the substrate. This is not the case with the user, who is directly exposed to the dyeing agent. This migration indicates low fastness to washing, perspiration or crocking and is a characteristic of textiles which have not been finished optimally.

By definition dyeing agents include dyestuffs (dyeing agents which are soluble in the application medium, soluble in water and/or solvents) and pigments (inorganic or organic, coloured or uncoloured dyeing agents which are virtually insoluble in the application medium). The characteristic property of pigments is their extremely low solubility in water and in the substrate. They are also only slightly soluble in organic solvents. Due to this low solubility they are practically no longer bio-available. The fact that dyeing agents are used almost universally in almost all articles used for daily life results in an extremely wide variety of exposure situations.

The largest potential exposure exists during production (Tab. 1), but only effects a relatively small group of people trained in the proper handling of chemicals. It is also relatively simple to carry out and monitor measures to reduce exposure in workshops. During technical use, i.e. for dyeing textiles, leather, paper, printing colours, paints and plastics, exposure to and absorbance of dyeing agents by humans is also possible. The extent of this is dependent on the industrial hygiene conditions when the dyeing agent is applied. In theory, exposure could be zero, although this is not possible in practice. Despite this, the aim must be to achieve minimum exposure, although this must at least lie below the level of

Exposure to dyes, auxiliaries and chemicals

Human exposure	Exposure potential *	Measures to reduce exposure
Production		
Operating staff	1	– Improved production technology – Good industrial hygiene and installations – Personal hygiene and appropriate washing facilities – Information and staff training
Public (via environment)	3	– Reduction of effluent pollution – Controlled garbage dump or incineration of waste
Use		
Dyers, printers etc.	2	– Use of suitable application technology – Good industrial hygiene conditions – Improved commercial forms – Personal hygiene and appropriate washing facilities – Information and staff training
Public (via environment)	3	– Reduction of effluent pollution (e.g. higher exhaustion level when dyeing)

Tab. 1: Exposure to dyeing agents during production and application.
** 1 = high, 2 = average, 3 = low.*

an unacceptable risk. The most critical is exposure during handling of dyeing agents, especially during weighing and mixing. Inappropriate equipment, the lack of suitable protective gear and insufficiently trained staff can lead to unacceptable values. Products which are particularly dustprone pose the largest problem. The best solution for this is liquid products. Unfortunately in spite of concentrated efforts, manufacturers have been unable to offer all dyeing agents in this form. Intensive efforts are also being made to develop products which are not very prone to dust and have already resulted in non-dustprone, fluid forms.

Particles of >7 µm are deposited from inhaled dust, mainly in the nasal, throat and tracheobronchial tree, and from here generally enter into the digestive tract, whereas particles <7 µm (alveolar dust) enter the lung. In companies where the workers were exposed to dust from benzidine dyestuffs (which are no longer available), benzidine and its metabolites can be detected in the urine. Calculations show that inhaling 2 mg/m^3 of a benzidine dyestuff during a working day (8 h) resulted in 14–24 ppb being passed in the urine. Estimates show that passing over 100 ppb benzidine and its derivatives per day could lead to a substantial increase in the risk of cancer of the bladder. In dyestuff manufacturing and application companies where care is taken that there is a good standard of industrial hygiene these metabolites could not be detected in the urine of workers who handled benzidine dyestuffs, even using sensitive measuring methods (detection limit 1ppb). It can be assumed that the potential risk in such cases is negligible. In general, the monitoring of the concentration of aromatic amines passed in the urine of people working with aromatic amines or compounds in which a metabolic decomposition to form such amines could be expected, is a good means of testing (monitoring) the adequacy of safety methods.

Wearing textiles which have been dyed is clearly the

Human exposure	Exposure potential *	Measures to reduce exposure
Textiles	4	– Use of the optimum dyeing technology
Leather	4	
Paper		– Use of products with the highest wearfastness properties
– Tissues	3	
– Newspapers	3	
Plastics	4	
Paints, print colours		
– General	3	
– Artist's paints	3	– Guidance for proper use
Foodstuff packaging materials	4	– Prevention of migration
Toys	4	– Legal control, principle of non-migration
Do-it-yourself dyes	2	– Adequate warning and safety instructions
Finger paints	2	– Usage results in exposure and therefore cannot be prevented
Foodstuffs	1	
Medicines	2	– Use of sufficiently tested, permitted products
Cosmetics	2	

Tab. 2: Exposure of users to products which have been dyed.
** 1 = high, 2 = average, 3 = low, 4 = very low, negligible.*

most common exposure of humans to dyeing agents (Tab. 2). Exposure is extremely low where the goods are colourfast as the migration of the dyeing agent onto the skin is very slight. Standard tests which simulate perspiration suggest that the potential exposure can be estimated at well under 1 mg per person per day. Penetration of the dye into the skin, spec. with ionic dyestuffs and insoluble pigments, is low, generally much less than 1% of the amount found on the skin. Consequently it can be estimated that even in the worst case scenario, a maximum of a few micrograms would be absorbed, although on average the figure is much lower. The risk of damage to health is practically zero given these amounts. Allergic effects are an exception, however.

The use of dyeing agents in consumer goods, e.g. coloured toys or foodstuff packaging materials is legally regulated in many countries. The laws require that no visible quantities of dyeing agents should be able to migrate from dyed material. Tests are carried out using prescribed standard methods. In the case of coloured packaging materials, the detection limit is generally 0.05 mg migrating dyeing agent per kg of foodstuffs, but this depends on the colour strength. The most suitable for this use are pigments which are practically insoluble, as they also have a low acute and chronic toxicity. In the case of finger paints on the other hand, exposure is incomparably higher. For toxicological reasons, the use of permitted food colourings is suggested for this purpose. Unfortunately, these are not very suitable as they stain clothes and home textiles very easily. It is preferable to use pigments which are virtually nontoxic and which can be more easily rinsed out of textiles. To prevent children from swallowing these finger paints, it is advisable to add a bitter substance such as sucrose octaacetate. Another area of application with a potentially high, uncontrollable exposure is do-it-yourself or domestic dyeing of textiles. Only selected dyestuffs which have undergone sufficient tests should be used for that purpose.

The use of colorants in foodstuffs, medicines and cosmetics leads to a widespread, relatively high exposure of a large number of people and is rightly strictly regulated in some countries. The ADI values (acceptable daily intake) recommended by the FAO/WHO expert commission are in the region of 0.15–15 mg/kg body weight. This is the equivalent of a max. acceptable daily intake of 10.5–1050 mg dyestuff per person (70 kg body weight) per day. These values were taken from the so-called "no observable effect level" (NOEL) with a built-in safety factor of 100–1000. In long term animal experiments this NOEL was approx. 2000 mg/kg body weight for some dyestuffs. Experience has shown that the quantities absorbed by the population lie well below the acceptable levels. In the case of cosmetic dyestuffs, the potential exposure is several times lower, although the number of people exposed is still very high.

Extended length → Crimp contraction.

Extender A term used for a textile auxiliary which can improve the processing effect of another product to such an extent that its concentration can be reduced.

Typical application: microporous membranes consist of polyester or polytetrafluoro- ethylene.These are either laminated to the outer material (outer fabric/membrane lining) or applied as insert laminates (outer fabric/membrane/nonwoven lining). A water-repellent impregnation is given to the outer fabric either alone or together with the membrane to achieve an outstandingly high degree of water repellency. Although water repellent formulations based on silicones were formerly used, fluorocarbon finishes which have a higher degree of permanence as well as stain-release properties are now preferred. A nonionic fluorocarbon resin can be combined with a silicone elastomer even where the highest demands are placed on softness of handle. For blend fabrics containing cellulosic fibres, a favourably priced suitable water-repellent finishing agent is preferred as an extender so that the amount of fluorocarbon resin can be significantly reduced whilst still achieving equally good water and oil repellent effects, thereby reducing the finishing costs as a result.

Extender for tensides Inorganic or organic products, generally inactive, that are used to adjust the market form and/or the concentration of a detergent. Examples: sodium sulphate, water, alcohol, etc.

Extenders (fillers, diluents), normally specific, inert additives used for standardizing the type or the commercial form, concentrated, also used for diluting and cheapening. Usual with dyestuffs (powder products e.g. + neutral salts, dextrine. hydrotropic substances, dispersing agents, preservatives and the like, with liquid products also + water etc.) and with tensides (e.g. + sodium sulphate, water, alcohol and the like).

Extinction (E), extinguishment (of light), cancellation; e.g. the whole light-absorbing black content of any full colour in colour measurement; here black appears as an extinguisher which remits no visible radiation energy. The definition of extinction is as logarithm to base ten of the reciprocal of the transmittance, that is the ratio of the light entering a solution Φ_0 to the light emerging Φ_{trans}, assuming that only the component i is absorbed at wavelength λ.

Lambert-Beer Law:

$$E_{i,\lambda} = \log \left(\frac{\Phi_0}{\Phi_{trans}}\right) i,\lambda = \varepsilon_{i,\lambda} \cdot c_i \cdot d$$

The extinction $E_{i,}\,\lambda$ is proportional to the depth d of the solution and its concentration c_i. The factor of proportionality $\varepsilon_{i,}\ \lambda$ is given as the concentration-dependent decadic extinction coefficients. It is a specific value and under application of → Lambert-Beer Law is only dependent on the wavelength of the radiated light. This law only applies, however, provided the molecules of the absorbing medium do not undergo concentration-related changes through interaction with one another (e.g. by displacement of dissociation or polymerization equilibria) or with other components of the mixture phase (e.g. solvation), which influence their light absorption. Lambert-Beer Law is therefore first and foremost a limit law for very dilute solutions, which in addition must be optically clear and homogeneous. Cases are, however, also known in which the deviations are low even at considerable concentrations. The Law is furthermore only precisely applicable to monochromatic light.

If several components are dissolved in a homogeneous solution, which absorb at the wavelength λ, then the total extinction $E\lambda$ is equal to the sum of the extinctions $E_{i,}\ \lambda$ of the individual components i. It is then said that

$$E_\lambda = \sum_i E_{i,\lambda} = \sum_i \log\left(\frac{\Phi_0}{\Phi_{trans}}\right) i,\lambda = d \cdot \sum_i \varepsilon_i\, c_i$$

Another frequently-applied value in accordance with the DIN standards is the pure absorption coefficient (= 1 – δ) or the percentage absorption A (= 100% transparency D). In addition the extinction in the case of modern colorimeters is read off direct from the extinction scale. Not to be confused with extinction are the extinction module m as extinction of the solution or of the body at thickness 1 and the extinction coefficient k (molar, at a concentration of mole/l) or k_1 (specifically at a concentration of g/l) as concentration-independent substance constants of the coloured substance. Another form of extinction by inorganic and organic substances is known as fluorescence, which has been proposed as a possible method for the quantitative determination of organic substances.

Extract A term used for a preparation containing the active principle or concentrated solution of a material, e.g. an aqueous extract.

Extracta Open-width washing machine (Fig.) with vertical zig-zag cloth passage (more efficient washing effect compared to horizontal arrangement). The additional division of an Extracta compartment enables different processes to be carried out with appropriate liquors in the individual sections.

Consists of a 5 m washing chamber with 2 vertical roller pairs for double fabric immersion. Available with 3, 4 and 6 chamber compartment (15, 20, 30 m fabric dwell); each compartment has an integral squeeze unit with 2 or 3 t pressure. Can be combined with e.g. a pretreatment steamer. – H.: Benninger.

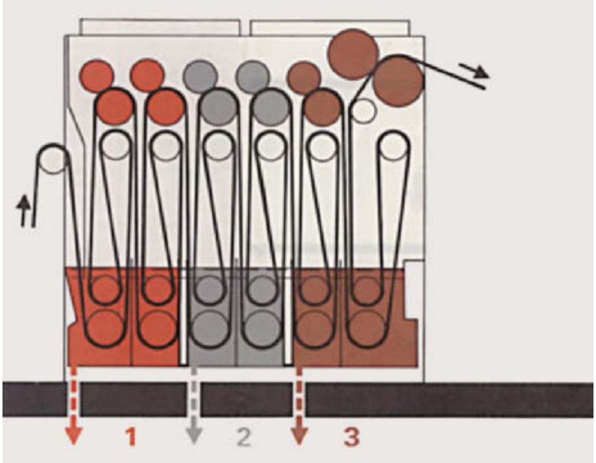


Fig.: Extracta washing machine (Benninger).

Extraction This relates to substances that adhere to fibres and are soluble in solvents, and usually takes place usually in the Soxhlet apparatus (e.g. for the determination of residual grease in wool). If the concentration gradient is significantly greater in the extraction than in the Soxhlet apparatus, i.e. if extraction is to take place with a significantly shorter bath ratio, then a continuous dosed delivery of the eluate is recommended; this way of working saves time. Using an extraction method as a system for checking residual chemicals was first thought of by Mahlo, this being the Chemocon system (Fig.) in the form of an injection of steam into the running fabric.

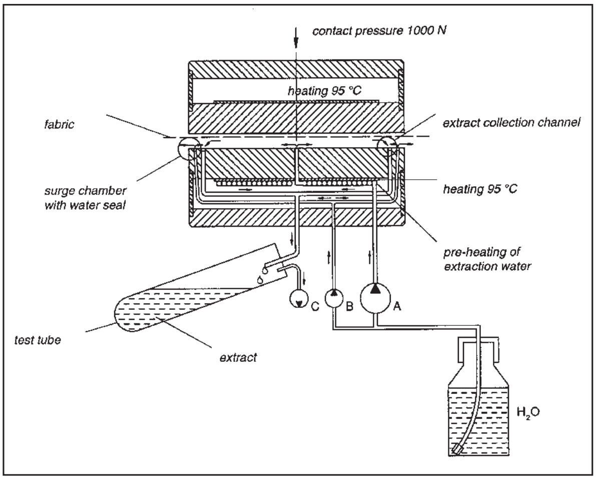


Fig.: Extraction unit according to Haus Bors . A = extraction water pump; B = water seal pump; C = vacuum pump.

Extraction of dyes from textiles → Dyes on textiles, quantitative determination.

Extraction of water from packages

I. → Marking off dyestuffs and prints.

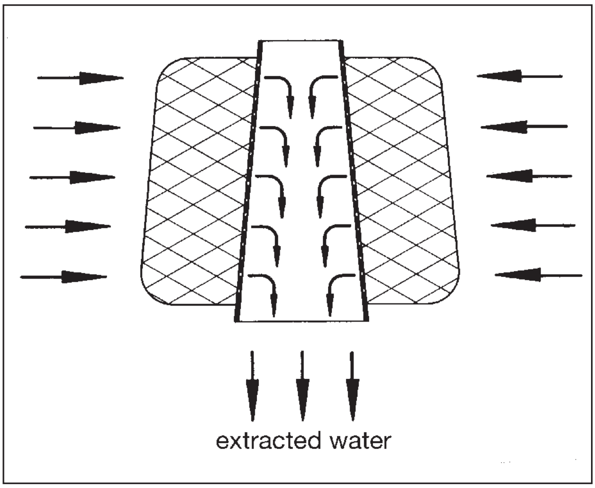


Fig.: Marking off yarn packages, flow direction outside-inside.

II. Hydroextraction of yarn packages (Fig.) in the → Pressure boiler.

Extraction scour/extraction bleach A pretreatment process chiefly used for cotton and cotton/synthetic fibre blends. Principle: the natural impurities in cotton are not only "bleached" but made soluble and washed out (extracted) by the application of appropriate wetting agents with high stability to electrolytes and complexing agents. A clean and hydrophilic material is achieved by this means without kier boiling or the use of HT steamers. The pretreatment can be carried out either as a short-dwell process (30–180 s) in the steamer, as a medium-dwell process (10–30 min) in a J-box with or without sump, or as a long-dwell process (5–10 h), e.g. in a pad-roll chamber.

Extractor fans Used in → Dust removal plants and → Fog dissipating plant. Belt, electric and steam driven (turbo-exhausters) mainly as centrifugal extractors. In the case of acid fumes the air propulsion components must be constructed of acid-resistant material.

Extract wool Term for class VI of → Reclaimed wool (regenerated wool). This is obtained from waste and rags (union knit, blended fabric) after carbonizing by tearing. As the cellulosic fibres are extracted by carbonizing, the term extract wool is still used from time to time.

Extra group Term used to indicate something additional and similar e.g. → Amino extra groups, Carboxyl extra group.

Extraneous fibres Faults arising from the presence of foreign fibres in a textile material. Generally present in low proportion and occurring as a contamination caused either by erroneous fibre mixing, residues from other processes or fibre fly from packaging material etc. that may be twisted, woven or knitted into a fabric. Consequences: irregular fabric appearance, colour differences, bleeding of dyes etc. Evidence only microscopic.

Extruded composites Flexible, net-like textile fabrics (→ Bonded fabrics), produced by extruders from thermoplastic polymer melts for felt underlays, camouflage nets and for carpet anti-skid protection etc.

Extruded tape In accordance with DIN 60 001 T2, an extruded ribbon usually from a slit-shaped extrusion aperture or a slit yarn cut from film, continuous, where appropriate drawn uniaxially, for textiles applications thickness up to approx. 0.08 mm, width 5 mm.

Extrusion coating A process used for the production of fusible interlinings. Principle: a molten thermoplast adhesive is extruded from a wide slitted jet and the resultant film is pressed on to the pre-warmed substrate (fabric or nonwoven) surface with the aid of cooled rollers.

Eyelet embroidery The ground fabric is fine count plain weave batiste. Before the actual embroidering process begins, the required eyelet effects are stamped in (openwork effect). The holes are then embroidered with grey ply yarns according to the pattern. Eyelet or batiste embroidery receives its snow white effect by bleaching. These embroideries are also offered coloured or additionally printed.

Eye sensitivity to hue, chroma and brightness Under certain conditions, the human eye distinguishes between approx. 10 million surface colours (→ Colour vision) and recognises 152 spectral colours. At different light wavelengths, however, even the normal eye (→ Colour stimulus) has a very varied sensitivity concerning:

1. Hue: most sensitive to yellow green and blue green; however weak for violet, orange and red, and zero for infra-red and ultra-violet; weaker in yellow and blue.

2. Chroma: is most easily perceived in violet and red, and least in yellow green. Extremely slight differences of 2–3% are also perceived with blue. The eye recognises average colour differences in dyeing (= differences in dyestuff concentration) of 5% and at the very best, with the same shade, of just 1%.

3. Lightness: most sensitive to yellow green, least sensitive in the range of violet, blue, orange and red (→ Adaptation). Reference should be made in particular to the difference in luminosity at low and high luminous intensity. A distinction is made between light-adapted and dark-adapted eyes. With the latter, spectral sensitivity is shifted slightly into the area of blue hues.

F

F

I. Chemical symbol for fluorine (9).

II. Symbol for farad.

III. Symbol for faraday.

f, symbol for: femto- (prefix indicating 10^{-15}), i.e. 1 quadrillionth ((US and Canada).

°F, abbrev. for degree Fahrenheit (→ Fahrenheit scale).

Fabinet A term used for a type of → Artificial leather produced from natural fibres that have been bonded together with a binding agent.

Fabric accumulators (cloth accumulators). Storage units which are in some cases identical with → Dwell units in processing machines. They include: conveyor-type accumulators, scray accumulators, roller accumulators, open-width accumulators (see Fig. 2). Fabric accumulators are important for nonstop batch changes in continuous and discontinuous processing ranges. In continuous plants they are interposed between individual machines in order to ensure a distortion-free fabric passage.

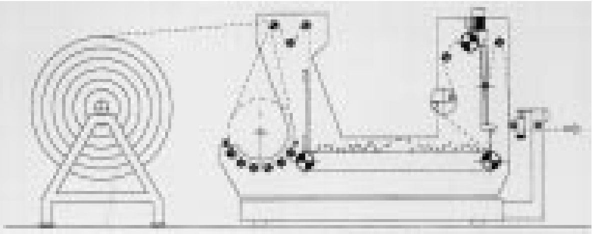


Fig. 1: Feed unit for knitted fabric from small and big roll. Placed at the inlet of printing machines, flatbed or rotary, feed unit allows to eliminate completely any tension of feeding fabric and assures a perfect alignment on the machine (Stamperia Emiliana).

Fabric accumulators for batch changing Nonstop batch changing is made possible by the installation of batch changing devices at the entry and exit of textile

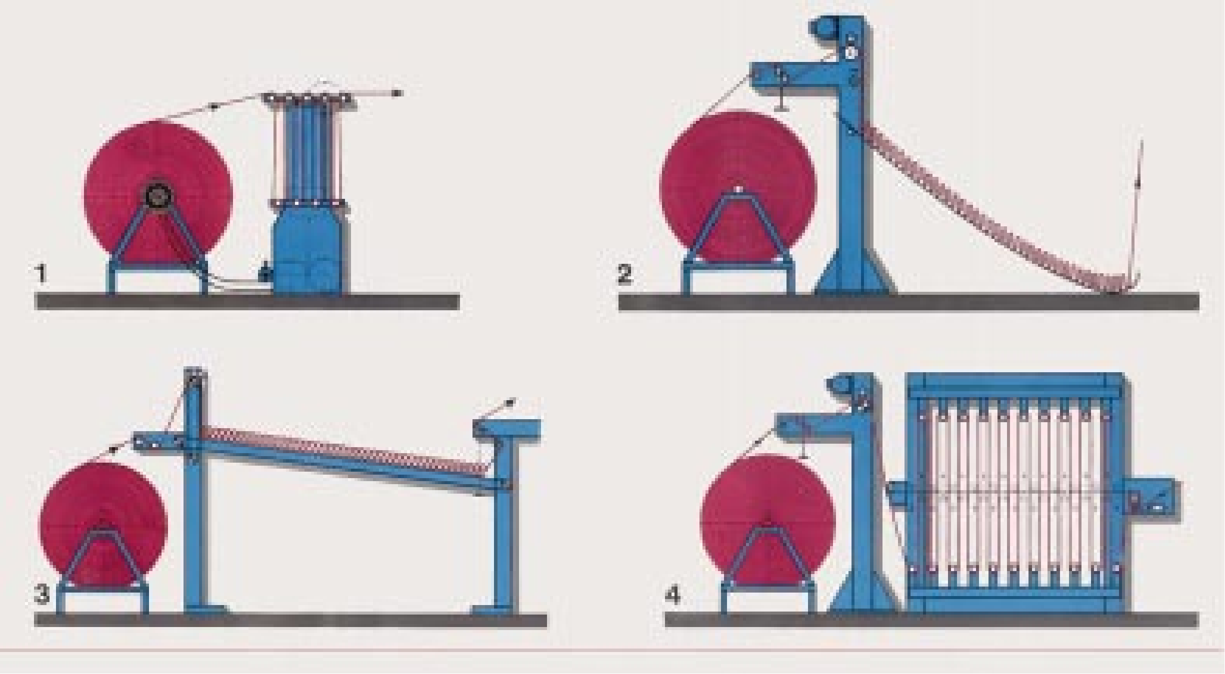


Fig. 2: Fabric accumulator examples (Krantz).
1 = large batch axial let-off with roller compensator; 2 = let-off unit with fabric trough; 3 = let-off unit and belt type fabric accumulator; 4 = let-off unit with chamber type fabric accumulator.

finishing machines. Advantages are increased productivity and more uniform processing.

Fabric bagging A fabric defect which can be caused, e.g. by milling. As a result, the longer interwoven warp or weft threads are milled to a greater extent than the shorter interwoven crossing threads.

Fabric batch → Batch roll.

Fabric batching machines → Batching machines.

Fabric clean flow wash process Two-stage hydrodynamic process performed in a Pullman laundering machine equipped with a vertical partition and a front-loading washing machine located on the same shaft. Operates with separate liquor flows, which are forced through the two internal drums. The capacity of the stage 2 internal drum is only 40% of that of the stage 1 drum. Since the liquors from stage 1 subsequently flow through stage 2 (overflow principle) there is 2.5 times more liquor on the wash load in stage 2 than is actually required to fill the drum. Stage 2 contains only fresh liquor, which changes from clear mains water to a caustic solution and then back to clear water as the temperature rises and then falls again. The hydrodynamic laundering process is suitable for the simultaneous washing of different kinds of laundry in one wash. Stage 2 is particularly suitable for heavily soiled goods.

Fabric cleaning and shearing machine Used to remove knots in loomstate fabrics using emery rollers and brushing rollers, with cropping of thread ends.

Fabric clean washing agent Detergent for clearing soiling (washing zone at maximum temperature, removes soil residues) in 2nd or 3rd wash bath using the multi-bath and hydrodynamic processes after wetting/prewashing. Compared to → Prescouring agents, clearing agents contain less alkali, a greater content of active detergent and optical brighteners, frequently also oxygen bleaches (sodium perborate, sodium peroxide).

Fabric compacting Compaction of a textile fabric, e.g. by relaxation of the yarn system or by felting as in → Milling.

Fabric content (cloth content). The fabric content of a textile processing machine or unit expressed either by length or by weight, e.g. the length of fabric (in metres) actually present in a continuous processing range (e.g. 15 m of fabric per roller vat), or in batchwise processing as the charge of material being processed (e.g. 100 kg. of fabric per tube in a jet-dyeing machine).

Fabric density

I. → Sett.

II. Signifies the apparent density of a woven fabric, e.g. densely woven cloth compared to loosely woven gauze, because the thread width in gauze is only a small fraction of the thread spacing. If the thread width is $^1/_5$ of the thread spacing, for example (calculated from the centre of a thread to the centre of the next thread) the "mesh" distance is 80%. With the same warp and weft thread density, the gauze is: $1–0.8^2 = 0.36–36\%$. In woollen and worsted cloths this is almost 100%, and somewhat lower in cambric. Fabric density in this case is a subjective factor that is rarely quantitatively evaluated. Fabric density should not be confused with → Sett. The thread density per running metre can be measured using lasers. Air permeability is also used as an evaluation criterion.

Fabric entry zone

I. General: equipment for the crease-free entry of piece goods on all textile finishing machines.

II. Specific: devices fitted to the entry zone of stenters such as overfeed, selvedge monitors, selvedge sensors, pinning-on systems, clipping-on devices, etc. (see Fig.).

Fabric feed device (automatic) → Fabric guiding/feeding device (automatic).

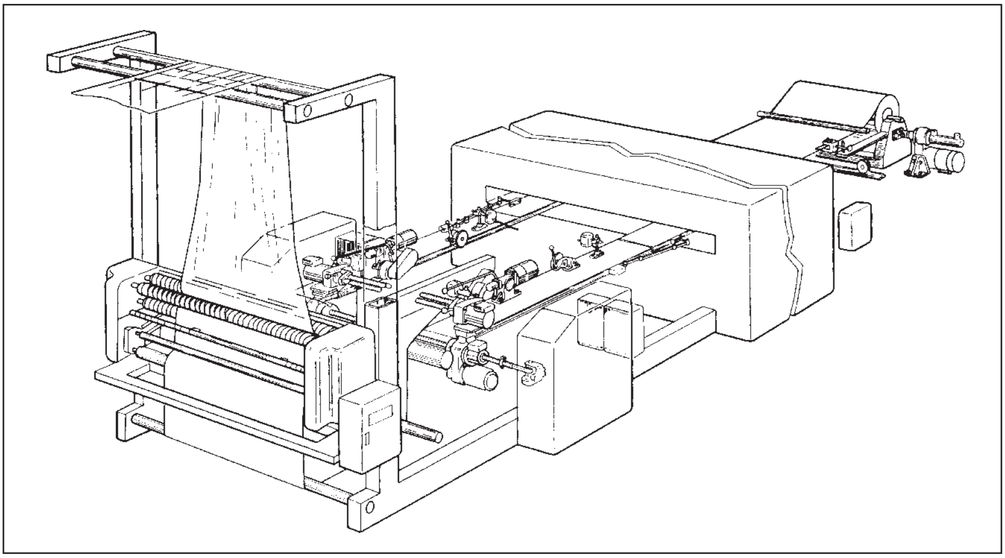


Fig.: Horizontal stenter fabric entry zone.

Fabric flow test → Fabric flow test (dyeing).

Fabric flow test (dyeing) Test for testing the fine distribution of disperse dyes that make extreme demands of fine distribution and stability in dye dispersions. The prepared dye liquor containing the product or disperse dye to be tested is pumped through a relatively large number of cylindrically arranged circular samples of polyester/viscose or polyester/wool fabric. Subsequently the separated fabric pieces are evaluated for their filtering action (deposits and fibre loss), shade and cleanliness.

Fabric folding machine Machine for folding piecegoods in layers of defined width and stack height (Fig.).

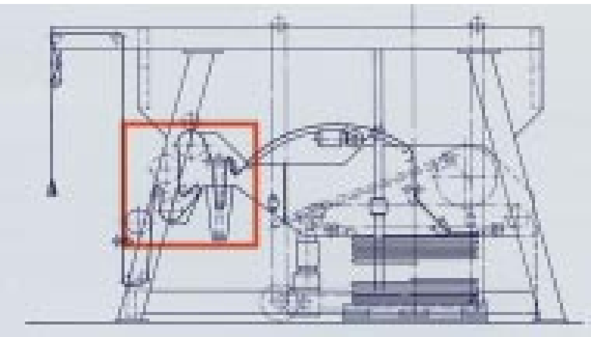


Fig.: Menzel fabric folding machine.

Fabric guiders (cloth guiders). Devices for the sideways control of fabric passage in a pre-progammed horizontal or vertical direction. Guiding elements with axially-movable profiled slats. Also expander rollers used especially for uncurling fabric selvedges, as well as swivelling rollers for the control of fabric direction. The reliable, crease-free, guiding of fabrics is a decisive quality factor for fast-running textile processing machines. Fabric guiders must be suitable for use under the widest possible range of applications as they are often exposed to caustic liquors, acids, moisture and heat. These conditions must not impair the function or precision of fabric guiders. The variety and specific properties of the materials to be processed make different control systems necessary.

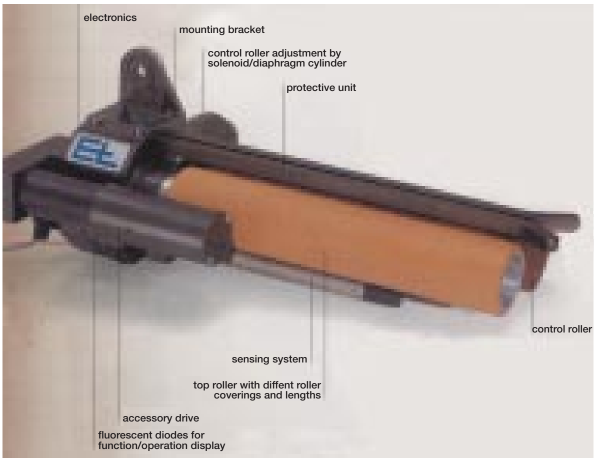


Fig. 1: Erhardt and Leimer fabric guides.

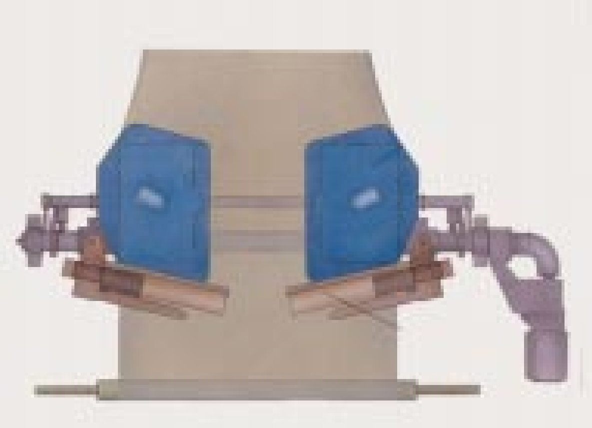


Fig. 2: Single jersey fabric guide with air jets in the top plate.

Fig. 3: Air jets on both sides in the spreader system.

Pneumatic selvedge uncurlers (Fig. 1) are used for uncurling and guiding surface-sensitive woven and knitted fabrics with curled or creased selvedges which cannot tolerate the mechanical contact of screw-spindle guiders.

This system is available in three types based on the use of air nozzles:

- with air nozzles in the lower plate for curled edges on the side of the guide rollers,
- with air nozzles in the upper plate for curled edges on the side of the upper roller (Fig. 2),
- with air nozzles on both sides (Fig. 3).

The air supply is provided by a blower with a high flow capacity and low pressure.

The selvedge uncurler is equipped with three motor-driven screw-type spindles (Fig. 4). The curled or creased selvedges of woven and knitted fabrics are

Fabric guiding/feeding device

Fig. 4: Selvedge uncurler with three threaded spindles.

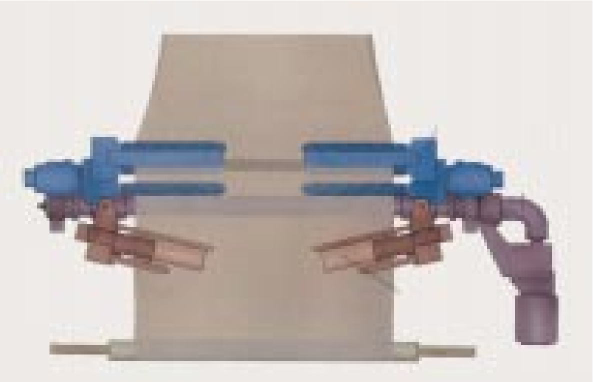


Fig. 5: Holding double jersey out to width.

opened as a result of the intensive uncurling effect above and below the fabric. Because of the swivel arrangement of the first screw-type spindle, the angle of contact and therefore the uncurling action, is progressively adjustable. By this means, double-jersey fabrics can be readily maintained in the open-width state (Fig. 5).

Fabric guiding/feeding device (automatic). Used to introduce pieces into open-width treatment machines (stenters, padders, jiggers, continuous bleaching and dyeing equipment) in an open-width state and for unrolling the selvedges of woven and knitted fabrics.

Fabric guiding systems These include entry frames, rollers, fabric guiders, guide rods, fabric spreaders (expanders), variable tension rails, reels and conveyors. Among other systems, the pin wheel used in weft straighteners represents a typical element (Fig. 1).

The correct choice of guiding system ensures the appropriate presentation of textile material (loose fibre, yarn, fabrics or made-up garments) to the mechanical and/or physico-chemical influences of the treatment medium or the finishing machine. The machine is in contact with its surroundings and the textile material by means of measurement devices and automation as well as with the treatment medium and chemical metering system. Appropriate sensors in fabric guiding applications for the development of true closed loop controls are only available to a certain extent at present.

The guiding system can be discontinuous (with machine set-up times) for batchwise operation or continuous (for long runs).

If there is movement of both the medium as well as the textile material in a particular treatment system, guidance of the material is determined by the form in which the material is being treated. Thus, loose fibres can be suspended in the medium or allowed to float in it. Combed tops or warp sheets may be wound or run continuously through the medium. Packages (yarn or fabric) are normally immobile during treatment whilst the treatment medium (liquor) is forced to flow through the package. Fabrics can be gathered in the width and processed in rope form. If fabrics are processed in the open-width state, the treatment is carried out either in tight strand form (under tension over rollers or spreaders) or in a loose (free) form (Fig. 2) where the fabric is usually plaited in the lengthwise direction on to transport systems (conveyors, roller-beds, underliquor zones). In the finishing of made-up items of clothing, the textile material (e.g. in the form of garments) is moved through the treatment medium either mounted on formers (as in hosiery dyeing machines) or in a loose random state (as in the paddle dyeing of garments).

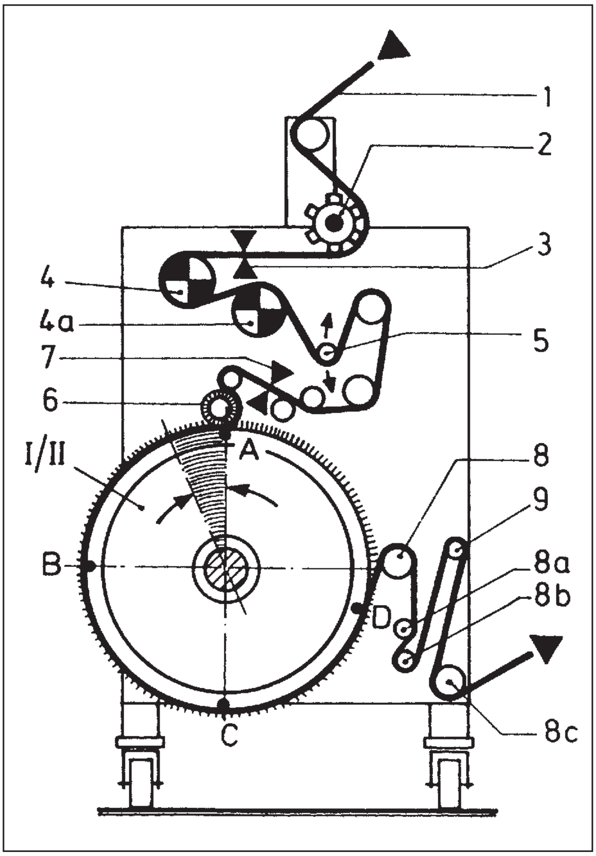


Fig. 1: Weft straightener based on the pin wheel principle. 1 = fabric entry in open-width; 2 = centring roller; 3 = optical edge scanner; 4/4a = drive rolls; 5 = compensator roller; 6 = rotary needling brush; I/II = two pin wheels with widthwise stretching between A and C; 8 = pair of rolls to prevent the straightened weft from springing back again; 9 = curved expander roll.

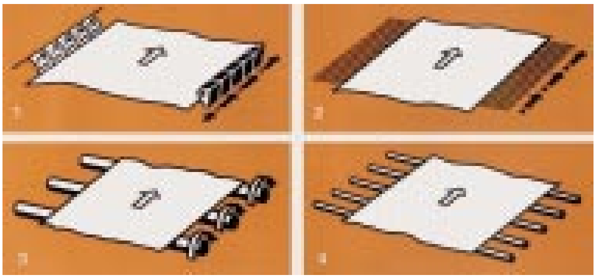


Fig. 2: Fabrics in drying machines with tight strand or loose fabric passage.
1 = pin or clip stenter chain; 2 = continuous stainless steel perforated belt conveyor; 3 = driven carrier rollers;
4 = continuous chain of carrier rails.

Fabric handle A large number of subjective and objective physiological and physical characteristics are involved in the determination of fabric handle. From various studies on correlations between the handle characteristics determined by subjective and objective means, it has been found that the measurable characteristics of stiffness, bulk and surface smoothness play a particularly important role in determining the handle of a textile material.

The tactile properties of textile fabrics, described by characteristics such as “handle”, “bulk”, “softness”, etc., are extremely important for the evaluation of fabric quality. With outerwear fabrics in particular, an equally high value is placed on these characteristics as on the colour of the fabric for example. However, although the coloristic properties can be measured objectively with the aid of spectrophotometers quickly and easily, the tactile properties of fabrics are still measured by subjective means, e.g. according to the prevailing mood and personal taste of the person carrying out the evaluation. This evaluation procedure lacks any semblance of objectivity at least when compared with the assessment of colour even when, for cost reasons, the advantages of a colour measurement system have to be dispensed with, and the assessment is carried out visually by means of standard illuminants and specified viewing geometry.

The Kawabata Evaluation System for Fabrics (KES-F-System), developed in Japan, represents an instrumental system specifically designed for objective evaluation of the tactile properties of woven fabrics which in Europe, however, has mainly found application as a research tool up to now. Because of the rather cumbersome and time-consuming test procedures and high cost of the instruments required, the KES method has so far not been commercially accepted on a wide scale in Europe (→: Kawabata system; Kawabata system of handle assessment).

In the meantime, other instrumental systems have been developed, with the aid of which those fabric properties that influence the tactile character of a woven fabric can be determined. These include the FAST (Fabric Assurance by Simple Testing) system and the ITV test system for tactile properties/fabrics (ITV-PTE/F). The FAST system was not designed originally for the evaluation of tactile properties, but primarily to assess the performance of woven fabrics in making-up. The ITV-PTE/F system was indeed developed for the determination of tactile properties although, in this case, the intended application was for nonwovens.

Fabric inspection machines In order to relieve the fabric inspector of as much manual work as possible, fabric inspection machines must perform the following functions (Fig. 1):

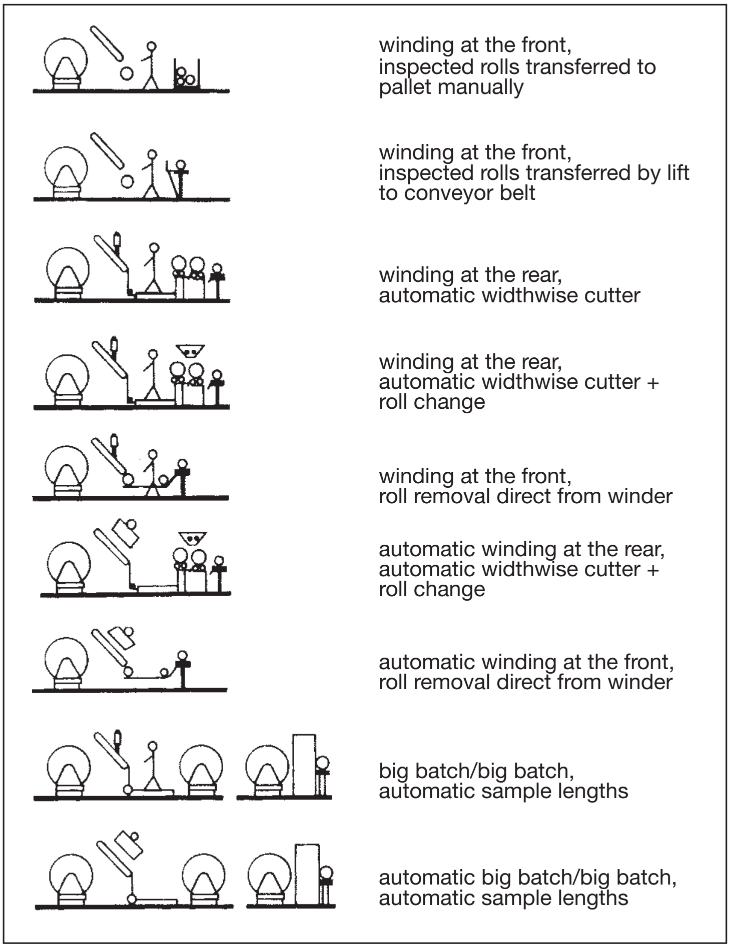


Fig. 1: Overview of fabric inspection concepts widely used in the textile industry (source: Silbernagel).

Fabric inspection machines

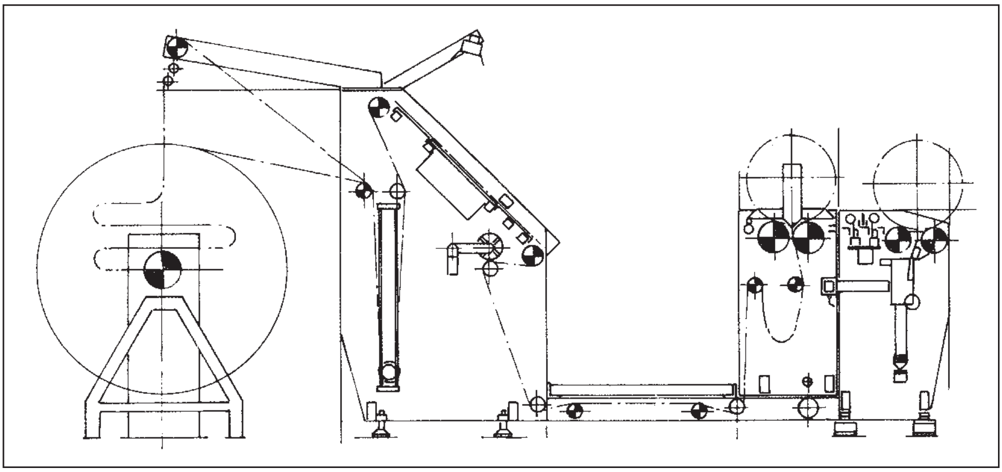


Fig. 2: Fabric inspection with unwinding of fabric from batch roll via rising roll batcher (Holthausen).

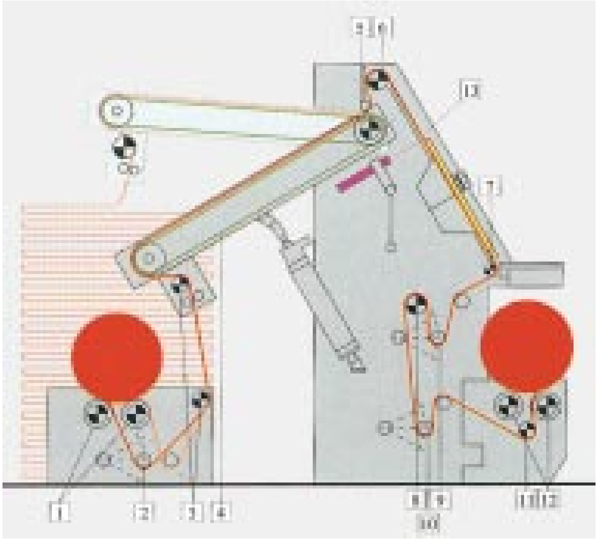


Fig. 3: Inspection machine (Menschner).
1 = unrolling cylinder; 2 = dancer with control for unrolling; 3 = spreader roll; 4 = transport belt; 5 = dancer with control for transport belt 4; 6 = transport roll; 7 = driven guide roll; 8 = transport roll; 9 = dancer with control for transport roll; 10 = dancer with control for rolling; 11 = spreader roll; 12 = rolling cylinders; 13 = measuring device.

- unwinding of fabric from batch roll via rising roll batcher (Fig. 2);
- delivery of inspected fabric rolls on to conveyors;
- automatic fault marking with automatic selvedge guiding system for the attachment of self-adhesive labels during fabric passage through the inspection machine;
- recording of faults during fabric inspection;
- automatic control of fabric width and automatic calculation of fault reimbursement;
- inspection by reflected and transmitted light with photoelectric support.

To simulate all the working functions of a human fabric inspector by means of a fully-automatic fabric inspection machine has not proved possible up to now because of the superior parallel calculating ability of humans compared to the linear operations of computers. At present, therefore, no fully automated fabric inspection machines are available in the market. Developments in measurement techniques for automatic inspection machines have been based on a virtually complete takeover of the fabric inspector's tasks by the system, i.e. the detection of faults, classification of fault types, geometric classification and recording of data.

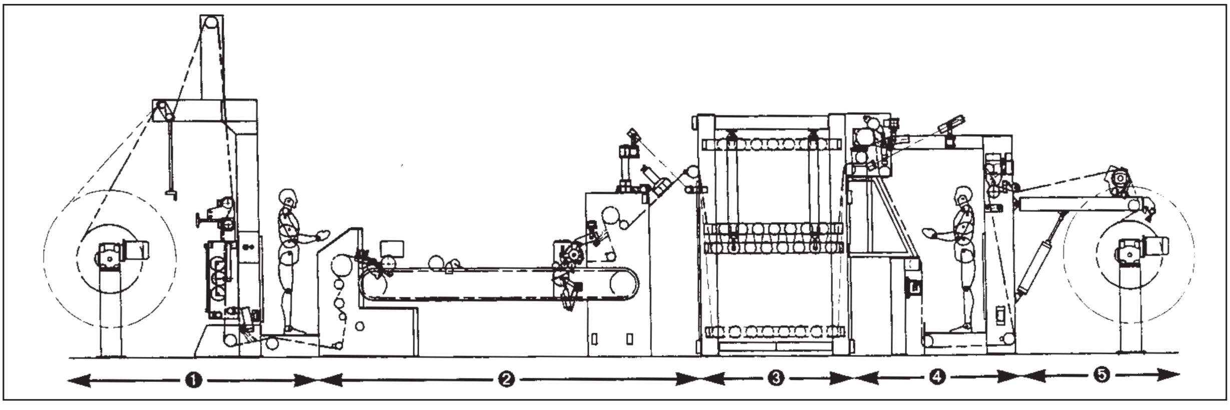


Fig. 4: Inspection unit (Erhard & Leimer).
1 = inlet; 2 = over feed shrinking and relaxation; 3 = fabric store; 4 = inspection; 5 = winding.

With fully automatic operation, there is no opportunity to carry out any corrections on the inspected fabric. In practice, it has been found that fabric inspection systems of this kind are associated with considerable technical problems and financial outlay, and often do not provide the desired efficiency and versatility.

The use of measuring technology solely for the independent detection of any deviations in the fabric appears to be a worthwhile alternative, thereby relieving personnel of actual fabric inspection. This concept allows fault classification and the reporting of data, even if technically assisted, to remain in today's well-established form. By this means, the operatives are relieved, above all, of the lifting operations involved (Fig. 5).

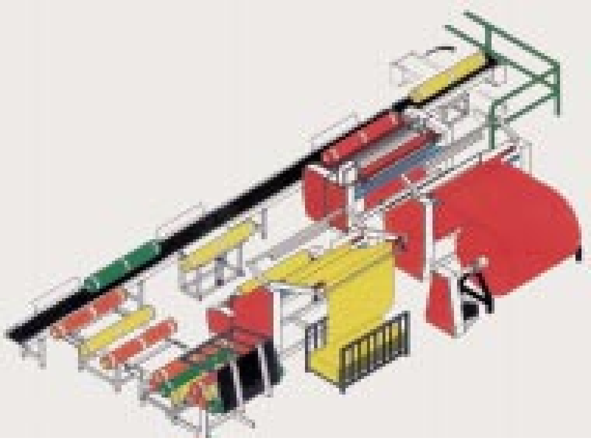


Fig. 5: Fabric inspection and making up system by ICBT.

An appropriate measuring technology performs the task of recognizing localized deviations in the fabric from fault-free material and, e.g. brings these to the attention of the fabric inspector by stopping the machine and emitting a warning signal. In the interests of technical preference, surface-related measuring technology is desirable for this purpose such as the modern image analysis methods or applications of moiré interferometry currently available. By employing appropriate image fields of individual data units (CCD cameras), the entire fabric width can be captured with just a few systems (Figs. 6 + 7). The problem up to now has been the high computing complexity, especially with regard to image analysis and the computing capacity necessary for real time measurements.

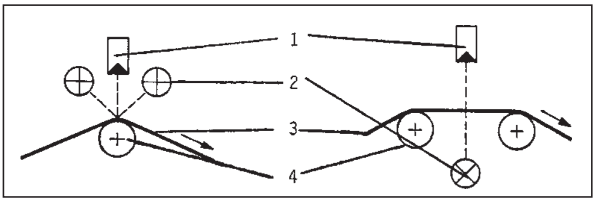


Fig. 6: Inspection by reflected light (left) and transmitted light (right) in photoelectric fabric inspection (Hell system). 1= photo element; 2 = light source; 3 = fabric path; 4 = guide rolls.

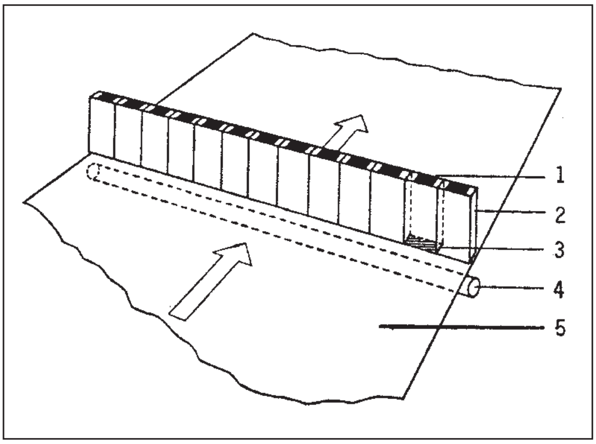


Fig. 7: Line-by-line scanning of the fabric width by means of photoelectronic inspection (Hell system). 1 = photo element; 2 = optical fibre rod to the photo element; 3 = visual range of the photo element; 4 = rod-shaped light source; 5 = fabric path.

Neural computing structures represent another alternative with a promising future. Specific algorithms capable of imitating the processes of human vision convert the imaging information into simple displays based on, e.g. one or more parameters. This image characterization is carried out in real time with the aid of hard-wired programs so that rapid image sequences (up to 50 Hz) are recorded and analyzed. The system should respond to deviations of measurements from the normal values, beyond set tolerance limits, with a standard signal, e.g. for a machine stop, or an acoustic signal to let the inspector know that an irregularity has been detected.

At present, three possible types of sensor are used in practice:

- laser scanner (telecentric and divergent),
- light scanner
- CCD camera systems.

1. Laser scanner: this consists of a laser light source (helium/neon or diode). The light beam is guided across the fabric path at high speed (approx. 6 km/s) with the aid of a polygonal reflector wheel. The scanning frequency is 3 kHz, i.e. the fabric path is scanned 3000 times per second. The size of the light spot is variable and lies between 0.1–2.5 mm. The laser scanner is suitable for reflectance and transmission measurements by the variable allocation of one or more receiving systems. In the case of the divergent scanner (Fig. 8), the focal plane and the fabric level can be made to coincide with the aid of special optics and a constant scanning speed is achieved. The angle of incidence of the inci-

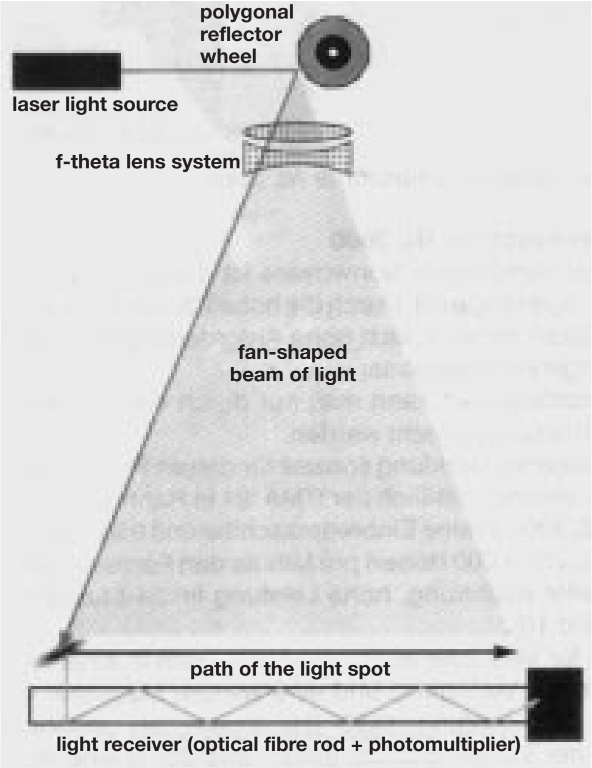


Fig. 8: Divergent scanner (opolix Opto Electronic GmbH) for fabric inspection.

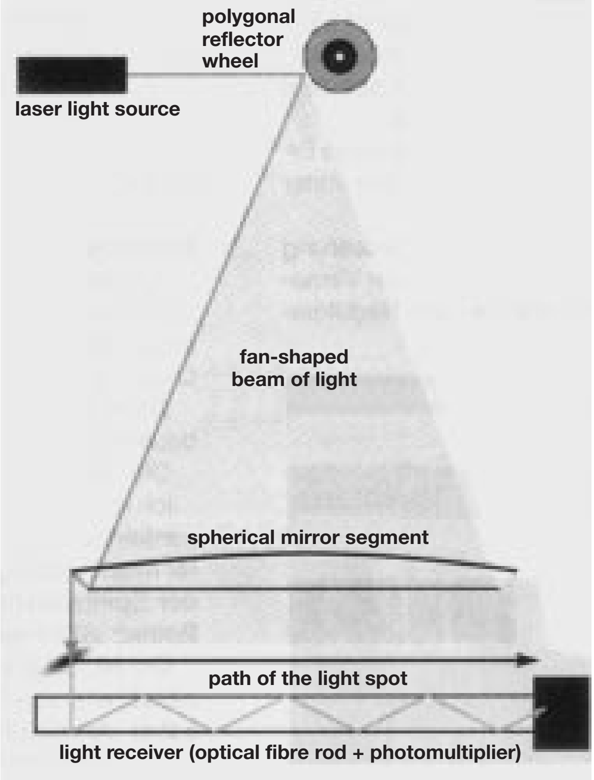


Fig. 9: Telecentric scanner for fabric inspection.

dent beam changes with the scanning location. With the telecentric scanner (Fig. 9), the angle of incidence over the scanning width is kept constant by means of a large optical element. Fabric widths greater than 2000 mm may be scanned more economically with the divergent scanner without having to accept any significant losses in fault detection. The telecentric scanner offers advantages with denser and more voluminous fabrics. Optical fibre rods which capture the transmitted or reflected light and conduct it laterally to a photomultiplier are used as receivers. Depending on the nature of the task to be performed, several such receivers can be used in parallel.

2. Light scanner: this is a scanning system in which the optical path length is contrary to that of the laser scanner. Instead of spot illumination, the entire fabric field is now illuminated with a more or less broad band of light. The advantage of the light scanner is the modular build up from 120 mm to over 6000 mm inspection width; it uses white light (fluorescent tube lighting). Because of the broad spectrum of the fluorescent lamps employed, application-specific spectral ranges may be selected which result in an extended range of appli-cation.

a) Transmission method: it is preferable to use this type of measurement if holes, thick or thin places, light or dark stains, or irregular fibre distribution have to be detected. For this purpose, fluorescent tubes are installed underneath the fabric path and the scanner, mounted above the fabric, is irradiated with their light after it has passed through the fabric. The fabric path is scanned by the scanner at high speed in 120 mm widths each time which converts the received light signals, after application-specific filtering, into electrical signals by means of photosensors which are processed by the evaluation electronics after amplification. Any width of fabric may be inspected by a combination of scanner modules. The chosen method of light guidance provides the light scanner system with a high depth of focus with the result that it is insensitive to fluttering movements.
b) Reflection method: with this procedure, surface defects in coated or uncoated materials can be detected. In this case, the light source and the scanner are mounted above the fabric path. The light reflected from the fabric is, in an analogous manner to the transmission method, detected by the scanner, converted into electrical signals and transmitted to the computer located in the evaluation unit. Through application of the so-called “averaging” process in the evaluation, even fine lengthwise faults may be analyzed. For this purpose the computer generates a fault signal average from numerous “scans” which results in a considerably improved signal-to-noise ratio. An exceptional feature of this system is its value in the field of coated interlining materials

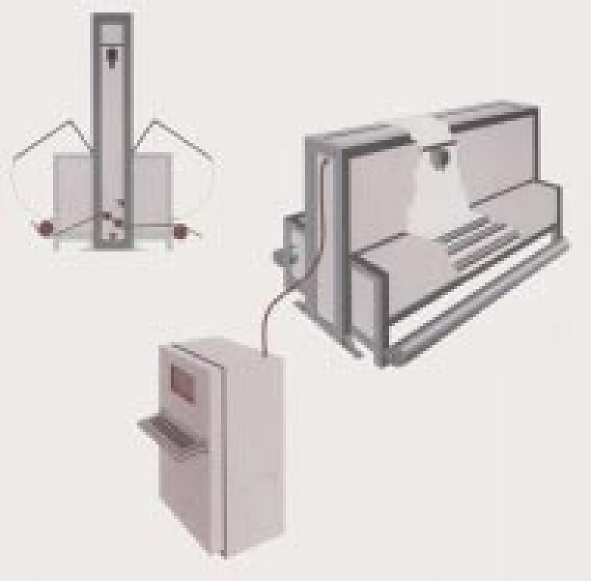


Fig. 10: Typical fabric inspection concept based on image processing with video cameras as in the EVS system.

resp. nonwoven interlinings. It is a prerequisite for these products that the base material contains no optical brightening agent, and that the coating compound (paste or powder) must be enriched with optical brightener and can be used with 11–30 mesh.

sensor type	advantages	disadvantages
laser scanner	● high optical resolution (0.1 mm) ● high line scanning frequency (→ 6 kHz) ● system data rate > 100 MHz possible ● point-synchronous parallel receiving channels possible ● angle of incidence constant (telecentric) ● many years experience with the system	● monochromatic, blind to some coloured faults ● high mechanical complexity (telecentric, up to now) ● limited scanning range (telecentric) ● joining together is problematic ● expensive (up to now) ● photomultipliers used as receivers (up to now)
CCD camera	● no movable mechanics involved ● suitable for colours with white light illumination ● telecentric imaging possible ● simple modular solutions ● long service life of sensor	● high power illumination necessary ● limited scanning rate ● number of pixels limited, i.e. supplementation necessary ● multi-channel reception channels are not point-synchronized (mechanical adjustment problems)
light scanner	● suitable for colours with white light illumination ● simple modular solutions ● long service life of sensor ● high system data rate possible ● suitable for dot-coated nonwovens	● high power illumination necessary ● limited scanning range, i.e. supplementation necessary

Table: Comparison of sensor types used in automatic fabric inspection (source: Schollmeyer).

3. Image processing with video cameras: this system is based on an illuminating unit consisting of a conventional light source and a cylindrical mirror which together produce a sharply defined band of light on the textile surface along the line of inspection. Both the reverse and face sides of the running fabric are monitored by cameras (Fig. 10), in which the illuminated inspection line is imaged by a diode array. Whilst one camera records the image of an illuminated inspection band by transmitted light and therefore detects holes, thin places, etc., among other things, the second camera records the image of the light band by reflection using such a flat angle of observation that all faults projecting above the surface of the fabric such as slubs, stains, creases, etc. are detected by the split beam process. The camera is provided with a diode array of approx. 4000 points so that the smallest recognizable faults of 1 x 1 mm can be detected over an inspection width of 2000 mm. A comparison of different sensor types is given in the table (source: Schollmeyer and Schicktanz).

Fabric length According to DIN: the length between two fully interlaced weft threads measured parallel to the warp at both ends of the fabric in a relaxed condition. The fabric length does not include the zones at the start or end of the piece.

Fabric opening machines →: Tubular fabric slitting machines; Rope opener.

Fabric relaxation → Relaxation.

Fabric slitting device → Cutting of textile fabrics.

Fabric slitting equipment Used for separating running fabric webs in the middle and into strips. Installed on production machines.

Fabric softener (Washing softener) → Washing aftertreating product for preventing boardy handle resulting from washing in a rotary washing machine with a lot of mechanical action and drying in still air. Provides considerable improvement to the handle of washes, provides full softness and makes synthetic fabrics antistatic by using fabric softener in the form of emulsions of mainly quaternary ammonium compounds, (such as distearyl dimethyl ammonium chloride), as a dilute aqueous emulsion, in the final rinse. Fabric softeners can be applied in varying percentages, can be washed out and prevent dye and pigment redeposition. They also have a soil-release effect on fat or pigment/fat soiling and make ironing easier. Practical conditions for fabric softeners: liquor ratio 1:5–1:7, liquor temperature after 5 rinse cycles around 15°C, addition 3–6 g/kg of washload, time 5–10 min.

Fabric softeners Special softening agents (→ softeners) in liquid ready-for-use form, sometimes containing fluorescent brightening agents. Applied in the final rinse after washing in commercial laundries and in household washes in order to achieve a soft handle, antistatic effect, and easier ironing. Since the introduction of drum type washing machines (relatively high mechanical stress) fabric softeners have been used on an increasing scale in order to prevent harshness of handle due to → Drying stiffness. The effect can also be observed visually with e.g. terry fabrics washed under comparable conditions: in the absence of a fabric softener the loop-pile surface appears quite irregular. In the presence of a fabric softener, however, the loop-pile has a much more even appearance.

Fabric speed control Systems to control fabric speed between two processing machines or machine elements in order to achieve a uniform fabric throughput.

Fabric spreading machines Machines used in garment making to unwind rolls of fabric and spread out the material for cutting. The machines are usually combined with measuring and cutting devices.

Fabric stabilisation In controlling the width of fabrics during drying on a stenter frame, a varying extension occurs from the centre to edge of the fabric (Fig. 1), which has a negative effect on the quality and subsequent processing of goods. In the early 1970s, a stretch method was devised by Raduner & Co., under the name ML (micro-expansion) process; this was later developed further in cooperation with Küsters. The principle is as follows: Through the adhesion of the goods on the surface of a roller, the fabric is stretched through the mutual penetration of the two combing rolls (Fig. 2), and after this pre-stretching process it is pulled to the new width (stretch width) by means of spreading devices. This functional principle of many small extensions gives the desired even stretching over the full width of the fabric.

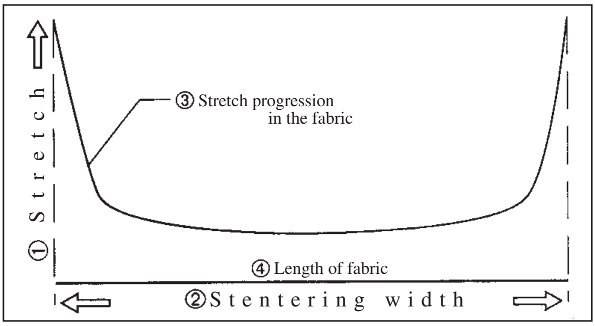


Fig. 1: Stretch progression over the width of the fabric when expanded on a stenter frame.

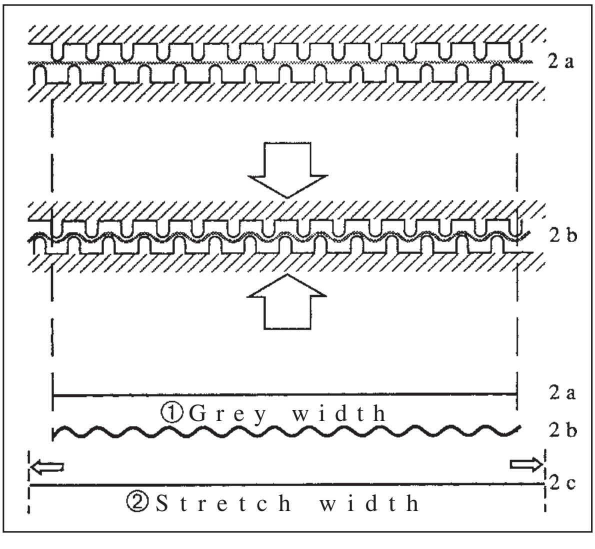


Fig. 2: Functional principle of stretching with two combing rolls.

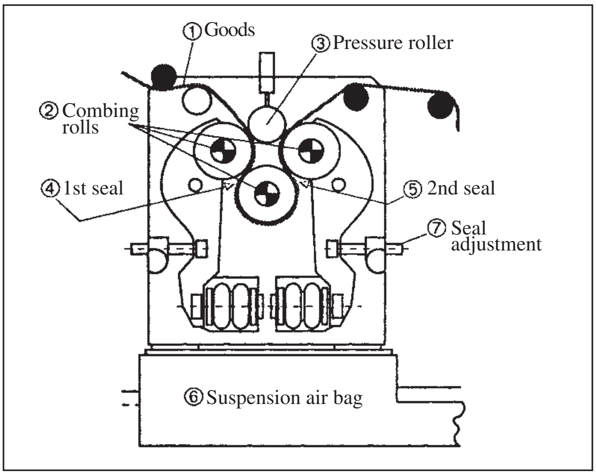


Fig. 3: Running of goods over the combing rolls of the Memotex machine (Küsters).

A uniform effect requires that the fabric is made extensible before processing by means of a swelling process. The macroscopic orientation (parallelisation) of the fibres is further fixed by the swelling process.

Two prerequisites are fulfilled by the Memotex machine concept (Fig. 3):

1. A fabric contact angle of more than 180° on the roller gives fixed cloth guidance.
2. Through a pressure roller, both the warp and weft are held evenly on the combing rolls. The pressure roller is pressed against the combing roll, and thus fixes the length of fabric on the surface of the rollers, which comb into one another.

Fabric straighteners Devices for straightening distorted fabric webs. → Weft straightening.

Fabric straightening machine → Straightening machine.

Fabric tension control A system for tension-free running of woven fabrics in continuous machines. The control functions are designed so that drives (DC motors or geared servomotors) as well as brakes (pneumatic or electric) can be controlled. An additional pneumatic unit is available for use with control systems for pneumatic brakes. Up to 6 brake callipers can be connected to it with a selected logic control (see Fig.).

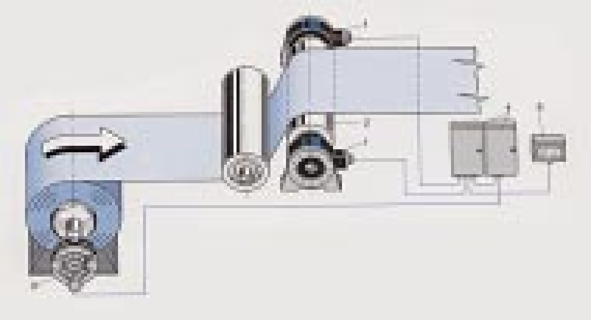


Fig.: Fabric tension plant of Erhard & Leimer.
1 = transducer; 2 = measuring roll; 3 = brake; 4 = control system with pneumatic unit; 5 = digital display.

Fabric tension measurement A system to determine the tractive forces acting on webs of fabric, e.g. by means of the Elmess web tension measuring system with a PD 21 transducer (Fig. 1): this determines the force produced by the tension of the web on a measuring roll where the angle of wrap between the web of fabric and the measuring roll should be 60–180°. The transducers on each side of the roll are connected via four wire cables to an electronic amplifier which evaluates the signals.

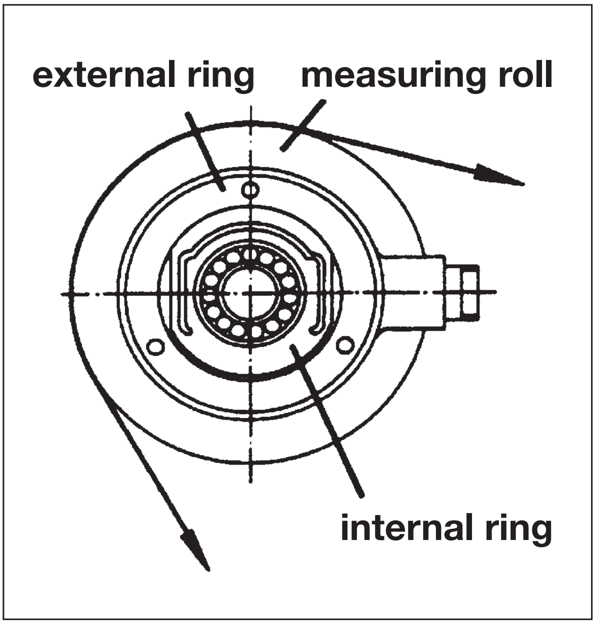


Fig. 1: Structure of the PD 21 for the fabric tension measurement (Erhard & Leimer).

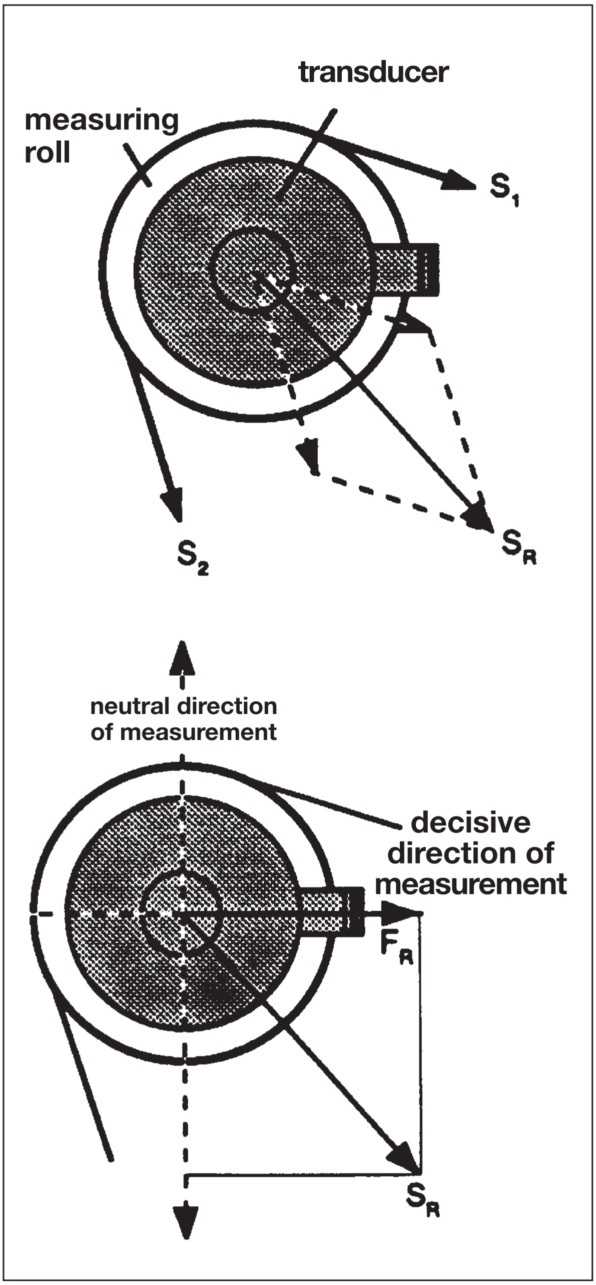


Fig. 2: Principle of measuring of the PD 21 (Erhard & Leimer) for the fabric tension measurement.

The transducer consists of an external and an internal ring and two flanges. Centring rings on both flanges make it possible to install the transducer precisely. The internal ring is designed to function as a measuring instrument; it also supports the ball bearing of the measuring roll. The measuring element itself consists of a double transverse beam assembly to which tension measuring strips in the form of a full electrical bridge are applied. Fixed stops protect the transducers against overloads up to 10 times the nominal measuring range. A stabilised direct current voltage from the electronic amplifier stores the balanced tension measuring strip-full bridge measurements. This bridge is “detuned” by the web tension and its output voltage is altered. The output voltage represents a signal which is proportional to the web tension force.

Both the web tension forces S_1 and S_2 are added together to give the resulting value S_R. Only the force component F_R acting in the direction of measurement is decisive for measuring the web tension (Fig. 2). The direction of measurement corresponds with the direction to the connector. All forces acting at right angles to this direction of measurement are not taken into account for the measurement of web tension (neutral direction of measurement). For example, the weight of the measuring roll itself no longer plays any part if the transducers are installed horizontally. Since the weight of the measuring roll acts in a downward direction, this force lies exactly in the neutral direction of measurement.

Fabric thread-up length The total length of fabric drawn over the rollers and/or suspended on rods in a textile finishing machine (e.g. steamer).

Fabric throughput For open-width processing machines throughput is expressed by the hourly throughput in dry weight per metre fabric width (kg/h/m). Fabric throughput is proportional to the weight/m^2 and the running speed.

Fabric transport

I. In-house: → Transport systems.

II. In processing machines: → Fabric guiding systems.

Fabric weight (cloth weight). Fabric weight may be expressed either as the weight per piece, per running metre, or per unit surface area.

I. Weight per piece or bale weight: the weight of an entire piece.

II. Weight per running metre: quotient of the weight of a full-width cutting of fabric (with or without selvedges) and its length. Since lightweight fabrics are currently of interest from the fashion point of view, efforts are made to reduce the weight per running metre, e.g. of wool fabrics (150 cm width) by suitable means. The use of fine yarns, either as single yarns or ply-yarns, and tighter weave constructions reduce the weight of wool fabrics within the region of 200 g per running metre. Fabric weights below 200 g per running metre are obtained with fine wool fibres of less than 20 µm (see Fig.). Because of the low number of fibres in the yarn cross-section, however, single yarns in the warp must be sized before weaving.

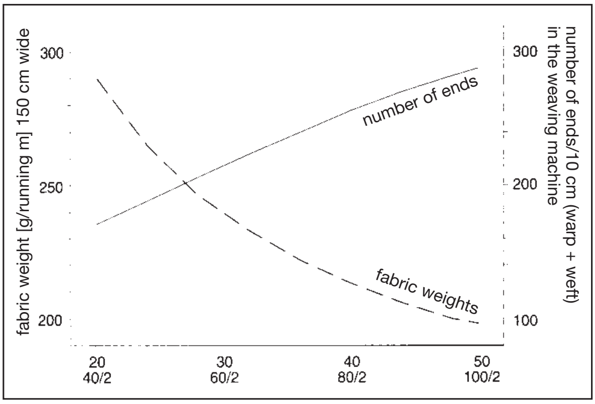


Fig.: Interrelationship between fabric weight and yarn type and number of ends.

III. Weight per square metre: quotient of the weight and length of a single layer of fabric without selvedges. → Fabric weight measurement.

Fabric weight measurement State of the art methods allow the continuous measurement of fabric weight on moving runs of fabric, based on the principle of mass-dependent absorption of a beam from a radioactive isotope passing through the fabric (see Fig.).

Absorption is calculated according to the following formula:

$$J = J_0 \cdot e^{-kF}$$

where

J_0 = radiation capacity of the source
J = residual radiation remaining after absorption by the fabric
F = fabric weight
k = material constant.

The nature of the radiation source, i.e. of the radioactive isotope, depends on the fabric weight that is to be measured. For the range of 500–5000 g/m^2, which is required in the carpet sector, an isotope of strontium (strontium 90) is usually used. This emits beta radiation (electrons) that, after passing through the goods, can be detected by means of an ionisation chamber. The strength of the ionisation current caused by the beta radiation is a measure of the material thickness in the measurement cross-section; thus with corresponding calibration it is also a measure of the fabric weight of the run of fabric passing through. Since with this measurement, the whole fabric is covered, to determine the weight of a coating, a differential measurement must be carried out; in other words, the weight before coating and the weight of the coated goods must be determined. The difference be-

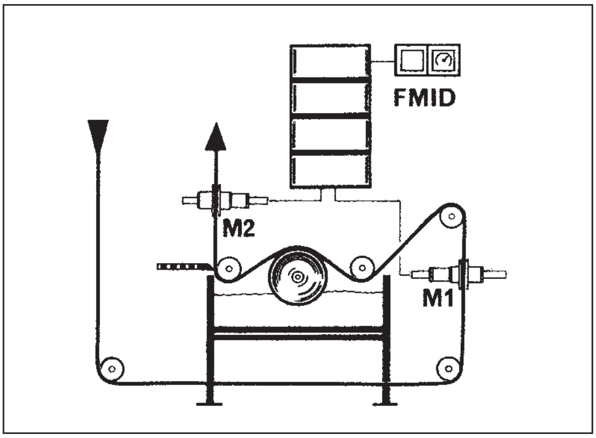


Fig.: Diagram of a fabric weight differential measurement plant, for determining coat weights (Mahlo).

tween the two values yields the coat weight. It is important to note that only comparative values are measured and a system for entering the fabric start weight for the difference calculation is required.

The measuring accuracy of the radiometric fabric weight measurement is better than 1% of the coat weight. In modern equipment, the natural decay of the radiation source, which within the half-life of the isotope leads to a reduction in the radiation intensity to half the initial state (approx. 27 years in the case of strontium 90), is compensated by automatic calibration. Furthermore, both the actual weight of the coat and its deviation from a set target value can be displayed digitally. The digital display of the raw weight and of the total weight is also possible. Devices such as these, which use isotopes, are subject to strict regulatory control and must have their approval continually renewed at regular intervals (source: Schellenberger).

Fabric widths Commercially conventional widths:
130 – 150 cm wool fabrics for outerwear;
80 – 90 cm silk materials;
75 – 200 cm bedding;
40 – 130 cm household linen;
80 – 130 cm tablecloths;
20 – 50 cm handkerchiefs;
80 – 140 cm materials for industrial clothing;
60 – 140 cm velvets;
70 – 80 cm shirtings,
trend toward standardisation of 150 cm.

Face-to-face carpets (double plush carpets). Carpets that are manufactured as a "sandwich" in a single operation, whereby the pile is attached to two substrates, one above the other. The pile weft forms the pile between the two warps, and two cut pile carpets are produced by cutting the pile yarns between the two substrates direct on the loom.

Face-to-face Tournay carpet (double Tournay). A → Face-to-face carpet produced on jacquard looms.

Fachgemeinschaft Textilmaschinen im VDMA → Technical and professional organizations.

Facing in roller printing A defect in roller printing caused by a printing roller with an inadequately polished surface (i.e. unsatisfactory smoothness): in this case the print paste is not entirely removed from the roller surface by the doctor blade leaving a fine film which is transferred to the fabric being printed causing the latter to be lightly stained in the unprinted areas. A similar defect can also be produced if the pressure applied to the doctor blade is not correctly adjusted.

Façonné A fancy material with a small pattern (including velvets and plush fabrics) of varying fibre types for scarves, blouses and ladies' cocktail or evening dresses.

Fade-Ometer Laboratory testing device used to determine the fastness of a coloured textile material to light exposure. → Light fastness.

Fading Loss of colour in dyeings and prints as a result of → Photochemical reactions.

Fagara silk (atlas silk). A → Wild silks produced by the atlas moth (East Asia). Similar to tussah silk, light brown in colour. Used for schappe spinning.

Fahrenheit scale (°F). A temperature scale invented by the German physicist, G. D. Fahrenheit (1686–1736) in which the separation between the freezing point (32°F) and the boiling point of water (212°F) at standard atmospheric pressure is divided into 180 equal parts.

Conversion into °C: $°C = (°F - 32) \cdot {}^{5}/_{9}$.

Faille A fine, cross-ribbed, poplin-like dress and coat fabric (silk, half-silk, viscose filament and staple fibres) in taffeta weave. Faille Français: pure silk, delicate and fine-ribbed. Faille-luisant: iridescent sheen. Luxury faille: fine-ribbed viscose filament with lustrous and matt sides. Faille-mirage: moiré appearance, viscose filament in the warp, metallic yarn in the weft. Faille-reversible, Faille-satin: 2-sided effect lightly ribbed and smooth on the reverse. Failletine: similar to Faille Français, very fine ribbed and delicate.

Fallen wool Wool originating from dead sheep. Is generally removed from the skin using lime before tanning. Its affinity to dyes differs from that of → Virgin wool.

Fallers Protrusions on a drum interior surface which turn and submerge the item being treated during drum rotation, thus increasing the mechanical action. Number of paddles usually 3 equally spaced. Shape of paddles (e.g. trapezoidal or flat) and height should not exceed a certain size, since otherwise the narrowing of the space available for movement would have a detrimental effect. High rotation speeds therefore require lower paddle sizes, which has proved to be more important than increasing the number of paddles. Experience has shown the most efficient paddle height to be ${}^{1}/_{3}$ of the drop height.

Fall height Function of action in application baths, e.g. the washing mechanism in drum washing machines (→ Drum partitions). Fall height = drum diameter in m – liquor level in the drum in m.

Fall-on in printing A partial overprint of a preprinted print paste by another print paste, e.g. a preprinted black outline overprinted with a coloured print paste, or the overprinting of one coloured print paste by a print paste of a different colour = combination shade.

False brocade In contrast to a genuine brocade, this is a woven fabric produced on normal looms where the brocade effect is formed as a rule by a second warp or weft thread system with figuring threads. "False" brocade produced on looms without a swivel embroidery sley can be recognized by its low mechanical resistance: the threads are easily drawn out of the fabric.

False selvedge chain Small support belt (linen warp) for men's ready-to-wear products.

False twist → Texturizing.

False twist yarn (textured) Higher speeds are being accomplished equally via machine and feedstock. Back in the 1970s the machine maker supplied machinery capable of achieving higher speeds whilst feedstock producers provided material that could easily be processed at these higher speeds – or if necessary at even faster speeds. Today the situation is reversed and machines have still greater reserves, being designed to operate at 1500 m/min (Fig. 1).

In order to make full use of the potential the feedstock must be improved. Research is concerned with producing still more uniform yarns by improvements in polymer and spinning process. Spinfinishes are being improved, application rates made more even and thread levelness better in order to attain a more advanced level of speed free from vibration by PC-control (Fig. 2).

→ Textured yarns.

Fan (Air) →: Extractor fans, Compressors, Ventilation systems. Also for steam boilers (forced draught firing, oil firing fan), atomization, pneumatic transportation.

Fancies Examples of fantasy figures plaited from straw.

Fancy A type of coarse flannel, napped on both sides, in linen or twill weave, of cotton or cotton-viscose blend. Double fancy is the name given to goods that are typically two-tone, e.g. with one side pink and the other a mottled blue. Used for cold-weather underwear.

Fancy-ply yarn A collective term for particularly fancy yarns with knots, loops, etc. Special effect yarns are produced on twist frames with additional feeder rolls which supply the main feeder roll at varying speeds.

Fancy print A term used for all types of printed articles which do not fit into the category of traditional Africa print styles. Fancy prints are usually produced with designs having large motifs. They are the cheap mass-produced printed fabrics in West and Central African countries.

Fans Devices for delivering or exhausting large volumes of air or gas with only a low increase in pressure (used in demisting, air conditioning plants and drying systems). Their mode of action is generally based on blowing (suction and blow principle: → Extractor fans; as well as induced-draught fans for steam boiler furnaces). Requirements: → Ventilation systems. Constructional features are determined by their field of use, e.g. centrifugal or airscrew (multi-blade) fans, special fans for acid vapours (exposed parts encased in vulcanite or constructed of stoneware). For industrial applications, belt, electric or steam-driven fans with speed control (variable speed fans) are mainly used.

FAS, abbrev. for: → Fatty alcohol sulphates.

Fashion There has always been a mutual dependency between textile technology and fashion. It is often

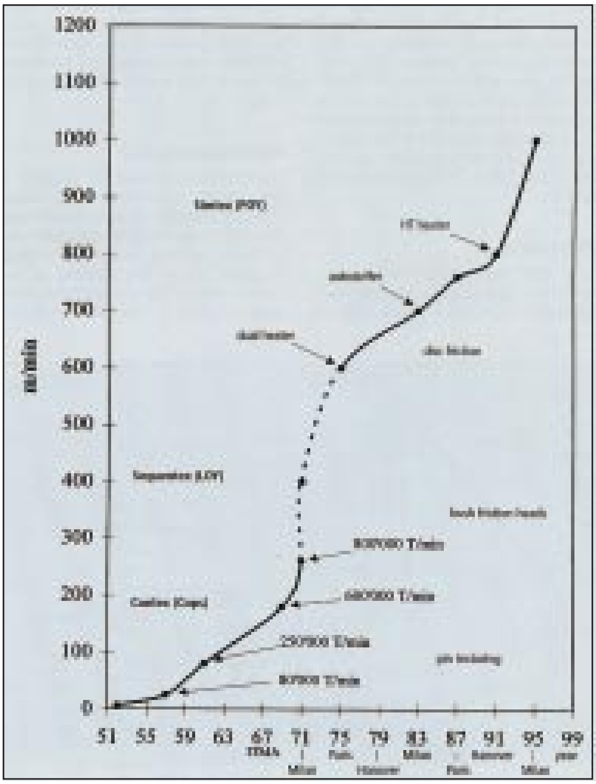


Fig. 1: False-twist texturing: Progression of speeds for texturing PET dtex 167 f 30 (Setila AG).

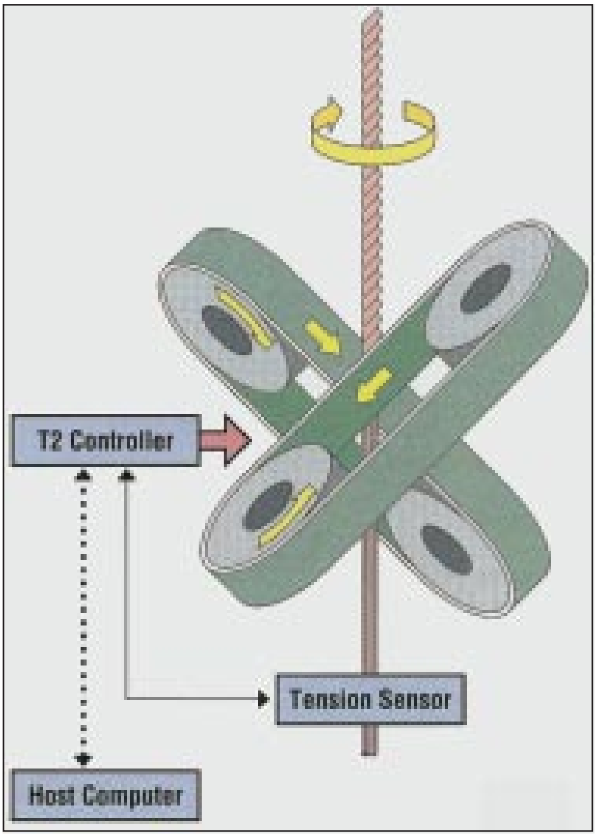


Fig. 2: Muratec NIP Twister with Tension Control System.

difficult to know whether the demand for decoration encourages technical development or whether new technical facilities awaken the demand for fashionable appeal and appreciation. Before the French revolution and the industrial age, it was mainly a question of making people's clothing from natural materials using craftsman's skills. Pictures from centuries past are evidence of how this developed from wearing bear skins to skirts made from bast and straw, linen to woollen doublets and finally to silk robes. Fashion was clothing which leading society figures were wearing and that which was usually unobtainable to the masses because of the scarcity of the valuable materials, and was often even forbidden because of existing clothing regulations. Only after the French revolution were all citizens permitted to dress "à la mode". During the last 150 years, this democratisation has led to increasing equality in clothing, the development in making-up and therefore the demands of the masses for dressing in accordance with fashion. Fashion has therefore become the driving force behind a major branch of industry. In parallel with this, the manufacture of clothing has been transformed from a craft into a technological process. The demand of the masses for standardised clothing encouraged the transformation of the spinning wheel into the spinning machine, and the handloom into the automatic weaving machine. There are many examples showing what textile technology had to do in order to meet increasing demand.

The increase in fibre consumption was initially met by extending cotton plantations, improving sheep breeding and starting to breed silkworms in the Near East. But what would fashion be today without the rapid development of synthetic fibres, without viscose and cupro fibres, and without the manifold uses of polyamide, polyester and polyacrylic fibres. Ladies' stockings, acetate silk dresses, leisure clothing made from textured synthetic yarns and the use of gold and silver thread incorporating metallized synthetic threads are some of the many examples. New fashionable effects have become possible using extremely elastic or shrinkable fibres and bi-component fibres. A comparison of the range of natural dyes more than 100 years ago with the current range of dyes clearly shows where fashion would be today without synthetic dyes. It is not just the brilliant colours of the reactive and cationic dyes that allow shock fashion and brilliant shades of turquoise; the high degree of realism is that which allows the wide range of bright colours to spread, not just in beachwear and leisure wear. Fluorescent dyes and so-called chameleon designs have opened up new avenues. The desire of the masses for fashionable clothing can only be met if the clothing does not require undue care. Textile finishing methods come some way to meeting this demand using new fibres, dyes and auxiliaries. Permanent creases, "Everglaze", non-iron, wash-and-wear, permanent press, "Sanforizing", oilproofing are just a few of the keywords, plus dry-cleaning, waterproof finishing and non-iron clothing. Finishes that were previously impossible from a fashion point of view are being achieved by metallizing, and technological effects using foam coating. In the field of machine technology, spinning machines and automatic weaving machines have been supplemented by hosiery and knitting machines, highly-developed sewing machines and equipment for nonwovens manufacture. Appropriate, continuously operating equipment in dyehouses, printing shops and textile finishing were the prerequisite for faster, better and cheaper processes for these operations. Recent developments are also expected to affect fashion in the future, such as woven and knitted stretch fabrics, nonwovens, sewing and tufting equipment, soil-repellent finishes, differential dyeing fibres and perhaps also with different finishing techniques and solvents. Other textile technology methods are in the pipeline in the form of direct spinning processes and the manufacture of yarn from split film.

Fashion clothing is not worn at the expense of comfort as it was in the days of crinolines and corsets. Manufacturers take clothing comfort into account and attempt to produce clothing that is compatible with the body without having to forego appearance and fashion, not just in the structure of the clothing but also the outward appearance. The sociological aspect of fashion is seen as being the driving force behind economically meaningful mass production in the field of textiles, and also prevents uniformity due to continuous change, and allowing adequate freedom for personal taste. With the aid of advertising and its almost dictatorial power, fashion is "engineered", taste is influenced and the consumer is persuaded to get involved in fashion unless he wants to be a social outcast. Fashion and textile technology therefore help to encourage and further develop an economically important branch of industry.

It is not easy to define the terms "fashion" and "trend". Reduced to a common denominator, one could say that fashion is the continuous further development of peoples' ideas. However, trends could be defined as style directions that run for many years and are continuously perfected. For this reason, curtains, for example, inbetweens, furnishing and upholstery materials and carpets are more difficult to design from a fashion point of view than clothing materials, not least because of the consumer's buying habits. Household textiles are usually only purchased at intervals of 5–10 years in 90% of cases. The reason for this phenomenon of the domestic textiles sector lies in the fact that it is still catching up from a fashion point of view in comparison to clothing. Many household textile manufacturers are constantly trying to become "more fashionable", although consumers counter this initiative with their buying habits. Modified lifestyles can only be sold to the

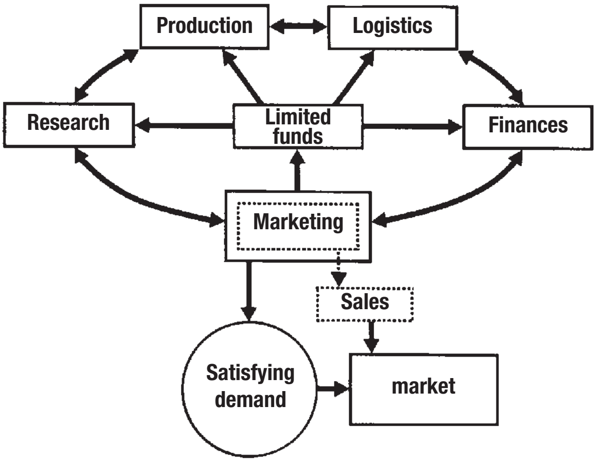


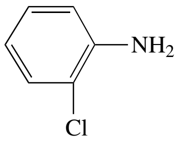
Fig.: Textile developments must meet consumer demand.

end consumer with the aid of intensive marketing. In order to encourage sales, new markets must be found and new material appearances must be developed using new yarns. The textile industry cannot produce just what it wants to, but has to produce products that meet and satisfy consumer demand. Determining consumer requirements is a marketing task.

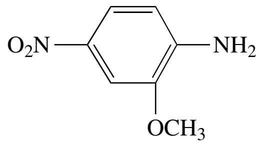
Marketing must formulate market requirements and pass them to research and development. The funds available for research projects should be geared to this. It appears to be natural that research and development can critically assess and differentiate between short and long term requirements and that the correct priorities with potential profit generation will be set in collaboration with marketing (Fig.).

Fashion leaders come into contact with the physiological dimension of their task, since colours have much to do with consumer attitudes. If things are going well, we want to wear red. If we see the future somewhat more pessimistically, the colours become darker and more subdued. There are periods in which warm, burnt colours are in demand. Then brighter colours follow again. Requirements derived from ecological considerations also have a considerable effect on colour selection; they give the fashion world the subtle, soft natural colours. The continuously recurring and accelerating cycle should not be forgotten: it used to take 10 years before a “colour wave” (red shades or green) came back. Now it only takes half as long. In other words: anyone closely involved with fashion can detect certain trends which send them down the correct path. In order to develop the correct sense, as much information as possible must be gathered. Examples of information sources are textile fashion bodies, for example: such groups contain specialists with a feel for fashion and have many years of experience. Additional information can be found in fashion magazines, fashion books and the collections of avant garde designers.

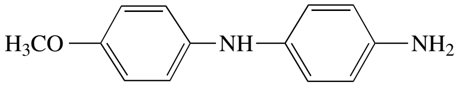
Fast colour bases Coupling products for the development of Naphthol AS dyes (Hoechst). They are not dyes, but soluble intermediate products with a basic character due to the presence of amino groups.Before use, these amino groups must first be diazotized before they can couple, exactly like → Fast colour salts, with Naphthol AS components to form insoluble dyes. Examples:



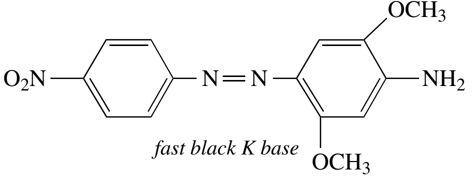
fast yellow G base



fast Bordeaux B base



variamin blue B base



fast black K base

The examples also serve, at the same time, to demonstrate the gradual shift in colour from yellow to black with increasing molecular size.

Fast colour salts These are already diazotized, water-soluble coupling products (so-called stabilized diazo compounds) of the corrresponding → Fast colour bases, used for the development of Naphthol AS dyes (Hoechst). Compared to fast colour bases, the salts offer advantages of better keeping properties, easy solubility, greater reliability, and simpler application.

Fastness Commission The German organisation (EK = Echtheits-Kommission) for colour fastness. Most member countries of the International Organisation for Standardisation → ISO, support its Technical Committee 38 (TC38) which was made responsible for all matters concerning textiles and, within TC38, Sub-Committee 1 (SC1), which became specifically responsible for all colour fastness test methods through the national committees of ECE countries. ISO/TC38/SC1 has continued to this day to encourage the development, international acceptance, and use of agreed methods of test for all the different colour fastness agencies. The two most active groups contributing to this work are the European Colour Fastness Establishment (→ ECE) and the American Association of Textile Chemists and Colourists (→ AATCC). Important technical contributions are also regularly made from countries outside Europe and the USA, including Australia, Canada, China, India, Japan and South Africa. Neither the ECE nor the AATCC are members of ISO – it is the national standards organisations of the respective countries that are ISO members. The national committees of ECE member countries (and others, including the USA) may be contacted through their specific addresses in the respective countries; → Technical organisations.

Fastness Convention European Convention for Fastness Tests of Dyeings and Prints (ECE).

Fastness evaluation of dyeings and prints → Fastness testing.

Fastness improvement → Fastness-improving agents.

Fastness-improving agents Textile auxiliaries or chemicals used to improve the colour fastness of dyeings and prints by means of an aftertreatment. Such products are generally used to improve the colour fastness to light, rubbing, and wet treatments. For this purpose products are used which form virtually insoluble compounds with dyes on the fibre (especially direct and acid dyes, as well as wool/cotton union dyeings). Other products are used to remove unfixed dye from the fibre (e.g. in naphthol dyeing).

Fastness properties →: Fastness standards; Fastness testing.

Fastness ratings of dyeings and prints Comparative numerical ratings obtained by the comparison of textile test specimens against either the → Blue scale or the → Grey scales after an appropriate fastness test.

Fastness requirements in manufacturing This is the sum of all the colour fastness requirements which, due to further processing stages, have to be fulfilled by the dyed or printed textile. For individual fabrics, these fastness requirements differ according to the type of fibre involved. → Fastness testing; → Colour fastness to processing.

Fastness standards (colour fastness standards). The drawing up of international standards for colour fastness determinations is an ongoing activity of → ISO in cooperation with various national standards organizations. It is recommended that guidelines issued by national fastness testing commissions for determining the colour fastness of textiles should only contain slight amendments from the ISO standards.

Fastness testing The purpose of colour fastness testing is to determine the resistance of dyed and printed textiles to various agencies at different stages of the manufacturing process (→ Colour fastness to processing) as well as in subsequent use (→ Colour fastness of textiles in use). Examples of the former category include: colour fastness to kier boiling; chlorination; bleaching (sodium chlorite); bleaching (hypochlorite); bleaching (hydrogen peroxide); decatizing; degumming; carbonizing; mercerizing; vulcanizing; soda boiling; cross-dyeing; stoving; metals in the dyebath; potting; milling; pleating; sublimation; resin finishes, etc., whilst examples of the latter category include colour fastness to light; weathering; washing; water; perspiration; rubbing; burnt gas fumes; chlorinated water (swimming bath water); seawater; ozone in the atmosphere.

The colour fastness testing of dyed and printed textiles has been systematically developed since 1911 by the DEK = Deutsche Echtheitskommission (German Fastness Commission). These tests are among the oldest of all standardized test methods. The Industrial Standards Committee founded in 1917, which was renamed as the DNA in 1926, assumed responsibility for colour fastness testing. In 1975 the name was changed again from the DNA to DIN (i.e. Deutsches Institut für Normung e.V. = German Institute for Industrial Standards). Since the DEK was re-established (after the Second World War) in 1949, the colour fastness test methods have been further supplemented largely as a result of close contact with similar bodies outside Germany (ECE and ISO) which led, in 1978, to the ISO Recommendations being published for the first time as international standards (ISO 105 A to Z) in English and French only. A second edition with a few additions appeared in 1982.

Many colour fastness tests are carried out as so-called “sandwich” tests, i.e. the test specimen is placed between two undyed textile fabrics (→ Adjacent fabrics) made from different fibres (dependent on type of fibre in the test specimen) and sewn together to form a composite for testing. The use of two different adjacent fabrics may, however, be replaced by standard → Multifibre strips in many cases. The composite sandwich is then subjected to the appropriate test procedure after which an assessment of change of colour and staining of adjacent fabric is carried out with the standard → Grey scales. These scales cover 5 full steps arranged in geometrical progression where a rating of 5 represents excellent, and a rating of 1 represents very poor colour fastness. With decreasing fastness, the degree of contrast in the grey scale increases by a factor of 2. The greatest difficulty in using the grey scales is to visually assess the degree of contrast or colour difference between the stained and untreated adjacent fabrics or between the test specimen and the original dyeing or print to coincide with differences in contrast in the grey scales. The degree of uncertainty is naturally higher the greater the colour difference of the test specimen from the grey of the grey scales. For the most reliable assessment, therefore, the average visual judgement of several assessors must be sought, which makes the process more time-consuming and laborious.

Almost all colour fastness assessments, with the exception of light fastness, are carried out with the grey scales. In the case of light fastness, 8 different dyeings which form the → Blue scale are exposed to light at the same time as the test specimen in order to determine and take into account differences between various light fastness testers. After exposure, the degree of fading of the test specimen is compared against that of the blue scale. If the test specimen has faded to the same extent as blue dyeing 5 for example, a light fastness rating of 5 is given. Up to now, there is no standard in existence for the colorimetric evaluation of test specimens against the blue scale so that light fastness ratings must continue to be decided by visual assessment.

Numerical key to assessments:

Evaluation:

Light fastness (Blue scale)		Other types of colour fastness (Grey scale)
very poor	1	poor
poor	2	moderate
moderate	3	quite good
quite good	4	good
good	5	very good
very good	6	
excellent	7	
outstanding	8	

The use of → Standard depths of shade makes it possible to express the depths of shade of the coloured samples being assessed. The problem of establishing standard depth of shade levels is mainly of concern to dye manufacturers since colour fastness testing of their products is extremely important. Colour fastness is, to a greater or lesser extent, highly dependent on the depth of shade. In order for the dyer to be able to compare the colour fastness ratings given in their pattern cards with the corresponding colour fastness ratings of products from other manufacturers, they must be determined under the same conditions worldwide at similar depth of shade levels. The most important depth of shade for testing textile dyes is the so-called 1/1 standard depth. This level has been defined since 1956 by 18 dyeings which have been recognized by the ISO Standards Committee ISO/TC38/SC1. These 18 dyeings are described as standard types. If, for example, it is intended to test the colour fastness of a new dye developed through research, then the dye concentration required to produce the 1/1 standard must be determined as a first step in order that the colour fastness tests can be carried out in accordance with the standards. For this purpose, dyeings are produced at various concentrations and the concentration which gives the same depth of dyeing as the 18 standard types is determined by visual assessment. The assessor has a wide latitude here, especially if the dye being tested differs greatly in shade and/or purity from the nearest standard type which is usually the case with only 18 standard types. Since the opinions of assessors with different levels of experience may vary considerably, a precise result can, once again, only be obtained through painstaking multiple assessments. The already expressed desire for a colorimetric method is therefore understandable.

Over the years, various methods have been proposed and discussed. In 1989, agreement was reached on a colorimetric method, which has been introduced as ISO Standard IS/DP 105-A06 (DIN 6174). By means of the formulae given in this standard, those lightness coordinates for a dyeing based on CIELAB coordinates can be calculated in the CIELAB system which would correspond to a dyeing with the same colour depth as a 1/1 standard depth of shade. By comparing the calculated value with the measured lightness of the dyeing, it can be established whether the dyeing lies within the desired 1/1 standard depth of shade of tolerance or whether it is too light or too dark. It is worthwhile to combine the formulae stipulated in the standard for the determination of 1/1 standard depths of shade with a computer colour matching program. By this means, it is also possible to calculate the concentration required to give a dyeing at 1/1 standard depth in addition to the calculation of lightness (source: Wehlow and Meyer).

Fastness test specimen Used in → Fastness testing often together with → Adjacent fabric. Guidelines: only textile materials in the flat state are suitable for testing. Yarns are knitted or otherwise converted into a flat form for this purpose. Loose fibre is converted into a fleece. Minimum size of test specimen 10 cm x 4 cm. The adjacent fabric specimen and the test specimen, of equal size, are joined together by sewing before the fastness test.

Fastness to cross-dyeing In order to meet the changing demands of the fashion market more quickly, some coloured textiles are produced as follows: yarn is dyed so that it is fast to cross-dyeing (e.g. reactive dyeings on cotton or chrome dyeings on wool); this yarn is then woven with undyed yarn to give a patterned fabric. The fabric is then pretreated and kept in store until a decision has been made on the colour required for the finished article. As soon as this has been decided, the fabric is piece-dyed. During this process, only the undyed yarn component is coloured and the already dyed component is not visible; the latter must not bleed otherwise cross-staining will occur. Colour fastness to cross-dyeing is determined in accordance with DIN 54 049 or BS 1006 X07.

Fastness to degumming This test determines the resistance of dyeings or prints to the effects of soap solutions used for the → Degumming of raw silk. Test specimens, sandwiched between undyed adjacent fabrics, are gently boiled under reflux in a soap solution (7 g/l) for 10 min (liquor ratio 100:1). After this treatment, the test specimens are rinsed in distilled water, followed by rinsing for 10 min in cold tap water, then dried in air (<60°C). Change of colour and staining of adjacent fabrics are assessed with the standard grey scales.

Fastness to hot air vulcanization Fastness of dye to the effects of a typical caoutchouc mixture and its decomposition products during hot air vulcanization. The sample is placed on the non-vulcanized bed of caoutchouc and suspended in the heating cabinet for 30 minutes at 125°C with air circulation. The test piece is allowed to cool and removed from the caoutchouc. The change should be assessed immediately and after conditioning for 4 hours at 20°C and 65% relative humidity.

Fastness to hot water (Fastness to crabbing), resistance to hot water. Test piece is wrapped around a glass rod, treated with 100 ml of acetic acid solution (7 mg/l of pure acetic acid) in a round flask for 30 minutes at 70°C and dried at max. 60°C without rinsing. Assess using grey scale.

Fastness to milling

I. Alkaline: determines the resistance to alkaline milling conditions, a) mild (light): the test specimen is treated in mechanical washing machines with 10 stainless steel balls for 30 min at 40°C with 10 g/l soap (liquor ratio 3:1), after which water at 40°C is added until a liquor ratio of 100:1 is reached, and treatment is continued for a further 10 min followed by rinsing and drying at a temperature up to 60°C; b) strong (severe): treatment as in a) above but with 50 stainless steel balls and 50 g/l soap as well as 10 g/l sodium carbonate (anhydrous) for 2 h at 40°C followed by a further 10 min at 40°C at a liquor ratio of 100:1. Assessment: change of colour and degree of staining are assessed visually by comparison with the standard grey scales.

II. Acidic: determines the resistance to acidic milling conditions, a) mild (light): the test specimen is treated with 1 ml/l conc. sulphuric acid at 60°C for 1 h at a liquor ratio of 40:1; b) strong (severe): treatment with 1 ml/l conc. sulphuric acid and/or 5 ml/l acetic acid 30% at 90°C for 30 min. The test specimen is constantly moved in the liquor and pressed with a glass rod every 2 min to ensure complete penetration during this period. After rinsing, the test specimen is opened on 3 sides and dried at a temperature up to 60°C. Evaluation: as in I above.

Fastness to organic solvents Resistance of dyed and printed textiles to the action of organic solvents, as used in dry cleaning. The guideline for all fibres is: treat test subject for 30 minutes at room temperature (liquor ratio 1:40) separately in each organic solvent. In manual testing, push the test subject to the bottom every 2 minutes using a glass rod. Then squeeze out any excess solvent and dry in warm air at 80°. Assessment: colour change and bleeding using grey scales.

Fastness to processing Fastness properties, i.e. the resistance of effects, dyeings or prints to various agencies fall into two categories: a) fastness performance in use (e.g. colour fastness to light, rubbing and washing) and b) fastness to conditions in processing, i.e. before the goods are finally finished. This latter category is unimportant to the end consumer since it is concerned with the effects of processes carried out after dyeing or printing before final finishing (e.g. carbonizing, decatizing, resin finishing, potting, etc.). Changes in the shade of dyed or printed cotton fabrics after crosslinking with a resin finish may be due to the dyes having poor fastness to the catalyst used. Changes in shade during carbonizing are usually reversible as soon as the accumulated protons, which block the conjugated double bond system of the chromophore, are removed again after neutralization. On the other hand, colour fastness to carbonizing is not given as a typical example of fastness to processing. Dye makers pattern cards contain information on the fastness to processing of their products so that, in the case of colour fastness to carbonizing, for example, care must be taken when establishing dyeing recipes to select dyes with adequate fastness properties.

Fastness to sea water Textile dyeing resistance to sea water. Wet the test piece and accompanying fabric with solution (distilled water containing 30g/l of sodium chloride). Place test piece between two plastic plates in apparatus such as the Hydrotest and expose for 4 hours at 37°. Dry the sample and the accompanying fabric separately in warm air (<60°C). Assessment: colour change and bleeding using the appropriate grey scales. AATCC test 106–1972: 30 g/l of sodium chloride and 5 g/l of anhydrous magnesium chloride, 38°C, 18 hours (DIN 54 007 or ISO 105).

Fastness to soda boiling The resistance of dyeings or prints to the effect of dilute boiling sodium carbonate solution. Test methods are applicable to cellulosic fibres. Two treatments with and without the addition of a reduction inhibitor are used: a) 10 g/l anhydrous sodium carbonate and 4 g/l sodium m-nitrobenzenesulphonate in distilled water; b) 10 g/l anhydrous sodium carbonate, without addition, in distilled water. The test specimen is rolled around a glass rod and boiled for 1 h in the test solution under reflux after which it is unrolled, rinsed for 10 min, squeezed, and dried at 60°C. Assessment: standard grey scale for assessment of change of colour.

Fastness to superheated steam vulcanization Fastness of colour to the effects of a typical caoutchouc mixture and its decomposition products during vulcanisation using open steam that a) is prevented from penetrating the test material, b) penetrates the test material. The sample is placed on a non-vulcanized bed of caoutchouc and wrapped around a steel pipe. Accompanying fabric, cotton and material impermeable to steam and water are placed on top (in condition a) or only accompanying fabric and cotton (in condition b). This assembly is treated for 20 minutes in pre-heated autoclaves at a heating jacket temperature of 141° and vessel temperature of 138°, then air cooled. Assessment: colour change and staining onto accompanying fabric using grey scales.

Fastness to washing In recent years, domestic washing practices have undergone considerable change. In addition to the use of more powerful detergents and the increased mechanical action to which household laundry is now subjected, the trend towards lower washing temperatures must also be mentioned. The textile industry will have to come to terms with these changed conditions by developing appropriate fastness tests on the one hand and by ensuring that the colour fastness of manufactured textiles is suitably adapted to meet these test requirements on the other. Important connections with general validity for the wet fastness of coloured textiles can be demonstrated by reference to the relevant ISO standard proposals. At any time, alternative procedures can be demonstrated for a variety of important substrates which allow new requirements for serviceability fastness to be achieved in practice.

The test conditions for wash fastness tests taken from DIN draft standard 54 017 are presented in condensed form in the Table. These conditions correspond largely with those specified in ISO Standard 105–C06. For each wash temperature indicated by a letter of the alphabet two variants are given: one without and one with the addition of sodium perborate. Particular attention is also drawn to wash test D 3 which is carried out at 70°C with 0.15 g/l available chlorine. If, for example, wash tests C 1 and C 2 are compared with the former ISO Wash Test No. 3 (60°C), the most noticeable differences are the change of washing agent (ECE Reference Detergent instead of soap and sodium carbonate), the inclusion of steel balls to simulate mechanical stresses and, in the case of test C 2, the addition of sodium perborate. Tests for fastness to repeated washing should be simulated by a greater number of steel balls (50 or 100 instead of 25) and a longer treatment time. It is clear that the effect of repeated washing actually carried out in practice is not always achieved with this test and that the dyeings are also subjected to a chemical as well as a mechanical influence instead.

The tendency of dyes to migrate from the dyed material into the wash bath under the given test conditions, as well as the affinity of migrated dye for adjacent materials under the given wash conditions, exercise a decisive influence on the degree of colour fastness of a dyeing or print.

Each test for wet fastness is based on kinetic processes where the same parameters as those involved in actual dyeing processes are applicable: a “dyeing” in the reverse direction, i.e. from the dyed material to the wash liquor takes place in the first stage, and a new dyeing of adjacent materials takes place in the second stage. The extent to which both these processes proceed is chiefly determined by the interactions between dye, fibre and wash liquor. If the first stage is predominant, then the colour of the test specimen becomes considerably lighter accompanied by only a slight staining of the adjacent materials and the migrated dye is retained in the wash liquor. If, however, the second stage predominates (the composition of the wash liquor then encourages a complete absorption of the migrated dyes) a severe staining of the adjacent fabrics occurs with either no difference, or only a slight difference in shade between the latter and the test specimen.

In both process stages, equilibrium reactions are involved which can be represented schematically (see Fig.)

An equilibrium exists between the dyed material and the liquor as well as between the liquor and the adjacent materials. The factors influencing these equilibria which are dependent on the dyed fabric include the type and stability of the dye/fibre bond, the water solubility of the dye and the dye concentration used; the factors dependent on the wash liquor include the presence of additives, the pH, the temperature and the liquor

test no.	temperature (°C)	pH*	liquor (4g/l detergent) (ml)	available chlorine content (%)	sodium perborate (g/l)	number of steel balls single test 30 mins	number of steel balls multiple test 45 mins
A1	40		150	0	0	0	10
A2	40		150	0	1	0	10
B1	50		150	0	0	0	50
B2	50		150	0	1	0	50
C1	60	10.5	50	0	0	25	50
C2	60	10.5	50	0	1	25	50
D1	70	10.5	50	0	0	25	100
D2	70	10.5	50	0	1	25	100
D3	70	10.5	50	0.015	0	25	100
E1	95	10.5	50	0	0	25	100
E2	95	10.5	50	0	1	25	100

Table: Wash tests ISO, 105-C06

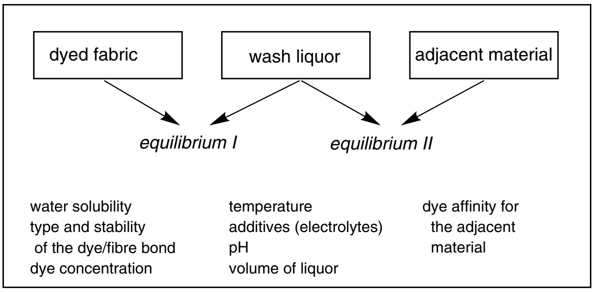


Fig.: Factors which influence wet fastness performance.

ratio, whilst those dependent on the adjacent materials include the types of fibre used and the consequent fibre-dependent affinity of the dyes for these fibres.

Optimum colour fastness is achieved theoretically if equilibrium I is shifted entirely to the side represented by the dyed material and equilibrium II is shifted to the side represented by the wash liquor. To the same extent as the above-mentioned equilibria can be positively influenced in the direction of improved colour fastness by technical manipulations, changes in washing practices can alter these equilibria in the opposite direction with the result that serious colour fastness problems can arise. → Colour fastness to washing considerations for dyeings and prints.

Fastness to wear → Wear fastness properties.

Fastran process

1. Printing: a wet transfer printing process for wool and polyamide in which transfer paper screen printed with water-soluble dyes is brought into contact with prewetted textile material in sandwich form under defined conditions of pressure in a calender and subjected to the action of a high-frequency current. As a result, dye migrates from the paper to the textile material and is fixed thereon in a quasi-steaming process. An aftertreatment is still necessary however.

2. Dyeing: a process for the continuous dyeing of loose wool in which dye fixation is achieved by high-frequency heating.

The Fastran dyeing system for dyeing loose stock and tops (see Fig.) utilizes high frequency current for dye fixation. The electronic fixation unit consists of 50 or 20 kW high frequency generators (each with high tension transformer, rectifier, and oscillator with ancillary equipment and cooling system) with 2 dye fixation chambers connected one behind the other. They are connected to a 3-phase alternating current, 140 kVA, at a voltage between 340 and 600 V.

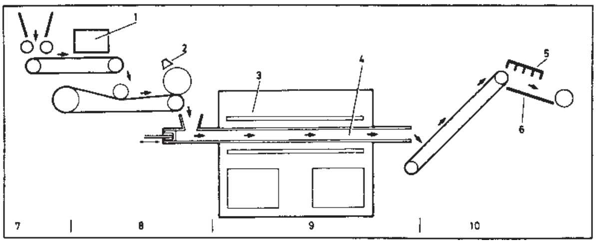


Fig.: Fastran dyeing machine (Smith Text. Mach.)
1 = metal detector; 2 = dye liquor spray unit;
3 = electrodes; 4 = pressure chamber; 5 = spray tubes;
6 = vibrator; 7 = material feed; 8 = material movement;
9 = Smith Fastran EDF unit; 10 = washing unit.

FAST system of fabric assessment The FAST system (Fabric Assurance by Simple Testing) was developed in Australia by the CSIRO. This system is used to determine the properties of woollen fabrics affecting both the way the fabric performs during cutting and making up, and the visual appearance of clothing fabrics when worn. The system comprises three simple instruments and a testing method and was developed principally for use by fabric manufacturers, finishers and dressmakers.

a) FAST-1 consists of a compression measurement device that measured the thickness of the fabric under two different loads.
b) FAST-2 is a device for measuring flexural rigidity, which measures the bending length of the fabric (the bending length can be used to determine the flexural rigidity).
c) FAST-3 is a device for measuring the elasticity, measuring the elongation of the fabric under two different loads in the warp and weft direction, and diagonally.
d) FAST-4 is a measuring method for the determination of the dimensional stability of the fabric (relaxation shrinkage and hygral expansion).

The parameters measured are entered on to a record card that can then be used to give a good forecast of the properties of the fabric. An important feature of the FAST system is the simplicity of the instruments and the testing procedures. The full evaluation of a fabric can be undertaken in less than 2 hours with a relatively short time requirement for laboratory personnel in operating the equipment.

Fat-free aromatic products Principally derivatives of benzene and naphthalene.

I. Benzene derivatives: products based on → Pyridine C_5H_5N are stable to hard water, acids and alkalis, have outstanding dye solubilizing properties, and are highly effective as levelling agents and dye penetrants in virtually all dyebaths where they are used to some extent in combination with Turkey Red oils and fatty alcohol sulphates, etc., to give additional wetting and softening effects. In the aftertreatment of (direct) dyeings, condensation products improve the colour fastness to water, washing, ironing and perspiration. By sulphonation of e.g. phenol, water-soluble sulphonated phenols or thiophenols are formed, among which condensation products of thiophenols or naphthalene sulphonic acids with formaldehyde or other components may also be included. Such products are useful, on the one hand, as single bath mordants and as valuable resist agents in the dyeing of blends on the other. For the latter application, they are used as dyebath additives in direct dyeing when dyeing at higher temperatures (better dye penetration of seams, etc.) and for the dyeing of two-colour effects where advantages of improved shade purity, higher rub fastness, more favourable dye utilization and better light fastness are obtained.

II. Naphthalene derivatives: as non-fat based products the salts of (alkyl) naphthalene sulphonic acids have taken the place of Turkey Red oils and other fatty products. They are more or less high foaming, stable to hard water, acids and alkalies, and are characterized in the main by outstanding wetting, dye levelling and dye solubilizing properties as well as the promotion of dye penetration. Used as wetting agents in practically all wet processes, and as virtually universal dyeing assistants, and also as emulsifiers to some extent.

Fat-free (synthetic) condensation products (→ Polyglycolether). In 1936 the synthesis of fatty alcohols from low molecular weight products of coal hydrogenation began. By condensation with ethylene oxide (C_2H_4O) products of the type:

$$R–(O–C_2H_4)_x–OH$$

were formed. These compounds, which were the first synthetic detergents and emulsifiers, had excellent wetting properties and protective colloid action with excellent stability to hard water salts, metal salts, acids and alkalis, besides being easily washed out. The → Alkylaryl polyglycolether form a very important group of nonionic surfactants.

Fat liquor Fat-liquoring agent used to treat leather after → Tanning in order to achieve the desired softness, suppleness, fullness, improved tensile strength and resistance to water.

Fat liquoring → Tanning.

FATM (Ger.), abbrev. for: Forschungsstelle für allg. und textile Marktwirtschaft an der Universität Münster (Research Unit for General and Textile Market Economy at the University of Münster). → Technical and professional organizations.

Fats Neutral vegetable or animal products composed of neutral fats and → Fatty acids. Glyceride esters of organic fatty acids, e.g. the glyceride of oleic acid $(C_{17}H_{33}COO)_3C_3H_5$. They are subdivided into → Liquid fats, → Semisolid fats and → Solid fats. Properties: insoluble in water, soluble in ether, white spirit, benzene, chloroform, carbon disulphide, chlorinated hydrocarbons and fat solvents. Fats melt but do not volatilize, they decompose at temperatures of 250–300°C, oxidize in air (become rancid; → Oxidation of oils), and are saponified by alkalis, i.e. split up into fatty acid salts (soaps) and glycerol. Fats also include non-ethereal oils, paraffins, and mineral oils (fats). Chemical characteristics →: Iodine number; Acid value; Saponification value.

Fats, hardening of → Fats, hydrogenation of.

Fats, high-pressure hydrogenation of The hydrogenation of fats under approx. 200 bar pressure at a temperature of approx. 300°C with hydrogen in the presence of a catalyst. Purpose: reduction of the fatty acid carboxyl group (–COOH) to the carbinol group ($–CH_2OH$) with the elimination of water, i.e. substitution of a divalent oxygen atom by two monovalent hydrogen atoms:

$$C_{17}H_{35}COOH \xrightarrow{(+\,4\,H)} C_{17}H_{35}CH_2OH\ \ (+\,H_2O)$$

stearic acid *stearyl alcohol*

By this means, higher fatty alcohols are formed from the corresponding higher fatty acids. The COOH group is destroyed (eliminated). The process is of great technical importance since, with its aid, a large number of fats can be used to make high quality textile auxiliaries.

Fats, hydrogenation of (fats, hardening of). The process involves heating oils or fatty acids to 160–170°C at 6 bar pressure in the presence of a catalyst and hydrogen. Purpose: conversion of cheap → Liquid fats into more valuable → Solid fats, or the conversion of unsaturated liquid fatty acids into the corresponding saturated and solid fatty acids (resp. their glycerides) by the introduction of two hydrogen atoms in place of the double bond: ($R–CH=CH–R$ into $R–CH_2CH_2–R$):

$$C_{17}H_{33}COOH \xrightarrow{(+\,2\,H)} C_{17}H_{35}COOH$$

liquid oleic acid *solid stearic acid*

Fat-solubilizing detergents (fat-solubilizing soaps). Homogeneous mixtures of soap and/or synthetic detergents with fat solvents (approx. 10–95%) and solvent promoters as well if necessary. The considerable variation in composition is responsible for the stability, quality, and utility of these products. Fat-solubilizing detergents generally possess an extraordinarily high wetting, dispersing and solvent action for linseed oil sizes, textile lubricants, dust-binding oils, mineral oils and, in special mixtures, also for particularly resistant impurities. Uses: desizing of linseed oil sizes, desizing washes, removal of textile lubricants, kier boiling assistants, milling assistants, cleaning agents in dyebaths, cleaning of heavily grease-stained textiles, pitch removal, spotting agents (stain removal), etc. (→ Drycleaning detergent).

Fat-solubilizing soaps → Fat-solubilizing detergents.

Fat-soluble dyes → Oil and fat soluble dyes.

Fat solvents Chemicals which are good solvents for fats include: ethanol, methanol, ethyl ether, ethyl acetate, acetone, butanol, carbon disulphide; hydrocarbons such as white spirit, benzene, turpentine, toluene, xylene; hydrated hydrocarbons such as decahydronaphthalene, cyclohexanol, methyl cyclohexanol; chlorinated hydrocarbons such as chloroform, tetrachloroethylene, carbon tetrachloride, trichloroethylene, etc. Uses: either alone or in emulsified mixtures for fat-solubilizing detergents of various composition with soaps, Turkey red oils, etc., fatty alcohol sulphates, fatty acid condensation products, synthetic fats, alkylnaphthalene sulphonates, etc. Also used for desizing (linseed oil sizes), scouring, kier boiling, dyeing, drycleaning (drycleaning detergent), spotting agents (stain removal), etc.

Fats, synthesis of → Fatty acids, synthesis of.

Fatty acid amide polyglycol ethers → Polyglycol ethers.

Fatty acid amides → Fatty acid condensation products.

Fatty acid amide sulphates Formed by the reaction of fatty acids and oxyalkylamines, e.g. monoethanolamine, and subsequent sulphation:

$$R–CO–NH–CH_2–CH_2–O–SO_3Na$$

Fatty acid amide sulphates have good stability and are suitable for use as detergents or for incorporation into mild washing agents.

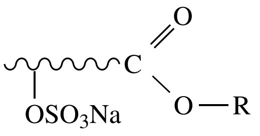
Fatty acid carboxyl group, R–COOH, functional group of all organic acids. → Carboxyl group.

Fatty acid condensation products

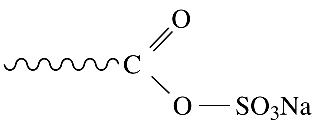
I. Condensed oils: these products are based on the principle of condensation and saponification, e.g. polyricinoleic acid with sulphonic acid groups and a reduced content of free carboxyl groups. By this means, typical wetting oils with good softening properties and good to excellent all-round stability, depending on the degree of sulphonation, are obtained.

II. “Masked” fatty acid (sulphonate) products: these are products in which the carboxyl group is protected by masking, i.e. by blocking the carboxyl group in its former position at the end of the long fatty acid chain.

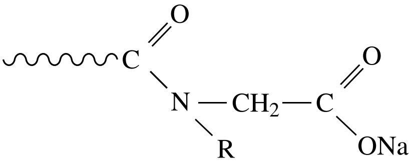
a) (Sulphonated) fatty acid esters: the first products were produced from castor oil by esterification and sulphonation; in general, these were ester oils with excellent wetting and softening properties of good average stability:



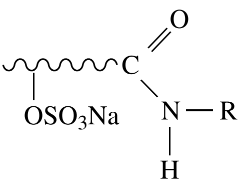
Shortly afterwards, a synthetic detergent, resistant to hard water, with excellent detergency but still limited stability to acids and alkalis was produced by the esterification of oleic acid:



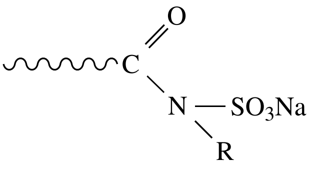
b) fatty acid amides: produced by the successful introduction of nitrogen compounds into the COOH group. Because of the shortage of solubilizing groups, however, the first commercial products of this type were typical water-insoluble emulsifiers. Next followed a surprisingly improved soap with remarkable stability properties due to its end group,



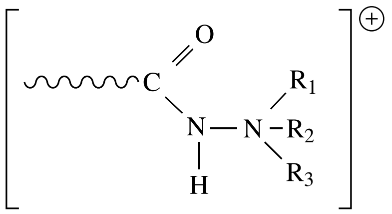
Used as a milling assistant, washing agent and dispersing agent. An example of a sulphonated fatty acid amide without carboxyl groups is:



Used as a non-foaming wetting and levelling agent. A large range of well-known products have been produced on a similar principle. A classic example of a synthetic detergent, stable to hard water, with excellent all-round stability is



Uses: virtually universal application (but not mercerizing and carbonizing). The following (cationic) condensation products of fat residues with amines or polyamines, which are of particular interest in dyeing, should also be mentioned:



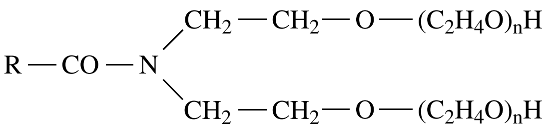
Fatty acid ethanolamides

These partially sulphonated products have high stability, powerful wetting and softening properties, and foam to some extent. Used to improve the fastness properties of direct dyeings.

Fatty acid ethanolamides Formed by the reaction of fatty acids with ethanolamines, e.g. a fatty acid monoethanolamide:

$$R{-}COOH + H_2N{-}C_2H_4OH \rightarrow$$
$$R{-}CO{-}NH{-}C_2H_4OH + H_2O$$

The mono and diethanolamides of higher fatty acids are yellow, wax-like or liquid products. They are used to improve foam stability and as skin-protective components in washing agents and detergents. Ethoxylated fatty acid ethanolamides, e.g.:



$$R{-}CO{-}N\begin{cases} CH_2{-}CH_2{-}O{-}(C_2H_4O)_nH \\ CH_2{-}CH_2{-}O{-}(C_2H_4O)_nH \end{cases}$$

are used as washing agents, softeners and emulsifiers.

Fatty acid ethoxylates, of the type: $C_nH_{2n+1}{-}CO(OCH_2CH_2)_m{-}OH$. Used as additives to spinning preparations.

Fatty acid hydrazides → Hydrazides.

Fatty acid modified synthetic resins → Water-impermeable finishes.

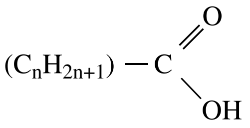
Fatty acid number, the → Acid value is used to measure the amount of fatty acid in the organic solvents used in dry cleaning. The acid number is calculated from the amount of 0.1 N alcoholic potassium hydroxide needed to neutralize 1 ml of the dry cleaning liquor; the amount should not be more than 0.2 ml.

Fatty acid oxyethylamides → Polyglycol ethers.

Fatty acid polyglycol ethers/esters → Polyglycol ethers.

Fatty acid-protein condensation products → Protein-fatty acid condensation products.

Fatty acids, correspond to the general formula



$$(C_nH_{2n+1}){-}C\begin{cases} {=}O \\ {-}OH \end{cases}$$

name	formula	melting point	neutralisation value mg KOH/g
caprylic acid	C_7H_{15}.COOH	16°C	389.1
capric acid	C_9H_{19}.COOH	31°	325.7
lauric acid	$C_{11}H_{23}$.COOH	44°	280.1
myristic acid	$C_{13}H_{27}$.COOH	54°	245.7
palmitic acid	$C_{15}H_{31}$.COOH	63°	218.8
stearic acid	$C_{17}H_{35}$.COOH	70°	197.2
arschic acid	$C_{19}H_{39}$.COOH	77°	179.5
lignoceric acid	$C_{23}H_{47}$.COOH	81°	152.2
melissic acid	$C_{29}H_{59}$.COOH	91°	101.7

Tab. 1: Important higher saturated fatty acids.

Monobasic organic (aliphatic) carboxylic acids (Table 1) derived from or contained in natural → Fats, or produced synthetically (→ Fatty acids, synthesis of). The lowest representative is → Formic acid (H–COOH). Fatty acids with 10–20 carbon atoms are the most important building blocks of naturally occurring neutral fats, fats, and waxes. Modern synthesis is also mainly geared to the production of these fatty acids.

Fatty acids of low and frequently high molecular weight, containing more than 20 carbon atoms, are made use of for particular applications. Fatty acids with 12 and 14 carbon atoms are primarily of interest for synthetic detergents. By contrast, fatty acids with 16 and 18 carbon atoms, although still of interest on account of their detergent-building properties are, however, chiefly used for the production of synthetic softeners, sizes, finishing agents, etc. → Soaps are obtained by treatment of fatty acids with alkaline liquors. Unsaturated higher fatty acids (Table 2) are of special importance as drying oils in linseed oil sizing because of their oxidizable double bonds. Uses: manufacture of soaps, textile auxiliaries, etc.

Fatty acids, alkali salts of → Soaps.

Fatty acids, synthesis of Of great technical importance. The starting product is synthesis gas which is used to produce synthetic paraffin by hydrogenation (Fischer-Tropsch process). The paraffin is then oxidized in the presence of contact substances by the injection of hot air at 80–170°C which brings about the decomposition of 1 molecule paraffin into 2 short-chain molecules of fatty acids with 12–18 carbon atoms (similar to coconut acid). Principle:

name	formula	melting point	neutralisation value mg KOH/g	iodine number
oleic acid	$C_{17}H_{33}$.COOH	14°C	198.6	89.9
elaidic acid	$C_{17}H_{33}$.COOH	44°	198.6	89.9
erucic acid	$C_{21}H_{41}$.COOH	34°	165.7	57.0
ricinoleic acid	$C_{17}H_{32}$(OH).COOH	6°	187.7	85
linoleic acid	$C_{17}H_{31}$.COOH	—18°	200.1	181
linolenic acid	$C_{17}H_{29}$.COOH	—11°	201.5	273.5
elaeostearins	$C_{17}H_{29}$.COOH	48°	201.5	273.5

Tab. 2: Higher unsaturated fatty acids.

Paraffin hydrocarbon $C_{24}H_{50}$ →
2 $C_{11}H_{23}$–COOH (lauric acid)

Raw soap is formed by saponification with caustic soda liquor from which paraffin residues are extracted by distillation. The pure synthetic → Fatty acids are obtained by adding acid to the raw mixture of fatty acids followed by fractional distillation. These acids behave in a similar manner to natural fatty acids, i.e. they form soaps with alkalis or fats with synthetic glycerol.

Approx. 75 t of synthetic raw fatty acids are obtained from 100 t of raw paraffin product.

Fatty alcohol condensation products For the production of highly stable textile auxiliaries it is logical to make use of the extremely useful higher → Fatty alcohols. By condensation of these alcohols with further substances, a lengthening of the fatty chain is achieved which increases the absolute effectiveness of these products still further in comparison to the starting materials. By this means, fatty alcohol sulphonates are obtained which, although stable to hard water salts, are nevertheless only stable to dilute acids etc. (carboxyl group). Products without sulphonic acid and carboxyl groups are obtained by condensation with ethylene oxide (C_2H_4O) which have good all-round stability and are used as levelling agents and dye penetrants in dyeing with cationic, direct, vat, 1:1 metal-complex, and naphthol dyes. These products are excellent stripping agents for the latter class of dye and have a simultaneous cleaning and wetting action. Levelling agents for 1:1 metal-complex dyeings, based on ethoxylated fatty alcohols, permit a 50% reduction in the amount of sulphuric acid required which results in a more gentle treatment of the fibre. Analogous products are also used for the washing of wool under acidic conditions, for levelling/brightening in acidic dyebaths, and as emulsifiers, etc. Sulphated and ethoxylated fatty alcohols are of importance as wetting, washing, and levelling agents.

Fatty alcohol derivatives, e.g. with sulphonic acid groups in the middle position → Fatty alcohol sulphates, fatty alcohol esters, pyrophosphoric acid esters, condensates with sulphonic acids, → Fatty alcohol ethoxylates, etc. Properties: most have high stability with good wetting, levelling, cleaning, and softening properties.

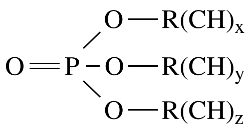
Fatty alcohol esters →: Fatty sulphuric esters; Fatty alcohol mineral acid esters.

Fatty alcohol ethoxylates Type: $C_nH_{2n+1}(OCH_2)_mOH$. → Spinning preparations.

Fatty alcohol ethoxylates and acetates Type: R–O–$(C_2H_4O)_n$–CH_2–COOH. Carboxymethylated fatty alcohol ethoxylates (e.g. sodium salt of C_{12}/C_{14} fatty alcohol-4,5-EO acetate). In contrast to soaps, these compounds possess condensed ethylene oxide units capable of hydration between the hydrophobic and hydrophilic parts of the surfactant molecule. This modification results in improved water-solubility and stability to hard water. Suitable for use as antistatics, dispersing agents, textile auxiliaries and surfactant components for washing agents and detergents. This class of anionic surfactants, produced by the reaction of fatty alcohol ethoxylates with chloroacetic acid, is of technical interest since, despite the anionic character of these products, they are not sensitive to calcium hardness. They also have a good lime-soap dispersing capacity. The detergency of these products is good and their soil-suspending properties are particularly noteworthy.

Fatty alcohol mineral acid esters Apart from the → Fatty alcohol sulphates (sulphuric esters of fats), these are esters of persulphuric acid, phosphoric acid and pyrophosphoric acid used as textile auxiliaries of similar composition. They are of practical significance as wetting agents with detergency properties and oxygen-releasing bleaching auxiliaries. Also used for the aftersoaping of fast dyeings, etc.

Fatty alcohol phosphates Anionic products with low detergency and wetting properties. They are of importance, e.g. as antistatics.



Fatty alcohol polyglycol ethers → Polyglycol ethers.

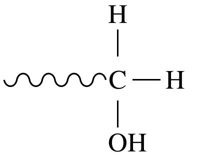
Fatty alcohols These compounds are formed as follows,

$C_{17}H_{35}COOH$ → $C_{17}H_{35}CH_2OH$

stearic acid → stearyl alcohol (octadecanol)

This reaction is accompanied by complete elimination of the problematic fatty acid carboxyl group. In principle, the complex R–COOH is reduced in the high pressure hydrogenation of fats to R–CH_2OH, as a result of which higher fatty alcohols with C_{8-18} are formed from the corresponding fatty acids.

The fatty acid glycerides or fatty acids of natural origin (coconut oil, palm oil, olein, lanolin, sperm oil, etc.) or the synthetic fatty acids obtained from the oxidation of paraffins are used as starting materials. The fatty alcohols thus formed are always primary alcohols in which one solubilizing group is missing.



The production of synthetic fatty alcohols is carried out by the following methods:

I. Oxidation of hydrocarbons in peanut oil with the addition of boron trioxide accompanied by the formation of secondary fatty alcohols (Baschkiroff process).

II. Ziegler process from ethylene (alfols).

III. Oxo process from olefin hydrocarbon vapours passed over cobalt catalysts in the presence of CO and H_2. The oxidation results in the formation of branched-chain primary alcohols (oxo alcohols).

Fatty alcohols are insoluble in water but soluble in many organic solvents. Together with soaps, Turkey Red oils, fatty alcohol sulphates and other solvents, they are used in textile auxiliaries as softeners and finishing agents. With paraffin they are also used for water-repellent finishes, etc. Low molecular weight fatty alcohols are useful as antifoams. The most technically important fatty alcohols are:

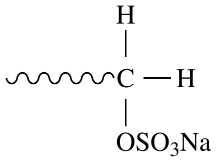
- Lauryl alcohol,
- Dodecyl alcohol,
- Myristyl alcohol,
- Tetradecyl alcohol,
- Palmityl alcohol,
- Cetyl alcohol,
- Stearyl alcohol,
- Octadecyl alcohol,
- Oleyl alcohol.

Fatty alcohols, oxyethylated → Polyethylene glycol ester.

Fatty alcohol sulphates

I. The type of sulphate (→ Sulphation) that contains $-C-O-SO_3Na$ as a fatty ester of sulphuric acid with the sulpho group connected to carbon through an oxygen atom.

II. Fatty alcohol sulphates (primary alkyl sulphates) are formed by the esterification of fatty alcohols with acids, e.g. sulphuric acid (after neutralization). Like Turkey Red oils, they are → Fatty alcohol sulphuric esters but without their carboxyl groups. The desired processing properties may be selectively determined by an appropriate choice of the number of carbon atoms. Sulphated oleyl alcohol and sperm alcohol are predominantly used as washing and wetting agents. A range of properties are obtained from mixtures of fatty alcohol sulphates, e.g. "synthetic detergents" with combined wetting, levelling, washing, softening and dye-penetrating properties. They are also used as brightening agents, delustrants, degumming and lubricating agents, besides oxidative bleach stabilisers, emulsifiers, etc.



$$\sim\!\sim\!\sim C(H)(H)(OSO_3Na)$$

Fatty alcohol sulphonates Sulphonates (→ Sulphonation) of the type $-C-SO_3Na$ exist as salts of fatty sulphonic acids with a direct C–S bond.

Fatty alcohol sulphuric esters Identical with → Fatty alcohol sulphates (→ Fatty sulphuric esters).

Fatty amine polyglycol ethers → Polyglycol ethers.

Fatty amines Higher → Alkylamines of the type: $R-CH_2-NH_2$. Uses: synthesis of surface-active compounds; corrosion inhibitors; as the acetates for emulsifiers and textile auxiliaries. Secondary fatty amines (distearylamine) are used as starting materials for the manufacture of laundry softeners. An interesting class of fatty amines are the hydroxy amines (cationic surfactants).

Fatty aromatic condensation products Obtained by the condensation of → Fatty acids (fats) with aromatic (benzene, naphthalene) derivatives.

Fatty chain ion The ion which, on dissociation of soap-like textile auxiliaries, contains the fatty residue (aliphatic hydrocarbon residue) which may be anionic or cationic.

Fatty sulphuric esters, alkyl sulphates, i.e. → Fatty alcohol sulphonates, sulphonation products (anionic character) of fats or fatty alcohols that are unsaturated or contain hydroxyl groups (→ Fatty alcohol sulphates). Typical groups: $-C-O-SO_3H$ or $-C-SO_4H$. The neutral sodium salts (→ Metal fatty alcohol sulphates) are produced by replacing the hydrogen atom with sodium. In contrast to "real" sulphonic esters, the sulphur atom is connected through an "oxygen bridge" (C–O–S–). This leads to the alternative names of "O-sulphonates", alkyl sulphonates or sulphuric acid alkyl ethers.

Fault detection in fabric inspection When inspecting goods faults may be detected either by visual evaluation or automatically by using appropriate optical systems. In both cases the fault detection is carried out on a moving length of cloth.

Automated fabric inspection makes use of either mobile video cameras or static "eyes" fitted with complicated computer hardware and software for the collection of information (Figs 1, 2 + 3).

Fault marking and recording devices Devices for the mechanical registration of fabric faults on index cards or in connection with fault marking threads on the selvedge of the fabric, during inspection by machine. Certain devices can be used at inspection tables on moving fabric.

Fault registration is carried out using devices that register the type, position and number of faults during fabric inspection and classify them into categories. The identification details of the pieces examined are also noted.

Faults in textiles A fault is a → Characteristic that does not fulfil a prescribed requirement. A fault does not necessarily affect the usefulness of the product. It is

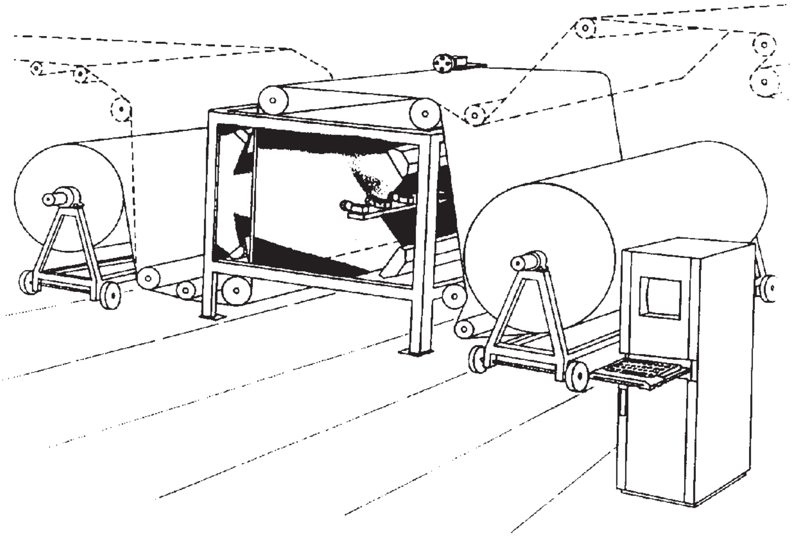


Fig. 2: I-TEX 200 video fault detection system (Israel)

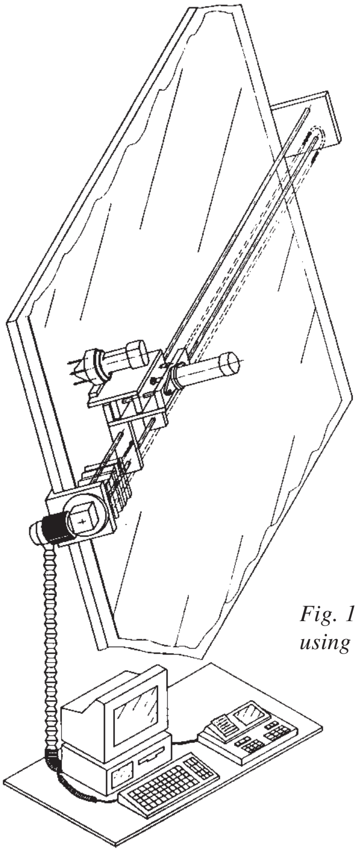


Fig. 1: Trial fault detection during fabric inspection using a mobile video camera

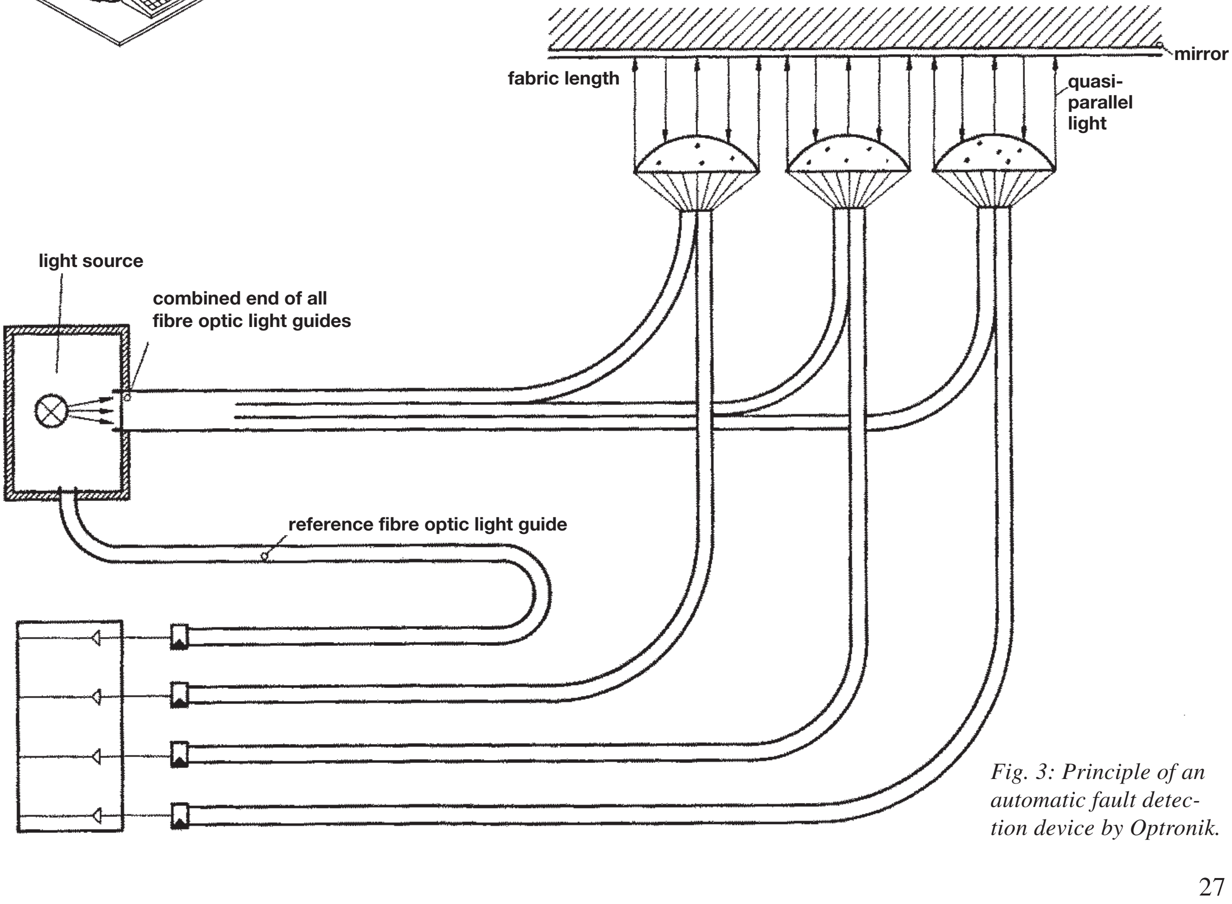
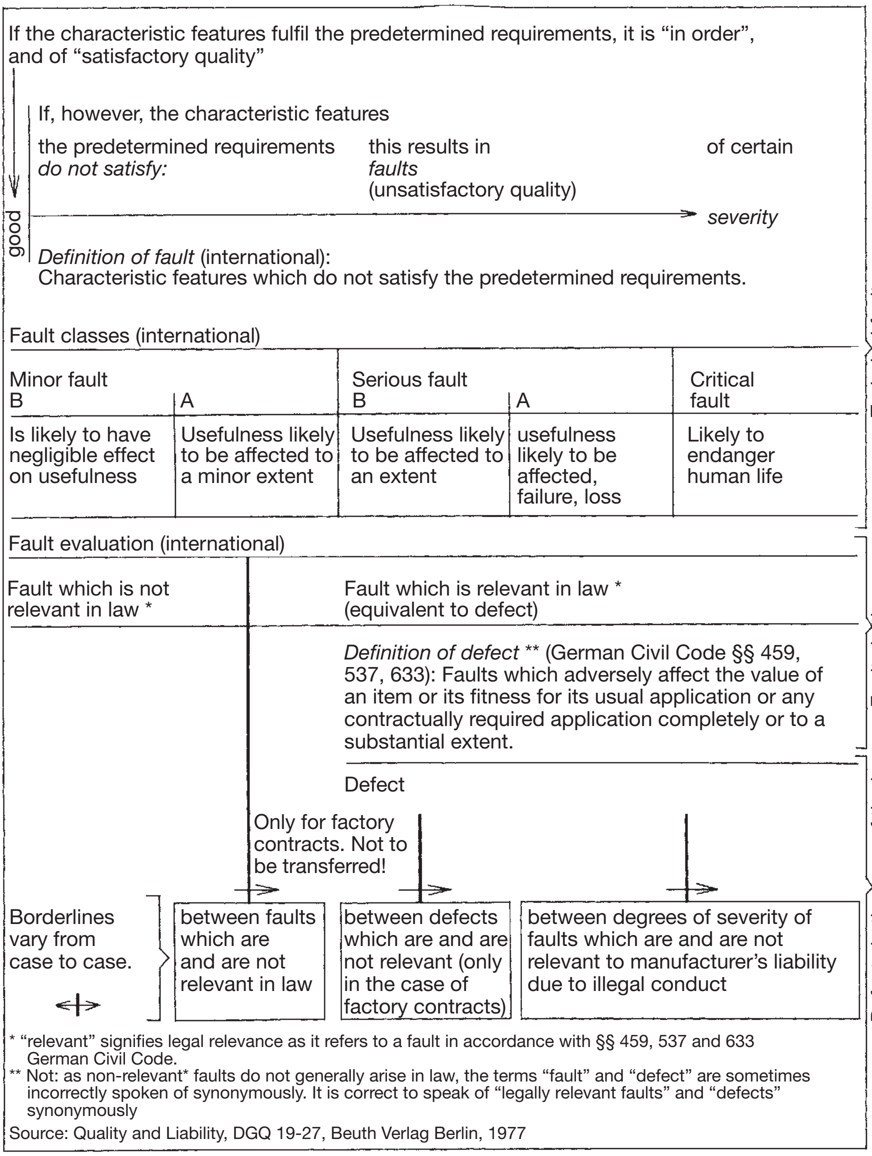


Fig. 3: Principle of an automatic fault detection device by Optronik.



If the characteristic features fulfil the predetermined requirements, it is “in order”, and of “satisfactory quality”

If, however, the characteristic features the predetermined requirements *do not satisfy:* this results in *faults* (unsatisfactory quality) of certain *severity*

Definition of fault (international): Characteristic features which do not satisfy the predetermined requirements.

Fault classes (international)

Minor fault B	Minor fault A	Serious fault B	Serious fault A	Critical fault
Is likely to have negligible effect on usefulness	Usefulness likely to be affected to a minor extent	Usefulness likely to be affected to an extent	usefulness likely to be affected, failure, loss	Likely to endanger human life

Fault evaluation (international)

Fault which is not relevant in law *

Fault which is relevant in law * (equivalent to defect)

Definition of defect ** (German Civil Code §§ 459, 537, 633): Faults which adversely affect the value of an item or its fitness for its usual application or any contractually required application completely or to a substantial extent.

Defect

Only for factory contracts. Not to be transferred!

Borderlines vary from case to case.

between faults which are and are not relevant in law

between defects which are and are not relevant (only in the case of factory contracts)

between degrees of severity of faults which are and are not relevant to manufacturer’s liability due to illegal conduct

* “relevant” signifies legal relevance as it refers to a fault in accordance with §§ 459, 537 and 633 German Civil Code.

** Not: as non-relevant* faults do not generally arise in law, the terms “fault” and “defect” are sometimes incorrectly spoken of synonymously. It is correct to speak of “legally relevant faults” and “defects” synonymously

Source: Quality and Liability, DGQ 19-27, Beuth Verlag Berlin, 1977

Tab.: Overview of the terms fault and defect from a technical and legal viewpoint.

therefore to be differentiated from the term → Defect that always represents an adverse effect on usefulness (Tab.).

Deviations of the actual value from the desired value are permitted within a certain tolerance and therefore not regarded as faults. There is a strong link here with the terms “characteristic” and “limit value”: often in practice limit values of a characteristic are encountered which are dependent on the size of one or more characteristics. These therefore also lead to similarly dependent faults. Apparent faults are immediately recognizable during required detailed inspection or testing procedures which must be carried out, for example in accordance with the standard conditions of the German textile finishing industry a clothing manufacturer must inspect all incoming goods before further processing. In contrast to this type are hidden faults which first become apparent in the course of time (e.g. whilst being worn) or whose presence is only detected as a result of complex tests. These include dye fastness defects, deviations from the blend proportions, chemical damage to the fabric.

Faulty batches Unlevel dyed or otherwise unusable → Dye batch or similar.

FBA, abbrev. for: → Fluorescent brightening agents.

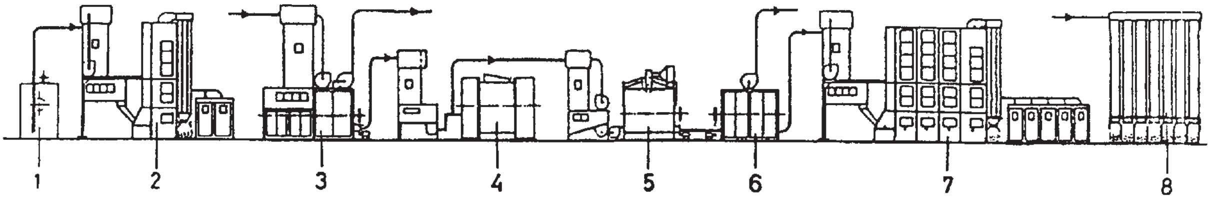
FC, abbrev. for → Fluorocarbons.

FCR (Ger.), abbrev. for: Forschungsstelle Chemischreinigung (Research Unit for Drycleaning); → Professional and technical organizations.

FCT, abbrev. for: → Fog chamber technique.

FdH (Ger.), abbrev. for: Forschungsinstitut der Hutindustrie (Research Institute of the Hat Manufacturing Industry); → Technical and professional organizations.

Fe, chemical symbol for iron (26).



1. **Shaking out machine for untreated feather bundles**
2. **Presorting machine**
3. **Dust extraction machine**
4. **Washing and centrifuge machine**
5. **Drier**
6. **Cooling and de-dusting machine**
7. **Sorting machine**
8. **Filter plant for all machines**

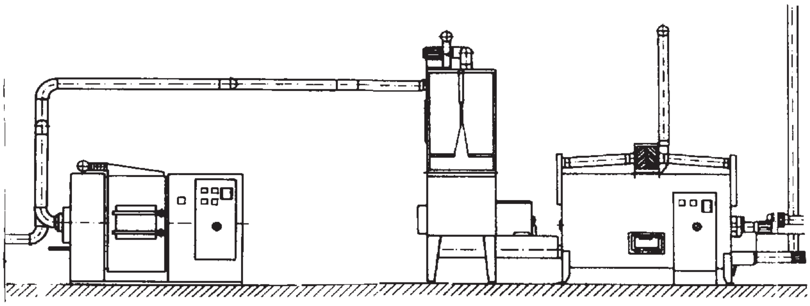


Fig.: Processing line for the automated treatment of feathers and down for bedding.

Feather processing Feathers and down used for the filling of quilts. After initial sorting they require washing in special machines. This is done in 60 kg batches in drum washers that are also capable of centrifuging for water-use minimisation (Fig.). The feathers are loaded and unloaded by air jet into a continuous tumble drier where they are also sprayed with disinfectant (and possibly light bleach) and then dried. The batch sizes are 60 kg/h per machine and this determines the line capacity. Problems may arise with black feathers, when only a small number contaminate a white batch.

Featherproof → Featherproof finishing of duvets, eiderdowns.

Featherproof finishing of duvets, eiderdowns Finishes for this purpose are mainly based on the application of thermoplastic synthetic resins followed by a calender treatment. In order to produce a satisfactory finish, a distinction must be made between bed ticking and downproof fabrics and, in the case of the filling material, between down and feathers.

Feeding addition A finishing term for the regular feeding of finishing liquors during continuous processing.

Feed unit A delivery system for feeding non-batched textile fabrics in open-width, rope or plaited form.

Fehling's solution A solution of copper sulphate, potassium sodium tartrate and NaOH used for estimating and detecting reducing sugars. Textile applications include the detection of hydrocellulose, oxycellulose and photocellulose as well as sugars (analysis of finishes). The Fehling's solution is freshly prepared from 69,278 g of copper (II) sulphate and Rochelle salt solution (173 g potassium sodium tartrate tetrahydrate in 400 ml water + 100 g sodium hydroxide made up to 500 ml). Both solutions must be mixed before use. The test is carried out by heating the material with 10% of a freshly prepared Fehling's solution to the boil on a water bath. An approximately quantitative evaluation is made with the aid of a colorimeter. The colour of the copper (I) oxide which is precipitated onto the affected area of the textile is pink to brick-red.

FEK (Ger.), abbrev. for: Französische Echtheitskommission (French Fastness Commission) Paris. → Technical and professional organizations.

Fellmongered wool → Skin wool.

Felt Textile fabric made of, or with, a random fibrous material. Classification according to type of manufacture:

I. → Needle punched felt.

II. → Milling felt (wool and hair felt): In accordance with DIN 61 205 surface effect or whole fabric made of feltable fibres, possibly mixed with non-felting fibres, includes nonwovens, consolidated through the effects of moisture, temperature, pressure and movement (felting and, if necessary, milling). From hairs = hair felt, from wool = wool felt, from wool and hairs = mixed felt (milled fabrics).

III. Fabric felt made of woven, milled and felted woollen system yarn. May be one-sided with felt and fabric layers or double-sided with 2 felted surfaces and a woven interior. Heavily milled, single or multi-layer fabric with a raised surface is called felt cloth or cloth felt. There are also doubled-sided felts with a carrier fabric made of cotton or jute and a double-sided wool fibre surface.

Wide range of applications. Light piece felt for clothing purposes (traditional costumes), cut as trimming instead of leather, sewed or stuck on (edging, braid, jacket, coat under-collar), similarly also for decorative purposes, in place of carpets, as carpet underlay and, if manufactured differently, as base for hat manufacture. Technical felts are widely used as felt jackets, calender felt, tubular felt, embossing felt etc. for winding around working rollers and heated drying cylinders, as back cloth, damping felt, shock absorbing foundation underlay, cushions, gaskets etc.

Feltability of wool → Felting propensity of wool.

Felt body → Hat body.

Felt calender (→ Calenders). A special type of calender at the delivery end of a stenter (see Fig.) used especially for linings.

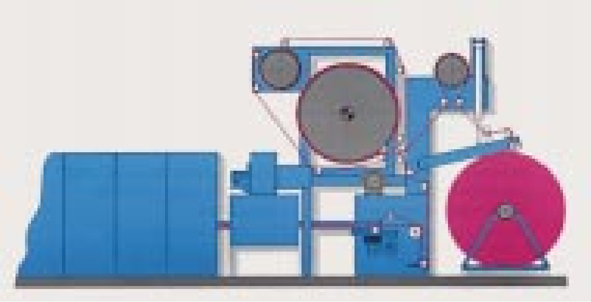


Fig.: Felt calender (Krantz).

Felt chromatogram → Levelling property test.

Felt cloth, woven felt → Felt.

Felt fabric A term used to describe a milled felt of a similar type to → "Feltine" which is not woven, bonded or stitched. It is made, e.g. from wool fleece (with/without man-made fibres) which has been bonded into a web by felting in a plate felting machine followed by subsequent milling.

Felt ground → Needle-punched carpets.

Feltine Proper name of a milled felt which has no woven structure and no chemical bonding, the textile fabric instead being created by the intensive felting of loose virgin wool. Feltine is piece dyed and may be impregnated. The brilliancy of the colours is typical. These materials are produced to defined thickness and handle (stiffness). Their use is traditional in certain types of clothing.

Felting An undesired process of superficial "felting" of woollens or an intentional process. This is used to mean the processing of loose fibres to form a dense and durable fabric, whereby mechanical effects (pressure, impact, friction) aided by moisture and warmth achieve a homogeneous combination of the fibre material. Milling is similar to felting. This is the processing of piece goods to give them a high density and strength. In milled fabrics, individual fibres or individual warp and weft threads are no longer recognisable, because they disappear under a uniformly dense hair cover. This felting process only occurs in animal hairs, particularly wool. In felting or milling the material shrinks in length and breadth, giving the material a completely different appearance and a different (full) handle and higher weight per metre. The shrinkage process is strongly dependent upon the pH of the treatment liquor. For certain applications, e.g. for carpets, the felting of woollen yarns is carried out using a discontinuous and continuous process in water or solvent. → Felting propensity of wool; Anti-felting finish.

Felting, degree of Measure of the tendency to felt according to the → Aachen felting test, expressed in terms of felt density in g/cm^3.

Felting density → Felting, degree of.

Felting propensity of loose wool Measured by means of the → Aachen felting test.

Felting propensity of wool This is a characteristic found in animal fibres, which shrink under certain conditions. The causes of → Felting are not precisely understood. There are many familiar felting theories, and we will only describe the most important theories. We referred earlier to individual characteristics of wool, and these are reflected in the felting theories:

a) Primary (causal) characteristics such as surface structure, frictional behaviour (DFE), lengthways or cross elastic characteristics;

b) Secondary characteristics such as fineness, length, crimp, grease content;

c) External factors, which represent the conditions during felting and milling, such as pH, temperature, milling auxiliaries.

A first theory originates from Short, and was later taken up by Martin. Fig. 1 (a) clarifies the most important phases of this theory.

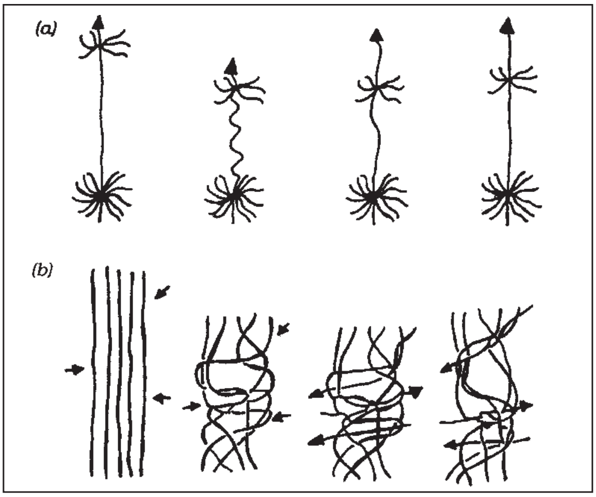


Fig. 1: Theoretical sequence of the felting process according to Shorter and Martin.
(a) = movement of the open knot (above) in direction of the fixed knot (below) by the action of the elastic, operative fibre; (b) = transfer of model (a) to multiple fibres.

In contrast to this theory, Arnold believes that the fibres come into contact due to friction, impact and pressure and wander due to their scale structure (earth worm theory). Another familiar theory is what Martin calls the "Loop Locking" theory (Fig. 1 (b)): The use of mechanical compression causes the fibres in yarn to bend into loops. Loose fibres (arrows) wander about, root end first, and repeated compression gradually makes these into loops. Finally, knots or kinks form, and the yarn can no longer return to its original length. A compressed fibre area of operative fibres with root ends is first penetrated, whereby knotting at the different points in the fibres is not necessary. After the external effect ceases, the fabric can no longer return to its original state.

Common to all theories is the recognition that the felting process is dependent upon many factors. The importance of the DFE (Directional Frictional Effect) is often stressed. According to this theory, a high frictional coefficient in the tip-base direction in comparison to the base-tip direction causes the wool fibre to move towards the base under frictional loading. This effect is dependent upon the scale structure of wool, which means that when wool fibres move in an unorientated, loose fibre compound, the fibres must move in the direction of the base (Fig. 2).

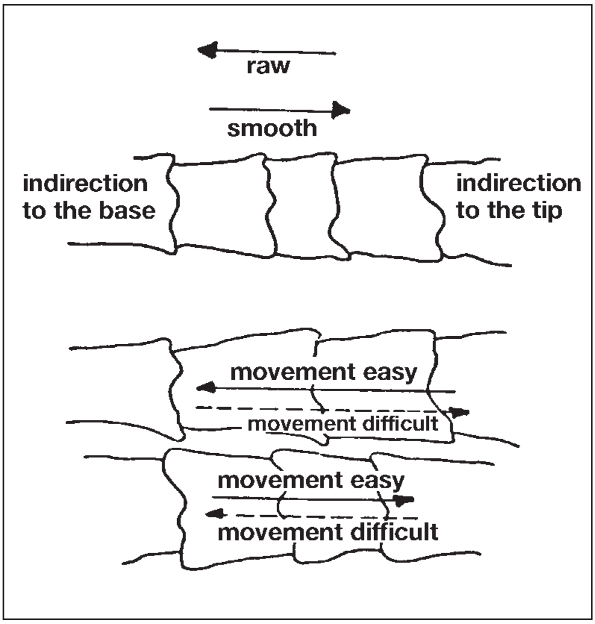


Fig. 2: Directional frictional coefficient and scale structure of wool.

In addition to the felting theories above, in the context of antifelting finishes, Stigter and Meichelbeck and Knitter have discussed the felting behaviour (or flocculation behaviour) of wool fibres in an aqueous medium and in solvent mixtures. They attributed felting behaviour to certain "charge relationships" in the wool and thus deviate significantly from previous theories. It was found that untreated short wools in aqueous solutions combine to form floccular aggregates. The relatively uncharged, hydrophobic nature of the fibre surface causes the fibres to move closer together, thus driving out the water, i.e. keeping the surface between the fibres (hydrophobic) and water (hydrophilic) as small as possible. If the fibres get closer together in a aqueous media, then the water molecules, which are located on the wool fibre are repelled, thus going over into a low energy state (state of lower order). The released energy works as a driving force on the fibres, so that the fibres are brought in close contact allowing them to form hydrophobic interactions. The charge of the groups on the surface of the fibre also influences the felting behaviour of the wool. Meichelbeck and Knittel made the following observation: Positively charged wool shows a strong tendency to felting in a aqueous solution with a high pH, because the charges repel each other (fibre/liquor) and the fibres move closer together. Negatively charged wool, on the other hand, demonstrates almost no tendency to felting in a aqueous liquor with a high pH, because the different charge relationships between wool and liquor counteract each other and thus distance the fibres from each other (= buffering), i.e. the fibres are separated by a liquor film.

The electrostatic interaction between the fibres thus influences the felting behaviour of wool. These findings help to explain the "antifelting" behaviour of wool in hydrophobic solvents such as tetrachloroethane. The wool fibres behave in a hydrophilic manner towards the hydrophobic solvent, forming stable suspensions. This characteristic is a result of the fact that hydrophobic interactions only exist in the presence of water. In contrast, there is a hydrophobic environment in the solvent tetrachloroethane, which prevents hydrophobic interactions occurring between the individual fibres. The absence of such interactions leads to the formation of a "buffering film" (of tetrachloroethane) between the fibres, which means that the fibres cannot get closer together and thus no felting takes place in the wool.

Felting shrinkage In contrast to → Relaxation shrinkage, e.g. this relates to the felting which takes place in woollen fabrics through mechanical movement of the fibres under conditions of moisture, and which can be counteracted by shrinkproof finishing. Adding synthetic fibres to wool counteracts the felting shrinkage. Effective improvement is achieved only with additions from 40–60%.

Felting test for loose wool → Aachen felting test.

Felt jacket Analogous to → Tubular felt, for pulling over working rollers, or as back cloth, etc.

Felt mat Hand-crafted → Flat carpet made of firmly felted natural wool, figured effects are worked-in, natural-coloured felt sections; used as carpet and wall hangings.

Felt press → Pressing.

Felt sleeve → Tubular felt.

Femto- (Danish or Norwegian: *femten* = fifteen). A prefix denoting 10^{-15}, i.e. one quadrillionth (USA and Canada), e.g. 10^{-15} second = 1 femtosecond (fs).

Fents Finished textile piece goods in short lengths (as metre goods) for retail sales. → Cut fabric.

Fermentation A type of chemical decomposition initiated by anaerobic bacteria, enzymes (desmolases, coenzymes), yeasts, moulds, and funghi which mostly involves acidic biochemical reactions without the development of foul-smelling odours (opposite → Putrefaction). As a rule, fermentation results in the cleavage of carbon chains, i.e. the biodegradation of compounds of higher molecular weight to those of lower molecular weight, often accompanied by the development of heat (life support for microorganisms) and waste gases, e.g. carbon dioxide. The fermentation of sugars to alcohols according to the following reaction:

$$C_6H_{12}O_6 \rightarrow 2\ C_2H_5OH + 2\ CO_2$$

is probably the most well-known fermentation process, as well as the fermentation of lactic acid, butyric acid and urea. The course of reaction is, however, considerably more complicated than would appear from the above reaction since a number of further intermediate or side products are formed which are, as a rule, transformed rapidly from one to another. In general, the most favourable temperature for fermentation lies between 30 and 37°C, and the most favourable sugar content between 20–25% (at 30–32% no more fermentation takes place).

Fermentation vats are still used occasionally in Africa and East Asia as a customary method for the dyeing of cotton and wool with indigo. Sugar-containing plants and fruits are used as a fermentation medium, and sodium carbonate (soda), calcium carbonate (lime), wood ash or potassium carbonate (potash) as the alkali.

Ferments (Lat.: *fermentum* = yeast). Any agents or substances, such as bacteria, moulds, yeasts or enzymes, that cause fermentation to take place.

Feronia rubber is a gum from East India → Vegetable gum, similar to → Gum Arabic, the primary constituent of which is arabinic gum, making it very water soluble.

Ferric salts Iron (III) salts; → Iron.

Ferrite A ceramic iron oxide compound having ferromagnetic properties with a general formula MFe_2O_4, where M is generally a metal such as cobalt, nickel or zinc.

Ferrous salts Iron (II) salts; → Iron.

Festoon ager A steaming chamber for short print runs. The fabric is transported in loops suspended on rotating upper rollers so that there is no roller contact with the printed side.

Festoon drier → Short loop drier.

Festoon dwell chamber → Festoon store.

Festoon scouring machine → Mezzera continuous scouring machine. Machine used in silk and artificial silk finishing for creping and shrinking, also used on knitted fabrics.

Festoon steamer (steaming chamber). A chamber type steamer of brickwork or cast-iron construction suitable for long runs (1000 m and above). The fabric is transported through the roof-heated steam zone suspended in loops from support rods attached to an endless moving chain. Disadvantages of this type of steamer are (1) extraordinarily large dimensions (up to 10 m in height), (2) high steam consumption and (3) difficulty in achieving uniform steam circulation.

Manuf.: Ramisch Kleinewefers.

Festoon stitch Identical with the so-called “buttonhole stitch”.

Festoon store Acts as a relaxing unit. Fabric is introduced via an adjustable slit and suspended on supporting rods. Open-width submerged fabric passage, tension-free, does not cause creasing. External direct and indirect heaters, automatic temperature control.

Festoon tape is thin, batiste-like edging and bordering tape with a dog-legged selvedge and decoration resembling eyelet embroidery.

FI, → Fique fibre, → Standard abbrev. for textile fibres, according to DIN 60 001 T4/08.91.

FIANN (Fr.), abbrev. for: Fédération Internationale des Associations Nationales de Normalisation (International Federation of National Standards Associations); → Technical and professional organizations.

Fiberset process A resin finishing process for cotton and polyester/cotton fabrics in which a reactive prepolymer is applied together with N-methylol compounds. Polymerization and crosslinking of the applied finish is achieved by treatment in the vapour of a low boiling chlorinated hydrocarbon.

Fibre The smallest unit of any textile material. The so-called raw fibre (→ Fibres) is converted by spinning into threads (yarns of various types).

Fibre affinity →: Affinity; Dye affinity; Textile auxiliaries with fibre and dye affinity in wool dyeing.

Fibre attraction Forces acting between soil particles and textile fibres: a) mechanical retention, b) chemical bonding (stains), c) adsorption, e) electrostatic attraction. The attachment of fat-free soil particles (pigment soil) is mainly due to geometrical factors, i.e. dimensional relationships between fibre surface roughness and pigment particles in aqueous dispersion which are not based on energetic bonding (e.g. adsorption, absorption).

Fibre blends, dyeing and finishing of Efforts to extend the ranges of woven and knitted fabrics have been increasingly associated with the use of natural and man-made fibres in fibre blends. The corresponding

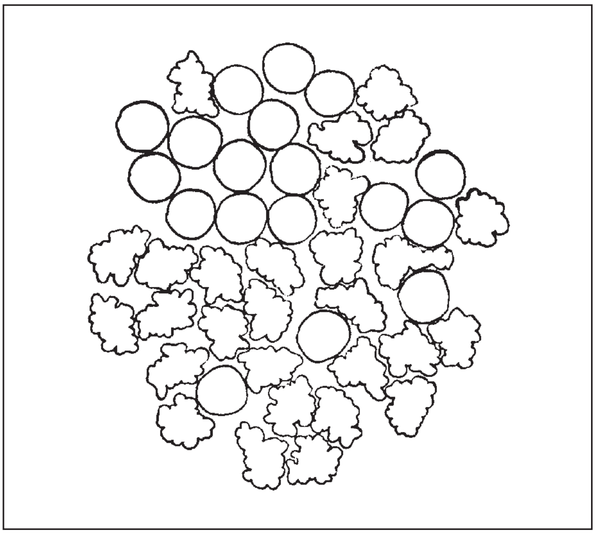


Fig. 1: Projection diagram of a polyamide 6 and viscose filament blended yarn.

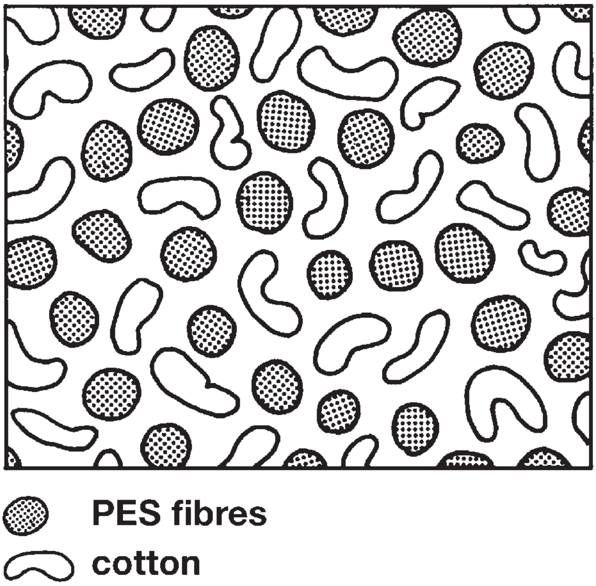


Fig. 2: Schematic cross-section through a 50/50 polyester/cellulose fibre blend.

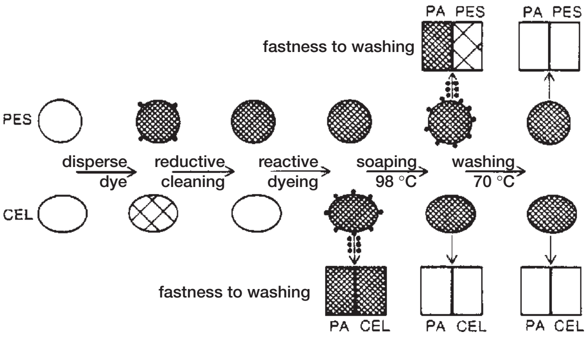


Fig. 3: Dyeing polyester/cellulose with disperse and reactive dyes.

dyeing methods	*weight (´000 tonnes)*
exhaust dyeing (warp knitted fabric)	720
exhaust dyeing (woven fabric)	390
exhaust dyeing (yarn)	460
cold dwell dyeing	35
continuous dyeing	1 350
white fabric	750
prints	650
	4 365

Tab.: World consumption of polyester/cellulose blends.

yarns are also described as heteroyarns (Fig. 1). Experience has shown that the use of such blends can significantly reduce the consumption of natural raw materials (such as wool or cotton) both for everyday products as well as technical textiles. At the same time, the quality of the article and its comfort in practical use can also be improved. The growing use of various fibre blends calls for the application of special finishing processes with the properties of each fibre component, as well as its behaviour towards dyes and chemicals, being taken into account. In principle, two types of process are used in practice: i.e. the two-bath method in which each component of the fibre blend is dyed separately, as well as the single bath method with only one process stage for all fibre components present. The single bath method is therefore more complicated since the processing conditions must be adapted to suit the most sensitive of the fibre components and the dyes selected for dyeing often have a different affinity for the fibres present. On the other hand, however, considerable savings of water, energy, chemicals and dyestuffs are achieved with the single bath method in most cases.

The popularity of polyester/cellulose blends has shown continual growth over recent years (see Table and Fig. 2).

A schematic representation of the distribution of disperse and reactive dyes in the dyeing of polyester/cotton blends is given in Fig. 3.

Fibre bonding device → Heat bonding of thermoplastics.

Fibre bundle strength The tensile strength of a cotton fibre bundle at zero gauge length per unit cross-section. It is determined in accordance with the → Pressley Index.

Fibre bundle tensile strength → Pressley Index.

Fibre composites Flexible, porous fabrics (→ Bonded fabrics) consisting partially or entirely of textile fibres formed by the bonding of → Nonwovens.

Fibre crosslinking agents Finishing agents with at least 2 functional groups capable of reacting with the fibre. →: Reactive resin; Cross-linker; Resin finishing agents.

Fibre cross-sections, preparation of → Microscopy fibre cross-sections, preparation of.

Fibre damage (cellulosic fibres), tests for Detection and determination of oxycellulose, hydrocellulose, photocellulose and pyrocellulose.

I. General determination of:
a) Degree of polymerization, e.g. fluidity;
b) Reducing properties (only for hydrocellulose);
c) Dye uptake of basic groups (only for oxycellulose);
d) Alkali solubility;
e) Tensile strength.

II. Qualitative methods of determination:
a) Fehling's solution: brick-red colour;
b) Ammoniacal silver solution: yellow-brown colour;
c) Lead-cochineal reaction: blue colour (oxycellulose);
d) Gold-purple reaction: red-brown colour (hydrocellulose remains unstained);
e) Methylene blue reaction: blue colour;
f) Nessler reagent: yellow colour turning grey later;
g) Schiff's reagent: red colour;
h) Berlin blue reaction: deep blue colour (oxycellulose);
i) Boil in caustic soda solution: yellow to brown colour;
j) "Mushroom" reaction (microscopic examination of fibre swelling in a 15% solution of caustic soda): undamaged cellulose produces a mushroom-like swelling at the ends of the fibres. Damaged cellulose, on the other hand, produces very little or no fibre swelling.

III. Quantitative methods of determination:
a) Copper number: hydrocellulose and other reducing substances;
b) Permanganate number: oxycellulose and hydrocellulose;
c) Methylene blue number: oxycellulose;
d) Alkali solubility: oxycellulose, hydrocellulose, pyrocellulose, photocellulose;
e) Degree of polymerization: oxycellulose and hydrocellulose;
f) Tensile strength.

IV. Detection of acids or alkalis on the fibre:
a) Test an aqueous extract with indicator paper (minimum detectable amount of sulphuric acid is 0,02%) or measure the pH.
b) The specimen is spotted with a 0,02% solution of methyl red in 50% alcohol. A red colour indicates the presence of acid whilst a yellow colour indicates alkali. Limit of detection is 0,005% of acid or alkali.

Fibre damage (regenerated cellulosic fibres), tests for Methods of detection and determination:

I. Presence of acids or alkalis on the fibre, oxycellulose, hydrocellulose, as under → Fibre damage (cellulosic fibres) tests for.

II. Degree of polymerization (→ Caustic soda liquor.

III. Solubility in sodium hydroxide solution.

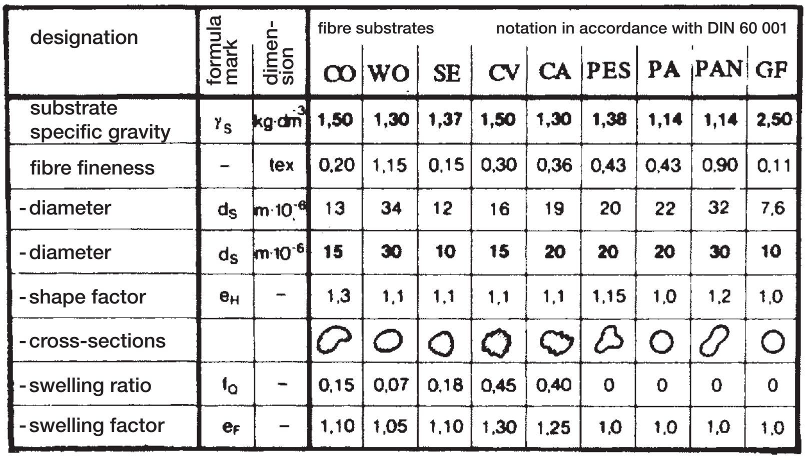
Fibre damage (wool), tests for

I. Qualitative methods: a) fibre microscopy; b) presence of acids or alkalis on the fibre (also including quantitative determination) as under → Fibre damage (cellulosic fibres) tests for; c) chemical tests →: Biuret reaction; Tin salt reaction; Diazo reaction for wool damage; Silver test; Elasticum reaction; Indigo carmine reaction.

II. Quantitative methods: a) alkali solubility; acid solubility; c) urea-bisulphite solubility; d) cystine and tryptophan content.

Fibre differentiation → Fibre identification.

Fibre dimensions and characteristics Dimensions and characteristics of importance in textile processing and finishing, together with typical fibre cross-sections and their corresponding form factors, are listed in the Table.



designation	formula mark	dimension	fibre substrates	notation in accordance with DIN 60 001							
			CO	WO	SE	CV	CA	PES	PA	PAN	GF
substrate specific gravity	γ_S	$kg \cdot dm^{-3}$	1,50	1,30	1,37	1,50	1,30	1,38	1,14	1,14	2,50
fibre fineness	–	tex	0,20	1,15	0,15	0,30	0,36	0,43	0,43	0,90	0,11
- diameter	d_S	$m \cdot 10^{-6}$	13	34	12	16	19	20	22	32	7,6
- diameter	d_S	$m \cdot 10^{-6}$	15	30	10	15	20	20	20	30	10
- shape factor	e_H	–	1,3	1,1	1,1	1,1	1,1	1,15	1,0	1,2	1,0
- cross-sections											
- swelling ratio	f_Q	–	0,15	0,07	0,18	0,45	0,40	0	0	0	0
- swelling factor	e_F	–	1,10	1,05	1,10	1,30	1,25	1,0	1,0	1,0	1,0

Tab.: Dimensions of various fibres.

Fibre dust Small fibre particles dispersed in the atmosphere.

Fibre engineering The production of tailor-made fibres which are structural modifications of basic man-made fibres types to meet specific requirements, i.e. fibre construction tailored to produce special types of fibre with preprogrammed properties in accordance with exact physico-chemical principles (molecular engineering). These modifications can be achieved, e.g. by:

1. Changes in molecular weight (= changes in degree of polymerization = changed fibre-technological properties).

2. → Copolymerization (e.g. for single-bath multicolour effects in dyeing).

3. Use of comonomers (e.g. special softening effects).

4. Aromatization (higher melting temperatures).

5. Modification of side groups (differential dyeing types, flame-retardancy, modified strength, stiffness, shrinkage properties, melting properties, solubility, etc.).

6. Use of polymer mixtures (polyblends, bicomponent fibres).

7. Polymer pigmentation (hydrophilic effects, antistatic effects, flame retardancy, fluorescent brightening effects, etc.).

8. Physical modifications (high-shrinkage fibres).

Fibre identification It is often necessary to make a rapid identification of the fibres present in a fabric. There are various methods, which may be used in combination or to confirm results:

- Burning test;
- Microscopic examination (normal and in cross-section);
- Determine the characteristic features;
- Solubility (solvent separation);
- Special confirmation tests;
- Staining tests for undyed materials.

1. Staining with Neocarmine W (Tab. 1): a small sample of the material, pre-wetted with alcohol, is immersed in the Neocarmine solution for 3–5 min., then removed, rinsed for 2 mins in running water and dried.

Fibre	Microscopic characteristic	Stain	Chemical reactions
Wool	Overlapping outer scales with internal length-wise lines. Coarse fibres may have internal dark blotches or rope-like marks.	yellow	dissolved in 2% potassium hydroxide solution, boil for 15 min.
Recovered wool	Scales more or less pronounced, fibrillated brush-like fibre ends.	yellow-brown	"
Coarse hairs	broad, often opaque, and form a very broad, striated cylinder.	yellow	"
Camel hair	Colour is grey, yellow to brown	"	"
Wool or lint fibre	scaly, unmarked, length-wise stripes		
Bristle	dark brown to black, generally contain blotches or continuous channelled markings with grainy content (natural dyes)		
Cashmere	Colour is white, grey or brown, the outer layer consists of fine, well-defined scales	yellow	"
Wool or lint fibre	display coarse stripes and split fibres		
Bristle	rope-like markings with fine-grained content		
Mohair	coarse stripes, wide, regular splits in the fibres, the scales are thin and often narrow to a point, fine hairs unmarked	"	"
Angora	Scales as with wool, but more pointed, groups of markings arranged like a string of pearls; coarser hairs have several rows of markings.	"	"
Raw silk	Single fibres are stuck together with gum (sericin)	olive green	soluble in formic acid zinc chloride solution, warm or boil for 1 min in conc. nitric acid.
Degummed silk	structureless, smooth, translucent, irregular length-wise.	dull yellow	"
Tussah silk (wild silk)	Individual fibres broad, band-like with fine length-wise stripes and creases, slightly twisted	green	dissolved by boiling for a few minutes in conc. nitric acid.
Raw cotton	thin ribbon-like with length-wise twists in either direction	light blue (red spots)	swells before dissolving in Cuprammonium hydroxide
Mercerized cotton	more cylindrical than ribbon-like structure with very few twists	deep blue (red spots)	dissolves without swelling in Cuprammonium hydroxide.
Viscose	longitudinal stripes, varying in intensity	red – reddish purple	swells before dissolving in Cuprammonium hydroxide
Cupro	structureless, smooth, translucent	deep blue	"
Cellulose Diacetate	1-3 longitudinal stripes, otherwise structureless	yellow (red or green spots)	soluble in acetone, glacial acetic acid and formic acid, not readily soluble in cold dichloromethane
Cellulose Triacetate	"	yellow (green spots)	soluble in cold dichloromethane and glacial acetic acid, practically insoluble in acetone
Kasein	partially smooth, partially striped longitudinally, usually with grained deposits	yellow-orange	
Polyamide	smooth, structureless	green (yellow spots)	soluble in cold 85% formic acid, turbid or precipitation on addition of water
Polyacrylonitrile	weak, longitudinally striped, slight twist	only slightly stained	soluble in cold nitric acid and boiling DMF
Polyester	smooth and structureless		soluble in molten phenol and boiling o-dichlorobenzene
Polyvinylchloride	smooth, fine to thick, some very thick sections	soiled	soluble in boiling dichloromethane and cold DMF

Tab. 1: Microscopic fibre identification after staining with Neocarmine W (plus chemical tests).
[Polyester may only be stained with Neocarmine MS (Merck)]

The staining process requires a white or only pale dyed material. Dyed material is not suited to this test method.

2. Staining with Neocarmine MS: a small sample of the material, pre-wetted with alcohol, is immersed in boiling Neocarmine solution for 5 min., then removed, rinsed for 2 min in running water and dried.

3. Dry distillation: the fibre sample is heated in a dry test tube. The gases released are tested with moistened litmus paper. Acid vapours turn blue litmus paper red, alkaline vapours turn red litmus paper blue. Acid vapours are released by: cellulose fibres (natural and recovered), acetate fibres. Alkaline vapours are released by: protein fibres (wool, silk, synthetic protein fibres), polyamide fibres, polyacrylonitrile fibres. Polyester fibres are initially neutral, then acidic.

4. Polyvinylchloride test: A fibre melted onto a copper wire colours a Bunsen burner flame intense blue-green.

5. Solvent separation (Tab. 2): Starting with dichloromethane, fibres are separated into groups by individual solvents. If the fibre is insoluble, a new sample is tried and then it is moved on to the next solvent. If a blended spun yarn is being tested, the sample must be dried between each stage and used for the next relevant solution test. The fibre materials are thus separated into different groups according to solubility and within each group identified by means of specific tests. To carry out the solution test: the fibre sample is placed in a test tube with approx. 5 ml of the solvent. The test can be carried out cold, but it is normally necessary to use hot solubility. A rule of thumb for the length of treatment is:

- cold: 30 mins, agitated, at room temperature,
- hot: 5 mins at the boiling temperature of the solution being used.

To ensure reliable evaluation of the solubility (esp. in the case of blended fibres) a control reaction is carried out (Tab. 2). After the solution test, approximately twice the volume of a "non-solvent" is added to the cooled solution. The dissolved fibre is precipitated out in the form of cloudiness or a flocculent precipitation. If using solutions which can be mixed with water, water should preferably be used, otherwise methanol. If the precipitated fibre material is to be used for further tests, it should be filtered out and dried.

Fibre identification by dry distillation A sample of fibre material is slowly heated in a dry test tube. The escaping vapours are tested with moistened litmus or pH indicator paper (see Table). Wool, animal hairs and casein (but not silk): blackening of moistened lead acetate paper (by H_2S). In the case of fibre blends, the components should first be separated by teasing them apart, and the fibres tested individually.

Solution/ fibre to be dissolved	control reaction
1. Dichloromethane cold: triacetate hot: PVC after chlorinated	with methanol: precipitation
2. Acetone cold $2^1/_2$ acetate	with water: turbidity
3. Tetrahydrofuran PVC not after chlorinated PVDC (polyvinylidene chloride)	with methanol: precipitation
4. Dimethyl formamide PA6, PUE, PAC	with water: precipitation
5. Formic acid 98% PA 6.6 (mulberry silk decomposes)	with water: precipitation
6. o-dichlorobenzene Polyester (PETP, PBTP)	cool off: turbidity
7. Xylene Polyethylene, Polypropylene	cool off: turbidity
8. Caustic soda 5% Wool, silk	cool off, with hydrochloric acid: turbidity
9. Formic acid/zinc chloride * 10 mins at 70°C: Viscose, modal fibre	with water: turbidity
10. Sulphuric acid 98% cold: cotton, flax	
There are no known solvents for polytetrafluoroethylene	

* 20% by weight of zinc chloride (anhydrous) dissolved in 80% by weight of conc. formic acid

Tab. 2: Solvent separation for the identification of fibres.

pH	fibre	odour
1	CLF	pungent (HCl)
2–3	CA	acidulous (vinegar)
3–4	PES	sweetly aromatic, slightly pungent
4–5	PVAL	burnt sugar
5–6	cell. fibres	burning paper
5–6	PE	burning paraffin
6–7	PP	"
9–10	Proteinf.	burning hair
10–11	PA	" (weak), not pungent
10–11	EL	like mouse droppings
10–11	PAN	sweetly aromatic

Tab.: Fibre identification by dry distillation. (Symbols in accordance with DIN 60 001 T4/08.91).

Fibre identification by luminescence Qualitative analysis of native and synthetic fibres by means of secondary luminescence produced by the exposure of fibres pretreated with rhodamine or fuchsin (magenta) to UV radiation. Optimum pretreatment: after 2–3 min prewash in sodium carbonate solution, treat for 10 min at 70°C in a solution having a specific dye concentration at a liquor ratio of 100:1 or 200:1. The pretreated fibre material is then observed under the microscope fitted with a luminescence accessory (mercury vapour lamp and light filter to allow the passage of radiation between 300–400 nm only). Each type of fibre gives a characteristic secondary luminescence colour depending on the indicator dye used, which also remains visible in fibre blends and dyed textiles.

Fibre identification by microscopy Fundamentals of microscopic and cinematographic methods of textile testing:

I. Examination in the magnifying glass range.

II. Methods of textile microscopy (light field, dark field, phase contrast, polarization and fluorescence microscopy).

III. Preparation of test specimens (impressions in Tylose, gelatine, elastomeric resins or by galvanoplasty in polystyrene/gold, microtome sections).

IV. Microscopic measurement and counting.

V. Use of filters and their effects.

VI. Scanning electron microscopy.

VII. Cinematography (HF and ultra short-exposure photography).

Fibre identification, rapid identification of man-made fibres Fibre solubility according to the scheme given below:

Cuoxam (cuprammonium, Schweitzer's reagent) (microscopic)	***soluble:*** **stir. CEL** **insoluble:**
Glacial acetic acid cold	***soluble:*** **CA, CT.** **insoluble:**
Glacial acetic acid boiling	***soluble:*** **PA6, PA6.6, PA11** **insoluble:**
6n hydrochloric acid cold	***soluble:*** **vinylal (PVA+)** **insoluble:**
Nitric acid conc. cold	***soluble:*** **PAN** **insoluble:**
Sulphuric acid conc. cold	***soluble:*** **PES** **insoluble:**
Dimethyl formamide, cold	***soluble:*** **PVC** **insoluble: polypropylene-F**

Fibre identification reagents →: Acetone solubility test; Aniline sulphate test; Caustic soda solubility test; Zinc chloride solubility test; Diphenylamine-sulphuric acid; Glacial acetic acid solubility test; Iodine-potassium iodide solution; Cuprammonium hydroxide; Methylene blue test; Nickel ammonium hydroxide; Persoz reagent; Phloroglucinol reaction; Nitric acid solubility test; Sulphuric acid solubility test; Zinc chlor-iodide solution; Zarts solution. → Fibre identification; Fibre identification scheme.

Fibre identification scheme (Tucci)

I. Homogeneous man-made fibres (i.e. not blended) are easy to separate and identify by their differing solubilities in organic solvents (Fig. 1).

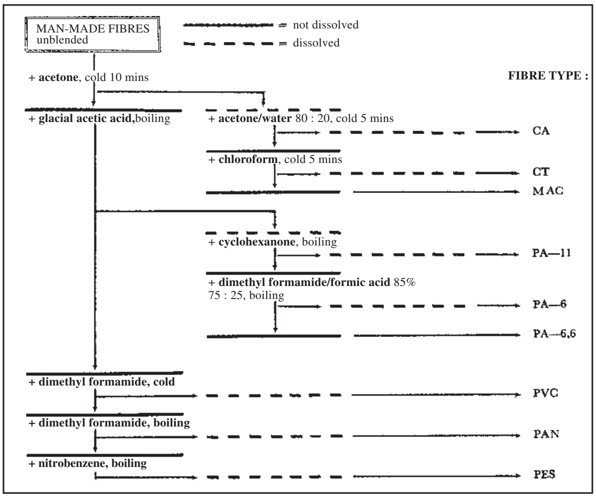


Fig. 1: Tucci's fibre identification chart (symbols in accordance with DIN 60 001 T4/08.91).

II. Fibre blends, especially intimate blends containing only a very small proportion of man-made fibres, are very difficult to identify by means of solubility alone. For this reason, a second test should be carried out to confirm whether the solvent does in fact contain dissolved fibre or not. After decanting the solvent off the fibre specimen it is tested according to the control reactions shown in the identification scheme (Fig. 2).

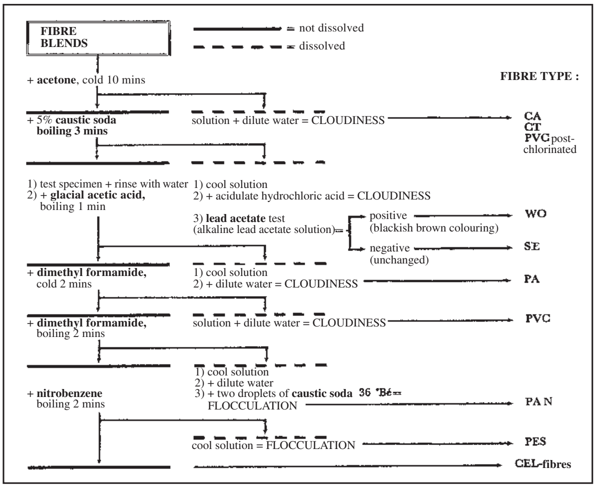


Fig. 2: Identification of fibre blends (according to Tucci). (Symbols in accordance with DIN 60 001 T4/08.91).

Fibre melting point →: Burning properties; Temperature characteristics of textile fibres.

Fibre modification

I. → Weight reduction of polyester fibres.

II. → Acetylated cotton.

III. → Affinity modification.

Fibre moisture content → Moisture absorption of fibres; Moisture regain.

Fibre plant → Natural cellulosic fibres.

Fibre polymers →: Macromolecules; Polymers.

Fibre pores (→: Vacuole; Medulla; Pore size of fibres). Intermicellar regions of fibre structure. In the case of wool, medullated fibres are somewhat more brittle. The abrasion resistance of a mixture containing a high proportion of medullated fibres (above 25%) is somewhat poorer than that of non-medullated fibres. On the other hand, the reproducibility is better.

Fibre pores, determination of Determined by → Mercury porosimetry. Under comparable test conditions the pore volume of the fibres increases as follows:

Polyester < Polyamide < Polypropylene < Cellulose < Polyacrylonitrile.

Within a fibre group the pore volume may vary considerably. It also varies considerably with different production methods. Thus, for example, dry spun fibres are more compact than wet spun.

Fibre protective agents Products of this type are used particularly for the protection of animal fibres in bleaching, dyeing and stripping. Fibre protective agents are also important in the wet processing of fibre blends. Even in the wet processing of cellulosic fibres, fibre protective agents have a role to play, e.g. to provide protective screening against oxidative/reductive changes in vat dyeing, and in oxidative bleaching, etc. Fibre protective agents are based on, e.g. protein degradation products, fatty acid protein condensation products, ammonium salts of alkyl sulphates and alkyl sulphonates as well as lignin sulphonic acid salts.

Fibre proteins (fibrillar proteins, chain proteins, scleroproteins). High molecular weight polypeptides consisting of long threadlike or chain molecules (→: Silk fibroin; Wool keratin). They are formed from → Amino acids.

Fibre quality testing Objective fibre testing is being increasingly automated. The classification of fibre quality using objective measurement methods has not yet penetrated the wool and silk market to the same extent as in the cotton. Specialists classified cotton by a subjective visual evaluation, assessing the fibre length, any impurities, the colour etc. and then gave the material a certain "class". The classifier was not, however, in a position to estimate the fineness, strength, elasticity and microdust content of the fibre etc. by mere visual inspection. During the last 50 years numerous types of test equipment have been developed for assessing the various fibre characteristics that can be measured with a sufficient reproducibility. The majority of these testing devices were, however, time-consuming and e.g. unsuitable for testing cotton in large quantities. They were used in cotton fibre research, by textile machine manufacturers and by some progressive spinning companies. The automation of fibre testing began in 1965 with collaboration between the US Department of Agriculture (USDA) and the Texan plant manufacturer Motion Control. This collaboration led to the first HVI (High Volume Instrument), followed by a further, similar device developed by Spinlab in 1984. Today a considerable proportion of the American cotton yield is tested by machine.

All earlier fibre testing procedures necessitated the preparation of a fibre sample, consisting of several thousand fibres, which were then combined to form a "bundle". As clips held the bundle, it was not possible to determine the proportion of short fibres in a "bundle test". Furthermore a bundle test did not allow fibre to fibre variations to be determined. It was not possible to determine the nep content by means of a bundle test. Neps occur where the fibres have formed lumps and are distinguished as natural (growth neps) and processing neps. The latter arise especially in cotton processing (scutcher, carder). Microscopic inspection will show that a large number of the neps consists of clumps of dead fibres or that they have been formed around the remains of a husk. The AFIS-N nep count and classification system employs evaluation of individual fibres to enable direct assessment of the nep content. The machine divides the sample into individual fibres, neps and trash (dust). The dust particles are separated off by means of a centrifugal process. The individual fibres and neps are caught up in a stream of air and led through an optoelectronic scanner. Here the nep responses are converted into a proportional voltage. The individual neps generate a characteristic pulse voltage, the size and length of which corresponds to the type of nep.

The availability of fibres in the fine yarn count region, from around 20 tex (Nm 50), is crucial to spinning success. The individual fibre count in terms of distribution has a considerable influence on the yarn quality and running properties. The fineness of the fibre therefore increases in importance as the yarn count increases. The fineness of cotton is usually given in micronaires. The micronaire value is a non-dimensional value representing the air permeability of a compressed cotton sample; it is direct relationship to the fibre surface area. This value, however, does not give a definitive value to the actual fineness in dtex, as it is also influenced by the maturity of the fibres. The effective average fibre fineness can be calculated in accordance with a formula devised by E. Lord, if micronaire value and degree of maturity are known.

The figure shows the relationship between the micronaire value, maturity and fibre fineness. It can be

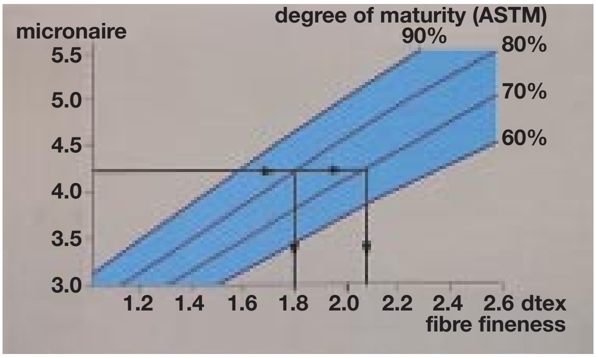


Fig.: Fibre testing: Fibre fineness of cotton in relation to degree of maturity.

seen that, given a constant micronaire value, different degrees of maturity affect the fibre fineness. The possible spin parameters are limited in this way. When spinning cotton there should be around 100–110 fibres in the yarn section in order to achieve stability in spinning and good breaking strength and regularity. Under particularly favourable conditions even yarns with a low average number of fibres may be spun successfully.

Fibre-reactive compounds → Reactant-fixable dyeings; Reactive resin.

Fibres (textile fibres). Linear-shaped raw materials capable of being processed into textiles and characterized by adequate flexibility, fineness and strength with a high ratio of length to thickness (Fig. 1).

They may be subdivided into:

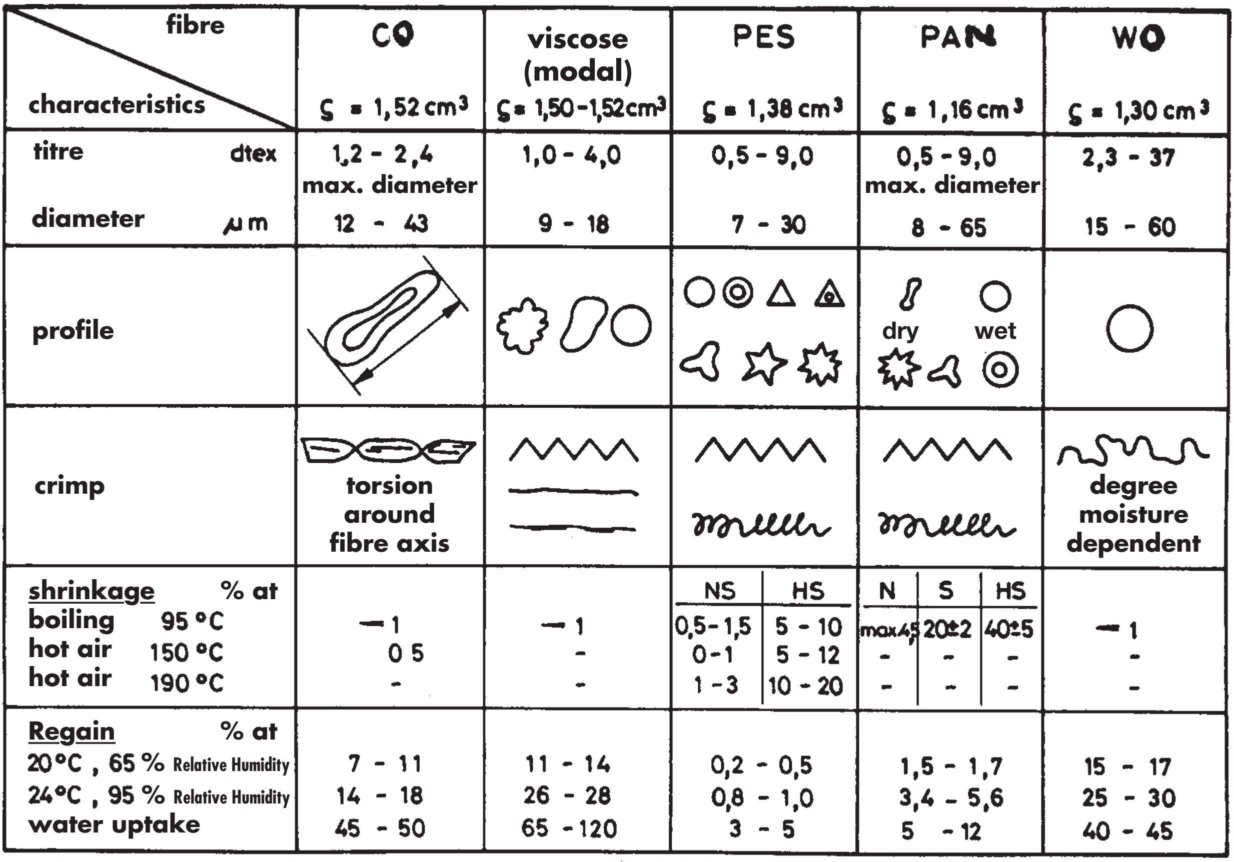
I. Natural fibres:

1. Vegetable fibres: a) vegetable hairs (seed and fruit fibres); b) bast fibres, soft fibres (bast fibre bundles from the stems of dicotyledenous leaf plants); c) hard fibres (sclerenchymatous fibres and vascular bundles from the leaves or fruits of monocotyledonous plants); d) other vegetable fibres.
2. Animal fibres: a) wool and animal hairs; b) silk fibres.
3. Mineral fibres.

II. Man-made fibres:

1. Produced from natural polymers: a) of vegetable origin; b) of animal origin.
2. Produced from synthetic polymers: a) polycondensation fibres; b) polyaddition fibres; c) polymer fibres; d) bicomponent fibres.

III. Other industrially-manufactured fibres of inorganic basis; glass fibres, mineral fibres, metallic fibres, etc.



fibre / characteristics	CO ρ = 1,52 cm^3	viscose (modal) ρ = 1,50–1,52 cm^3	PES ρ = 1,38 cm^3	PAN ρ = 1,16 cm^3	WO ρ = 1,30 cm^3
titre dtex	1,2 - 2,4	1,0 - 4,0	0,5 - 9,0	0,5 - 9,0	2,3 - 37
diameter µm	max. diameter 12 - 43	9 - 18	7 - 30	max. diameter 8 - 65	15 - 60
profile				dry wet	
crimp	torsion around fibre axis				degree moisture dependent
shrinkage % at			NS | HS	N | S | HS	
boiling 95 °C	~ 1	~ 1	0,5-1,5 | 5 - 10	max 4,5 | 20±2 | 40±5	~ 1
hot air 150 °C	0 5	-	0-1 | 5 - 12	- | - | -	-
hot air 190 °C	-	-	1 - 3 | 10 - 20	- | - | -	-
Regain % at					
20 °C, 65 % Relative Humidity	7 - 11	11 - 14	0,2 - 0,5	1,5 - 1,7	15 - 17
24 °C, 95 % Relative Humidity	14 - 18	26 - 28	0,8 - 1,0	3,4 - 5,6	25 - 30
water uptake	45 - 50	65 - 120	3 - 5	5 - 12	40 - 45

Fig. 1: Important fibre characteristics of natural fibre materials in comparison to regenerated cellulose fibre materials and synthetic fibre materials.

Depending on their form, fibres are also subdivided into:

- Staple fibres = fibres of predetermined short lengths (approx. 15–500 mm);
- Continuous filaments, of practically unlimited lengths;
- Flock fibres = very short fibres which cannot be spun < 15 mm.

Individual fibres form the basic building blocks of threads in the form of yarns used in the production of textile fabrics by weaving and knitting as well as nonwoven fabrics. Textiles are morphologically-determined structures produced from spinnable fibres of the staple variety and/or continuous fibres. In the spinning process, fibres are bonded together into threads by drafting.

I. Natural fibres:

Cotton: In terms of quantity this is the most important of the natural fibres. In its physical structure it reveals a large number of extremely strong fibrils of high order. These fibrils form an unusual spiral structure which can be easily penetrated by water and which, due to its chemical structure, is capable of forming bonds with a wide variety of chemicals, dyes, crosslinking agents, flame-retardants, water-repellent agents, etc. The same swelling properties make thorough washing treatments possible. Since the cotton fibre is not thermoplastic, it can be washed at the boil. The surface characteristics of cotton are to a large extent responsible for its comfort in wear, its rapid water absorbing properties, and its ability to retain good whiteness throughout its serviceable life. The main weakness of cotton is its lack of easy-care properties insofar as it is unable to satisfy the expectations of today’s consumer. The basic problem is not that cotton cannot be given an easy-care finish, but the fact that this improvement can only be achieved at the expense of significant strength and abrasion losses when cotton is resin finished to obtain improved wrinkle resistance.

Wool: The chemical structure of the wool fibre (even more than that of cotton) makes it possible to form chemical bonds with a great number of chemicals, dyes, etc. Among the many textile properties characteristic of the wool fibre, its three-dimensional, highly stable crimp, which is largely responsible for the bulk and handle of wool fabrics, as well as the reversible changes in crimp intensity due to variations in moisture content, are particularly noteworthy. The different swelling properties of both halves of the bicomponent wool structure cause a flattening of the crimp curvature when wet with a consequent reduction in the pore volume of yarns or finished goods. The wool fibre is a compound system of keratin fibrils in a network of cell membrane complex and matrix proteins. This structure, which is partly responsible for the good wearing comfort of wool, gives the fibre good temperature stability in the dry state and, at temperatures below 100°C, also in the wet state. Its felting propensity is one of those characteristics which, in contrast to cotton and man-made fibres, make the fibre particularly desirable in certain branches of the textile industry on the one hand, such as the manufacture of cloths, felts and hats but which, on the other hand, is a disadvantage in other applications. A further unfavourable property of apparel textiles made from wool fibres is their pilling propensity and (as in the case of cotton) their inadequate easy-care properties by today’s standards although these can be improved by the application of appropriate finishes.

II. 1. Man-made fibres from natural raw materials: The specific properties of viscose and modal fibres may be discussed under this category. The raw material for the manufacture of these fibres is cellulose. Whilst the chemical structure is identical to that of cotton, important differences in the physical structure of both these fibre types can be identified.

Viscose: In contrast to cotton, the average degree of polymerization of viscose fibres is lower. Moreover, the degree of order, which is approx. 30–40%, is likewise lower than that of cotton (50–60%). The major proportion of the fibre is present as an amorphous intermicellar region. Due to these structural deviations in comparison with cotton, viscose reveals certain differences in its range of properties. The conventional viscose fibre thus exhibits lower strength properties, a higher water absorption, a greater creasing propensity and a higher extensibility than cotton. Its easy-care properties are likewise inadequate by today’s standards. Viscose fibres are particularly valued for their high degree of lustre in textile fabrics.

Modal fibres: Developments in the manufacture of regenerated cellulosic fibres have made it possible to control the processes of manufacture in such a way that the morphology, degree of order and orientation of the fibre can be modified as desired. As a result of this knowledge, a group of regenerated cellulosic fibres with properties very similar to those of cotton has been developed. As examples of these modal fibres, the properties of polynosic and HWM (high wet modulus) types will be discussed. The polynosics have good form stability, increased linear strength properties and can be readily mercerized. The HWM types have an approx. 50–70% higher transverse strength; as a result they can also be mercerized under certain conditions, their bending rigidity is lower, and they are not subject to fibrillation. Their water retention capacity of 60–70% lies within the same range as that of cotton. The above properties predestine these fibres for blending with natural and synthetic fibres.

II. 2. Man-made fibres from synthetic polymers: The synthetic man-made fibres include the three important polymer groups of polyester, polyamide and polyacrylonitrile. Although of somewhat lesser importance

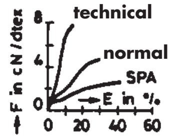
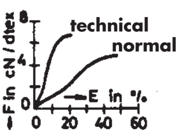
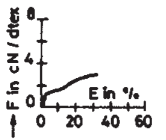
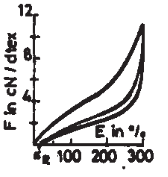
FIBRE TYPE	temperatures 1) glass 2) fixation/ ironing 3) melting in°C	density in g/cm^3	Humidity 1) regain 2) up take %	stress-strain curve modulus of elasticity in cN / dtex	Light resistance	dyeability	characteristic properties	textile fields of application
POLYESTER	1) 80 2) 130-220/ 100-180 3) 256	1,38	1) 0,2 - 0,5 2) 3 - 5		good	HT or good with carriers	High strength, good abrasion resistance, supple, full handle, easily texturised, easy care, poor hydrolysis resistance, not for voluminous knitted fabrics	Clothing and household textiles, in blends with cotton, wool, viscose, decorative fabric, nonwovens, filling material.
POLYAMIDE-6	1) 40 2) 185-195/ 120-140 3) 215	1,14	1) 4,5 2) 10 - 15		satisfactory light stabilising possible	very good	High strength, easily texturised, very good abrasion resistance, very good crease recovery, easy care, however soft handle, moderate shape retention when wet.	as filament yarn, leisure clothing and ladies stockings and tights, floor covering, nonwovens
POLYACRYLONITRILE	1) 80 2) none 80 - 120 3) shrinks from heat	1,16	1) 1,5 - 1,7 2) 5 - 12		very good	very good	Wide range of characteristics, very good weather resistance, high bulking and heat retention capacity, pleasant handle, easy care, moderate recovery capacity after deformation in hot water	pure and in mixtures with wool or synthetics, outer clothing, particularly knitted fabrics, decorative material, imitation fur, filling material, blankets, furniture velours
ELASTHANE	1) - 40 resp. - 60 2) 185 - 195 / 120 - 140 3) shrinks from heat	1,16 -1,19	1) 1,0 2) 3 - 5		good to adequate	good to satisfactory	extensible elastic multifilament yarn, with adhering individual filaments, easy care, resistant to dry-cleaning. The manufacture of very fine filament yarns is possible	In textile fabrics, which should have a high extensibility and high elastic recovery, in quantities of 2 - 30 % foundation garments, swimwear, underwear, outer clothing

Fig. 2: Characteristic properties of synthetic fibre materials.

in terms of quantity, the polyolefins such as polypropylene, polyvinyl derivatives and elastomers based on polyurethane also deserve to be mentioned here. The introduction of all these fibres into the various textile end-products took place rapidly. During this introductory phase, the textile processing industries quickly learned how to exploit the specific properties of the individual synthetic fibres to the best advantage (Fig. 2).

The various synthetic fibre producers already started to extend their market position further during this introductory phase by exhausting the diverse possibilities offered by the selective formation of polymers, spinning dope modifications, and variations in the manufacturing processes. The development of these chemically and physically-modified types and their subsequent introduction into the market has considerably increased the range of synthetic fibres.

Polyamide: Although in terms of quantity, the polyamide fibre has now fallen back to second place, it is a fact that the polyamides were the first mass-produced synthetic fibres which found rapid acceptance in the textile market. They have a sound raw material basis; the melting points of the polyamide-6 and 6.6 polymers are well-suited to fibre manufacture and application. The specific gravity is low without reaching a minimum value. The most important properties of polyamides are their high strength characteristics, their extensibility which can be adjusted over wide limits, very good abrasion and flexing resistance, good dyeability which is relatively easily modified, good texturing characteristics and satisfactory form stability. In practical terms, these specific fibre properties make polyamide fibres particularly suitable for applications where the durability properties of the end-product need to be increased. The most important fields of application for polyamide fibres therefore include floorcoverings, women's hosiery, women's underwear, leisurewear and hard-wearing clothing. Unfavourable properties of the polyamide fibres are, however, their moderate wet form stability and the limp handle of polyamide fabrics.

Polyester: As one of the earliest synthetic fibres this fibre, which is based on polyethylene terephthalate, has enjoyed an outstanding growth in production volume in recent years which has far outstripped all other fibres. The reason is due to the fact that textiles produced from polyester fibres have good easy-care properties and excellent wear resistance. Moreover, polyester fibres can be readily modified and have good texturing characteristics. The chemical and physical structure is responsible for this range of properties. The melting point of the polymer is sufficiently high for fibre manufacture and application. Its glass transition temperature of between 68–80°C (depending on degree of orientation) and its high degree of order help the polyester fibre to withstand the various industrial processes and care treatments without permanent deformation. In addition to the fibre characteristics which can be varied during manufacture such as fibre fineness, fibre length, tensile strength and extensibility, it is also possible to modify the pilling propensity, dyeability and shrinkage properties of the polyester fibre. The wide diversity of applications of polyester fibres, especially in apparel articles, already gave rise to an early desire to match the pilling propensity of the fibres to the particular article construction. The resultant fibre type developments are today included within the standard fibre type program of the man-made fibre manufacturer.

Polyacrylonitrile: The chemical structure of polyacrylonitrile as well as its physical structure make chemical and/or physical modifications of this fibre possible. Accordingly, fibre manufacturers are able to offer fibre types with different dyeability as well as flame-retardant types. Due to the high bulk and good thermal retention properties, pleasant handle, excellent resistance to light and weathering, as well as the interesting coloration possibilities, articles produced from polyacrylonitrile fibres enjoy an established niche in the textile market. The high glass transition temperature of 95°C (dry) and low swellability are responsible for the easy-care properties of textiles produced from polyacrylonitrile. The thermoplastic properties of these fibres makes it possible to achieve permanent pleating and shaping effects etc. which are also resistant to washing. The physical structure of the polymer allows the production of shrinkable fibres. Also dependent on their structure, polyacrylonitrile fibres can be produced with varying degrees of crimp and crimp stability. These possibilities for fibre variation allow the production of a great number of different fabric characteristics. By appropriate selection of the draw ratio and drawing temperature with subsequent gentle drying in spinning, fibres having different degrees of shrinkage are produced which are used in blends with non-shrinking natural or man-made fibres for the production of high-bulk yarns.

Elastomers: Unaffected by the stormy development of the synthetic fibres, highly-elastic fibres remained the exclusive domain of sulphur-vulcanized rubber threads for a long time. It was only at the beginning of the 1960's that highly-elastic polyurethane elastomers began to find wide application. In the meantime, they have displaced a considerable proportion of rubber threads from their traditional fields of application. Due to their chemical and physical structure, as well as the possibility to spin fine titres of approx. 20 dtex, elastomer filaments based on polyurethane have a very good range of properties which will allow them to find a still wider field of application (partly contributed by von Falkai).

Fibres, abbrev. for → Standard abbrev. for textile fibres.

Fibre saturation value is a measurement of the dye up-take potential of a fibre.

Fibres harmful to health Fibres which can have a harmful effect on the health of humans, e.g. asbestos.

Fibre sheath → Covering layer.

Fibre softening range → Softening range.

Fibre strength Strength of individual fibres. The → Tensile strength of textile fibres can only be considered in relation to their elongation (→: Stress-strain behaviour; Mechanical properties of fibres). Due to the specific morphological structure of textile fibres, both properties are dependent on the moisture content. It is for this reason that the tensile strength and elongation of fibres are given for both the dry as well as the wet state (see Table).

fibre material	strength		elongation	
	dry [cN/tex]	wet [%]	dry [%]	wet [%]
CO	25–50	105–110	6–10	7–11
LI, HA (1)	40–60	102–106	3– 4	4– 5
(2)	50–80	102–106	2– 3	2– 3
RA	50–60	115–125	2– 3	2– 3
JU	30–35	100–105	1,3	1,3
WO	10–16	80– 90	25–45	30–60
SE	30–50	80– 90	18–25	25–30
CV (F)	12–20	50– 70	15–24	20–30
(S)	22–28	55– 65	15–19	19–23
CA (F)	10–15	56– 68	20–25	25–35
(S)	13–16	58– 70	15–30	25–45
PA (F)	40–60	85– 90	20–45	24–52
(S)	30–40	85– 90	30–65	35–80
PES (F)	40–60	95–100	20–30	21–31
(S)	30–55	95–100	25–50	26–52
PAN (S)	18–32	75– 95	20–60	22–65
PVC (F)	24–27	100	10–25	10–25
(S)	20–24	100	10–40	10–40
PE (F)	30–70	100	10–45	10–45
PP (F)	25–60	100	15–50	15–50
AR (m-)	44– 53	75– 80	15–30	–
(p-)	140–190	98	3– 5	–
CF	100–170	100	1	1

Tab.: Fibre strength and elongation symbols in accordance with DIN 60 001 T4/08.91).
(1) = elementary fibre; (2) technical fibre; (F) = filament; (S) = staple fibre; (m-) = meta; (p-) = para.

Fibre surface area includes both the external and, predominantly, internal surfaces of the fibre. The latter is dependent on the numerous capillary-like canals and intermicellar spaces. The surface area of 1 g of cotton is approx. 5000 m^2, and the area of wettable surfaces is approx. 100–400 m^2 for 1 kg of fibres. It is accordingly much greater than the surface area of the liquor at the fibre sites where surfactant molecules responsible for the wetting process are located. In practical terms this means that an enormous, newly-formed boundary layer consisting of a micellar structure with surfactant molecules is built up within the shortest possible time from surfactant molecules which must be available in the solution as a reserve supply.

Fibre surface area, calculation of The fibre surface area may be calculated from the fibre surface O, the fibre weight G, the specific gravity of the fibres, and the diameter of individual fibres D:

$$O = \frac{4 \cdot G}{s \cdot D}$$

For the same weight, fibre surface area is greater the thinner and lighter the individual fibres are. This explains, e.g. the excellent warmth retaining properties of angora rabbit hair (∅ = 12 µm) compared to wool (∅ = 20–30 µm).

Fibre swelling →: Swelling; Moisture properties of fibres and yarns.

Fibre texture Fibre texture describes the state of order or orientation of the macromolecules in fibre structure (→ Texture). It can be understood by the presence of crystal aggregates with individual arrangements of crystallites in such a way that all the crystallites possess a definite lattice structure in approx. the same direction, i.e. a symmetry of the fibre axis exists which is detectable by X-ray crystallography. Fibre texture is characterized in other respects by the anisotropy of fibre crystallite orientation, i.e. higher orientation in the direction of the longitudinal axis due to primary valency bonds (which means greater strength, lower extensibility and swellability as well as easier cleavability) and lower orientation in the transverse direction due to secondary valency bonds (which means lower strength and higher swellability). Thus, the strength of regenerated cellulosic fibres in the transverse direction is only approx. 10% of that in the longitudinal direction (which is revealed by lower abrasion resistance and lower flexural strength) and the degree of swelling in the longitudinal direction is only about 10 % of that in the transverse direction. Rubber and related substances only assume a fibre-like texture in the stretched or drawn state, with the fibre axis lying along the direction of applied tension. All variants of fibre texture form spherical and spiral fibre textures.

Fibre tow → Tow.

Fibre wettability → Wettability.

Fibrids Synthetic binding elements with a fine structure resembling that of “wood pulp”, i.e. a netted filamentary or fibrillar structure, produced from polyamide, polyester, polyacrylonitrile, etc. They are used as a binding medium after the extraction of water from synthetic fibres on paper making machines. Fibrids (e.g. copolymers) have lower melting points than the main fibre component so that bonding of the latter is easily achieved by heat treatment. This process has been further developed for the manufacture of nonwoven webs, e.g. wet-laid synthetic papers.

Fibrillar proteins identical with → Fibre proteins.

Fibrillatable Short staple fibres used for the manufacture of nonwovens by the wet blending system used in paper manufacture.

Fibrillated film fibres Staple fibres produced by cutting, chopping or stretch-breaking fibrillated yarn or fibrillated film tow. See → Split fibres.

Fibrillated split yarns Fibrillated → Tape yarns, monoaxially drawn or e.g. split by needle rollers as a continuous material.

Fibrils

I. A very fine cellulosic fibre (∅ = 0,4 µm) formed from lamellar filaments resp. individual filaments (approx. 100 fibrils).

II. Fine fibrils have also been detected in cellulosic fibres under the electron microscope.

III. In → Wool structure the fibrils are spindle-shaped, tightly packed, twisted, fine fibres in the so-called spindle cells. These fibrils are composed of fibril bundles which, themselves are composed of individual fibrils.

IV. By analogy with wool, individual fibrils and fibril bundles are likewise present in the structure of → Silk. In the case of silk, however, fibrils are also understood to include the individual small fibres projecting from the surface of silk fabrics formed by the action of abrasion.

Fibroin Structural component (from → Fibroinogen) of → Silk (comprising 71–82%), in the form of a double fibroin filament which is covered by → Sericin in the form of silk gum. Contains the amino acids alanine, glycine, serine comprising approx. 75% as essential components of high molecular order crystallites, whereas with tyrosine the remaining amino acids which represent the low-molecular portion are the presumed components of the amorphous areas, which may include the “cuticulin”. Composition ($C_{15}H_{23}N_5O_6$): 49% carbon, 25% oxygen, 19% nitrogen, 6% water. Fibroin is insoluble in water, can be hydrolyzed to form amino acids and detectable as a polypeptide in a similar way to wool keratin, but without the cystine content. The length of a fibroin-amino acid residue in the polypeptide chain corresponds to 0.00035 µm and the length of the fibroin approx. 0.046 µm, which is equivalent to approx. 150 amino acids, of which only approx. 84 are glycine residues and 45 are alanine residues. As with wool keratin, elongated fibroin chain molecules (∅ approx. 0.0005 µm) are arranged together parallel to the chain sheet or grid, in which the grid repeats at a spacing of just 0.0005 µm. With the dimensions referred to, the main polypeptide chains of the fibroins

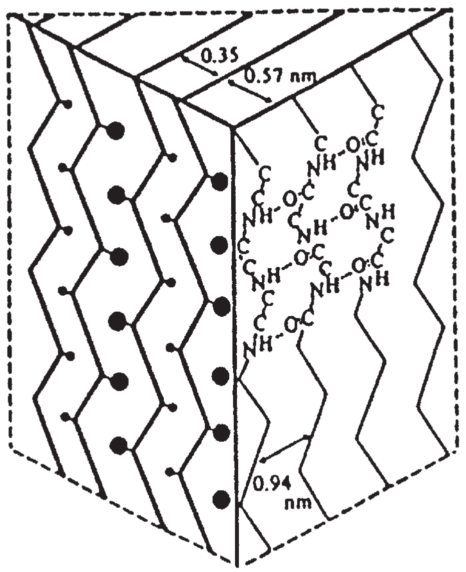


Fig.: Pleated sheet structure of fibroin polymer chains at a spacing which can be detected by radioscopy in a three-dimensional space (unit cell).

are accordingly extended substantially parallel to the fibre axis (similarly to β keratin) and are tightly packed, leaving no space here in the crystalline structure of the crystals or micelles for amino acids with large side groups. Consequently with side chains in fibroin, hydrogen bonds occur which determine the cohesion of the main chains and consequently the strength (Fig.).

Consequently, additional salt linkages are improbable, at least in the tightly packed area of the crystallites. This is another area in which a distinction can be made between fibroin and wool keratin. Another difference is that fibroin contains proportionally far fewer diaminocarboxylic acids with so-called amino extra groups, and therefore has a lower isoelectric neutral range between pH 3.8–4.7 (wool approx. 4–7) and a lower acid equivalent of 0.023 g/100 g (wool, 0.085).

Fibroin fibre A → Man-made protein fibre produced from silk fibroin. A fibroin solution is obtained by the dissolution of silk wastes which can be spun into fibre again. Fibroin fibre has no commercial importance.

Fibroin filaments → Continuous filament of silk composed of → Fibroin.

Fibroinogen soluble, water-extractable protein that is a precursor of silk fibroin. After standing for several hours a fibrous precipitate forms spontaneously as a linear aggregation of individual fibrils (length up to 0.35 µm, diameter 0.01 µm). Can be considered to be analogous to → Prekeratin of wool.

Fibrous webs Textile materials produced from textile fibres laid in a more or less random orientation which are held together by fibre cohesion or adhesion. They are classified in various ways:

I. According to method of manufacture (mechanical, aerodynamic or wet/hydrodynamically formed fibrous webs, → Spunbonded fabrics).

II. According to the bonding process (→: Nonwovens, Wadding, Stitch-bonded nonwovens, Stitch-bonded pile fabric).

III. According to fibre orientation (oriented webs; cross-laid webs; random webs).

Fick's equation, describes the diffusion processes for the quantitative diffusion of dye in terms of rate of transfer per unit area within e.g. a fibre:

$$n = -D\frac{dc}{dx}$$

From this equation, the term

$$\frac{dc}{dx}$$

is a concentration gradient, which represents an important prerequisite for the → Diffusion.

Fick's laws of diffusion In the simplest case when the concentration gradient is maintained in a constant state and the number of particles diffuse through an area with the cross-section q per unit time, the change in concentration with time at this position of surface q and the concentration gradients

$$\frac{dc}{dx}$$

are proportional.
Fick's first law of diffusion:

$$\frac{dc}{dt} = -D \cdot q \cdot \frac{dc}{dx}$$

where D = the diffusion coefficient (cm^2/s).

The change in concentration with time is given by Fick's second law of diffusion:

$$\left(\frac{dc}{dx}\right)_x = D\left(\frac{d^2c}{dx^2}\right)_t$$

The differential equation may be solved by fixing the starting conditions (t = 0, x = 0, c = 0). Finally, D can be calculated with the aid of the Gaussian error integral if the time t and the distance to the origin of diffusion x are known.

FID

I. (Fr.) abbrev. for: “Fédération International de Documentation”, international association for documentation, with headquarters in The Hague, Holland; → Technical and professional organizations.

II. Abbrev. for: → Flame ionization detector.

Fiddlestrings → Shiners.

Field of vision In the resting position, the human field of vision with both eyes extends from an angle of approx. 65° to both sides of the direction of view and can measure approx. 50° in the upper and lower directions. The powers of vision are greatest in the centre of the field of vision and lowest at its periphery. This fact can be explained by the higher image definition in the Fovea centralis where the greatest number of retinal cones are located which, in contrast to the rods (lightness/darkness receptors), are responsible for colour vision. Towards the periphery, the capacity for colour perception decreases greatly, and the sensitivity to lightness/darkness increases due to the higher number of rods. The centre of the field of the vision forms a viewing angle of approx. 20° so that when a sample is viewed at a distance of approx. 50 cm from the eye, an elliptical to circular surface area of approx. 30 cm diameter exists which corresponds to the size of colour matching samples including the original. The part which lies outside this area is known as the surrounding field.

FIFT (Ger.), abbrev. for: Forschungsinstitut für Textiltechnologie (Chemnitz) = Research Institute for Textile Technology, Chemnitz; → Technical and professional organizations.

Filament A fibre of indefinite length. Also used in connection with the now obsolete term “artificial silk”.

Filamentary molecules → Chain molecule.

Filament yarn Yarn which is composed of → Filament. Yarns produced from one or more filaments are preferably referred to as → Monofilament yarn or → Multifilament yarn respectively.

In filament yarn production (Fig.), direct spinning outweighs extruder spinning, the yarn being spun directly from the polymerisation plant. Extruder spinning machines fitted with chips are used, primarily for producing special yarns, as in compact equipment for example.

Particular regard is paid to an optimum melt temperature distribution and dwell time possible. Energy is saved by improved heat insulation and by reducing the areas irradiated. There are various developments for cooling the filaments in the quenching chamber, the use of a perforated tube which draws the cooling air through the movement of the filaments, therefore providing self-regulation, being emphasized in this connection. This process is used at very high spinning speeds.

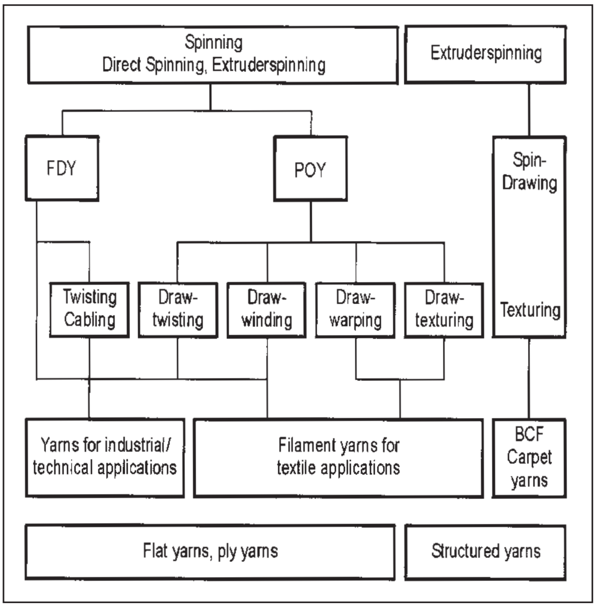


Fig: Filament yarn production.

In primary spinning, partial drawing is achieved, producing LOY/POY yarns (low oriented yarn, preoriented yarn). POY yarns must retain residual stretch in further processing. Fully drawn yarns are described as FOY or FDY yarns (fully oriented yarn, fully drawn yarn). On FDY machines, drawing is effected mainly by godets.

Filled soap Soap without excess electrolyte produced by saponification without salting out and using the calculated quantity of alkali. The glycerol formed is retained in the soap by the inclusion of neutral fat.

Filling doctor Two-bladed doctor in form of a box used as a counter-doctor for introducing dye liquor when using printing paste.

Filling factor, Concerns the ratio between vessel content in litres and material weight in kilograms → Load ratio; Liquor-to-goods-ratio.

Filling fibre Used to fill cushions, duvets, sleeping bags etc. Nowadays mainly consists of synthetic fibres.

Filling finish A type of finish used to increase the weight of a textile fabric by the application of so-called filling agents (which are cheaper than the textile material). The finish also produces a “compacting” effect and a fuller handle which may or may not be resistant to washing. → Weighting.

Filling warp Consists of coarse warp threads which provide fabrics with a coarse fullness and allow less interlacing. Filling warps are supplied for weaving on separate beams.

Film Any thin layer of a substance, e.g. size film, synthetic resin film, paint film, etc., which can also be removed from the surface of the parent substance and is likewise referred to as a film. The term film is, however, associated more with the idea of a non-independent film of a more or less elastic nature. Photographic film is actually a carrier-foil with a coating of light-sensitive film (photographic plate).

Film application The application of finishing liquors to textile fabrics, mainly in concentrated form (liquor pick-up of 40%). By this means, a film of liquid is transferred to the textile which completely saturates the fibres, e.g. kiss-roll application, slop padding (→ Low wet pick-up).

Film-forming agents Polymers which form coherent → Film after evaporation of their solvents or dispersants. The → Minimum film forming temperature is important in textile applications. The main applications are as follows:

a) Hard film-forming agents (glass transition temperature >25°C): Used for stiff finishes, interlinings, bonding of nonwovens, filtration fabrics, bonding of needle-punched felts, tufting precoats, carpet backcoating, glass textiles, selvedge gumming of knitgoods, binders for net curtains, mouldable textiles.
b) Less hard to soft film-forming agents (glass transition temperature –10 to +20°C): Finishes for tickings, linings, mattress tickings, glass textiles, backcoatings for woven carpets, textile coatings, coating of roller blinds.
c) Soft to very soft film-forming agents (glass transition temperature –10 to –30°C): Used for nonwovens, coating of knitted plush, bonding, pigment binders, flock adhesives.
d) Very soft, high tack film-forming agents (glass transition temperature <–30°C): Adhesives.

Film-release transfer printing A → Transfer printing process in which the transfer of dye from the support medium (paper) to the textile substrate does not take place via the gaseous phase as in conventional dry transfer printing, nor via the liquid phase as in wet transfer printing, but from dyes (which can belong to any colorant class) embedded in a film on the support medium which is released mechanically and transferred to the textile. Subsequent fixation of the dyes is carried out by the usual dry heat or steaming treatments depending on the type of fibre and dye class. Pigments can also be used with a soft binder. The transfer printing temperature and the required pressure are variable from room temperature up to 200°C resp. from rotary iron pressure upwards depending on the composition of the film. The dye-containing film is also degradable under the influence of temperature so that no deterioration in handle occurs and afterwashing of the printed goods can be dispensed with.

Filter breakdown The filter is saturated and full and needs cleaning.

Filter cartridge Replaceable cartridge filter for the purification of solvent liquors in particular in small dry cleaning machines. Consisting of metal grains, filter paper, active carbon etc. → Filter auxiliaries.

Filter fibre finish Well proven media for filtering, air conditioning and ventilation technology or liquid filtration made of layers of fibrous material in the form of fabrics, nonwovens or needle felts. Synthetic fibres with relatively smooth surfaces are modified during manufacturing processes and aftertreatments, so that the total available filtering surface of the individual fibres is significantly enhanced. This generates better circulation and radial flows that have a favourable and beneficial effect on the degree of separation of the total system. The fibre surface gives significant flow improvements in the form of eddies near the surface of the fibre. This results in a marked increase in speed. The smooth surface of the synthetic fibre can also be modified by a special finishing process so that the total avail-able filtering surface of the individual fibres is greatly increased. Due to the high degree of distribution of high molecular products and their small size even the finest fibre hollows are then filled. The particle fineness and the extent of the internal surface are increased by 50 times compared to conventional filter media. The media surface is matched to the size of the largest particles of the absorbed product. The external energy required caused by the pressure difference at the filter media is enough to create turbulence in the direct vicinity of the fibres. A further effect of the micro particles is caused by the fact that the so-called detachment effect is achieved in fibre flows by turbulent effect of the boundary layer. Because the filter resistance is made up of a component that is dependent upon the pressure field and fibre compound and a component determined by the friction of gases at the fibre surface, and the pressure resistance usually far exceeds the frictional resistance, the overall filter resistance is not negatively influenced.

Filter for waste water treatment Waste water treatment plants are subject to the requirement of low suspended material and BSB_5 content, whereby the undissolved and suspended substances are generally the BSB_5 carriers and originate from biological or chemical cleaning. The biological and chemical flake residues can be removed from the waste water using various filtration processes. The main methods used in waste water treatment in practice are the microsieve and rapid sand filter.

In microsieving, the waste water is filtered through a very tightly woven steel fabric using the natural pressure difference. Mesh sizes of 23 µm or 35 µm are normally used, with larger particles being filtered out and retained on the grid. This causes a precoated filter layer made up of waste water particles to form during the filtration process. This intrinsic filter layer has significantly smaller pore holes, so that particles of particle size 5–10 µm and even smaller can be retained. Micro sieving is a continuous process, because the sieve fabric is stretched onto a rotating sieve drum. This is always $^2/_3$ immersed and waste water flows through it from inside to outside. The settled suspension layer is continuously washed down the apex line.

A rapid sand filter can be viewed as a pile of sand, for example, forming a filter bed. The suspended material from the waste water is trapped in the pore space of the grain pile as it flows through the filter bed. If the filter capacity has been exhausted, i.e. the filter bed is full, the settled suspended material must be removed. Thus the rapid sand filter is operated discontinuously, alternating between a filtration phase and a backwashing process. The backwashing takes place using water or in combination with air, which requires an intensive turbulence in the filter body to loosen and wash out the suspended material. Continuous operation is possible if several units are connected in parallel. For the filtration of suspensions with a broad particle size spectrum it is advantageous if the water flows through increasingly small pore cross sections, initially trapping the coarse particles, followed by increasingly fine particles. Such a filter medium permits an optimal space filtration over the entire depth of the filter bed. Within certain boundaries the possibility of nitrification exists due to the colonization of micro-organisms on the grain pile in rapid sand filters. This means that two treatment stages can be combined in one unit.

Filtration with microsieves and rapid sand filters is employed where strict discharge conditions regarding filterable substances or BSB_5 make this necessary. These methods are also employed as an intermediate stage before an active carbon unit, to avoid deposits of suspended material, which impair the adsorption process.

The elimination of dissolved, refractory organic substances is a further process step in waste water cleaning, which can be determined by the residual CSB in the waste water treatment plant. A procedure that is suitable for the elimination of these substances is the adsorption on active carbon. This can be used to eliminate organic substances from the waste water. Molecular weight and hydrophility are critical for the adsorption capability of the individual organic molecules. It is generally true that large molecules can be better bound by adsorption than small ones. Furthermore, it is also true that the more hydrophilic side chains a molecule possesses, e.g. $-OH$, $-COOH$, $-NH_2$ and $-SO_3H$, the less well it is adsorbed on active carbon. In the after-cleaning of mechanical-biological discharges primarily homopolar organic substances are eliminated, as are adsorbable organic halogen compounds (AOX); the easily soluble, low molecular organic substances must be broken down microbially beforehand. If the waste water to be cleaned is not cleaned biologically in advance, or is insufficiently biologically cleaned, the adsorption of biologically degradable substances on active carbon leads to microbial growth in the pore area of the carbon grains. The microbial colonization of the adsorption grains this causes must lead to a decrease in the available sorption area, thus limiting the filter potential.

Active carbon as an adsorbing agent is usually used in the form of granules in contact columns. The waste water is passed through filters filled with granular active carbon. As the water passes through the filter layer the organic substances are gradually adsorbed. The cleaning performance of an adsorption stage depends exclusively upon the contact time between active carbon and waste water. All other operating parameters are of lesser importance for the effectiveness of adsorption. A contact time or throughflow time of 20–30 min (in relation to the empty column) can be considered adequate. Adsorption is a process that follows an exponential function until equilibrium and thus must be allowed sufficient time. Active carbon can be charged with organic material of up to 80% of its own weight. If it is fully charged, regeneration must take place. The sorptive capacity can be restored chemically by extraction or physically by thermal processes. Thermal regeneration is generally used, freeing the sorption areas in the pore space at temperatures from 750–950°C. There are two alternative methods of operating contact columns:

1. Discontinuous operation, which requires the connection of several units in parallel to prevent interruptions to operation.

2. Continuous operation of contact columns, which requires that the carbon moves in the column by means of a sliding bed, and can thus be passed through the regeneration cycle and then recirculated.

Sludge is created by various waste water cleaning processes, the further treatment of which depends upon its character and composition. Waste water sludge has a water content of 90–98%. There are two main techniques available to separate out the water: Filtration and gravity separation.

Filtration separates solid and liquid phases using filter material. Common procedures are negative pressure (vacuum) and overpressure (pressing) filtration, sieving devices and sedimentation devices. Gravity separation is based upon the different densities of water and solids. The separating effect is dependent upon the difference in density. Common processes are thickening, flotation thickening, centrifuging (increased gravity field). The remaining solids after sludge dewatering must then be disposed of along with the remaining water (residual water content 30–70%, depending upon water binding ability of the sludge). Several possibilities can be considered for this:

1. In the case of suitable, toxin-free sludges, agricultural reuse or sludge composting.

2. Sludge burning or incineration.

3. Depositing on waste tips or special waste tips depending upon the sludge composition.

Filtering charcoal → Activated carbon.

Filtering powder → Filter auxiliaries.

Filter inserts for dye tubes Dyeing tube inserts made of special paper or filter material, which filter out impurities undissolved dyes etc. Elastic filter inserts help the inner yarn layers resist slipping if the package is mishandled. Application: For tubeless cross-wound yarn packages (muffs) made of continuously prebulked HB yarn, for the dyeing of HB yarn and hank yarns in cross wound package form, in hank dyeable yarns in cross-wound form, for the bulking and dyeing of bulked yarns in cross wound package form. In polyester union yarns the previously necessary autoclaving and rewinding is avoided but the filter tubes become disposable items.

Filters → Filtration plants.

Filter saturation describes the degree of saturation of an adsorption bed.

Filters for dry-cleaning plants →: Sewerage filter; Cartridge filter.

Filters for gas purification Textile filter media for separating out dust, primarily from air, use one or more of three main principles:

1. Dust removal by the adsorption of the smallest particles onto a high surface-area substrate.

2. Mechanical separation mainly of fibre-fly whereby the air passes the fabric but the fibres cannot.

3. Electrostatic forces are exploited by the systematic charging of filter material and/or dust, in order to separate components with opposing charges from each other. The filter material must be chemically treated so that the polarity, the charge intensity and the charge decay rate can be matched to the characteristics of the dust, if an agglomeration of the dust particles is to be achieved (Fig.).

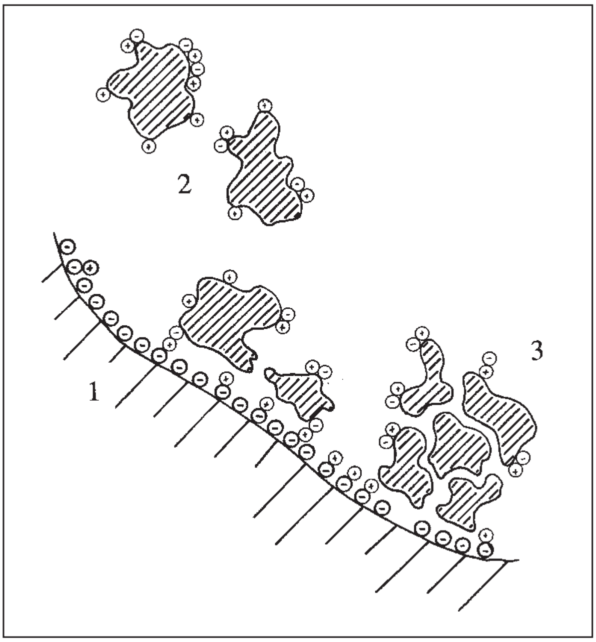


Fig.: Agglomeration by electrostatic in filters.
1 = fibre surface with predominantly negative charged sphere; 2 = predominantly positive charged dust particles; 3 = neutral agglomerated dust particles.

In electrostatically charged dust, which may have a dust resistance of up to 10^{22} Ω, the individual particles, which largely have the same polarity, tend to repel each other. If some of the charge is taken by the fibre surface, the particles can meet together and agglomerate more easily. They form large, and often more dense, dust aggregates than the original finely dispersed particles. This process of charge neutralisation always occurs between charged dust and a filter medium with the opposite charge. Positively charged dust can be made to agglomerate on the fibre by contact with negatively charged polyester fibres.

Filtration The separation of dispersed or dissolved particles by appropriate methods (Fig. 1).

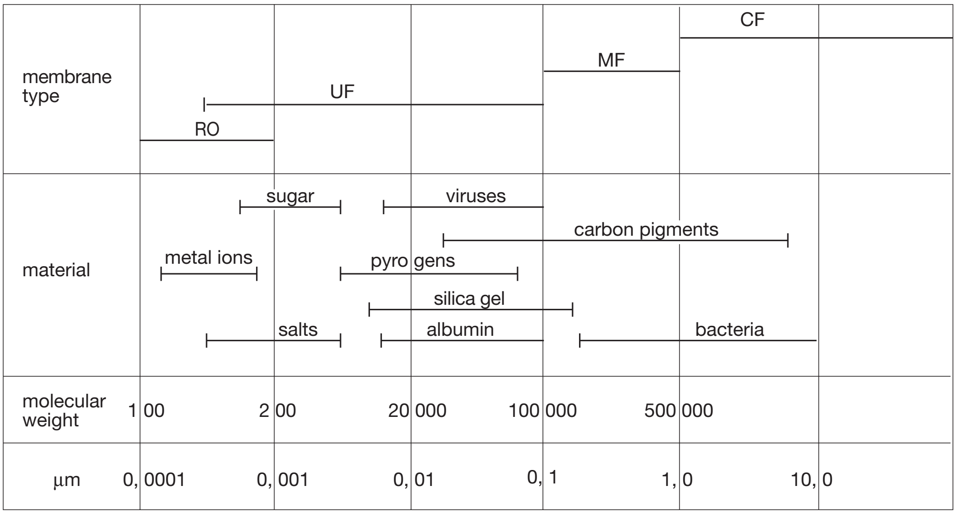


Fig. 1: Application range of different filtration methods.
RO = reverse osmosis; UF = ultrafiltration; MF = microfiltration; CF = conventional filtration.

Filtration auxiliaries (Clarification aids), are used in pressure filtration systems (effluent filters) to assist in the formation of a porous “filtration cake” that serves to remove solids. They also play a large role in dry cleaning. In addition, filtration aids are often used for other filtration processes such as the removal of oil from condensates, chromatographic and analytical tasks etc. In dry cleaning filtration aids must fulfil the following requirements: no adsorption of cleaning intensifiers, no chemical reaction with the solvent, high throughput at maximum clarification, no contamination due to sand etc. (mechanical damage to filters and pumps), no coagulation in the presence of water (applies particularly to kieselguhr).

I. Absorptive or inert filtration aids for the filtration of dye impurities. These should be chemically inactive and form a flushable coating, which resists compaction, be porous to solvents and impervious to particulates. These requirements are best fulfilled by → Kieselguhr, particularly with regard to the uniform pore size structure and plate-form. Metallic salts (aluminium, iron) and clay, sand and organic components must not be present. A wide variety of types of kieselguhr are available on the market. They can reduce in volume with increasing pressure and thus reduce the permeability of the filtration cake. Different types cannot simply be interchanged. High water and moisture volumes work most economically when a small amount of filtration aid is used.

II. In addition to I., adsorptive filtration aids (also called effluent filtration aids) serve primarily to bind molecular dissolved impurities, specifically fatty acids, body fats etc. and dissolved dyestuffs. This includes → Activated carbon, active earths, kieselguhr with alumina, magnesium silicate etc. Such filtration aids work selectively, they therefore do not trap all substances dissolved in the solvent in the same way. This depends upon the type of dissolved substances (e.g. tar, bitumen, resin, mineral oil are difficult to adsorb), and on the temperature and retention time.

Filtration aid dosing equipment is incorporated into the machine – pump – filtration – machine circuit so that the filtration aid need not be added with the filter mass, and to allow the correct amount of additive to enter the system at the correct time (dosing).

Filtration plants Many different types, depending upon application, e.g. mainly for liquids (→ Water filter) and solvents (→ Sewerage filter).

I. Cartridge, rod, pipe filter: Usually porous hollow cylinder (kieselguhr, carbon, quartz/bakelite, quartz/fireclay, earthenware etc.).

II. Air filter.

III. Membrane filter: For fine colloidal liquids and bacteria free water.

IV. Plate filter: Covered with a) cotton, asbestos, polyvinylchloride, PA 6/PA 6.6 etc.) or b) metallic cloth, metal wires.

V. Shock filters: Spring reinforced filter hose with precoating, removal of the filter cake by momentary shock filter cleaning, i.e. pressure over the whole filter element.

VI. Centripetal filter: The tangential entry and exit of liquid causes streamlines parallel to the eddy current, foreign bodies tend towards the central axis of the eddy, sieving filter inserts made of metal, porcelain etc.; also for higher pressures (up to 46 bar and above).

Final finishing

I. All finishing processes after dyeing or certain specific mechanical finishing processes for coloured woven fabrics (dry finishing): rubberizing and proofing, waterproofing, drying, shearing, pressing, decatizing, crease-proofing, calendering, embossing and suchlike.

II. Post-finishing of dry-cleaned garments → Dry finishing of fabrics.

III. By final finishing is meant all the → Chemical finishing treatments applied to a textile fabric after dyeing and/or printing which provide fitness for purpose resp. the desired wear characteristics, e.g. wash-and-wear finishes, easy-care finishes, etc.

Final inspection → Quality control.

Final inspection and make-up of finished goods Comprises fabric inspection, roll cutting, labelling, packaging, storage and despatch (Fig.).

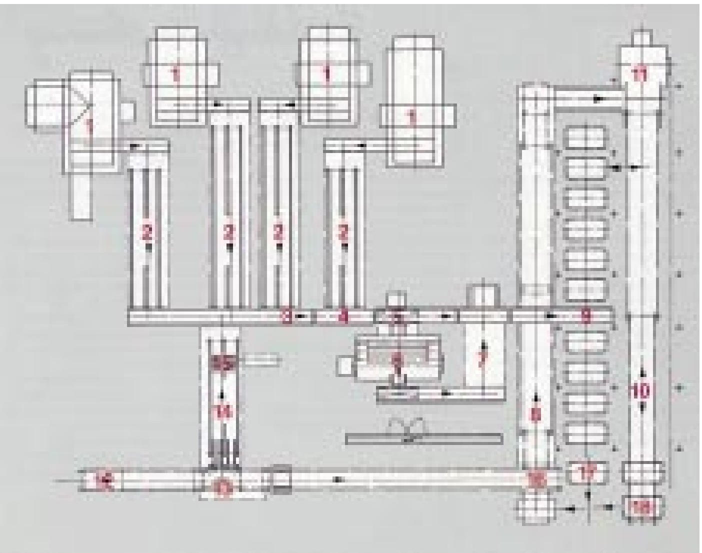


Fig.: Colsman and Kirschner automatic final inspection and make-up of finished goods plant in a cloth mill.
1 = rolling machine; 2 = intermediate storage; 3 = roll transfer; 4 = scales/labelling machine; 5 = automatic input roll feed; 6 = automatic packaging machine; 7 = roll return; 8 = intermediate empty pallet storage; 9 = palletting on 10 different pallets; 10 = lower level: pallet change, upper level: full pallet buffer; 11 = full pallet stacker; 12 = full pallet feed; 13 = pallet emptying; 14 = roll segregation; 15 = sorting by scanner; 16 = empty pallet feed; 17 = urgent pallet removal; 18 = store pallet removal.

Fine chemicals In contrast to → Heavy chemicals, these are chemicals produced in comparatively small quantities of relatively high purity. They are used as e.g. pharmaceutical and biological products, perfumes, photographic chemicals and laboratory reagents.

Fine dispersion → Dispersion, degree of.

Fineness of natural fibres This describes the “thickness” of textile fibres and is usually expressed in dtex as a rule (→ Linear density of fibres and yarns) or, in special cases, in µm (diameter) or, the micronaire value for cotton. The fineness of fibres is an important factor which has a direct influence on yarn properties with regard to strength, spinnability limits, yarn character and uniformity. The usual fineness ranges of the main natural fibres are:

Cotton	1,5– 5	dtex
Flax	10–40	dtex
Wool	2–15	dtex
Silk	1– 4	dtex

The fineness of man-made fibres is controlled by the spinning process.

Various methods are available to determine the fineness of natural fibres:

1. Gravimetric procedure: by determining the weight of spun fibre sections of known length.

2. Determination of the micronaire value: by measurement of the air flow rate for cotton.

3. Measurement of fibre diameter: microprojection of a number of individual fibres.

Fineness of synthetic fibres The man-made fibre industry has been successful in producing finer and finer fibres. In the filament yarn sector, fibres of 1,0–0,3 dtex have been produced by European fibre manufacturers, i.e. the so-called microfibres (see Fig). In the meantime, Japanese developments have been aimed at fibres with a fineness of <0,3 dtex. Such fibres are logically described as so-called super microfibres. In the staple fibre sector, fibre fineness of up to 2,4 dtex for polyester have been available for some time. In mixtures with wool, such fibres have optimum spinnability limits from approx. 12,5 tex (as yarn); the weight of fabrics produced from these mixtures is approx. 230–330 g per running metre depending on the type of weave used. The ever-increasing trend towards finer, softer, and therefore lighter fabrics in the outerwear sector is subject to limits in blend fabrics with regard to the fineness of polyester fibres in polyester/wool blends, since titres finer than 1,3 dtex have a negative influence on fibre distribution in the yarn cross-section. As a result, there is no more agreement between fabric aesthetics and serviceability.

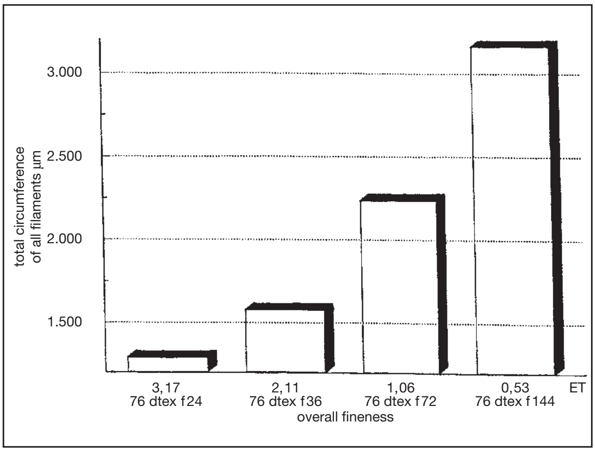


Fig.: Dependency of filament circumference on individual fineness with the same overall fineness (Hoechst).

In the meantime, polyester fine titre fibres with a fineness of 1,3 dtex have been processed with fine wool fibres of approx. 18 µm in order to obtain fabrics with particularly flowing drape and high strength properties and low wrinkle propensity typical of polyester/wool fabrics. In this case, fabric weights of approx. 170 g per running metre (plain-weave) up to 270 g per running metre (twill weave) are achieved with yarns of 9–14 tex fineness. With a decrease in individual titre, the total surface area of fibres with increases the same total titre. Fibre finenesses up to 1 dtex are recorded in the old DIN 60 800 which has now been withdrawn. Up to now it has not been possible to establish an exact definition for the finenesses given below. The following descriptions are used in practice:

Coarse fibres	>7,0	dtex
Fine fibres (Normal fibres)	7,0–2,4	dtex
Very fine fibres	2,4–1,0	dtex
Microfibres	1,0–0,3	dtex
Super Microfibres	<0,3	dtex

Fine ribbed woollen fabric (Drapé = a French term for woollen cloth). A generally high-quality finely-ribbed woollen material. It is woven either with worsted yarns in the warp and weft or with a worsted warp and a fine carded yarn weft in 7, 9, 11 or 13 shaft reinforced satin weave (corkscrew weave) and is given a fine, close-napped finish with the weave structure still largely visible, to achieve a matt shimmering lustre. The three classic business suits of former times were produced from fine-ribbed woollens, foulé and piqué. The two former qualities have, however, lost much of their former importance and are now only produced on a small scale, mainly for black business suitings.

Fine rib fabrics 1 x 1 rib fabrics are double face knit goods. The fabric has a similar appearance on both sides and single wales of face loops alternate with single wales of back loops. Rib fabrics are very elastic widthwise and are therefore used for cuffs, collars and trimmings as well as underwear.

Fine soda (soda, calcined; soda ash), anhydrous → Sodium carbonate available commercially as small or fine crystals.

Fine structure of fibres (Fibre fine structure). The molecular textile technology (according to H. Zahn) seeks to explain the mechanical properties of fibres by the spatial structure (conformation) of the chain molecules of the fibre polymers on which they are based. The fine structure of a fibre denotes the composition of the smallest components such as the chemical constituents (polymer chains), their bonding into crystalline and non-crystalline (amorphous) regions and fibrils. The colloidal structure when spinning a synthetic fibre or during the biosynthesis of a natural fibre affects the fine structure of the fibre and its morphology, i.e. the whole structure is composed of its smallest components.

Synthetic fibres that are manufactured from thermoplastic polymers are forced through spinnerets into the spinning chamber where they are met by a blast of cold air. The rapid cooling in the spinning line does not cause the fibres to crystallise, as the rigid molecules need more time to arrange themselves spatially. The fibres are given textile characteristics and final molecular structure by stretching and thermal treatment. The macromolecules and crystalline structures undergo complex orientation and arrangement processes and transformation of the lamellar structure into a fibrous-fibrillar structure. Filament yarns spun at a moderate speed (1800–3000 m/min) and at high speed (3000–4000 m/min) (POY filament yarns) are stretched as they leave the spinning nozzles due to the high drawing-off speeds and the prevailing conditions in the spinning nozzles. This is the basis of the fibre structure; there is a high degree of crystallization. The resultant crystalline forms are more stable, as the extension and orientation of the macromolecules occurs at the same time as spinning. Filament yarns pre-oriented in this way are initially used in draw texturing; once they have been further stretched they can be used like all other filament yarns. Yarns spun at high speeds, called stretch-spun yarns (4000–6000 m/min and more), effectively obtain a higher degree of ordering and orientation during the spinning process, so that the structural, physical and chemical properties are comparable to those of the classic yarns which are spun and then stretched, with the difference, however, that they have greater regularity. The dyeing properties of the partially crystallized polymers are dependent on their structure, i.e. from the amount of the crystalline and amorphous fractions, their arrangement and the movability of the macromolecules (Fig. 1).

If an attempt is made to describe synthetic fibres by means of a two-phase model, it must ideally be assumed that the material consists of an amorphous and a crystalline phase, whereby the physical properties of each phase can be assumed independent of the presence and quantity of the other phase. An analysis of the central quadratic fluctuations in density shows, however, that, for example, the polyethylene terephthalate structure in polyester cannot be described with precision by means of a two-phase model. Research has led, through the assumption of a transitional area of finite width between the amorphous and crystalline areas, to a three-phase model of crystalline, non-isotropic and non-crystalline areas. In principle the non-crystalline areas are built up of the following types of chains (Fig. 2): chains which bind the crystallite (t_1; t_2), those with a free end (f) and loops (s_{1-4}), the border zones containing sharper folds. The border areas of the crystallite are arranged in parallel to one another.

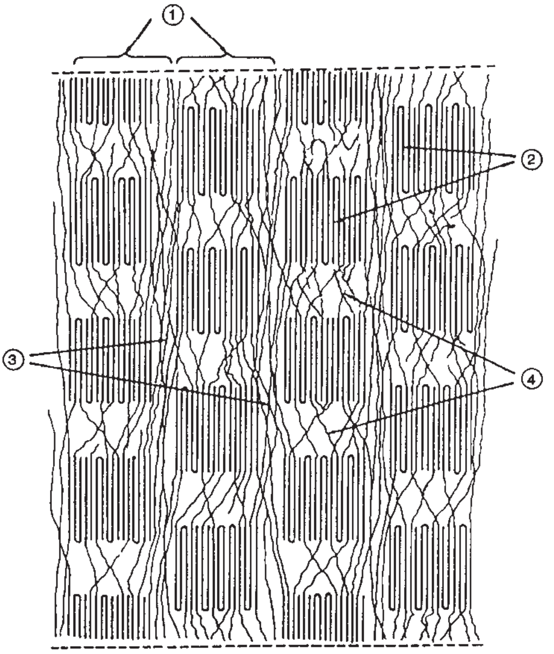


Fig. 1: Fine structure model for synthetic fibres (source: Prevorsec).
1 = microfibrils; 2 = crystallite; 3 = stretched amorphic molecules (anisotropic); 4 = random areas (isotropic).

The fine structure of natural fibres essentially shows more the character of the hierarchy of the structural components (→ Hierarchical fibre structure), which can be reproduced in biosynthesis by the sequence of the basic components (the amino acid sequence in the case of wool), or the growth conditions (for cotton, the vari-

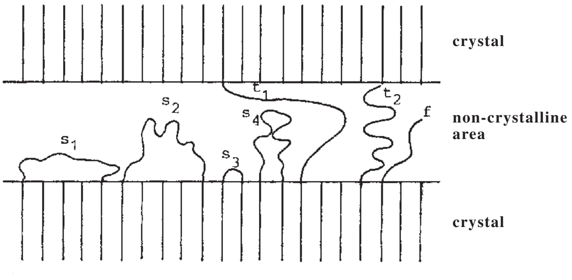


Fig. 2: Diagram of the different chain types of the non-crystalline area in the fine structure of fibres.

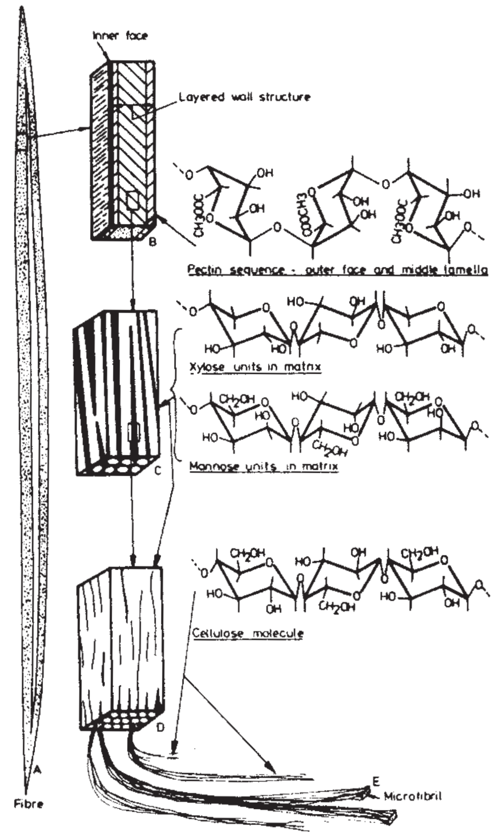


Fig. 3: Fine structure: Cell wall structure of a wood fibre cell. A: the fibre has a layer structure. The main composition of polysaccharides in the different layers is shown in the sections B, C, D (Rees 1977).

ation in cellulose content of the primary and secondary walls and in the growth rings) (Fig. 3).

Fine turbidity meter (Based upon scattered light measurement), for liquids → Photometer. It is used to monitor ground water sources and for treatment process in water works (fine turbidity measuring). Principle: A scattered light is generated by a lamp and passes the in- and out lenses of a measuring cell. The reduction in light returning to the measuring cell represents the turbidity of the water. This is varied in some photometers by a) the choice of cell dimensions, b) black glass located at the exit point of the beam of light, and c) by a double image of the scattered light bundle and a system of screens to keep the stray light away from the measurement cell.

Finger test Used to evaluate dye penetration in transfer-printed textile floorcoverings. The complete back-coated and printed carpet sample is wrapped around the little finger: if no white fibres are visible, penetration is considered to be satisfactory, even for carpet laying on staircases which is one of the most critical carpet applications.

Finish Final treatment, →: Proofing, Dressing; (more generally, also) Improving, Processing; (often also) Ironing, Pressing, etc. (cleaned or dyed clothing). Finisher: proofer, dresser.

Finish decatizing, wet steam decatizing → Decatizing.

Finished goods → Textile finished goods.

Finishing Besides washing, this includes desizing, steaming, setting, and the production of various effects such as calendering, raising, etc., as well as treatments to improve serviceability properties such as water-repellent, shrink-resistant, wrinkle-resistant and soil-release finishes, etc. Finishing is understood to involve all those processes which cannot be classified under dyeing and printing. Bleaching, dyeing and printing are concerned with the production of colour, whilst finishing provides additional characteristics beyond coloration. In the case of textile fabrics, these characteristics are imparted both before coloration (pretreatment) as well as in final finishing after coloration. The major part of finishing takes place at the interface between the textile and garment industries and it is therefore important for the finisher to have a very wide knowledge of the influences of all processing stages. A rapid technological change is taking place both in the textile as well as the garment industry accompanied by increasing specialization. The traditional separation of both branches of industry is becoming less distinct as a result of their closer interdependence.

A distinction is made between wet and dry finishing. Where wet finishing is concerned with the preparation of textiles for subsequent coloration, it is referred to as pretreatment. When bleached, dyed or printed fabrics are treated with chemicals for the achievement of wrinkle-resistant, permanent-press or easy-care properties, in addition to dry finishing processes, this form of finishing is referred to as resin finishing. The development of characteristics in finishing processes may be subdivided into:

- Cleaning processes (including relaxation and the development of bulk),
- Setting, to achieve stabilization of the desired dimensions,
- Surface finishing to achieve certain physical and optical properties such as handle and lustre,
- Resin finishing for the achievement of serviceability and easy-care characteristics in proportion to the basic fibre properties.

Yarns: Sewing threads are lubricated, e.g. by impregnation with waxes, paraffins or silicone auxiliaries to reduce friction during sewing. A finish is applied to synthetic fibres after spinning to prevent the development of electrostatic charges during subsequent processes. This type of yarn finish can be regarded as being at the boundary between spinning and finishing as the process forms part of the actual spinning process and is carried out immediately after the fibres are spun. The treatment of cotton yarns with liquid ammonia in yarn mercerizing is a finishing process aimed at the achievement of specific yarn properties (lustre, bulk, handle, improved dyeability). The raising of yarns to achieve the typical hairiness for certain hand knitting yarns also represents a treatment carried out independently of yarn production which is included under finishing.

Fabrics: The main attention in finishing is devoted to the treatment of fabrics where processes which cause chemical changes to the fibres are mainly used. Other finishing processes also involve mechanical treatments for the achievement of specific effects. Particularly smooth napless fabrics can be produced by singeing or shearing.These treatments are considered as mechanical processes, although chemical processes are also involved (burning process, cutting of fibres on shearing machines with depolymerization of affected polymers. Opposite effects, e.g. for the production of voluminous, soft, rough or uneven surfaces are achieved by emerizing or raising (which are likewise mechanical processes). Also in the case of fabric finishing there are areas which border on other fields. If, e.g. loomstate fabrics are inspected for faults in the mending department of a weaving plant, or floats are removed on corduroy cutting machines in weaving plants, these processes are, in efect, preparatory treatments for finishing. The cut loomstate corduroy fabric is only converted into a real corduroy fabric by the finisher after numerous passages on brushing machines, etc. The anti-felting finishes given to made-up pullovers in paddle machines by the knitgoods manufacturer may likewise be considered as finishing processes.

Finally, in the widest sense, each drycleaning treatment can be regarded as a finishing operation since typical cleaning processes are involved. Moreover, when garment pieces are “re-proofed” with a water-repellent finish after the drycleaning process, this is carried out according to the same principles as any water-repellent treatment applied in fabric finishing.

Finishing agents These are products which give textile materials the desired end-effect, e.g. in the form of more or less fullness, stiffness or even weighting, etc. Such finishes are mainly produced with vegetable or animal glues, starches, starch derivatives, water-soluble plastics and plastic dispersions, cellulose derivatives and preparations, if necessary with the co-application of pigments.

Finishing and decatizing machines → Decatizing.

Finishing mangles In general, the requirements for uniform liquor pick-up on finishing mangles (see Fig.) are not as high as those placed on dye padders.

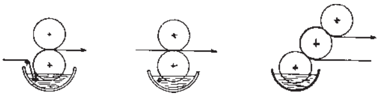


Fig.: Finish padder types: immersion path in a trough (left), slop padder (centre), inclined padder.

Finishing of hat felts

I. Shellac finish (Stork-Morawsky reaction): heat approx. 0.5 g finely shredded hat felt with 10 ml acetic anhydride for 3 min, cool and filter. Transfer the filtrate to a porcelain dish and allow 1 drop conc. sulphuric acid to flow down the inside wall of the dish. When the sulphuric acid mixes with the filtrate, a cherry red colour develops. This test is only suitable for natural resins containing abietic acid (e.g. colophony, beeswax, etc.).

II. Polyvinyl acetate finishes: boil approx. 0.5 g finely shredded hat felt in acetone for 15 min (reflux condenser), cool, filter, and allow the filtrate to dry. Polyvinyl acetate forms a film with the following characteristic reactions:

- iodine test with potassium iodide solution gives a violet-brown colour.
- saponify the dried film to polyvinyl alcohol (resinous mass) by boiling with 1 g caustic alkali in 10 ml methanol. Dissolve the polyvinyl alcohol in distilled water and add 1 ml hydrochloric acid and a pinch of sodium tetraborate. Depending on the quantity present, polyvinyl alcohol gives a blue-green colour, turbidity or precipitation.

III. Water-repellent impregnations with aluminium salts (test for aluminium): extract approx. 0.5 g of finely shredded hat felt with 50 ml 5% sulphuric acid for 10 min at the boil. Neutralize the filtrate with sodium acetate and add a few drops of morin: a yellow-green fluorescence confirms the presence of aluminium.

Finishing of textiles → Textile finishing.

Finishing soaps These products confer soft handle characteristics on textile fabrics and generally increase the wetting and penetrating properties of sizes and finishes. Suitable sizing compositions containing these products are more easily desized. Certain impregnating agents used for water-repellent finishes are also based on finishing soaps.

Finishing wash A treatment carried out after the production of textile fabrics in order to remove substances present in, or applied to, the fibre during previous stages of processing and thereby achieve a further improvement in the properties of the material (e.g. scouring of wool fabrics). In the discontinuous finishing wash, the material remains in a machine and wash/rinse liquors are introduced and exchanged as required by the process. The greatest disadvantage here is the fact that specific tasks are not performed in the individual process stages. In the continuous finishing wash, the fabric passes through several separate machines and sections in which the state of the wash/rinse liquors is more or less constantly maintained. A disadvantage in this case is the relatively low speed of the goods which means that their kinetic energy cannot be utilized to improve the washing effect and further contribute to the improvement of quality. For the continuous finishing wash in particular, the use of wash-active detergents must be suitably adapted to the processing conditions or optimized for the complex system represented by soiled fabric/machine/process.

Finish stains Such stains are usually stiffer than the surrounding material and are mainly round, oval, of matt appearance with a distinct dark ring. They may be removed by: a) a suitable detergent (with glycerol and, if necessary, ammonia); b) 1% ammonia solution. Care is necessary in the case of poor colour fastness. Ring removal: water/acetone. If necessary, matt areas (on wool) can be removed by covering with a piece of damp cloth after drying followed by hot ironing.

Fique fibre (Cabuya) → Mauritius hemp.

Fire A process of → Combustion, accompanied by the development of heat, smoke or flames.

Fire alarms Various types are available to comply with specific standards and regulations, e.g. differential alarms, push-button alarms, electronic alarms, smoke alarms, molten-metal alarms, scattered light detectors, early-warning fire alarms, etc.

Fire behaviour The behaviour of a textile fire is increasingly simulated by burning complete textile arrangements (e.g. net curtains in a living environment) (pilot plant test) rather than by tests alone. The illustration shows the interrelationship of this type of fire behaviour from the outbreak of fire via flash-over to the fully developed fire with temperature.

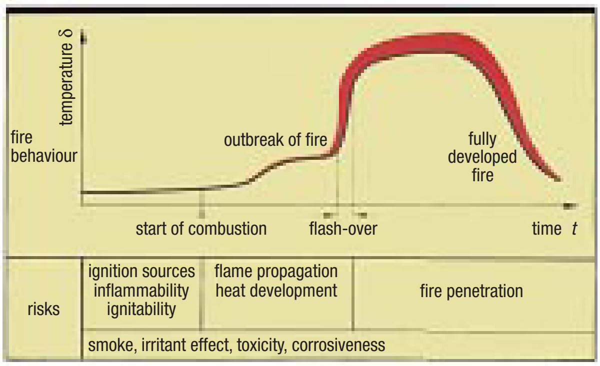


Fig.: Fire behaviour relative to substrate temperature.

Fire extinguisher, dry ice type A fire extinguisher consisting of a pressure cylinder (containing 5–6 kg of compressed liquid carbon dioxide) and a so-called snow-tube in which (during operation) approx. 70% of the carbon dioxide rapidly turns to gas (production of latent heat causing evaporative cooling) and the remainder is cooled to – 80°C in the form of solid dry ice. Fire is immediately extinguished by the dry ice (cooling down effect and dilution of oxygen). The dry ice evaporates without residue thereby causing no damage. This type of fire extinguisher can, therefore, be successfully used for gasoline, oil, paint, factory and motor fires, etc. (Dry ice fire extinguishers must not be kept in rooms at temperatures above 35°C).

Fire extinguishers Include a) ammonia extinguishers, b) halon fire extinguishers, c) dry ice, d) wet fire extinguishers, e) foam extinguishers, f) sprinkler systems and g) powder-type fire extinguishers. Each type of fire extinguisher is only suitable for a specific kind of fire. For this reason, combustible materials are classified under so-called fire hazard classes (DIN EN 2):

A. Combustible solids (capable of supporting flames/incandescence), e.g. wood, paper, textiles, coal.
B. Combustible liquids (flame-forming), e.g. gasoline, oils, fats, varnishes, ether, alcohol.
C. Combustible gases (flame-forming), e.g. propane, hydrogen, town gas, natural gas.
D. Combustible metals, e.g. aluminium, magnesium and their alloys, sodium, potassium.
E. Fires in electrical equipment.

On this basis, powder-type fire extinguishers are used for fires in classes ABC, BC, BCE and ABCDE. In addition, portable fire extinguishers of the dry ice and carbon dioxide mist type are used for category B, carbon dioxide gas extinguishers for category C, halon extinguishers for categories BC and water extinguishers for category A. In addition to the extinguishants mentioned above fire extinguishers also contain propellants for sustained depression extinguishers (air or gas under pressure), gas propellant extinguishers (pressurized gas in propellant containers) and pressurized gas extinguishers (gas produced by chemical action for immediate use). Each type of fire extinguisher is clearly labelled with the permitted applications for which it is suitable.

Fire extinguishers, carbon dioxide type System: distributor and gas supply tube with spray nozzles fitted on the ceiling of the space or room being protected. These are fed from carbon dioxide cylinders stored in another location. In the event of fire risk, metal plugs on the gas supply tubes melt due to the developing heat (at 72°C). The gas supply from the cylinders is then released and carbon dioxide gas flows through the nozzles into the fire zone causing rapid smothering of the fire. Applications: for all departments where a fire risk exists, especially for drycleaning plants which use flammable solvents, e.g. white spirit. Also used as an automatic fire extinguishing system in stenters.

Fire extinguishers for drycleaning plants Water is totally unsuitable for drycleaning plants which employ flammable solvents such as white spirit. In practice, the following types have proved to be the most suitable: ammonia extinguishers, carbon dioxide extinguishers, dry ice extinguishers, foam extinguishers and powder-type extinguishers.

Fire extinguishing powders Used as extinguishants in → Fire extinguishers. Designation according to fire classification:

1. Flame-propagating fires (e.g. for fire classifications BC, BCE): sodium bicarbonate basis. The extin-

guishant action is due to a fire-inhibiting effect (prevention of further combustion processes).

2. Incandescent fires (e.g. for fire classifications ABC and ABCDE): ammonium phosphate, ammonium sulphate, aggregates. The extinguishant action is due to an inhibiting effect in the case of BC and a barrier layer effect in the case of AD.

3. Metal fires (for fire classification D): based on inorganic chlorides and silicates. The extinguishant effect is due to the formation of a molten salt barrier layer on the burning metal.

Fire hazard classification → Fire extinguishers.

Fire load The totality of all combustible materials in the area surrounding the source of a fire which is of decisive importance for the progress of any outbreak of fire. The fact that a very hot updraught of air from an open fire requires an incoming flow of cold air close to floor level has been confirmed by large scale fire tests. This cold air flow is favourable against the spread of fire on floors by counteracting its propagation through floorcoverings to some extent. As a result, textile floorcoverings, for example, generally represent only a small proportion of any fire load. This quantitative ratio between floorcoverings and other fire load components justifies the claim that the former can be disregarded as far as their contribution to the formation of → Combustion gases is concerned.

Fireproof This term relates to the property of remaining unchanged through the action of fire, e.g. as in the case of asbestos. All other textile fibres can be given a → Flame-retardant finish but these are not normally fireproof. Developments in the spinning technology of carbon fibres have resulted in the production of fibres with heat resistance up to 2500°C which therefore qualify as fireproof fibres. Fireproof properties begin at 1500°C; the most common oven temperatures are between 1500–2000°C.

Fire protection The installation of a reliable in-house fire protection system is to be recommended. Localized installations based on connections to water hydrants in the form of portable fire hose reels may be considered here. Although such systems can be installed at relatively low cost, they are not always sufficient. Hand fire extinguishers (→ Fire extinguishers) are particularly effective, as well as halon extinguishers. All installations for fire protection can be made readily identifiable with red paint. For large industrial plants either one or several centralized fire alarm systems are recommended.

Fire protection equipment (→: Fire extinguishers; Fire alarms). Fire protection equipment is particularly important in the textile industry in order to keep the outbreak of fire under control. Electronic smoke, heat, spark and flame alarms are recommended because of the special importance of early warning. It is also most important for all the factors which can influence the outbreak of fire to be thoroughly analyzed by fire protection experts. The integration of fire protection into the entire safety organization of a plant ensures an optimum level of safety in medium to large textile plants.

Fire protection in textiles Organic substances, including the majority of textiles in common use (with the exception of asbestos and glass fibres), are combustible under certain conditions even if they do not appear to be combustible under the usual test conditions. This means that expressions such as "incombustible" and "non-combustible" are to be avoided at all costs for organic substances. Textiles produced from aramid fibres or polyvinyl chloride (PVC) are indeed non-combustible at normal temperatures (and consequently also in the usual small flammability tests) but suddenly become combustible, on the other hand, at higher temperatures, e.g. from 150–200°C. Fabrics declared to be "flame retardant" can likewise become flammable if they have been soiled or roughened during use or as a result of laundering and dry cleaning. In this connection, it should be emphasized that washing instructions attached to "flame retardant" textiles must be strictly observed. Any deposits formed on the fabric during laundering, e.g. lime soaps, can have an adverse effect on its burning properties even if the flame retardant chemicals are still present. In these cases, the original flame retardant properties may be restored again by appropriate washing. Every fire represents the external manifestation of complex chemical and physical processes which can vary greatly from one fire situation to another. It is, therefore, not possible to include all the criteria relating to a particular fire in a single laboratory test method. Consequently, the test principles underlying attempts to reconstruct a particular fire situation in the laboratory are also correspondingly varied. For this reason, different test methods are often resorted to in order to provide reliable information on the burning behaviour of a specific material.

- Textiles made from natural fibres and common blends of natural and synthetic fibres which lie within the range of normal flammability include those produced from cotton, acrylic, acetate, viscose, polyester/cotton, polyester/viscose, and polyamide/cotton.
- Textile raw materials which are less flammable include blends such as polyester/wool (55/45), polyamide/wool, polyester or polyamide alone, as well as modacrylic fibres, flame-retardant viscose, flame-retardant acetate and wool.
- Textiles produced from man-made fibres, which burn less readily on their own than the substrates mentioned above but which nevertheless must be described as combustible, include the aromatic polyamides, specific modacrylics, polyvinyl chloride, specific polyester fibres and the polyamide imides.

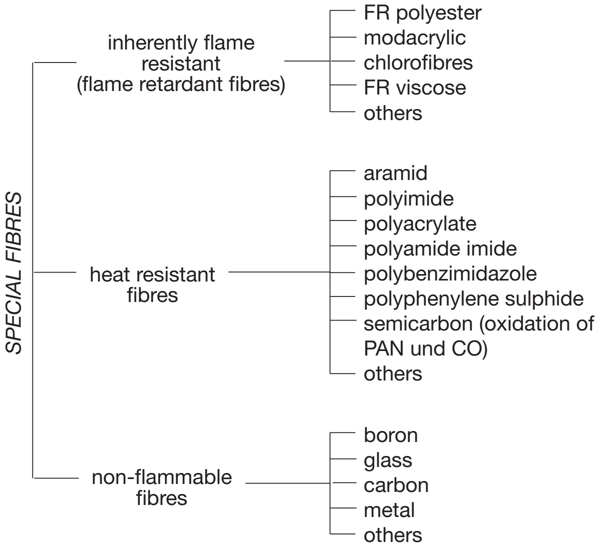


Fig.: Man-made fibres and textiles for fire protection. FR = flame resistant.

- Textiles produced from man-made and other fibres which are practically non-flammable on their own and are capable of withstanding temperatures up to approx. 1000°C, can be produced from boron carbide, carbon, glass or metals (see Fig.).

Workwear capable of protecting the wearer against exposure to high risks of fire but which has to be worn throughout the day is not only expected to offer protection from flames but must also be comfortable to wear, have a normal wear life, and allow cleaning by methods in common use. In addition, intelligently conceived products are needed which are capable of fulfilling the required properties as far as possible throughout their entire working life with the same level of protection. Quality assurance is extremely important here especially since the safety of human lives is at stake. Textiles designated as flame retardant or flame resistant must therefore exhibit these properties even if the wearer is not particularly at risk. Appropriate test methods and classification procedures are required for control purposes.

Since the supply of oxygen is greater in the case of lightweight fabrics with an open structure (e.g. curtains) compared to heavy, tightly-woven materials (e.g. textile floorcoverings and wall hangings), the former burn more rapidly and more intensely than the latter and therefore represent a greater fire hazard. The spatial arrangement of the material represents another criterion here. Textiles which hang vertically (curtaining or drapes) are more hazardous than those which lie on the floor (e.g. textile floor coverings) since the spread of flames takes place primarily in a vertically upwards direction. Decomposition products formed during pyrolysis represent another important criterion here. They are dependent on the chemical composition of the fibre and applied finishing agents. If all the decomposition products are combustible, flammability is obviously greater than in cases where non-combustible gases are released. The latter displace oxygen and inhibit or prevent the combustion process. In principle, all organic natural and man-made fibres are combustible. However, the amount of energy released per unit time and the combustibility of decomposition products varies greatly from one type of fibre to another. The decomposition products can be influenced above all by additives to the fibre polymer or by the application of appropriate finishing agents. Whilst man-made fibres are generally made flame retardant by introducing additives into the fibre polymer, finishing agents have been developed for natural fibres (cotton, wool) which are applied to dyed or printed fabrics. When these materials are burned, non-combustible gases are liberated from the additives and the atmospheric oxygen surrounding the textile is displaced. A large number of finishing agents capable of making textiles flame retardant are now available. In order to select a suitable finish for a particular application it is important to consider both the durability of the finish (especially to laundering) and the quantity which must be applied to the textile in order to achieve an optimum effect. The problem of skin compatibility with such finishes must be checked separately. Requirements for the flame retardant properties of textiles are dependent on their fields of application (clothing, home textiles, technical textiles). Before a specific range of requirements is laid down, however, it must first be ascertained whether an appropriate technology exists which can be expected to produce a fabric with the properties required by the market. These technologies also need to be checked for their environmental compatibility and other possibly harmful consequences. It is pointless to stipulate requirements for materials that can only be produced by methods according to the present state-of-the-art which alone are not above reproach with regard to questions of environmental compatibility or other harmful consequences. A typical example of an undoubtedly hastily introduced government regulation was the Flammability Regulation for Children’s Nightwear at the beginning of the 1970’s in the USA which ended in the notorious TRIS debacle: tris(dibromopropyl) phosphate, a flame retardant which was primarily used as a finish for children’s nightwear made of polyester so that these garments could satisfy the test requirements demanded by the fire protection legislation at that time, turned out to be a suspected mutagen and carcinogen some years after its use in the trade and therefore had to be withdrawn from the market overnight.

Fire-resistant cover → Pressing.

Fire-resistant fibres Fibres based on inorganic materials (mineral fibres) take first place here, e.g. glass, ceramic or asbestos. → High temperature fibres.

First strike A term used for the concentration gradient at the beginning of a pad dyeing, e.g. with direct dyes on cotton.

Fischer-Tropsch waxes Synthetic → Wax obtained as the products of coke hydrogenation (Fischer-Tropsch process). These include the kogasin waxes (boiling limits 160–320°C) and soft wax at 320–450°C which are used as the basis for fatty acid synthesis and degradation products such as fatty alcohols, esters, etc. and hard wax or hard paraffin at 450°C. Further processing results in oxidized and partly-saponified waxes which are dispersible or emulsifiable in water with emulsifiers. Fischer-Tropsch waxes have a comparatively low molecular weight (approx. 600–700). Because of their narrow molecular weight distribution, they are nevertheless relatively hard and high melting. Compared to polyethylene waxes, they are characterized particularly by their lubricity.

"Fished" wool Short-fibre wool which has been "fished out" of the wool washing plant. It is usually returned for process in the woollen yarn spinning system.

Fish glue → Glue.

Fish test Procedure for monitoring the contamination of bodies of water. The average lifespan of certain species of fish under such conditions is used as a measure of the contamination of the water. Specially bred fish are released at given intervals of time into a section of water (or tributary) which is isolated by wire netting. The occurrence of dead fish is counted, and from the mean lifespan the degree of contamination is derived. →: Lethal limit; Toxicology.

Fish toxicity → Fish toxicity of textile waste water.

Fish toxicity of cationic surfactants The acute toxicity of cationic surfactants lies within the range 1,5–4 mg/l or lower in the case of cationic surfactants with specific disinfectant properties. At concentrations between 5 and 30 ppb found in water courses, no harmful effects on fish and other aquatic organisms are to be expected. (→ Fish toxicity of waste waters; Fish test).

Fish toxicity of textile waste water Increased attention must now be paid to the waste water problems of dyehouses and textile finishing plants situated near water courses. From tests, e.g. the following effects have been found (various sources): Up to 5 mg/l chlorine at 12°C led to fish lying on their sides after 76 min and death after 6 h (tench); the toxicity threshold of 0,3–0,4 mg/l for many kinds of fish to this pollutant is, however, considerably lower. Quicklime (waste water treatment process): amounts of quicklime up to 70°C at 16°C caused death after 26 min (trout): the critical upper pH levels are 9,2 for trout, 9,2 for perch, 10,7 for pike, and 10,8 for carp. Amounts of chrome alum up to 200 mg/l at 9°C had no harmful effects after 75 min (trout). Soap in amounts up to 1000 mg/l at 14°C caused fish to lie on their sides after 2 hours (trout), but they recovered again after 67 min in pure water. The → Lethal limit of anionic surfactants for fish is 5–10 mg/l. Cationic compounds are, in some cases, even more toxic (1–5 mg/l). As far as fish toxicity is concerned, additional synergistic effects of various components also need to be considered, as well as the chemistry of the receiving water course (e.g. water hardness) which can greatly alter the toxicity of individual substances. For receiving water courses with a low flow rate, the high → BOD of textile waste waters (e.g. due to carbohydrates) can also be hazardous to fish if oxygen depletion occurs. The frequency distribution of different kinds of fish in water courses is dependent on the degree of eutrophication.

Fishy odour (amine odour). A defect in finished textiles which manifests itself as the development of an unpleasant odour in fabrics with urea or melamine-formaldehyde crease-resist finishes due mainly to trimethylamine $N(CH_3)_3$. It is prevented by a thorough alkaline afterwash with sodium carbonate, and in the USA also by means of an ozone treatment. A preliminary examination of resin-finished fabrics can be carried out by odour analysis (fabric specimen 2 x 4 cm in size + hot 5% sodium carbonate solution in a test tube. The tube is immediately closed and tested for the development of odour after 5 min: a fishy odour indicates with certainty that problems can be expected during storage, a negative test is an indication that the finished goods can be stored without risk). A more reliable test is to boil a 3 g fabric specimen in water and distil over an iodine potassium iodide solution when quantities as low as 0,5 mg trimethylamine are still detectable. Findings: a brownish-black to black precipitate indicates large quantities of trimethylamine which will definitely result in claims for defective goods. Brownish-black stains or rings at the bottom of the sample are an indication of borderline goods. Where neither precipitation nor cloudiness, stains or rings at the bottom of the sample are present, experience up to now indicates that subsequent development of fishy odour is not to be expected. Tests based on gas chromatography can also be included in the series of tests.

Fitted carpets Carpets as floor coverings, in roll form, for wall-to-wall fitting. → Contract carpet.

Fittings Mountings or fittings for the installation of pipework (bushings, flanges, T-pieces, junctions, etc.).

Fittings for high-pressure steam boilers (→ Fittings), these include, e.g. steam traps; steam trap regulators; pumps; gilled pipes; pipework; dampers; safety systems; valves.

Fixanal, exactly weighed amounts of pure chemicals in ampoules for preparing normal solutions. The contents of the ampoule are dissolved in 1 l of distilled water (volumetric flask) to give a solution of the stated normality. An accuracy of ±2% is guaranteed. Handling is very straightforward.

Fixation (→ Heat setting). In the course of the manufacturing process for a textile, from the yarn to the finished fabric, heat treatment may be necessary at various stages. When the process is used to facilitate the next process it is called intermediate fixation; if it is a final operation for establishing the characteristics of the finished article, it can be called final set or final fixation.

Intermediate fixation operations mainly serve the following purposes:

1. Preshrinking of yarn (amongst other things) for removing the potential for shrinkage from subsequent piece goods processing and to reduce the shrinkage in a subsequent yarn dyeing process.
2. Equalisation of tension differences from the spinning process.
3. Stabilisation of a yarn twist, for better subsequent processing capability.
4. Fixation of dyes.
5. Development and fixation of yarn crimp or fibre crimp, which in respect of the crimp is a final setting, but which in respect of the piece goods is an intermediate fixation.

Final fixation is above all for the purpose of:

- shaping,
- stabilising a fabric against subsequent stress in wear and laundering,
- establishing the desired material appearance,
- reducing creasing,
- Influencing the handle of the goods.

First and foremost, fixation is a temperature treatment. Air, water or steams are used to transfer the thermal energy. The choice of fixation medium depends on the purpose and the fibre type, amongst other things. The following essential differences between hot air and (water) vapour should be noted:

- Steam has a greater capacity for heat transfer than air;
- Water (including steam) acts as a swelling agent and thus supports the temperature effect, particularly in the case of polyamide;
- Steam has the ability to act as a protective medium and prevents oxidation.
- At high temperatures, steam can lead to hydrolysis (e.g. polyester);
- Steam and water can promote the separation of monomers and oligomers.

The macro-molecular synthetic fibres have a mixed amorphous-crystalline structure. The macromolecules, which are oriented in the fibre axis, are bound in the amorphous areas by means of hydrogen bonds. If a yarn (fibre) is mechanically deformed during subsequent processing (through elongation, flexing, twisting), amongst other things, the distance between the bonding points becomes greater, and stresses develop. These have the effect of making the yarn tend to return to its original form, when the processing tensions are removed. In the fixation process, these structures are affected according to the temperature of exposure, the duration of treatment, and the yarn tension. The crystalline state is altered, the cross-linkages are broken. During steam setting, the latter is supported by the addition of water molecules at the junctures (swelling). During the cooling process, and depending on the speed of cooling, a mixture of amorphous and crystalline zones forms once again. Here, the cross-linkages adopt the new mechanical form of the yarn, and fixation takes place. Through renewed temperature treatment, the process outlined above can be repeated. Here, the state after the first fixation is overcome only by applying a higher temperature. If the permitted conditions are exceeded during fixation, additional degradative reactions occur, which lead to irreversible changes (damage). Various physical and chemical characteristics of the yarn are heavily dependent on this inner structure (source: Kaufmann and Häussler).

Fixation accelerator A fixation accelerator increases the diffusion of a disperse dye in a print thickener to such an extent that it is no longer a rate-determining step in the rate of reaction during the fixation of prints on polyester.A fixation accelerator thus speeds up, or lowers the temperature required for reaction. Moreover, the fibre structure is changed by a fixation accelerator in such a way that diffusion of dye into the substrate is improved without the accelerator itself remaining behind. Fixation accelerators also have wetting and dye-dissolving properties.

Fixation bath Used in all two-phase printing processes. The liquor contains all the necessary chemicals and additions to bring about the fixation of dyes printed without fixation auxiliaries and prevent the dyes from dissolving out during passage of the printed fabric through the fixation bath. Thus, in the continuous dyeing of e.g. polyester/cotton blend fabrics with combinations of disperse and reactive dyes, the disperse dye is first “dissolved” in the polyester fibre by a thermosol treatment before caustic soda solution (as a fixation bath) is applied prior to steaming in order to fix the reactive dye. The thermosol treatment also protects the disperse dye from alkali saponification due to the subsequent application of caustic soda.

Fixation goods Expression used to describe the fixation of interlinings, used for interlining and the outer fabric.

Fixation of reactive dyes in direct printing by hanging The fixation of prints produced on cotton with highly reactive dyes may also be achieved by hanging (similar to the print and lay process). The textile material, printed with a paste containing alkali and dye is allowed to hang, without intermediate drying, in a warm, humid atmosphere for 3–4 hours until fixation is complete. This process is particularly attractive for small scale production (no energy required), e.g. colleges of art, handicraft industries, etc.

Fixation press → Ironing machines.

Fixation ratio, proportion of fixed dyestuff to dyestuff used.

Fixation temperature The temperature range in which dyes become firmly anchored (fixed) to an appropriate textile material.

Fixation time The time span required for a dye to become firmly anchored (fixed) to a textile substrate at a specific → Fixation temperature.

Fixing (Lat.: fixus = fix, durable)

I. Of textiles in the sense of fixing the size or form →: Alkaline scouring, Crabbing, Decatizing, Potting, Hose setting, Heat setting (→ Fixation). The degree of fixation, i.e. the structural alteration which arises through the effect of heat, can be determined in polyester by solubility determination in phenol/tetrachloroethane; similarly through differential thermal analysis (DTA), which can also be used for polyamide.

II. Of dyeings, takes place e.g. through auxiliaries for increasing the fastness, and → Developers.

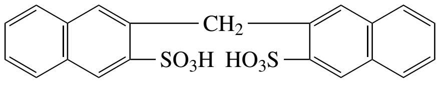
III. Of prints: fixative development. Takes place normally on the steamer.

IV. Of dyestuffs, mostly through hot air (→ Thermosol process), direct contact (hot-roll fixation machines) or steaming.

Fixing joint When fixing interlining fabrics to an outer fabric, the position of the adhesive mass where the (hot) sealing temperature must be reached.

Fixotest apparatus A test apparatus used to determine the colour fastness of dyeings and prints to contact heat (colour fastness to dry heat pleating and dry heat setting according to DIN 54 060, colour fastness to hot pressing according to DIN 54 022). The test is carried out on three plate pairs, each in a single operation at 150, 180 and 210°C. Manuf.: Original Hanau.

Fixtanes, organic compounds consisting of two aromatic ring systems connected by aliphatic chains, as e.g. fixtane acid,



the mercury salt of which is used as a fungicide. Fixtanes have no affinity for fibres but become insoluble after drying. Solutions of the mercury salt can only be made at up to 0.25%; however concentrations of up to 2.5% (density 1.53 to 1.94) can be made by adding free acid.

FL

I. abbrev. for: Finnish Patent.

II. → Polyfluoroethylene fibres, standard abbrev. after the → EDP Code (→ Textile fibre symbols).

Fl → Flax, → Standard abbrev. for textile fibres, according to DIN 60 001 until 1988; from 1991 → LI.

Flaking off Certain thickeners with a high solids content used in textile printing produce hard and brittle films on textile fabrics after printing and drying. Such films may have a tendency to → Split off or flake off the material. In the latter case, there is no addition of the second colour in → Fall-on in printing.

Flame A region in which combustion occurs in the gas phase accompanied by the evolution of heat and visible light.

Flame a fabric, to → Singeing.

Flame backcoating A gas flame is used for back coating. The fabric/foam sandwich is led over a burner strip across the entire width (see Fig.). The gas flame melts the surface of the foam, and a solid connection is provided by subsequently applying pressure. This form of backcoating produces exhaust gas.

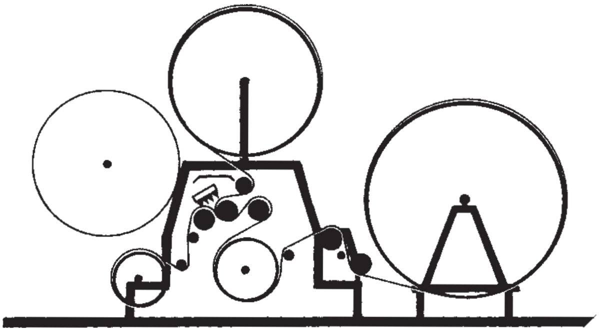


Fig.: Flame backcoating system (Mohr).

Flame drying → Remaflam process.

Flame emission spectroscopy Like → Atomic absorption spectroscopy, flame emission spectroscopy is a method used for detecting traces of heavy metals.

Flame ionization detector (FID). A technique used for the monitoring of toxic atmospheric pollutants, e.g. to determine the content of organically-bound carbon in exhaust air streams. Part of the exhaust air flow is withdrawn as required by a heatable probe. The analyzer compares the unknown concentration of the measured gas with the known concentration of a calibration gas. An electrical field is applied to a pure hydrogen flame which burns in a supply of hydrocarbon-free air. If organic compounds are introduced into the flame by the gas being measured, a measurable ion current develops during combustion. The resultant signal is proportional to the number of non-preoxidized carbon atoms introduced by the gas. Preoxidized and halogenated carbon atoms are only partially detected by this means whilst carbon monoxide and carbon dioxide are not detected at all.

The substance-dependent response factor r describes the signal/concentration ratio in gas chromatography detection. Propane is indicated by a factor of r = 1 per definition, whilst formaldehyde has a factor of r = 0,3. Moreover, the proportion of carbon in formaldehyde is only 40% so that, in comparison to propane, the sensitivity is 13,4 times poorer. For this reason, formaldehyde is difficult, if not impossible, to detect with an FID.

Flame laminating A process used for bonding woven or knitted textiles to a layer of foam which is melted by application of a flame.

Flame-lamination → Laminating.

Flame-proof finishes → Flame-retardant finishing.

Flame retardance The property of a textile material, either inherent or by virtue of an applied finish, to inhibit or suppress the propagation of flame (ISO).

Flame retardancy theories Examination of the burning behaviour of organic fibres or the course of → Pyrolysis reveals various mechanisms for the action of flame-retardant finishes, i.e. possibilities for bringing influence to bear (→ Flame-retardant finishing).

I. Endothermic reaction: under the action of heat at comparable temperatures the flame-retardant chemical and the fibre are decomposed. Thermal breakdown of the flame-retardant chemical extracts energy from the combustion process which has an endothermic effect.

II. Development of non-combustible gases: during fibre pyrolysis, flame-retardant chemicals form gases which are either non-combustible or only slightly combustible. As a result, the local oxygen content is reduced and combustion is consequently made more difficult.

III. Melt theory: under the action of heat and the expenditure of energy, flame-retardant chemicals are converted into a melted state which impedes the access of air and inhibits the evolution of combustible gases.

IV. Formation of radicals: with the provision of energy, flame-retardant chemicals form gases capable of intercepting the reactive radicals of the combustion process so that less energy is released during combustion.

V. Dehydration: flame-retardant chemicals intervene in the pyrolysis reaction with a dehydrating effect. This promotes the formation of carbonization residues and, at the same time, reduces the production of combustible gases.

The optimum flame-retardant action exists when as many of the described mechanisms as possible act in combination so that synergistic effects often occur.

Flame-retardant chemicals Most of the processes developed for cellulose are all based on achieving a permanent reduction of combustibility through the *in situ* insolubilization on the fibre (covalent reactions with the hydroxyl groups of cellulose and/or polymerization) of organic phosphorus compounds in the presence of nitrogen. It has been recognized that nitrogen contributes to the efficacy of organic compounds. The high nucleophilic character of nitrogen and the high electrophilic character of phosphorus in flame-retardant chemicals are important conditions for the achievement of an effective nitrogen/phosphorus synergy. An exceptionally good source of nitrogen to provide the desired synergistic contribution is trimethylmelamine because of its high nitrogen content as well as its adequate nucleophilic character.

Classification:

I. According to washing fastness:

1. Not fast to washing (mostly inorganic salts) or with limited fastness to washing (reduced solubility through heating or condensation, e.g. urea-phosphoric acid).

2. Fast to washing as in a) the single-bath process (e.g. inorganic salts with synthetic resins or chlorinated paraffins) and in b) the two-bath process (mainly with inorganic titanium, antimony and tin salts).

II. According to chemical characteristics:

1. Inorganic compounds: a) Halogenides and also fluorides and bromides to some extent. Improved fastness to washing is achieved by combinations with chlorinated paraffins, synthetic resins, etc.; b) Metal oxides, especially those of titanium and antimony (with afterglow; antimony oxychloride prevents afterglow), also used in plastic dispersions; c) Salts of sulphamic acid, e.g. 85% ammonium sulphamate (afterglow when used alone) and 15% ammonium phosphate. Improved fastness to washing following e.g. an aftertreatment with aminoplasts and condensation; d) Inorganic phosphates, chiefly ammonium phosphates; e) Other inorganic compounds: sodium silicate (20% solution) and sodium tetraborate (alone or in combination with boric acid, ammonium phosphate, etc.), also zinc borate, zinc carbonate and aluminium silicate.

2. Organic compounds: a) Organophosphorus compounds, e.g. THPC; b) The aminated and alkoxylated derivatives of the polymer dichlorophosphornitrilechloride or chlorinated paraffins (excellent fastness to washing) are of great importance in combination with antimony salts for military fabrics and workwear; c) Organosilicon compounds such as the water-soluble sodium methylsiliconate produce effects with high resistance to washing; d) Other organic compounds, e.g. polyvinyl chloride (for flame-retardant coatings), organic esters of titanic acid, phosphates with alkyl substitution.

Flame-retardant fibres

I. The fact that many products recommended and applied as flame-retardant finishes are suspected of being carcinogenic has, above all, induced fibre producers to increase their efforts to produce intrinsically flame-retardant fibres. In the case of synthetic fibres this can be achieved by e.g. grafting, or by making suitable additions to the spinning mass. Native cellulosic fibres can be made flame-retardant by modification (phosphorylation), and regenerated cellulosic fibres by the deposition of flame-retardant products (e.g. organophosphorus derivatives).

II. The burning properties of textiles are influenced by a wide variety of factors (→ Flame-retardant finishing; High-temperature resistant fibres). In addition to substrate-specific properties, the presence of foreign substances in particular, are responsible for initiating synergistic as well as catalytic effects. It is therefore very difficult to predict the behaviour of the end product from the burning properties of individual components due to the influence of many diverse factors (Fig. 1).

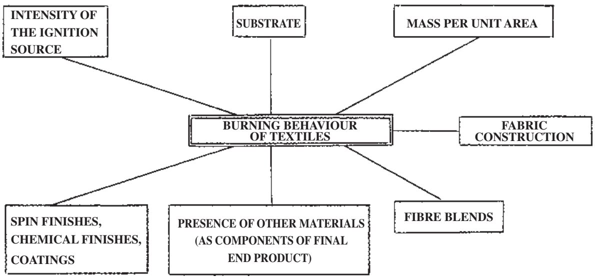


Fig. 1: Factors influencing the burning behaviour of textiles.

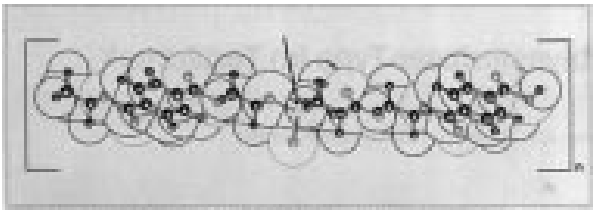


Fig. 2: Flame-retardant action produced by organophosphorus compounds (source: Hoechst).

A flame-retardant polyester fibre contains, e.g. 0.6% of phosphorus as a co-monomer which is polymerized in the spinning mass. The essential difference of a fibre modified in this way (Fig. 2), in comparison to a conventional polyester fibre, is its self-extinguishing property. A test carried out in accordance with DIN 4102, B2 demonstrates its typical burning behaviour. Although exposed to a flame for 15 s, the test specimen only burns for approx. 1–2 s before burning is extinguished and the fibre melts a little without burning. In order to maintain the flame retardant properties of the fibre starting product right up to the textile fabric end product, all the finishing processes such as dyeing, printing, finishing (including coating, where applicable), must be appropriately adapted to prevent any impairment of the flame retardant properties.

Flame-retardant finishing The oft-quoted expression “flameproof” is incorrect, since only certain fibre materials can be said to be flameproof or inflammable, mainly those of inorganic origin. Polyacryl nitrile fibres and cellulose fibres are the easiest to ignite and burn. The flameproofing procedure therefore mainly concentrates on these textiles. For decades, the cotton materials used for interior decoration in public buildings, for example, have been given flame-retardant finishing with relatively few problems. However, problems started when certain countries (initially the USA) started to issue legal regulations for clothing materials and ban the sale of easily flammable articles. The processes that had been previously used were no longer viable, since there was inadequate wash-fastness and the handle had been too greatly affected. It soon emerged that state regulations had exceeded technical feasibility. It was difficult to find a flame-retardant finish of adequate wash-fastness that did not irritate the skin and did not adversely affect the handle of the material. Countless test methods and testing devices were developed, and it was discovered that there were discrepancies between the results of such tests and the actual behaviour of the material during use.

The combustion behaviour of a fibre in textile products cannot be characterised by a single parameter. The tests mainly relate to flammability, flame spread and smoke production. Another test that has been introduced is the test for oxygen demand. This LOI (Limiting Oxygen Index) specifies the minimum oxygen concentration in the mixture with nitrogen that is just about adequate for continued burning; it is also known as the VTO2 index (Fig. 1).

Ignition temperatures:	
Cotton	400°C
Wool	600°C
Acetate	525°C
Triacetate	540°C
Polyester	510°C
Polyacryl nitrile	560°C
Polypropylene	570°C

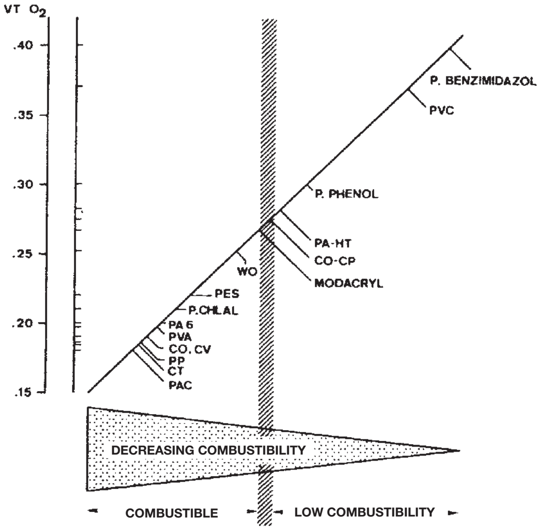


Fig. 1: Limiting oxygen index (VTO_2) for several fibre materials [-CP = Pyrovatex CP finish (Pfersee); -HT = High temperature resistant; P - Poly-].

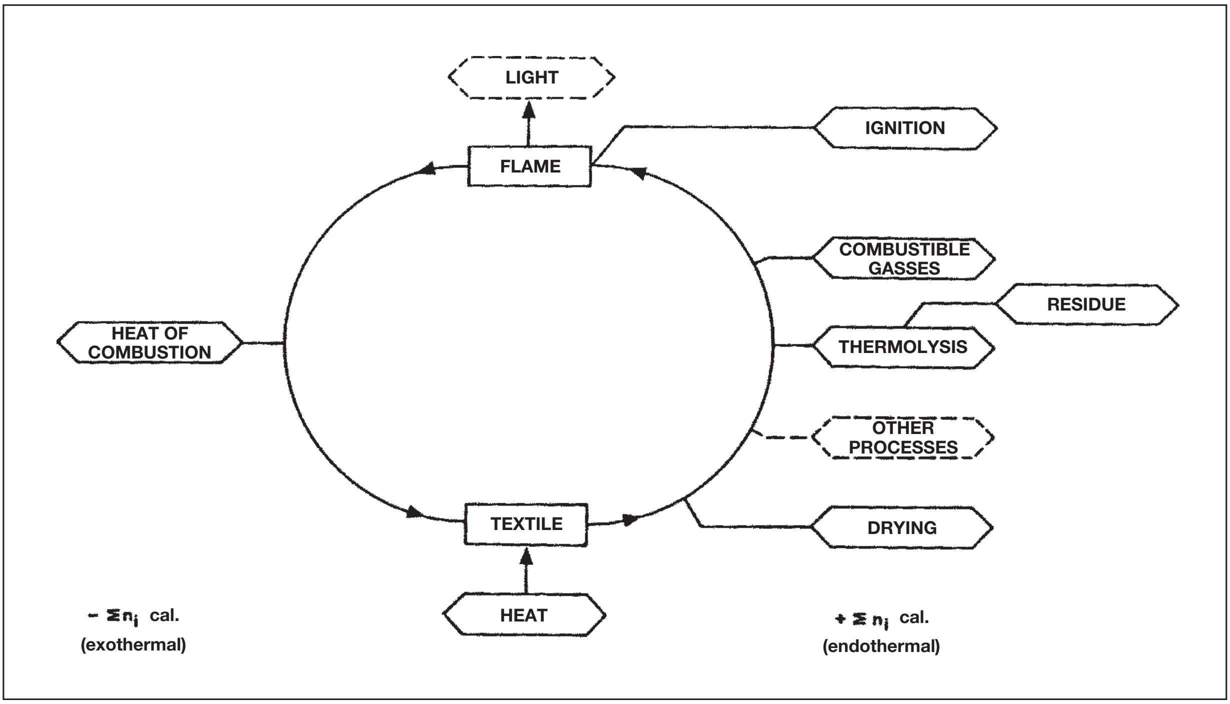


Fig. 2: Schematic diagram of the ignition and combustion of textiles in the form of an energy audit. Σn_j *cal. signifies the sum total of all thermal energy that is absorbed or emitted during the individual phases.*

Synthetic fibres present a particular problem in that they melt and drip when heated. It has emerged that dyes can even increase combustibility (e.g. in polyamide).

When a fibre burns, a state of equilibrium is reached between oxidative flame burning and pyrolysis inside the fibres (Fig. 2). The exothermic combustion feeds the endothermic pyrolysis with energy, whereas the pyrolysis produces gases that diffuse within the flame if oxygen is excluded and therefore feed the flame. A thermal balance is reached in this system by the sum total of the thermal energy that is absorbed or emitted in the individual phases (textile combustion process). Several theories concerning flame-retarding finishing can be derived from this knowledge:

– Gas theory: dilution of the easily combustible gases with gases of low combustibility (N_2, Br_2).
– Coating theory: creation of an inert atmosphere over the substrate surface with CO_2, H_2O, HCl (from PVC coatings).
– Thermal theory: reduction of substrate temperature below the ignition temperature by adding heat-absorbent substances that do not degrade (Na_2MoO_4, $NaVO_3$).
– Chemical theory: catalysis of pyrolysis by producing of gases of low combustibility and carbon. Reduction of the tendency to depolymerize. Promotion of water removal (P-N synergism).

Known flame-retardant concepts can be grouped as follows:

1. Dense material structure.

2. Fibre spinning mass modification: a) copolymerization of modacrylics (instead of polyacryl nitrile); b) additives (viscose, acetate, polyacryl nitrile); c) aramids, polyvinylchloride.

3. Chemical modification: a) Grafting (vinyl chloride to polyacryl nitrile); b) reaction between cellulose and phosphor-nitrogen compounds.

4. Finishing: a) low molecular compounds (tris-(2,3 dibromopropyl) nitrile chloride); b) polymers (polyvinylchloride Sb_2O_3 mixture); c) in situ polymerisation (tetrakis (hydroxymethyl) phosphonium chloride; d) salts.

In order to have the desired effect, the fibres must be charged with large quantities of these products (10–20%). The finishes that are not washproof are only used in exceptional cases. The same applies to the metal oxide deposit process, e.g. the “Erifon” process (DuPont) that is used to impregnate a titanyl chloride and antimony trichloride solution with subsequent passage through a sodium carbonate bath, and similar processes. Finishes containing antimony have a tendency to after-glow. This process also causes the handle of the material to be adversely affected. The permanently flame-retardant finishes are therefore of primary interest, some of which can be used for synthetic fibres.

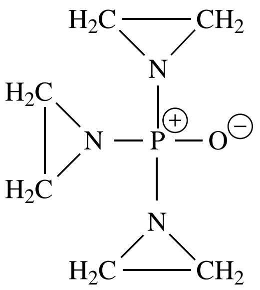
The products that are used must not be toxic or carcinogenic, which also applies to the vapours and gases that are produced during pyrolysis. They must also be skin-compatible. Flame-retardant finishes free from antimony and chlorine are therefore required for environmental reasons. There is also the additional problem of effluent, since most phosphor nitrogen compounds are not biodegradable.

The most important phosphorus-based product groups are structured as follows:

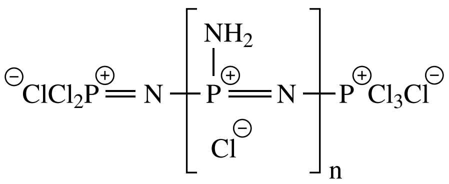
- tetrakis hydroxy methyl phosphonium chloride (THPC):

$$(HOCH_2)_4P^+Cl^-$$

- Tris-aziridinyl phosphin oxide (APO):

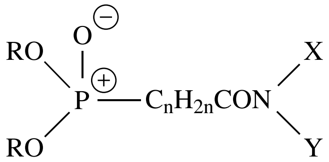


- Phosphor nitrile chloride polymers (PNC):



$$^{\ominus}ClCl_2\overset{\oplus}{P}{=}N-\left[\overset{\oplus}{P}(NH_2)(Cl^{\ominus}){=}N\right]_n-\overset{\oplus}{P}Cl_3Cl^{\ominus}$$

- N-methylol dialkyl phosphonium carbonic acid amide:



R = alkyl
X = hydroxymethyl
Y = H or hydroxymethyl

The individual working stages of a typical flameproofing finishing are:

1. Impregnation on a two or three roller padder with adequate depth of submersion.
2. Drying on the stenter frame, loop drier or hot flue, whereby shock drying must be avoided at all costs.
3. Heat setting in a condensing oven with good air circulation and a working temperature of at least 160°C.
4. Washing on a full-width washing machine with four or more washing compartments.
5. Final drying.

Although wool is naturally difficult to ignite and burn, flame-retardant finishing has been sought for wool carpets. The IWS "Zirpro" process uses potassium hexafluoro titanate and zirconate for this purpose. These products can be applied in exhaust and pad processes (even in a dye liquor in some cases). Other flame-retardant agents for wool are zircon wolfram complexes and tetra bromphthalic acid.

Flame-retardant finishing of carpets Flame-retardant finishing of carpets is becoming increasingly important because of the constant increase in the use of fitted carpeting. The combustion behaviour of the floor coverings is influenced by the substrate and pile materials, the carpet structure and the backing system. It is complicated by the fact that different materials interact. Cotton carpets can be given a flame-retardant finish using THP derivatives whilst titanium or zirconium salts are used for wool carpets. Aluminium hydrate is added to the back coatings in order to increase flame retardancy. The finish is applied by slop padding or spraying carpet materials with solutions or dispersions containing flame-retardant materials (→ Flame-retardant finishing). It is possible to subdivide textile floor coverings into different combustion classes as per the test methods of DIN 54 332. DIN 66 081 describes division into three classes. Flame-retardant finishing increases the static charging of the coverings.

Flame retardant reactive finishing of cotton Fixation of flame-retardant agents via reactions with cellulose. In this process the methylol group reacts with the cellulose hydroxyl group. With → THPC a reaction with ammonia also takes place due to condensation and soluble polymers are formed. The advantages of this process lie in the good washing and dry-cleaning fastness of the finish produced. However, the often unavoidable disadvantages are: some complicated processes requiring special equipment; loss of tensile strength; harsh handle; detrimental effect on dyeing; ineffective on cotton/synthetic fibre mixtures.

Flame retardants and COD The → COD of flame-retardant finishing liquors arises not only from the flame-retardant product itself but also from additional auxiliaries. For example, the COD values of various commercial flame-retardant products examined were between 0–900 mg O_2/l, i.e. still relatively low in comparison to the other auxiliaries investigated with up to 2200 mg O_2/l. In the cases investigated here, a COD of 200 000–300 000 mg O_2/l per litre of discharged residual finishing liquor was determined.

Flame shearing machine Piece of singeing equipment for producing a non-pile finish to textile fabrics affecting the textile ground. The material is introduced to the singeing flame at an acute angle via a water-cooled singeing bed. More economical when the material is presented twice for singeing. Burners work in dual-jet system. Carpet singeing machine in which the material is passed over the flame at an acute angle via a water cooled bed. This produces in-depth singeing for a non-pile finish.

Flame spread The extent of propagation of a → Flame on the surface of a material.

Flame spread rate The rate of propagation of a flame front on the surface of a material under specified test conditions.

Flammability

I. → Flame-retardant finishing.

II. Flammability and → Burning properties are influenced not only by the type of textile fibre, but also by the weight, weave and degree of yarn twist. Flame retardant finishes as well as the type of binders used in laminates also influence the flammability of textiles. → Burning behaviour of textiles.

Flammability directives A number of EC directives which deal, among other things, with the flammability of textiles and products containing textile materials include the following:

- Construction Products Directive (CPD)
  Council Directive 89/106/EEC, 21.12.1989.
- Personal Protective Equipment Directive (PPE)
  Council Directive 89/686/EEC, 21.12.1989.
- Safety of Toys Directive
  Council Directive 88/378/EEC, 3.5.1988.

I. The EC directive on construction products (CPD = Construction Products Directive): this directive describes the essential requirements for materials to be used for construction purposes. These requirements are mainly concerned with various aspects relating to the safety of persons and goods, which also includes safety in the event of fire. Textile products affected by this directive consist exclusively of materials used for interior decoration firmly bonded to various supporting materials which cannot be removed under normal conditions of use and can therefore be compared with actual construction materials. This applies particularly to:

- wall and ceiling coverings as well as
- floorcoverings.

II. The directive on protective equipment for persons (PPE = Personal Protective Equipment Directive): this directive stipulates the requirements placed on protective clothing for persons exposed to physical risks by the nature of their work (mechanical, electrical, radioactivity, noise, rigours of the weather) or chemical risks (chemicals hazardous to health) or those persons who come into contact with fire, heat and molten materials at high temperatures.

III. The directive on the safety of toys (Safety of Toys Directive): this directive specifies the essential requirements for the safety of toys with regard to physical, mechanical, chemical and electronic risks where particular attention is given to burning behaviour. Tests specifically designed for toys are carried out in accordance with Standard EN 71 which is one of the few standards harmonized throughout the European Community. Additional directives:

1. Draft directive on the burning behaviour of upholstered furniture, related articles and sub-products (8.2.1991). Articles affected by this directive include:

- upholstered furniture, i.e. upholstered chairs, seats, seat cushions etc.;
- related articles, i.e. mattresses, moveable cushions, bed-settees and similar articles;
- sub-products, i.e. filling materials (e.g. polyurethane or latex foams), sandwich inserts and upholstery fabrics.

Requirements:

- primary ignition level,
- heat and smoke development and their influence on the time of escape,
- labelling information.

Fields of application:

- private sector,
- public sector,
- high risk sectors.

2. The directive on the contents of buildings (Buildings Contents Directive): this applies to, e.g. textiles such as curtains and furnishing fabrics as well as bed linen.

3. Apparel: no official EC draft directive exists at present for apparel.

4. Industrial and technical applications.

(source: Horak).

Flammability guidelines → Flammability directives.

Flammability test Flammability test should be capable of providing information on a wide range of burning criteria. Such variable criteria can only be determined by different kinds of test methods. It is particularly important here to distinguish between burning behaviour at room temperature (i.e. at the start of a fire) and burning behaviour at high temperatures. Criteria for flammability tests include:

1. Ignition properties: a) energy requirement; b) ignition time.

2. Burning behaviour (at room temperature): the test specimen, a) does not burn independently; b) burns slowly and is self-extinguishing; c) burns slowly and is not self-extinguishing; d) burns rapidly.

3. Secondary effects: smoke development (density, toxicity).

4. Burning behaviour (at elevated temperatures (e.g. third-degree fires): the test specimen, a) remains unaffected (e.g. ceramics); b) decomposes (smouldering fire); c) continues to burn up to a critical heat flux density; d) ignites and causes the fire to spread to non-burning areas (fire propagating).

Tests are necessary in order to be able to estimate the complexity and risks of fires by their most important parameters. To facilitate reproducible results, therefore, standards have been developed which make it possible to describe and evaluate the burning process by means of standardized tests with the aid of unambiguous questions. The following procedure is therefore appropriate:

- determine the specific requirements;
- specify tests capable of controlling and matching these requirements, then
- stipulate the appropriate standards, and finally
- establish, and under certain circumstances, classify the properties of the article which are commensurate with its expected performance.

Since a permanent and maximum flame retardant effect is not necessary in all cases and is dependent on the intended purpose, the standard tests should indicate the classes in which the respective article belongs. During standardization, the present state-of-the-art, the market situation which may possibly include considerations of fashion, the appearance, the serviceability properties and finally the price of representative functional textiles must be taken into consideration in all cases. Test procedures to determine the burning behaviour of textiles, as well as any observed secondary manifestations, may be divided into two groups:

- methods for scientific investigations (Fig. 1),
- methods for practical situations (Fig. 2).

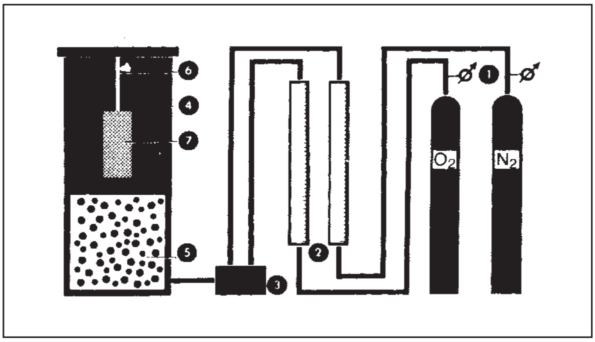


Fig. 1: Limiting Oxygen Index test (LOI test), schematic representation of a more scientifically based flammability test.
1 = manometer with fine regulation; 2 = gas flow meter; 3 = glass mixing chamber; 4 = Pyrex glass cylinder; 5 = bed of 5 mm size glass balls; 6 = specimen holder; 7 = test specimen.

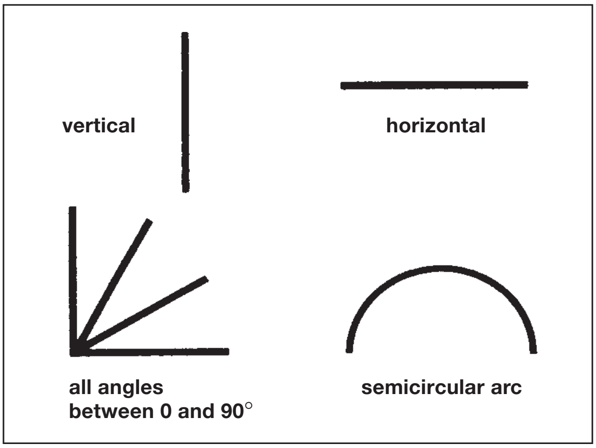


Fig. 2: Diagram illustrating test procedures for practice-relevant flammability testing.

Standardized test methods:

I. The vertical test is one of the most stringent tests of all. This test measures the resistance of the material to flames although the degree of flammability is not determined. It is suitable for non-flammable textiles or those which burn with difficulty. The test can also be used to evaluate the effects of flame retardant finishes.

II. The 45° test is used for readily flammable textiles and represents a compromise between I and III. This test has been the subject of extensive criticism.

III. The horizontal test. In this case, the test specimen is secured horizontally so that no chimney effect can occur. For this reason, it is only used for special articles and/or for the determination of flammability.

IV. Arch tester to determine burning and smouldering behaviour with the aid of an arch test assembly. The effect of exposing test specimens stretched in a semicircle to a flame for a specified length of time is determined.

(source: in part by Carl).

Flammability testing (→ Burning properties, → Flammability, → Burning tests for fibre identification). Various (defined) ignition sources are used in this test. The textiles to be tested are subjected to these sources for a specific time. The textile finisher's problem is that each country has its own testing methods that stipulate different test subject positions and ignition sources, e.g. glowing cigarettes, different kinds of gas flame, even alcohol flames, waste paper baskets filled with wood shavings, electrical radiators, wooden cribs, hot metal nuts, cigarette lighters and matches.

In principle, the combustion time after the source has been removed or burned off is used as a criterion for measuring and evaluation, as is the after-glow, and above all the size of the destroyed area of the test subject. However, even if the regulations are strictly adhered to within a test method, it is often difficult to reproduce the test results. In order to make a scientific analysis of the combustion behaviour, thermal gravimetry, differential thermal analysis, differential scanning calorimetry and thermo-mechanical thermal evolution analysis are used. The combustion behaviour and the pyrolysis products of fabrics finished with flameproofing agents containing chromium or phosphorus can be analysed by gas chromatography and mass spectography. Many test procedures and pieces of equipment have been developed in the various countries, some of which have been declared obligatory, although experts consider the results thereof to be inconclusive. A test that meets all requirements must include the fol-

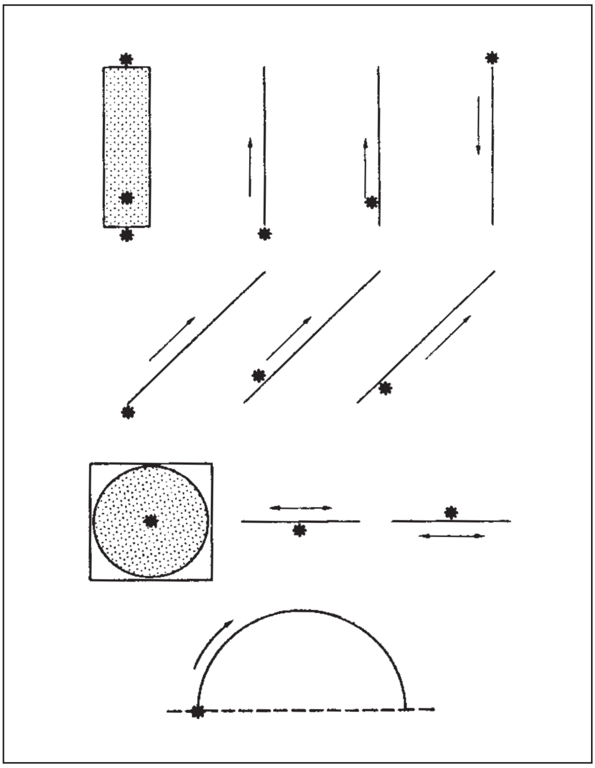


Fig.: Possible ignition points on samples in the flammability test.
** = ignition point; → = main direction of flame spread.*

lowing: residual ignitability, combustion time, extinguishability, shrinkage, melting, smoke emission and toxic gas build-up. Special test regulations and different equipment must be used for some textiles. A distinction is made between the test subject's position in relation to the vertical, horizontal, angle and arc tester. The vertical test (DIN 53 506) is for testing low combustibility, the horizontal test (DIN 54 333) is for testing the flame spread (see Fig.) and other criteria can be measured using the angle and arc test (DIN 54 331). → Flammability test.

Flammability – test method requirements The following demands have been placed on test methods for flammability:

a) Determination of flammability (from a small flame to independent ignition with flames);
b) Fire propagation speed (flame spread rate, burning rate);
c) Determination of the heat of combustion generated;
d) Tendency to form burning melt droplets;
e) Flammability of home textiles at high ambient temperatures and high ventilation;
f) Determination of smoke and/or (toxic) gas development;
g) Determination of heat shock behaviour.

From the numerous test methods for the determination of flammability, only those which correspond to the particular requirements of the article must be selected. An important criterion is the form of the test specimen; for example, this can be vertical, horizontal, inclined at an angle or in the form of an arch. → Flammability testing.

Flammable liquids Flashpoint and ignition point: the burning point of a liquid lies mostly approx. 20–60 °C above the → Flashpoint. With certain liquids, however, e.g. ethyl ether or gasoline, it falls almost to the same level as their flashpoints. Attention is drawn to the low ignition temperatures (auto-ignition temperatures) of ether and carbon disulphide (see Table). → Hazard classification of flammable solvents.

combustible	flash point (˚C)	ignition point (˚C)
acetone	–19	540
ethanol	12	425
i-amyl alcohol primary	43	340
benzene	–20 bis +10	250
benzol	–11	555
diesel oil	55	220
dioxane	11	375
acetic ether	–4	460
ether	–40	170
hexane	–26	240
machine oil	135/300	400/610
methanol	11	455
paraffin	158 bis 195	220 bis 250
pentane	–20	285
petroleum ether	–20	280
carbon disulphide	–20	102
toluene	6	535
xylol	25	525

Tab.: Flash point and ignition point of different combustible liquids.

Flammé effect on hank yarn → Dyeing of flammé effects.

Flammé yarn

I. Hank-printed yarn, e.g. for shirt flannel.

II. Dyeing → Dyeing of ombré or shaded effects.

III. Spinning; a yarn spun with irregular thicknesses (slubs, nepps, etc.).

Flanged bobbin → Cylindrical package, cheese.

Flannel Collective term for single-sided or two-sided napped fabric made from wool, cotton, union fabric or viscose filament; usually with plain or twill weave. The soft, supple handle is characteristic and is created by milling, with the clear nap still allowing the weave pattern to be clearly seen. The napping process causes the colours to merge gently into each other; the fibre nap is fairly short in these materials, and is sometimes evened out by emerizing. Wool flannels are either made from worsted or woollen yarn, usually soft-spun from fine merino, i.e. easily milled wools. Flannels are mainly light mixture shades (grey and beige shades), light weight (approx. 240–440 g/m^2) materials. Variously named according to fibre type, weave or end-use (wool, twill, crepe, dress, blouse or shirt flannel). Type of finish: light to medium melton finish. Used for dress, costume, suit and coat materials (wool) and sports shirts or pyjamas (cotton).

Flash ageing A modern form of the → Two-phase printing process. The flash ageing process is characterized by the use of short steaming times at high temperatures. Principle: thickened vat dyes are printed without fixation chemicals, dried, padded with an alkaline solution of a reducing agent (caustic soda liquor and sodium dithionite), then steamed immediately without intermediate drying for 20–60 s at 120–140°C in a special rapid steamer (e.g. flash ager as in Figs. 1 and 2, rainbow or arch steamer, tower steamer). There is no contact with the face side of the printed fabric during its passage through the steamer in order to prevent marking off. Thickener combinations which coagulate in the alkaline fixation liquor are employed. Fixation is completed by subsequent oxidation and soaping at the boil.

In order to avoid the use of urea, reactive dyes can also be printed by the two-phase method as follows: Stage 1: the reactive dyes are printed without fixation chemicals and dried. Stage 2: the printed fabric is padded with an alkali solution containing an addition of electrolyte and steamed.

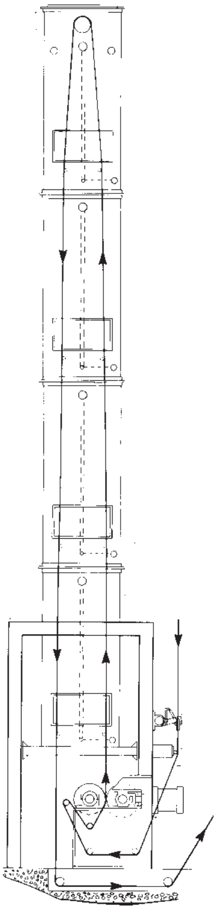


Fig. 1: Flash-ager by Dinting.

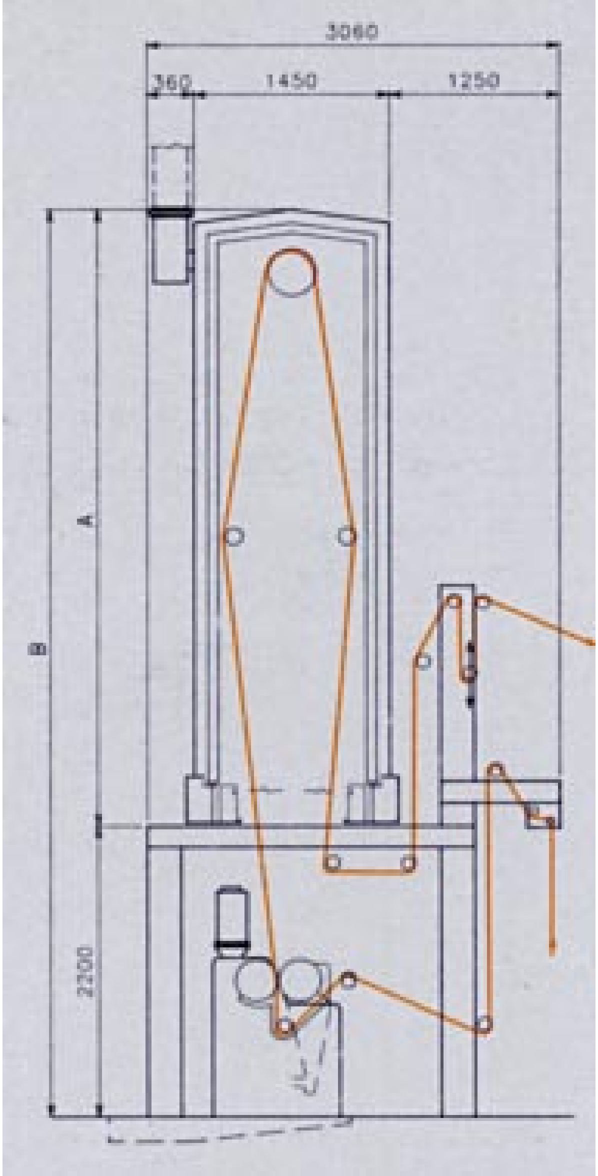


Fig. 2: Flash-ager by Arioli.

This method of fixation has the advantage of simplified print paste formulation and less hydrolysis of the reactive dyes.

Flash ager Energy and room economized → Rapid ager.

Flash point (FP). The temperature at which sufficient vapour builds up over a flammable liquid to form a combustible mixture with air near the surface of the liquid. The application of a small naked flame at the flash point temperature produces a momentary flash only since the temperature is still too low for sustained combustion. The latter only takes place at a somewhat higher temperature (the so-called auto-ignition temperature). General principles: a low → Boiling point means a low flash point, high volatility and higher risk of fire. The flash point is therefore an important measure for comparing the flammability of → Flammable liquids.

Flatbed laminating machine The goods to be laminated are heated by feeding between two Teflon-coated continuous belts. The belts hold the goods flat and even whilst the melt adhesive is heated by contact heat (Fig. 1). This allows treatment of a wide variety of flexible or rigid sandwich constructions.

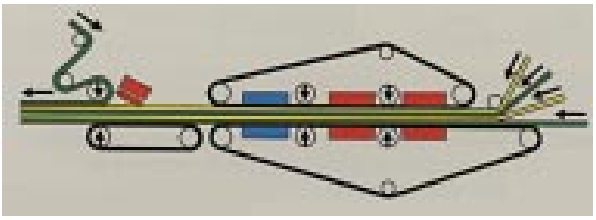


Fig. 1: Meyer flatbed laminating machine with down-stream laminating roller station and IR heater, e.g. for thermo-sensitive substrates, or ones which are heavily insulating, or for the production of multiple laminates in one work cycle.

The concept of laminating in an open width passage makes it possible to vary the gap height by raising or lowering the upper heating zone. A single machine can be used to laminate materials of the most diverse thickness. The height is adjusted mechanically, or by means of servomotors. Whilst the goods to be laminated pass, flat, between the heating zones, a slight pressure is exerted via the upper and lower belts. In order to reach the necessary bonding values, additional pre-setting takes place by means of a pair of pressing rollers in the middle of the system; at the end (before the outlet and cooling), a second pair of pressing rollers creates the end pressure. The pressing force is adjustable. The lamination speed depends on the density and thickness of the material (thermal transfer coefficient), the processing temperature of the thermoplastic adhesive and the length of the heating section. In standard machines, it moves between 2–15 metres per minute; in the case of types with a heating section of double the length, up to 30 metres per minute are possible.

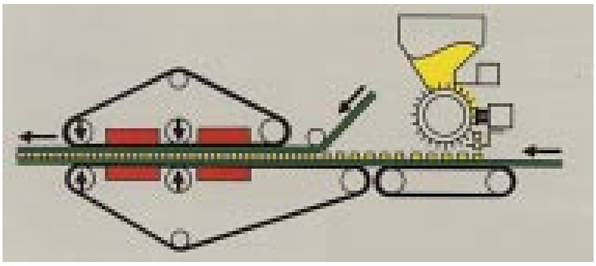


Fig. 2: Meyer flatbed laminating machine with up-stream powder dispersion system.

In the last few years, there has been a marked development in the area of thermoplastic adhesive polymers and their blends. Depending on the application, from the variety of compatibilities, processing temperatures, thermal stabilities, chemical fastnesses and the like, the correct adhesive can be determined. Ecologically safe adhesive systems include e.g. thermoplastic adhesive films, bonded nets, powder, powder spot, paste spot, hot-melt glues, self-adhesive films (Fig. 2).

Flat carpet

I. (→ Smooth carpet), carpet without pile or napped surface as per DIN 61151. Examples: coir and sisal mats, → Gobelin tapestry.

II. Carpets without pile or nap such as hand-woven carpets → Kilim carpets, and carpets with extraneous decorative effects →: Allgaeu carpets, Applique carpets, Skin rugs, Felt mats with and without decorative materials incorporated, or mechanically woven carpets in plain weave made from hair yarn, wool, coir, sisal, cotton. Opposite: → Pile carpets.

Flat conical cheese A precision-wound conical yarn package in the form of a narrow wound (short traverse) large diameter cheese (→ Crosswound yarn package).

Flat foam → Smooth foam backing.

Flat iron A pressing iron used for the manual → Ironing of garments.

Flat iron with interchangeable base plates A type of flat iron, formerly in common use, with interchangeable sole plates which can be heated up individually and placed in the iron again when hot.

Flat packings → Seals, mostly cut from discs, are placed or clamped between the metal surfaces that are to be joined, or held fast in a groove.

Flat press A hydraulic press used for → Pressing (see Fig. 3) in which transverse-folded layers of woven fabric (or, more rarely, knitgoods) are interleaved in the open-width state with heated or cold press papers and the pile so formed is subjected to pressure. Heating is achieved by inserting pressboards heated by electrical resistance wires at intervals throughout the batch.

Flat screen printing A discontinuous form of → Screen printing in contrast to continuous → Rotary screen printing. In screen printing a print paste is applied to a textile fabric through a screen engraved with a design in the form of a "negative" by means of a squeegee. The term "screen printing" is derived from the process of making printing screens which are coated with a light-sensitive film and dried. The coated screen is then exposed to light only in those areas where the coating is to be made insoluble, i.e. where no print paste is required to pass through the screen mesh on to the fabric being printed. Flat screen printing on long tables (hand screen printing) is the original form of screen printing and is still used for printing short runs of high quality prints. In this method the length of textile fabric is glued or pinned on to the printing table and then printed by hand with flat

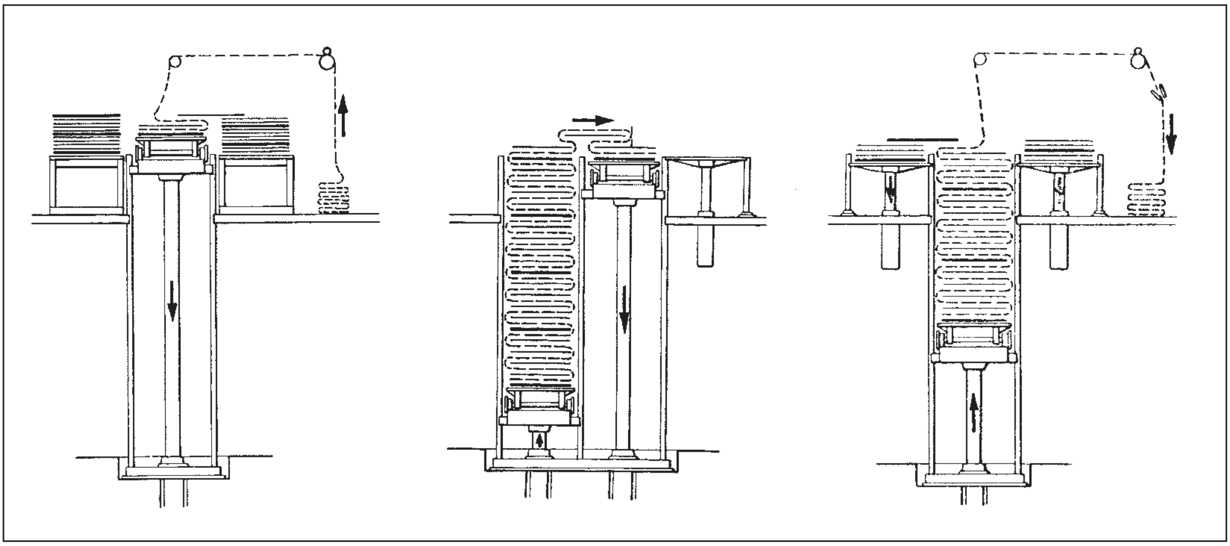


Fig. 3: Pressboard press by Krantz.
left = insertion of press boards; centre = reversal of press batch; right = removal of press boards (thick black line = electrically heated press boards).

screens using squeegees. The procedure has been simplified by the use of a screen printing carriage which moves on rails from repeat to repeat along the table and is lowered into the printing position at each repeat stop. Fully-automatic screen printing carriages take care of screen transport, stopping at the repeat point, and electrically-driven squeegee operation. Mechanized screen printing involves the use of stationary screens supported in frames. The screen frame serves the purpose of raising the screen whilst the textile fabric which is glued to an endless rubber blanket is transported the length of one repeat after which the screen is lowered into the printing position once again. Printing is carried out by applying print paste through the stationary screen by means of a squeegee, i.e. in contrast to roller printing the process is intermittent.

A flat-bed screen printing machine consists essentially of a fabric feed unit, a glueing system and the printing unit itself. A liquid adhesive is applied to the printing blanket by the glueing system; in the case of printing blankets precoated with a thermoplast adhesive, however, a heated plate is used instead of the glueing system so that the heated fabric is attached to the thermoplast layer by pressure. After the fabric has been printed it is detached from the printing blanket and dried in the drying chamber. The rubber printing blanket returns under the printing machine where it passes though a washing zone before receiving a new coating of glue.

Various squeegee systems are employed in flat screen printing:

1. Blade squeegees: single and double squeegees or tilting squeegees (Fig. 1).
2. Roller squeegees.
3. Magnet-roll squeegees.

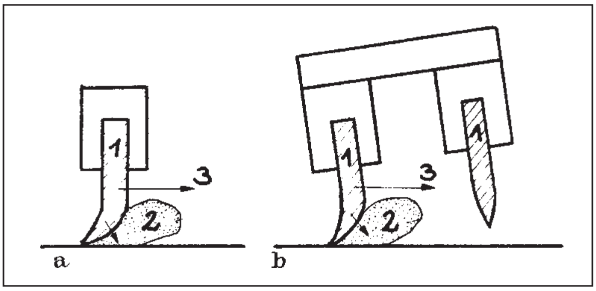


Fig. 1: Method of operation of the single doctor blade (a) and double doctor blade (b).
1 = Doctor blade; 2 = printing paste; 3 = doctor blade direction.

In the case of blade squeegees the application of print paste and print paste penetration are controlled by the squeegee angle and the pressure (Fig. 2).

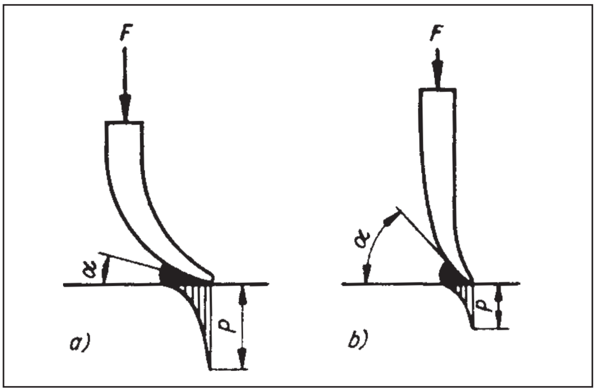


Fig. 2: Through print dimension p relative to doctor blade angle α and doctor blade pressure F.

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Flat screens → Screens for screen printing.

Flat sheets for fibre manufacture Initial raw materials are flat sheets of polyethylene or polypropylene, with additives such as stabilisers for increasing the resistance to heat, oxidation and UV radiation, as well as antistatic agents, possibly dyestuff pigments, adhesion agents etc. Extruded, (tubular film / blown film, then split and laid open to form flat sheets), subsequent processing into → Tape yarns.

Flat spotting Flat spot formation, a reversible indentation in a vehicle tyre in the region of the ground contact area, caused by stress whilst stationary caused by differential stretching of the cord fabric inlay → Non-flat spotting.

Flat-table pantograph → Engraving.

Flattening and glazing calender → Glazing and flattening calender.

Flat yarns By slitting a polyolefin flat sheet, flat yarns of a rectangular cross-section are formed. These can be spool wound for weaving and knitting; they may be processed directly onto weaving or knitting machines. Mono- and multifilament forms can also be combined with conventional yarns. Twisted/ doubled flat yarns have the character of round yarns or round twist yarns. Using another method, by means of fibrillation or capillarization → Split film yarns can be used to create flat yarns as pseudo-multifilaments, or similar connected in a net-like manner, with further processing via twisting/ doubling (split round yarns, split twist) or crimp texturing and twisting (split crimp yarn, e.g. for carpet pile). Similarly also from tape yarns a) directly into flat yarns (for warp beams or cross-wound bobbins) or b) likewise via splitting fibrillation (split or fibrillated yarns) and crimp-textured and twisted (split crimp yarn). A further process involves passing the yarns through a subsequent processing of tape yarns, is through splitting through fibrillation, crimping or fibre cutting into → Split fibres (Split non-wovens), and by twisting into split fibre yarn. Used for bast fibre substitutes, binder warp / backing fabric for tufted carpets, needle-felt carpets, coating fabric, pile for outdoor carpets, furnishing fabrics, automobile / furniture upholstery fabric, wall coverings, the packaging sector (for textiles and sacks, slip-proof/stackable through the application of wax), workwear, rainwear, high-visibility clothing, tablecloths, awnings, tarpaulins, tent materials, filter fabrics, technical purposes.

Flax (linum, linen) → Bast fibres belonging among the → Natural cellulosic fibres (up to 120 cm long) with a smooth surface structure and increased natural lustre. Preformed in the stem of the flax plant (small seed form = fibre flax, large seed form = oil flax; also hybrids; different fibre content) as described under → Flax long fibre structure. Microscopic: cylindrical, smooth, narrow lumen, transverse fracture is typical, wall displacement, knotty. Fibre production:

1. Mechanical fibre separation of woody core and bark stems.

2. Retting and then mechanical processing (: → Scutching, hackling. Byproducts: woody pieces or shavings, short fibres and →: Oakum and flax oil).

3. → Cottonising (→ Flax cell structure).

Raw flax contains celse, water, fat, wax, dyestuff, up to 25% incrustation (impurities) (→ Flax composition). Pure flax (linen): like cotton, almost pure cellulose, but thicker cell walls (greater resistance to alkalis and oxidizing agents). Raw flax requires to be scoured and bleached before dyeing (10–20% weight loss).

Flax cell structure In retted and raw (green) flax the individual fibre cells are separated by middle lamellae (→ Flax long-fibre structure). Each individual lamella forms an elongated polyhedral prism which is spindle-shaped with extremely fine points at the top and the bottom. Due to the growth in thickness of the individual cells, a clear layer structure can be seen in the cross-section of the entire wall substance. The structure is built up as follows from the outside to the inside:

1. The middle lamellae as the external membrane, which has a high proportion of pectins.

2. The primary wall (primary membrane, external cell wall), which is very thin and smooth with hardly any pectin content.

3. The secondary wall which is of greater thickness and very solid; it contains hemicelluloses as well as protein substances and increasing amounts of pectins up to the fibre cell core.

4. The tertiary wall forms the boundary to the

5. Lumen or cell canal which, after maturity, is mainly linear in shape or fissured and contains approx. 4% protein residues.

Flax, composition of (chemical). The composition of flax can vary considerably depending on the state of the fibre (see Table).

% content	Raw flax	Retted flax	Hackled flax
Cellulose	56,5	64,1	65–89
Hemicellulose	15,4	16,7	–
Epidermis/wood residue	–	–	5,0
Pectin	3,8	1,8	2–7
Protein	–	–	2–5
Lignin	2,5	2,0	1–5
Soluble	10,5	3,9	–
Fats/waxes	1,3	1,5	1,8–5
Water	10,0	10,0	9–10
Ash	–	–	0,5–1,3

Tab.: Percentage composition of flax in different processing stages (pectin content can be up to 25% in the event of poor retting).

Flax (linen)-cotton, tests to distinguish between
I. → Methylene blue test.

II. After removal of any finish etc., allow the test specimen to lie for 15 min in a 1:10 copper sulphate solution, rinse thoroughly under a stream of water, then allow to lie for 15 min in a 1:10 solution of potassium hexacyanoferrate (II) solution, rinse thoroughly: flax = copper red, cotton = uncoloured.

III. Quinoline test: allow the test specimen to lie for some minutes in a lukewarm quinoline solution, rinse and treat with dilute sulphuric acid: flax = blue colour, cotton remains uncoloured (reagent: alcoholic quinoline solution diluted with water and glycerol).

Flax long-fibre structure The so-called bast layer forms a layered ring of adjacent bast fibre bundles in the → Flax stem structure. Each bundle tightly joins a group of individual fibres together and itself becomes entwined in the cortical layer. Two types of compound, which are caused by the different type of the so-called centre lamella functioning as a binding membrane layer, are distinguished in the fibre structure according to the following:

1. The woody centre lamella seals the elementary fibres or individual bast cells (→ Flax cell structure), which are 20–25 mm long and 20–25 µm thick and offset spirally side by side and on top of each other into a self-contained bundle in parallel. Calcium-containing pectin with lignin inlays appear here in particular as a binding membrane layer. This centre lamella is extremely resistant to chemical and enzyme attack. It is not damaged by normal types of rotting (so-called wood or woody fibres), but it is intentionally destroyed in cottonizing. The latter results in fibre foreshortening, in extreme cases up to single-cell elementary fibre length, and simultaneous refining (→ Cottonized flax).

2. The parenchyma centre lamella surrounds each of the fibre cell bundles (300–1300 mm long) as a membrane made of pectin and seals it with the cortical cells. These centre lamellas are destroyed by rotting caused by gradual pectin degradation so that the now loosened fibre bundles can be isolated from the remaining stem layers by breaking, scutching and hackling. This is how, besides the shives from the wood strands, the 100–600 mm long multicellular flax long fibres arise and become shorter random fibres of → Bast fibre tow, both now spinnable.

In the past, numerous experiments using morphological tests were carried out with the aim of obtaining information about the quality of the flax, e.g. via light microscopy. The anatomy of the fibres and fibre bundles depends on the type of linen, growth conditions and position within the stem and influences the fibre yield and fibre quality (Figs. 1 + 2). The fibre quality is calculated from the percentage share of fibre bundles over the total stem cross-sectional area in the microscopic display. It is also characterised by the type of fibre cell bonds (fibre bundles) from the closed oval to kidney-shaped contour. Irregularly shaped bundles are characteristic of a poor quality flax. Besides the shape of the fibre bundles, the shape of the individual fibre cells is also important. A qualitatively high-grade flax has a quadrilateral shape with 3–7 edges in its elementary fibres. Poor fibres are oval. The fibre strength is influenced by the thickness of the cell wall, which, amongst other things, depends on the degree of ripeness. High-grade fibres have extremely thick cell walls, which can cover more than 98% of the fibre cross-sectional area (according to Kessler).

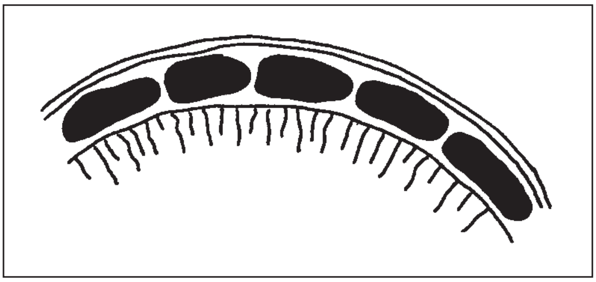


Fig. 1: Fibre bundle of qualitatively high-grade flax.

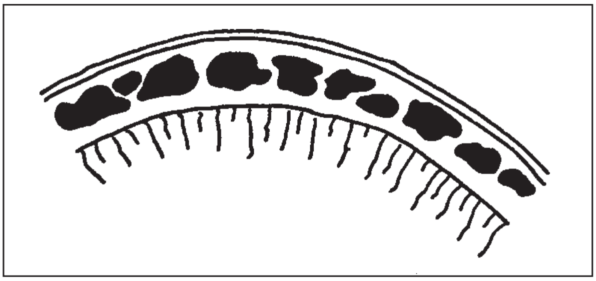


Fig. 2: Fibre bundle of low-grade flax.

Degree of resolution: The term should be explained more clearly with Fig. 3. This concerns a schematically

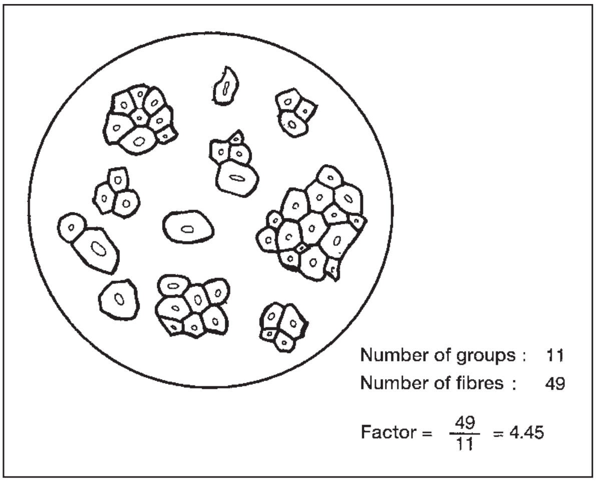


Fig. 3: Degree of resolution of flax fibres.

represented cross-section of flax fibres. In order to calculate the degree of resolution, the total fibres per cross-section and the number of connected fibre groups G is counted. The number of groups is divided by the total number of fibres F and this then gives a metric measurement for the degree of resolution A.

$$A = \frac{F}{G}$$

The larger this metric measurement, the lower the number of fibre groups is and the lower the degree of resolution. An image analysis system can in future take over this counting and calculation process. Another important variable is the dispersion of the degree of resolution. A large dispersion means that a batch contains both individual fibres and a multitude of fibre bundles. But the more irregular a fibre sample is the worse the spinning properties and later also the thread uniformity are. The degree of resolution is also a measurement of the quality of the fibre degradation. The worse the degradation (from rotting and similar), the larger fibre bundles the fibre sample contains. Coarse and short fibres, so-called stick fibres, always lead to processing difficulties in spinning.

Divisibility: As the degree of resolution varies with increasing mechanical treatment, another parameter is important. This is the divisibility, i.e. the propensity of a fibre sample to be refined in the ongoing processing stage. The better the divisibility the more regular the fibre sample is with increasing processing and the less problematic the spinning is. The divisibility T is calculated via the change in the degree of resolution, which is measured before (Av) and after (An) a mechanical process. The higher the divisibility the better the ability is to process in the spinning later.

$$T = \frac{An}{Av}$$

Flax processing Flax is a typical example of a renewable raw material. There are few plants which can be employed and used so completely, and in such diverse areas. In the preparation of the flax straw, long fibres and short fibres occur, with the long fibres being useable in all textile areas, depending on their quality. Besides clothing purposes, they can also be used for geotextiles, insulation materials and (in conjunction with synthetics) preforms for vehicles.

Approximately 100 days after the seed has been collected, the flax straw is harvested at the point of yellow-green ripeness. In order to harvest the bast fibre bundle in its full length, the flax is not mown, but pulled out with the roots. Harvesting takes place with specially constructed flax-pulling machines. Separating the bast fibre strands located in the flax stem requires extensive processing (Fig. 1). Here, the fibre bundles have to be separated from the other constituents of the stem. Since flax – unlike other natural fibres – does not have an inherent length and fineness to start with, the way in which the bast fibre bundle is exposed or split is decisive for the subsequent appearance of the fibre and for the running characteristics during spinning.

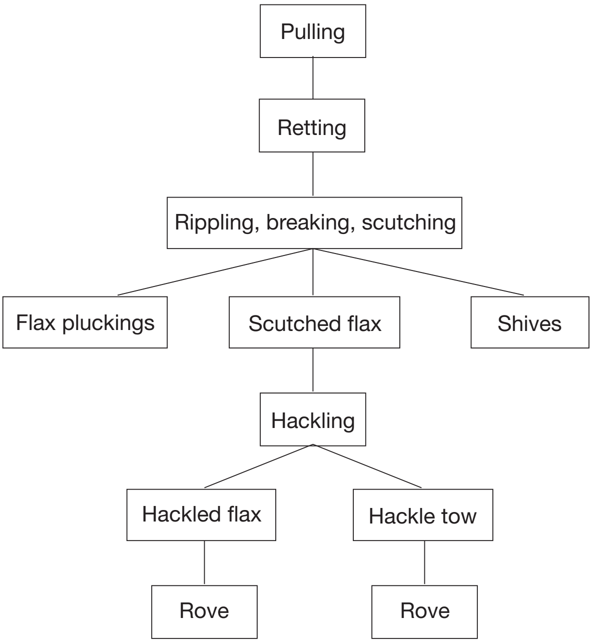


Fig. 1: From flax straw to linen fibre.

From time immemorial, the mechanical preparation has been preceded by a biological or chemical process that decomposes the pectin-containing lamellae of the plant layer surrounding the fibre, so that after this cement substance has been dissolved or partially dissolved, the subsequent separation of the fibre bundle can be carried out carefully. The technical extraction of the flax fibres is divided into several sections, from the preparation of the flax straw, the so-called flax retting, to the partial solution of the middle lamellae (vegetable glue), to the mechanical preparation for exposing and dividing the loosened fibre strands, and for removing the remaining stem parts. The following degradation methods are distinguished:

- dew retting,
- water retting,
- microbial degradation methods,
- enzymatic degradation methods,
- steam pressure methods,
- chemical degradation methods,
- tenside degradation.

Lignin has a considerable influence on the quality of cellulose fibre substances. The view is that the role of lignin in ligno-containing plants consists in the formation of cellulose fibres: lignin as a cementing material lends the plant parts a mechanical stability. The lignin content in plant parts that are compressed during growth is considerably higher than in areas that are stretched. However, the role of lignin in the resistance to tearing is not sufficiently convincing, since in the dew retting of flax, a partial decortication takes place, which does not affect the strength of the dry technical fibre, but results in improved spinning performance in the wet spinning process.

The main glue substances of the bast fibres are pectins. They are contained in the composition of all bast connective tissue, and even impregnate the walls of the elementary fibre. During the flax preparation, the pectic substances are subjected to decomposition. The processing properties of the retted flax can be deduced from the degree of decomposition. An increased pectic substance content results in brittleness of the fibre, hardness, and poorer separation properties. This applies both to the dressed bast as well as to the industrially prepared, steam-retted flax fibre. On the other hand, excessive removal of the pectic substances can lead to a breakdown of the technical fibre. Since the pectic substances are highly moisture absorbent, and serve as moisture regulators in the living plant tissue, one can assume that it is expedient to leave a certain amount of pectic substance on the fibre (Table 1), in order to intensify the relaxation processes during softening through storage in water.

Fibre	Component content to absolutely dry material, %						
	Cellulose	Lignin	Wax-like substances	Pectic substances	Nitrogen	Ash	Pectose
Flax	72.9	4.6	2.1	3.7	0.35	0.86	3.3
Cotton	84.3	1.87	1.12	1.21	0.26	1.0	1.73

Tab. 1: Composition of dew-retted flax fibres compared with cotton fibre.

During dew retting and water retting, the fermentation action is specific and leads to elimination of the polyuronic acids from the fibre. In respect of the lignin content, the water-retted fibre is similar to the dew-retted fibre, although more acid-insoluble lignin is contained in the water-retted fibre (Table 2). The steam-retted fibre differs considerably from the dew-retted and the water-retted fibres. The thermal treatment leads, just like the fermenting treatment, to the elimination of the non-cellulose polysaccharides from the bast. However, in the case of the steam-retted fibre, the reduction in the total content of polysaccharides results from the elimination of the pectic substances and hemicelluloses. This treatment does not cause any other significant changes in the ratio of the carbohydrate components in the remaining pectic substances and hemicelluloses; the component composition of the polysaccharides in the steam-retted fibre is similar to that of the initial bast. These two circumstances are evidence of the fact that during the thermo-chemical treatment, a random hydrolysis of the polysaccharides takes place. Compared with the better quality dew- and water-retted fibres, the steam-retted fibre has the highest pectic substance content and polyuronic acid content and a lower amount of hemicellulose. The raised content of polyuronic acid that is present evidently worsens the quality of the linen fibre, since the polyuronic acids are responsible for the formation of cross-linkages between the components of the plant tissue. However, more cross-linking means poorer spinning properties. On the other hand, leaving the hemicelluloses in the linen fibre is evidently desirable, since they contribute towards raising the mechanical strength. The steam-retted fibre is also characterised by an increased content of acid-resistant lignin faction, which because of the brittleness and greater difficulty in bleaching thus caused means a reduction in quality.

Hackled fibre	Bast	Dew-retted	Water-retted	Steam-retted
Ash content, %		1.37	1.01	
Lignin, %	8.4	5.71	5.96	6.3
of which:				
acid-insoluble	–	4.32	4.98	–
acid-soluble	–	1.39	0.98	–
Pectic substances (PS), % of the originally weighed-in amount	6.88	3.03	2.28	4.7
of which in % to PS				
Polyuronic acids	49.42	40.8	50.3	52.4
Hexosans	33.14	43.8	34.2	31.0
Pentosans	17.44	15.4	15.5	14.5
Hemicelluloses (HC), % of the originally weighed-in amount	8.3	7.41	7.14	6.10
of which in % to HC				
Polyuronic acids	18.7	9.4	13.3	17.2
Hexosans	56.3	71.8	69.2	62.4
Pentosans	25.0	18.8	18.4	20.4
Sum total of carbohydrates, % of the originally weighed-in amount	13.4	10.7	9.4	10.8
of which in % to total carbohydrates				
Polyuronic acids	29.69	18.87	21.6	32.6
Hexosans	49.03	64.9	62.1	49.88
Pentosans	21.28	16.5	16.3	17.59

Tab. 2: Analysis results of the chemical composition of flax fibres produced from a uniform section of straw.

Following the conventional treatment (Fig. 2), the dried retted flax is brought in and de-seeded through rippling. Subsequently, the wood layer of the stem is disintegrated by means of a mechanical breaking process, in the course of which it emerges partly as shives, without the pliable fibre bast being damaged. This breaking process is followed by scutching. Here, the broken flax straw is freed of short fibres and any wood parts that may still be attached, so that the bast fibre bundles are exposed. Here, rapidly circulating rails which sit on a shaft, the so-called fly cutters, beat out

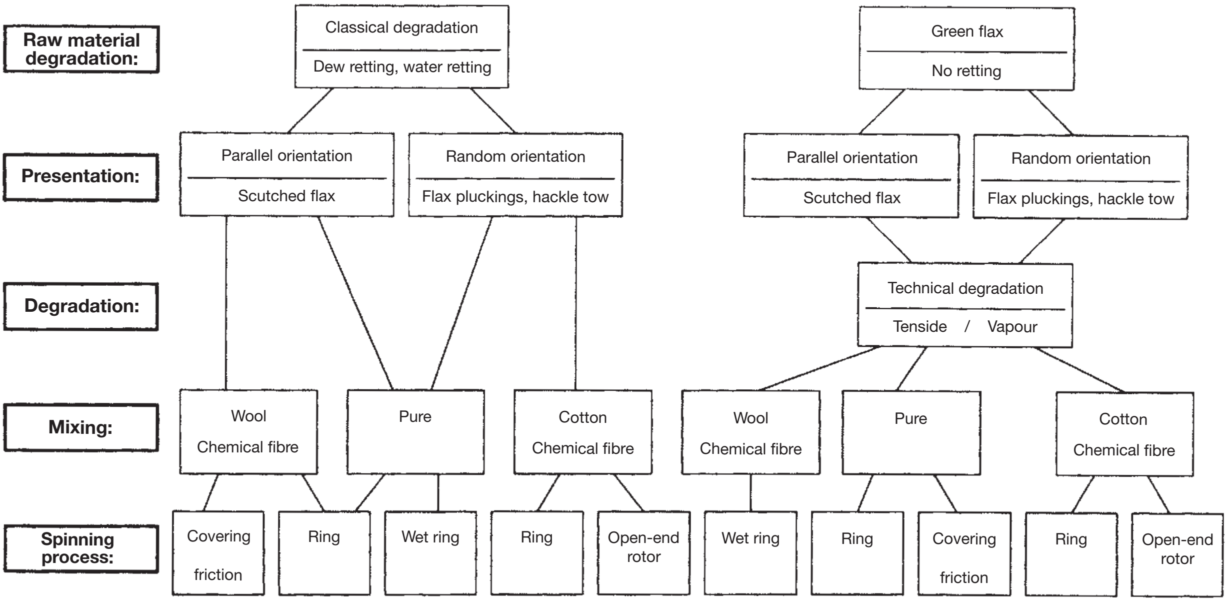


Fig. 2: Examples of types of degradation and processing technology for flax (source: Fischer & Topf).

the shives and the short fibre material (flax pluckings) from the jammed and dangling material. What is obtained is the scutched flax, which is largely free of wood constituents. The preparation processes that have been described can be classified as agriculture, whereas the further processing of the fibre material takes place in the spinning mill.

Refining the still straggly, coarse and unseparated fibres still further, and separating out fibre parts that are too short and weak, is the aim of hackling. This is a type of combing process with faller gills that run perpendicularly downwards on continuous belts, the so-called hackling areas. These have a needle density that increases in the direction of passage, so that as the material passes through, an increasing fineness is achieved. During hackling, high-quality hackled flax is produced, as well as the shorter hackle tow that is once again in random orientation. (source: Wurster, Chodyrew).

Flax stem structure The outermost single-layer cell wall of the stem forms the epidermis. It supports a resistant wax layer, the cuticle. Further in is the cortical layer, in which ca. 20–50 bast fibre bundles are located arranged in rings. Each of these bundles contains ca. 10–30 elementary fibres, which are stuck together within the bundles using pectins. The cortical layer is surrounded by the cambium. After the cambium comes the woody layer, which consists of concentrated wood cells. The innermost fabric layer forms the medulla. In the centre of the stem is a dried out pore, the medullary canal. Only the bast fibre bundles stored in the cortical layer are important for textile processing.

Differences in the form of layers from outer to inner (see Fig.):

1. Cuticle, small thin outer skin with wax coating.

2. Epidermis, outermost layer of water-rich cells with numerous slot openings as breathable pores (30–40/mm^2).

3. Cortical layer made of parenchyma cells, bonded with the so-called starch border as the innermost cell layer.

4. Bast layer made of numerous concentrically arranged bast fibre bundles, in which both the individual fibres mutually and each bundle are bonded with the cortical layer by centre lamellas (→ Flax long-fibre structure). Each bundle is separated from the subsequent one by the medullary ray. The soft bast (phloem) forms the transition to the perforated layer.

5. Perforated part made of transverse walls pierced like a sieve, forms a joint laminated area with the first arising bast fibres as the bast part in the immature stem state (procambium), but lies under the bast layer in the

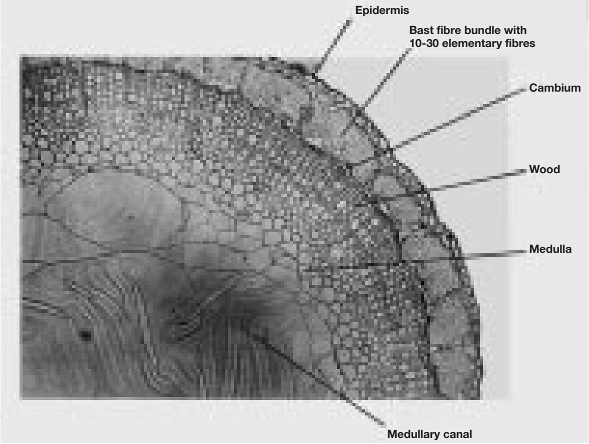


Fig.: Cross-section through a flax stem.

mature state. The part between the cortical layer and perforated part is also described as the vascular bundle or differentiated as the primary and secondary cortex.

6. Cambium (split pin layer), thin growth layer, which continually forms new perforated and wood cells.

7. Wood layer, made of already thicker walled, strongly lignified cells.

8. Medulla layer.

9. Air-filled hollow canal, pushes through a large part of the stem length.

Fibre exposure by (rotting), breaking, scutching and hackling. Extract 730 g of flax straw, 584 g of rotted flax, 184 g of scutched flax and 74 g of hackled flax from 1 kg of flax stems. Other bast fibre stems are similarly constructed in principle. The jute stem contains ordered fibre bundles in medium strength bands made of individual fibres stored closely together in groups, almost always permeated with lignin. In the hemp stalk, bast fibre bundles of varying fineness are formed in succession from different growth periods; fibre wall greatly thickened. On the other hand, the ramie stalk only contains smaller groups of less stripe-formed bundled individual fibres and some isolated embedded individual fibres.

Flax straw The → Flax stem structure is composed of approx. 73% flax straw. The term is also used to describe air-dried flax stems harvested by plucking.

Fleawort Seeds of a Eurasian plantain (*Plantago psyllium* or *Plantago indica*) which, after aqueous swelling, are still used from time to time as a finishing agent for lustre finishes on plush, silk etc.

Fleece The still coherent wool mass obtained after sheep shearing which is of variable length, fineness and quality. It is divided up into various qualities by wool sorting, e.g. back wool, skirtings, bellies and crutchings (DIN 60 004). The average fleece weighs 7 kg, special breeds yield 10 kg per sheep per shearing.

Fleece wash → Backwash.

Flexibility → Suppleness.

Flexible dye tubes Elastic radial or axial → Dye tubes which are capable of absorbing fibre shrinkage in yarn packages during dyeing.

Flexible roller A flexible pressure roller consists essentially of a special steel outer tube covered with vulcanized rubber and a concentric steel core firmly attached to the roller tube in the centre. Flexible rollers of this type are always paired with a counter roller of conventional construction. The conventional roller deflects under pressure to a known extent. In the case of the flexible roller (see Fig.), which is always installed as a pressure roller, the applied pressure causes a corresponding deflection of the core whilst the roller tube, on the other hand, conforms to the elastic line of the conventional roller. The hardness of both rollers are matched to each other in such a way that they produce the same elastic line across the entire pressure zone. By this means, a uniform nip is achieved across the full width of the rollers without the assistance of compensating forces. The nips of padders with flexible rollers therefore always have a clean cut zero position without the application of compensating forces.

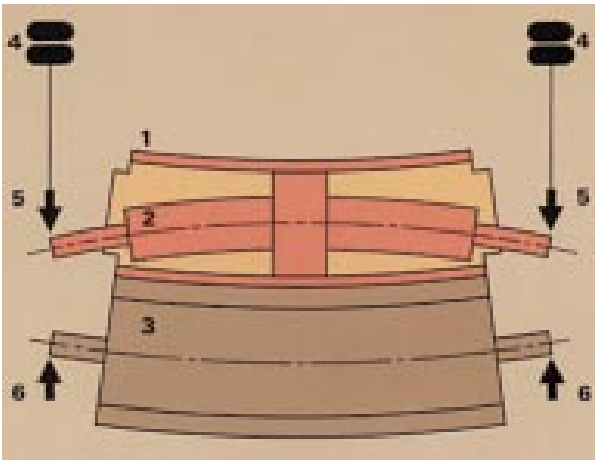


Fig.: Functional principle of a flexible roller.
1 = roller shell; 2 = roller core; 3 = counter roller;
4 = pneumatic pressure loading; 5 = pressure application;
6 = roller bearing.

Flexing abrasion resistance → Abrasion resistance test carried out with the specimen flexed by 90° (→ Flexing fatigue limit).

Results for individual fibres:

Polyamide	100
Polyester, cotton-type	60
Polyester, wool-type (pilling resistant)	15
Cotton	10
Viscose	5
Wool	1

Flexing fatigue limit (Bending fatigue resistance). Fibres, yarns or fabrics are tested by subjecting them to an alternating backwards and forwards bending action at a specific bending or flexing angle (as a rule ±180°) until breaking point under a simultaneous pretensioning load. The result of the test is the so-called flexing fatigue factor or bending resistance factor for which Böhringer has provided the following rounded values:

flax	880
jute	1050
acetate filament	300
viscose filament	2500–7000
viscose spun fibre	800–1400
cuprammonium filament	20 000
cotton	65 000
silk	75 000
wool	156 000
polyamide 6.6	45 000
polyamide 6	500 000

Attention is drawn to the fact that even small variations in the clamping pressure and state of the clamps can produce highly variable measurements. Furthermore, the degree of flexing fatigue is, in principle, dependent on the raw material, yarn type, fabric construction and also the effect of finishes. Low values in this test are indicative of a high degree of brittleness and poor abrasion resistance (especially at the edges of fabrics and in fold areas). Flexing fatigue testing instruments are therefore not only used to evaluate the so-called wear resistance of textiles, i.e. the strength and wear resistance under practical conditions, but also to test the effects of all kinds of finishes.

Flexnip The first high wet pick-up liquor application system developed by Küsters in 1987 (see Fig.). Mainly used for addition pick-up in the pretreatment of cotton fabrics.

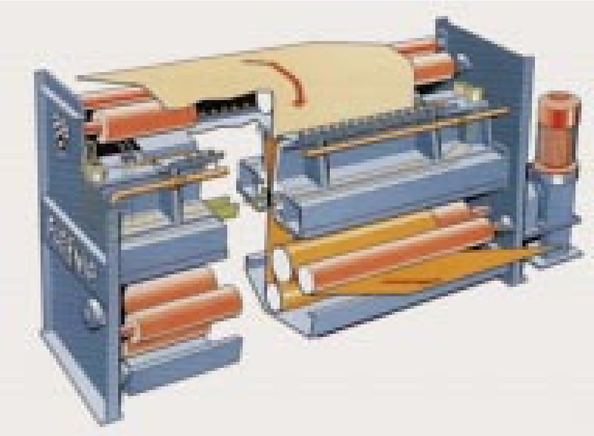


Fig.: Flexnip (Küsters).

Due to the high quantity of liquor retained in the free volume of the fabric after Flexnip application, good levels of whiteness, high absorbency and removal of seed husks can be achieved with a single-stage peroxide bleach.

Flexographic printing A form of → Letterpress printing for the printing of paper or foil, in which the relief rubber or plastic printing plates are attached to a rotary printing cylinder. Mainly spirit-soluble thin printing inks are used to transfer printed images to the substrate which dry rapidly by evaporation of solvent. The process is important for the production of transfer printing papers.

Flexography → Flexographic printing.

Flexometer American NBS testing device for determining bending resistance and evaluating crease-resistant finishes. The torque and the angle of the folded test subject are used to determine the amount of work that is required for folding and unfolding the subject. The bending resistance level during unfolding is used as a measure of crease resistance.

Flexural strength or resistance The force of bending together a single or multi-folded strip of fabric to a specified bending angle, or the permanent and elastic bending together under a specific load (→ Flexing fatigue limit).

Flinserl → Frosting.

Flip-flop mechanism → Dual action.

Flipper Name given to tension-free open-width washing and relaxing machine for woven and knitted fabrics. Control by free-floating rollers with no mechanical drive, super-light rotation due to hydrostatic buoyancy. Almost tension-free cloth passage produces relaxing action due to positive control by floating hollow rollers, whose hydrostatic drive produces extremely light rotation and therefore low-tension material movement. Gravity driven by the downwards path of the liquor-saturated cloth. – Machine maker: Küsters.

Float A control valve used in → Steam traps.

Floating A term used to describe a length of yarn or thread usually on the surface of a fabric lying in any direction between adjacent intersections in the woven or knitted structure.

Floating bell Alternatively bell float. Controller for → Steam trap.

Floating bell steam trap → Steam trap with a mechanical operating mechanism similar to the ball float, but with the advantage that the outlet valve is in the upper area, i.e. outside the contamination zone. Also, steam never reaches the valve because the steam is always beneath the bell (Fig. 1).

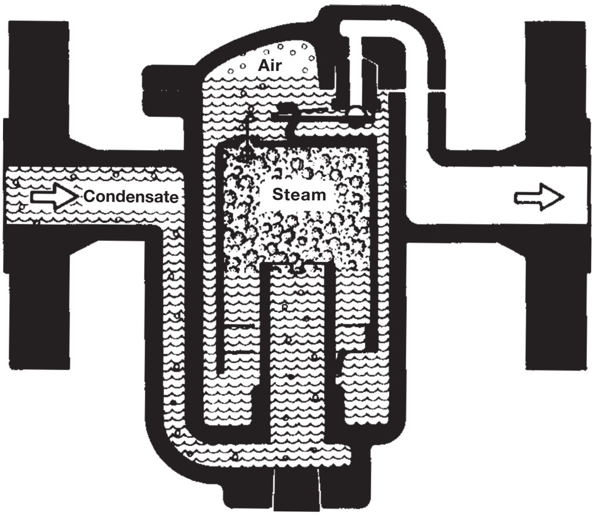


Fig. 1: Method of operation of a floating bell steam trap.

The bell is an open float and cannot be destroyed by water impact like the ball. Furthermore: automatic venting, unaffected by contamination, no loss of fresh steam, easy to check, trouble-free operation with 99% counterpressure. Can be connected in any location, maintenance-free.

Floating of textile materials An undesirable occurrence in dyeing processes due to the use of high foaming textile auxiliaries (wetting, dispersing and levelling agents) and inclusions of air as a result of which textile materials show an increased tendency to float on the surface of the dyebath. The consequences are unlevel dyeings, dye stains and tangling of the textile material.

Prevention: use of antifoams, low-foaming textile auxiliaries, periodic interruption of the seams in the dyeing of tubular knitted fabrics. → floating.

Floating of textile materials in wet processing A problem in which yarn or piece goods float on the surface of the liquor, e.g. at the beginning of dyeing, or do not sink uniformly. The problem is caused by inclusions of air which are slow to escape due to the inadequate wetting out of the textile material.

Floating threads Threads or yarns present in a fabric structure in → Floating.

Float valve A type of → Valve used to control the level of liquid in a vessel.

Flocculation → Coagulation.

Flocculation and precipitation Flocculation and → Precipitation are coupled processes of effluent treatment. Here emphasis is on the colloidal chemistry of flocculation. The poor sedimentation of solid particles formed by precipitation mainly has the following causes:

1. The small mass and the resulting lower precipitation speed of the contaminants.

2. The Brownian motion, which moves the very fine, solid particles in all directions, also against the force of gravity, thereby keeping them in suspension.

3. The analogous charging of the solid particles and colloids in the water causes mutual repulsion, thus preventing their meeting.

The purpose of using precipitation and flocculation chemicals is to overcome these difficulties. Colloids or finely dispersed impurities in the water are usually negatively charged with 15–25 mV. The precipitant cations destabilise the suspended particles by partial neutralisation of their negative surface charge, the effect of the ions increasing with their specific charge. Thus bivalent ions (Ca^{2+}, Fe^{2+}, Zn^{2+}) are better than monovalent, and trivalent ions (Fe^{3+}, Al^{3+}) are better than bivalent. These processes are simply illustrated in Figs. 1–3, in this case with iron ions.

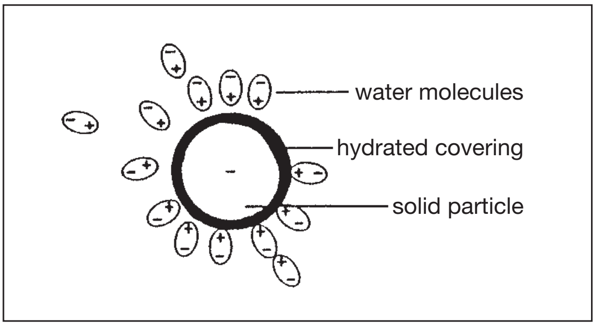


Fig. 1: Hydrated covering of a solid particle in water.

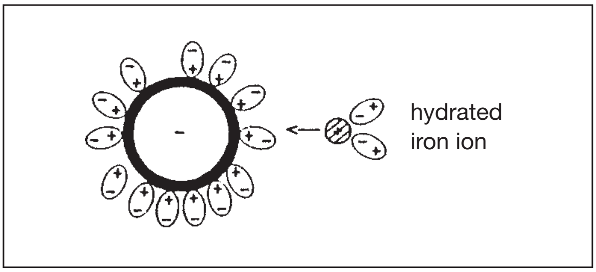


Fig. 2: Admission of iron ions.

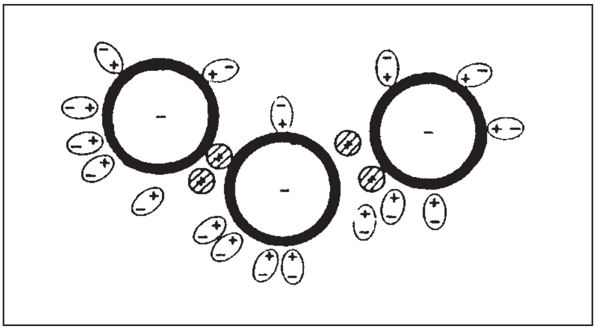


Fig. 3: Flocculation by coagulation.

The electro-negatively acting hydrated solid particles and the electro-positively acting hydrated iron ions collide due to high turbulence (important at this stage), causing partial or complete outward discharging. Thanks to the equalisation of solid particle and colloid charges, these no longer repel each other but adhere on collision, due to electrostatic proximity forces, i.e. they coagulate. This causes the formation of “floccules” with a greater mass and better sedimentation characteristics. At this point, the turbulence is largely undesirable and should be compensated by slowly stirring. Moreover, during dissolution of the metallic salts in the water as precipitant and flocculent, the flocculating metal hydroxide forms as absorbent in a counterreaction to precipitation and coagulation. To promote the formation of the hydroxide floccules, during which the acid components of the salt are released, the alkalinity of the effluent is taken advantage of. In some cases, the addition of a base substance, such as caustic soda or milk of lime, is necessary. The addition of alkali is necessary when ferrous sulphate is used as flocculent, in order to accelerate oxidation of the bivalent iron to trivalent with oxygen (by stirring or aerating).

In their amorphous formation covering a large surface, the hydroxide floccules, which precipitate as jelly-like deposits, absorb the destabilised and flocculated

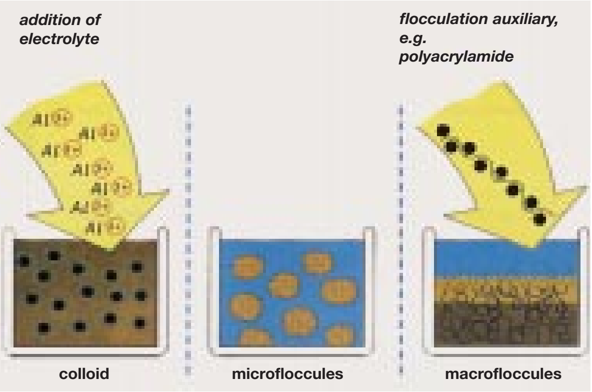
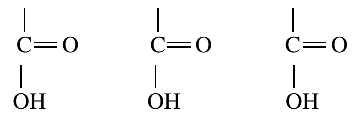


Fig. 4: The chemocolloidal processes during precipitation with aluminium sulphate and polyacrylamide, by courtesy of Röhm GmbH.

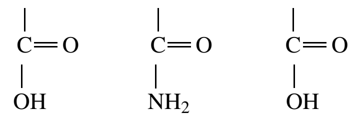
contaminants such as polyphosphates and, above all, dyestuffs. In general, it is usual for the reaction to be effected at the so-called isoelectric point, i.e. at the pH at which charging of the colloidal particles disappears, and the colloidal solution is especially unstable and thus flocculates easily. However, effluent purification does not merely consist of coagulation processes, but is governed by absorption effects for which it can be to advantage for the suspended particles to be charged.

The application of ferrous chloride together with calcium hydroxide has a synergetic effect. Whether this effect is due to the improved absorption properties of the floccules, the formation of associates, the formation of salts of low solubility, or for other reasons, is not certain. The process of flocculation of colloidally dissolved and suspended substances in the effluent is called primary flocculation. If the floccules thereby formed do not have an adequate sedimentation ability, a flocculent can be added. These secondary flocculents are high-molecular compounds which, besides absorption of the primary floccules, cause a further increase in the size of the floccules and thus have a weighting effect, resulting in improved sedimentation properties. Such synergetic flocculents are, for example, compounds on the basis of polyacrylamide (Fig. 4). Depending on the type of effluent, ionic or non-ionic flocculents are used.



$$\begin{array}{ccccccc} -CH_2- & CH & -CH_2- & CH & -CH_2- & CH & - \\ & | & & | & & | & \\ & C{=}O & & C{=}O & & C{=}O & \\ & | & & | & & | & \\ & OH & & OH & & OH & \end{array}$$

polyacrylic acid



$$\begin{array}{ccccccc} -CH_2- & CH & -CH_2- & CH & -CH_2- & CH & - \\ & | & & | & & | & \\ & C{=}O & & C{=}O & & C{=}O & \\ & | & & | & & | & \\ & OH & & NH_2 & & OH & \end{array}$$

polyacrylamide

Polyacrylamide with the carbon amide group ($-CONH_2$) is electrically neutral in an aqueous solution, i.e. is "non-ionic". The carbonic acid groups in polyacrylic acid, which are reduced to sodium salt, dissociate in water, so that a negatively charged oxygen atom remains in the carboxyl group. This results in an "anion-active" flocculent. An important characteristic of such a flocculent is the chain length and, therefore, the number of active groups per molecular unit. A polyacrylamide with a molecular weight of approx. 7 mill. is made up of around 100 000 elements. It therefore contains up to 100 000 active groups. The chemical industry supplies such flocculents with molecular weights of over 10 mill. Their application quantities are very low, being around 1 g/m^3, which is why they are always used in highly diluted solutions. It should not be forgotten, however, that flocculents increase the volume of sludge in the precipitated substances in effluents.

Traditional flocculation plants comprise three separate plant sections for the process stages.

1. Mixing of the effluent with the flocculents and flocculation auxiliaries (comparatively high turbulence and short dwell time).
2. Flocculation (during which there is merely a slow stirring action).
3. Sludge separation by sedimentation.

In the so-called sludge contact process (Fig. 5), either the process stages 1–3 or 2 + 3 are combined, or a specific quantity of sludge is recycled to the flocculation reactor, thus achieving an improvement in the flocculation process and reduction in the amount of sludge.

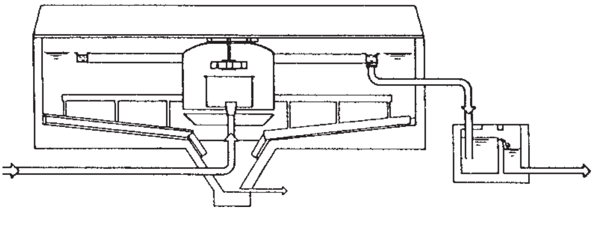


Fig. 5: Reactor, operating by the sludge contact method.

Flock To → Flock; short pieces of monofilament fibre, i.e. short fibre material made of viscose, polyamide, polyester, polyacryl nitrile, acetate or natural fibres (wool, cotton) and frequently also so-called metal flock made from aluminium, brass or bronze powder (see Table) prepared for flocking and flock-printing. The most frequently-used fibre titres are in the range of 0.9–22 dtex, and the usual fibre lengths are between 0.5 and 2 mm. "Glow" or reflective flock is always prepared by static electrical means using electrolytes, and therefore conducts electricity to a certain extent.

Fibre material	Benefits	Disadvantages
Viscose	- Soft, silky surface - Possibility of achieving crush effects	- Moderate resistance to wear and tear, particularly when wet
Polyamide	- High resistance to wear, even when wet - High crush resistance	- Perceptible harder compared to viscose with the same length-to-titre ratio
Polyester	- Very high abrasion resistance, particularly when wet - Easy to dye using disperse dyes, e.g. by sublistatic process	- Very low water absorption property - Harsher handle than viscose
Polyacrylic	- Soft, silk-like surface - Possibility of achieving high colour brightness and colour fastness - Possibility of achieving crush effects - Better abrasion resistance than viscose, particularly when wet	- Susceptible to crushing - More susceptible to abrasion than polyamide and polyester
Modal	- Flock of modal fibre is comparable with polyacryl nitrile flock, with the additional advantage of having low flammability	

Tab.: Raw materials for flock production

Manufacture:

1. By grinding in the ball mill, cotton and wool, occasionally viscose, in average lengths of approx. 0.2 to 0.3 mm.

2. By precision cutting with a precision of 0.1 mm. Usually standard lengths of 0.3, 0.5, 1.0, 1.5, 2.0, 3.0 mm etc. The cut edges should be right-angled and clean-cut. As well as synthetic fibres, viscose filaments are used. In fine filament capillaries and lustrous, e.g.: 0.3 to 0.5 mm for simulated suede, 0.8 to 1.0 mm for simulated velours, 1.2 to 1.5 mm for simulated velvet.

This kind of flock is available in many different shades with customized dyeing and finishing, including water repellent etc. to meet all specifications. Defective short fibres create potential sources of faults, e.g. overheating in milling (creating a grey shimmer, as though it was dusty), blunt cut ends, fused cut edges (because of knife being too high), kinked or bent flock. For this reason a perfect cut and careful screening is required.

Flock prepared by a special process is almost always applied in the textile sector by electrostatic or electrostatic/mechanical means. The main tasks of the flock adhesive are to retain the flock fibres during flocking in order to achieve a high flock density and provide the required anchorage once the adhesive has been applied (Fig.). The variety of effects that can be produced by flocking extends from fine velour, e.g. for clothing, to velvet or suede-like decorative fabrics and simulated fur and floor coverings.

Flock adhesive From a chemical point of view, flock adhesive may be categorized as follows:

I. Thermoplastics:

a) Polyvinyl acetate

b) Polyacrylic acid ester

c) Polyvinylchloride

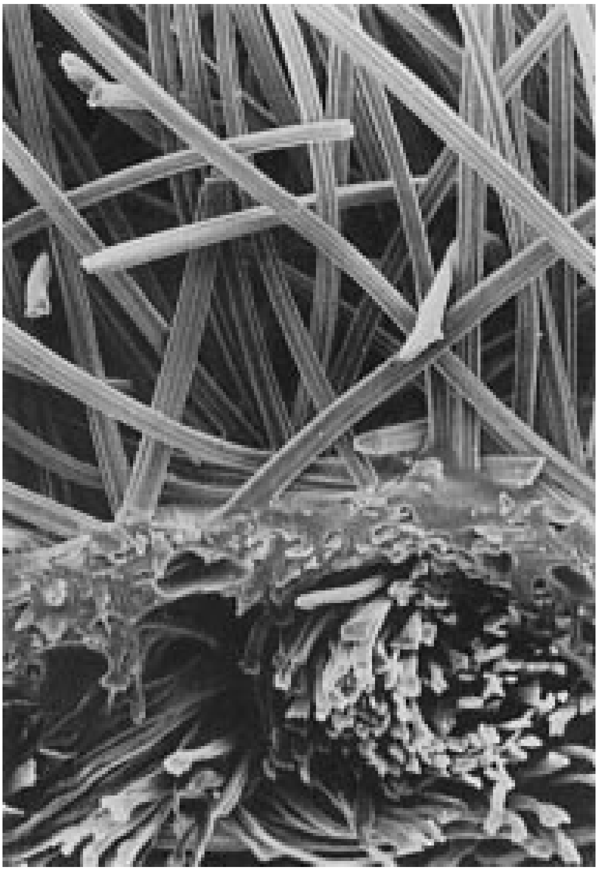


Fig.: Scanning electron micrograph of the fibres anchored in adhesive by flocking.

d) Copolymerisates such as ethene vinyl acetate, vinyl acetate acrylic acid ester, acrylic acid ester-acrylic nitrile

II. Duroplastics:

a) Phenolic resins

b) Formaldehyde/urea resins
c) Melamine resins
d) Epoxy resins
III. Elastomers:
a) Polyurethane
b) Polybutadene styrol
c) Polybutadene acryl nitrile
d) Polyisoprene
e) Polychlorophene
f) Polysiloxane.

Curing by solvent evaporation: In the case of polyacrylic acid ester, the acrylic acid must be esterified with alcohols of longer chain length if the side chains resulting in the polymer are to act as spacers, keeping the main chains apart in the sense that solvents (as a constituent of the adhesive) can easily diffuse between the chains and swell the polymer. When the adhesive sets, the solvent evaporates.

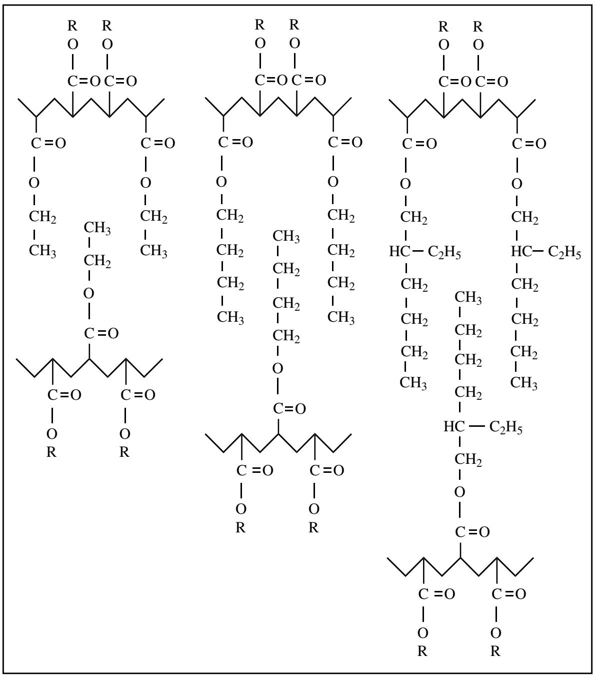


Fig. 1: Acrylic acid ester adhesive.

Condensation curing: if cross-linking or self cross-linking acrylic acid esters are used, these contain, as well as the ester, N-methylol acrylamide in the chain, a compound that has terminal hydroxyl groups that react with each other to separate water when heated and form a covalent bond (ether crosslinking), provided that two such hydroxyl groups are close enough to each other from a purely spatial point of view (Fig. 2). It is natural that such cross-linking occurs more easily with short side chains and greater molecule chain packing density, and it therefore becomes clear that a cross-linked acrylic acid and methacrylic acid methyl ester has the best solvent fastness but at the same time also has the harshest handle of the acrylic acid esters. This example shows that there can be no dry-cleaning resistant acrylic acid 2 ethyl hexyl ester, since the main chains are far apart and cross-linking is almost impossible. This means that a compromise always has to be made between softness and handle on the one hand and solvent fastness on the other.

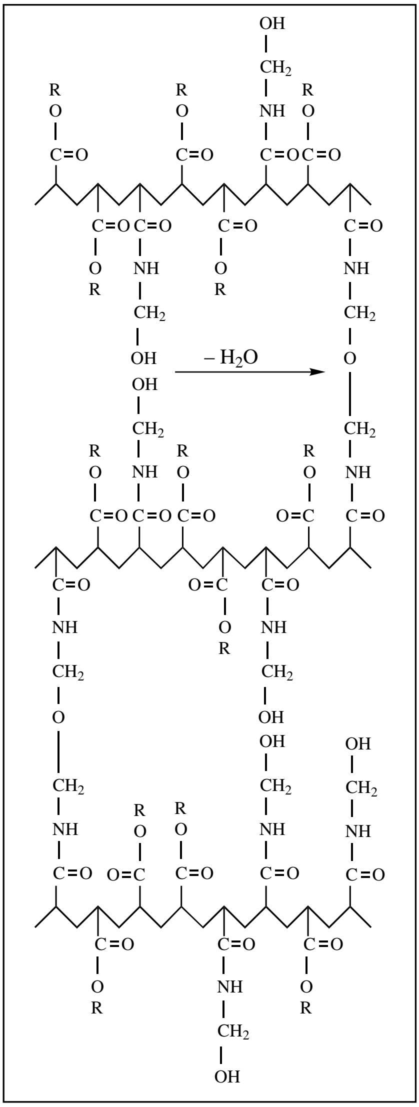


Fig. 2: Condensation

Polyaddition curing: Polyaddition, shown in Fig. 3, between an epoxy resin and an amine, progresses in such a the way that the terminal ethene oxide group in the resin reacts with the amino group of the hardener (polyamine, diamine etc.). This in turn creates a network of covalent links that give the resin formed more strength and resistance to modification, since the mobility of the segments in relation to each other declines and the entire system becomes more rigid.

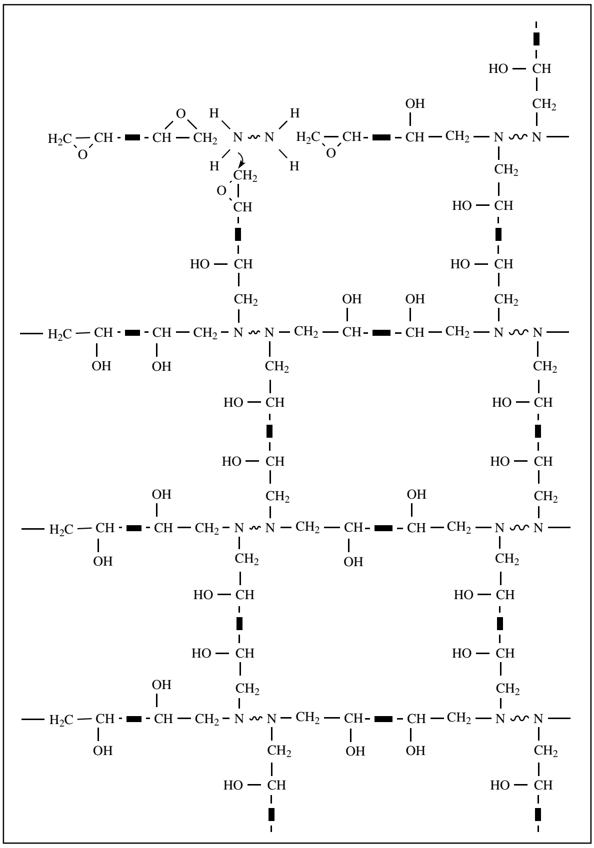


Fig. 3: Epoxidic cold cross-linking.

A typical addition process is the creation of polyurethanes from isocyanates and bivalent or polyvalent alcohols (Fig. 4). The link between various molecules in a diisocyanate with a trialcohol is evident between terminal –N=C=O and OH groups that react with each other as shown in the previous example by means of polyaddition and form covalent bonds. Here too a three-dimensional network with good chemical resistance is formed (source: Stukenbrock).

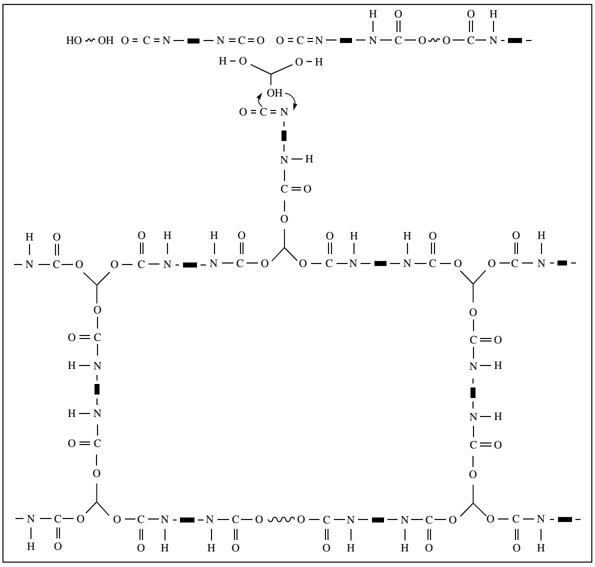


Fig. 4: Creation of polyurethane.

Flock coating → Flocking.

Flocked carpet → Contract carpet produced by → Flocking on to a substrate consisting of a ground fabric, nonwoven, or rubber sheeting. The applied flock is in the form of, e.g. short cut polyamide fibres.

Flocked fabrics → Flocked textiles or textiles with → Flock yarn.

Flocked textiles These are defined by the German standard DIN 60 000 as fabrics in which textile fibres are bonded at one of their ends to a textile or non-textile base material by means of an adhesive. → Flocking, flock coating.

Flocking On the market there is a variety of aqueous-based acrylic emulsions, which meet the demands of adhesives for the textile flocking industry. Films of these emulsions range from the very soft and elastic to firm. All have excellent adhesion to a wide variety of substrates. Durability, including excellent solvent resistance, along with the softness of hand, can be had by proper selection of grades. Simple formulation and subsequent ease of clean up are additional advantages of these products.

The beater-bar flocking machine was patented in 1938 by F. L. Foster (U.S. Patent 2,128,811). It was discovered that if freshly flocked fabric were beaten on the underside, the fibres would become more deeply embedded in the adhesive and would acquire a more vertical orientation. In beater-bar machines, adhesive-coated fabric passes over a series of polygonal bars that spin at high speed, spanking the underside of the fabric as they rotate, making it vibrate up and down very rapidly. Flock is sifted down onto the adhesive-coated surface and moved into an erect postion by a slight electrostatic field. Continued beating works the fibres well into the adhesive. Although the fibres are embedded deeply in the adhesive, many of them are oblique rather than perpendicular to the surface. Flock density is usually restricted to about 4650 fibres per cm^2. The basic elements of a beater-bar flocking machine are shown in Fig. 1.

In machines designed for electrodeposition of flock, the adhesive-coated fabric passes between two oppositely charged grids, impelling the fibres to become embedded into the adhesive. Fibres that are blocked from attaching themselves the the adhesive fly back to the pole from which they originated. See Fig. 2 for a diagram of electrostatic flocking equipment.

There are two types of flocking equipment in use: Alternating Current and Direct Current. In the alternating current machine one of the two grids is connected to an alternating current generator while the second grid is grounded. The flock particles travel through the

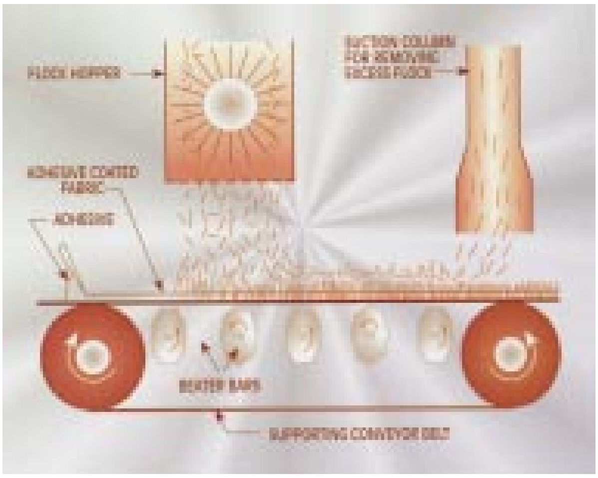


Fig. 1: Beater-bar flocking.

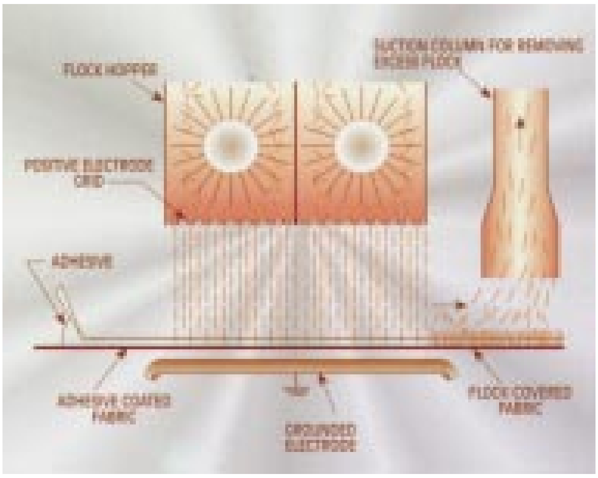


Fig. 2: Electrostatic flocking.

magnetic field oscillating toward the adhesive coating, trying to adjust to the varying field being created. These machines can operate at very high speeds. In the second type of machine, using direct current, the two poles are oppositely charged and the flock particles tend to travel and embed themselves perpendicular to the adhesive layer. Greater flock density can be achieved with this method than with the alternating current equipment. In practice very often both the mechanical and the electrostatic methods are combined.

For applying adhesive knife coating is the most common method employed. Speciality fabrics with a continuous repeated pattern are usually produced by printing the adhesive on the substrate. The level of adhesive applied depends on the length of the flock used as well as on the end-use of the fabric itself. Suede and velvet-type flocked fabrics are ususally prepared with precision-cut rayon or nylon flock which ranges in length from 10 to 20 mm. Closely woven fabric such as cotton sheeting is usually used as a sustrate. Wet adhesive thicknesses of 0.15 to 0.3 mm have provided a durable bond for fibres in this range. This thickness is equivalent to 40 to 80 gms of resin solids/m^2.

When the substrate for flocked fabric is jute or some other open material, conventional thickening alone may not be sufficient to provide an even adhesive layer. In such cases, a two-coat adhesive system is required. A base coat or scrape coat is applied and dried, but not cured, which will fill in the interstices of the weave and give a level base for the application of the flock coat. The base fabric can also be calendered to make it smoother. Producers of flocked carpet commonly use a base coat of about 0.25 mm. For this application, flock fibre is usually nylon from 30–50 mm long. Total film thickness (including the base coat) should range from 0.5–10 mm.

To improve hand Rohm and Haas has developed a crushed foam basecoat. This type of basecoat is capable of producing a superior hand and can be used with virtually any substrate. A Primal TR-934TK based adhesive can be used in conjunction with a crushed foam basecoat to produce a durable flocked fabric with superior hand – a hand that will remain unaltered after drycleaning and flexible during exposure to cold weather. In the past, a typical – though not totally adequate solution to this problem has been the addition of plasticiser. Although this results in a softer hand at virtually all temperatures, the most efficient plasticisers are completely removed in a single dryclean cycle. There is also a limit on the amount of plasticiser that can be used. Excessive amounts will cause a reduction of the internal cohesion of the adhesive, resulting in a reduction of dry and wet abrasion resistance.

Crushed foam can be used on low-yield nylon, low-yield acetate and tricot knits, all fabrics that were formerly considered either too open or too irregular to be used for flocking. The soft flexible foam fills in all irregularities in the substrate with virtually no strike through. A crushed foam formulation based on Primax 210 is recommended for the basecoat. Primax 210 was designed specifically to withstand the higher shear encountered in foaming devices. It provides a good balance of properties including a soft, non-blocking coating which is durable to laundering and drycleaning and good low temperature flexibility without the need for external plasticiser. Because Primax 210 is not self-reactive, a crosslinking agent is used. Thickening is achieved by neutralisation with ammonia.

Foam flocking adhesive technology is an expansion of the crushed foam technique except that when the foam is applied to the fabric and flocked, the dried foam is not crushed. The advantages gained by foaming the adhesive are that it limits the penetration of the foam into the fabric substrate, yielding a soft, aesthetic hand and tends to "bridge over" the interstices in loosely woven fabrics minimising strike through. It also retains a degree of air permeability which is important in upholstery and apparel applications as the foam is usually blown to a density of 1.5 gm/cc (a 2 to 1 blow-up) and not crushed.

Before application to the fabric, the foam should have a consistency similar to that of aerosol shaving cream. Over the fabric, the gap setting of the metering knife (or stationary roll which is frequently employed for the same purpose) should be approx. 0.4 mm to give a dry add-on of approx. 20 to 25 dry g/m^2.

Immediately after coating, the fabric should be put into a tenter frame. The tenter frame carries the fabric through an oven at a temperature of 120°C for 60 seconds. An accurate schedule must be maintained since overdrying will cause problems in crushing. The foam will crush best with a moisture content of 5 to 10 percent. High temperatures should be avoided in the initial stages of drying to prevent "mud-cracking". High air turbulence in the oven should also be avoided, particularly when open fabrics are being coated. In cases of extreme turbulence, it is possible to flow the foam coating right off these fabrics.

After the foam is dried, it can be crushed. The best method of determining proper conditions for crushing is to squeeze the coated surface between the fingers. If the foam is overdried, it will spring back; if under-dried the foam can be pushed off and a wet layer will be obvious at the bottom of the coating; if properly dried, the foam will crush readily and stay crushed when the pressure is removed. The crush rolls are similar to a pad mangle configuration, although the top roll, which crushes against the coating, is frequently metal. A cleaning doctor may be mounted on the top metal roll. The total pressure applied for crushing will vary depending upon the width of the goods (which can vary from 1 m to 2 m) and the type of foam coating being employed. Crush roll pressures generally range anywhere from 50 to 70 Kg/Linear cm total pressure on the full width of the goods. The flockcoat formulation based on Primal TR-934TK can then be applied to the crushed foam basecoat by any of the standard application methods.

The resistance of flocked fabrics to drycleaning is often evaluated by AATCC Test Method – 1963T, "Durability of Applied Designs and Finishes". In this test, samples are subjected to 30 minutes of tumbling in the Launder-Ometer at room temperature in a stainless steel container with perchloroethylene and 100 stainless steel balls to simulate the kind of mechanical action that occurs in a drycleaning machine. The samples can then be examined visually or weighed to determine the extent of flock lost. Commercial coin-operated drycleaning machines are often used where a Launder-Ometer is not available.

The cold temperature flexibility of a flocked fabric is determined by measuring its drape flex at a specified temperature in a cold box. A wide variety of factors affect cold flex, including substrate used, direction (warp or fill) in which the measurement is made, the nature and amount of basecoat and flockcoat adhesive applied and the presence of a plasticiser in the system. Cold flex is measured by the Cantilever Bending Method as described in U.S. Government Test Method No. 506. In this test, a 2.5 to 15 mm specimen is mounted flockside up on a Drape-Flex Stiffness Tester set in a cold box at a controlled temperature. The sample is pushed slowly off the edge of the stiffness tester until it bends under its own weight to an end point angle of about 45°. The length in inches which the sample must be pushed before meeting the 45° angle is defined as its cold flex at a given temperature. (The test should be done on both the warp and fill directions and the average of the two measurements taken as the fabric's cold flexibility). Just what constitutes an acceptable cold flex is debatable. However, all flocked fabrics will feel considerably stiffer to the touch at –30°C than they do at room temperature. In research done at Rohm and Haas, a cold flex value of 3.5 at –30°C is considered to be the maximum acceptable value.

A specified number of cycles in an automatic washer (drying between cycles) at 60°C are used to test the durability of flocked fabrics to home laundering. A half cup of detergent and a ballast of eight terry cloth towels should be added to the load. As with the durability to drycleaning test, the samples can be examined visually or weighed to determine the extent of flock lost.

The abrasion resistance of flocked fabric depends on the abrasion resistance of the flock and the ability of the adhesive to retain the flock during abrading action. The sample fabrics are conditioned for 24 hours at 20°C and 65 percent relative humidity and then tested on a Taber Abraser. The abraser should be fitted with H-10 wheels and 500 gram weights and run for 500 cycles. Although these are severe conditions, they can serve to differentiate between the different variables present. The test can also be run on fabrics which are still wet after washing or drycleaning.

Flocking adhesive → Flock adhesive.

Flocking, flock coating Also known as flock pile process and → Flock printing. These are surface finishing techniques for the comparatively inexpensive production of high quality suede, velvet, velour or imitation fur effects (→ Bonded fabrics) as well as floorcoverings (see Fig.). Flocking methods include several process variants.

(Prerequisites for the base fabric are: well desized material if, e.g. woven cotton; surfaces to be as smooth and compact as possible: unlevelness results in unsatisfactory flock effects). The main processes in flocking are as follows:

1. Application of adhesive: e.g. by squeegees, rollers, screens or spray methods. The adhesive (bonding

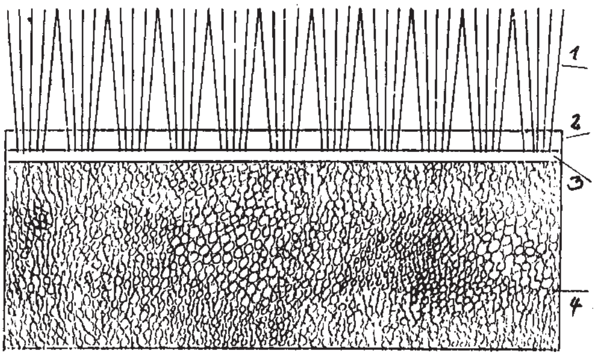


Fig.: Structural diagram of a flocked textile floor covering.
1 = pile layer; 2 = adhesive; 3 = textile substrate; 4 = foam back.

agent, binder) must make good contact with the textile surface without penetrating too far into the material (to maintain flexibility). Consumption of bonding agent is approx. 130g/m^2.

2. Flock application: the flock is applied from above the material or, against the force of gravity, from below the material (for moulded articles). Flocks of precise staple length and titre, a flock moisture content of approx. 13% and dyeings fast to boiling (spun-dyed flocks) are essential prerequisites for optimum results in flocking.

3. Drying: the drying conditions are dependent on the requirements of the particular bonding agent used. Drying is generally carried out at approx. 70°C (solvent-based adhesives) for 3–8 min. Suitable drying units include steam-heated warm or hot air tunnel driers, air jet driers, chamber driers or loop driers, as well as cylinder or plate-contact driers and infra-red radiation in combination with hot air.

4. Final treatment: removal of excess flocks by brushing with brush rollers together with a mechanical suction unit.

→ Flocking processes.

Flocking processes According to the present state-of-the-art, the following methods are used for flocking:

- mechanical,
- pneumatic,
- electrostatic,
- combination of mechanical/electrostatic,
- combination of pneumatic/electrostatic.

According to the principle of mechanical flocking, the flocks are, as a rule, supplied from a dosing device by a brush system and their anchoring in the bed of adhesive is improved by the use of rotating polygonal metal rods (beater rolls) underneath the substrate. The metal rods, which rotate at high speed, cause the material to vibrate continuously within the flocking zone. Purely mechanical flocking processes are, for the most part, hardly ever used in practice nowadays. In pneumatic flocking, the flock is supplied from a dosing device and blown on to the layer of adhesive with the aid of an air current. Alignment of the flocks on the substrate is not achieved with either of these methods and they are therefore only suitable for the application of ground flock.

Electrostatic flocking is entirely different from mechanical or pneumatic methods. The physical principles of electrostatic flocking are based on the attraction of unlike, and the repulsion of like charges. Electrostatic forces are therefore produced on long-shaped particles, e.g. flocks, which are capable of carrying electrical charges (Fig. 1). The fibres, which have become charged by contact or ionization, are subjected to a force in the strong electrical field which causes the fibres to move in the direction of the oppositely-charged electrode. During this movement, the fibres are oriented in the direction of the force line and are separated from each other due to the repulsion of their like charges. The fibres are shot into the adhesive film previously applied to the substrate surface being coated, which functions as the opposite electrode, where they are anchored in the aligned state. The electrical charges are discharged over the adhesive film. Those fibres which have not been able to penetrate into the bonding agent fly back to the other electrode after charge reversal has taken place and participate in the flocking process once more. The purely electrostatic process is mainly used for the flocking of made-up garments or moulded articles.

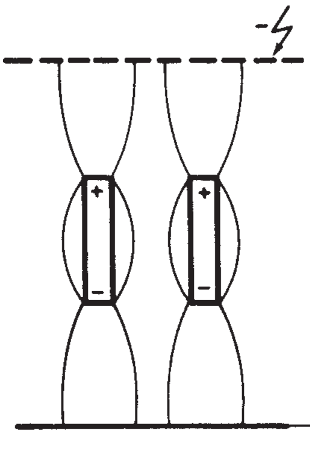


Fig. 1: Orientation of flock fibres in an electrical field.

In combination processes, i.e. electrostatic/mechanical resp. electrostatic/pneumatic, the characteristic features of both techniques are combined. In the first case, the electrostatic process is assisted by dosing the flocks with a brush system (Fig. 2) and vibration of the substrate (using beater rolls or vibrators). In the 2nd process, the transport of flocks in the electrical field is supported by a current of air. The electrostatic/mechan-

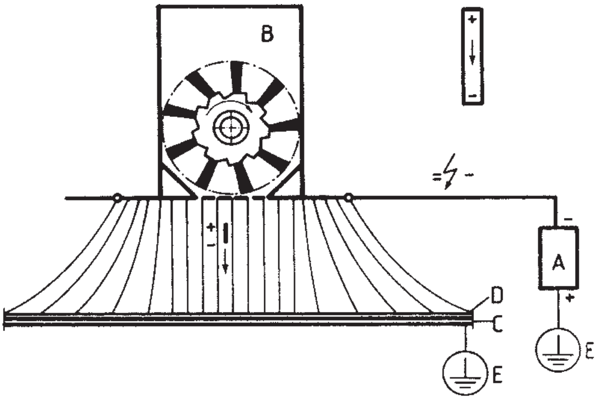


Fig. 2: Flocking plant with high-voltage source (A) and metering system (B).
C = goods; D = adhesive; E = earth electrode.

ical combination is the standard flocking process for continuous webs of fabric. Because of their geometry, the electrostatic/pneumatic process is often used for flocking hollow articles where the use of purely electrostatic flocking would result in unsatisfactory flock densities (source: Brenner and Römpp).

Flock printing Once the adhesive has been applied to the entire surface of the substrate, i.e. including the motif, and this has been produced in the flocking zone using templates, sharpness and resolution power are established by flocking. Flocking may be performed in a downward or upward direction with the parameters of the flocking process determining the sharpness of the contours of the flocked motif. When the flock motif is produced by downward flocking (Fig.) flock 1 is on the upper electrode 2, which is in the form of a screen. During flocking the screen makes oscillating movements on a horizontal plane. The substrate with the adhesive 4 is on the lower electrode 3. The template 5 with the openings 6 for the flock is between the substrate and the high voltage electrode.

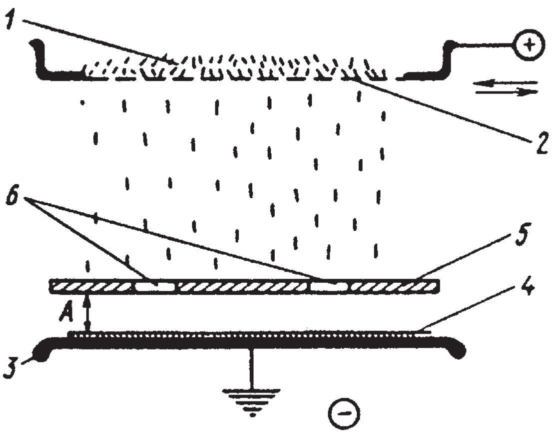


Fig.: Schematic diagram of a laboratory apparatus for flocking using the downward method (explained in text) for flock printing.

In upward flocking the substrate with the adhesive on it is attached to the earthed upper electrode. The flock is on the lower electrode which is connected to the high voltage source. Between the electrodes there is a template containing slits or openings in the shape of the motive. The force of the electrostatic field causes a flock particle that has become charged by contact with the high voltage electrode to be attracted to the earthed electrode. On the substrate these particles can only reach the electrode through the openings in the template. The flock fibres form the motif by being anchored to the adhesive coating. Subsequently they become fixed by the condensation of the adhesive. The sharpness of the flock motif mainly depends on distance A between the substrate and the template. → Flocking.

Flock radiator → Flocking.

Flock silk Less valuable natural silk such as silk waste →: Bourette; Frisons.

Flock transfer printing A process for the individual application of flock patterns to e.g. ready-made garments such as T-shirts. No after-cleaning is required although the preparation is laborious as far as the printing technique is concerned: a flocked release paper is screen printed with a single or multicolour design first of all (Figs. 1 + 2).

Fig. 1: Printing of flock paper with dye paste based on a special printing recipe (Tubi trans. CHT).

Fig. 2: Completed print in three colours on the flocked ground (Tubi trans. CHT).

Fig. 3: Adhesive printing (Tubi trans. CHT).

Fig. 4: Application of hot-melt granulate (and intermediate drying of the adhesive print) (CHT).

Next, a cover adhesive is then also applied by screen printing (Fig. 3). It is most important here to ensure that the flock is only surface printed with adhesive in this operation, i.e. the adhesive layer must not penetrate through the flock. Immediately afterwards, a hot-melt granulate is strewn on to the adhesive layer whilst still wet (Fig. 4) before intermediate drying. Excess granulate is removed by brushing after the material has been dried (Fig. 5).

Fig. 5: Intermediate cleaning (dry) to remove the excess granulate (source: CHT).

Fig. 6: Final flock transfer print (source: CHT).

The print paste/s and dye/s must then be fixed by condensation since the fastness achieved after subsequent transfer to the garment by hot ironing is dependent on this stage. The final transfer is obtained by placing the flock print (paper side upwards) on the substrate and subjecting it to heat in an ironing press (120°C for at least 10 s). The spent paper is then peeled off leaving the flock transfer behind (Fig. 6).

Flock yarn Velvet-like polyamide-based compound yarn, manufactured using a carrier thread with a firmly bonded adhesive sheath consisting of almost right-angled radial flocking. The flock cannot be removed without damaging the core thread = high abrasion resistance, resistance to shedding, resistant of high-frequency fusion, easy to clean, tetrachloroethane resistant. Used to add texture to woven fabric, warp-knitted fabric and knitwear with high-bulk yarns, as an appearance, to impart visual, handle and abrasion-resist properties for raised and velvet-like areas, particularly car upholstery, upholstered furniture and decorative materials.

Floconné (Fr. flocon = flock). A term used for thick, soft double fabrics (900–1000 g/m^2) made from carded yarns produced mainly with high-grade merino wools. The characteristic appearance is achieved by means of a separately picked 3rd weft yarn, the flock weft, which floats lengthways, and is subsequently raised (it is therefore also referred to as “napped cloth”) which gives rise to flock-like fibre tufts on the surface of the fabric. Depending on the weave, it is produced with rib, diagonal or herringbone effects; wool or piece-dyed. Used for high quality men’s coats.

Floorcoverings → Textile floorcoverings.

Floorcoverings, textile → Textile floorcoverings.

Floret silk → Schappe (silk).

Florida earth A → Bleaching earth originating in Florida.

Floss (Duvet, Fiochetti, Pelosität). Partially fluffy silk, caused by stray drops of secretion from the silk worm or as a result of aberrant spinning process, localized fluffing during the degumming process, effects of wear etc.)

Flotation (French: flotage = floating on top), term derived from ore preparation where flotation is used for concentrating slurries and flotation agents increase the water-repelling character of metals, so that they escape to the surface of the water, so to speak, in air bubbles when air is blown through the water and lighter fractions are separated from heavier fractions (Fig.). Fibre mixtures can also be separated in a quantitatively viable way using this method (margin of error only ± 1%), provided that the relative density of the individual components differs by at least 0.08 g/ml. Separation takes place using inert solvent with a relative density between that of the fibre components. For example, 100 g of fine, cut fibre pieces no longer than 0.5 mm and dried at 105°C is mixed with the solvent. After a settling period, the heavy fibres sink, and the floating, lighter fibres collect on the surface. The two fractions can now be determined separately after removing the solvent by weighing. Test apparatus has been designed to accomplish this (glass tube with outflow on the side at the top). A mixture of tetrachlorocarbonate (density 1.6) and alcohol (density 0.79) or xylol (density 0.86) for example is suitable as a separating fluid.

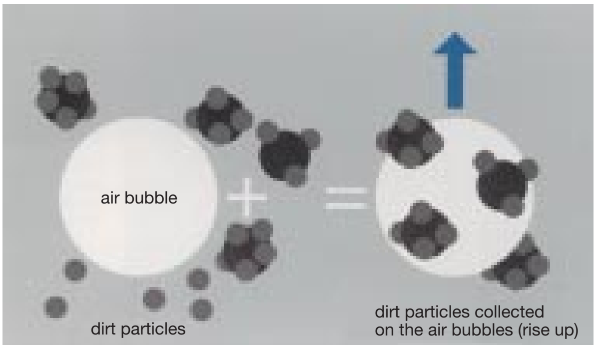


Fig.: Basic principle of flotation: fine particles collect on air bubbles, and are carried by them to the surface, where they are skimmed off.

Fibre group classification:

I. Synthetics (density 1.16–1.20) polyamide, polyacryl nitrile, without polyester.

II. Protein fibres and acetate fibres (density 1.27–1.32) with wool, silk, protein man-made fibres, acetate fibres.

III. Cellulose and polyester fibres (density 1.40–1.53) with natural fibres (wool, flax, jute, hemp, ramie), regenerate fibres (viscose and cupro fibres) and polyester fibres.

IV. Mineral fibres (density 1.90 and above).

Flour → Locust bean flour.

Flow characteristics of printing thickeners and print pastes The tack of printing thickenings and other viscous pastes is a measure of their thread-forming properties (see Fig. 1).

Fig. 1: Flow characteristics of print pastes demonstrated on an ACS datacolor metering valve.

Such pastes are correspondingly described as having short or long flow characteristics. The longer a thread can be pulled from a paste, the higher the tack value of the thickener. The tack value is dependent on the viscosity but is not identical to it since although viscosity rises with increasing concentration, the tack value reaches a maximum at a specific concentration. A practical test can be made with the fingers: by placing a small quantity of the thickener between the thumb and the index finger and slowly drawing them apart, the respective tack value can be estimated by the length of the thread formed. Tests on thickening agents and print pastes have shown that the optimum concentration almost coincides with the maximum tack value. To this extent, the determination of maximum tack value provides an ideal and simple measure for establishing the optimum concentration for good → Print definition (not print penetration). For example, the tack value of starch and gum arabic at first increases with the concentration, reaches a maximum, then decreases again. However, the absolute value of the maximum is quite different for both these thickenings, and is due to the fact that starch produces short flow, and gum arabic long flow thickeners. Made up print pastes often exhibit different flow properties than the pure thickeners they have been prepared from due to the chemicals and dyes which have been added.

Flow dyeing Obsolete procedure for achieving cheaper dyeing. The warp or weft yarn is immersed in a strong dye, dried without rinsing and woven with non-dyed weft or warp yarn. The fabric is simply passed through hot water on the padder, whereby dye is transferred to the non-dyed material.

Flow limit → Rheological behaviour of solutions.

Flow measurement Measuring the flow of materials in pipelines is not an easy task, since per definition flow is a quotient that has to be calculated by volume over time. This means the quantity of a material flowing through a certain pipe cross-section within a certain unit of time (e.g. m^3/hr. or l/s.). Devices that primarily determine the quantity are called volume flow measuring devices or meters. The quantity can be calculated as mass m or volume V. Adding a differential time element to a counter produces a flow meter that calculates either mass flow (q_m) or volume flow (q_v) (Fig. 1).

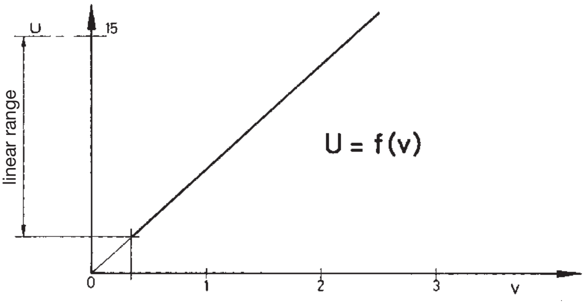


Fig. 1: Optimum relationship between solution flow speed v [m/s.] and voltage U.

Some of the many demands that textile processors make of the use of flow measuring devices are:

1. The measuring device should be independent of the Reynolds number over as wide a range as possible, and the transition from laminar to turbulent flow should not affect the measurement. The measuring range should be as wide as possible. The display should not be affected by the viscosity or viscosity changes caused by temperature fluctuations.

The Reynolds number ($Re = v \cdot d/\nu$) is calculated from the flow speed v, the pipeline diameter d and the kinematic viscosity of the material ν. It determines whether the flow in a pipeline is laminar or turbulent flow. Since some measuring systems cannot be used in the laminar range and measuring errors could occur in the laminar/turbulent transition area, the Reynolds number is extremely important. Considerable attention should therefore be paid to the Reynolds number range within which a measuring device can operate.

2. The flow measurement systems should be as independent as possible of the flow profile and the flow form. Measuring devices intended for use in the field should have straight entry and exit sections upstream and downstream of the device which are as short as possible.

3. The considerable demands made of measuring equipment in dyehouse systems with regard to corrosion, temperature and pressure resistance make it important to use measuring systems without moving mechanical parts wherever possible.

4. Measuring the flow of liquids that are dirty or contain solids is often extremely important when dealing with water and effluent. The measurement should not be affected by the inclusion of gas or air. The pipe cross-section of the measuring device should be as unobstructed as possible in order to minimise pressure loss. This requirement applies to both gas and liquid measurement. Since there is no linear relationship between flow and/or volume and the displayed value in many measuring systems, linearisation is desirable.

5. The dynamic characteristics of the measuring devices may also be important regarding device selection. For example, this applies to pulsating flows and/or the use of the devices in control applications.

Flow forms and flow profiles, i.e. the distribution of the speed component v over the cross section, take many different forms in pipelines. This particularly applies if the pipeline is not straight, or if there are deviations such as bends, elbows and sudden cross-section changes such as valves, flaps etc. upstream or downstream of the measuring devices (Fig. 2). The flow is usually laminar if the Reynolds number is <2300. If the Reynolds number is greater than 4000, the flow is turbulent. Ideal uninterrupted flow should only have v_z speed components in the direction of the pipe axis z. However, in practice other flows occur which contain flow components that go in all three directions v_x, v_y and v_z (turbulence). The optimum flow and quantity measuring device that is required should be completely independent of the flow profile. This means that the same measuring result must be achieved irrespective of whether the flow is laminar or turbulent, symmetrical or asymmetrical. Furthermore, turbulence and any other flow interference factors should not affect the measurement. Only volume meters have been able to meet these requirements up to now. This does not apply to all measuring systems operating on hydrodynamic principles. Differential pressure systems are extremely sensitive with regard to flow conditions and need particularly well designed entry and exit routes.

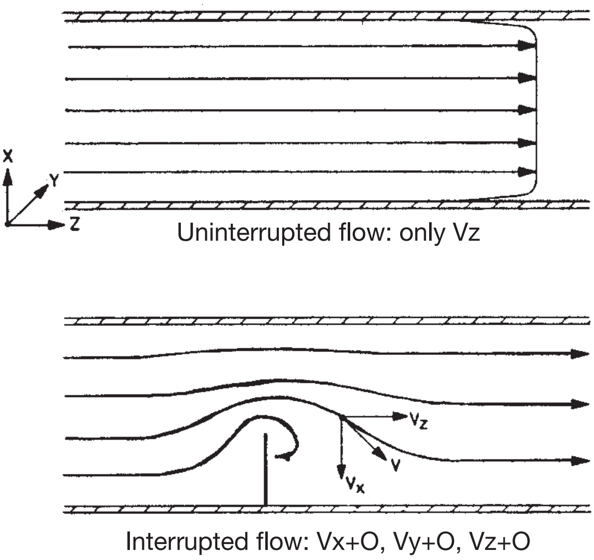


Fig. 2: Installation interference in flow measurement. Top: Laminar flow; bottom: turbulent flow.

This also applies to the same or a slightly lesser extent to other measuring systems such as axial-flow meters, vortex measuring devices, ultrasonic devices etc. Magnetically inductive flow meters are relatively insensitive in terms of flow profiles. Differential pressure measuring devices utilise the presence of differential pressures in the measuring section and therefore also belong to the classical group of mechanically or pneumatically operating processes such as suspended solid particle flow meters, positive-displacement meters (baffle plate meters) and axial-flow meters. On the other hand, vortex, ultrasonic, gyrostatic (coriolis force principle) and magnetically inductive flow measuring devices work on the principle of magnetic induction. One example from each group of devices is described in the following:

1. Hydrodynamic principle (Fig. 3):

The continuous measurement propeller is a hydrometric measuring device for determining flow speeds.

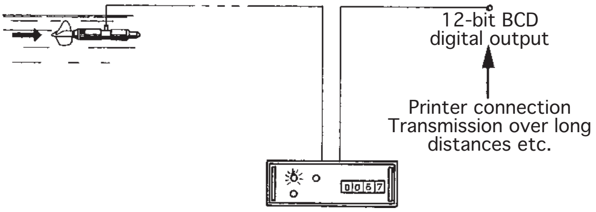


Fig. 3: Hydrodynamic flow measurement principle with stationary propeller.

Unlike the use of the metering process that is normally used for outflow measurements, this propeller allows direct flow speed calculations to be made. It outputs a signal voltage that is proportional to the water speed, The water speed can be read off in m./sec. using a display instrument. The device is maintenance free and is therefore mainly used in applications that require continuous measurement. The measurements can be transmitted elsewhere. A precision direct current signal generator is built into the propeller, which produces a direct current proportional to the propeller speed. Correspondence between the propeller rotation speed, the signal that is produced and the water speed is controlled by the conversion constant. The conversion constant in (V[m/s.]) is calculated for each propeller with a moving load of 50 000 Ω by calibrating in a standard measuring channel.

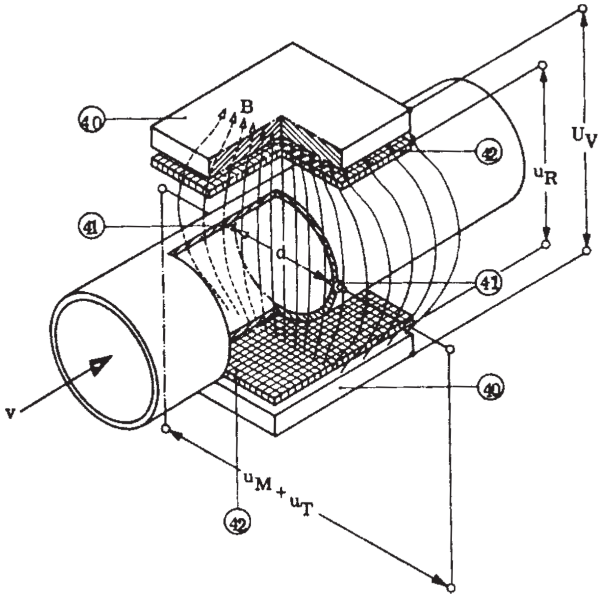


Fig. 4: Magnetic induction flow measurement.

2. Principle of magnetic induction:

The magnetic flow meter (Fig. 4) consists of a transmitter and a converter. It is suitable for measuring flow in all electrically conductive liquids whose conductivity does not exceed 10–1 µS/cm depending on the nominal range of the transmitter. The transmitter and the converter convert a volume flow of zero upward linearly into an electrical signal of 0–220 mA or 4–20 mA. Since measurement is possible in both directions of flow, measurement converters are also available with an output signal ranging from – 20 mA to 0 to + 20 mA. The device can also be calibrated to measure mass flow if the measured material has a constant density. The measurement is essentially independent of pressure, viscosity and conductivity, and is also independent of temperature and density when calibrated for volume flow. It is also largely unaffected by the flow valve. If a liquid flows at speed v through an alternating magnetic field generated by electromagnets with an induction value of B, an AC current of $u_M = B \cdot d \cdot v$ is induced vertically to the magnetic field and the direction of flow. It is picked up at two electrodes that have a distance d between them and is a measure of flow. At the electrodes there is also a transformational voltage of

$$u_T \sim \frac{dB}{dt}$$

The reference voltage of

$$u_R \sim \frac{dB}{dt}$$

is induced in the reference coils by magnetic field B (source (partial): Engelhardt).

Flow mechanism in dyeing → Mass transfer kinetics. The flow of liquor through a randomly oriented mass of textile fibres in dyeing is quite turbulent since it has to pass through numerous differently sized interstices and cross-sections. It has been calculated that the cross-sectional flow narrows and widens 18 times during the passage of liquor through a single layer of woven fabric of thickness $S_T = 0.399$ mm. If the batch roller of a beam dyeing machine is wrapped with this woven cotton fabric to produce a batch of 200 mm in depth, there would be $n = 18 \cdot 200 \div 0.399 = 9000$ constrictions and openings in which the liquor flow is subjected to turbulence during its passage through the batch. It can therefore be assumed with reasonable approximation that during the transport of dye in a liquor flowing through the randomly oriented fibre mass, an integrally uniform turbulent flow of material occurs in which the transport speed in the same direction as the main flow, as well as that at right angles to it, is equally great. For a semi-quantitative and trendwise consideration of dye flow behaviour, the flow rate and quantity of dye liquor, the surface area of the fibre mass and the weight of textile material, as well as the quantity of dye and the chemistry throughout the entire time of dyeing, is the same. Changes in liquor temperature, quantities of auxiliaries, distribution equilibria, etc. dependent on dyeing time are considered as overlapping activities as far as their influence, or their ability to be influenced, is concerned so that the action and interaction of the dye flows remain easily comprehensible. Because of the different dye transport mechanisms in the liquor-related and substrate-related region of the fibre mass through which the dye liquor flows, a separate study of liquor and substrate dye flows is recommended. For this purpose, and based on functional conformity, it is assumed that the dye is transported by the adsorption flow to the surface of the fibres in the fibre mass where it is deposited or stored temporarily. It is further assumed that the dye which has diffused into the volume of the substrate is abstracted from the deposited or temporarily stored layer of dye and adsorbed on the surface of the fibre mass independent of the liquor flow. An S-shaped curve progression is characteristic for the dependence of dye concentration c_{PFx} on the dyeing time z_x resulting from the interaction of flow and adsorption transport during a convective (circulating liquor) dyeing.

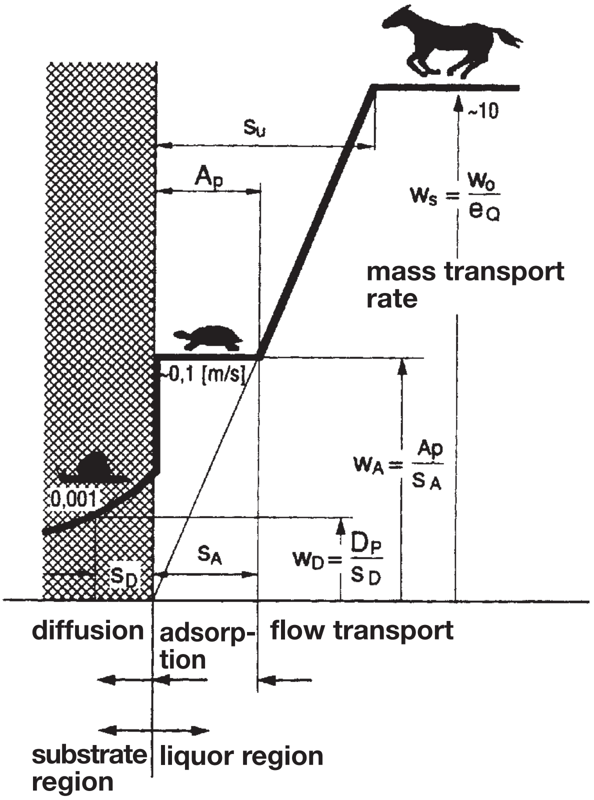


Fig.: Schematic representation for a quantitative examination of dye flow regions in the fibre mass through which dye liquor is circulated (Kretschmer).

The local mass transport rate is the same as the locally identical flow rate of the liquor; the flow rate of the liquor and consequently the mass transport rate across the boundary layer thickness s_U also decreases linearly to a value of zero at the surface of the fibrous mass. The dye transport speed w_A which determines the liquor-related dye flow is available at distance s_A from the surface of the fibre mass in which the dye transport speed of the flow and adsorption regions is exactly the same. The available dye transport speed w_A is considerably smaller than that of the liquor flow w_S in the fibre mass through which the liquor circulates. This is emphasized by the animal symbols depicted in the figure (reduced in size for didactic reasons). From this it can be seen that the relationship between dye transport speed w_S in the flow region and that in the adsorption region in close proximity to the fibre surface w_A is comparable to that between a horse and a tortoise. With the aid of a further analogy, it may be concluded that the flow speed represented by the horse can only be taken advantage of if the speed of the (adsorption) tortoise is high or when it can be raised above the adsorption coefficient A_P. The dye transport in the adsorption region, i.e. the region represented by the tortoise in the figure, is determined to a decisive extent by the substrate-dependent chemistry of the dyes and auxiliaries as far as the supply of dye for the textile fibre mass up to the surface of the fibrous mass is concerned. In order to describe the dye transport processes taking place in the adsorption region, the adsorption coefficient A_P m^2/s has been introduced which, as a material-related integral parameter, includes the adsorption-influencing factors determined by the substrate-dye and auxiliary chemistry as well as the adsorption influences dependent on the process, concentrations, temperatures, times, etc. Since the adsorption coefficient A_P integrally includes both the decisive influences of substrate and dye/auxiliary chemistry as well as the process technology, it can be used to advantage for the characterization and/or evaluation of process-dependent chemistry, process physics and machine technology, especially in the field of computer-assisted process control. For this purpose, it is advantageous if the adsorption coefficient

A_P can be derived from the liquor-related measurements with sensor technology currently available in the market as well as online in computer-controlled dyeing, pretreatment, washing and wet finishing processes (source: Kretschmer).

Flow properties →: Rheology in printing and coating; Rheological behaviour of solutions; Rheopexy; Thixotropy.

Flow resistance in yarn packages → Mass transfer kinetics.

Flow washing process A continuous washing and rinsing process in a flowing current of liquor (constant water inflow and drain-off), in which only the temperature and concentration of the wash liquor flowing through the machine are controlled. The throughput of laundry may be cyclic or continuous. Two alternatives are available, i.e. the → Clear flow laundry wash process and the → Counter current washing process. The opposite principle is represented by the → Multi-bath washing for laundry.

Flue gas analyzer (electrical). An instrument for checking the levels of CO_2, CO, $(NO)_x$, SO_2 and H_2 exhaust gases produced in boiler furnaces in order to achieve more reliable, economic and environmentally friendly combustion of the fuel used. It is based on determining the thermal conductivity of the exhaust gas mixture. For this purpose, the exhaust gases are brought into contact with a platinum wire heated electrically to 100°C from which their composition is determined by thermal conductivity. This provides a measure of the gas mixture from which it can be seen whether the composition lies within acceptable parameters or not.

Flue gas neutralization A process for the neutralization of alkaline waste waters by the carbon dioxide (CO_2) contained in flue gases. A large quantity of CO_2 is produced in boiler furnaces. Even if only 10% of the hot gases at 100–200°C are used for the neutralization of alkaline waste water, the procedure is still ecologically sound. More CO_2 cannot be utilized because of its great excess by stoichiometric comparison with the alkali content of the waste water. For this purpose, a system is used without a storage reservoir (see Fig.), based on the principle of the loop-type bubble column reactor which is already well-proven in the textile finishing industry, or the introduction of flue gas by "submersed circulation". This latter method requires an additional treatment reservoir but results in a simultaneous thorough mixing and a degree of ventilation via surface movement. The introduction of air into the neutralization tanks may be necessary to prevent putrefaction.

Fluff → Down.

Fluff formation → Pile formation.

Fluid Liquid or liquid product.

Fluid-bed process (hot sand dry fixation process). In this process sand or glass pearls of 100–200 µm diameter are used as a heat transfer medium from the heat source to the material being treated. In the case of materials produced from synthetic fibres, the fluid-bed process is used for heat-setting, thermosol dyeing, the curing of pigment dyeings and prints, the curing of synthetic resins and drying operations. The material being treated passes through the mass of hot sand/glass pearls in a V-shaped chute. Manuf.: British Tufting Machinery Ltd., Blackburn (GB).

A system based on the same principle for the heating of laboratory dyeing equipment is also manufactured by Roaches (GB).

Fluidic oscillator Name given to acoustic measuring device for controlling the moisture in exhaust air

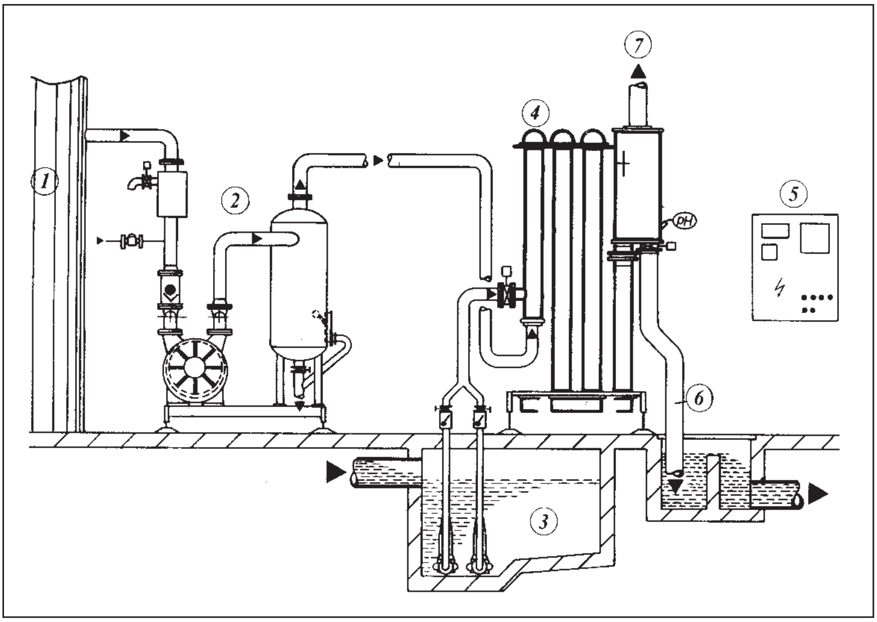


Fig.: Typical layout of Göttsche and Schwarzlmüller flue gas neutralization system.
1 = chimney (residual gas);
2 = flue gas compressor;
3 = waste water collecting tanks;
4 = neutralization reactor;
5 = control cabinet;
6 = neutralised waste water.

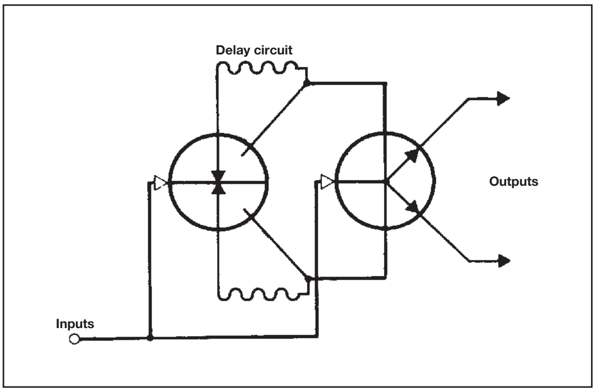


Fig.: Fluidic oscillator (Mahlo) for exhaust air moisture control.

(Fig.). Uses speed of sound U as the measuring parameter, which changes with the amount of water vapour in the air. In water vapour U is approx. 25% greater than in dry air; mix ratios therefore provide easily measurable intermediate values. The effect of temperature can be included in the electronic analysis of the moisture measurement by measuring the temperature at the same time. The acoustic radiation produced by an oscillator of constant frequency, penetrates the medium (exhaust air) and is then converted into electrical vibration by a microphone. The water vapour content is immediately read off on an instrument that is calibrated in % volume. The main advantage of this measuring method is that a probe can be installed directly in the exhaust air channel or the dryer, so that different flow speeds and gaseous or solid components in the exhaust air cannot falsify the measuring result. Switched on/off using pushbuttons in the scale section. – Machine maker: Mahlo.

Fluidimeter

I. Flowmeter, various systems such as flow-measuring devices, choke systems, floats, damming devices etc.

II. Liquid level meter, mechanical, hydraulic, pneumatic and electrical.

III. Volumeters, volume recording by piston, dial, float, etc.

Fluidyer Name given to dye liquor application mechanism with foam distribution system for plain and differential carpet dyeing. – Machine maker: Küsters.

Fluorescence A type of → Luminescence in which substances exposed to a light source emit light of another wavelength or colour. In contrast to → Phosphorescence, the phenomenon ceases immediately the source of light is cut off. It is explained by the fact that fluorescence-exciting molecules reflect the absorbed light energy again at two different wavelengths of light visible to the eye so that a mixture of reflected colours is unavoidably formed. Thus fluorescein for example, in dilute solution, has the property of appearing in its complementary colour, i.e. since in this case the blue portion is absorbed from the sun's spectrum, the reflected colour appears yellow. In addition, a further portion of the absorbed blue light is converted into light of higher wavelength which is always reflected as green so that the solution appears yellow and green at the same time which is recognized as fluorescence. In general, fluorescence is concentration-dependent and is the more pronounced, the lower the concentration of the fluorescent substance.

Fluorescence colorimeter → Fluorimetry.

Fluorescence quenching The intensity of fluorescence of solutions of fluorescent substances is reduced by the addition of certain inorganic salts or organic substances. The fluorescence may be completely quenched (→ Extinction). The quenching varies with different fluorescent substances, e.g. with the same quenching agents, the fluorescence of acridine is strongly quenched, the quenching is somewhat less with quinine and even less with fluorescein. Inorganic salts that act as quenchers can be put into a series of decreasing quenching power, iodides being the strongest quenchers. This is in the same order as the refraction of the anion, which is related to the number of free electrons in the quencher. On the other hand, the cation is not very important in the quenching effect of salts. Organic quenchers are in particular substances that contain iodine or sulphur as a hetero atom and conjugated unsaturated systems (e.g. diphenyl butadiene, furan, thiophene), benzene derivatives with continuous conjugated systems (substituted with OH-, OCH_3-, CH_3-), acids and esters, especially disubstituted ones, other aliphatic compounds, many substances with a double bond, saturated ring systems and conjugated systems (benzene, pyridine). Although the quenching is somewhat greater in methanolic solutions than in water because of the lower viscosities, the not very large differences cannot be used reliably to compare the quenching effects of salts with those of organic substances.

The equation for quenching is:

$$F = F_0 \cdot \frac{1}{1 + b + c}$$

where c is the concentration in mol/l and b is a quenching constant that is characteristic for each substance, h values from $^1/_c \cdot b$ are given in Tables 1 and 2.

Fluorescent bleaching agent → Fluorescent brightening agents.

Fluorescent brighteners – application to textiles The treatment of textiles with → Fluorescent brightening agents is carried out to improve the quality of the white. To the textile finisher, white is not a specific colour since he is concerned with many different "whites" in practice, e.g. whites with a neutral, greenish, violet,

Quenching Substance	b	h
Potassium iodide	250	0.0040
Potassium thiocyanate	167	0.0060
Potassium bromide	154	0.0065
Potassium chloride	125	0.0080
Potassium oxalate	56	0.0180
Potassium acetate	30	0.0330
Potassium sulphate	< 1	> 1
Potassium nitrate	< 1	> 1
Mercury chloride	< 1	> 1
Silver acetate	24	0.0420

Tab. 1: Salts for quenching the fluorescence of quinine sulphate (0.0025 mol/l) in acidic solution (after West, Müller, Jette).

Quenching Substance	b	h
Diphenyl butadiene carboxylic acid	3000	0.0003
Diphenyl butadiene	330	0.003
Stilbene	228	0.0044
Hydroquinone	217	0.0046
Hydroxymethyl ether	216	0.0046
Resorcinol	150	0.0067
Naphthalene	120	0.0083
Dihydronaphthalene	85	0.012
Furan	72	0.014
Thiophene	50	0.018
p-xylene	≈ 50	≈ 0.02
m-xylene	20	0.05
o-xylene	11	0.09
Benzene	< 1	> 1

Tab. 2: Organic substances for quenching the fluorescence of quinine sulphate ($2.06 \cdot 10^{-4}$ mol/l) in acidic methanol solution (after Eisenbrandt).

reddish and bluish cast. As a rule, the finisher will be given a standard pattern from the customer which he is expected to match in bulk. He must therefore “colour” white goods like dye batches and, in the past, this had been accomplished with small amounts of blue and violet dyes. In the finishing of cotton and linen, these dyes were added to the final finish bath (“blueing”). A radical change in the tinting of whites came about after the discovery of optical brighteners or fluorescent brightening agents which dates back to an observation of Krais in 1929 who noticed that when linen yarn was treated with a solution of aesculine (a glucoside from horse chestnuts) it became whiter in appearance.

Commercial fluorescent brightening agents are mainly derivatives of stilbene and coumarin. They are colourless or only slightly self-coloured substances with fluorescent properties. These substances have the ability to absorb the UV wavelengths of daylight which are actually invisible to the human eye and transform them into rays of longer wavelength which now lie in the visible spectrum. As a result, blue rays are formed which supplement the natural yellowish self-colour of the fibre so that it appears white. A bluish, reddish or greenish fluorescence is produced depending on the chemical constitution of the fluorescent brightening agent. Since the fluorescence is only produced by UV rays, the effect of fluorescent brighteners depends on the UV content of the light source.

As far as their behaviour towards the fibre is concerned and their application properties, fluorescent brightening agents are similar to dyestuffs. Some products are therefore available with reactive groups for example. The same standards of fastness have to be met by white goods which have been treated with fluorescent brighteners as coloured dyeings. Manufacturer’s recommendations for the achievement of maximum fastness ratings with fluorescent brighteners must be strictly adhered to. Suitable brighteners are now available for almost any fibre and any method of application. The weak self-colour of fluorescent brighteners is masked by the fluorescence up to certain concentrations, but becomes noticeable if these concentrations are exceeded.

It is incorrect to assume that the application of higher quantities of fluorescent brightening agents can compensate for poor bleaching. The higher the base white of the bleached material, the better the effect of the fluorescent brightening agent. Its effect can, however, be further improved by the co-application of small amounts of toning dyes (mainly blue or violet). The toning dye compensates for the yellowish cast by producing a neutral grey which is perceived to be “whiter”. However, if the base white is deficient, the grey cast will be too pronounced. As toning dyes, those selected from product ranges appropriate for dyeing the fibre in question are not necessarily the most suitable here. Dyes having the least possible affinity for the fibre are preferred for this application. For example, acid or disperse dyes are the preferred choice for cellulosic fibres.

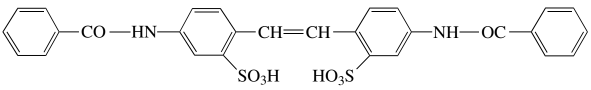
Wherever possible, the finisher will avoid applying fluorescent brighteners by a separate process, especially when continuous processing is involved. These products can already be incorporated in scouring or bleaching baths since many of them are stable to bleaching chemicals. As in the case of dyes, fluorescent brighteners can be classified in terms of their affinity. Exhaustion on to the fibre may be controlled by the addition of salt and the application temperature. If the affinity is too high, levelling problems are likely to occur under certain circumstances. Fluorescent brighteners also have different fastness properties. For this reason, consideration must be given to subsequent finishing processes when selecting the most suitable fluorescent brightener. Certain products are suitable for application in the final stages of finishing, e.g. along with resin finishes or flame retardant (FR) finishes. For the application of fluorescent brighteners to polyolefin fibres, attention must be paid to the fact that certain products have a tendency to exude from the textiles during storage which can lead to yellowing.

For the application of fluorescent brighteners to fibre blends, it is very seldom that the same product can be applied to all the fibres and the most suitable product for each fibre must be used. In these cases "cross-staining" cannot be avoided and, for this reason, additional clearing treatments are necessary to achieve optimum white effects. This applies, for example, to polyester/cotton blends where, under certain circumstances, the disperse-type fluorescent brightener used for the polyester component must be removed from the cotton component by treatment in a sodium dithionite bath. In the case of polyester/wool blends, a fluorescent brightener is applied to the polyester component first, then the wool is bleached in a bath containing a different fluorescent brightener suitable for the wool.

When the results of fluorescent brightener application are "off-shade" or otherwise defective, the product can be stripped from the goods in a similar manner to dyes. Depending on the fibre and the particular fluorescent brightener used, certain precautions are necessary. For example, when fluorescent brighteners based on stilbene are applied to polyamide fibres, they must not be stripped with chlorite since the decomposition products subsequently turn yellow.

Fluorescent brighteners are not only used for white goods but also to enhance pale blue, red, violet and green pastel shades. However, in the case of subdued pastel shades, e.g. beige, the application of a fluorescent brightener causes alterations in the shade. Since practically all household detergents contain fluorescent brightening agents, these products exhaust on to the textiles in the first wash. It is for this reason, therefore, that dyers are recommended to dye pastel shades in the presence of fluorescent brighteners in order to avoid complaints or claims from customers. Fluorescent brighteners may also be applied to synthetic fibres by heat transfer printing and suitable transfer papers are commercially available. Some fluorescent brighteners are sensitive to ferric ions. Deterioration of the white effects (yellowing, greening or greying) occurs when excessive concentrations of fluorescent brighteners are used. The maximum recommended concentration is product-dependent. Where thermofixation methods are employed, e.g. on synthetic fibres, incomplete development of the fluorescent brightener will result if the thermofixation temperature is too low. When fluorescent brighteners with inadequate stability to subsequent resin finishes are used, e.g. on cellulosic fibres, shade changes can occur after finishing.

Fluorescent brightening agents (optical brightening agents, brighteners, white dyes), organic compounds that fluoresce in a colour that is complementary to that of the textiles and can be used to compensate the natural colour. The brightening effect comes from fluorescence, which depends on the property of certain organic compounds to convert short wavelength light, in the 300–400 nm range, into longer, 400–500 nm, wavelengths. An example of a typical brightener is dibenzoyl diaminostilbene disulphonic acid:



Such chemical substances can be considered as light transformers, substances that "transform" the light energy; as the transformed blue component is added to the incident visible light, the total of all the colours of reflected light (additive colour mixture) is greater. Consequently, fluorescent brightened textile materials appear not only whiter (depending on the light source) but in fact also brighter, i.e. without chemical bleaching, there is an increase in the light reflected.

Light is one of the energy forms carried by photons. When a photon meets a molecule its energy is transformed into chemically bound energy, i.e. it is completely absorbed into the chemical substance. The energy absorbed converts the chemical molecule from its original ground state into an excited state (singlet state). From this excited state the molecule can return to the ground state in various ways:

1. Immediate return by converting the absorbed energy into a photon; the molecule radiates in a new colour. When the original absorption is of invisible u.v. light, this radiation is visible and is called fluorescence.

2. A radiationless transition from the excited state back to the ground state takes place if the absorbed energy is given up piecemeal and hardly affects the environment. Absorbers of u.v. light, such as protecting substances for human skin (sun protection creams), automotive paints or dyed fibres, convert the absorbed energy into heat in this way.

3. Delayed radiation arises from conversion of the first excited state into a second excited but stable state, which much later gives up a quantum of light (when visible light has been taken up, e.g. with fireflies or glow-worms in the night, this is called phosphorescence).

4. The molecule can come down to a lower energy level from the second excited state, by a chemical reaction (e.g. with other molecules), the absorbed energy being stored in the new chemical compound.

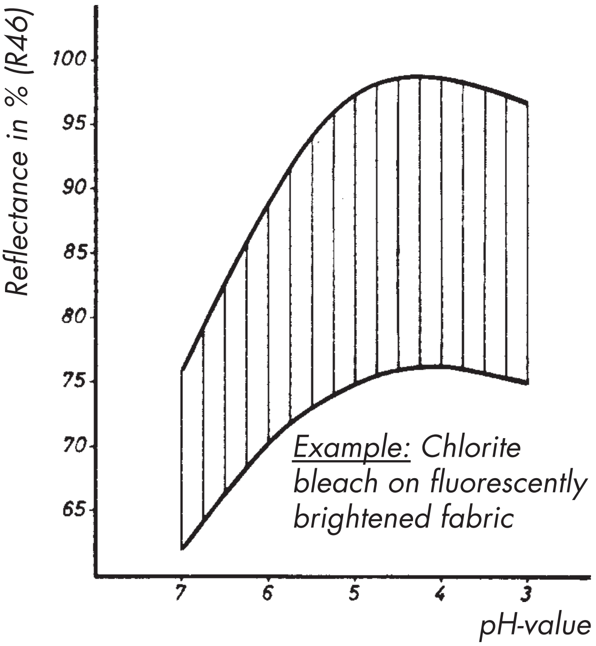


Fig. 1: Increase in fluorescence as a function of the degree of whiteness of the substrate.

The lower line in Fig. 1 shows the chemical white from chlorite bleaching at various pH values. This curve is significant for the fluorescence. Although the same amounts of brightener were applied to all the samples, the fluorescence of the brightener increases sharply with an increasing degree of chemical whiteness. This clearly shows that part of the fluorescence is quenched by the yellow component of the cotton/polyester fabric and only returns when the degree of chemical whiteness is improved. The conclusions from this are clear: if the chemical bleaching is neglected, the degree of whiteness will be reduced (Fig. 2); however, even a small reduction in the degree of whiteness of the substrate will block a considerable part of the brightening effect. This double effect is not the least of the reasons for the large variations in whiteness that can appear during production of cotton/polyester fabrics.

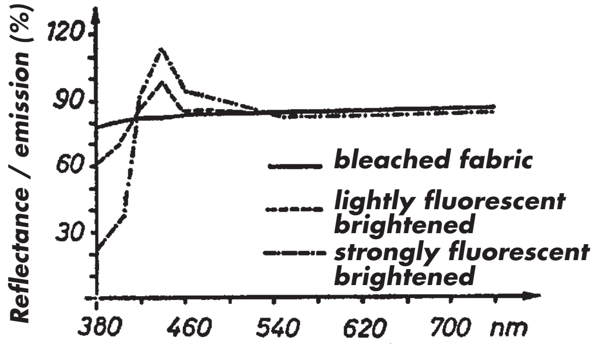


Fig. 2: Spectral reflectance curves of an unbrightened and two different fluorescently brightened fabrics.

The presence of conjugated double bonds is essential in the constitution of fluorescent molecules (substantivity), e.g.:

–C=C–C=C–C=C– (stilbene type)

–N=C–C=C–C=C– (imidazole type)

A large number of the fluorescent brightening agents used in the textile, paper and detergent industries are based on diaminostilbene disulphonic acid. Besides these, there are also products based on coumarin and benzimidazole. A fluorescent brightening agent may be anionic, cationic or a dispersion, depending on its structure. Care has to be taken with applications in combination with other compounds (detergents, finishing agents). Fluorescent brightening agents are available for all types of fibre. When they are chosen correctly, they fulfil the requirements for good fastness to water, washing and light and also for skin contact. The affinity of individual types varies, so the best product has to be selected for each fibre.

Fluorescent brightening agents – affinity for cotton/polyester High, medium and low affinity types are used for brightening cotton. Products with high affinity have lower average diffusion coefficients in the fibre than medium or low affinity compounds. However, under comparable conditions, the mass transport/unit time is greater with high affinity products and hence the exhaustion and rates of build-up are higher than with the lower affinity products. The consequences are increased concentration at the fibre surfaces and better exhaustion of the bath. For cotton brighteners addition of electrolyte (with low, medium and even high affinity leads to a significantly higher degree of exhaustion and better reproducibility, but also to significant differences in products with different affinities) and bath temperature are significant. The Figure shows

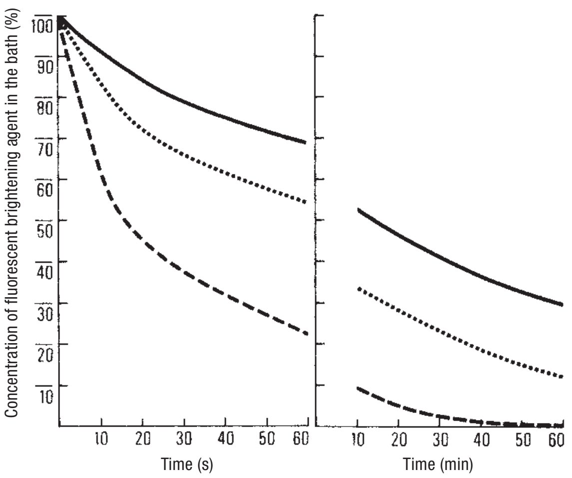


Fig.: Exhaustion curves for various fluorescent brighteners on bleached cotton at 40°C.
— low affinity product; – – low to medium affinity product; · · · high affinity product.
Liquor ratio 30:1; 5 g/l sodium sulphate.

typical exhaustion curves for application to bleached cotton, where even at 40°C there is a difference in the rates of exhaustion of high, medium and low affinity types of brightener.

Similar curves are also produced from applications at 90°C. Here it can be seen that the degrees of exhaustion of low and medium affinity types are significantly reduced, while those of the high affinity types remain relatively constant. Because of this, high affinity types of cotton brighteners are used especially for batchwise exhaustion processes with good bath circulation or movement of the material, preferably in the higher temperature range of > 60°C, and bleaching processes with high wash off temperatures, but only used with reservation for semi and fully continuous bleaching processes. Generally they provide good build up and high yield, but they can also lead to levelling problems; for effective development on the substrate, higher temperatures are required than with the lower affinity products. On the other hand medium to low affinity types (types of decreased affinity) are especially suitable for all types of padding processes, and also for semi and fully continuous bleaching systems. Their rapid diffusion ensures good levelness in exhaust processes, even under unsuitable working conditions and in processes with immediate drying they are developed quickly on the substrate; care must be taken that with these types of brightener the fastnesses to washing and water can be poor because of their low affinities. On the other hand, with the water-insoluble brighteners for polyester, differences in affinity in the temperature range of 40–90°C are not very significant.

Fluorescent brightening agents (FBA's), application in spinning This application of fluorescent brightening agents (FBA's) serves to improve the appearance of the raw white shade of regenerated cellulosic and other man-made fibres as well as to achieve a high degree of whiteness in yarns and fabrics produced from these fibres. For this purpose, special fluorescent brightening agents are mixed, in the form of aqueous dispersions, with the fibre starting products for the polymerization or condensation reaction or, they are mixed in the dry state with fibre polymer granules in tumbling mixers.

Fluorescent brightening agents in the preparation of print screens Fashion materials which are only to be printed in relatively small yardages are often printed by screen printing processes. Screens of nylon or polyester gauze are used, with the pattern in the form of permeable and impermeable, lacquer coated areas. The emulsions used for this are made with light sensitive sensitizers. On exposure to light, the emulsion hardens to form the pattern. Finishing a polyester screen gauze with a brightening agent produces an increase in the total light reflected to more than 100% because of the fluorescent emission in the blue part of the spectrum. This additional energy in the light sensitive region of the emulsion (390–450 nm) accelerates the hardening of the lacquer and consequently saves time.

Fluorescent brightening agents / quantitative determination on cellulosic materials

1. Cadoxen method: 20 mg of the cellulose fibre with the fluorescent brightening agent is dissolved by shaking in 10 ml of cadoxen (cadmium-ethylene diamine) over 2 hours at room temperature (protected from light). The u.v. absorption of the solution is measured at the wavelength of the absorption maximum in the u.v. region (optical density). From the measured optical density, the amount of the fluorescent brightening agent in the dissolved sample is determined (with a calibration curve) and from that, the content of the fluorescent brightener in the fibre is calculated. The values obtained are higher than those determined by the pyridine method.

2. Pyridine method: 20mg of fibre is extracted by leaving overnight in 10 ml of 25% aqueous pyridine solution. The extraction solution is analysed in the same way as in the cadoxen method and the concentration of brightener determined.

Fluorescent brightening agents, spectroscopic conditions, a) the absorption should be as strong as possible as close as possible to 400 nm; b) there should be practically no absorption above 400 nm; c) the fluorescence should be in the required region of the spectrum; d) the fluorescent light should have the strongest possible intensity. These properties are best calculated by the PPP (Pariser, Parr and Pople) method. Fluorescent brightening agents can have a violet or a blue-green tint or be toned down with shading colours. Polyester brighteners are often sold as mixtures of several components. The supplier seeks to get the required fastness, stability and tone and to meet his commercial requirements in this way. A brightener with a strongly violet tone, e.g. with a reflection maximum at 430 nm, can be modified by mixing it with a component with a blue-green tone (λ max. 440 nm) so that a visually and colorimetrically neutral white is produced (Fig. 1).

There is also a synergy from a mixture of two different brightener species (Fig. 2). This means that the overall effect of the combination of substances is greater than that of the same amounts of the individual components. For example, for polyester brighteners at a definite proportion of two components, A and B, in a mixture the whitening effect is better than that of either of the components. A ratio of 65 parts of component A and 35 parts of component B produces an increase in the whiteness of 14 units in the whiteness (total whiteness calculated by a whiteness and colour formula) and a shift in the tone. The technical and economic advantages (brilliance and the difference in the production costs) need no further explanation.

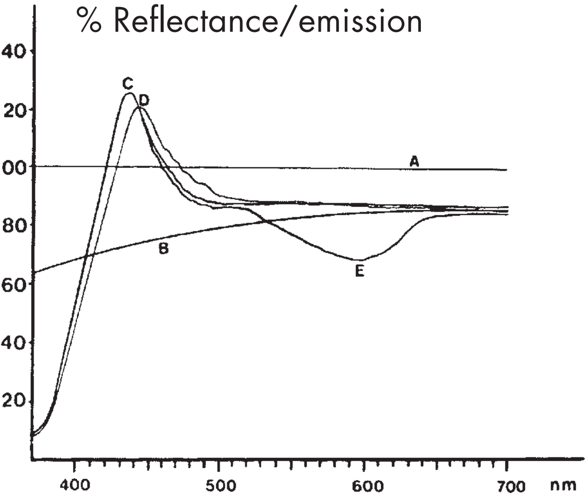


Fig. 1: Reflection/emission curves of fluorescent brightening agents.
A = 100% reflection (MgO); B = ground white of the substrate; C = brightener with a violet tone; D = brightener with blue-green tone; E = brightener with a violet tone with a toning dye.

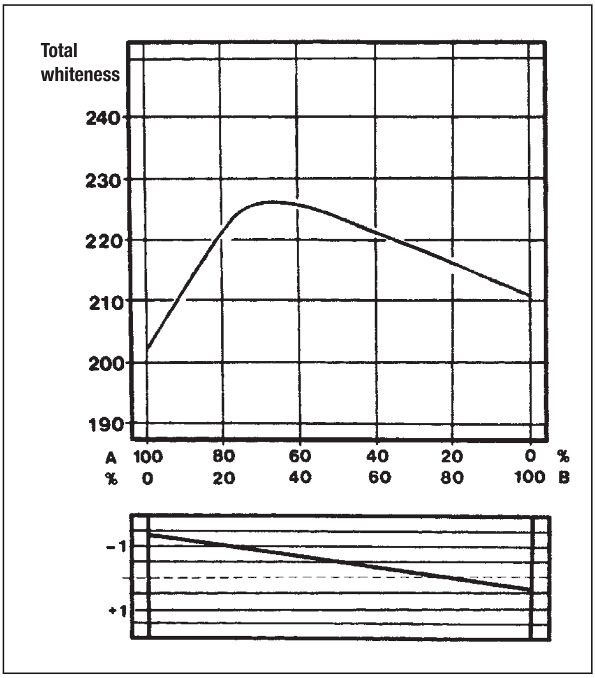


Fig. 2: Synergistic effect and colour shift of a mixture of brighteners.
A = Stilbene benzoxazolyl derivative; B = Pyrenyl derivative.

Fluorescent brightening of textiles Treatment of textiles with optical brighteners or, more correctly, → Fluorescent brightening agents. If possible, the application of fluorescent brightener is combined with other processes (combination processes) and not given as a separate treatment, e.g. the fluorescent brightening agent is applied in the scouring, bleaching or finishing bath. Fluorescent brightening agents are also frequently applied together with very small quantities of "blueing" dyes (→ Tinting of bleached goods). For certain fabrics, application by heat transfer processes represents an elegant method. Attention should be paid to the fact that the presence of iron and copper ions can have a negative influence on the whiteness of cotton treated with fluorescent brightening agents.

Fluorescent dyes

I. A group of organic dyestuffs which, when applied to a textile material, give rise to → Fluorescence under UV radiation (some also fluoresce in daylight; → Dayglow colours). The practically colourless → Fluorescent brightening agents and many individual dyes from various dye classes which produce very intense effects are also included in this category. These products and other types with different constitutions, with and without solubilizing groups, have been introduced by various dye makers in special ranges of fluorescent dyes, most of which can be applied together with curable plastic dispersions to textiles by padding, spraying, screen printing, etc. Since the fluorescent effect can often be invisible at high dyestuff concentrations (e.g. in the region of 3%) optimum percentage concentrations must be established in each case. Uses: evening wear, theatre props, protective clothing for emergency services, marine applications, etc.

II. Range of so-called → Luminous dyes that are highly fluorescent in daylight and under UV light. Suitable for coloration of plastic mass (polyvinyl chloride, celluloid, urea formaldehyde resins, lacquers), used in a similar way in pigment printing.

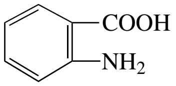
Fluorescent lighting → Fluorescent tube lighting.

Fluorescent salts A collection of soluble salts that may be applied to all textile substrates to give fluorescent effects typically in (yellow-) green, blue and blue-violet colours. Certain types show a similar affinity for wool to acid dyestuffs and will resist washing-out. Other fluorescent salts, without fibre affinity, may be applied without an end-rinse and are directly dried onto the fibre. On cotton the effects are notably fugitive. The combination of dyestuffs and fluorescent salts allows the production of brilliant colours that cannot be achieved with normal daylight colours. Similarly, print pastes with suitable thickening systems allow the development of colours of otherwise unachievable brilliance on dark grounds. A further use of fluorescent salts in print systems is as an indicator for print faults.

Fluorescent tube lighting Also mistakenly known as neon lights or fluorescent tubes. Gas discharge lamps with either glowing electrodes as high voltage fluorescent lights (mainly for advertising purposes) or with glow electrodes as low voltage fluorescent lights. Preferred lighting source for lighting work rooms, workshops, offices, shops etc. Much longer service life than light bulbs and 3–4 times the illumination, allows more economic use, particularly as a strip light in two or more levels, with special reflective coating for high work rooms, also with two different coatings, in various colours and dimensions and bar, ring and U shape etc. Multipurpose model; dust, moisture, acid, explosion-proof fluorescent lighting groups; a) with extremely high illumination for lighting systems with maximum economy; b) with even better illumination and good colour reproduction for general use; c) with particularly good colour representation, also as dual level lamp with colour rendering of incandescent and “white light”. High frequency fields excite fluorescent lights in their effective range to light without contact, meaning that these lamps can be used as indicators for HF fields.

Fluorescent whitening agents (fluorescent brightening agents). A fluorescent brightening agent is a compound which, when applied to a textile material, absorbs the short wavelength electromagnetic radiation (UV light) which is invisible to the human eye and converts it into visible light of longer wavelength which is emitted either as violet, pure blue or greenish blue. When this radiation is combined with the more yellowish self-colour of a bleached textile material, a brilliant white is produced. Thus, a bleached fabric does not appear pure white but somewhat yellowish since a certain amount of blue radiation is absorbed from the incident white light so that the re-emitted light is deficient in blue and the proportion of red-yellow-green predominates to some extent. This blue deficiency is therefore supplemented by a fluorescent brightening agent in an additive manner, unlike the use of “blueing” dyes where the “whiteness equilibrium” is restored by the absorption of excess yellow radiation. Although a neutral white is also achieved by this means, it is greyer in this case which results in a lower level of whiteness, i.e. the effect is subtractive (Fig. 1).

Fluorescence is produced by the molecule absorbing high energy radiation and re-emitting it as lower energy radiation, i.e. as radiation at longer wavelengths; the energy difference is lost as kinetic energy. For a molecule to be capable of fulfilling this function, certain constructional principles are an essential prerequisite and these may be determined empirically. Hence, fluorescence is associated, above all, with the aromatic character of a molecule although the presence of an aromatic ring by itself is still not sufficient to provide the molecule with the characteristics of a fluorescent brightening agent. Anthranilic acid, for example, produces an intense blue-violet fluorescence in aqueous solution but, despite this, it is not suitable for use as a fluorescent brightening agent.



Anthranilic acid

Most fluorescent brightening agents do not fluoresce in powder form but only in solution. Some types are also known which do not even fluoresce in solution but only after application on the fibre. Fluorescence is therefore not only dependent on the structure of the molecule, but also on its actual condition. Whether or not a fluorescent compound is suitable for use as a fluorescent brightening agent can only be assessed after its application on a textile fibre. Apart from the fact that the molecule must satisfy certain coloristic requirements and, e.g. possess satisfactory fastness to light and washing, it is the fluorescent effect which must compensate for the yellowish cast of the fibre that is of decisive importance as far as its suitability for use as a fluorescent brightening agent is concerned.

A fluorescent brightening agent is actually a dyestuff which, instead of the typical chromophore system of a dye, contains a fluorescing system and, exactly like a coloured dye, contains certain substituents which favour affinity for the particular type of fibre it will be applied to. In the case of cotton, for example, suitable fluorescent brightening agents are more or less substantive derivatives of diaminostilbenedisulphonic acid (Fig. 2, example I) like the compounds with the basic

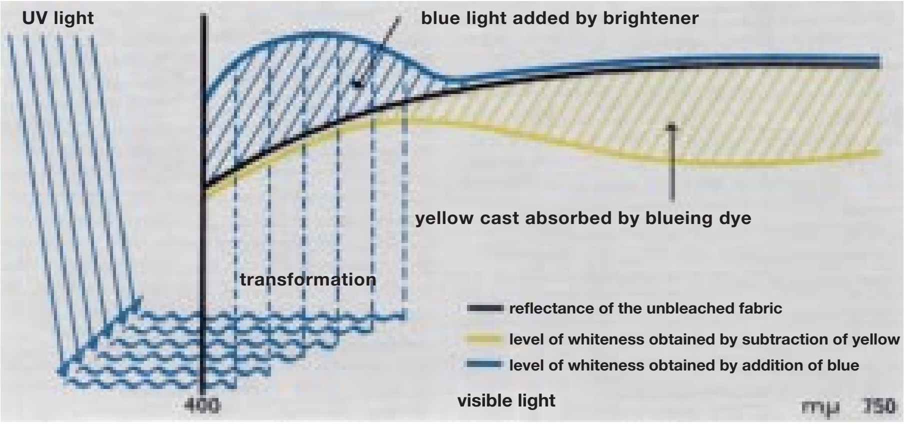
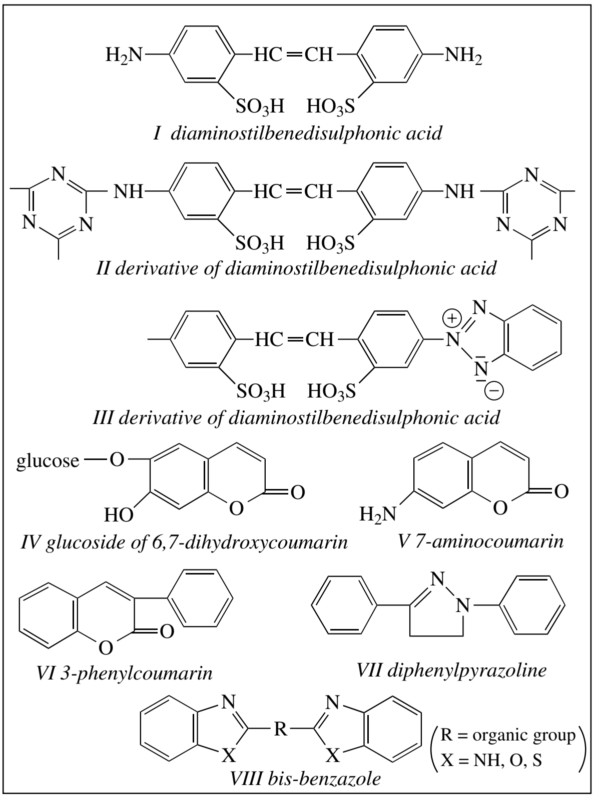


Fig. 1: Influence of a fluorescent brightening agent on a “neutral” white.



I diaminostilbenedisulphonic acid

II derivative of diaminostilbenedisulphonic acid

III derivative of diaminostilbenedisulphonic acid

IV glucoside of 6,7-dihydroxycoumarin

V 7-aminocoumarin

VI 3-phenylcoumarin

VII diphenylpyrazoline

VIII bis-benzazole

Fig. 2: Structural formulae of a few compounds from which fluorescent brightening agents are derived.

skeleton represented in formulae II and III. However, compounds derived from formula II are not stable to chlorine in solution although, by contrast, they generally have excellent chlorine fastness on the fibre. Compounds based on formula III are also stable to chlorine in solution.

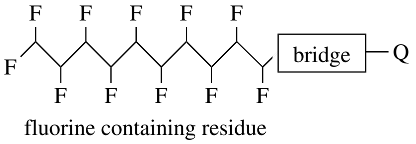
Stilbene derivatives may also be present in isomeric forms, i.e. in the cis and trans configurations. As powder brands and typical commercial liquid brands these fluorescent brightening agents are present in the trans form. The cis form, which is rapidly formed by the action of light on the trans form, does not exhaust on cotton and, for this reason, solutions of this type of fluorescent brightening agent should be protected against the action of light.

Aesculine is the glucoside of 6,7-dihydroxycoumarin (formula IV). Although this particular coumarin derivative is of no commercial significance, a large number of useful products have been derived from 7-aminocoumarin (formula V). Interesting products are likewise found among the 3-phenylcoumarins (formula VI). Many fluorescent brightening agents are derived from heterocyclic compounds containing nitrogen such as those represented by formulae VII and VIII (source: Wagner).

Fluorides Salts of hydrofluoric acid $HF \cdot H_2O$, some of which are neutral (type: sodium fluoride) but most are acidic (type: potassium hydrogen fluoride KHF_2) as well as complex salts.

Fluorimetry An analytical technique concerned with measuring the fluorescence of liquids or solutions induced by UV light or X-rays, either by comparative visual assessment, dilution, fluorescence quenching or with the greatest reliability using photoelectric measuring instruments in a similar manner to → Colorimetry.

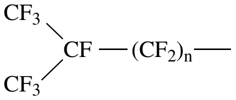
Fluorinated surfactants, fluorine containing surface active substances. The hydrophobic part of the molecule contains a perfluoroalkyl chain on the following principle:



Q = hydrophilic residue (anionic, cationic, non-ionic).

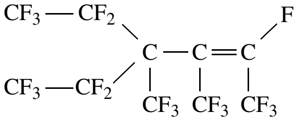
Suitable fluorine containing residues are e.g.:

$CF_3(CF_2)_n$— straight chain, unbranched



$$(CF_3)_2CF{-}(CF_2)_n{-}$$

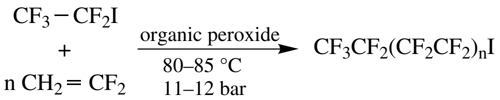
terminal branching



$$(CF_3{-}CF_2)_2C(CF_3){-}C(CF_3){=}C(CF_3)F$$

heavily branched

Amongst others methods, they can be produced by telomerization of tetrafluoroethylene to perfluoroalkyl iodides according to the reaction:



$$CF_3{-}CF_2I + n\,CH_2{=}CF_2 \xrightarrow[\text{80–85 °C, 11–12 bar}]{\text{organic peroxide}} CF_3CF_2(CF_2CF_2)_nI$$

The products with chains of 1–10 carbon atoms are valuable raw materials that can be used to produce a wide range of interesting fluorinated surfactants by replacement of the iodine, e.g. by addition of ethylene, esterification with nitric acid and hydrolysis to fluorine containing alcohols, or oxidation to fluorine containing carboxylic acids, or by reaction with thiourea to fluorine containing sulphonic acids etc., giving a large number of possible fluorinated surfactants with perfluoroalkylene groups and normally hydrophilic end groups. The surface tensions of the surfactants in water vary. Fluorinated surfactants can affect the foaming properties of normal surfactants, acting as defoamers or foam suppressers, and also bring hitherto unknown advantages with their stability to heat, acids and oxidizing conditions and e.g. can reduce the danger of dye spots during dyeing and printing.

Fluorine (F). A nonmetallic → Halogen element in group VIIA of the periodic classification. Atomic weight 19, the most electronegative element and powerful oxidizing agent known. Fluorine is a pale yellowish-green toxic gas with a pungent odour. It reacts vigorously with water (formation of hydrogen fluoride HF, salts → Fluorides). It also reacts vigorously with virtually all elements, frequently with ignition (except *inter alia* lead, and only attacks the surface of copper).

Fluorine based water- and oil-proofing agents, apart from fluorinated surfactants, fluorine-containing finishing agents for textiles, leather and paper are important members of the series of perfluoroalkyl products that are produced by electrofluorination, telomerization or oligomerization of perfluoroolefines. The technically significant intermediates for producing these types are OH-functional compounds, e.g.:

C_8F_{17}-$SO_2N(R)CH_2CH_2OH$ (R = e.g. CH_3, C_2H_5)
C_8F_{17}-$SO_2N(CH_2CH_2OH)_2$
$R_FCH_2CH_2OH$ (R_F = e.g. perfluorinated C_6-C_{12})

Fluorinated alcohols serve for the production of water- and oil-proofing agents (based on acrylates, methacrylates or urethanes) as well as components of polymer systems such as polyurethanes and polyesters. In particular water- and oil-repellant products for fibrous substrates are very important commercially. Fluorinated alcohols are produced by hydroxyalkylation of primary or secondary perfluorooctyl sulphonamides with e.g. ethylene carbonate. The largest group of textile impregnating agents are usually perfluorocarbon resins produced from the copolymerization of fluorine-containing esters of acrylic/methacrylic acid with fluorine-free monomers or mixtures of different polymers. They can be used either as aqueous, cationic or non-ionic emulsions or in solvents such as 1,1,1-trichloroethane, thermal fixation being carried out after the application. Combinations of perfluoroalkyl compounds with silicones are also used and are not only water- and oil-repellent but also impart a soft handle to textile goods that is fast to washing and dry cleaning, e.g. based on the reaction of Si-H containing organopolysiloxanes with N-allyl-N-perfluoroalkyl sulphonamide.

Fluorine chemicals These are mainly products of the → Perfluoro compounds.

Fluorocarbon chemicals → Perfluoro compounds.

Fluorocarbon fibres → Polyfluoroethylene fibres.

Fluorocarbon finishing Fluoropolymers that are correctly applied to textiles modify the surface properties of these textiles with regard to staining and dirt repellency. Whereas paraffin or silicone-based water repelling only has a water-repelling effect on the textile fibres, fluoric chemicals repel both water and oil. Compared to conventional waterproofing, fluoric chemicals have the advantage of being resistant to washing and dry-cleaning. The “breathability” and therefore wearer comfort is not affected. The same also applies to the handle of the treated textile. Fluoropolymers do not have the same conventional property of silicones for attracting fatty dirt because they are naturally oil-repellent. In physical terms fluoric chemicals reduce the surface energy of the treated fibres. This energy is brought to such a low level that neither aqueous nor oily substances impregnate the surface of the material.

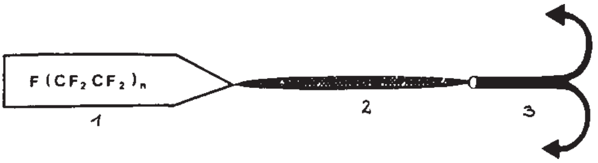


Fig. 1: Model of the mechanism of monomer fluorocarbon agents.
1 = Perfluoroalkyl group: 2 = Spacer; 3 = Anchoring or holding group.

Fluoric chemicals can be divided into three molecular areas (Fig. 1); the perfluoralkyl groups are responsible for waterproofing, oilproofing and dirt repellency. A spacer provides the required molecular mobility so that the substance is soluble or emulsifiable.

An anchoring (holding) group is extremely important, since this guarantees permanence by means of chemical, physical or cross-linked bonding. Polymer fluorocarbon agents (Fig. 2) usually consist of various constituents. As well as long-chain components containing fluorine that are responsible for the finish produced, fluorine-free monomers for improving film formation and/or reactive components for increasing permanence are copolymerized. Areas with components containing fluorine can be alternated with zones

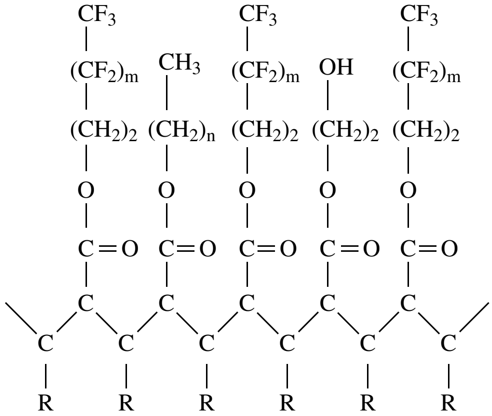


Fig. 2: Fluorocarbon polymer.

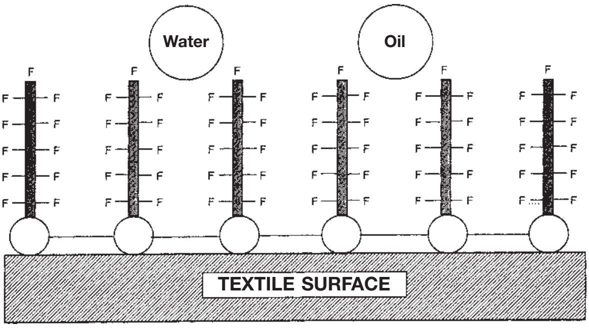


Fig. 3: Water and oil repellency by fluoric chemicals.

containing fluorine-free components. The reactive components are statistically distributed between these areas.

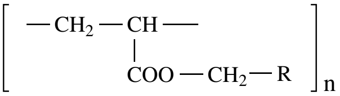
With increasing length of the perfluorinated groupings arranged vertically to the surface of the textile, other components have the effect of increasing the distance between the oil and/or water drops and the textile, thus producing better repellency (Fig. 3).

Perfluoric alkyl alcohol can be converted to monomer urethane-based agents by adding multifunctional isocyanates or converted to acrylates with polymerisation capability by means of transesterification. After polymerisation you have long-chain agents with perfluoric alkyl side chains; the polyurethane or polyacrylate components provide good fixation by direct bonding or polymer dissemination. Extenders are used in the form of fat-modified melamine derivatives in order to "extend" the requirement profile at low cost by reducing the quantities of fluorocarbon (therefore extenders in the form of waterproofing agents), particularly with regard to the water-repellency. The surface of the textile must be completely tenside-free before the fluorocarbons are applied.

Fluorocarbon plastics → Fluorocarbon resins.

Fluorocarbon polymers These include → Polytetrafluoroethylene as synthetic resins. Both are characterized by extraordinarily high chemical resistance and are stable within the temperature range from – 180 to +280°C. Nonstick surfaces are obtained by spraying these synthetic resins on to metal rollers which are used e.g. in sizing and finishing machines. Of greater interest for textile applications are the polymers of fluoroalkyl esters of acrylic acid, e.g.:

(R = perfluoroalkyl residue)



$$\left[-CH_2-\underset{\substack{|\\ COO-CH_2-R}}{CH}- \right]_n$$

These compounds are used in soil-release and stain-release finishes.

Fluorocarbon resins Polymers of → Fluorocarbons. →: Polytetrafluoroethylene; Polytrifluorochloroethylene.

Fluorocarbons These are hydrocarbons in which the hydrogen atoms have been substituted by fluorine atoms. Mixed fluorocarbons contain other halogens in addition to fluorine, e.g. chlorine → Chlorofluorocarbon. Fluorocarbon polymers are thermoplastic → Fluorocarbon resins.

Fluorochrome, fluorescent dyestuff; used as a stain in fluorescence microscopy.

Fluorofibres According to textile labelling regulations and the EDP code system, fluorocarbon fibres are classified as → Polyfluoroethylene fibres.

Fluorosilicates Salts of hydrosilicofluoric acid.

Fluorozirconate process A flame-retardant finish for wool based on → Titanium potassium fluoride or → Potassium hexafluorozirconate.

Flushed printing Overprint with extremely fine colour transitions and colour mixtures, usually on silk, viscose, or triacetate; e.g. on viscose, triacetate with azo print or print with cationic dye. Dry the print, steam for 30 minutes using wet steam, treat with hydrophilic polymers (e.g. polyacrylate) for 5–10 minutes. Rinse and dry.

Flushing of prints in roller printing A defect caused by print paste being pressed out of the engraved areas of a printing roller. It can be due to the lapping of the printing cylinder and the back grey being too hard, i.e. lack of a resilient printing surface, or when the depth of engraving and scale of engraving are not suitable for the particular fabric being printed.

Fly Unwanted loose fibres on a textile material. It is caused by the attraction of fibre dust (mainly as a result of electrostatic attraction).

Fly catchers Devices used to clean fibre dust, fly, loose pieces of yarn, etc. from machinery in order to prevent possible malfunctions due to their accumulation which could impair machine functional performance. Manual or electrically-operated fly catchers are available.

Fly dropping spots Typical round, dark grey to black spots. Removal: a) fatty alcohol sulphate solution with 5% ammonia (warm), with 20% sodium tetraborate for silk; b) petrol or concentrated solvent soap (with alcohol) possibly warm, repeated application; c) alcohol/ammonia 10–15:1 (warm) or 20% alcohol/sodium tetraborate solution (particularly for coloured silks); d) fatty alcohol sulphate/detergent (neutral) warm. Any residue, 5% ammonia.

Fly spotting → Fly dropping spots

Fm, chemical symbol for fermium (100).

FNA (Ger.), abbrev. for: Fachnormenausschuß (Technical Standards Committee) in the → Technical and professional organizations.

FNM (Ger.), abbrev. for: Fachnormenausschuß

Materialprüfung (Technical Standards Committee for Material Testing) in the → Technical and professional organizations.

Foam Foams are microheterogeneous colloidal systems in which gases are distributed within a liquid or solid dispersing agent. When air is passed through a surfactant solution the surfactant is adsorbed on the surface of the bubbles to form a film. As the bubbles break through the liquid/air interface, a double film is formed, i.e. a foam lamella consisting of two monomolecular films of surfactant and the interlamellar liquid. The accumulation and reciprocal contact of the bubbles in the liquid also plays a part in this film formation process. When solutions of substances with low surface activity are used for the generation of foam, e.g. short-chain alcohols or acids (e.g. humic acids in waste waters as direct pollutants in biological waste water treatment plants) foams are formed which are often only stable for a few seconds. Foams with considerably longer stability are produced with substances which cause a considerable decrease in the surface tension of water (e.g. soaps, non-ionic, cationic and amphoteric surfactants). Thermodynamically, foams are unstable systems as they have a higher free surface-energy potential than the starting materials (liquid and air) from which they are formed. Consequently, all foams have a tendency to decompose and are therefore unstable or, at best, metastable.

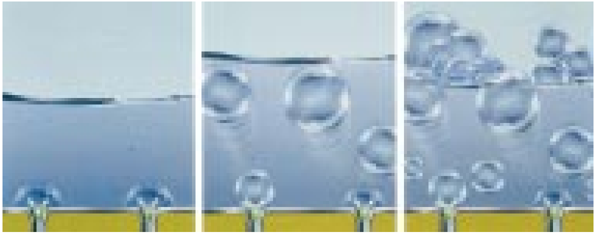


Fig.: Foam.

At the air/water interface of air bubbles in water produced by mechanical action the surfactant molecules accumulate in such a way that, depending on their structure, the hydrophilic part is aligned in the water phase and the hydrophobic part in the air phase. When a concentrated assembly or accumulation of such discrete bubbles are present in a liquid a spherical foam exists. By contrast, a polyhedron foam is an aggregation of polyhedron-shaped bubbles which have lost autonomous existence. Polyhedron foam may be formed through drainage of the interlamellar liquid from a spheroid foam. The thickness of the liquid lamellae is approx. 500 nm, and the “isolated” spherical foam is considerably less stable than the connected polyhedron foam. Metastable foams are characterized by the fact that, after a certain time, the liquid ceases to drain and a metastable structure comes into being. This state is achieved by retarding the thinning of the lamellae so that bursting of the bubbles is delayed. In many cases foam formation causes problems in dyeing and finishing processes and the foam must be destroyed or prevented from forming. On the positive side, dyeing and finishing baths can be foamed in order to achieve a low wet pick-up of dyes, auxiliaries and finishing agents. → Foam application.

Foam application Processes used for the → Low wet pick-up of concentrated foamed finishing liquors, especially for wash and wear finishes on textile fabrics with a possible pick-up of 40% and mainly between 10–20%. Foamed liquors are applied to the textile directly then brought to the desired thickness by means of squeeze rollers or a knife coater, e.g. two-sided foam application in a horizontal 2-bowl padder, one-sided application to carpets, foam application with an air-roll squeegee.

The foamed liquors must be stable for a limited time appropriate to the application method selected. From this it follows that metastable polyhedron foam must be tailor-made for the selected application method. The following foam properties are required for continuous finishing:

- uniformly homogeneous foam,
- variable blow ratio,
- low foam stability (foam decay half-life period),
- rapid breakdown of foam on contact with the textile substrate.

The two media water and foam differ greatly from each other as far as handling is concerned so that new application techniques are necessary for finishing with foamed liquors. Compared to conventional finishing with aqueous solutions it has been found that, despite its different nature, the application technique involving foamed liquors can be smoothly integrated into existing processing operations.

Foam application is characterized as follows:

1. Foaming agent: surfactants developed for the production of foamed liquors allow the generation of tailor-made foams suited to the application method and the substrate.

2. Continuous generation of foam by mechanical means: mechanical foaming of the finishing liquor (resin finishing agent and foaming agent) is achieved continuously by means of typical commercially available mixer. The actual foam is generated in a so-called mixing head by mixing liquor and air. In order to ensure a constant blow ratio, the mixer is designed in such a way that the quantity of air is synchronized with the output of foamed liquor. The generated foam is then delivered to the foam application system.

3. Application methods: in principle, two methods are possible for the application of foamed liquor to a textile material, i.e. direct and indirect foam applica-

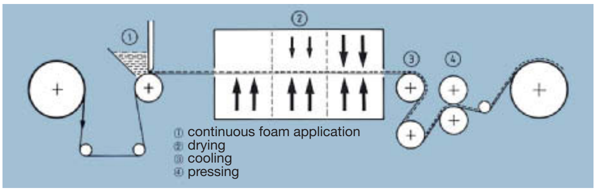


Fig. 1: Doctor knife on roller foam application; subsequent drying.

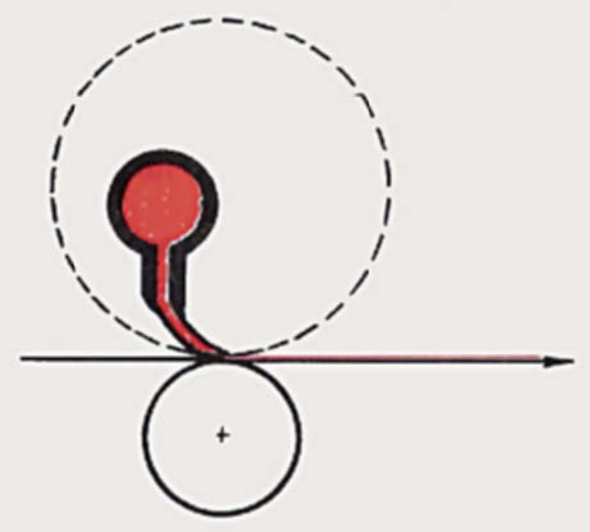


Fig. 2: Foam application by means of rotary screen and internal nip squeegee.

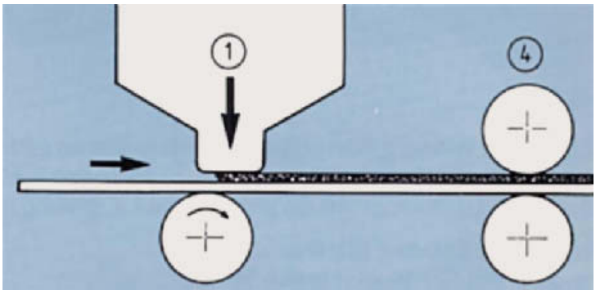


Fig. 3: Foam application by pouring (slot squeegee 1) followed by nip padder (4).

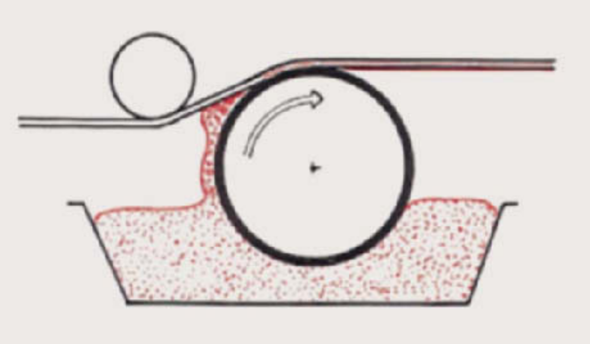


Fig. 4: Foam application by slop padding technology.

tion. With direct application, the total amount of generated foam is brought into contact with the textile material so that reproducibility of the finish is only guaranteed for a specific running speed, a constant blow ratio and a constant quantity of foam since the metastable foam applied is drained by release of the interlamellar liquid. This release of liquid is accelerated by contact with the textile material so that any change in fabric running speed and/or the quantity of foam supplied to the textile results in a different liquor pick-up. In the case of indirect foam application, i.e. the supply of a specific quantity of foam to the textile material, liquor pick-up is independent of the production speed. The following methods are available for the application of foamed liquors to textile fabrics:

- The fabric to be foam finished is guided over a roller in such a way that a blade or knife is positioned over the upper crown of the roller and out of contact with the fabric. By this means foamed liquor is fed to the fabric in amounts determined by the height of the gap between the knife edge and the fabric surface (Fig. 1).
- This method can be modified by applying the foamed liquor from a rotary screen in which all the perforations are open using a double squeegee (Fig. 2).
- Foam can also be applied to carpets through a slotted hopper across the entire width. The foam height is precisely defined by passage through a padder with a pre-set gap between the rollers (Fig. 3).
- Slop padding is also employed as a foam application technique (Fig. 4).
- Finally, foam may be applied between the nip of a horizontal padder (Fig. 5).

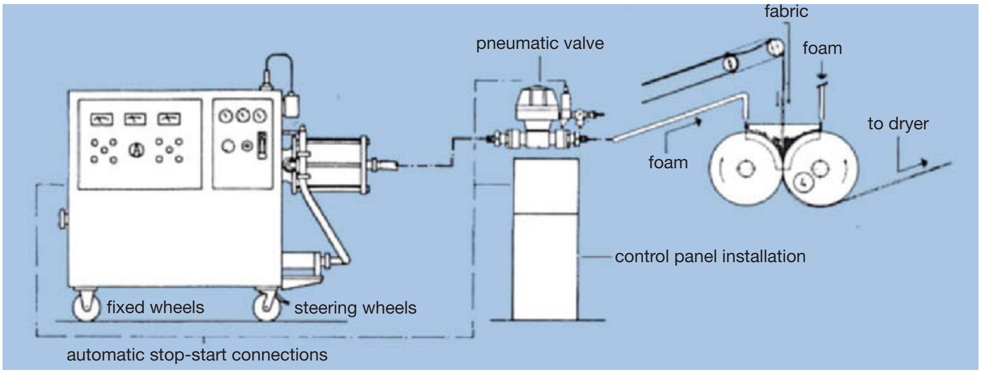


Fig. 5: Foam dosing on a nip padder.

Foam as a source of problems in textile wet processing The following problems can arise in textile wet processing:
- insufficient liquor uptake in padding processes,
- uneven liquor distribution in the textile material,
- formation of stains (inadequate processing treatment, deposition of "dye foam"),
- liquor channeling in yarn packages,
- bursting of yarn packages,
- blockage of machine functions (pumps, rollers),
- malfunction of metering and measuring devices.

The formation of unwanted foam in aqueous solutions is always dependent on two prerequisites:

1. The surface tension between air and water must be lowered (by surfactant action).

2. Air must be entrained in the liquor by mechanical action, i.e. below the surface of the liquor.

Foam does not result from the surfactant alone and is only formed in combination with mechanical influences. The following factors can be responsible for the formation of unwanted foam:
- high production machines (e.g. continuous plants),
- inappropriate impregnation baths (e.g. with a high degree of air contact),
- pumps and liquor circulation systems (e.g. jet dyeing machines),
- "open" fabrics with a high content of air,
- textile contaminants containing emulsifiers (e.g. spinning preparations),
- saponification of natural impurities (e.g. fats, waxes),
- dispersing agents released in wet processing (e.g. from dyestuffs),
- incorrect or excessive amounts of surfactants,
- foam-stabilizing substances.

A high degree of mechanical action is also co-responsible for unwanted foam, i.e.:
- high fabric running speeds,
- high liquor throughput,
- high package densities in yarn package preparation,
- reduced treatment times,
- savings in water consumption (use of short liquor ratios).

It is for these reasons that highly efficient surfactants are required which do not lead to the production of unwanted foam (low-foaming surfactants). A higher degree of activity is thus expected at the textile/liquor resp. soil/liquor interfaces, i.e. the surfactant should be ineffective at the "critical point" of the air/liquor interface.

Foam backing → Back coating of carpets.

Foam breaker →: Defoamer; Antifoams; Drycleaning antifoams.

Foam cleaning Process for cleaning carpets and upholstery materials without complete wetting (so-called shampooing method). The open-structured foam applied to these materials by shampooing emulsifies and disperses the particles of soil adhering to the surface so that they may be easily wiped, brushed or suctioned off again. → Shampoos.

Foam coating The process can be carried out on certain foam application machines. A foam coating system (see Fig.) consists of the following elements: mixer for mixing the compound with the required volume of air, roll-coater, drying unit, pressing cylinder, kiss-roll or padder, and curing oven.

Foam decay Occurs by self-drainage of a foamed liquid. The self-drainage rate (collapse rate) of a foam can be established by determination of the → Foam decay half-life period.

Foam decay half-life period The most widely used and technically simplest method of determining the stability of a foam is measurement of the half-life

Fig.: Stork foam coating.
1 = air inlet; 2 = foam generator; 3 = pump; 4 = microprocessor; 5 = doctor roll; 6 = screen; 7 = operating panel; 8 = bypass.

period of the foam. The time recorded is that required for one half of the liquid in the initial foam to separate from the foam by self-drainage. → Foam evaluation criteria.

Foam degumming A process for the → Degumming of natural silk under mild conditions. Instead of immersing hanks of yarn in the soap bath they are suspended in the soap foam produced by the introduction of live steam into the bath.

Foam density The foam density is calculated according to the formula:

$$\frac{\text{volume of solution consumed foam density}}{\text{volume of foam}}$$

Foam drainage on textile contact This property of a foamed liquid is influenced by several factors, e.g. the → Blow ratio, → Foam decay half-life period (→ Foam performance evaluation), the surfactant combination used to produce the foam and the state of the textile material. In order to evaluate this property of foam a specified quantity of foam is placed on an absorbent cotton test fabric in a tray of defined diameter. The percentual surface enlargement serves as a measure according to the formula:

$$\text{increase in area } [\%] = \frac{D^2 \cdot 100}{d^2}$$

D = diameter of the wetted area after x seconds,
d = diameter of the area of applied foam.

The "wetting power" of the foam must be different depending on the particular application of the foam (dyeing, printing, finishing).

Foam dyeing Dyeing processes based on the use of finely porous foam either as a dyeing medium itself or as a dye carrier. Foam dyeing can be carried out by exhaust and continuous methods. Foaming of the dye liquor serves to increase the liquor volume and is hindered by the presence of electrolytes.

Foam dyeing and finishing units These consist of a foam generator with a foam delivery system, foam applicator, and monitoring device for automatic process control. Advantages: up to 80% savings in water and chemicals, no migration problems (the fabric is almost dry immediately after application), wet-on-wet treatments saving an intermediate drying process are possible. Because of the very low tension and pressure involved, sensitive fabrics can be processed without distortion.

Foamed nonwoven These are three-dimensionally-oriented → Nonwovens based on a synthetic foam with an approx. 50% microcell structure. They are produced in several strengths mainly by synthetic resin impregnation (insensitive to water/moisture). Foam-sandwich nonwovens have been developed to replace the least stressed part of glass fibre reinforced polyester sandwich constructions (higher flexing resistance with greater strength; lower costs compared to full glass laminates with the same flexing resistance; lower specific gravity of the sandwich construction; higher compressive strength). This kind of nonwoven bonded fabric is chiefly used as a composite material for containers, large pipes, flanges, etc. These materials have good resistance to chemicals such as acids, alkalis and nonpolar solvents; they are less resistant to polar solvents, esters, ketones and halogenated hydrocarbons.

Foam evaluation criteria → Foam performance evaluation.

Foam extinguishers Fire extinguishers which mostly contain two separate solutions: a) sodium hydroxide solution and foam-generating additives such as saponine, sulphonated oils and b) mostly acidic-reacting aluminium sulphate solution. When required for use, both solutions are mixed by inverting the fire extinguisher which causes the immediate formation of a light foam with fine bubbles (large quantities of foam from a few litres of liquid). This foam is then directed on to the fire through a connecting tube or hose. Applications: widely used for factory, laboratory, gasoline and garage fires, etc.

Foam finishing technology (FFT technology). A foam application process developed by Union Carbide Corp. and propagated (machine-wise) by Gaston County in which precisely metered quantities of foamed chemicals, etc., are applied to a textile substrate. Penetration of the porous textile fabric by foam results in a uniform distribution of the conc. solution of chemicals at a minimum liquor pick-up of approx. 10%. Migration problems are also eliminated at the same time. The applied foam breaks immediately on contact with the fabric. Foam density is below 0,2 g/cm^3. In contrast to padder applications, the liquor pick-up can be considerably reduced to 10–25% of the fabric weight with this process. Since the greatest part of the water required in conventional padder applications is substituted by air in this process, energy consumption in subsequent drying is also reduced. The precise, independent and automatically controlled volumes of air and highly conc. liquor applied directly to the fabric are the distinctive features of the FFT process in comparison with other foam application systems. The FFT process is particularly suitable for the application of wash and wear finishes. →: Minimum pick-up; Foam application.

Foam formation

I. Unwanted formation of → Foam during wet processing operations. Causes problems in dyeing and printing, etc. and should be prevented. See → Foam as a source of problems in textile wet processing.

II. Foam formation as a desired effect for applications in dyeing and finishing. When solutions of substances with low surface activity are used for foam generation (e.g. short-chain alcohols or acids), the resultant foam is often only stable for a few seconds. Foams with considerably greater stability are produced with substances capable of causing a considerable reduction in the surface tension of water (e.g. soaps, non-ionic, cationic and amphoteric surfactants). → Foam application.

Foam generators Since the end of the 1960's, foam technology has been adopted by the carpet industry for the application of latex compounds in foam backing. Nowadays, foam technology represents an important technique in the carpet and textile industries for various stages of finishing. Compared to liquid compounds, processes based on foam technology allow the volume of application to be increased for the same weight of compound. These conditions ensure high accuracy of application and facilitate e.g. the precise adjustment of product penetration into the carpet backing. The high and varied demands placed on these foams, which are not only used in the carpet industry, call for mixer concepts which can be adapted to the actual operating conditions as far as performance and control are concerned.

The quality of the foamed compounds stands or falls on the quality of air dosing. The smallest fluctuations in air content will change the litre weight of the foam and consequently reduce the quality of the end product. It is therefore necessary to apply a very rapid air measurement with a high degree of linearity. A block diagram illustrating the principle of air control is presented in Fig. 1. Measurement of the flow rate of the compound is of great importance for the control system of a high quality foam mixing system since the actual values detected for the product form the basis for the air quantity control system which further processes this value into the control target value. In Fig. 2, the combined action of both control systems is explained. With the aid of such combined control systems, a predetermined foam litre weight is constantly maintained under different production conditions.

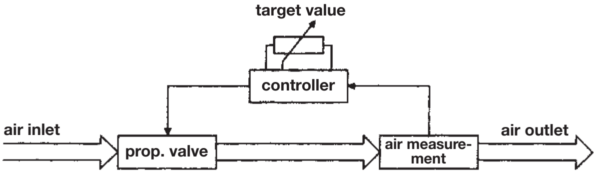


Fig. 1: Block diagram illustrating the principle of an air control system (Wolfgang Groth).

Very exacting requirements are placed on the seals of a foam mixing system. Double-action axial face seals have become established for handling aggressive materials. Individual adaptation to the medium being sealed is achieved by an appropriate pairing of the axial face surfaces. In the carpet industry, hard axial surfaces are used mostly on the product side, e.g. tungsten carbide/tungsten carbide, which have given the best results with highly filled materials. On the atmosphere side, soft seal surfaces are used, e.g. silicon carbide/carbon. Double-action axial face seals provided with a pressure retaining cooling system represent the optimum in the field of shaft seals for foam generating systems.

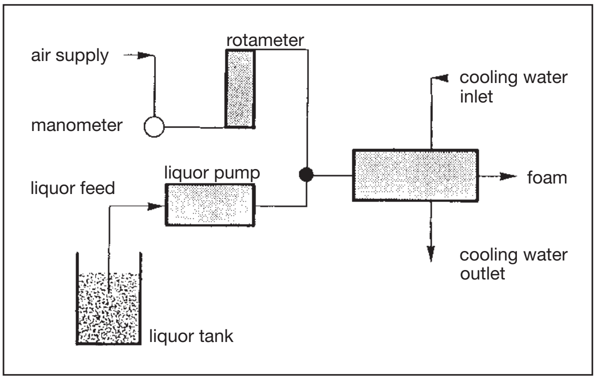


Fig. 2: Foam generator (flow diagram).

Apart from simple operating features, foam generators should be designed for easy cleaning and maintenance since problem-free production can, of course, only proceed if the necessary cleaning and maintenance work is executed quickly and easily. Modern foam generating systems are accommodated in a glass-blasted stainless steel housing, the extremely fine-pored surface of which is effective in preventing deep penetration and adhesion of soil particles. Environmentally-friendly cleaning may be carried out with conventional detergents. The short cleaning process reduces the consumption of water and detergents. The maintenance of foam generating systems has been reduced to a minimum and is limited mainly to topping up the pressure retaining tank and the routine checking of connections (source: Conrad).

Foam generators are of two types, static and dynamic. In static mixers (Fig. 3), air and liquor are brought into contact with each other in a mixing head containing glass beads or Raschig rings. In order to produce a homogeneous foam, the surfactant solution is distributed over the largest possible surface area so that the interface with the incoming air is increased. In this way, the entire surfactant solution is foamed over a selected unit of time to give the desired degree of foaming by the injection of an appropriate amount of air.

The mixing of air and surfactant solution may also be carried out in a dispersion turbine (Fig. 4), which is still based on the same physical principles, although the

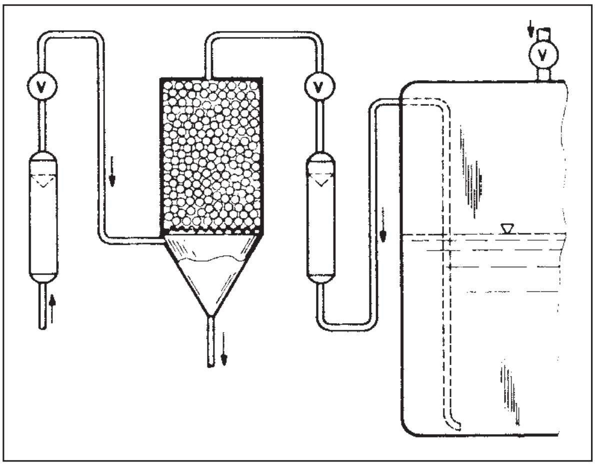


Fig. 3: Schematic representation of foam generation based on the principle of a static mixer.

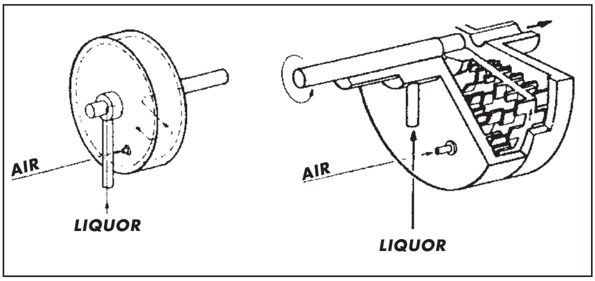


Fig. 4: Schematic representation of a dispersion turbine for foam generation.

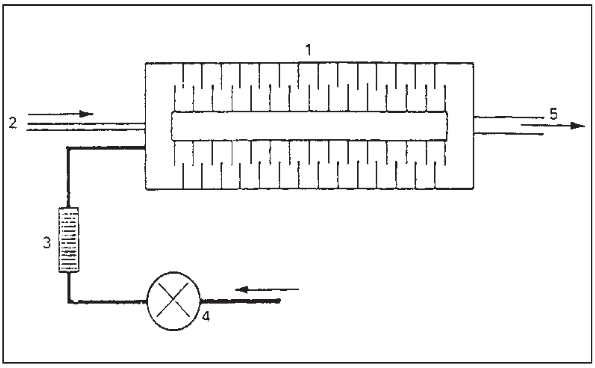


Fig. 5: Dynamic mixer.
1 = rotor/stator in mixing head; 2 = compound; 3 = air flow meter; 4 = air pressure meter; 5 = ready made foam.

size of the unit is somewhat reduced, the ease of cleaning is improved and the system possibly offers more constant conditions.

A dynamic mixer consists of a stator and a rotor (Fig. 5). This system provides control of foam supply quantity, air dosing and gelling agent quantities according to the speeds of the coating plant. These computer-assisted systems represent the present state-of-the-art.

Measuring and control equipment for foam generation is also available. For the supply of coating compound in front of the squeegee, a measuring and control system is available (Fig. 6) which is designed for installation at the coating plant. This system offers the possibility to measure the quantity of coating compound supplied to the squeegee continuously and to control the height of the squeegee by means of a geared motor and/or the supply of coating compound via a standard signal at the mixer. The effects achieved with this measurement and control unit are revealed by the more constant and uniform feed quantity and, above all, by a greater uniformity of the coating thickness.

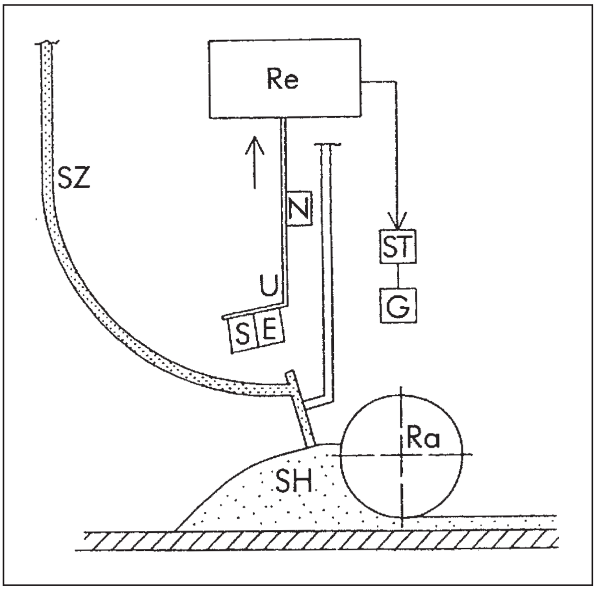


Fig. 6: Foam feed measurement system of Hüls.
U = ultrasonic measuring device; S = transmitter;
E = receiver; N = proximity switch; Re = regulating device;
ST = control unit; G = geared motor (operating side);
SH = foam height; Ra = squeegee; SZ = foam feed.

Foaming The foaming of surfactants is always associated with their desirable properties such as wetting, dispersing or emulsifying. → Foam.

Foaming backing The application of foamed compositions to textile fabrics by bonding or laminating. → Carpet back coating.

Foaming capacity The ability to form an air bubble enveloped by a double film of surfactant. → Foaming power.

Foaming power The capacity of a product to form → Foam. Calculation:

$$\frac{\text{volume of foam}}{\text{volume of solution used}}$$

The ratio of the volume of foam of a sample to the volume of foam of a sodium oleate solution which has been allowed to stand for 1 min is used as a comparative measure of foaming power.

Foaming power of surfactants In the case of non-ionic surfactants the foaming propensity increases with rising ethylene oxide content. Foaming is most pronounced with anionic surfactants having good water solubility. Mixed surfactants have a medium foaming propensity. The foam formation of most non-ionic surfactants foam varies only a little over a wide concentration range compared to the enormous changes in their wetting, dispersing and emulsifying power. With non-ionic surfactants the influence of temperature on the foaming of surfactant solutions at elevated temperatures can be seen. The addition of an electrolyte to a surfactant liquor, e.g. 5 g/l sodium sulphate, causes a distinct lowering of the foaming propensity only in the case of alkylphenol ethoxylates and not with the corresponding oxo alcohol derivatives. With anionic surfactants the influence is non-uniform: the addition of electrolyte appears to exercise more of a foam intensifying influence, whilst the dependence of foaming propensity on temperature is only slight. Non-ionic surfactants with a low degree of ethoxylation produce an even lower amount of foam with addition of electrolytes and temperature changes. Pure anionic surfactants, on the other hand, are among the most highly foaming and difficuluence products. From the foaming point of view, therefore, non-ionic surfactants with a low degree of ethoxylation are to be recommended. Their use is also well-established in practice but only in cases where their electrolyte stability is sufficient to meet requirements. Unfortunately, however, their efficacy or stability is inadequate for the majority of textile wet processing applications so that surfactants with a higher foaming propensity have to be used.

Foam problems and consequent disruptions in processing are only caused by surfactant liquors with foam half-life decay periods which are (significantly) lower than their foam build-up rates. For this reason, a surfactant which foams readily, the foam from which quickly collapses again outside the turbulence zone, can present less problems in practice than a less highly foaming surfactant which produces a stable (tenacious) foam. The foam may indeed build-up slowly but keeps on doing so (until it reaches a level at which it causes disruptions in processing). In order to investigate this problem as well, e.g. in continuous pretreatment, it is necessary to observe not only the absolute level of foam but also the extent of foam collapse which takes place after foam formation. Thus measurements are taken not only of the foam level directly at the end of mechanical actions but also after 30, 60 and 120 s, and even after 3–5 min. → Foam performance evaluation.

Foam inhibitors Substances capable of preventing excessive foaming of wash liquors in washing machines which would otherwise reduce the mechanical washing action and consequently impair washing efficiency. Suitable compounds include, in particular, long-chain soaps (behenates) as well as amine oxides and silicones. An essential prerequisite for the foam regulating action of a substance is a high degree of water insolubility and a high surface spreading pressure. Displacement of surfactant molecules from the liquid/air interface or penetration of the liquid/air interface occupied by surfactant molecules thereby producing disruptions which weaken the mechanical strength of → Foam lamellae causing breakdown of the latter may explain the action of foam regulators. Soaps with a wide chain-length spectrum and silicone oil systems have largely established themselves for these applications. → Foam regulators for wash liquors.

Foam intensifier A substance used to increase the → Foaming power of surfactants.

Foam lamellae Liquid interfaces between individual bubbles of → Foam. Foam is therefore said to possess a “lamellar structure”. Due to capillary action in foam lamellae strong attraction forces for soil particles are released, as a result of which the latter are loosened (by mechanical action such as liquor movement, friction, pressure and squeezing) and removed from the fibre surface. The foam lamellae contain a film of liquid between the surface pellicule layers which consist of a monomolecular surfactant film, i.e. so-called interlamellar liquid.

Foam laminated textiles These are defined in DIN 60 000 as laminates of textile fabrics and sheets of foam. Garments produced from such materials offer increased protection against weather and cold, and are particularly suitable for fashionwear, sportswear and workwear. Such garments are lighter in weight than fur garments. An essential requirement is resistance to washing and drycleaning.

Foam laminates → Foam laminated textiles.

Foam latex Alternative term for → Foam rubber.

Foam latex coating of tufted carpets → Backcoating of carpets.

Foam mixing units Used for foaming latex, polyvinyl chloride, acrylic and polyurethane dispersions for coating and laminating. Foam mixing units capable of faultless operation are a prerequisite for optimum quality and cost-effective latex foam coatings. High performance foam mixing units provide continuous adjustment (variance comparison) of foam weight per litre, compound density, mixing capacity and gelling agent quantities in relation to changes such as the machine running speed. The weight per litre of the foam is also displayed continuously.

Foam padder The Fig. illustrates a foam dyeing unit for carpets which does not require a foam generator. A dye liquor is applied to the carpet pile with the aid of a kiss-roll and subsequently foamed *in situ* by

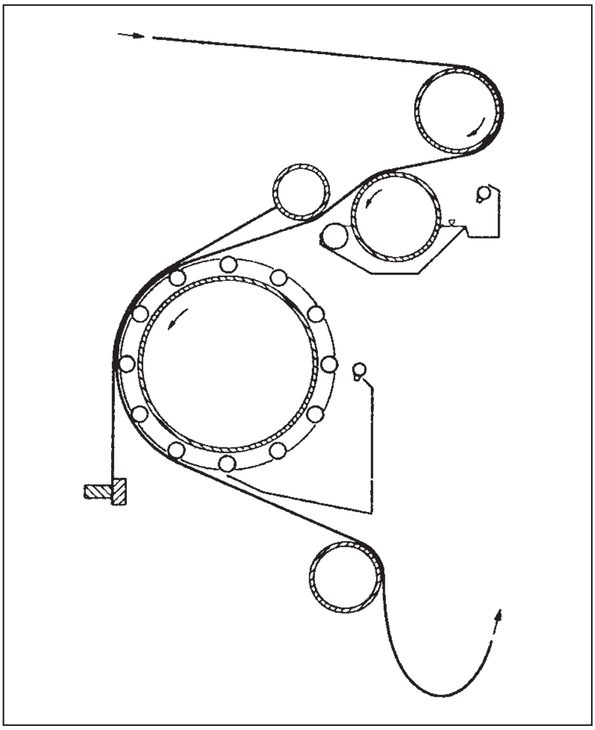


Fig.: Foam production on the fabric by bar rotor in a carpet foam dyeing unit (Fleissner).

mechanical action on passing between a rotating cylinder of rods and a pressure plate at the back of the carpet.

Foam performance evaluation Test methods for the evaluation of foam properties are important in terms of their application in the textile sector. The requirements placed on foam properties in textile finishing processes are given in the Table.

	Field of application	
Criteria	Finishing/dyeing	direct print
Homogeneity of the foam	regular	regular
Degree of foaming	variable	high
Foam stability (foam disintegration half-life)	slight	great
Dehydration of the foam upon contact with the textile	fast	fast

Table: Profile of requirements for foams used in textile applications.

The degree of foaming is the ratio of the starting liquor to the dispersed air in the foam. It plays an important part in foam application since it helps to determine the liquor uptake. The following parameters are possible:

$$\text{Volume ratio} = \frac{\text{Volume of liquor}}{\text{Volume of foam}}$$

$$\begin{array}{l}\text{Ratio of weight}\\ \text{with constant volumes}\end{array} = \frac{\text{Weight of liquor}}{\text{Weight of foam}}$$

$$\text{Foam density} = \frac{\text{g foam}}{\text{cm}^3}$$

$$\text{Foam litre weight} = \frac{\text{g foam}}{\text{l}}$$

The foam weight per litre is determined by calibrating a beaker at 1 litre volume, taring the beaker, filling it to the mark with foam and weighing. For the liquid/air mix ratio, the density of the foam must also be taken into account. If this is $\neq 1$, a correction must be made to the liquor or air supply in order to achieve the desired degree of foaming.

The rate of self-drainage of a foam is determined by the half-life period of decay. The time recorded is that required for one half of the liquid in the initial foam to separate from the foam by self-drainage. For a given foam volume and foam density (S_s), the half quantity of liquid may be calculated as follows where the density of the liquid is $S_F = 1$.

$$V_f = \frac{V_s \cdot S_s}{2\,S_f}$$

V_s = foam volume; S_s = foam density;
S_f = liquid density; V_f = liquid volume.

The more quickly the syneresis (self-drainage) of a foam is completed, the shorter the half-life period of decay (HPD). The drop emergence time (DET) test method is of particular interest in cases where small quantities of liquid have a disruptive effect in foam application. With this method, the point at which drainage of the foam begins can be determined. The drop emergence time provides an indication of the time at which the first drop of liquid flows out of the foam. This determination can be carried out at the same time as the test for HPD in an Imhoff funnel. The more quickly the formation of the first drop occurs, the more unstable the foam.

Another method of characterizing foam collapse measures the time-related re-formation of liquid (kinetics of foam collapse). In this test, a constant foam volume is placed in a funnel which is then covered with a plane glass sheet, and the emerging liquid is measured at discrete intervals of time. The increase in weight is recorded and a graph illustrating the dependence of weight increase on time is plotted. The resultant curves are evaluated as follows: the steeper the gradient, the more unstable the foam (Fig. 1).

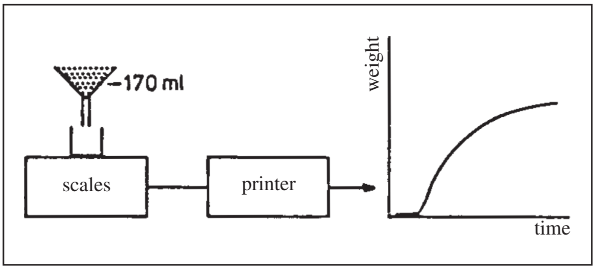


Fig. 1: Method for the determination of foam drainage kinetics.

The drainage of a foam on contact with a textile substrate is dependent on the type of fabric (nature of fibre, fabric construction) in addition to the properties of the foam itself (e.g. degree of foaming, drainage characteristics). This foam characteristic is tested by placing a beaker with a specified diameter filled with foam upside down on the test fabric (ideally this should be the same as the material to be used). The wetted area of the material is determined after a specified time. The measurement parameter here is the percentual growth in wetted surface area which may be calculated as follows (Fig. 2):

$$\text{surface increase [\%]} = \frac{D^2 \cdot 100}{d^2}$$

D = ∅ of the wetted surface after x seconds
d = ∅ of the beaker

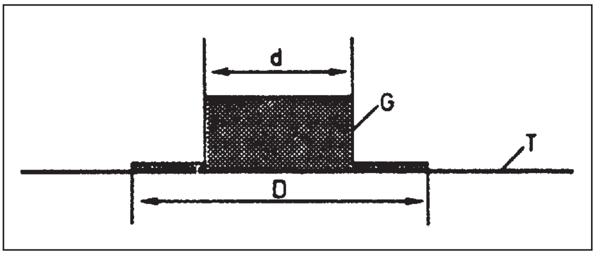


Fig. 2: Method for the determination of foam drainage on contact with the substrate.
d = diameter of the glass beaker; D = diameter of the wetted surface; G = glass beaker with foam; T = textile.

The rheological behaviour of metastable foams is characterized by their pseudoplastic flow, whereby apparent thixotropy or rheopexy can also occur. For the measurement of viscosity, rotary viscometers are used and the following three measurement procedures are recommended:

1. Viscosity measurement with a constant shear gradient D as a function of time t.

2. Viscosity measurement with several specific shear gradients. For this purpose, the speed of the rotating device is increased by degrees, in the process of which the reaction times of the individual shear gradients should be identical.

3. Viscosity measurement with a continuously increasing speed of the rotating device. Both the influence of the increasing shear gradient as well as the time are determined by this means.

The determination of this foam property is of particular interest in foam printing. Evaluation is based on the flow or viscosity curves obtained.

The bubble size provides information on the homogeneity and stability of foams. Fine foams are more stable than coarse. For textile applications, the foam bubbles should be small and uniform (optimum size range 50–100 µm). The bubble size is determined objectively by microphotography. It can also be carried out subjectively by visual evaluation.

Besides the characterization of an existing foam, foaming kinetics can also be of interest to the textile finisher. To this end, the methods of foam formation as well as the measurement procedures of foaming kinetics are subdivided into static and dynamic procedures.

a) Static procedures include those in which
– the air supply is introduced at the bottom of the solution,
– the air supply is produced by manual or mechanical agitation or,
– the air supply is discharged through the solution.

The modified Ross-Miles method (Fig. 3) as specified in DIN 53 902, Part 2 is an example of such a procedure. With this method, the discharge time and foam height of a surfactant solution are measured 30 s, 3 and 5 min after the free outflow of 500 ml water with a hardness corresponding to a calcium carbonate content of 300 mg/kg from a specified height above the liquid surface of the same solution.

Another method is the perforated disc beating procedure in accordance with DIN 53 902, Part 1: in this case, the foam is produced by beating the surfactant liquor in a glass cylinder for 30 s with the aid of a perforated plate attached to a pillar (Fig. 4).

b) Dynamic methods include those in which the air supply is provided by continuous pumping (Fig. 5) or by a stream of the solution. The advantage of these methods is that the speed of circulation, fall height and temperature of the liquors can be varied

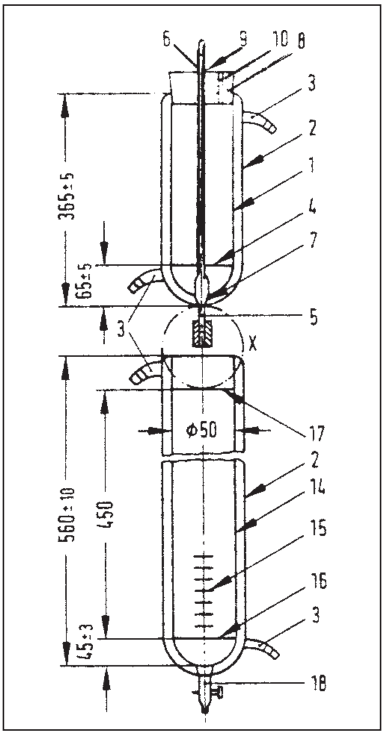


Fig. 3: Modified Ross-Miles apparatus.

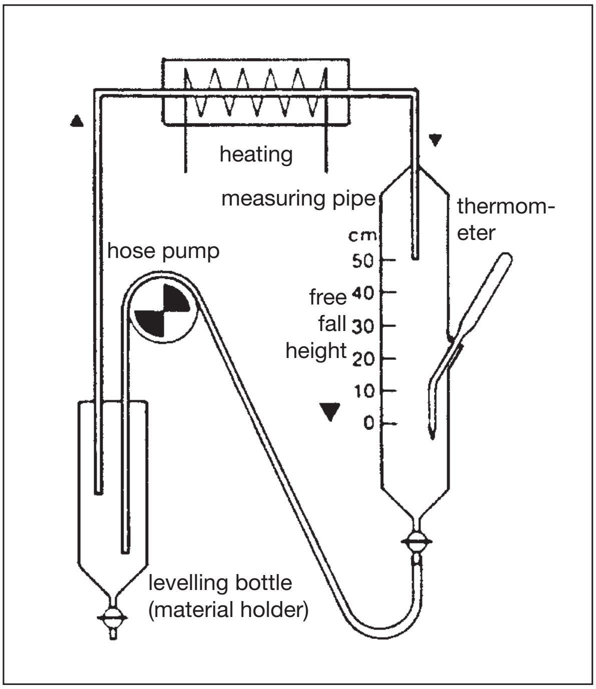


Fig. 5: Foam apparatus for dynamic foam measurement.

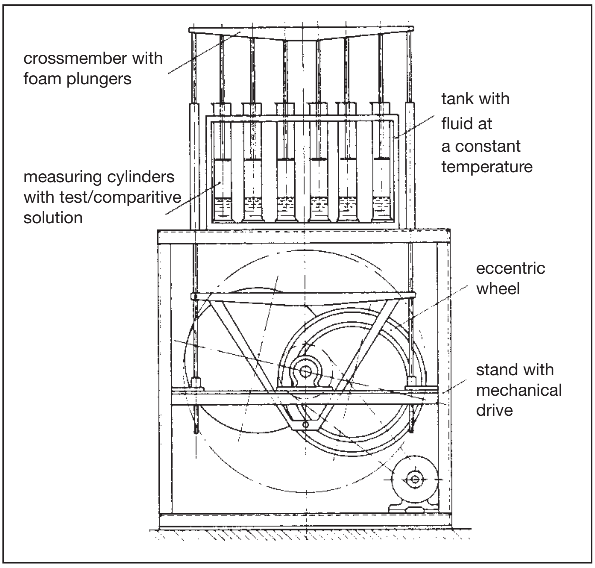


Fig. 4: Schematic representation of an apparatus for the uniform production of foam in several measuring cylinders (DIN 53 902, Part 1).

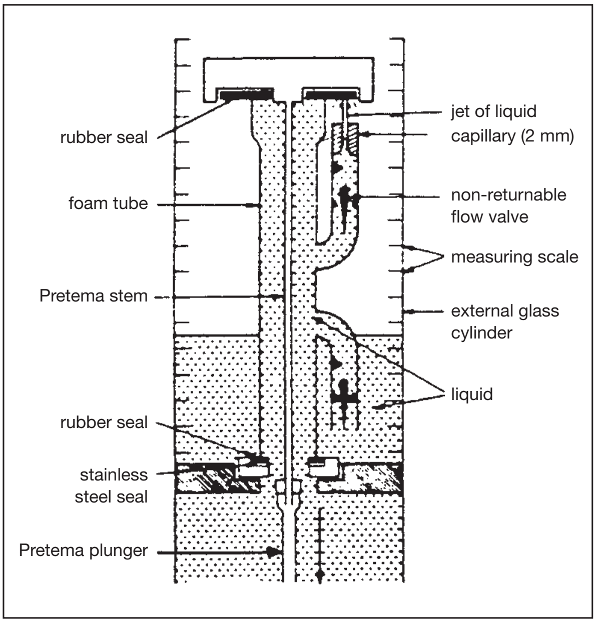


Fig. 6: Schematic representation of the glass foam tube.

and therefore adapted to the conditions encountered in practice.

In the case of one dynamic foam test method of Derbyshire and Leaver (Imperial Chemical Industries Ltd., Manchester), a development based on the use of a modified Pretema Multicolor dyeing machine, Ellner system, manufactured by Pretema AG, is involved. The usual material carriers for dyeing in this machine have been replaced by a glass tube with two valves (Fig. 6). As a result of the up and down movement of the glass tube in the liquor, turbulence is created in the liquor which allows the introduction of air. By this means, information on the kinetics of foam development which are dependent on the concentration of surfactant (Fig. 7) or the temperature is obtained (Fig. 8).

The VSI foam testing apparatus is a joint development of the firm “Haake-Meß-Technik” in Karlsruhe, Germany, and the German Verband Schmierfett-Indu-

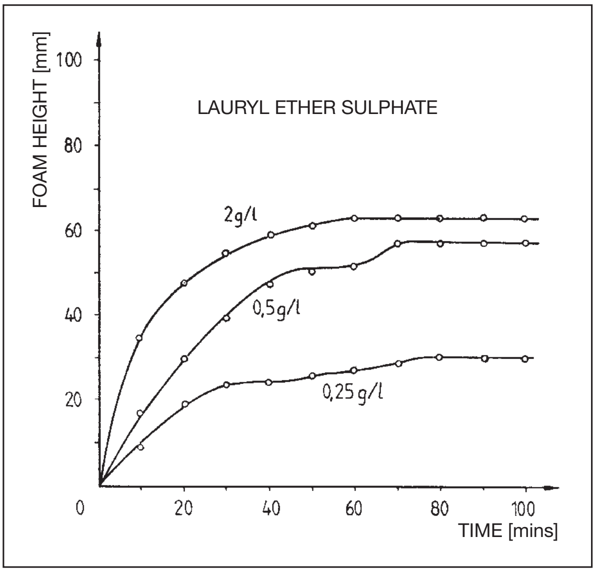


Fig. 7: Dynamic foam test on lauryl ether sulphate (dependence on time and influence of surfactant concentration).

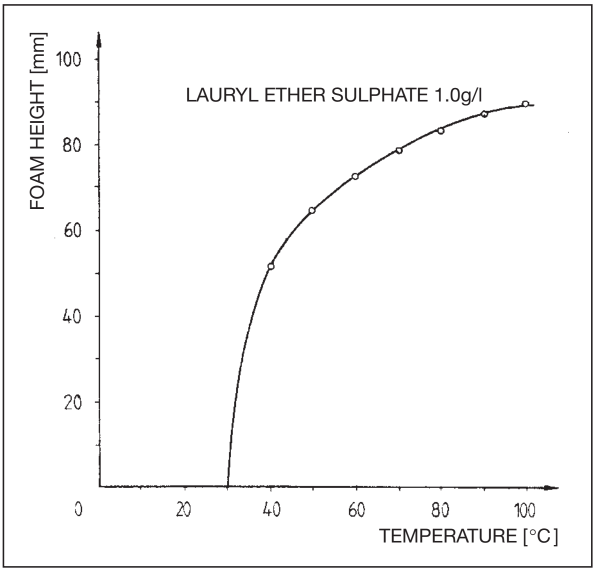


Fig. 8: Dynamic foam test on lauryl ether sulphate (dependence on temperature).

strie e.V. (German Association of the Lubricants Industry). It was developed for controlling the foam resp. foaming behaviour of water-miscible coolants and cutting fluids used in the engineering industry. With this method, the test substance is subjected to specified mixing and showering phases whereby the speed of foam formation as well as the rate of foam collapse are determined. The apparatus (Fig. 9) measures the volume of foam as well as the speed of foam formation and collapse in a vertical cylindrical glass tube in which the test liquid is sprayed perpendicularly downwards under pressure from a shower head on to a baffle plate which causes air to be carried along with it thereby producing foam. The foam rising in the cylindrical tube makes contact with three sensors positioned at different predetermined heights, one after the other, which transmit a measurement signal on foam contact. These signals are recorded dependent on time. Adjustable test parameters of the foam testing apparatus include: the feed pressure (0.5–1.5 bar), the positions of the individual three sensors above the level of the liquid and the target temperature of the test liquid within the limits of 10–60°C by means of a low-temperature thermostat.

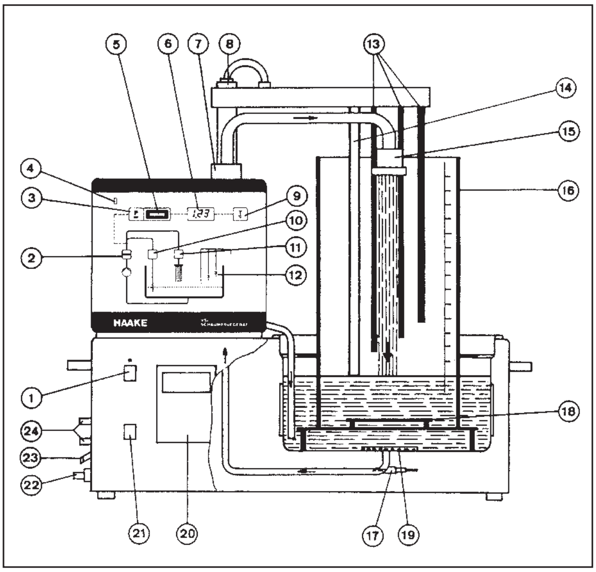


Fig. 9: VSI foam test apparatus (Haake).
1= main switch; 2 = feed pump stop button; 3 = pressure set value-actual value changeover switch; 4 = external control indicator; 5 = pressure set-value adjuster; 6 = digital display pressure/temperature; 7 = shower arm union; 8 = sensor arm union; 9 = temperature display changeover switch; 10 = "pumping" switch; 11 = "shower" switch; 12 = sensor contact indicator; 13 = sensor holders with sensors;
14 = liquid level marker; 15 = shower head unit; 16 = glass cylinder; 17 = temperature sensor; 18 = baffle plate;
19 = outflow sieve; 20 = printer; 21 = printer switch;
22 = drain nozzle; 23 = drain valve tumbler switch;
24 = temperature equalizing connections.

Test procedure:

- the stainless steel tank is filled with 5 l of test liquid;
- the test liquid is conditioned, i.e. the test liquid is thoroughly mixed by recirculation and the liquid temperature is brought into line with the required test temperature at the same time;
- measurement of foam formation (showering) and foam collapse.

The measurement values are detected by the 3 sensors positioned in the shower zone. When an electroconductive foam forms during the showering stage and contact is made with sensors 1–3 one after the other, an electric circuit (sensor – apparatus housing – test liquid – foam) is closed on each occasion. By this means, a gradually rising voltage level measurement signal is generated. In addition, the measuring times t_{01} to t_{23} are determined. During foam collapse, the foam detaches itself from the sensors one after the other thereby disconnecting the corresponding electrical circuits in turn. The times t_{43} to t_{21} are measured and the voltage level measurement signal is reduced by stages.

Test results:

a) foam formation:
  - t_{01} = time taken for the foam to rise to the 1st sensor.
  - t_{12} = time taken for the foam to rise from the 1st to the 2nd sensor.
  - t_{23} = time taken for the foam to rise from the 2nd to the 3rd sensor.

b) foam collapse:
  - t_{43} = time taken for the foam to lose contact with the 3rd sensor after switching off the feed pump.
  - t_{32} = time taken for the foam to lose contact with the 2nd sensor (O_S = loss of contact with 3rd sensor).
  - t_{21} = time taken for the foam to lose contact with the 1st sensor (O_S = loss of contact with 2nd sensor).

Another type of foam testing apparatus analyzes the foam height at 3 points with the aid of sensors. The essential feature of this apparatus is the continuous foam test both during foam formation and foam decay. This is accomplished by means of a light metal plate which is supported by the foam and a polyamide thread connected to a counterweight via a gauge for measuring the angle of rotation (Fig. 10).

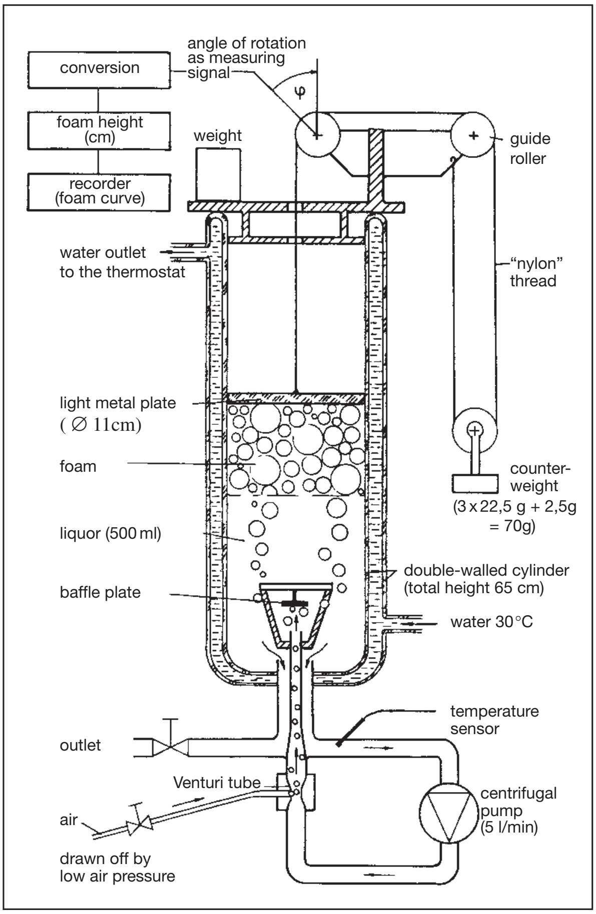


Fig. 10: Schematic representation of the Herrig + Rüttiger foam testing apparatus, developed by Schramm.

500 ml of the liquor under test is introduced into the double-walled cylinder, taking care to keep the liquor as free of foam as possible, and heated to 30°C. During this heating stage, the centrifugal pump is switched on to ensure thorough mixing of the liquor. After reaching the set temperature, the air valve is opened whereupon air flows into the liquor due to the partial vacuum created by the flow of liquor through a constriction in the tube underneath the cylinder (analogous to a venturi nozzle). The air/water mixture is pumped against the baffle plate and the liquor begins to foam as a result of which the light metal plate moves upwards due to the build up of foam beneath it. The counterweight to the metal plate now causes the polyamide thread attached to the metal plate to actuate the wheel of the gauge measuring the angle of rotation. This determines the length travelled by the polyamide thread via the angle of rotation which provides an indirect measure of the foam height.

As soon as the foam reaches a height of 25 cm, the air valve is closed and the centrifugal pump switched off. The maximum foam height of 25 cm is fixed by the ability of the integrated plotter to indicate the height reached. Furthermore, the centrifugal pump must be switched off during collapse of the foam which now begins since, otherwise, the liquor would become too hot due to the relatively high pump capacity (5 l/min) and the resultant heat of friction. The foam collapse is measured by the angle of rotation in a similar manner to the foam formation. The signals from the gauge measuring the angle of rotation are converted into recording signals and plotted as foam curves by an integrated printer (paper transport 1 cm/min). The test is carried out three times on each liquor.

In order to obtain a decisive value from the foam curves for the foaming characteristics of wash liquors and consequently the washing activity, the curves are evaluated by reference to the following points (Fig. 11):

1. Angle of ascent (α).
2. Angle of descent (β).
3. Time of ascent until the max. foam height is reached (a).
4. Distance covered for different foam heights (b).
5. Total distance covered in foam collapse (c).
6. Integration of the foam curve by weighing the area of printer paper enclosed by the curve. Conversion

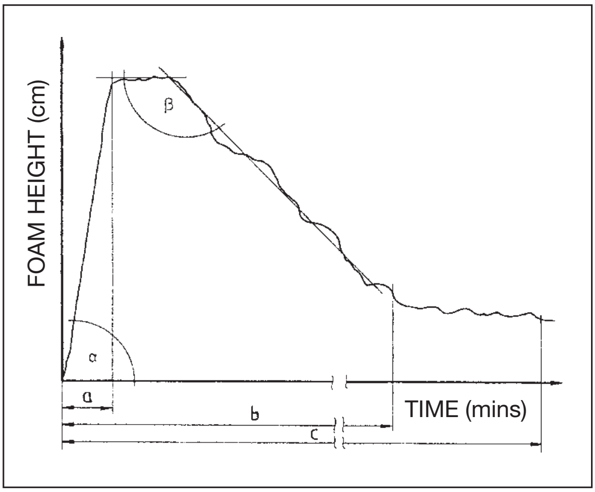


Fig. 11: Values for foam formation/collapse (foam measurement apparatus according to Herrig + Rüttiger).

to give the corresponding surface content is made by reference to a weighed surface area of 1000 cm^2.

Foam preventing agents →: Antifoams; Foam inhibitors.

Foam printing A textile printing variant of low wet pick-up in which a large proportion of the water in print pastes is substituted by air; thickening agents are superfluous and therefore do not need to be washed out. The advantages are reduced soiling of water during afterwashing and lower energy requirements in drying and steaming. The main disadvantage is the need for a separate foam generator for each print paste in the design and the resultant increase in costs. Printing of outlines is also difficult with foam print pastes. A typical foam printing system for rotary screen printing is illustrated in the Fig.

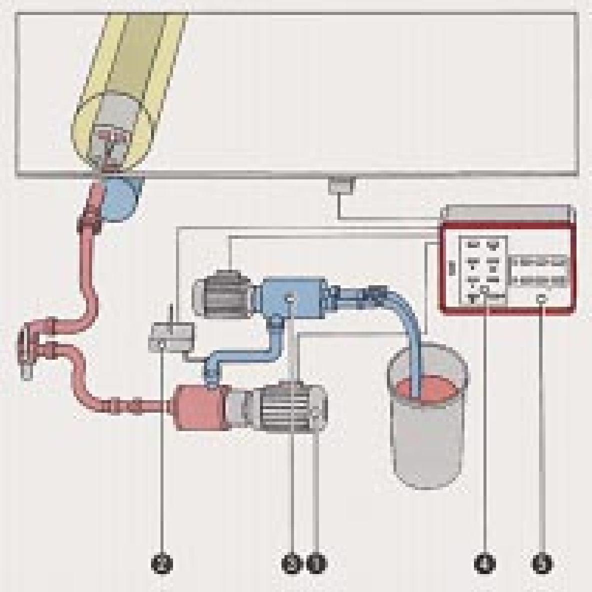
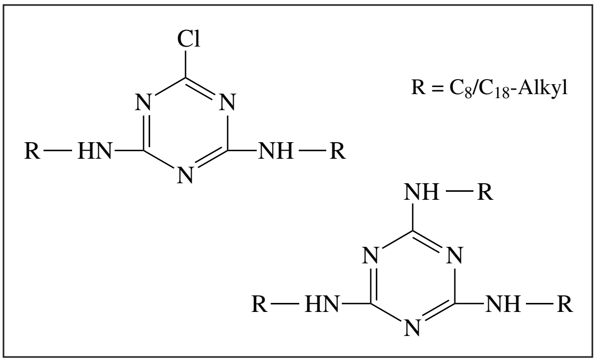


Fig.: Stork closed foam printing system.
1 = mixing head; 2 = air regulating valve; 3 = paste pump; 4 = microprocessor; 5 = operating panel.

Foam regulators for wash liquors (→ Foam inhibitors). Products designed to prevent excessive foaming of wash liquors which is essential for the drum type washing machines widely used throughout Europe (foaming is an unwanted occurrence). New foam regulators are required for new surfactants (e.g. alkane sulphonates, sulphonated olefins, α-sulphonated fatty acid esters, fatty alcohol sulphates and non-ionic surfactants as well as phosphate substituents) for which, besides the sodium salt of behenic acid, monochlorodialkylaminotriazine and trialkylmelamine (as well as combinations) are recommended as suitable foam regulators for all types of surfactants:



Foam rubber (latex foam). An → Expanded foam produced from → Rubber or synthetic rubber. It consists of approx. 15% rubber and 85% entrapped air or gas cells. Foam rubber is of low weight, odourless, elastic, dimensionally stable, absorbs body transpirations and conducts them away, prevents heat accumulations, provides noise insulation, is resistant to parasites, washable and has a long service life (especially synthetic foam rubber, as well as natural foam rubber which is protected against the action of sun and air). Used in garments (only suitable provided the stability to solvents and drycleaning is adequate); special paddings (incorporation of textile fibres, horsehair glass fibres, etc. provide increased strength) for mattresses, seat upholstery, cushions, carpet underlays; fracture-proof packing; automobiles; shoulder paddings (resistance to drycleaning); trouser webbings (resistance to drycleaning); underarm pads; sponges, etc.

Foam-sandwich nonwovens → Foamed nonwoven.

Foam sizing The process of foam sizing calls for a change in the auxiliaries by which the “add on” to the yarns is applied. An emulsion which typically contains 20% solids or “additives” and 80% water is converted into a foam by the careful introduction of air, the viscosity of which is adjusted empirically in such a way that a good wet add-on is achieved. An appropriate mixture consists of a 4:1 ratio of water to solids with air making up the remainder. This is in contrast to classical size mixtures which can consist of a 9:1 ratio. The resultant properties of both emulsions are approximately the same so that, in each case, the yarn fibres are enveloped and to some extent penetrated with the same add-on quantities. In foam sizing, only 4 parts of water (and not 9 parts) need to be subsequently evaporated so that an energy saving of around 56% is achieved.

Since less water must be used in foam sizing, considerably less mechanical change occurs during application and drying. A lower water content means lower wet elongation stresses are involved so that the original strength of the yarn is maintained. During drying, there is considerably less separation of the filaments from one another as they are already in a much drier state. The separation of sized yarns by the splitting rods is noticeably a more gentle operation so that a stronger and more uniform yarn is obtained free from loose fibres and lumps of size. The composition of the size recipe must nevertheless be modified in order to adapt the process to sizing with foam mixtures.

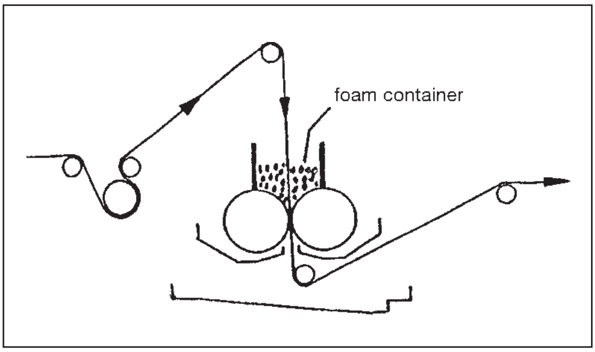


Fig.: Foamed size application.

The size solution is pumped into the foam generator from a size kettle or container where air and water in precisely metered quantities are introduced into the mixture. The generated foam is monitored constantly in order to ensure a uniform consistency which is independent of the processing speed. The composition of the size solution is formulated so that it has a viscosity which ensures a complete covering of the yarn and its stability is also good enough to cope with extended downtimes. The foamed size solution is supplied to the foam container of the size trough or the foam applicator (see Fig.) through a distributor which distributes it uniformly. The container is also sufficiently large to deal with different rates of size consumption. The level of size is controlled to within ± 4 mm by a sonar probe. The set-value can be easily adjusted to adapt the size levels in the container to the types of yarn and production speeds of the sizing machine.

The warp sheet is threaded through a series of rollers into the foam applicator. It passes over a running roller then vertically in a downwards direction through the foam bath. The foamed size liquor is retained at the bottom by two rubber-coated rolls forming a closed nip and by guide plates at the sides and frontal zone shaped to provide a close fit to the rolls. The warp sheet passes downwards through the foamed size liquor and the nip between the rubber-coated rolls then out of the applicator unit via a deflection roller into the drier. During passage of the warp sheet through the container bubbles of size emulsion are taken up by the yarns and transported as far as the nip between the rolls. The rate of size uptake is proportional to the contact time of the yarn sheet in the foamed size liquor. The bubbles burst as soon as the yarn enters the nip; the sun is raised, and the solution of water and size is spread uniformly across the warp sheet. The semi-wet warp then continues its passage into the drier.

Foam stability The ability of a → Foam to remain in a stable condition. Calculation:

$$\frac{\text{foam volume after x min}}{\text{foam volume immediately after preparation}}$$

The rate of self-drainage of a foamed liquid can be established by determination of the foam decay half-life period. The more rapid the foam drainage, the smaller its half-life period of decay.

The foam decay half-life period is the time required for half of the liquid in the initial foam to separate from the foam by self-drainage. In order to determine the half-life period of decay of a foamed liquid, the quantity of liquid present in a specific volume of the foam must first be calculated. For calculation purposes the density of the initial solution S_f is assumed to be 1 g/ml.

For a foam volume V_s and the density of the foam S_s, the half quantity of liquid V_f contained in it may be calculated by means of the following formula:

$$V_f = \frac{V_s \cdot S_s}{2\,S_f}$$

In determining the half-life period of decay, the time taken for the quantity of liquid V_f to drain from the foam volume V_s is measured.

Foam stabilizers Special products used to increase → Foam stability.

Foam structures Foam structures can be regarded as fundamental characteristics for the visual distinction of unstable and metastable liquid foams. With a sufficiently high stability of the surfactant adsorption film, a continuous transition from unstable foams, due to drainage between → Foam lamellae, into metastable foams takes place. With unstable foams an accumulation of only slightly deformed spherical air bubbles is built up. Provided these foam bubbles are distributed as discrete bubbles in the liquid medium a spherical foam exists (→ Foam). In the case of metastable foams, liquid drains between the individual foam bubbles; their autonomy is lost and an aggregation of polyhedron-shaped bubbles is formed, a so-called → Polyhedron foam consisting of an air-filled honeycomb-like structure of liquid lamellae. Due to gravitational forces the interlamellar liquid has a tendency to drain off the lamellae. It is possible to produce metastable polyhedron foams with stabilities tailor-made to meet specific requirements, e.g. by addition of thickeners or the use of appropriate surfactant mixtures. As far as stability is concerned, attention must be paid to external influences (e.g. evaporation of liquid, action of heat, pressure, mechanical shock, antifoaming agents). Foam stability is also affected by textile auxiliaries, dyes, and chemicals which, from time to time, however, may even contribute to better foaming.

Foam suppressants (defoamers, → Antifoams). Products used to prevent the formation of → Foam or considerably reduce foam stability. In general, a foam suppressant should (a) be sparingly soluble in water, so that it is already present at low concentration on the lamella surface, (b) have a positive spreading coefficient relative to the surfactant solution and (c) should form quasi-gaseous interfacial films. These requirements are fulfilled by, e.g. the following products: straight or branched-chain and hydroaromatic alcohols (with 5–18 carbon atoms in the hydrophobic part of the molecule, such as isooctanol), pine oil (main component is terpineol), phosphoric acid alkyl esters (such as tributyl phosphate), alkyl polysiloxanes, as well as lower alcohols. A distinction is made between a “defoamer” which destroys already existing foam and an “antifoam” which prevents the formation of foam.

Foam suppressants in washing detergents → Foam inhibitors.

Foam suppression in dyeing The following procedure has proved beneficial in practice: pretreatment of the material in a liquor containing a → Defoamer only at below 50°C for 15–20 min. Subsequent addition of surfactant (wetting agent, dyeing auxiliaries) and processing as usual. In cases where extensive formation of air bubbles is observed initially, the material is “deaerated” by this means. The effect of defoamers is more economical and longer lasting with this procedure (a single pretreatment is generally sufficient). This method has proved particularly worthwhile for fine cotton yarns, wool hanks which have a tendency to “float” in dyeing machines, wool piece goods which have to be dyed in the winch with high foaming levelling agents as well as for materials made from synthetic fibres.

Foam test methods These are subdivided into two groups:

1. Static methods: in this case, the foam is determined in accordance with DIN standards, i.e. the perforated disc beating procedure and the modified Ross-Miles procedure, in which the surfactant liquor under test is foamed once (by beating with a perforated disc or the surfactant liquor is allowed to run out into a container). A measure of the foaming properties of surfactants is the foaming capacity in ml or the foam height in cm.

2. Dynamic method: a continuous procedure according to the Ross-Miles method. With this procedure, the speed of circulation, fall height and temperature of the surfactant liquor can be varied so that they can be adapted to conditions encountered in practice.

→ Foam; Foam performance evaluation.

Foam viscosity Metastable → Foams exhibit pseudoplastic flow properties similar to non-Newtonian liquids, i.e. the higher the shear stress the lower the viscosity. The viscosity of foams is influenced by the → Blow ratio and the viscosity of the initial solution. Flow properties play an important role in the application of foamed print pastes.

Fog Air which is heavily laden with fine water droplets (fog) encountered in some dyehouses and similar textile finishing operations (→ Fog dissipation plant). Amongst other applications, mist is used in shrinkage (relaxation) machines for the anti-shrink treatment of wool fabrics, e.g. as in the → London shrinking process.

Fog and its consequences in textile finishing plants As air becomes increasingly cooler, its capacity to absorb moisture naturally decreases – a condition which can develop rapidly in bleaching, dyeing, printing and washing departments, especially during the colder months of the year. Air with a high moisture content accompanied by cooling leads to increasing precipitation of water droplets and their condensation in the form of mist or fog. Air with a fog content of 1 g still allows a visibility up to approx. 40 m whereas a fog content of 9 g, on the other hand, reduces the visibility to 1 m maximum. The consequences are: lower efficiency, nuisance, damage to health, possible danger to life (e.g. machine drive transmissions, centrifuges), damage to textile materials caused by drops of condensed water, as well as premature destruction of machinery, plant and equipment, roofings, walls, etc. Simple extraction of the surrounding air to eliminate fog is completely inappropriate (frequently this only leads to an even higher build up of fog), just as the use of fans and downstream heater units alone are not enough to produce a satisfactory distribution of warm air. → Fog dissipation plant.

Fog chamber technique (FCT). A method for the application of → Formaldehyde scavengers to textile fabrics in the form of a mist.

Fog dissipating plant This type of plant is based on the principle of a constant exchange of air adapted to suit local requirements and weather conditions with a) induction of warm air by means of a fan blower (installed approx. 50 cm below ceiling height), and b) the simultaneous extraction of moisture-laden air from the inside to the outside of the building (by means of a suction hood or extractor fan installed as deep as possible within the building space). Control of the air supply and necessary air extraction is absolutely essential in order to eliminate the build up of excess temperature and pressure in the workplace. Typical plants designed for industrial applications already incorporate these constructional features. Centralized fog dissipation plants are preferable for dyehouses with uneven free air space and individual units are only suitable for individually enclosed machines, etc. In all cases, however, the volume of the fresh air supply is greater than the volume of exhaust air (up to 80% for the latter).

Fogging Ever since textiles started to be widely used in car interiors, as well as the odour problem in new cars there has also been the problem of fogging on the inside of the cold front windscreen with milky-opaque substances, which obstructs the driver's view and presents a safety hazard. By definition, the term fogging is not considered to be fogging of the windscreen caused by fresh air from the outside, but the condensation of volatile substances evaporating from interior trim and therefore changing the refractive index of the windscreen. The fogging problem can last for quite a long time in new vehicles, because the evaporation of the substances responsible (spin finishes, additives, polyvinyl chloride plasticizers, synthetic fibre oligomers, stabilizers, emulsifiers, substances in the phenol resin-reinforced non-woven materials that have not been fully cured, dyeing auxiliaries, flame-retardant finish chemicals, fungistats, antisoiling substances, sewability aids) may be a relatively slow chemical cleavage process (age-induced cracking) and prolonged diffusion into the textile material ensues. Fogging, which can also be reaction or diffusion controlled, may be promoted by air convection from the interior air circulation system.

A fogging test takes the temperature situation in the passenger compartment that is fitted with textiles into consideration: there is a negative temperature difference between the location of the textiles (e.g. as thermal insulation) and the very cold windscreen. The vapour pressure of potentially volatile substances is brought about in the test (Candea method) by heating the textile (in the extended Volvo method, DIN draft 75 201, this takes place in beakers on thermostatically controlled heating baths) and substances can condense on the cooled covering plates (Fig. 1). The opacity (Candea) or optical transmission ratio is measured using a reflectometer, but the amount of precipitation is measured gravimetrically; the exact composition can also be analysed using gas chromatography and coupled mass spectrometry and the cause thereof determined.

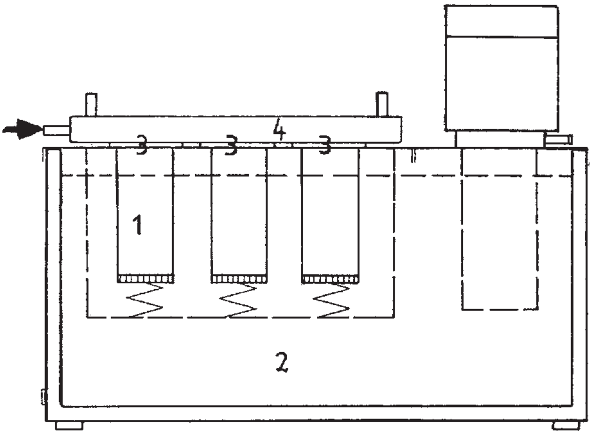


Fig. 1: Fogging device diagram, DIN 75 201 E.
1 = Beaker with sample; 2 = Temperature-controlled bath (100°C); 3 = Glass plate; 4 = Cooling plate.

Measuring method	60° reflectometer	Gravimetry
Test duration	3 h ± 5 min.	16 h ± 10 min.
Temperature		
Heating bath	100 ± 0,3 °C	100 ± 0,3 °C
Cooling water	21 ± 1 °C	21 ± 1 °C
Condensor material	Pane of glass	Aluminium foil

Tab.: Fogging test to DIN 75 201, Draft March 1989.

The DIN 75 201 fogging test, March 1989 draft, was drawn up by the "Fogging" Working Group of the "Commercial Vehicle" and "Plastics" standards committees starting in 1980 and includes both a reflection measurement with a 60° reflectometer and a gravimetric measurement. A test device manufactured by Haake (Fig. 2) meets the criteria of the DIN draft and has prov-

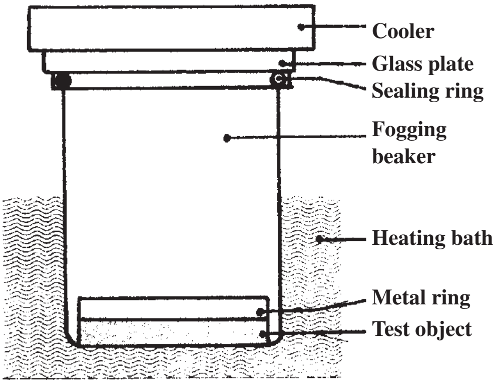


Fig. 2: Diagram of Haake fogging apparatus.

en itself in practice. The temperature of the heating bath and the cooling water is defined in the test procedure.

The cleanliness and the wettability of the glass plates play an important part in the fogging measurement using the reflectometer method. Coating the plate with a test ink with a defined surface tension has proved to be a good control method. An automatic cleaning program developed for cleaning the glass plates and the components in the fogging chamber makes it possible to use the glass plates up to 50 times.

Materials with a high water content, e.g. leather, and also textile materials must be dried before testing. The DIN draft specifies a 7-day drying period over phosphorus pentoxide. However, the results are frequently required within a shorter time. The temperatures that actually occur and how they vary over the course of time are shown in Fig. 3. The dependency of the surface temperature of the test object on its layer thickness and thermal conductivity is of particular interest.

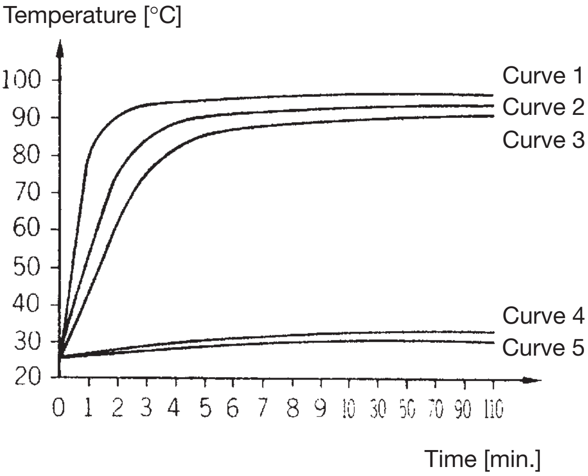


Fig. 3: Temperatures during the fogging test.
1 = Inside of floor; 2 = Car upholstery (approx. 8 mm top side); 3 = Car upholstery (approx. 1.2 mm top side); 4 = Aluminium foil (underside); 5 = Glass plates (underside).

Foil A term in general use for materials in thin, sheet-like form, e.g. aluminium, plastic foil, etc. In this context, therefore, a plastic foil is a flat, autonomous, and more or less elastic material with a thickness of approx. 0,01–0,1 mm, whilst the still thicker forms are described as plates largely because of their stiffness. The term foil should not be confused with → Film.

Foil colorimeter Used for self-determination of pH by submerging paper foil (as an indicator) and comparing with a supplied colour scale. It is advisable to work quickly because of the fast colour change, which is time dependent. Measuring accuracy approx. pH ± 0.1.

Foil wrapping and packing machines Machines for the automated packing of finished textile fabrics in foil which is cut from rolls. The final packing unit is usually heat-sealed.

Fold creases Formed by the compression of tubular (knit) goods through squeeze rolls, padders, etc. Differences in thickness arise between the crease folds at the edges and the rest of the double-layer fabric (Fig. 1) which can result in the non-uniform impregnation or penetration of liquor into the fabric thereby forming crease marks.

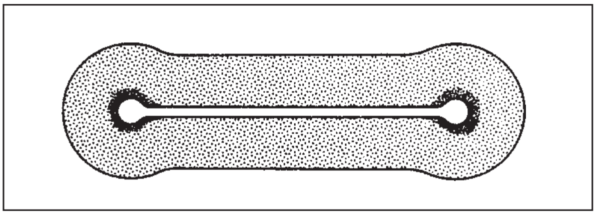


Fig. 1: Material density differences in tubular knitted fabric as a result of fold creases.

Crease marks formed in this way can be prevented by the following measures:
- Application of low nip pressure on the padder.
- Use of soft rubber coatings on the padder bowls.
- Good aeration in the padder trough.
- Vacuum impregnation.
- All-round spraying.
- Ballooning of the tubular fabric (Fig. 2).

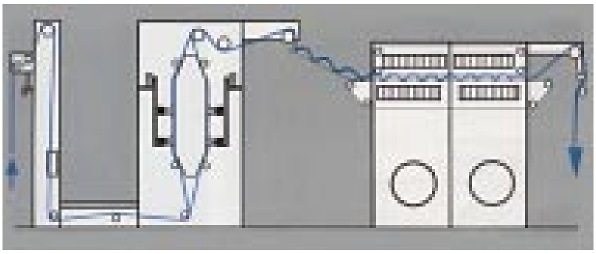


Fig. 2: Inflating unit for tubular knitted fabric for preventing fold crease setting during drying.

Folding machines Used a) for make-up of piece-goods on completion of finishing or b) for individual laundry items. Can be directly connected to a packaging machine → Fabric folding machine.

Folding number With folded, doubled or plied yarns, the folding number represents the total number of individual threads that have been twisted together to form the yarn.

a) In the case of length counts, it is denoted by a number separated from the yarn count by a forward slash (e.g. Nm 30/2),
b) In the case of weight counts, it is denoted by a number separated from the yarn count by a multiplication sign (e.g. 150 tex x 2).

Folding of yarns The doubling of single yarns as a partial stage in the process of → Twisting. The folding process represents a stage in the production of ply yarns. Starting from single yarns, ply yarns are produced in two stages, i.e. firstly by combining the threads on the doubling machine, and secondly by imparting twist in the yarn on the twisting frame. Folding is an essential process for the production of three-fold or multi-folded yarns by the now popular two-for-one twisting or pot spinning methods. Two processing methods for the production of two-fold yarns in two-for-one twisting have established themselves in practice: in the first case by the classic method which involves feeding from doubling bobbins and, in the second case, by means of the so-called direct feed technique in which two bobbins of single yarns are placed side by side (Fig. 1).

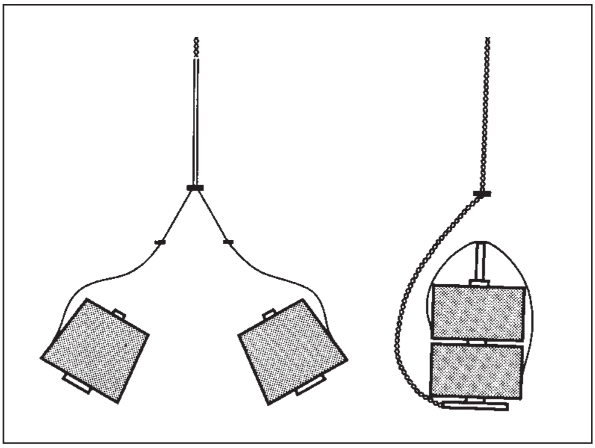


Fig. 1: Twisting by feeding from doubling bobbins (left), and twisting by the direct feed technique (right).

At first sight, the avoidance of the folding stage appears to offer a desirable saving since, in direct twisting, the packages of single yarns are fed directly into the (two-for-one) twister. However, all the influencing parameters must be taken into account in order to be able to decide when it is better to use doubling bobbins or the direct feed technique. In principle, it is true that efforts should be made to use the shortest possible path in yarn production. However, as soon as quality begins to suffer, savings in process costs should not be the only factor to take into consideration.

A perfectly twisted yarn is characterized by having its two component threads twisted together symmetrically (Fig. 2). By contrast, a covered yarn consists simply of one thread with a second thread wrapped around it. The quality enhancing effect is lost in this case since one thread can slip in relation to the other. Yarn covering takes place, e.g. when a very high tension is applied to one thread and virtually no tension is applied to the other. In this case, the taut yarn has no opportunity to become deformed during twisting and the loose yarn wraps around the taut one. A yarn covering effect can occur with direct feed when no uniform thread tension exists and the feed of the respective threads is unbalanced.

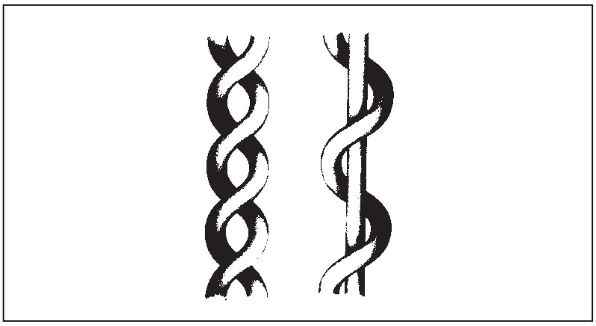


Fig. 2: left: uniformly twisted yarn; right: covered yarn.

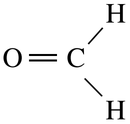
Fold marks These are usually seen as length-wise creases that can cause considerable problems, e.g. in the case of dyeing sensitive polyester fabrics that are thermo-plastic, or alkaline treatment in cellulose processing. For cellulose, similar conditions may be found during bleaching processes but, due to the lower quantities of alkali, heavy creasing is rare and is easier to remove. Alkaline fabric treatments used in boiling off, mercerization and caustic treatment generally involve an initial cold treatment and progress to the alkaline treatment at increased temperatures. All alkaline treatments cause cellulose fibres to swell with the consequent contraction in fibre length and, dependent on time and temperature, this will have a fundamental influence on the formation of fold marks.

Food packaging dyes These are exceptionally pure textile dyes and must conform to the specific purity requirements demanded for food packaging purposes, e.g. coloured nets for oranges, black-dyed net coverings for smoked ham, etc.

For → Cotton maturity index.

Foreign solvents, e.g. in the distillation process in normal dry cleaning, substances apart from tetrachloroethylene and water are distilled over and, depending on their solubility, may be dissolved as “contaminants” in the tetrachloroethylene or run off with the water from the water splitter. They may also make the separation of the water and tetrachloroethylene more difficult; e.g. alcohols used as cleaning auxiliaries.

Formaldehyde (methanal), MW 30, density 0,81. A readily polymerizable colourless gas. It is commercially available as an aqueous solution with a pungent and characteristic odour; 30–40% solution (formalin)



$O=CH_2$

which usually contains 10% methanol to inhibit polymerization. Properties: powerful reducing action; causes proteins to coagulate (principle of tanning) and the hardening of casein fibres; it is a powerful germicide either in solution or vapour form.

Formaldehyde has been classified as an allergen and a suspected carcinogen. The German DFG Commission with responsibility in this area has stated that formaldehyde, which is widely used in laboratories and as an industrial product, also belongs in the category of substances for which a clear carcinogenic potential exists. In this regard, the great number of inhalation tests carried out on test animals in the USA have shown that concentrations of formaldehyde up to 15 times the valid MAK value produced a high rate of cancer development in the nasal mucous membranes of rats, and to a lesser extent with even 6 times the MAK value.

Uses: aftertreatment of substantive dyeings (improved wash fastness); wool protection agent; hardening of casein fibres (during wet finishing); crosslinking agent in resin finishing (formaldehyde finishing); manufacture of resin finishing agents (methylolation); addition to naphthol dyeings; preservative; component in disinfectant solutions; component in numerous fillers, adhesives, etc.

Formaldehyde aftertreatment of direct dyeings Improves the colour fastness of suitable direct dyes to water, washing and perspiration. Suitable direct dyes contain free amino or oxy groups; mainly black dyes.

Formaldehyde/ammonium salt reactions Many dyes which exhibit no changes in the absence of ammonium ions are unstable in the HT-dyeing of polyester/wool blends at 120°C in the presence of formaldehyde, as a wool protection agent, and ammonium salts as buffers or acid donors. With an extended range of dyes it is possible to use buffer mixtures which are free of ammonium salts. The reasons for the unsatisfactory stability of many dyes in a dye/formaldehyde/ammonium salt system are the numerous possibilities for reactions with different reaction products and their intermediate stages as well as their reaction equilibria (see Fig.).

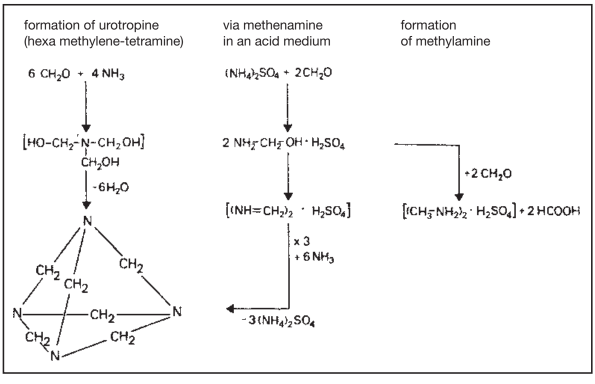


Fig.: Formaldehyde/ammonium salt reactions.

Formaldehyde contamination of waste water, treatment of Waste waters containing formaldehyde cannot be discharged into receiving waters or biological water treatment plants due to the toxicity of formaldehyde towards microorganisms and fish. A new process developed by Degussa for this purpose involves the treatment of waste water with hydrogen peroxide and milk of lime (aqueous suspension of calcium hydroxide) which easily and quickly breaks down formaldehyde. The reaction products are non-toxic and have no disadvantageous effects on receiving waters or biological waste water treatment plants.

Formaldehyde content in resin finishing agents The free formaldehyde content results from the state of equilibrium which is dependent on the chemical constitution, concentration and temperature.

Formaldehyde determination A range of analytical methods is available for the determination of formaldehyde in resin finishing, especially the different types of formaldehyde in crosslinking agents based on N-methylol and N-alkoxymethyl compounds, finishing liquors, as well as finished fabrics. Relatively precise methods are available for the determination of total formaldehyde, free formaldehyde, and the content of N-methylol groups. The formaldehyde released by hydrolysis is extraordinarily dependent on the test conditions. Total formaldehyde is understood to be the total amount of formaldehyde detectable in finishing agents, finishing liquors, and on textile fabrics. It represents the sum of free and combined formaldehyde. The combined formaldehyde is subdivided, in turn, in methylol and methene compounds. The determination of formaldehyde released from textiles by hydrolysis is also important. After hydrolysis in the distillate, the total formaldehyde can be determined iodometrically. The determination of free formaldehyde is mainly carried out by the sulphite method and, in a different manner, by the hydroxylamine method. Methylolformaldehyde can be determined together with the free formaldehyde. The determination of free and hydrolytically-released formaldehyde on textiles can be carried out according to various methods. However, these test methods determine not only the actually available free formaldehyde but also the formaldehyde released by partial hydrolysis in the preparation of the sample.

Formaldehyde donors → Formaldehyde-liberating compounds.

Formaldehyde emission Examinations of people exposed to formaldehyde at work showed that low formaldehyde concentrations can trigger nasal mucous membrane changes in humans that are predisposed to carcinomatous degeneration. In 1989 this led to a situation where formaldehyde was categorized as a potential carcinogen for human beings in the USA. Formaldehyde's ability to trigger allergies is less controversial. Inflammation and eczema can occur if formaldehyde comes into contact with the skin. People who encounter relatively high concentrations of formaldehyde at work are worst affected, e.g. people working in the fields of medicine or textiles. Dermatological investigations have shown that textiles containing formaldehyde can cause skin allergies when worn. Formaldehyde concentrations of 750 ppm are enough to trigger and maintain corresponding reactions in sensitized individuals. Highly sensitized persons can even be affected by concentrations as low as 300 ppm. According to the current state of knowledge, it is assumed that products with a formaldehyde content of less than 0.03% do not usually lead to allergic reactions even on sensitized persons. In various countries, this kind of medical knowledge has led to the introduction of legislation and tolerance limits (e.g. Japan, Finland, Austria). These kinds of restrictions also exist in Germany. According to the hazardous substances legislation that came into force in 1986, in § 9, paragraph 3 for timber products, it was stipulated that these materials may not be brought into public use if the concentration of formaldehyde caused by the timber product that is released into the air of a test room exceeds 0.1 ml/m^3 (ppm). According to paragraph 4, furniture may not be brought into public use if it contains timber products materials that do not meet the requirements in paragraph 3. According to the legislation, clothing textiles with a mass content of 0.15% of free formaldehyde must be marked as such if they contain a finishing agent and come into contact with the skin during normal use.

Area	Law	Tolerance limit
Textile	Hazardous materials legislation (Appendix I) (Chemicals act)	> 150 ppm (must be marked)
Product	Hazardous materials legislation (Appendix VI) (Chemicals act)	> 1 % (must be marked)
Workplace	TRGS 900 (Hazardous materials legislation)	< 0.5 ppm (workplace threshold limit)
Emitted air	Technical directive on air pollution control (BIMSchG 1, VwBV)	< 20 mg/m^3 (Mass flow > 100 g/hr.)

Tab.: Legal regulations for formaldehyde emission.

Whereas timber products and furniture have to observe emission limits (Tab.), domestic textiles have not been included. A regulation for domestic textiles and wallcoverings (among other things) was also discussed in the draft of the hazardous materials legislation but was not initially included. Based on the Ministry of Health recommendation of a maximum formaldehyde concentration of 0.1 ppm for interior rooms and because of the stipulation of this limit for timber products in the hazardous materials legislation it would make sense to use the same value for domestic textiles.

Formaldehyde fastness A form of → Colour fastness to storage conditions test for finished and packed coloured textiles to possible formaldehyde-containing adhesives in packing paper, pleating paper, etc. Test procedure: a dyed or printed textile specimen is exposed in the dry state for 24 h to rising formaldehyde vapours (contained in a small open bowl under a glass bell jar or in closed boxes). The grey scale is used to evaluate change of shade.

Formaldehyde finishes Crosslinking processes for cellulose with formaldehyde or so-called → Formaldehyde-liberating compounds in the presence of acid catalysts. The formaldehyde is mainly applied from aqueous solution by the wet crosslinking process. Such finishes were originally applied to textiles composed of regenerated cellulose to reduce fibre swelling, increase wet tensile strength and improve shrink resistance; also used for the wash-and-wear finishing of cotton. Disadvantages: severe losses in tensile strength and abrasion resistance.

Formaldehyde finishes on cotton in the swollen and partially-swollen state were also of importance (wet and moist crosslinking processes): →: Form D process; Form V process; Form W process.

Formaldehyde-free finishes These finishes are based on the use of compounds which do not contain formaldehyde (Fig. 1) or do not release formaldehyde due to the action of heat or during the storage of finished fabrics (→ Low-formaldehyde resin finishing) such as 4,5-dihydroxy-1,3-dimethylurea and 4,5-dihydroxy-1,3-bisethyleneurea. A finish with reaction products of acrylamide and glyoxal or glutaraldehyde gives poorer effects than usual. A comparison of both basic structures of a low-formaldehyde type finish and a formaldehyde-free finish clearly shows that the number of reactive hydroxyl groups for crosslinking with cellu-

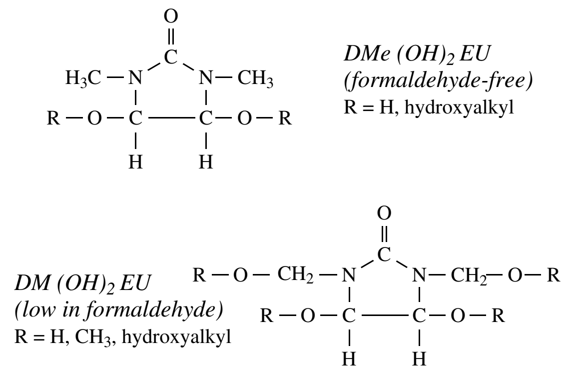


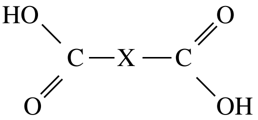
Fig. 1: Comparison of DMe(OH)$_2$EU and DM(OH)$_2$EU by formula.

lose in low-formaldehyde glyoxal monoureins is approx. double that in the formaldehyde-free dimethyldihydroxyethyleneurea. Amongst other things, this is the reason why formaldehyde-free crosslinking agents must be applied in at least double the usual crosslinker concentration in order to achieve roughly comparable finishing effects.

In order to achieve the required quality standards in practice, it is frequently necessary to increase the application concentrations of such products by two to four times the concentrations normally used; despite this, however, the level of effects obtainable with the low-formaldehyde glyoxal monoureins (especially in the finishing of regenerated cellulose) is not achieved in many cases. The main problem here is dimensional stability. On considering the fact that approx. double the usual price level must be estimated for dimethyldihydroxyethyleneurea, the great importance of the economic aspect becomes obvious, which translates into a noticeable increase in the price of the end-product. Since both reactivity and stability to hydrolysis are positively influenced by the higher electron density at the nitrogen atom, theoretical disadvantages for fromaldehyde-free crosslinking agents can already be derived, i.e. the need for stronger concentration conditions for bonding to the cellulose fibre and, in addition, the lower stability to hydrolysis. The application of formaldehyde-free crosslinking agents by moist and wet crosslinking methods is not possible.

In comparing both product groups, differences in the quality of crosslinking also exist; bonding to the cellulose via a N-methylol group is accordingly more stable than a crosslink via a hydroxyethylene group, and is produced under milder curing conditions. The well-known structure-related disadvantages of dimethyldihydroxyethyleneurea can, however, be compensated to some extent by suitable pretreatment and the use of appropriate additives.

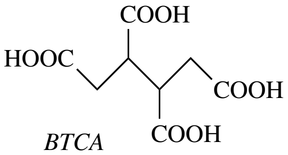
Polycarboxylic acids, e.g.



are also known as cellulose crosslinking agents.

Besides technological parameters, other factors such as availability, ease of production (Fig. 2) and price play a decisive role in the successful marketing of formaldehyde-free crosslinking agents.

Up to now, only butane tetracarboxylic acid BTCA (white solid in powder form; empirical formula $C_8H_{10}O_8$; MW 234,2; mp 192°C; pH approx. 2; solubility in water 130 g/l) can fulfil all these criteria to a large extent.



BTCA

As catalysts for the crosslinking of cellulosic materials with polycarboxylic acids, completely different systems are required compared to the amines, ammonium salts, metal salts and inorganic or organic acids formerly used as catalysts for formaldehyde-based crosslinking agents. Suitable catalysts for this process are mainly the alkali metal salts of phosphorus-containing acids. The majority of these catalysts are weak bases. Catalysis with hypophosphites has proved to be particularly effective; phosphites are somewhat less reactive. In both cases, substances with a high reduction potential are used. They are especially suitable for use on white goods. Phosphates or polyphosphates are also capable of bringing about satisfactory crosslinking. Because of their minimum influence on changes in shade they are preferred in the finishing of coloured goods. The catalysis mechanism is still not understood. Purely as a hypothesis, a three-stage mechanism has been postulated (Fig. 3).

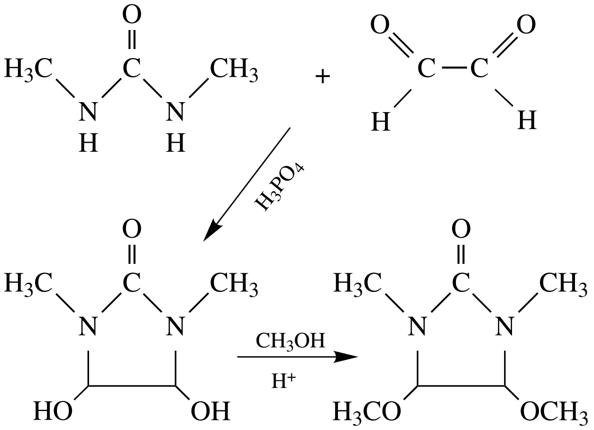


Fig. 2: Production of formaldehyde-free cross-linkers.

Under the action of heat during the curing stage, cyclic anhydrides can be formed from suitable polycarboxylic acid structures. Thermogravimetric and mass spectroscopy investigations have shown that a rapid loss of water takes place which may be taken as further evidence of a possible anhydride formation. In the second stage, the more reactive anhydride is in a position to react with corresponding catalysts to form acyl phosphinates, acyl phosphonates or mixed anhydrides. This hypothetical intermediate stage can finally result in crosslinking of the cellulose by esterification and liberation of the catalyst.

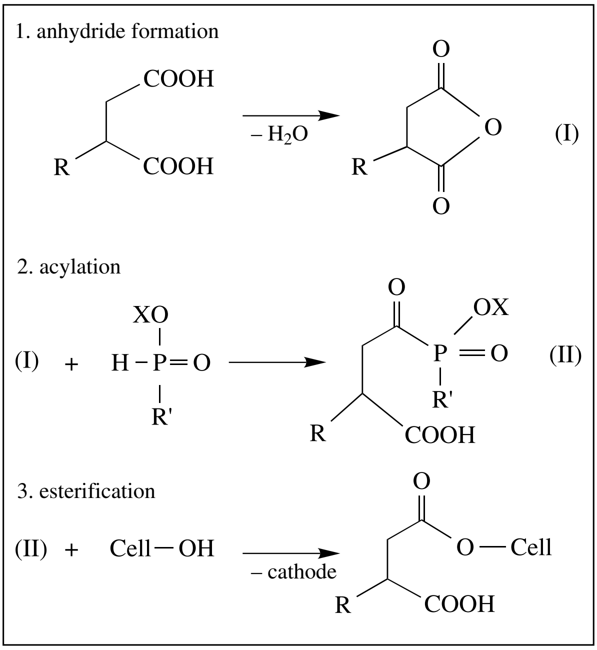


Fig. 3: 3-stage catalysis mechanism.

Formaldehyde-free finishing agents These are, more precisely, formaldehyde-free resin finishing agents used to produce → Formaldehyde-free finishes on cellulosic materials. Crosslinking agents are available for the resin finishing of cellulose which contain no formaldehyde and do not release formaldehyde in the finishing process or during storage of the finished goods.

These products stand in contrast to the resin finishing agents based mainly on N-methylol compounds formerly used. A range of compounds containing reactive groups, but which are formaldehyde-free, have been examined in the development of formaldehyde-free finishing agents. Suitable reactive groups include the aziridine, carboxy, epoxy and chlorohydroxy groups as well as carbon double bonds. Apart from commercial considerations, these compounds suffer from other disadvantageous problems including toxicity. Suitable alternative cost-effective and non-toxic products capable of meeting acceptable finishing standards are difficult to find. Special products based on polyurethane as well as → Silicone elastomers only represent a partial solution. Polycarboxylic acids are also of interest here.

Knowledge of the relationships between chemical constitution and the properties of crosslinking agents based on N-alkoxymethyl compounds has led to the development of extremely low-formaldehyde crosslinking agents for cellulose. This fundamental knowledge has led directly to the practical development of the most important reactant crosslinking agents at the present time based on the low-formaldehyde → Dimethyloldihydroxyethyleneurea with excellent stability to hydrolysis (already marketed since 1975). These partially or fully etherified types of crosslinking agents ensure full compliance with current legislative regulations regarding MAK values in processing as well as the formaldehyde content of substrates which have been resin-finished with these products. Moreover, these products leave nothing to be desired from the ecological, toxicological and dermatological points of view and ensure the production of maximum resin-finishing effects with regard to the easy-care properties of the end-product. Despite this, in all respects, entirely satisfactory situation by today's standards, there is a growing body of opinion calling for still further optimization and absolutely formaldehyde-free finishing variants. These changed quality standards have, in the meantime, been taken into account with the development of formaldehyde-free crosslinking agents for cellulose.

The concept of formaldehyde-free alternative products begs the question as to which basic chemical structures are still available, besides the long established N-methylol or N-alkoxymethyl compounds which are suitable for application by the usual process machines and processing conditions. In principle, possibilities exist for crosslinking between the following basic chemical structures and the hydroxyl groups of cellulose (see Fig.):

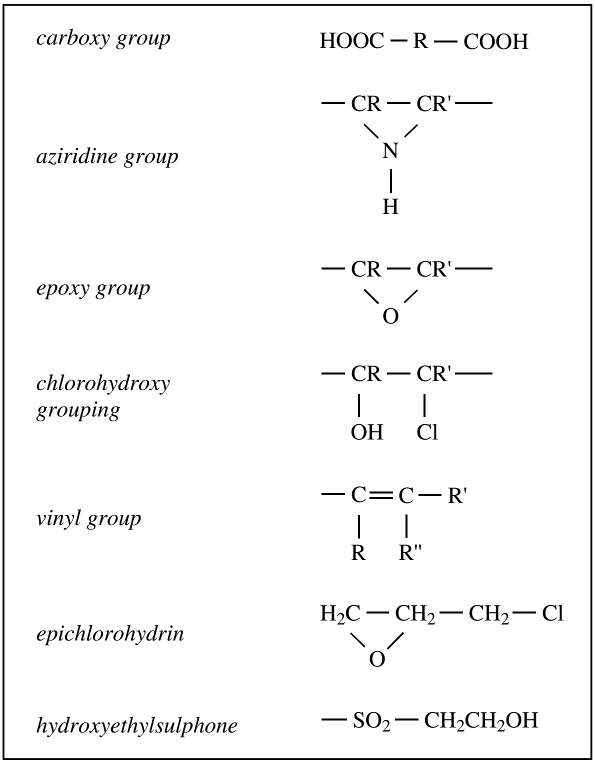


Fig.: Crosslinkings between hydroxyl groups of cellulose and formaldehyde-free basic chemical structures (Pfersee).

- aziridine group,
- epoxy group,
- chlorohydroxy grouping,
- vinyl group,
- epichlorohydrin,
- hydroxyethylsulphone.

On closer examination from the technical point of view, it has been established that in many cases such products result in pronounced yellowing or brown discoloration or an unacceptable effect-strength loss relationship as well as unsatisfactory resin-finishing effects. In addition, the application of such compounds would, in many cases, result in an unacceptable increase in the cost of resin-finishing.

Formaldehyde in HT wool dyeing A variety of technical and ecological disadvantages are associated with the use of formaldehyde as a wool protection agent at 120°C as a short-term stopgap measure:

1. Variations in the concentration of commercial formaldehyde qualities: these differences can be considerable, which makes reliable dosing difficult without previous analysis.

2. Transport and storage shelf-life: limited due to high volatility; formaldehyde is also subject to different import, packing and safety regulations in various countries.

3. Reactivity: the high reactivity of formaldehyde is a safety risk in transport, storage and application: The very rapid reaction with wool (wool keratin/formaldehyde reactions) makes it necessary, in HT dyeing, to add formaldehyde to the dyebath at 40°C in order to eliminate irregular reactions and uneven wool protection.

4. Volatility during dyeing: the addition of formaldehyde at too high a temperature can already result in partial evaporation losses before the wool reaction takes place (temperature-dependent, only completed in the HT range) = risk of possible under-dosage.

5. Impairment of fabric handle: this problem occurs especially with dyed piece goods in blends with cotton.

6. Development of disagreeable smell: this problem is unavoidable especially when the dyeing machine is opened; samples during dyeing must always be taken from a sampling lock.

Formaldehyde in textiles Textile fabrics which have been resin finished with N-methylol or N-alkoxymethyl compounds contain both bound and free formaldehyde. The free formaldehyde is formed during the finishing or storage of resin-finished textiles and can cause skin irritations. The proportions of free formaldehyde are variable and are dependent on the crosslinking conditions (→ Low formaldehyde resin finishing). The free formaldehyde content in textiles is subject to specific ppm limits. Methods for the determination of free formaldehyde → Free formaldehyde, determination of.

Formaldehyde-liberating compounds These are compounds which break down with the release of formaldehyde, e.g. polyoxymethylene (→ POM derivatives). Used as resin-finishing agents. Formaldehyde in the labile form is more or less firmly bound and is released gradually during the finishing process. The result is a much more uniform crosslinking of the cellulose (in comparison with aqueous formaldehyde solutions).

Formaldehyde limits in air At high concentrations free formaldehyde attacks the mucous membranes in humans. The permissible concentrations of formaldehyde are therefore subject to maximum limits in room air (MAK value = 1,2 mg/m^3 air) and in exhaust air (TA-Luft emission limit concentration of 20 mg/m^3 at a flow rate >0,1 kg/h).

Formaldehyde release during ironing When textiles finished with N-methylol compounds are ironed in the moist state formaldehyde may be released which can be very aggravating. In principle, the following ironing procedure is used to determine the released formaldehyde. During the ironing of a fabric sample under specified conditions 10 l of air next to the iron is withdrawn by suction and passed through an alkaline iodine solution. The formaldehyde content is then determined by titration with a 0,02 n thiosulphate solution as the difference compared to a blank test. The result is expressed as the “ironing value” and runs parallel to the sensation response during ironing. The formaldehyde release is influenced considerably by the pH of the fabric and its control with buffering agents or the application of → Formaldehyde scavengers.

Formaldehyde resins A collective term for organic compounds which contain formaldehyde mainly in the form of methylol compounds which may also be etherified, and which are capable of crosslinking reactions (→: Self-crosslinking resins; Reactive resins). The term “formaldehyde resin” is mainly understood to refer only to the self-crosslinking resins such as aminoplasts and phenoplasts.

Formaldehyde scavengers These are substances which are capable of binding formaldehyde. They are used variously in resin finishing, especially in low formaldehyde finishes, e.g. urea, ethylene urea. A reduction in the release of formaldehyde is achieved through the addition of formaldehyde scavengers to resin-finishing baths both in finishing with N-alkoxymethyl compounds as well as during the storage of resin-finished fabrics. In general, however, the desired effect is not satisfactory. Hydrazides and carbohydrazides are also recommended, among other products, to reduce the content of free formaldehyde from glyoxal crosslinking agents. Ethylene glycol and diethylene glycol also reduce the release of formaldehyde and do not cause chlorine retention. In the case of formaldehyde scavengers such as urea, ethylene urea, dicyandiamide and hexamethylene tetramine, adjustment of the pH at the same time is of considerable importance.

Formaldehyde sulphoxylates → Sulphoxylates.

Formaldehyde, tests for Simple preliminary test (e.g. on fabrics containing formaldehyde-based finishes): briefly boil a 3–4 cm^2 fabric specimen in a test tube with 5 ml approx. 2% sulphuric acid: in the presence of formaldehyde, formaldehyde vapour escapes during this test and can be easily recognized by its odour. Other preliminary tests can also be carried out with Nessler's solution or Fehling's solution. More precise methods of formaldehyde detection are based on, e.g. chromotropic acid, Schiff's reagent, carbazole-sulphuric acid and xanthydrol.

Formaldehyde test for Japanese exports: according to Japanese regulations and laws, certain textiles for export must be checked for their content of free or readily releasable formaldehyde.

Formate of alumina → Aluminium formate.

Formates Salts of → Formic acid.

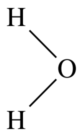
Formatted piece method Used to determine edge/centre evenness (→: Tailing; Ending) in rotary screen printing. A specified quantity of material is mechanically cut into pieces of exactly the same format. The pieces are weighed, printed on the right or left side or centre of the backing cloth using a non-patterned rotary screen and then re-weighed. The dye paste quantity differences that are measured provide a way of gauging whether the printing mechanism and the screen produce level results.

Form D process A formaldehyde finish for cotton in the partially-swollen state (moist crosslinking process) with formaldehyde dissolved in organic solvents in the presence of water.

Formic acid (methanoic acid), HCOOH. A colourless pungent liquid of MW 46, miscible with water, alcohol and ether. Salts: formates. The 98–100% acid has a density of 1,22. It is mostly available as a very pure product. Undesirable impurities include acetic, oxalic, hydrochloric and sulphuric acids, as well as lead, iron and copper. Formic acid is a medium strength acid and has practically no action on cellulose. In use, formic acid is cheaper, more volatile and 12 times stronger in comparison with acetic acid. It is a strong reducing agent and brings about the complete reduction of chrome mordants. Formic acid is corrosive to skin and tissue with the formation of blisters. It is stable to hard water, alkalis and salts. Used as a substitute for sulphuric acid (for wool dyeing under strongly acidic conditions) and acetic acid (wool/cotton union dyeing); dyeing of silk (for slow dye exhaustion); neutralization in wool/cotton dyeing; spotting agent (for grass, fruit and ink stains) etc.

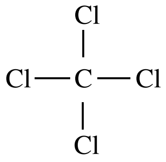
Forming time Within the context of total → Handling time factor, the forming time is the proportion → Processing time and → Transportation time.

Formula, chemical A means of representing a chemical compound by using symbols (as a rule, in the form of the initial letter of the respective element) to indicate the elements or atoms present (either metals or non-metals). Subscripts are used for the numbers of participating atoms (water = H_2O). The same system also applies to molecular groups in brackets, e.g. $Fe(OH)_2$. Since matter cannot be lost, all chemical reactions can be expressed by equations using chemical formulae where the number of atoms in both sides of the equation must be equal. The same applies to molecular weights:



water
H_2O

If the elementary composition and the molecular weight of a compound is known, the chemical formula is first represented by the molecular formula (empirical formula or total molecular formula) which only expresses, in the simplest form, the relative number and the kind of atoms participating in the structure of a molecule, e.g. water = H_2O. In order to illustrate the arrangement of the individual atoms pictorially with their valencies, structural or constitutional formulae are used, e.g.:



$$\begin{array}{c} Cl \\ | \\ Cl-C-Cl \\ | \\ Cl \end{array}$$

carbon tetrachloride
CCl_4

In addition, electronic formulae (→ Atomic bond), →: Configurational formulae are also used.

Formulations Mixtures and solutions of two or more substances.

Form V process (formaldehyde vapour process). A formaldehyde finish for cotton in the gas phase which takes advantage of the fact that pure formaldehyde is a gaseous compound. Formerly, gaseous hydrochloric acid was used as a catalyst.

Form W process (formaldehyde wet process). A formaldehyde finish for cotton in the swollen state (wet crosslinking process). Formaldehyde dissolved in water is allowed to react with cotton in the presence of aqueous hydrochloric acid.

Forschungskuratorium Gesamttextil Headquarters: Frankfurt. Permanent committee of → Gesamtverband der Deutschen Textilindustrie-Gesamttextil e.V. =

Confederation of the German Textile Industry: established in 1951. Members are expert representatives from all areas of the textile industry in matters of research. Task: to promote cooperative textile research and act as mediators to encourage co-operation between the textile industry and research institutes in the mutual interest of both parties. As well as processing research project proposals from industry to the research institutes, the main focus is on evaluating the results of research for industrial use and appropriate publicity. As part of this task the Gesamttextil Research Council has set up a comprehensive consultancy service with the institutes, and produces annual research reports on the work carried out in the research institutes. As well as co-ordinating the activities of the textile research institutes in Germany, the Gesamttextil Research Council strives to obtain financial resources for the ever increasing number of activities of the research institutes by providing funds from industry or obtaining public funds.

Forschungsvereinigungen e.V. Working Group of Industrial Research Associations (AIF); Headquarters; Cologne. Actively promotes exchange of experience and co-ordination of research work. Members are German industry representatives, including the → Gesamttextil Research Council.

Fossil meal → Kieselguhr.

Foulard A soft, lightweight fabric of silk or man-made filament fibre, either plain-dyed or printed, in twill, satin or plain-weave construction (similar to → Pongee). Uses: blouses, dress fabrics, skirts, scarves and ties.

Foulardtherm process A process developed by Ciba-Geigy for the application of fluorescent brightening agents to polyester; also applicable to polyamide, polyvinyl chloride, acetate and triacetate. Fixation of the fluorescent brightening agent is achieved with hot air (150°C) in the heat-setting zone of stenter driers.

Foulé (Fr.: fouler = milled). A soft, serge-like worsted fabric with a rough, fibrous melton-like surface. Its characteristic appearance is produced by prewashing and subsequent raising and milling of the face side; the weave (usually a 2 up, 2 down twill) can still be easily recognized on the back side of the fabric. Used as a ladies dress fabric either plain-dyed or as coloured checks. Also used for men's outerwear, mostly piece-dyed in black.

Fouling, irreversible adsorption of dyestuffs.

Foundation garments The requirements for these materials involve consideration of the following four factors:

- easy-care properties,
- fashion,
- wearing comfort,
- functionality.

The nature of the chosen finishing route and the selection of finishing products are very much dependent on the above quality standards as well as on the respective substrate (the parameters include, e.g. fabric weight, weave, type of fibre blend). In the case of knitgoods for so-called "elastic articles" in the swimwear and sportswear sectors, as well as foundation garments, blends of polyamide filament yarns and polyurethane filaments have established themselves. The proportion of polyurethane in such materials generally varies between 15–20%. These qualities can be dyed either in rope form in winches and overflow machines or in the open-width state in tensionless jiggers and beam dyeing machines. The following dye classes are suitable:

- anionic (acid) dyes,
- disperse dyes,
- 1:2 metal-complex dyes,
- reactive disperse dyes,
- afterchrome dyes.

Four-colour printing A subtractive printing technique based on the half-tone process with the three primary colours of yellow, magenta and cyan. A fourth printing in black or grey is added to enhance the final result (→ Trichromatic printing).

FP (fp), abbrev. for → Freezing point.

FPT textiles American term signifying Fire Proof Textiles. Textile meeting the legal fire prevention regulations in the USA.

Fr, chemical symbol for francium (87).

Fractional solubility of dyes A method used to investigate the homogeneity of dyes which is based on the different solubilities of individual dyes in various solvent mixtures. The solvents mainly used are water, ethanol, ether, benzene, methanol, carbon tetrachloride, etc., or mixtures such as aniline and amyl alcohol (pentanol) 1:1; ethanol and chloroform 3:2; dichlorohydrin and carbon tetrachloride 1:3.

Fractionated dyeing Dye uniformity investigation, based on the fact that dye mixtures can be identified by the different rates at which the individual dyes are absorbed. For example, fresh pieces of material are dyed in succession in a normal dye bath (extremely inaccurate method) for instance for about 1–2 or 15 minutes. After the dye having a quick absorption rate has been fully exhausted, the dye with a slow absorption rate remains and can now also be dyed out separately. The conditions can be varied with regard to temperature, liquor pH, fibre material etc.

Fractionation A process of gradual stepwise separation; e.g. fibre cell layers by stepwise dissolution or "peeling" in order to isolate a specific inner cell layer (fraction). Fractional distillation: the process of separating a mixture of liquids into a series of fractions of different volatilities by distillation. It begins with the liquid of lowest boiling point, follwed by the next higher and so on.

FR additive Abbrev. for flame-retardant additive.

Fragrant finishes Prepared fragrance complexes.

Each fragrant finish is a conglomerate in which each individual component has a purpose that can cause completely different odours and even discoloration, staining and fibre damage if the wrong substance is selected or there is the slightest amount of overdosing or underdosing. The basic materials are natural or synthetic odours with a characteristic smell of their own (for example, phenyl acetaldehyde and cinnamon alcohol are the odours in hyacinths and cinnamon alcohol or geraniol or nerol are the odours in roses). Additional substances for rounding off a more delicate fragrance are esters, aldehydes and alcohols. Fixing agents reinforce the uniform overall effect, reduce the vaporization pressure of the easily volatile components, slow down evaporation and increase permanence. A distinction is made between vegetable fixatives (cedarwood oil, benzoin, gum mastic, styrax, etc.), organic fixatives (ambergris) and synthetic fixatives (benzoic acid, benzyl benzoate, piperonal, etc.).

Framework Administration Regulation of Waste Water (Ger.), Rahmen-Abwasser-Verwaltungsvorschrift (VwV). The base of the german Framework Administration Regulation of Waste Water is the → Water Resources Law.

Franchise system Authorization granted by a manufacturing enterprise to a suitable individual or company for, e.g. the exclusive production of a particular product, range of products, or the use of a particular process or processes. Often takes the form of an association between a central organization and concessionary companies bound to the former by contract.

Francium → Alkali metals.

Free formaldehyde, determination of on textile materials Various methods are available for the determination of free formaldehyde on textile materials (e.g. the Japanese MITI recommendation). Formaldehyde is determined mainly by colorimetric methods according to the respective test procedures (→ Formaldehyde, tests for). Formaldehyde determination by titration with cold sodium sulphite solution is one of the most frequently employed methods.

Free interfacial energy Amount of work required to create or enlarge an isothermal or reversible interface separating 2 phases. Manifests itself as an increase in free energy (free interfacial energy) in the system, expressed in joules.

Free liquor The state of a → Liquor which is difficult to control under practical conditions since the "free" volume is always dependent on the type of material/quantity of material. On the other hand, terms such as "short or long liquor" represent definite relationships between liquor volume: weight of material, i.e. the → Liquor-to-goods-ratio.

Free liquor space The space located between the inner and outer drums in dual drum type machines for the uptake of liquor.

Freezing point (FP). The temperature of transition between the liquid state of a substance to the solid state. The terms "solidification point", "freezing point" and "melting point" are the same. The opposite of freezing is → Melting.

French chalk → Talc.

Fresco (Ital.: fresco = fresh, new)

I. Fresco twist yarn: high-twist 2 to 6-fold yarn composed of relatively fine individual yarns, produced by multiple twisting stages.

II. Fresco fabric: light-weight worsted or woollen fabrics in plain weave woven with the twist yarn of the same name; relatively harsh, slippery handle (due to the high twist), open set; usually yarn dyed but also piece dyed. The special attribute is the high air permeability and considerable resistance to creasing. A distinction is made between:

a) Fine worsted frescos ("Tropicals"), 220–330 g/m^2; all-wool or mixed with polyester (55%); smooth finish.
b) Woollen frescos ("Fresco imitations"), not as fine, approx. 500 g/m^2, usually only made from 2-fold yarn in crossbred wool; clear finish.
Used for summer suits and dresses.

FR fibres → Flame-retardant fibres.

FR finishes → Flame-retardant finishing.

Friction In all fields of textile manufacture, frictional forces and efforts to overcome them play a major role. Thus, softeners are used to improve the sewability of textile fabrics in garment manufacture. Spin finishes are applied to fibres in order to optimize their running properties in spinning and weaving. A few examples of textile technology where friction is an important consideration are given below in order to provide a better understanding of the laws of friction.

I. Spinning: friction occurs in spinning on the ring spinning frames as well as between the yarn and ring traveller and also between the ring traveller and the ring (Fig. 1). The production speed is limited by friction. At unacceptably high speeds, for example, the ring travellers would be spoiled by high temperatures due to the high heat of friction. In the case of OE rotor spinning machines, the tensile strength of the yarns after the rotor and other factors is influenced by the frictional forces between the yarn and the base of the

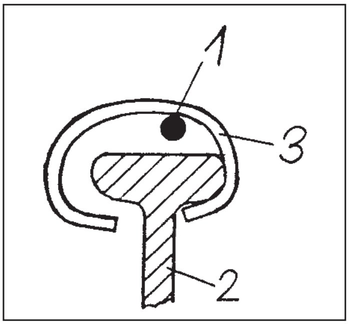


Fig. 1: Schematic representation of yarn (1), ring (2) and ring traveller (3) in ring spinning.

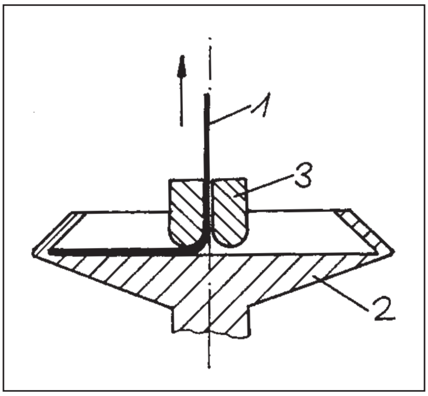


Fig. 2: Schematic representation of yarn (1), rotor (2) and doffing tube (3) on the OE rotor spinning machine.

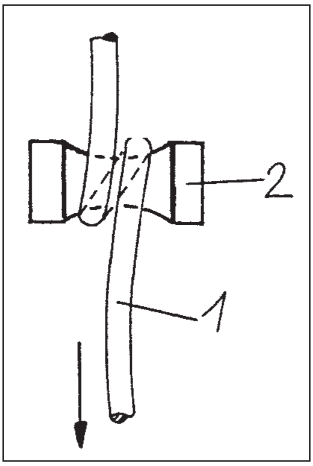


Fig. 3: Schematic representation of yarn (1) and aggregate (2) in false-twist texturing.

rotor as well as between the yarn and the doffing tube (Fig. 2).

II. Texturing: in the false-twist texturing process (Fig. 3) with twisting tubes, certain frictional forces must develop between the yarn and the aggregate of rotating discs for the insertion of twist to occur.

III. Weaving: in the projectile shuttle loom (Fig. 4), the desired tensile force for the weft yarns is regulated by the weft brake (friction brake). In the case of an air-jet loom, weft insertion is only possible as a result of the frictional forces between the weft yarns and the air jet (Fig. 5).

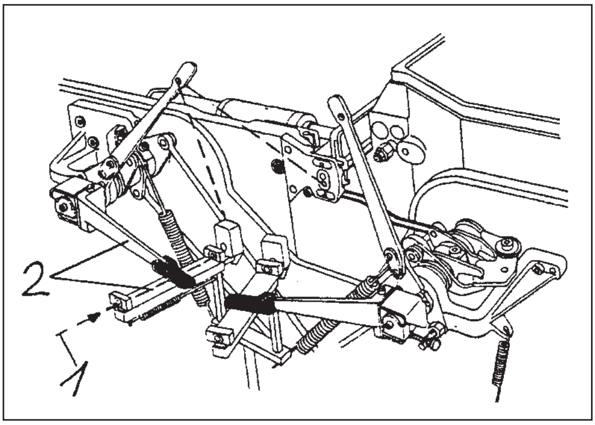


Fig. 4: Projectile shuttle loom with weft yarn (1) and weft brake (2).

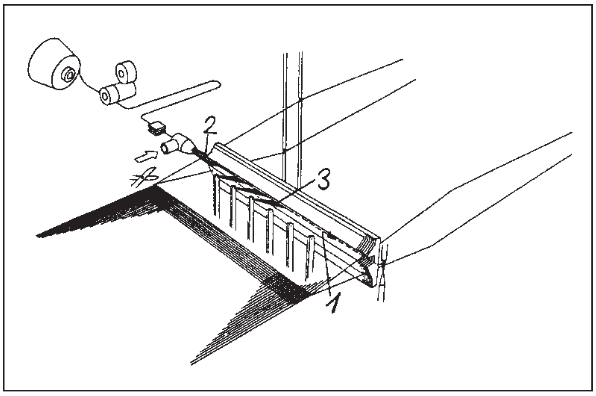


Fig. 5: Principle of the air-jet loom with weft yarn (1), air stream of main jet (2) and air stream of supplementary jets (3).

IV. Finishing: among all the fibre raw materials used in the manufacture of textiles, only wool and a few fine animal hairs have scales on their surface and, consequently, a propensity for felting. This characteristic of the wool fibre is exploited industrially in the manufacture of all milled fabrics produced from carded yarns as well as to achieve a particular fabric appearance with worsted materials and knitted articles and also in the production of felted garments. On the other hand, this property can also have negative effects with other articles that are subjected to frequent washing since the very conditions under which felting can easily occur are present during wet washing treatments.

Since the scales on the surface of wool and other animal hairs project towards the tip of the fibre, they oppose motion in that direction. Consequently, friction is less from root to tip than from tip to root. In the movement of wool fibres against each other, therefore, there is higher resistance in the tip to root direction than vice versa. The so-called directional frictional effect (DFE) according to Mercer, is used as a measure for the different frictional forces here and may be defined as the ratio of the difference of the coefficients of friction to their sum (Table 1). Other formulae for the calculation of DFE found in the literature may give values that are not comparable with each other (see also Fig. 11).

Apart from differences in frictional resistance in both directions of the scales, Table 1 also shows that, as a result of wetting the fibre and consequent swelling, the absolute values of frictional resistance in each direction have increased almost twofold and the differences in frictional resistance in both directions are even 3–4 times higher so that the felting propensity now appears much greater. It is also clear that, in the case of the antifelting finish, the coefficient in the direction against the scales is not reduced by simple smoothen-

	Central stat. coefficients of friction (before start of slippage)			Central dyn. coefficients of friction (after start of slippage)		
	in .. against direction of scaling		DFE	in .. against direction of scaling		DFE
untreated fibre	0,24	0,37	0,21	0,17	0,30	0,28
chlorinated fibre	0,91	0,92	0,01	0,82	0,78	0,02
64 s South American merino wool:						
– dry				0,11	0,16	0,19
– wet				0,20	0,38	0,31

$$\text{DFE} = \frac{\text{difference in the coefficients of friction}}{\text{sum of the coefficients of friction}}$$

Tab. 1: Coefficients of friction for different wool fibres.

ing of the scale edges to approximately the value of the coefficient in the direction of the scales, but that both coefficients are increased significantly, and to a different extent, with the result that they are almost the same.

As an intrinsically unstable fabric construction, knitted material is often over-stretched in the lengthwise direction after a wet treatment. These tensions are more or less highly blocked depending on the intensity of the frictional forces between the threads of neighbouring loops. In the compressive shrinking process, knitted fabric is compressed, i.e. the frictional forces within the stretched loops are raised; as a result, the loops can be brought back intentionally into their energetically most favourable round form. In compressive shrinking, the contact pressure, i.e. the normal force, should be chosen in such a way that, on the one hand, the fabric is bound to the rubber blanket of the shrinking machine and can be reconstructed by the change in length of the rubber blanket. On the other hand, the frictional force between the shrinking cylinder and the knitted fabric must be overcome. During the compression process, the frictional forces within the binding points of the loops between the fibres have to be overcome. Polysiloxanes, especially silicone elastomers, are used to reduce the friction. These products provide the textile material with excellent recovery characteristics.

The influence of softeners on the shrinkage process may be explained as follows:

a) When a knitted cotton fabric is finished with softeners before mechanical shrinking, the cotton fibre is enveloped with a smooth hydrophobic film. This lubricant reduces the frictional forces between fabric and metal, as well as between fibre and fibre; as a result, the fabric can now be compressed more easily.

b) For the compressive shrinking process, a rubber blanket is provided as a further component in addition to the textile material and metal cylinder. Adherence of the knitted fabric to the rubber blanket is absolutely essential for the success of the shrinking process.

V. Test procedures: in the KES-F-4 procedure of the Kawabata system for the measurement of fabric handle, which is used to determine the friction of fabric surfaces, the friction sensor employed has been adapted from the grooves on the finger tips of the human hand. It consists of 10 wires arranged one behind the other which, together, occupy a surface area of 0.5 cm^2 (Fig. 6).

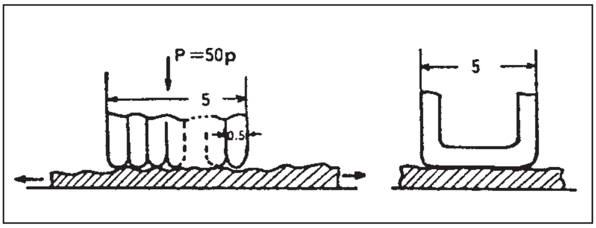


Fig. 6: Friction sensor used to determine surface characteristics.

The friction sensor is loaded with a weight of 0.5 N and firmly anchored in the measuring cell. The test specimen is secured at one end by means of a clamp. This clamp is suspended from a movable lever arm which is loaded with an additional weight of 0.6 N which provides a pretensioning force to smoothen out the test specimen. The test specimen then passes via a guide roller between the friction sensor and the metal plate. The actual measurement is carried out on the metal plate. At the other side of the apparatus, the test specimen is firmly clamped to a large diameter metal roller by means of a metal pin housed in a recessed notch. By turning on its own axis, this metal roller causes the test specimen to move forward beneath the friction sensor (Fig. 7).

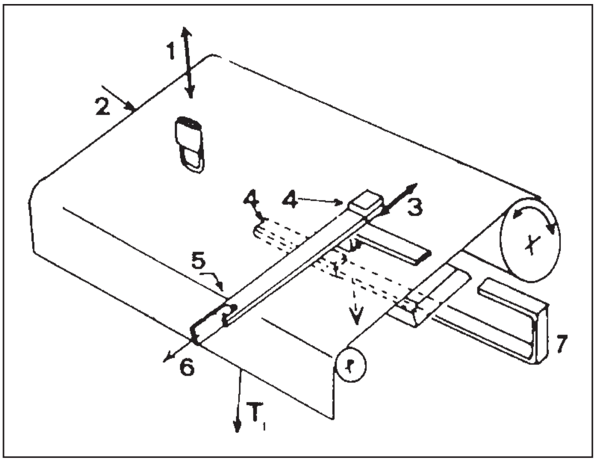


Fig. 7: Principle of the apparatus for determining surface characteristics (friction and profile).
1 = sensor for the measurement of roughness (profile); 2 = fabric test specimen; 3 = sensor for the measurement of friction; 4 = counterweights; 5 = bolt connection; 6 = connection to measuring device for frictional force.

Friction

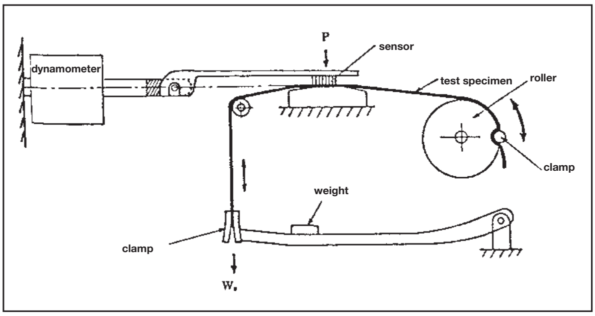


Fig. 8: Functional principle of test apparatus for the measurement of surface characteristics (KES-F-4).

After conditioning the fabric in the standard atmosphere for textile testing, two samples in both the warp/knitted wale and weft/knitted course directions are cut out to the dimensions of 2.5 x 20 cm required for the test specimens. Two measurements are taken on each test specimen; i.e. after the first measurement the test specimen is turned through 180° (the face side remains uppermost). In this way, four measurements are obtained in each of the warp and weft directions. All the data from these measurements is directly displayed with the aid of the in-built computer. It is therefore unnecessary to plot a graph.

The test specimen is laid out, with its threads aligned as parallel to each other as possible, and tensioned at both sides (Fig. 8). The friction sensor is now loaded with the 0.5 N weight, anchored in the measuring cell and the fabric specimen laid out on the test apparatus. The test specimen is transported progressively at a speed of 1 mm/s beneath the friction sensor. The test distance is 2 cm after which the direction of movement is reversed and the test distance is scanned in the opposite direction. The integrated values for the forward and reverse movement are determined directly by the computer and do not need to be recorded during measurement. If a plotter were to be connected to the test apparatus, the recorded curve would appear as shown in Fig. 9.

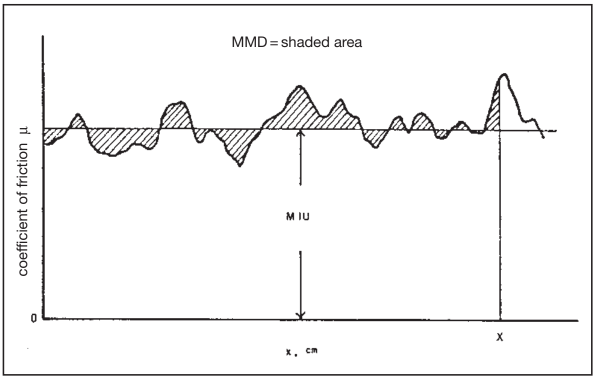


Fig. 9: Friction measurement curve.

Friction is defined as the force of resistance opposing the movement of one surface over another with which it is in contact. It acts parallel to the frictional surface and against its direction of movement. For stick-slip friction, the following formula applies:

$$F_R = \mu \cdot F_N$$

The coefficient of friction μ represents a proportionality factor, i.e. the greater the value of μ the higher the frictional force F_R.

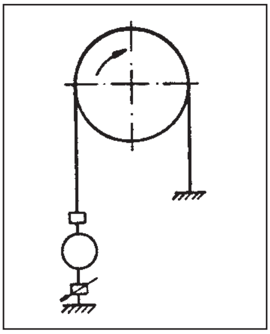


Fig. 10: Sketch of apparatus for determining the coefficient of friction.

The coefficient of friction between fibre and metal cylinder can be established as follows (Fig. 10). The textile fabric is stretched over a roller and subjected to a pretensioning force F_1. As soon as the roller is set in motion by a motor, an increase in force is registered on the measuring meter. The coefficient of friction can be calculated by means of the Eytelwein equation. The mathematical background is as follows:

$$\frac{F_2}{F_1} = e^{\mu \cdot \alpha}$$

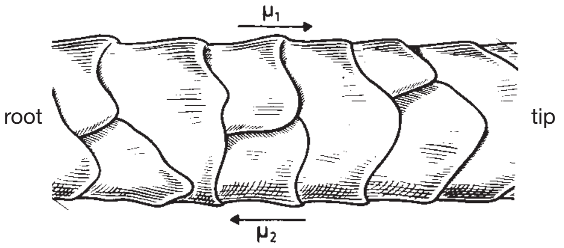
$$\ln \frac{F_2}{F_1} = \mu \cdot \alpha$$

$$\mu = \frac{\ln \frac{F_2}{F_1}}{\alpha}$$

for the angle of wrap α:

$\alpha = 180°$
$\alpha = \pi$

The coefficient of friction is dependent on:
- condition of the roller surface,
- fabric tension,
- speed,
- applied force,
- angle of wrap,
- moisture content.



Capstan method: $P_2/Pi = e^{\mu\Theta}$

directional friction effect (DFE) = $\dfrac{\mu_2 - \mu_1}{\frac{\mu_2 + \mu_1}{2}}$

Fig. 11: Definition of the coefficients of friction on the surface of the wool fibre.

To determine the directional coefficient of friction of wool fibres (Fig. 11), the individual fibres are rubbed over a horn (keratin). The coefficient of friction between a textile fabric and other materials can be determined in a similar way. Since the friction values between a textile fabric and the rubber calender within the fibre material itself are important in the case of shrinking machines, the metal cylinder would have to be substituted by a rubber cylinder in order to obtain coefficients of friction between the fabric and the rubber. Likewise, the metal cylinder would need to be wrapped with textile material in order to determine the fibre/fibre friction values.

cloth moisture (%)	6	6	6	65	65
cloth speed (m/min)	20	20	20	20	20
F_1 (N)	50	100	200	50	100
cloth tension (N/m)	71	142	284	71	142
F_2 (N)	75	140	260	80	133,3
cloth tension (N/m)	106,4	198,6	368,8	113,5	189,1
coefficient of friction μ	0,13	0,11	0,08	0,15	0,09

Tab. 2: Dependence of the coefficients of friction of a cotton fabric on process-specific parameters.

The fibre/fibre coefficient of friction for cotton is μ = 0.22. The friction values presented in Table 2 for a cotton fabric of 105 g/m^2 were determined between the fabric and a Teflon-coated steel cylinder.

These empirically determined results allow the following conclusions to be made:

a) The higher the tensile forces acting on the fabric (with the same moisture content), the lower the coefficient of friction.

b) Low tensile forces on moist fabric cause an increase in the friction values compared to air-dry fabric.

c) With high tensile forces, the moisture content of the textile fabric exercises only a minor influence on the coefficients of friction.

VI. Garment manufacture: in order to prevent loop damage in knitted fabrics during making up it is possible to apply a finish to increase the sliding characteristics of the individual yarns so that the loops can widen during insertion of the sewing needle. In the textile industry, silicone oils in emulsified form are widely used as softeners and sewing thread lubricants. Silicone products have excellent sewability properties. They have an extremely low surface tension with the result that they are able to spread very easily on almost all types of surface.

Friction between sewing needles and knitted fabrics can also be reduced with polyethylene dispersions so that the needle can slide past the loops with very little effort. As a result, better sewability is achieved and the risk of loop damage is reduced. To improve sewability therefore, the use of softeners offers significant advantages.

Friction calender In the treatment of cotton fabrics the gloss finish imparted by calender bowls rotating at the same speed only is insufficient to achieve a high surface glaze with a greater closing of the yarns. For this purpose, friction calenders are used in which a highly polished chromium-plated steel bowl travels at a higher circumferential speed than the fabric itself so that the fabric receives a lower or higher degree of glazing depending on the preselected advance speed (friction) of the calender bowl (Fig. 1). An important prerequisite for imparting a closed glaze effect on the fabric surface is an adequate fabric density, i.e. the type of fabric weave. In the case of fine weaves and fabrics composed of thermoplastic fibres, it is possible to close the woven structure by pressure and temperature to such an extent that the high gloss on the surface of the steel bowl is transferred to the surface of the textile

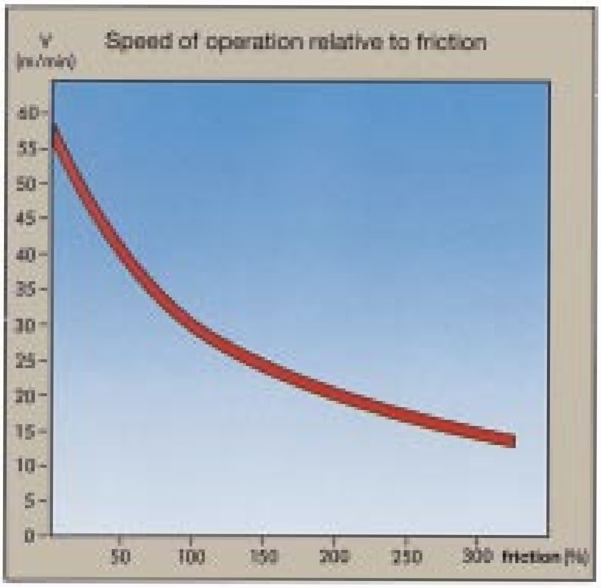


Fig. 1: Speed of operation relative to friction.

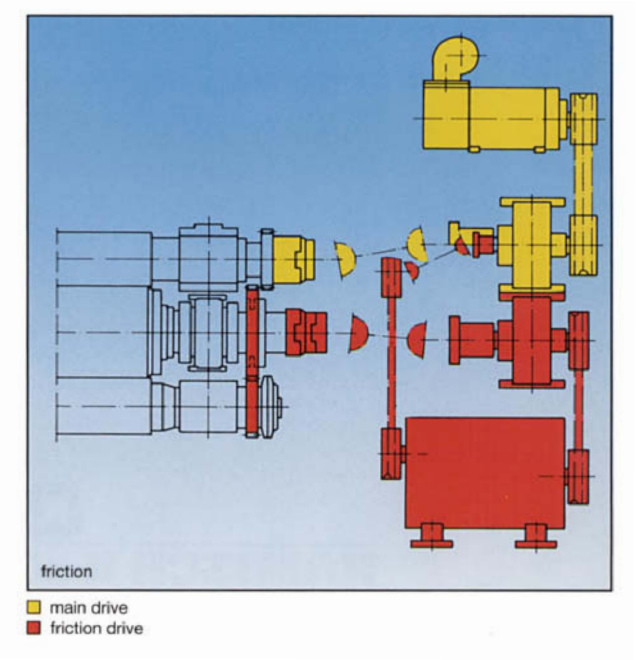


Fig. 2: Ramisch-Kleinewefers friction calender drive.

material with the bowl travelling at the same speed as the fabric (laqué effects). The required gloss can be graded from a mild silk-like lustre to an extremely high glaze.

The friction range is infinitely variable from 0–300%. Pressure is applied hydraulically. The upper steel bowl can be heated by gas, hot oil or electricity, whilst the lower steel bowl which functions as the glazing or support bowl, is mainly heated by steam. A typical arrangement of bowls in a three-bowl friction calender consists of the upper highly polished chromium-plated steel bowl, a highly-elastic cotton or paper bowl, and a lower steel bowl (Fig. 2). The upper steel bowl and the elastic centre bowl are controlled by a variable speed drive in such a way that they can be driven at the same speed or at relatively different speeds.

Friction, coefficient of The coefficient of friction is a measure of the frictional force opposing the movement of one body over another in the area of contact:

$$\mu = \frac{\text{frictional force}}{\text{normal force}}$$

The coefficient of friction is not a fixed parameter since it is dependent on frequently changing boundary conditions such as material pairing, state of the surfaces, frictional load (surface pressure, frictional velocity, temperature of surfaces under friction), type of lubricant and the quantity of lubricant applied. A reduction in the coefficient of friction, as well as a constant coefficient of friction are very important factors in the generally apparent trend towards increased productivity in spinning, throwing, texturing and winding processes, as well as embroidery and warp-knitting, etc. Progress in this development is opposed by highly variable machine productivity and variations in fabric densities which become manifest as transverse and lengthwise streakiness, variable repeats and fabric weight per m^2, as well as variations in the frequency of defects and fabric structure. The dependence of the coefficient of yarn friction (polyester/wool 55/45) on the quantity of lubricant applied is shown in the Figure.

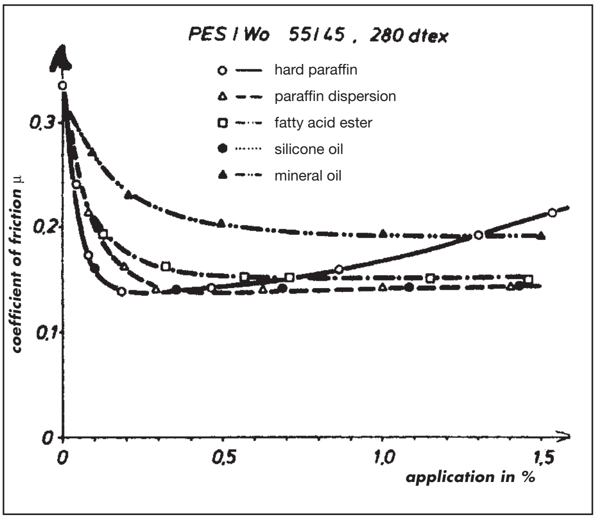


Fig.: Influence of the application of different softeners on the coefficient of friction.

After the application of softener, the mean coefficient of friction is approx. 0.1 µ. Such yarns, especially when they have received a uniform application of lubricant, give problem-free running in subsequent processing. Yarn processors sometimes demand coefficients of friction in the range 0.15–0.18 µ as an “indispensable condition” although it has been established that yarns which have been uniformly softened with paraffin to give a constant coefficient of friction even above 0.2 µ are still capable of further processing without problems. On the other hand, it has been observed that changes in the coefficient of friction exceeding +30%, especially above 0.2 µ, can cause problems on knitting machines such as torn threads, broken loops, dimensional changes and horizontal stripes. → Friction.

Friction marks These defects are formed, e.g. in the dyebath by friction between the surface of a fabric and the walls of the dyeing vessel and/or other hard surfaces. Fabrics of acetate and silk are particularly susceptible to this kind of defect. Appearance of affected areas: darker, matt and roughened surface, fabric surface bulges on one side. Often accompanied by tears and holes. Individual fibres exhibit pressure marks. Some improvement may be possible by rubbing the affected areas with a paraffin-gasoline solution.

Friction testers These instruments are used to check the characteristics of yarn friction (→ Friction, coefficient of). The following types of instrument are available for this purpose:

- simple, non-recording mechanical instruments (e.g. friction balance);
- simple, recording mechanical instruments (e.g. micron meter);
- electronic (computer-controlled) instruments with full data print-out facility for variable measurement conditions.

Complaints have often been made when using these instruments that the measurements obtained can sometimes deviate considerably from one another. The reason for this is due to variations in frictional conditions. If, however, these frictional conditions are brought more into line, then identical measurements will, in fact, be produced.

Friction texturing → Friction texturizing.

Friction texturizing Texturing method in which appropriate overtwist is applied to the running thread using overlapping friction discs (torsion discs, friction discs). The required false twist is achieved by subsequent counter twisting and twist setting. Up to 1960 a rigidly mounted spindle with axial drive was used (friction elements). As entirely uniform, reproducible speeds could not be obtained, spring-mounted magnetic spindles are now used (instead of rigidly mounted friction components).

Friele MacAdam Chickering formulae → Colour difference formulae.

Friezé

I. Handknitting and craft yarns with brushed woolly finish.

II. Soft, thick woollen fabric in plain or twill weave, can also be double cloth with two warp and weft systems, generally with pepper-and-salt effect on face and checked on reverse. Mossy thick hairy nap, either heavily raised on both sides or lightly raised on reverse only. Friezé cloth is simlar to velour but with rougher longer nap. Distinction may be made between randomized nap (with non-directional lay) and brushed nap (with directional lay). Used for ladies winter skirts, jackets and coats.

III. Thick, soft woollen material with raised and laid nap (milled and raised) or may be closely cropped.

Friezing A process used for the production of local patterning on a pile fabric where the pile has usually been formed by raising. The fabric passes between a fixed friezing bed and a moving friezing plate mounted above it which is clothed with sandpaper, plush, cloth or rubber (see Fig.).

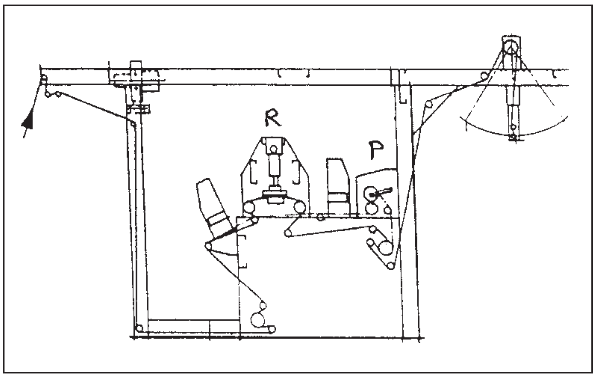


Fig.: Schematic diagram of pile patterning machine with friezing (R) and embossing (P) devices for optional use (Franz Müller).

Depending on the extent to which the friezing plate carries out its short to-and-fro motion, the following effects are achieved: large or small pills or burls (pearl ratiné), fine blocks (Floconné), warpwise stripes (lengthwise or warp ripple), weftwise stripes (transverse or weft ripple), diagonal stripes (diagonal frisé), or even whirl-like effects (plush with whirl effects).

Fringed micelle → Cellulose.

Fringe twisting machines Machines which automatically twist a certain number of warp yarns in woven blankets and plaid travel rugs to form a fringe held in place by the insertion of auxiliary threads until the end of the finishing process (Figs. 1 + 2).

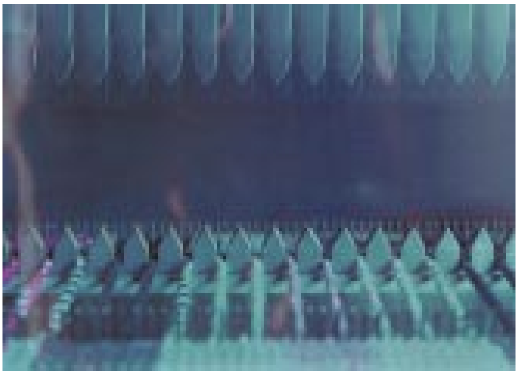


Fig. 1: Fringe twisting machine.

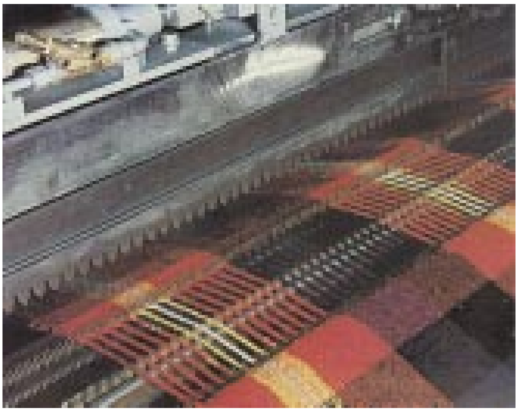


Fig. 2: Lafer fringe twisting unit.

Frisé

I. Originally the finest grade of linen made in Friesland, Holland.

II. A French term meaning "curled".

III. A coarse ratiné fabric made with slub yarns in a plain weave.

IV. A looped pile fabric usually of uncut loops which may be cut at various heights to provide a pattern.

V. A coarse, stout cotton or linen fabric made in a plain weave with a flat, wiry texture and a pronounced rib.

VI. This term is sometimes used for terry or bouclé fabrics.

Frisé carpet A cut pile carpet of twisted yarns in solid colour or produced with vari-coloured yarns. According to DIN 61151, a carpet with alternating closed and cut loops.

Frisons Flock silk (→ Bourette). The first silk waste obtained in the course of cocoon preparation for reeling by agitation in a water bath.

Front fusing A process used in garment making to give garments form stability by bonding with an interlining (with a hot-melt adhesive). Bonding takes place by the action of heat and pressure in heated presses. Problems are encountered with fabrics which have been finished with silicones or fluorocarbon derivatives. Adhesion is improved by double-spot coating. →: Powder bonding; Interlinings.

Front line Upper demarcation line for front of eluent in → Paper chromatography and → Thin-layer chromatography. Parallel distance from start line 15 cm in paper chromatography and 10 cm in thin-layer chromatography.

Front loading washing machine (Front loading washer), cylinder washing machine with a one-piece internal cylinder that is supported at one end and has a loading/unloading opening at the front end, usually with a transparent door made from heat-resistant safety glass. Capacity 8–50 kg of dry material.

Frosted wool process A process for the degreasing and removal of all impurities from raw wool by cooling to –10 to –17°C followed by beating to break off the solidified brittle foreign matter (grease, burrs, sand, etc.). Burrs become so brittle in this treatment that they are easily pulverized by attrition.

Frosting

I. → Sandwich effects in dyeing.

II. Whitish sheen on carpets containing wool and polyamide pile that have been continuously dyed by the pad-steam process. When the padded carpet enters the steamer, condensing steam rinses dye liquor from the tips of the pile, thus giving it a whitish appearance. A remedial measure is to add film and foam-forming agents to the padding liquor. Foam pushes the dye liquor back towards the tips of the pile, thus compensating for the loss of dye.

III. Light patches occurring in viscose crepe in the warp direction consisting of flat, deformed viscose capillaries that are in fact dyed but reflect much more light because of their flat shape. Visible under the microscope as short, thin apparently white capillaries that can be proven to originate from the feedstock and can no longer be rectified. These patches are created during the viscose spinning process and appear to be due to some kind of local stretching.

Frosting in carpet printing (tippiness). Rather than remain uniformly distributed along the individual pile fibres in the printing of carpets, especially those with a high pile) the print paste may flow from the tips of the pile towards the carpet backing before the dye fixation stage. This results in a depletion of dye at the tips of the pile, i.e. frosting.

Froth dyeing A variant of → Foam dyeing. Principle: the process is carried out in an open vat as the dyeing vessel. Foam is produced by the vigorous boiling of a dye liquor containg soap or other high-foaming detergent. The dye liquor occupies approx. 20% of the dye vessel volume, and the material is dyed by suspension in the foam above the dye liquor.

Frotté Name for

I. Yarn: 5–7 fold effect twist yarn in form of knop yarn, loop yarn, in cotton, viscose, wool (woollen spun).

II. Plain-weave fabric with smooth warp and knop yarn weft, irregular, contoured surface; brushed, rough finish. Sold as piece goods or by the metre; also used in outerwear.

Fruit fibres → Hard fibres of the coconut fibre type.

Fruit-ice stains The stains are tacky when fresh and often hard when old. Most have a fairly sharp outline and can be of various colours. Removal: white spirit or trichloroethylene (tetrachloroethane), then ammonia 1–3%. Colour residues are subsequently best removed with alcohol.

Fruit juice stains (from berries). The stains can be of various colours with a sharp outline when fresh or more blurred when old, often only on the surface of the fabric. Removal: a) treat the affected area in a fatty alcohol sulphate solution 3–15 min (warm/hot), if necessary with ammonia or ammonium carbonate 2–5%, soak (with formic acid); b) treat with a fatty alcohol sulphate solution plus 10% formic or citric acid (or sodium bisulphite especially for bilberry stains). Colour residues: treat with sulphurous acid (sodium hypochlorite-oxalic acid, potassium permanganate or hydrogen peroxide).

Fruit wall hairs Vegetable hairs of the inner fruit skins of tropical plants such as the cotton tree (Bombax species). Fruit wall hairs are seed fibres such as those of the kapok tree, etc. (Bombax cotton, Ceiba fibre).

FSDC, abbrev. for: Fellow of the Society of Dyers and Colourists, Bradford, U.K. Professional qualification.

	Wood %	Peat %	Brown coal %	Coal %	Anthracite %
Carbon C	50	55—65	65—75	75—90	94
Oxygen O	44	30—40	20—30	5—18	2—3
Hydrogen H	6	5,5—7	5—6	4,5—5,5	2—3
Nitrogen N	0,1—0,5	1—2	1,2	0,5—1,5	0,1—0,5

Tab.: Composition of various heating fuels.

FSW (Ger.), abbrev. for: Forschungsstelle Wäscherei (Laundry Research Unit), Hohenstein; → Professional and technical organizations.

FTC,

I. Abbrev. for: Federal Trade Commission. A US government customer protection agency which, amongst other activities, has been responsible for the definitions of most of the internationally valid man-made fibre classifications.

II. Abbrev. for: Fastness Tests Commission.

FTCC, abbrev. for: Fastness Test Coordinating Commission, the British Fastness Tests Commission; → Professional and technical organizations.

FTI, abbrev. for: Fellow of the Textile Institute, Manchester, U.K. Professional qualification.

Fuchsin B. A cationic dye used *inter alia* as a special indicator for anionic substances: aqueous Fuchsin solution + anionic solution = colour change from red to cornflower blue.

Fuchsin dyes Rosaniline, cationic red, violet and bordeaux dyes. These dyes are chemically very sensitive: reaction with acids = yellow (brown), reaction with alkalis = brown precipitate, reaction with oxidizing agents (chloride of lime) and reducing agents (sodium bisulphite) = decolorization. They are still used in the Far East as cationic red dyes for dyeing textiles and leather. Also used as a colour reagent in the laboratory for aldehydes (→ Schiff's reagent).

Fuel composition Varies according to the intensity of carbonization and the age of the fuels (Tab.).

Fuel gas →: Natural gas; Liquefied gas.

Fuel oil Liquid fuel, mainly from mineral oil processing. The subject of standards in Germany in accordance with DIN 51 603. Types of fuel oil: production and use almost exclusively restricted to EL fuel oil (extra light) which is mainly used for space heating and is also used for heating processes in commerce and industry, and S fuel oil (heavy), which is the preferred fuel for most industrial heating processes (Tab. 1). L fuel oil (light) and M fuel oil (medium heavy) are exclusively products of tar oil processing and only play a quantitatively minor role (less than 1% in the Federal Republic of Germany).

Full bath treatment A dyeing process carried out at a long liquor ratio by → Exhaust dyeing, in contrast to the → Foulard therm process.

Full cover print A printed design which covers the entire surface of a textile fabric.

		Fuel oil EL		Fuel oil S	
		Minimum requirement as per DIN 51 063	Mean failure values	Minimum requirements as per DIN 51 063	Mean failure values
Density at 15°C	G/ml	Max. 0.860	max. 0.850	—	0.92 – 0.96
Ignition point	°C	Above 55	above 55	above 65	above 80
Kinematic viscosity	M^2/s. (50°C)	—	—	max. $450 \cdot 10^{-6}$	$80\text{-}300 \cdot 10^{-6}$
	M^2/s. (20°C)	max. $6.0 – 10^{-6}$	approx. $2.5 – 5.5 \cdot 10^{-6}$	—	—
Pour point	°C	below –10	below –10	—	approx. +30
Sulphur content	% by weight	0.4 – 0.5	0.8	max. 2.8	max. approx. 2.0*
Water content	% by weight	max. 0.1	max. 0.05	max. 0.5	approx. 0.1
Sediments	% by weight	0.05	0.01	max. 0.5	approx. 0.1
Calorific value H_u	kJ/kg.	min. 42000	min. 42700	min. 39800	40600 – 41000
Oxide ash	% by weight	max. 0.01	max. 0.01	max. 0.15	approx. 0.02 – 0.05

*Tab. 1: Fuel oil parameters. (*Some fuel oil S with lower sulphur content (max. 1%) available).*

Full depth shade in printing The maximum depth of shade which can be achieved with a normally engraved screen or printing roller.

Fuller's earth Impure clay (refined and pulverized) with a greyish-green to yellowish-brown colour and a greasy feel, often of variable composition (e.g. 11–18% aluminium oxide, 44–42% silica, 5–4% lime, 2% magnesia, 10–6% iron oxide, 5% sodium carbonate, 3% water).

Quality test: stir the sample with water and allow to swell and crumble into a paste-like mass. On standing, a powdery precipitate should be gradually formed (without sandy, granular or dirt impurites). Uses: after-washing and milling of woollen materials which have been washed in soap (especially for fine cloths, white and semi-coloured flannel, woollen blankets, etc.).

Fulling stock Mechanism in open-width milling machines in which woollen fabric is compressed in a stuffer box using a hinged top board.

Full penetration dyeing The full penetration dyeing of fibres or textile materials occurs when a completely uniform distribution and penetration of the fibre occurs, i.e. when the interior of individual fibres is fully penetrated (not ring-dyed) and when the closely packed fibre material in slivers are completely dyed. Full penetration in dyeing is a function of the dye exhaustion rate, the control of which determines the degree of dye penetration.

Fully automatic In the context of textile wet processing, a fully automatic process is understood to involve the automatic operation of all machine processing stages (including the metering of additives) according to a program with preselected parameters. → Automation.

Fully fashioned A term used for knitgoods produced on a flat-knitting machine that have been shaped by adding or reducing stitches. The material has ribbed edges (not cut) as it leaves the knitting machine. Fully fashioned flat-knitted materials are referred to as true to shape articles. Fully fashioned knitgoods are used e.g. for socks, stockings, tights, underwear, outerwear, pullovers, etc. Fully fashioned fabrics are the opposite of → Cut fabric.

Fully fashioned dyeing → Garment dyeing.

Fully-washable textiles Finished textiles which can be washed in a washing machine without excessive shrinkage, creasing or other significant deterioration in quality. The term is particularly applicable to blend fabrics of polyester/cotton or polyester/acrylic (→ Machine-washable wool; Easy-care finishes).

Fumaric acid Exists in the cis form. Used especially in synthetic resins. Fumaric acid polyester is used as a plastic.

Functional clothing Clothing that is designed to be light, comfortable, pleasant to wear and easy-care; e.g. → Active wear; Sportswear.

The human body tends to sweat heavily during any strenuous activity, particularly when taking part in many forms of sport. The evaporating perspiration cools the skin and the body, which feels extremely pleasant because of the occurrence of the chill limiting temperature on the skin. Clothing that is in contact with the skin absorbs moisture and releases it to the outside air. If the moisture absorption is greater than the evaporation rate, the textile material stays wet on the skin and usually causes an unpleasant sensation. For example, the way in which functional knitwear functions is to wick perspiration away from the body as quickly as possible, whereby the textile surface that is in contact with the body may not remain wet. This is caused by the structure of the material. Fabrics are mainly double-faced knits, the inner surface of which comprises hydrophobic synthetic fibres and the outer surface of which comprises absorbent cotton or modal fibres. Most fine fibril synthetic fibres (polypropylene, polyester, polyamide) quickly transport moisture to the absorbent outer layer via the capillary spaces, without absorbing moisture.

An important prerequisite for a clothing system to function correctly can be described as follows: the comfort of textiles worn next to the skin is determined by two things: thermophysiological and skin sensation properties. Wearer comfort associated with skin sensation is considered to be the way that materials feel to the touch, i.e. pleasant sensations such as softness and suppleness, but also unpleasant sensations such as scratchiness, sticking to sweaty skin etc. The thermophysiological wearer comfort of textiles is determined by the heat and moisture transmission processes within and through the layers of textiles. The two transmission processes serve to provide a balance between the temperature of the body and its environment. The textile layers next to the skin have to provide good sweat evaporation to the surface of the skin. However, in many practical cases the evaporative heat flow in the clothing is inadequate, because the body produces superfluous amounts of perspiration that cannot evaporate on the surface of the skin and remain there in the form of liquid perspiration. These quantities of perspiration have a thermoregulatory effect on the one hand and produce an unpleasant skin sensation on the other. Textiles worn next to the skin therefore have to remove these excessive perspiration components as rapidly as possible.

The climate of the skin involves two factors: the microclimate (→ Clothing physiology): during strenuous activity the skin must be capable of releasing water vapour from its pores to the outside air without hindrance, which is only possible if there is a partial pressure differential of vapour pressure between the skin and the air in the environment. It should therefore be attempted to make the air next to the skin as dry as possible. In the reverse case, in cold weather conditions there should also be dry air next to the skin i.e. within the textile surface structure, in order to provide the necessary heat retention, the insulation characteristics. The clothing therefore becomes part of the person's energy balance, with its moisture penetration resistance and thermal insulation, expressed as the moisture transmission index i_m. Both values can be measured on the Hohenstein thermal regulation model/system (heated sintered metal plate that emits steam and therefore simulates the human skin), or “Charlie”, a life-sized metal mannikin that moves, sweats and is fitted with a range of measuring probes, and can also be used to measure the wearer comfort of textiles.

Functional group control (Automatic function group system), control using the principle of program control, whereby the technological process is split into self-contained function groups.

Functional groups Typical groups of atoms responsible for the characteristic reactions of entire classes of chemical compounds, e.g. functional hydroxyl groups (OH) are characteristic of alcohols, carboxyl groups (COOH) are characteristic of organic acids, amino groups (NH_2) are characteristic of amines, etc. Compounds are described as mono, bi, tri or polyfunctional depending on the number of such functional groups present in the molecule.

Fungi as textile parasites → Moulds; Microbial damage to textiles.

Fungicidal finishes These finishes are applied especially to textiles which frequently come into contact with the ground, soil, wind and weather, such as tenting, truck tarpaulins, fire hoses, etc. Suitable preservatives for such articles include, in particular, organic acid salts of zinc, copper, and mercury, phenols, chlorophenols, anilides of aromatic acids, sodium salts of chlorocresols, chloroxylenols, tri and pentachlorophenols, copper salts of cellulose glycollic acid, as well as quaternary ammonium bases, etc. Free aromatic compounds of the above type generally have a stronger fungicidal action than their salts, but are more susceptible to volatilization and are more easily removed by wet treatments. For this reason, it is preferable to precipitate the heavy metal salts of these fungicides on the surface of or within the fabric. From an American survey, the parameters used to evaluate the suitability of a fungicide for textile use are stability, efficacy, toxicity, odour and effect on colour. Stability is required against heat, UV radiation, weathering and oxidizing substances; only a few chemical compounds have all these properties. A fungicide should remain unchanged during the entire working life of the fabric as well as during prolonged storage. Effective fungicidal action must already be achieved with relatively small doses of the fungicide.

Fungicide (Lat.: *fungus* = mushroom, fungus). A substance or product capable of killing or destroying fungi.

Fungistat A substance or product that inhibits the growth of fungi.

Fungistatic finishing Prevents the growth of fungus on textiles; the same products as those recommended for → Antimicrobial finishes are usually used.

Funnel test A test method for the evaluation of water-repellent finishes on textiles (not as severe as the → Permeability bag test or the water pressure test, but of advantage for lightweight fabrics since less distortion and extension of the test specimen is involved). Procedure: a test specimen measuring 30 x 30 cm is folded into a filter form and placed in a glass funnel supported on a stand (width at top approx. 15 cm, angle of 60°), then filled with 500 ml water. The water-repellency is evaluated by the time taken for the first penetration of water to occur (1 h or 1 day) and also, if necessary, by measuring the quantity of water collected in a measuring cylinder placed beneath the funnel.

Furan (furfuran) →: Furfural; Furfuryl alcohol.

Furan polymers → Furfuryl alcohol.

Fur bleaching → Bleaching of animal fibres, carried out on a previously prepared skin which must not have been subjected to chrome tannage.

Fur dressing → Fur finishing.

Fur dyes Metallizable types. These dyes are applied on the same principle as metallizable wool dyes and produce fast dyeings on fur skins by brushing or dipping. The classical dyeing technique is based mainly on the application of aromatic amine bases at a temperature of 30°C from which dyes are synthesized on the fur hairs by oxidation (probably by a process analogous to → Aniline black) and fixed with the aid of metal mordants. Appropriate azo dyes capable of exhausting on to mordants are also used in fur dyeing. Similar dyes can also be dyed to some extent by oxidation. However, these dyes exhaust more rapidly with improved levelling and better fastness to storage and light when applied on fur skins which have been pre-mordanted with a metal salt. The metal-complex dye lake thus formed exhibits a considerably increased colour intensity and covering power the properties of which are greatly dependent on the respective type of mordant employed. In Europe, fur dyeing can only be carried out nowadays with non-toxic and non-carcinogenic dyes.

Fur finishing The finishing of fur materials covers all the processes and technical operations which affect the original character of the fur. These changes are mainly concerned with the fur's natural colouring.

The dressing of fur materials includes all the operations carried out with the objective of exploiting the characteristics of the fur in clothing applications to the widest possible extent. A properly dressed fur should not be susceptible to putrefaction and should be largely insensitive to the effects of water. The skin should be of low mass and exhibit a high degree of softness, flexibility and durability; the hairs of the fur must be clean and firmly rooted in the skin and should not be susceptible to any changes which could impair the results of further finishing or the serviceability of the fur. Specific finishing effects are already achieved during the dressing treatment. The entire dressing process must be optimally adapted to possible further finishing involving dyeing or other operations as well as subsequent use of the fur as far as fitness for purpose and fashion requirements are concerned.

During the course of dressing, the fur is subjected to a variety of treatments which have a physico-chemical or mechanical effect on the skin and thereby bring about the required changes in its properties. Both types of treatment are applied one after the other in the overall dressing process but the sequence differs from one type of fur to another as well as from source to another.

In the initial stages of fur dressing, the fur is reconverted by the softening process into the fully hydrated (water-saturated) state, as it existed on the live animal and, during subsequent digestion of the skin, the skin protein material, i.e. the collagen, is broken down. Any non-leather-forming tacky impurities are removed. The loosened state of the skin is then fixed with tanning agents or other substances which create a similar effect (pseudo-tanning) whereby the skin is converted into a non-putrefiable water-resistant leather or, at least, a non-putrefiable leather-like form. Furs with soiled hairs are cleaned by a washing treatment which is usually given after the softening process. Softening, washing, skin digestion and tanning resp. pseudo-tanning, involve physico-chemical processing of the fur material and are mainly carried out in the bath in aqueous media on a large number of fur pieces in a single batch.

Mechanical treatments are interposed as required before, after or in-between other processes. The objective of these treatments is to remove redundant parts of the fur material such as heads, paws, etc., as well as skin resp. leather substances which are not absolutely necessary for the strength of the leather and the secure anchoring of hairs and which would otherwise increase the fur's mass unnecessarily. Moreover, the more or less firm adhesion of leather fibres which occurs during drying of the fur material is eliminated, prevented or reduced by the mechanical treatment. If necessary, the hair coat is likewise loosened and shortened. The mechanical treatments are carried out manually or by machine either individually or in batches. The flexible and soft character of the fur leather is further increased by fat-liquoring. The hair and leather are cleaned by a treatment with abrasive and absorbent materials in the clarifying process. A treatment in organic solvents is given to achieve a light leather through the removal of excess fats as well as a further cleaning of the hair coat.

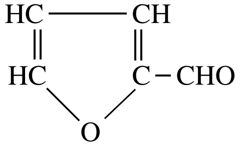
Bleaching (a process which is usually coupled with dyeing in practice) is a treatment to change the natural shade of the fur. Chemical reactions between the fur and the chemical substances used play the key role in this process. Because of the naturally variable appearance of fur materials, an absolute levelling out of the shade is not possible when a large number of fur pieces are treated as a single batch.

Depending on the animal's age, sex and nutrition as well as the origin of the live animal to some extent, furs react very differently to each other and this is further influenced by all the physico-chemical processes involved in the course of finishing. An additional problem here is the fact that not only do the woolly and long coarse hairs behave differently in dyeing, but a range of different types of fur over the entire surface of the fur material (e.g. the back of foxes, belly parts, etc.) react differently in terms of dye uptake and therefore in the uniformity of shade obtained.

As far as creation of the shade is concerned, imitations of genuine wild furs were originally produced on cheap commodity materials. Nowadays, the line between the terms fur dyeing (which was formerly understood to mean a uniform dyeing, e.g. black) and fur finishing has become blurred since, besides the production of imitations, the production of standard fashion shades on all types of furs by all processors of hides and furs is now of equal importance.

In addition, the hair length of the fur, the original composition of the hair coat, or the form of the individual hairs, are changed by the mechanical operations applied in fur finishing. Only in the rarest cases are these operations unconnected with changes in the dyeing properties of the hair coat. Shearing can not only result in the achievement of a uniform hair length, but certain effects such as furrows or patterns can also be produced in the fur. The ratio of woolly hairs to long coarse hairs is changed by depilation or plucking whereby the long coarse hairs are removed from the fur mechanically. The production of rumbled nutria should be mentioned as an example of a very labour intensive process (removal of the dense long coarse hairs already begins in the dressing stage). Processes which influence the shape of the individual hairs themselves are of relatively recent introduction. On the one hand, this involves stretching out the woolly hairs which are crimped or curly on the live animal and the production of crimp in naturally straight hairs on the other, e.g. to achieve Persian curls or South American markings.

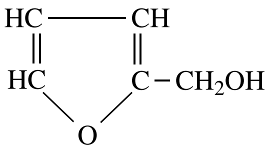
Furfural, Lat.: *furfur* = bran (furfuraldehyde, 2-furaldehyde, bran oil).



A readily accessible starting product for furan derivatives. In the USA it is manufactured on an industrial scale from cereal wastes (oat hulls, rice hulls, corn cobs, etc.). Used as an intermediate product in the fabrication of polyamide 6.6; as a solvent for decolorizing natural rosin for varnishes; for the production of phenoplast resins in place of formaldehyde, etc. Hydrogenation results in the formation of tetrahydrofurfuryl alcohol.

Furfuran → Furan.

Furfuryl alcohol, $C_5H_6O_2$, density 1,13, b.p. 170–171°C, a derivative of furfuran. A colourless to yellowish liquid with a characteristic odour. Soluble in water, alcohol, ketones, etc.



Solvent for nitrocellulose, certain dyes, synthetic resins, etc. Manufactured on an industrial scale in the USA for solvents, wetting agents, synthetic resin components, etc. It forms furan polymers, e.g. in aqueous solution with phosphoric acid (as catalyst). The low-viscosity furan polymers are soluble in alcohol, whilst high-viscosity types, on the other hand, are soluble in acetone, ethyl acetate, aromatic and chlorinated hydrocarbons. Also used for high quality cold-curing sealants, cements and plastics (transparent, elastic) which are also used as components of other synthetic resins, e.g. for improving the alkali stability and adhesive properties of phenoplasts.

Furnisher roller (colour furnisher roller). Used in roller printing to supply the engraved printing roller with print paste from the colour box in which it rotates. Both brush furnisher rollers and smooth rubber-coated rollers are used. → Brush furnisher roller.

Furnishing fabrics Collective term for printed, plain-dyed or jacquard-woven textile fabrics for room decoration purposes, e.g. upholstery fabrics, curtains, drapes, etc. Dyes with very high colour fastness to light are required for these applications.

Fused bonded nonwoven → Bonded fabrics which have been bonded, e.g. through the loops of the warp threads with a thermoplastic compound.

Fusel oil → Amyl alcohol.

Fusible fibres These are used in the form of fibres, threads and monofilaments to achieve adhesive-free consolidation/permanent bonding of textile fabrics. After thermal fusion with the aid of an ironing press, hot air, etc., the cohesive strength is intense and permanent. Fusible fibres are of particular interest for nonwovens, textile floorcoverings and in the making-up of garments. (→ Binder fibres).

Fusible interlinings → Interlinings produced with a fusible adhesive coating by the powder-dot process.

Fusible seaming A textile bonding technique in which fabrics are joined by fusion of thermoplastic fibres in the fabric or a thermoplastic resin that has been applied to the fabric. The latter requires special nozzle applicators. From experience with knitted and woven fabrics, felts and nonwovens, seam strengths corresponding to those of conventional seams are obtained. In addition to the high shear strength of welded seams, savings in time are also achieved; moreover, the mechanical piercing of fabric with sewing needles is dispensed with. The speed of operation is determined solely by the rate of feed of the material being seam welded.

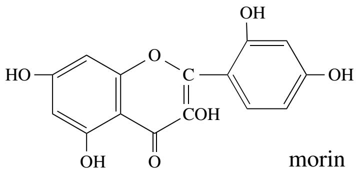
Fusion lamination A special process in which the surface of a foam sheeting is liquefied under the controlled influence of heat and bonded in this state to the material being coated. The liquid foam hardens on cooling to form a firm bond between the foam sheeting and the textile material. Advantages: good drape characteristics and extensibility, perfect air permeability, the bonding is resistant to washing and drycleaning, and the process is suitable for knitgoods. The loss in thickness of the foam is approx. $^1/_{32}$.

Fustian A general term used to describe a group of cotton fabrics, usually heavily wefted, raised on one or both sides, and produced in various weaves, e.g. twill fustian, satin fustian, corduroy fustian. The description also refers to the end-use, e.g. bed-fustian, lining fustian, dress fustian.

Fustic (yellow wood)

I. Brazilwood, Cuba wood, fustic wood: tropical dyewoods; hard, solid, light yellow or pale lemon yellow, turning darker with age. Available commercially in block form, raspings and powder.

II. Yellow dyes of the flavone type. Fustic consists mainly of morin or morin acid ($C_{15}H_{10}O_7$) and maclurin or morintannic acid ($C_{13}H_{10}O_6$).



morin

Fustic is completely soluble in a 50% water/alcohol mixture. Fustic extracts are highly viscous or solid (yellowish-brown/olive) waxlike lustrous lumps with a conchoidal fracture. Fustic gives coloured precipitates with metal salts: alumina, tin and chrome mordants = yellow; lead acetate = orange; copper sulphate like antimony potassium tartrate oxide = brownish-yellow; iron salts = olive green. Fustic is still used from time to time in silk dyeing, often combined with weighting. → Logwood.

Fuzz A term analogous to → Lint, used mainly to describe small hairs, fibres, etc. projecting from, or lying on, the surface of a textile fabric.

FWA, abbrev. for → Fluorescent whitening agent (→ Fluorescent brightening agents).

G

G, symbol for giga, i.e. 10^9. A prefix used in the metric system to denote one thousand million times, e.g. 10^9 joules = 1 gigajoule (GJ).

g, symbol for gram, a metric unit of mass equal to one thousandth of a kilogram. 1 g = the weight of 1 cm^3 of water at +4°C. 1 cm^3 = 1 g = 1000 mg. 1000 cm^3 = 1 l = 1 kg (of water). 1000 l = 1 m^3 = 1000 kg = 1 t.

Ga, chemical symbol for gallium (31).

Gabardine The word gabardine (alternative spelling in U.K. = gaberdine) is a collective term for certain woven fabrics and also describes a type of woven pattern. Gabardine is generally a fine, tightly woven warp-faced fabric. The warp density is generally considerably greater than the weft density and the diagonal cord or rib (steep twill line) is distinct, closely set, and raised. Gabardine is produced from carded or combed, single or ply yarns of wool, cotton and viscose. In one type of gabardine, the rib effect is produced with a secondary twill or a multi-shaft satin weave but most gabardines are usually woven in 2/1 and 2/2 twills where the higher the warp density the steeper the twill line. Without exception, coat fabrics (e.g. for trench coats) are woven in 4-shaft reversible twill or 2/1 or 3/1 warp twill. Some gabardines are produced with changeant or shot effects but, as a rule, this type of fabric has not attracted much interest for fashion goods or fashion styling. Good quality gabardine coat fabrics are woven from folded yarns in the warp, or even in both weft and warp. Because of the fine, uniform appearance of wool gabardine fabrics, they are produced almost exclusively with combed yarns in medium-fine to fine yarn counts from pure wool as well as wool blends based on all the usual blend ratios. Even blends with up to approx. 20% max. of polyamide fibres are possible (for alpine and ski gabardines). In practice, carded yarns have only found application as weft material and some fabrics of this type also have a viscose warp. Gabardines are closely cropped to emphasize the weave structure. Commercially, wool gabardine is vigoureux printed, yarn and piece-dyed, with the latter being the most important. Gabardines are usually produced in weights between 240–400 g/running metre and even up to 600 g/running metre in exceptional cases.

Galactomannan (mannogalactan). The main chemical component of e.g. → Carob (locust bean gum) and guar which is built up from the two simple sugars ($C_6H_{12}O_6$) → Mannose (which forms the main long straight chain of the basic skeleton) and galactose (as side chain linkages).

Galacturonic acid The fundamental building block of → Pectins; similar to → Glucose in starch and cellulose.

Galalith → Casein plastics.

Galanga gum A medium quality grade of → Senegal gum.

Gall extract Produced from the gallbladders of mammals, e.g. ox gallbladders, as a brownish-green mass giving a clear solution in water. Cattle gallbladders contain 6–8% dry substance consisting chiefly of so-called bile acids. Cholic acid, $C_{23}H_{36}(OH)_3–COOH$ is the main constituent linked to glycocoll in an amide-like form as glycocholic acid $C_{23}H_{36}$ (OH)3–CO–NH–CH_2–COOH or to → Taurine as taurocholic acid $C_{23}H_{36}(OH)_3–CO–NH–C_2H_4SO_3H$, the alkali salts of which possess soap-like properties. The gall soaps, which contain approx. 8% gall extract and above, are characterized by a high emulsifying capacity and outstanding surface activity. Despite the useful properties of pure and concentrated gall extract preparations as good scouring soaps their importance has declined since the development of synthetic wash-active detergents.

Gall nuts Plant growths containing tannins which in Europe are mainly spherical and in Japan of irregular shape. The former are formed by the sting of the gall wasp on oak leaves and the latter by aphids. European gall nuts contain 7–28% of readily water-soluble tannins (→ Tannic acid) whilst the Japanese variety contain 58–75%.

Gallon,

I. British or imperial gallon. Non-metric unit of capacity equivalent to 4.543 l or 1.20 U.S. gallons.

II. U.S. gallon. Non-metric unit of capacity equivalent to 3.785 l.

Galloon A narrow band of cord, embroidery, braid, etc., used as a decorative trimming. → Braid.

Gall-Riedel formula → Depth of shade of dyeings and prints.

Gall soaps → Gall extract.

Galvano screen → Rotary screens for screen printing.

Gambier A Chinese textile speciality consisting of deep black clothing suitable for everyday use made from non-degummed, heavily-weighted butterfly silk (lightweight base fabric, plain weave) glaze-calendered on one or both sides (with polished stone rollers). Highly resistant to wear (washable, suitable for dry cleaning). The deep black is produced by piece dyeing with a reaction product from a gambier-like tanning substance (juice of the so-called kaki fruit) and a river sludge containing iron.

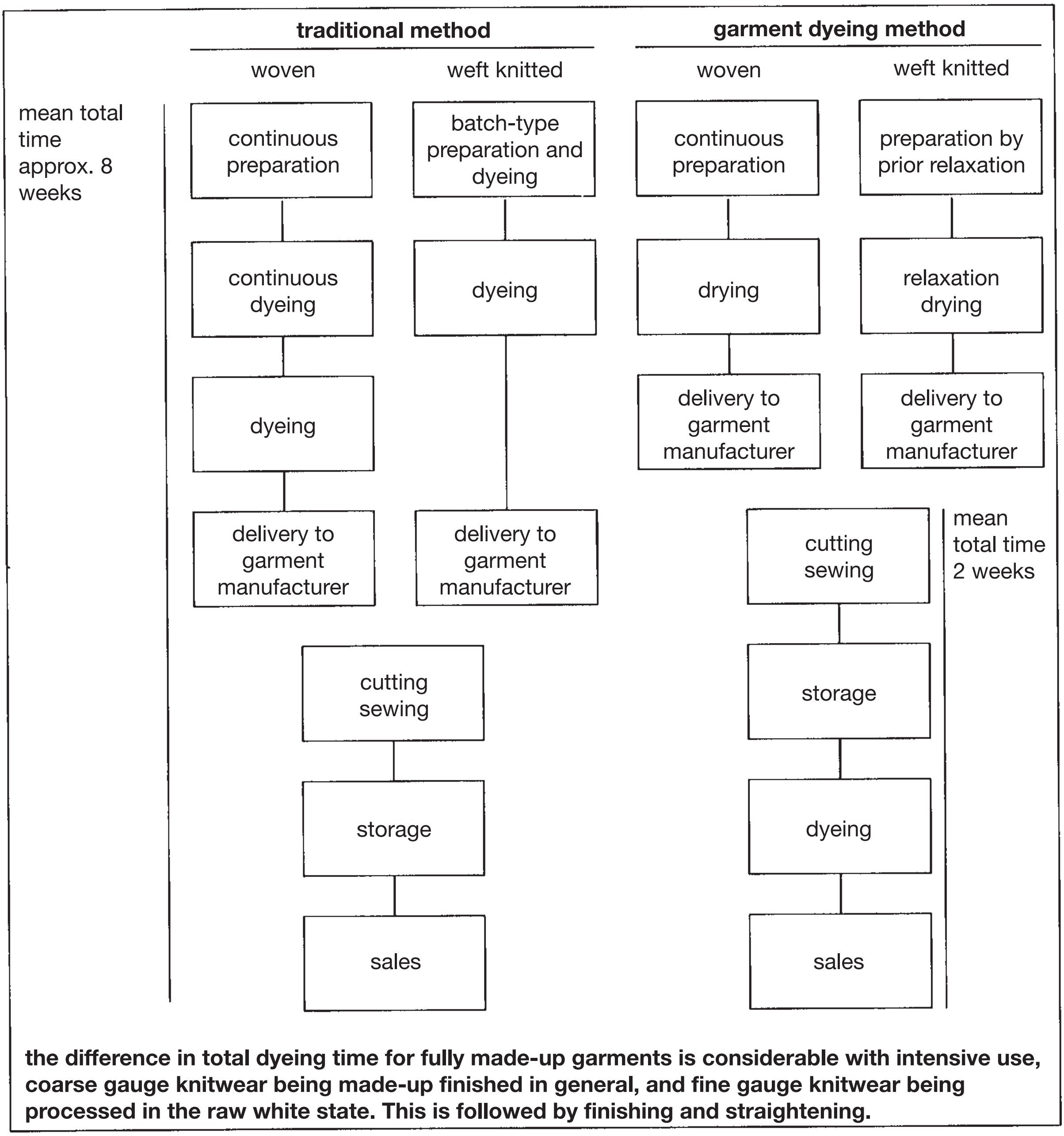
Gambo hemp (gombo hemp) → Kenaf.

Gamma rays → Radioactive emission.

Gamut A term used in the dyeing and finishing industry for colour scale or palette (e.g. dye ranges illustrated in pattern cards).

Garden carpets Oriental carpets with designs representing gardens, e.g. the garden carpet of Chosroes, a Persian carpet of the Sassanid dynasty (AD 224–641) in which the whole design depicts a garden in springtime.

Garment brushing in dry cleaning pretreatment A treatment given to garments before



the difference in total dyeing time for fully made-up garments is considerable with intensive use, coarse gauge knitwear being made-up finished in general, and fine gauge knitwear being processed in the raw white state. This is followed by finishing and straightening.

Fig. 1: Garment cutting and sewing, up to dyeing.

basic dry cleaning. Purpose: the brushing treatment reduces the time taken to dry clean garments which have been particularly heavily soiled and improves both the cleaning effect and the stain removal with little or no necessity for further aftertreatment.

Garment dyeing (fully fashioned dyeing). For garment dyeing, textile material passes through all stages of manufacturing (with the exception of dyeing) up to the completed garment stage in order that garments can be stored and dyed in appropriate shades on demand. The dyeing of completed garments in the greige state has become increasingly important in recent years especially in the leisurewear and sportswear sectors. There can be no doubt that this form of dyeing represents a particularly economic alternative to conventional dyeing methods (Fig. 1). The significant growth in the demand for garment dyeing has, however, accelerated since the early 1980's due to the greater dependence of retailers on quick colour changes to meet their need for rapid fashion response (just-in-time concept) e.g. the dyeing of fashionable denim garments and T- shirts. Because of the reduction in lead times between garment dyeing and traditional dyeing methods (e.g. 4/5 days compared to 2/3 weeks), the dyeing of ready-made garments has proved so successful that the market place now has a tremendous demand for leisurewear and casualwear garments produced by the garment dyeing route, and these types of garments are very much colour and fashion orientated .

In 1989 the proportion of textiles dyed in garment form in the Federal Republic of Germany amounted to just 6%. It is obvious that, in Germany, only a limited opportunity has been seen to dye greige garments from the warehouse at short notice in the rotary dyeing machine even in the case of single-colour items. On the other hand, the potential advantages of this technology have been recognized in Italy and the U.K. for a long time both on the side of the manufacturer as well as that of the retailer. Benetton (Italy) and Marks and Spencer (U.K.) have both successfully embraced garment dyeing technology. Moreover, rapid developments in this field have also been observed in other countries, e.g. the USA and Japan. The reason for the cautious response of many companies to this technology is, to some extent, based on the fact that garments dyed in rotary dyeing machines have not always met required quality standards in the past. Insufficinet knowledge regarding the preparation requirements for garments to be dyed in rotary machines was one of the reasons for this market hesitancy. Another important reason, however, was the design of the rotary dyeing machine itself. These machines work on the principle of "movement of textile material and a stationary liquor". In order to achieve faultless dyeing, especially as regards seam penetration and levelness, the rotational speed of the dyeing drum must be relatively high in order to ensure intensive liquor exchange. This movement subjects the garments to a considerable amount of mechanical stress causing the garments to have a "used" appearance after dyeing which is not always desirable. One possible solution for a more gentle treatment of the garments involves dye liquor circulation by means of a pump. With this system liquor is pumped from the lower part of the machine through a by-pass circuit and then sprayed into the inner drum (Figs. 2 and 3).

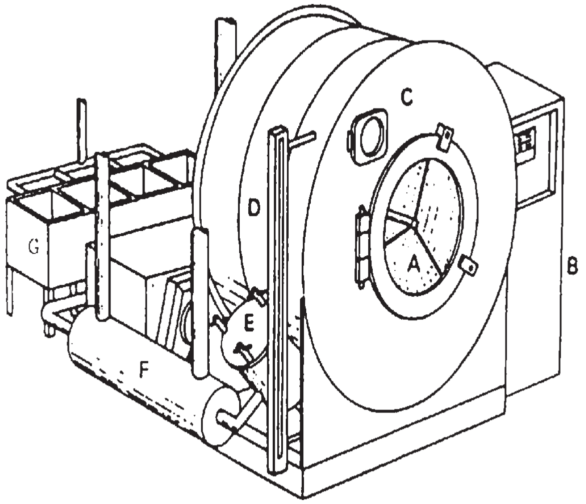


Fig. 2: Sketch of a drum dyeing machine for garment dyeing. A = perforated drum (with or without different subdivisions); B = machine control; C = sampling unit; D = liquor level indicator; E = fluff filter; F = heat exchanger; G = chemicals and liquor tanks.

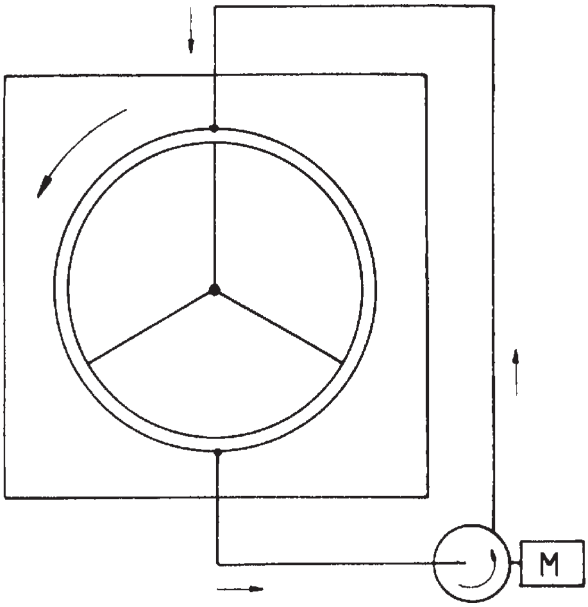


Fig. 3: Garment dyeing with liquor circulation (Proll & Lohmann) – old system-

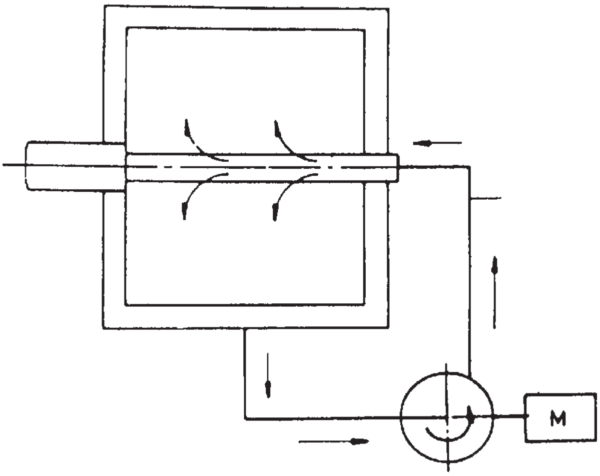


Fig. 4: Colour combi system, introducing the circulated liquor through the drum axle resulting in better dyeing liquor exchange.

This design was not, however, successful in providing the desired results since dye liquor was deflected by the revolving drum on entry. As a consequence, a ring of liquid was formed between the outer and inner drums which was unable to penetrate the perforations of the inner drum and could not therefore reach the textile garments. This shortcoming has since been eliminated with the development of the Colorcombi dyeing system of Proll & Lohmann, Hagen. This system is based on the principle of “movement of textile material and movement of liquor”. With this system, dye liquor is pumped from the lower part of the machine and returned to the dyeing drum via its central axle (Fig. 4).

In principle, all completed textile garments suitable for dyeing by the exhaust process can be dyed by the garment dyeing route. All the chemical and technological considerations involved in the dye/fibre interactions in conventional dyeing are equally applicable to garment dyeing, i.e. all the various dye classes used in exhaust dyeing are, in principle, also suitable for application in garment dyeing. As far as the textile composition of garments for dyeing is concerned, most of the experience gained up to now relates mainly to cotton garments. However, wool, polyamide, acrylic and, to a lesser extent, polyester garments, may also be dyed successfully by this process. Since mixtures of textile materials are always involved in garment pieces (in the simplest case, the garment fabric itself and the sewing thread), account must be taken of the dyeing and chemico-technological properties of the various textile components present. In this regard, particular attention must be paid to the selection of component materials having similar shrinkage properties if problems of puckering, crimping, garment distortion and sewing thread breakages, etc., are to be avoided. Garments produced from several components (e.g. different outer materials, linings, interlinings, elastic waist bands) are particularly likely to give rise to problems of this kind; such cases demand considerable technical know-how, not only to ensure minimum possible damage to the respective materials during dyeing as well as their optimum pretreatment, but also to achieve the same hue and depth of shade on all the garment components. The various accessories attached to garments such as studs, buckles and zip fasteners can also represent a frequent source of problems in garment dyeing. These components must be constructed of non-ferrous metal alloys or break-proof plastic materials. In practice, however, it has been found that these requirements have, in many cases, not been observed. The consequences are rust stains, catalytic damage in bleaching with consequent fibre damage, and dye stains. It also has to be borne in mind that the surface effects given to the undyed, pretreated, fabrics before making-up (e.g. embossed and chintz effects, calender glazes) may be either partially or totally lost after treatment under dyeing conditions. On the other hand, unwanted changes in the surface appearance of sensitive articles such as surface roughening or felting, and irreversible creasing can result from the relatively high mechanical stresses to which the garments are subjected in the dyeing machine, during hydro-extraction, e.g. in the centrifuge, or in tumbler drying.

It is not only for economic reasons that dyeing processes where the maximum temperature of dyeing is as low as possible should be selected, without having to make concessions to full penetration of the textile material. A few machines capable of garment dyeing under high temperature conditions (140°C) are, in fact, available, e.g. as required for the dyeing of polyester. However, for the most efficient dyeing of garments, the use of polyester sewing thread in the making up of garments should be avoided in all cases. It is for these reasons that only specially selected articles are suitable for garment dyeing. Thus, leisurewear, sportswear, and jogging suits made from cotton, or cotton blends with polyamide, acrylic or modal fibres are particularly predestined for the garment dyeing route. For such articles, preference is given to woven or knitted fabrics which, in addition to having a low propensity to creasing or shrinking, also possess good dimensional stability to tensile stresses (Krämer and Hilden).

Garment leather Leather manufactured from skins and hides subjected to various tanning and dressing treatments suitable for the production of leather garments of all kinds. Both garment → Leather itself and the garments produced from it, whether in part or entirely, must always be labelled with the name of the animal from which it has been produced (e.g. leather, calfskin, goatskin, sheepskin, lambskin, deerskin, buckskin, etc.). Garment leather should only be labelled as “washable” if it has sufficient resistance to washing; likewise "drycleanable" garment leathers should only be labelled as such providing no significant changes in dimensions, handle and shade occur after a proper drycleaning treatment and appropriate testing.

Garment-making accessories These include all the various items necessary to produce a completed garment, e.g. underarm pads, interlinings, linings, belts, buttons, sewing thread, zip fasteners (zip fastener tapes), buckles, shoulder pads, edgings, stiffeners, waddings, etc. To be correct, consideration should also be given to garment accessories in the respective care labels since otherwise, e.g. unwanted staining or discoloration of the garment can occur due to differences in colour fastness of the various components.

Garment manufacturing A term for the standard production of garments, garment pieces and various items of clothing.

Garment manufacturing technology If the process of garment manufacturing is divided into its basic elements, then in almost every clothing type the following sequence can be observed: cutting, arranging, pre-fabrication, intermediate ironing, assembling, final ironing, press finishing. This process-related sequence is not suitable for discerning technological trends in manufacturing technology. Depending on the actual garment, the scale of process etc., this sequence can change completely. It is therefore expedient to systematically subdivide the manufacturing processes. Accordingly, one divides into original forming, re-shaping, separating, joining and finishing, and it appears expedient to sub-divide the terms once more.

1. Original forming: injection moulding, e.g. buttons, creation of endless threads (polymer shape forming).
2. Re-shaping: ironing, styling, shape fixing, hot forming, knitting to shape etc.
3. Separating: cutting, stamping, pinking, weld-stamping.
4. Joining: sewing, fixing, gluing, welding, riveting, tacking, clipping.
5. Changing the material characteristics: heating, steaming, drying, cooling.
6. Coating: printing, applying adhesive.

A precise study of this system shows that a manufacturing process changes the work piece in order to achieve a certain state and a certain appearance. As a rule, tools and machines are necessary for this. Through mechanisation, automation and control, the individual elements are linked together, in conjunction with planning and organisation, to form garment technology.

Garment prebrushing in drycleaning → Garment brushing in dry cleaning pretreatment.

Garment steamer A steaming unit for garments; → Steaming dummies.

Gas → Natural gas; Thermal value of fuels.

Gas bubble The hollow space in a → Foam which is filled with gas (air) and surrounded by a thin envelope of liquid.

Gas bubble method A procedure for determining the maturity of cotton (→ Cotton maturity index). It is based on the permeability of the fibre wall to nitrogen; the thin walls of immature fibres have higher permeability.

Gas burner Multiple gas burners may be required for singeing, IR-driers or cylinder driers. Taking the AGI linear gas burner (see Fig.) as an example, a system of this kind can be explained as follows: the burner

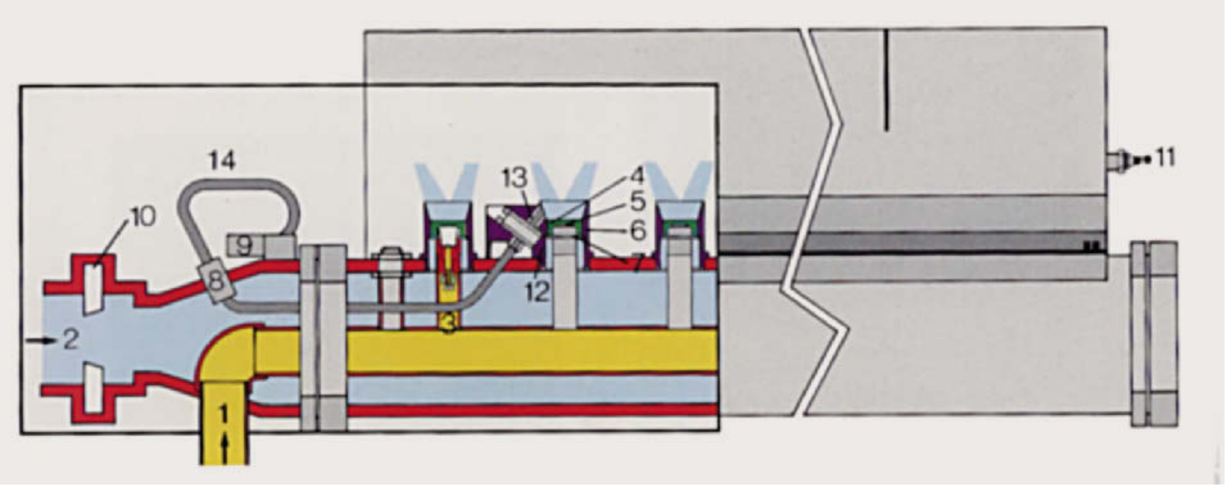


Fig.: "Gaz de France" (AGI) gas burner.
1 = gas; 2 = combustion air; 3 = calibrated opening; 4 = premix zone; 5 = open jet gas injector; 6 = observation port; 7 = turbulence ring; 8 = special glass fibre exit via stuffing box; 9 = signal converter (converting the optical into an electrical signal); 10 = pin diaphragm for limiting combustion air quantity; 11 = ignition plug; 12 = plug-in connection for ultra-violet flame detector; 13 = special glass fibre entry side; 14 = special ultra-violet glass fibres.

itself consists of two concentric tubes, the inner one for the gas supply and the outer one for the air supply. The openings in the outer tube for the individual burners are provided with impeller wheel turbulence rings for the combustion gas. In the middle of the turbulence ring is the injector which is supplied with gas from the inner tube. A mixture of gas and air is formed in the head of each individual injector.

The gas injectors are precision screw machine parts which ensure an extremely accurate throughput of gas. The injectors of the AGI burner are so-called "open-jet burners" and are manufactured under licence from the company Gaz de France, which also participated in the development of the linear gas burner. For flame monitoring purposes a special inspection hole is located in the burner itself, in which the entry end of a special glass fibre is mounted. From here the glass fibre cable is led through the air channel between the inner and outer burner tubes to a signal converter, i.e. it is protected from any mechanical damage. The UV radiation from the burner flame is converted by means of a UV cell into an electrical signal by the signal converter which is then further processed by a control unit.

Gas chlorination of wool Combed wool tops can be given an antifelting finish by chlorination when the chlorination process is followed by a polymer treatment. The chlorine bath (Hercosett process) has been developed for the chlorination of wool tops (see Fig.: Gas chlorinating bath) with chlorine water (chlorine gas dissolved in water) and bleach liquor (aqueous solution of sodium hypochlorite). All parts of the applicator unit in contact with this very aggressive liquor are constructed of glass-reinforced plastic (GRP), polyvinyl chloride, or the hydrochloric acid resistant Hastelloy C4 grade of stainless steel. The combed slivers are drawn from the entry zone through a separator grid and allowed to run parallel with a slight overfeed into the pair of feed rollers. The wool is opened by immersion in the liquor held in the nip of the rollers. An extremely uniform application of liquor is assured by a spray pipe with an inclined applicator plate on each side of the sliver. By this means, the chlorination liquor is able to reach each individual fibre through immersion.

The required quantity of chlorine gas is injected into the process water in an injector and a wetting agent added at a subsequent point before the liquor is uniformly applied to the sliver via the application system. On passing chlorine gas into water hypochlorous acid (HOCl) and hydrochloric acid (HCl) are formed in accordance with the following reaction:

$$Cl_2 + H_2O \rightleftharpoons HOCl + HCl$$

In this reaction, the pH of the bath is automatically set at approx. pH 2–2.5 and must not be further adjusted. Compared to sieve drum chlorination, there is no requirement for sulphuric acid to lower the pH; and cooling of the bath, which is typical of all other existing chlorination processes up to now, is also unnecessary in gas chlorination because of the precise and absolutely uniform application system. Even at process water temperatures of up to 30°C, a faultless and uniform chlorination of the sliver takes place. The reaction of wool with hypochlorous acid proceeds very rapidly and is essentially completed in the first third of the bath. With this treatment, oxidation takes place to a greater extent on the surface of the fibre so that the actual wool fibre receives less damage. The scales of the wool fibre are smoothed out by this process, the fibre surface becomes homogeneously hydrophilic and, at the same time, a negative (anionic) charge is produced which gives the fibre affinity for the subsequent resin treatment. The hypochlorous acid reacts very rapidly with the protein layer (exocuticle) of the fibre surface as a result of which the disulphide bridges are partially oxidized and the peptide chain partly hydrolyzed.

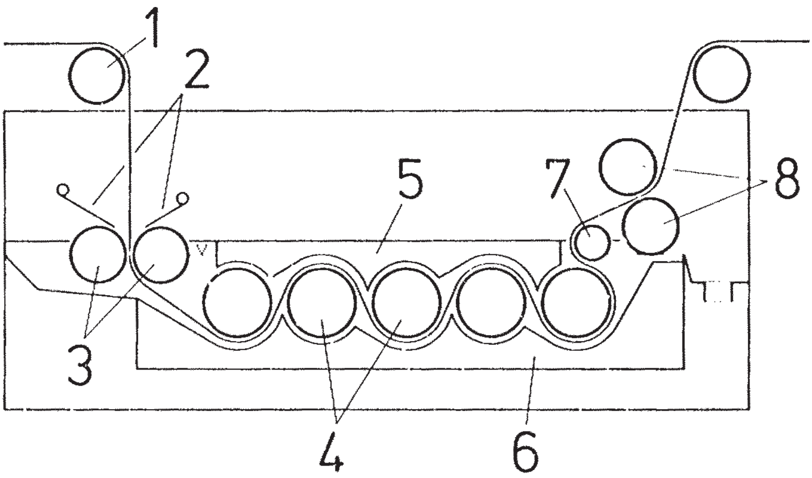


Fig.: Gas chlorinating bath (Fleissner GmbH & Co).
1 = feed roller; 2 = liquor application system; 3 = entry roller pair; 4 = bath guide rollers; 5 = top displacing element; 6 = bottom displacing element ; 7 = application roller; 8 = presser roller pair.

Gas chromatography (GC). This analytical technique is based on the sorption processes between a mobile phase and a stationary phase. Different components in the mobile phase move through the stationary phase at different rates due to their different distribution coefficients and so appear separately at the effluent end of the bed of packing where they are detected and measured by thermal consductivity changes, density differences, or ionization detectors. GC provides two results:

1. Retention time: the time taken for a substance to pass through the stationary phase. Under the same apparative conditions it is always the same; a substance may thus be indirectly identified by this means.
2. Signal response: in the case of ionization detectors the field under the detected signal is proportional to the concentration of the substance. This enables the concentration of a particular substance in a mixture to be determined with precision provided that substance-specific indication errors are taken into account.

The mixture of substances under investigation is passed through a column coated with a specific stationary phase by an inert carrier gas (e.g. helium). Thus the mixture to be separated is injected directly into the capillary column (i.e. "on column injection") and passes through the column by the gas current. By this means, a distribution of substances between the mobile (gas) and stationary (coating) phases takes place. Since the distribution coefficients of most substances are different, they will be retained for different lengths of time. Temperature-dependence of the distribution coefficients can be used to advantage in the separation of components at their boiling points provided the stationary phase layer has a similarly high affinity for all the substances present. Discrete bands (peaks) are formed which, corresponding to their different retention times, pass through the detector one after the other.

There are two possibilities for sample introduction:

1. Injection technique: the mixture under investigation is dissolved in a solvent and an aliquot of this solution (µl range) is injected and detected.
2. Gas sample injection (head space GC). The material on to which the sample under investigation is adsorbed (silica gel, textiles, etc.) is transferred to a head space vial that is sealed and placed in a thermostat at a preselected temperature to drive the desirable components into the head space for sampling. To achieve better desorption, the material is often covered with solvent and the resultant gas phase introduced into the GC system. The technique can also be used for the direct investigation of liquids such as textile auxiliaries for analysis of their readily volatile components.

The choice of stationary phase (column material) and its degree of activity is determined by the sample to be analyzed. To separate a polar mixture such as alcohols a different column material to that used for the detection of alkanes is used. In addition, different detector systems are also available. One of the most frequently used is the → Flame ionization detector (FID). For special applications, e.g. a photo-ionization detector (PID) by means of which substances are ionized and made detectable through the action of light may be suitable. A mass spectrometer can also be coupled to gas chromatography as a detector system (GCMS).

Gas chromatography is in very widespread use as an analytical tool, almost entirely for organic materials; the technique is rapid, simple, and can cope with very complex mixtures (100 or more components) and very small samples (nanograms); useful for both qualitative and quantitative analysis. Relative precision of 2–5%. Disadvantages: samples must be volatile and thermally stable below about 400°C; most commonly used detectors are non-selective; published retention data is not always reliable for qualitative analysis.

Gas fading A change in shade of dyed or printed fabric caused by chemical reaction between certain disperse dyes and gaseous contaminants in the atmosphere, chiefly acidic gases from fuel combustion (NO_x; SO_2). →: Colour fastness to atmospheric contaminants: nitrogen oxides; Burnt gas fumes.

Gas fading inhibitors → Inhibitors which offer protection against → Gas fading.

Gas fastness →: Colour fastness to atmospheric contaminants: nitrogen oxides; Burnt gas fumes.

Gas-flow transfer printing A further development of vacuum transfer printing technology.

The process uses a hot flow of gas directed on to a dye carrier medium (e.g. gas-permeable transfer printing paper) which it penetrates. The sublimed dye is carried along with the hot gas and deposited on the continuous web of fabric which rests on a gas-permeable conveyor belt. The direction of the gas flow passing through the dye carrier medium and the fabric is assisted by suction applied from beneath the conveyor belt. The choice of dye carrier medium, gas flow temperature, pressure difference between the upper and under sides of the fabric and the contact time are decisive parameters for control of the process. The degree of colour penetration achieved on pile fabrics by this process is far superior to that obtained by other transfer printing processes up to now. Since the dye carrier medium is only in light contact with the fabric being printed, no pile deformation occurs.

Gas fume exposure test → Gas fume fading.

Gas fume fading →: Colour fastness to atmospheric contaminants: nitrogen oxides; Burnt gas fumes.

Gas fume fading inhibitors Additives made to print pastes in order to prevent the reaction of nitrogen oxides (normally present in the atmosphere as contaminants, especially in industrial centres and areas of high population density) with disperse dyes belonging predominantly to the anthraquinonoid class.

Gas heating Used in textile driers, curing machines and stenters. Auxiliaries which are liable to volatilize or sublime must not come into direct contact with the flames in order to prevent their decomposition. Damage to the textile material can also occur.

Gas phase crosslinking A commonly used term for crosslinking reactions, e.g. with cellulose in the gas phase. →: VP3 process; Form V process; Cross-linking.

Gas phase processing Gases diffuse in fibres much more quickly than liquids (see Fig.). It is for this reason that attempts to promote gas phase processing have been made again and again in the recent past. For environmental reasons, however, the handling of gases is frequently problematic. Moreover, appropriate machinery for gas phase processing is expensive in many cases. However, in the case of heat transfer printing, gas phase processing, which involves the sublimation of disperse dyes, is quite simple.

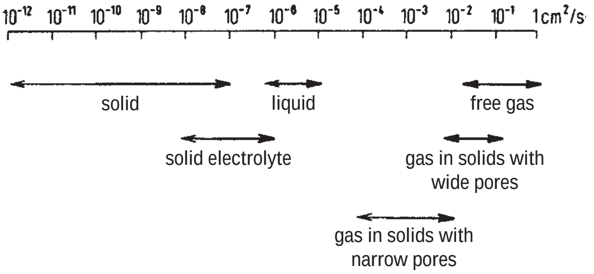


Fig.: Orders of magnitude of diffusion coefficients (D_0) as a prerequisite for gas phase processing.

The thermosol process (thermofixation) represents a special dye fixation technique for the continuous dyeing of polyester fabrics. It involves the following process stages: application of dye by padding, drying, thermosol treatment and afterwashing. The processing elements of immersion, squeezing-off and spraying predominate in the wet treatments whilst heating-up and cooling-down operations predominate in the thermal treatments. At the thermofixation temperature, only a few typically basic processes occur which, apart from coloration, would not be relevant. These can be described by the following primary functions: at 200–220°C, many crystals in the polyester fibre exist in the molten state, just as in heat-setting, and are therefore accessible to the dye. Depending on its molecular weight, the disperse dye actually sublimes under these conditions, i.e. it is converted from the solid state on the surface of the fibre to the gaseous state and diffuses rapidly and extensively into the fibre in the form of a gas before it becomes solid again at lower temperatures. On cooling, some of the dye co-crystallizes with the fibre polymer and thus becomes firmly anchored to give a fast dyeing.

Gas propulsion (in jet dyeing machines). In the Airflow system developed by Then, propulsion of textile fabrics is achieved by means of an inert gas so that movement of fabric without liquor load, or with a desired proportion of moisture is assured. The necessary dyes and auxiliaries are atomized and injected into the circulating gas stream where they are brought into contact with the fabric. Advantages: very short liquor ratios with consequent savings of water and energy. In adition to the dyeing and rinsing processes, fabrics can also be dried in the machine.

Gas sampling (pumps). In order to determine emissions in the laboratory qualitatively and quantitatively, the gaseous substances to be examined must first be adsorbed on to a suitable medium, preferably silica gel, activated carbon, etc. and then desorbed in the laboratory to facilitate measurement. To obtain quantitative measurements the pumps used to collect the gases must comply with certain conditions. For this reason, they are provided with automatic air flow control and can pump a specific volume minimum and maximum over a given time period. These parameters can be preprogrammed.

Gassing → Singeing.

Gassing machines (yarn singeing machines). Machines used for the singeing of yarns.

Gas testing tube A gas detector in the form of a small tube filled with a gas-permeable chemical which changes colour (due to a chemical reaction) when the air being tested is sucked through it. The length of the colour zone is a measure of the pollutant concentration. Accuracy of measurement ± 25%.

Gas trace analysis Analysis in the ppb or ppm range. Achieved mainly by means of electrochemical measurement.

Gas turbines in combined heat and power generation If it is assumed that the effective costs for electricity generation by electricity supply companies are too low since too many costs are externalized to the community, then the cost of electricity can be expected to rise further. These circumstances already dictate that production prices for electricity must reach appreciable levels. In many cases, therefore, in-house electricity generation can become viable within a short time. This is especially true if total energy plants and emergency power capacities can be combined, or existing emergency electricity generators can be converted to gas power or waste heat utilization. In principle, the use of gas engines for small total energy plants is to be recommended. Block-type thermal power station modules are available in the market for the generation of electrical power outputs from 90 kW with the entire waste heat exchanger system built into the base of the unit. These modules can be supplied with a complete control system ready for connection. For larger plants, especially where steam also has to be generated, gas turbines with a generating capacity of around 500 kW should be considered.

A gas turbine for combined heat and power generation operates as follows: the gas turbine compressor sucks in air for combustion via a sound muffler and compresses it to, e.g. 12 bar. This air is then heated in the combustion chamber of the gas turbine to approx. 1000°C. Combustion takes place with a large excess of air (lambda from 3.5 to 5). The pressure of the hot gas drops to atmospheric pressure in the turbine and the mechanical energy of the turbine is supplied to the compressor. The power requirement for the compressor lies considerably below the power output of the turbine. Consequently, the resultant excess power is converted into electrical energy in the generator. The exhaust gases are cooled down from approx. 1000 to 500°C by the pressure drop in the turbine and the heat contained in the exhaust gases is then converted, for the most part, into steam in the downstream waste heat boiler. The high vapour pressure, e.g. 10 bar, means that the exhaust gases are not cooled down to a desirable operating point level, i.e. the water vapour dew point of the waste gases, but only to considerably higher temperatures, e.g. 170°C.

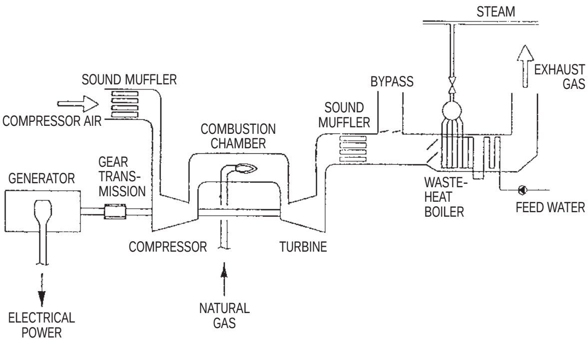


Fig. 1: Combined heat and power generation with a gas turbine.

The combination of a heat pump circuit with a gas engine is of interest if the gas heat pump is produced by heat recovery from the engine cooling water and the exhaust gases. On average, the energy saving achieved is in the region of 50%. If, however, waste heat is available from any other processes which would otherwise be released into the atmosphere, but can be used with the heat generated by the gas heat pump (Fig. 2) to the lower temperature level (exhaust gas heat recovery to the dew point) then, by including the former wastage due to non-utilization of waste heat in the calculation, energy savings of approx. 60% are arrived at. Gas heat pumps are economically interesting for outputs of about 400 000–600 000 kJ/h. Further additional energy-saving opportunities with industrial gas engines can be exploited because two shaft ends are available (simultaneous generation of electricity and heat). A particularly useful energy saving application of a gas heat pump, especially in textile processing plants with a high consumption of hot water during the summer, is to use the gas heat pump as a refrigeration unit for air conditioning systems or other cooling applications. Since waste heat is still produced by the engine despite application of the heat pump circuit as a cooling machine, its effective utilization must be ensured.

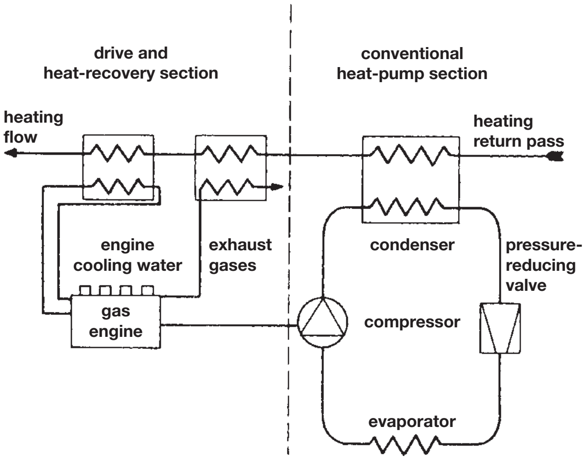


Fig. 2: Schematic diagram of a gas heat pump.

The open-cycle gas turbines are of the single-shaft type, i.e. compressor, turbine and power turbine are arranged on a common shaft. Major turbine components: air intake casing, two-stage centrifugal compressor, two- or three-stage axial turbine (depending on the turbine type) with exhaust diffuser, and single can combustor with central nozzle and high-energy ignition. The casing components are of ductile cast iron. The compressor wheels are of stainless cast steel, while the turbine's vane assemblies are precision castings of high-temperature steel. The turbine rotors consist of discs, with the rotor blades retained by a fir tree arrangement. The rotors and shaft components are centered with radial toothing and connected by a tie rod. The turbines designed for continuous duty are supported in plain bearings. Turbine cooling is by air taken from the air compressor. Cogeneration of power and heat or Combined Heat and Power (CHP) as it is called – the concept for efficient utilisation of primary fuel energy – is making vast inroads. Gas turbine generator sets (Fig. 3) provide electrical power at a location where it is needed, and at the same time produce useful heat for production and administration.

Gaufre (Fr.: *gaufre* = waffle, emboss). Flat fabrics in plain-weave, twill, or satin construction as well as plush materials and velvets with an embossed waffle-like pattern (→ Embossing) or a low lying pile

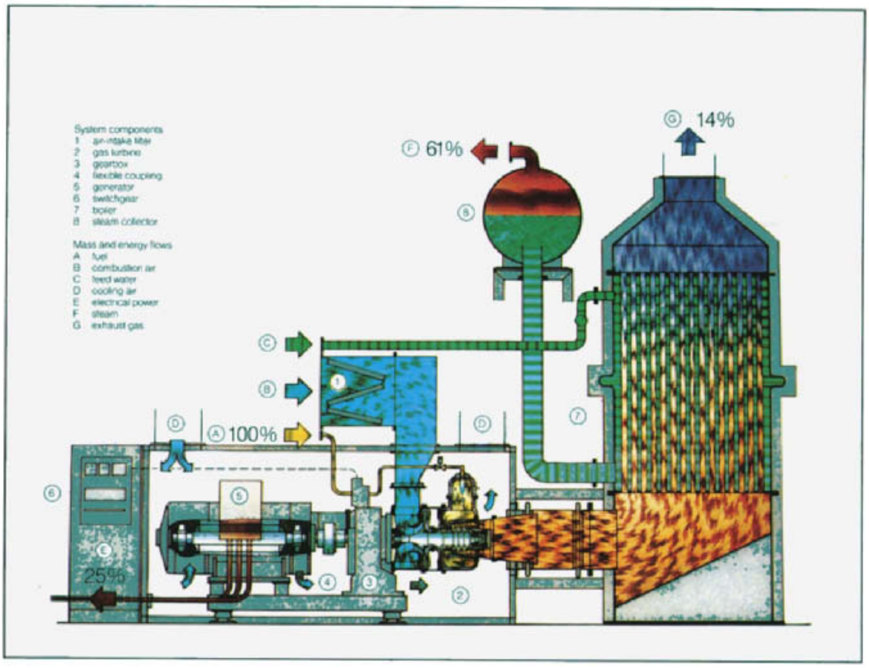


Fig. 3: Cogeneration System with M1A-13 Gas Turbine from Deutz MWM.

(= velvets). Gaufre fabrics include, e.g. →: Moiré fabrics; Reversible, etc.

Gauge (g),

I. A measure of the number of needles per unit length in knitting and hosiery. The greater the number, the closer and finer the knit. (e.g. raschel machine = 2 English inches; fully-fashioned knitting machine = 1.5 English inches; circular hosiery knitting machine = 1 English inch).

II. The number of wales per inch in a knitted fabric.

Gauze Lightweight, open-texture, net-like woven fabrics named after the Palestinian town of Gaza where they were originally used for veils. They mostly consist of thick yarns with a full finish or fine yarns with a veil-like appearance. Gauze fabrics (gauze weave) should not be confused with those produced by the leno weave, which is also a loose, open weave. Different types of gauze include: screen gauze (for screen printing), silk gauze, bolting cloth, cotton gauze (damask gauze, net curtains), wool gauze (→ Étamine, Marquisette), lining gauze, embroidery muslin, cotton muslin, etc. Cotton gauze is mainly used for surgical dressings.

Gauze weave A weave used in very thin fabrics, e.g. gauze, or for the production of woven effects (see Fig.). With a full leno weave, the warp threads are made to cross one another between the picks. In simple leno weaving, one warp thread (generally referred to as a crossing or leno end) is caused to lift alternately on one side and then on the opposite side of the neighbouring thread (usually referred to as the standard end) thereby producing “crossed” or “open” sheds. The leno ends are also drawn through a second heald which changes its position between the individual weft insertions. Advantage of the leno weave: the weft is anchored and therefore resistant to slippage.

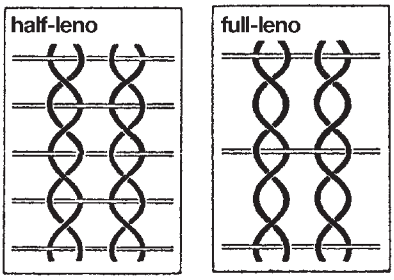


Fig.: Comparison between half-leno and full-leno weave.

GB, prefix for: British patent.

GC, abbrev. for: → Gas chromatography.

Gd, chemical symbol for gadolinium (64).

GDCh (Ger.), abbrev. for: Gesellschaft Deutscher Chemiker (German Society of Chemists).

Ge, chemical symbol for germanium (32).

Gear drives The stepless changing of the drive speed on process machinery can be facilitated by using mechanical gearboxes with constant motor speed or by directly adjusting the motor speed with electronic controls. Machinery with frictional drive gears and drive belts have no alternative electronic control of comparable price. For higher requirements, a mechanical ball/disk control mechanism has been developed, for outputs of up to 3 kW, which can regulate the speed down to a stop. Belt contact drives transmit outputs of up to 150 kW. Parallel to that, and for outputs which are higher still, three-phase current drives with a frequency converter are of interest (Fig. 1).

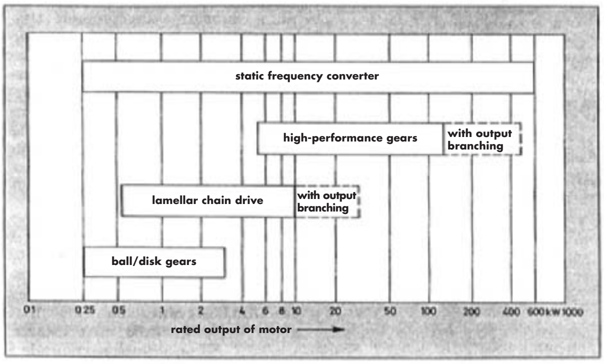


Fig. 1: Output ranges of infinitely variable drives.

Gears are torque converters. They consist of several machine elements and have the task of transmitting movements and forces, or of converting them. They transmit movements

a) by friction, i.e. actuated by pressure contact, e.g. belt drives, friction wheel drives;
b) via interlocking forms, i.e. with positive locking, e.g. toothed wheel gears, worm drive pairs, chain drives.

The speed change of drives can be regulated in steps (toothed wheel gears, chain gears) or in an infinitely variable manner (PIV drives, Variomat, etc.).

I. Toothed wheel gears consist of two or more gearwheels which work together. Depending on the type of teeth and the position of the gearwheels in relation to one another, we speak of:

- spur gears,
- spiral gears,
- bevel gears,
- worm drive pairs.

The speed change takes place step-wise through a train of gear wheels. The torque between two shafts or over a small distance are transmitted directly by gearwheels, in a positive locking manner. It is also possible to produce transmissions and direction changes. Transfer takes place when the projections of the one wheel – teeth – engage with corresponding gaps between teeth on the other wheel.

By "meshing" with one another, gearwheels transfer forces and movements. They are often combined to form toothed wheel gears. Here, it is important to permit only those that have identical tooth dimensions to mesh. The number of toothed wheels with their teeth must be in the same ratio as that of their reference circles. There are toothed wheels with spur teeth and also those with helical gearing. Helically-geared wheels demonstrate little play, little wear and run with less noise. Various gearwheel types are used in toothed wheel gears (Fig. 2), e.g.:

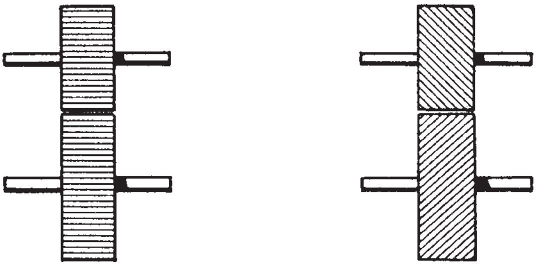


Fig. 2: Spur-toothed and helically-toothed gear pair.

1. Spur wheels: these have teeth on the frontal face.
2. Bevel wheels: they have teeth arranged in a conical manner. Bevel wheels are used when torque and forces of two non-parallel shafts are to be transmitted; in the case of spur gears, the shafts must lie parallel in order to transmit movement.
3. Helical gear wheels: these are spur gears whose teeth are cut in a helix. They are used in gears where shafts cross one another. Here there is also the possibility of transferring forces and torque of shafts which cross one another, by using a worm and worm wheel (worm gear pair, Fig. 3). If gearwheels are used as intermediate wheels, then they can be disregarded for the purpose of calculating the speed. Please note: Intermediate wheels can effect a change of rotation direction, but never a change of rotational speed.

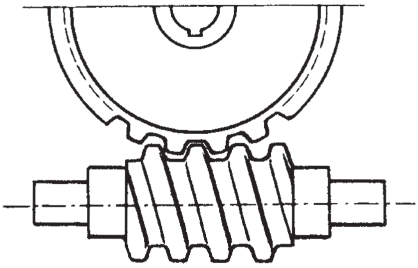


Fig. 3: Worm and worm wheel drive.

II. Chain drives (Fig. 4) transfer forces in a positive locking manner via two shafts, the distance between which cannot be bridged by means of gearwheels. Here, links of a chain engage into the teeth of chain wheels.

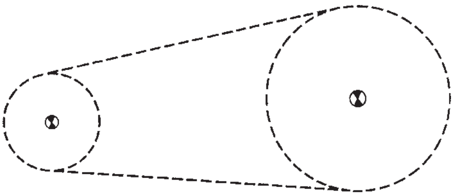


Fig. 4: Chain drive principle.

Gear drives

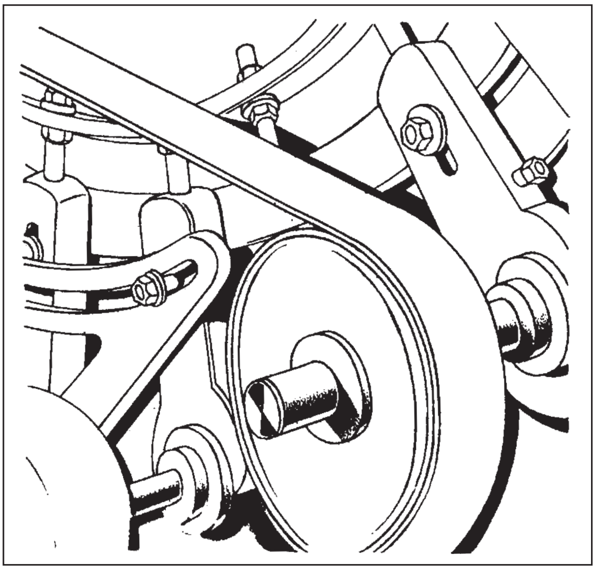


Fig. 5: Flat belt drive.

III. Belt drives (Fig. 5) transmit torque through friction. They transmit forces between shafts either via flat belts or via V-belts. Depending on the way in which the flat belt is guided (open or crossed), by changing the angle of belt contact, friction losses (slippage) can be avoided and changes in rotational direction can be achieved. V-belt drives (Fig. 6) have very low slippage. Here, a V-shaped belt runs in a groove of the pulley. The changes in speed are effected here in a step-wise manner through so-called step transmission, pulleys with varying disk diameters.

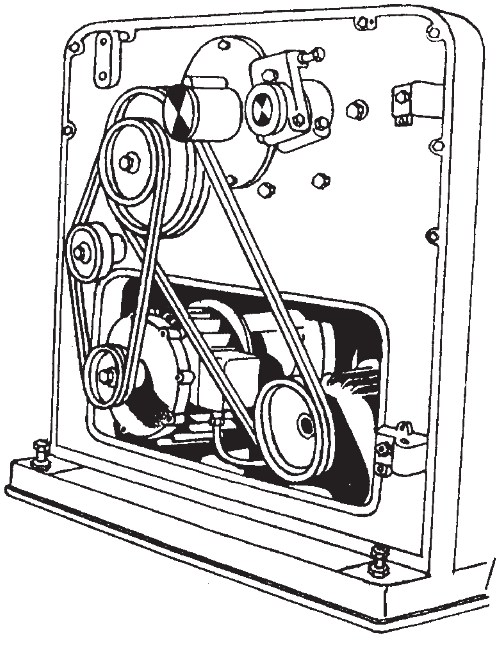


Fig. 6: V-belt drive.

IV. Friction gears (Fig. 7): If torque is to be transferred between two parallel shafts which cross or cut across one another, with only a small distance between them and with high circumferential speeds, frequent changes in speed and in direction, then friction gears are used. They can be regulated in an infinitely variable manner, by varying the position of the drive element relative to the driven element.

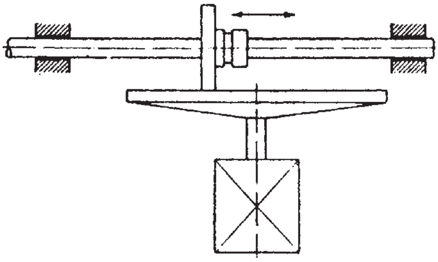


Fig. 7: Friction gears: crown gear with sliding gear wheel.

V. Infinitely variable gears: Infinitely variable drives run quietly and vibration-free; they can adjust the desired rotation range to the given working conditions. With them, speed changes can be effected whilst the machine is running. The following types are known:

1. PIV drives.
2. Würfel-Kopp-Tourator (balls control the adjustment range).
3. PC drive: (cones control the adjustment range).

In a PIV drive (Fig. 8), a V-belt or a link chain can act as a connector between the pulleys. The shaft (1) is the driving shaft; the power flows to the shaft (4) via toothed bevel disk pairs (2) and a wide lamellar chain (3). By means of a hand crank (5) via a rod linkage, the distance between the bevel disks can be changed and thus also the speed of the shaft.

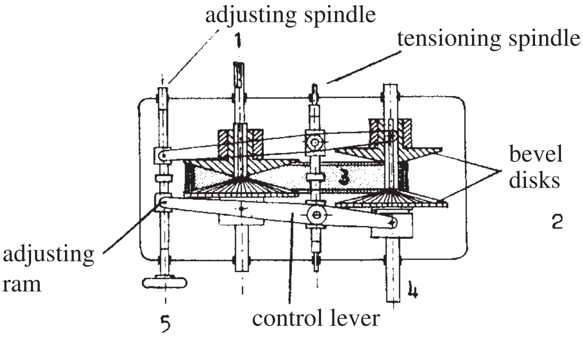


Fig. 8: PIV gears.

VI. Cam drives: If movements are to be converted, in modern textile machines increasingly the trend is to use cam drives. A cam (Fig. 9) (eccentric or cam disk) transmits the movement to the drive element (lever,

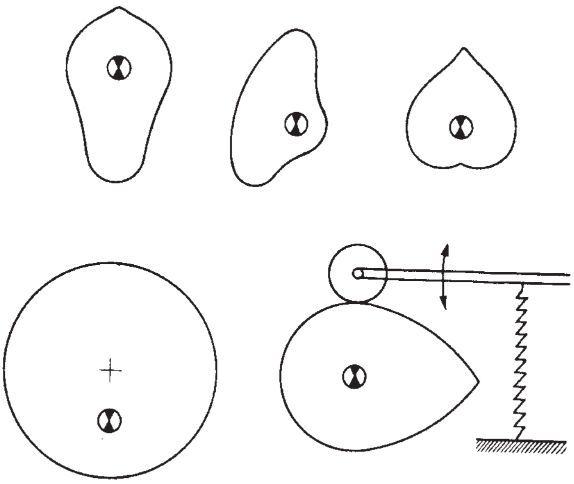


Fig. 9: Various cams for cam gears.

rod), usually by means of a roller. Transmission of movement is possible only when the cam follower is constantly in contact with the cam. There are two possibilities for this connection:

a) the cam contour is on the circumference (open cam gear), the cam follower is held down by means of springs,

b) the contour is milled into the cam as a groove; the cam follower is guided in this link by rollers.

Cam drives permit all types of movement, including movement intervals, but no movement of the cam follower can be achieved through arcs of the cam (dead position). Cam gears can be executed in open and closed forms.

Gedda gum → Gum arabic.

Gel A gelatinous, glassy, easily deformable mass comprising a disperse system of at least two components, i.e. of a colloidally distributed solid substance (e.g. →: Gelatin; Silicic acid) and a liquid (→: Lyogel; Xerogels). A gel can be prepared from a → Sol. Gels consist mainly of two components: the dispersed substance (gel binder) and the dispersion medium (solvent). Both components penetrate each other and join together. The coherence of both systems is the main characteristic of a gel, i.e. any point within the respective system can be reached from any other point without ever having to leave the system itself. The coherence of the dispersion medium is characterized by the fact that the diffusion of small molecules takes place at practically the same rate as in the pure solution. The gel structure consists as a rule of molecules which are connected to each other at adhesion points or adhesion zones depending on which type of energetic interactions between the (mainly) filamentary molecules exist. In the first case, they are referred to as primary valency gels: the chain molecules are bound by homopolar bonds into a three-dimensional network. In the second case, a secondary valency gel is present which is formed by the bonding of linear polymer chains by secondary valency forces (e.g. gelatin). It is in the nature of things that the second type of gels can be transformed into the solution state by changes in the environmental conditions whilst the primary valency gels are very stable under all conditions. If the solvent is removed from such a gel, or better, the swelling medium, it shrinks in most cases (xerogel), only to swell again on adding the dispersion medium. The size of the gel pores depends on the degree of swelling and this, in turn, depends on the solvent as well as the number of linkage points between the polymer chains. A range of porous polymers do not lose their structure, or only slightly, if the dispersion medium is removed (drying).

Gelatin The pure glue obtained by hydrolysis of collagen by boiling hides, cartilages and bones. Available as thin flakes or powder. Properties: transparent, glassy, lustrous material; colourless, odourless and tasteless. Water-soluble after prior swelling giving more or less viscous solutions. The addition of formaldehyde reduces water-solubility. Quality evaluation: 1 g in 100 ml water must still set to a jelly above 0°C. Uses: finishes, sizes and printing thickeners.

Gelatinizer → Plasticizers.

Gel dyeing (wet tow dyeing). Here, polyacrylonitrile fibres which have been produced by the wet spinning method are passed, still in the swollen state, through an aqueous dye bath (40–60%) during or immediately after drawing. A subsequent drying (heat treatment at 105–150°C) closes the pores of the fibre surface, by which the dye is fixed. Dark, intense shades are achieved with dye penetration and fastness equivalent to exhaust dyeing. Whilst polyacrylonitrile fibres are still predominantly dyed according to the exhaust method, it is apparent that gel dyeing has become the second most important dyeing method and has clearly overtaken continuous dyeing (pad-steam method). For its part, tow finishing (gel, spun dyeing, pad steam and exhaust methods) has been dominated by gel application for years. Wet tow dyeing is carried out following on from the extrusion spinning of the fibre, by the fibre manufacturer, and for this reason has a special position compared with other continuous dyeing methods with which the textile finisher is more familiar.

As is well known, polyacrylonitrile fibres are manufactured either according to the dry or wet spinning method. Whereas in dry spinning, the fibre is created from a solution of the polymer, predominantly in dimethyl formamide, by evaporation of the solvent, in wet spinning the fibre formation takes place in an aqueous precipitation bath with various additives. Besides dimethyl formamide, solvents include dimethyl acetamide, aqueous sodium thiocyanate, nitric acid, etc. The fibres produced in this way are initially present in a hydrated - i.e. swollen or gel-like - state, and show a particularly high affinity for dyestuffs. For this reason,

Gel dyeing

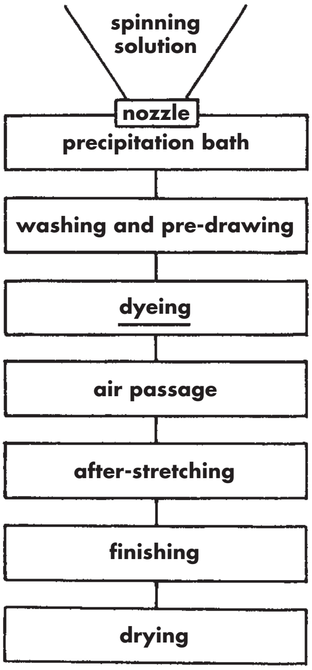


Fig. 1: Schematic sequence of polyacrylonitrile fibre manufacture according to the wet spinning method, with integrated dyeing process.

fibre type (3.3 dtex)	specific surface "BET" m²/g wet tow	 drawing	 dry tow
NaSCN, A	160	hot-drawn	0.3
NaSCN, B	140	cold-drawn	0.33
DMF	90	hot-drawn	0.25
DMA	114	cold-drawn	0.27
HNO_3	204	cold-drawn	0.35

Tab.: Specific surface of wet-spun polyacrylonitrile fibres.

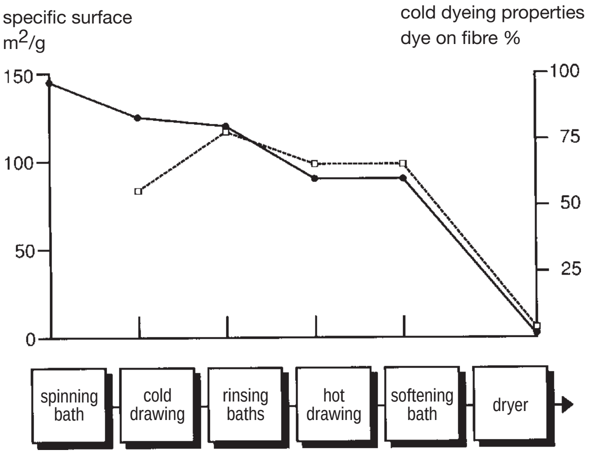


Fig. 2: Specific surface – cold dyeing properties in the course of the spinning process (as a precondition for gel dyeing).

dyeing can be integrated in the continuous process of fibre production (Fig. 1).

Depending on the spinning solution, precipitation bath composition and the working method, fibres are produced which often differ considerably in terms of their dyeing behaviour. For this reason, not all wet-spun polyacrylonitrile fibres are equally well suited for the wet tow process. The most important requirement for dyeing is sufficiently good accessibility of the tow, since only a few seconds are available for the contact between the wet tow and the dyeing liquor. In wet tow dyeing, diffusion plays only a subordinate role as compared with the dyeing of conventional polyacrylonitrile fibres. The dye absorption takes place via a pure adsorption mechanism which progresses very rapidly and is influenced very little by temperature. Gel application refers to dyeing or optical brightening in the spinning production line, namely after the rinsing section but before the drying unit. The dyeing mechanism is determined by the fibre structure - which is very open in this area - and the degree of orientation of the macromolecules, which is still relatively low. The amorphous structure means a high porosity of the fibres, and thus a very large specific fibre surface being available to the dye or optical brightener. It can be determined comparatively on freeze-dried tows in accordance with the Brunauer-Emmet-Teller method, and at room temperature it can amount to several times that of a dried, collapsed fibre of the same type (see Tab.).

How the specific surface of the fibre has changed in the course of the spinning process, and what this means for cold dyeing properties (an indicator of the dyeing properties under gel conditions), is shown by the block diagram in Fig. 2, which takes the example of a fibre type which has been wet-spun from DMF.

After fibre formation (145 m²/g), a constant slow reduction in the specific surface (90 m²/g) is to be observed over cold drawing, rinsing sections and hot drawing. Only after drying does this drop to the very low level. The so-called cold dyeing properties also move within a similar frame. In the present case, they were established by determining the relative degree of absorption of dyeing (3 seconds at 40°C) with C.I. Basic Red 46 (5 g per litre). Furthermore, the dyeing duration chosen here lies within the upper range of the actual ones customary in gel application, which are determined by the dimension of the dyeing unit and the run speed of the tow at the place of dyeing. Even though various hypotheses about the dyeing mechanism exist, it nevertheless seems to be clear that due to the strongly developed surface, the adsorption represents the dominant step in gel dyeing. Whilst most sources point to Langmuir's theory by way of explanation for this, there are also observations according to which the → Adsorption isotherms in equilibrium approximate more to those according to Freundlich. It must also be assumed that the mechanism extends beyond a normal ion exchange, and the gel fibre can, to some extent, also take up ion pairs.

The advantage of wet tow dyeing lies in the elegant inclusion of dyeing in the process of fibre manufacture, with a relatively rapid change of colour being possible. This makes the dyeing of even small batches worthwhile. In the case of bulk dyeing, on the other hand, batches of less than about 20 tonnes are usually regarded as economically uninteresting. The variety of the shades which can be achieved in wet tow dyeing is also larger, and corresponds approximately to that of exhaust dyeing. However, besides these advantages of wet tow dyeing, there are also certain problems. There can be difficulties with dye levelness. In view of the rapid dye uptake, it is not exactly easy to dye the tow – which consists of several hundred thousand individual filaments – evenly. The dyeing unit assumes particular importance. Dyeing can take place on a type of roller vat according to the counter-flow or co-current flow principle (source: Jenny).

Gelling machine Drying machine (suspension drier) for drying coated fabrics and nonwovens impregnated with a plastic solution (see Fig.).

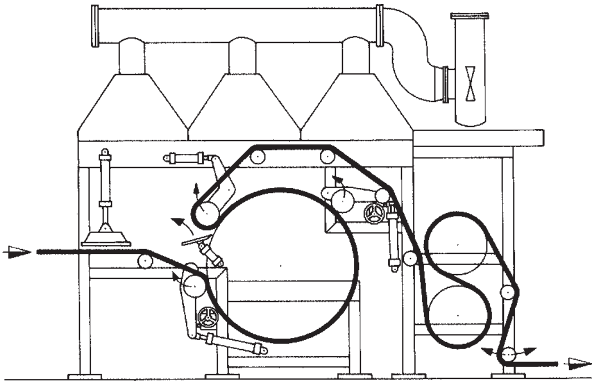


Fig.: WUMAG gelling machine for pre-gelling glass fibre matting (substrate for polyvinyl chloride floor covering).

Gel-permeation chromatography The principle of gel-permeation chromatography is the separation of materials according to molecular size and shape by passage of a solution through a column or across a surface consisting of a polymeric gel. The process is described as “gel-permeation”, “gel-filtration” or “exclusion chromatography”.

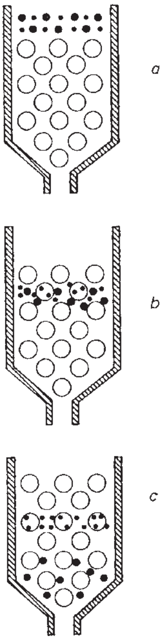


Fig.: Representation of gel chromatography in three phases.

If a macromolecular substance is introduced into a chromatography column (packing: dextran cross-linked with epichlorohydrin), the macromolecules are at first located outside the pores of the gel in the freely mobile solvent, but then diffuse into the pores until a distribution equilibrium is reached (see Fig.). The achievement of this distribution equilibrium depends on molecular size and shape and is, amongst other things, a function of molecular weight. Molecules which exceed a certain minimum size cannot penetrate inside the gel (upper exclusion limit) and are therefore eluted first. Medium-size molecules which could penetrate the pores, diffuse in the flowing solvent front in accordance with the concentration gradient. With decreasing molecular size (corresponding to a greater depth of penetration) an increasing quantity of solvent must be used to elute them. Within this “fractionation range”, an empirical linear relationship exists between the quantity of solvent necessary for elution (elution volume Ve) and the logarithm of the molecular weight:

$$Ve = K_1 - K_2 \log M$$

If the molecules fall below a certain size (lower exclusion limit), they will move unhindered throughout the entire volume of solvent and will not be separated by their size.

From a theoretical point of view, it is possible to imagine that when dissolved molecules of different sizes flow past such surfaces a separation takes place. The separation must be much more effective if the gel is granulated so that the interfacial surface area is increased many times, i.e. the time taken for a diffusion equilibrium to become established is considerably reduced. On allowing a solution of different sized molecules to trickle over gel particles filled with solvent in a vertical glass column, the molecules will be separated if the column is washed through with pure solvent. The procedure is reproduced schematically in the figure where only two sizes of molecule (represented by large and small dots) and the gel particles (represented by circles) have been shown for the sake of clarity. The gel offers no resistance to the diffusion of small molecules and they spread uniformly over the entire cross-section of the glass column whilst the larger molecules are unable to penetrate within the gel so that only the solvent between the gel particles (external volume) is available to them. During afterwashing with solvent, however, transport of these molecules only takes place in this external volume so that larger molecules are transported more rapidly than the smaller ones which, in the meantime, are delayed by diffusion in the (stationary) gel phase. If the mixture still contains medium size components, these would only occupy a certain part of the gel phase at diffusion equilibrium. Therefore, the components of a mixture will leave the column filled with gel particles in order of decreasing molecular weight corresponding to their diffusion-related retention times in the stationary gel phase.

Gel-permeation chromatography is used for the separation and desalting of high-molecular-weight materials and the determination of molecular weights.

Gel spinning The development of gel spinning for polyethylene began in the early 1980’s. With this technique it is possible to produce fibres with high tenacity and modulus from polymers with flexible molecular chains. The main characteristics of this process are the use of polymers having ultra-high molecular weights and the processing of dilute spinning solutions. The strength of the fibre increases with increasing molecular weight. The low concentration of the spinning solution allows a high draw ratio to be applied to the fibre. A linear increase in modulus with draw ratio exists (Fig. 2).

For a number of years now, several high-performance polyethylene fibres produced by gel spinning technology have appeared on the market.

The attainment of extremely high strength can be explained by so-called shish-kebab spinning (Fig. 1). High strength is more easily achieved the more the C-chains are statistically disoriented in the solution (or in the melt) and the less the shear forces acting on the extruded filaments so that complete orientation of the molecule chains is achieved by the drawing process only from a normal ratio of 30 : 1 to 100 : 1 (however, draw ratios up to 1000 : 1 are possible). The plates of folded molecular chains can be fully drawn. Polyethylene of MW ≥ $1.5 \cdot 10^6$ has been stabilized with 0.5% w/w di-tert-butyl-p-cresol (DBPC) at 150°C and then dissolved in 2% w/w decalin at 130°C, spun through 0.5 mm ∅ orifices, extracted and drawn in a hot air oven at 100–140°C. When drawn 32 times, the filaments had a modulus of elasticity of 90 Gpa and a tenacity of 3.0 Pa with 6% elongation at break. The relationship of the e-modulus to the draw ratio is shown in Fig. 2.

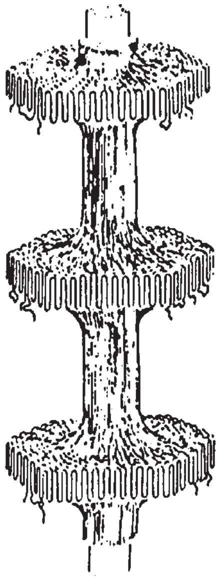


Fig. 1: Schematic representation of a micro-shish-kebab. The close relationship between the folded plates and the longitudinal fibre structure is to be emphasized here.

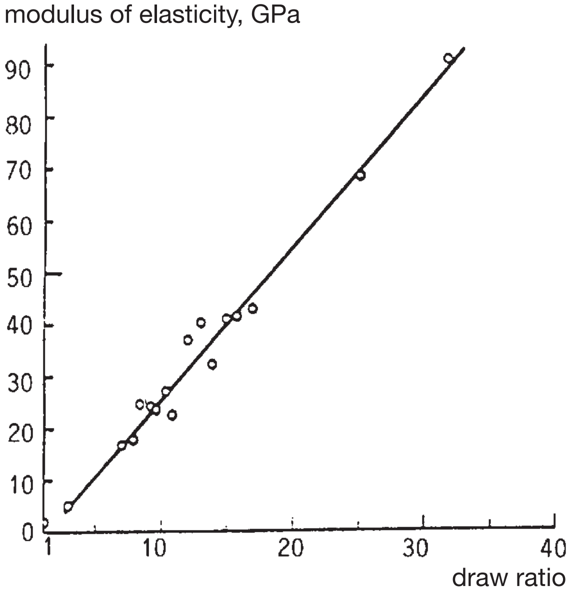


Fig. 2: Relationship of the e-modulus of gel-spun polyethylene filaments to the draw ratio.

In a similar manner to the gel spinning of polyethylene, the textile-mechanical properties of polyacrylonitrile are also improved by gel spinning with increasing draw ratios. The stress-strain behaviour of various highly drawn filaments spun from a 5% solution is shown in Fig. 3. The optimum drawing temperature is 160°C. At higher temperatures no further drawing appears possible; lower temperatures do not allow the application of high draw ratios.

The spinning solutions are produced by dissolving a polyacrylonitrile homopolymer (MW 540 000) in DMF. With the aid of a piston spinning machine, the spinning solution is extruded through a single hole spinneret into a spinning bath cooled to –30°C. Coagu-

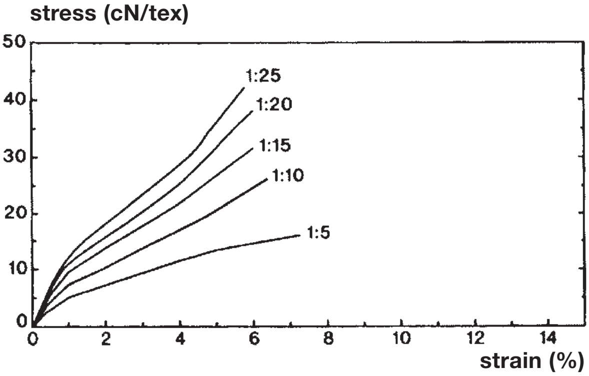


Fig. 3: Stress-strain behaviour of gel-spun polyacrylonitrile filaments in relation to draw ratio.

lation takes place in a spinning bath filled with n-butanol. The resultant gel filament is milky and translucent, extensible and soft. It is very tacky in this state and therefore cannot be wound immediately, but has to be passed through a second spinning bath filled with acetone (Fig. 4) where partial solvent exchange takes place. Acetone absorbed by the filament evaporates during the air passage between the acetone bath and the winder. During winding, the filament is externally dry and solid. The bobbins of gel filaments are stored in a DMF atmosphere until the drawing operation.

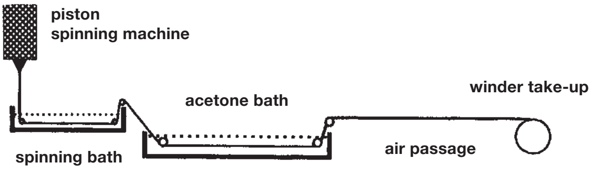


Fig. 4: Schematic representation of the gel spinning stage.

A xerogel is defined as a solvent-free gel. The discontinuous xerogel process consists of two stages: the production of a gel filament and its extraction, as well as the final hot drawing stage (Fig. 5).

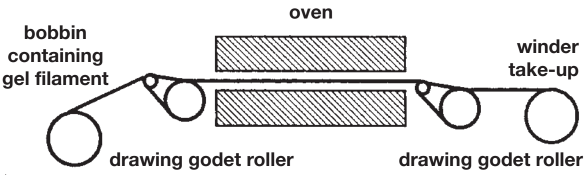


Fig. 5: Schematic representation of the gel drawing stage.

Gel time The → Processing time or potlife, i.e. the time during which a product remains sufficiently plastic to be workable up to solidification.

Gel, to When coatings are produced from polyvinyl chloride (PVC) without solvent, the polymer is made pliable by the addition of plasticizers. The material can then be coated before the compound begins to gel (set) during subsequent passage though the drying tunnel.

Generations of fibres In the somewhat rapid development of textile products, e.g. types of fibres, the respective stages of development for a particular family of products are referred to as generations. Thus, synthetic fibres for the tufted carpet sector have evolved through the following stages:

1st generation: normal fibre.
2nd generation: soil-hiding.
3rd generation: fibre + antistatic.
4th generation: fibre + fluorocarbon.
5 th generation: (1987): a) fibre + stainblocker + fluorocarbon; b) 4 th generation + stainblocker; c) fibre with built-in fluorocarbon.

Generative photography A photographic technique used for design creation based on the following technical possibilities: a) modification of existing motifs (figures, geometric shapes or crystals in UV light, polarized light, etc.) by translation, addition or rotation; b) exposures with a multiple camera (camera with several objectives, the shutters of which can be operated simultaneously or successively); c) by additive colour mixing; d) colour generation by polarized light; e) colour generation by filters.

Genetic engineering The example of insulin production by genetic engineering techniques is indicative of the enormous advances made e.g. in the field of protein synthesis. In 1963 Zahn succeeded in achieving the

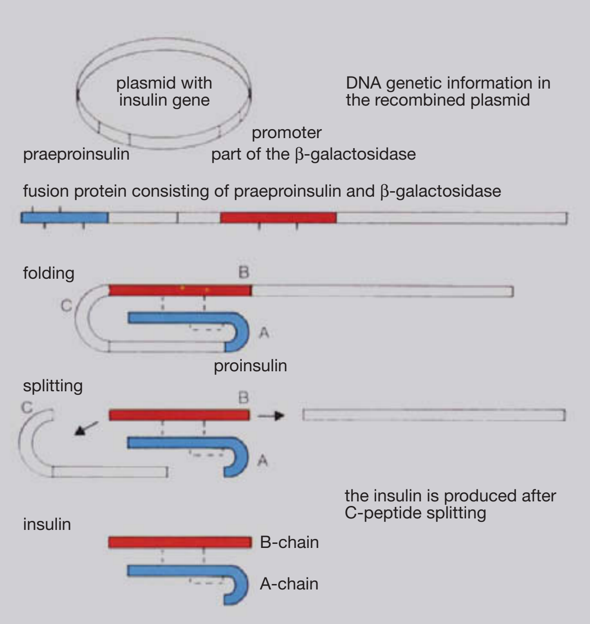


Fig.: Genetic engineering steps to biosynthetic human insulin.

chemical synthesis of insulin after years of studying the structure of this protein. Genetic engineering makes use of bacteria for synthesis purposes. Bacteria implanted into an animal or human gene will treat it as one of its own genes. If the appropriate genetic "code" is introduced it will produce proteins according to its own instructions. Moreover, the instructions for production continue to be given with each cell division. When a particular cell density is reached (usually two to three thousand million cells per millimetre of culture medium) the bacteria stop further growth. In the next stage, the bacterial culture can be "harvested": the cells are separated from the medium and "isolated". Insulin is then separated from the other components of the bacteria in a series of biochemical purification stages. Finally, the C-chain polypeptide must be separated from the molecule as a compound in order to convert the insulin from its precursor into its active form. The end-product is pure human insulin (see Fig.).

Genoa cord (→ Corduroy, Manchester velvet, corded velvet → Velvet). A velvet with characteristic weft ribs (1 warp + 2 wefts, ground weft and 2–3 long-floating pile wefts which are cut during finishing).

Genuine oriental rugs A quality label ("Echte Teppiche" in German) used for hand-knotted → Oriental carpets which was introduced in the middle of the 19th century as a protective label to distinguish them from machine-made carpets with "oriental" designs which were beginning to appear on the market at that time.

Geometric formula → Configurational formula.

Georgette A sheer, lightweight, somewhat transparent open-texture fabric with a fairly pronounced crêpe effect, usually produced in a plain weave with crêpe yarns from almost all types of fibres. It is generally woven with alternating pairs of S- and Z-twisted yarns in both warp and weft. The handle and appearance are characteristic, i.e. the fabric has a crinkly texture and is harsher and more opaque than chiffon. Georgette has a soft and flowing drape. It is mainly dyed in the piece or printed. These materials are very extensible and elastic due to the crêpe yarn twist, and are also highly permeable to air and virtually crease-free. Used for dresses, blouses, skirts, gowns and millinery.

In addition to the usual lightweight, more or less transparent georgette fabrics, there are also so-called winter georgettes, i.e. women's winter coat materials which have the typical georgette appearance on the face side, whilst the reverse side consists of a special backing fabric produced from carded yarns which is raised to confer better heat insulation.

Geotextiles A collective term for any textile material forming an integral part of civil engineering structures of earth, rock or other constructional materials. The use of these materials is rapidly increasing wherever cost savings in the use of other construction materials can be realised. The fields of application for geotextiles include the balancing of forces in road and rail construction, the reinforcement of embankments, filtration and drainage, agriculture and building construction (concrete floors during setting), sea bed protection, watertight structures/sewers (swimming pools), dam construction; coated and bitumen-impregnated materials. Geotextiles are produced from polyester, polypropylene, polyamide, polyethylene and blends. As a rule, geotextiles are, for the most part, water-permeable nonwoven filtration sheets (membranes) which have been manufactured by needle-felting and similar nonwoven bonding technologies. Their properties correspond to actual application requirements or must be adapted to the circumstances of use. Due to their porous structure (when introduced between the subsoil and upper ground strata) they ensure the successful separation and integrity of the bottom strata with most types of ground as well as the drainage of ground water and precipitation. Requirements: controlled quality, quick installation, water permeability, high tensile strength, good shear strength, toughness and a high modulus of elasticity. In addition, geotextiles should be resistant to rotting, mould, microbial attack and changes in temperature.

The profile of requirements dictates that only synthetic fibres can be considered as suitable materials for use in geotextiles.

Geotextiles fall into two important categories, i.e. "classic gotextiles" as typical products of the textile industry including fabrics and nonwovens, and "geotextile-related" products. The first stage in the fabrication of classic geotextiles involves the production of linear elements such as filaments, fibres, slit membranes (ribbons) and yarns. These linear elements are combined in the second stage to produce a permeable flat structure such as a woven fabric or nonwoven. Thus, typical, well-known processes employed by the textile industry are used in their manufacture. The geotextile-related products, on the other hand, have a coarser structure than classic geotextiles and include belts, mats, nets and lattices which are mainly used for the reinforcement of ground structures. "Composite geotextiles" are composed of several layers of geotextiles or related materials. A prefabricated drainage mat, in which an open core material is sandwiched between two nonwovens and mechanically bonded, is an example of this type of product. Synthetic polymers such as the polyolefins (polypropylene, polyethylene), polyester and polyamide are the main raw materials.

For the description and identification of a geotextile, details relating to the raw materials, among other things, are indispensable. Geotextiles have physical characteristics just as the ground conditions themselves. They are permeable and have certain mechanical properties which can change the environments where they are used.

Five characteristics, in particular, are typical for geotextiles used as construction materials:

1. The properties of the fibres, which are of a similar size to the fine components of the soil and exhibit considerable tensile strength in relation to their cross-section.
2. The nature of the bond between the soil and textile fibre: due to the incorporation of a continuous element into the loose stones, etc., the strength and deformation characteristics of the composite system are fundamentally changed.
3. Deformable structures based on poor building ground sensitive to subsidence, which can also suffer significant long-term deformation without their strength and stability being impaired, are of interest to the engineer.
4. Savings in transport, since geotextiles are considerably lighter and easier to handle than mineral construction materials.
5. The simple construction techniques as well as the reliability of geotextile building materials ensures the quality of building structures.

Geotextiles are used in all sectors of foundation and hydraulic engineering. They are employed in major construction projects such as earth embankments and motorways as well as in minor access roads or the construction of shafts. The four general fields of application for geotextiles in civil engineering are:

- transport engineering,
- hydraulic and dam engineering,
- land reclamation and environmental engineering,
- coastal defences.

The great majority of textiles incorporated into roadworks and highway construction are nonwovens. They are formed by bonding webs (mats) of continuous filaments, or 3–15 cm long staple fibres, laid flat on top of one another. The fibres are laid with or without a predominant direction. Depending on the type of fibre used, either staple fibre or filament nonwovens are produced. Mechanical, adhesive or thermal bonding techniques are employed to achieve the necessary bonding of the nonwoven structure.

A further classification of nonwovens, depending on the method of bonding employed, can also be made:

a) Mechanically-bonded staple fibre or filament nonwovens can be manufactured with the aid of special needles. Bonding with special needles provided with hooks or beards is achieved by interlacing the staple fibres and filaments. The fibre crossover points produced by mechanical bonding are movable, not rigid.
b) Adhesive-bonded nonwovens are obtained by impregnating or printing nonwovens with binder dispersions. Rigid bonds are formed at the fibre crossover points when the binder is cured.
c) Thermally-bonded nonwovens fall into three distinct groups: during thermal bonding with binder fibres, a small percentage of staple fibres or filaments with a low melting point assume the role of an adhesive binder after melting under heat. Core-sheath bicomponent fibres have a sheath (outer covering) with a lower melting point than the core which becomes tacky on heating. For thin nonwovens, made from fibres or filaments, thermal bonding can also be carried out by pressure and heat.

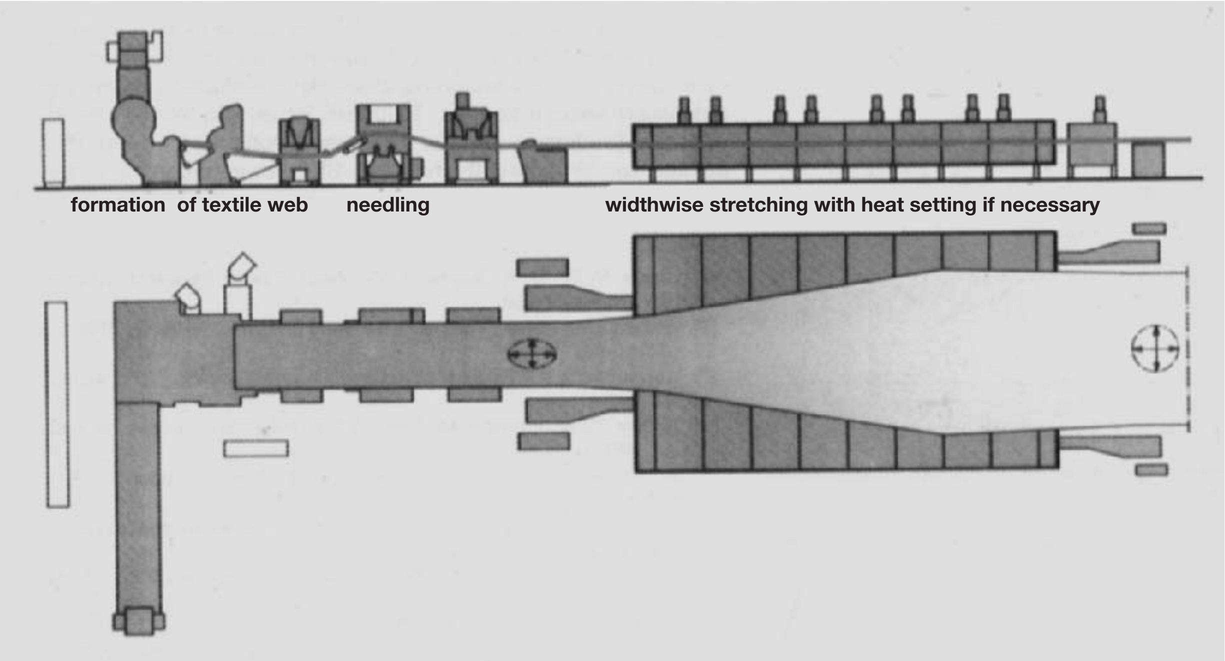


Fig.: Production plant for geotextiles.

Composite geotextiles consist of two-dimensional nonwoven, woven or other types of fabrics bonded together. A plant for the production of nonwovens is a high performance machine for the manufacture of two or three-dimensional random-laid webs. Working widths up to 5.4 m are achieved without the need for a crossfolder. Since stretching of the random web takes place with this technology, wide working widths can also be achieved. Random fibre orientation in the nonwoven is a fundamental requirement of this technology as the strength in the nonwoven before needling lies in the range of approx. 1 : 1 (lengthwise to widthwise direction). After needling, this ratio changes to approx. 1.5–1.8 : 1. However, values of approx. 1 : 1 can be achieved once again by subsequent stretching in the widthwise direction. For the geotextiles mentioned here, fibres with linear densities in the range of 3–7 dtex are well-proven in practice with staple lengths between 60 and 75 mm. The needling of geotextiles is carried out on both sides of the material. During this needling process, the strength ratio changes to approx. 15 : 1 (machine direction : widthwise direction). The ideal machine combination in this case is a pre-needling machine with a special feed system followed by a double-bed machine and a machine in which needling is carried out from the lower to the upper side. The final treatment is carried out on a stenter during which an increase in width of approx. 35% in relation to the initial width is achieved. During this stretching in the widthwise direction at a temperature close to the softening point of the synthetic fibre, an increase in overall strength is achieved both in the machine direction as well as in the widthwise direction which results in a final strength ratio of approx. 1 : 1.

Woven geotextiles consist of two perpendicular crossing yarn systems. Staple fibre yarns, multifilament yarns, ply yarns, monofilaments, slit film yarns or split yarns (as well as various combinations of these) are used in the warp and the weft. Woven fabrics also differ in type of weave, e.g. plain weave, panama weave, twill weave, the number of yarns per unit length and a possible additional bonding of the yarn crossover points. The thickness of yarns used in woven fabrics for foundation and hydraulic engineering applications range from 200–14 000 dtex.

German hardness degree (°d). An obsolete unit of measurement for water hardness. It is not an SI unit. Now replaced as a unit of measurement by mmol/l. → Water hardness units.

Germfree condition → Sterility.

Germicidal finishes → Antimicrobial finishes.

Gesamttextil (Ger.), abbrev. for: Gesamtverband der Textilindustrie in der Bundesrepublik Deutschland e.V. (Head Organization of the Textile Industry in the Federal Republic of Germany). → Technical and professional organizations.

Gesamttextil Research Council → Forschungskuratorium Gesamttextil.

Gesamtverband der deutschen Textilveredlungsindustrie e.V. (Ger.) → Technical and professional organizations.

Gesamtverband der Textilindustrie in der Bundesrepublik Deutschland e.V. (Gesamttextil; Head Organization of the Textile Industry in the Federal Republic of Germany). Representative top-level organization of the German textile industry; → Technical and professional organizations. The → Forschungskuratorium Gesamttextil is a branch organization, established in 1951.

Gesellschaft Deutscher Chemiker (GDCh). Society of German Chemists. A leading German professional organization which, since 1946, has taken on the tradition of the Verein dt. Chemiker. Publications include the journals: Angewandte Chemie, Chemie-Ingenieur-Technik, Nachrichten aus Chemie und Technik, Chemische Berichte, Werkstoffe und Korrosion. → Technical and professional organizations.

GF, → Glass fibres, → Standard abbrev. for textile fibres, according to DIN 60 001 T4/08.91.

G_F German system of assessing the toxicity of pollutants in relation to fish in accordance with the waste water levy act [ABwAG – Abwasserabgabengesetz]. Used to determine the dilution factor ($G_F = 2$ is the zero point), where tested effluent is no longer toxic to fish → Waste water evaluation.

g-factor Term frequently used in technical specifications for centrifuges: indicates how many times greater the centrifugal acceleration of the machine is than the acceleration due to gravity. In the absence of manufacturer's specifications, it can also be calculated from the drum diameter d(m) and the rotational speed n (rpm):

$$\text{g-factor} = \frac{d \cdot \pi^2 \cdot n^2}{2 \cdot 30^2 \cdot 9.81}$$

GH (Ger.), abbrev. for: Gesamtwasserhärte (→ Water hardness units).

Ghatto gum → Asiatic gums.

Ghiordes rugs Ghiordes rugs are the cream of Turkish manufacture. They are rugs of ancient origin and their design has affinities with the very beautiful and rare sixteenth century → Prayer mats. They are named after the town of the same name in western Turkey some 100 km from the port of Izmir. Ghiordes rugs are woven with 150 000–300 000 knots/m^2. Various colours are used for Ghiordes rugs. Firstly, these rugs must be divided into two categories: those over 150 years old which date from the court period, and those dating from the middle of the nineteenth century onwards. The first group have rather drab colours. The niche is in dark blue or ivory or, more rarely, dull green.

Also the number of colours used in the border motifs is limited and the shades used are quite light. The second group, however, have vivid colours. The niche is often red and the border motifs stand out in brilliant hues. Among the predominant colours are yellow, orange, red and ivory. In spite of their vividness, the colours used in this group of Ghiordes rugs harmonize perfectly with one another.

Ghosting effects A distinction is made between the following types of ghosting effects:

I. Abrasion ghosting: If the drying or cooling down of transfer paper after printing is inadequate, part of the dye film marks off on to the back side of the following layer of paper during roll batching. The effect is independent of time and is also described as short-term ghosting. Preventive measures: use of a suitable binder in the print paste.

II. Sublimation ghosting: Caused by the gradual sublimation of disperse dyes, especially those with a high vapour pressure, from the printed paper to adjacent layers of paper lying above or below in the roll during storage over several weeks or months (long-term ghosting). This type of ghosting is dependent on the storage temperature. Prevention: backcoating of the transfer paper with a thickening agent having no affinity for disperse dyes.

III. Migration ghosting: Caused by migration of disperse dyes in the print paste components in the dissolved form and results in the bleeding of dye around printed outlines (likewise long-term ghosting) which is temperature-dependent. Preventive measures: avoidance of solvent components in the print paste formulation which do not immediately evaporate.

Ghosting in transfer printing A defect in sublimation transfer printing due to inadequate storage stability of the transfer printing paper. During the storage of transfer printing papers, an undesired migration of dyes can occur which can cause disruptions in the sublimation transfer printing process and defects in the transfer printed fabric. The ghosting effects can be subdivided into 3 different categories: migration ghosting, abrasion ghosting and sublimation ghosting (Fig. 1).

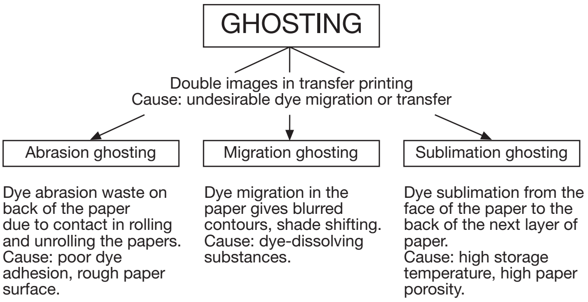


Fig. 1: Faults in transfer printing due to inadequate transfer paper storage stability.

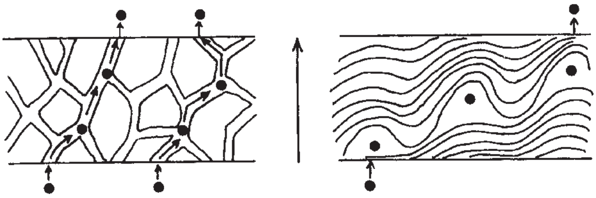


Fig. 2: Transfer dye migration (migration ghosting). Left: in the paper due to the cavity structure; right: in polyester film due to chain segment mobility.

Disperse dyes are able to move (Fig. 2) in transfer printing paper by pore diffusion (in contrast to polyester where dye movement takes place according to the model of free volume theory).

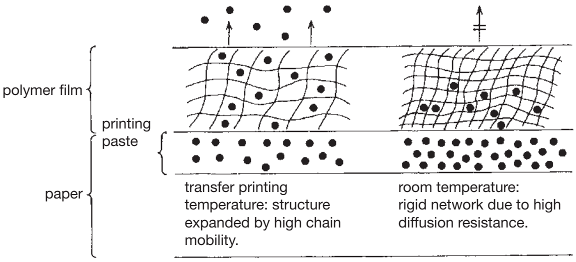


Fig. 3: Polymer properties necessary for preventing sublimation ghosting during face coating.

For this reason, sublimation ghosting (Fig. 3) should be preventable by coating the paper with a polyester film (Herlinger).

Ghost print A defect in transfer printing which takes the form of unwanted (usually paler) „ghost“ design images on the printed fabric due to the transfer of disperse dye from one layer of the rolled printed transfer paper to the layer of paper lying immediately on top of it. Such → Ghosting effects are dependent on the dye, thickener, paper quality and the storage conditions (temperature) of the printed transfer paper.

GI (Ger.), Ginsterfaser (broom fibres), → Standard abbrev. for textile fibres, according to the → EDP code.

gi, abbrev. for: → Gill.

Giant batch rolls Textile fabric is wound on to a movable batching unit in which a horizontal roller is supported by 2 A-shaped frames (A-frames). These giant batch rolls are used to wind fabric on or off in beam form for either intermediate storage or wet processing. Savings in fabric losses in piece end sewings favour a short payback period. In addition, the use of giant batch rolls considerably improves the efficiency of production (especially in continuous processes such as shearing, singeing, bleaching, dyeing, printing, etc.) due to the greater length of the batch (less batch changes/machine stoppages). Less batch changes means that processes are less labour intensive. An important innovation for more economical processing is the possibility to increase the size of batch diameters in jiggers to 1200 (1250) mm. With such batch sizes, increases in machine capacity of up to 40% may be realized and 4000–5000 m of lightweight poplin shirting qualities can be processed per batch (e.g. pretreatment and bleaching). Plant modifications necessary to handle giant batch rolls may mean that → Rising-roll batchers mounted at each side of processing machines must be replaced by special giant roll batchers or hydraulic centre spindle batchers. Squeeze rollers are substituted by a suction device. A particularly efficient system is the use of a non-stop giant batch changer at the end of a stenter (see Fig.).

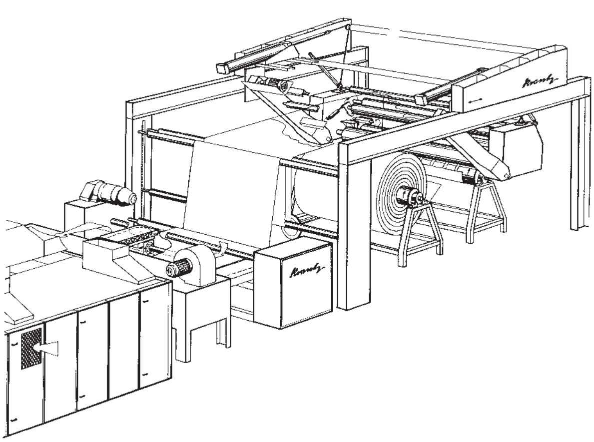


Fig.: Non-stop giant batch winder with no fabric store, A-to-A system (Krantz).

Gibb's Phase Rule Single-component systems normally exist as homogeneous and pure substances in a single phase. Multicomponent systems are mixtures which represent solutions of homogeneous phases. When liquids exhibit only limited mutual solubility, more than two liquid phases are present in equilibrium with a large number of components. A phase is that part of a system which is physically homogeneous down to the molecular level. Liquids are grouped into miscible and immiscible types and separate into two mixed phases which exist in thermal equilibrium with each other. Every solid substance with a uniform crystal structure, including mixed crystals, represents a single phase. Mixed crystals are built-up homogeneously like miscible liquids and represent a mixed phase. The point being emphasized here is that a single phase or mixed phase is characterized at the molecular level by its homogeneity.

A system is built-up from its components. The number of components is the smallest number of independent chemical compounds necessary to describe the composition of all phases of a system. The relationship of the phases, components and degrees of freedom involved is given by Gibb's Phase Rule. This describes equilibrium systems which always represent the lowest energy state. The rule was established empirically and is expressed by:

$$F = C - P + 2$$

F = the number of degrees of freedom in the system; i.e. the number of any varying state variables, temperature, pressure, concentration, which can participate in producing a state of equilibrium,

C = the number of components which determine the composition of each phase in the equilibrium system,

P = the number of physically distinct phases in the system.

The phase diagram (constitution diagram) gives a graphical representation of the relationship between solid, liquid and gaseous phases and their transitions over a range of conditions (e.g. temperature and pressure) at the same time. In an equilibrium system consisting only of a single substance (H_2O), the variables p and T are sufficient to establish the system.

Fig. 1 may be interpreted as follows: the curves A, B and C separate the temperature and vapour areas into three fields. Within the single-phase regions, p and T can be varied independently of each other without a new phase being formed = a divariant system. The curves describe two phases existing next to each other: the vapour pressure curve (C), sublimation pressure curve (A) or the melting curve (B). A single state variable is sufficient here to establish the system = a monovariant system. At point T, the three phases are in equilibrium with each other. This point is called the triple point. All state variables are fixed at this point = a nonvariant system.

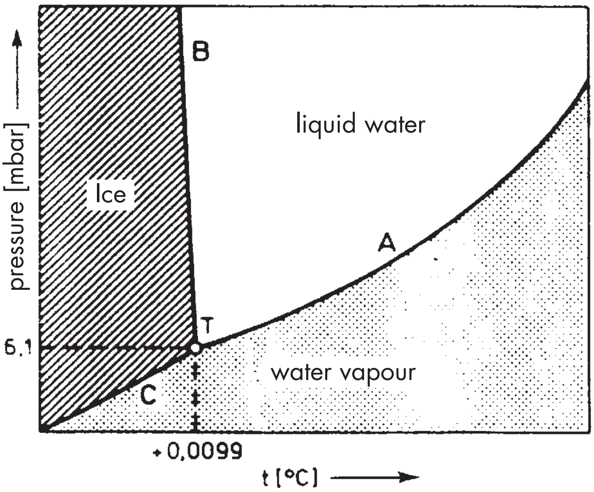


Fig. 1: Phase diagram of water (schematic).
A = vapour pressure curve (of water); B = melting curve (of ice); C = sublimation curve (vapour pressure curve of ice); T = triple point.

Emulsions are systems consisting of at least two phases of mutually immiscible liquids. Depending on the ratio of the components, either oil-in-water (O/W) or water-in-oil (W/O) emulsions are formed. In textile finishing, oil-in-water emulsions are used exclusively because there is no problem in diluting them with water. The basis for the emulsification of oils in water is a reduction in surface tension, so that dispersion of oil in the aqueous phase is made easier. The area, within which the emulsion exhibits maximum stability must be found in the emulsion triangle (Fig. 2). Only a very small area within this triangle is capable of forming micro-emulsions.

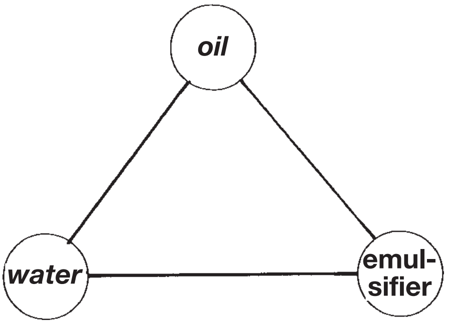


Fig. 2: Emulsion triangle (basic form of Gibb's three-phase triangle).

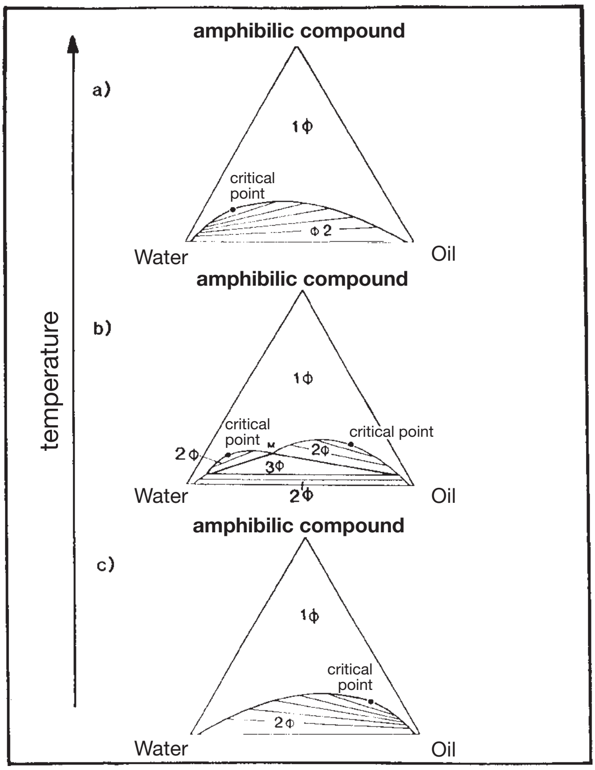


Fig. 3: Gibb's phase triangle (schematic) for a ternary system consisting of water, oil and an amphiphilic compound (source: Kahlweit and Strey).
n-Φ = n-phase area; M = coexistence point of the single-phase, two- phase and three-phase areas.

Any increase in the hydrophobic character of the oil, e.g. by increasing the length of the carbon chain, enlarges the three-phase area. On the other hand, hydrotropic electrolytes, or an increase in the hydrophobic character of the non-ionic surfactant, e.g. by increasing the number of carbon atoms in the molecule structure, and increased pressure, bring about a reduction in the size of the three-phase area until it disappears, i.e. at the tri-critical point of such systems.

Wash media used for textiles are normally single-phase multicomponent systems consisting of water, surfactant and the hydrophobic soil originally adhering to the textile. Such multicomponent systems exhibit different areas in the phase diagram which are dependent on pressure, temperature and composition. Consequently, single, two and even three-phase areas may occur which can be represented in the so-called Gibb's phase triangle (Fig. 3).

According to Danielsson and Lindmann, the optically isotropic, thermodynamically-stable systems of water, oil and one or more amphiphilic compounds, are described as micro-emulsions. At normal pressure, the phase relationships are largely independent of the pressure. Only during the transition to higher pressures does the position and size of the different phase areas in the ternary system change due to the influence of pressure on the binary system water/non-ionic surfactant. In addition to an extensive single-phase area, a two-phase area often occurs with the critical point on the side facing the oil side at low temperatures in the Gibb's phase triangle. With increasing temperatures, some systems have the following appearance: in addition to a single-phase area, three two-phase areas and one three-phase area is formed. A further increase in temperature leads to the disappearance of the three-phase area. The phase relationship resembles that at low temperatures but, in this case, with the critical point on the water-rich side (source: Schollmeyer).

Gifu dyeing process for polyester A Japanese dyeing method which employs phenol as a swelling agent and organic or inorganic acids at high concentration.

Giga (Gk.: *gigas* = giant). A prefix used to denote one thousand million times = 10^9; e.g. 1 GHz = 10^9 Hz.

Gilet black Used in the → Weighting of silk.

Gill A non-metric English and American unit of liquid measure equal to one quarter of a pint.

Gill box A device used for the production of fibrous webs to be subsequently printed with relief rollers. A prerequisite for → Vigoureux printing (printing of wool tops).

Gimp,

I. A helically wrapped core yarn in the form of a stiff cord. Often consists of cotton or wire wrapped with silk or viscose yarn for use in embroidery, lace or trimmings. Gimp can be used to sew buttons on clothing.

II. A narrow strip of fabric used in trimming furniture; often has a stiffening of wire or heavy cord running through it.

Ginning A process for separating cotton fibres from the seed in order that the fibres may be spun into yarns. Machines used for ginning may be either saw gins or roller gins.

GK (Ger.), abbrev. for: Grenzkonzentration (→ Limit concentration).

GL, → Glass fibre, → Standard abbrev. for textile fibres, according to the EDP code; → GF.

gl → Gill.

Glacé,

I. A term used for glazed yarn or polished thread.

II. Fabrics: a high-lustre fabric, a lining fabric with a lustre-imparting finish, a lustrous satin lining, etc.

III. A woven wool fabric.

IV. A lightweight British fabric with a cotton warp and mohair or lustre worsted weft produced in a plain weave.

Glacial acetic acid → Acetic acid.

Glacial acetic acid solubility test Action when hot: dissolves acetate, polyamide and silk. Action in the cold: dissolves acetate. In both cases triacetate also dissolves.

Glacial acetic acid test for dye class identification,

I. Vegetable fibres: boil the test specimen for 1–2 min in glacial acetic acid. Solution remains unstained: phthalocyanine dye (confirmation: nitric acid = violet; test for presence of copper or nickel). Solution is stained: vat or naphthol dyes.

II. Animal fibres: treat the test specimen in cold glacial acetic acid. Solution is stained: cationic (basic) dyes. Solution remains unstained: acid, direct and reactive dyes. → Dye class identification on fibres.

Glass An alkali calcium silicate. Fusion product of silica (silicon dioxide), calcium oxide (lime), and sodium carbonate (soda ash) = common lime-soda glass. Potash glass is obtained by substituting soda ash with potassium carbonate (potash). Glass is decolorized by the addition of manganese (principle: complementary colour). The addition of lead oxide (for flint glass, lead crystal glass) gives higher transparency and light refraction and is used inter alia for the manufacture of highly refractive lenses (especially convex lenses) for persons with acutely defective vision in order to obtain a thinner lens (aesthetic requirement); the disadvantages of such lenses include reduced sharpness of contours (higher prismatic characteristics) and greater weight than crown glass lenses. Glass is coloured with appropriate metal salts (dark glass and filters characterized by their transmission curves). The modern glass industry has made it possible to manufacture glass capable of meeting an ever increasing range of individual quality standards with the result that, over the past few decades, the applications of glass have become much more versatile. Special types of glass, such as borosilicate glass, are used in chemical apparatus and in heat exchangers for the heating and cooling of liquids and gases (i.e. for applications where extremely high resistance to corrosion against very aggressive products is required with virtually no sensitivity to temperature changes). Gasproof and moisture-proof glass is used for the inner lining of chimneys to prevent the aggressive condensates from flue gases pnetrating the chimney wall and destroying the chimney material. The condensate runs down the inner side of the glass lining where it is collected and disposed of by ecologically-

glass names	Ø-composition	softening temperature °C	properties
lead glass (lead crystal)	SiO_2 ....52% PbO ....35% K_2O 13%	400—500°	easily melted. Heat sensitive. Corrodible by hot water, hot KOH, $KMnO_4$ solution, salt solution
soda glass (standard glass; windows, bottles etc.)	SiO_2 ....75% CaO ....13% Na_2O 12%	600—600°	similar to lead glass but somewhat less corrodible
Jena equipment glass 20	SiO_2 .... 74.5% Al_2O_3 .... 8.5% Na_2O .... 7.7% B_2O_3 .... 4.6% BaO .... 3.9% CaO 0.8%	600—700°	difficult to melt, fairly insensitive to heat. Chemically hardly corrodible except by lyes and hydrofluoric acid
potassium glass (Bohemian crystal)	SiO_2 ....71% K_2O ....18% CaO 18%	700—800°	similar to Jena equipment glass 20
quartz glass	quartz 100%	1.700°	very difficult to melt. Completely insensitive to heat. Chemically non-corrodible except by hydrofluoric acid.

Tab.: Properties of the most important types of glass (all soluble in or corrodible by hydrofluoric acid).

acceptable means. Possibilities also exist for the use of special types of glass in filtration plants (see Table).

Glass batiste A glass-like, almost transparent and usually stiff batiste fabric. The character of this pronounced stiff and glassy material, produced by a special chemical treatment, is also resistant to washing. As far as cotton materials are concerned, which were formerly used exclusively for this purpose, the finish consists essentially of mercerization, bleaching, and a treatment in conc. sulphuric acid. Nowadays such fabrics are also woven from viscose filament yarns and, especially, fully-synthetic filaments. Organdie is a type of glass batiste fabric. The transparent character of such cotton fabrics produced by the acid treatment is often combined with a matt or milky patterning by preprinting the material with an acid-resisting thickener.

Glass buttons → Buttons.

Glass cement is magnesium oxide.

Glass fabrics Collective term for all textile fabrics produced from → Glass fibres.

Glass fibres Fibres may be drawn very easily from glass in the molten state. As spun yarns in wicks, ropes and woven fabrics, glass is an ideal insulation medium for continuous and short term exposure up to temperatures of around 300°C. Because of the relatively low price (10–20 DM/kg), glass textiles have, in the meantime, found wide application, e.g. in chemistry, chemical technology, insulation of machines, pipes and containers, in sound insulation and in electronics. Glass fabrics are used for interior furnishings wherever high demands are placed on safety, e.g. in ships, hotels, cinemas, wall coverings, etc. Estimated production capacities exceed 1 million t (1990) and are still increasing. In technically advanced countries, the production volume of glass filament yarns has reached approx. 10% of the production volume of synthetic fibres.

For over 30 years now, glass filaments have been produced mainly by the spinneret drawing process (Fig. 1) from spinning baths with drawing speeds of 3000–4000 m/min – a speed which only became practicable for some organic synthetic fibres a few years ago. It can be assumed that further significant progress has been made in recent years especially with regard to process reliability and increased productivity. Whilst, initially, only about 200 spinneret capillaries per bath were used, this has been increased in the meantime to 1200–2000 with corresponding increases in throughput quantities from 10 kg/h to, e.g. 55–60 kg/h.

The patent literature also contains references to experiments aimed at achieving further increases in the speed of glass filament extrusion from spinnerets by pressure spinning. Work has also been carried out on reducing investment costs by means of an electrochemical melting process in which the lining material of the spinning bath can be reduced in a ratio of almost 100 : 1 for the same melting performance. Greater technical flexibility is also achieved at the same time (Pochet oven).

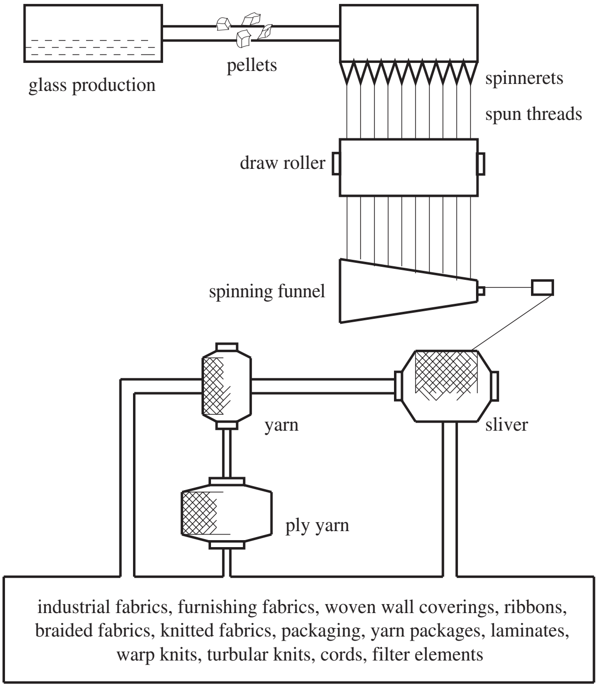


Fig. 1: Glass fibre production.

Although, initially, it had only been possible to apply the spinneret drawing process by a two-stage method, the single-stage process has, in the meantime, been widely adopted as was the case in organic synthetic fibre development (Fig. 2). A solid intermediate stage (glass marbles) is thereby eliminated which, in particular, brings about a reduction in the specific energy costs. It is common practice to melt E-glass (alkali-free glass) in spinning baths heated by natural gas with recuperative heat recovery to achieve melting capacities of 6–20 t/day. At present, experimental work is being carried out with all-electronically heated melts which,

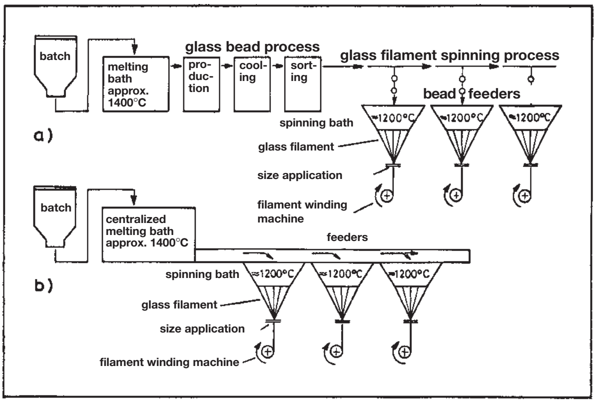


Fig. 2: Glass filament production.
a) discontinuous; b) continuous.

it is hoped, will bring a reduction of 20–30% in melting costs. In the meantime, spinning reliability has been considerably increased by process analysis. The knowledge gained with regard to the technological parameters forms the basis for process models with the aid of which computer-assisted process control will probably be achieved more easily for glass fibres than for organic synthetic fibres. The structure of glass filaments can only be compared with organic synthetic fibres to a limited extent, since subsequent drawing of the filaments is not possible. After cooling, glass fibres immediately assume a solid state. The more quickly cooling takes place (especially in the case of extremely fine individual filaments), the more their structure corresponds to that of the glass melt.

A "frozen-in induced orientation birefringence" exists in glass fibres which is, however, difficult to determine. Structural changes in the fibre are caused by ageing or reheating; disassociation (micro-heteregeneity), in particular, increases which, at the same time, causes the density to rise but also initiates contraction phenomena. The reasons for the fact that glass fibres can be 50–80 times stronger than the solid glass from which they were produced are also to be sought in the exceptional structure of the fibres (Fig. 3). The commercial exploitation of glass fibres is determined primarily by their properties and costs. Both depend essentially on the diameter of the individual filaments. For standard reinforcing materials, fibre diameters of 9–11 µm are generally employed although, for economic reasons, there is a tendency to increase the range to 13–15 µm.

No less important is the composition of the glass used in the production of reinforcing fibres. E-glass is used for general thermal and duroplast reinforcement applications. E-glass is an aluminium borosilicate glass with less than 0.8% alkaline oxides, which has a market share of 95%. HM-glass, on the other hand, is a glass containing titanium and beryllium oxides with a high modulus of elasticity. S-glass is an aluminium manganese oxide glass with increased linear strength. If the tensile strengths and e-modulus of current reinforcing fibres is compared, it can be seen that glass fibres occupy a middle position. In terms of mass-related parameters, those reinforcing fibres whose density lies considerably below that of glass fibres show up very favourably; this is especially true for aromatic polyamides (source: von Falkai).

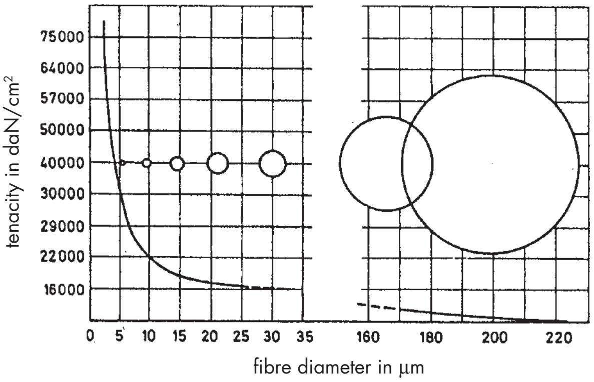


Fig. 3: Tenacity of glass fibres in relation to fibre diameter.

Glass fibre wallpaper, finishing of The treatment involves bonding the extremely loosely woven glass fibre fabric by coating. The fabric runs from batch rolls through a dispersion consisting of latex and starch as a filler. After passing through the finish applicator the liquor pick-up is reduced to approx. 150–190% by running slowly through the entire plant (production speed 5–15 m/min) and the nip between two horizontal padder bowls. The impregnated fabric then passes without contact through an infrared heating tower mounted above the padder where it is dried to a residual moisture content of approx. 15–30%. In order to flatten the protruding glass fibres the residual moisture is removed by a final passage over a cylinder drier. Overdrying at this stage must be avoided to prevent the starch turning brown since the glass fibre ground should be pure white.

Glass filament yarn → Glass fibres.

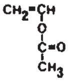
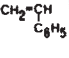
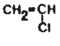
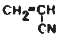
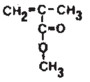
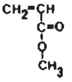
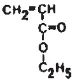
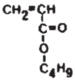
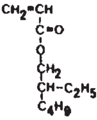
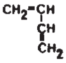
Glass plate test A commonly used test to check the correct vatting of vat dyes in dyeing as well as the rate of re-oxidation after dyeing (greening). Procedure: a glass plate is dipped in the prepared vat and immediately removed; if vatting is correct the dye liquor should remain clear as it drains off the plate without revealing any solid dye particles. Indigo vats should, e.g. drain off clear yellow and only begin to green after 20–30 s, i.e. colour change to blue.

Glass roving Consists of a multitude of parallel glass filaments without any significant twist.

Glass silk → Glass fibres.

Glass staple fibres Drawn or blown fibres produced from molten glass of finite length (staple fibre) of specific fibre diameter (→ Glass fibres).

Glass transition temperature (glass-rubber transition temperature; T_g). The temperature range within which an amorphous material (such as glass or a high polymer) changes from a brittle vitreous state to a plastic or rubbery state. The glass transition temperature does not occur at a single temperature but takes place over a short temperature range because real polymeric materials have a molecular weight distribution. The single point temperatures which are quoted in the literature etc., are obtained by interpolation. Unlike crystalline materials, amorphous materials do not melt when they are heated, but go through a glass transition. In the glass transition range, many physical properties of amorphous materials undergo a more or less drastic change. The most obvious change is that from a viscous or flexible material above T_g to a hard, sometimes brit-

monomers	vinyl acetate	styrene	vinyl chloride	acrylonitrile	methyl methacrylate	methyl acrylate	ethyl acrylate	butyl acrylate	ethyl hexylacrylate	butadiene	ethylene
melting point	- 93°C	- 31°C	- 160°C	- 82°C	- 48°C	- 75°C	- 75°C	- 65°C	- 90°C	- 109°C	-169°C
boiling point	+ 72°C	+146°C	- 14°C	+ 77°C	+146°C	+ 81°C	+101°C	+148°C	+ 216°C	- 5°C	-104°C
chemical formula	 $CH_2=CH-O-C(=O)-CH_3$	 $CH_2=CH-C_6H_5$	 $CH_2=CH-Cl$	 $CH_2=CH-CN$	 $CH_2=C(CH_3)-C(=O)-O-CH_3$	 $CH_2=CH-C(=O)-O-CH_3$	 $CH_2=CH-C(=O)-O-C_2H_5$	 $CH_2=CH-C(=O)-O-C_4H_9$	 $CH_2=CH-C(=O)-O-CH_2-CH(C_2H_5)-C_4H_9$	 $CH_2=CH-CH=CH_2$	$CH_2=CH_2$
homopolymer glass transition temperature	+ 29°C	+100°C	+ 83°C	+105°C	+107°C	+ 6°C	- 24°C	- 55°C	- 50°C	- 78°C	-125°C
film hardness at room temperature	hard	brittle →				soft	very soft →				

Tab.: Glass transition temperature and properties of some monomers (RT = room temperature).

tle, solid below. On a molecular level, as the temperature is raised to the glass transition temperature and above, segments of the molecules are able to rotate. In high polymers, these segments consist of 25–50 chain atoms which may be estimated from the activation enthalpy of relaxation processes in semicrystalline or amorphous polymers. It is probable that trans/gauche transformations are involved here which proceed cooperatively over a wide range.The actual value of T_g for a polymer is clearly method- and rate-dependent; T_g is that temperature at which the molecular relaxation times are of the same order as the experimental times. From the structural point of view, the molecular arrangements in an amorphous material (or glass) below Tg possess the permanence of crystals and the randomness of liquids. As a crystalline arrangement of the molecules has a lower energy, for a glass to form on cooling from the melt there must be some barrier to crystallization. This may be caused by steric hindrances in the molecule such as bulky side groups, or, if the material is cooled quickly enough, by insufficient thermal energy, or by a combination of both. T_g is always less than T_m (melting temperature) since a crystal has a lower energy than an amorphous structure. T_g can be measured in a number of ways because most material properties change on going through it. For this reason, it is not sufficient to just quote a value for T_g; it is important to give the method and the rate of measurement. The glass transition temperature of high polymers is closely related to the effects produced on textile materials (see Table) and, for such polymers, is usually measured by differential thermal analysis.

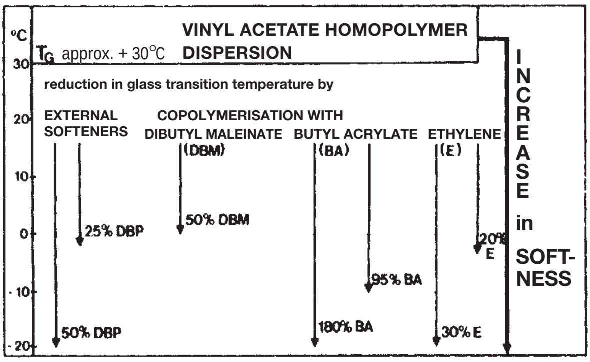


Fig.: Connection between softener quantities and glass transition temperature.

The Figure shows that the same quantities of various softener components produce different degrees of softening on textile materials which is why T_g provides a reliable measure of the softening effect of these components.

Glass-tube heat exchanger Heat can be recovered from polluted, aggressive exhaust air with such systems. Fresh incoming air can be heated in recuperative systems without an additional heat transfer medium, i.e. by air/air transfer only (separated by glass). Heat exchange occurs over the large surface area of small glass tubes through the heat content of exhaust air passing through them (used e.g. as internal heat exchangers in stenters). Condensation of water from the exhaust air is desirable since this raises the heat recovery capacity as the heat of condensation is conducted away and the heat transition coefficient is improved (see Fig.). Glass has smooth surfaces which are less susceptible to dirt accumulation (e.g. through fibre fly), does not corrode, and is relatively temperature-resistant. The thermal conductivity of glass is negligible. The only disadvantage of glass-tube heat exchangers is the fragility of the glass tubes.

Glass wool → Glass fibres.

Glass yarn A collective term for multifilament, spun and textured yarns produced in a range of different yarn thicknesses from → Glass fibres.

Glauber's salt → Sodium sulphate.

Glauconite A naturally occurring hydrated silicate of potassium, iron and aluminium. An intense green mineral found in marine sediments, especially greensands. After comminution and chemical stabiliza-

Fig.: Glass tube heat exchanger.

tion it is used as a natural base exchanger for water softening (e.g. as the former Neopermutit).

Glazed millboard → Pressboard.

Glazed yarn → Glacé.

Glaze finishing The production of lustre effects on textiles by certain finishing processes is followed, in most cases, by a mechanical treatment, e.g. chintz finishing. Processes which increase the lustre of textile materials include mercerisation, lustring and polishing. In the case of polyester blouse fabrics, another process used to achieve increased lustre involves a passage through a transfer printing calender.

Glaze finishing auxiliary These products are used to produce lustre effects on textiles with or without a subsequent mechanical treatment. For lustre effects where high requirements do not have to be satisfied, the usual finishing agents are satisfactory, e.g. paraffin wax emulsions, polyethylene glycols, etc. The production of permanent lustre effects resistant to water and washing (chintz and embossed effects) is achieved by mechanical means and the co-application of methylol compounds, urea or melamine resins and subsequent curing. Wash-resistant lustre effects can also be produced by the application of suitable plastics in the form of dispersions or solutions in organic solvents.

Glazing and flatting calender → Smoothing and calibrating calender.

Glazing calender → Friction calender.

Glen check (derived from Scottish: glan = tribe and check = chequered). In former times, Scottish families used different check patterns (tartans) to distinguish themselves from each other. Through subsequent generalization, the term glen check is now used to characterize materials with a typical block check pattern. The term is therefore only a description for a particular type of check pattern which is produced in a 2/2 twill weave with a 4:4 and 2:2 order of colouring in both warp and weft. This type of fabric is produced with worsted yarns as well as carded yarns from virtually all types of fibres. The former are normally closely cropped for men's suitings, womenswear and costumes. Besides the usual very muted tones, these designs are also available in more vivid sporty colourings. Glen checks with carded yarns are produced for men's fine suits and costumes (some of which are available in a Saxony quality, i.e. from fine merino wool with a flannel-like finish). Coarser qualities are also used mainly for men's suits and coat fabrics. Synonyms: glen plaid, glen urquhart plaid.

Glide rods Brightly polished rods or tubes positioned at right-angles to the direction of fabric transport instead of rollers to ensure faultless fabric passage in processing machines, etc. Used for centring the tightness in fabrics passing over the rod at a blunt angle by bending the fabric in a slightly downwards direction.

Glitter pigments A distinction is made here between polyester and polyoxide glitter pigments. They are produced by the comminution of metallized foils followed by sieving. Because of the risk of blocking screens or engraved rollers in printing, these pigments are only suitable for screens with a maximum of 9 threads per cm or engravings with a minimum depth of 30/100. Other problems may be caused by the print pastes separating out during printing. For this reason, the use of high viscosity, short print pastes is recommended.

Glitter threads Man-made fibres with a ribbon-shaped cross-section in coarse counts, mainly produced in a variety of spun-dyed colours.

Glitter, to This finish is achieved by angled inclination of the engraved lines on the upper roller in the schreiner or silk-finish calender.

Globular proteins Or simple → Protein, although in chemical terms often quite complex, are nonetheless structurally of spherical molecule form (e.g. egg albumin, globumin, haemoglobin); in contrast to the higher cell organisation of the chain proteins. (→ Pre-keratin).

Globulins Proteins insoluble in water, soluble in dilute salt solutions. Globulins are examples of simple proteins and occur naturally in milk, wheat and other cereal grains. The description, globulin fibres, is also used in connection with man-made protein fibres.

Gloria silk Smooth closely woven fabric; warp: cotton or (originally) organzine silk; weft: schappe silk or fine worsted yarn; in twill or satin weave for linings, umbrella cloth, etc.

Glossing A mechanical aftertreatment given to hanks of silk, linen, cotton and synthetic fibre yarns to loosen up the yarn structure, achieve increased lustre and a softer handle. Originally, wet hanks were placed over a wooden peg and wrung out.

Gloss value A measure of lustre for, e.g. textile filaments before delustring (e.g. 40) and with increasing delustrant additives (to below 4) or for raw cotton (15–17) before mercerising and with increasing density of caustic liquor after mercerization (up to 30°Bé = 76, after which it decreases again). It is also used for testing bleached materials (e.g. chlorine bleach on cotton = 59, oxygen bleach = 51, combination bleach = 58). The higher the lustre index, the greater the lustre. → Lustre, measurement of.

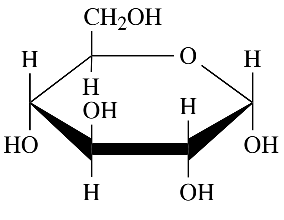
Glossy printing →: Chintz prints; Lacquer printing.

Glow Burning without forming flames, but with visible light.

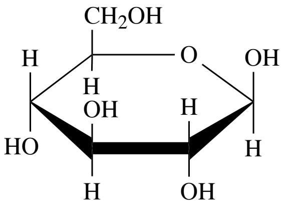
Glowing time → Flammability testing.

Glucopyranose Another name for cyclic → Glucose. The term is used because of similarity with the pyran structure. α and β-glucopyranose are stereoisomers of the same glucose modifications.

Glucose (dextrose, grape sugar, corn sugar, corn syrup), $C_6H_{12}O_6$, density 1.544. Colourless, transparent crystals, fine white powder, granular white lumps, or a viscous colourless syrup. Very hygroscopic, readily soluble in water up to 817 g/l at 15°C (anhydrous glucose) and up to 878 g/l (glucose containing water of crystallization). Glucose solutions have a sweet taste and a neutral reaction. Glucose is the end-product of the complete degradation of starch resp. desizing with diastases. The oxidation of glucose results in the formation of gluconic acid. A gallic acid ester of glucose forms tannin. Like all known → Sugars, exists in two isomeric α and β-forms, i.e. α-glucose and β-glucose. Both forms differ only in the position of the OH group relative to the 1st carbon atom, i.e. (α) below and (β) above:



α-glucose



β-glucose

During hydrolytic degradation with enzymes the respective isomeric forms are maintained. Under certain conditions, α and β-glucose easily become rearranged with one another. This occurs particularly rapidly in aqueous weakly alkaline solution. The new state of equilibrium is recognized by a change in optical rotation. The initial specific rotation of the β-form is 17.5° and that of the α-form is 111.2°, but the specific rotation of a solution containing both forms approximates to 52.5°. This change in rotation towards an equilibrium value is called mutarotation. Such a mixture of both forms is described as normal glucose or, frequently, as D-glucose (D indicates dextrarotatory = plane of polarization is rotated to the right); the same word root is likewise present in →: Dextrin and Dextrose.

β-glucose molecules form the basic building blocks of cellulose: 2 molecules each combine to form the disaccharide cellobiose; the resultant polycondensed macromolecules can form cellulose chains (polymers) through hydrogen bonds which represent the basis of all vegetable fibres (see Fig.).

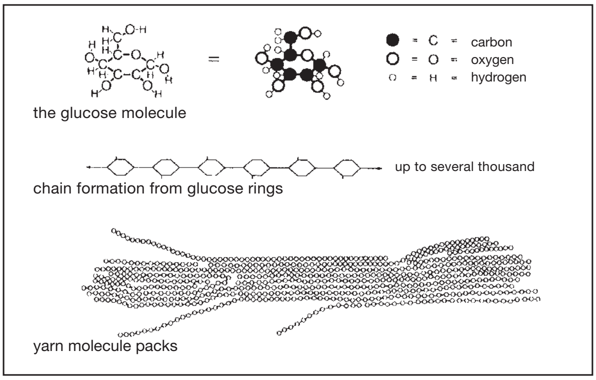


Fig.: From the molecule to the yarn.

Glucosidases A group of enzymes (belonging to the → Carbohydrases) which break down specific glucosides (into carbohydrate and aglycone) and as, e.g. maltase and cellobiase, also break down disaccharides (→: Maltose; Cellobiose) into glucose. Just as there are α and β-glucosides, there are also α and β-glucosidases which, in each case, react specifically only with the α and β-configuration.

Glucosides → Glycosides.

Glucosidic bond The chainlike linkage of cyclic glucose building blocks by oxygen bridges, e.g. starting from → Glucose via → Cellobiose to the high molecular weight cellulose chain molecule. → Cellulose.

Glue Most familiar are glues derived by boiling or steaming animal hides, tendons or bones which are high in collagen. Glues may be classified in order of quality as follows: isinglass, hide glue, leather glue, cartilage glue, bone glue and fish glue. Produced in various forms as (a) slabs (also Cologne glue), longest swelling time, poor core swelling, goes off quickly, small losses; (b) pearls (neutral bone glue, hide glue): (c) hide glue crumbs; (d) glue in plate form; (e) powdered glue. Advantages of glue in forms (b) to (e) include uniform quality, easy handling, easy solubility, (mostly) light in colour and acid-free, low water content, short swelling times, no losses, good yield and good keeping properties. (f) glue jelly (immediately soluble in boiling water).

The active constituent of glue is → Gelatin. Evaluation: comparative determination of softening points as a measure of adhesion power (hide glue : bone glue = 1.5 : 1). Uses: important sizing and finishing agent; protective colloid (dyeing); promotes better rub fastness and levelling in vat dyeing. Preservatives: nitrobenzene, salicylic acid, etc., (good quality glue can be kept for 1–2 days after preparation).

Glued carpets These fall into two categories:

I. Hand bonded: e.g. →: Appliqué carpets.

II. Machine bonded: e.g. → Flocked carpet as bonded bouclé carpets, bonded chenille carpets and similar products.

Glued composite fabrics Imitations in the style of woven → Cloqué fabrics are produced (→ Adhesive-bonded textiles) by, e.g. the superimposition of a crêpe fabric on top of a flat fabric (taffeta) and bonding them together locally. They can also be produced to a pattern, if desired, through application of the bonding agent by screen or roller printing. After damping, blister-like motifs appear in the upper fabric as in, e.g. adhesive-bonded cloqué. Fibre webs can also be included in a similar manner. The bonded areas are usually resistant to dyeing. Products based on nitrocellulose, rubber, chlorinated rubber, cellulose acetate, synthetic resins, etc., with the addition of plasticizers if necessary, stabilizers or mobile solvents, are employed. Adhesive-bonded cloqué is usually well dried in the air after bonding and dampened without tension to develop the crêpe effect. This is achieved by laying the material in layers in open becks (the upper layer is weighed down with a wooden grid) or the process can be carried out continuously in crêping machines. Finally, the material is centrifuged and dried without tension. Other important products of this type include, e.g. cheap blankets consisting of a jute fabric bonded on both sides with a wool web. Fashion variants of bonded fabrics include products produced by (→ Flocking), plush, velvet or velour effects, imitation suede, skins and furs, bonded coat fabrics, bonded pile carpets (on nonwovens) and laminates.

Glueing carriage Used to glue fabrics to screen printing tables for printing. The liquid glue is applied by means of a roller applicator and the fabric is brought into contact with glue film by means of pressure rollers.

Glueing systems for printing At the same time as the partial mechanization of the actual screen printing operation occurred, systems were also developed to mechanize and improve the efficiency of auxiliary operations such as glueing, removal of running fabric webs from the printing blanket, blanket washing, etc. The first stage was to mechanize the glueing of fabric to the printing blanket. For this purpose, a carriage with lifting and lowering functions carries the rolled textile fabric. This carriage is equipped with a glueing unit which applies a film of glue before laying the fabric and a pressure device to ensure complete contact with the glue film. In semi-automatic flat-bed screen printing the printing blanket is coated with a film of glue by a special glueing unit before the fabric is brought into contact with it. Various systems have been developed for this operation. Some systems are based on applicator rolls where the thickness of the glue film is controlled by a doctor blade. Another system uses a fully-engraved 1000 point roller which does not allow any variation in the thickness of glue film applied although it ensures an absolutely uniform application. Yet another method uses a brush roller for glue application and a rubber squeegee on the printing table itself to ensure even distribution of the glue film. Thermoplast adhesives, which only develop their adhesive properties under the action of heat, have also been used for some time. With this system, the fabric to be printed is pressed against the thermoplast film by a heated roller and the thermoplast film is heated by the fabric and becomes tacky as a result. Since the thermoplast adhesive is water-insoluble, it is not removed during blanket washing and can therefore be used for a long period of time before it needs to be renewed. To renew the thermoplast film, the old film is removed from the blanket with an organic solvent and a new film applied thereafter. In rotary screen printing similar glueing systems are employed to those used in semi-automatic flat-bed screen printing.

Glueing unit A device for the application of glue to printing blankets on screen printing machines.

Glutamic acid (2-aminopentanedioic acid). → Amino acids contained in wool and silk.

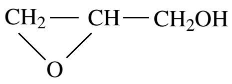
Glutine → Gelatin.

Glycerides Esters of glycerol, e.g. with low (acetin), or high molecular weight fatty acids resp. resin acids (→ Resin ester). The most common glycerides are based on fatty acids which occur naturally in oils and fats.

Glycerol (glycerine; glycyl alcohol; 1,2,3-propanetriol), $C_3H_5(OH)_3$, MW 92. A clear, colourless (pure 30°Bé, lightly coloured 20°Bé), odourless, hygroscopic and very sweet-tasting syrupy liquid. Combustible. Miscible with water, alcohol and acetic acid; insoluble in ether, white spirit, benzene and chloroform. Used as a universal solvent for salts, sodium carbonate (soda), sodium tetraborate (borax), potassium iodide, alkalis, alkaline earths, certain metal oxides, water-insoluble lime soaps, etc., tannin, St. John's bread, dyestuffs (especially cationic, acid, mordant and vat dyes; has a slight affinity-increasing effect); dyes which are insoluble in alcohol become soluble in alcohol if previously mixed into a paste with glycerol. Applications: as a hygroscopic agent (sizing; softening finishes), dye solvent in textile printing in amounts up to 100–130 g/kg of print paste. Component in print pastes for discharge printing (e.g. for wool and silk). Spotting agent (solvent action improved when warm).

Glyceryl phthalate resins → Phthalate resins.

Glycidol (2,3-epoxy-1-propanol). As a glycerol anhydride the simplest alcohol with an epoxy group. Very reactive, chlorine-free, with high purity and stability. Unlike halogen-containing analogues, no undesirable salt residues are formed in reactions with organic chemicals and, under careful conditions, higher yields are frequently achieved. Glycidol is 3-hydroxypropylene oxide 2,3-epoxypropanol and is a dehydration product of → Glycerol. Properties: colourless liquid, b.p. 162°C, soluble in water, alcohol and ether. Glycidol is used as a reactive solvent for epoxy resins, textile auxiliaries (levelling agents, dye-binding agents, etc.) and for the stabilization of halogenated hydrocarbons.



Glycidol vapour Reagent for improving the anti-crease properties of cotton.

Glycine → Glycocoll.

Glycine fibre → Regenerated protein fibre from the soya bean protein, glycine. Developed in the 1930s, but no longer relevant today due to the inadequate strength values (5–7cN/tex, wet strength 50%).

Glycocholic acid → Gall extract.

Glycocoll (aminoacetic acid, aminoethanoic acid, glycine). Glycocoll is the simplest of the amino acids (monoamino-monocarboxylic acid), $HOOC–CH_2–NH_2$, and is a substantial component of silk (42.3%) as well as wool (6.5%).

Glycol derivatives Chiefly the ethers or esters of → Ethylene glycol, such as ethylene glycol monoethyl ether (cellosolve), diethylene glycol, diethylene glycol ethers, thiodiethylene glycol (thiodiglycol), polyglycerols. Glycol derivatives of the above and similar types are excellent auxiliaries for dyeing and printing, especially for cationic, acid and vat leuco ester dyes, as well as for pasting vat dyes and, to some extent, also as penetrating agents in dyeing, and as substitutes for glycerol, etc. Other applications include: the manufacture of oxyethylated cellulose, polyglycol ethers, polyethylene glycols, cellulose glycolate.

Glycollic acid (hydroxyacetic acid, hydroxyethanoic acid), $HO–CH_2–COOH$; m.p. 78°C; colourless crystals, deliquescent, very soluble in water and alcohol. Decomposes below the boiling point. Glycollic acid has solvent properties for tannates (especially zinc tannate thereby making the preparation of basic (cationic) dye print pastes with tannin and a metal salt; the coloured lake only forms during subsequent steaming). Together with chloroacetic acid it dissolves cationic dyes (substitute for acetic and formic acids). Glycollic acid is also used for printing without steaming (ready-for-use print pastes, especially suitable for spray printing).

Glycosides Widely distributed group of compounds in plants as well as synthetic compounds consisting of carbohydrates and non-sugar compounds (aglycones). Glycosides are broken down (hydrolyzed) into these two components by boiling in water, action of enzymes or dilute acids, e.g.:

$$\underset{\text{methyl glycoside}}{C_6H_{11}O_5(OCH_3)} + H_2O \rightarrow \underset{\text{glucose}}{C_6H_{12}O_6} + \underset{\text{methanol}}{CH_3OH}$$

Hydrolytic cleavage of the glycoside bond into sugar and alcohol readily takes place with dilute acids (e.g. as in the acid tendering of cellulose). In contrast, glycosides are completely stable to alkalis. Besides →: Polysaccharides; Glycosides also include the compounds of complex alcohols and phenols with sugars. The various glycoside compounds exist in D-, α-, and β-glycoside forms.

Glyoxal (ethanedial, biformyl). The lowest dialdehyde:

$$\begin{array}{c} HCO \\ | \\ HCO \end{array}$$

Properties: yellow crystals, mild odour, readily rearranged into polyglyoxal, soluble in water (tetrahydroxydioxan), alcohol, ether and other solvents, powerful reducing action. Used in the manufacture of resin finishing agents, e.g. DMDHEU, tetramethylolacetylenediurea, glyoxal resins, as used in the Sanfor-set process for non-swelling and shrink-resistant finishes on regenerated cellulosic fibres. Glyoxal can also be used under mild curing conditions for formaldehyde-free finishes; catalyst: aluminium sulphate and polyhydric acids, shock catalysts. The addition of ethylene glycol prevents yellowing.

Glyoxal crosslinking agents A term in common usage for resin finishing agents which are representative of the reaction products of → Glyoxal with urea in particular, e.g. → Dimethyloldihydroxyethyleneurea.

Glyoxal resins → Glyoxal.

Glyptal resins → Phthalate resins.

Gminder fabrics Hard-wearing fabrics of various types (similar to linen/cotton unions) produced from cotton and cottonized hemp (process developed by the firm Gminder, Reutlingen, Germany).

GMW, abbrev. for: → Gram molecular weight.

Goat hairs The hairs of the common goat, Angora goat, Cashgora goat, Tibetan cashmere goat and the Persian goat can be spun into textile yarns. The quality of goat hairs varies considerably between the different breeds of goat. The hair of the common goat may be classified amongst the coarser animal fibres whilst the hairs of the other goats mentioned above may be grouped amongst the finer → Animal fibres. A distinction is also made between the finer wool-like, but mostly shorter undercoat hairs and the coarser outercoat hairs. Goat hairs are used in outerwear (wovens and knits) as well as for felts.

Gobelin French tapestry. Genuine Gobelin tapestries are hand-woven and have a similarity to → Rib fabrics with coloured designs (occasionally with gold and silver threads). Imitation Gobelin tapestries are produced with jacquard designs (3–5 warp and 3–4 weft systems) or by printing. Used as tablecloths, heavy upholstery and wallcoverings, etc.

Gold (Au), atomic weight 197.2; a golden-yellow (powder = brown), relatively soft, ductile, noble metal, density 19.3, m.p. 1062.5°C. Gold is resistant to air, water and alkalis; soluble in aqua regia (mixture of sulphuric and nitric acids) and potassium cyanide solution. Forms alloys with copper and silver. The carat is used as a measure of the proportion of gold in an alloy.

Gold bronze → Metal powders.

Gold purple reaction A very sensitive and specific test for → Oxycellulose. A test specimen is soaked in a weak acetic acid solution of stannous chloride (tin (II) chloride) and then placed in gold chloride solution. Oxycellulose absorbs tin (II) oxide as a result, and thereby assumes a red-brown colour.

Goldthwait test A differential dyeing test developed by Goldthwait *et al* as a practical method for estimating the maturity of cotton. The test is especially helpful in mill situations for detecting the presence of thin-walled or immature fibres which often cause problems in processing. The test employs a mixture of Chlorantine Light Green BLL (C.I. Direct Green 26) and Direct Fast Red 5B (C.I. Direct Red 81), two dyes with different dyeing properties and contrasting colours: Mature fibres absorb the red preferentially and immature fibres the green.

GOLEM (Ger.), abbrev. for: großspeicher-orientierte, listenorganisierte Erfassungsmethode. A method for the storage and rapid retrieval of an unlimited large quantity of documents and information by means of a medium-sized EDP system.

Golfers → Reclaimed wool from pullovers and knitted garments.

Gombo hemp → Gambo hemp.

Goniophotometer (Gk.: *gonia* = angle). An instrument for the → Photometric measurements of angles (see Fig.); e.g. as a measure in the evaluation of lustre on textile fabrics (measurement of the luminance factor).

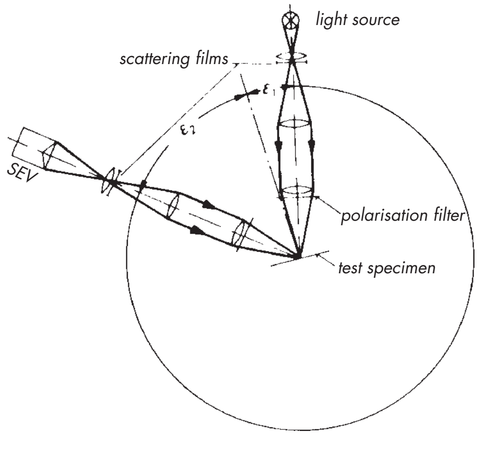


Fig.: Optical structure of the goniophotometer. ε_1 = entrance angle; ε_2 = angle of reflection.

Gore-Tex A water-repellent, windproof membrane with good water vapour transmission properties made from oriented polytetrafluoroethylene film. These properties are due to the presence of approx. 1.4 thousand million pores/cm^2, the size of which is so designed that although water vapour can diffuse through it, water drops are unable to penetrate it. Used as a laminate sandwiched between 2 fabrics for weatherproof clothing (see Fig.) as well as for technical purposes. Manuf. W.L. Gore & Associates.

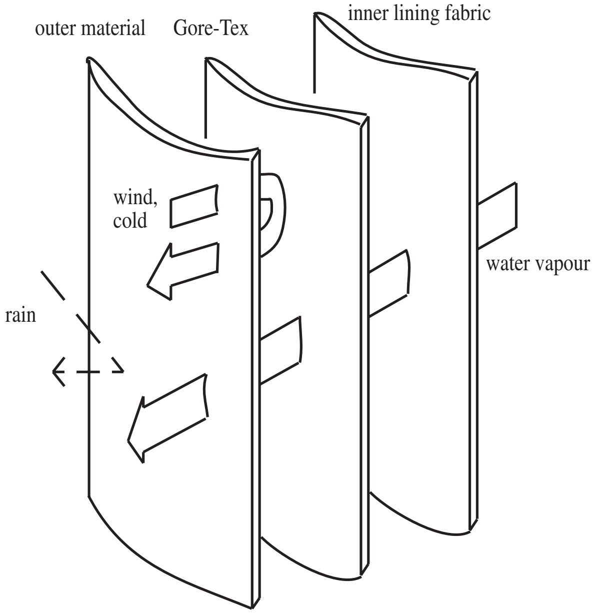


Fig.: Structure of weatherproof clothing with Gore-Tex membrane.

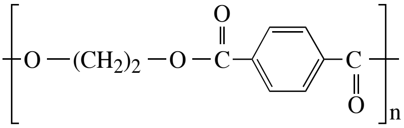
Görlitzer steamer A star steamer for the fixation of printed fabrics. In contrast to other systems in which printed fabric pinned to the star frame is positioned in the steaming chamber from above or below, in the Görlitzer steamer the star frame is loaded into the steaming chamber from the side.

GOST, abbrev. for: Gosudarstwennyi Standart (All-Union State Standard), Moscow, Russia.

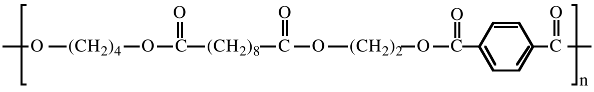
Gouache print A fashion print in the style of a water colour painting.

Gradel (Grad'l). Dense twill canvas, made using strong thread (of linen, as half-ticking), plain or multi-coloured; also cotton and linen cloths in herringbone weave, the latter often having a striped pattern.

Graduated-shrinkage fibres Polyester types which shrink progressively (→ Shrinkage fibres), as a form of chemical modification (co-polyester). The aim is to control and retard the shrinking processes, which by reducing the crystallization tendency in the linear polymer zone has the effect of producing progressive shrinkage, which is of benefit to the largely non-crystalline structure, i.e. after pre-shrinking at the lower temperature, when the temperature is increased, a further contraction phase can follow (in contrast to → High-shrink fibres).



The programming on the polyester molecule is brought about by inserting suitable co-monomers (di-functional compounds such as adipic acid, sebacic acid, etc.), which serve as a means for opening up the structure:



This chemical change to graduated-shrinkage fibres can be adjusted to meet requirements, thus for the knitting sector to somewhat more bulky yarns, which are mostly hank-dyed: with relatively large shrinkage at the boil and lower residual shrinkage during thermal after-treatment; on the other hand for the weaving sector with low shrinkage at the boil and very high residual shrinkage during setting at approx. 185°C, thus creating the desired voluminous fleecy handle. Side effects: Higher dyeing affinity, lower tendency to pilling. For graduated-shrinkage yarn mixtures (e.g. with wool, non-shrink polyester, regenerated cellulose), the non-shrink proportion in each case migrates to the yarn surface (influencing the handle); excessive interlacing of fibres should be avoided (= impeded contraction).

Graft copolymers → Graft polymers.

Grafting reactions When radical-creating media, e.g. electron irradiation or plasma, are allowed to act on olefinic fibres, e.g. polypropylene, fibre radicals are formed along the polymer chain. This behaviour enables grafting reactions to be carried out. Electron beams or electron accelerators are particularly suitable for the production of polypropylene radicals. Entirely different secondary reactions can occur depending on whether the irradiation is carried out in a nitrogen atmosphere (Fig. 1) or in the presence of oxygen (Fig. 2). Irradiation in a nitrogen atmosphere results in chain scissions and the formation of radical chain ends. Moreover, carbon radicals can be formed likewise at the tertiary carbon atoms by hydrogen abstraction. Crosslinking reactions can occur by the combination of two such tertiary carbon radicals. When the irradiation is carried out in the presence of polymerizable monomers, grafting reaction can take place which is accompanied by homopolymerization.

When the treatment is carried out with β-rays in the presence of oxygen, peroxide radicals, or peroxide groups, are formed from the resultant primary carbon radicals by the addition of oxygen molecules. These peroxide groups are stable up to approx. 60°C. If the polypropylene fibres pre-irradiated in the presence of oxygen are subsequently treated with monomers above 60°C, the peroxide groups break down with the formation of radicals which then initiate graft polymerization. With this procedure, there is only a limited likelihood of homopolymerization.

The mechanical technological properties of polypropylene fibres are negatively influenced by irradia-

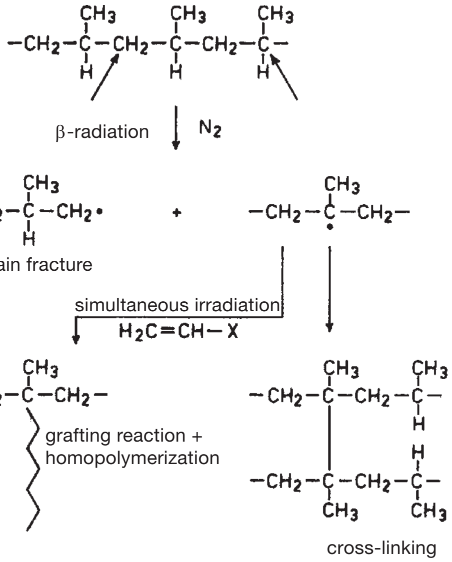


Fig. 1: Radical formation and follow-on reactions in polypropylene irradiated in nitrogen.

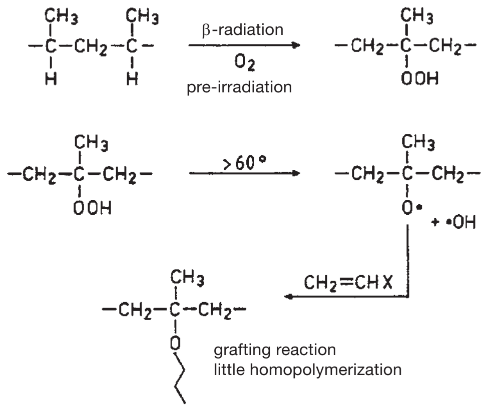


Fig. 2: Radical formation and follow-on reactions in polypropylene irradiated in air.

tion in nitrogen. Both the tensile strength and extensibility decrease with increasing dosages of radiation. At a radiation dosage of 100 kGy the tensile strength is still 80% of the initial value. A slight reduction in the degree of whiteness also occurs (Einsele).

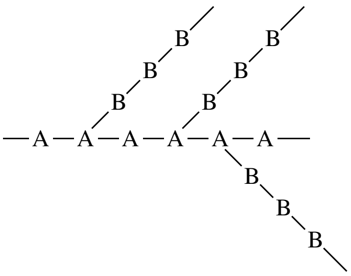
Graft polymerization of silk Amongst the chemical modification techniques, graft co-polymerization of vinyl monomers on silk fibres has proved to be an effective method of improving some original fibre characteristics. Grafting was proposed as a means of improving characteristics such as crease recovery, easy-care behaviour and light fastness, without impairing the handle and lustre of the silk fibre. A large number of vinyl monomers were applied to silk, and their effect on the fibre characteristics was investigated. A chemical modification of silk through reaction with epoxy resins was introduced in the early 1970s. This technique was mainly developed in Japan and was relatively well known, since it effectively improves the crease recovery in both dry and wet states, as well as light fastness, and laundering fastness of dyeings. The use of dibasic acid anhydrides as a modification agent was proposed; the modified silk fibres showed increased resistance to light decomposition. Furthermore, a slight chemical modification (carried out under mild conditions) led to a drastic change in the dyeing behaviour of silk.

The physico-chemical characteristics of the grafted silk depend heavily on the chemical nature of the functional side-groups which the monomer provides, but also on the degree of polymerization and the molecular weight of the chains which are polymerized in the interior of the fibre. Depending on the type of vinyl monomer used and the grafting conditions applied, the silk fibres undergo a slight or drastic change in their original characteristics. Graft polymerization of vinyl monomers on silk fibres can be effected by various methods, e.g. by irradiation, chemical or photo-induced initiation. The use of chemical redox systems in aqueous medium has played a large role for technical purposes. The chemical and photo-induced graft polymerization of polymethylmethacrylate (PMMA) was investigated in detail on silk. The influence of various parameters (such as monomer and initiator concentration, temperature, time, composition of the polymerization medium, additives such as salts and surface-active compounds) was investigated, in order to explain the kinetics and the mechanism of the graft reaction. The reaction mechanism includes the formation of free radicals on the basic structure of the silk fibroin. Carboxyl, amino and hydroxyl side chains of acidic, basic and hydroxyl group containing amino acid residues are regarded as the main reaction centres for vinyl monomers. The mean molecular weight and the molecular weight distribution of the poly-MMA which has been grafted onto silk depend on the selected initiator system and the reaction conditions. A linear relationship was found to exist between the weight increase and the mean molecular weight of the poly-MMA chains. Furthermore, the mol ratio between poly-MMA chains and the silk fibroin yielded a constant value. This suggests that after the initial stage of the graft polymerization, the growth of the grafted polymer chains plays a significant role in increasing the degree of grafting. MMA monomers and oligomers with a mean molecular weight of approx. 1000 form during the graft polymerization and appear on the fibre surface when the weight increase is 40–50%. They are not chemically bonded to the fibre, and can easily be removed by means of solvent extraction.

Alteration of the physical characteristics in the case of grafted silk can be summarised as follows: infra-red spectra clearly show the characteristic absorption bands of the silk fibre with the beta-conformation and the polymers grafted onto the fibre substrate. DSC measurements show that the decomposition temperature of the silk remains almost unchanged. Endothermal transitions were found which are attributable to the vinyl monomer in the silk matrix, with their intensities being approximately proportional to the degree of grafting.

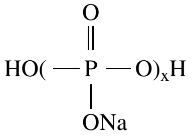
From these results, it can be seen that there is a low compatibility between the silk fibroin and the grafted polymer chains. Double refraction and isotropic refractive index show that the average molecular orientation and crystallinity of the grafted fibres decrease with increasing weight. X-ray diffraction curves have shown, however, that the crystalline structure remains unchanged even with high weight increases. This suggests that graft polymerization takes place primarily in the amorphous areas, as well as in the laterally arranged areas at the end of each crystalline segment, aligned along the filament axis (source: Tsukuda, Shiozaki and Freddi).

Graft polymers (graft copolymers). Polymers to which side chains from other building blocks are subsequently “grafted” on to the backbone of an already formed macromolecule (which may be obtained by polymerization, polycondensation or polyaddition, or as already existing polymers from natural sources resp. modified natural products). In principle, graft polymers have the following basic structure:



Such graft polymer structures are particularly suitable for modified fibres and textiles. Oxyethylated polyamide represents a typical example. The fibre backbone consists of polyamide 6.6. polymer on to which ethylene oxide polymer has been grafted. As revealed by infrared spectroscopy, the oxyethyl groups, or polyglycol chains, are actually attached to the amide nitrogen atoms of the polyamide chain. The graft polymer thus formed combines the individual properties of polyamide with those of polyethylene oxide to a greater or lesser degree. It is therefore possible to combine the desirable properties of both polymer components in the graft polymer. The graft polymerization process may also be applied to the combination of cellulosic molecules with synthetic polymers to form modified fibres with improved flame-retardant properties, dimensional stability, resilience, and bacterial resistance.

Graham’s salt Also known as sodium hexametaphosphate. A highly condensed, vitreous, sodium polyphosphate, i.e. a predominantly straight-chain condensed phosphate with the general formula $H(NaPO_3)_xOH$:



$$\mathrm{HO}\left(-\underset{\displaystyle \mathrm{ONa}}{\underset{|}{\overset{\displaystyle \mathrm{O}}{\overset{\|}{\mathrm{P}}}}}-\mathrm{O}\right)_x\mathrm{H}$$

in addition to a few percent of true metaphosphate (with cyclic structure). Readily soluble in water. Graham’s salt softens water without precipitation. It forms complexes with alkaline earths and metal ions.

Gram atom The quantity of an element numerically equal to the → Atomic weight expressed in grams, i.e. all gram atoms contain the same number of atoms.

Gram calorie → Calorie.

Gram equivalent The equivalent weight of a substance expressed in grams, i.e. the quantity of a substance by weight which corresponds to a gram atom of hydrogen. It may be calculated from the → Equivalent weight expressed in grams. →: Valency; Normal solutions.

Gram molecular weight (GMW). The → Molecular weight of a compound in grams.

Gram molecule → Mole.

Grams per litre The most commonly used measure of concentration in the textile bleaching, dyeing, printing and finishing industries and indicates the number of grams of a solid substance dissolved in 1 litre of a liquid.

Gram stain The most widely used differential diagnostic staining procedure for bacteria with cationic dyes (developed by the Danish physician H.C.J. Gram in 1884). This process divides bacteria into two major groups, gram positive and gram negative, depending on the structure of their cell walls. Procedure: The gram staining method involves first treating a dried and fixed film of bacteria with gentian violet (crystal violet) followed by a KI-I_2 solution to form a dark purple complex in the organisms. Subsequent treatment with polar solvents such as ethanol or acetone removes the complex from some species – the gram negative ones – but not others – the gram positive ones. The procedure involves 4 steps as follows:

Step Treatment Gram positive Gram negative

1. Initial stain Gentian violet for 30 s stains purple stains purple.
2. Mordant Iodine for 30 s remains purple remains purple.
3. Decolorization 95% Ethanol for 10–20 s remains purple becomes colourless.
4. Counterstain Safranin for 20–30 s remains purple stains pink.

Granite The name is probably derived from the mineral of the same name (granite = a coarse-grained igneous rock). In textiles, the term is used as a somewhat vague description for worsted cloth with a napless finish (chiefly in a 3/2 twill weave) often used for women’s dresses and costumes.

Granule A particularly finely ground product. The term is usually applied to disperse dyes in granule form which are non-dusting and easy to dispense in the dyehouse. → Commercial forms of dyestuffs.

Granule dyeing → Spin dyeing.

Graph A diagram depicting a functional relationship between two or more variables by means of a curve joining those points whose coordinates satisfy the relation. A diagrammatic representation of a series of measurements or calculated values, etc.

Graphic recorder Graphic output unit for graphic representation of work results from a digital computer.

Graphite (black lead, plumbago). An allotropic form of carbon, steel-grey to black, non-transparent plates or hexagonal crystals with a metallic sheen in various particle sizes. Density 2.1–2.3. Used in rust-protective coatings and paints, graphite printing, etc.

Graphite prints Dark printed effects with a metallic sheen dependent on the particle size of the graphite grade used. Fixed on textile fabrics to give prints with serviceable fastness properties.

Graphite stains Mainly dark, dust-like deposits on textiles frequently containing iron as well. The stains are removed in stages: any grease components are first removed with an organic solvent, benzene or white spirit after which the iron stains are removed with a mixture of oxalic acid, acetic acid and water.

Grass bleaching (grassing). A process formerly used for the → Bleaching of linen by spreading the linen out in the fields so that bleaching takes place gradually by exposure to the elements. The process has been almost entirely replaced nowadays by chemical bleaching.

Grass fibres → Esparto.

Grassing → Grass bleaching.

Grass stains Typically yellow-green or green in colour. Removal: a) hot fatty alcohol sulphate/sodium carbonate solution (for white goods); b) ethanol/ammonia in the ratio 10–15 : 1 (warm/hot); c) fatty alcohol sulphate/ammonia solution (warm) with the dropwise addition of hydrogen peroxide 3%; d) dilute lactic acid (warm) with addition of ethanol if necessary, and a treatment of up to 60 min for old stains, then treat with ammonia 5% (for coloured silks lactic acid/ethanol is particularly recommended); e) ethyl ether; f) ethyl acetate/chloroform/benzine soap 2 : 2 : 2, then white spirit. It is often necessary to repeat the treatments.

Gravimetric analysis (gravimetry). A method of quantitative analysis that depends on weighing. Principle: weighed quantity of the substance to be determined in solution + weighed quantity of a known substance in solution = precipitate of known composition from which, after filtration, washing, drying or ignition if necessary, and weighing, the quantitative composition can be calculated (→ Stoichiometry); e.g. according to the equation:

$$AgNO_3 + NaCl = AgCl\downarrow + NaNO_3$$

Although gravimetry usually offers a very high degree of accuracy, it suffers from the disadvantage that it requires careful and time-consuming procedures in comparison with other analytical methods (→: Titrimetry; Complexometry; Colorimetry, etc.). Moreover, the development of considerably less time-consuming quick tests of ever-increasing accuracy have led to a situation where recourse to gravimetry is only required in special cases.

Gravimetry → Gravimetric analysis.

Gravure printing An intaglio printing process using etched copper cylinders or plates. The Fig. illustrates a gravure printing plant for glass fibre matting. In order to achieve a perfectly smooth substrate surface as a prerequisite for gravure printing, it is necessary to apply a ground coat before printing (Ramisch-Kleinewefers), i.e. before print paste transfer takes place by contact between the inked roller and the substrate using an applied pressure (see Fig.). The process is also used for the production of high quality printed papers for → Transfer printing, e.g. for the sublimation transfer printing of polyester fabrics, etc. Very high printing speeds can be achieved (60–120 m/min) in gravure printing.

Grease content → Residual grease content.

Grease milling → Milling.

Grease stains Darker when fresh, generally lighter, and of a more matt appearance when old. In lightly coloured thin fabrics mainly transparent. Grease stains always have blurred edges. Removal: a) white spirit or, better, benzene or carbon tetrachloride, ethyl ether, ethyl acetate, carbon disulphide; b) chloroform/ether/carbon tetrachloride or chloroform/ether/alcohol; c) benzene/carbon tetrachloride 1 : 1.5; d) glycerol/benzene (carbon tetrachloride) 1 : 2 (especially for sensitive coloured goods); e) conc. benzine soap or solvent soap with alcohol if necessary and, possibly, trichloroethylene. Residues removed with benzene and, finally, chloroform; f) fatty alcohol sulphate/detergent solution (neutral) warm (if necessary with glycerol). In the case of particularly resistant stains, the use of increased temperatures, treatment overnight, or repeated treatments (e.g. a repeated drycleaning operation) is recommended.

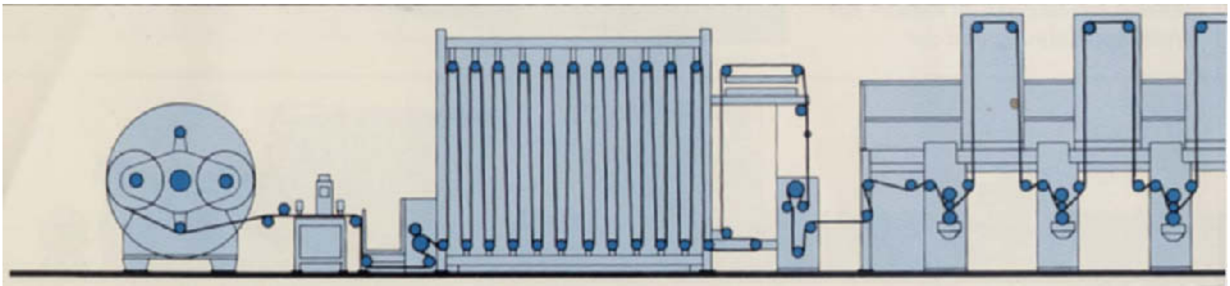


Fig.: Gravure printing plant for glass fibre matting (Kleinewefers KTM).

Greasy lustre Unwanted sheen on fabrics; results, e.g. due to rotary pressing (can be reduced by decatizing), wear “shine” in worsted fabrics, frictional “shine”, etc.

Greasy wool Unwashed → Raw wool.

Greek alphabet Individual letters of the Greek alphabet are frequently used in physical, physicochemical, and chemical terms and are also used as symbols in mathematical and chemical formulae.

Α α	alpha	Ν ν	nu
Β β	beta	Ξ ξ	xi
Γ γ	gamma	Ο ο	omicron
Δ δ	delta	Π π	pi
Ε ε	epsilon	Ρ ρ	rho
Ζ ζ	zeta	Σ σ, ς	sigma
Η η	eta	Τ τ	tau
Θ ϑ	theta	Υ υ	upsilon
Ι ι	iota	Φ φ	phi
Κ κ	kappa	Χ χ	chi
Λ λ	lambda	Ψ ψ	psi
Μ μ	mu	Ω ω	omega

Green Cotton A brand name for T-shirts produced in accordance with specific ecological requirements. Manufacturers of these shirts which are labelled with a number and the inscription “green” are bound by a self-obligation to fulfil the following conditions:

- only cotton grown under ecologically acceptable conditions may be used;
- only the most environmentally-friendly wet processing treatments are to be used.

The material may be washed, if necessary, in the greige state, ie. not scoured, bleached or dyed. The relatively good resistance to shrinkage in washing is achieved by drying in a special tumbler during finishing.

Green eater A characteristic of certain yellow vat dyes of poor light fastness which, in admixture with vat green dyes of high light fastness, promote → Catalytic fading of the latter. → Blue “eating” yellow dyes.

Green ground style A characteristic style of Africa print produced on cotton fabrics that have been prepared with Naphtol AS-G (Hoechst) in which red, yellow resists (Fast Colour Salts or Bases) and white resists are produced by overprinting with sodium thiosulphate as the resist agent. After printing and drying, the fabric is padded all over with an indigo blue dye (in the form of a vat leuco ester with sodium nitrite) and the colour finally developed in a sulphuric acid bath. (The characteristic green ground of these prints is produced by a combination of the yellow naphtol combination and the indigo blue component). → Africa prints.

Greenhouse effect Two environmentally-related phenomena are taking place in the earth’s stratosphere and atmosphere: thinning of the ozone layer (ozone depletion) and increasing amounts of CO_2 in the air (see Fig.). The so-called greenhouse effect, i.e. the gradual rise in average global temperature and the slower dissipation heat from the earth’s surface, is independent of the processes taking place in the ozone layer and is ascribed mainly to the burning of fossil fuels, especially coal, aided by aerosols and other contaminants. Atmospheric research has revealed that the content of trace gases, resulting from human activities, has increased constantly since the beginnings of the industrial revolution. These man-made trace gases include carbon dioxide from the burning of fossil fuels (coal, petroleum, natural gas), methane from the wet cultivation of rice, animal husbandry and poultry farming as well as waste disposal, nitrous oxide (laughing gas) from the earth’s nitrogen cycle, and chlorofluorocarbons (CFC’s).

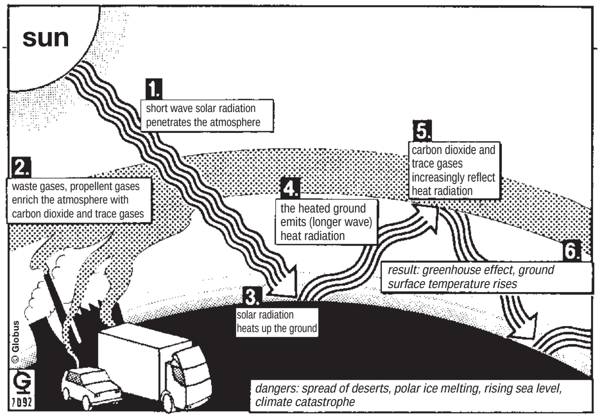


Fig.: The greenhouse effect and its origin.

Greening An unwanted “greening” of dyed and printed colours on textiles, especially blacks, during storage and in wear. The problem is mainly confined to sulphur dyes and aniline black.

Greensand → Glauconite.

Green unripe cotton Cotton seed hairs which have developed too late on the outer skin of the cotton seed or which originate from cotton bolls which have been harvested too early. These immature cotton fibres are thin walled and generally have only few convolutions, in contrast to mature fibres. Moreover, they still contain protoplasmic residues in the lumen. The natural green colour of immature cotton fibres cannot be destroyed by the usual bleaching processes. Cotton with a high proportion of immature fibres is therefore unsuitable for white goods.

Grège Raw silk; the raw silk strands or filaments (reeled from several cocoons), i.e. silk still covered by sericin (gum).

Greiz-Geraer fabrics (Greiz-Geraer ladies’ dress fabrics), obsolete German brand name for fine worsted fabrics made of merino wool, plain coloured or patterned, and in designs following Paris and Milan fashions. In the "Greiz-Geraer genre", 80% of the ladies' dress fabrics were woven in worsted spun yarns and 20% in pure silk.

Grenadine,

I. Silk yarn produced from doubled twisted → Organzine but with a higher degree of twist organzine silk).

II. A term used for various fabrics. That produced with a silk warp and worsted or mercerized cotton weft is called satin grenadine which is executed in a satin weave. The term also applies to a lightweight, almost transparent, type of → Étamine (silk/mercerized cotton) and fine loosely-woven women's dress materials similar to marquisette, or damask type fabrics. The term has also been used for fine stockings (viscose filament), from which crêpe stockings (yarns with a half voile twist) were developed (1933).

Grey goods inspection → Inspection of incoming goods.

Greying inhibitors for laundry detergents An explanation of the mode of action of these substances is as follows: soil in the wash liquor is first detached from the fibre and then prevented from redepositing on the fibre surface during rinsing by preferential adsorption on to the greying inhibitor. In the first phase of rinsing, the dissolved and dispersed soil is transported away and in the second phase, the adsorbate/synthetic fibre/greying inhibitor is broken down again so that these substances are also transported away in the rinsing water. Carboxymethylcellulose has proved particularly effective as a greying inhibitor for cellulosic fibres, whilst hydrophilic polyamide and polyester oligomers are recommended for polyamide and polyester fibres. The most effective greying inhibitors are mainly water-soluble high molecular weight compounds which are adsorbed strongly both by textile substrates as well as soil pigments. The adhesion of certain cellulose ethers is, e.g. so great that they are not even removed from garments by rinsing and such compounds have a soil-repellent action. Greying inhibitors have increased in importance due to the changes in detergent recipes and lower washing temperatures.

Greying of textiles in drycleaning The problem occurs mainly by redeposition of the previously loosely detached soil, dye particles or fibre lint (abraded fibres) in a now more finely distributed form from the solvent, or the small amounts of water in the drycleaning detergent (Fig. 1), on to the textile material, with the participation of electrostatic attraction forces between fibre and soil. Preventive measures include, e.g. filtration using filters of adequate dimensions, the use of drycleaning detergents with good soil suspending properties, efficient rinsing and, especially, the additional application of antistatic agents.

Excessively long drycleaning cycles, especially in soiled liquors, are to be avoided. Greying values (Fig. 2) between 30 and 50% relative humidity (RH) reach their lowest state at 50% RH and rise constantly again, under certain circumstances, until the point at which soil detachment is exceeded from approx. 75% RH. The range from 75–80% RH corresponds to optimum cleaning = maximum removal of water-soluble soils. A further increase in the RH results in pronounced yellowing; for the procedure used for measuring the degree of whiteness see → Yellowing during wear.

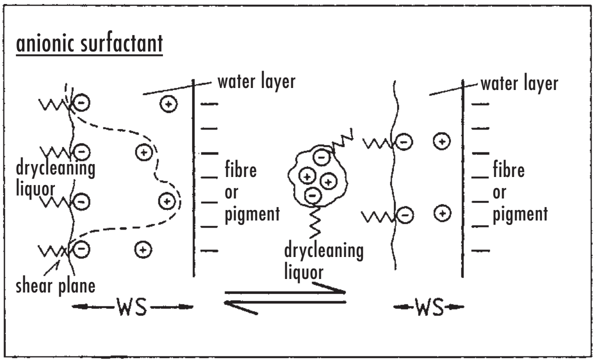


Fig. 1: Model presentation of the structure of surface charging in the adsorption layers (WS) of the water on the fibre surface and its shearing by the cleaning mechanics.

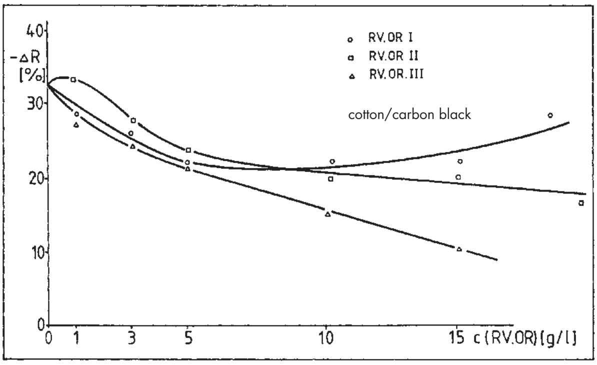


Fig. 2: Greying of cotton relative to type and concentration of drycleaning detergent.

Greying of textiles in washing A problem caused by the use of wash liquors with insufficient soil suspending properties, i.e. inadequate dosage of detergent. For the procedure used to measure the degree of whiteness see → Yellowing during wear.

Grey scales for colour fastness testing,

I. Grey scale for the assessment of staining (BS 1006 A03: 1990). Consists of a scale of 5 pairs of grey and white coloured plates in which each pair of plates indicates a different degree of contrast with the 5 full steps being arranged in geometrical progression. The degree of staining of the adjacent (undyed) fabric specimen subjected to a colour fastness test together with the dyed (or printed) textile specimen is assessed by placing the adjacent fabric next to the dyed (or printed) test fabric and comparing the degree of contrast against the grey scale. The number of the contrast pair in the grey scale (from 1–5) which corresponds as closely as possible to the degree of staining is noted and serves as the fastness rating. Half steps are provided in the grey scale to improve the accuracy of assessment:

1 = heavy staining,
2 = moderate staining,
3 = medium staining,
4 = slight staining,
5 = no staining.

II. Grey scale for the assessment of change in colour (BS 1006 A02: 1990). Consists of a scale of 5 pairs of grey-coloured plates in which each pair of plates indicates a different visible degree of contrast. In a like manner to that in (I) above, the visual difference between the grey scale and the test specimen is compared and rated as follows:

1 = very poor (severe change),
2 = poor,
3 = fairly good,
4 = good,
5 = very good (negligible change).

Besides the numerical rating for change in colour, the rating may be supplemented by a letter to indicate an accompanying change of hue or brightness, e.g. D = duller, Br = brighter, R = redder, Y = yellower, Bl = bluer, G = greener.

Grey series According to Ostwald, grey is that non-chromatic colour between black and white. The entire series of non-chromatic colours from white through grey to black is known as the grey series or grey scale. It consists of 8 colours referred to by standard letters, a (white), c (very pale grey), e (somewhat darker grey), g, i, l, n, p (deepest black), which can also be combined as a degree of → Saturation (greyscale) in the case of shades with the shade number of the chromatic circle. → Pure spectral colour.

Grey tufted carpets Tufted carpets, back coated only and held in store. Only after an order is received is the carpet cut to the required size, piece-dyed and dispatched.

Grinding burrs As a final stage in the grinding of doctor blades for printing, the grinding burrs which are formed along the edge of the doctor blade after it has been filed to the correct angle are removed from both sides of the ground edge with an oil stone.

Grinding machine,
I. → Sanding.
II. → Doctor blade grinding machine.
III. → Shearing blade.

Grinding machine for shearing knives A machine used for grinding and sharpening the helical shearing knive cylinders used in shearing (cropping) machines, i.e. precision sharpening of the upper cylinder and lower knife to ensure an absolutely uniform fit between the two (see Fig.).

Grinding mill In order to comminute disposable plastic materials (especially disposable plastic dye tubes) a shredder is first used for coarse comminution followed by treatment in a grinding mill for the production of small granules.

Grinding stone for printing rollers A special grinding stone used for repairing and polishing engraved copper printing rollers.

Grinning,

I. A term used in textile printing to describe a printing defect in the form of small, unprinted areas in a design caused by the printing of colours bordering each other with screens or printing rollers where the engraving allowance for the bordering colours has not been sufficiently generous to ensure an unbroken border between the adjacent colours thus allowing small white (unprinted) areas to “grin” through.

II. In dyeing: lighter appearance of a fibre type in dyeing mixed fibre fabric. In printing: irregular or light-coloured, unprinted places, poorly wetted out as a result of too highly concentrated thickener (→ Print definition).

Gripper Axminster A machine-woven velour carpet in which the differently coloured dyed yarns for

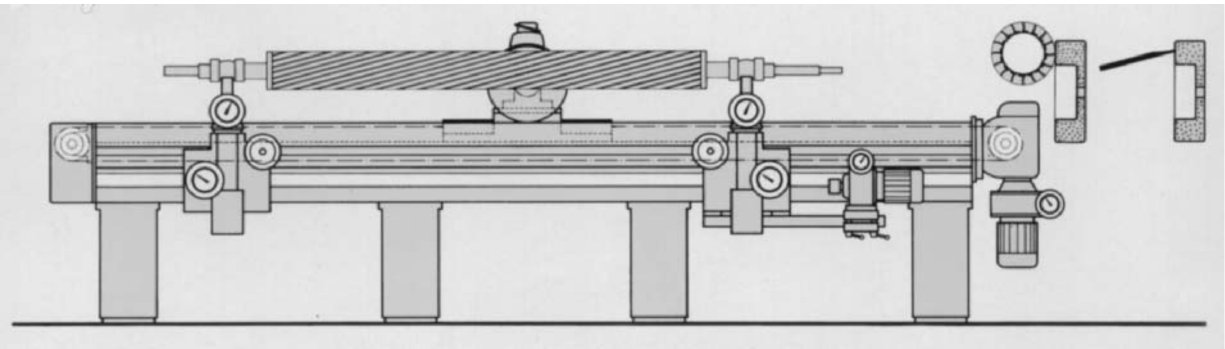


Fig.: ESB model grinding machine for shearing knives (Menschner); max. roller width 6000 mm.

the warp pile are supplied as required from bobbins carried on a creel behind the weaving machine. Jacquard-operated yarn carriers present the appropriate coloured yarns to the grippers which grasp the required length of pile, which is then severed. The grippers, holding the tufts, then swing down to insert the tufts of yarn at the point of weaving across the entire width of the carpet. The maximum number of colours is usually limited to 8 but may be as high as 12.

The design of a gripper Axminster is also clearly recognizable on the back of the carpet.

Gripping clamp in screen printing Serves to grip the screen gauze. Broad tabs faced with sandpaper hold the screen more effectively than can be achieved by hand tensioning.

Grooved embossing → Embossing.

Grooved roller Application roller with grooves. The depth and spacing of the grooves are dimensioned in such a way that one warp thread is assigned per groove. The main use is for sizing warp yarn. Warp yarn finishing processes are also possible.

Gross A unit of quantity equal to 12 dozen = 144.

Ground The background of a patterned textile which provides a contrast in weave, colour or profile (embroidery) to the design. In printed fabrics the ground is either the white (unprinted) background of a printed design or the coloured (printed) background of a multicolour design.

Ground colour (carpet). In true carpets, the colour of the area against which the pattern (motif) stands out in other colours.

Groundnut fibre → Arachin fibre.

Ground water Subterranean stagnant or flowing water which occupies cavities in the earth's crust in a coherent manner. Depending on their origin, different chemical constituents are dissolved out of the rock (minerals, alkalis, sulphates, chlorides, water hardening substances, iron, manganese etc.) or soil (nitrites, nitrates, humic acid etc.) as water flows through.

Ground white Substrate luminance (depth of bleaching) after pre-treatment and bleaching; its importance for max. luminance is shown in the Figure, taking cotton goods as an example.

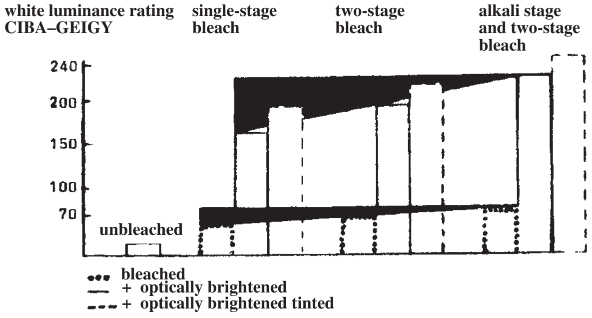


Fig.: Luminance on cotton goods which have been subjected to different pre-treatments.

The lower black wedge shape demonstrates the intensification from 1-stage bleach through 2-stage bleach to 2-stage bleach with prior alkali stage, with the luminance rising from 63 through 69 to 78. However, as can also be seen from the upper black wedge, the relatively low difference in the depth of bleaching has a much greater effect on the whiteness of goods which have already been brightened, for here the luminance rises from 164 through 194 to 222. Accordingly, here the increase in ground white through good pre-treatment or bleaching brings about a 4-fold increase in luminance in the case of optically brightened goods. As the corresponding columns in the diagram show, additional toning or blueing leads to a further increase in luminance. Even in the case of optimum bleaching and brightening, the luminance can consequently be increased some more by this means. Thus small increases in ground white have a very positive effect on the luminance of optically brightened goods. On the other hand, even slight deterioration in the ground white (e.g. through poor stability of the bleach) has a very noticeable negative effect on the final luminance. As a rule of thumb for prescribing toning additives for optical enhancement, one can assume that this can also be established on the basis of the reflectance curve (exception: samples with a strong yellow cast, frequently declining reflectance, a saddle point occurring after optical brightening in the green zone on the right next to the fluorescence point, which imitates the effect of a dye additive). In the case of optically brightened and toned samples, conclusions concerning the ground white can be drawn only from the reflectance level on the long-wave spectrum end (700 nm), but even that is no longer possible with heavy toning and in the case of turquoise dyes. For this reason, the aim is to achieve a high ground white or good bleaching, since then less blueing material is needed; greying and loss of brightness are thus to be kept as low as possible.

GSA (Am.), abbrev. for: General Services Administration; American Standards Organization.

GSB test Test for determining the maturity of cotton, otherwise called the Red/Green Test or simply → Goldthwait test, devised by Goldthwait, Smith and Barnett.

Gu → Guanaco, → Abbreviation according to DIN 60001 until 1988, as from 1991 now designated → WU.

Guanaco The yellow-brown hairs of the guanaco, a llama-like animal that roams wild over a large area of South America. Guanaco belongs to the group of → Natural protein fibres. Only the under hairs are of textile value. The fibre is extremely soft and silky, the finer hairs are approx. 20 µm and the coarse hairs approx. 75 µm in diameter. Guanaco hairs have about 118 scales/mm. The fibre is of little economic importance. → Animal fibres.

Guar gum (Guaran), Asiatic type of gum (Cyanopsis tetragonoloba), fraction of the endosperm ground from the seeds (diameter approx. 5 mm) of the guar plant, a grey-white powder comprising 65% mannose and 35% galactose (→ Galactomannan), aqueous-colloidal neutral solution, has an approximately 8-fold starch thickening power, and is used as a fine powdery thickener in carpet printing and dyeing processes, amongst other things (see Fig.).

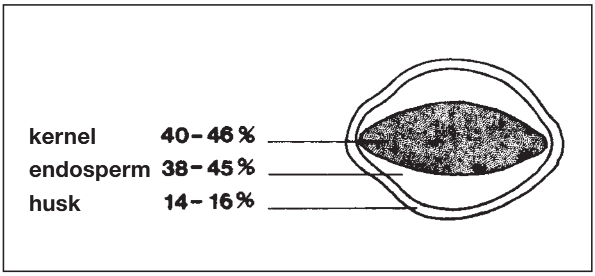


Fig.: Section through a guar seed.

Dispersibility: Hydrophilic guar gum is difficult to disperse (rectify by pre-mixing with alcohol or glycerine, as well as through more intensively-acting homogenizers), whereas easily dispersible guar gum derivatives in vigorously stirred water are considerably easier to handle. Such dispersible guarans require the addition of acid for hydration, through which complete dispersion is assured before viscosity increases. Hydration through the addition of acid must be initiated only after thorough dispersion; to avoid critical situations, possibly with initial adjustment with weakly ammoniacal water. Water temperature has a great influence on the hydration time: the colder it is, the slower the rise in viscosity; however at low temperatures, higher end viscosity can be achieved. For this reason, control/regulate the water temperature as precisely as possible. Once lumps have occurred they are insoluble, even when high shear forces and longer hydration times are used. Lumps can be caused by poor quality of guar gum, incorrect procedures, extreme water temperatures, pH too low. Avoid lumps by fast and even incorporation whilst stirring vigorously, monitoring the temperature and pH. The viscosity of guaran solutions is heavily dependent on temperature and on concentration (logarithmically, not in a linear manner), i.e. doubling the concentration can lead to a 10- to 15-fold rise in viscosity (small metering variations can cause large variations in viscosity). Fully effective increase in viscosity requires good dispersion. Under normal mixing conditions, with guar gum 95% of the maximum achievable viscosity is reached in 30 minutes, whilst guar gum derivatives hydrate even more quickly. Microbial attack can cause drastic losses in viscosity: for this reason, ensure absolutely clean working and storage conditions, as well as proper use of preservatives where printing pastes are stored for longer periods. Additives should best be added only after complete hydration; one must take into account the tendency of some dyestuffs to gel at high concentrations (possibly add counteracting agents), and also the fact that most guaran derivatives can even gel under alkaline conditions unless specific additives are used in accordance with the manufacturer's recommendations. In the alkaline range, guar gum can gel in the presence of borate ions and antimony ions, whilst oxides of lead, cobalt, antimony and chromium ions encourage gelling in the acid range. Guaran solutions are relatively stable in the presence of most acids at pH 2 and at room temperature, whilst oxalic acid in the presence of iron very quickly lowers the viscosity through acid hydrolysis. The oxidative breakdown of the galactomannan (and other water-soluble polymers) is catalysed by iron ions and tin ions, accelerated by sequestering agents (EDTA); for this reason, polyphosphates are more suitable than EDTA.

Guide pins Brass pins on the → Block for pattern repeats.

Guide rod Fixed rod for guiding the cloth.

Guide roller Device, fitted on textile machines, for guiding the cloth by means of an idler roller which rotates freely as the cloth is passed over it. The purpose of guide rollers is to ensure the correct passage of the cloth, i.e. at low tension, and free of creases (poor guide rollers are the main cause of creasing). With regard to low-tension travel, the weight of the roller is critical: a high dead weight impedes free running characteristics, since the frictional forces in the bearings are dependent on the load, and the inertia increases in proportion to the mass. As a result, high tensions occur as the cloth starts to run. For crease-free cloth guiding, the necessary conditions are achieved only with sufficiently rigid guide rollers. If a guide roller sags, then the cloth migrates to the centre and forms creases, with the material usually lying in three layers one over another. Here, the outer layer is stretched more than the inner one, and through stretch tension, compression forces arise which act on the cloth lying underneath, which can lead to lasting crease marks. The smaller the guide roller diameter, the greater the outer layer is stretched. Guide roller flexing is prevented by inelastic roller material (high modulus of elasticity) and by large diameter. With regard to the crease marks, a large roller diameter is thus the better solution.

Rollers with special steel coatings and special steel journals are predominantly used. A strong core barrel with a wall thickness of 6–7 mm in plain steel is the load-bearing element. This tube is encased in a no-knock stainless steel sheath 1.5 mm thick. The stainless steel journals are pressed-in hydraulically and welded to the stainless steel sheath. Guide rollers with diameters of 100/125 mm are specified as standard equipment. For more demanding requirements, i.e. at higher speeds, larger widths or more delicate fabrics, diameters of 125/150 mm are used.

Industrial trials of guide rollers with a steel barrel and those with a barrel of glass fibre reinforced plastic show that GFRP (glass fibre reinforced plastic) rollers offer advantages with regard to crease-free passage of the cloth, due to higher specific flexural strength (approx. 4–5 times higher than for steel and for larger diameters); as a result, higher loadings are possible in the short-term without permanent roller deformation. The surface roughness of smooth-ground GFRP rollers is superior to that of smooth-ground stainless steel rollers (the surface smoothness of GFRP rollers is particularly advantageous where there is any risk of contamination by dyestuff/finish). Currently, GFRP rollers can be used in dry/damp air at up to 120ºC, taking into account mechanical stress. When submerged rollers are used, the roller strength must be considered in conjunction with temperature and mechanical stress.

Guide roller bearings Guide rollers and their bearings are important components in open-width washing machines, since it is essentially on these that a crease-free and low-tension cloth travel depends. The dimensions of vats are independent of the guide roller diameter; rollers which are not submerged do not dip into the liquor and thus run dry (Fig. 1).

All machine types have carbon bearings for submerged guide rollers as standard equipment. These are mounted in pendulum bearings with zero backlash. Lubrication is via the liquid in the trough (Fig. 2). The stainless steel mount can be removed quickly and easily for replacing worn carbon bearings. The pendulum bearings merit special emphasis, thanks to the design (in contrast to horizontal bearings); one thus achieves automatic compensation without edge pressure (Fig. 3). Non-submerged guide rollers run in roller bearings in all cases. For more demanding requirements, external bearings are used, with the stainless steel journals being externally sealed against the vat wall by a rotating carbon slip ring (Fig. 4). This provides a roller bearing mount. This results in speedier replacement, smoother running, lower maintenance, acceptance of high tensions, perfect long-term parallel alignment of the rollers.

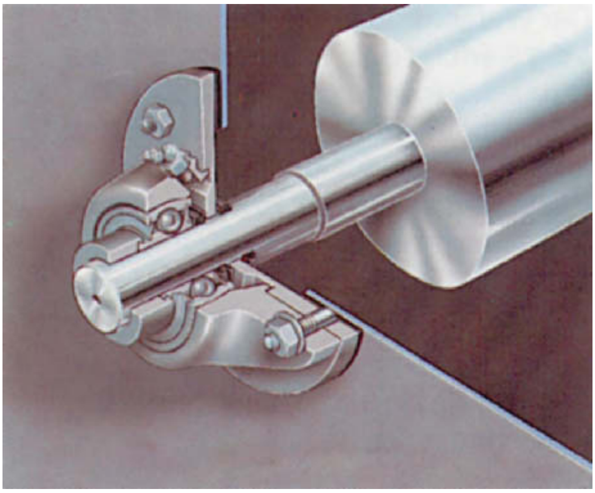


Fig. 1: Dry-running guide roller.

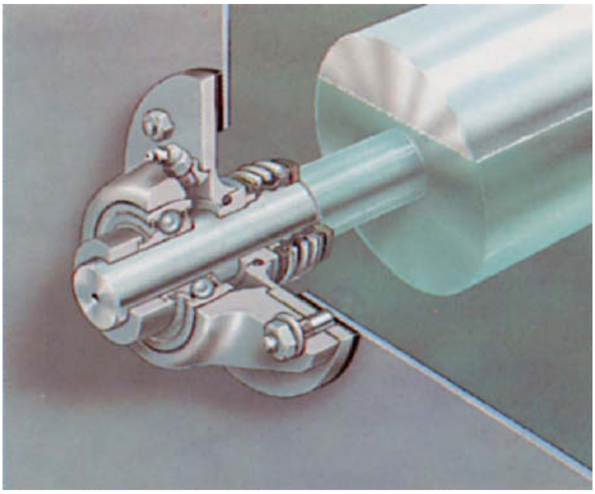


Fig. 2: Guide roller with under-liquor seal.

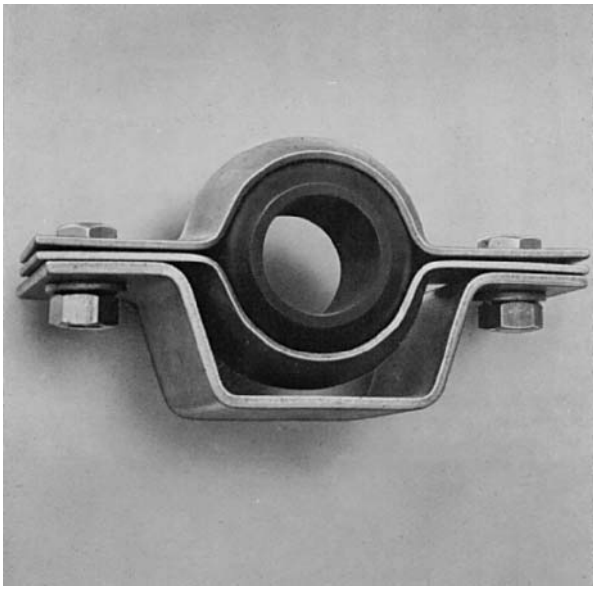


Fig. 3: Dry roller bearing, interior (carbon bearing).

Guide stops Guide stops are used in hand screen printing on tables to achieve more accurate register of difficult or very intricate designs. For this purpose, the

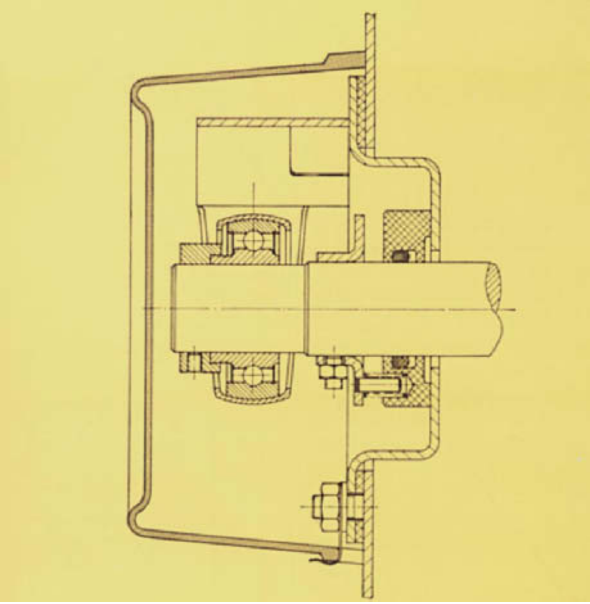


Fig. 4: In-vat roller bearing, exterior.

screen repeat is assisted on both sides of the printing table. Movable guide stops are attached to rails at each side. The stops for the design repeat (→ Printing screen locking units), which determine the repeat length as well as the transverse position of the screen frame, are positioned along one side of the printing table. The guide stops, which have the task of maintaining the screen at right angles to the fabric being printed, are fixed along the opposite side.

Guideline concentration → Technical guideline concentration.

Gum arabic Senegal gum, acacia gum, African vegetable gums which contain up to 80% arabic acid. Most highly prized is gum kordofan from Sudan (2 cm droplet length, slightly yellowish or of a deep amber colour, rarely colourless). Much less pure is Geddah gum from the area around Aden (grainy, deep yellow, brown to black; when dissolved leaves quite heavy insoluble sediment), similar in appearance and quality to Moroccan mogador gum.

General facts about gum arabic: the colour is pale yellow or brownish to reddish-brown/black, droplets 1-2.5 cm diameter, glassy on the inside, cracked and clouded on the outside, globular, longish, droplet-shaped, worm-shaped; fractions (grains) up to 1 mm diameter. Good gum (soaked overnight) is fully soluble in twice the amount of water (100 g per litre = approx. 5°Bé); solution almost clear, thick, slimy, rather sticky, weakly acidic. High adhesive strength requires high viscosity. The polarity of solutions is laevorotatory. Precipitations by sodium silicate, sodium tetraborate, albumin, ferric chloride, pure yellow with iodine solution; tannins do not cause precipitation. Applications: finishing auxiliary, printing thickening, for producing emulsions, etc.

Gum precipitate Isotropic electrolytic soap solution which may be separated from the neat soap after the finishing stage of soap production by either settlement or centrifuging.

Gums → Vegetable gums.

Gum tragacanth → Tragacanth.

Gütegemeinschaft für sachgemäße Wäschepflege (GG – Quality association for the proper handling of laundry). → Technical and professional organization.

Gütezeichenverband Textilveredlung e.V. (GüTV – Quality label association for the textile finishing industry). The purpose of this association is to promote the concept of quality in the textile finishing industry, to create quality labels and to set up rules for quality labels, with minimum requirements for the use of the quality labels, monitoring of the established minimum requirements with the involvement of independent public institutions, and initiation and implementation of corresponding promotional features.

Gütezeichen Weißmaßstab (White scale quality label). This quality label is awarded by the → Gütegemeinschaft für sachgemäße Wäschepflege e.V. and the Hohenstein research institutes, produced and issued on the basis of the Ciba-Geigy white scale (cotton). Aid for determining the degree of whiteness and shade variation.

Gutta percha (trans-polyisoprene). The name is derived from Malay getah = gum + percha = name of a tree from which it is extracted. A natural latex product, similar to rubber, from the latex of any of several tropical trees of the sapotaceous genera palaquium and payena. It can be vulcanized with sulphur. Gutta percha is brown to grey-white (purest grade: white) in colour. Pure gutta percha ($C_{10}H_{16}$) is a stereoisomer of polyisoprene). Properties: stiff, hard, and inelastic, but not brittle, when cold; thermoplastic, combustible; insoluble in water, soluble in chloroform, carbon disulphide, as well as in warm turpentine oil. Gutta percha is harder than rubber and is a better (electrical) insulating medium. It is obtainable in both liquid and dried forms. Applications: gutta percha bottles, container linings, formerly used for insulating electrical submarine cables before the introduction of plastics, also formerly used widely for golf ball covers. It may be used for painting on silk in the form of a solution with a honey-like consistency to produce resists on the fibre (it forms a film on drying which is impervious to water and dyes) and thus makes separation lines in coloured designs possible (similar effect to window leading in stained glass church windows). Gutta percha bottles are used, inter alia, for conc. hydrofluoric acid (spotting agent).

GüTV → Gütezeichenverband Textilveredlung e.V. Quality labelling association for the textile finishing industry.

Gypsum Hydrated calcium sulphate, ($CaSO_4 \cdot 2\,H_2O$). Gypsum has a low solubility in water (approx. 0.26% at 20°C). It is a component of permanent water hardness (→ Dried gypsum) and calcium precipitations in processing liquors as well as calcium deposits on textiles (→ Lime soap). It is also present in → Boiler scale.

Gypsum expansion Concrete cancer, the harmful effect of sulphates (→ Sulphate hardness of water) on mortar. This involves an initial formation of gypsum from the lime in the mortar, then to double bonds with the mortar (calcium aluminate), crystallises out in the presence of a volume of water (calcium sulphoaluminate). Consequence: strong crystallisation pressure, splitting of the mortar structure, structural damage. Penetration of a sulphate solution into concrete leads to a so-called "cancer" growing inside the hardened cement as aluminium compounds form calcium aluminium sulphate hydrate ($3\,CaO \cdot Al_2O_3 \cdot 3\,CaSO \cdot 32\,H_2O$), which, as ettringite takes up more space than any of the original compounds in the concrete ($3\,CaO \cdot 2\,SiO \cdot 3\,H_2O$; $3\,CaO \cdot Al_2O_3 \cdot 6\,H_2O$), and can lead to cracking and brittleness of concrete structures (e.g. in sewer pipes). This process of expansion is different to the simpler dissolving out of the concrete constituents, which can lead to a hollowing of concrete structures. A determination of maximum concentrations (e.g. 400 mg/l SO_4^{2-}) is therefore useful and can be met by diluting effluent containing sulphates and passing them through plastic pipes in the immediate vicinity of a textile finishing process, or until they achieve the required degree of dilution. Meeting relevant legislation may initially be costly and difficult to implement (e.g. installing plastic piping), but overall, the textile finisher is protected from the consequences, including those which may result from the polluter pays principle, if extensive sulphate damage is caused to the drainage or sewage systems.

H

H, chemical symbol for hydrogen (1).

h,

I. Symbol for → Hecto- (prefix indicating 100, as in hm = hectometre), factor 10^2.

II. Abbrev. for hour.

HA,

I. → Hairs, → Standard abbrev. for textile fibres, according to the → EDP code.

II. → Hemp, → Standard abbrev. for textile fibres, according to DIN 60 001 T4/08.91.

Ha, → Hemp, → Standard abbrev. for textile fibres, according to DIN 60 001 until 1988, from 1991 → HA.

Hackling A mechanical process given to flax stems after → Scutching. Its purpose is to remove short fibre, motes (or neps) and non-fibrous material. Hackling involves drawing the fibres through inclined steel combs, each successive comb being finer than the previous one. As a result, the coarse bundles of fibre are separated into finer bundles and the fibres are thereby aligned parallel to one another. The outcome is approx. 20–70% hackled flax (long fibre), 60–20% flax tow (short fibre) and remaining motes. → Flax processing.

Hair dye stains These stains vary in type and appearance; frequently brown to brownish-black in colour. In most cases, old stains cannot be removed. Removal: a) white spirit or solvent soap (warm), followed by ammonia 5%, and finally hydrogen peroxide 3% or dilute hypochlorite bleach liquor; b) Höllenstein brown (typical hair dye) can be removed as under a) above followed by the treatment recommended for → Silver nitrate stains.

Hair felt → Felt.

Hair fibres This group includes all animal fibres with the exception of wool (→ Natural protein fibres).

Hairiness A term used to describe the projection of free floating fibre ends or loops from the surface of a fibre assembly (Fig. 1). It is a desirable characteristic in raised, brushed, fleecy fabrics (confers good heat retention properties). However, hairiness reduces the strength of yarns. Undesired hairiness can be influenced within certain limits, i.e. in spinning and also by subjecting the material to various aftertreatments mainly by shearing, singeing and dressing. It is possible for hairiness to cause warp yarns to "cling" during movement in the shed of the weaving machine (warp yarn breaks). The German textile machinery manufacturer Osthoff has developed a hairiness tester (which determines the degree of hairiness on running webs by means of an opto-electronic scanning system (Figs. 2, 3

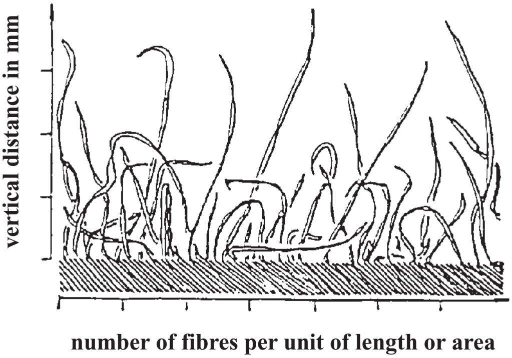


Fig. 1: Sketch illustrating hairiness on a fabric surface.

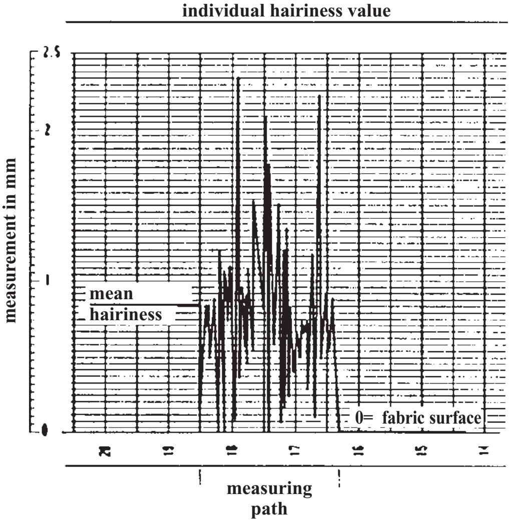


Fig. 2: Measurement curve of a hairy surface.

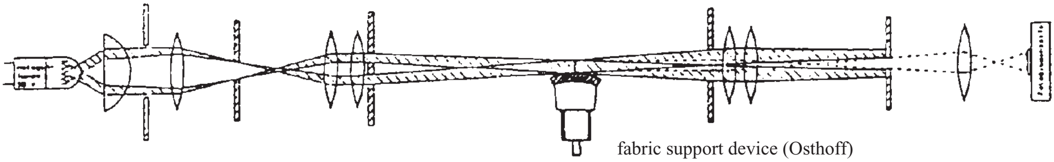


Fig. 3: Principle of the scanning beam system in the hairiness tester (Osthoff).

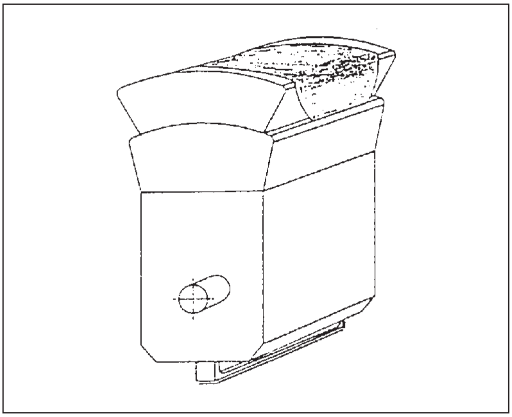


Fig. 4: Fabric support device (Osthoff).

and 4). This system was primarily designed to measure the hairiness of fabrics after singeing but can also be used to measure the pile height after raising or emerizing.

Hair linings Interlinings with a finish to give elastic resilience. The main purpose of the finish is to provide good recovery from deformation (highly dependent on the hair content of the weft). For these applications, horsehair in particular (→ Horsehair lining), goat hair, camel hair, mohair, alpaca as well as spun viscose in coarse counts are used. The hair fibres are often blended with wool or spun viscose. Wool, cotton, spun viscose or blend yarns are used in the warp.

Hair migration A disadvantage of → Hair linings caused by the hairs gradually working their way through the outer fabric after repeated dry cleaning thereby forming a nap which is visible on the fabric surface. It is particularly noticeable in dark materials. The problem can be solved by laminating.

Hair mordants (before milling), → Mordants for animal fibres.

Hair papilla → Human hair.

Hairs →: Natural protein fibres; Human hair.

Hai-Tao A variety of Asiatic algae with a flat fibrous structure, approx. 30 cm long. Swells in cold water and dissolves in hot water (as a mucilage); the solutions gelatinize again on cooling. Used mainly in Asia for the production of soft finishes, especially on fine fabrics (in combinations with starch or dextrine for cotton finishing).

Hajdu-method These include the Siotex process and the texylon process invented by Hajdu to improve the abrasion resistance of textiles. Principle: the deposition of silicon particles on textile materials.

HaKa A German acronym for “Herren und Knabenoberbekleidung” = men’s and boys’ outerwear. → DOB.

Half-bleach A term used to describe a bleaching effect which is adequate for goods to be subsequently dyed (but not for whites).

Half-dyeing, time of The time taken in minutes for a textile substrate to absorb 50% of the dye it will absorb at equilibrium under the same conditions. As a dye characteristic, it is less suitable for the selection of combination dyes for dyeing acrylic fibres with cationic dyes. In this case, the → Compatibility value K, is a much more reliable parameter.

Half emulsion Combination of an → Emulsion thickener and a conventional thickener (e.g. alginate). Used in direct printing for the application of most dye classes with the exception of indigo and oxidation dyes.

Half-milled hat bodies (half-planked felts). Premilled → Hat body for the production of felts.

Half resists →: Half-tone resists; Resist printing.

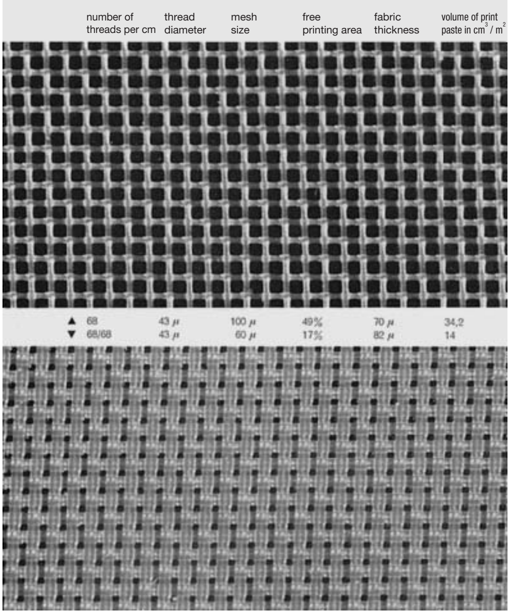
Half-shadow photometer → Colour measurement.

Half-tone Tone-in-tone effects in printing, i.e. a range of tones or tonal gradations in addition to the full depth tone with a sharp or gradual transition from the latter. → Half-tone process.

Half-tone autotype screens Half-tone effects in screen printing are produced with the aid of a cross-screen (autotype) grid which breaks up continuous tones into rows of dots of different sizes, i.e. large dots for darker areas and smaller dots for lighter areas. Since the human eye can no longer distinguish small dots below a certain size, they appear to merge into gradations of progressively weaker tones corresponding to the different sizes of dots. There is a certain relationship between the dot size and the viewing distance. In textile printing, half-tones between 20–40 are used, i.e. 20–40 half-tone dots per cm, where the spacing between the dots is dependent on their diameter.

When half-tones produced in this way are used to prepare printing screens, there is a risk of moiré formation (interference patterns) unless the angle of the half-tone positive is appropriately adjusted relative to the printing screen mesh.

Half-tone printing on textiles Unlike the continuous areas of colour in normal prints, half-tone prints consist of numerous closely spaced small dots which cannot be detected by the naked eye but give the impression of a shaded print surface. This is only possible if the dots do not collapse and are still present after fixation of the print paste has been carried out since otherwise the half-tone effect would disappear. Compared to half-tones on paper, which has a much smoother surface, textiles require a considerably smaller number of dots, i.e. a coarser cross-line → Screen with a maximum density of 30 dots/cm = 900/cm^2 or, for screen printing, only 12–20/cm = 144–400/cm^2. By interposing a cross-line screen of this type and colour filters, the negative of the original design is obtained with the reproduction camera and, after copying on to film, can be joined together to produce large diapositives from which the design may be transferred to the screen with a printing frame (for flat screen printing). By using different half-tones, variable print effects are obtained. For example, a seven-colour print effect may be achieved with just three printing screens if two of these screens contain, in addition to the full tone, a further two half-tone gradations in each case. Half-tone printing therefore allows the production of multicolour prints with various tonal gradations. It is, however, necessary to take into account the greater sensitivity of half-tone screens, e.g. with regard to mechanical damage, screen blocking, etc. To obtain more durable and, in particular, moiré-free screens, the mesh density (number of individual threads/cm) should be 1.5–2.5 times or 3–4 times greater than the half-tone density (Fig. 1). The angular position between the half-tones and the thread system of the screen gauze should be adjusted to 4–5° but never to 0°, 45° or 90° (which nearly always results in moiré formation). In 4-colour printing, the angle of the half-tones in the colour separations is adjusted to, e.g. 5°, 35°, 58° and 81° in relation to the printing screen mesh. Satin and taffeta weaves have proved particularly suitable for



	number of threads per cm	thread diameter	mesh size	free printing area	fabric thickness	volume of print paste in cm^3 / m^2
▲	68	43 µ	100 µ	49%	70 µ	34,2
▼	68/68	43 µ	60 µ	17%	82 µ	14

Fig. 1: Comparison between a normal screen gauze and a screen gauze with reduced open area for lower print paste throughput in flat screen printing.

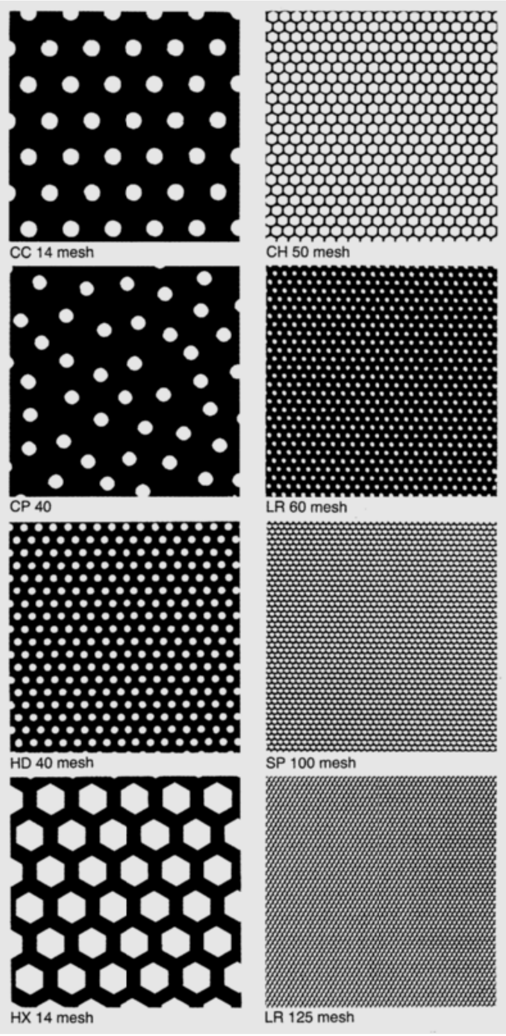


Fig. 2: Different screen mesh sizes of Stork rotary screens.

half-tone printing. In addition to the so-called cross half-tones, net half-tones (completely uniform mesh) are used for more precise shading, circular grain and worm grain half-tones (which produce an image in irregular dots with a “hammer blow” effect) are employed for somewhat coarser prints. Finally, structural effects may be achieved in printing if normal commercially available structural or half-tone films are also used in transferring the negative on to the screen. Thus, with the aid of the Idento(graphy) process, tonal gradations are achieved with transparent (Idento) film embossed with a grain effect and drawing over it or tracing with a black litho crayon. The colour difference is then reproduced in half-tone dots of varying size by the application of fairly intense pressure. The embossed film with the design can be used directly as a diapositive for copying on to the screen as long as the design repeat extends over the entire screen.

The production of designs on galvano screens demands considerable experience. In principle, there are two possibilities, the first of which is the least laborious. A uniformly thin light-sensitive coating is applied to steel mandrels of exactly the same diameter with smooth polished surfaces then, after drying, the half-tone colour separations obtained by photo-mechanical means are copied on to them (Fig. 2). During subsequent development, the light-sensitive emulsion dissolves out of the non-exposed areas. Nickel is then electrodeposited by galvanic means on to the steel mandrels, which are now covered with the design as half-tone dots, in a suitable rapid nickel deposition plant using appropriate nickel salt solutions. The cylindrical nickel covering which results from this process is then perforated in those areas wherever the half-tone dots in a colour separation are present. During the nickel deposition stage, care must be taken to ensure that uniform, homogeneous layers of metal are formed which should be as thin as possible.

In other cases, steel matrices which have been given a half-tone grid in dot form over their entire surface, taking care to position the half-tone at a suitable angle, are coated with a light-sensitive layer and the colour separations containing no half-tones are copied on to them. After development, the half-tones in the exposed areas are covered, but still remain in the unexposed areas so that during subsequent nickel deposition, perforations corresponding to the areas of the design are formed in the all-metal screens.

Half-tone process A process for the production of half-tone effects or tonal gradations. Two methods are used in practice, i.e. half-tone resists and half-tones produced with film. Half-tone resists are obtained either by using several screens with progressively weaker print pastes or by preprinting or overprinting → Half-tone resists on full depth print pastes. These resists affect the fixation of the preprinted or overprinted colour pastes thereby giving weaker printed shades in these areas. Half-tones produced with film achieve the tonal gradations by using screens which allow all the print paste to pass through for the full tone but which only allow part of the print paste to pass through the half-tones thereby breaking up the printed surface into smaller areas. By varying the proportion of white area lying between the printed half-tones, a reduction in the depth of colour is obtained. The individual elements within the printed areas can be uniform in shape, in which case they are known as autotype gradations, or irregular in shape with different grained effects (e.g. circular grain, worm grain or Idento half-tones). No special screen-making technique is involved in the half-tone process since the half-tone cross-screen grid is already present on the negative or positive and transferred in this form on to the screen gauze by the methods described.

Half-tone resists Resist effects produced by pre-printing a colourless print paste, i.e. containing no dye (with or without the inclusion of resist agents) followed by overprinting with a normal coloured print paste. A lighter colour is produced in those areas of the printed design where the second print paste falls on the first. Pre-printing with a high solids content thickener alone will already give a certain resist effect which can be further intensified by the addition of a white pigment (e.g. titanium dioxide, zinc oxide) or a white pigment incorporated into a plastics dispersion (= matt white).

Half-tone screen A half-tone screen is used to produce a range of tonal gradations by covering some parts of the screen’s printing surface with very fine mesh gauze and other parts with coarser gauze. Some parts of the screen are even covered with several layers of gauze in order to reduce still further the amount of print paste passing through the screen.

Halides Compounds of → Halogens (chiefly) with metals. The most important are the → Chlorides (e.g. sodium chloride, NaCl) which form salt-like halides in solid form. The halides of typical metals are ionic.

Halo,

I. A narrow pale (often blurred) outline surrounding a coloured discharge or resist print caused by the outward diffusion of the resist or discharge chemicals into the ground.

II. A ring surrounding the area of a stain on a textile material following attempts at stain removal by local application of a spotting agent (organic solvent). The ring or halo thus formed is caused by the outward diffusion of colouring matter, soil particles, grease, etc.

Halochromic effect Research around the triphenylmethyl radical led Baeyer to propose his theory of halochromy, whereby a colourless compound is rendered coloured on salt formation, e.g. → Oxonium compounds. The term “halochromism” is still used today to denote a colour change of a dye on the addition of acid or alkali. The effect is based on the formation of mesomeric resonance (→ Methyl sulphinyl carbanions).

Halogenated hydrocarbons Halogen derivatives of hydrocarbons. The most important representatives of these compounds in textile chemistry are the → Chlorinated hydrocarbons.

Halogens (Gr.: *halogen* = salt producer). The elements chlorine, bromine, iodine and fluorine. They react with metals to form ionic halide salts, e.g. iron chloride $FeCl_3$. Their hydrogen compounds are called hydrohalic acids, e.g. hydrochloric acid HCl. Halogens are represented as a summation parameter in pseudo formulae by the symbol "X", e.g. as in AOX (adsorbable organohalogens).

Halogen test lamp (haloid lamp). Gas detector and leakage indicator for chlorinated hydrocarbon and chlorinated fluorocarbon (CFC) solvent vapours according to the → Beilstein test. It is based on the principle of a propane/butane gas cooker detector which, in the presence of chlorine gas or chlorine compounds, reacts with a green flame colour. At higher concentrations of solvent vapours the colour of the flame changes from green to blue. The halogen test lamp should not be used too frequently since the gases formed in the flame are very detrimental to health and also attack metals and textiles.

Haloing (halo formation). Haloing takes the form of an uncoloured intermediate zone which develops occasionally between the printed colour and the ground in coloured discharge or resist printing. The effect is caused either by incomplete drying of the printed fabric, steam which is too wet during steam fixation of the printed colours, or excessive dosing of the discharging or resist chemicals. This printing defect is prevented by pre-padding the fabric with sodium m-nitrobenzene sulphonate (e.g. Ludigol) before discharge printing, adjusting the quantities of discharging or resist chemicals to suit the particular ground dyeing, the use of appropriate thickening agents in print paste preparation, and the use of less soluble or less hygroscopic substances in the discharge or resist pastes.

Halyde Meter A sensitive American measuring instrument used for monitoring the tetrachloroethane (perchloroethylene) content of the air, e.g. in dry cleaning plants.

It is based on the principle that a copper halide is formed from copper and tetrachloroethane in the heated arc of an electrode system. The spectral intensity of the resultant copper halide is measured by photoelectric means via an ammeter connected in the circuit. This provides a direct reading of the tetrachloroethane content in the workplace air environment in ppm. With this instrument, therefore, the air can be tested quickly allowing appropriate corrections to be made to the working conditions.

Hamadan carpets Especially hardwearing rustic → Knotted carpets from the region around Hamadan which rises above the Iranian tableland at some 2000 m above sea level. Hamadan and the villages of the province are the most important centres of carpet production in Iran. In the main, they have a typical brown natural colour from the wool and camel hair used in their production. Hamadan carpets are, on the whole, rather mundane as far as decoration and weave are concerned. The materials, by contrast, are of a very good quality. Approx. 250 000 Turkish knots per m^2.

Hammer blow A description usually applied to a silk fabric with a hammer blow appearance produced from warps with flat yarns and an irregular crêpe weave with alternating S and Z twist yarns, widely separated from each other (4–6 threads), in the weft. During subsequent washing and dyeing, the individual groups of weft yarns form blister-like areas on different sides of the fabric to achieve the desired effect.

Hammer blow effect A defect which occurs in various types of textile fabrics, e.g.:

I. A generally structure-related unlevelness of colour in cotton velvet, especially in the form of "lumps" caused by the presence of a large proportion of motes (these can be detected under the microscope as hard fibre tufts adhering to seed husk residues) which disrupt the pile uniformity.

II. A "hammered" surface appearance in crêpe fabrics produced from man-made filament yarns by the change of direction of highly-twisted yarns as well as changes between flat and crêpe yarns.

III. A moiré appearance in plain weave wool fabrics after crabbing.

Hammer clips → Clips.

Hand block printing The cloth to be printed is attached to the resilient surface of a strong and relatively short table (approx. 8 m long). The actual printing operation is carried out with → Hand printing Blocks on which the design is formed in relief. The printer presses the block on to the surface of a print paste contained in a vessel known as a "swimming tub" or "sieve" in two opposite directions to ensure an even coating of colour paste on the block. When the block is correctly positioned on the cloth, it is struck with the fist or a printer's mallet in order to transfer the print paste from the block to the cloth. This process is then continued as necessary by repositioning the printing block on the cloth each time in accordance with the design repeat.

Handcoater A simple and effective system for the manual production of colour strike-offs on paper (or textile material) with the aid of short stainless steel rods. The quantity of colour paste applied is determined by the circumferential grooves in the rod surface which range from fine to coarse.

Hand creasing test By means of the so-called fist method the fabric to be tested is crumpled, wrinkled, pressed or folded for a few seconds in the tightlyclenched fist and assessed, after opening the fist, whether the fabric recovers immediately from its creased state, or only after some time by hanging or lying, or whether the creases can only be removed after smoothing out or ironing.

Hand flocking device A flocking device for small articles which consists of a spherical sieve to hold the flocks and an electrostatic field to achieve flock alignment immediately prior to their application on the substrate surface. The device is operated manually. → Flocking, flocking coating.

Hand ironing test (→ Ironing test procedures). A simple procedure to determine the shrinkage resistance of outer fabrics and wool-containing fabrics (ready for making-up). Procedure: the fabric to be tested of 1 m measuring length is placed on an ironing felt and the entire test area covered with a prewetted (150%) cotton cloth. This is then ironed with a conventional iron (without sliding or shifting, only by lifting and repositioning etc.). The ironing temperature for outer fabrics and wool-containing fabrics is approx. 250°C (contact time 15–20 s); and 150°C for fabrics containing acetate or polyamide. Shrinkage measurements are taken after the fabric has cooled down directly on the smooth underlay in % from the measuring length.

Handkerchief printing machine (flat press machine). A semi-mechanical machine for the 4-colour printing of headscarves on a horizontal printing table (the size of the headscarf) which turns around its own axis with a colour box that can be raised and lowered containing two felts to which different colours are applied diagonally.

Hand-knotted carpets Carpets produced by the manual knotting of pile yarn tufts in a warp yarn substrate. → Knotted carpets.

Handle The handle of a textile fabric is determined by numerous different parameters. In commission finishing, the finisher is usually presented with a sample of finished fabric by the customer, in addition to a colour sample, which he is required to match in bulk production. Comparisons between the sample and the production batch are, however, subjective. It is for this reason that efforts have been made to find precise methods for the measurement of handle, e.g. →: Nozzle-test; Handle-Ometer, drape test. In Japan, attempts have been made to evaluate the handle of a textile fabric by measuring 15 mechanical and physical properties. →: Kawabata system of handle assessment; FAST system of fabric assessment.

Handle modifiers (hand modifiers). Descriptive term for a group of textile auxiliaries the primary function of which is to modify the handle of textile fabrics. They represent a sub-group of textile finishing agents. → Handle-modifying finishes.

Handle-modifying finishes Finishes applied to textile fabrics after bleaching, dyeing or printing for the purpose of achieving a particular handle which differs according to end-use. The following subjective descriptions are in common usage: full handle, wool-like handle, silky handle, soft handle, hard handle, stiff handle, fleshy handle, firm handle, scroopy handle, etc.

Filling finishes, which involve the application of cheap substances to increase the weight of a textile fabric (→ Weighting), may also be included in this category.

Handle of textile fabrics → Fabric handle.

Handle-Ometer An American instrument for evaluating the handle of textile fabrics including the determination of flexibility, compressibility, extensibility, elastic resilience, density, surface friction and thermal properties. The test procedure involves placing the textile material over a 6.35 mm wide slit where a rotating load arm brings pressure to bear on the sample in the slit. A load-measuring device determines the various resistance values of the fabric sample, the sum of which can be read off an electrical display.

Handling of hazardous substances A number of auxiliaries, dyes and chemicals used in textile wet processing are so-called hazardous substances. The handling of such hazardous substances in the textile finishing industry is a normal everyday activity. It is, however, not free of risk. The majority of hazardous substances used in textile finishing include, e.g. chemicals and auxiliaries with carcinogenic, toxic, corrosive or skin-irritant properties, or those which are combustible or present a risk of explosion. The German Ordinance on the Handling of Hazardous Substances (Gefahrstoffverordnung) sets out the statutory relationship in § 15 to § 18 between man and chemicals (= hazardous substances). This requires the proper handling of chemicals, the accurate labelling of hazardous substances, the precise instruction of employees on handling hazardous substances, and further requires that management are responsible for inspection and the provision of employee welfare. → Legislation on environmental protection.

The handling of hazardous substances is laid down in the “Technical Regulations on Hazardous Substances” (TRGS). These technical regulations are revised annually. In handling formaldehyde-releasing finishing agents, for example, a maximum workplace concentration (MAK-Wert = 0.5 ppm) has been laid down. Since the introduction of low-formaldehyde finishing, this value is hardly ever exceeded. In the TRGS 900, azo dyestuffs which contain amino components derived from benzidine are described as “substances suspected of having a carcinogenic potential”.

Data on substances necessary for work safety may be extracted from the Safety Data Sheet which contains a classification of the hazardous substance in the form of advice on particular hazards (R-sentences) together with symbols in concise form. The purpose of this information is intended to provide users of hazardous substances and preparations with advice on measures necessary to ensure health protection and safety at the workplace. The Safety Data Sheet must also contain, among other things, instructions on first-aid and fire-fighting measures, as well as particulars concerning toxicology, ecology and disposal. It is for this reason, that a Safety Data Sheet containing pertinent, correct and complete information on each chemical auxiliary used in the finishing plant must be readily available.

The nature and scope of the particulars required is given first of all by the specific working practices in the dye and chemical kitchen. Those employees engaged in the handling of hazardous substances must be instructed on the risks involved as well as the protective measures required by means of operating directives. Recommendations for drawing up such operating directives, and suggested instructional procedures, are given in TRGS 555. In order to avoid intimidation of employees engaged in handling hazardous substances, verbal instruction is to be recommended just as much as the instructions to be gained from reading a clearly produced operational directive limited to the essential points (Marzinkowski).

Handling time factor An individual element in the → Processing sequence for the time in which material is transported, processed or stored. The material handling time is subdivided into forming time (operation time, production time) and idle time (storage time as well as the idle time dependent on work flow, disruptions and labour factors).

Hand printing Blocks (printing blocks). For hand block printing the blocks are cut from wood which are then infilled with felt and, where necessary, copper strip and pins (depending on the intricacy of the design) are also incorporated. Fairly hard woods are used for all printing blocks, e.g. ash, box, lime, sycamore, holly and particularly pearwood. To facilitate registration in hand block printing, brass pins are driven in at the corners of the block to indicate the position of the next repeat (→ Block cutting).

Hand screen printing Textile printing carried out with flat screens on long tables up to 100 m in length. The process is mainly limited to the production of high-quality prints today as it is more labour-intensive and less productive than screen printing by machine. → Screen printing table.

Hand-sewing machines Used in wet processing departments for joining loose piece ends, e.g. after taking fabric quality control samples at various stages of processing, joining successive batches of fabric at processing machines etc. The majority of these machines produce a seam joined by the chain stitch.

Hanging black → Aniline black.

Hanging of velours carpets The hanging of velvet carpets and other pressure-sensitive fabrics in festoon accumulators (see Fig.) to achieve relaxation of the grey goods and prevent → Shading.

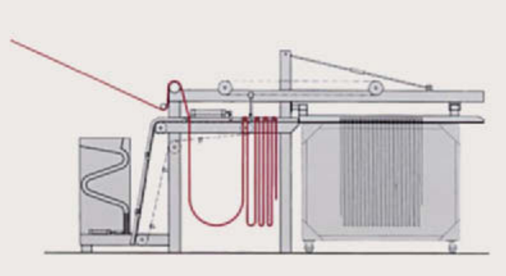


Fig.: Festoon accumulator for the relaxation of pressure-sensitive fabrics (Menschner).

Hank,

I. An unsupported assembly of yarn in coiled form (yarn hank, skein). The so-called round hank consists of 7 or 10 → Skeins for cotton and viscose (English counts: 1 hank = 7 skeins of 109.728 m = 768.096 m length of yarn. Metric counts: 1 hank = 10 skeins = 1000 m). The reeled hank yarn, which is bound with tie threads to hold the hank together, contains yarns which lie side by side (flat hank) or cross over each other to a large extent (cross yarn hank).

II. The so-called long hank composed of numerous 5000–20 000 m long (warp) threads. This form is convenient for wet processing in bleaching or dyeing and may be (a) wound into a ball (ball warping), (b) machine-wound on to a roller into a cross-ball cheese or (c) shortened into a link chain (chain warping).

Hank drying After dyeing, hanks are normally dried before further processing. The first stage, especially with natural fibres, is by centrifuging (hydro-extraction) in which the hanks of yarn are contained in a basket and subjected to high gravitational forces. Depending on whether high or low-speed centrifuges are used and the type of yarn (synthetic or natural fibres), centrifuging reduces the moisture content to levels of 4–35%.

Hanks of yarn based on natural fibres require further drying in hot air to reduce the moisture content to an acceptable degree. This is achieved either discontinuously by suspending the hanks on horizontal poles in a thermal chamber with hot air circulation, or continuously in modern thermal driers (hot air circulation) by suspending the hanks on rotating poles supported at either end on endless transport chains. → Festoon drier with rotating guide rollers. An alternative to this type of machine is a thermal drier based on the suction drum principle. In this case, hanks are processed individually on a belt feed. → Suction-drum drier. Radio-frequency drying (RF-driers) can also be employed for hank drying.

Hank dyeing machines The dyeing of yarn in hank form is the oldest method of yarn dyeing. Traditional rectangular-type machines (Fig. 1) in which the

Hank dyeing machines

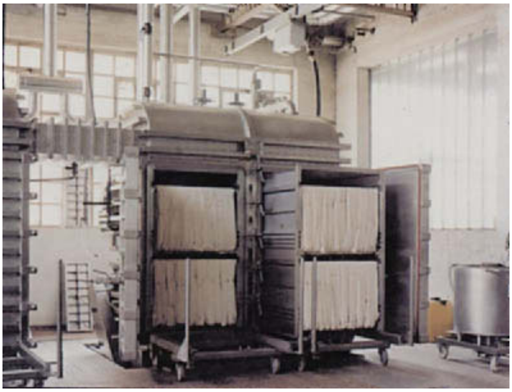


Fig. 1: *Minox hank dyeing cabinet.*

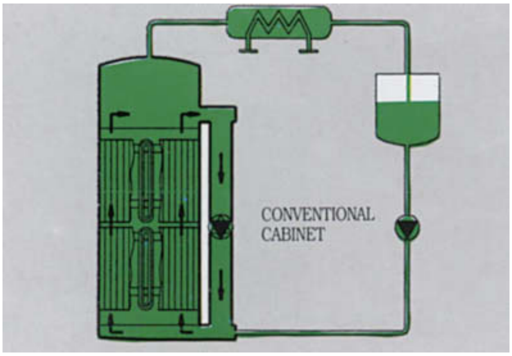


Fig. 3: Typical structure of a cabinet dyeing machine for hanks.

dye liquor is heated by open or closed-coil steam pipes, and the liquor is circulated over a weir and through the yarn by means of a reversible impeller mounted at one side of the machine, are still widely used for the dyeing of carpet yarns (hanks up to 5 kg and machine capacity up to 4000 kg).

More recently, vertical cylindrical dyeing machines (with or without pressure) in which the hanks of yarn are contained in special cages, represent alternatives to the rectangular-type machines (Fig. 2).

In Western Europe (with the exception of Italy), the dyeing of yarn in hank form has declined markedly (due to the labour-intensive handling involved) in favour of package dyeing. However, too little consideration has been given here to the experience of the knitter that hank-dyed yarn is more voluminous (has better bulk) than package-dyed yarn. The Italian machinery and textile industry have followed a different route, whereby the widely used rectangular-type machines, with relatively high liquor ratios and labour-intensive handling in hydro-extraction and drying, have been improved and extensively automated (Fig. 3):

- The hank carriers, in the form of transportable frames, are loaded externally.
- Due to the compact construction (low pressure up to 108°C with an air blanket) the liquor ratio has been reduced to between 15 : 1 and 18 : 1.
- Up to four machines can be coupled together in tandem.
- Fully-automated systems for hydro-extraction, drying and unloading, even up to the automated packaging of hanks in heat-sealed plastic bags, may be integrated into the hank dyeing operation.

In addition to rectangular-type and circular hank-dye-

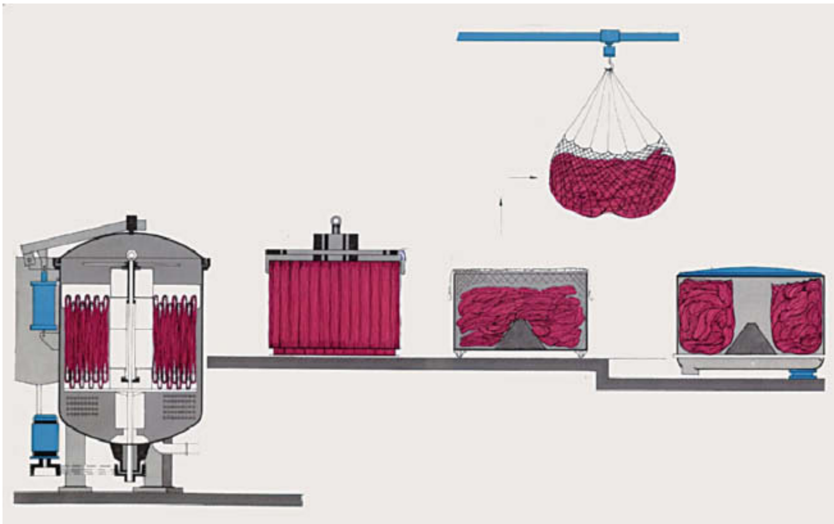


Fig. 2: Krantz dyeing machine with hank yarn material application plus centrifuge water extraction of the dyed yarn hanks.

Fig. 4: Mezzera spray dyeing machine for six yarn hank rows.

ing machines, the spray-dyeing principle has also been employed (→ Spray dyeing machine) in which hanks of yarn are suspended on slowly-rotating perforated pipes (Fig. 4) and flooded with dye liquor.

Hank loading Hanks of yarn for dyeing, drying, etc. are spread out and suspended on sticks or poles to ensure uniform treatment.

Hank mercerizing machines → Yarn mercerizing.

Hank, skein, reel The traditional unit of length for yarn in hank form. In metric notation, a hank (consisting of 70 turns, each of 1.428 m circumference) = $^{1}/_{10}$ of a standard hank = 100 m. For ply-yarns, different numbers of turns are used. In general, hanks are loosely fastened at various positions around the bundle of yarns with tie-bands to maintain the integrity of the hank and prevent tangling during processing. If the tie-bands are too tight, the yarn in these parts of the hank will resist the dye during dyeing thereby resulting in undyed places.

Hank spreading machine A machine used to stretch hanks of yarn intended, e.g. to be mercerized or treated in a stretched state.

Hank stretching Treatments applied to hanks of silk and mercerized cotton yarn to achieve increased lustre. The dry hanks are suspended between two rollers and the distance between the rollers is then increased by a controlled amount.

Hank tensioning An operation which involves tightening hanks of yarn on a trestle before suspending on poles prior to bleaching, dyeing, etc.

Hank test Test for fibre bundle strength. → Pressley-Index.

Hank yarn printing machine A machine used for flammé yarn printing on hanks made of wool, polyamide, staple fibre, cotton and silk. With the automatic Timmer hank yarn printing machine, printing is effected in four phases. In every phase, one quarter of the total circumference of the hanks is printed. Movement in longitudinal hank direction is automatic, so that the next quarter can be printed in the next phase. Movement in transverse direction and stopping are also automatic. This means that the hanks are passed four times through four pairs of rolls. These four pairs of rolls consist of four small rolls running through the colour troughs, and two counter-rolls. The print pattern depends on the colour combination and on the design engraved on the rolls. On account of the width of the rolls, which must be one quarter of the circumference of the hanks, and because of the longitudinal hank transport (which is also effected always by one quarter of the hank circumference) the machine is only suitable for a definite hank length (circumference).

Hansa-Mixer A mixer designed for the continuous foaming of latex coating compositions at a production rate of up to 6000 kg compound/h as fine foam containing 200 g/l. Foam density and metering are controlled automatically. The mixer is provided with a continuous-flow heat exchanger for cooling, heating, or maintaining the foam at a constant specified temperature, as well as a continuous-flow filter, etc. Manuf.: Hansawerke.

Hard boiler feed water → Boiler feed water.

Hard fibre matting Floor mats containing coconut or sisal fibres in warp and weft.

Hard fibres Leaf and fruit fibres of monocotyledonous plants (→ Vegetable fibres) obtained from the supporting tissue of large luxuriant leaves of tropical and sub-tropical plants. In contrast to the → Bast fibres (commonly described as “soft” fibres) hard fibres are much longer, i.e. between 110–250 mm long as technical fibres (only 1.5–4.4 mm long as elementary fibres), coarser and stiffer. Hard fibres are produced by treating the leaves in machines which scrape the pulpy material from the fibres, followed by washing and drying; retting is not necessary. The hard fibres include: →: Sisal; Henequen; Manila fibre; Abaca; Fique fibre; Phormium fibre; New Zealand flax; Alfa grass; Esparto. Hard fibres are used mainly for cordage, mats and rugs.

Hard lead An alloy of lead with 5–25% antimony. In contrast to pure lead, it is suitable for vessels used in peroxide bleaching.

Hardness of water →: Water hardness; Water softening; Water hardness salts.

Hardness ranges of water In accordance with the German Detergent Law, public water supply companies are required to suitably advise their consumers of the hardness range applicable to the drinking water supplied by them. Inscriptions on the packaging (in-

hardness range	German degree of hardness	mval total hardness/l
1	7	up to 1,3
2	7-14	1,3 - 2,5
3	14-21	2,5 - 3,8
4	over 21	over 3,8

Tab.: Hardness range of water.

cluding papers accompanying loose products) of washing agents and detergents must contain graduated dosing instructions for the respective water hardness ranges 1–4 (see Table).

Hardness scale (Mohs' scale of hardness). A scale introduced by Mohs to characterize the hardness of minerals, metals, etc., which is still in widespread use. This hardness scale provides only an approximate indication of the comparative hardness of materials but is nevertheless simple to apply. The 1–10 scale begins with the softest mineral talc (1) and ends with the hardest mineral diamond (10). Between these extremes are gypsum (2), calcite (3), fluorite (4), apatite (5), feldspar (6), quartz (7), topaz (8), and corundum (9). Thus corundum will scratch or abrade quartz but not vice versa. True hardness comparisons are, however, better indicated by a progressive numerical series (Rosiwal's attrition process) in which e.g. diamond is shown to be 140 times harder than corundum.

Hard rubber (ebonite). A hard form of → Rubber in which the latex molecules have been crosslinked with 30–35% sulphur by curing at 100–150°C. Lime or magnesia is used as activator. Properties: black, hard, brittle mass which on heating becomes sufficiently plastic to be moulded into shapes. Hard rubber is resistant to water, chlorine, alkalis, most acids, gasoline, oils and alcohols. Uses: tank linings, pipes, handles, cocks and valves, etc.

Hard segments The segments of polyurethane groups in elastane structures.

Hard soap (household soap). A → Soap with an approx. 60–70% fatty acid content used for domestic washing and cleaning, etc.

Hard stoneware Stoneware with particularly high mechanical strength and breakproof properties. Its resistance to corrosion is roughly equal to that of hard porcelain.

Hardware A general term for all the mechanical, electrical, electronic and magnetic components of a computer or electronic data processing system including peripherals. Hardware represents the physical part of a computer system which is supplemented by the → Software (programs).

Hard water →: Water hardness; Water softening.

Hare and rabbit fibres Apart from → Angora rabbit hair, these are more or less short hairs. Depending on the breed, hare and rabbit fibres are very variable. Preference is given to natural colours. In most cases the entire hair (excluding the cuticle) is pigmented (if red-brown often only the cortex, if brown also the medulla). Hare and rabbit fibres may be distinguished particularly by their respective felting and milling properties (see Table). Uses: very largely used for making felts, hatmaking, knitted goods such as cardigans, ladies' dresses, gloves and berets, usually blended with other fibres.

Harmful pollutants May be defined as all those substances introduced into an ecosystem which either harm the ecosystem itself or its value for living organisms to a measurable extent.

1. Harmful pollutants, in the ecotoxicological sense, are substances causing undesirable changes in affected systems which markedly exceed the usual ranges of population conditions.
2. Harmful pollutants, in the sense of emissions from the air pollution point of view, are substances which occur in higher concentrations at local, regional or global levels, and which can result in an acute indirect or direct impairment of the biosphere.

For many harmful pollutants the extent of harm is a concentration problem. In ÖTN 100 the term "harmful pollutant" is defined as follows: "In the sense of this directive, harmful pollutants are substances contained to a specified extent in a textile product or which, in normal expected usage, are formed to a specified extent, and have some kind of effect on the human population which, in the present state of knowledge, may be harmful to human health." The limitation that a substance is only regarded as a harmful pollutant if, in normal expected usage, it has some kind of effect on humans, excludes those substances which are chemically bound to a textile in such a way that they can neither migrate through the air we breathe nor through the action of water, perspiration (in clothing), saliva (chil-

	cystine content	swelling %	water solubility %	density	alkali solubility %	HCl absorption mval/g of hair
hare hairs	14—15.0	54—56	4—4	1.28—29	10.0—12,0	0.72—73
wild rabbit	11.5—12.0	58—62	4—5	1.25—26	12.5—14.0	0.75—76
tame rabbit	11.5—12.5	60—70	5—7	1.29—30	12.5—13.5	0.76—78

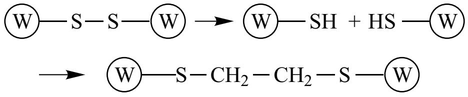
Tab.: Hare and rabbit hair parameters.

PROCESS	HARMFUL POLLUTANTS
grey fabric heat setting	fibre spin finishes, oils and their products of oxidation etc.
dyeing (incl. drying and heat setting; also thermosol)	carriers, auxiliary agents with affinity for fibres, levelling agents, emulsifiers, anti-foaming agents, organic acids etc.
steaming	acids, sulphides, sulphites
coating	solvents
textile printing	urea, very volatile additives
finishing (chemical finishing, soil release, flame-retarding finish etc.)	formaldehyde, acids, softeners, wetting agents, fluorocarbon compounds, phosphorus compounds etc.

Tab.: Harmful pollutant compounds in the textile processing industry.

dren's clothing) and skin contact. The limitation "in normal expected usage" is also very significant. This certainly excludes burning and the resultant formation of such combustion gases as CO and CO_2 (as occurs with all organic materials). The listing of those substances regarded as harmful pollutants (see Table) is given in product-specific standards (e.g. Ecotex). Such standards also specify the limit concentration above which a substance is regarded as a harmful pollutant within the scope of that particular standard. The standards also specify the test methods to be followed for the determination of harmful pollutants, or their emissions in air, in aqueous extracts, etc. These tests are selectively designed for the specific pollutants laid down in the standards (contributed by Herzog).

Harris stripping process A process for the regeneration of wool wastes which involves cleavage of the unstable disulphide bonds as a first stage, followed by the reformation of stable bonds with the introduction of methyl groups:



The wool keratin becomes more resistant to alkalies, oxidizing and reducing agents as a result of this chemical conversion. The process is first carried out at temperatures above 80°C and pH 7.5–9 with e.g. sodium dithionite and the addition of an emulsion of ethylene dibromide whereupon an intensive abstraction with sulphoxylates etc. takes place.

Harris tweed A woollen fabric formerly spun, woven and finished by hand (→ Homespun) in the Outer Hebrides of Scotland; the fabric is still hand-woven even today on the islands of Lewis, Harris, Uist and Barra. Harris tweed is made with carded yarns produced from pure Scottish virgin wool in twill or plain weave with a loose construction. There are two types: (1) fabric woven from handspun yarn and (2) fabric woven from machine-woven yarn. Harris tweed fabrics are relatively coarse and strong. Coloristically, melanges or designs with small areas of colour predominate. Finish characteristics: a light melton finish often with bristly effects. The fabric is used for sports jackets, suitings and coats.

Harsh wool Rough, hard, brittle wool of poor quality due to damp storage conditions usually accompanied by bacterial damage.

Hartshorn → Ammonium carbonate.

Hartshorn salt → Ammonium carbonate.

Hat blocking Used for shaping or stretching hats which, e.g. have been dry cleaned. As a rule, they consist of electrically heated cast aluminium moulds with a hand regulated stretching scale.

Hat body During the course of (wool and fur) felt hat manufacture, the following important forms of hat material are produced successively (see Fig.):

1. The body in the first stage of felting, which is roughly hat-shaped in the form of a hollow cone, and consists of fibres or hairs which are still only loosely bonded together, but which become mutually interlocked and further consolidated during premilling to give
2. a half-milled hat body which is about half the size of the body in 1 above. On continuation of milling until felting is complete, the next smallest form of the compact felt is obtained, i.e.
3. a fully-milled hat body consisting of a felt cone whose surface area has been reduced to approx. $^1/_8$ the size of the original form by milling and from which the desired final shape of the felt hat is achieved after further shaping steps (stiffening, stretching, decatizing, pressing).

In the hat body factory, preformed bodies for women's hats with a broad crown are known as cornet bodies. Hat bodies similar to men's hats with crown and brim are known as capeline bodies. If the latter have a raised fish skin and a horizontally aligned pile they are described as soleil bodies. Soleil is a lustrous fur felt with a shorter nap than velour.

Hatching Fine parallel lines resp. grooves on pad rollers or printing rollers (roller printing) set at an oblique angle to the direction of the running fabric which determine the depth of the engraved areas of the design. Their function is to hold the print paste, especially in large motifs, by preventing it from being scraped out of the engravings due to the action of the doctor

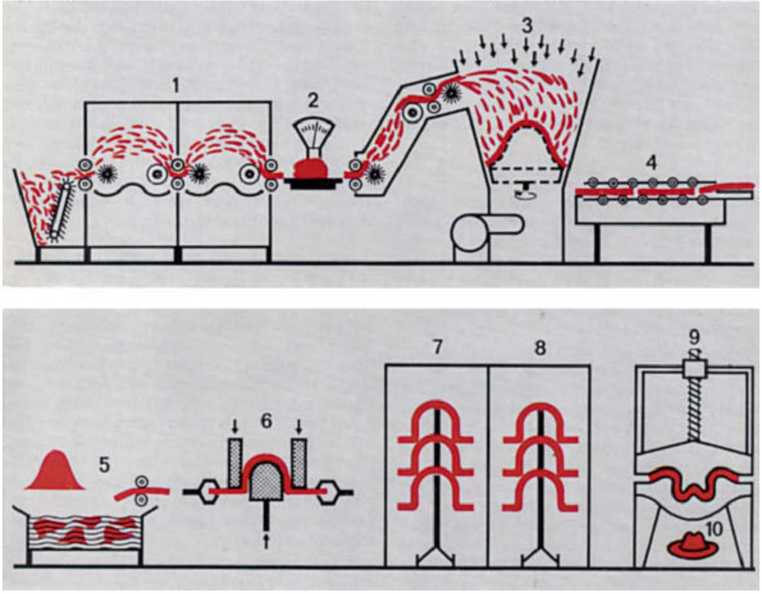


Fig: Schematic representation of hat production by the felt-bonding process.
1 = blowing machine (4–8 boxes); 2 = weighing scale; 3 = hat-forming machine with a whirling perforated cone and vacuum; 4 = multi-roller (milling); 5 = dip impregnation; 6 = pre-shaping with steam; 7 = drying (60–70 °C); 8 = curing (130–150 °C); 9 = after-pressing (80–120 °C); 10 = untrimmed hat (source: Bayer).

blade during printing, thereby ensuring a uniform print.

Hatching screen A screen with engraved hatching lines. It is used to engrave the hatched ruling lines into the printing roller and lies next to the design film. →: Engraving; Screen making.

Hatching tool A small engraving tool made of fine quality steel bar with a cutting point at one end which is driven by hand along the lines produced by the → Hatching screen on the printing roller.

Hat dyeing The high colour fastness of reactive and metal-complex dyes and fibre-protective dyeing methods in the isoelectric pH range, give the hat maker greater freedom in production technique. The hat maker can dye the material at any stage of manufacture and achieve good levelness. There are no problems of penetration and level dyeing with heavy fabric qualities in conventional dyeing machines. It is possible to dye loose fur qualities, half-milled hat bodies or $^3/4$ hat bodies without any risk of a noticeable decrease in the felting propensity of the material or change in shade.

Hat felt finishes – identification test → Finishing of hat felts.

Hat making form A loosely constructed cone of fur produced by drawing a specific quantity of blown fur on to a revolving perforated metal cone. The resulting form represents the first stage in hat manufacture.

Hat material Rabbit and hare fur, which has been mordanted by various means, used as raw material for the manufacture of fur hats (some are produced with different types of → Hair mordants). These materials differ from each other in shade and are chemically damaged to a greater or lesser extent; there are considerable differences in dye affinity.

HATRA, abbrev. for: Hosiery and Allied Trades Research Association (Nottingham, U.K.). → Technical and professional organizations.

Hazard classification of flammable solvents In Germany, the Verordnung über brennbare Flüssigkeiten, or VbF (Ordinance on Flammable Liquids) has classified organic liquids according to their flammability into 4 hazard classes. Distinguishing characteristics are the respective flash points as well as possible miscibility with water. The VbF regulates structural requirements for the storage of flammable liquids as well as the need for notification and licencing of plants where they are used:

Hazard Class A: Liquids with a flash point not above 100°C, which do not exhibit the properties of Hazard Class B with regard to water solubility.

Hazard Class A I: Liquids with flash points below +21°C (e.g. gasoline between –55°C and –25°C , ether –40°C, acetone –17°C, benzene –8°C, methanol +6°C, ethanol +11°C).

Hazard Class A II: Liquids with flash points between 21–55°C (kerosene, cleaning oils).

Hazard Class A III: Liquids with flash points between 55–100°C (diesel oils, heating oils).

Hazard Class B: Liquids with a flash point below +21°C which dissolve in water at 15°C in any ratio, or liquids containing flammable components which dissolve in water at 15°C in any ratio.

Hazardous substances act The hazardous substances act (Gefährstoffverordnung = GA) which came into force in the Federal Republic of Germany on 29.7.1980 includes various definitions of hazardous properties (→: Toxic substances; Legislation on environmental protection). In addition to the substances covered by the above definitions, a further category of so-called “particularly hazardous substances” has been introduced without any precisely defined criteria. The following data is based on the classification of the Deutsche Forschungsgemeinschaft (DFG) = German Research Council, and the Swiss Federal Health Ministry in Berne, as contained in the official Swiss Index of Toxic Substances (list 1):

1. Category IT = inhalation toxicity. Mean exposure limit < 4 ppm/h (e.g. phosgene, thionyl chloride).
2. Category Kw = probable human carcinogen (e.g. chloroform, dioxan, epichlorohydrin, trichloroethylene).
3. Category Ks = confirmed human carcinogen (e.g. benzene).
4. Category KT = carcinogenic in animal tests (e.g. hydrazine sulphate).

Hazen colour unit An American colour scale for determining the colour of chlorinated hydrocarbon solvents based on a platinum-cobalt stock solution designated as 500 Hazen units.

Hazen stock solution: 1.245 g potassium chloroplatinate + 1 g cobalt chloride ($CoCl_2 \cdot 6H_2O$) dissolved in 100 ml conc. hydrochloric acid and made up to 1000 ml with distilled water. Dilution of 1 : 100 with distilled water = 5 Hazen; 3 : 100 with distilled water = 15 Hazen. A chlorinated hydrocarbon control is contained in a small glass tube of the same diameter and filled to the same level with/without a comparative solution. The sample is viewed from above against a white background with the exclusion of side light.

HBL (Ger.), abbrev. for: Harnstoff-Bisulfit-Löslichkeit (→ Urea-Bisulphite solubility).

HB Yarn, abbrev. for: → High-bulk yarn.

HDPE, abbrev. for: high-density polyethylene.

HE, → Henequen fibre, → Standard abbrev. for textile fibres, according to DIN 60 001 T4/08.91.

He,

I. chemical symbol for helium (2).

II. → Henequen, → Standard abbrev. for textile fibres, according to DIN 60 001 until 1988, from 1991 → HE.

Heat absorbing dyes and dyeings → Infrared-absorbing dyeings.

Heat accumulator High performance thermal clothing made from, e.g. acrylic gel fibres containing microcapsules (see Fig.) which absorb and store heat then release it as required over a period of time due to their heat-accumulating properties.

Heat ageing → Ageing of textile materials.

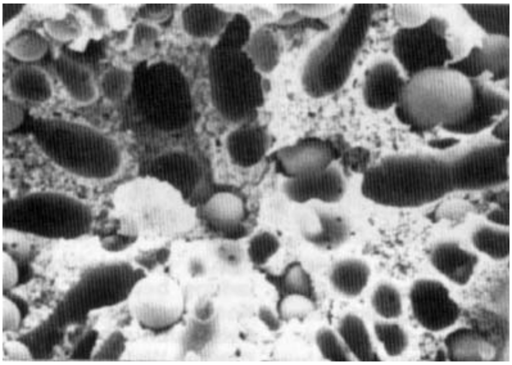


Fig.: Acrylic gel fibres with PCM microcapsules: magnification % 2000.

Heat and power generation The classic method which, in former times, was often used by many textile plants and may still be seen occasionally today, was based on the use of → Back-pressure steam turbine (Fig. 1). A high-pressure steam boiler generates superheated steam at 60 bar and, e.g. a temperature of 480°C. This steam is used to drive a steam turbine, the exhaust steam pipe from which is connected to the plant’s steam distribution line. Compared to a gas turbine, which gives a power output of 0.35–0.4 (kWh electric current/kg steam), a power output of only 0.15–0.2 kWh is achieved with a steam turbine process. This is one of the reasons for the decline of industrial heat and power plants equipped with steam turbines.

The schematic representation of heat and power generation from a gas turbine (Fig. 2) can be explained as follows: the gas turbine compressor sucks in air for combustion via a sound muffler and compresses it to, e.g. 12 bar. This air is then heated in the combustion chamber of the gas turbine to approx. 1000°C. Combustion takes place with a large excess of air (lambda from 3.5–5). The pressure of the hot gas drops to atmospheric pressure in the turbine and the mechanical energy of the turbine is supplied to the compressor. The

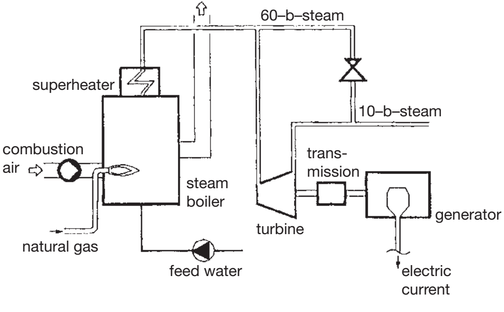


Fig. 1: Heat and power generation with a steam turbine

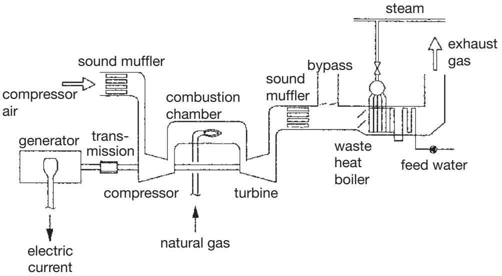


Fig. 2: Heat and power generation with a gas turbine.

power requirement for the compressor lies considerably below the power output of the turbine. Consequently, the resultant excess power is converted into electrical energy in the generator. The exhaust gases are cooled down from approx. 1000 to 500°C by the pressure drop in the turbine and the heat contained in the exhaust gases is then converted, for the most part, into steam in the downstream waste heat boiler. The high vapour pressure, e.g. 10 bar, means that the exhaust gases are not cooled down to a desirable operating point level, i.e. the water vapour dew point of the waste gases, but only to considerably higher temperatures, e.g. 170°C even if residual cooling takes place in a feed water preheater. It should therefore be possible to recover this residual heat by means of an additional downstream exhaust gas cooler for subsequent reuse in the textile plant or even in an external consumer's plant.

Heat balance (thermal energy balance). The word "balance" is derived from the Latin "bilanx", or scales, and means a comparison by weighing different factors or quantities against each other. A commercial balance sheet, in which assets are set against liabilities, enables us to assess the profitability of a company. In textile finishing, energy consumption is a critical yardstick for determining the operating costs and environmental impact of various processes. The energy balance of a process allows us to assess its cost-effectiveness, or that of the plant in which it is carried out. Such a balance compares the energy inputs used (assets) with the breakdown of their benefits for the process and the losses involved (liabilities).

We can now examine how this can be applied to two important finishing processes:

1. processes involving heat treatment, e.g. drying, and
2. the washing process.

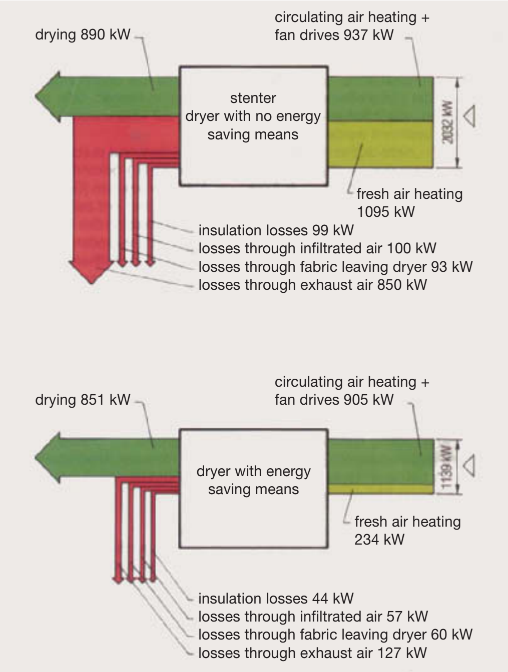


Fig. 1: Energy flow diagram of dryers with and without energy saving means (Babcock).

Fig. 1 shows two heat balances for the same drying task. In this particular process, a woven cotton fabric, 2 m in width, weighing 150 g/m^2, is dried from an initial moisture content of 80% to a residual moisture content of 8% at a production speed of 99 m/min. The upper diagram shows the performance of a conventional stenter as used everywhere and which is even found occasionally in new installations. From the 2032 kW input, only 890 kW, or 43%, is actually used to dry the

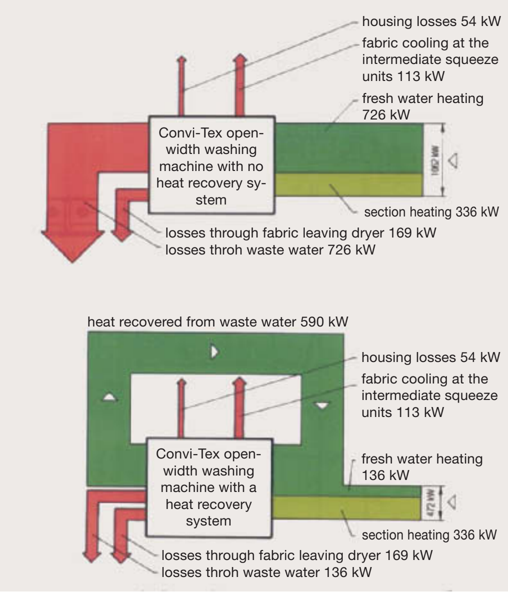


Fig. 2: Energy balances for washing processes with and without heat recovery (Babcock).

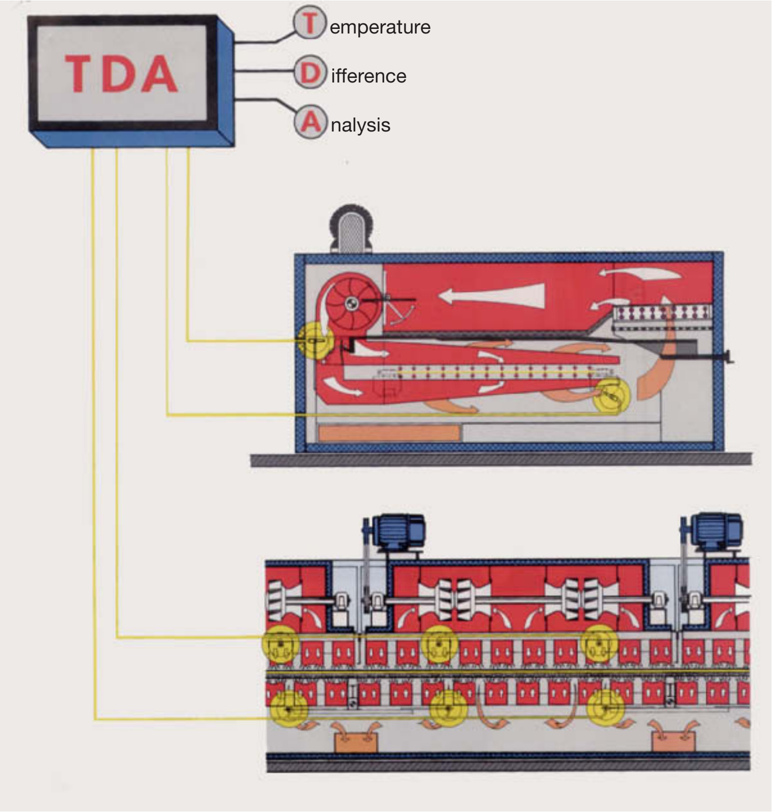


Fig. 3: Temperature difference analysis as a thermal balance of heated air and exhaust air containing water vapour (Krantz).

fabric. 57% is accounted for by various losses. A more modern, energy-saving process (lower diagram) uses only 1139 kW for the same task, and only 25% of this is lost. At a price of 0.04 DM/kWh for heat energy and 4000 hours annual production, the saving of 893 kW corresponds to a cost saving of DM 143 000 per annum. This fact, and the reduced environmental impact resulting from the lower energy consumption, cannot be ignored.

Even in continuous washing processes, a heat balance enables a better heat utilization to be achieved in the recovery of heat from the waste water. Fig. 2 demonstrates, with the aid of energy flow diagrams, the positive effects of a heat recovery system in a continuous washing range (Convi-Tex system of Babcock Textilmaschinen GmbH) for the same washing task. It assumes a closed heat exchanger system, with which an efficiency of approx. 80% can be achieved in practice.

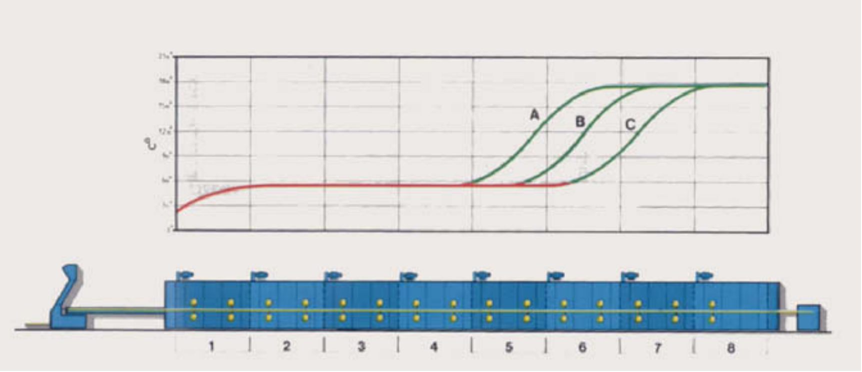


Fig. 4: Graph of fabric temperature during the drying (B + C) and heat setting (A) of mixture woven fabrics.

The energy balance shows that a washing range without heat recovery requires 1062 kW for the washing operation. As much as 726 kW of this, i.e. 68%, goes down the drain with the hot waste water.

The same washing range with a heat recovery system has an energy requirement of 472 kW which is only 45% of the previous requirement! Considering that a heat recovery system can pay for itself within approx. 6 months, it is remarkable that even today washing ranges are still operating in Europe without heat recovery systems. Both the energy balance and the payback period clearly demonstrate the need to fit heat recovery systems with a high degree of efficiency.

By comparing the temperature of circulating air in a stenter chamber as it leaves the blower with the temperature of exhaust air containing water vapour as it leaves the drying zone between the nozzle plates, with the aid of thermocouples (temperature difference analysis, see Fig. 3), the heat consumed in the drying process may be determined by calculation (with microprocessors). From the heat consumed, the surface temperature of the fabric may be deduced and a curve can be produced for the temperature of the fabric surface as it passes through all the stenter chambers (Fig. 4).

Heat balance diagram of a stenter drier → Exhaust air heat recovery.

Heat bonding of thermoplastics These are produced by the thermal bonding of thermoplastic materials, e.g. in the case of fabrics composed of polyvinyl chloride or polyethylene fibres by fusion at the thread crossover points. The welded seam can be so strong that it is not the seam itself that breaks down in a tensile test but the material adjacent to it. Various methods are employed in practice including, e.g. a) heat-impulse welding (an electrically-heated band, heated in short impulses, is pressed against the material being welded under pressure); b) hot wedge welding (the pieces of material to be welded are fed in direct contact over the upper and lower surfaces of an electrically heated wedge directly across the seam area then firmly bonded by passage through a pair of pressure rolls); c) hot air welding (a procedure involving a concentrated jet of hot air and a welding thread of the same material – this process is unsuitable for coated fabrics); d) high frequency welding (in this case, the maximum temperature develops in the centre of the welding zone within an alternating electrical field); e) ultrasonic fusing (fabrics are joined by focusing ultrasound waves to concentrate heat in the desired seam area).

Heat capacity,

I. Specific heat capacity (symbol c): the heat required to increase, or decrease, the temperature of 1 kg of a substance by 1°K (→ Specific heat). The word specific means per unit mass. Formerly, the specific heat capacity was derived from a mass of water = 1 kg at + 4°C and 1 bar = 1 litre.

The SI unit of specific heat capacity is given by:

$$\frac{\mathrm{J}}{\mathrm{kg} \cdot \mathrm{K}}$$

Conversion formula:

$$\frac{\mathrm{kcal}}{\mathrm{kg} \cdot \mathrm{K}} = 4\,186.8 \ \frac{\mathrm{J}}{\mathrm{kg} \cdot \mathrm{K}}$$

II. Combustion (heat potential, heat of combustion): the quantity of heat released by the complete combustion of a specific amount of textile material. Specific heat capacity: the heat energy released by the combustion of a specific quantity of textile material under specified conditions.

Heat conductivity (thermal conductivity, calorific conductibility, thermal conductivity coefficient), symbol λ, K or k.

I. General: the thermal conductivity of a substance is defined as the quantity of heat which will flow across unit surface area in unit time when the temperature difference across a unit thickness of the material is 1°K. The thermal conductivity of materials varies depending on the type of substance. It is particularly high in the case of metals which have good heat transport characteristics due to their molecular structure. For gases, on the other hand, it is particularly low since relatively few molecules are available for energy transport per unit volume. Textiles fall between these two extremes but also vary because of their different structures.

This parameter was formerly measured in SI units of thermal conductivity:

$$\frac{\mathrm{W}}{\mathrm{m} \cdot \mathrm{K}}$$

Conversion formulae:

$$\frac{\mathrm{W}}{\mathrm{m} \cdot \mathrm{K}} = 0.860 \ \frac{\mathrm{kcal}}{\mathrm{m} \cdot \mathrm{h} \cdot \mathrm{K}}$$

$$\frac{\mathrm{kcal}}{\mathrm{m} \cdot \mathrm{h} \cdot \mathrm{K}} = 1.163 \ \frac{\mathrm{W}}{\mathrm{m} \cdot \mathrm{K}}$$

II. Specific thermal conductivity of fibres: polypropylene fibres have the lowest thermal conductivity of all textile fibres. Consequently, clothing containing this fibre has good heat insulating properties (thermal textiles, blankets). The relative thermal conductivities of some textile fibres are as follows:

– air	1.0
– polypropylene	6.0
– polyvinyl chloride	6.4
– wool	7.3
– acetate	8.6
– viscose	11.0
– cotton	17.5

Heat creases → Running creaser.

Heat dissipation → Radiation heat losses from dye liquors and dyeing machines.

Heat exchanger A heat exchanger may be defined as any device that transfers heat from one medium to another. Heat exchangers which utilize steam are designed to transfer heat energy from the steam to another medium through a heated surface which keeps them physically separated. For dyeing machines, heat exchangers can be installed either externally (Fig. 1) or within the dyeing vessel (Fig. 2). External heat exchangers are of two types, i.e. the shell-and-tube heat exchanger (Fig. 3) and the floating head, baffled shell space, shell-and-tube heat exchanger (Fig. 4).

To determine the external dimensions of heat exchangers for textile driers, the form of the heating surface itself, as well as the air flow, is important. In the case of fully-integrated systems, the dimensions of geometrically smaller units can represent a convincing argument for their use. Unavoidable maintenance costs (= dismantling of dirty equipment, separate units for chemical auxiliaries, heating of wash liquors, etc.) are significant disadvantages of the recuperator in addition to the time involved. For the regenerator, however, these costs are much lower (automatic running with fixed units). A daily follow-up cleaning period is also necessary so that the stenter can be operated without interruption on the following day. In addition to the various types of heat exchanger already mentioned, heat exchangers with so-called heat pipes are also of interest. Water/water heat exchangers (Fig. 5) are available for collecting the waste heat from effluents.

Fig. 2: Steam/water heat exchanger tubes in a beam dyeing machine (Platt Longlose).

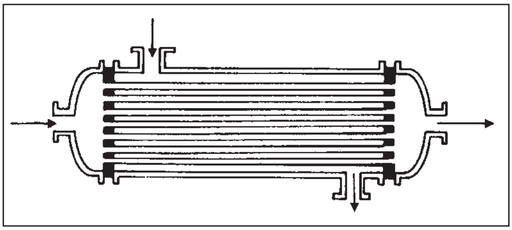


Fig. 3: Shell-and-tube heat exchanger: horizontal liquor flow, steam flow from top to bottom.

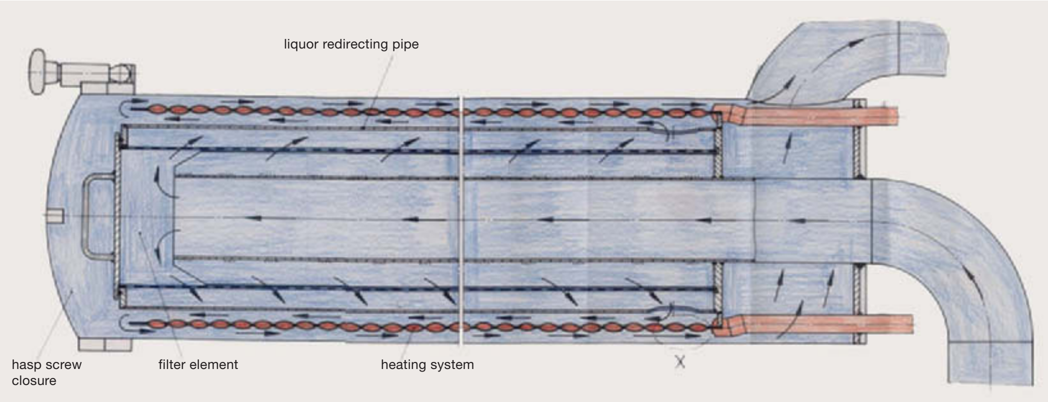


Fig. 1: Steam/water heat exchanger with integral filter (Jasper).

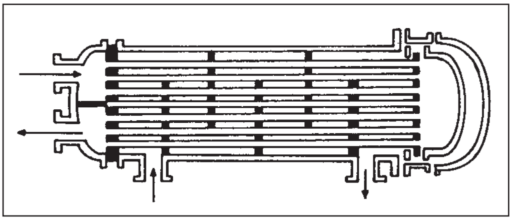


Fig. 4: Floating head, baffled shell space, shell-and-tube heat exchanger: liquor entry and exit on the left, steam entry and condensate exit at bottom.

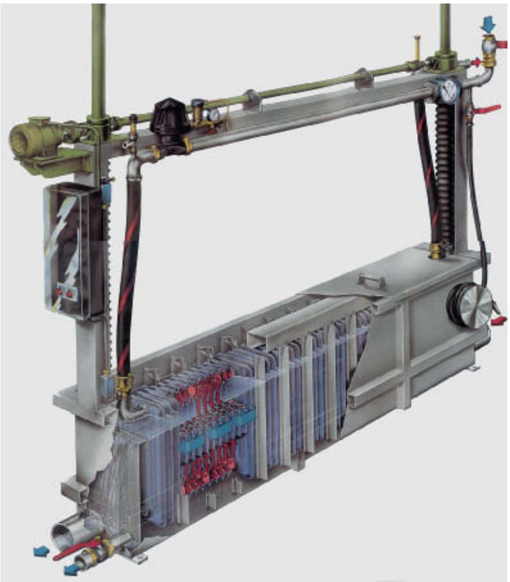


Fig. 5: Water/water heat exchanger (source: Brugmann).

Heat fixation → Heat setting.

Heat generation from primary energy Steam is used for heating purposes, as a source of motive power for machinery, and as a reaction and/or dissolving medium in many production processes. Depending on the particular application, the pressures, temperatures and quantities of steam required vary widely. For problem-free steam distribution, therefore, it is very important to install a correctly planned steam distribution system. A supply system for a steam using plant can therefore only be drawn up when the specific consumption requirements of all the various steam consumers are known. Steam consumers can be subdivided into three groups:

- direct steam consumers,
- steam consumers with indirect heating,
- steam turbines for electricity generation with subsequent steam condensation for the production of heat (increased efficiency).

1. Direct steam consumption: in such equipment the steam is in direct contact with the medium being heated. A typical example of such an application is the heating of water or aqueous solutions by means of perforated steam pipes. In general, it can be said that direct steam consumption involves the highest operating costs since the entire condensate (treated feed water) is lost. Such equipment has a high consumption of feed water which means high feed water preparation costs. There are some processes, however, where direct steam consumption is the most appropriate method since, e.g. the immersion of a heat exchanger unit in an autoclave

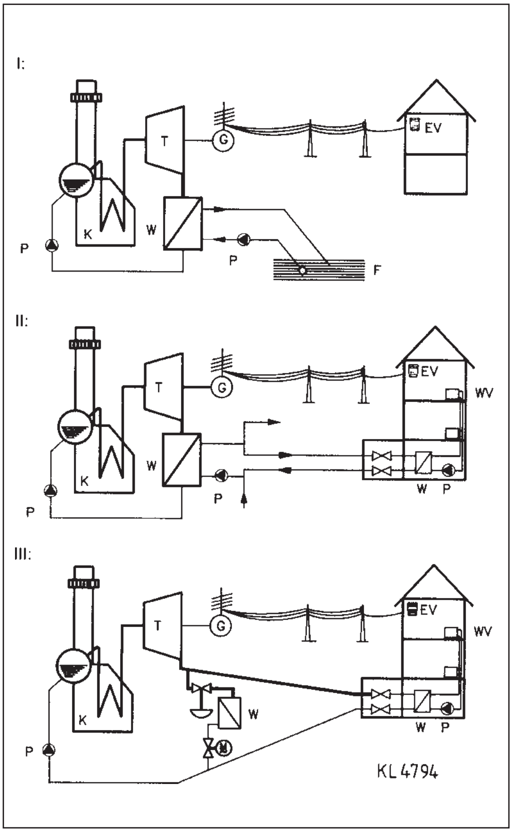


Fig. 1: I = basic power station for electricity generation, efficiency 33%; II = combined heat and power station for electricity generation and hot water distribution, efficiency 80%; III = combined heat and power station for electricity generation and steam distribution in a closed loop thermodynamic steam-condensate system with an efficiency of 80% (source: Baelz).
EV = electrical energy consumer; F = river; G = electricity generator; K = steam boiler with superheater; P = pump; T = turbine; W = heat exchanger.

would interfere with the function of the stirring mechanism. The low investment costs represent an additional advantage in view of the fact that no heat exchangers, steam traps, condensate return pumps and associated pipework are required.

2. Indirect steam consumption: this is the most customary method of using steam. In this case, steam is used to heat a series of pipes, heating banks, and double-jacketed vessels in order to transfer heat to, or evaporate, the medium on the other side. With indirect steam consumption, all the condensate is returned to the boiler house. The investment costs needed for containers, pumps, steam traps and pipework must be set in relation to the feed water preparation costs for direct steam consumers.

3. Steam consumption in steam turbines with subsequent condensation for heat generation: in general, power stations designed solely for the generation of electricity operate at an efficiency of only around 33%, whilst plants for combined heat and electric power generation achieve efficiencies of 80% and above. Three power plant concepts are illustrated in Fig. 1: a basic electricity power station, a combined heat and power station with hot water distribution, and a combined heat and power station with steam distribution.

When all the various steam consumers, with their required steam quantities, pressures and required temperatures have been determined, a steam distribution network (Fig. 2) can be planned. The various consum-

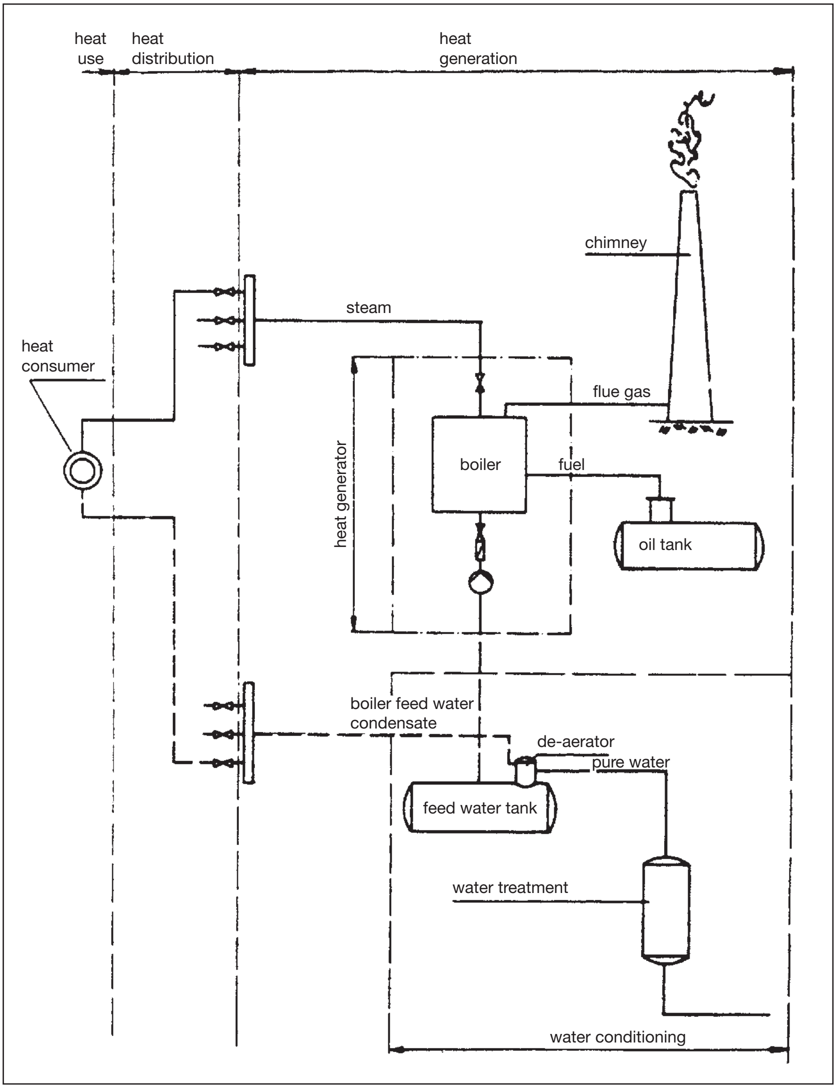


Fig. 2: Heat generation plant based on steam.

Heat generation from primary energy

type of fuel	quantity	total heat content	energy generated
combustible refuse 20.8 MJ/kg	5000 kg	24 752 000 Kcal 28 912 KWH 104 000 MJ	25 t **steam**
fuel oil 41.8 MJ/kg	2000 kg	19 896 800 Kcal 23 240 KWH 83 600 MJ	25 t **steam**
natural gas 42 MJ/kg $\rho N = 0.78 \text{ kg/m}^3$	2315 m^3 1806 kg	18 050 000 Kcal 21 080 KWH 75 840 MJ	25 t **steam**
coal 29.31 MJ/kg	2600 kg	18 137 000 Kcal 21 185 KWH 76 206 MJ	25 t **steam**

1 KWH = 860 Kcal = 3.6 MJ
1 MJ = 0.278 KWH = 238 Kcal

Tab. 1: Quantities of primary energy sources required to generate 25 t of steam in a boiler.

primary energy consumption	steam consumers	energy extraction from heat	electricity
100 KWH	electricity power station	—	33 KWH
100 KWH	thermal power station	66 KWH	14 KWH
100 KWH	heat generator	80 KWH	—
125 KWH	heat generator	100 KWH	—
60.6 KWH	electricity power station	—	20 KWH
Σ 185 KWH	separate heat and separate electricity generation	100 KWH	20 KWH
150 KWH	thermal power station	100 KWH	20 KWH

Tab. 2: Examples of primary energy usage (see also Fig. 1).

ers must be split into groups according to the required pressures and temperatures before the pipeline routing with the necessary desiccation stations can be established. The technology of the network has an important role to play here, and whether the network must remain operational around the clock or has to be shut down every evening and started up again the next day also needs to be known. In principle, it needs to be established whether the condensate lines can be installed for a 2-phase flow (steam and water) or water only. In Tables 1 and 2, some reference values and data on primary energy consumption according to steam usage have been given in order to provide a better understanding of the energy saving possibilities with modern steam technologies.

Steam is generated principally from primary energy sources. The high-pressure steam boilers for this purpose should be installed with a closed loop supply sys-

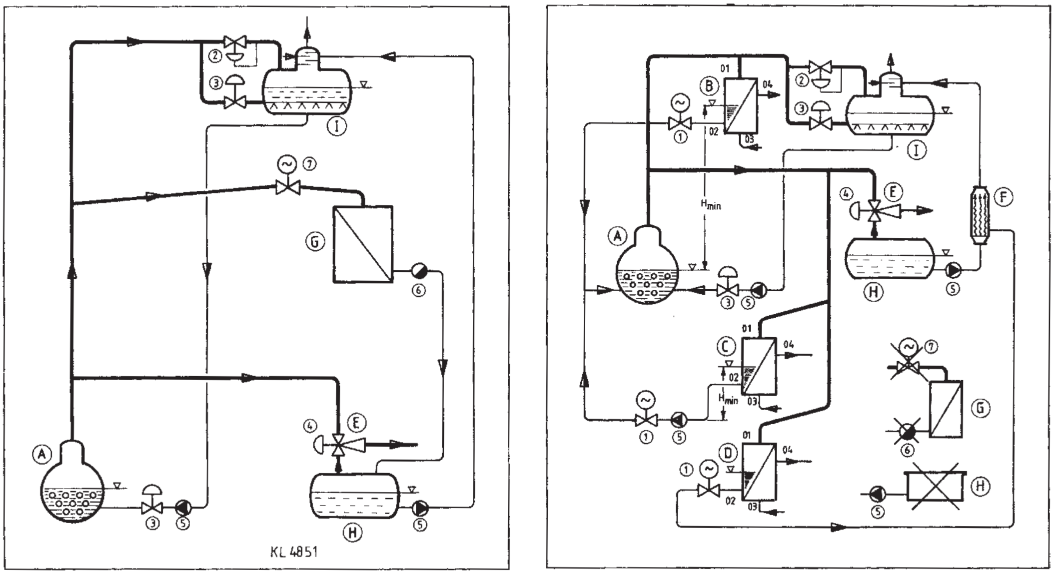
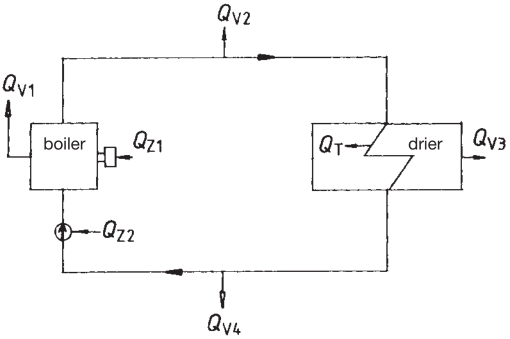


Fig. 3: Schematic representation of a steam consuming plant. Conventional technology on the left, Baelz steam technology without steam traps, with condensate cooling in the heat consumers, and condensate return under steam pressure, without oxygen ingress (source: Baelz).
A = steam boiler; B = heat exchanger with condensate-side control valve to regulate accumulation 0–100%; C = heat exchanger controlled from the condensate-side with pressure booster pump to feed condensate return directly into the boiler; D = heat transfer station with condensate-side control valve and condensate return feed, without pumping, into the de-aerator without condensate tank or steam trap; E = steam jet pump which functions as a steam compressor to compress exhaust steam; F = condensate delivery of hot condensate into cold condensate by means of a spray cooler; G = conventional heat transfer station with steam-side control (7) and steam trap (6) at outlet; H = open condensate collection tank with return feed pump (5); I = de-aerator; 01 = steam inlet; 02 = condensate outlet; 03 = inlet for secondary medium; 04 = outlet for secondary medium; 1 = condensate-side control valve to regulate accumulation of condensate in the heat exchanger for 0–100% capacity; 2 = steam reducing valve; 3 = control valve; 4 = steam jet pump; 5 = pump; 6 = steam trap; 7 = steam-side control valve.

tem (Fig. 3). Such a system allows optimum energy recovery for boiler water conditioning and heating. Natural gas and light fuel oil (with dual fuel burners) are the optimum fuels for firing steam boilers. As with electricity, natural gas is supplied by the respective utilities under customer contracts which involve off-peak and peak time tariffs. For this reason, boilers should be fired with light fuel oil only during the periods of peak demand specified by the utility supply company, in order to avoid paying correspondingly higher tariffs for gas supplies during such periods. Depending on location, other fuels may, of course, prove more cost effective. The question of environmental protection must be included during all considerations and planning of energy generation and utilization. A complete steam supply system for a production plant consists of: water conditioning, fuel supply, high pressure steam boilers and burners, safety systems, containers, pumps and motors, pipelines and fittings, control and regulating systems. All such installations are subject to approval and licencing by the relevant factories inspectorate authorities (source: Baelz).

Heating efficiency The heating efficiency of a textile drier is the proportion of heating energy supplied to the machine during its production time in relation to the energy η_H fed into the heating system. Its definition and calculation may be represented by a schematic example of a steam and oil circulation heating system:



The heating efficiency is given by:

$$\eta_H = \frac{\Sigma Q_Z - \Sigma Q_V}{\Sigma Q_Z} = \frac{Q_T}{Q_Z}$$

$$= 1 - \frac{Q_{V1} + Q_{V2} + Q_{V3} + Q_{V4}}{Q_{Z1} + Q_{Z2}} \cdot \frac{Q_S}{Q_P}$$

where:
Q_P = energy consumption during production time,
Q_S = energy consumption during total time,
Q_T = energy consumption of the drier,
Q_Z = total energy supplied,
Q_V = energy loss.

Energy Q_{Z1} in the form of fuel, and energy Q_{Z2} used to drive the pumps, is fed into the heating system. The energy components Q_{V1}, Q_{V2}, etc. represent losses outside the system. The energy Q_T is supplied to the drier by the heating system. Energy losses are further influenced to a significant extent by the heating system during the heating up phase as well as during production stoppages. Under these conditions, the losses arising during production are further increased by a factor Q_S/Q_P. This factor is difficult to calculate but very easy to measure. Q_P is the energy supplied per unit product during continuous running production. In order to determine Q_S the energy consumption is measured over a relatively long period, e.g. one week, and divided by the quantity of product/s produced in that time.

Heating gas → Natural gas.

Heating rate Information on the following parameters is important for the customary heating up rate in dyeing processes for synthetic fibres and wool:

1. the start temperature T_{start},
2. the heating rate h,
3. the maximum temperature T_{max} ,
4. the necessary dyeing time t_{max} ,
5. if applicable, the exhaustion on cooling.

The maximum rate of absorption $\nu_{BE,max}$ for a dye in the exhaust process is virtually independent of the initial temperature T_{start} of the dyeing; on the other hand, $\nu_{BE,max}$ is proportional to the heating up rate and the activation energy E_D of diffusion:

$$\nu_{BE,max} = \text{const. } E_D \cdot h.$$

The question as to what % of available dye per min should be fixed by the rate of dyeing, i.e. the procedure for selecting the heating rate h [°C/min], is given by the formula:

$$h = \frac{\nu_{BE}}{r}$$

where r, as a constant of the activation energy, is proportional to the diffusion and indicates the % of available dye in the liquor that is absorbed per °C rise in temperature within the middle absorption range (between approx. 20–80% bath exhaustion). The value of r for different dye/fibre systems is as follows:

- 8% of av. dye/°C for acrylic fibres with cationic dyes,
- 4% of av. dye/°C for polyester fibres with disperse dyes,

– 2% of av. dye/°C for polyamide fibres or wool with acid dyes
(source: Hoffmann).

Heating surface A surface or partition (usually metal, glass or plastic) which physically separates a product being heated and the heating medium, e.g. as in a heat exchanger. By maximizing the area of contact under otherwise identical conditions, the greater the heating surface area, the greater the amount of heat transferred (→ Heat exchanger).

Heating-up energy Curves for heating-up textile material in dry air (drying) or in superheated steam (steaming) are different. The corresponding heat contents of textile materials to be treated may be represented by a J-X curve.

Heating-up of textile materials A specific heating-up time is necessary in order to bring a textile material to the required treatment temperature. During the drying of woven fabrics in stenters, the actual temperature (Fig. 1) approaches the target temperature asymptotically (e.g. the temperature of circulating air in heat-setting).

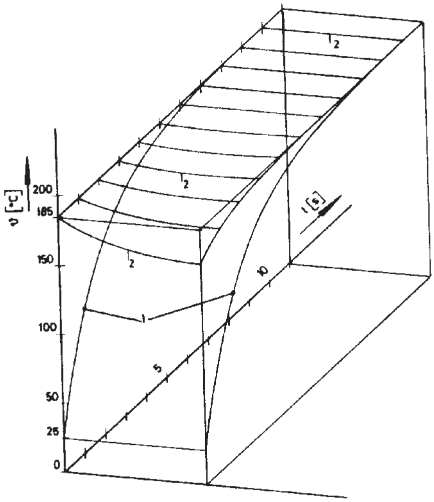


Fig. 1: Three-dimensional curve of air and fabric temperature during the heating-up of a textile fabric.

In this three-dimensional graph (Fig. 1) the abscissa represents the fabric width. The congruent curves 1 represent the heating-up of textile fabric. The group of curves 2 show the temperature curve of the hot air from the nozzles, i.e. before reaching the fabric (the incoming hot air temperature from the nozzles is constant at 185°C) and its cooling down after leaving the fabric. The fabric temperature is constant across the width. The temperature curve represented by the group of curves 2 indicates the change in temperature of the hot air before and after it has made contact with the fabric and must, under no circumstances, be related to the constant temperature curve across the width of the fabric. The t axis represents the time or, if multiplied by the fabric speed, the length of the stenter. Temperatures are in °C.

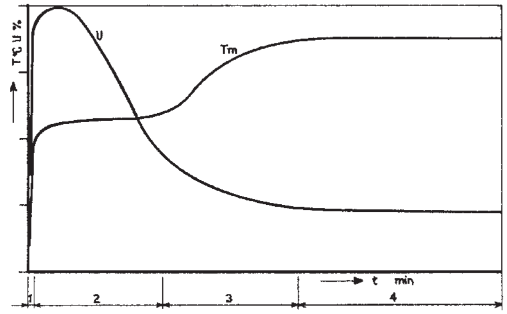


Fig. 2: Heating-up curve for a textile fabric in superheated steam.
t = time; T = temperature scale; Tm = temperature of fabric; U = moisture content of fabric.

During the steaming of a printed fabric, water vapour condenses at first on to the fabric as it heats up (Fig. 2) before the water evaporates again in the superheated steam later in the steaming process. Only then is the wet bulb temperature exceeded and the final temperature achieved on the fabric.

Heating-up time for exhaust dyeings To establish the bath exhaustion rate for an exhaust dyeing, the heating-up time (from start temperature to dyeing temperature) must be determined by the degree of levelness or unlevelness acceptable at the end of the heating-up phase, i.e. whether the levelling process is to

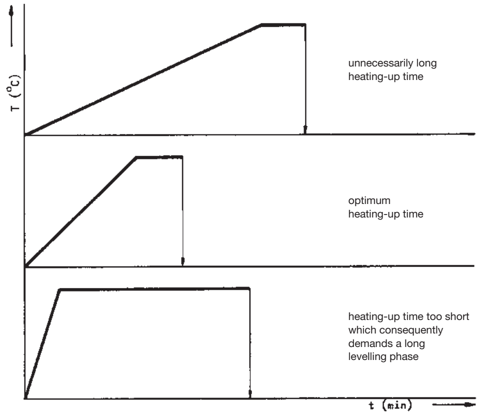


Fig. 1: Schematic representation of the minimum time required for a level dyeing, taking account of the heating-up and levelling phases.

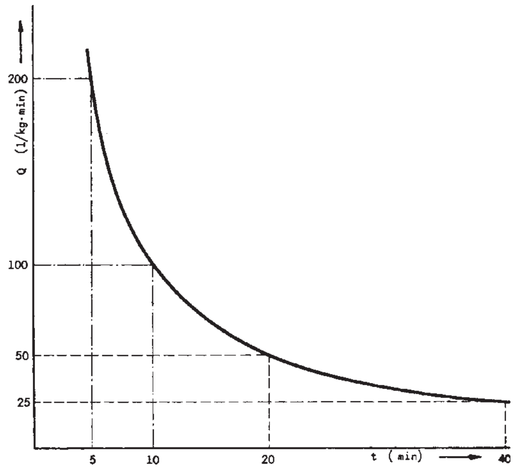


Fig. 2: Relationship between liquor throughput rate and the time required for the heating phase during the critical rate of dyeing.

take place at the dyeing temperature (Fig. 1). Normally, some degree of unlevelness at the end of the heating-up phase is acceptable in order not to prolong the heating-up time unnecessarily. A higher liquor throughput rate must be employed (Fig. 2) to save time in the critical temperature range.

Heating-up time for rapid dyeing systems The heating-up time is inversely proportional to the liquor circulation rate. Limits apply in practice, however, since textile material can be damaged at very high liquor circulation rates (e.g. package deformation), or the dye liquor may be insufficiently stable under such conditions.

Heat insulating materials Subdivided into three groups according to their structure, i.e. fibres, foams and filling materials. The actual heat insulating medium in these structures is air or, in the case of foams, the gas entrapped in the foam which was generated by a blowing agent during manufacture. Glass or mineral fibres, in particular, are used as effective components in various heat insulating materials. Natural fibres have seldom found application for heat insulation in the construction industry up to now.

Plastics such as polystyrene or polyurethane, as well as glass, are used as base materials for heat insulating foams. Glass foam is an ecologically sound product since the blowing agent, carbon dioxide, is formed by the oxidation of carbon monoxide during manufacture. The ecological safety of glass foam, as certified by the Association for Environmentally-Compatible Building Materials must, however, be qualified by the customary method of bonding foamed glass plates with bitumen during installation.

As filling materials, paper chips (cellulose granules) are the most widely used product and are blown into the cavities requiring insulation. Granulated cork may also be used. Cellulose granules are increasingly obtained from the recycling of waste paper. No reliable information on possible heavy metal contamination from the printing inks applied to paper is available up to now. As in the case of glass foams, other substances are added in the form of assistants to achieve specific characteristics during production (e.g. flame retardants), or to assist in making-up and installation.

Thermal conductivity λ, is an important parameter in the physical assessment of heat insulating materials. It provides a measure of the amount of energy transported away from the material per metre of insulating layer and per degree difference in temperature. The lower the value of λ, the better the heat insulation. A typical value for heat insulating materials is approx. 0.040 W/m°K (see Table) (source: Schenk).

Heat insulation (thermal insulation). To achieve a high degree of effective heat insulation, a garment must enclose as large a volume of static air as possible in order to create a microclimate. This means, however, that the size and number of garments worn in combination on the body must be optimally suited to each other. As illustrated schematically in Fig. 1 (left-hand side),

	fibres glass and mineral fibres	chemical foams	foamed glass	filling materials cellulose granules
hermal conductivity [W/m°K]	0.035–0.040	0.030–0.040	0.040–0.055	0.040–0.045
additives	3 % bakelite	0.5 %	not known	20 % boron salts
combustible	no	yes	no	yes
dioxin in combustion gases	no	yes	no	not known
health risk	carcinogen	suspected of evolving toxic gases	safe product, but bitumen used for installation	not known
handling	easy	easy	requires a specialist	applied by blowing
resources	unlimited	petroleum	unlimited	waste paper

Table: Classification and characteristics of heat insulating materials.

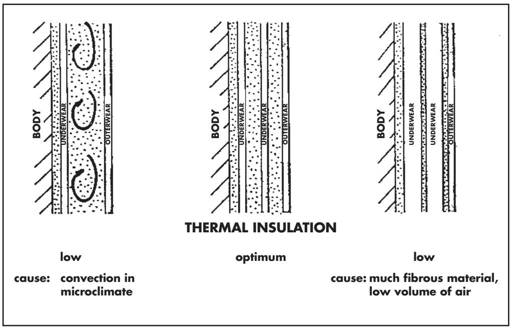


Fig. 1: Adaptation of outer and underwear to achieve optimum thermal insulation (source: Umbach).

an outer garment which does not fit closely in relation to the underwear leads to air convection in the microclimate which has the effect of reducing heat insulation. It would be false, however, to attempt to compensate for the loose fit of the outer garment by wearing a greater number of layers of thick under-garments. In effect, the resultant accumulation of fibre material would simply displace the heat-insulating air from the microclimate. By contrast, the optimum solution is to wear several items of underclothing (as in Fig. 1, centre), the thickness and size of which are adapted to the outerwear in such a way that as many small air voids are created as possible (but too narrow for convection, which reduces heat insulation). → Clothing physiology.

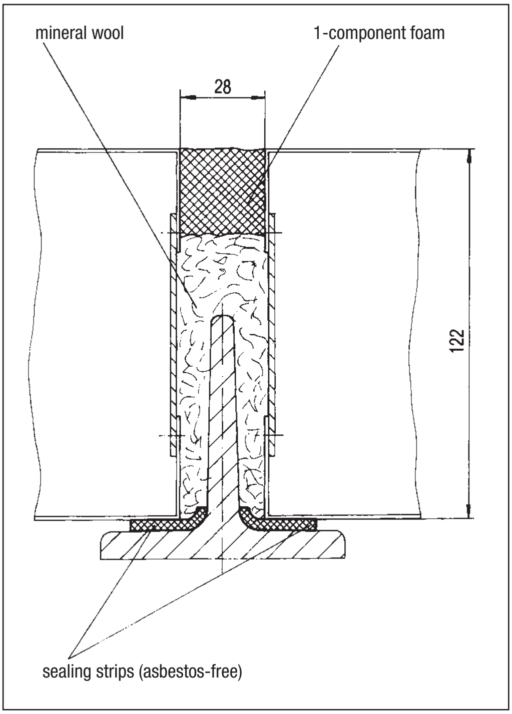


Fig. 2: Seal and insulation between framework and roof insulating plates on stenter.

Also in the case of machines consuming heat, e.g. stenters, good heat insulation from the surroundings is important in order to save energy (Fig. 2). Attempts to provide dyeing machines with heat insulation based on expanded foam materials have so far failed to bring any benefits.

Heat losses → Radiation heat losses from dye liquors and dyeing machines.

Heat-measuring papers → Thermometer papers.

Heat of a liquid The quantity of heat required to raise the temperature of 1 kg of a liquid from 0°C to the boiling point (expressed in J resp. kJ).

Heat of combustion → Heat capacity.

Heat of vaporization (heat of evaporation). The heat required in J/g to convert 1 g of a substance from the liquid to the gaseous state at the boiling point. The heat of vaporization for water is high, as is also that of alcohol because of the strong intermolecular forces (hydrogen bonds) in the liquid. By contrast, non-polar solvents have considerably lower heats of vaporization.

Heat pumps, reverse cycle heating systems A heat pump is a system for extracting heat from a fluid that is at a slightly higher temperature than its surroundings, i.e. it transfers heat from the low-temperature source to a high-temperature region by doing work on a working fluid which involves a reversible cyclic thermodynamic process. Compression heat pumps of this kind need mainly high-grade energy inputs such as electric current for electric motors or gas resp. oil for internal combustion engines to drive a reciprocating piston compressor. Possible primary energy sources include: ground water, water from rivers or lakes, soil, the atmosphere, waste heat in water and air. The heat pump (see Fig.) consists of a reciprocating piston compressor, a heat exchanger known as a condenser, an expansion valve and a second heat exchanger known as an evaporator.

The fluid, in vapour form, is compressed by the compressor so that its temperature rises. The vapour then passes through the condenser where it gives off heat to the heating medium (e.g. water for heating a finishing machine) and in doing so condenses to a liquid. This liquid, which is under high pressure, is then allowed to expand through an expansion valve. The evaporation of the fluid results in a considerable degree of cooling and, on passing into the evaporator it absorbs heat from the primary energy source, e.g. ground water, and becomes a vapour again before re-entering the pump. This cycle is repeated continuously. The efficiency of a heat pump is measured by the performance

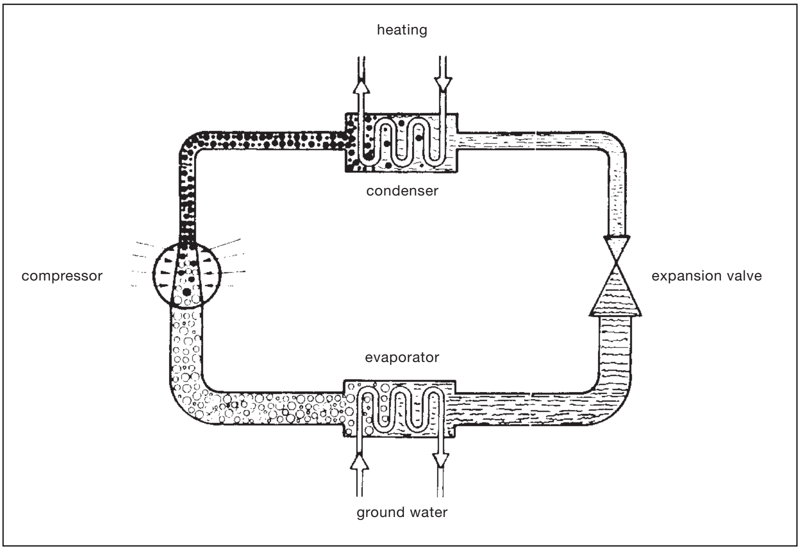


Fig.: Heat pump concept.

factor E. This gives the ratio of useful heat to the electrical energy consumed. Mean annual performance factors between 1.6 and 5 are usual. The theoretical maximum attainable performance factor is given by the Carnot cycle:

$$Ec = \frac{T_2}{T_2 - T_1}$$

where T_1 corresponds to the evaporation temperature (e.g. temperature of the ground water), and T_2 corresponds to the condensation temperature (flow temperature for heating). Performance factors which can be achieved in practice are approx. 0.5% the theoretical values. From the formula it can be seen that the smaller the value $T_2 - T_1$, the greater the value of Ec. The smaller the difference between the temperature of the heat source medium (e.g. ground water) and the flow temperature for heating, the higher the performance factor of the heat pump. The maximum temperature achievable with heat pumps is approx. 60°C. In the textile industry, heat pumps are particularly useful for utilizing the waste heat from effluents and exhaust air.

Heat recovery Hot exhaust air from driers or hot effluent from dyehouses can be used to preheat cold air or water. Heat exchangers based on this principle are designed to effect heat exchange between a) gas/gas, b) gas/liquid and c) liquid/liquid. The first requirement is the availability of a central hot water supply. The nature and scope of heat recovery depends on a variety of factors and therefore demands an in-depth evaluation of each individual case. In textile finishing plants, heat recovery from hot effluents and hot air from stenters, driers, hotflues, curing machines, etc. represent the most obvious opportunities.

Heat from hot effluents alone may be recovered from a variety of sources, e.g.: from wash liquors, from indirect cooling systems (e.g. dry cleaning machines and water-cooled compressors), from boiler desalination (reactor water) to maintain a specific conductivity of the boiler water, and finally from the waste water produced during boiler blow-down demineralization. The utilization of flue gases from boilers is only possible if the boilers are heated by natural gas. This source of heat from oil-fired boilers (light or heavy fuel oil), on the other hand, cannot be used because the Federal Emissions Protection Law in Germany (TA-Luft) does not allow a dewpoint below 185°C. Because of their heat content, exhaust air from textile driers can make a useful contribution to heat recovery (→ Exhaust air heat recovery).

If the above-mentioned heat sources are converted into kilowatt hour units and discharge temperatures of 32–35°C, as laid down in practically all communal regulations, are taken as a basis, the question arises as to how the recovered energy is to be reused in production processes through all seasons of the year if possible. A precondition for heat recovery is the availability of waste heat and a requirement for heat energy at the same time. Consequently, there is a necessity for a buffer which can store the waste heat and release it again as and when required. Since, however, there are considerable differences in the temperature ranges of various sources of waste heat, e.g. flue gas from 250–270°C, and water for indirect cooling from 40–45°C, the temperature gradients have to be taken into account. For

Heat recovery

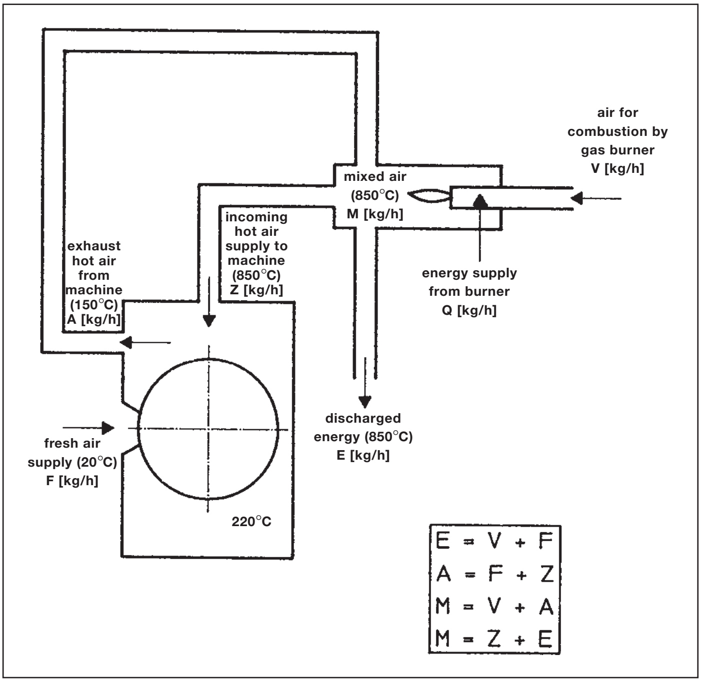


Fig. 1: Combined heat recovery and exhaust air cleaning system for a through-flow drier.

this reason, different buffer storage units are therefore required in practice.

Fig. 1 shows a typical heat recovery system in which different buffer storage units have been installed corresponding to the temperature gradients of the various sources of waste heat. In addition to these buffer storage units, circulation systems are provided in which water, circulating as a heat transport medium, is heated step by step and also cooled down again according to the temperature requirement.

In the heat recovery process, flue gas is cooled down in a flue gas heat exchanger (Fig. 2) from 130°C to approx. 35°C which means that the gas falls below its dewpoint at the same time. As a result, water present in the flue gas condenses in quantities of approx. 3 l min at a pH of 1.5–3 depending on the efficiency of the burner. This highly acidic flue gas condensate is collected and used for neutralization purposes. The flue stack, which is lined internally with stainless steel, is provided with a sump at the bottom to collect the flue gas condensate.

500 m of 40 mm diameter black PVC piping, as used for domestic water supply conduits, is contained in a typical waste water heat exchanger. This material, which is resistant to the alkalis, acids and oxidizing agents likely to be present in waste waters is, at the same time, resistant to temperature environments up to 50°C as well as pressures up to 5 bar. Although the temperature transfer is not as high as that achieved with,

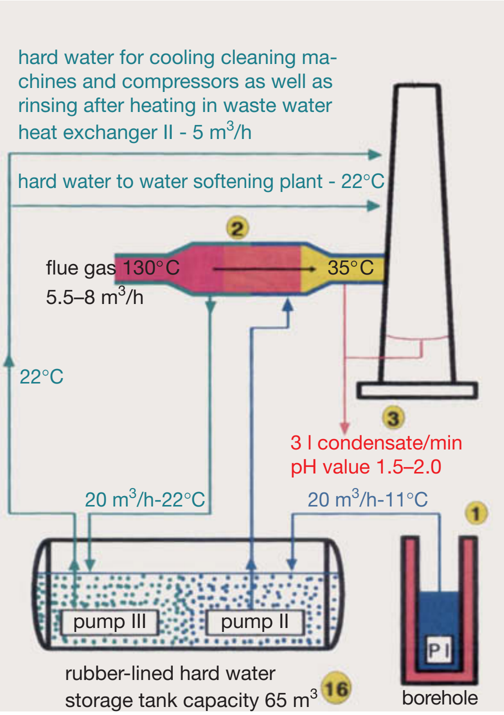


Fig. 2: Heat recovery in a flue gas heat exchanger (source: Kamm).

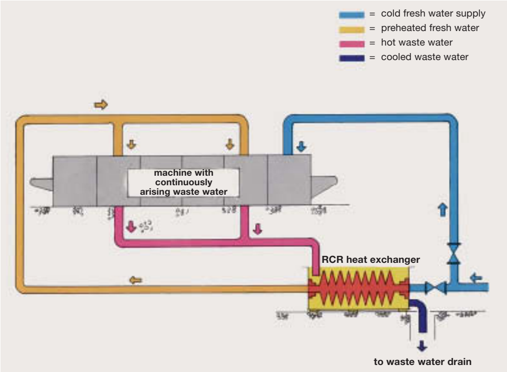


Fig. 3: Heat recovery in a continuous desalinator (source: Pozzi).

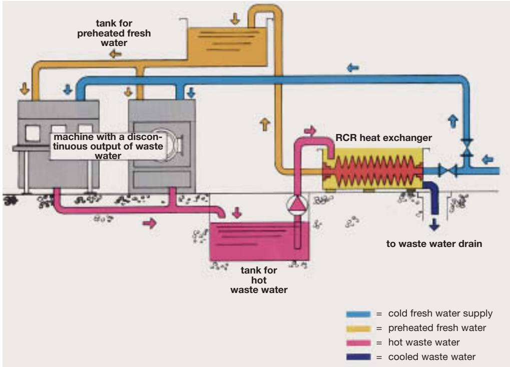


Fig. 4: Heat recovery with a discontinuous output of waste water (source: Pozzi).

e.g. stainless steel piping, it is considerably cheaper from a cost point of view. Since, however, a dwell time of 1 hour is involved, the disadvantage of a less efficient heat transfer can be disregarded in this case. Hard water, which is passed through the 500 m of PVC pipe and heated to approx. 38°C in the process, is then used for rinsing purposes. In the 65 m^3 capacity soft water tank, the soft water used for rinsing purposes undergoes a further rise in temperature. With heat recovery from the calender exhaust air and the flue gas heat exchanger, a circulation of rising and falling temperatures is involved. Heat recovery is also possible in a boiler feed-water treatment plant.

Heat exchangers can be used in heat recovery plants where effluents are produced continuously as well as discontinuously (Figs. 3 and 4).

For stenters, especially, the temperature gradient between the exhaust air and the incoming fresh air is so great that heat recovery is particularly worthwile.

Both integrated and external heat recovery systems are available for energy savings on stenters. The integrated systems are user-friendly, take up little space, and do not involve expensive installation (Fig. 5).

The highest efficiency is achieved with external systems (Fig. 6) which can be installed separate from, and next to, the stenter or above it. Operators are relieved of cleaning tasks by a fully automatic cleaning system which also ensures greater reliability in operation.

In principle, an external heat exchanger (Fig. 7) functions as a filtration system for the removal of harmful pollutants by cooling the exhaust air to such an extent that the pollutants condense to form droplets

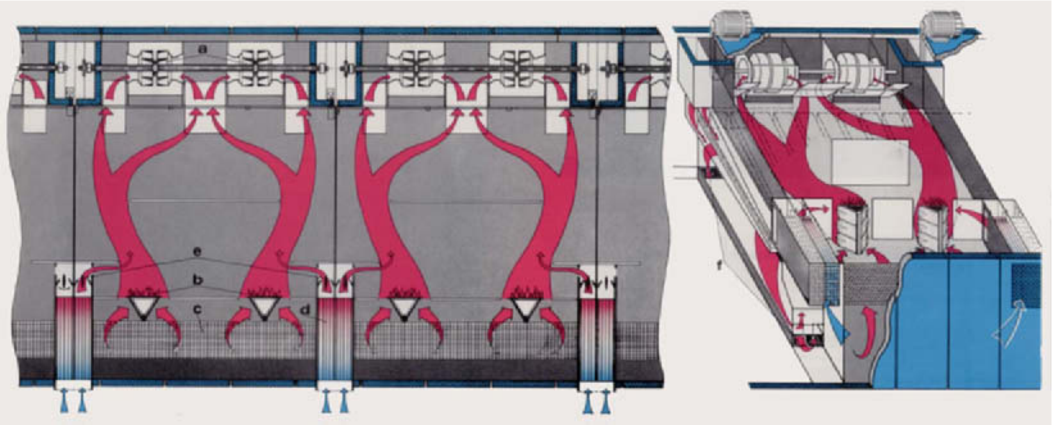


Fig. 5: Air circulation system with integrated heat recovery K.WI (Krantz).
a = 4 radial ventilators on a common shaft with external bearings; b = heating, example with direct gas heating; c = large air filters; d = bare tube heat exchanger in the exhaust air outlets; e = fresh air supply regulators; f = exhaust air extraction below the fabric web.

Heat recovery

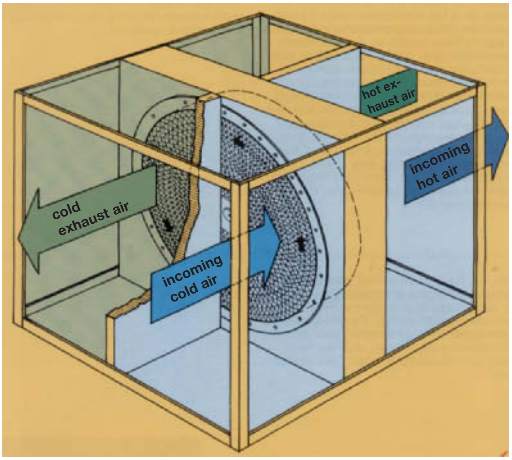


Fig. 6: Heat wheel (Babcock) used as an external heat exchanger for heat recovery.

which are then removed from the air through high-performance filters. The exhaust air from the machine is first passed into an external air/air heat exchanger. Fresh air impinges on the secondary side of this air/air heat exchanger (recuperative heat exchanger) which is then heated in the heat exchanger. This heated fresh air is then supplied to the machine so that heat is recovered from the exhaust air. The exhaust air is cooled down on flowing through the air/air heat exchanger. If possible, this pre-cooled exhaust air is passed through an air/water heat exchanger in a second cooling stage where process water is heated. After this air/water heat exchanger, or even after the air/air heat exchanger, the temperature of the exhaust air must have fallen to 60°C, at which temperature most pollutants condense to form aerosols (source: in part = H.A. Kamm).

Heat recovery from exhaust air is effected in three ways:

I. Regenerative: heat from the exhaust air is transferred in turn to a storage system and then to the incoming fresh air. Advantages: higher heat recovery. Disadvantages: complete separation of the exhaust and fresh air streams is not possible so that a risk of contamination exists if the exhaust air contains a high proportion of pollutants. For this reason, this type of heat exchanger is mainly employed in air conditioning applications.

II. Recuperative: heat is supplied and transported away continuously. There is a complete separation of both exhaust air and fresh air. Tubular or plate type heat exchangers constructed of metal, glass or plastic materials are used. In dyehouses it is possible to combine

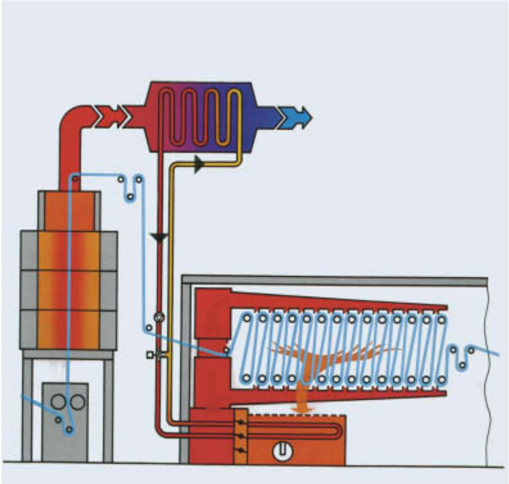


Fig. 8: IR predriers heat recovery (Monforts).

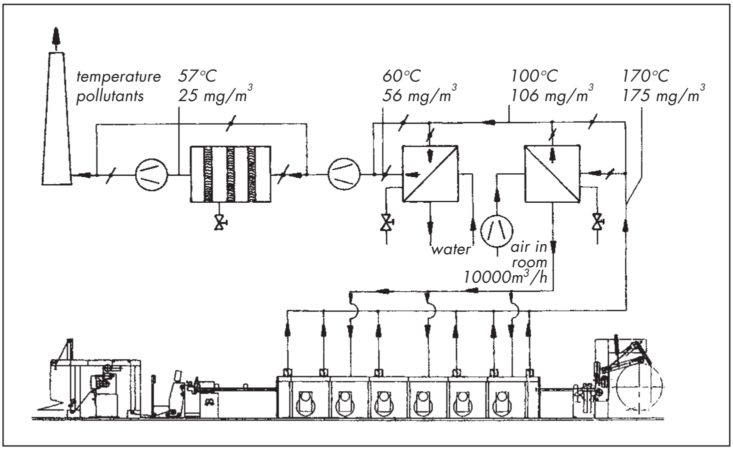


Fig. 7: Schematic diagram of an exhaust air cleaning system with heat recovery and filter (source: Behr).

the ventilation system with a heat recovery plant. The Hoval company has constructed a system of this kind which consists of a roof fan, air heater and a recuperative heat exchanger.

III. Babcock-Famatex heat wheel: specifically designed for stenters; heat exchange takes place via a metal body. The exhaust air is freed of condensate and completely cleaned by combustion.

The heat from the waste air expelled by the gas heated IR predrier is used to preheat the hotflue circulation air (Fig. 8). The transfer takes place in an air/oil heat exchanger system (Monforts).

Heat resistance → Thermal stability.

Heat resistance of cellulose This is primarily dependent on the degree of polymerization of the cellulose and becomes more sensitive to chemical and physical action with increasing stages of degradation. Also important is the content of oxycellulose and hydrocellulose as these forms are unstable at elevated temperatures. Changes resulting from the action of heat are dependent on the temperature and time of heat exposure. → Thermal stability of fibres.

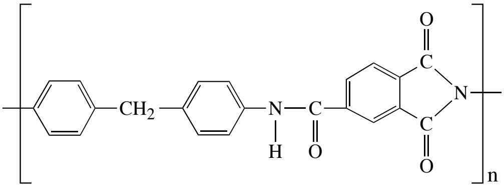
Heat-resistant fibres (thermostable fibres). The heat resistance of a polymer is characterized by three independent factors:

- the standard of general properties (mechanical and chemical),
- the retention of these properties for a given temperature range,
- the retention of these properties over a specific time and temperature.

For the special application of heat-resistant fibres in flame-retardant and heat-resistant protective clothing, three factors are decisive, i.e.:

- specific properties required for actual use in a garment (mechanical strength parameters and chemical resistance parameters),
- integrity of the textile surface during short-term exposure of the protective garment to radiant heat for possible protection against fire,
- retention of fabric surface properties during prolonged exposure to heat (firefighters' jackets generally consist of several layers of textile material for this reason, e.g.: wool cloth, nonwoven material, membranes or microporous linings).

Concepts for the specific thermal resistance of protective clothing to fire and heat are influenced more by the physical properties (functions of time and temperature involving a few seconds at 1000°C, or a few minutes at 250–350°C) of the raw material (e.g., melting point, second degree transition temperature) than the chemical properties such as, e.g. resistance to heat, hydrolysis or oxidation. These latter properties are important when thermostable fibres are used for the filtration of hot gases. Chemically, thermostable fibres are based on polyamide-imides (meta-aramid types), see → Aramide (fibres):



These fibres are manufactured by the polycondensation of trimellitic anhydride with di-isocyanatodiphenylmethane. The solutions, after incorporation of pigment, are wet spun into fibres followed by drawing at very high temperatures (this is necessary in order to achieve good resistance to light and washing).

Heat-resistant finishes Finishes which are intended to improve the resistance of textiles (strength, etc.) against the effects of high temperatures below the point of ignition. Such finishes are important for ironing cloths, paper machine felts and, possibly, tyre cords. Heat-resistant finishes for cotton include e.g. → Acetylation, treatment with dicyandiamide, etc.

Heat retention (thermal retention). This is an important serviceability characteristic of a garment (→ Wesel triangle). It follows from the → Thermal conductivity coefficient of textile fibres that all fibres, without exception, are better conductors of heat than air. Consequently, the heat retentivity of textile fabrics and similar materials is largely dependent on the respective pore volume and air content (→ Porosity). Since the thickness of the layer of air (= thickness of fabric % pore volume) is roughly proportional to total heat retentivity, an approximate estimate of the degree of heat protection of apparel fabrics to be expected can be obtained by determining the thickness of the layer of air. Determinations of this kind are, however, technically difficult, laborious, and also require special equipment. In order to avoid false conclusions, two methods which take into account the specific gravity are carried out at the same time:

- measurement of the → Air retentivity
- the so-called cooling measurement (with liquid at 37°C) on a copper cylinder wrapped with the test fabric. The percentual heat loss (kJ/°C) per unit time (h) and unit surface area (m^2) is determined by this means.

Heat retentivity → Heat retention.

Heat sealable paper A release paper, coated on the reverse side, used in the garment making industry to produce cutting layouts on textile fabrics. It adheres to any textile material with the aid of a hot iron and is easily removed again after cutting without leaving any residue.

Heat sealing A thermoplasticizing operation representing a primary stage in the bonding of nonwovens, collar interlinings and the fusing of fusible interlinings, etc. The temperature and duration of thermal bonding depends on the type of resin coating and the end-use of the substrate. Products suitable for thermal bonding see →: Melt-flow index; Sintering.

Heat-sensitive granules Small granules which have a precisely known melting point. Used for checking the temperature of steam pipes, calender bowls, ironing presses, etc.

Heat-set clothing → Heat-set garments.

Heat-set garments Heat-set garments are made from circular-knit fabrics where the desired body shape has been permanently set on heated three-dimensional metal mannekins. Collars and sleeves are welded to the main garment. This process eliminates the need for side seams and darts.

Heat setting An essential process in the pretreatment of man-made fibres which is also of importance in subsequent stages as intermediate setting or post-setting. The effect of heat setting is greater in fibres with an increasingly hydrophobic character and is carried out on polyolefin, polyester, polyurethane, polyacrylonitrile, polyamide, triacetate, acetate and viscose fibres (the fibres are listed in order of decreasing hydrophobic character). The objectives of heat setting processes include structure homogenization and the elimination of internal tensions within the fibre resulting in reduced shrinkage, improved dimensional stability, reduced creasing propensity and reduced edge-curl in woven and knitted fabrics. To this extent, the process may be better described as thermal relaxation. Heat setting changes not only the mechanical, but also the dyeing properties of man-made fibres. The principle is based on heating the fibre within a fibre-specific temperature range which is limited at the upper end by the melting point (softening range) and the respective glass transition temperature (necessary to break the secondary bonds) at the lower end.

The basic functions of heat setting are as follows:

1. Heating up the fibre with the evaporation of residual water and, with increasing material temperature, the “unblocking” of internal tensions and initiation of chain segment mobility.
2. Presentation of the material to the setting medium either under tension or tension-free passage as desired.
3. To subject the material to the setting medium for a specified period of time during which unstable crystallites melt and the polymer mass is partially recrystallized so that crystallites are formed the thermal stability of which is dependent on the parameters of temperature, dwell time and fibre tension during their formation.
4. On cooling, additional crystallization occurs in the crystallites of low stability and setting of the noncrystalline regions of the fibre takes place under the state of tension at the time of falling below the glass transition temperature.

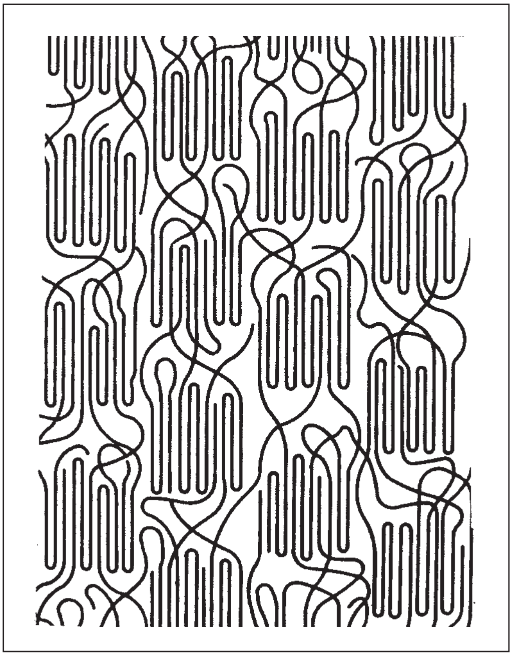


Fig.: Fringe fibril structure with chain back-folding according to Peterlin (1975). Shown in the vertical direction are four fibrils consisting of alternating crystallites with chain over-folding and amorphous areas. Between the fibrils lie the semi-crystalline, interfibrillar spaces.

The most important parameters of these functions are temperature, the given dimensions and the dwell time. A longer dwell time at the required temperature serves no useful purpose and therefore wastes energy. Heat setting processes within a temperature range of 130–220°C are possible; the selected temperature determines subsequent dyeing properties as follows: with increasing temperatures (e.g. in the case of polyester up to 200°C) the proportion of crystalline regions increases and, on exceeding this fibre-specific temperature, the proportion of noncrystalline regions increases (see Fig.) at the expense of the interfibrillar semi-crystalline interstitial spaces (→ Supramolecular structure of polymers). The greater the proportion of noncrystalline regions after heat setting, which is also influenced by the rate of cooling (rapid cooling reduces recrystallization), the better the subsequent dyeing properties. The temperature described as the “effective temperature” is that temperature which is necessary to cancel out the heat setting effect. Thus the heat setting temperature should be at least 25–30°C (for polyester 30–40°C) higher than temperatures to which the textile material will be subjected in subsequent processing or use.

Heat setting, determination of degree In the processing of synthetic fibres determination of the degree of heat setting is especially important since it contributes to the properties of the finished product. For polyamide fibres, swelling in sulphuric acid, and for polyester the critical solubility (phenol/tetrachloroethane) represent possibilities for determining the degree of heat setting.

Heat setting of carpet yarns Polyamide carpet yarns are set continuously in hot air at 205°C or in equipment where heat setting is carried out in saturated steam. See also → Carpet yarns, setting.

Heat setting of man-made fibres →: Fixation; Heat setting.

Heat setting processes Depending on the effective heating medium, heat setting processes include the following methods:

I. Hot air setting: the most common method of heat setting carried out on stenters or hot flue machines.

II. Contact heat: e.g. hot roll setting carried out on hot roll machines.

III. Saturated steam (steam setting): a method used for printed goods, socks, hosiery, woven and knitted fabrics, ply yarns, etc. since excellent resistance to shrinkage, creasing and high dimensional stability can be achieved. Setting is carried out discontinuously in vacuum or pressure steamers.

IV. Hot water treatment: under conditions below the boil the setting effect is not stable since the "effective temperature" is too low (these temperatures are already attained in making-up and in domestic washing). In the case of polyamide, on the other hand, effects which are equally as good as hot air setting are achieved e.g. at temperatures of 120–130°C in the beam dyeing machine (hydro-setting).

With polyamide and polyacrylonitrile fibres (no contact heat setting), the swelling properties are increased by setting in hot water or saturated steam and, by contrast, reduced by setting in hot air and contact heat. With polyester, the swelling properties are reduced in all three suitable media (I.–III.).

Demand is growing for seamless leisurewear and underwear (Fig. 1). Improved transverse elasticity and determined fabric weights are required. Presetting of knitwear with elastic fibre content just like heat setting of synthetic fabrics has, until now, been performed on stenter frames with the fabric cut open. Apart from the undesired sewing seams this process causes additional work and cost due to fabric slitting, fabric loss due to selvedge glueing and cutting, fabric doubling and sewing to avoid selvedge curling during dyeing, fabric reslitting etc.

The latest Dornier product – the Ecofix thermosetting range (patent applied) (Fig. 2) – is the first machine of its type on the world market capable of performing this heat setting operation on circular knits in their tubular form. With this solution, all the usual hosiery widths can be continuously and optimally steam-relaxed, thermoset with hot air and then treated with cold air. The patented automatically adjustable circular expander system – already thoroughly proven in the Dornier singeing, mercerising and bleaching ranges, ensures during the EcoFix treatment that the tubular

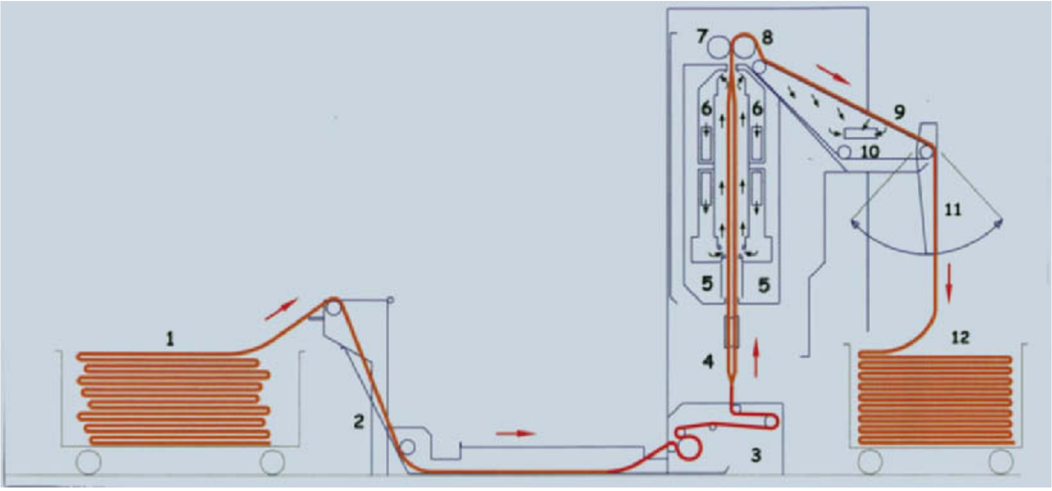


Fig. 1: Vertical thermosetting of tubular knitted fabrics containing Lycra on the Rollset-machine from Heliot.
1 = fabric to be treated; 2 = "J" of feeding; 3 = fabric tightening control; 4 = stretcher; 5 = treatment chamber; 6 = suction; 7 = movable cylinder; 8 = fixed cylinder; 9 = conveyor belt; 10 = suction; 11 = folding device by swinging or pallet folding device (optional); 12 = folded fabric.

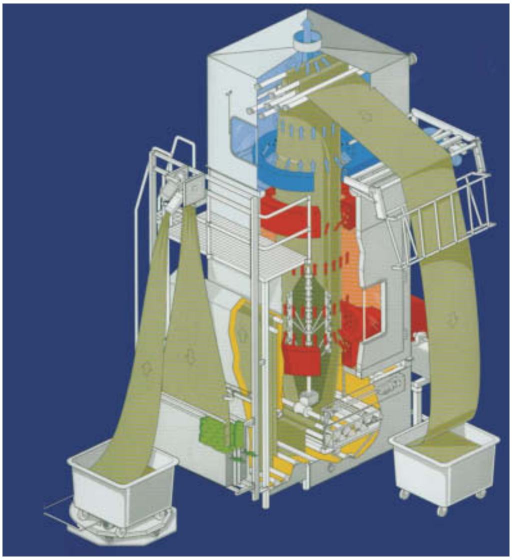


Fig. 2: Heat setting of tubular cotton/lycra knitted fabric; technical drawing of Dornier thermosetting range EcoFix.

fabric is held in its compressed condition with maximum control. Opening the stitches on the circular expander enables the hot air flow to pass uniformly around and through the tubular fabric. This system sets new standards in the field of heat setting, with shape stability, stretchability based on defined elasticity plus the required specific weight, all ensured on a reproducible basis.

Heat setting zone The dry zone in stenter driers for the heat setting of fabrics composed of synthetic fibres or their blends with special supplementary heating.

Heat, specific → Specific heat.

Heat stability The stability of dye dispersions/solutions to treatment temperatures in dyeing, for example especially when dyeing under HT conditions. The term must not be confused with dispersion stability since, under the action of heat, changes in the dye molecule can also occur which may result in reduced dye yields.

Heat transfer → Convection.

Heat transfer coefficient The capacity of a material (or combination) associated with heat transport to oppose the passage of heat through it with greater or lesser resistance (→ Heat transfer). A low heat transfer coefficient (k) corresponds to good heat insulating properties. In contrast to thermal conductivity, this parameter is not related to the length but to the heat flow per unit time through unit area.

The SI unit for the heat transfer coefficient is given by:

$$\frac{\mathrm{W}}{\mathrm{m^2 \cdot K}}$$

Conversion formulae for units no longer in use:

$$\frac{\mathrm{kcal}}{\mathrm{m^2 \cdot h \cdot K}} = 1.163\ \frac{\mathrm{W}}{\mathrm{m^2 \cdot K}}$$

$$\frac{\mathrm{W}}{\mathrm{m^2 \cdot K}} = 0.860\ \frac{\mathrm{kcal}}{\mathrm{m^2 \cdot h \cdot K}}$$

Heat transfer medium Heat transfer liquids for → Circulating hot oil unit used in the textile industry and as heat transfer fluids in → Heat exchanger. They are used exclusively in liquid form. Requirements:

– easily pumped at room temperature (20°C),
– boiling point must lie above the max. required temperature,
– non-toxic,
– non-corrosive in contact with machine components.

Raw materials for heat transfer agents include:

– mineral oil products,
– synthetic products (aromatics) with a max. operating range up to 350°C. Exceptions are diphenyl and diphenyl oxide (may be used up to max. 400°C, boiling range begins at 270°C, i.e. above this point, vapour pressures up to max. 13 bar must be taken into account), chlorinated hydrocarbons (no longer permitted).

The heating of machines, vessels, buildings, etc. with water or steam is a well-known application. In this case, water or steam serves as the heat transfer medium. At temperatures above 100°C, however, an increase in temperature is associated with a corresponding increase in pressure (saturated steam curve). For many industrial heating applications temperatures up to 300°C and above are required.

Whilst, in the case of water or steam, a pressure of 10 bar already prevails at a temperature of e.g. 180°C, and even 120 bar at 320°C, these temperatures can be achieved virtually pressure-free by thermal oil heating using suitable heat transfer agents produced by the mineral oil resp. chemical industry (i.e. such heating systems are not subject to the official regulations governing the use of pressure vessels).

Heating equipment based on the use of heat transfer oil is used to solve numerous industrial heating problems, e.g. for heating reaction vessels, mixing vessels, storage tanks, distillation columns and, not least, heat exchangers. With such heating/cooling systems, cooling can be carried out as well as heating. In principle,

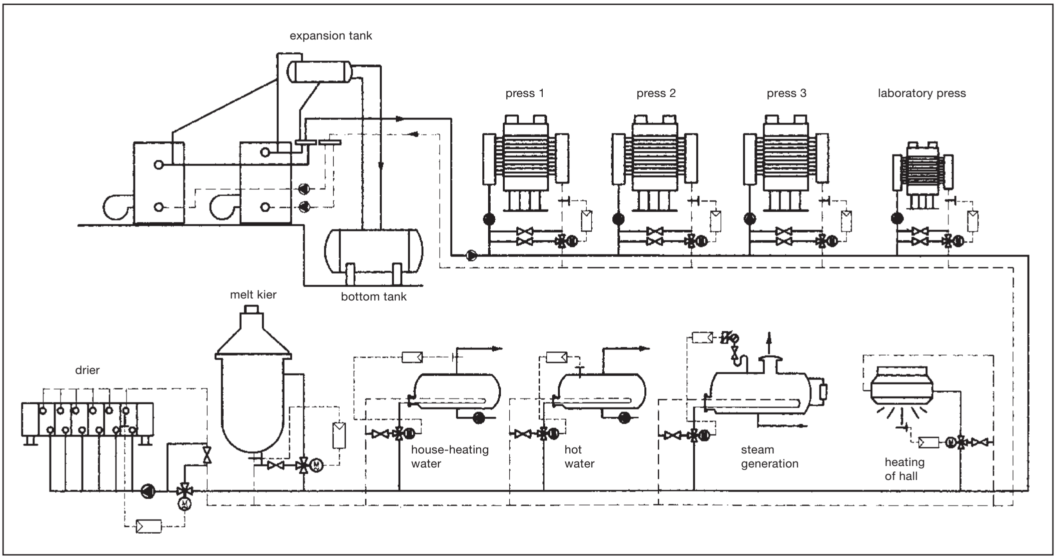


Fig.: Plant layout of a heat transfer oil system (source: Baelz).

indirect heating using oil as a heat transfer medium makes the gradual heating of machines possible since it is easy to control the temperature of the medium.

In plants where heat transfer oil boilers are already in use, it is usual for all the heat-consumers to be connected to this heat supply system; typical heat supply stations include:

- steam boilers heated by means of heat transfer oil,
- water heat exchangers for heating and the provision of hot water.

Since effective external sealing of such heat transfer oil systems is extremely important, glandless fittings are always employed.

A flow diagram of a heat transfer oil system used in the wood and plastic processing industries is shown in the Figure. This includes 3 large presses and 1 small press, 1 agitating mixer, 1 drier, 2 heat exchangers, 1 steam boiler and 1 air heater. The number of heat consumers may be increased or reduced exactly in accordance with requirements.

In general, a temperature difference of 10–30°C between the entry and exit of a heat consumer is sufficient to ensure the desired heating of the product as far as the thermal oil is concerned. Where precise control is desired, this can be achieved by means of a secondary circulation with a control accuracy of 1°C between entry and exit of the consumer in terms of thermal oil temperature. This control system is shown for the presses and the drier. A second circulating pump feeds the consumers with a large volume of thermal oil supplied through a secondary circuit. The temperature is controlled by a motor operated 3-way valve which controls the addition of hot oil as required. Programmable controllers may be used to meet special requirements. Fully-automatic control of pre-selected temperature/time profiles for heating and heating/cooling processes can be achieved with systems of this type (source: Baelz).

Heat transfer number A numerical expression of → Heat retention.

Heat transfer oil → Heat transfer medium.

Heat transfer oil circulation plant → Circulating hot oil unit.

Heat transfer printing → Transfer printing.

Heat transfer printing with cationic dyes Acrylic fibres, which only absorb sublimable disperse dyes at low colour yields, as well as cationic-dyeable polyester, can be transfer printed with transfer papers produced with cationic dyes in brilliant shades at acceptable colour yields. Improved colour yields are possible by means of a pretreatment with a 2% ammonium sulphate solution (3–5 min at 88–98°C) as a result of which the sodium ions contained in the fibre are exchanged by ammonium ions. → Transfer printing.

Heat transmission The heat transfer coefficient is that quantity of heat which can be transferred from a hotter to a cooler medium through a metal surface of 1 m^2 per hour per 1°C difference in temperature. Heat transfer plays a considerable role in, e.g. the thermosol dyeing process.

Heat and mass transfer from the air mixture to the material is determined by the volume of the flow directed parallel to the surfaces of the textile material. A laminar boundary layer is created along a textile surface by

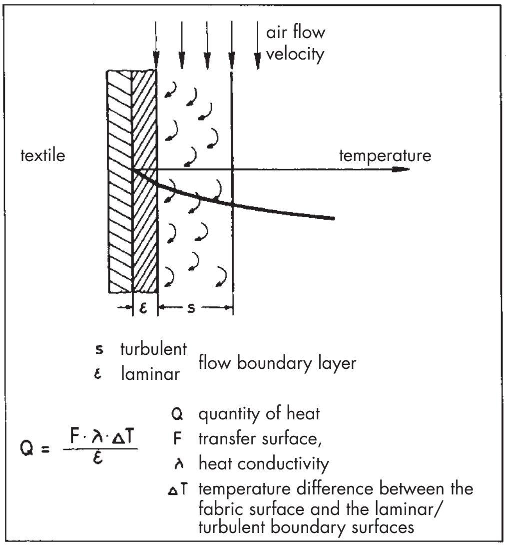


Fig. 1: Heat transfer to material with air flow parallel to the surface.

the air flow bounded by a turbulent flow boundary layer. The thickness of the laminar boundary layer with a flow parallel to the textile surface is determined by the speed of the flow. The transport of heat quantity Q from the medium flowing, over the textile within the laminar boundary layer (Fig. 1) by heat conduction into the turbulent boundary layer, is achieved by convection. Consequently, the heat conductivity of the boundary layer determines the rate of heat transport to the material.

In addition to the influence of temperature or vapour pressures, the → Heat transfer coefficient k plays a decisive role in the determination of the heating surface as demonstrated by the equation:

$$Q = k \cdot F \cdot \Delta T$$

The heat transfer coefficient k is influenced by three variable parameters (Fig. 2):

a) heat transfer from material A to the partition characterizes heat transfer coefficient α_i as defined by the equation:

$$Q = \alpha_i \cdot F_i \cdot (T_A - T')$$

b) continued conduction of heat through the material partition wall with a thickness S_W characterizes the heat conductivity value λ_W as defined by the equation:

$$Q = \frac{\lambda_W}{S_W} \cdot F_W \cdot (T' - T'')$$

c) heat transfer from the external partition to material B characterizes heat transfer coefficient α_a as defined by the equation:

$$Q = \alpha_a \cdot F_a \cdot (T'' - T_B)$$

Q = thermal output in kW,
α_i = heat transfer coefficient of the inner surface in kW/m²K,
α_a = heat transfer coefficient of the outer surface in kW/m²K,
F_i = internal surface area in m²,
F_W = partition surface area in m²,
F_a = external surface area in m²,
λ_W = heat conductivity value of the partition material in kW/m°K,
S_W = partition thickness in m,
T_A = mean temperature of medium A in °K,
T' = temperature of the internal surface in °K,
T'' = temperature of the external surface in °K,
T_B = mean temperature of medium B in °K.

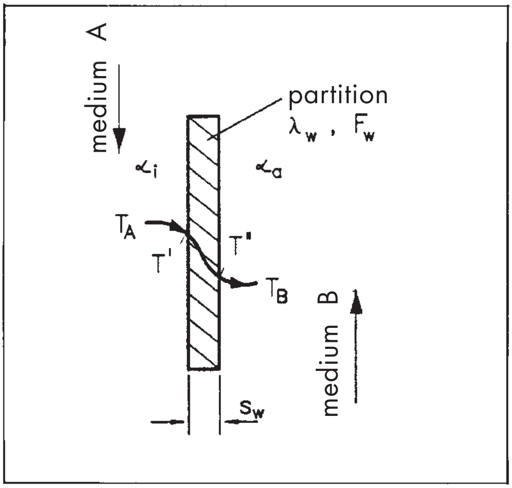


Fig. 2: Heat transition at a partition.

Heat transmission coefficient The heat transmission coefficient is a characteristic for the heat exchange or heat transfer between the boundary layer of a body and the adjacent medium (e.g. air). A high heat transfer coefficient corresponds to a rapid heat exchange. → Heat transfer.

Heat transmission resistance → Heat transfer coefficient.

Heat transmission surface → Heating surface.

Heat treatment zone (drying chamber). The heated sections in stenters and continuous drying machines in which textile fabric is subjected to increasing temperatures. Consists of a drying section (where moisture is driven off the moving web) and a dry heat section (in which heat setting or dye fixation, etc., is carried out at specified temperatures).

Heat tube roller A device to improve the heating of fabrics in thermosol dyeing ranges. The figure shows a heat tube roller installed in a Krantz hotflue which transfers heat to the fabric by contact with the uniformly heated roller as well as hot air circulated through recessed nozzles in the roller surface.

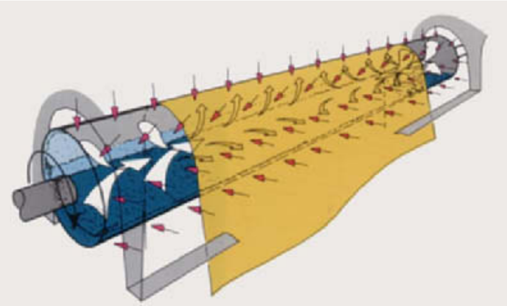


Fig.: Heat tube roller (Krantz).

Heat Utilization Ordinance When it is realized that the efficiency of converting energy sources into heat, even with the integrated power supply and recycling concepts known up to now, is at best only 50% and often considerably less, then a heat utilization concept specifically aimed at the energy-intensive textile finishing industry appears highly appropriate in view of limited global energy resources. A corresponding Heat Utilization Ordinance has been in existence as a draft statute of the German Federal Ministry of the Environment (Umweltbundesamt) since 5.9.1991. Under the terms of this statute, new plant and machinery, in particular, subject to licencsing for heat utilization will have to satisfy a relevant heat utilization concept within three years after a licence has been approved.

The law for protection against harmful environmental effects due to air pollution, noise, vibrations and similar nuisances, i.e. the Federal Air Pollution Control Act in Germany (Bundes-Immissionsschutzgesetz [BImSchG]) describes in § 5 the obligations of companies operating licensable plants. Among other things, § 5, clause 1, No. 4, states that plants subject to licensing must be constructed and operated in such a way that any heat generated has to be used for other plant operated by the company or else supplied to third parties who have already indicated a desire to make use of such surplus heat provided, of course, that this is technically feasible and reasonable having regard to the type and location of the plant (→ Environmental legislation).

The objective of the Heat Utilization Ordinance, HUO (see Fig. 1) is to achieve a reduction of air pollutants formed during the combustion of fuels by lowering energy consumption. This will achieve, above all, a reduction in carbon dioxide (CO_2) emissions in addition to a reduction of other airborne pollutants such as sulphur dioxide or nitrogen oxides. Under previous air pollution control legislation, the required reduction of airborne pollutants was largely achieved by taking retroactive measures. In the case of carbon dioxide, however, this is not possible due to the lack of appropriate technology. Consequently, in order to achieve a reduction in CO_2 emissions, a start must be made at the outset, i.e. by a reduction in the use of energy.

On the 7.11.1990, the Federal Government in Germany decided on a target reduction of at least 25% in CO_2 emissions which cannot be achieved without the legislative powers of the Heat Utilization Ordinance.

Audits of energy consumed by production plant and machinery result, as a rule, in significant energy savings without the need for high investment. From this it can be seen that a Heat Utilization Ordinance does not necessarily increase the costs of production, but probably reduces energy costs.

In this article, discussion of the published draft of the Heat Utilization Ordinance is restricted to its implications for the textile finishing sector and the relevant plant and machinery. The first part of the Ordinance, which comprises § 1 and § 2, contains general regulations. The scope of application of the Heat Utilization Ordinance is given in § 1. The Ordinance applies to the construction, condition and operation of plant and machinery subject to licencing as listed in Annex 1 of the Heat Utilization Ordinance. These items of plant are designated as being subject to compulsory heat utilization licensing. In Annex 1, the plant and machinery used specifically for textile finishing is included under paragraph 10.23, as already listed in the 4th BImSchV. This establishes the inclusion of textile finishing plant and machinery within the scope the Heat Utilization Ordinance.

The second part, comprising § 3 to § 5, describes fundamental requirements. Obligations with regard to the use of heat and energy are formulated in § 3. These are subdivided into the following categories: a) energy use within the plant itself (§ 3, clause 1), b) heat utilization within the company itself (§ 3, clause 2, No. 1), and c) heat supplied to third parties (§ 3, clause 2, No. 2).

As far as textile finishing plant is concerned, it is only the energy used by the plant itself and, possibly, the heat utilization within the company that are relevant in most cases. In order to satisfy the obligations relating to energy use within the plant itself, ten measures are listed in § 4, clause 1, which have to be taken into consideration. Of these, the following measures are important for textile finishing plant, (the numbers correspond to those given in the ordinance):

Heat Utilization Ordinance

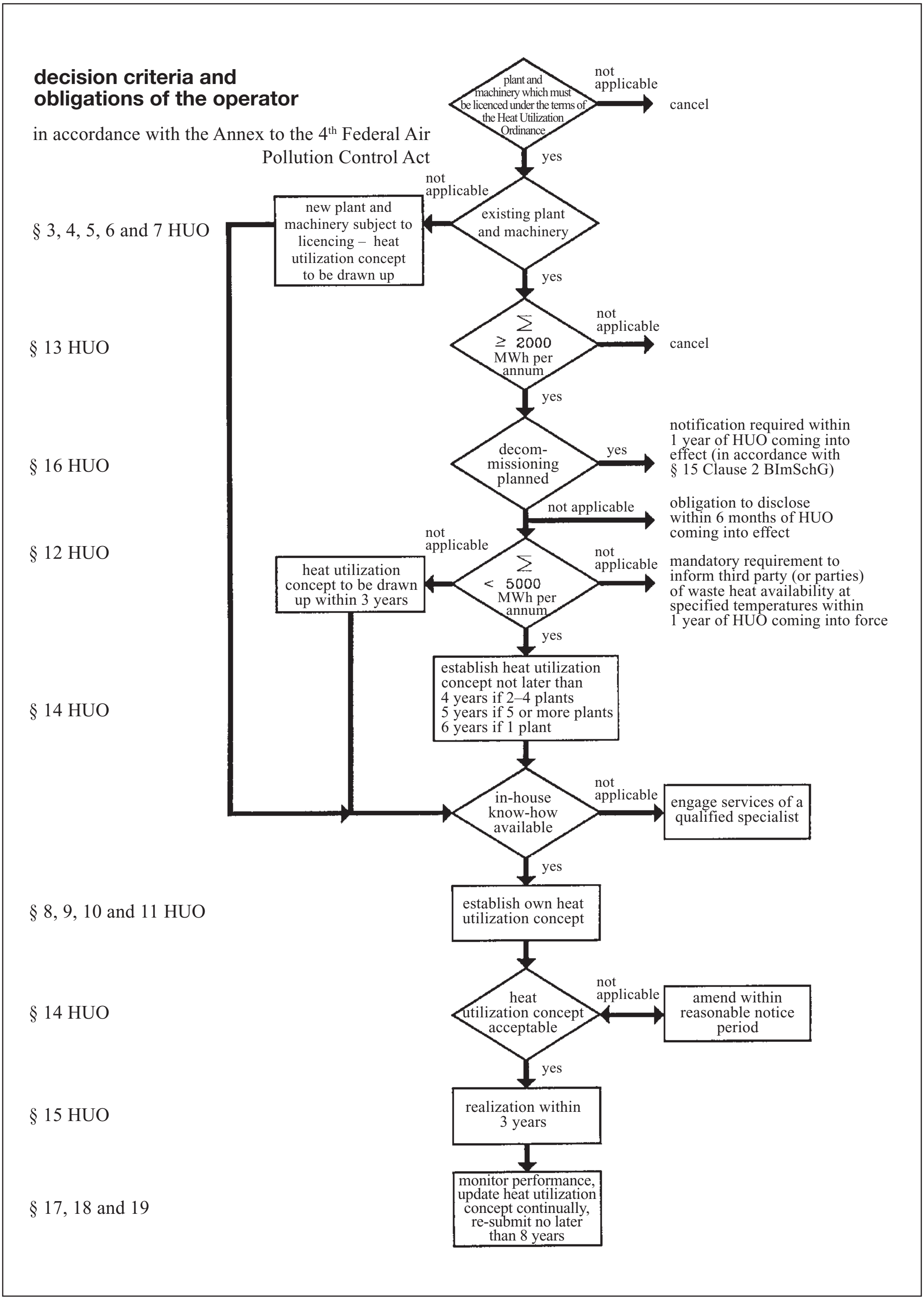


Fig. 1: Heat Utilization Ordinance (HUO), 1991 draft (according to PSB).

1. An energy-saving concept for the process sequence within the plant is required.
2. Provision must be made for the limitation of heat losses.
3. Realization of high energy efficiencies and a high degree of utilization.
4. Heat recovery within the plant.
5. Avoidance of waste heat.
8. Satisfy own requirements for mechanical work, electrical energy and heat by means of combined heat and power generation.
9. Energy-saving integration of energy supply to the plant within existing energy systems at the plant location.
10. An energy-saving concept for operation of the plant is required.

Measures which must be taken into consideration in order to satisfy the obligations relating to heat utilization are listed in § 4, clause 2. As far as textile finishing plant is concerned, the measure under No. 1 is important if the need should arise, i.e. 1. utilization of waste heat in plants operated by the company.

In § 5, it is stated when the measures required to satisfy obligations relating to energy and heat utilization are to be carried out. This stipulation must come as a shock to any business manager since it is laid down therein that measures are to be carried out if they are reasonable. In § 5, clause 1, measures are considered "reasonable" if the payback period is less than the serviceable life of a plant subject to heat utilization licencing and no other significant factors stand in the way.

$$n_a < n_N$$

where

n_a = payback period in years, and

n_N = serviceable life of the plant in years.

In Annex 1 to the Ordinance, compulsory figures are given for the useful life of the plant involved that have been taken from the depreciation tables of the Inland Revenue authorities. For textile finishing plant this corresponds to a serviceable life of $n_N = 10$.

In order to prevent the use of unauthorized economic formulae for the calculation, a simple formula to calculate the payback period n_a is given in Annex 2.

$$n_a = \frac{K_i}{E - 0.1 \cdot K_i}$$

where

K_i = investment capital necessary to carry out technically feasible measures relating to energy and heat utilization (in DM), and

E = savings and returns (in DM per year).

Further explanations are also given in Annex 2.

The third part, comprising § 6 to § 9, describes the required heat utilization concept. § 6, clause 1, describes the circumstances when the operator of a plant subject to the provisions of the Heat Utilization Ordinance is required to draw up a heat utilization concept. This becomes necessary where the energy supplied to the plant, in a proper and actually feasible scale of operation, is 2000 MWh/year or more. In clause 2 of this paragraph, it is stated which information the heat utilization concept must contain. This includes information on the energy supplied as well as the energy and heat utilized within the plant. It is explicitly stated that the operator must engage the services of outside specialists (e.g. engineering) if he is not in a position to draw up such a concept himself.

Information relating to energy utilization within the plant (§ 7) must contain the following:

- A description of the heat utilizing plant subject to the Ordinance in terms of its energy and process technology. To this end, energy flows represented by heat circuit diagrams, energy flow diagrams and process technology flow charts must be indicated and carbon dioxide emissions given.
- A presentation of additional or further measures for energy utilization within the plant which have been checked for carbon dioxide emissions and energy consumption.
- Reasons for decisions taken to adopt particular measures for energy utilization within the plant.

The fourth part (§ 10 to § 13), describes requirements for construction and operation and is therefore probably not relevant to the plants under consideration for textile finishing.

The fifth part (§ 14 to § 16), describes procedures for measurement and monitoring. § 14 is of relevance to textile finishing plant. It lays down that the operator of such plant must monitor energy consumption at regular intervals and take steps to counteract any increases in energy consumption. Where possible, a specific energy consumption should be given.

The sixth part (§ 17 to § 20), contains interim provisions. The duty to disclose details on existing plant according to the requirements of § 17 is important here. Operators of existing plant are allowed 1 year after the Ordinance comes into force to notify the responsible authorities of:

- the nature and location of the plant concerned,
- the energy supplied to the plant in a proper and actually feasible scope of operation.

In § 18 it is stipulated that a heat utilization concept has to be drawn up for existing plants consuming at least 4000 MWh/annum. It is further laid down when the concept is to be submitted. Depending on the amount of energy supplied, a notice period of 3–5 years has been set for this purpose. It is also mentioned

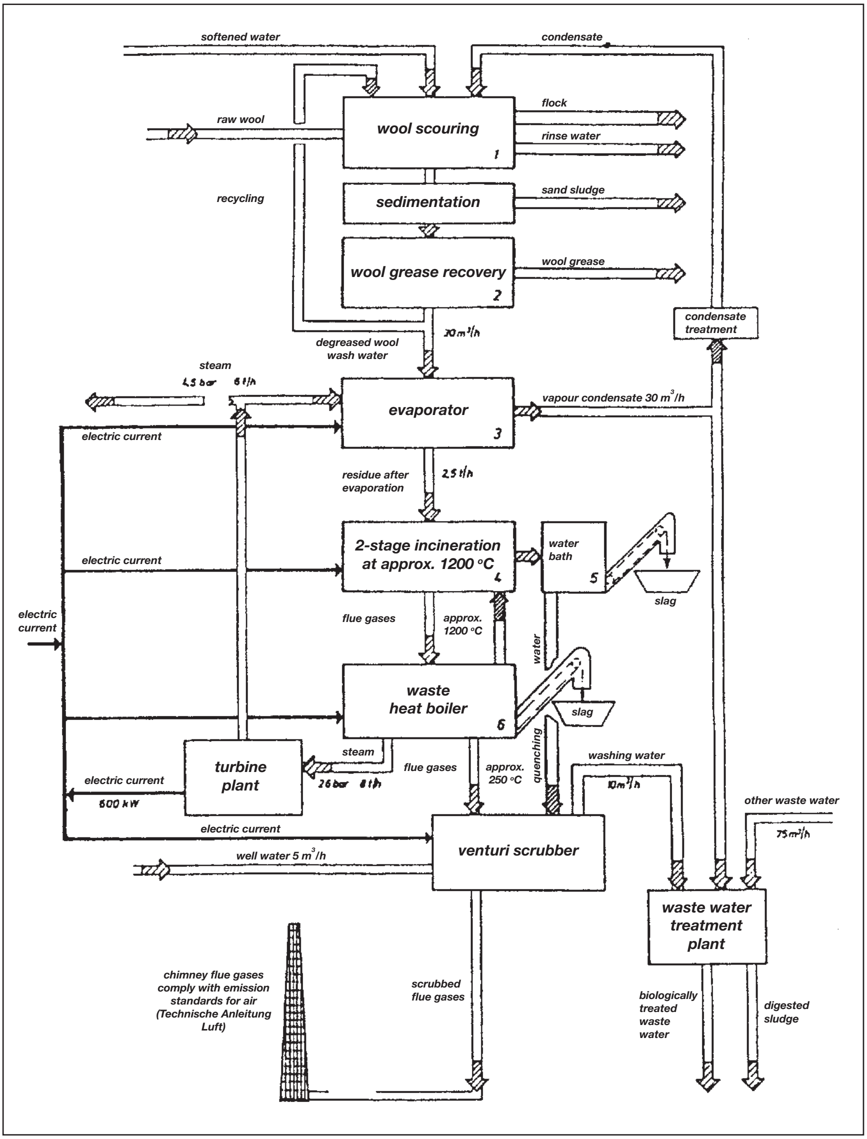


Fig. 2: Comprehensive heat utilization by cascade-form utilization of heat in the recycling of useful material (lanolin wool-fat) at BWK (Bremer Wollkämmerei AG) in Bremen.

that the remaining serviceable life of the plant may be notified.

The seventh part (§ 21 to § 25), contains general regulations, e.g. including breaches of the regulations (source: Fischer).

In order to comply with the Heat Utilization Ordinance, a survey of actual energy flows within a textile finishing plant is necessary. By taking this as a starting point, an integrated heat utilization concept (Fig. 2) can then be drawn up as a target standard.

Heat zone dwell system An open-width treatment for the scouring, bleaching and dyeing of woven fabrics composed of cellulosic fibres and cellulosic/synthetic fibre blends by the → Pad-Roll-Process.

Heavy chemicals Inorganic chemicals for industrial purposes produced in bulk quantities and often in a relatively impure state (technical grade), e.g. acids, alkalis, salts, chlorine, etc. See also → Fine chemicals.

Heavy coating → Heavy duty waterproof finishes.

Heavy duty detergent A universal detergent suitable for all washing processes and usually for all wash temperatures (→ Syndets).

Heavy duty detergent booster Intensifier for exceptional circumstances (difficult washing conditions) or where the laundry is particularly soiled, e.g. more intense soiling appearing locally, such as soiled edges on collars and wristbands. Generally pasty concentrate of suitable surfactants and compounds. → Detergent booster.

Heavy duty waterproof finishes A term used for waterproof finishes applied to tarpaulins and similar articles to provide resistance to water pressure. → Waterproof impermeability testing.

Heavy metals Effluents from textile wet processing plants can be contaminated with heavy metals such as copper, cobalt, nickel and chromium. They may be separated off by precipitation or the use of ion exchangers specifically designed for heavy metals.

The term “heavy metal” is understood to apply to metallic elements with a density greater than 6 g/cm^3. Both essential → Metals (iron, copper, zinc) as well as non-essential metals (not essential for the structure of the biosphere: cadmium, mercury, lead) can, at increased concentration levels (through bioaccumulation), result in growth inhibition and metabolic disturbances (by recomplexing, i.e. the exchange of essential by non-essential metals in metal-complexes). The chemical coordination behaviour of a heavy metal determines the distribution of a metal in nature. A-metal cations (calcium, magnesium, sodium) are present in water as free aquo ions; transition metal cations (iron, manganese, chromium) form hydroxo complexes in the solid or dissolved state; B-metal cations (mercury, cadmium, zinc, lead) form stable complexes with organic ligands. The residence time of a heavy metal in a biomass is inversely proportional to the affinity (tendency for adsorption, incorporation, precipitate formation) for the respective system. The toxic concentration range is highly dependent on the state of the heavy metal; thus the lethal copper concentration of a copper salt is convertible by the addition of an organic complexing agent such as EDTA in optimum (i.e. low) concentration. Mercury becomes more lipophilic (fat-soluble) by methylation and, in this form, can be more readily taken up by cells and enter the food chain.

Hecto- (Gr.). Metric prefix denoting 100 = 10^2, e.g. hectolitre (hl), a measure of capacity equivalent to 100 litres.

Helanca principle The classic resp. conventional Helanca principle or true twist process, developed by Heberlein & Co. AG, Switzerland, for the batchwise production of torque crimp stretch yarn from man-made continuous filaments, chiefly polyamide or polyester. The yarn is produced by combining highly twisted Z-twist and S-twist filaments, followed by heat-setting at high temperatures, and final untwisting:

1. S and Z-twist filaments are twisted with 2000–3500 turns/m and then combined as ply yarns with a few turns/m.
2. Steam setting: the ply yarns are heat-set on aluminium or cardboard tubes with overpressure or saturated steam in a vacuum steamer. The yarn packages are preheated dry, given a short steaming 2–3 times with as much vacuum as possible, then subjected to the action of saturated steam for 1.5–2 h (approx. 130°C) at 1.8–2 bar pressure (shorter steaming times = flabby handle, longer steaming times = stiffer handle) after which the yarn is finally allowed to cool and condition for at least 24 h. These conditions apply to aluminium tubes of 70 mm diameter for approx. 120 g of yarn material. Material damage during steaming in the form of stains or discoloration (not removable) is caused, e.g. by rust-contaminated condensate, interior paintwork in the steamer, twisting machine oil, spin finishes, etc.
3. Untwisting in the opposite direction at approx. 100 turns/m.

Helanca stretch yarns have mainly been used in hosiery, tights, underwear, lingerie, sweaters and some woven fabrics. The process has now been largely superseded by false twisting.

Helianthine Identical to → Methyl orange.

Helio-Klischograph An electronic engraving system used in the production of gravure printing rollers for heat transfer printing. Prints from Helio-Klischograph engravings produced by etching can be used to advantage on synthetic fibres, especially on fine woven fabrics with a smooth surface. This procedure is currently employed by printworks already in possession of a Helio-klischograph and/or those who produce paper for transfer printing with such engravings, and are also engaged in the printing of textiles themselves. In addition, the process is suitable for independent printers with appropriate design selections and colorations. – Manuf.: Hell.

Helix (wool, hair fibres). An elementary building block of the → Macrofibrils in animal fibres with a screw-like structure. According to Pauling, the microfibrils are formed with a central helix in the chain molecules of wool keratin in order to combine with others by means of a right-hand twist to form a unit. The helix has a high elastic recovery and can be pulled apart (breakdown of stabilizing hydrogen bonds) and relaxed again (reformation of hydrogen bonds), a property which is referred to as reversible denaturation. For a more recent account see → Intermediate filament.

Helmholtz colorimetric measures → Colorimetric measures.

Hem An edge to a piece of textile fabric (edge reinforcement) made by folding the raw edge under and stitching it to the body of the fabric. Hemming: the process of producing a hem. Hemstitch: a decorative edging stitch, usually for a hem, in which the cross threads are stitched in groups.

Hematine (hematein, haemateïn) → Logwood.

Hematoxylin (haematoxylin) → Logwood.

Hematron An electronic device for the control of rope length and milling shrinkage on rotary milling machines. A measuring strip sewn into the seam transmits an impulse to the sensor mounted at the entry to the machine which is then stored in the display unit and compared with a preselected value. As soon as this value is reached, the machine is stopped. The entire unit consists of a transmitter, speed monitor for the lower cylinder, a combined display and preselector as well as the electrical switching system.– Manuf.: Hemmer.

Hemicellulose Besides → Cellulose and lignin, hemicellulose is a component of wood and, to a slight extent, also of natural cellulosic fibres. It consists of an ill-defined group of various complex → Polysaccharides. Hemicellulose has a lower molecular weight than cellulose (degree of polymerization of 150 or less) and lower chemical resistance. It is only sparingly soluble or insoluble in water, and is broken down by plant ferments into sugars, but does not reduce Fehling's solution.

Hemicolloids →: Colloid; Macromolecules.

Hemp Flax and hemp are → Bast fibres. It is derived from the stem of the hemp plant (cannabis sativa) 50–250 cm tall, accompanied by a fair amount of woody matter.

The fibre is harvested and processed in a manner similar to that used for flax:

I. Mechanical process to separate hemp fibre from the straw (to give "green" hemp).

II. By → Retting to free the fibre from woody matter, then as in I above. (→ Flax).

III. By → Cottonizing.

Hemp fibres are greyish-white, matt yellow or greenish-black in colour, and have a greater or lesser degree of lustre. Strands of hemp are 1–2 m in length and 50–500 µm thick; individual fibres are 15–25 mm long and 10–50 µm thick. Tensile strength of the latter 3.0–7.0 cN/dtex, 10–20% greater in the wet state than dry. Extensibility is only 3–4 %. Hemp fibres are composed of approx. 9% water, approx. 78% bastose (cellulose-lignin compound), 0.5 % fats, waxes and colouring matter, over 9% deposits (impurities: pectin substances), approx. 1% mineral substances. The chemical properties of hemp are similar to flax (woody matter resp. lignin is soluble in hot alkali). Uses: Gminder fabrics, carpets, mats, sacking, cord, twine, etc. (→ Fibre identification).

Hemp line Fine, straight, parallel hemp strands produced by hackling long hemp fibres.

Hemp/jute discrimination tests,

I. → Phloroglucinol reaction.

II. → Aniline sulphate test.

Hemp stalk structure Comparable to → Flax stem structure. Differences: two bast bundle layers: a) primary bast fibres (combined in groups) of the outer layer as well as b) secondary bast fibres (individual bundles) of the inner layer formed on further growth of the plant to reinforce the skeleton structure. The first type are of greater value for obtaining long fibres than the shorter, coarser, secondary fibres which yield mainly hemp tow. The division of hemp bast bundles is considerably less than flax because of the higher lignification of the middle lamella. The fibre appears to be a mixture of cellulose and lignocellulose.

Hemp tow The short fibre stock of varying lengths removed in breaking, scutching, hackling, or combing. It is often very gnarled, matted, and very irregular.

Henequen A vegetable fibre, closely resembling sisal, belonging to the → Hard fibres group. Henequen is produced from the leaves of the Mexican plant (agave fourcroydes).

Henry's law The behaviour expected for a non-electrolyte solute of any dilute solution is obedience to Henry's law relating the solute vapour pressure p to the solute concentration c through an empirical constant k (G = free energy).

$$p = k \cdot c \cdot G = G_0 + RT \cdot \ln \frac{c}{c_0}$$

Derivation from the thermodynamic potential is analogous to that of → Nernst's distribution law.

Hercosett process (chlorine-Hercosett process). A process for the continuous shrink-resist treatment of wool which involves a prechlorination stage followed by the application of a preformed polymer resin, i.e. polyamide epichlorohydrin resin (Fig. 1), that is substantive to wool.

The process is carried out on wool tops in the backwashing machine. The first stage involves a weak chlorination in order to reduce the surface tension of the

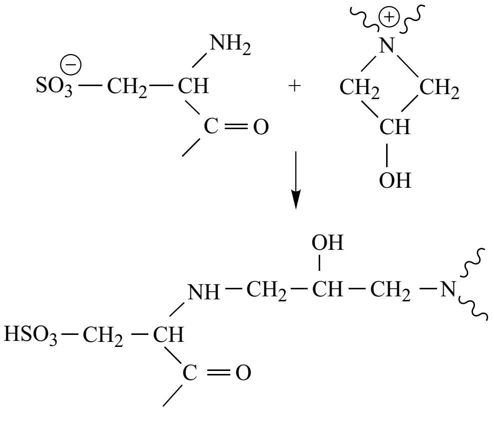


Fig. 2: Polymer bonding to the wool amino acid.

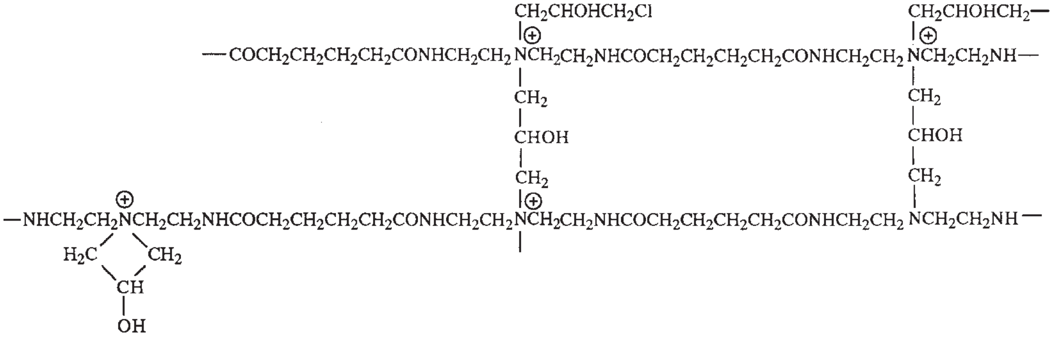


Fig. 1: Chemical structure of the Hercosett felt-free finish polymer.

wool fibre in order to facilitate subsequent wetting with the polymer resin. In the second stage, the positively charged polymer resin is applied and is attracted by the sulphonic acid groups (negatively charged) of the cuticle, the cystine of which has been partially oxidized by chlorination to cysteic acid. In the progress of finishing, the polymer becomes reactively bound to the amino groups of the wool keratin (Fig. 2).

The antifelting effect of the Hercosett process is probably due to the binding of a water film around the fibre by the charged polymer deposit thereby masking the scales and preventing fibre attraction.

Hereke carpets Especially valuable → Knotted carpets from the time of the last Turkish sultans (beginning of the 19th to the 20th century). The carpets are woven with a wool or silk pile on a fine cotton or silk ground fabric. 300 000–400 000 Turkish knots or over 1 000 000 Persian knots/m^2.

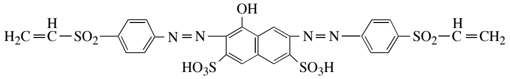
The design consists of tightly arranged strewn flowers as well as, to some extent, motifs inspired by the French rococo period.

Herringbone weave Herringbone is executed in a broken twill weave with alternating twill direction in a balanced chevron pattern that resembles the skeleton of a herring.

Hertz (Hz). SI unit of frequency, defined as the frequency of a periodic phenomenon that has a period of 1 second, i.e. 1 Hz = 1 oscillation/s.

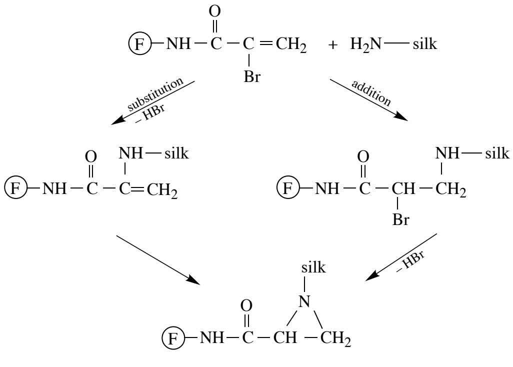
Hessian A coarse, heavy, plain-weave fabric of jute or similar yarn. Natural colour is brownish. Used for wrappings, wall hangings, etc.

Heterobireactive dyes Depending on their reaction mechanism during reaction with the fibre, reactive dyes with a single reactive group are subdivided into two types, i.e.:
a) substitution type
b) addition type.
Bifunctional reactive dyes such as C.I. Reactive Black 5 (20 505) can also react twice with the fibre (bireactive, bifunctional):



Reactive dyes with two different reactive groups, which can react according to both the addition as well as the substitution mechanism, are heterobireactive. They react both in the sense of a nucleophilic substitution as well as in the sense of a nucleophilic addition at a double bond.

Monofunctional reactive dyes of the α-bromoacrylamido type react according to both mechanisms and the same 3-membered aziridine ring is ultimately formed:



The use of bireactive dyes to improve selectivity and the degree of fixation is an old concept.

Let us consider a monoreactive dye (A) with a selectivity of around 60% (degree of fixation 60%) and a dye (B) with two reactive groups, both of which have a selectivity of 60%. From Fig. 1 it can be seen that dye (B) achieves a degree of fixation of almost 85% compared to barely 60% for the monoreactive dye (A).

Bireactive dyes conform to one of the three types schematically represented in Fig. 2 where R_1 and R_2

Heterobireactive dyes

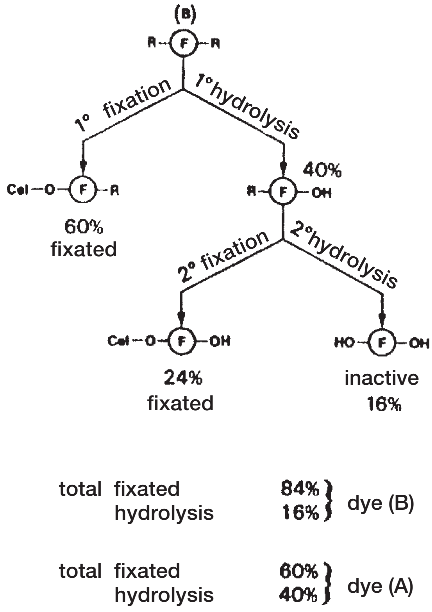


Fig. 1: Fixation and hydrolysis in their effect on reactive dyeing with heterobireactive dyes.

can be either two identical (bireactive dyes) or two different reactive groups (heterobireactive dyes). Exhaust dyes correspond mainly to types 3 or 2, although type 1 is also suitable.The type 1 dyes are, however, to some extent less substantive, less bulky, and are therefore often more suitable for textile printing or continuous dyeing.

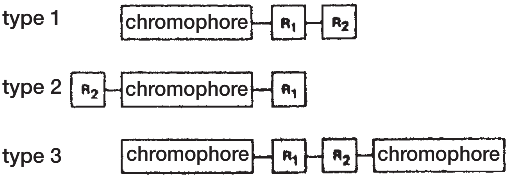


Fig. 2: Three types of heterobireactive dyestuffs.

Bireactive or heterobireactive dyes are already included is some commercial dye ranges:

- The most important representatives of the Cibacron E (Ciba-Geigy), Procion HE (ICI), Procion SP (ICI), and Basilen (BASF) ranges are bi-monochlorotriazine dyes of type 3.
- The Remazol range (Hoechst) contains some bi-vinylsulphone and monochlorotriazine-vinylsulphone dyes of types 1 and 2.
- Sumifix Supra (Sumitomo) dyes are monochlorotriazine-vinylsulphone dyes of type 1.
- The Cibacron F range contains some bifluorotriazine dyes of type 2.
- The most important representatives of the Cibacron C range are bivinylsulphone (type 2) or fluorotriazine-vinylsulphone dyes (type 1) illustrated in Fig. 3.

The second reactive group and the higher degree of fixation have a positive influence on reproducibility of shade since the degree of fixation is not only higher but also more constant.

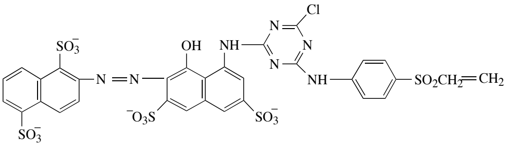


Fig. 3: Vinyl sulphone/monochlorotriazine (Cibacron C). Heterobireactive. Blue-cast red with good acid and alkali bonding stability.

If both different types of reactive group are positioned at each end of the planar dye molecule (Fig. 4) the question arises as to whether, e.g. in the bifunctional linking reaction with cellulose, the spacing of the hydroxyl groups are reached under dyeing conditions.

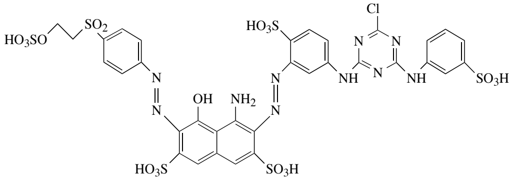


Fig. 4: Structure of a heterobireactive dyestuff.

The number of possible reactions and reaction products with multifunctional dyes is considerably greater than for monofunctional dyes. If the latter react both with the substrate as well as the water in the dye liquor, then two reaction products are formed and, at the end of dyeing, the dye is present as three variants altogether (including its unchanged reactive form). Two of these are present in solution and the third is linked to the cellulose. Taking a heterobireactive dye as an example, on the other hand, eight reaction products are possible and, by analogy with the monofunctional dyes, a total of nine dye variants can exist in this case (Fig. 5).

5 variants are linked to the substrate (c, f, g, h, i), and 4 remain in the dye liquor or can be extracted from the fibre with suitable solvents. The 5 fixation products are especially interesting. However, their analytical identification is difficult due, on the one hand, to their similarity, and the fact that they are not accessible by classical wet chemical methods in the solid state due to

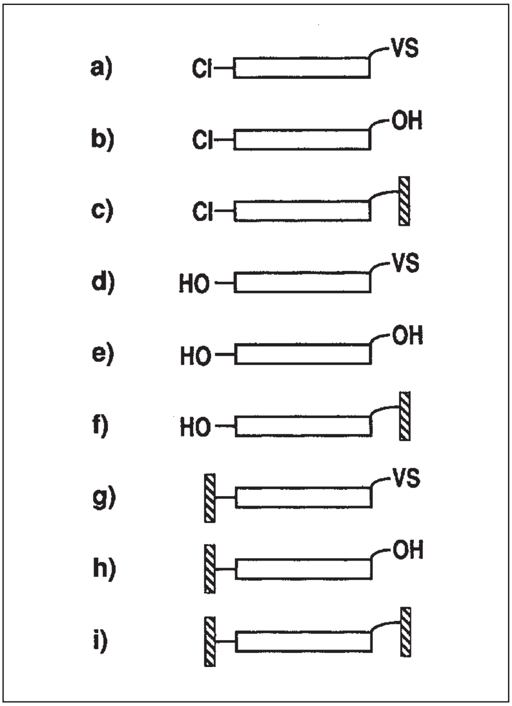
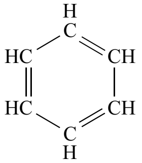


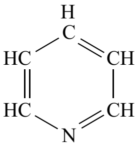
Fig. 5: Diagrammatic view of a heterobireactive dyestuff (a) and its possible reaction products (b-i) on stopping the dyeing process. Cl = monochlorotriazine; VS = vinyl sulphone; hatched = cellulose. The sulphuric acid ester of VS has not been illustrated, because it exists for only a very short time under alkaline conditions.

their linkage with the cellulose high polymer on the other (contributed by Meyer and Rys).

Heterocyclic compounds Cyclic compounds which, in contrast to isocyclic → Cyclic hydrocarbons, contain one or several other atoms (nitrogen, sulphur, oxygen, etc.) besides carbon in their ring structure. The most widely known type is represented by the compound pyridine which has structural similarities to → Benzene.



benzene

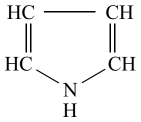


pyridine

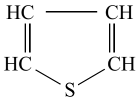
At the same time, pyridine represents the most important 6-membered ring heterocyclic compounds. In addition, there are numerous technically important 5-membered ring structures which are used in dye synthesis (principally vat dyes) as well as some textile auxiliaries, the comparative constitution of which is of interest.

Examples:

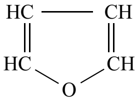
I. 5-membered ring structures with one hetero atom:



pyrrole (azole)

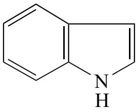


thiophen

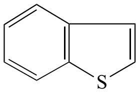


furane

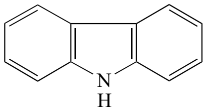
Condensed pyrrole ring systems form e.g. indole and carbazole, whilst thionaphthene (for thioindigo dyes) is derived from thiophene:



indole

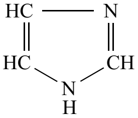


thionaphthene



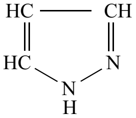
carbazole

II. 5-membered ring structures with two hetero atoms:

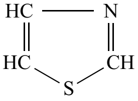


imidazole (glyoxaline)

(isomers)

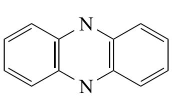


pyrazole

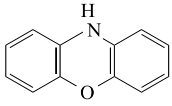


thiazole

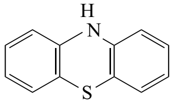
III. 6-membered ring structures linked by hetero atoms:



phenazine
(azine dye)



phenoxazine
(oxazine dye)



phenthiazine
(thiazine dye)

Heterofil fibres Core-sheath bicomponent fibres in which a core of polyamide 6.6 is surrounded by a sheath of polyamide 6. Due to their different melting points, nonwovens and needlefelt floorcoverings can be permanently bonded by a simple thermal treatment (the fibres being bonded at cross-over points through sintering of the outer sheath) without the need for a binder.

Heterogeneous Composed of dissimilar, unrelated or differing parts or elements; e.g. from a dyeing point of view, the wool fibre has heterogeneous properties since, in contrast to the cortical cells with high dye affinity, the outer scale cells have a very much lower affinity due to their different composition.

Heteropolar → Polar.

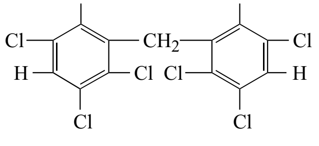
Heteropolar bond → Ionic bond.

Heteropolar compounds Compounds containing → Ionic bonds through the transfer of electrons as is particularly the case with salts.

Heteropolymerization → Polymerization.

Heteroyarns → Core-spun yarns, i.e. yarns produced from two filaments combined in spinning which, e.g. contract differently in thermal treatments to give a texturing effect (e.g. heteroyarns from triacetate and polyamide). Heteroyarns are not → Bicomponent fibres.

Hexachlorophene (dihydroxyhexachlorodiphenylmethane),



White, free-flowing powder; odourless; insoluble in water; soluble in alcohol, acetone, dilute alkalis and soaps. It does not cause skin irritation and is a powerful bactericide. Prevents bacterial decomposition of perspiration.

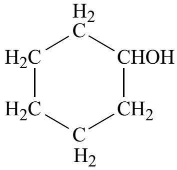
Hexachlorophene test (colorimetric method). A colour which can be measured in a colorimeter is produced from a solution of → Hexachlorophene in methanol with an ammoniacal-alcoholic solution of copper chloride. The test is likewise suitable for the detection of pentachlorophenol and trichlorophenol.

Hexafluoropropene, teflon.

Hexahydrophenol → Hexalin.

Hexahydropyrimidone resins → Propylene ureas.

Hexalin (hexahydrophenol, cyclohexanol),

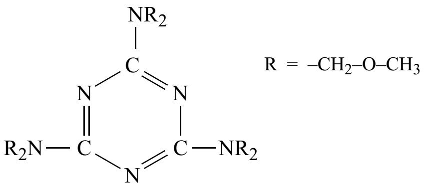


A colourless, oily liquid with a camphor-like odour, hygroscopic, sparingly soluble in water, miscible with most organic solvents and oils. MW 100, density 0.947, combustible. Hexalin is a good solvent for fats, oils, mineral oils, waxes, resins, asphalts, rubber, metal soaps. It also dissolves acetate filament/staple fibres.

Uses: in soap making for the incorporation of grease-solubilizing solvents; spotting agent; thinner for paints, lacquers and varnishes, etc.

Hexametaphosphate, sodium → Graham's salt.

Hexamethoxymethylmelamine → Methoxymethylmelamines:



Hexamethylene (cyclohexane, hexanaphthene, hexalhydrobenzene), $(CH_2)_6$; → Alicyclic hydrocarbons.

Hexamethylenediamine, $H_2N–(CH_2)_6–NH_2$; the chemically correct name is 1,6-diamino- hexane. In the synthesis of polyamide 6.6, hexamethylenediamine forms important base components which represent the main raw material costs. It is derived from the reaction of adipic acid (likewise a raw material for the synthesis of polyamide 6.6) with ammonia (catalytic vapour-phase) to yield adiponitrile, followed by liquid-phase catalytic hydrogenation as follows:

$$\begin{tikzcd} HOOC\text{—}(CH_2)_4\text{—}COOH \arrow[d, "2\ NH_3"] \\ NC\text{—}(CH_2)_4\text{—}CN \arrow[d, "4\ H_2"] \\ H_2N\text{—}(CH_2)_6\text{—}NH_2 \end{tikzcd}$$

adipic acid

adipindinitrile

hexamethylenediamine

Hexamethylenetetramine (hexamine; methenamine; urotropine), $(CH_2)_6N_4$. White, crystalline, hygroscopic powder. Soluble in 1.5 parts water and 10 parts alcohol, readily soluble in chloroform, insoluble in ether. Uses: e.g. metal powder printing.

Hexane, C_6H_{14}. → Saturated hydrocarbons.

Hexanol (hexyl alcohol), $C_6H_{13}OH$. → Alcohols.

Hexon bases A term used to describe amino acids containing a basic amino group of the diamino-carboxylic acid type, e.g. arginine, histidine and lysine.

Hexoses Carbohydrates with six carbon atoms →: Sugars; Carbohydrates.

Hexyl The straight chain group C_6H_{13}. → Alkyls.

Hexyl alcohol → Hexanol.

HF, abbrev. for: → High frequency current.

Hf, chemical symbol for hafnium (72).

Hg, chemical symbol for mercury (80).

Hierarchical fibre structure In their morphology, natural fibres in particular are characterized by a marked hierarchical fibre structure (Figs. 1 and 2).

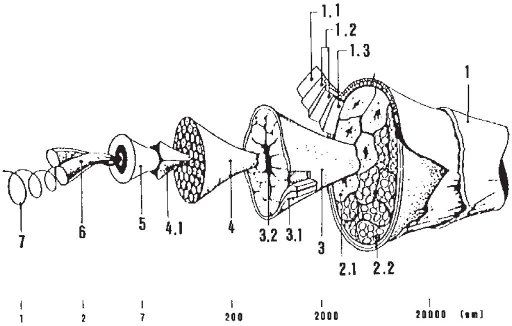


Fig. 1: Hierarchy of a fine merino wool fibre.
1 = cuticle; 1.1, 1.2, 1.3 = epicuticle, exocuticle, endocuticle; 2.1, 2.2 cell in the paracortex and orthocortex (cortex); 3 = cortex cell; 3.1 = cell membrane complex; 3.2 = nucleus residue; 4 = macrofibril (50–200 nm); 4.1 = interfilament material (matrix) of intermediary filament associated proteins (IFAP); 5 = intermediary filament (microfibril) of keratin (IF, 7–11 nm); 6 = dimer (left-handed double cord); 7 = right-handed a helix.

With cotton fibres, the individual layers of this hierarchy (see Tab.) can be reached with the aid of swelling agents having different action which makes them accessible for textile finishing processes. In the case of wool, as a biological composite, this accessibility is more difficult.

name of structural element	diameter	number of cell molecules in the cross-section	swelling agent	individually insulated after swelling	bonds still in existence after swelling
fibre	0.06 up to 0.2 mm	10^9	CsOH	convex and concave part (the latter swollen)	all in the convex part
macrofibril (crystallites)	0.4 µ = 400 nm	500 000	morpholine	microfibrils (i.e. crystallographically aggregated elementary fibrils)	crystals in elementary fibril bundles (no more intercrystalline interactions)
microfibril	200 up to 30 nm	2 000	$ZnCl_2$, ether	4 elementary fibrils	crystallisation and hydrogen bridges (cell I)
elementary fibril	3.5 nm	42	4 n NaOH	elementary fibril defects	cell I, intermolecular hydrogen bridges
elementary cell	0.6 nm	2	conc. NaOH (mercerising lye)	“sheets” (antiparallel)	intramolecular hydrogen bridges, cell II van der Waal’s interactions
molecule	0.5 nm	1	cuprammonia	polymer chain	transdiglycols form complexes, i.e. triggering the intramolecular hydrogen bridges and consequently rigidity and van der Waal’s interactions

Tab.: Hierarchical structure of cotton cellulose.

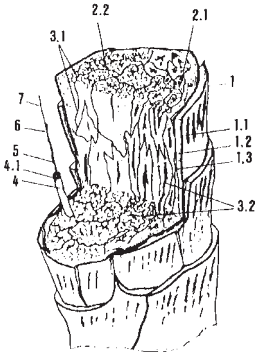


Fig. 2: Longitudinal and transverse cross-section of a fine merino wool fibre for explaining the hierarchical wool fibre structure (explanation in Fig. 1).

High-bulk yarn (HB yarn) → Textured yarns.

High capacity yarn packages
Yarn packages with a maximum diameter of 300 mm weighing up to 3.6 kg which are used particularly for wool and acrylic yarns. They offer advantages of shorter liquor ratios, e.g. down to 4.5 : 1, and a doubling of the dyeing machine capacity.

High concentration bleach A continuous bleach process in which high quantities of chemicals are applied by impregnation resp. padding, and bleaching takes place by a subsequent dwell stage or steaming.

High density polyethylene → Polyethylene.

High frequency current An alternating current with over 100 000 oscillations (frequencies) per second. Whilst the tension (volt) can certainly be high at these frequencies, the current (ampere) is greatly reduced.

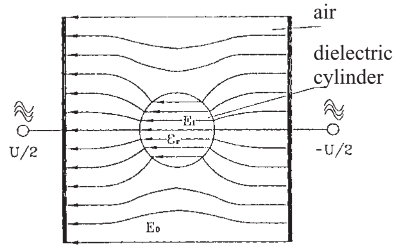


Fig. 1: Schematic field distribution between electrodes.

High frequency driers High frequency driers employ high frequency electromagnetic waves at frequencies from $v = 10^5–10^{12}$ Hz with corresponding wavelengths from $\lambda = 3$ km (radio waves) up to 300 μm (Hertzian waves). However, officially designated frequencies have been allocated for industrial applications in order to avoid possible interference with radio communications. Frequencies approved by inernational agreements for industrial use are:

13.56 MHz ± 0.05%
27.12 MHz ± 0.60%
40.68 MHz ± 0.04%

High frequency driers used in the textile sector are based on dielectric heating in the megahertz range since, in the microwave heating range, i.e. in the gigahertz range (10^9 Hz), there is a risk of yarn packages bursting due to excessive build-up of steam pressure in the wet medium. Most high frequency driers work with voltages of 10 000–30 000 V at an operating frequency of 13.56 or 27.12 MHz. High frequency generators have a power rating of 30 and 60 kW. The principle of dielectric heating is based on the fact that a dielectric material is either an insulator, i.e. non-conducting, or a very poor conductor of electric current. In high frequency drying, an electrical field is produced inside the dielectric material (e.g. yarn package) as a result of which the dielectric becomes polarized, i.e. a separation occurs between the positively and negatively charged sites in the molecule (Fig. 1). A dielectric material increases the capacity between the capacitor plates by a factor ε (the dielectric constant) compared to the capacity in the absence of the dielectric.

The arrangement of the yarn package as a dielectric cylinder in the originally homogeneous field between the plate electrodes represents a particularly favourable solution as far as an even distribution of high frequency field strength in the material being dried is concerned. In this case, the field distribution between the electrodes is to be understood as a homogeneous electrical field where a constant field strength E_i prevails:

$$E_i = E_0 \frac{2}{\varepsilon_r + 1}$$

where
E_0 = air field strength,
ε_r = relative dielectric constant of the material being dried.

The ruling field strength E_i which is responsible for the high frequency power density in the material being dried depends on the air field strength E_0 determined by the distance between the electrodes a and the electrode voltage U. When $\varepsilon_r = 78$, e.g. (pure water at 25°C), E_i is only 2.5% of the air field strength E_0 but when $\varepsilon_r = 3$ (dried material), the field strength at $E_i = 0.5\ E_0$ in the material would be 20 times higher.

The high frequency power density P/W cm^{-3} in the material being dried is given by:

$$P'' = E_i^2\ 2\pi f\, \varepsilon_0\, \varepsilon_r \tan\delta\ \mathrm{W/cm^3}$$

where
f = frequency,
$\varepsilon_r \tan\delta$ = loss product of the material (dependent on type of

material, moisture content, temperature and frequency),
ε_0 = $0.886 \cdot 10^{-13}$ As/Vcm.

By having the electrodes inclined in the direction of passage, the air field strength E_0, and thus the material field strength E_i, can be adjusted to the loss product $\varepsilon_r \tan \delta$, which changes during the progression of drying, in such a way that the power density P“ is adapted to the progression of drying (e.g. high power density during the heating up and initial evaporation stage, low power density towards the end of the drying operation). By ignoring any heat exchange with the surroundings, a good approximation of the total high frequency power requirement P_{HF} of a high frequency drier is obtained from the energy required to heat up the wet textile material to the evaporation temperature of water and from the energy required to evaporate the water:

$$P_{HF} = \frac{m_1}{t} c \Delta T + \frac{\Delta m}{t} q_{H_2O}$$

where
m_1/t = initial mass throughput,
c = specific heat,
ΔT = temperature increase to approx. 100°C,
$\Delta m/t$ = quantity of water evaporated per unit time,
q_{H_2O} = heat of evaporation of water.

This power requirement P_{HF} is given, on the other hand, from the mean value of the power density P” and the volume of material in the working capacitor:

$$P_{HF} = \bar{P}'' V_{Mat}, \qquad \text{i. e.}$$

$$\frac{m_1}{t} c \Delta T + \frac{\Delta m}{t} q_{H_2O} = V_{Mat} \bar{E}_i^2 \, 2\pi f \varepsilon_0 \, \overline{\varepsilon_r \tan \delta}$$

The higher the dielectric constant and the lower the conductivity, the greater the capacity of the capacitor. Examples of dielectric constants for a few technically important materials are given below:

vacuum	1.000000	benzene	2.3
air (18 °C)	1.00058	water	81.1
paraffin	1.7–2.3	ice	3.2
paper	1.8–2.5	glycerol	56.0

Separation of the positive and negative charges in the molecule or atom, i.e. the orientation of the molecules (dipoles) in the insulator is the reason why uniform heating is possible in each element of the yarn package volume. This uniform heating is created by oscillations of the molecules or atoms from the position of rest to 13.56 million times a second (at 13.56 MHz). This kinetic energy, and the frictional heat developed from it, is due to frictional forces formed by the uneven rhythm of the atoms or molecules. The intensity of molecular mobility is dependent on the polarity of the alternating field which is controlled by the generator frequency. Dielectric heating generates heat directly within the material itself, e.g. in a yarn package, there is no flow of air from inside to outside or vice versa, as in conventional through-circulation drying with hot air. The water inside the package is therefore evaporated by frictional energy and driven to the surface of the material in gaseous form from where it is transported away by the hot air system before condensation can take place. Since the intensity of drying is ultimately dependent on the dielectric constant, dry fibres absorb less high frequency energy than wet fibres so that a conditioned drying is possible. Since the turnover of heat energy is directly proportional to the water content, the conditioned weight is achieved to an accuracy of within ± 1%. The material itself is virtually unheated by the evaporation process since the yarn is only heated indirectly by the outflowing steam. In this case, the temperature barely exceeds 100°C. Consequently, migration of substances to the surface of the material does not arise since this can only occur in a wet medium.

In practice, material to be dried in a high frequency drier is, as a rule, hydro-extracted beforehand by centrifuging in order to achieve a low initial moisture content and therefore ensure an economical drying process (energy, time, efficiency, costs). Furthermore, high frequency drying is independent of the package density, size of package, the dyed shade or variations in the initial moisture content for the same height of package and the same material. Natural fibres such as wool, cotton and their blends can be dried without any problem, whereas polyamide, acrylics and their blends must be dried with care since spontaneous decomposition can begin due to the steep rise in the dielectric loss factor at higher temperatures. However, if the dwell time is correctly controlled, these products can also be dried without problem. This danger does not apply to polyester fibres. In the case of plastic polymers, heating does not take place by molecular movements and resultant fric-

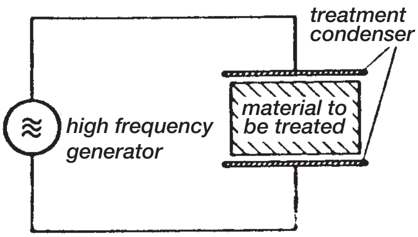


Fig. 2: Plate type electrode system.

tional heat, but by oscillations, rotations, etc. (directional transposition) of individual polarizable sites in the polymer chains which is then converted into heat energy. The frictional theory is not applicable in this case, since the molecules are firmly anchored within the chains.

1. Plate-type electrode systems (Fig. 2) are used in the drying of flat substrates and yarn packages, cheeses and the pre-warming of bales of fibre, etc.
2. Stray field and staggered field electrodes consist of tubular rod electrodes positioned at right angles to the direction of the moving web of material. The rods are staggered in relation to each other. The electrodes, positioned above and beneath the web of material, are connected in parallel in each case to one pole of the high-frequency generator. Compared to plate electrodes, the energy density produced by stray field electrodes (Fig. 3), in fibrous webs or similar materials is higher by a power of ten. They are used for drying open-width fabrics and yarn sheets.

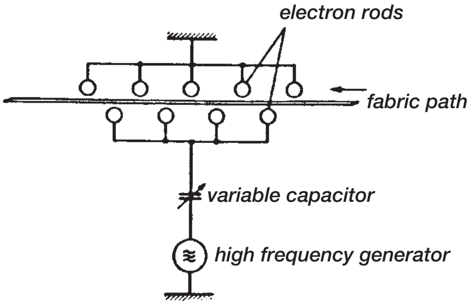


Fig. 3: Stray field electrodes.

In principle, a high frequency drier consists of three main components:
- the machine frame,
- the drying chamber with electrodes,
- the high frequency generator.

All necessary equipment for the operation of the drier is installed on and within the machine frame, e.g. the transport system, air heater, fan, air ducts, electrical control panel, cooling water vessel and pump, electrical heating, etc., which vary from one manufacturer to another. The drying chamber, usually of stainless steel construction, is built into the main frame in such a way that the entire machine is screened to prevent interference with radio and television transmissions. The drying chamber is a closed unit with openings at the entry and delivery ends. The installed electrodes are adjustable in height and the material being dried is passed between the capacitors continuously (continuous machine) or discontinuously (heating chamber). Water molecules in the material are set in motion and evaporated by a generated alternating current. The water vapour is absorbed by a supply of dry air and discharged into the atmosphere through exhaust air ducting before condensation can take place. The incoming air for this purpose is heated first of all in order to remove moisture since the drier the air, the more moisture it can absorb. Drying of the incoming fresh air is carried out in a heat exchanger in which fresh air is heated by the heat loss from the generator so that transformation losses are recovered. The electrode voltage must also be high enough for the electrodes to withstand any voltage surges.

The high frequency generator consists of the components illustrated in Fig. 4.

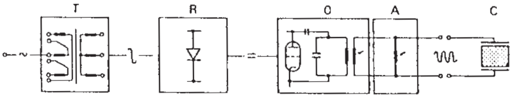


Fig. 4: High frequency generator wiring diagram principle.

The high frequency energy required for the heating process is produced by a high frequency generator in which the normal low tension of a three-phase network is converted into high tension by the transformer T. The static rectifier R converts the generated AC voltage into a DC voltage which is then converted into a higher frequency voltage by the tube oscillator O. The resultant high frequency voltage is then fed to an adapter unit A via a coupling coil where the working voltage can be regulated by hand or motor drive. Depending on the design and site of the drier, the high frequency generator is installed either above or adjacent to the drying chamber in a sealed metal housing (Fig. 5).

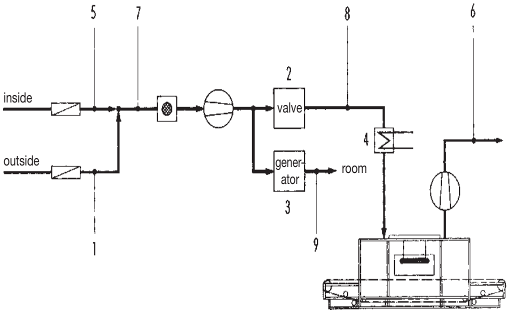


Fig. 5: Generator and processing parts of a high temperature drier.
1 = air supply; 2 = valve; 3 = generator; 4 = preheater; 5 = room; 6 = exhaust air; 7 = air supply suction duct; 8 = valve cooling; 9 = exhaust air control cabinet, i.e. rectifier, filter and grid resistances.

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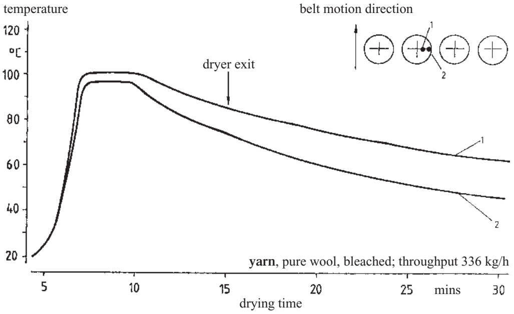

Fig. 6: Temperature curve in drying dye bobbins (100% wool) in an industrial high frequency drier.

In a high frequency drier for the continuous drying of yarn packages forced ventilation of the drying chamber is necessary. During the course of drying (Fig. 6), no temperatures higher than 110°C have been measured in yarn packages (source: Böhnke).

High frequency drying (HF-drying, RF-drying, dielectric drying). Drying takes place between two capacitor plates supplied with a constant high frequency AC voltage. The textile material is heated and dried by high frequency electrical oscillations whereby the depth of penetration is independent of material thickness so that HF-drying is particularly suitable for drying yarn packages. High frequency drying can also be used for warp sheets, tops, loose stock, hanks and garments. High frequency heating is employed in the bonding of polyamide-based nonwovens. →: High frequency driers; Drying systems.

High frequency dye fixation Dye fixation with the aid of high frequency energy. For high frequency applications the form of the electrodes is of decisive importance.

High gloss finish, high lustre finish → Embossing.

High grade synthetic resins. Synthetic resins free of fillers. Mainly → Phenolic plastics, used for a variety of applications.

High humidity measuring instrument Control systems for the contact-free continuous measurement of liquor content across the full width of fabrics during impregnation processes. These units are typically installed behind liquor application systems, e.g. padders, coating machines as well as for the control of predriers on thermofixation ranges, etc. Two different types of measuring system have been developed, i.e. a) direct measurement and b) difference measurement between dry and wet material. In all cases, however, the principle is based on the reflection of microwave or beta-ray transmissions.

Highly sulphonated oils → Sulphonated surfactants.

High modulus fibres → High wet modulus fibres (HWM fibres).

High performance liquid chromatography (HPLC). Like → Gas chromatography, HPLC is based on the separation of mixtures of substances by sorption processes between a stationary phase and the individual components of the mixture in the mobile phase. In HPLC a solution of the component mixture is pumped through a column containing the stationary phase under pressure. As a chromatographic technique, HPLC is always preferred to gas chromatography when the substances in the mixture are non-volatile (in general, substances with high molecular weights) or thermally unstable. For this reason, HPLC is used for the analysis of medicinal (pharmacological) materials, the determination of active substances in biological matrices and the analysis of synthetic polymers, etc. The obvious prerequisite for HPLC is that the mixture of substances, or substance, to be analyzed is soluble in a suitable solvent or solvent mixture. HPLC is also extensively used in the environmental protection field. Its main applications include the detection of polar non-volatile substances and the analysis of pesticides. Aldehydes may be separated and identified after derivation with 2,4-dinitrophenylhydrazine. An interesting application is e.g. the identification of formaldehyde in cigarette smoke. To this end, 30 ml of smoke are intensively mixed with 1 ml of reagent solution and eluted with water/acetonitrile at a flow rate of 1.5 ml/min. Detection is by spectrophotometer at 350 nm.

In dyeing investigations, HPLC permits the simultaneous separation and quantitative determination of reactive and hydrolyzed dye components, and is therefore particularly suitable for investigations into the course of reactions in reactive dyeing (→ Chromatography).

In addition to purely qualitative investigations, HPLC also enables quantitative comparisons to be carried out. Essentially, HPLC represents a more efficient further development of column chromatography with many separation layers in which newly developed packing materials (e.g. modified microparticulate silicas) are used, thus drastically shortening the material transport diffusion path. Constant flow rates are also achieved in HPLC with the mobile phase being pumped at pressures between 100–500 bar.

High polymers (macropolymers). Polymolecular mixtures of → Polymer homologues.

High pressure atomisers Atomisers used, e.g. for lubrication purposes, which employ centrifugal force high performance jets for lubricant emulsions subjected to liquid pressures between 50–150 bar and higher produced by high pressure pumps.

High pressure drier A drier for yarn packages in which the packages, supported on a carrier frame, are hydro-extracted/dried with high velocity hot air.

High pressure dyeing → High temperature dyeing.

High pressure hydrogenation → Fats, high-pressure hydrogenation of.

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High pressure spray washing tower An open-width washing machine for viscose fabrics in which the goods are laid on rippled metal plates and sprayed with wash liquor through high-pressure nozzles. The working principle is the same as that employed in the → Spray washing machine with high-pressure jets. The liquor is fed to the nozzles by a centrifugal pump.

High pressure steam Steam at a pressure greater than 2 bar. Both → Saturated steam and → Superheated steam can be handled in this form. The difference between the two is given by the respective temperature.

High pressure steamer → HT pressure steamer.

High pure water Water of reagent quality. Produced from pure water with the following aftertreatments: prefiltration, activated charcoal adsorption, mixed bed ion exchange, sterile filtration. Highly pure water is low in ionized and organic impurities, free from germs and solid particles without the operating costs of the plant exceeding those of simple distillation.

High shrinkage yarns High-bulk yarns containing 30–40% → High-shrink fibres, also used in blends with wool. → Textured yarns.

High-shrink fibres Physically modified types of synthetic fibres which undergo shock shrinkage (by approx. 40–45%) in boiling water or hot air (heat-setting temperature 185°C). Normal acrylic and polyester fibres are used in blends with pre-shrunk fibres for the production of high bulk yarns (→ Textured yarns). The physical modification of, e.g. the homopolyester is concerned with texture only and is achieved by changing the degree of orientation and crystallinity of the polymers. Polyester high-shrink fibre types, which exhibit optimum molecular orientation after drawing but only a relatively low degree of crystallinity, shrink during heat-setting and are transformed into a crystalline system with a lower energy content which gives deeper shades after dyeing with disperse dyes. Moreover, polyester high-shrink fibres, for example, also undergo a boiling shrinkage of approx. 45% at dyeing temperature (98–125°C). Consequently, after dyeing in the form of loose stock, tops or yarn, the material is already fully shrunk and cannot, therefore, give rise to any further contraction in fabrics produced from such fibres during subsequent thermal aftertreatments (heat-setting).

High solids thickener → Low/high solids thickeners.

High-speed spinning The demands for higher quality, increased productivity and lower production costs which began in the 1970's, led to modifications in spinning technologies. In the classic → Melt-spinning process, filament extrusion speeds of approx. 1000 m/min are employed. The desired physical and textile properties are achieved in subsequent drawing. Initially, the combined spin-draw-wind process represented an alternative to this technology. Filament yarns produced by this method gave similar properties to those produced by the classic technologies. Consequently, high-speed spinning and winding technology was developed as an economically attractive variant. The properties profile of these filament yarns is, however, not identical to that achieved by conventional spinning technologies. For this reason, production of fibres by high-speed spinning methods has to be taken into account (especially by the textile finisher). Two-stage methods offer the greatest flexibility. Starting from partially-oriented yarn (POY), a fully-oriented flat yarn is obtained by simple drawing in draw twisting, stretch winding or stretch warping. The same POY serves as feedstock for the air-jet and false-twist texturing processes. Flat yarns may be produced by the particularly economical single-stage process. In this case, a distinction is made between spin drawing and high-speed spinning. In both cases, the product is a bobbin of fully-drawn yarn. In the spin drawing process, however, final orientation is achieved in two steps whilst in high-speed spinning, the polymer filaments are drawn only in the cooling zone below the spinnerets where they assume their final orientation.

Single-stage processes for the production of flat filament yarns are compared schematically in Fig. 1. The simplest process, in terms of machine technology, is shown in Fig. 2. In this case the polymer melt is extruded through spinnerets and, after the resulting filaments have cooled down, a spin finish is applied and they are wound on bobbins. In the two other cases, however, an additional drawing stage is interposed between cooling and winding by drawing the filaments through godet rolls or against air friction. Both these drawing variants are practically the same as far as the physical structure of the yarn is concerned.

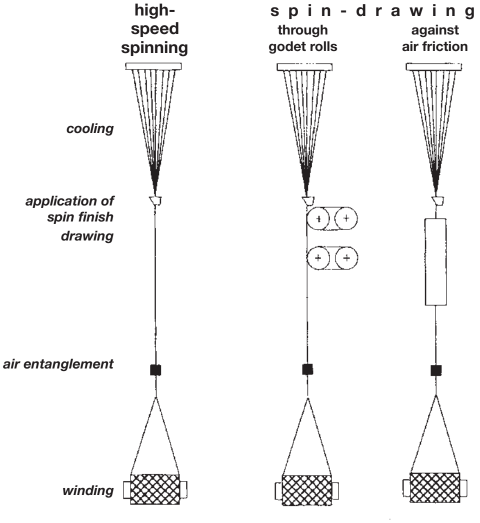


Fig. 1: Single-stage high-speed spinning processes (source: Tekaat).

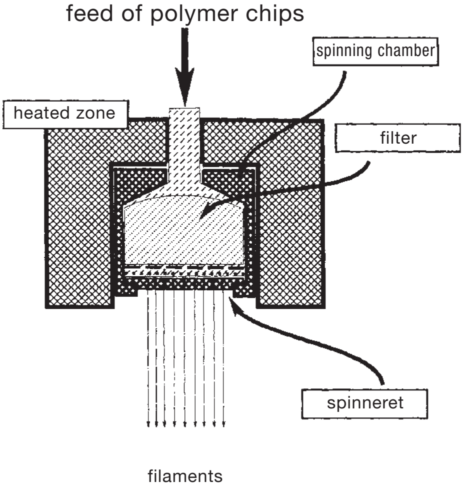


Fig. 2: Flow of molten polymer in the spinning chamber (source: Tekaat).

Stress-strain curves for filaments spun at different speeds are shown in Fig. 3. It can be seen that filaments spun at a speed of approx. 3000 m/min, which corresponds to that usually employed in draw-texturing, still have a delayed deformation (creep) of approx. 40%. It is only at speeds above approx. 5000 m/min that the first rise of the stress-strain curve is so steep that the filaments could be processed on normal textile machines. The precise drawing speed depends on the cooling conditions as well as the linear density of the individual filaments: the finer the filaments, the more quickly they cool down and a high orientation of the filaments is achieved at quite low drawing speeds which results in a steep stress-strain curve (source: Tekaat).

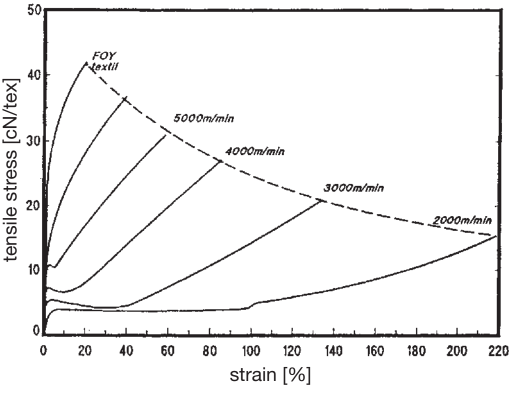


Fig. 3: Stress-strain curves for polyester filaments spun at different speeds (source: Tekaat).

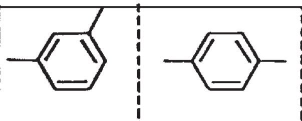
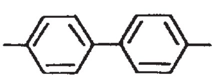
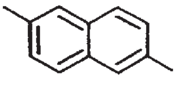
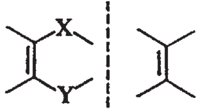
High speed washer A rope washing machine for wool piece goods with increased throughput speed. Manuf.: Hemmer.

High-tech fibres The synthetic filaments and fibres with breaking strengths of 3–10 cN/dtex and E-modulus of approx. 35–130 cN/dtex, which are presently used in great quantities, achieve only approx. 10–25% of the theoretically possible strength or E-modulus. This is due, on the one hand, to irregularities in the partially crystalline fibre structure and the molecular weights of the fibre materials and orientation of the molecular chains on the other. By using materials with an extremely high molecular weight and drawing the filaments to the limits of possibility, a much closer approach can be made to the theoretically possible strengths and E-modulus. However, these procedures are only possible up to now for polyethylene and other linear chain molecules without large side chains (e.g. polytetrafluoroethylene, polyvinyl chloride and, perhaps, also polyacrylonitrile and polyvinyl alcohol). In the case of polyethylene, molecular weights of $2 \cdot 10^6$ with filament strengths of 30–35 cN/dtex have been achieved. Compared to the classical synthetic fibres, these so-called “high-tech fibres” are of increasing importance for technical textiles (geotextiles, filter materials, composites, protective clothing, etc.). The wide spectrum of chemical structures for such fibres can be summarized, in a highly simplified form, by the most important building blocks, i.e. the aromatics, as well as the temperature-resistant linkages and resultant polymer classes (see Table: Survey of technically used high performance fibre materials).

The properties of these fibres (with differences in relative importance) include high tensile strength, high thermal stability, low combustibility, high chemical resistance and good electrical resistance. The fields of application for these fibres demand a wide range of properties which are not adequately covered in generally available technological tests. Thus, for example, when such fibres are used in the filtration field they are subjected to short-term mechanical stresses in both longitudinal and transverse directions of the fibres due to the frequent cleaning cycles required (contributed by Falkay).

High temperature amylases A term used to define a new generation of desizing agents in the form of starch-degrading enzymes obtained by microbiological processes. These enzymes are still active at working temperatures of 100°C and above, thereby requiring extremely short reaction times.

High temperature contact process A process used for surface bonding of fibrous webs, coated and milled or needled felts, back-coated and tufted carpets on a contact drying machine. The process is based on the principle of direct contact drying between the coated side of the substrate and the cylinder surface at high temperature.

Aromatic components				
Temperature-stable bonds	$-CF_2-$	$-S-$ $-O-$ $-\overset{O}{\overset{\|}{C}}-$	$-\overset{O}{\overset{\|}{C}}-O-$ $-\overset{O}{\overset{\|}{C}}-\overset{H}{\overset{\|}{N}}-$	
Polymer types	Fluoropolymers	Polyaryls	aromatic polyester and polyamides	heterocyclic and conduction polymers
		CHAIN RIGIDITY →		
Fibre materials	**PTFE** (Teflon, Gore-tex, Rastex, Tyoflon)	**PPS** (Ryton) **PEEK** (Zyex)	**PM I** (Nomex, Conex) **PPTA** (Kevlar, Twaron) **PEA** (Technora, PA, PPSO, T sulphone)	**PA I** (Kermel) **PI** (P84) **PBI** (PBI fibres) **PEI** (Ultem) **POD** (Oxulon type)

Tab.: Survey of technically used high performance fibre materials.

High temperature dyeing (HT dyeing). The dyeing of textiles at temperatures above 100°C in pressurized equipment → High temperature dyeing machines. The chief advantage is prevention of pump cavitation and consequent secure liquor circulation. High temperature dyeing has specific advantages for the dyeing of various fibres, especially the low-swelling or non-swelling synthetic fibres without reactive groups, i.e. above all polyester and triacetate fibres and their blends with other fibres. For cellulosic fibres, high temperature dyeing also offers advantages of reduced swelling and the de-aggregation of dye molecules, especially direct dyes, above a certain temperature with consequent improvement in dye penetration, more rapid levelling and therefore the possibility of reduced dyeing times. A strict selection of direct dyes and the addition of textile auxiliaries to prevent dye decomposition on boiling is necessary. New dyes have been developed for high temperature dyeing (Ditherm Fast dyes). Under HT conditions, vat dyes are better applied in the pigmented form only and then vatted in the usual way. Sodium dithionite (hydrosulphite) is not satisfactory as a reducing agent for dyeing under HT conditions, and a more temperature-stable reducing agent must be used. For wool, HT dyeing offers advantages of increased dye levelling and shorter dyeing times compared to dyeing at the boil. in order to maintain optimum wool quality, however, a maximum dyeing temperature of 106–108°C must not be exceeded. It has to be borne in mind that wool suffers the least damage under low temperature dyeing conditions at 80°C. For this reason, HT dyeing is less important for dyeing 100% wool articles than for wool/synthetic fibre blends. For synthetic and triacetate fibres, HT dyeing offers advantages of higher dye yields due to the increased dye diffusion rate, the achievement of deeper shades without carriers, a reduced tendency for stripiness in dyeing (modacrylic, polyester) and optimum dye levelling.

High temperature dyeing machines (HT dyeing machines). These machines offer the possibility of a closed dyeing system suitable for all dyeing temperatures under pressure (besides temperatures near the boil below 100°C) to achieve the objectives of → High temperature dyeing by raising the boiling point of the dye liquor and eliminating pump cavitation problems. In the dyeing process, which takes place under total exclusion of the external atmosphere, a static pressure prevails (produced by an auxiliary pump, water pressure, steam pressure, or compressed air) which either maintains the vapour pressure of the dyebath (static pressure) or lies above it in order to achieve the desired temperature above the boiling point of the liquor. Most high temperature dyeing machines use so-called expansion vessels (Fig. 1) which can be maintained at the same pressure as the entire dyeing machine to absorb liquor expansion and facilitate dyeing additions, or they may be open and can then receive the quantity of liquor which corresponds to the increase in liquor volume by means of a special valve. Other constructions provide space for liquor expansion underneath the cover of the autoclave or they also function without any expansion and overflow tank (Fig. 2). Such machines are subject to regulatory control (regional and state regulations often vary). The upper dyeing temperature limit of 130°C is not due to dyeing considerations but has been laid down by the German TÜV (Technische Überwachungsverein = Technical Inspection Association) as the material-specific upper limit for steel walls of high pressure vessels of normal thickness. Depending on the field of application, high temperature dyeing machines include the following types:

I. Pressure jiggers (→ HT-jigger).
II. Pressure star frames, give good results but suffer from low performance.
III. → HT beam dyeing machines (horizontal); most are also designed for yarn package dyeing.
IV. Automatic hosiery dyeing machines.
V. → HT dyeing machine for yarn and loose stock dyeing.
VI. HT jet dyeing machines.
VII. HT winch dyeing machines.

High temperature exhaust dyeing → Vat dyeing.

High temperature fibres Organic and inorganic fibres such as →: Ceramic fibres; Glass fibres; Aluminium silicates; Metal fibres. A collective term for especially → Fire-resistant fibres and heat-resistant fibres composed of organic macromolecular compounds which exhibit heat stable properties over a time-related

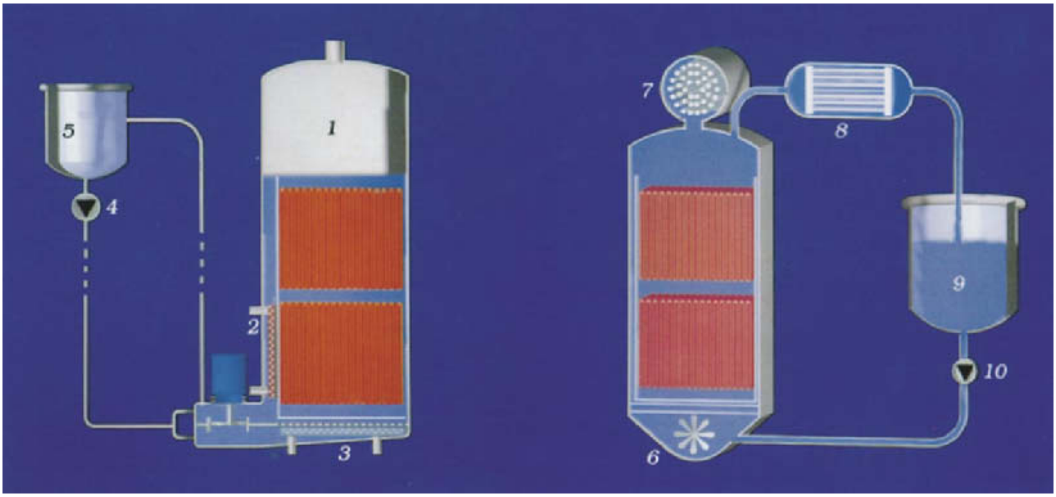


Fig. 1: Cabinet for hank dyeing. Left-hand side: APPC-LV cabinet; right-hand side: traditional cabinet.
1 = air pad pressurization; 2 = independent heating exchanger; 3 = independent cooling exchanger; 4 = external reversible axial pump; 5 = automatic add tank or kitchen; 6 = internal axial pump; 7 = heat exchanger; 8 = continuous liquor cooling; 9 = lateral expansion tank; 10 = static pump in continuous operation.

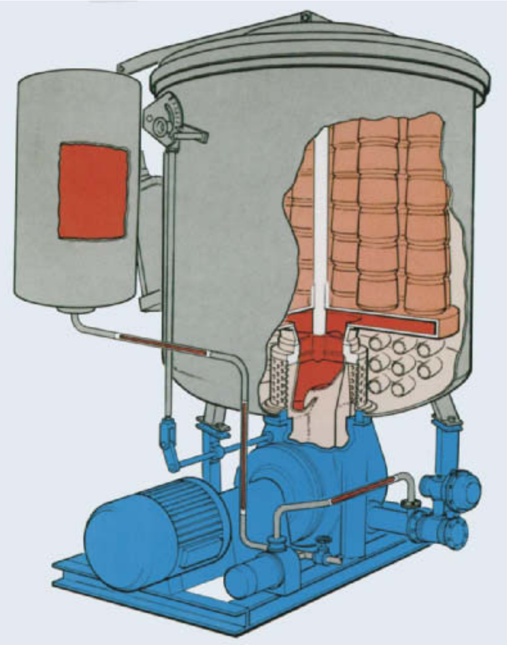


Fig. 2: Longclose "union" yarn dyeing system.

period whilst largely maintaining their technological characteristics and whose strength only falls to zero under normal atmospheric conditions at approx. 3000°C. The basic polymer molecule consists mainly of aromatic ring systems which are linked together by carbon, oxygen or nitrogen atoms, possibly via heterocyclic groups, and which contain only a few hydrogen atoms. High temperature fibres include a variety of macromolecular groups; linear macromolecules, ladder polymers, molecular networks up to the graphite fibre type (→ Carbon fibres), aromatic polyamides (→ Aramide (fibres)), polyimides (→ Arimide (fibres)), polyamide-imide fibres (→ Aramideimide fibres), polybenzimidazole (PBI), poly (bisbenzimidazobenzo) phenanthroline, polyterephthaloyloximidazol-metal chelate, polypyrone, poly-2,6-diphenyl-p-phenylene oxide.

High temperature heat transfer medium → Heat transfer medium.

High temperature light fastness Upholstery materials, glove boxes, parcel shelves, etc., in automobile interiors are subjected to relatively high temperatures due to the extensive area of glass in windows and windscreens. These conditions favour colour fading due to the action of UV radiation. A normal light fastness test is therefore not adequate for automotive textiles. An additional effect is due to the fact that absorbed light not only results in the photochemical degradation (of dyes and fibres) but also causes heating. UV light is primarily responsible for degradation reactions initiated by light. With dyes which are known to cause fibre tendering, visible light also contributes to accelerated degradation. Besides initiating photoreaction, absorbed light produces heat. Thus, in → High temperature light fastness tests for example, considerable differences in the test specimen temperatures can be found depending on the shade (see Table).

dyestuff	quantity (%)	absorbed radiation capacity (W/m²)	test specimen temperature (°C)
undyed	—	246	83
Irgalan yellow	0.05	379	84
GRL 200 %	1.05	620	
Irgalan Bordeaux	0.06	472	86
EL 200%	1.20	690	
Irgalan blue	0.07	559	87
3 GL 200%	1.40	804	93
Irgalan black BGL 200%	3.50	869	97
spun-dyed black, soot		1075	99

Tab.: Comparisons of absorbed radiation capacity with test specimen temperature in a hot exposure test (polyamide tricot; black body temperature 89 °C ; Irgalan dye = Ciba-Geigy).

High temperature light fastness tests In addition to the usual requirements (surface uniformity, shade conformity, rubbing fastness, fibre comfort), extremely high requirements have now been placed on the high temperature light fastness of textiles for automobile interiors. These requirements can differ quite markedly depending on the automobile manufacturer as well as the intended use in the automobile interior. It

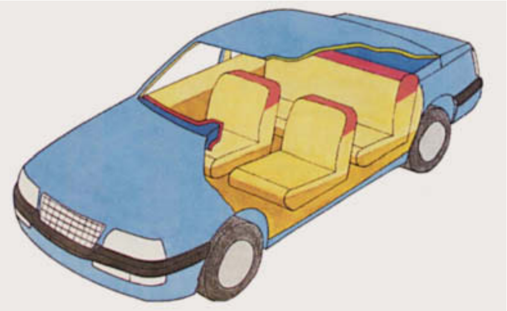


Fig.: Motor car textile light fastness requirements. brown = low; green = average; yellow = high; red = very high; dark blue = highest.

Specification/ description	Important criteria	Remarks
SN-ISO 105-B 02 „Xenon“	- Xenon radiator - light filtering: UV radiation < 310-320 nm remote IR radiation with glass or water filter 90% radiation in the 380-750 nm range - black body temp. < 45°C - rel. humidity ~ 60% - return run (light/dark 1:1)	- usual method of determining light fastness - numerical light fastness evaluation against blue scale 1-8
DIN 75.202 „Fakra“ Determination of the light fastness of motor vehicle interior fitting materials	- Xenon radiator - light filtering: UV radiation < 290 nm remote, rel. irradiation intensity of 290-400 nm, approx. 10% (relative to irradiation intensity 290-800 nm) IR radiation with glass or water filter - black body temperature 100-115°C } depending on type of equipment - test room temp. 40-72°C - air humidity 20±10% - same direction	- latest specification; hot exposure method particularly German car manufacturers; numerical light fastness evaluation against blue scale 1-8 (= single test cycle of 80 ± 16 hours), inaccordance with grey scale 1-5, if multicycle - all time data in this table relates to DIN 75.202, draft 11) 1984; i.e. single test cycle = 96 hours.
Other hot exposure tests:		
- SAE Standard Test Meth. J 1885	Xenon radiator	important American car manufacturers’ test
- in acordance with Toyota/Nissan	carbon arc light	important Japanese test
- AFNOR G07-208, 1982 draft	Xenon radiator	French car manufacturers’ method
- Ford EU-BO-50-2	Xenon radiator (max. UV light)	Ford Europe method

Tab.: High temperature light fastness tests.

is certainly possible for different automobile manufacturers to specify different colour fastness requirements even when following the same test specification. This means that the test specifications and the required results are to be regarded as fundamentally separate. In general, a clear trend towards even higher requirements can be detected where, in most cases, the same test specification is used, but with extended times of exposure. An overview of the strictness of the requirements, corresponding to the location of use of the textile material can be gained from the Figure.

At the beginning of the 70’s, a few automobile manufacturers switched over to newly developed test methods due to the fact that more and more glass was used in automobiles and the light fastness requirements were raised correspondingly. On the one hand, the light fastness tests introduced into the textile field many years ago were too slow and, on the other hand, the degree of correlation between laboratory results and the actual exposure under conditions of use was often unsatisfactory. Consequently, a great number of test specifications were drawn up requiring different types of apparatus and filter systems, besides specifying different conditions of temperature, humidity and time of exposure (→ Automotive textiles, light fastness testing). Comparisons between test results are therefore extremely problematic and is made even more difficult by the generally moderate reproducibility of the tests. This has led to a situation where certain dyes or their combinations give very good results in some tests and only moderate results in others. Correlation with conditions in practical applications are therefore questionable even when the ranking changes depending on the test method. It is clear that, in some tests, unnecessarily severe test conditions have obviously been specified for the raw materials to be used. With improved knowledge of the relationships involved a better, and to some extent, even more economical product selection should be possible. This unsatisfactory situation for all participants has led to efforts by various standards organizations to standardize the test methods.

In addition, efforts have been, and are being, made by various countries to a greater or lesser extent, to achieve better correlation of laboratory results with actual applications in practice (see Table).

The practical application of the high temperature light fastness test according to DIN 75 202 has been investigated in an interlaboratory trial involving 5 test centres. The results of the interlaboratory trial have shown that the wide tolerances of the test parameters and other factors can influence the test results considerably. With specified preconditions, however, it is possible to reduce the variation of test results and thus improve the reproducibility of the DIN procedure.

It has furthermore proved to be the case that, with increasing times of exposure, the Grey Scale is more suitable as an evaluation standard than the co-exposed blue standards.

High temperature resistant →: Thermal stability of dyes; Thermal stability of fibres.

High tenacity fibres (high tenacity rayon). Special fibres (filament or staple) with reduced swelling and increased dry/wet strength. They are mainly produced from viscose or partially-saponified acetate. The most important are → Viscose high tenacity fibres produced by a modified spinning process. Under the microscope such fibres are differentiated from regular viscose by their smooth-edged and mostly cylindrical outline with correspondingly fewer striations in longitudinal view. The cross-section is mainly cylindrical and smooth occasionally flattened on one side. (→ All-skin fibres).

High tension → Voltage ranges.

High vacuum metallizing A process for metallizing textiles (yarns, fabrics, knitgoods, plastic films, metal-effect yarns) from natural or synthetic fibres. Metal is deposited on the textile material in a high-vacuum vesselat a pressure of 1.33–0.0133 Pa. High vacuum metallizing can also be carried out continuously by drawing the material through a horizontal cylindrical vacuum chamber by a roller over the vacuum metallizing zone and batching on to a roller again. Many nonmetals and even organic compounds (certain dyes) can be deposited on textile surfaces using the same principle. The better the high vacuum, the higher the lustre and adhesion of the deposited films. In principle, all materials which do not release large quantities of volatile substances (e.g. moisture) and disruptive gases under these conditions, which would break the vacuum or impair adhesion of the film, are suitable for high vacuum metallizing. Scorching or burning of the material being processed is prevented by screening the radiant heat at the high vacuum deposition zone. On the other hand, the slight amount of condensation heat on the material is insufficient to cause burning.

High wet modulus fibres (HWM fibres). Modified regenerated cellulosic fibres of the → Modal fibres group. The strength and wet modulus of these fibres are similar to cotton. They have lower strength but higher extension than → Polynosic fibres. Used alone or in blends for easy-care textiles, etc.

High wet pick-up The use of liquor ratios which are too short can result in too little water, as a medium for the necessary diffusion processes, being available for the dyeing of pile fabrics by continuous methods as well as in the pretreatment of cotton fabrics. With conventional padding techniques, however, it is difficult to exceed a maximum pick-up of 70–90%. Higher applications of liquor are described as high wet pick-up (wet on dry) or addition impregnation (wet on wet). The following processing machines are available:

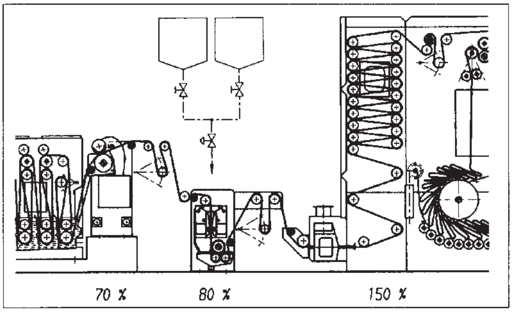


Fig. 1: Single-stage continuous pretreatment line. (detail): 70% squeezing effect after the pre-scour section, bleaching liquor addition of 80% by "Flexnip" (centre of diagram), fabric reaches steamer with 150% liquor content (Küsters).

I. Küsters have introduced an efficient pretreatment technology with the integration of a "Flexnip" unit (maximum pick-up of bleach liquor) into a continuous bleaching range (Fig. 1). Compared to conventional saturators, a number of advantages are realized with the "Flexnip" application system:

a) higher liquor application and therefore lower concentration of chemicals;
b) by dispensing with a separate scouring stage, a single-stage process can be used thus reducing fibre damage;
c) liquor strength factors of only 1 : 1.2–1.5 compared to the former 1 : 3–5;
d) only the liquor is added, without any liquor exchange, thus ensuring a constant chemical concentration on the goods;
e) less caustic soda solution is required compared to conventional scouring processes and there is considerably less residual liquor to be drained (saturator 500–600 l, Flexnip 8–10 l), i.e. considerable reduction in effluent pollution;
f) smaller machine concept with a consequent lower energy consumption and space requirements, simpler operation (titration no longer required).

II. Babcock have introduced the "Super-Sat" saturator unit as an alternative to internal or external boosters with which the application of chemical liquors is possible (Fig. 2). The liquor content of this saturator unit is only approx. 5 l/m fabric width. The liquor volume in the pipework and distribution system is included in this Figure. The liquor content of the dedicated metering system "Polycomat" amounts to an additional 5 l approx. The "Super-Sat" unit, which is located just before the steamer entry, is capable of providing liquor loads on textile fabrics up to the limits of their liquor-carrying capacities. To this end, liquor is not only applied, but also compelled to penetrate the fabric. Due to the large quantity of liquor, the concentration of the im-

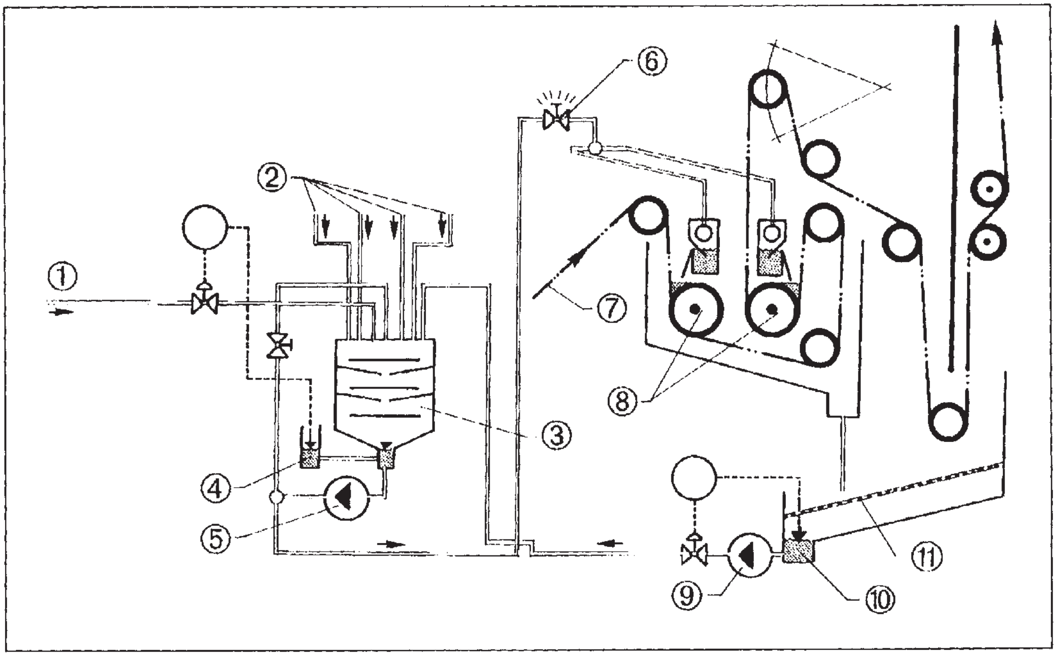


Fig. 2: "Super-Sat" (Babcock) impregnating unit.
1 = fresh water; 2 = chemical solutions; 3 = mixing tank; 4 = level control; 5 = circulation pump; 6 = quantity adjusting valve; 7 = fabric; 8 = impregnating rollers; 9 = recirculating pump; 10 = escaped liquor; 11 = lint filter.

pregnation liquor is only approx. 10–30% higher than the concentration on the fabric. As shown in Fig. 2, the unit consists of a double nip trough with liquor distributors (similar to the "Econ-Tex" open-width washing machine). Liquor distribution is achieved by means of pouring channels above the impregnation rolls.

Impregnation of the fabric and the resultant approx. 50% exchange of water in the fabric with the chemical liquor is achieved by forced penetration in the liquor wedge between fabric and saturator roll on both sides of the fabric one after the other. The higher liquor exchange achieved with the "Super-Sat" ensures a uniform bleach effect even with different fabric weights. The quantity of liquor is controlled and limited by the amount of liquor fed to the saturator rolls and an adjustable spar above the saturator rolls. Excess liquor is collected in a trough below the steamer entry and recirculated. The excess liquor flowing from the sides of the saturator rolls is also collected and recirculated. Liquor losses are avoided by the proven principle of weight-proportional metering which ensures economical processing. Even application of the liquor in and on the fabric is completed by guide rollers in the steamer entry zone. This can be used as a supplementary measure, i.e. by applying a slight overfeed (up to 5%) to the rollers, further penetration is promoted by rubbing against liquor adhering to the surface of the fabric. The liquor pick-up of the fabric, limited only by the carrying capacity of the fabric itself, is so high that, on the one hand, the risk of crease marks is minimized and the prerequisites for effective cotton seed removal are optimized on the other.

III. With the "Raco-Yet" system (Figs. 3–6), Kleinewefers KTM have developed a high wet pick-up process based on a different principle. By means of a two-component mixing nozzle an aerosol is formed by the combination of chemicals (dissolved in water) and steam (both streams meet at the outer nozzle tip which ensures that the liquor is simultaneously heated and at-

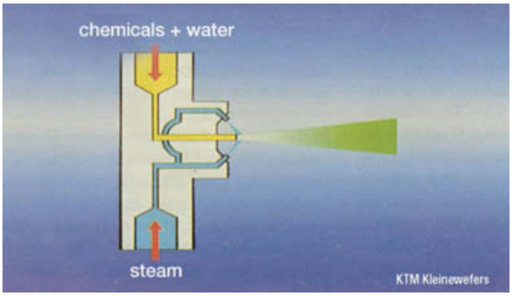


Fig. 3: Two-substance mixing nozzle with external mixing (Raco-Yet, Kleinewefers KTM).

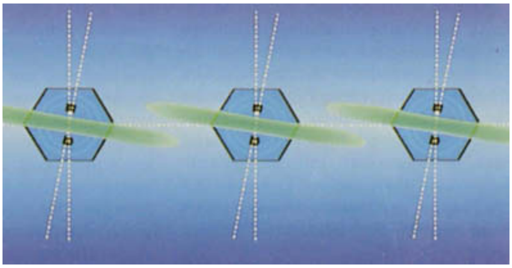


Fig. 4: Nozzle jet overlapping in the Raco-Yet (from Kleinewefers KTM).

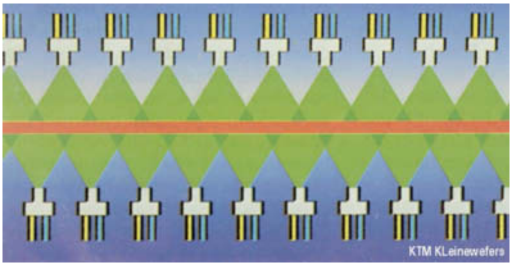


Fig. 5: Offset nozzle banks on the face and reverse of the fabric in the Raco-Yet.

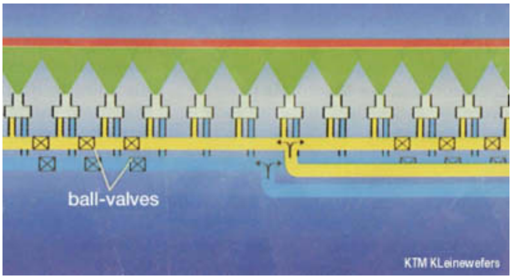


Fig. 6: Liquor and steam feed across the fabric width.

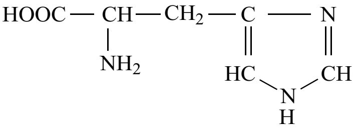
omized to form an aerosol), and the micro-droplets are able to penetrate well inside the fibre with the aid of thermal and mechanical energy. With this aerosol a product application of 130–150% (liquor pick-up) is achieved. Since the aerosol penetrates deep into the fibre structure and the reaction is not controlled by diffusion, short reaction times in the subsequent steaming stage are sufficient.

Through the application of "Raco-Yet" process technology in cotton pretreatment with tight-strand fabric passage, desizing (starch is broken down by oxidative degradation), scouring and bleaching (alkali and hydrogen peroxide) are achieved in a single-stage process with average steaming times of 2 min to give a degree of white suitable for dyeing. In cases where size recovery is to be carried out, a wet-on-wet prewash stage can be incorporated.

H ions → Hydrogen ions.

Hirschburger process A → Space dyeing method for yarn sheets similar to the → Hörauf process, except that in this case 2 threads can be wound at the same time on to a carrier with only one winding head. The working speed of the winding head is between 600 and 1000 m per min, and can be varied in three stages. The dwell time in the steamer is 1–5 min and depends on the kind of winding as in the Hörauf process (close winding or widely spaced winding), i.e. it depends on the speed of winding and transport as well as the thickness of the material. During the transport of material through the steamer, the carrier rotates five times around its own axis to ensure uniform steaming.– Manuf.: Maschinenfabrik E. Hirschburger KG.

Histidine An amino acid (α-amino-β-imidazole-propionic acid) contained in wool (0.7%) and silk (0.47%):



Historical development of textile fibres Until about 1900, natural fibres such as wool, silk, cotton and the hard fibres were the principal raw materials for the manufacture of textiles. In the 20th century the relative proportion of natural fibres has declined (with the same rise in natural fibre production) to approx. 55% (see Table) due to the development of man-made fibres (from natural and synthetic polymers). On the other hand, provision of the world population with textiles (without synthetic fibres) would now be unimaginable since the capacity for growth of the raw materials (natural fibres and wood for regenerated cellulosic fibres) is limited.

In the case of man-made fibres, the market today is split between 58% staple fibres and 42% continuous filament fibres. At the end of the 1940's, the synthetic fibres were only used as continuous filaments at first until today's equilibrium between staple and filament was reached by gradual stages. Although at the beginning of man-made fibre development, polyamide fibres were the most important raw materials, the market today is broken down into 54% polyester fibres, 24% polyamide fibres, 15% polyacrylonitrile fibres and 7% other fibres (e.g. poly-propylene, etc.)

HLB-temperature → Phase inversion temperature.

HLB value The HLB system (HLB = hydrophile-lipophile balance) was introduced by Griffin, as an empirical scale from 1–20, to characterize the balance between the hydrophobic and hydrophilic moieties in sur-

year	cotton	wool	silk	hard fibres	man-made fibres	total
1900	3 162	730	10	1 500	1	5 403
1910	4 200	803	k. A.	k. A.	5	–
1920	4 629	816	k. A.	k. A.	19	–
1930	5 870	1 002	k. A.	k. A.	208	–
1940	6 907	1 134	k. A.	k. A.	1 132	–
1950	6 647	1 057	19	3 000	1 677	12 400
1960	10 113	1 463	31	5 152	3 358	20 117
1970	11 784	1 659	56	4 865	8 397	26 761
1980	13 884	1 599	64	4 800	14 182	34 529
1989	17 582	1 936	65	4 900	19 057	43 540

Source: CIRFS (numbers for silk and hard fibres for 1900 are estimated)

Tab.: World production of textile fibres 1900–1989 in 1000 t (k. A. = no data).

face-active textile auxiliaries (surfactants, emulsifiers) and is independent of their constitution (but highly temperature-dependent). A low HLB value (< 10) signifies a predominance of hydrophobic groups indicating that the surfactant is lipophilic, and a higher HLB value (> 10) that more hydrophilic properties predominate. The HLB describes the ratio of relative intensity between polar and apolar portions of a surfactant molecule. The HLB value is therefore determined by the type and size of the hydrocarbon chain as the apolar representative and the strength of the dipole in the polar portion. Consequently, a long straight-chain hydrocarbon portion has greater intensity than a short branched hydrocarbon chain. In the polar range, an ethylene oxide group is less, and a carboxyl, phosphate, sulphate, sulphonate group (in order of increasing effect) more intensive. The following properties are determined by the HLB value:

a) surfactant solubility,
b) emulsifying properties of a surfactant,
c) soil suspending properties of a surfactant.

In simplified terms, the 1–20 scale of the HLB system has the following significance:

1 – 3	solvent soluble, water insoluble
3 – 7	solvent soluble, water dispersible
7 – 10	solvent soluble, water soluble
10 – 13	water soluble, solvent soluble
13 – 18	water soluble, solvent dispersible
18 – 20	water soluble, solvent insoluble

From the above classification, the fields of application of individual surfactants are determined. Thus, for example, general-purpose detergents and textile washing agents are found in the range from 13–18, whilst highly-active washing agents with fat-dissolving properties as well as pre-spotting agents for drycleaning with especially high activity against wet soiling are found in the range from 10–13. Drycleaning detergents, which can also be used as pre-spotting agents, are included in the range from 7–10. Drycleaning detergents with, for the most part, finishing properties as well, are found in the range from 3–7. On this basis, for example, an emulsifier for a particular purpose can be selected. Hydrophilic groups include, e.g.: $-OH$, $-NH_2$, $-SO_3Na$, $-OSO_3Na$, ethylene oxide, etc.

Application fields of surfactants according to their HLB values:

1.5 – 3	antifoaming agents
3 – 6	drycleaning detergents
4 – 6	W/O emulsifiers
7 – 9	wetting agents
8 – 13	O/W emulsifiers
13 – 15	wash-active surfactants
15 – 18	solubilizers.

Methods of determination:

I. Emulsion comparison method (oils with known HLB values are used as reference parameters).

II. Cloud point determination on heating (precipitation of water soluble surfactants with HLB values from 12–18).

III. Turbidity titration with water (by differential solubility in benzine/water and water).

IV. From the → Spreading coefficient for HLB values of 7–15.

V. Chromatographic methods (influence of the migration capacity by HLB values of 0–18).

VI. Rapid calorimetric method according to Orben.

VII. Titration.

The practical value of the scale lies in the fact that the required HLB value for the preparation of an emulsion with emulsifiers of known HLB values can be ascertained from simple emulsification tests, and other emulsifiers of known HLB values can be selected. Moreover, the HLB value of a mixture of emulsifiers is proportionate to the HLB values of its components, which makes possible the preparation of an emulsifier mixture of known HLB value. Unfortunately, despite

$HLB = \frac{H_M}{G_M} \times 20$ H_M = hydrophilic molecule content G_M = total molecular weight		$HLB = \frac{H}{5}$ H = % hydrophilic content		$HLB = 20\left(1 - \frac{VZ}{SZ}\right)$ VZ = emulsifying agent saponification number SZ = fatty acid number		
hydrophilic percentile groups	lipophilic percentile groups	HLB value	behaviour in water	field of application		
0	100	0	not dispersed	1	antifoaming agent	
10	90	2				
20	80	4	very poor dispersion	3	water/oil emulsifying agents	
30	70	6		6		
40	60	8	milky dispersion	7	wetting agent	8
50	50	10	stable, milky dispersion	9		
60	40	12	clear, translucent dispersion			
70	30	14		13	washing agent	oil/water emulsifying agents
80	20	16	clear, colloidal solution	15		
90	10	18			solubiliser	
100	0	20		18		18

Tab.: HLB values and calculation bases.

the clarity and usefulness of the HLB system, in practice its value is limited by the fact that the emulsion type is frequently also affected by numerous other parameters, e.g. the water/oil ratio, temperature and viscosity, so that optimum HLB values for the preparation of a particular emulsion must be determined experimentally in every case (→: PIT; Cloud point index). Calculation is possible for emulsions whose structure and molecular weight are known. The HLB value is accordingly a function of the weight ratio of the hydrophilic portion to the total emulsifier molecule.The table shows such possibilities for calculation (according to Griffin), together with properties dependent on the HLB values.

HL-process A process for dry cleaning establishments in which a dry cleaning detergent/water emulsion may be added directly to the cleaning liquor with a dry cleaning detergent concentrate.

HM process (H = Habis Textil AG, M = Monforts). A plant for the curing of finishes and fixation of prints on woven fabrics in textile finishing. It combines a rapid heat-up phase in hot air and a short dwell time in a steam atmosphere.

Ho, chemical symbol for holmium (67).

Hog's bristles (pig bristles). Depending on the method of slaughtering, the approx. yield is 300 g of stiff, coarse bristles per pig by scraping. Special fermentation processes are used to remove skin particles. Uses: apart from brooms and paint brushes, hog bristles are also used as a padding material and in fur hats.

Holbein rugs Oriental rugs or carpets mainly from the Bergama area in western Turkey and named after the painter Hans Holbein the Younger, who portrayed some examples in his pictures.

Hole etcher A variant of the burn-out print style. This process was already being carried out during the middle of the 20th century before synthetic fibres appeared in the market, and should therefore be described as the classic burn-out style. Print pastes containing an acidic component are applied to 100% cotton in order to burn holes out of the fabric in specific areas corresponding to the printed design. Fraying of the burned out holes in the fabric during washing is avoided by selecting tightly woven fabrics for this style of printing. The problem does not arise if the burn-out areas are surrounded by a border printed with pigment colours since, in this case, the polymer film of the pigment binder prevents frayed edges by bonding the exposed fibres.

Hole in milling A technical term for a fabric defect (hole) caused by sudden high pressure or impact during fulling or milling (rotary cylinder, perforated roller).

Hollow cop (tubular cop). A → Cop of yarn with no internal support, i.e. a form of yarn package consisting of wound yarn only without any bobbin or tube. The yarn is unwound from the inside of the hollow cop.

Hollow squeegee (→ Double squeegee). A squeegee system used on flat-bed screen printing machines consisting of a pair of parallel rubber squeegee blades mounted in a single support. The print paste held between the two blades is transported across the printing screen by the rear blade only during each pass, the leading blade being raised at the same time. Thus, the leading blade for the first pass becomes the rear blade for the subsequent pass.

Home furnishings Together with household textiles, home furnishings account for approx. 30% of all textile fibre consumption. Apart from woven articles such as upholstery materials, carpets and bed covers, various special techniques are also used for the manufacture and finishing of home furnishings, e.g.:

- stitch bonded fabrics (Malimo): textile wallcoverings;
- knitted fabrics: upholstery materials;
- flocked fabrics: textile wallcoverings, net curtains, furnishing fabrics;
- layers of superimposed yarns: textile wallcoverings;
- nonwovens: textile wallcoverings;
- tufting technique: upholstery materials, carpets;
- coated fabrics: glassfibre wallcoverings.

Homespun Plain-weave coarse fabrics originally produced in the British Isles from hand-spun Cheviot wool, generally undyed and characterized by their uneven quality which was due to the hand weaving and spinning. Today, homespun is frequently used as a general term for loosely woven fabrics produced from very coarse, rough-haired, mottled or even slubby woollen yarns mainly in plain-weave constructions, often with a light melton finish. Used for lightweight suits, men's jackets, costumes and coats.

Homogeneous Composed of similar or identical parts or elements. A composition in which the components are of the same kind. A homogeneous system consists of a single phase, e.g. a common solution such as a salt or sugar solution. Homogenization: intimate mixing, e.g. of importance in the preparation of particularly fine emulsions.

Homogenizers High-speed mixers in which coarse and polydisperse emulsions are transformed into almost monodisperse systems by subjecting the liquid to high shear forces.

Homologous series A series of related chemical compounds in which each successive member has one more CH_2 group in its molecule than the preceding member. For instance, CH_3OH (methanol), C_2H_5OH (ethanol), C_3H_7OH (propanol), etc., form a homologous series.

Chemical compounds forming a homologous series have great physical similarities, especially neighbouring members. Other examples are: methane, ethane, propane, butane, etc., and benzene, toluene, xylene.

Homopolar → Polar.

Homopolar bond → Atomic bond.

Homopolymers Natural or synthetic → Polymers derived from a single type of building block (monomer) in contrast to → Copolymers.

Honeycomb backing (embossed foam, structured foam) → Backcoating of carpets with foam having an embossed honeycomb-like pattern.

Honeycomb fabric Cotton fabric in which the warp and weft threads form ridges and hollows to give a cellular appearance which may be evident on one or other, or both faces of the fabric. The honeycomb weave is achieved with groups of short running warp and weft floats.

Honeycomb screen An arrangement with a honeycomb grid used in the transfer of designs on to rotary printing screens during exposure to a light source in which oblique incident rays from all directions are, for the most part, screened out by the honeycomb grid so that they have no effect on the copying process.

Honeydew A descriptive term for secretions on cotton hairs caused by whitefly or aphids during cotton growing. The sticky deposit is composed of various sugars. The spread and intensity of honeydew infestation almost always has a direct correlation with the use of various insecticides. In the selection of suitable insecticides for cotton plants, it is important to protect the natural enemies of the aphids. Besides problems caused by insecticides, cotton contaminated by honeydew causes processing problems in spinning and frequently impairs the quality of yarns spun from such cotton. It is known that the honeydew components (i.e. sugars and various proteins) corresponding to the non-enzymatic (brown) reaction scheme, form brownish-black pigment stains. This reaction proceeds even at low temperatures, albeit relatively slowly, and is accelerated by the action of heat. The presence of additional substances such as organic acids can likewise contribute to the reaction as well as stimulate the formation of sugar caramel structures which results in similar yellow-brown pigments.

Hörauf process A → Space dyeing process for yarn sheets in which yarns from cross-wound packages/cops are passed through a dye liquor applicator. The amount of dye applied to the yarn can then be reduced to the desired liquor pick-up by means of a patented procedure (which is similar to the OPI method). The yarn is then conducted to a winding machine (Buddecke system) to obtain a continuous, hank-like wound package consisting of individual layers of yarn held by four endless conveyor bands. These layers are transported along a bar over a distance of 2.7 m through a steamer in a tension-free state to fix the dyes. The winding rate can be varied between 400 and 1200 rpm. The dwell time in the steamer is 7.25 min for yarn which is generally closely packed (16 threads per cm), the winding speed being 600 rpm. The dwell time is only 3.6 min if the yarn is spaced wide apart during winding (4 threads per cm) at a winding speed of 300 rpm. After steaming, the yarn is drawn off from the carrier and wound on bobbins.– Manuf.: M. Hörauf.

Horizontal emerizing machine For woven fabrics, with emerizing rolls and a dust bag filter for dust extraction from the machine. Fabric feed and delivery via batch rolls.

Horizontal flammability test → Flammability testing.

Horizontal HT-beam dyeing Machine → High temperature dyeing machines.

Horizontal jet drier → Jet air circulation driers with an electrically-driven wash unit for the fabric conveyor. Universally applicable for thin fabrics which can be subjected to powerful repeated suction pressure. Adhering water is removed by suction.

Horizontal migration Selective horizontal migration is due to the different migration rates of the components in a dye combination. It causes → Dichroism which results in an irregular and uneven appearance of the dyed fabric.

Horizontal open-width washing machines (→ Horizontal washing machines). This design of washing machine has wash compartments in which the guide rollers are arranged in vertical banks between which the fabric passes upwards in the open-width state in a series of almost horizontal loops with liquor flowing from top to bottom (see Figs. 1 and 2).

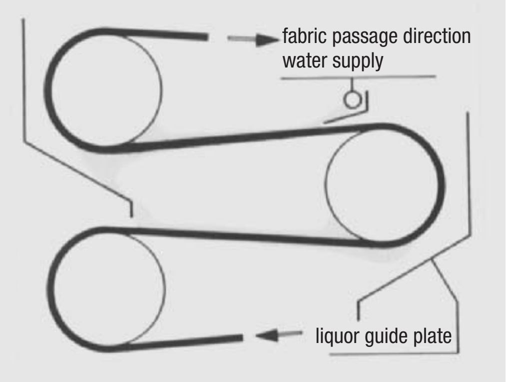


Fig. 1: Schematic fabric path in horizontal passage open-width washing machines.

Horizontal package dyeing machine → High temperature dyeing machines for yarn packages and spinning cakes with a horizontal dyeing chamber to accomodate dye tubes each containing approx. 10 individual packages. Short liquor ratios of around 4 : 1.

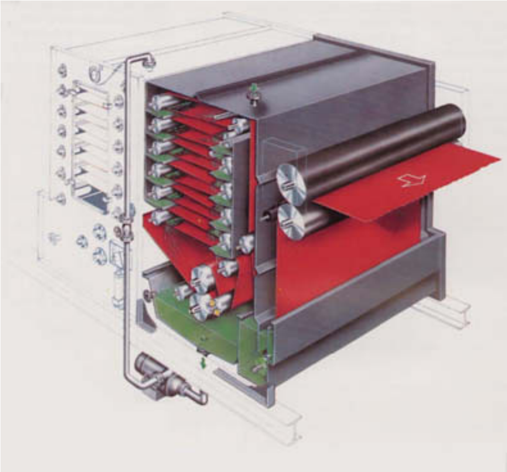


Fig. 2: Küsters horizontal passage open-width washing machine.

Horizontal padder (horizontal foulard). A → Padder, without a liquor trough, in which fabric is padded through a wedge of liquor held in the nip between two horizontally arranged padder rolls. → Horizontal two-bowl padder.

Horizontal rope washing machine → Horizontal washing machines.

Horizontal star dyeing machine A → Star frame in which the frame loaded with fabric is rotated through the dyebath.

Horizontal stenter A stenter with an air-cushion nozzle system for the drying and heat-setting of textile fabrics (see Fig.). The machine can be incorporated into an integrated finishing line for the finishing of wovens and knits and is provided with a double batching system on giant batch rolls at the delivery end for fully-continuous operation.

Horizontal test → Flammability test.

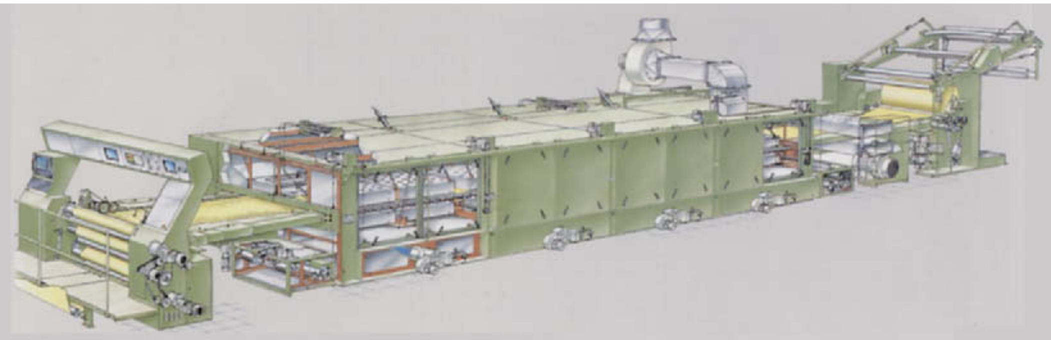


Fig: Horizontal stenter (Babcock).

Horizontal two-bowl padder A padder in which piece goods are run vertically downwards through the nip of a horizontal padder containing the liquor (see Fig.).

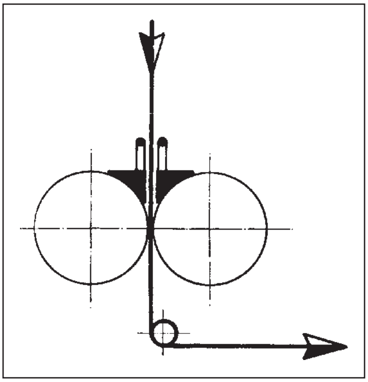


Fig.: Horizontal two-bowl padder.

Horizontal washing machines (tangential washing machines). Industrial long drum washing machines mostly with Pullman divisions (horizontal separators) for larger units and a lengthwise (tangential) opening for loading/unloading.

Horizontal washing machines for piece goods These machines are based on a horizontal fabric passage from the bottom to the top of the wash compartments and are used for washing piece goods in rope form or open-width depending on the particular design (→ Horizontal open-width washing machines). Liquor flow is from top to bottom thereby providing an ideal countercurrent flow washing system.

Horsehair Coarse, stiff, elastic hairs, usually white, brown and black in colour. Natural horsehair is obtained from the tail of the horse (60–80 cm in length, ∅ 80–400 µm) or the mane (25–45 cm in length, ∅ 50–200 µm). Synthetic horsehair consists of coarse viscose, acetate, polyamide and other monofilaments as well as partially dissolved and re-solidified cellulose threads. Horsehair substitute: apart from synthetic horsehair, so-called vegetable horsehair from leaf bast fibres (agave, manila, sisal), as well as glazed yarns, are also used. Yarn: chiefly of horsehair wrapped with cotton or other fibres, also as ply yarns with cotton (horsehair ply yarn). Uses: → Horsehair cloth, and as weft in stiff interlinings for jackets, skirts, upholstery fabrics, hat trimmings, etc.

Horsehair cloth Fabrics woven from pure horsehair are used as hair sieves. Haircloth, which consists of a cotton or wool warp and → Horsehair (natural or synthetic) wrapped with two fine cotton yarns (alternate S and Z-twist) to produce so-called horsehair ply yarns in the weft is used in → Horsehair linings.

Horsehair lining A half-horsehair fabric, i.e. usually with cotton or wool in the warp and horsehair in the weft used as a stiff interlining in coats and suits to retain the shape, and in women's hats. The crosswise elasticity of the material is determined by the number of horsehair yarns in the weft.

Hosiery finishing machines, automatic Integrated production lines for the cleaning, dyeing, plastification (heat-setting), softening and drying of hosiery.

Hosiery goods Textile knitgoods produced by the intermeshing of loops of yarn from one or more yarn systems in which the loops may run in a horizontal, i.e. widthwise (weft-knit) or vertical, i.e. lengthwise (warp-knit) direction. → Knitted fabrics.

Hosiery setting (boarding). A process carried out on (polyamide) hose or other knitted garments to achieve a desired shape or size which involves the action of heat under moist or dry conditions whilst supported on formers (Fig. 1) in so-called boarding machines (with steam hoods) or pressure steamers, as well as in special continuous machines (→ Boarding).

Fig. 1: Heliot machine for the continuous setting of hosiery.

To shape and set stockings or socks after circular knitting and making-up, they are therefore transported through the steaming and drying zone on aluminium boards or templates (Fig. 2).

Hospital textiles Since organic materials are subject to microbial attack and are eventually broken down, various products and methods have been developed to protect everyday articles and equipment from this kind of damage. Textiles used in the medical field, above all, are exposed to the damaging effects of microbial attack which, in the absence of preventive measures, would undermine general hygiene in hospitals. Consequently, the antimicrobial treatment of textiles employed in the medical sector serves a dual purpose:

- to protect the textile material against damage,
- to maintain a high standard of hospital hygiene.

A variety of methods are used for this purpose:

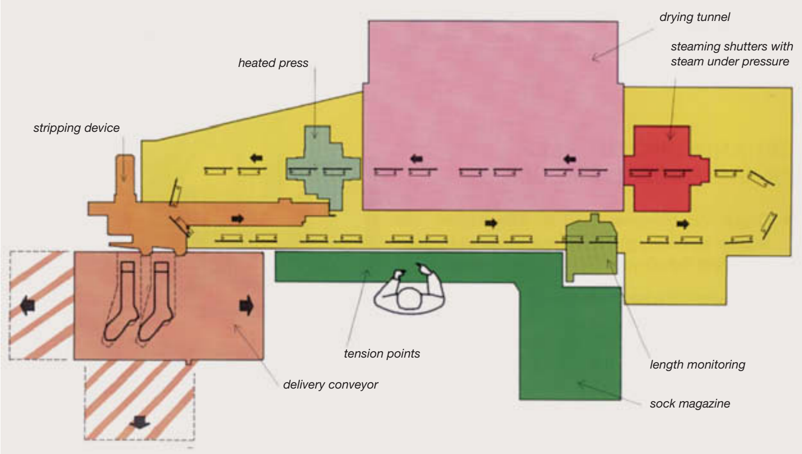


Fig. 2: Process flow in a hosiery setting machine (Heliot).

1. Sanitation: processes to control the number of microorganisms at low levels with the aim of (i) preventing the risk of uncontrolled proliferation of undesirable microorganisms, (ii) achieving an inhibiting effect and/or (iii) counteracting any damage due to microbial attack. Whilst efforts are made to destroy microorganisms as far as possible by disinfection, the aim of sanitation is to keep the number of microorganisms as low as possible by microbistasis, which is why such methods are referred to as having a fungistatic or bacteriostatic action. The gradual, uncontrolled reproduction of microorganisms is prevented by these measures. Undesirable microorganisms, in this context, include those microorganisms which give rise to problems in the usual application of a particular material (e.g. mildew on shower curtains or unpleasant odour formation in socks as well as certain kinds of damage to materials).

2. Inhibition: this term specifically refers to the antimicrobial finishing of articles in daily use. The effect of these processes is that odours caused by the products of microbial metabolism cannot arise in the first place if microbial metabolism is prevented. Inhibition differs from deodorizing by preventing the development of microbial odour in the formative phase, whereas deodorizing only covers up such odours (use of fragrances), i.e. by masking or chemical blocking (so-called neutralization).

3. → Antimicrobial finishes: the treatment of materials with antimicrobial substances to control the number of microorganisms at low levels. This form of finishing is directed exclusively towards the matrix and not its surroundings, e.g. human skin. Depending on the serviceability of the article, this type of finish should be bonded to the substrate to a greater or lesser degree, and therefore exhibit a growth-inhibiting action to provide the material with the required protection.

Hygiene requirements for the various risk categories in a hospital demand specific precautionary measures. In addition to general cleanliness, precautions also have to be taken with regard to cleaning, disinfection and sanitation. Depending on their field of use, these textiles have to meet different requirement specifications with regard to quality and hygiene, e.g.:

a) Textiles in the sickroom, such as bedsheets, covers, blankets and towels, as well the patient’s clothing. These articles are required to be:
- skin-friendly,
- absorbent,
- hygienically clean.

Textile fibres capable of satisfying these requirements include cotton in particular, as well as wool with certain limitations. Cotton has a high absorbency for liquids of all kinds. Cotton textiles are, in many cases, reinforced with polyester fibres to improve their mechanical properties which, to some extent, results in a loss of absorbency. The fabric construction should be specified to ensure good launderability. Wherever possible, long staple fibres should be used and the finish applied should give rise to minimum dusting. Disinfection must, of course, also be possible. Certain laundering processes in which oxidizing agents such as peracetic acid are used, can damage the cotton component in the sense that the absorbency is reduced due to degradation of the cellulose. Finishes with crosslinkable resins can likewise cause a partial loss of absorbency and, in the case of resins containing nitrogen, also give rise to chlorine retention.

b) Clothing for nursing and hospital staff as well as textiles used in the nursing and catering fields: the following requirements specification applies to these materials:
- skin-friendly,
- hygienically clean,
- soil-repellent,

- non-dusting,
- antistatic,
- limited absorbency.

Complete absorbency is not a requirement for textiles in this category. On the other hand, good soil-repellent properties which can be achieved, e.g. with a fluorocarbon finish, are important. A resin-based hydrophobic finish combined with soil-repellency is a particular requirement to prevent splashes of blood or secretions penetrating clothing worn by medical staff. In addition, these textiles must be easily laundered. As most of these materials are made from cotton/polyester blends, they cannot be laundered at the boil. In the main, such textiles are laundered at a temperature of 70°C to prevent creasing which, of course, does not achieve the same quality of hygiene as laundering at the boil. The remedy to this problem involves thermochemical laundering processes, although oxidative degradation of the cellulose by peracetic acid cannot be ruled out in this case. This has a negative impact on the wear comfort and absorbency as well as the tear strength of the material. For certain textiles in the catering sector, special requirements must be fulfilled, e.g. high absorbency in the case of tea towels, hand towels and wipes. Since these are mainly composed of 100% cotton, laundering at the boil is possible.

c) Clothing worn by doctors as well as other textiles exposed to risk areas (operating theatres) such as surgical gowns, covering sheets, screens, face masks, headgear, etc. The highest requirements with regard to hygiene and special finishes are placed on materials exposed to these risk areas. Such textiles must have the following characteristics:

- skin-friendly,
- hygienically clean,
- capable of sterilization,
- soil-repellent,
- low absorbency,
- non-dusting,
- antistatic.

These requirements are necessary both for the surgical gowns as well as for all other textiles used in high risk areas. Special precautions must, of course, be observed with regard to cleaning and laundering of such finishes. Since woven polyester fabrics or polyester/cotton blends are mainly used for these applications, laundering at the boil is not possible. Other means must therefore be resorted to in order to achieve an optimum standard of hygiene in laundering. Although thermochemical laundering methods achieve a satisfactory level of hygiene, degradation of the cellulose occurs at the same time with consequent breakdown of the finish. Moreover, oxidizing agents can also lead to the formation of protein coagulates which prevents optimum cleaning (source: Mebes). → Antibacterial textiles.

Hostaphan film A physiologically harmless polyester-based film without plasticizer. The film is transparent, extraordinarily resistant to tearing and impact with excellent abrasion resistance; it is soft and flexible in thinner qualities. Good fatigue strength at elevated temperatures and suitable for insulation. Resistant to heat at temperatures up to approx. 150°C and to cold at temperatures down to –60°C. Also resistant to water, common organic solvents, fats and oils. Virtually unlimited application for lamination with fabrics of all kinds or vacuum coating with metals. Hostaphan film is also used in the production of metallic yarns.– Manuf.: Kalle.

Hot On care labels refers to hot water (54-60°C).

Hot air bonding plant Spraying device as a → Spray bonding plant for binder-free bonding using fibre bonding: an appropriate percentage of fusible fibres is mixed with the main fibre material. Bonding is carried out in the one or two-way circulating air drier. Nonwoven fleece lies loose on the conveyor belt. Air temperature up to 220°C.

Hot air drying chamber → Drying chamber for printed goods.

Hot air drying machine → Hotflue.

Hot air fixation → Heat setting.

Hot bath flat setting Collective term for work stages in the finishing of wool such as boiling, crabbing, potting, decatizing, etc.

Hot cutting process The greater use of synthetic fibres and the constant trend towards improved performance has led increasingly to the use of the hot cutting process, which has the advantage of better performance whilst simultaneously sealing the cut edges. The hot cutting process is separation by means of thermal contact: the textile being separated is melted in a narrow cutting area by means of a hot blade and separated under slight pressure. This is limited to thermoplastic textiles. It can also be used for sealing the selvedges of woven fabrics made of thermoplastic fibres.

The hot cutting process can be used whenever:

- thermoplastic fibres are used,
- fabric is being processed,
- selvedges are able to bear the increased loading.

In addition to the question of the material and the quality demands made on the cut, an essential aspect is the economic efficiency of the cutting process. In small industrial enterprises with a low cutting requirement, manually operated equipment can be successfully employed. However, larger enterprises with many metres to process and, in particular, industrial plants with continuous manufacturing processes are dependent on machine cutting systems.

Hot dissolving method Dissolving method for naphthols in piece dyeing and in printing for generating insoluble azo compounds on the fibre material. The naphthols are made into a paste with, for example, Turkey-red oil and caustic soda solution and then made into a solution with boiling water. Other classes of dyes in powder form, such as direct, acid, reactive and cationic dyestuffs, are applied according to the hot dissolving method.

Hot-dyeing dyes Vat dyes which exhibit their highest affinity for cellulosic fibres at 50–60°C and are applied by the → IN dyeing method. They are referred to as hot-dyeing dyes to distinguish them from so-called cold-dyeing vat dyes which have the highest affinity for cellulosic fibres at 25–30°C and are applied by the → IK dyeing method.

Hotflue Hot air drying machine for fabric, preferred for intermediate drying. Passage of fabric is usually either vertical, alternating up and down through a drying area with circulating hot air, or diagonally in an up and down zig-zag fashion with double-sided air flow (air jets) from above and below.

With the “Quadro Dry” from Babcock (Fig. 1) each section has 2 circulation fans in the top and the bottom of the system. In the direction of the fabric movement, these fans are top left and bottom right, then top right and bottom left. The 4 fans of a section are therefore 4 times reversed.

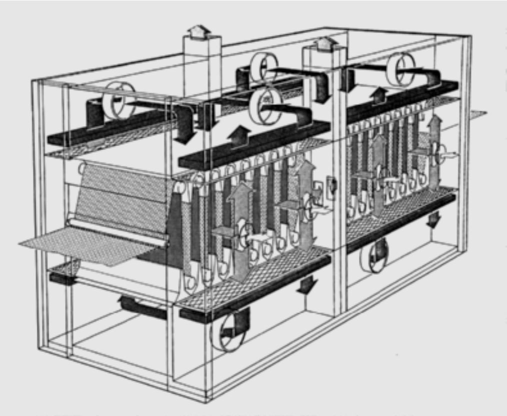


Fig. 1: Babcock dyeing hotflue Quadro Dry.

The 2 air circulating fans (1) per modular unit with the „Thermex“ from Monforts (Fig. 2) are symmetrically arranged and, aligned with whichever heating system is installed, suited to drying, thermosol dyeing and curing processes. Before the air conveyed from the two fans reaches the jets (2), it is brought together in a chamber (3). The controlled exhaust extraction occurs through a shaft (4) built into the processing area. Heat recovery (5).

With the Krantz hotflue, the heat flow on the process rollers (Fig. 3) is directed by a special metal slot.

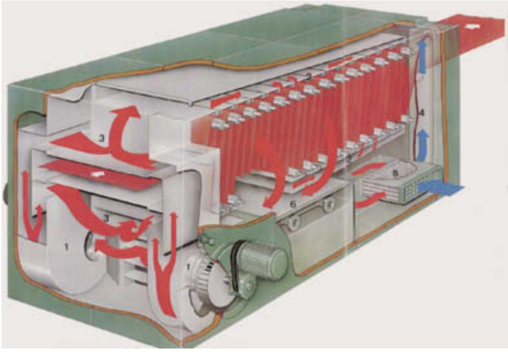


Fig. 2: Thermex from Monforts.

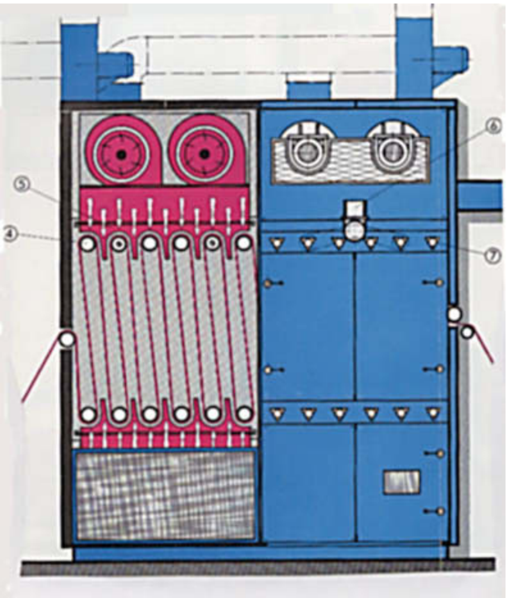


Fig. 3: Hotflue from Krantz.
4= Deflecting roller with special drive (6 + 7); 5 = metal slots for intensifying the heat flow.

Hot impregnation process For selected synthetic resins and additives. Impregnation of hot finishing liquors gives increased efficiency of the squeezing, spin drying or dewatering processes. The viscosity of the water falls with increasing liquor temperature. The water penetrates the fibre better at a greater temperature and it may also be removed better through the operation of mechanical forces.

Hot melt adhesives The use of thermoplastic hot melt adhesives in the manufacture of composites is an environmentally friendly method of processing, which makes use of thermally activated melt adhesives based on copolymers. These high-grade polymers are employed chiefly in the coating of interlining materials, which are used widely in the clothing industry. Besides this traditional market, the products increasingly have a technical application, e.g. in the car industry for manufacturing composites for door panels, roof canopies, headlinings, masking fabric, decorative PVC materials, etc. Copolyamide and copolyester hot melt adhesives are also gaining in importance in the manufacture of laminates.

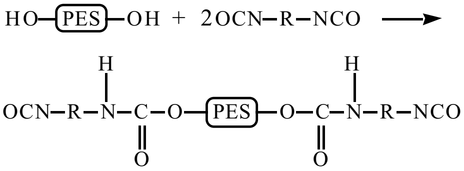
Hot melt adhesives bond the components of the sandwich in the laminate. Adhesives can generally be classified according to the setting mechanism (physical and chemical hardening):

I. physical:
- hot melt adhesives
- plastisols
- contact adhesives
- tack adhesives
- solvents/dispersion adhesives
- glues

II. chemical:
- unsaturated polyesters
- cyanacrylates
- methacrylates
- reactive PU systems
- polymethylol compounds
- silicone adhesives
- polyimides/polybenzimidazolines

Active adhesives are referred to as physical when the setting process follows physical methods and chemical systems are cross-linkable and based on a chemical reaction.

Hot melt adhesives are physically setting systems which normally are not cross-linked. They are activated by means of temperature. Developments are at a laboratory scale to cross-link hot melt adhesives on the basis of copolyamides. These serve to improve the properties of such products in relation to their thermal stability and their resistance to washing treatments and solvents. The cross-linking may occur thermally, photochemically or by means of moisture; certainly, only inline laminations are possible with finishing on the appropriate coating equipment, whereas with thermoplastic melt adhesives bonding may occur independent of time and place. A typical hot melt formulation reacts as follows to the further reacting polymers:



$$HO-\boxed{PES}-OH + 2OCN-R-NCO \longrightarrow$$

$$OCN-R-\overset{H}{\overset{|}{N}}-\underset{O}{\underset{\|}{C}}-O-\boxed{PES}-O-\underset{O}{\underset{\|}{C}}-\overset{H}{\overset{|}{N}}-R-NCO$$

The Table shows a classification of hot melt adhesives. Hot melt adhesives result from the manufacture of copolyamides in granular, powder and film form. In addition hot melt adhesives are supplied on the basis of copolyesters, ethenvinyl acetate, and high and low-pressure polyethylenes. The advantages of copolyamides are specifically:
- thermal shock resistance from – 40°C to + 120°C
- resistance to ageing
- resistance to petrol, oils and fats of all kinds
- 100% adhesive paste, unplasticised and environmentally neutral
- stable in storage
- high bonding speed, rapid availability for further processing
- good adhesion to textiles, leather, foam, plastics, phenol resin bonded mouldings, metal, etc.

The choice of suitable hot melt adhesive type is based on an understanding of the requirements profile of the composite in order to obtain an optimum coating result.

Common applications are based on:
- the powder dot method (woven and knitted fabrics)
- the paste dot method (nonwoven fabrics)
- the scatter coat method (wovens, nonwovens, foams, etc.),

which require the use of fusible powders. There are a series of mechanical innovations based on the application of granulates.

The following are three important processes:

	Polyamide	Polyester	EVA	PU Hot Melt Adhesives	Block Polymers
Manufacture	dicarboxylic acid + diamine	dicarboxylic acid + diols	radical polymerisation	polydiols + diisocyanates	styrene + isoprene or butadiene
Possible variations	molecular weight of end groups	end groups	molecular weight of vinyl acetate content	molecular weight of end groups	molecular weight of monomers
Melting viscosity	generally low	medium to high	mostly very high	thermoplast. PU: low	medium to high
Thermal stability	good to very good	good	weak	thermoplast. PU: weak reactive PU: very good	weak

Tab.: Classification of hot melt adhesives

- application with gravure-printing embossing cylinders (meltprint process, Rototherm),
- hot melt application via rotary print screens (Villars, Caratsch),
- hot melt application using slot extruder (Hardo).

The scatter coat method is very important for the manufacture of composite materials. There is the classical scatter coat system consisting of scatter head, IR channel, laminating calender; and the more recent variant of scatter head, IR field, flow press, laminating calender. In both cases lamination or coating only may be carried out with these systems. For scatter coating, copolyamide and copolyester powders in the particle size range of 200–300 µm or 300–500 µm are used. With coating from the melt, the granulate is melted on directly and applied either via engraved rollers/screens as a design or as a sheet by means of slot extruders.

Dry laminating calenders are designed for the use of environmentally friendly adhesive systems. Suitably equipped, they permit the application of thermoplastic materials in film, mesh, nonwoven, hot melt and powder form. There are two systems distributed on the market:

a) flat-bed laminating systems (Fig. 1),
b) dry laminating calenders.

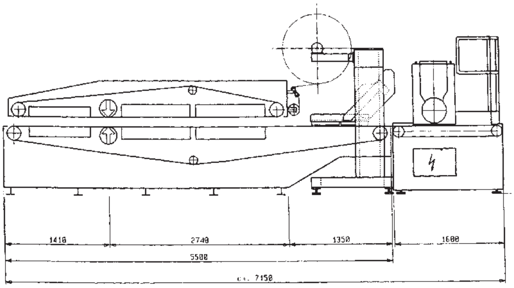


Fig. 1: Laminating system with IR radiator and powder distributor (Elf Atochem, Germany).

The following represent a selection of examples for the manufacture of composite with nonwovens using thermoplastic hot melt adhesives. In addition, there are more possibilities for combining nonwovens with other materials than those given.

I. Nonwoven laminate for “breathable” interliner systems: laminate structure (Fig. 2). Laminate production: 1st stage: dot coating of pastes by means of rotary printing on nonwovens or film. 2nd stage: composite manufacture on continuous dry laminating systems. Properties and use: water vapour permeable interliner systems are often used for the manufacture of rain and sportswear and protective clothing. They are sewn between the outer fabric and the lining and thus allow the garment manufacturer to give free form to the outer material. In addition, interliner constructions have a softer handle than membrane film directly laminated onto the outer fabric. The composites have good resistance to washing and cleaning.

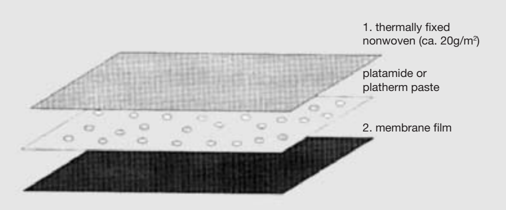


Fig. 2: Nonwoven laminate for “breathable” interliner systems: laminate structure.

II. Roof linings for minibuses: laminate structure (Fig. 3). Laminate production: 1st stage: lamination of the nonwoven with film on a dry laminating system or continuous flow press. 2nd stage: reactivation of the hot melt adhesive film by means of temperature and binding with the basic material in a mould. Properties and use: instead of the hot melt adhesive film, a spunbonded nonwoven or powder could be used. In this particular instance, the film is used because it serves simultaneously as a “dust barrier” (delivery van). Hot melt adhesives in the form of spunbonded fabric or powder would be more advantageous with regard to the acoustics; dependant on the air permeability at the non-covered places, the dust might collect there, which would lead to irregular soiling.

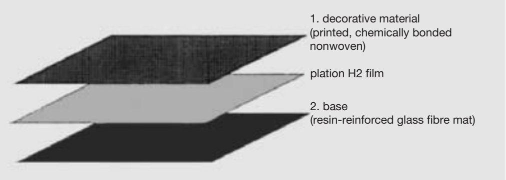


Fig. 3: Laminate structure for minibus roof linings.

III. Roof linings for cars: laminate structure (Fig. 4). Laminate production: 1st stage: spunbonded fabric made of granulate is applied/extruded directly onto the base nonwoven. 2nd stage: pressing of the nonwoven/spunbonded with a premoulded, hot base material in a cold mould. Properties: the copolyamide spunbonded fabric has very good adhesive properties and, at the same time, a high degree of thermal stability. The direct application of the spunbonded onto the decorative fabric saves one operation: no thermal loading through additional lamination.

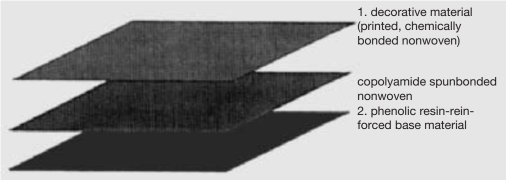


Fig. 4: Laminate structure for car roof linings.

IV. Sound insulation elements, upholstery materials: laminate structure (Fig. 5). Laminate production (inline process): coating of the nonwoven with powder on a scatter system, which is connected to a dry laminating system. The powder is sintered with IR radiators. The PU foam is conveyed in front of the flow press and bonded with the nonwoven fabric. The heating is made from the nonwoven side. Properties: copolyester hot melt adhesives have good adhesion properties to polyether and polyester urethane foams. Depending on the requirements, copolyamides hot melt adhesives may be used (according to Jahn).

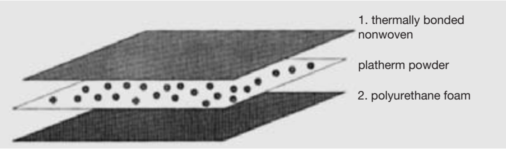


Fig. 5: Laminate structure for sound insulation elements and upholstery materials.

Hot melt adhesives as interliners and stiffening materials (iron-on materials, ironing fabric). In the form of fabric, tape or non-woven as modern, work-saving interliners and stiffening materials (instead of, for example, linen interlining, stiffening cloth and the like). Hot melt adhesives are used in the most important interliner materials. They are either woven or nonwoven fabrics that are coated with thermoplasts. Cotton, viscose, polyamide, polyester or polyester/cotton blend fabrics can be used as the ground fabric, whilst polyethylene, polyurethane, polyvinyl chloride, polyvinyl acetate, etc. are used as the coating materials. Cellulosic fabrics are given a pretreatment with urea based resins. Coating follows by various methods and usually involves covering most of the fabric surface in something like a film extrusion coat. To avoid a stiff handle with larger surfaces, e.g. with garment front interlining, the adhesive paste is applied in dot form. Here scatter coating machines are used to apply the adhesive as a powder. The material may also be applied as a paste by means of rotary screen printing machines. Modified rotary screen printing machines also permit powder application (→ Powder point process). Gravure printing machines are also used for this purpose, while another type of machine allows the thermoplast to be applied in the melted state.

Hot melt coating,

I. Hot adhesive finishing, surface or spot-form coin laminating of interliners (see Table: thermoplastic materials for hot melt coating), especially for front fusing with thermoplasts (copolymers vinylacrylic, polyester urethane). →: Laminating technology; Hot melt adhesives.

II. Indirect application (transfer coating) on such fabrics as the backs of tufting carpet by means of hot melting (hot melts, plastic dispersions, →: Elastomers; Latex), also highly filled plastic masses used in blade coating (heavy coating). With the polyurethane transfer process, the foaming reaction mixture is applied to a hot drum, steel band or release paper and then the back of the carpet is placed in the resulting foam. Hot melt coating systems normally cause more air pollution than water pollution.

Hot melt laminating Laminating process as an alternative to flame bonding. The fabric being laminated is bonded with melted polymer, which is heated up in the appropriate form (Fig. 2) and transferred to the web shortly before the sandwich is formed (Fig. 1).

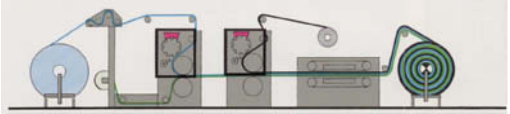


Fig. 1: Powder dot application (Villars) in hot melt laminating.

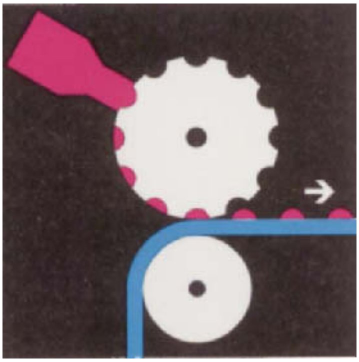


Fig. 2: Powder dot application (schematic).

The hot melt technique of Stork (Fig. 3) is based on the following principle: finely atomized, heated polyurethane glue is applied to one of the two substrates

Hot melt laminating

	melting point or softening point °C	resistance to chlorinated hydrocarbons	washing fastness	main field of application	form of application
copolyamides	75—103 depending on copolymer			men's and boys' wear, women's outerwear (laminating)	powder dot, paste dot and powder scatter process
high pressure polyethylene	100	capable of swelling	fast to mild washing	ribbons interlinings, women's outerwear	film extruder, paste and powder scatter process
low pressure polyethylene	128	good	fast to boil washing	shirt collars, cuffs, temperature-sensitive outerwear, leather,	ditto paste printing
polyvinyl acetate	75—90	—	—		paste printing
ethylene vinyl	60—85	very moderate	fast to mild washing	leather	paste printing powder scatter, powder dot process
copolymers (saponified)	90—115	good to moderate	fast to 60°C washing	leather	paste printing powder scatter, powder dot process
PVC copolymers (plasticised)	120—160	good	good	laminating siliconised woven fabrics, stabilising soft nonwoven and knitted fabrics	dot coating

Tab.: Thermoplastic materials for hot melt coating.

being laminated by means of spray heads (Fig. 4). The second substrate is then pressed onto the first. The glue hardens due to the air moisture content and after 8 hours the substrate can be processed again. The glue reaches full adhesion after 24 hours.

This laminating technique (Fig. 5) has the following advantages:

- environmentally friendly since no solvents involved;

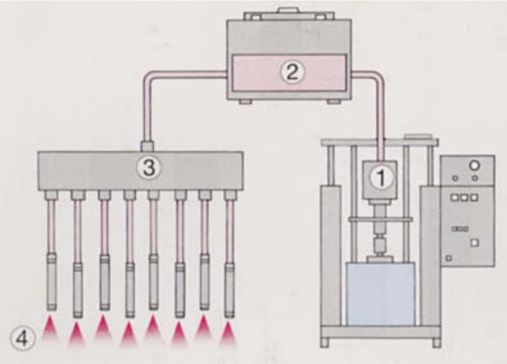


Fig. 3: Heating, conveying and aerosol system for polyurethane (Stork).
1= polyurethane melting unit; 2= conditioner; 3= dosing pump; 4 = spray nozzles.

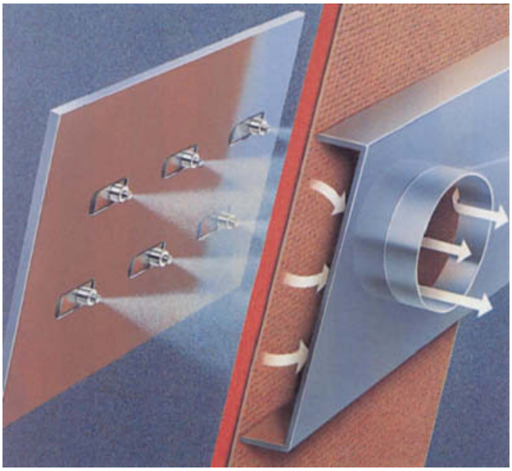


Fig. 4: Spraying of melted polymer (Stork).

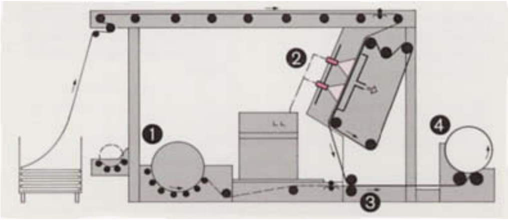


Fig. 5: Hot melt laminating (Stork).
1 = feed unit; 2 = hot melt spray unit; 3 = laminating unit; 4 = winding unit.

- energy-saving since only the glue is heated;
- sensitive substrates can be processed;
- the laminate continues to “breathe” since the glue does not form a closed layer;
- the laminate retains its good feel and remains soft since the quantity of glue is small;
- minimum glue consumption (up to 1.5 g/m^2).

Hot melt lamination Flame lamination is questioned for environmental reasons. Hot melt lamination (using hot melt adhesives) is a possible alternative. This involves the use of thermoplastic polymers, which wet out the substrate in a very short time, in the molten form without significant fabric penetration. Thus the melt viscosity is significant. Three temperatures are important:

- T_M = melting temperature
- T_A = processing temperature
- T_F = temperature of thermal stability

For hot melt adhesives acting as physical binders, the relation of these temperatures should be

$$T_F < T_M < T_A$$

If a cross-linking hot melt adhesive is used, however, this relation changes to

$$T_M < T_A < T_F$$

A typical processing situation is depicted in Fig. 1. The hot melt adhesive is melted in the coating head and extruded; at the same time, the engraved roll takes up the low-viscosity molten material and releases it upon contact with the first substrate on the transfer cylinder onto the fabric as a design. The coated substrate on the laminating roller comes into contact with the IR preheated second substrate in a sandwich form over the entire width and the hot melt adhesive binds the substrates together in the nip of the two rollers. The laminate that results is cooled in a subsequent ribbon calender. Instead of the hot melt adhesive applied by the dot-print method, hot melt film may be used to bond the laminate. Perforated film that remains air permeable is made by the deliberate shrinking of longitudinally cut film in the IR field (Fig. 2).

Hot melt sizing Process developed by Burlington/USA for sizing with a thermoplastic, water soluble polymer (hot melt), which is applied via a roller at 135–155°C. Each individual warp thread runs in a groove. Advantage: energy saving on conventional methods. Disadvantages: high investment costs, expensive sizing material, non-recoverable, additional operation of assembling.

Hot mercerisation Mercerisation with an alkaline solution of approx. 60°C on raw goods causes less change in dye up-take on dyeing. Swelling of the fibres is less, and thus hot and cold mercerisation is often combined. Since swelling is an exothermic process, the

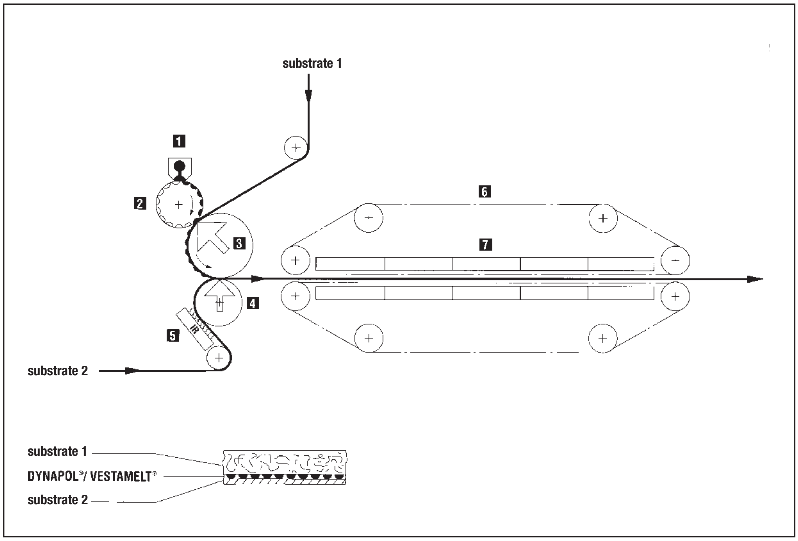


Fig. 1: Typical laminating system for hot melt adhesive application (Hüls).
1 = coating head;
2 = engraved roller;
3 = transfer cylinder;
4 = laminating roll;
5 = IR drier;
6 = ribbon calender;
7 = cooling plates.

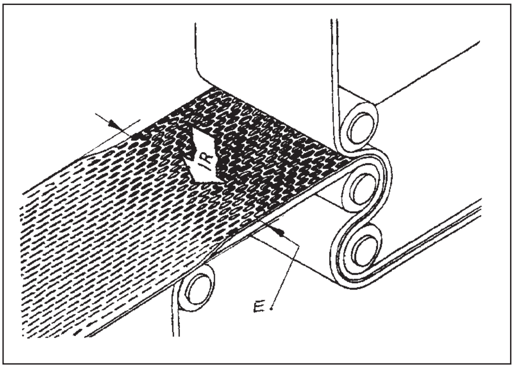


Fig. 2: Hot melt lamination using perforated film.
E = shrinkage; IR = infrared heat source.

hot impregnation of cotton fabrics promotes the even penetration of the less swollen mass of fibres with caustic soda solution, while a subsequent reduction in temperature initiates the swelling process. With an increasing concentration of the caustic soda solution, cotton will swell increasingly at 80°C and very rapidly independent of the concentration. If the used liquor in the test apparatus is replaced by a mercerising liquor of – 10°C, then the pre-wetted cotton will swell substantially more, and demonstrates that an exothermic reaction is involved in this swelling process of two-stage mercerisation.

Hot plate press Used for → Transfer printing of textiles and fully fashioned goods. As a rule a protective paper sheet is laid across the lower of the two plates, on top of which the textile substrate is then laid together with the transfer printing paper. A pedal mechanism is used to press the upper plate down onto the lower for a period of 20–30 seconds, during which time a constant temperature is maintained under the control of a thermostat.

Hot roller fixation →: Heat setting; Hot roll fixation machines.

Hot roll fixation machines Hot roll fixation machines are used for thermal fabric fixation through contact with hot metal rollers. The rollers are double-walled and usually heated from inside by gas. Final fixation through passage over air- or water-cooled rollers. Also combined with hot air fixation.

Hot sand drying process → Fluid-bed process.

Hot seal laminating →: Hot melt coating; Heat sealing.

Hot system optical brightener White tint with optimum effect at boiling temperature. → Cold system optical brightener.

Hot unit American term for an enclosed dry cleaning system (so-called WR types = washer-recovery driers), in which the goods are cleaned, spun, dried, aired, whilst solvent is recovered simultaneously. Opposite → Cold unit = transfer system.

Hot water development Continuous dyeing process for vat dyes. Reduction of the padded vat pigment occurs in a 75–95°C hot blank vat. Light tones are developed without any intermediate drying. Process today has no practical signficance because colour conformity and levelness fail to satisfy all standards.

Hot water reservoir Appliance for preparing and storing hot water up to 80°C, equipped with an adjustable two-position controller.

Hot wetting agents → Wetting agent.

Houndstooth check (dog's-tooth). Pattern description of fabric with similarities to a houndsfoot. In terms of technical design, two forms are found based upon colour and weave; however there is no precise commercial definition thus all types are recognised e.g. coarse designs → Shepherd's check designs (especially with coarser woollen yarns) are described as houndstooth check.

House dust mites Mites cause allergies, 3 to 4% of the population suffering from them, and therefore the antimicrobial finishing of household textiles for example in "the allergy age" is always important. If microorganisms are prevented by suitable means from multiplying, there is a resultant break in the mites' food chain, and consequently a massive population reduction. The best known allergies are caused by the excretions of spider types like mites for example, or by microorganisms like mould spores, and by pollen, animal hair or certain foodstuffs or many other materials. The number of affected persons varies a very great deal depending on the method of investigation. In the case of mould allergies, figures from 5 to 8% of the population are quoted, and 3 to 4% for mite allergies in the household. Altogether 12 to 16%, which is a not insignificant part of the population, are treated medically – and the trend is rising. There are various reasons for this: on the one hand, doctors are paying increasing attention to allergy problems, no longer regarding them as just impairing the quality of life, but as genuine diseases. On the other hand, the increasing demand for comfort and the requirements for new buildings, e.g. insulation, produce a moist, warm climate in living accomodation, providing ideal conditions for mites, fungi and bacteria to breed in.

Mites prefer the same climatic conditions as fungi and bacteria, this is to say warm and moist. These creatures which belong to the spider family, are very unpleasant for many persons, and endanger their health. They are only 0.1 to 0.5 mm in size (Fig.), and are virtually invisible to the naked eye. They live between the textile fibres, and are not dependent on any particular substrate. In the course of their lifetime, they produce excretions equivalent to 200 times their net weight. Only in the sixties was the allergen responsible for this

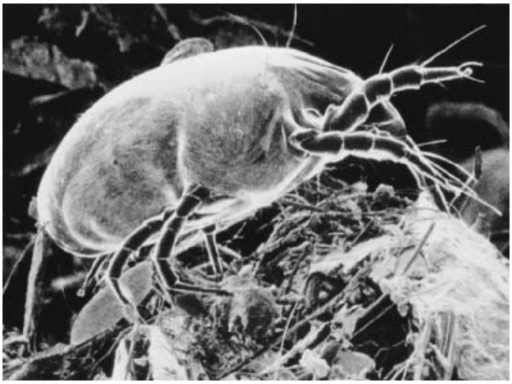


Fig.: The average size of house dust mites is 0.3 mm. About 10 mites could fit inside the dot at the end of this sentence. (Picture: David Scharf, Los Angeles, USA).

kind of allergy discovered. About 3 to 4% of the population, but 50% of asthmatics, suffer from this allergy, which is characterised by dizziness, sneezing, red and watering eyes, shortage of breath, asthma attacks etc. Mildew allergies can give rise to the same symptoms. The weight of skin particles shed daily by a person is about 1.5 g, and is sufficient to provide sustenance for over a million mites. Moulds contribute to this by breaking down the fat layer of shed skin, thus rendering the mites' food more digestible. A temperature of 20 to 30°C and a relative humidity of 65 to 80% are the right conditions for rapid mite population growth. In one generation, i.e. in 3 to 4 months, an original population of 1000 units can easily develop into a colony of over 40 000. Mites are to be found everywhere in a house or flat. Their number depends largely on the climatic conditions.

Household laundering → Domestic washing.

Household laundry → Fastness to washing.

HP, high pressure (→ High pressure steam).

HPD dyeing process for sulphur dyes A hot-pad-dry continuous dyeing process for lightweight cotton or regenerated cellulose fabrics. The liquor contains dye, sodium sulphydrate, caustic soda, glucose and thiourea. After padding, the material is dried or steamed then aftertreated.

HT beam dyeing machines → High temperature dyeing machines, in which piece goods can be treated horizontally at temperatures above 100°C (up to 140°C). The fabric is wound on perforated beams; the liquor is pumped through in either direction. Can also be used for cheeses with special carriers. The heart of all HT beam dyeing machines is the pump. Its output has to adapt to frequently different operating conditions (fabric thickness, winding density). Tailing and shade difference of the selvedge is better on a HT beam dyeing machine than on a winch or jigger.

HT bleach Peroxide bleaching at temperatures of 110–120°C on HT machines (autoclaves) or in special → Pressure steamer for cotton piece goods.

HT bleaching process By using pressure reaction chambers, e.g. Vaporloc (Mather & Platt) with hydrogen peroxide, it is possible to obtain a good bleaching effect on cotton and cotton/polyester blends in 2 min.

HT dyeing machine → High temperature dyeing machines.

HT-Fabric Beam Dyeing Machine → High temperature dyeing machines.

HT-jigger A jigger for the high temperature dyeing (HT-dyeing) of textile fabrics in open-width under pressure (at pressures up to 4 bar). Now largely replaced by HT beam dyeing machines.

HT loop steamer Used as a universal → Continuous steamer. Characteristic features are: low-tension cloth guide, high productivity and the facility for operating with both saturated steam (100°C) and superheated steam (up to 180°C). This allows synthetic fibres (such as polyester, triacetate) to be continuously steamed. In addition, HT loop steamers are ideally suited to setting fabric that is sensitive to tension, such as knitted fabrics made of textured polyester.

HT pressure steamer → Pressure steamer in which woven and knitted fabrics are steamed on a continuous basis with saturated steam at temperatures up to 140 °C and can thus be used for pad dyeings/print development.

HT rapid draining device Assists in polyester HT dyeing in removing oligomers. Controlling the HT rapid draining device on any HT dyeing machine allows the liquor draining temperature to be adjusted as preferrred, e.g. to 130–140°C and in a range where oligomers are not attached to the fibre and can be discharged to drain. The hot dye-liquor is mixed with used, cold process water under controlled conditions and eventually led into the effluent discharge system when the temperature is suitable.

HT steam Steam at a higher temperature (→ Superheated steam) can also exist under normal pressure and be further used at atmospheric pressure (→ High pressure steam).

HT steaming This takes place in continuous → HT loop steamer. Hot steam above 100°C is the heat transfer medium. Specially suitable for fixing polyester or triacetate when printing with disperse dyes. It is possible to work tension-free so they are especially suited for processing tension-sensitive knitwear. Opertaes at temperatures between 160–180°C for 6–8 min. Higher fixation temperature and dwell time require careful selection of dyestuff (above-average fastness to sublimation); as a rule, printing paste contains a fixation accelerator. They are also used, with suitable dyestuff choice and fibre type, with saturated steam (100°C) so these steamers have a temperature range between 100–180°C.

HT steam process → Reactive dyes in direct printing.

Huckaback A hard-wearing cotton, linen or linen/cotton fabric with a characteristically rough-surface effect and very firm handle. The huckaback weave is produced on a plain ground texture by (usually) two regular short floats, warp on one side and weft on the other. The weft yarns are slack twisted to aid absorbency. The small weft floats give the fabric a "barleycorn-like" appearance on the face of the fabric which also causes it to be more absorbent. Huckaback hand towels are produced from cotton, linen and linen/cotton unions. Borders and designs may be woven with coloured yarns. Better qualities are produced with finer yarns and are occasionally woven with warp sateen stripes. Some of the pure linen and linen/cotton union qualities, which contain red pattern stripes woven with cotton, are sold unbleached whilst other qualities are supplied to the market in the fully-bleached state only.

Hue (shade, tint) → Colour.

Human factors engineering As a branch of → Ergonomics, human factors engineering deals with the relationships of man-machine systems with the aim of achieving the best possible combinations of man and machine in terms of overall compatibility. Efforts are made to achieve this objective by the optimum adaptation of machines to the size and proportions of the human body (e.g. through the provision of visual display units, user-friendly devices and anthropometric process control systems).

Human hair Hair is formed by hair follicles (Fig. 1) found in the dermis. At the ends of these follicles, mitotically active tissue forms cells from which the hair is ultimately composed. While the cells are pushed to the skin's outer surface, keratinisation takes place and cells will differentiate into cuticular, cortical and medullar cells. In general a distinction is made between two parts of the hair: the hair shaft emerging from the skin and the hair root hidden in the skin. The latter develops as a pocket-like inlet in the outer skin from the third embryonic month onwards. Its lower wider end (bulb) sits on an upturned projection of the connective tissue, the papilla. This is shot through with smaller blood capillaries, which transport the nutrients necessary for hair renewal. The cells immediately surrounding the papilla are called matrix cells. Through constant cell division they continue to produce fresh hair substance, which pushes upwards and gradually forces itself out of the skin as visible hair.

The freshly formed cells will already differentiate in the bulb of hair. They divide in a spatially characteristic way, change their form and take on various functions, forming the cortex, cuticle and the individual root sheaths. The root sheaths serve, on the one hand, to anchor the hair firmly in the skin while, on the other, they form a kind of "conducting tube" for the developing hair. The hair root sits in the skin at an angle. On the side of its obtuse angle to the skin surface, it is connected with a small muscle (hair-raising muscle), which pulls together in the cold or with a shock and, in doing so, causes the hair to become upright. Just above the hair-raising muscle are the sebaceous glands, arranged like grapes around the hair root. They lead into the follicle funnel and produce a white tallow-like secretion, sebum. A network of fine nerve fibres envelops the hair root below the sebaceous glands, making it sensitive to pain. Hairs do not grow incessantly, but rather are subject to growth and rest cycles. Here the individual body hairs will behave differently. Head hairs grow the longest in terms of both time and elongation. They actively grow for 2–6 years and reach lengths of 70 cm and above. With the transition from the active growth state to the rest phase, the bulbs of hair will recede, shorten

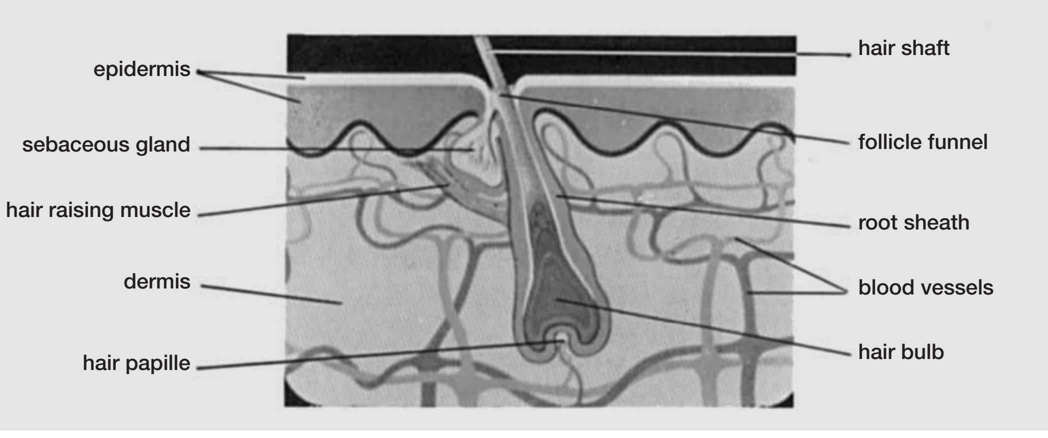


Fig. 1: Diagrammatic view of hair structure in the hair follicle.

keratinise, become bristly and lose the cohesion with the hair papilla. The hair with an atrophied root of this kind can be easily and painlessly combed out. After some time, the hair root will recover again, grow down and form a new hair. The cells responsible for producing the pigmentation melanin, the so-called melanocytes, decrease in number and efficiency of synthesis with progressive age. The hair, which is no longer uniform and pigmented throughout, appears grey and, in extreme cases when no pigment is present at all, white.

The initial material from which the melanin is synthesised is tyrosine, an amino acid. Synthesis occurs in four stages according to the diagram:

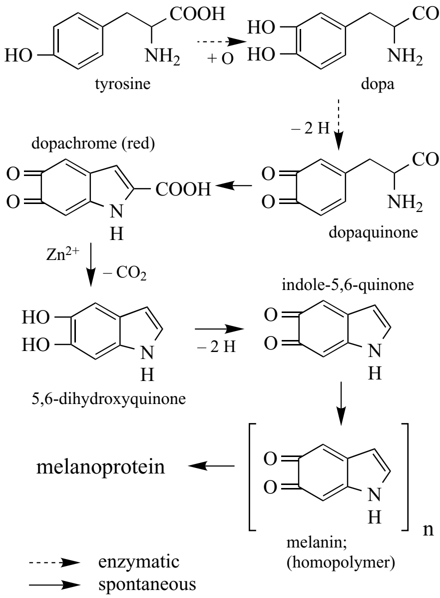


Fig. 2: Melanin synthesis diagram.

1. A series of enzymatic oxidation reactions (dependent on the genes) initially results in dihydroxphenylalanine (DOPA) and then in dopaquinone.
2. Another series of intermediate reactions (molecular rearrangements in conjunction with a cyclisation, without the involvement of enzymes, but in the presence of metal ions) results in indole 5,6 quinone (eventually also other indolequinones).
3. A non-enzymatic polymerisation results in great melanin molecules.
4. These three-dimensional polymers form, together with proteins, complexes that represent the final pigment. A distinction is made between:
   a) the eumelanins, which provide colourings ranging from black to brown; they have a high molecular weight and are insoluble in alkali;
   b) the pheomelanins, which provide yellow colourings; they contain sulphur, which stems from the combination of cysteine and dopaquinone (cysteyl dopa); their molecular weight is lower and they are soluble in alkali;
   c) the trichochromes, which produce lively red and purple colourings; they likewise constitute sulphurous melanin, but have a low molecular weight.

A large part of present knowledge about human hair has been handed down from research into wool. The structure principle (Fig. 3) of a multiple composite system can be found with all keratin fibres. The outer cover is formed by the cuticle, which surrounds the inner strand, the cortex, in the centre of which an axis of medullar cells can be found. The individual morphological components are:

1. Cuticle: outermost layer of the hair, consisting of 6–8 layers of flat, superimposed cells, which make up a 20% share of the weight of the hair. The cuticle is the first part of the hair which comes into contact with environmental influences. In accordance with its protective function, it is very hard and chemically resistant.
   a) Exocuticle: resistant to enzymatic decomposition and heavily disulphide bonded. Since it contains relatively few polar groups, it works as an

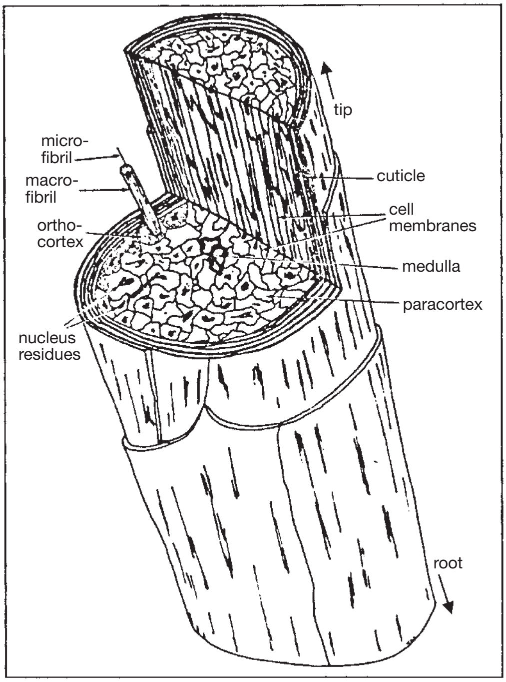


Fig. 3: Diagrammatic view of the internal structure of a typical Caucasian human hair.

effective barrier for the diffusion of hydrophilic substances.

b) Endocuticle: is not as resistant and is solubilised by proteolytic enzymes. In it is found cell detritus from the cytoplasm of the formerly living cells.

2. Cortex: makes up the largest part of the human hair and consists of dead cells and intercellular connective material. The cell membranes of cuticle and cortex are connected here. The network of membranes of all former cuticular and cortical cells are described as a cell membrane complex (CMC). The cells of the cortex are approx. 100 µm long and contain primarily the macrofibrillae, important for the mechanical properties of the hair.
3. Pigment granules containing the hair colouring melanin are found both in the cuticle and between the macrofibrillae.
4. The material between the macrofibrillae, the intermacrofibrillar cement, consists of residue from cytoplasm and nuclei of earlier active cells.
5. The macrofibrillae themselves are made up of microfibrillae, highly organised fibrillar proteins and matrix, a supposedly less organised structure, which sheathes each macrofilament. The great resistance and flexibility of the fibre is due in the main to this microfibrillae-matrix complex. Its strength is chiefly guaranteed by the number of disulphide bridges, which (it is believed) develop within and between the proteins of the macrofibrillae. These proteins are described as keratins (partly according to Hüsken).

Humidity measuring instrument (→ High humidity measuring instrument). With modern processing technology in textile finishing it is important to be able to measure the moisture content of running webs continuously and contact-free (→ Residual moisture content). The measuring range of the system should be as wide as possible since moisture content levels can vary between extremes of 1–150%. Various measuring techniques are used in practice (Figs. 1 and 2).

To control the moisture content of steam, a system based on measuring the oxygen content of the steam can be employed, e.g. by measurement with a zirconium element.

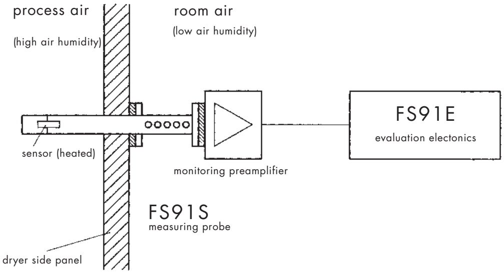


Fig. 1: Block diagram of a humidity measuring instrument (Pleva).

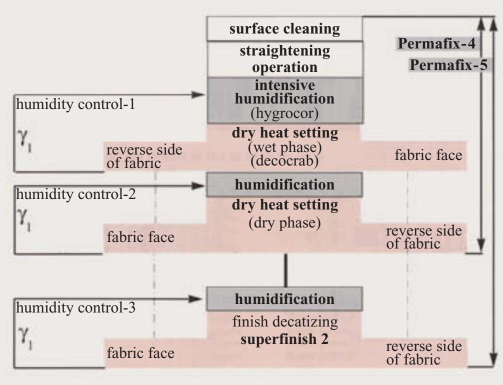


Fig. 2: Processing cycle of the Permafix-4/5 humidity measuring instrument with zirconia element (Menschner).

Humidity monitors → Humidity measuring instrument.

Humification Decay caused for example by → Moulds and bacteria.

Hungry cloth Loose, transparent knitwear. Not always faulty production. Such cloth is deliberately manufactured according to fashion trend demands in a suitable character (e.g. fine, extremely thin lisle stockings).

Hunter coordinate system This occurs through converting the → CIE tristimulus value to the illuminant D65/2° observer according to the following relations:

$$L = 10\sqrt{Y},$$
$$a = 17{,}5 \cdot (1{,}052\,X - Y) : \sqrt{Y}$$
$$b = 7 \cdot (Y - 0{,}919\,Z) : \sqrt{Y}$$

L is the luminosity axis (achromatic axis) analogous to the Y axis in the standard valency system. a and b characterize the chromaticity (and can have positive and negative values). The physical ideal white here has the coordination L = 100 and a = b = 0.

Hup dyeing apparatus Serves to dye fully milled (not well balanced) hat bodies in a floating liquor: relatively low liquor ratio (max. 1 : 30); liquor is circulated by a propeller which automatically changes its direction of flow; the dye liquor is pushed and drawn through the mass (Fig.). Attainable dyeing temperatures with closed apparatus around 98°C. Best results with level dyeing acid dyestuffs.

Hurdle drier Box drying machine for flock, hank yarn and cross wound spools, with perforated floors (cabinet drier).

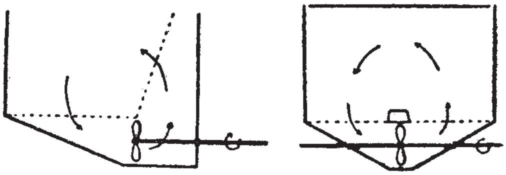


Fig.: Hup dyeing apparatus (Obermaier).

HVI, abbrev. for: High Volume Instrumentation System. A series of integrated semi-automatic electronic instruments for the classification of cotton quality. The system is being used on an increasing scale and has already replaced the subjective conventional classification system in many countries.

HVM → High wet modulus fibres (HVM fibres).

Hyamines Quaternary ammonium type bactericides, algicides and fungicides, available in the form of water-soluble crystals or aqueous solutions.

Hybrid bond, hybrid structure → Mesomeric resonance.

Hybrid composites These may be engineered for a great variety of dynamic effects. A light-weight composite with a higher degree of stiffness and at the same time higher burst strength may, for instance, be required. A hybrid of aramides for high tensile strength and carbon fibres load bearing zones is constructed. Hybrid materials made of aramides and carbon fibres give an optimum balance between mechanical properties and adequate tolerance to damage in many types of application. Often the dynamic load distibution demands a high interlaminar shear strength and, at the same time, optimum flexing behaviour, which can be achieved by a hybrid of these fibres. Property changes can be created with texture variance, too. Hence, for example, a clear loss in tensile strength due to moisture absorption will occur with 90° laminates, whereas this is not noticeable with 0°–45° laminates. A similar effect can be shown with the modulus. Swelling elasticity coefficients and thermal elasticity coefficients can be affected by composites of layers with various angles of fibre position. In addition, besides the two-dimensional fibre arrangement, the 3-D structure can be selected (e.g. three-dimensional woven fabric, needled nonwoven fabric, etc.), allowing important composite properties to be determined. Besides these examples of multilaminar hybrids, there are also intralaminar multiple-fibre materials with which different fibres are combined within one plane, e.g. a fabric with aramide in the warp and glass in the weft.

Hybrid computers Computers consisting of a coupled analogue and digital computer, a digital computer complemented with analogue elements or an analogue computer complemented with digital elements. They combine the advantages of both analogue and digital computers and find application in process computers.

Hybrid fibres Fibres based on polymer blends. The extrusion spinning occurs from a common solution (or melt) of at least two fibre-forming polymers, of which one is a native polymer, e.g. cellulose or casein. Ideally hybrid fibres may be regarded as filament composites. Examples of hybrid fibres (polymer blends and solvents) are:

PAI/Cell	$(HCHO)_X$/DMSO
PAN/Cell	$(HCHO)_C$/DMSO
Cell/PAN	N_20_4/DMF
	LiCl/DMA_C
PAN-Co/Cell	$ZnCl_2/H_2O$
PAN-Co/Fib	NaSCN/H_2O/DMSO
PAN-Co/CA	DMF

(PAI = polyamidimide, Cell = cellulose, PAN = polyacrylonitrile, Co = Copolymerisate, Fib = fibroin, CA =acetate).

Hybrid yarn manufacture Since the development of new high-temperature resistant thermoplasts, interest in using these materials as a matrix with high-performance composites has increased particularly in the air and space travel industry. The techniques illustrated above (see the following Fig.) are principally available for the manufacture of suitable prepegs.

Hydracids, hydrogen acids Oxygen-free acids, such as halogen acids (typically hydrochloric acid HCl).

Hydrate (Gk.: hydor = water), molecular compound formed through → Hydration with bound water molecules.

Hydrated cellulose → Regenerated cellulose.

Hydrated terpene Mixture of tetraline and pine oil (hydrated terpene) as oil of turpentine substitute.

Hydration Reaction of the dipole with ions forming stable "hydrate sheath". Each negatively charged ion (anion) attracts the positive end (H^+) of adjacent water molecules and endeavours to bind certain water molecules, a phenomenon which the usually smaller positively charged ions (cations) show to a greater degree. Each cation attracts the negative ends (O^-) of ambient water molecules and binds some of these to the hydrate sheath, which can have considerable stability, particularly with 3 to 4 valent ions. This property already characterizes the hydrogen ion, which is known to be constantly present as a hydronium ion H_3O^+ ($H_2O + H^+ \rightarrow H_3O^+$). Similarly, water molecules bond together with other ions, too, to form hydrated ions, on which the characteristically good dissolving power of salts is based. The same explanation also applies to colloidal electrolytes. Forces of attraction between cations and water molecules may be so strong that in many cases cations, upon insertion into a crystal, will trap and mo-

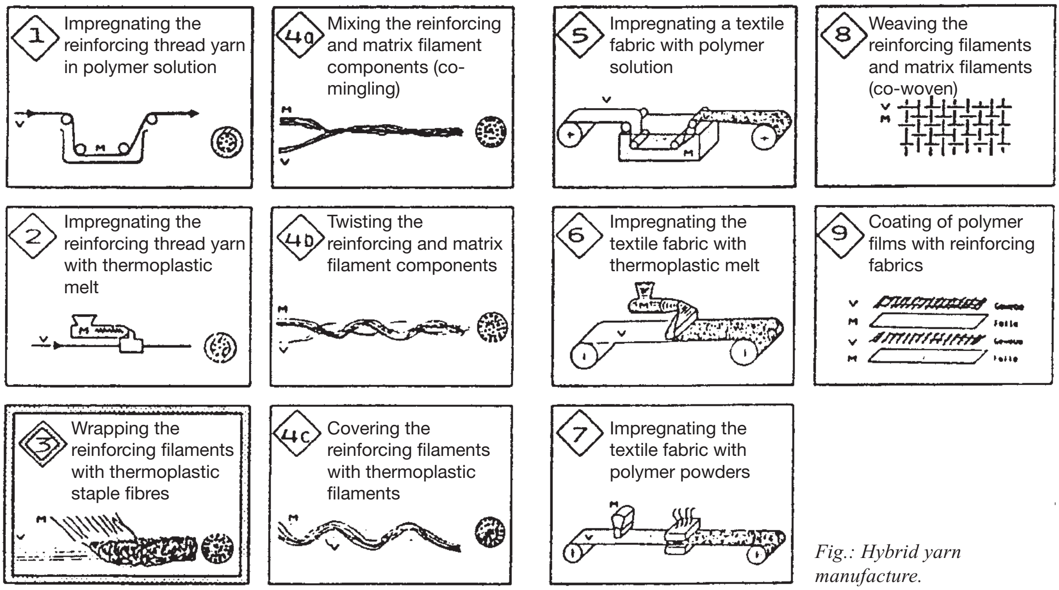


Fig.: Hybrid yarn manufacture.

lecularly bind a sheath of water molecules as so-called hydrate water (hydrates). Polyvalent ions have this ability more so than monovalent ions. Hence larger ions like Mg^{2+}, Al^{3+}, Fe^{3+} will even bind a plurality of water molecules. Such hydrate complexes are found in the following salts and also in the solutions:

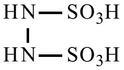
$A1C1_3 \cdot 6\ H_2O$
$CuSo_4 \cdot 5\ H_2O$
$FeCl_3 \cdot 6\ H_2O$
$Kal(SO_4)_2 \cdot 12\ H_2O$
$MgCl_2 \cdot 6\ H_2O$
$MgSO_4 \cdot H_2O$ / $MgSO_4 \cdot 7\ H_2O$
$Na_2CO_3 \cdot 10\ H_2O$
$Na_2SO_4 \cdot 10\ H_2O$

Hydraulic (Gk.) moved by the pressure of fluid (pumped); e.g. high-pressure atomizers for increasing air or fabric humidity (jets) or mechanical drives for step-less speed control (control devices) consisting of driven oil pump and driving fluid motor.

Hydrazides Derivatives of → Hydrazine. Carbohydrazide or fatty acids find their use in the flame-retarding and permanent-press finishing as formaldehyde acceptors. Carbohydrazide is not regarded as being particularly toxic and has a considerable antibacterial effect in finishing.

Hydrazine (Diamide), $H_2N–NH_2$. Fuming, caustic alkaline fluid, reducing agent. Application: inter alia as oxygen binding agent with boiler feed water preparation in the form of hydrazine hydrate $N_2H_4 \cdot H_2O$ in 25% aqueous solution; protects against corrosion. Caution: overdosage in laundering causes yellowing and poor wash effects. Activated hydrazine for boiler use (oxygen binding already occurs at room temperature under the release of nitrogen).

Hydrazine sulphate (Diamide sulphate),



$$\begin{array}{l} HN-SO_3H \\ \,| \\ HN-SO_3H \end{array}$$

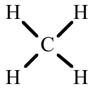
Density 1.38. Colourless crystals, low solubility in cold water, readily soluble in hot water. Separates free metal from noble metal salt solution. Application as a reducing agent in analytical chemistry and cupro-ion dyeing process.

Hydrocarbons Compounds of carbon and hydrogen derived principally from petroleum, natural gas, coal tar and plant sources.

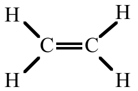
Subdivided into the following groups:

I. Aliphatic hydrocarbons (fatty compounds) with open chains (straight or branched)

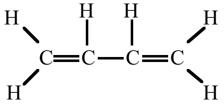
a) → Saturated hydrocarbons, e.g. methane:



b) unsaturated:
- with one double bond (olefins), e.g. ethylene:



– with two double bonds (dienes), e.g. butadiene:

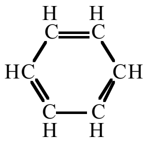


– with a triple bond (acetylenes), e.g. acetylene:

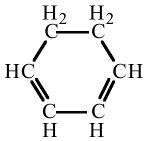
$$H-C\equiv C-H$$

II. Aromatic hydrocarbons (cyclic hydrocarbons)

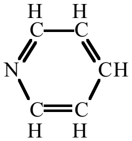
a) with C-rings (isocyclic) (→ Cyclic hydrocarbons), e.g. benzene:



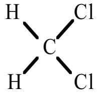
b) as IIa, but with an increased number of hydrogen atoms (alicyclic) (hydroaromatic hydrocarbons), e.g. cyclohexene:



c) hybrid ring structures (heterocyclic compounds), e.g. pyridine:



III. → Chlorinated hydrocarbons, e.g. dichloromethane:



Hydrocellulose Mineral acid damage to → Cellulose is shown through water absorption and splitting of oxygen links bewteen glucose building blocks. Properties: reduced strength, increased reducing power, modified dye affinity. Detection: hydrocellulose alone →Ammoniacal silver nitrate solution. Also with → Prussian blue reaction, Turnbull's blue reaction, Fehling solution, methylene blue and solubility test (which also indicate → Oxycellulose). No staining with Diamine Blue 2B, Congo red or Benzopurpurine.

Hydrochloric acid HCl; molecular weight 36.46. Salts → Chloride. Colourless (highly concentrated) to slightly yellowish liquid, fuming in air, often impure (sulphuric acid, arsenic, ferrous salts: then yellowish); pure hydrochloric acid is volatile, aggressive to the skin, strong acid, miscible with water and alcohols, acetone, etc. Application: acidification after chlorine bleaching or washing, diazotization, stain removal (for rust and ink stains), descaling. Residue in cotton fabrics have a carbonizing effect with drying or ironing.

Hydrochloric acid test For → Dyestuff group identification on fibres, especially for cellulose dyeing of genuine red and black dyes. Method:

I. For red: boil test fabric and concentrated hydrochloric acid = colouring and solution light yellow. After addition of caustic soda solution = both violet = Turkey red (→ Paraffin test).

II. For black: saturate the test fabric with concentrated hydrochloric acid, colouring and solution turn red. After addition of sufficient ammonia and allowing to stand longer, a bluey black sediment will form with a colourless supernatant solution = logwood black.

Hydrodynamic processes in printing The explanation of the mechanisms found in printing is not only of theoretical interest, but also practical relevance since processes are involved which can positively affect the quality of print and the economic process management. From a hydrodynamic standpoint, such an explanation means investigating those factors which affect the size and distribution of pressure on the paste and in the printing zone, as well as an analysis of the hydraulic loss occurring during the printing process, namely through the paste diffusing through the screen openings. In practice, this means first and foremost:

1. Calculating the pressure generated in the nip between doctor blade and screen.
2. Determining the width of the printing zone in which the paste diffuses through the screen opening.
3. Calculating the hydrodynamic resistance to which the printing paste is subjected during diffusion.
4. Ascertaining the effect of the geometry of the doctor blade, the printing speed and the rheology of the printing paste on these processes.
5. Determining the connection between the paste pressure and the quantity of printing paste applied to the material.

In practice, the paste begins to flow when its pressure reaches values that overcome the screen's resistance and guarantee its diffusion at a particular speed. The rate of diffusion of the paste is very low at the edge of the printing zone; it will increase gradually as the contact line between doctor blade and screen is approached. Thus an even film of printing paste is formed on the material as it passes through the printing zone, whose thickness is dependent on the printing conditions, the printing paste properties and the capillary forces of the material.

Hydroentanglement Spunlace technology has been applied for bonding of nonwovens for years already. In the middle of 1995, Messrs. BBA Inc., USA developed the Interspun process and applied for its patenting. This process is used for treating textile-structure surfaces by means of water jets and has a positive influence upon structure and properties of woven fabrics. Contrary to the spunlace technology for bonding of nonwovens where free-moving individual fibres are subject to high energy water jets (Fig. 1), fibres of woven and knitted goods are firmly integrated in the yarn resulting in a distinct change of inner structure.

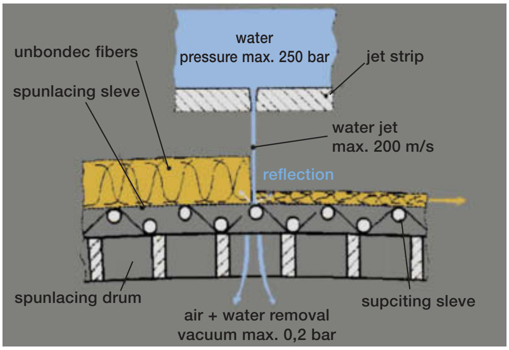


Fig.1: AquaJet Spunlace System.

In 1998, BBA and Fleissner signed a cooperation agreement making Fleissner the exclusive machinery supplier for this technology. Thus the years of experience in the field of nonwoven hydroentanglement through the AquaJet system (Fig. 2) developed by Gerold Fleissner can now also be applied to fabric treatment in an ideal manner. Fabric finishing can no longer be imagined without the AquaTex system for fabric enhancement which will have a lasting influence upon fabric treatment. Enhancement here means a textile finishing process that, besides improvement of the product's quality, is especially linked to saving of costs and energy, environmental protection and reduction of textile finishing steps such as washing processes etc.

The Interspun process uses micro water jets of 0.1–0.15 mm impinging from perforated nozzle strips with 60 jets/inch in form of a curtain onto the cloth with a pressure of 150–250 bar and speeds of up to 300 m/s. This water is sucked off by means of a suction slot arranged underneath the injector and is led to the high pressure pumps passing an air/water separator and filtration system in this circuit before being pressed through the high pressure jet heads again. During this passage, part of the water (depending on the type of fibre between 3 and 5%) is constantly added as fresh water to compensate for the loss by fabric moisture evaporated in the dryer, water drops in the air/water separator, and back-wash water in the filter system. When subject to the water jets, the material is transported either on a suction drum or a conveyor belt. The fabric can be hydroentangled on either one side or both sides.

By high energy water impinging on the cloth, the yarns blossom and the loose ends of the fibres both within the individual yarns and between adjacent yarns

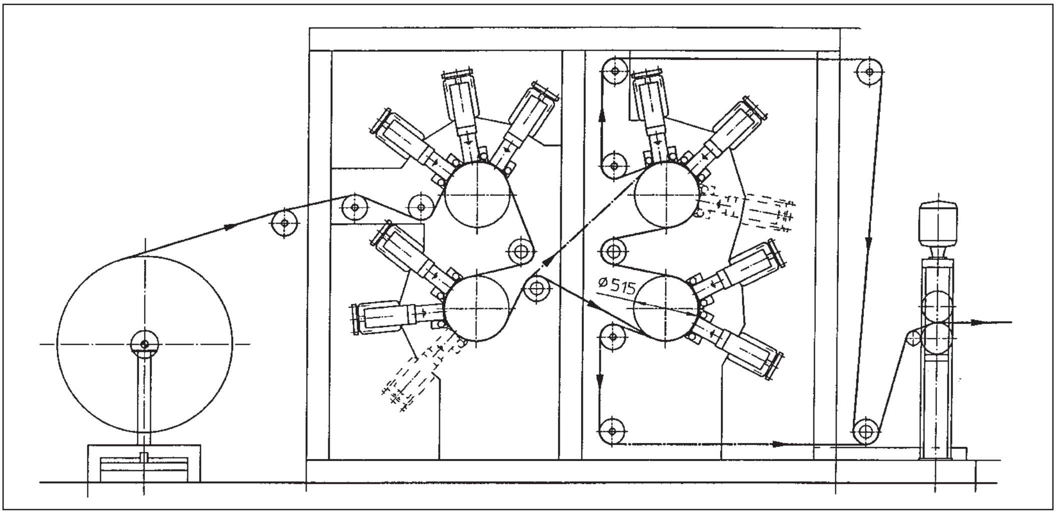


Fig. 2: Water jet for nonwoven bonding (AquaJet from Fleissner).

entangle. With the water being pressed through very fine jet nozzles, an impure, turbulent jet caused by turbulence in the jet head or particles/soiling at the jet nozzles may result in uneven treatment of the fabric, in turn leading to streaky effects. The AquaTex system jet heads are designed such as to distribute the water over the width evenly and at uniform pressure thus ensuring each water jet delivers the same energy. The belt or drum(s) to transport the material during water treatment is used for exhausting excess water in a vacuum slot before the next water curtain. Too much water on the fabric surface during impingement of the water jet may cause uneven enhancement or a Moirée effect. The vacuum in the suction slot at the same time keeps the material in place. The slot is arranged directly underneath the jet curtain to achieve efficient enhancement.

Hydroextracted goods → Centrifuge hydro-extraction.

Hydroextraction by centrifuge (spinning), → Water extraction by → Centrifuges.

Hydroextraction effect (centrifuging effect). A measure of the amount of liquor remaining on a textile material after hydroextraction (centrifuging), expressed as a percentage based on the weight of dry material.

Hydroextraction index → Hydroextraction effect.

Hydrofixation → Heat setting of polyamide piece goods in HT beam dyeing machines using hot water (up to 140°C), mostly combined with bleaching, scouring or dyeing.

Hydrofluoric acid Hydrofluoric acid (HF) is a 40% aqueous solution of hydrogen fluoride (a colourless gas) in the form of a fuming liquid. MW 20.01. Salts of hydrofluoric acid are known as → Fluorides. Both the fumes and the solution are strongly acidic. Hydrofluoric acid is highly corrosive and toxic by ingestion and inhalation. It dissolves virtually all metals (except gold, platinum and lead) and attacks glass and porcelain (by the formation of silicon [tetra]fluoride) on heating. The potassium salts are only sparingly soluble in water or dilute acids whilst the silver salts are readily soluble. Uses: for etching glass; its salts are used as a substitute for antimony potassium tartrate (tartar emetic); as a spotting agent (e.g. for removal of iron stains) as an alternative to oxalic acid, etc.

Because of its corrosive properties, hydrofluoric acid is handled in monel, PTFE or platinum equipment.

Hydrogel → Gel.

Hydrogen Chemical symbol H (Lat.: hydrogenium). Atomic weight 1.01 → Non-metals, a gas; colourless, odourless, tasteless; lightest gas (14 times lighter than air); combustible (pale blue flame) under intense heat development and formation of water; 2 parts with 1 part oxygen form an explosive mixture. Only slightly water-soluble, hydrogen extracts the oxygen from oxides (especially in the presence of catalysts) (→ Reducing agent). As a dissociated component (→ Hydrogen ions H^+) of water-dissolved compounds, hydrogen is the carrier of acidic reaction (hydrogen ion reaction). It is produced through the action of acid on base metal (Zn + HCl), whereby liberated H atoms escape from the solution and the metal dissolves as ion. ($Zn + 2H^+ + 2Cl^- \rightarrow Zn^{2+} + 2Cl^- + H_2\uparrow$).

Hydrogenated hydrocarbons → Alicyclic hydrocarbons.

Hydrogenated phenols Hydroaromatic compounds of the type hexaline and methyl hexaline play a significant role in solvent-containing textile auxiliaries of many kinds solvating assisitants (→ Hydrotropic property), where they serve as solvents for fats, oils, resins, waxes, tar, linoxyn, etc.

Hydrogenation (Hydrogenium = hydrogen), to attach hydrogen, e.g. with carbon liquefying (Bergius process). Principle: hot splitting of the carbon molecules (under pressure) and simultaneous hydrogenation (hydrogen gas) produces paraffin, petrol, etc. → Fats, high pressure hydrogenation of; Fat, hydrogenation of.

Hydrogen bonds A hydrogen bond is a type of electrostatic interaction between groups in molecules that have hydrogen atoms bound to electronegative atoms (e.g. so-called → Donor, such as oxygen, nitrogen, sulphur, chlorine, fluorine). Hydrogen bonds may therefore be regarded as electrostatic bonding forces between dipole molecules with a high dipole moment, in which the hydrogen atom is at the positive end of one polar group and forms a linkage with the electronegative end of another polar group. (→: Secondary valency forces; Dipoles).

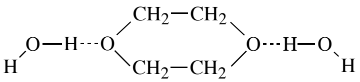
$$\overset{\delta-}{X} \longleftarrow \overset{\delta+}{H} \cdots\cdots \overset{\delta-}{Y} \longleftarrow \overset{\delta+}{Z}$$

Hydrogen bonding is responsible for the self-association of H_2O molecules in water and ice. In this structure, the hydrogen of one molecule is always bound to the oxygen of another molecule through a shared electron pair which, however, lies somewhat closer to the oxygen so that the oxygen atom is at the negative end, and a hydrogen atom (or, more correctly, a H^+ [proton]) is at the positive end of a dipole.

Hydrogen bonds are characterized as relatively loose bonds which are usually completely disassociated again in the vapour phase since the H^+ is generally more strongly attached to one of the two electronegative atoms than the other. From the foregoing, it can be seen that the hydrogen bond is relatively weak and certainly weaker than the usual → Ionic bond and → Atomic bond. Hydrogen bonds are, in fact, only about one tenth to one thirteenth as strong as normal covalent bonds but have pronounced effects on the properties of substances in which they occur. Such bonds are therefore readily broken and re-formed again, which is one of their important features. They are, however, stronger than → Van der Waals forces.

The electrostatic intermolecular dipole interaction involved in hydrogen bonding is of considerable practical importance in almost all branches of textile chemistry:

I. Solvation: water is a good solvent for electrolytes or polar solvents such as dioxane through the action of hydrogen bonds:



Highly polar liquids are suitable as solvents for synthetic polymers if the bonding energy between solvent and polymer is greater than between solvent and solvent.

II. Fibre structure: in many cases, hydrogen bonds play a decisive role in fibre structure. They are formed in virtually all fibres through functional OH and/or NH groups between the chain molecules, thereby creating structural elements that are of considerable importance for the crosslinking and elastic resilience of the macromolecular fibre structure. Good orientation of the fibre molecule is due to the close proximity of polar groups and the electrical interactions created by hydrogen bonding. This, in turn, is largely proportional to the degree of crystallinity and is therefore more or less responsible for the close packing of the molecules which is not only manifest in the specific strength of the fibre but also, e.g. in dyeing mechanisms and in the interstitial inclusion of synthetic resin particles (in cellulose), etc. The temporary breakdown of hydrogen bonds is also responsible for the swelling processes, the thermoplastic properties and, with subsequent re-formation of hydrogen bonds, the heat-setting of textile fibres.

III. Dyeing: hydrogen bonds are often involved in dye/fibre attractions and can participate in dyeing mechanisms in many ways, especially in the case of synthetic fibres. Typical examples include, e.g. bonding between direct dyes (azo groups) and cellulose (OH groups) where the linear and planar structure of direct dyes is largely responsible for their attraction to cellulosic fibres by allowing close alignment between the dye molecule and the cellulose chain molecule, which makes it easy for hydrogen bonds to form. The bonding between disperse dyes (NH-, NO- groups) and polyamide fibres represents another important example.

Hydrogen halides Oxygen-free, acid compounds formed between hydrogen and → Halogens, e.g. HF, HCl, HBr and HI. Hydrogen fluoride differs from the other hydrogen halides because of its strong hydrogen bonding and consequent association.

Hydrogen-ion concentration (H^+ concentration). Chemically pure water reacts neutrally since both types of ions (H^+ and OH^-) are fully dissociated in practice. Since according to the law of mass action the product of the concentration of H and OH ions must always be the same (10^{-14} g/l), it is sufficient to only specify the H-ion concentration each time. Should this increase, the solution becomes more acidic, causing the OH ion concentration to fall and vice versa if the reaction shifts towards the alkaline. For the purposes of simplification, only the respective exponential of the tenth power without minus signs are used. Applied to the H-ion concentration, as a generally valid yardstick, instead of 10^{-7} g/l "7" is written as an expression of the H ion concentration or → pH (from "pondus hydrogeni" = weight of H), written pH 7.

From this it follows for pH and solution reaction:

0–3	highly acidic
4–6	weakly acidic
7	neutral
8–10	weakly alkaline
11–14	highly alkaline

The change in a full pH degree corresponds to a tenfold (900%) increase or reduction in action each time. According to this, the pH is the measure for the reaction strength, not for the particular amount of acid or alkali in g/l.

Hydrogen ions (H ions, hydronium ions, hydroxonium ions), H^+ or H_30^+. Electrically positively charged particles of hydrogen atoms, which cause the acidic reaction of acids and acid salts to occur.

Hydrogen methyl polysiloxane (HMPS), is used in silicone finishing in the textile industry. It is reactive and can react with itself to form cross-links. It then forms a polymolecular, coherent film around individual fibres of a yarn bundle or fabric. Chiefly emulsions made of dimethyl polysiloxane (DMPS: does not react with itself at normal concentrations) and small parts of HMPS (for increasing the viscosity) are incorporated. In order to obtain good water repellancy and a soft handle, the fabric requires a hydrophilic support layer of heavy metal hydroxides, e.g. zircon hydroxide.

Hydrogen peroxide (Hydrogen superoxide, hydroperoxide → Peroxide), H_2O_2, structure H–O–O–H. Molecular weight 34.016. Besides water, hydrogen and oxygen form hydrogen peroxide H_2O_2. In its anhydrous state, this is a liquid whose physical properties are very similar to those of water. The boiling point is at 150.2°C, the freezing point –0.43°C. The molecule is diamagnetic; its structure is reproduced in Fig. 1. The metastable original state of H_2O_2 is separated from the product water in the model (Fig. 2) by an energetic barrier, the "activation peak". This makes the decomposition of hydrogen peroxide thermodynamically possible:

$$H_2O_2 \rightarrow H_2O + {}^1/_2\, O_2;\ \Delta G^\circ = -96\ \text{kJ/mol}$$

However, at room temperature only a few molecules are so rich in energy that they reach the free activation enthalpy (ΔG^*) of 76 kJ/mol. Decomposition may be greatly accelerated by heating, whilst catalysis speeds up the reaction rate (catalytic activity of simple metal ions).

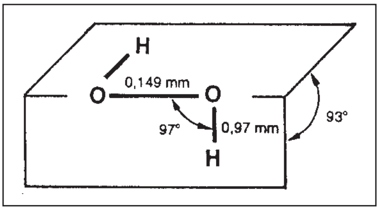


Fig. 1: The structure of H_2O_2.

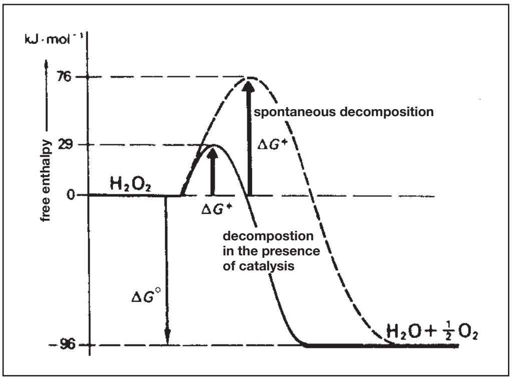


Fig. 2: Activation energy (ΔG^*) with spontaneous and catalysed decomposition of hydrogen peroxide (besides ΔG° = exothermic energy gain).

Hydrogen peroxide salts: peroxides, solid hydrogen peroxide: → Carbamide peroxide. Forms: 3–40% Vol. Hydrogen peroxide is water-clear, colourless and odourless, weakly acidic (normally stabilised with sulphuric acid). The more concentrated (apart from anhydrous hydrogen peroxide), the more readily it decomposes. Store in a cool, dark place and, for use, preferably in partially filled bottles with drilled corks. Dust contamination can cause severe decomposition. Storage: receptacles made of glass, stoneware, porcelain, special steel, super-pure aluminium etc. Strong oxidation and bleaching agent (→ Bleaching agent, hydrogen peroxide). Catalyst presence in water or on fabric (rust, iron, manganese, brass, copper, etc.) causes premature decomposition (fibre damage). Effect of heat and light and the presence of dust, heavy metals, enzymes and alkalis (also alkali leached from glass) cause decomposition to water and oxygen.

Should H_2O_2 encounter greater oxidation agents, it acts reductively, e.g.:

$$2\ KMnO_4 + 3\ H_2SO_4 + 5\ H_2O_2 \rightarrow$$
$$K_2SO_4 + 2\ MnSO_4 + 8\ H_2O + 5\ O_2$$

Louis-Jacques Thénard first introduced the hydrogen peroxide molecule in 1818. This symmetrical molecule forms a dihedral with the base of the oxygen atoms O–O, to each of which a hydrogen atom H attaches itself in both directions below an angle of 96°. Modern physics characterises this molecule through various, quantifiable movements of the electrons visible in the spectroscope (rotations and vibrations Fig. 3).

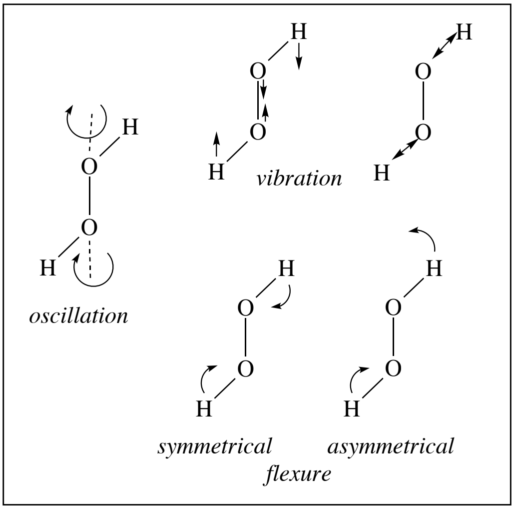


Fig. 3: The hydrogen peroxide molecule can be stimulated to produce vibrations in various ways.

The intramolecular vibrations represent oscillations of the atoms around their equilibrium state, comparable to a mass suspended on a spring (chemical bond) (Fig. 4). Since a molecule with n atoms (n = 3–6) shows the same types of vibrations, there are for H_2O_2 six types of vibrations (Figs. 3 and 4).

Application: bleaching agent for wool, cotton, silk, linen, viscose filament yarn/staple fibre, synthetic fibres, viscose, hair, bristles, feathers, animal hair (with oxygen stabilisers), furs, wood, straw, sponges; glue, gelatine, fats, wax; oxidation agent for sulphur and vat dyeing. Desizing agent for viscose fabrics. Disintegrating agent for starch (sizes). Scouring agent (scorch marks, blood, dye, coffee, tea and sweat stains, etc.).

Hydrogen peroxide bleaching

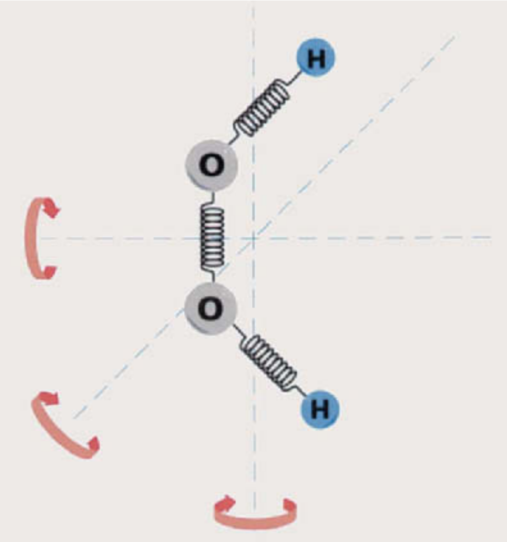


Fig. 4: Rotational axes around the atomic bonds of the hydrogen peroxide molecule (according to Fornelli).

Concentrated hydrogen peroxide solutions have a damaging effect on virtually all materials.

Hydrogen peroxide bleaching In a three-stage preparation range for cotton fabric (Fig. 1), the following demands are made on the process chemicals in the hydrogen peroxide bleaching stage:

- swelling effect (H_2O)
- wetting and washing
- emulsifying
- dispersing
- complexing
- peroxide stabilisation
- activation (NaOH)
- fibre protection

Depending on the type of fabric, rope bleaching (Fig. 2) or under-flow bleaching (Fig. 3) is used. New kinds of bleaching systems for hydrogen peroxide make use of high-moisture application (Fig. 4).

Flexnip (Küsters, Fig. 4): Starting with a moisture content of around 70%, the fabric enters from top to bottom into a 10-litre trough in which the bleaching bath is replaced every few seconds. At the lower exit, the fabric passes between two flexible squeeze rollers, which control the application to 150%, hence guarantee a liquor uptake of 80%. A seal prevents the loss of fluid. The liquor is replaced automatically to keep a constant liquor level. The entrance to the steamer is horizontal to prevent liquor spotting. Wet-on-wet impregnation (Fig. 5) is possible in this system. Very precise control of the bleaching chemicals is necessary (Fig. 6).

Optimax system (Menzel, Fig. 7): High pressure on the fabric is followed by a strong decompression,

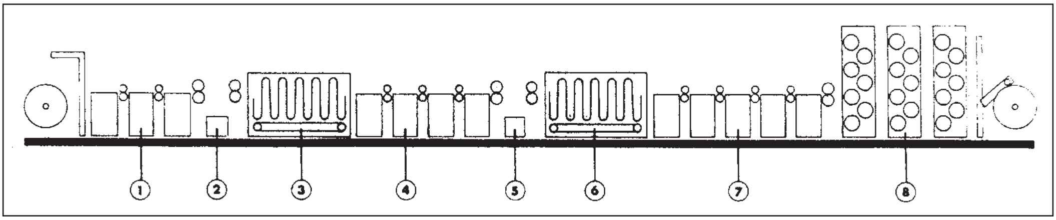


Fig. 1: Classic 3-stage pretreatment system for desizing, boiling and bleaching. 1= desizing; 2–4 = boiling; 5–7 = H_2O_2 bleaching; 8 = cylinder dryers.

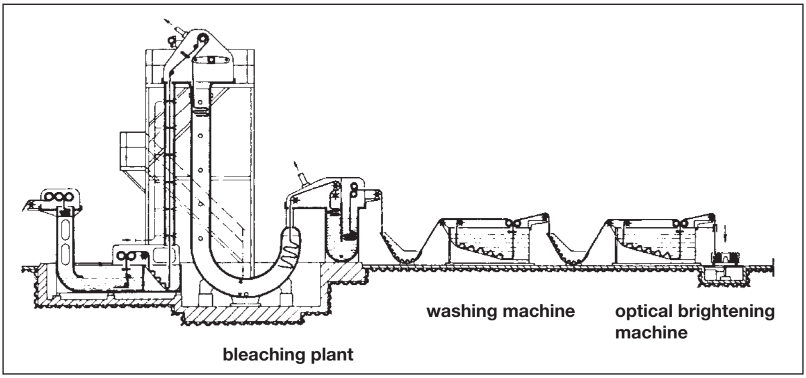


Fig. 2: Rope bleaching system of Friedrichsfeld GmbH.

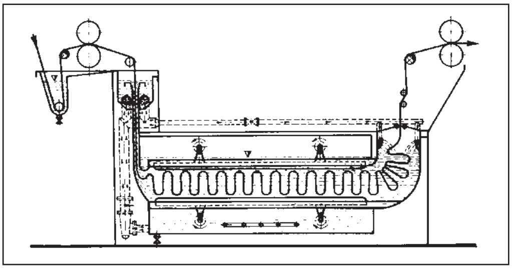


Fig. 3: Menzel under-flow bleaching system.

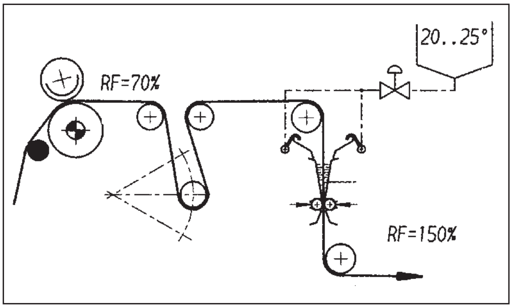


Fig. 5: Flexnip wet-on-wet application (Küsters).

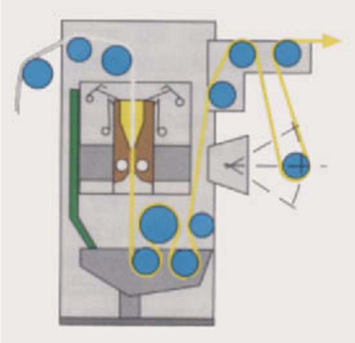


Fig. 4: Flexnip by Küsters for pretreatment.

which effectively acts like a suction of the liquor, similar to a sponge. The desized and warm-scoured fabric is squeezed between two Rowatex rollers; then it absorbs the liquor found in the nip formed by the two rollers. Two small rollers prevent any loss of fluid. The fabric circulates from under to over. In front of the entrance to the steamer, two rollers regulate the maximum liquor application. The system is flexible because it allows minimum and maximum application values.

Super Sat system (Babcock, Fig. 8): The special aspect of this system is its use of the nip for the passage of

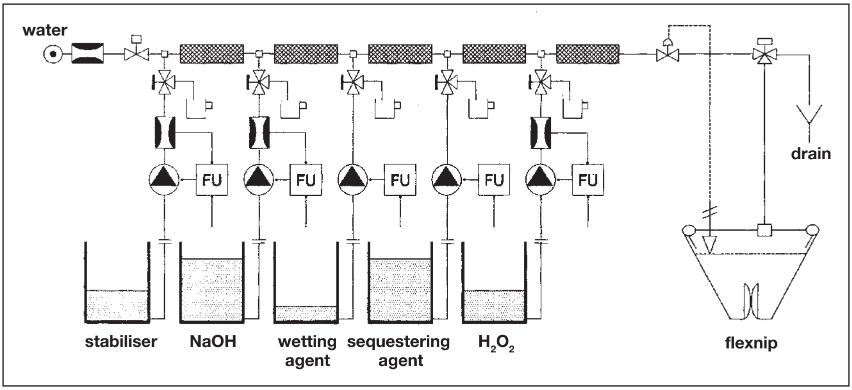
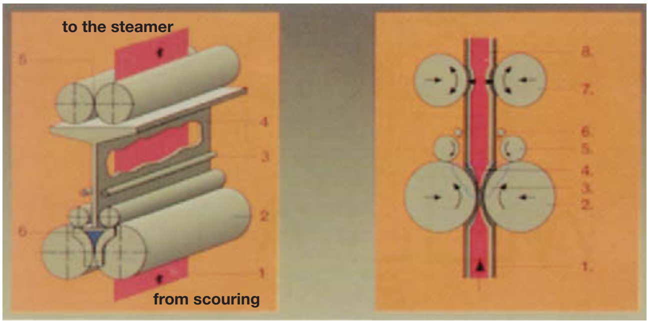


Fig. 6: Functional diagram of continuous chemical dosage (Küsters).

Fig. 7: One-stage bleaching using the Optimax system (Menzel).
Left-hand picture: 1 = desized fabric (hot); 2 = Rowatex rollers; 3 = liquor feed; 4 = liquor feed; 5 = conrol of the liquor uptake; 6 = impregnating liquor.
Right-hand picture: 1 = fabric entry; 2 = Rowatex rollers (squeezing); 3 = impregnation; 4 = liquor addition; 5 = sealing rolls; 6 = liquor feed; 7 = controlled squeezing; 8 = control of application level.



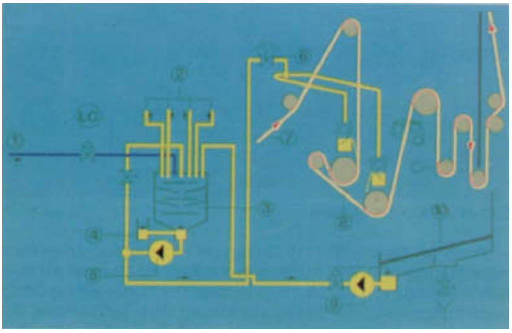


Fig. 8: Super Sat system (Babcock).
1 = water; 2 = chemicals; 3 = mixer; 4 = height adjustment; 5 = circulation pump; 6 = flow rate control; 7 = fabric; 8 = impregnation cylinder; 9 = recovery pump; 10 = fibre filter.

the fabric between the rollers. The desized, warm fabric squeezed to 70% expression passes through the 5-litre Super Sat system to enter the steamer with maximum application. The system is characterized by an automatic inflow of liquor direct to one side of the fabric, then out the other side. The liquor uptake reaches the absorption limit, promoting the penetration of the bleaching chemicals. The excess liquor is re-circulated. Continuous dosing through the polykomat ensures constant chemical concentration.

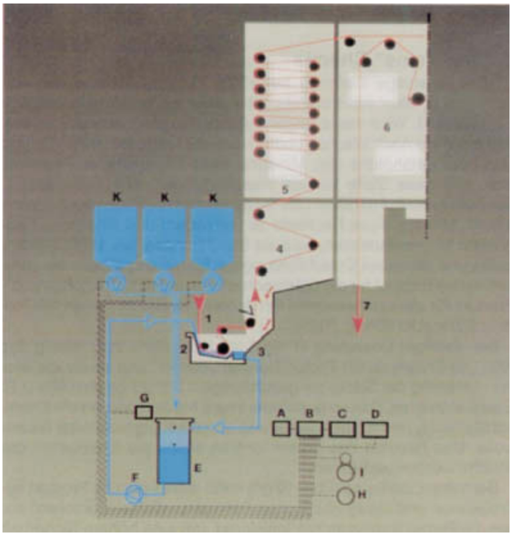


Fig. 9: Dip Sat system (Goller).
1 = fabric passage; 2 = short liquor impregnation; 3 = return flow of the bath surplus; 4 = with 140% impregnated fabric; 5 = special influx zone for the 140% impregnated fabric; 6 = roll steamer; 7 = exit of the bleached fabric.

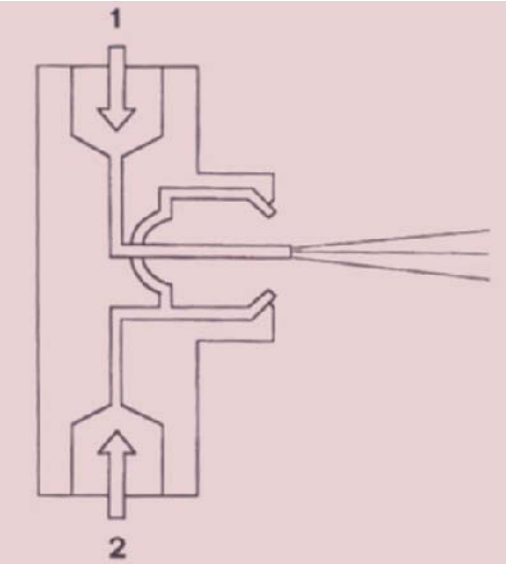


Fig. 10: Binary nozzle schematic with external mixing for chemicals. Water and steam (Kleinewefers KTM).
1 = chemicals and water feed; 2 = steam supply.

Dip Sat system (Goller, Fig. 9): This system is based on the free application of the liquor, i.e. without squeezing the fabric. The substrate absorbs a maximum amount of the liquor; the surplus returns to the first trough. An automatic system controls the concentration

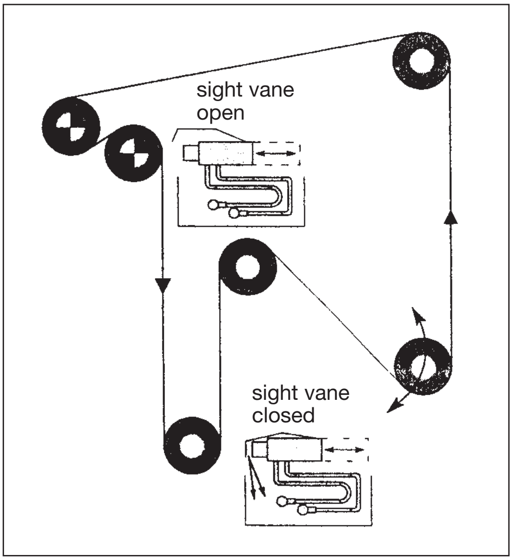


Fig. 11: Structure of the process simulator with closed fabric loop (source: Kleinewefers KTM).

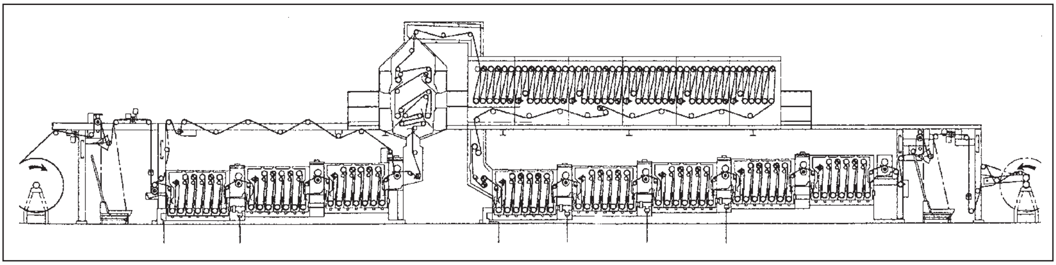


Fig. 12: System design for dry-on-wet and wet-on-wet processes according to the Raco-Yet principle of Kleinewefers KTM.

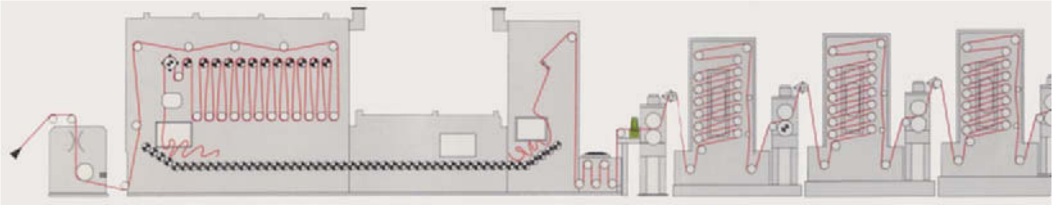


Fig. 13: Küsters Flexnip with processing time = 15 min in the steamer for bleaching with hydrogen peroxide.

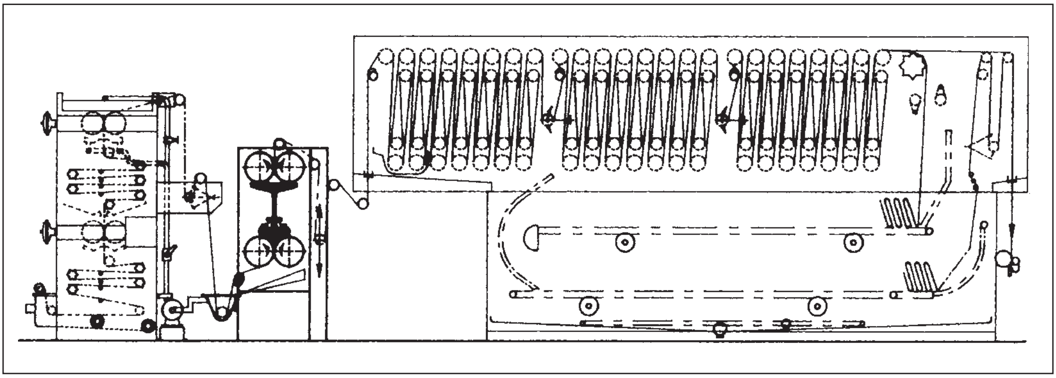


Fig. 14: Elementary diagram of the universal application system Optimax in a pretreatment system (Menzel).

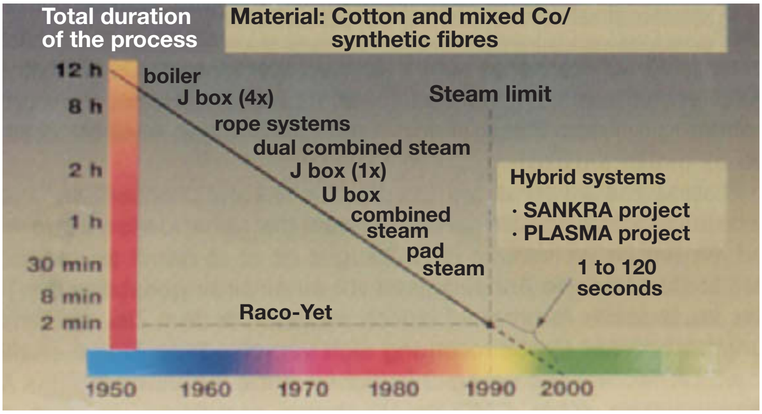


Fig. 15: Shortening of the bleaching times by changing the process engineering (Fornelli).

of the chemicals. The fabric passes in this way through the Dip Sat system (10 l capacity) with a moisture of 60%, then horizontally into the steamer with a maximum application of around 140%.

Raco-Yet (Kleinewefers KTM, Fig. 10): Steam and bleaching liquor are mixed in a binary nozzle and sprayed onto the passing fabric. Only 2 min steaming are then required. Pretrials for determining the bleaching formulae are possible on a Raco-Yet simulator (Fig. 11). Because of the short steaming time, a Raco-Yet bleaching system can treat the fabric in the steamer entirely in a fixed fabric guide (Fig. 12). This is impossible with other types of high-moisture content hydrogen peroxide bleaching due to the need for longer steaming times necessitating combined steamers with fixed and free fabric guides (Figs. 13 and 14).

If the aim is to achieve even shorter reaction times than the Raco-Yet by means of hybrid systems (Fig. 15), as with the Sankra process, which is not yet state of the art, or with Plasma applications (research project), then in short it is necessary to create a reaction-controlled process from the diffusion-controlled bleaching process.

Hydrogen peroxide bleaching mechanism Hydrogen peroxide is the most frequently applied textile bleaching agent. If fibre damage is to be limited, then it is essential to fully understand the mechanism of the bleaching process. Although numerous studies have been carried out, there is no conclusive evidence whether an oxidative and/or a radical decomposition of the yellowness occurs. The predominant opinion is that ionic decomposition products of the hydrogen peroxide have a bleaching effect and radical decomposition products cause damage. Dannacher and Schlenker postulate, on the other hand, a direct involvement of the perhydroxyl radical ion as a bleaching agent.

Several mechanisms are considered possible with regard to the bleaching effect of hydrogen peroxide:

a) Because bimolecular oxygen has no bleaching effect, oxygen "in statu nascendi" (in the nascent state) is assumed to be an intermediate stage of decomposition from H_2O_2 to O_2, and atomic oxygen (O) is actually produced. Since normal atmospheric oxygen has no corresponding bleaching effect, it is conceived that a reactive progenito is formed in decomposition and then converted into harmless oxygen. This aggressive stage which the oxygen molecule passes through at "the hour of its birth" is happily accorded the term "active oxygen" in older literature.

There is no experimental indication of atomic oxygen under bleaching conditions. An examination of the energy released in the decomposition reaction also contradicts this hypothesis:

$$H_2O_2(fl) \rightarrow H_2O(fl) + {}^1/_2\, O_2(g)$$

For the components in their standard state, the energy balance of this reaction is exothermic. The standard state of oxygen, however, is molecular oxygen. If the reaction is formulated with atomic oxygen, then there is an energy deficit, which results from the bonding of the oxygen molecule. The reaction becomes strongly endothermic. Oxygen in statu nascendi is liberated as active oxygen for thermodynamic reasons.

b) As with straw bleaching, → Singlet oxygen is formed in the redox reaction of H_2O_2 with hypochlorite. When used as antichlor in the intermediate stage bleaching, H_2O_2 is oxidized as follows:

$$H_2O_2 + ClO^{\ominus} \xrightarrow{pH\ 10} H_2O + Cl^{\ominus} + O_2$$

The balance of the hydrogen peroxide bleaching, on the other hand, remains exothermic if molecular oxygen is not formed in its normal electronic state, but rather in the initial electronically activated one, a singlet. This singlet oxygen can actually be generated under washing conditions and proven by catching with a trap compound.

A common method of forming singlet oxygen in an aqueous medium is oxidation of alkaline hydrogen peroxide solution with hypochlorite. Whether the singlet oxygen produced in this way actually bleaches can only be verified by means of experiment. Bleached cotton fabric dyed with black tea has served as standard staining. This staining is often used with bleaching tests for domestic detergents.

The chosen method for producing singlet oxygen has one disadvantage: the educts themselves are bleaching agents. At room temperature, the bleaching effect of hydrogen peroxide within the chosen test peri-

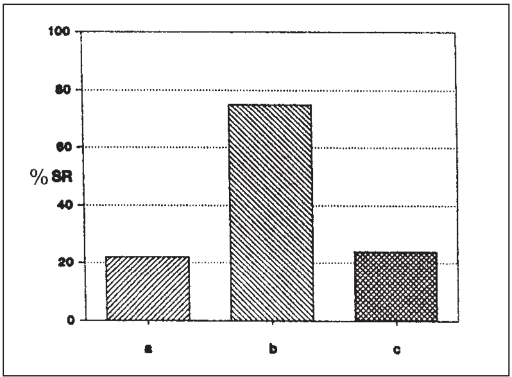


Fig. 1: Overall cleaning effect of tea staining at room temperature (according to Dannacher and Schlenker).
a = $4.6 \cdot 10^{-3}$ mol/l H_2O_2; b = $9.2 \cdot 10^{-4}$ mol/l HOCl;
c = $9.2 \cdot 10^{-4}$ mol/l ${}^1O_2$ and $3.68 \cdot 10^{-3}$ mol/l H_2O_2.
% SR = relative soil removal.

od of 30 min is slight. The concentration of hypochlorite used, however, will produce a good bleaching result. To inhibit a direct bleaching effect of the reactive hypochlorite, hydrogen peroxide has been used at five times higher concentration (according to Dannacher and Schlenker).

The bleaching effect obtained under these conditions with singlet oxygen ranges within the limits of experimental error. The result is no better than it is with hydrogen peroxide alone, which is still present in great excess (Fig. 1). Singlet oxygen is obviously not the “active oxygen” of hydrogen peroxide bleaching.

Hence, no bleaching effect has been obtained using this system where hydrogen peroxide is used in excess.

c) Perhydroxyl anion: hydrogen peroxide is a weak acid with an affinity constant in water at 20°C of $K = 2.4 \cdot 10^{-12}$. If alkali is added to an aqueous hydrogen peroxide solution, perhydroxyl anions are formed.

$$H_2O_2 + HO^{\ominus} \rightleftharpoons H_2O + HOO^{\ominus}$$

The characteristic decomposition according to

$$HOO^{\ominus} \longrightarrow HO^{\ominus} + [O]$$

increases with rising pH of the liquor. Although the perhydroxyl anion formation as the characteristic decomposition is exothermic, the activation energy is relatively high, however, with the result that aqueous solutions of hydrogen peroxide itself are metastable at boiling temperature; decomposition, though, is catalysed by heavy metals and readily oxidizable substances. The activation energy of the characteristic decomposition is reduced in alkaline liquors.

Cellulose is broken down via radical mechanisms, preferably forming keto groups in the process. The chain scission will then occur via a nucleophile substitution by the perhydroxyl anion. However, a reaction chain is conceivable which commences with a hydrogen peroxide adduct; Fe^{3+} will increase the speed of this process, but produce the same end products.

The bleaching reaction can be initiated by nucleophile substitution by means of the perhydroxyl anion. Conversely, chromophores also act as free-radical scavengers, with the result that, besides the bleaching effect of the radicals, the breakdown of the cellulose by dyes is generally prevented.

Perhydroxyl anion HO^{-}_2 functions as a nucleophile and can therefore be added to an electrophile carbonyl group. The peroxidation mechanism may correspond to a Dakin rearrangement (Fig. 2).

The decomposition of the hydrogen peroxide develops according to the equations

$$H_2O_2 + HOO^{\ominus} \longrightarrow H_2O + HO^{\ominus} + O_2$$

or

$$H_2O_2 + HOO^{\ominus} \longrightarrow {}^{\bullet}OH + H_2O + {}^{\bullet}O_2^{\ominus}$$

The perhydroxyl anion is the conjugated base of the weak acid hydrogen peroxide. In the strongly alkaline pH range, this anion is present in considerable concentration. With a pH that is greater than the pK of the acid dissociation, its constituent part will exceed that of the non-dissociated hydrogen peroxide. This is borne out by the observation that the bleaching effect of a hydrogen peroxide liquor visibly increases with alkali addition.

There is some indication, however, that this so-called “alkaline activation” may be taken too far and then change into its opposite. Test stains were bleached by Dannacher and Schlenker under very mild conditions, 60 min at 60°C, using hydrogen peroxide in a buffer solution. The result was a pH dependency with a

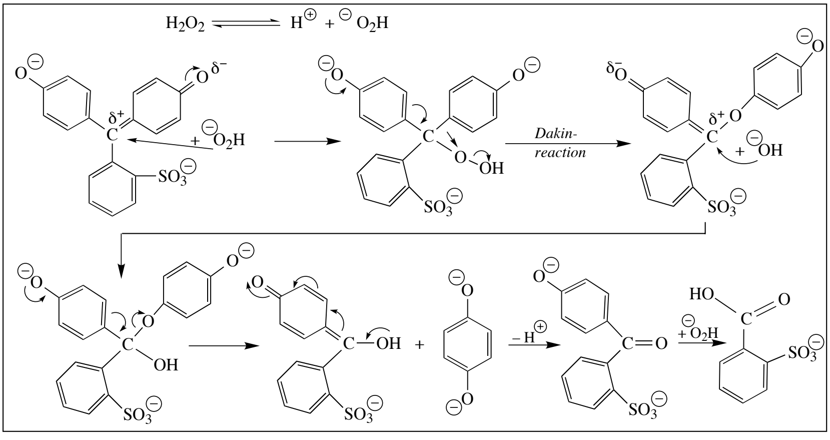


Fig. 2: Oxidation mechanism involving the perhydroxyl anion.

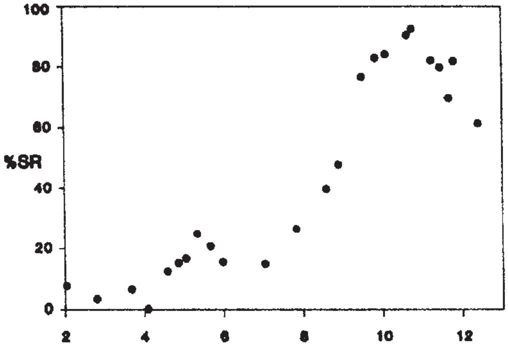


Fig. 3: Relative soil removal (% SR) after 60 min bleaching at 60°C (according to Dannacher and Schlenker). 6.5 · 10^{-3} mol/l H_2O_2 in a buffer solution.

considerably marked maximum (Fig. 3). The similarity with the concentration progression of the perhydroxyl anion is conspicuously slight. Precisely where the hydrogen peroxide is dissociated to more than 50%, the bleaching effect will decrease again. This finding is utterly incomprehensible if the perhydroxyl anion is assumed to be the sought-after "active oxygen".

d) Hydroxyl radical is formed with radical decomposition of H_2O_2. The pH dependency of the bleaching effect recalls the speed at which the decomposition of hydrogen peroxide develops. It is assumed that this decomposition occurs in a radical chain reaction. This reaction is started by the transfer of an electron by an electron donator to hydrogen peroxide. The closed loop of hydrogen peroxide decomposition is interrupted by the recombination of two radicals.

$$\begin{array}{lll}
\textit{start:} & H_2O_2 + \text{donator} \rightleftharpoons & HO^{\ominus} + HO^{\bullet} + D^{\oplus} \\
\textit{chain:} & H_2O_2 + HO^{\bullet} \longrightarrow & HO_2^{\bullet} + H_2O \\
 & H_2O_2 + HO_2^{\bullet} \longrightarrow & H_2O + HO^{\bullet} + O_2 \\
\textit{termination:} & 2\,HO^{\bullet} \longrightarrow & H_2O_2
\end{array}$$

The intermediate radicals here (the hydroxyl radical and the perhydroxyl radical) have likewise been postulated to be the species of hydrogen peroxide bleach active in the bleaching. Dannacher and Schlenker attempted to prevent this bleaching reaction with suitable free-radical scavengers. The test conditions were chosen according to the maximum pH dependency, where a deterioration in the bleaching effect is the most discernible. First of all, free-radical scavengers were selected whose rate constants of reaction with the hydroxyl radical are several orders of magnitude above the reaction with the perhydroxyl radical. Hence the aim was to selectively prevent the reaction of test-soiling with hydroxyl radicals. The experiment shows (Fig. 4) that these free-radical scavengers are not in the position to affect the bleaching result in the least. This bears out the numerous critics of a radical bleaching mechanism: the active species of the hydrogen peroxide bleach is not the hydroxyl radical.

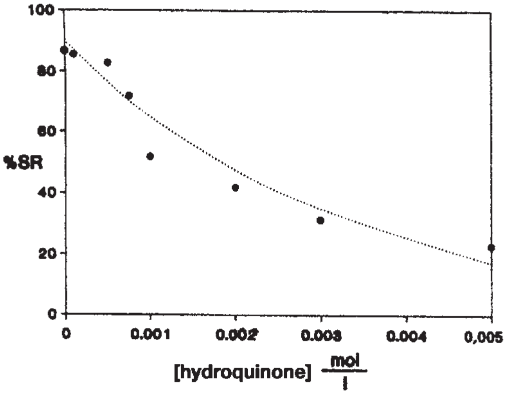


Fig. 4: Suppression of the bleaching reaction of hydrogen peroxide with hydroquinone (according to Dannacher and Schlenker). Relative soil removal after 60 min with 6.5 · 10^{-3} mol/l H_2O_2 at 60°C and pH 10.5.

e) Perhydroxyl radicals are very acidic, comparable with acetic acid: they are therefore almost totally dissociated in the pH range of the bleaching maximum (Fig. 3). The conjugated base is known under the name superoxide. Dannacher and Schlenker chose hydroquinone as a free-radical scavenger for this and, analogous to the tests with hydroxyl radical scavengers under the conditions of the bleaching maximum, waited for a deterioration in the bleaching. With increasing hydroquinone concentration, the bleaching effect is in fact increasingly suppressed (Fig. 4). This radical is obviously immediately involved in the bleaching reaction.

$$HO_2^{\bullet} \xrightleftharpoons{pK_A\ 4.8} {}^{\bullet}O_2^{\ominus} + H^{\oplus}$$

With a pK of the perhydroxyl radical of 4.8, one would expect to find the observed rise in the bleaching effect with a basically lower pH. According to this view, a decrease in the bleaching effect, once an optimum pH has been exceeded, should not be seen. Such a view of the equilibrium, however, completely ignores the kinetics of formation and decomposition of the radicals involved in this equilibrium. Most kinetic constants of the individual reactions of this chemical decomposition mechanism of hydrogen peroxide are known. As for the rest, an upper limit can be specified. These values allow the pH dependency of the superoxide concentration to be estimated. A comparison with the development of the bleaching effect of hydrogen

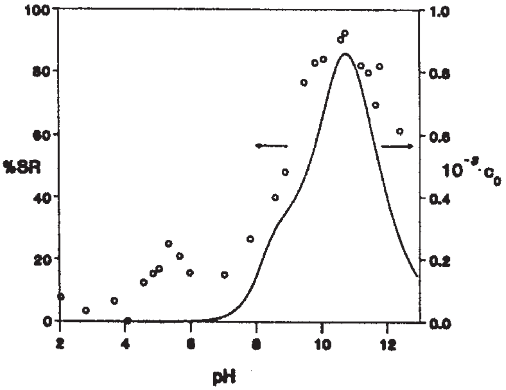


Fig. 5: Interpretation of the pH dependency of the bleaching effect (according to Dannacher and Schlenker).
0 = experimental values using a buffered hydrogen peroxide solution ($c_O = 6.5 \cdot 10^{-3}$ mol/l) after 60 min bleaching at 60 °C, left ordinate: estimation of superoxide concentration, right ordinate and drawn-through line.

peroxide reveals clear similarities according to Dannacher and Schlenker (Fig. 5).

The radical anion "superoxide" is the only one of the species observed to consistently account for all the experimental findings.

Hydrogen peroxide bleaching regulators With bleaching, hydrogen peroxide is used for

- increasing the degree of whiteness
- avoiding chemical damage to the fibre
- degradation of impurities
- suppressing the release of oxygen;

the particular portion is system dependent.

Bleaching systems contain regulators to reduce fibre damage and oxygen release. Buffers are used to maintain the correct pH for activation since alkali is required to neutralize the cellulose breakdown products. In addition, complexing agents are required to chelate any heavy metals present. Bleaching systems with built-in catalyst present do not inevitably cause a corresponding breakdown of cellulose: the catalyst also needs to be activated.

In the two-phase system of fibre with yellowing impurities and bleaching liquor, then different reactions need to be considered: Firstly the yellowing impurities remain in the fibre and are peroxidised there. The oxidizing agent is adsorbed onto the fibre surface and builds up a chemical potential gradient and diffuses into the fibre, reacts there in the core of the fibre with the yellowing impurities and breaks down its chromophore system. The resulting chemical products may then remain in the fibre or they may be small enough to diffuse to the fibre surface and eventually into the bulk phase.

In the second case, the yellowing impurities diffuse into the bulk phase and may be oxidized there. For a real bleaching system one can assume that both processes take place. A real model must take account of the diffusion coefficients of the different species and will mainly occur in a diffusion-controlled manner.

The objective of the pretreatment should not be overlooked; these are, for cotton and polyester/cotton piece goods in particular:

- high degree of whiteness dependent on the subsequent processes;
- freedom from seed husks;
- good rewettability;
- low ash content;
- free from size and preparation;
- optimum removal of the impurities in the native cellulose.

Besides the chemico-technological demands on the pretreatment, there also needs to be a guarantee that the pretreatment effects are absolutely uniform (edge/middle/edge, beginning/end) (Fig. 1). Good production safety, reproducability, flexibility with regard to the range of fabrics, and the least possible effluent loading should also be ensured (Table).

Whiteness: measured as % reflectance on the Elrepho apparatus (Zeiss), filter R 46 or by means of colour measurement as a numeric value → Whiteness formulae. Absorbency: by DIN 53 924 mod., measured as height in mm on 20 mm wide strips of fabric from the warp after 2, 15, 30, 60 and 120 s. Desizing: according to the TEGEWA violet scale; DP (fluidity) value: in accordance with the EWNN method, DIN 54 270-T 3-77, on warp yarn. The seed husk content is determined by count per 10 cm^2.

The objective of the bleaching of textiles consists of achieving a satisfactory or, in the extreme cases, high degree of whiteness with the least possible fibre damage. This last requirement is particularly important insofar as already partially damaged cellulose is known to be successively broken down in subsequent processes including care processing, with the result that ulti-

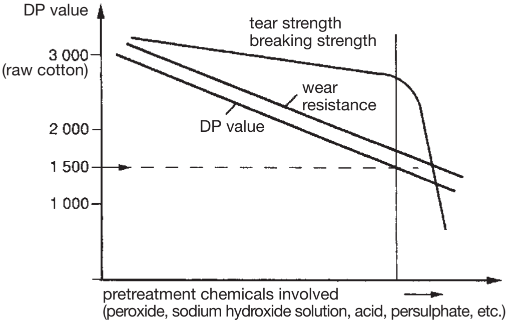


Fig. 1: Dependency of DP value, breaking resistance, tear strength and wear resistance on the pretreatment method.

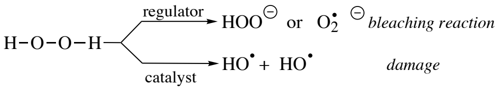
Hydrogen peroxide bleaching regulators

fabric	raw	desized	boiled
absorbency	0	0	60 mm
whiteness value	52.0	52.2	58.2 (Elrepho 46)
fat content	1.02%	0.80%	0.19%
size content	6.75%	0.55%	0.33%
ash content	1.26%	1.01%	0.22%
iron content	62 ppm	53 ppm	11 ppm
DP value	3020	2940	2810

Tab.: Measurements of quality factors.

mate strength may be too low. That is also the reason why fibre damage caused by catalysts, especially localised form, may not be recognized until the post-bleaching treatment stages or even in use.

With peroxide bleaching in an alkaline medium, the following are the main reactions:



$$H{-}O{-}O{-}H \xrightarrow{\text{regulator}} HOO^{\ominus} \text{ or } O_2^{\bullet\,\ominus} \quad \textit{bleaching reaction}$$

$$H{-}O{-}O{-}H \xrightarrow[\text{catalyst}]{} HO^{\bullet} + HO^{\bullet} \quad \textit{damage}$$

The bleaching reaction takes place at the same time as the decomposition reaction so that the concentration of peroxy anion sinks with increasing decomposition, while the bleaching effect decreases. At the same time, active species are formed. Heavy metal compounds catalyse the peroxide decomposition by forming free radicals, which statistically attack the cellulose fibres, leading to a reduction in the DP value. It is conceivable that the coloured impurities are also broken down by the peroxide decomposition so that an increase in whiteness is achieved. Owing to the expected reduction in the DP value, peroxide decomposition initiated by heavy metal compounds must be avoided during the bleaching.

Peroxide decomposition in bleaching liquors occurs by an ionic mechanism that can be described as a reaction of the 1st order. Here is actual decomposition reaction

$$HOO^{\ominus} \longrightarrow HO^{\ominus} + [O]$$

the so-called activation reaction as a rate-controlling step is shown as:

$$H_2O_2 + HO^{\ominus} \rightleftharpoons H_2O + HOO^{\ominus}$$

$$-\,dc/dt = k \cdot c$$

The reduction in the peroxide concentration is therefore proportional to the peroxide concentration itself.

After integration in the limits c_0 and c_t according to the peroxide concentration at the start and the time t, there follows:

$$\ln \frac{c_0}{c_t} = k \cdot t$$

If one therefore applies $\ln c_0/c_t$ to the time t, straight lines result, whose gradient corresponds to the constant k for the rate of peroxide decomposition. These values are shown graphically in Fig. 2 for a buffered system.

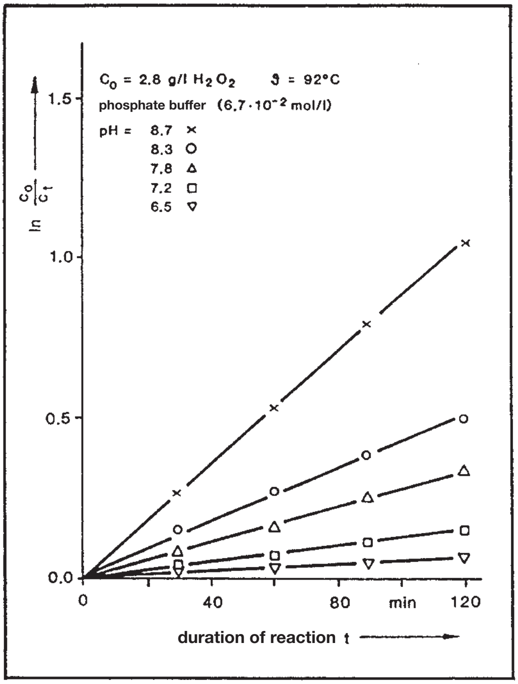


Fig. 2: Peroxide decomposition with a change in the pH without textile material (according to Heidemann).

This produces the familiar, distinctive dependency of the peroxide decomposition on the pH of the medium, which is to be expected due to the activation reaction mentioned. The rate of peroxide decomposition is already relatively high even in the weakly alkaline range for bleaching processes at the typical temperatures, with the result that the use of regulators is advisable. As shown in Fig. 3, in the presence of magnesium polysilicate under the limits of a standard bleach for a pH of 12, even with a high peroxide concentration the expected decomposition is minimized. As expected, decomposition occurs at a given temperature, again

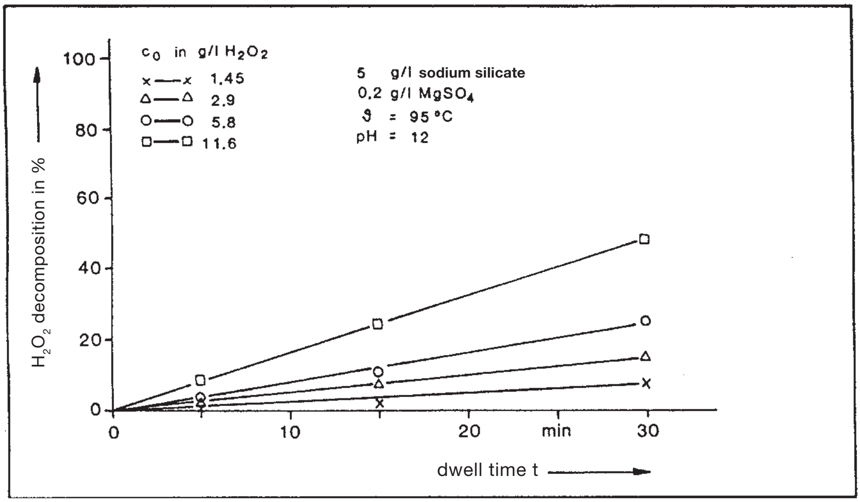


Fig. 3: Peroxide decomposition in bleaching liquors without textile material (according to Heidemann).

proportional to the original concentration, i.e. as a 1st order reaction. While in virtually catalyst-free systems the relations are relatively easy to see, this does not apply to radical peroxide decomposition initiated by heavy metal compounds. Hence, in the presence of iron (III) ions, for example, a complex sequence of decomposition reactions develops, which is triggered by the formation of a hydroperoxy radical:

$$Fe^{3+} + HOO^{\ominus} \longrightarrow Fe^{2+} + HOO^{\bullet}$$

The Fe (II) ion formed reacts with peroxide by forming hydroxyl radicals and represents, from the well-known Haber-Weiss mechanism, the start reaction for the development of further decomposition reactions in the form of radical chains. Here iron (III) ions may continue to react not only with the peroxy anion, but also with the free H_2O_2 itself in line with the Haber-Weiss mechanism. It is to be assumed, therefore, that the peroxide decomposition found in catalyst-containing bleaching liquors is of a complex nature, the properties of the regulator used also playing a role here.

The following demands are made of the auxiliary agent system:

- good wetting action on raw fabric also at impregnation temperatures < 20°C,
- non-foaming,
- good soil-suspending property,
- good electrolyte tolerance,
- stable to the bleaching agent,
- good dispersing and emulsifying ability even at low temperatures,
- good scouring,
- good silicate dispersing ability,
- good rinsing ability.

The stabilization of the peroxide bleaching liquor with sodium silicate and magnesium ions with semi- and fully continuous processes offers clear advantages: on the one hand, costs are considerably lower while, on the other, the risk of catalyst damage is much lower. In addition, the optimum stabilizing quality leads to a better use of peroxide in the bleaching process, a fact which is likewise reflected in cost savings. The very mild action of the bleaching process (optimum ratio of stabilization to activation) is qualitatively beneficial too.

The disadvantage of inorganic stabilization to date has been the fact that the exclusive use of sodium silicate in hydrogen peroxide bleaching has meant a deposit of silicate on machine parts and the bleached material. Especially critical points (with continuous systems) are the initial lead rolls in the reactor unit and the initial washing stage. These deposits have an extremely disruptive effect since a creaseless passage of the cloth can no longer be guaranteed. They continue to cause chafe marks, which may become visible in the subsequent dyeing. It has only been possible so far to remove these obstinate impurities mechanically with a great deal of expense, whereby a drop in production due to the machinery being idle had to be accepted.

Addition sequence: H_2O, Mg salt, organic stabilizer, surfactant, (sodium silicate), NaOH, H_2O_2.

The most common stabilizer is sodium silicate in colloidal polymer form (water glass). Its stabilizing ability is increased by the presence of the hardness-producing substances of the water. Colloidal Mg silicate is together with a dispersing agent the most effective stabilizer.

$Si(OH)_4 + H_2O \rightleftharpoons H_3O^+ + SiO(OH)_3^-\ {}_{2-}$ (pK = 9.46)
$Si(OH)_3^-\ {}_{n-} + H_2O \rightleftharpoons H_3O^+ + SiO_2(OH)_2^-$ (pK = 11.8)
$SiO_n(OH)_{4-n} + HO_2^- \rightleftharpoons SiO(OH)_{3-n}(OOH)^{n-}$ (n = 0; 1; 2)

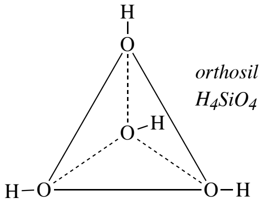
Hydrogen peroxide bleaching regulators

Magnesium is indispensable as a co-stabilizer. The effect of Mg salts as stabilizers is due to a complex being formed involving the superoxide radical $^{\cdot}O{-}O^{\ominus}$, where the radical chain reaction is interrupted by immobilisation.

$$Mg(OH)_2 + {}^{\bullet}O{-}O^{\ominus} \longrightarrow HOMgOO^{\bullet} + HO^{\ominus}$$

The main disadvantage of the silicate stabilizers consists in them forming deposits on the fabric and the machine, which is particularly critical in continuous processes; hence the trend for substituting the stabilization with sodium silicate. Frequently, oligophosphates and polyphosphates are used, their application being limited to the weakly alkaline range on account of their hydrolysis. Organic stabilizers are based on sequestering agents, organically substituted phosphonic acids, proteolysis products and their condensation products with fatty acids, and free-radical scavengers each with dispensing agents.

Stabilization with silicate is described as inorganic stabilization.



orthosilicates
H_4SiO_4

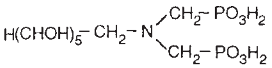
What is usual is the mixture of a salt formed from the weak acid SiO_2 and the strong base Na_20. The NaOH concentration is crucial for activation: 1 min steaming = 20–30 g/l NaOH; discontinuous = 1–2 g/l NaOH.

Sequestering is understood to mean the effect of complexing agents, which should be distinguished from the anticatalytic effect, when ferric ions are deactivated in the peroxide bath without magnesium being found. Organic complexing agents such as EDTA, NTA or pyrophosphate work as stabilizers.

The "threshold effect" refers to the inhibition of calcium carbonate precipitation (boiler scale) or chelate formation of Fe^{2+} in the peroxide bleach with greater efficiency than should be anticipated from the plausible coordination possibility. Thus there is very good dispersing ability per constituent of weight of complexing agents.

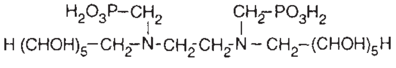
The crucial processes for radical peroxide decomposition are, on the one hand, the rate of dissolution of contamination of the cotton and, on the other hand, the interaction between the dissolved heavy metal ions and the regulator. These findings can no doubt be derived from the studies of peroxide decomposition with the addition of iron hydroxide and of dissolved ferric ions and, in addition, can be applied to the cotton contaminated with iron hydroxide with regard to the bleaching result (Fig. 5).

The following compounds, among other things, are used as regulators:



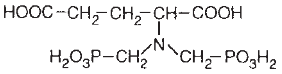
GDP

$H(CHOH)_5-CH_2-N(CH_2-PO_3H_2)_2$



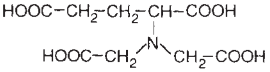
DGEDDP

$H(CHOH)_5-CH_2-N(CH_2-PO_3H_2)-CH_2-CH_2-N(CH_2-PO_3H_2)-CH_2-(CHOH)_5H$



GSDP

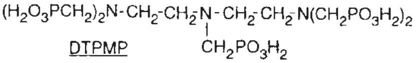
$HOOC-CH_2-CH_2-CH(N(CH_2-PO_3H_2)_2)-COOH$



GSDA

$HOOC-CH_2-CH_2-CH(N(CH_2-COOH)_2)-COOH$

$(HOOCCH_2)_2N-CH_2-CH_2-N(CH_2COOH)_2$ EDTA



DTPMP

$(H_2O_3PCH_2)_2N-CH_2-CH_2-N(CH_2PO_3H_2)-CH_2-CH_2-N(CH_2PO_3H_2)_2$

Their effect compared with different cations is depicted in Fig. 4.

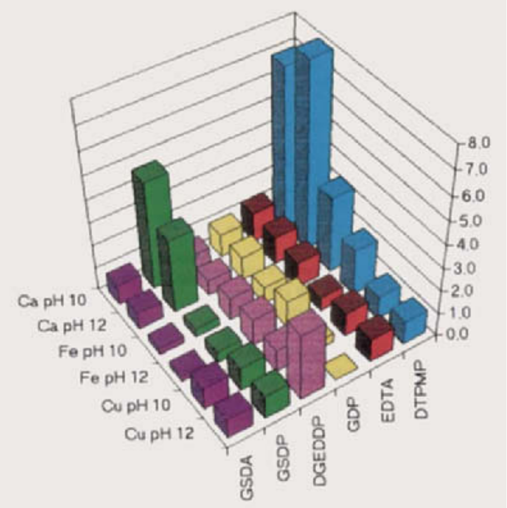


Fig. 4: Bonded cations [mol] per complexing agent [mol].

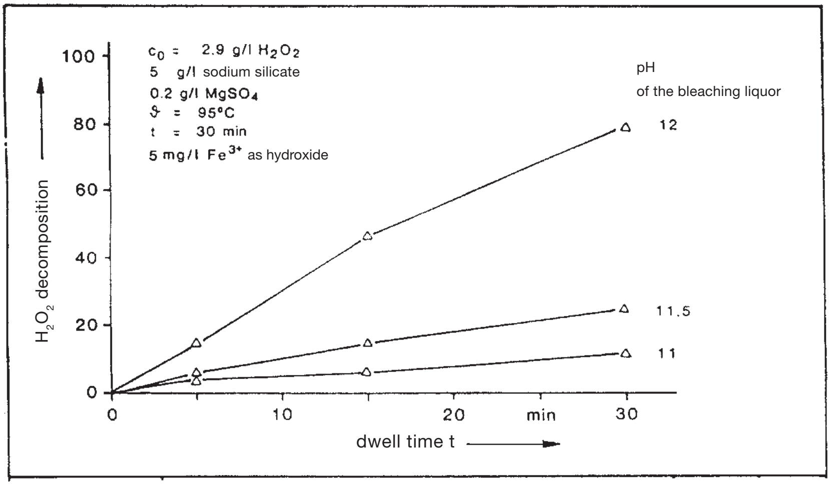


Fig. 5: Peroxide decomposition in bleaching liquors without textile material.

Hydrogen peroxide decomposition May occur homolytically and heterolytically.

In an acidic medium, heterolytic splitting will occur

$$(HOOH_2)^+ + H_2O_2 \rightarrow 2\ H_2O + O_2 + H^+$$

or peroxy acids which have a bleaching effect will be formed

$$(HOOH_2)^+ + RCOO^- \rightarrow RCO{\cdot}OOH + H_2O$$

Homolytic splitting in the acidic range $H_2O_2 \rightarrow 2\ (^{\cdot}OH)$ would require too high an activation energy. In the alkaline environment, decomposition occurs in accordance with Fig. 1.

For anti-catalysts to stabilise hydrogen peroxide solutions in commercial conditions, barbituric acid, urea and phosphoric acid (for complexing Fe^{2+}) are used.

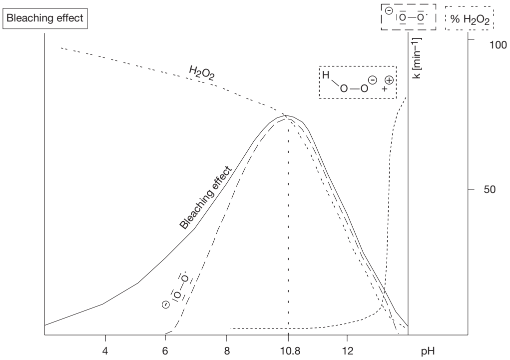


Fig. 1: Decomposition of H_2O_2 dependent on pH.

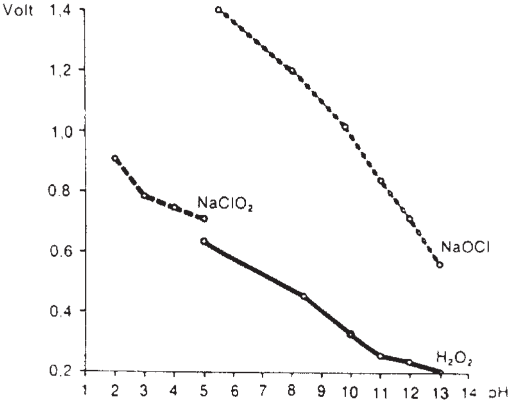


Fig. 2: Redox potentials of bleaches specific to the normal hydrogen electrode.

The redox potential (Fig. 2) of H_2O_2 is smaller in comparison to hypochlorite or chlorite. The quantitative analysis occurs in a redox process:

$$MnO_4^- + 2\ H_2O + 3\ e^- \rightarrow MnO_2 + 4\ HO^-$$
$$H_2O_2 \rightarrow O_2 + 2\ H^+ + 2e^-$$

Hydrogen peroxide is also enzymatically decomposed. Blood contains the enzyme peroxidase. This accelerates the reaction between hydrogen peroxide and the organic molecule benzidine so much that a blue pigment results almost instantaneously in the presence of the smallest quantities of peroxidase and acid. The reaction itself, therefore, serves to establish proof of blood traces. Peroxidase consists of a protein body to which a so-called porphyrin group is attached. This porphyrin group is geometrically in a single plane and contains at its centre a ferric ion Fe^{3+}. Perpendicular to this molecular plane, a H_2O_2 molecule can now make its approach and be bonded with the Fe^{3+} ion (Fig. 3).

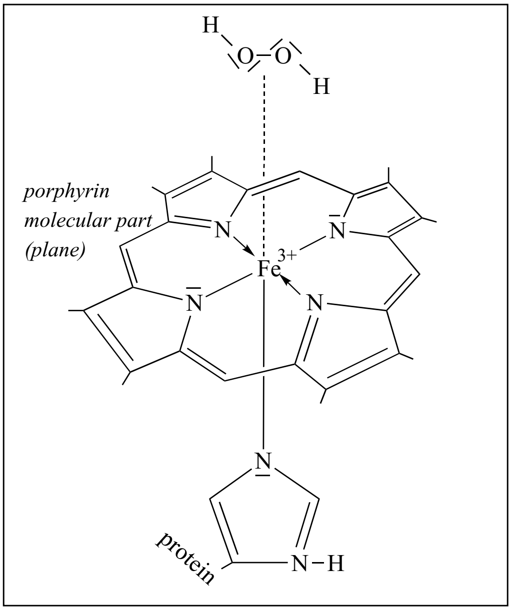
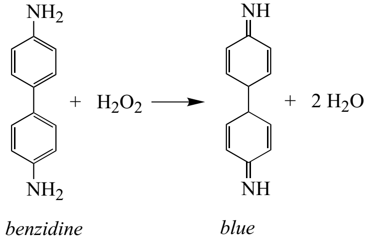


Fig. 3: Attachment of H_2O_2 to the porphyrin remnant of peroxidase.

Two hydrogen atoms are now given off in succession from the benzidine, from which two molecules of water, the blue pigment and the regenerated catalyst are formed:



benzidine

blue pigment

The peroxidase fails to appear at all in this reaction equation, but the reaction requires a basically smaller activation energy when the H_2O_2 is attached to the porphyrin group of a peroxide molecule.

The radical decomposition starts a chain reaction as follows:

$$H_2O_2 + {}^\bullet O_2^- \rightarrow {}^\bullet OH + HO^- + O_2$$
$$HOO^- + {}^\bullet OH \rightarrow H_2O + {}^\bullet O_2^-$$
$$H_2O_2 + {}^\bullet OH \rightarrow H_2O + HOO^\bullet$$

This chain reaction can also be initiated by heavy metal ions in line with the Haber-Weiss mechanism:

$$H_2O_2 + Fe^{2+} \rightarrow {}^\bullet OH + HO^- + Fe^{3+}$$
$$HOO^- + Fe^{3+} \rightarrow {}^\bullet OOH + Fe^{2+}$$

Hydrogen peroxide has a smaller oxidation potential than ozone under normal conditions. Owing to the catalytic effect of iron or other heavy metal ions, a radical reaction mechanism is set off, in the course of which OH radicals are produced, which have a greater oxidation potential (Fig. 4). The combination of hydrogen peroxide and ferrous salt is known as Fenton's reagent. The hypothetical reaction mechanism is reproduced in Fig. 5. In the initiating reaction, the hydroxyl radical is produced from the divalent iron and hydrogen peroxide. Besides its oxydizing effect due to its greater oxidation potential, the hydroxyl radical in a subsequent chain reaction enters into radical reactions with hydrogen peroxide and organic compounds, which cause, among other things, their oxidation and breakdown.

$$O_2 + 4H^+ + 2e^- \longrightarrow 2H_2O \qquad E_o = 1.229\ V$$
$$H_2O_2 + 2H^+ + 2e^- \longrightarrow 2H_2O \qquad E_o = 1.776\ V$$
$$O_3 + 2H^+ + 2e^- \longrightarrow 2H_2O_2 + O_2 \qquad E_o = 2.07\ V$$
$${}^\bullet OH + H^+ + e^- \longrightarrow H_2O \qquad E_o = 2.28\ V$$

Fig. 4: Oxidation potentials of some oxygen compounds.

$$H_2O_2 + HOO^\bullet \longrightarrow H_2O + O_2 + OH$$
$$RH + OH^\bullet \longrightarrow H_2O + R^\bullet$$
$$>C=C< + OH^\bullet \longrightarrow HO-\overset{|}{\underset{|}{C}} - -\overset{|}{\underset{|}{C}}{}^\bullet$$
$$Fe^{2+} + HOO^\bullet \longrightarrow Fe^{3+} + HOO^-$$
$$Fe^{3+} + HOO^\bullet \longrightarrow Fe^{2+} + O_2 + H^+$$

Fig. 5: Radical reactions with Fenton's reagent.

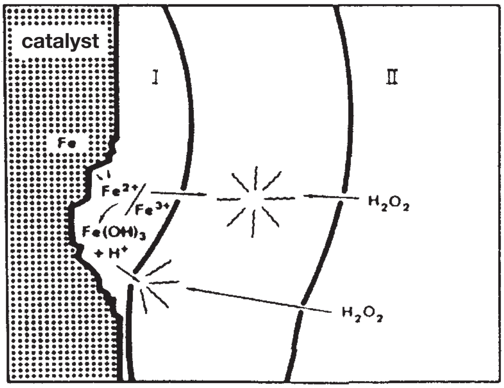


Fig. 6: Catalyst damage to cotton caused by iron (according to Meier).

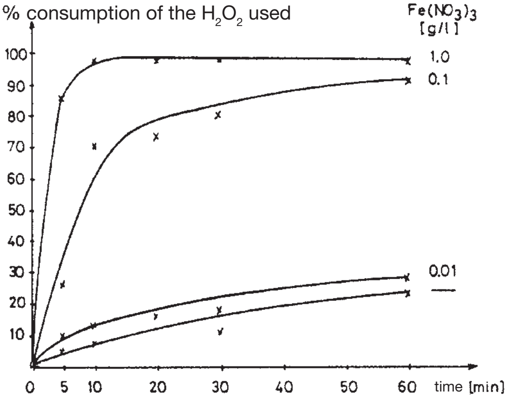


Fig. 7: Decomposition curve of the H_2O_2 present in the bleaching liquor with various $Fe(NO_3)_3$ concentrations.

The attempt to explain catalyst damage might take the following form (Fig. 6): oxidation causes ferric ions to become detached from iron particles which become attached to the fabric. Resulting Fe^{3+} ions catalyze "locally" the peroxide decomposition and, with it, the over-oxidation of the cellulose because in the stagnant area of liquor (I) high concentrations of Fe ions exist and unused peroxide is transported to it by the moving liquor (II).

metall/ sample	1	2	3	4	5	6
Al	23	21	32	47	25	22
Ba	1.5	1.5	1.6	12	2.0	1.5
Ca	580	600	840	830	580	630
Cu	3	4	2	5	3	2
Fe	34	100	110	790	36	94
K	4 500	4 600	4 500	5 300	4 700	4 700
Mg	490	510	520	530	520	550
Mn	3.2	3.5	4.0	6.7	3.3	3 7
Na	220	230	230	330	330	320
Ni	dl.	1.2	dl.	2.1	dl.	1.0
P	240	270	260	330	270	270
Pb.	dl.	dl.	dl.	7.6	dl.	dl.
S	340	360	360	430	380	380
Sr	5.4	5.6	5.6	5.9	5.7	6.0
Ti	0.3	0.25	0.7	1.4	0.8	0.7
Zn	4.5	7.3	5.3	35	4.9	13

Tab.: Metal content of the raw cotton fabric of various batches (1–6) in mg metallic ions/kg fabric. dl = virtually undetectable (identification limit with Ni 1 mg/kg and with Pb 3 mg/kg).

Because cotton takes up traces of metal from the finishing bleach process, the decomposition in the presence of iron is important (Fig. 7). At the same time, iron is converted into ferrous ions according to the mechanism depicted in Fig. 8 and then has a catalytic effect on the hydrogen peroxide decomposition as a ferrous ion.

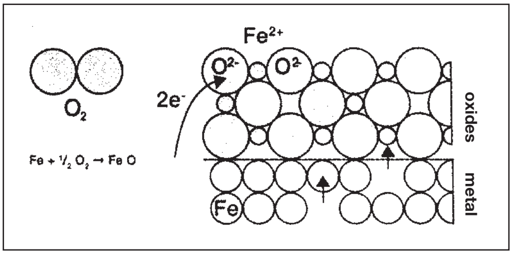


Fig. 8: Conversion of iron into ferrous ions (according to Fornelli).

Studies of Heidemann describe peroxide decomposition by using three regulators common in practice, whose chemical composition is shown in Fig. 9. In Figs. 10 + 11 and in Fig. 12, the time characteristic of the peroxide decomposition is shown at a given temperature, each time in a pH range dependent on the ferric ion concentration, in comparison to a virtually catalyst-free liquor. The concentration range selected up to 10 mg/l ferric ions corresponds here to a practically relevant loading of the liquor when the contamination with iron compounds completely dissolves. Accordingly, a content of 100 mg/kg for a liquor ratio of 1 : 10 and of 10 mg/kg for a liquor ratio of 1 : 1 results, which represents the usual ratios for batch and pad-batch processes.

The findings reveal a different characteristic of peroxide decomposition depending on the type of regulator, which cannot be described by a simple function. For this reason, to represent the dependence of peroxide decomposition on the pH and ferric ion concentration in the bleaching liquor, the decomposition with the same dwell time and temperature is used. As Heidemann's findings, illustrated in Figs. 13–14 and shown in Fig. 15, the peroxide decomposition increases sharply above a regulator-specific, critical pH. As is shown in the example of the magnesium polysilicate regulator, even minimal concentrations of ferric ions of 1 mg/l are

Hydrogen peroxide decomposition

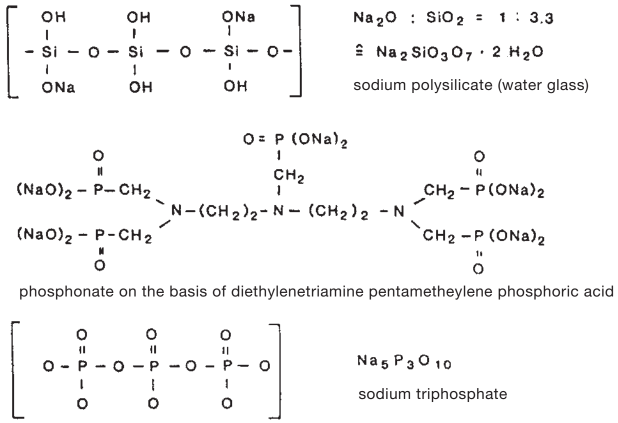


Fig. 9: Regulators used in the peroxide bleach.

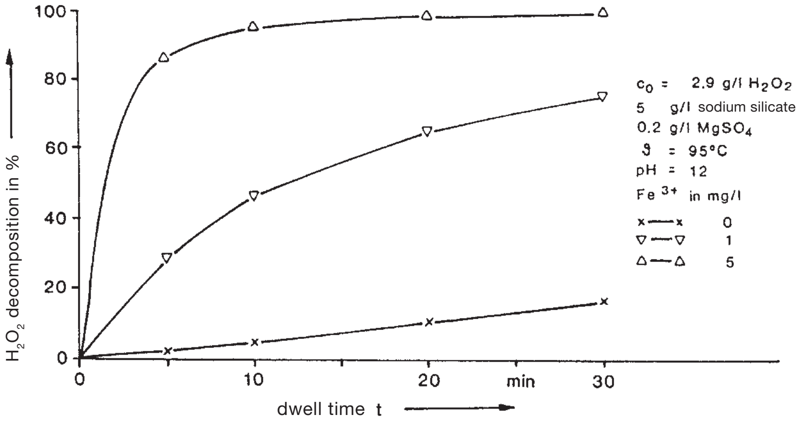


Fig. 10: Peroxide decomposition in bleaching liquors (with sodium silicate) without textile material dependent on the dwell time (according to Heidemann).

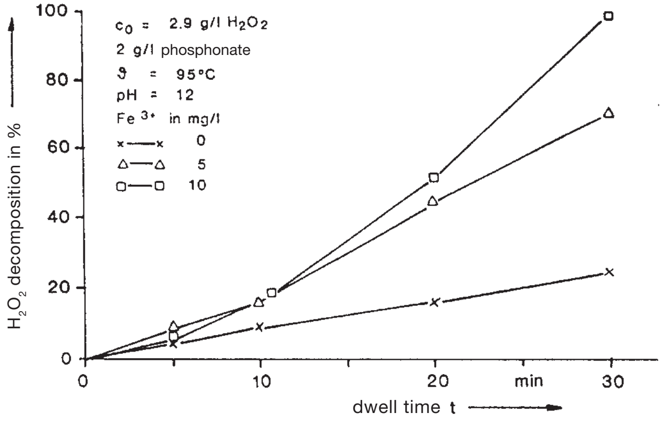


Fig. 11: Peroxide decomposition in bleaching liquors (with phosphonate) without textile material dependent on the dwell time (according to Heidemann).

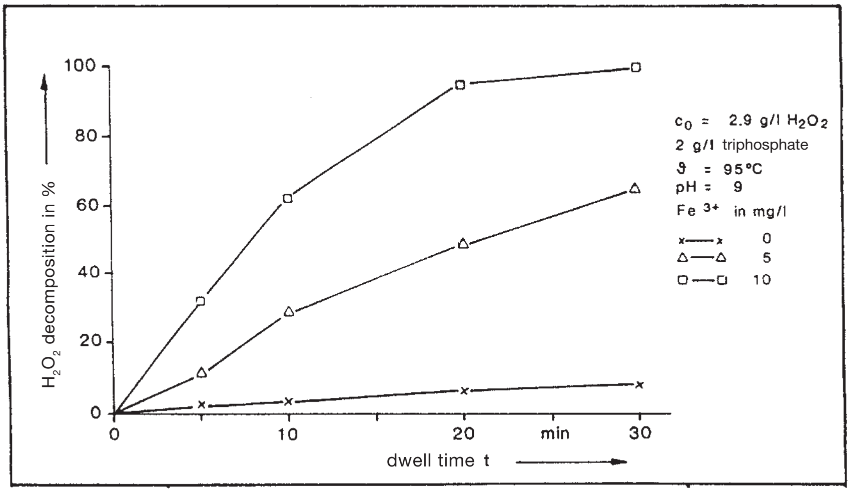


Fig. 12: Peroxide decomposition in bleaching liquors (with triphosphate) without textile material dependent on the dwell time (according to Heidemann).

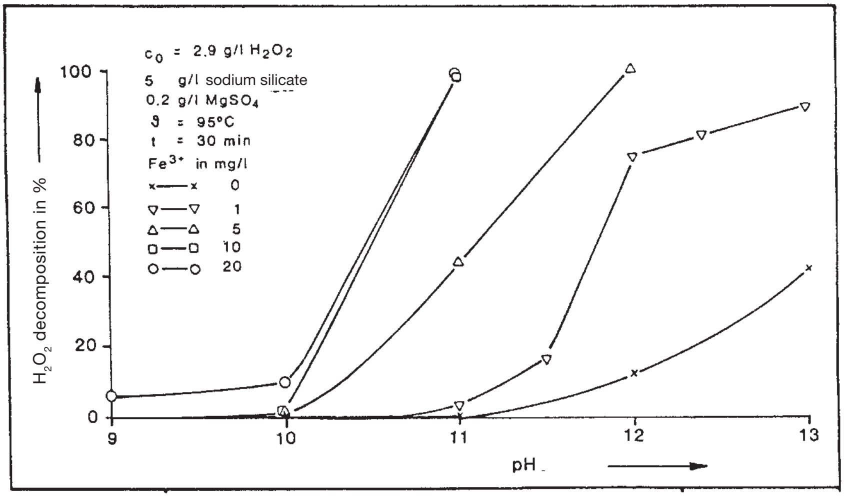


Fig. 13: Peroxide decomposition in bleaching liquors (with sodium silicate) without textile material dependent on the pH (according to Heidemann).

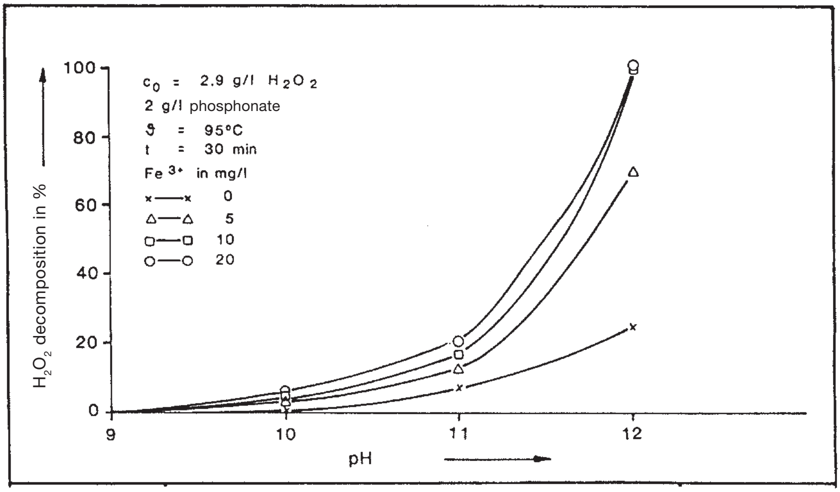


Fig. 14: Peroxide decomposition in bleaching liquors (with phosphonate) without textile material dependent on the pH (according to Heidemann).

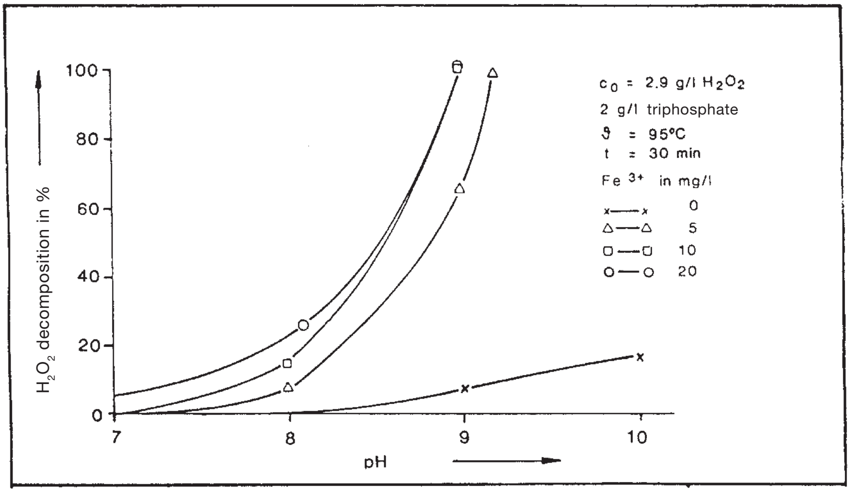


Fig. 15: Peroxide decomposition in bleaching liquors (with triphosphate) without textile material dependent on the pH (according to Heidemann).

enough to trigger greater than average peroxide decomposition above pH 11. The complexing ability of the individual regulators is therefore distinctly pH-dependent. Since complex formation, etc. depends on the concentration of the reaction partner, it is to be expected that, through increasing the concentration of regulators, peroxide decomposition is reduced with a given concentration of ferric ions.

Hydrogen peroxide dry-in process (blanchiment rapide). Since the end of the 1920s, continuous H_2O_2 bleaching of wool has been used, mainly for the brightening or bleaching of loose wool or combed top and occasionally yarn. Operating principle: impregnation with various H_2O_2 solutions, squeezing off and drying, with temporary H_2O_2 concentration, H_2O_2 decomposition and bleaching occurring in the course of the drying process. The degree of whiteness is naturally dependent on the quantity of H_2O_2 present on the fibre. The amount of H_2O_2 per unit of weight of wool used is limited by the levels that lead to damage to the wool. As a working liquor, either a weakly alkaline, weakly acidic or neutral solution of e.g. 20 ml/l H_2O_2 35% w/v is used, depending on the neutral or alkaline quality of the scoured wool.

Hydrogen sulphide test for sulphur dye identification The fibre specimen under test must be freed from substances containing sulphur (sodium dithionite, etc.) by boiling in water with a few drops of sodium carbonate solution. Rinse and boil again with diluted hydrochloric acid until dampened lead acetate paper no longer turns dark. Remove hydrochloric acid. Add stannic chloride/hydrochloric acid solution and warm slowly. If the lead acetate paper is now coloured between brown and black with simultaneous change of colouring to yellow, then sulphur dye is present. Only thioindigo derivatives of vat dyes show a weak reaction to this test after prolonged boiling.

Hydrolases The most extensive main group of → Enzymes which catalyze the hydrolytic cleavage of C–O and C–N bonds in the breakdown of large molecules.

Hydrolysis Chemical reaction of molecules or ions with water to form more molecules or ions. A typical example is the hydrolysis of cellulose, i.e. hydrolytic splitting of cellulose, known as → Hydrocellulose.

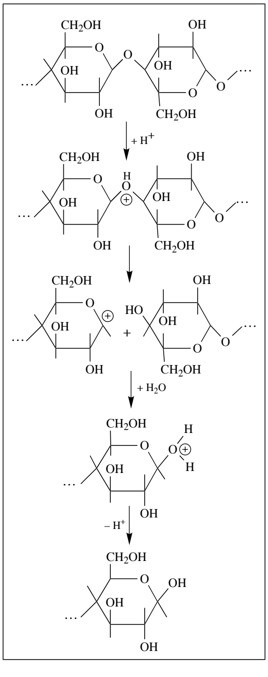


Fig.: Acid-catalysed hydrolysis of cellulose.

The glucosidic bonds in cellulose are split by acid catalysed hydrolysis (see Fig.), where a high yield of d-glucose is created. It is assumed that some glucosidic bonds in which the oxygen atom is initially protonized are weaker towards hydrolysis (compared with the rest of the glucosidic bonds) because an aldehydic or carboxyl group is found near them.

Partial hydrolysis on solution in water occurs with many salts with a slightly acidic or slightly alkaline reaction in water. An excess of H ions (acidic reaction) or OH ions (alkaline reaction) is seen:

salts from			hydrolysing with solution action	type-example
acid		base		
strong	+	weak	→ acid	$Al_2(SO_4)_3$, $ZnCl_2$
weak	+	strong	→ alkaline	Na_2CO_3
strong	+	strong	→ neutral (no hydrolysis!)	NaCl.

Hydrolysis, reversible The effect of water on the ions of a dissolved salt, lead to a state of equilibrium where ions and molecules of the acid or base forming the salt exist together. If the conditions change, acid or base molecules may change back into ions. This is especially significant with salts of weakly organic acids or weakly organic amines with large hydrophobic tails.

Hydrolysis, sensitivity to In the USA, it is normal to neutralise alkaline laundering of resin finished goods with the addition of acidic reacting salts (e.g. zinc silicone fluoride) in the final rinsing-bath, in order to prevent yellowing that can easily occur as a result of hot tumble drying. Overdosing of the acidic salt will create acidity on the fabric, which will affect the finished effect. Hence, fabrics destined for the American Market require the best hydrolysis stability.

Hydrolysis, stability to Resistance of a type of finish, particularly an easy care finish or the resin-finishing agent itself, to acidic or alkaline → Hydrolysis. With insufficient stability to acid hydrolysis, splitting of the cross-linked resin-finishing agent may occur, which considerably impairs the finishing effects; there is no risk with resin finishing in the alkaline range.

Hydrometer A device for measuring the density of liquids consisting of a sealed cylindrical glass tube with a density scale at the upper end and weighted with mercury or lead shot at the lower end. When placed in a liquid, the hydrometer floats upright with the tube partially immersed, the degree of immersion depending on the density of the liquid which can be read off directly from the scale at the liquid/air interface. Hydrometers are based on the principle that the density of a solution corresponds to a particular concentration so that they provide a rapid means of determining the percentage of a dissolved substance in water, e.g. sodium hydroxide, sulphuric acid, etc. The presence of foreign substances leads to incorrect measurements. The lower the density the deeper the hydrometer sinks and vice versa. Different hydrometers are available for liquids with a higher or lower density than water. The scale may be calibrated directly in specific gravity or in arbitrary units such as, e.g. °Bé (Baumé scale) in France and Germany, or °Tw (Twaddell scale) in England.

Since the densities of different substances dissolved in water differ from one another, hydrometer readings have to be compared against tables of densities for the particular substance being measured. In some cases, this can be avoided with special hydrometers for a specific application only, e.g. the alcoholometer, which gives a direct reading of the alcohol content.

Hydrometers do not provide a reliable means for measuring densities of solutions in the following categories: a) old liquors below 1°Bé (specific gravity 1.006), b) chlorine bleach baths (especially used baths), c) solutions containing mixtures of different substances and d) to determine the alkalinity or acidity of a solution.

Hydronium ion → Hydrogen ions.

Hydrophile-lipophile balance → HLB value.

Hydrophile-lipophile ratio The hydrophile-lipophile balance is a measure of the ratio between the hydrophobic and hydrophilic components of a surfactant, i.e. between the → Nonpolar group (lipophilic) and the → Polar group (hydrophilic) and is related to surface activity. It determines the affinity of an emulsifier to water or to weakly polar organic solvents. See → HLB value.

Hydrophilic group Group of molecules whose behaviour towards water is → Endophilic.

Hydrophilic groups – effectiveness comparison Approximate quality classification for practical evalua-

	A	B	C	D
Washing power	3	2	1	3
Dirt carrying capacity	3	2	1	2
Pepticising action	3	2	1	2
Net power	1	2	3	1
Fat emulsifying capacity	1	2	3	3
Foaming power	1	2	3	1
Foam resistance	3	2	1	1
Effectiveness (concentrated)	1	2	3	3
Chemical resistance	0	1	2	3
Resistance to hard water	0	2	3	3
Solubility	1	2	3	3
Colour	2	2	1	2
pH	1	3	3	3
Affinity for wool	3	2	1	1
Affinity for cellulose	2	2	2	2

A = carboxyl, B = sulphate, C = sulphonate,
D = oxyethyl 8-10

Tab.: Effect of different washing agent components on the efficiency of the washing agent (figures explained in the text).

tion of textile auxiliaries. The Table shows comparisons based upon the following values: 0 = no effect, demonstrably bad; 1 = clear effect, acceptable; 2 = Effect notably better, good; 3 = effect pronounced, very good.

Hydrophilic properties of textiles Consideration of the criteria which the consumer uses to make their choice of textiles and their relationship to hydrophilic and hydrophobic properties, gives the following critical properties:

- moisture absorption and transport,
- static charge or discharge of the static charge resulting from friction,
- soiling (dry, wet),
- soil removal with washing and cleaning.

Processes such as water vapour absorption, migration and capillary transport are decisively influenced by the surface characteristics, with a hydrophilic surface being positively assessed from a physiology of clothing perspective. Microporous "breathable" multilayered types (e.g. Gore-Tex, Sympatex) are increasingly gaining in importance. Permanently hydrophilic body contact layers also increase the wearer comfort in such cases.

Definition of the most important terms:

1. Moisture absorption: amount of water on and in the fabric after establishing the equilibrium between the fibre and standard climate humidity (20±2°C, 65±2% relative humidity).
2. Water retention: amount of water retained in the fibre after a defined centrifuge process.
3. Capillary height: measure of the rate at which water is transported in textile fabrics against the force of gravity.
4. Water absorption ability: amount of water (in %) which a textile fabric, adapted to the standard climate, absorbs from immersion in water.
5. Wetting: primary: surface spreading of a fluid; secondary: associated with deep penetration. Wetting may also be expressed as a function of time and surfactant concentration. It is also controlled by interaction of the surface tension at the limits of the fixed and fluid stage.
6. Penetration: ability of a fluid (e.g. water) to completely penetrate a textile material (effect below the fibre surface).
7. Heat of hydration: the heat that is released with the hydration (wetting) of dry fibres with water and is regarded as a measure of the hydrophilic property. Apart from the actual fibre's hydrophilic property, it is also dependent on the moisture content of fibres prior to wetting. A fibre whose moisture content reaches the saturation limit, produces a heat of hydration which is equal to zero. Some values of dry fibres:
    - wool 113.1 kJ/g
    - polyamide 31.8 kJ/g
    - polyester 3.4 kJ/g
8. Fibre wettability: wettability of the fibre capillaries.
9. Hygroscopicity: swelling capacity (sorption) of the fibrous material in water.

The wettability of the fibres depends on the chemical groups found on their surface that are able to accumulate water (e.g. by means of hydrogen bonds, ion and dipole forces). A distinction is made between:

- strongly hydrophilic groups $-S0_3H$
  $-COO^-$
  $-SO_3^-$
- weakly hydrophilic groups OH
  OR
  $-NH_2$
  $>C=O$

In addition, the wetting is also dependent on the surface tension of the wetting fluid, as well as on the physical parameters such as temperature, time and surface character. The assessment of hydrophilic property is either direct or indirect:

Direct methods:

- test of water retention ability (in %),
- test of moisture transport and moisture bonding power,
- calorimetric test of the heat of hydration of dry fibres.

Indirect methods:

- wetting values of fibres (time),
- capillary rise (time and height),
- wicking time (water spreading time in s),
- test of the static charge and discharge (e.g. field decomposition half-life [F_{HZ}] in s),
- soil release and soil redeposition behaviour.

A single methods as listed is not enough to permit a reliable evaluation of the hydrophilic property. This requires at least the following tests:

- moisture bonding power at a constant temperature,
- water retention ability.

The indirect methods are influenced above all by the wetting effect of the products, which does not develop parallel to the hydrophilic property. Hence a wetting agent may, for example, significantly improve the absorbency and capillary rise without, however, affecting the moisture transport.

Hydrophilic property Tendency of a material, to take up water (opposite → Hydrophobic).

Hydrophilic rendering property Ability to make soluble, e.g. with textile auxiliaries the elimination of water insoluble of hydrophobic hydrocarbon groups and increase of → Hydrophilic group which, owing to their great affinity with water, enable hydration and dispersion of the textile auxiliary to take place. This occurs in auxiliaries with ionic or non-ionic groups.

Hydrophilic treatment process Process for increasing the absorbency of textiles made of synthetic fibres. Through improved absorption of moisture and perspiration, the treated garments, stockings etc., are more pleasant to wear. Principle: e.g. impregnation with a dispersion of polyamide derivatives.

Hydrophobic Property of a material to have a water-repellent effect (opposite → Hydrophilic property).

Hydrophobic finishes, evaluation of To assist in determining the hydrophobic properties, there is:

I. Rain test according to Bundesmann (DIN 53 888): Here a test specimen is held under tension whilst a fixed quantity of water is "rained" upon it. At the same time, a device rubs the fabric from the underside with a turning motion. Any water passing through the cloth is collected in a glass beaker and its volume measured. Any surface water is removed by centrifuge and any weight increase for the test specimen is determined. The amount of water absorbed by the sample and passing through the sample serve as a measure of its performance. In addition, the water-pearl effect is determined visually by comparing the appearance of the specimen with a series of standard appearance pictures.

II. Spray test (following AATCC 22-1971): This assesses the water-pearl effect. The test device (Fig.) allows a gentle spray of water to fall on a pre-tensioned test specimen at an angle of 45°. 250 ml of water is sprayed during 30 s, the test specimen is then struck twice to loosen surface held water and any remaining water and wet-out area is assessed. A value from 0 (worst) to 100 (best) is rated by visual comparison with standard appearance pictures.

III. Tegewa drop test: Method for determining the absorbency. The fabric under test is held without tension whilst defined size droplets (0.050 ml ±10%) of a 2% solution of patent blue V are applied from a height of 40 mm. The absorption time of the drops and the diameter of any staining is recorded.

Hydrophobic group Group of molecules whose behaviour towards water is → Exophilic.

Hydrophobic interactions If non-polar molecules such as hexane are introduced into water, then they will tend to congregate to form larger units. At the same time a "cavity"is formed in the water that was previously homegeneous, in which a number of hydrogen bonds of the water (→ Iceberg structure of water) are temporarily broken. The water molecules suppressed in this way reorientate themselves to form a maximum number of hydrogen bonds again, even if the opportunities for doing so are limited in the immediate vicinity of the hexane micelle. The water molecules around the hexane micelle are inevitably arranged higher than otherwise in the homogeneous solution, while the entropy of the solution decreases due to the absorption of the hexane. Non-polar molecules do not associate in the water because they have a greater affinity to each other, but because water molecules are forced into more bonds with each other due to their presence. Polar interactions (e.g. in salts) are weakened by water (salt dissolves in water).

Not only salt linkages or ion-pair bonds, but also hydrogen bonds are weak in the presence of water (e.g. in a protein solution or in a swollen fibre protein such as wool). It is in the presence of water, however, that the hydrophobic interactions have a stabilizing effect. These come about because the numerous non-polar side chains with a paraffin or benzole structure also

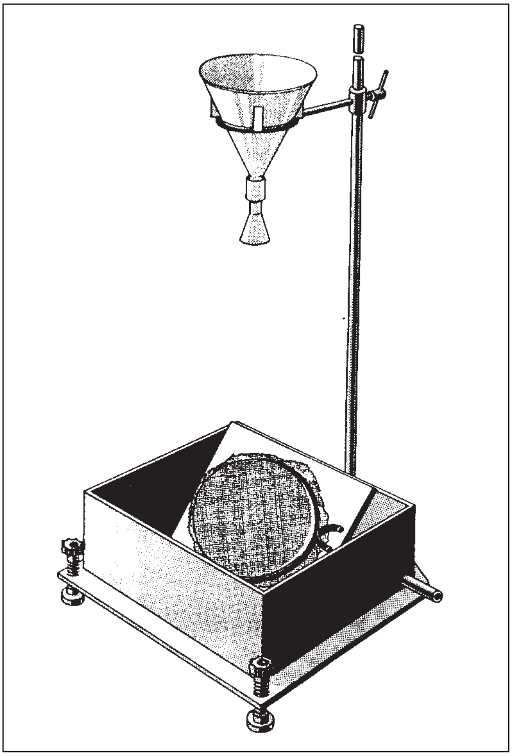


Fig.: Spray test apparatus for hydrophobic effect evaluation.

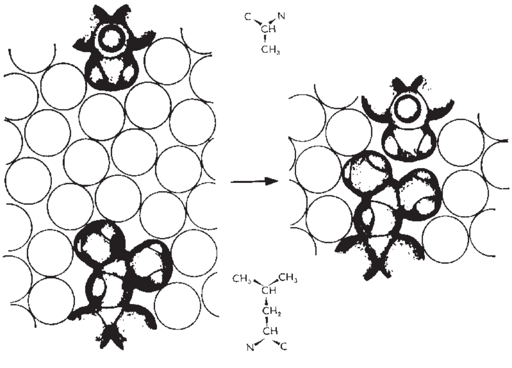


Fig.: Approximation of protein-bonded methyl groups due to hydrophobic interactions in water.

built into the wool congregate in a micelle-type manner inside the protein molecule, in order to withdraw from the aqueous environment of the solvent or swelling agent. As a result of the agglomeration of the non-polar groups, the contact area between the non-polar groups and the solvent water is reduced to a minimum (see Fig.). Hydrophobic interactions, on the other hand, are weakened in alcohol.

Hydroplastic Deformable in the wet state, e.g. cotton through hydrate formation of the cellulose OH groups, where even slight quantities of water in humid air are enough to break the hydrogen bonds produced by OH groups. → Thermoplastics.

Hydroplasticity factor The wearing properties of textiles made from regenerated cellulose fibres depend, among other things, on the wet and dry crease angles. Both should be in a certain ratio to each other. A good dry crease angle in itself is not sufficient.

Hydropneumatic fabric guiding system This may have, for example, 4 control rollers and a width-adjustable scanning head (for non-contacting control of the material's edge), which emits a control impulse for the hydrocylinder via a hydropneumatic relay, which then in turn moves the 4 control rolls in an appropriate way to control the fabric.

Hydropulsation Perforated drum-Pulsing-Open width washing machine especially for process-sensitive and extremely loosely constructed fabric. With dwell section (over immersed incline that lays the cloth onto a perforated conveyor belt) and pulsation perforated drum. Fold height and layer thickness controlled by belt speed. Overflow height and liquor flow rate. – Manuf.: Hemmer.

Hydro salts e.g. → Sodium dithionite.

Hydrosol → Colloidal solution in water.

Hydrosulphite → Sodium dithionite.

Hydrosulphite discharges (→ Reductive discharges), sodium dithionite has not completely replaced tin salt- and zinc-dust stripping (too rapid decomposition in alkaline solution). Against it, → Formaldehyde sulphoxylates strips are widely used (better stability and protection of cellulose fibres).

Hydrosulphite-glucose vat This is used mainly with → Sulphoxylates together with glucose, resulting in increased reductive capacity and stability.

Hydrosulphite vat Reduction vat used in vat dyeing and in indigo-sodium dithionite vats. Sodium dithionite reduction baths prodcue sulphate as an end-product (concrete-aggressive).

Hydrosulphuric acid → Thiosulphuric acid.

Hydrotimeter Special burette with graduations according to German degrees of hardness for (total) → Water hardness, determination of, after Boutron and Boudet.

Hydrotrope Registered trade name for a group of substances which show → Hydrotropic property and are used in the detergents industry.

Hydrotropic property The ability to improve the solubility of compounds which are either of low solubility or insoluble, e.g. to turn completely water-insoluble hydrocarbons, chlorinated hydrocarbons, mineral oils, fats, etc. into an aqueous solution or at least an emulsion form, as required by many fat-dissolving soaps, stain removers, emulsions, etc.

compound	solubility in dist. water	100 ml with 25 °C 40% sulphonate sol.
ethyl acetate	8.80 ml	42.60 ml
benzole	0.16 ml	0.37 ml
toluene	0.04 ml	1.20 ml
calcium sulphate	0.22 g	0.48 g

Tab.: Hydrotropic dispersion of the strong hydrotrope meta-xylosulphate-Na (after Booth/Everson).

Hydrotropic property is therefore the ability to confer solubility, where a low solubility substance dissolves or has improved solubility when the added substance is not a solvent for the dissolved substance (Table); such substances, are known as hydrotropic agents (hydrotropes). If the substance is an interfacial active compound, one also talks of → Solubilisation. The solvency is based on a strong reduction in the surface tension of the water and the dispersion effect on the poorly soluble substance. The hydrotropic substances work as

- wetting agents, dispersing agents, penetrating agents or detergents, or as
- emulsifiers, stabilisers.

The dissolved substances in the solutions, emulsions, dispersions may be subsequently separated by dilution. The modes of action of the auxiliary substances are very varied. However, no chemical reactions take place between the components. If the auxiliary agent is a surfactant, for example, the reason for the improved solubility is to be found in the fact that the solubility of the poorly soluble substance is greater in the surfactant micelles than in the aqueous phase of the individual surfactant molecules. "Structure breakers" are substances such as urea and short-chain acid amides, especially N methyl acetamide. They break down the water structure around the hydrophobic group of a poorly soluble substance. It is assumed that these substances are only found for geometric reasons in unstructured areas of water and that they reduce the chemical potential of these areas. At the same time, they break down three-dimensional water structures just as an iceberg melts ("iceberg hypothesis"). An increase in the solubility may also be achieved in some cases by the poorly soluble substance forming mixed crystals with the auxiliary substance. Hydrotropic substances are usually strong electrolytes with a polar hydrophile molecular part, e.g.

carboxyl groups, hydroxyl groups, sulpho groups, sulphide groups, and with an apolar organophile hydrophobic molecular part such as aliphatic, aromatic, saturated cyclic, alicyclic and heterocyclic hydrocarbon groups. Aqueous solutions of the alkaline and alkaline-earth salts of these compounds are used. The substances dissolved are, for example:

- phenols
- high-molecular alcohols
- nitrobenzene
- aniline
- proteins
- carbohydrates.

Hydrotropic solutions are used in chemical reactions such as hydrolysis and condensation, in the manufacture of detergents, cosmetics, azo dyes (coupling of diazonium compounds with amines that are poorly soluble in water), and in electrolysis. Compared with organic solvents, hydrotropic solutions are, among other things, non-volatile, non-flammable, readily capable of being regenerated. They demonstrate good electrical conductivity and their solvent effect is independent of the pH.

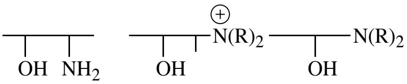
Hydroxides Compound or radicals with → Hydroxyl group. They usually form alkalis (or bases) with metals, alkaline metals, alkaline-earth metals; exceptions: permanganic and chromic acid. With non-metals, on the other hand, they form acids (boric, silicic, sulphuric, etc.). Organic hydroxides are described as either → Alcohols (non-ionising OH) or → Acids (hydrogen ion-eliminating hydroxyl → Phenols).

Hydroxonium-ion → Hydrogen ions.

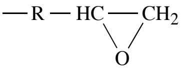
Hydroxy- Name for complex-bound hydroxyl (→ Hydroxyl group).

Hydroxyacetone Rarely used reducing agent for water-soluble sulphur dyestuffs.

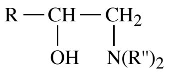
Hydroxy amines (hydroxyalkylamines), class of → Fatty amines:



through complex industrial processing as longer chain olefin epoxides:



through replacement of the reactive H atom to:



$$R-\underset{\displaystyle OH}{\underset{|}{CH}}-\underset{\displaystyle N(R'')_2}{\underset{|}{CH_2}}$$

The resultant hydroxy amines are similar to the fatty amines in their properties and may replace these in their classical areas of application. Tertiary hydroxy amines can be alkylated to quaternary ammonium compounds and convert to betaines or sulphobetaines or oxydised to amine oxides. They have surface active properties, some with anti-microbial action and are used in the manufacture of textile auxiliaries, rinsing, disinfecting and softening agents.

Hydroxyethyl cellulose Non-ionic, water-soluble → Cellulose derivatives (cellulose ether) in various states of viscosity.

Hydroxyethyl or hydroxypropyl starches Important → Starch ethers as conversion product of starch with ethylene or propylene oxide (in presence of alkali). Degree of etherification of 0.3–0.5 produces good water-solubility and avoids any tendency to reversal of the reaction.

Hydroxylapatite Phosphate water softening (→ Phosphate process for softening and silicate removal) usually based on tricalcium phosphate, results in calcium-rich complex salts.

Hydroxyl group (OH group), typical component of → Bases (→ Hydroxides), alcohols and acids (as an auxochrome in dyestuffs), caustic soda liquor, phenol. As a dissociated component of water-soluble compounds, the hydroxyl group is the source of the alkaline reaction and degree of alkalinity (→ Hydrogen-ion concentration).

Hydroxy methylation reaction of synthetic resin compounds The reaction kinetics of the manufacture of reactant resins are believed to occur via the hydroxy methylation reaction on the ionized form of the basic compounds. It is important that the marketed products contain the least free formaldehyde possible so that both the direct cross-linking of the cellulose with formaldehyde and chlorine retention by free NH groups are avoided. Understanding the mechanism of the reaction allows control over the equilibrium of the reaction mixture and prediction of the finishing process results. When the intermediate products are considered, there are two basic mechanisms possible.

With the acid catalysed hydroxy methylation reaction (Fig. 1) formaldehyde is activated by the addition of a proton (1). The carbonium ion reacts with the NH group-containing compound (2) until a protonized N hydroxy methyl compound is formed, which deprotonizes at the next stage (3). The alklaine catalysed reaction starts with the NH group-containing compound (4). The reaction rate is determined by the bimolecular reaction (5) and leads to the formation of the hydroxy methyl anion. The latter reacts quickly with the protonized base, causing a hydroxy methyl compound to be formed (6).

Another view of the trimolecular mechanism is reaction mechanism 2 (Fig. 2). Here two relatively stable

ACIDIC CATALYSIS:

$$CH_2O + H^+ \rightleftharpoons {}^+CH_2OH \qquad (1)$$

$$>NH + {}^+CH_2OH \rightleftharpoons >{}^+NH{-}CH_2OH \qquad (2)$$

$$>{}^+NH{-}CH_2OH \rightleftharpoons >NH{-}CH_2OH + H^+ \qquad (3)$$

BASIC CATALYSIS:

$$>NH + B \rightleftharpoons >N^- + BH^+ \qquad (4)$$

$$>N^- + CH_2O \rightleftharpoons >N{-}CH_2O^- \qquad (5)$$

$$>N{-}CH_2O^- + BH^+ \rightleftharpoons >N{-}CH_2OH + B \qquad (6)$$

Fig. 1: Reaction mechanism 1.

addition products are formed, and the addition of the third participant in the reaction proceeds according to the scheme of the general acid-alkaline catalysis without proton transfer, avoiding the trimolecular mechanism.

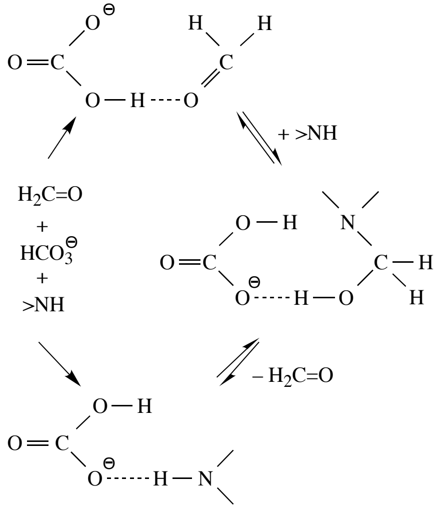


Fig. 2: Reaction mechanism 2.

The reaction mechanism is the same for both pure compounds and for mixtures: the catalyst probably participates to a small extent, with the transitional state representing the ionized form of the basic compound. The presence of acetyl di-urea does not affect the process kinetics, nor the production suitability. The speed of the hydroxy methylation reaction for 4.5 dihydroxyimidazolidone and acetyl urea as well as the activation energies vary, which is probably attributable to the non-comparable energy state of the non-active molecules. The weak N-C bond probably favours the redistribution of the formaldehyde in that the second NH group of the 4.5 dihydroxyimidazolidone is hydroxy methylated. However, the synthetic resin manufactured from the market production of the three substances should not affect the suitability of the textile product any worse than resin finishing using product on the sole basis of 1.3 to (hydroxy methyl) 4.4 dihydroxyimidazolidone 2.

Hydroxypropylmethyl cellulose Methyl-hydroxypropyl cellulose, a mixed cellulose ether used as a greying inhibitor.

Hygienic laundering care Laundering of textiles, a) in accordance with the guidelines laid down by the Bundesgesundheitsamt (Federal Ministry of Health) in Germany for the disinfection of laundry and b) according to the guidelines laid down by the → Gütegemeinschaft für sachgerechte Pflege (Quality Mark Association in Germany) for appropriate laundering care.

Hygienic state Extensive removal of pathogens from the textile material, e.g. with → Textile care.

Hygral expansion Change in length per 1% change in the moisture content. Has a fundamental effect on shrinkage values. Hygral expansion and relaxation shrinkage are the two main causes of the dimensional instability of woollen fabrics, a further cause being ironing shrinkage.

1. Relaxation shrinkage is irreversible. It occurs through the relaxation of prior temporarily set tensions that develop during the fabric processing. Such tensions occur most frequently during the finishing processes, particularly with dry finishing such as shearing, pressing, decatising (especially roller decatising).
2. Hygral expansion effects, on the other hand, are the dimensional changes that occur through changes to the (woollen) fabrics. The amount of hygral change depends chiefly on the fabric structure and the degree of fixation. The more the yarn is crimped by the cross-linking, the greater is the hygral expansion. With stronger fixation in finishing, higher hygral expansion values are found in comparison to a lower degree of fixation. Hence a reversible dimensional change occurs with the hygral expansion, which is determined by the fluctuating moisture content of the woollen fabric (→ Hysteresis).
3. Ironing shrinkage occurs on the steam press. The dimensional changes here may consist of the addition of relaxation and hygral changes.

Hygrometer Indicating device for relative humidity. The most important is the hair hygrometer, with a measuring element consisting of specially degreased and prepared human hair or a bundle of hair. Under the influence of changing humidity, these hair elements will show a change in length that is converted into changes on a scale calibrated in % relative humidity. With the larger hygrometers, used for monitoring relative humidity in factory areas, the measuring element is only used as an indicator and the values are converted via an electromechanical control device and an electric motor drives the display unit (unit connection 220 volt a.c.). Contact hygrometers are hygrometers with an electrical contact device for measuring relative humidity. Built-in hygrometers, with a rear-ventilated mounting, are inserted into air ducts, dry rooms, etc. for taking measurements.

Hygroscopic agents Water-absorbing products as additives for finishes, printing pastes, sizes, to balance the air and fibre moisture and influence the fabric weight and handle.

Hygrotester German appliance for electrical → Moisture content measurement.

Hyperfiltration → Reverse osmosis.

Hyphomycetes → Moulds.

Hypo- (Gk.), prefix with the meaning of “under, beneath, below”. In chemistry it is used to identify compounds in which the central atom is found in a lower state of oxidation than is normally the case.

Hypochlorite bleach Bleaching with sodium hypochlorite is seldom used as a single bleaching stage. The chief importance of this process is based on the following facts. Since peroxide bleaching is associated with a tendency to cause catalytic damage to cellulosic fibres in the presence of heavy metal ions, the inclusion of a prior hypochlorite bleach in the continuous bleaching of woven fabrics has made it possible to employ milder conditions in subsequent peroxide bleaching. This measure thus ensures a high degree of white with a greatly reduced risk of catalytic damage. At the same time, a reduction in chemical costs is realized for the production of full whites with this combined process in comparison to a pure peroxide bleach. The combined sodium hypochlorite/hydrogen peroxide bleach offers the following advantages for the continuous bleaching of woven fabrics:

a) high process reliability,
b) low risk of fibre damage,
c) uniform whiteness (which is, to a large extent, independent of the cotton fibre provenance),
d) cost-effective process.

As a disadvantage, however, is the fact that chloroform has been identified in effluents from bleaching plants originating from the hypochlorite bleach. Such waste waters therefore give rise to increased → AOX values.

The reaction mechanism of hypochlorite bleaching proceeds as follows:

hydrolysis:

$$NaOCl + H_2O \rightleftharpoons NaOH + HOCl$$

bleaching agent release:

$$HOCl \longrightarrow HCl + O$$

max. HOCl development:

$$NaOCl + HCl \longrightarrow NaCl + HOCl$$

formation of free chlorine:

$$HOCl + HCl \rightleftharpoons H_2O + Cl_2$$

The actual bleaching agent is not the sodium hypochlorite (NaOCl) itself but the hypochlorous acid (HOCl) produced from it (see Fig.). The concentration of the actual bleaching agent HOCl in bleach liquors is greatly dependent on the pH. In order to ensure mild bleaching conditions, a pH range between 9–11.5 must therefore be selected. Since, under practical conditions, pH levels below 10 are difficult to keep constant, an initial pH beween 11–12.5 is selected as a rule in order to take into account consumption of caustic soda by the cotton. → Chlorine bleaching; Sodium hypochlorite bleaching.

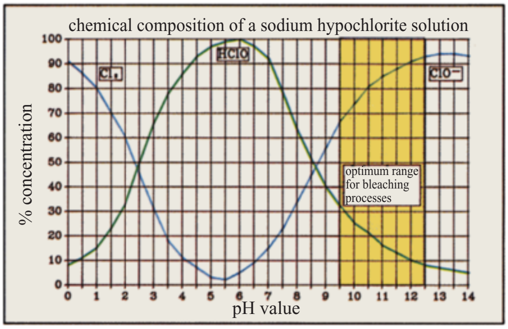


Fig.: Chemical composition of sodium hypochlorite bleaching liquors at different pH.

Hypochlorite bleach fastness Resistance of the shade to hypochlorite bleach.

Hypochlorite oxy acids → Chlorine oxoacids.

Hypochlorite-Peroxide Bleach → Chlorine-Peroxide bleach.

Hypochlorites Salts of the hypochlorite → Chlorine oxoacids.

Hypochlorite wash fastness → Fastness to washing.

Hypocotyl Botanical description for part of the embryo plant, e.g. with → Bast fibres, the transitional stage from the root to the stem. Hypokotyl fibres: bast fibres already existing in the hypocotyl below the cotyledon axis, individual fibres up to 15 mm long, still very uneven, wooden, brittle, low strength, technologically without value. Mechanically destroyed in fibre extraction.

Hypohalide Compound form: Hypo and → Halides.

Hypophosphites → Phosphoric acids.

Hyposulphite → Sodium hyposulphite.

Hypothetical As yet unproven scientific assumption, e.g. listing of hypothetical structural formulae.

Hypsochromic group Substituent group that causes a hypsochromic shift in dyestuff synthesis. Opposite of the → Bathochromic group.

Hysteresis (Gk.: remaining behind), elastic aftereffect, i.e. the change in form by which some (e.g.

rubber-like) substances do not recover fully or only recover slowly once the elastic stress has ceased to be applied (see Fig.).

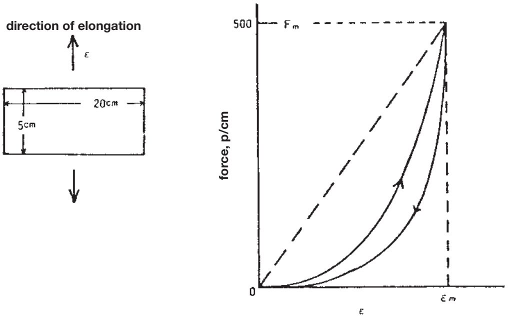


Fig.: Curve of the determination of tensile elastic properties of a textile fabric.

1. Fibres with different loading and subsequent unloading show varied functions f (fibre behaviour) = (type of loading). The diagram shows a typical hysteresis curve, for the load:un-load cycles, where the curves are not identical.

2. In the Kawabata handle evaluation system, any hysteresis recorded is evaluated in relation to
- shearing hysteresis width of load:un-load curves
- recovery ability with elasticity of elongation measurement
- bending hysteresis width
- hysteresis with compression measurements.

3. The hygral expansion or contraction of woollen fibres also follows an hysteresis. Hygral expansion, a special property of all fabrics made of hygroscopic fibres, can be observed most often with woollen fibres due to their specific swelling properties. The scale of this only temporary dimensional change depends in part on the degree of fixation, though chiefly on the fabric structure, and can be predicted in most cases. Relaxation shrinkage and hygral expansion may overlap, which is why the hygral expansion can only be determined from test specimens which are completely relaxed, i.e. through repeated immersion in warm water, and dried free from tension. Each moisture content corresponds to a particular length and width, whereby the hysteresis needs to be taken into account: with a definite moisture content, the dimensions are somewhat larger if the moist state is reached by evaporation from the wet side than they are by adsorption of moisture from the dry side. This effect is really small with normal worsted fabrics, but may become quite marked with fabrics that have an open structure.

The hygral expansion has its origin in the fibres themselves: if the moisture content of a practically dry, crimped woollen fibre (moisture content approximating 0%) is increased, then swelling of around 16% will occur in a radial direction even before the saturation limit is reached, while the swelling simultaneously taking place in a longitudinal direction is slightly more than 1%. The consequence of the radial swelling is that the fibres stretch or straighten, which is equivalent to an enlargement of the span of the curl geometry or to an extension of the arc radius. Theoretically, the radius of the arc should increase by 16% as the fibre changes from the dry to the moisture-saturated state, which has actually proved to be the case with coarser fibres such as Lincoln wool. With finer wools, such as merino fibres, the change in the arc radius is on average 52% higher. Orthocortex and paracortex are arranged side by side in such fibres. If a fibre is bent with this cortex arrangement, then it will turn in such a way that the paracortex lies on the inner side of the curvature and the orthocortex on the outer side. In the same orientation, both cortex segments are located in the growth-based curves of the natural fibre crimp. Hence, the differences in the distribution of the cortex parts seem to be chiefly responsible for the greater changes in the arc radius found with finer fibres. If the moisture content of the fibre again drops to its original value, then in all cases the radius of the arc also returns more or less to its previous value, with the result that the fibre regains its original length. Consequently, whenever the moisture content of the fibre is either increased or decreased, an expansion or contraction will occur in a longitudinal direction, but on two different "paths" in the diagram "Moisture content expansion".

Hz, symbol for → Hertz.

I

I,

I. Chemical symbol for iodine (53).

II. Indanthren symbol → Indanthren Trademark Association.

IAQ, abbrev. for: International Association for Quality. A U.S.-based quality control organization. → Technical and professional organizations.

IBK (Ger.), abbrev. for: Internationale Beleuchtungskommission (Commission Internationale d'Éclairage → CIE); → Technical and professional organizations.

IBN (Fr.), abbrev. for: Institute Belge de Normalisation, Brussels, Belgium. Belgian standards organization. → Technical and professional organizations.

ICAR Indian textile research organization. → Technical and professional organizations.

ICC, abbrev. for: International Cooperation Committee (for the testing and classification of textile floor-coverings). Members: Austria (ÖTI), Switzerland (EMPA), Federal Republic of Germany (TFI), Spain (IME), Italy (Grupo Italiano Prod. Tappeti e Moquettes). → Technical and professional organizations.

Iceberg structure of water Of all known liquids water has the highest heat of vaporization per gram. The reason for this particularly high value is the network of hydrogen bonds which still hold the structure of water molecules together even in the liquid state. In the iceberg or cluster model of the structure of liquid water, more or less small clusters of of water molecules are held together by hydrogen bonding in an ice-like structure. The hydrogen bonds are constantly disintegrating and reforming (Fig. 1) so that at one instant a certain molecule can be bound to another and in the next instant become freely mobile again. These bonds must be broken if the liquid is to evaporate. To achieve this, energy is necessary, which results in a higher heat of vaporization than for liquids without hydrogen bonds (e.g. tetrachloroethylene).

Hydrogen bonds between O- and H- atoms in different molecules are closed and broken again over time. On average, the percentage of H atoms participating in the hydrogen bonding remains constant although individual bonds are continually changing. At a particular moment, perhaps one group of molecules forms an ice-like cluster, and a moment later, another group is bound in a cluster (Fig. 2), or an individual water molecule (e.g. at room temperature) momentarily as such before becoming bound in the cluster again.

Ice colours Produced directly on the fibre by preparing cotton with beta-naphthol followed by development with ice-cooled diazotized aniline. Obsolete process; now substituted by Naphthol AS types.

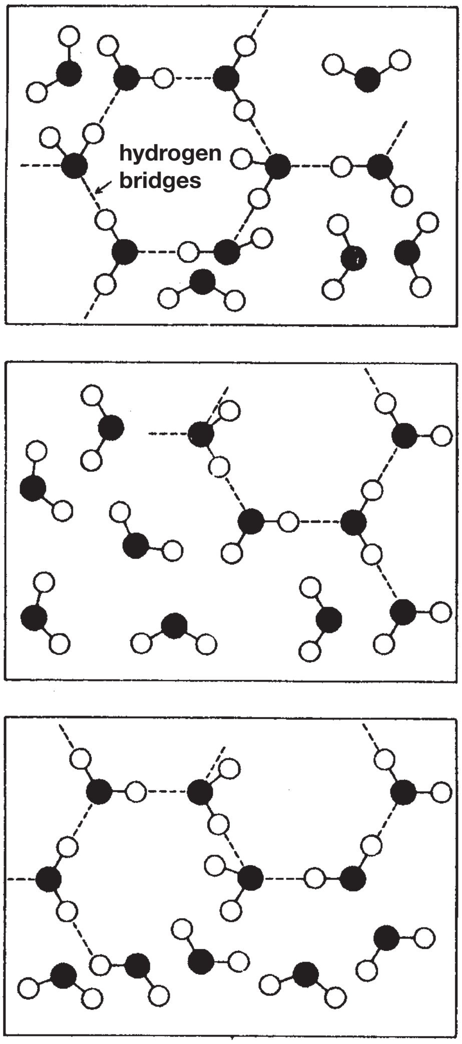


Fig. 1: Three momentary conditions of liquid water molecules.

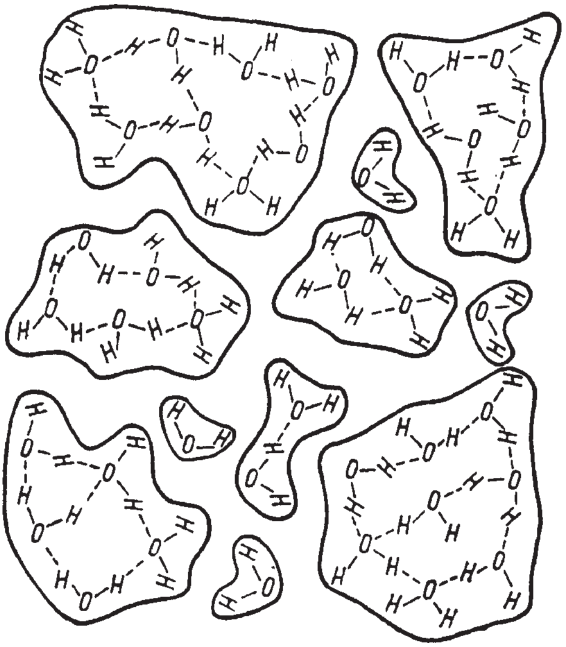


Fig. 2: Cluster model (iceberg structure) of liquid water.

Iceland moss This is the name given to islandicus lichen or Cetraria islandica, a lichen from the northern countries which is exported from Iceland, Norway and Sweden. Phenotype: Fruticose, bushy, lobed upwards, with bark on both sides, base tapered, drop-like, tubular, leathery, 10–15 cm in height; colour: olive green to light, otherwise grey-white. Reddish base, dried; top greenish brown, underside grey. Approx. 60% mass is released from the powdered lichen during boiling with very diluted sodium hydrogen carbonate solution, and a gelatine is formed when the solution is cooled. The extract consists of a polysaccharide mix of lichenins and isolichenins, a range of lichen acids (fumaric protocetraric acid, protocetraric acid and cetraric acid) and protolichesterinic acid which is converted into lichesterinic acid during processing. Usage: for sizing, proofing and printing thickeners.

ICR (Ger.), abbrev. for: Informationsstelle Chemischreinigung, Stuttgart, Germany (German Information Office for Drycleaning); → Technical and professional organizations.

Ideal black (physical). A black which absorbs 100% of the incident light at all wavelengths, i.e. the reflection amounts to zero. See also → Ideal white.

Ideal white (physical). Also described as normal white; closely approximated with barium sulphate with a reference point ≅ 100. In colour space it corresponds to the → Achromatic point, to which a colour approximates after bleaching. Ideal white is a borderline case insofar as 100% of the incident light is reflected at each wavelength (counter term: → Ideal black). The commonly used term "100% reflection" corresponds to the spectral energy factor β = 1 (also described as the luminance factor β).

Idle machine time → Useful life of working.

IDRC, abbrev. for: International Drycleaning Research Committee. Contact organization of the drycleaning research offices of different countries. → Technical and professional organizations.

IEK, abbrev. for: italienische Echtheitskommission (Italian Fastness Commission); → Technical and professional organizations.

IFAI, abbrev. for: Industrial Fabrics Association International.

IFAT (Ger.), abbrev. for: internationale Fachmesse für Abwasser- und Abfalltechnik, Munich, Germany (German international trade fair for waste water and waste technology).

IFATCC, abbrev. for: International Federation of Associations of Textile Chemists and Colorists; → Technical and professional organizations.

IfT (Ger.), abbrev. for: Institut für Textiltechnik der RWTH Aachen, Germany (Institute for Textile Engineering); → Technical and professional organizations.

IFVTCC (Ger.), abbrev. for: Internationale Föderation der Vereine der Textilchemiker und Coloristen (International Federation of Associations of Textile Chemists and Colorists); → Technical and professional organizations.

Igedo (Ger.), abbrev. for: Interessengemeinschaft Damenoberbekleidung (Community of Interest for Ladies' Outerwear). Responsible since 1949 for the "Internationaler Modemesse" (International Fashion Fair) held each Spring and Autumn in Düsseldorf, Germany.

Ignition In the sense of flammability testing, ignition represents the initiation of the burning process. → Burning behaviour of textiles.

Ignition point,

I. → Spontaneous ignition temperature (SIT).

II. The specific point (see Fig.) on a textile specimen at which a → Flammability test is initiated.

Ignition point of flammable liquids → Flammable liquids.

Ignition time (minimum ignition time). The ignition time is the time required to ignite a textile material under the conditions prescribed in a flammability test. That is, the time it takes to achieve continuous independent combustion. → Burning behaviour of textiles.

IGPAI (Port.), abbrev. for: Inspeccão General dos Productos Agrícolas e Industriais, Reparticão de Normalizacão, Lisbon, Portugal (General Inspectorate for Agricultural and Industrial Products, Department of Standards. → Technical and professional organizations.

IIC, abbrev. for: International Institute for Cotton (GB); → Technical and professional organizations.

IIRSC Irish Standards Organization; → Technical and professional organizations.

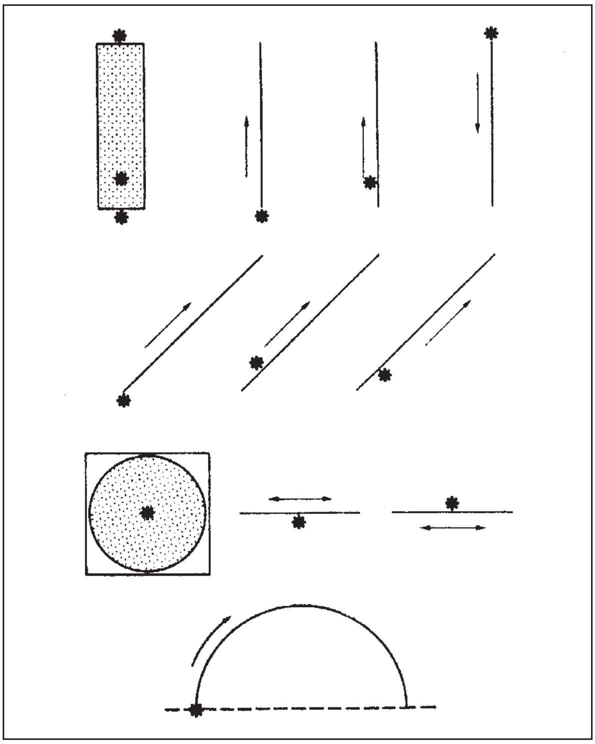


Fig.: Ignition points (*) of samples in standard flammability tests (arrow = direction of combustion).

Ikat The word "ikat" is derived from a Malaysian word *mengikat*, which means to tie, knot, bind or wind. In this technique, attractive designs are produced by the successive localized application of dyes to threads before weaving. The technique was also highly developed in Indonesia, India, Madagascar, Central and South America, etc. In ikat dyeing, predetermined sections of the threads are bound tightly, knotted, or otherwise made resistant to dye penetration, e.g. as may be seen in the bundle of cotton yarn shown in the figure in which the areas bound with one knot are for a white resist, and those with two knots are for a red resist. Depending on how the dyed resist yarns are woven, there are warp ikat, weft ikat and double ikat (in which both warp and weft yarns have been resist dyed) variations. Careful control and planning results in the typical and characteristically attractive designs of ikat dyeing. When the yarns are woven, the edges of the design motifs have a blurred or soft effect caused by bleeding of one colour into another (some dye always penetrates underneath the edges of the resist areas) or when the coloured areas do not coincide exactly in weaving. Ikat is a laborious dyeing technique involving the application of several colours often still carried out with vegetable dyes.

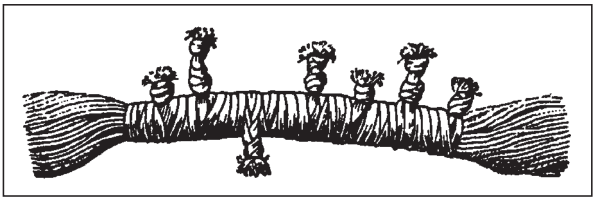


Fig.: Knotted substrate for the Ikat technique.

IK dyeing method Dyeing method for vat dyes (IK dyes) which have the highest affinity for cotton at 25–30°C. Because of inferior fastness properties the so-called cold-dyeing vat dyes which can only be applied by this method have diminished in importance. → Vat dyeing.

Illuminating colours An old term for textile colours used in resist and discharge printing. Illuminating colours are produced mainly with brilliant dyes from a different dye class to supplement the shades missing from a particular dye range.

Illuminating dyes In textile printing, illuminating dyes are those dyes which are used to substitute the missing shades in a particular dye class, e.g. vat leuco ester dyes as coloured resists under naphthol and aniline black dyeings. In discharge printing, a distinction is mades between white discharge printing and coloured discharge printing. In coloured discharge printing, coloured grounds (produced with dischargeable dyes) are printed with discharge printing pastes containing dyes resistant to the discharging agent. Since these dyes are required to produce shades which stand out coloristically from the ground colour, dyes which yield particularly brilliant shades are used for reasons of optimum design effect and these may also be considered as illuminating dyes. If vat dyes are used for the production of coloured discharges, the reducing agent not only has the task of destroying the ground dye but must also, at the same time, convert the discharge-resistant vat dyes into their leuco form to facilitate their exhaustion on to the fibre:

$$\begin{aligned}&HOCH_2SO_2Na + H_2O + O{=}dye{=}O \rightarrow\\&HOCH_2SO_3Na + HO{-}dye{-}OH\end{aligned}$$

During further processing the vat dyes are reoxidized on the fibre where they are ultimately restored to their original chemical form again. On a Colour Index system dischargeability scale of 1–5 (where 1 = virtually undischargeable and 5 = readily dischargeable to white) only those dyes classified as 1 or 2 are suitable as illuminating dyes in coloured discharge printing. Discharge-resistant dyes may be found among various dye classes, e.g. direct, acid and cationic (basic) dyes, as well as vat and vat leuco ester dyes (see Fig.).

A few acid dyes, especially certain blue and green types, are anthraquinone derivatives which, in some cases, are very difficult or impossible to discharge, so that they can be employed in the production of coloured discharges. Greens and other shades are obtained by

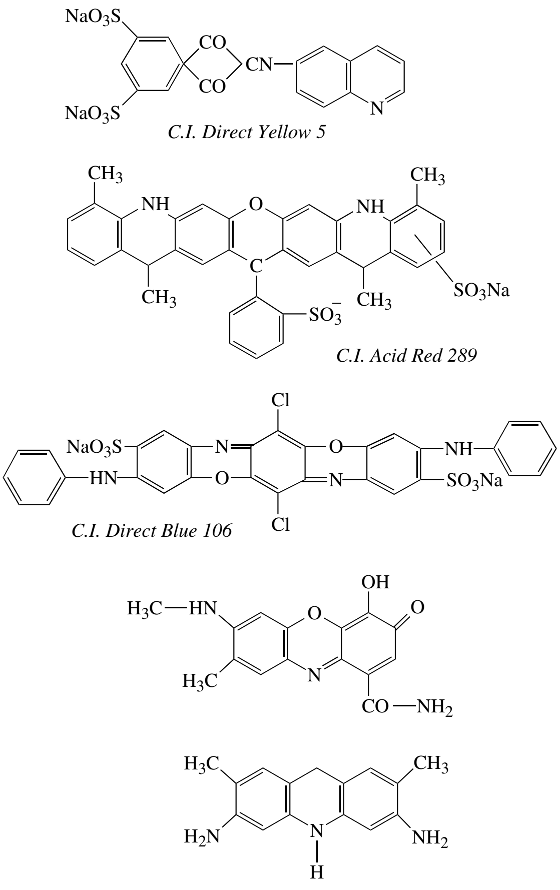
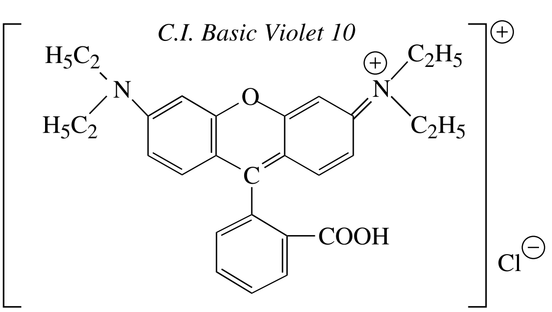


Fig.: Examples of illumination dyes for wool and silk discharge printing.

using mixtures. It is advisable to limit the dyes used in mixtures to one dye class; mutual precipitation of acid and cationic dyes can occur in mixtures resulting in losses. Diphenylmethane and triphenylmethane dyes are, in some cases, either not decolorized, or decolorized only with difficulty by reduction. With some of these dyes, the original colour returns on exposure to air or after treatment with oxidizing agents. A few direct, acid and cationic dyes belong to the group of triphenylmethane dyes, e.g. rhodamine, and are also known as xanthene dyes since they may be derived from xanthene.



These dyes yield exceedingly vivid, clear and brilliant prints which are virtually impossible to achieve with other dyes. Rhodamine B is a brilliant bluish-red dye. On esterification with ethanol, Rhodamine 3B is formed which yields an even bluer red shade than Rhodamine B. The discharge-resistant Rhodamine 6GP is a dye with a similar chemical constitution. The two discharge-resistant acid dyes, quinoline yellow and rhodamine are only used because of their stability to zinc formaldehyde sulphoxylate since their fastness properties leave much to be desired. The discharge-resistant rhodamine acid dyes are obtained by sulphonation of the basic rhodamine. Other discharge-resistant xanthene dyes include the resorcinol dyes such as eosin and Bengal pink.

Discharge-resistant dyes of different dye classes include, e.g.: C.I. Acid Yellow 5, C.I. Direct Yellow 28, C.I. Acid Yellow 99, C.I. Acid Red 87, C.I. Acid Red 52, C.I. Acid Blue 59, C.I. Acid Blue 102, C.I. Basic Blue 3, C.I. Acid Violet 90.

Illumination The quantity of light or luminous flux falling on unit area of a surface. Illumination is inversely proportional to the square of the distance of the surface from the source of light and directly proportional to the intensity of the light. The derived SI unit of illumination is the lux (symbol lx). 1 lux is defined as the uniformly distributed illumination of 1 lumen of luminous flux over an area of 1 m^2, i.e.

$$1\ \text{lx} = \frac{1\ \text{lm}}{1\ \text{m}^2}\ ;$$

Since 1 lm is equal to 1 cd · 1 sr (cd = candela; sr = steradian; lm = lumen), it follows that:

$$1\ \text{lx} = \frac{1\ \text{cd} \cdot 1\ \text{sr}}{1\ \text{m}^2}$$

As a comparison: 1 phot = 10 klx = 10 000 lx.

The Hefner candle (light intensity 0.903 cd) radiates a power of 95 µW in a horizontal direction on 1 cm^2 of surface at a distance of 1 m. The steradian is the SI unit of solid angle.

ILMAC (Ger.), abbrev. for: internationale Fachmesse für Laboratoriumstechnik, Meßtechnik und Automatik in der Chemie (German Technical Fair for Laboratory Technology, Metrology and Automation in Chemical Applications). Held annually and concurrently with the Schweizer Mustermesse (Swiss Trade Fair).

Image analysis in fabric inspection On-going quality requirements must be translated into measurable terms in order to control the fabric quality during production. Sensors and measuring methods must also be developed. Optical sensors will play an important role. The use of photodiodes, laser scanners and video cameras is conceivable. The signals from these sensors must be processed in order to obtain relevant product properties. Where images are concerned, this is referred to as image processing (see Fig.). Image processing is predominantly used for video images. A distinction can be made between applications where the images are merely improved and those where the images are analysed, producing one or several values as an end result. With industrial applications, values are generally derived from the images. Robots with "vision" systems determine the position and orientation of individual components. In such cases, reference is made to "pattern recognition". Image processing is used for textural analysis to describe an image using one or more parameters without describing all the objects within the image in detail.

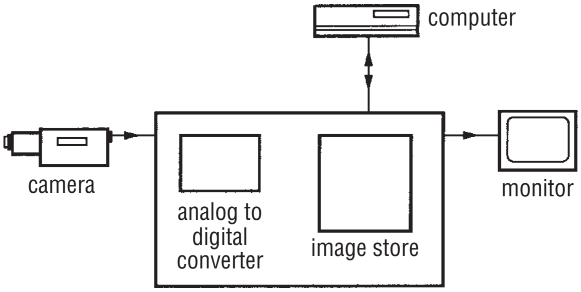


Fig.: Diagrammatic view of an image processing system as a basis for image analysis in fabric inspection.

A video camera is generally used to record the images. An analogue to digital converter is used to digitise the information concerning an image and this is then stored in part of the computer memory which is known as the visual storage. The image then consists of e.g. 512 x 512 image elements, each of which reproduces the average picture grey scale value of a small part of the original image. This image may now be processed using a computer. The changes can be tracked on a second screen which continually reproduces the contents of the visual storage. The computer is able to alter the grey scale values of the image elements. It is therefore possible to add a value to all the image elements in order to make the image lighter as all the grey scale values are changed. It is however more interesting to make the new value of an image element dependent on the values of its adjacent image elements. Such operations are referred to as "window" operations as the new grey scale value is dependent on the image elements within a specific window. By repeating the application of such operations, images can be enhanced for the eye and specific features can be derived from an image. If an image is to be characterised using several values without the objects within the image being described in detail, methods can be used to analyse the texture of an image. The texture can be defined as a surface composed of smaller parts without it being necessary to describe the precise form of these individual parts in more detail.

Image processing The automation of visual test and inspection processes for textiles poses a range of complicated tasks for digital image processing. Solutions which have been drawn up for the interactive mode of the test laboratory can be transferred gradually into the areas of production, finishing and making-up. A basic prerequisite for this is that the computer operates sufficiently quickly. Fault analysis on a moving length of cloth using a CCD matrix camera gives a rough estimate ($b = 2m$, $v = 60$ m/min, resolution $\Delta x = \Delta y = 0.2$ mm, 20 operations/image spot) of at least 10^9 operations/s. This value is not achieved by many computers. Steps are being taken to find new types of working principles and computer architectures and to advance into the region of 10^9 operations/s. One of the key terms used is "parallel computer technology", a concept which has been realised in transputer and neuronal networks. The basic concept is that the programme is broken down into blocks which are transferred to be processed on computers which operate in parallel to one another. Another option is to use algorithms in parallel. Acceleration factors of 10–100 can be expected overall.

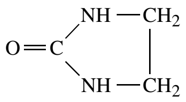
Imago effects → Transparent and opal finishes.

Imbibition A measure of the liquid or water-holding capacity of a textile material.

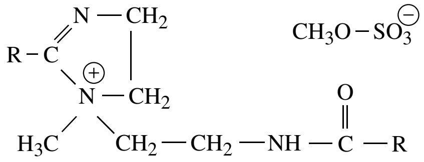
IMDG/IMCO, abbrev. for: International Maritime Dangerous Goods code/Inter-governmental Maritime Consultative Organization. Hazard symbols and warning signs for dangerous goods or substances.

Imidazole → Heterocyclic compounds.

2-imidazolidone Trivial name for (cyclic) ethylene urea. As dimethylol compounds (e.g. DMEU, DMDHEU) 2-imidazolidone resins and derivatives are important reactant resins for textile finishing.



Imidazolinium compounds A classical raw material for fabric softeners and tumbler auxiliaries is the tallow-alkyl imidazolinium salt:

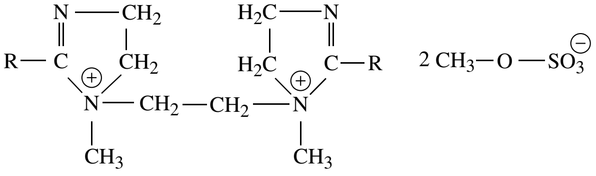


1-methyl-1-fatty alkylamidoethyl-2-fatty alkyl-imidazolinium methyl sulphate

R= glyoxaline

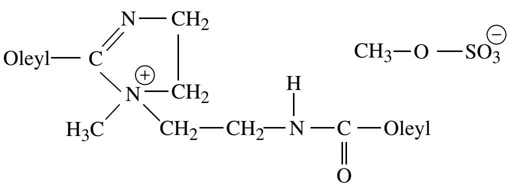
which is dispersible in cold water as a fabric softener. It is produced from fatty acids and diethylenetriamine to obtain a ring-closed condensate with dimethyl sulphate via ditallowalkyl.

Another interesting di-quaternary softener additive is derived from the series of bis-(imidazolinium) compounds:



1,1-Ethen-bis(-1-methyl-2-talgalkyl-imidazolinium)-methylsulfat

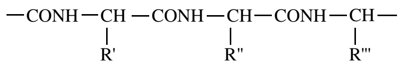
An imidazolinium methyl sulphate with oleyl groups as alkyl substituents is also a very suitable compound in many respects:



1-Methyl-1-oleylamidoethyl-2-oleyl-imidazoliniummethylsulfat

Imido, imino groups (NH groups). Imines are compounds containing the group –NH– (the imino or secondary → Amino group) joined to two other groups. Imides, on the other hand, contain the imido group –CONHCO–. From a dyeing point of view, these groups represent the most important components of the peptide bond, e.g. in protein (wool, silk) and polyamide fibres:

WO-type:



$$-CONH-\underset{R'}{CH}-CONH-\underset{R''}{CH}-CONH-\underset{R'''}{CH}-$$

PA 6-type: $-CONH-(CH_2)_5-CONH-(CH_2)_5-CONH-(CH_2)_5-$

PA 6.6-type: $-CONH-(CH_2)_6-NHCO-(CH_2)_4-CONH-(CH_2)_6-$

Imines Compounds containing the group –NH– (the imino group) joined to two other groups; i.e. secondary amines.

Imitation fur (simulated fur, imitation skin). A collective term for numerous imitations of natural furs and skins. Synthetic fibres are predominant as raw materials for the production of simulated fur pile fabrics with increasing use being made of hollow fibres. Imitation fur fabrics are often foam-backed.

Imitation lambskin Materials of this kind are, as a rule, woven from wool as → Double plush, and can be white, piece-dyed or mottled. The wool tufts, as so-called pile loops, are unevenly distributed in different sizes. These imitations achieve their characteristic appearance through milling. Imitation lambskin fabrics are also produced as knitgoods and are then softer and more elastic.

Imitation skin → Imitation fur.

Imitation suede (imitation suede leather). These materials may be subdivided into the following categories depending on the manufacturing process:

I. Imitation suede 1st generation: → Artificial leather produced mainly from textile random webs, woven or knitted base fabrics: a) either by flock coating or b) artificial leather coatings (mainly polyurethane and polyvinyl chloride).

II. Imitation suede 2nd generation: available commercially since the middle of the 1970's as special fibre laminates in e.g. polyurethane resin compounds. The special fibres are produced as matrix/fibril (M/F) bicomponent fibres from several polymers with different solvent solubilities. If the matrix phase is extracted or dissolved from such M/F systems (e.g. with dimethylformamide) the microfibril composite fibres are left as the fibril phase whilst, if the reverse procedure is followed by dissolving out the fibril phase, the matrix phase remains behind as a multiple hollow fibre with a longitudinal porous structure (Figs. 1 + 2).

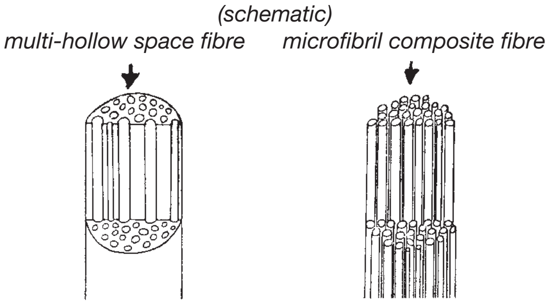


Fig. 1: Microfibril fibres for imitation suede.

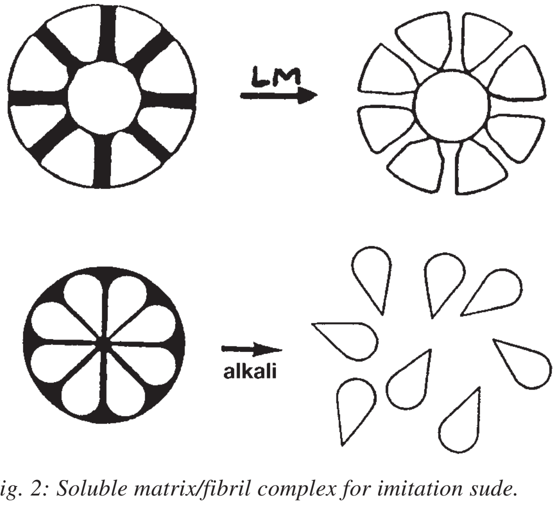


Fig. 2: Soluble matrix/fibril complex for imitation sude.

The technical manufacturing principles involve a) the extraction of at least one fibre component from the pre-bonded M/F random fibre web, followed by impregnation with a binder (e.g. a polyurethane elastomer) and coagulation of the system; or b) impregnation of the pre-bonded random fibre web followed by coagulation of the system and then the extraction of one component of the fibre material. Finally, the slubby surface of the bonded elastic laminate is subjected to a mechanical treatment, e.g. emerizing. c) Bicomponent fibres of polyester/polyamide in knitted fabric form are subjected to a thermal treatment, or a treatment in sulphuric acid, followed by emerizing.

Properties: depending on the needle felting conditions, average fibril count (approx. 20–400) and fibril Ø (approx. 1.3–2 µm. An increase in the number of bundled fibres increases the tensile strength and resistance to tear propagation/unit weight, but also reduces dyeability and results in decreased elasticity at the same time (= a less rubber-like handle). On closely examining the surface of an emerized imitation suede fabric it is found that more than 80 fibrils or those with a Ø of approx. 2 µm or less are responsible for the characteristic leather-like lustre and considerable chalking effect. → Synthetic velours.

Imitation yarn Soft-twisted, bulked coarse cotton yarn consisting of short fibres spun in the manner of carded yarn (→ Condenser yarn).

Imi-Wax An abbrev. for imitation wax print. The purpose is to imitate real wax prints by avoiding the laborious wax resist printing process. The crackle or veining effect in Imi-Wax Africa prints is produced by direct printing and the indigo of real wax prints is imitated by printing blue diazo fast colour salts on naphtholated grounds. In the vast majority of cases, the same typical designs and colours are used as for real wax prints. The production of Imi-Wax prints is mainly carried out on roller printing machines. → Indigo styles in Africa prints.

Immature cotton Cotton picked before it is fully mature. The fibres are not properly formed and the yarn made from them is generally weaker and inferior. Immature cotton tends to form small neps in the spinning process. In contrast to → Dead cotton, the fibre contains a considerable amount of protoplasm and therefore has changed dyeing properties. → Cotton maturity index.

Immersion (Lat.: *immergere* = to dip or submerge). A term used, for example, in the sense of immersing cotton yarn during mordanting for Turkey red. The term is also used in microscopy with immersion objectives, i.e. immersion of the plane surface of the front lens of an objective in a drop of water or oil on the cover glass of a microscope slide to reduce refraction at the front lens at higher powers. Besides aiding aplanatism the numerical apperture of the objective is increased by this process, which therefore increases resolving power. → Immersion fluid.

Immersion accumulator An intermediate storage compartment in a continuous pretreatment range in which, e.g. a cotton fabric impregnated with a peroxide bleach liquor is allowed to dwell for several minutes in a reservoir of hot bleach liquor to allow sufficient time for reaction to take place. The fabric is transported slowly through the compartment at a relatively long liquor ratio by means of a conveyor which ensures that the treatment is carried out entirely below the surface of the liquor (see Fig.). This type of unit has proved popular for the bleaching of weft-knit cotton fabrics.

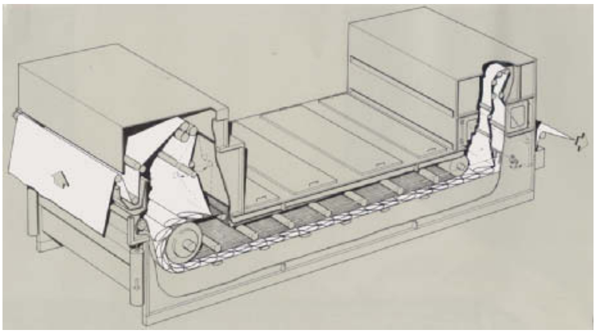


Fig.: Immersion accumulator "Steepmaster" (Küsters).

Immersion bleach process With these processes, the material being bleached remains submerged in the liquor for a specific period of time, e.g. in a "wet" J-box (or sump) in contrast to other continuous bleaching processes where the fabric is simply impregnated with bleach liquor and plaited down in a storage unit. The under-liquor treatment is a technology for wet processing of textile piece goods which represents both a breakthrough in the process technology of "discontinuous exhaust methods" towards continuous treatment as well as an extension of existing continuous treatments towards the use of "longer liquor ratios". The advantages of providing a greater supply of liquor, even in typical continuous treatments, have been known for a long time as amply demonstrated by the use of:

- sumps in J-box installations for fabrics in the rope and full-width state,
- boosters in pretreatment steamers,
- immersion zones in HTP steamers (high-temperature and pressure) as e.g. in the plaiting system shown in Fig. 1.

From a process technology point of view, considerable advantages have been achieved by this means, e.g.:

- more complete removal of impurities from the substrate,
- greater uniformity of the achieved effects and the prevention of crease and rope marks,

Immersion bleach process

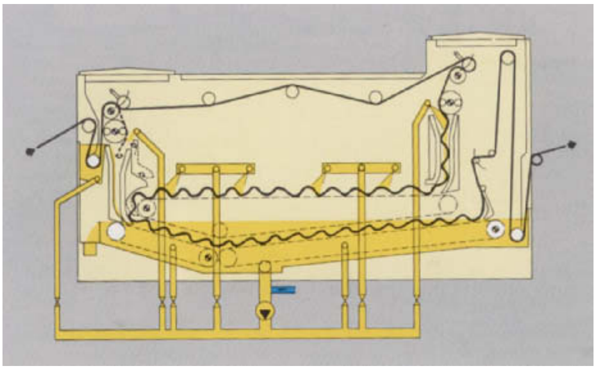


Fig. 1: Wicoflex immersion tray system allowing band material to reside both in a steam chamber and immersed in liquor in the same system (Kleinewefers KTM).

- development or preservation of particular fabric characteristics,
- reduced chemical concentrations with consequent protection of the material against excessive chemical damage and sensitivity.

On the other hand, efforts have continually been directed towards the substitution of relatively time, water and energy-intensive discontinuous (batchwise) long-liquor processes such as the jigger, winch and, more recently, overflow and jet treatments, by continuous methods without sacrificing the advantages of the former, e.g.:

- use of long treatment times with low chemical concentrations on the goods,
- allowing the material to float with consequent possibilities for the goods to relax at long liquor ratios.

Machine designs incorporating the following concepts are used in practice:

- spiral passage of material through winch becks,
- immersion of open-width material in suspended loops (e.g. Mezzera system)
- washing and shrinking machines for polyester textile materials which have also followed this trend.

In 1976, Bayer developed a bleach process known as the PKS process (i.e. the “Peroxid-Kontinue-Schnellbleiche” in German), a continuous rapid peroxide bleach in which the principles of both methods of treatment have been intentionally combined. From considerations of process flow, discontinuous and continuous long liquor systems differ considerably.

In discontinuous (batchwise) processes, the chemical reaction usually begins at a maximum concentration of the particular chemicals used and a minimum treatment temperature. The system is gradually brought to the maximum temperature within a certain time and maintained at that temperature for a specified period. The chemical concentration undergoes continual degradation so that the maximum temperature and maximum concentration do not normally coincide which simplifies the recipes for such processes and, in the case of hot peroxide bleaching especially, is also favourable for peroxide stabilization and control. The reaction products are removed in rinsing operations and the detached impurities are carried away. In the next treatment cycle, processing is carried out in “clean” baths again.

With continuous processes, on the other hand, the reaction is carried out in a “standing” bath at a constant temperature and chemical concentration on continuously running fabric. After a certain treatment time, a dynamic equilibrium establishes itself between chemical consumption, liquor input and output, chemical supply and the asymptotic maximum of bath impurities resulting from detached fibre contaminants and their reaction products with the treatment chemicals. Since exposure of textile materials in continuous under-liquor baths (Fig. 2) involves considerably longer standing times, this can lead to harmful degradation and saponification reactions proceeding much further than in discontinuous processes causing unwanted precipitation reactions. Precipitations of lime-soap-like stain

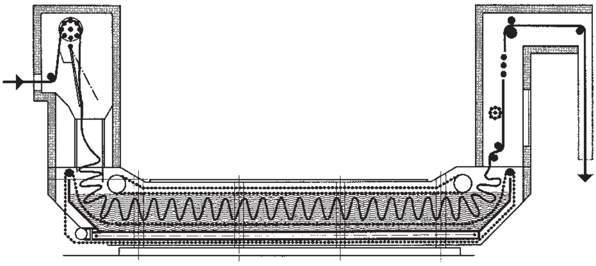


Fig. 2: Typical steeping machine (Menzel).

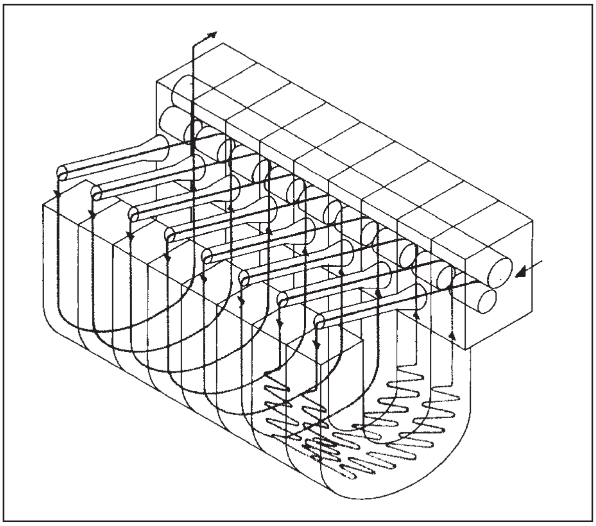


Fig. 3: Typical immersion tray system for strands of material.

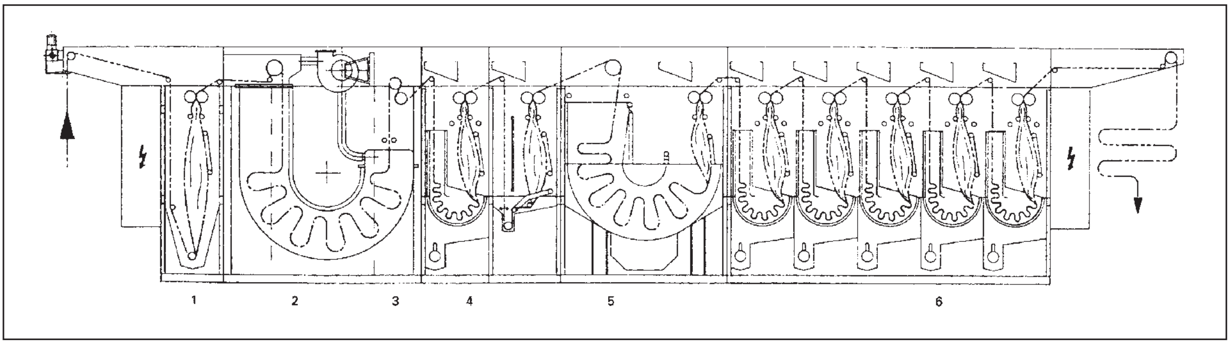


Fig. 4: PKS immersion bleach system in the Brückner continuous bleaching facility for broad tubular fabric.

forming substances are examples of such reactions. Since the maximum temperature (80–90°C) in continuous peroxide bleaching coincides with the considerably higher chemical concentrations, self-decomposition of the peroxide also reaches considerably higher levels than in discontinuous processes which becomes manifest as a higher specific peroxide consumption. These peculiarities make it necessary to employ special recipes for continuous long liquor processes, especially in the peroxide bleach.

Continuous treatments, especially those based on J-boxes (Fig. 3) and the conveyor belt bleach, are well-established in practice. These are steaming processes combined, in some cases, with cold pad-batch treatments.

Another alternative which gives better whiteness and better fibre protection (e.g. higher DP values) is the PKS process developed by Bayer. This under-liquor bleaching system (Fig. 4), gained importance in the past since suitable machines for its application were already available. Many machine makers now offer appropriate machines for the treatment of knitted fabrics in rope and open-width form (open-width tubular and slit goods), e.g. Brückner, Thies, MCS, Goller, Argathen, KTM Kleinewefers and Jemco, etc.

These multifunctional processing ranges (precleaning, bleaching, extraction, afterwashing of dyeings and prints) have led to a greater acceptance of processes based on “under-liquor treatment” in practice. The liquor temperature and dwell times, as well as the chemical concentrations and choice of stabilizer and surfactant are of decisive importance in these processes (source: Guth, Broglin and Günther).

Immersion centrifuge Textile material is wetted out in the basket of a particular type of → Centrifuges and subsequently centrifuged. An immersion centrifuge is used to saturate or impregnate textile materials with liquors by centrifugal force as well as for rinsing, souring and neutralizing. Processing liquors may be collected during centrifuging and re-used.

Immersion fluid A liquid used for immersion objectives in microscopy, e.g. water, monobromonaphthalene, cedar-wood oil, to reduce the refraction at the front lens of the objective.

Immersion jigger A type of jigger which was often used in the past for dyeing with vat dyes. In this type of jigger the draw rollers are not mounted above the liquor as in a normal → Jigger but below the surface of the liquor so that the problem of atmospheric oxidation of the vat dyes during dyeing is prevented.

Immersion length The total length of the immersion zone in, e.g. the impregnation troughs of padders and other machines in order to ensure satisfactory and uniform wetting out of textile piece goods.

Immersion squeezing In order to intensify the liquor exchange in wet-on-wet processing or the wetting out of textile fabrics in wet-on-dry treatments at high production speeds in a padder trough with a low liquor content (i.e. with a short immersion path), squeeze rollers are also employed below the level of the liquor in addition to the usual squeeze rolls mounted above the trough (see Fig.).

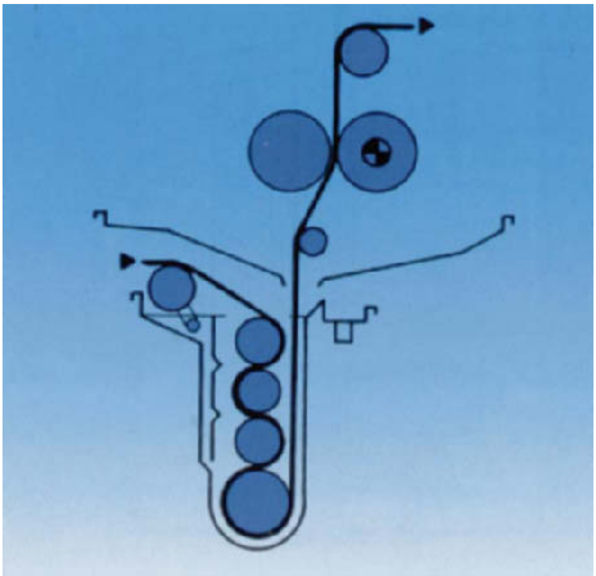


Fig.: Immersion squeezing in a padder of Kleinewefers KTM.

Immersion test A test method for water-repellent impregnations on textiles (especially for yarns and knitted fabrics). Procedure: The textile test specimen is weighed then submerged in a sieve for 5 min under 10 cm of water (the sieve is jerked a few times to remove collected air). The specimen is then taken out of the water, allowed to drain for approx. 10 min, weighed again and the water uptake calculated.

Immersion wettability test Determination of the → Wetting power of a surfactant with the aid of a standard cotton specimen which, as a round-cut dry substrate hung on a thread, is pulled by a hook under water. The time required for this specimen to sink to the bottom is measured. With the aid of this test, the wetting power of different surfactants can be compared by determining the respective concentration required to achieve a wetting time of 25 s. This value (log C_{25}) can be entered against the abscissa value for the chain length of the surfactant to obtain straight lines in homologous series. In the immersion wetting test, branching in the chain molecules and longer chain lengths lead to a reduction in the "C_{25}" value. For a specific wetting action, however, a minimum concentration is always required irrespective of the molecular structure of the surfactant.

Immunization A chemical process for the surface modification of fibres to achieve a different affinity towards dyes, e.g. in connection with processed untreated fibres in order to obtain two-colour effects, fancy edges, local printed effects, etc. Since the introduction of acetate and triacetate fibres the importance of such processes has declined or has led, on the one hand, to the development of so-called resisting agents and to the numerous animalized fibres on the other.

The immunization of cotton fibres results in a reversal of their affinity for direct dyes in favour of acid, cationic or disperse dyes. The process is carried out by e.g. esterification of the cotton fibre with acid chlorides or p-toluene sulphochloride:

immunize

or with isocyanates, acetic anhydride = passive yarns (→ Acetylated cotton).

The immunization of wool and similar fibres results in a loss of affinity for acid and chrome dyes in favour of cationic dyes. The oldest process of this kind was based on the action of tannic acid solution and subsequent fixation with metal salts. Such immunized wool can be produced as white or dyeable fibre, but has poor stability to boiling acidic liquors. For this reason, numerous other treatments have been developed, the practical results of which are based on the application of resisting agents.

Immunized yarn → Immunization.

Impinging flow Within the medium surrounding the fibre, a distinction should be made between the diffusion boundary layer and the flow boundary layer on the surface of the fibre. A state of equilibrium arises between the material concentration in the fibre surface and the diffusion boundary layer. The time it takes for this equilibrium to be reached is dependent on the substrate. The concentration gradient between the diffusion boundary layer and the flow layer, however, is determined by the rate of the flow layer. Where the impinging flow rate is constant, the so-called hydraulic diameter, which is composed of pores of various sizes in the yarn and fabric, or the modification to this profile during flow governs the rate of the flow layer and thus the material exchange. The blending of the 2 liquor layers is encouraged by a turbulent flow which arises at specific impinging velocities, as well as by the profile of the pores in the textile.

The macro-kinetics of dyeing processes which occur on impinged surfaces can be described using the convective diffusion model (Fig. 1).

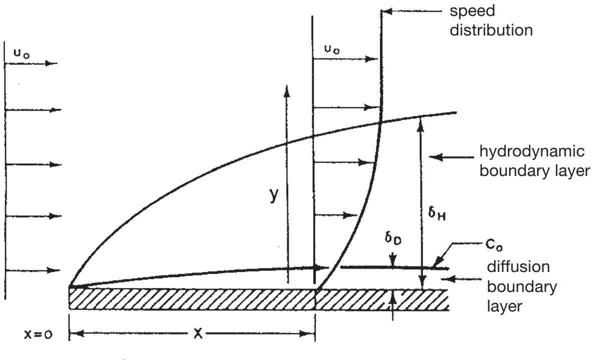


Fig. 1: Impinging flow profile on substrate surfaces. The convective diffusion model combines the impinging flow profile of the liquor with the concentration declivity of the dye on the substrate surface. The bondary layer dimensions are defined for the 95% value of u_o and c_o.

In a stationary liquor across a fibre surface, the adsorption velocity of the dyestuff will fall as the diffusion boundary layer δ_D increases. In the event of a tangential flow of dyestuff across the substrate surface at a velocity of u_0, the diffusion boundary layer which has been depleted in dyestuff is cleared and replaced with fresh liquor, with the result that dyestuff with increased velocity can once again be combined with the substrate by a considerably reduced diffusive boundary layer.

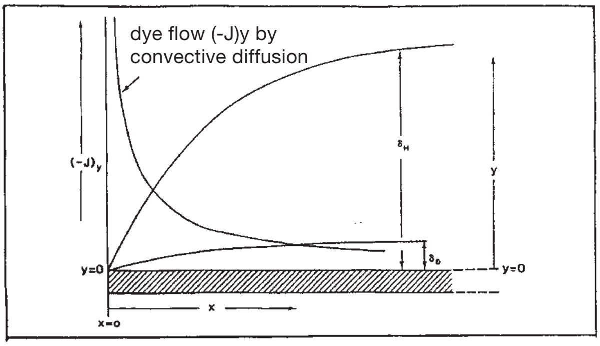


Fig. 2: Dye flow by convective diffusion.
The dye flow J, maintained by convective diffusion on the substrate surface, tapers off after passing the starting section x to a constant value characteristic of the dyeing system.

The effective mass flow on the fibre surface required for the adsorption of dyestuff (Fig. 2) is given as the result of the contrasting convective and diffusion flows. These determine the thickness of the hydrodynamic or diffusion boundary layer. As shown in Fig. 3, dyeing in a liquor which is only circulating slightly is characterised by a relatively thin hydrodynamic and an extended diffusion boundary layer. In a liquor which is flowing strongly, the relative ratios of size of the two boundary layers are reversed. The characteristic equilibrium required for the absorption of dyestuff on the substrate surface is therefore achieved more quickly by impinging flow.

Loose stock, yarn packages, nonwovens and multi-layered fabric batches as well as single layered sheet textiles are regarded as textile waste. These are amassed randomly, and this, together with the different fibre geometries, result in complex flow mechanisms. This type of textile waste can be regarded as a branched channel system. When the impinging flow velocity is increased, turbulent flows arise in addition to the laminary flows.

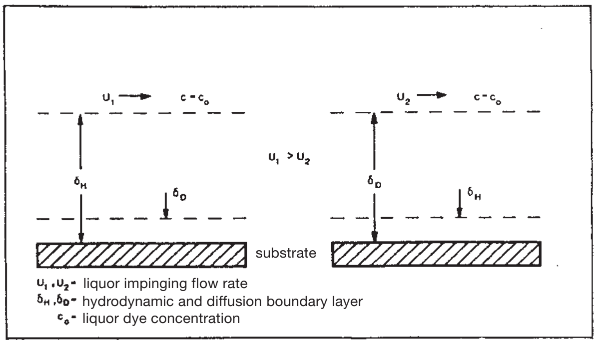


Fig. 3: Boundary layer impinging flow.
The dye absorption on the substrate surface causes a dye concentration gradient in the liquor layers adjacent to the surface, reducing the diffusion-controlled dye flow. The dye deficit occurring can be balanced by increasing the liquor flow.

When a fluid flows upwards via a granular or a powdery fill, a vortex occurs (i.e. the particles are suspended) if the loss of pressure in the fluid is equal to the surface pressure of the fill (loosening point). With solid/gas vortex layers demixing occurs as the rate at which the tube empties increases (formation of bubbles and channels) because the homogenous vortex layer does not represent the most stable state at high gas velocities (as the gas is not sufficiently dense) or when the impulse to be transferred is large (due to the significant difference in density). As the flow velocity continues to increase, there is a tendency towards a reciprocating vortex layer, i.e. a layer is raised like a piston. Particles fall away from the underside of this once again and form a new layer.

One characteristic of these individual channels is that they cannot be assigned a uniform tubular cross section q, nor consequently any uniform flow mechanisms. Fig. 4 shows by way of an example the ratios with a sudden expansion of a pipe with the radius r to a larger cross section. It is observed that the impinging fluid with the (laminary) velocity distribution w (r) does not flow as a closed jet from the narrower into the wider cross section. There is a contraction of the incoming flow before the flow expands to follow the wall of the pipe after a certain distance. A dead water zone with a vortex build-up forms between the contracted jet and the wall of the pipe.

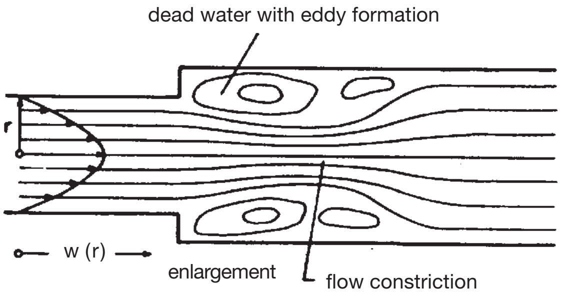


Fig. 4: Flow conditions after sudden pipe widening in the case of laminar flow.

By mixing the contracted jet with the dead water surrounding it, there is a loss in flow energy. The flow mechanisms for a sudden narrowing of the pipe are shown in Fig. 5, and Fig. 6 shows these mechanisms where a stop plug is used by way of example causing the jet to taper off. A channel system does not represent

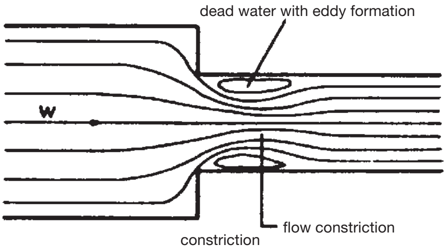


Fig. 5: Flow conditions after sudden pipe narrowing in the case of laminar flow.

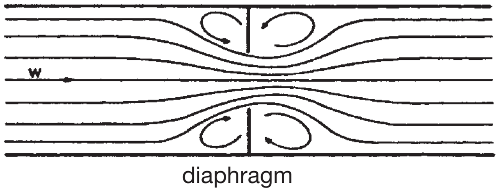


Fig. 6: Flow conditions caused by sudden pipe narrowing in the case of laminar flow.

a standard pipe combination and moreover this kind of system is characterised by a number of dead water areas, caused by sudden changes in cross-section. (Source: Schollmeyer).

Even on the immediate surface of a fabric passing through a wash liquor in open-width, there is an adhesive layer which displays unfavourable flow properties and which significantly reduces the washing off properties of the fabric. This layer contains some of the impurities already removed from the fabric itself or from the surface of the fabric, the diffusion coefficients of which increase as follows:

soluble substances > colloidal systems >
insoluble pigments.

The viscosity of the adhesive layer is correspondingly high, and can increase to a semiliquid state. The adhesive concentrate is surrounded by a water film which consists of detergent solution and which is entrained depending on the velocity of the moving length of cloth as a laminary boundary layer (i.e. it "flows" with the length of cloth).

The following methods can be used to effectively break through the two barriers, i.e. the adhesive concentrate and the laminary boundary layer, so that the detergent solution can pass through the length of cloth:

- reducing the surface tension of the boundary layers by means of surfactants;
- washing mechanics to move the fabric;
- construction of concentration gradients by means of squeezing off and adding fresh water;
- longitudinal flow and predominantly cross-currents;
- increasing the temperature.

A distinction can be made between laminary and turbulent impinging flow by measuring if the differential pressure is plotted against the flow velocity in a flow system. Straight lines with slightly different gradients are formed (Fig. 7).

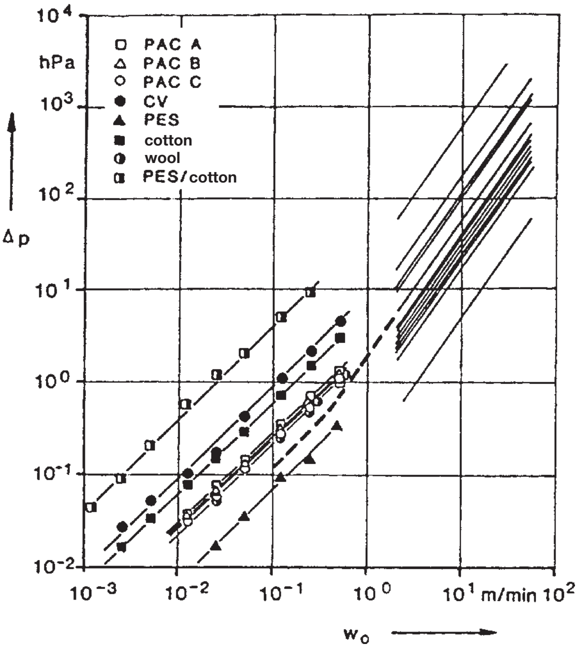


Fig. 7: Pressure losses p relative to the impinging flow rate wo of woven fabrics in the log-log system for distinguishing laminar (left) and turbulent (right) flow (Heidemann).

Impregnating machine Roller vat or rope device with squeezing unit used for wetting with bleach concentrates in rope bleaching and open-width continuous bleaching, e.g. → J-box.

Impregnation (Lat. Impregnare = to soak, saturate). In a general sense, impregnation refers to treatment of textiles by impregnation with solutions, dispersions or emulsions. Impregnation is one of the most important operations in finishing, less for yarns than for fabrics and knitwear. It is required for all continuous and semi-continuous processes including boiling off, bleaching and dyeing (Fig. 1). Impregnating fabrics with various chemicals is the most common process in textile finishing. It forms an integral part of desizing, washing, mercerizing, bleaching, dyeing and proofing. The effect of impregnation on the quality and the economic success of a finishing process is therefore of considerable importance.

Impregnation is understood to refer to the passage of a fabric through an impregnating solution, after which the fabric is mangled evenly across its width and length. In dry-on-wet impregnation (Fig. 2), dry goods are fed into the impregnation bath. This process is es-

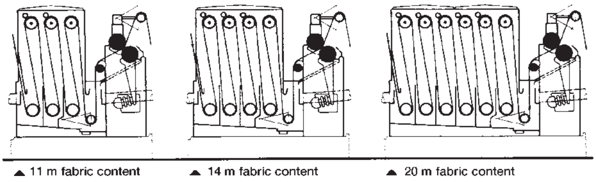


Fig. 1: Different versions of a roller vat for impregnation in cotton pretreatment (Babcock).

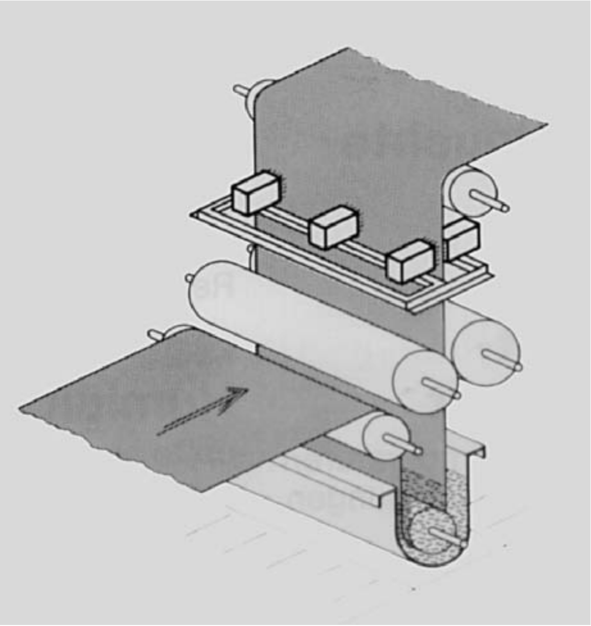


Fig. 2: Dry on wet impregnation of a textile fabric running in open-width into the trough with squeezing of excessive liquor and measuring of the liquor coat (Pleva).

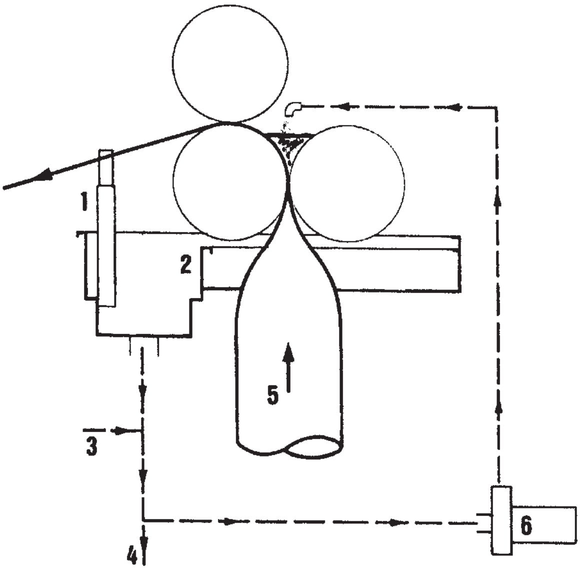


Fig. 3: Wet on wet impregnation of a tubular knitted fabric (Fabcon).
1 = level sensor; 2 = liquor trough; 3 = liquor supply; 4 = liquor drain; 5 = inflated knitted fabric; 6 = circulation pump.

sentially a wetting process during which the impregnating solution is absorbed by the fabric. There is no exchange of concentrations and substances. Where non-refined chemicals are used, the concentration of the impregnating solution remains unchanged. Wet-on-wet impregnation (Fig. 3) signifies that moist or wet fabric is introduced into the impregnation bath. No significant further wetting can therefore take place, although the impregnating solution is absorbed further if the fabric which enters the impregnation bath is drier than when it exits. A characteristic feature of wet-on-wet impregnation is that a greater or lesser proportion of the fabric moisture is exchanged for the impregnating solution, which gives rise to a change in concentration in this solution. The term impregnating solution is given to the liquor which passes through the fabric for the purpose of impregnation. The concentration of this solution is given in g/l. The concentrated chemical solution which is continually added to the impregnating liquor during impregnation is referred to as a feed or stock solution. As this is added, the chemicals absorbed by the fabric are continually replaced thus maintaining a constant concentration of impregnating solution. In practice, the feed or stock solution is 5–10 times more concentrated than the impregnating solution. The concentration is given in g/l. The ratio of the moisture content added to the weight of the fabric when dry is expressed as a % of the weight of the fabric when dry (liquor pickup). The proportion of the moisture content deposited by the fabric in the impregnating solution which has been exchanged for an equal quantity of impregnating solution is referred to as the exchange. The exchange is given as a % of the total moisture content deposited by the fabric and is a factor which only arises in wet-on-wet impregnation. When expressing the exchange, the difference in the liquor pick-up before and after impregnation is not taken into consideration. The exchange must not be confused with the total moisture content which the fabric has removed from the impregnating solution.

$$\text{exchange factor F} = \frac{\text{exchange in \%}}{100}$$

The current chemical consumption is given in g/kg of the weight of the fabric when dry or as a % of this weight. In contrast, the concentration of the impregnating solution or feed solution should never be given as a %.

The impregnation of dry goods generally takes place in pre-washing, desizing, dyeing and proofing.

Dry-on-wet and wet-on-wet impregnation occur equally frequently in mercerization. Dry-on-wet impregnation is very seldom used in bleaching as the fabric has generally already been subjected to a wet treatment before bleaching. The prerequisite for an effective dry-on-wet impregnation is that the fabric has been thoroughly wetted . The reaction time is relatively short as impregnation occurs extremely quickly and the impregnation temperature cannot always be set at the desired level. Consequently, a good wetting agent must be used. If the thorough wetting of a fabric can be guaranteed, the desired concentration of the impregnating solution can easily be calculated as a function of the liquor pick-up and the desired chemical concentration on the fabric. An example follows:

With a liquor pick-up of 80%, 1% (10g/kg) of chemicals should remain on a specific fabric. The concentration of the corresponding impregnating solution is calculated as follows:

$$\frac{10 \cdot 100}{80} = 12.5 \text{ g/l} \quad \text{or} \quad C_1 = \frac{C_2 \cdot 100}{FA}$$

C_1 = concentration of the impregnating solution,
C_2 = desired chemical concentration on the fabric in g/kg,
FA = liquor pick-up.

During dry-on-wet impregnation, the liquor is continually reduced as moisture is being absorbed by the fabric. The concentration of the liquor does not change, however (this does not apply where non-refined chemicals are used). In dry-on-wet impregnation, the feed solution therefore has the same concentration as the impregnating solution. The calculation and control of the impregnation bath is more complicated in the wet-on-wet process. In dry-on-wet impregnation, only the liquor pick-up needs to be taken into consideration as a calculation factor, whereas in the wet-on-wet method, three factors need to be recorded:

- the liquor pick-up of the incoming fabric (input moisture content) = FA_1,
- the liquor pick-up of the outgoing fabric (output moisture content) = FA_2,
- the exchange.

In theory, there are three options relating to the liquor pick-up:

1. $FA_1 > FA_2$: The fabric releases more moisture into the impregnating solution than it removes after impregnation. Consequently, the impregnation bath will soon overflow. This option is therefore impractical.
2. $FA_1 = FA_2$: The fabric releases just as much moisture into the impregnating solution as it removes. Where the bath volume remains constant, the concentration of the solution would soon be exhausted as a result of the exchange. The addition of more chemicals would also result in the bath overflowing. It is therefore not possible to use this option in practice.
3. $FA_1 < FA_2$: The fabric releases less moisture into the impregnating solution than it removes. The decreasing liquor volume can be compensated by the addition of more chemical solution. This addition also maintains the concentration of the impregnating solution which is decreasing as a result of exchange. This is the only option which can be used in practice. The greater the difference between the two liquor pick-ups, the better the results which will be achieved. FA_1 must in any case be at least 15–20% lower than $FA_{2.}$

If the definition of exchange is also considered, all the factors and ratios are significant for the calculation of the concentration of an impregnating solution .

Impregnation agents → Water-repellent finishing auxiliaries.

Impregnation centrifuge Centrifuges for loose fibre or single yarn packages in which the textile material is impregnated with a treatment liquor by pumping and centrifugal force.

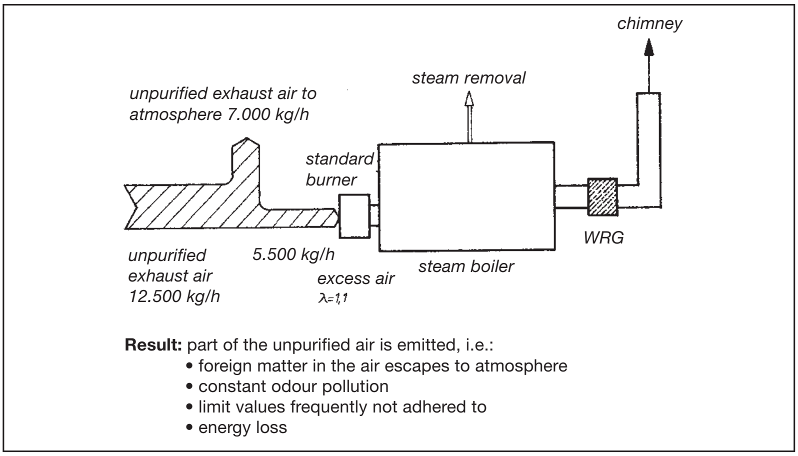
Impressioning machine A single-colour roller printing machine for the production of test prints as a means of checking the engraving quality of engraved printing rollers, or to produce strike-offs of new designs, as well as small samples.

Imprimeuse Samuel A machine which began the development of partial mechanization in block printing. The pattern in relief was not applied to a flat wooden block but to the surface of a roller rotating on bearings. Print paste transfer was provided for by means of an endlessly running felt blanket. The process is now of historical interest only.

In, chemical symbol for indium (49).

Incineration for waste disposal The combustion of exhaust air from finishing processes such as singeing, heat-setting and, in certain circumstances, drying, eliminates combustible pollutants and noxious-smelling foreign matter from the exhaust air whilst allowing energy recovery at the same time. In order to cope with large quantities of exhaust air, the combustion must be carried out, as a rule, with a high excess of air. The elimination of pollutants and energy recovery are only partially achieved in processes which do not employ a high excess of air in the boiler (Fig. 1).

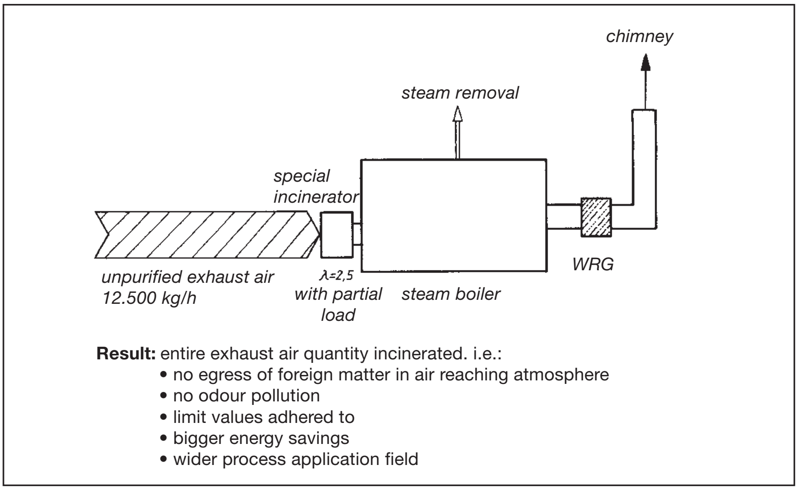
One method used in practice combines the incineration of airborne pollutants in existing steam or hot water boilers with a high excess of air, and energy recovery from the boiler flue gases (Fig. 2). This method is thermally viable when the temperature of the exhaust air before reaching the boiler is higher than the cleaned and cooled exhaust gases in the chimney. Even in the case of low exhaust air temperatures, however, this still represents a relatively favourable method although the energy saving is no longer particularly significant.



Result: part of the unpurified air is emitted, i.e.:

- foreign matter in the air escapes to atmosphere
- constant odour pollution
- limit values frequently not adhered to
- energy loss

Fig. 1: Normal excess air operation.



Result: entire exhaust air quantity incinerated. i.e.:

- no egress of foreign matter in air reaching atmosphere
- no odour pollution
- limit values adhered to
- bigger energy savings
- wider process application field

Fig. 2: Operation with large quantities of excess air (Sparal).

In the case of effluents containing low concentrations of pollutants, incineration after a preceding multistage evaporation treatment can represent a worthwile method of treatment. In this way, even low concentrations can be made accessible. Whether this method offers a viable solution depends on the calorific value of the effluent which can be estimated from the COD value ($1\ g\ O_2/l = 13\ kJ$) and the concentration range. This method is applicable within the range of 100 000–200 000 mg O_2/l.

The Bremer Wollkämmerei in Bremen, Germany, incinerates the residues from its raw wool scouring process with gas as an added fuel in a two-stage combustion chamber at 1200°C. The ash is withdrawn via the flue gas dust collector as well as in the convection zone of the boiler plant. The flue gases are cooled down from 1200°C to 250°C in the downstream waste heat boiler. The energy from the flue gases is utilized for the generation of steam at 26 bar, the pressure is reduced to generate electricity, and the steam is then used in the evaporation plant. In general, incineration should be regarded as an alternative option; the higher the concentration of inorganic components in the effluent, the more worthwile the recovery of useful substances is likely to be. →: Waste disposal; Waste management; Recycling.

Inch (abbrev. as in. or "). The commonly used non-metric unit of length in Anglo-Saxon countries. 1 inch = 2.5399956 cm. In industry the usual conversion is 1 inch = 2.54 cm; 1 cm = 0.3937 inches. 12" = 1" (foot).

Incoming goods inspection (incoming fabric inspection). The preliminary inspection of all textile goods received by a textile finishing plant for processing in order to check conformity to specification, quantity of goods supplied, quality as received (especially defective goods) before the goods are accepted for processing. → Quality control.

Incompatibility reactions of the skin This problem has attracted increasing public interest. Possible interactions between the skin and particular items of clothing are to be associated with the health disorders resulting from them. Pre-eminent among these are the allergic and non-allergic types of eczema, as well as intolerance allergies, pseudo-allergies and other reactions of the skin (→ Skin diseases). Physical irritation and chemo-toxic effects are considered as probable causative factors here. Among the most frequent contact allergies are those induced by substances based on formaldehyde, specific disperse dyes in particular, metallic compounds, materials containing rubber, as well as textile preservatives and/or detergent components.

The methods used to isolate and identify individual allergenic materials deserve great attention especially with a view to the epidemiological detection of textile-induced skin disorders and the preventive measures which can be derived for them. The great number of irritative textile and, above all, wool intolerance reactions of the skin are not infrequently attributed erroneously to the allergy phenomenon. They arise principally in cases of individual increased skin sensitivity, i.e. in patients with atopic skin conditions which leads to the triggering or worsening of eczematous reactions (source: Klaschka).

INCONOR (Sp.), abbrev. for: Instituto Colombiano de Normas, Bucaramanga, Colombia (Columbian

Institute of Standards); → Technical and professional organizations.

Incorporation (Lat.: *incorporare* = to embody). In the widest sense all processes in which non-reactive compounds are applied by conventional means to (incorporated in), synthetic fibres especially, via the melt spinning process (in the spinning dope) or during finishing processes (dyeing, wet processing). Taking polyester as an example, the figure shows the conventional incorporation of a fluorescent brightener in spinning on the one hand, and the reactive incorporation on the other.

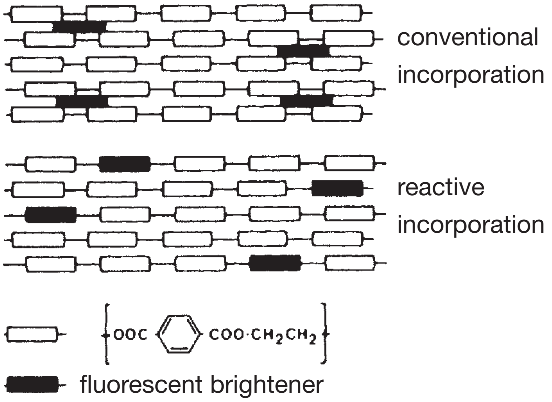


Fig.: Classic incorporation of spinning fluorescent brghtener in comparison with reactive incorporation.

For incorporation phenomena all the free sites in the fibre interior are not necessary and a non-continuous distribution is sufficient for finishing effects since according to the law of mass action the concentration of finishing chemicals on/in the fibre is uniformly adjusted during incorporation. Such "islands in the sea" distribution of finishing chemicals on fibre surfaces can be detected in practice by stereoscan photographs.

Incubation In the context of textile chemistry this is a term used in enzyme chemistry, i.e. the time of reaction between an enzyme and a substrate. Degradation of starches to water-soluble dextrins begins as soon as an enzyme solution comes into contact with the size. A satisfactory degree of degradation is only achieved, however, if the enzyme concentration in the impregnation bath is correctly adjusted to the incubation time and temperature. A long incubation time (as for plaited goods) permits the use of a low enzyme concentration whilst short incubation times require a combination of higher enzyme concentrations and higher incubation temperatures (e.g. as in pad-steam desizing). If desizing is carried out in the jigger, incubation (on the roll) alternates with impregnation in the bath; in this case the entire duration of the desizing treatment is determined by the number of passages (ends).

Indanthren dyeing Cellulosic textiles can be dyed with → Indanthren dyes in the form of yarn and knitted or woven fabrics. Indanthren dyes are applied by continuous, semi-continuous and batchwise methods as follows:

1. Batchwise methods (exhaust process):
   - leuco process,
   - semi-pigmentation process,
   - pigmentation process,
   - high temperature process (HT process).
2. Semi-continuous method (pad-fixation process):
   - pad-jig process.
3. Continuous methods:
   - pad-steam process,
   - wet-steam process.

The pad-steam process is the most important continuous dyeing method for Indanthren dyes and was developed by Dupont in the 1940's. The technology is geared to the specific properties of vat dyes. The water-insoluble non-substantive vat dye pigment is first applied to the fabric on a padder. After intermediate drying and impregnation with the reducing chemicals, the dye is reduced and fixed on the fibre in an air-free atmosphere of saturated steam in a steamer. Depending on the depth of shade, only 30–60 s are required for reduction and fixation of the dye. Restoration of the dye to its original water-insoluble pigment form is usually carried out by oxidation in a continuous open-width washing range. After oxidation, a hot soaping treatment is given as near to the boil as possible in order to achieve the final shade and high level of colour fastness. Continuous dyeing with vat dyes has been successfully practised for many years. Through further technical developments in machinery, including electronic control and metering systems, this method is now capable of meeting most requirements with regard to optimum utilization of natural resources (water, energy, etc.).

On the other hand, the situation in batchwise dyeing is markedly different. Innovations in machinery and process technology are still being sought. The pigmentation process, above all, has established itself for the dyeing of vat dyes by exhaust methods. In this process, the dye, in its non-substantive pigment form, should be distributed as uniformly as possible at a high percentage on the textile material. It is a well-known fact that the degree of pigmentation can be increased by raising the bath temperature. This can be attributed to the formation of aggregates of dye pigments. It has also been established that, despite the formation of coarser dye pigment particles, uniformity of pigment distribution on the textile material can likewise be improved by raising the temperature.

The high affinity of vat dyes in the reduced state can lead to uneven exhaustion of the dye in the initial phase of dyeing. It is therefore common practice to level out this initial unlevelness again by increasing the dyeing temperature and adding levelling agents. The question arises, of course, as to whether this initial unlevelness can be avoided or limited by a controlled vatting of the dye. As a consequence of the introduction of metering systems in reactive dyeing, suitable metering devices are available in many dyehouses. It seems reasonable to suppose that this technology could also be used for metering the reducing agent in the dyeing of vat dyes. However, the metered addition of sodium dithionite can only influence the bath exhaustion curves of these dyes to an insignificant degree. The metered addition of sodium dithionite does actually slow the rate of exhaustion to a certain extent but does not produce the desired flat exhaustion curve. → Vat dyeing.

Indanthren dyes In 1901 René Bohn succeeded in producing an insoluble blue dye by fusing 2-aminoanthraquinone in alkali to which he gave the name Indanthren. Besides anthraquinone derivatives and more highly condensed aromatic ring systems there are only a few representatives of other chemical classes among the Indanthren dyes. The precursors and chains of synthesis of these dyes may be classified according to production lines: the α-chemistry of Bayer and the β-chemistry of BASF.

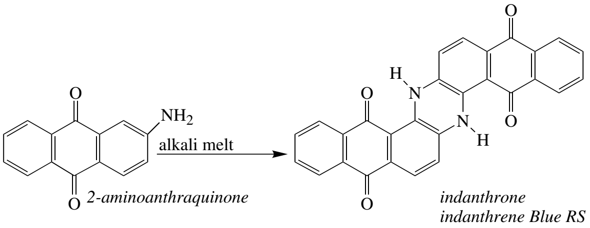


Fig.: Indanthrene Blue RS, Bohn synthesis.

Before 1914, Bayer, Agfa and BASF as well as Hoechst, Cassella and Kalle collaborated in the manufacture of Indanthren dyes. Bayer built the α-chemistry production line and BASF the β-chemistry line. Until the First World War a range of fast vat dyes was available. Production lines were developed from the patent applications of the dyes and essential precursors which are still valid today for dye manufacturers. Many of the dyes discovered up to the time of the IG Farben Amalgamation are very important members of vat dye ranges. Their proportion still amounts to approx. 40%. By comparison, the dyes which were developed in the IG Farben period, i.e. from 1925 to 1939 still represent 45%. The proportion of new individual dyes introduced since the Second World War is relatively small at 15%.

1. Indanthrone is characterized as a hot dyeing product. It is the basis of important dyes in the blue sector. Their high tinctorial strength, high affinity and good fastness profile resulted in the first success of vat dyes, e.g. Indanthren Blue RS.
2. Violanthrone and iso-violanthrone are classical dyes in the navy-blue, dark blue and green sectors, e.g. Indanthren Dark Blue BOA and Indanthren Brilliant Green FFB. Their levelling properties and affinity are of a similar order to the indanthrones although on average, however, their colour fastness to light and weathering are somewhat poorer.
3. Pyranthrone dyes such as e.g. Indanthren Gold Orange G, are classical representatives of β-chemistry. Further dyes such as Indanthren Orange RRTS, as well as Indanthren Direct Black RB and RBS are derived from the pyranthrone dyes in the imide group. Flavanthrone and anthraflavone are of no importance.
4. The carbazoles are an extensive class of dyes. They belong to the category of IW dyes, have average rates of exhaustion and good to very good levelling properties. The fastness properties, especially colour fastness to light and weathering, are of a high order, e.g. Indanthren Brown LBG.
5. Thiazole and oxazole compounds are IW dyes with good fastness properties. They are manufactured by complex synthesis, e.g. Indanthren Red FBB. (contributed by Nahr and Ruppert).

Indanthren IW dyeing process → IW dyeing method.

Indanthren label A trademark of BASF for certain vat dyes of the anthraquinonoid series (→ Indanthren dyes) as well as selected Naphtol AS combinations (Hoechst) and certain Phthalogen dyes, provided these are able to meet specific colour fastness requirements such as light, washing and/or weathering fastness. The name is attributed to Indanthren blue which was synthesized in 1901 by Bohn in Ludwigshafen and is a contraction of indigo and anthracene. Bohn considered this dye to be an indigo derivative at first. Since the dissolution of the → Indanthren Trademark Association, the trademark rights have been taken over by BASF; beneficiary licencees also include Bayer, Cassella and Hoechst.

Indanthren normal-dyeing process → IW dyeing method.

Indanthren reaction A test used for the detection of benzene hydrocarbons in white spirit and other solvent mixtures. Indanthren Violet RT is added to the mixture: the dye dissolves only in the absence of benzene (or homologues).

Indanthren Trademark Association (Indanthren-Warenzeichenverband e.V.). An association founded on the 15th May 1952 and dissolved in 1974 (former headquarters: Frankfurt) to which the dye manufacturers BASF, Bayer, Cassella, Hoechst, Produits Chimiques Ugine Kuhlmann (today: Pechiney Ugine Kuhlmann) as well as the head organization of the German textile finishing industry (Gesamtverband der deutschen Textilveredlungsindustrie) belonged. The association made available to its members the labelling requirements which must be met by the dyes, dye components and the dyed and printed textiles produced from them for the use of the registered trademark. The registered trademark is composed of the word "Indanthren" and the pictorial trademark with the letter "I" (initial letter of Indanthren) flanked by the sun's rays on the left and a rain shower on the right to indicate resistance of the dye to weathering, etc. The printing and dyeing conditions, purity and test criteria were summarized in handbooks and loose-leaf folders with dyed patterns, etc. accompanied, in some cases, by foreign language texts. Since the dissolution of the association, BASF is the registered owner of all rights relating to the Indanthren trademark.

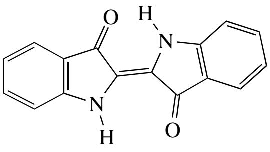
Indanthren yellow paper (vat yellow paper). Yellow indicator paper (strips) coloured with indanthrene yellow. Indanthrene yellow paper is used to test vats in vat dyeing. If the vat conforms to regulations, then the yellow visibly changes colour to cornflower-blue within 3 s. If however the resultant dyeing is yellow olive-greyish blue (dirty) in colour to any extent, the vat is not composed correctly, i.e. there is insufficient sodium hydrosulphite and/or caustic soda solution.

Indentation Permanent pile deformation in upholstery velour fabrics visible as pressure marks resulting from the normal everyday use of upholstered chairs and seats.

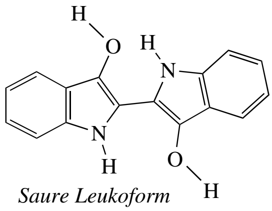
Indicator (Lat.: *indicare* = to point out, compare). A reaction-sensitive substance which allows the progress of a chemical change to be followed, but generally a substance which marks a precise stage in certain chemical reactions, e.g. acidic, alkaline, neutral reaction, by a characteristic change in colour. The determination of pH is a typical application for indicators of this kind. Thermopapers which show when a particular temperature has been exceeded represent another type of indicator.

Indienne Indienne was formerly a term used to describe printed cotton fabrics from India. Today it is used as a general term for lightweight cotton prints achieved by specific printing techniques.

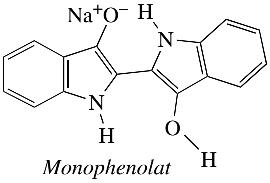
Indigo Originally a natural blue vat dye extracted from plants, especially of the *Indigofera tinctoria* genus grown principally in eastern India and China. It represents the oldest blue vat dye (Fig. 1).



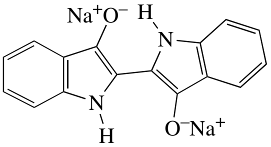
Indigo



Saure Leukoform



Monophenolat



Biphenolat

Fig. 1: Spherical indigo model (BASF).

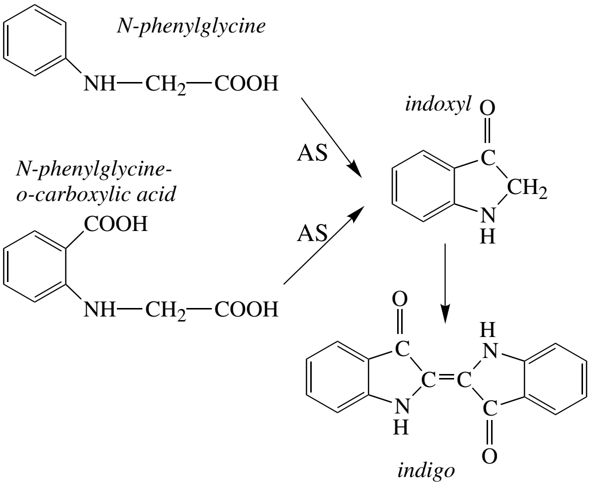


Fig. 2: Indigo synthesis (AS = alkali melt).

The active component, indigotin, is obtained by fermentation, oxidation and boiling the dried plant leaves; in this process 100 kg of dried plants yields 1.5–2 kg of indigo dye. The initially colourless compound is converted into the yellow vatted form by fermentation and various alkaline additions in the form of plant and bark juices. The blue colour develops only after exposure to air by oxidation through the action of atmospheric oxygen. After its first arrival in Europe in the 16th century, indigo entirely superseded the formerly used woad because of its higher tinctorial power. Natural indigo quickly declined in importance with the development of synthetic indigo in 1880 (Fig. 2).

Indigo carmine (sodium salt of indigo disulphonic acid). A blue water-soluble powder. Very sensitive to oxidizing agents. Uses: test for nitrates, chlorates, wool damage.

Indigo carmine reaction Used as a test for wool damage. Wool hairs are allowed to lie in a small amount of a cold saturated solution of → indigo carmine mixed with a little sulphuric acid.

A microscopic preparation is made in conc. glycerol. Damaged areas of wool hairs are stained blue. A 1% aqueous solution of Benzopurpurin 10B (cotton red) produces a similar reaction; treat at the boil.

Indigo detection → : Wash test; Paraffin test; Indigo test.

Indigo dyeing In exhaust dyeing, it is necessary to maintain the correct pH (Fig. 1) besides ensuring sufficient additions of reducing agent. If cotton is dyed with indigo by continuous methods, the dyeing has to be carried out in a series of several dips, i.e. in several stages. A distinction is made between machines for the continuous dyeing of yarn in cable form (ball warps) or in the open-width state. The dyeing of cable began in the USA whereby 300–400 individual warp threads are combined to form a single cable (ball warp). Later, in Europe, the dyeing of full-width warp beams was developed in which the yarn was dyed, dried, sized, and wound directly on to weaving beams ready for weaving in a single operation (Fig. 2).

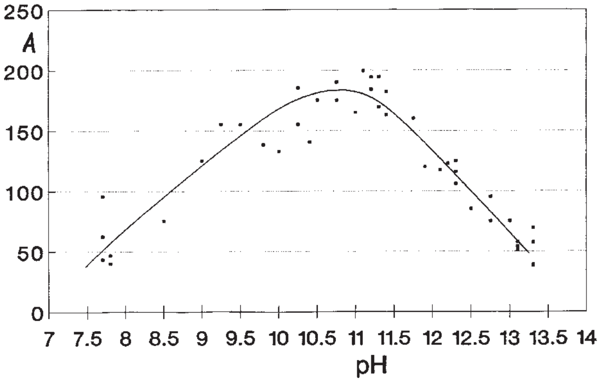


Fig. 1: Dye yield (A) in dyeing cotton yarns with indigo vat at different dye liquor pH values.

I. Cable dyeing (ball warp dyeing): the dimensions of machines for cable dyeing are quite striking since plants of this type can be up to 60 m in length. Yarns for the warp cable are taken from cross-wound packages and batched on so-called ball-warpers as ball warps. The length of the cable can be up to 25 000 m. These ball warps, with 300–400 threads per cable, are displaced by a distribution system before the machine so that on running the cable into the first wetting bath the entry angle between individual cables differs as little as possible. By this means different tensions in the threads are prevented. Continuous dyeing without machine stoppages for batch changing is possible since the cable containing the warp lengths of the new ball warp can be tied to the end of the first ball warp. Particular attention must be paid to thread tension since, in indigo dyeing, different thread tensions lead to differences in yarn coloration which results in warp stripiness. Usually, 3–4 wetting troughs are provided in ball warp dyeing ranges. Depending on the desired degree of precleaning, an additional boil off must be given for which purpose a further 4 troughs are necessary because of the need for after-rinsing.

In ball warp dyeing, approx. 10–18 kg of warp/min can be dyed. Mainly OE-spun cotton yarns are used from which impurities such as hemicellulose, waxes, as well as calcium and magnesium salts are partially removed in the pretreatment. These substances sometimes form a layer several centimetres thick on the surface of the wetting baths which would cause soiling of the yarn as it leaves the bath. Here it is appropriate to remove this layer of dirt by intensive hot rinsing with overflow. Not all plants are able to meet the technical prerequisites for adequate rinsing baths and heat energy. From the machine technology point of view, optimum conditions for a uniform overflow across the width of the troughs are not always available since some machine makers do not have a complete understanding of the physico-chemical processes involved in yarn treatment. After pretreatment and wetting, the ball warp enters the dyebaths. The dye vats are designed in such a way that immersion times of 20–25 s are achieved. In order to prevent an excessively high consumption of reducing agent, relatively deep troughs with a small liquor surface are used. The liquor volume is approx. 2000 l per day. A very long air passage (up to two floors high) is necessary to ensure the complete oxidation of dye including that within the ball warp itself. In ball warp dyeing plants the oxidation time is approx. 1–2 min.

Formerly, 6 dye vats were used. New cable dyeing plants are, however, equipped with 8 vats. Their advantage lies in the fact that, for the same depth of shade, the indigo bath concentration is lower. This results in the formation of finer layers of indigo on the yarn. Two advantages are gained from this, i.e.:

- Less indigo penetrates into the interior of the yarns in the first dipping operation which is consistent with the desired high proportion of white in the core of the yarn.
- The finer layers of indigo result in somewhat better colour fastness to rubbing and washing.

After dyeing and oxidation, the ball warp passes through 2–3 rinse baths. Usually, it is sufficient for the rinsing operation to be carried out at room temperature. It is, however, important to ensure that at least 3–4 l of water per kg of warp yarn is energetically sprayed against the warp; this applies to each of the rinse baths. If rinsing is carried out at temperatures in the region of 50°C, stripping of the dye is unnecessarily high. Ball

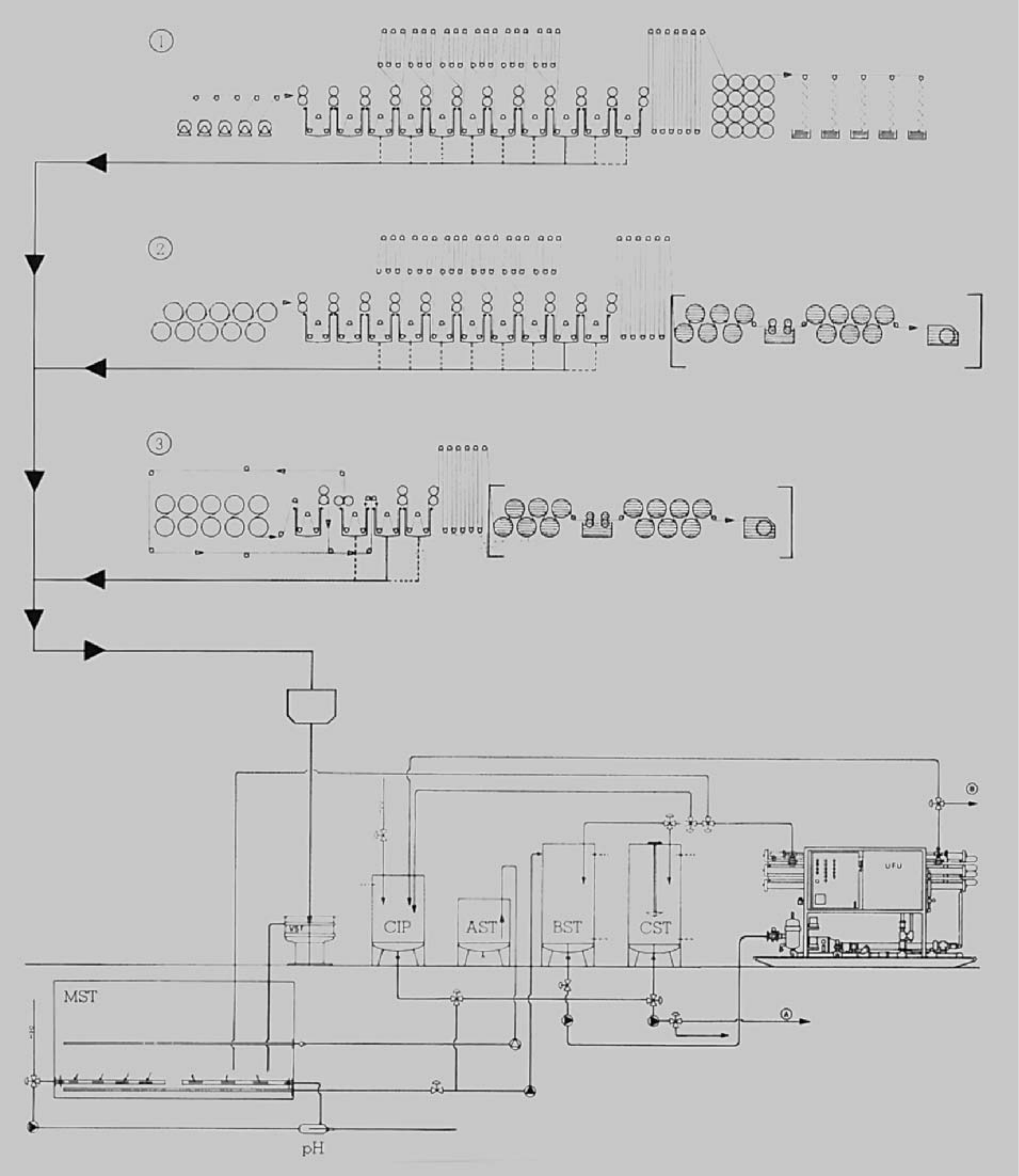


Fig. 2: Comparison of tow dyeing (1), open-width dyeing (2) and so-called loop dyeing (3) by the dyeing methods usual in the USA for indigo with effluent preparation.

warp dyeing does not end with the rinsing operation and the cable passes through a following softener bath in which 0.5–1.0% (based on dry substance) of a cationic softener is applied to the yarn. This softener application facilitates a better opening of the cable in the long-chain beamer. The cable is opened to such an extent at this stage that the individual threads are brought into parallel alignment with the aid of a comb so that they can be wound on to beams for sizing. Even with perfect yarns and an effective softener, the operating efficiency of such beamers lies below 50% in some cases.

Depending on size and width, the capacity of ball warp dyeing machines is between 12, 24 and 36 cables of yarn. If the number of threads in a dyeing machine in which the yarn is dyed in the form of a full-width warp beam is compared with that in a ball warp dyeing machine, the following comparison figures are obtained:

1. Open-width dyeing machine: 3800–4200 threads,
2. Ball warp dyeing machine: 4800/9600/14 400 threads.

With 36 ball warps, material throughput is more than 3 times higher than that from an open-width machine. In ball warp dyeing machines the squeezer rolls are of appropriately large dimensions. Rubber against steel rolls are employed in the squeezer units. The applied pressure is dependent on the particular function of the squeeze rolls. If, e.g. squeezing is carried out after the last wetting bath at 10 bar, a somewhat lower pressure setting is used for the following squeezes in order that the yarn can take up dye liquor. A pressure of 10 bar is used to express the rinse liquor from the last rinse bath before the ball warp enters the softener bath. All other squeezer pressures are set to 4–6 bar. In Fig. 3 the liquor pick-up along the vertical axis of a graph is plotted against the squeeze pressure along the horizontal axis. From this it can be seen that liquor pick-up becomes uniformly less with increasing pressure (up to approx. 4 bar). Above 5 bar, however, the curve flattens sharply. High pressures are required to exert a mechanical influence on the ball warps. Under these conditions the yarns are squeezed apart better and can open out up to 20 cm in width. This promotes more uniform dyeing and a somewhat quicker oxidation.

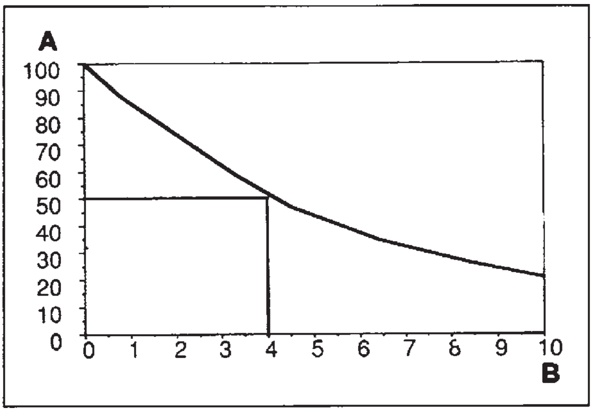


Fig. 3: Liquor uptake (A as a %) relative to squeeze pressure (B in bar).

II. Open-width dyeing (slasher dyeing): after 1970 a second type of dyeing machine was developed in Europe in which the warp threads are run parallel to each other, instead of in cable form, followed directly by sizing. These dyeing machines are also known as “slashers” like the sizing machines. This may be due to the fact that sizers had probably already experimented with size dyeing on their machines. Trials were carried out with pigment colorants as well as indigo. If indigo is applied as a pigment in sizing, only a dull bluish grey colour is obtained. The obvious solution was to approach the machine makers with the desire to develop a separate dyeing machine which could be installed in front of the sizing machine. Today, practically all well-known manufacturers of sizing machines include open-width indigo dyeing machines in their product ranges. As in the case of ball warp dyeing machines, slasher machines also have advantages and disadvantages.

Advantages:

- The open-width dyeing machine is smaller than a ball warp dyeing range so that investment costs are also lower;
- The opening of ball warps (cables) is by-passed;
- Because of the parallel warp threads, the wetting stage is shorter and a single wetting trough can be sufficient;
- The adjustment or stabilization of dyebaths is quicker;
- The liquor content of the vats seldom exceeds 800 l.

Disadvantages:

- In contrast to cable dyeing, no friction occurs between the threads in the region of the guide rollers during dyeing of warps in the open-width state. As a result, a comparable level of colour fastness to rubbing and washing to that obtained in cable dyeing is often not fully achieved.
- The consumption of sodium dithionite is significantly higher due to the greater surface area of the textile material.

Nevertheless, more slasher machines are in use world-wide than ball warp dyeing machines. Since 1989, on the other hand, it appears that more ball warp dyeing machines are being installed once again. This applies especially to countries in the Asian region.

Consideration of the individual treatment stages in the slasher machine reveals the following machine requirements and process times:

1–2	wetting vats,
4–8	dyeing vats,
3	rinsing vats.

Dipping and oxidation times are 10–20 s and 45–60 s respectively.

III. “Loop-dye 1 for 6” dyeing machine: a variation of the open-width machine is the “Loop-dye 1 for 6” machine which was developed in Switzerland and built by Küsters (Fig. 4). In this machine, the warp continually runs back into the same dyebath after dipping and oxidation. As a result, the machine is considerably shorter and sodium dithionite consumption is appreciably less. The warp is passed through the dyebath several times. After the last dipping, a separate air passage is given and the warp is subsequently rinsed and sized. Due to the superimposition of dye in 5–6 dips, a dyed effect similar to that achieved in cable dyeing is ob-

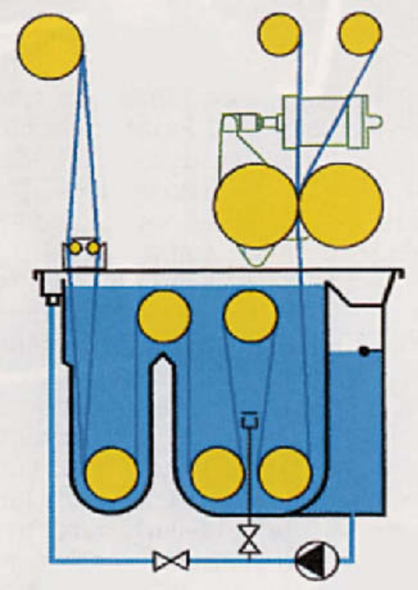


Fig. 4: "Twin-Pad" application in indigo dyeing (Looptex).

tained. Slight friction between the warp yarns also occurs in this case with similar advantages to those described earlier (contributed by Haas).

Indigo dyeing/sizing machines Continuous plants for dyeing warp yarns with indigo in full open-width followed by sizing. A continuous plant of this kind from the warp beamer is illustrated in the Figure. The entire plant consists of: 1–2 wetting troughs for wetting out or pre-dyeing/rinsing; 4–5 dye troughs, approx. 100% residual liquor with subsequent air passages (vertical); 1–2 rinsing troughs; cylinder pre-drier (approx. 30% residual moisture content); accumulator/compensator (for approx. 40 m warp length); sizing machine (various models, single or double size box, running speed approx. 20 m/min; final drier. All the dye compartments are provided with individual pairs of squeeze rollers (infinitely variable pressure setting), effective pressure indicator, pneumatic lifting of guide rollers and upstream adjustment mechanism (compensator control for yarn tension). Dip times in the dye vats from 1–6 s. Vertical air passages for oxidation approx. 4 m in height; each of approx. 2 min with a final passage of approx. 3 min.

Indigo print (blue print). Cotton fabric with white motifs on a blue ground. The existence of blue prints in Egypt had been reported by Pliny the Elder (c. 23–79 AD). The technique was first introduced into Europe at the end of the 17th century by Jeremias Neuhofer of Holland via Augsburg in Germany. The technique is still occasionally practised today in Westphalia and Bavaria and more extensively in Slovakia. It involves the production of a white or coloured resist as an illuminating colour under indigo blue. The printing operation is carried out with the aid of wood blocks. Because of its high solids content (mechanical resist action = paste resist), high adhesion, good chemical resistance and its easy removal during washing off, crystal gum, which has ideal viscosity characteristics, is used as thickening agent for the print paste. Dye fixation is prevented in the printed areas by metallic salts with oxidizing or acidic properties added to the print paste. After application of the resist paste, the fabric is dried and dyed in the dipping vat. The paste develops its action only in the vat and has the disadvantage of having a high lead content ($PbSO_4$, $Pb(NO_3)_2$,

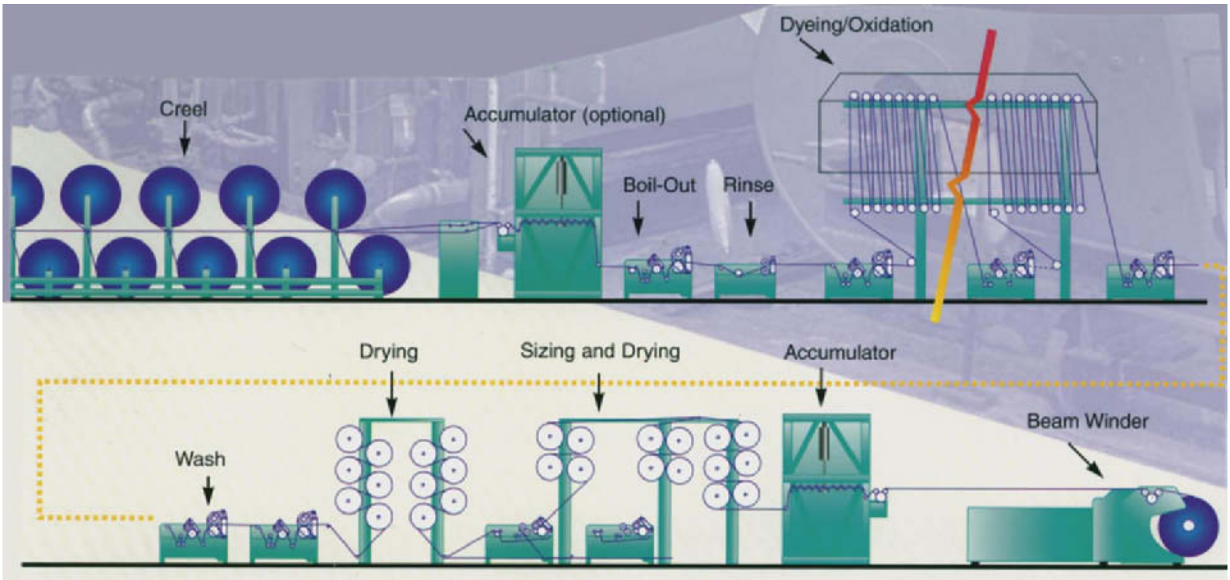


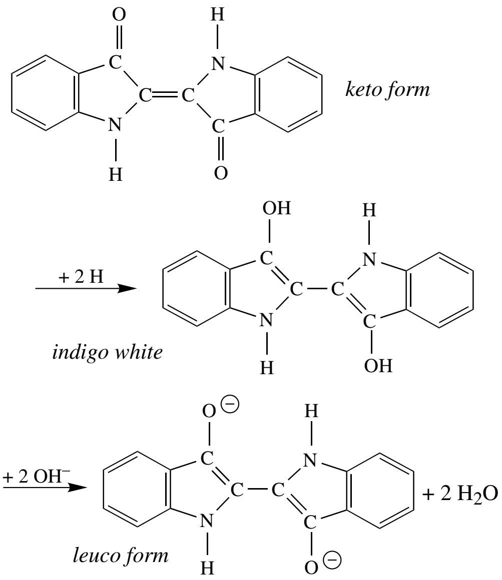
Fig.: Open-width dyeing-sizing with indigo more suitable for lightweight denim than the traditional rope system (from West Point).

$Pb(OH)(CH_3COO)$, PbO). A so-called “copperas vat” brings about the following chemical reactions:

$$FeSO_4 + Ca(OH)_2 \longrightarrow Fe(OH)_2 + CaSO_4$$

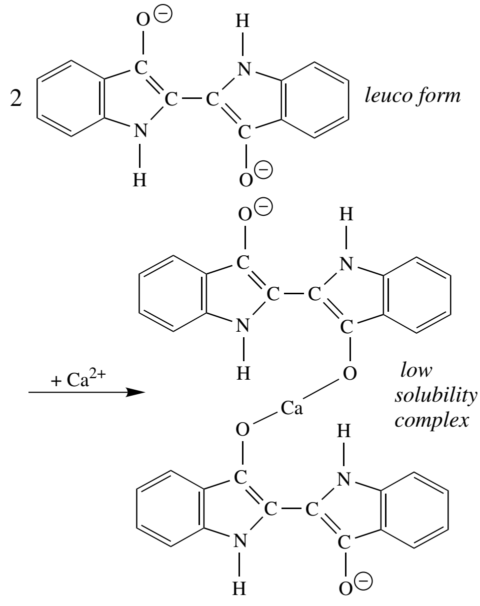
$$2\,Fe(OH)_2 + 2\,H_2O \longrightarrow 2\,Fe(OH)_3 + 2\,H$$

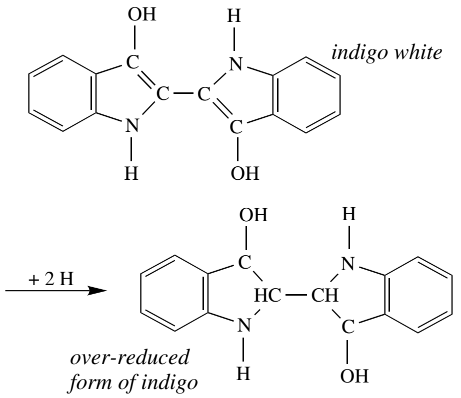
$$Ca(OH)_2 \longrightarrow Ca^{2+} + 2\,OH^-$$



In the “copperas vat” additional, and undesirable, side reactions also take place: these are mainly precipitations of calcium carbonate and over-reduced indigo as well as indigo precipitated by calcium. Besides reoxidized indigo and fibre impurities, these precipitations contribute to the formation of vat sludge.

$$Ca(OH)_2 + CO_2\ \text{(air)} \longrightarrow CaCO_3\!\downarrow + H_2O$$





The chemical resist is produced by the oxidative and alkali-binding action of the metal salts with the aid of catalysts. The indigo vat formed by alkaline reaction is thus destroyed locally by the applied resist. In this process, semi-permeable films of metal hydroxides and reoxidized indigo are formed which prevent the penetration of colloidally dissolved indigo in the liquor. In addition, the thickener itself, together with added printing oils, also has a mechanical resist action.

$$2\,Pb(NO_3) \rightleftharpoons PbO + 4\,NO_2 + O_2$$

catalysts: PbO, $PbSO_4$

$$CuSO_4 + 2\,H_2O \rightleftharpoons Cu(OH)_2 + H_2SO_4$$

$$Pb(OH)(CH_3COO) + H_2O \rightleftharpoons Pb(OH)_2 + CH_3COOH$$

The released oxygen oxidizes the leuco form of indigo and the acids liberated neutralize the alkali present in the vat.

Indigo recovery and reuse Substances present in effluents, wastes or exhaust air can certainly be described as valuable substances, after recovery and cleaning, when they can be used again without any detriment compared to the original finishing agents, dyes, etc.

The draft of the German 38th Administrative Regulation contains precisely defined limits on the discharge of dyes into waste waters which, in most cases, demands compulsory treatment of such waste waters. This also applies, e.g. to the rinse liquors which accumulate during indigo dyeing. As a rule, these have a dye concentration of 0.2–0.4 g/l and contain between 12 and 20% of the original amount of dye used depending on the particular dyeing process.

Ultrafiltration membranes are ideally suitable for the elimination of this dye. In practice, inorganic (dynamically formed ZrO_2 coated) or organic membranes are used which are capable of retaining up to 90% and more of the indigo molecules (as long as these are present in the oxidized state). As a result, a practically dye-free permeate is obtained.

In the case of indigo recycling, elimination of the "pollutant" can be combined with recovery of a "valuable substance". After reduction, the dye concentrate produced by ultrafiltration (50–80 g/l) can be used for dyeing again without any problem. The permeate is at least partially recycled and used for pre-wetting or prewashing even when it contains sulphite due to the use of sodium dithionite as a reducing agent. The percentage of unfixed dye and the indigo price obviously play a major role in the economics of indigo recycling. On the basis of several analyses, payback periods of between 2 and 3.5 years are typical. → Recycling.

Indigo styles in Africa prints,

I. Real Wax: the oldest and most artistic technique involves covering (resisting) parts of the textile material with a wax-colophony mixture. The design is produced by subsequent dyeing with indigo. Since the wax resists are fairly brittle, irregular and extremely fine cracks are formed which results in the typical veining or crackle effects. After dyeing, the wax is removed (e.g. by saponification) and the remaining colours are applied either by repeating the wax resist treatment or by block or screen printing. Sequence of operations:

- wax printing,
- indigo dyeing,
- wax removal,
- application of colour pastes (e.g. substantive dyes, reactive dyes),
- fixation,
- washing/drying.

II. Imi-Wax: the industrial production of Real Wax prints is extremely laborious and costly. For this reason, a technical imitation under the name Imi-Wax has been introduced in practice. The Imi-Wax technique is based on the same designs and colours typically used for Real Wax prints. However, Imi-Wax prints are mainly produced on naphtholated grounds in order to imitate indigo with diazo fast colour salts which are also used to obtain all other shades that are technically possible. Other dye classes are used to obtain shades which cannot be achieved with diazo fast colour salts. Sequence of operations:

- application of naphthol ground,
- printing (diazo fast colour salts supplemented with e.g. Phthalogen blue, reactive dyes, etc.),
- fixation,
- washing/drying.

III. Real Indigo: for this style, the white cotton fabric is printed directly with indigo followed by fixation and washing off. This technique is used to produce high coverage blue/white prints often supplemented by other colours. Sequence of operations:

- printing with indigo,
- fixation/washing/drying,
- overprinting (e.g. reactive dyes),
- fixation,
- washing/drying.

IV. Imi-Indigo: the Real Indigo style described above is also imitated industrially. In this process all the dyes are applied in a single operation and then fixed. Mainly vat leuco ester dyes are applied alongside fast colour salts on naphtholated grounds by direct printing. Sequence of operations:

- application of naphthol ground if required,
- printing (e.g. vat leuco ester dyes, diazo fast colour salts, reactive dyes),
- fixation,
- washing/drying.

V. Fancy-Print: in this style traditional effects applied in Africa are brought together. The style involves discharge and resist printing techniques which were common in Europe from 1900–1955 but which have since gradually disappeared on that continent due to the rationalization of production methods (e.g. aniline black resists, indigo resists, etc.). No general sequence of operations.

VI. Plangi: this is a very old technique for the production of resist effects by gathering, folding, or rolling the fabric, usually held with stitching, to form specific patterns on subsequent dyeing. The plangi technique is an ethnologically-based and artistically valuable craft. It is, unfortunately, seldom practised today. In this case also, the resist effects obtained can also be supplemented with additional colours applied by direct printing. Like the other handcraft techniques described above, very attractive plangi imitations have also been developed. Sequence of operations:

- binding the textile material,
- dyeing with indigo,
- washing/drying,
- printing (e.g. reactive dyes),
- fixation,
- washing/drying.

Indigo test The most commonly used test for the identification of indigo dyeings. Spotting with conc. nitric acid produces a yellow stain surrounded by green edges (= oxidation of indigo to the yellow coloured isatin).

Indigotin, sulphonated indigo as an acid dye.

Indirect polluter → Waste water pollution sources.

Indirect steam → Steam as a liquor heating medium.

INDITECNOR (Sp.), abbrev. for: Instituto Nacional de Investigaciones Tecnólogicas y Normalización, Santiago, Chile (Chilean Standards Institute); → Technical and professional organizations.

Individual fibrils (elementary fibrils, basic fibrils, microfibrils, protofibrils, capillaries). This refers to the initial developmental stage of the next highest cell organisation of the fibril bundle or → Fibrils and is constructed of micelles or crystallites in parallel bundles. Approximate diameter in wool: crystallite 0.005 µm, individual fibril 0.01–0.04 µm, fibril bundle 0.1–0.3 µm.

Individual value The individual value is the statistical term for the characteristic value of a unit (sample) in a → Populations or random sample.

Indole → Heterocyclic compounds.

Induction (Lat.: *inducere* = to introduce). Electromagnetic induction is the generation of an electric current or voltage in a conductor.

Induction forces → Secondary valency forces.

Industrial cleaning This refers to the cleaning of industrial textiles, industrial clothing of all types, uniforms, machine cloths, etc.

Industrial gloves → Protective clothing.

Industrial gum (printing) → Industrial gums.

Industrial gums (industrial printing gum, crystal gum, labiche gum, sheet rubber, drying rubber). Industrially manufactured → Vegetable gums, preferably from Asia. Gum and → Rosaceae rubber which is dissociated under pressure or using oxidation methods, as a result of which the gum is already cold water soluble and suitable for sprinkling in powder form to thicken print dye pastes. The gum is available in irregular pieces, uncoloured (bleached) through to deep red and brown. Generally preferred as a powder (poss. modified using starch gum or starch). Type reaction (according to Grafe) as follows: Tannic acid does not give a precipitate (as with gelatin/adhesive). An alkaline copper solution at 70°C does not give a red deposit (as with starch gum). There is no typical discolouration with iodine solution (starch = blue, starch gum = red). There is no blue colouring (as with starch gum) with molybdic acid ammonia and a little nitric acid.

Industrial hygiene In order to reduce the risk of handling textile finishing agents as far as possible, both in production and in use in terms of their carcinogenic and allergy-inducing effect on humans, industrial hygiene measures are intended to limit the effect of dyes and chemicals on both staff and the environment. The risk results from the harmful effects of the substance and exposure to it (effect). The following measures are required:

1. well planned and safe work stations; partition of the colour kitchen from the other areas; good ventilation in the colour kitchen (4 changes of air/hour), slight overall negative pressure so that dye dust does not escape outside; dust extraction from scales and areas where dyestuff has been handled - this should be carried out from top to bottom using a low flow rate; good facilities to clean floors and walls with water should be available (no packing units should be stored directly on the floor); the packing units should be transported to the scales for collection and there should be short transport paths for products regularly used.
2. extensive automation (weighing and setting up stations) and robotisation (dyestuff stores).
3. suitable working equipment: long-handled withdrawal blades, one for each packing unit opened; drum pumps with separable motor section; no paint brushes, even to clean the weighing scales; no brooms should be used – special vacuum cleaners, jets of water or mops should be used instead; large quantities of dyestuff which have been spilled should not be disposed of with the waste water.
4. suitable recreation and wash rooms; eating, drinking and smoking should be prohibited in the colour kitchen.
5. protective clothing, in particular protective glasses and gloves must be worn as per guidelines (safety data sheets for the relevant chemical products); compliance with guidelines should be monitored.
6. staff training, particularly in all aspects of safety. Information should be made accessible to everyone involved; working procedures and safety regulations must be formulated in writing.

The following is expected of the workers:

7. order and cleanliness at the workplace.
8. observance of all safety regulations; wearing protective clothing; initiatives to prevent accidents, unnecessary exposure and considered, appropriate handling of dyestuffs and chemicals.
9. good personal hygiene, regular washing of hands and face; protective clothing and work clothing must not be taken home; dyestuffs on the skin should not be removed with hypochlorite or reducing agents as these may damage the skin and cause toxic decomposition products to be absorbed.

Industrial noise pollution (industrial noise). Industrial noise pollution refers to general noise in or from the workplace which is sustained for any length of time. Industrial noise pollution may affect the general well-being of the workers (even resulting in permanent damage to hearing) and cause interference within the company or disturb neighbouring communities. Industrial noise pollution must therefore be kept to a minimum. The industrial noise pollution situation is generally complex and is dependent on a number of variables which to a certain extent can only be understood empirically, e.g. from the type and number of machines in use, their stress and load, the position of those exposed to noise and from the space considerations. Industrial noise pollution is very rarely at a constant level. In the textile finishing sector, industrial noise pollution is essentially determined by the technical status of the machinery and the type of heating systems in use. To assess the workplace (see Fig.), sound levels with sound pressure level values in dB (decibels) are used.

The Figure shows how procedural measures can be used to actively combat industrial noise pollution: acoustic emissions of 95–105 dB (A) are given off when the baths are directly heated. The sound pressure level values can be reduced to 78–85 dB (A) however if the baths are filled with hot water or the heating process

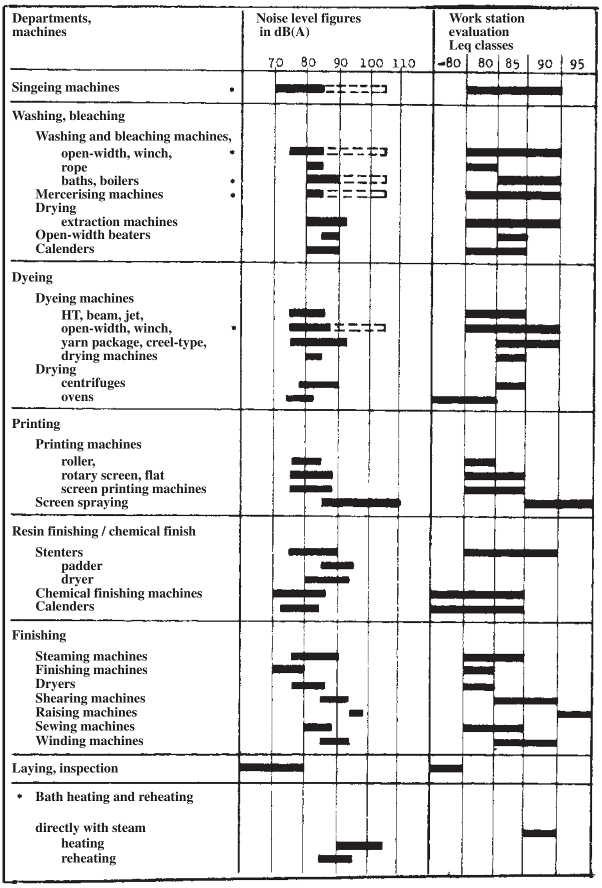


Fig.: Noise pollution at textile finishing work stations according to SUVA (Swiss Accident Insurance Company, Accident Prevention Department).

is carried out using sealed systems (e.g. using the HT process). A similar improvement can be achieved by installing special steam nozzles or mixing zones. In flat screen printing, film screens are still occasionally cleaned using spray guns and blow guns, which results in noise pollution of between 95–110 dB (A). In comparison, a screen cleaning machine operates at approx. 80 dB (A). Technical working measures to combat this are already in place. These include acoustics, architectural acoustics, process technology and mechanical engineering. The following concrete considerations are also possible: separating compressors, circulating pumps, vacuum pumps, and hydraulic units (with divided working areas) or where there is insufficient space, soundproofing these machines. If the vibrations from these machines affect the foundations, pipework and casing, insulation elements should be incorporated. This type of targeted measure may reduce the average industrial noise pollution level by approx. 3–8 dB. In certain circumstances, hearing protection such as ear plugs, ear cushions and ear muffs are available for those exposed to noise, although this does not offer an ideal solution. → Noise protection.

Industrial organization (management). Industrial organization is the task of optimising industrial processes and is directly linked to increasing productivity and production figures. This involves looking into specific aspects such as control/measurement and the bearing of this on costs by deployment of personnel or technical qualifications.

Industrial protective clothing Workwear which must be worn for certain tasks (e.g. the industrial safety shoe). The employer must provide this clothing. → Protective clothing.

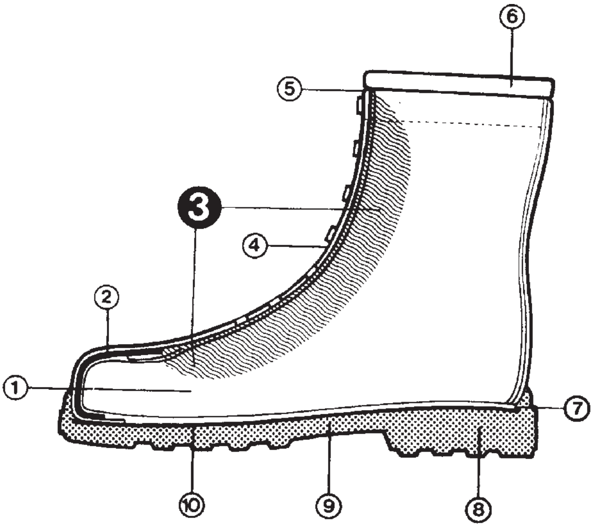


Fig.: Industrial protective shoe.
1 = top quality cowhide; 2 = integral steel cap; 3 = aramid fibre interlining; 4 = closure; 5 = protective strap; 6 = upholstered edging; 7 = leather insole; 8 = elastic heel; antiskid, solvent and temperature resistant sole; 9 = steel sole (protection against nail penetration etc.).

Industrial salt Denatured common salt (made inedible for human consumption). As denaturants the following products are used, e.g. petroleum, dyesuffs, etc. Industrial salt is free of salt tax.

Industrial soaps (technical soaps). Special soaps used for particular technical applications, e.g. textile soaps, etc.

Industrial standards Until a few decades ago, industrial standards were primarily the domain of engineering departments in most medium and large companies. With the arrival of "profit-centre concepts", however, the predominance of pure engineering became less marked. From its conventional objective, interest in standardization at company level was chiefly limited to works standards. Aspects such as efficient production, interchangeability, limitation of products and simplification of stock-keeping were predominant for the company; industry-wide co-operation in this field was initially restricted to the national level. The ever-increasing division of labour in the economy, intensified technology transfer and the further expansion of international integration in the global economy have brought increasing demands for nationally and internationally agreed standards. The aspects of standardization are numerous and, among these, the traditional ones such as e.g. the collective use of available know-how, the limitation of variety by standardization and the classification of sizes and dimensions, the easing of relations through increased uniformity of organizational structures, modes of behaviour and expression both within and outside the company, are to be emphasized. Implementation of these measures results in simplified stock-keeping, greater rationalization and, above all, a contribution to quality assurance and increased safety (e.g. as provided in the draft of DIN ISO 11 111 for textile machines). The effects of these aspects on the environment and their compatibility for human beings are also the objectives of standardization. These latter aspects contribute considerably to the protection of consumers as well as their health and habitat, which are particularly important from the point of view of the state.

Standardization has been defined by → ISO as “the laying down and application of appropriate rules in order to realize, within a given field of activity, a systematic order to the benefit of, and the participation of, all interested parties and especially to achieve optimum economies throughout, taking functional circumstances and safety into account.” The declared objectives of the EC, namely the dismantling of technical obstacles to trade, the abolishment of national borders in commerce, the achievement of transparency in the European market, has not only triggered a hitherto unknown, almost frenetic level of activity, but has also led to a full-blown revolution in standardization. Consequently, the safety of people and machines, health, consumer protection, environmental protection, quality assurance, as well as activities in conformity to standards certification for example, the mutual recognition of testing laboratories etc., merely represent stages in the new direction of advancement in European standardization. An international standard (with worldwide validity) can be contemplated if national standards (on the same subject) already exist in various countries. Such a harmonized standard has as its objective the conformity of frequently contradictory national standards. In certain cases, the standard may also be completely new, especially if no national standard on this particular subject exists yet. Such a standard can be regarded as a preview of the future, since the standard can exist before the product for which it has been designed. The

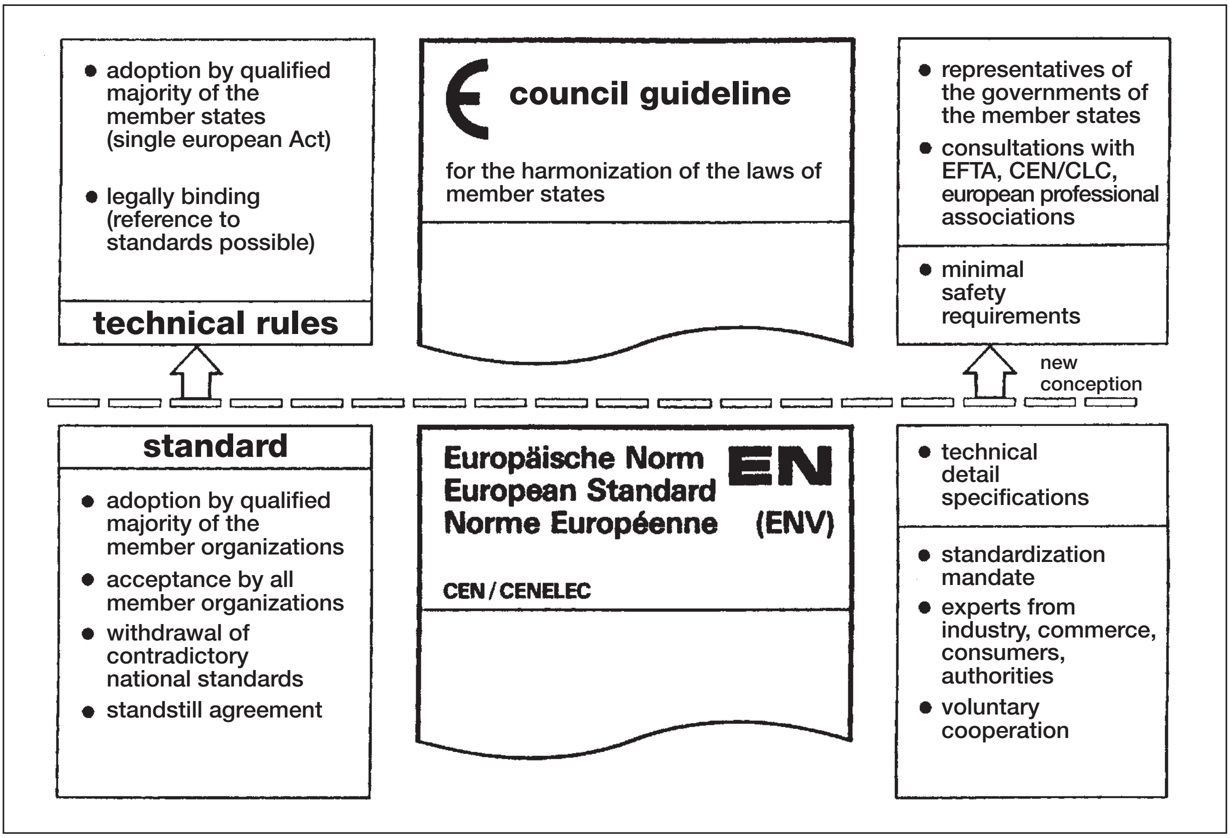


Fig.: Concept for industrial standards.

importance of an internationally harmonized standard is obvious especially in the case of products which are used as various components in a finished product, or as interchangeable elements for finished goods in numerous countries. A new concept (see Fig.) from now on is the formal separation of the technical specification and the private standard. The legally binding technical specification should contain only the necessary minimum of essential safety requirements, whilst the formulation of the technical details should be entrusted to the well-proven procedures of private industrial standardization by CEN/CENELEC (source: Thiévent).

Industrial textiles,

I. In Anglo-Saxon countries and the Netherlands a term used in the sense of → Technical textiles which are not always used for industrial purposes but also for consumer goods with a technical function.

II. A term used for → Rental linen.

Industrial workwear Materials for industrial workwear belong to a category of textiles which have to meet particularly high requirements. They must have high stability and outstanding durability in order to withstand the high mechanical stresses to which they are subjected in most fields of use. Since industrial workwear in many fields is provided by employers under leasing arrangements, mechanically stable and therefore particularly hard-wearing clothing materials are of great importance. Inextricably linked with the cost performance of industrial workwear are also the requirements placed on easy-care properties and wash-and-wear resistance. The specific application conditions or soiling to which industrial workwear is subjected in the field means that it is not possible to clean or wash such articles effectively and hygienically in household equipment but only in commercial laundries and drycleaning establishments. The materials used for industrial workwear must correspond to the latest state-of-the-art technology as regards their suitability for a particular field of use. For good cost performance it should not be necessary for articles of industrial workwear to require a time-consuming and expensive steam pressing after washing and cleaning, but should rather achieve a good external appearance after final treatment in the so-called “tunnel finisher”.

In addition to these requirements, industrial workwear must also protect the wearer from climatic influences at the workplace. Despite the often highly variable climatic conditions and work load during the course of a working day, industrial workwear must be capable of supporting the human body’s temperature-regulating processes so effectively that an agreeable „microclimate“ develops close to the skin in order to achieve good wearing comfort. Only under such conditions can the working man develop his full performance capacity. By contrast, industrial workwear with poor physiological wear properties not only impairs the well-being of the person and thereby increase the stress at the workplace, but also reduces the physical performance of the wearer and can even prove harmful to health under certain circumstances.

Industrial workwear materials have been developed principally to meet the first-mentioned technological requirements of durability and wash-and-wear properties. In view of the fact that synthetic fibres, especially polyester, are able to meet these requirements, e.g. high abrasion resistance and tensile strength, dimensional stability, high luminosity with fluorescent safety colours, cost-saving finish possibilities after laundering/ cleaning treatments, etc., comparatively better than natural fibres, industrial workwear used under leasing contracts consists almost exclusively of blends with a predominant proportion of polyester (contributed by Umbach).

Industrievereinigung Chemiefaser e.V. (IVC). Industrial Association of Man-Made Fibre Producers in the Federal Republic of Germany. Affiliated to → CIRFS; → Technical and professional organizations.

IN dyeing method A method for dyeing those vat dyes (IN dyes) which have the highest affinity for cotton at 50–60°C. → Vat dyeing.

Inert (Lat.: *inertia* = inactive, sluggish). Slow to react, unreactive, indifferent, passive. Polytetrafluoroethylene, for example, is practically inert to all organic solvents and common chemicals.

Inert gas drier Coatings with explosive solvents are dried in driers in which an inert gas (nitrogen) is used as the circulating gas (circulating air in conventional driers) when solvent-containing coating compounds, e.g. adhesives, are applied. The drier housing is completely gas tight and the separating partition be-

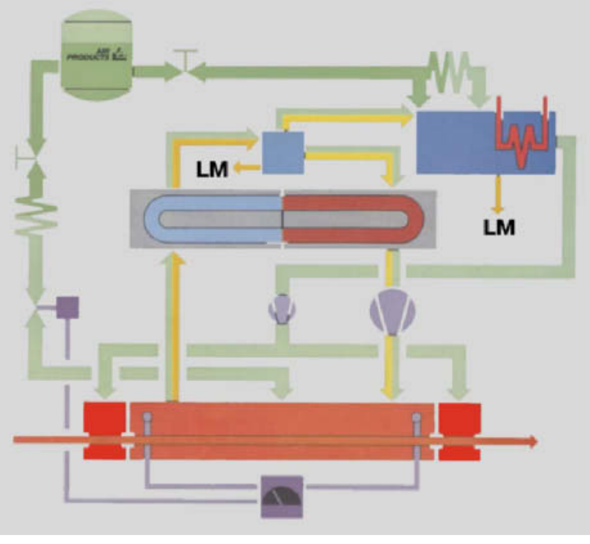


Fig.: Drier (bottom) for solvent coating with inert gas operation (green = N_2 flow) and nitrogen recovery after condensing solvent (LM) out (top).

tween the upper and lower sections of the drier is sealed with an endless seal to exclude ingress of oxygen and prevent explosions. Both the entry and exit slots of the drier are provided with air locks with separate inert gas systems which also prevents the ingress of oxygen into the system. A continuous loss of inert gas occurs in these air locks which is, of course, minimized by the special design of the air locks.The concentration of oxygen in the drier is continuously monitored and automatically maintained at ≤ 6%. In this way, the circulating gas can be loaded with solvent up to its theoretical saturation point so that solvent-recycling in a condensation plant is an economic possibility. For this purpose, a definite quantity of circulating gas is withdrawn from the individual drier zones by means of a circulating gas fan (exhaust air fan in conventional driers) and conducted into the condensation plant where the solvent condenses out and the purified inert gas (fresh air in conventional driers) is again recycled to the drier zones (see Fig.) (contributed by Olbertz).

Infeed frame An infeed frame is a frame above a skein or a carriage at the infeed of a continuous plant consisting of tubes (in its simplest form made from timber) in order to feed the web into the plant at full-width and as smoothly as possible. → Variable-tension rolls or Slatted expanders are often connected to infeed frames.

Information flow in textile finishing The introduction of information technology into a textile finishing mill is extensive and demanding due to the variety and complexity of the manufacturing processes which are subject to continual rapid changes. In many places, the necessary experience is not yet available which is, among other things, to some extent an expression of the still inadequate training of textile practitioners in information management. Moreover, there is a lack of information technologists in the textile finishing industry. Many mills are therefore in a transitional phase from the introduction of a few computers (e.g. for recipe prediction based on colour measurement in the dyehouse laboratory or the automation of batchwise dyeing processes) to a comprehensive application of information technology which not only covers the manufacturing processes but also the entire organizational structure of the company. The application fields for information management etc., can therefore include the following areas (Fig. 1):

- Modern measurement and control technology, in conjunction with microprocessors as universal control and monitoring elements, is used to an increasing extent in all stages of textile finishing for batchwise as well as continuous processes.
- The control of processing operations, recipes and

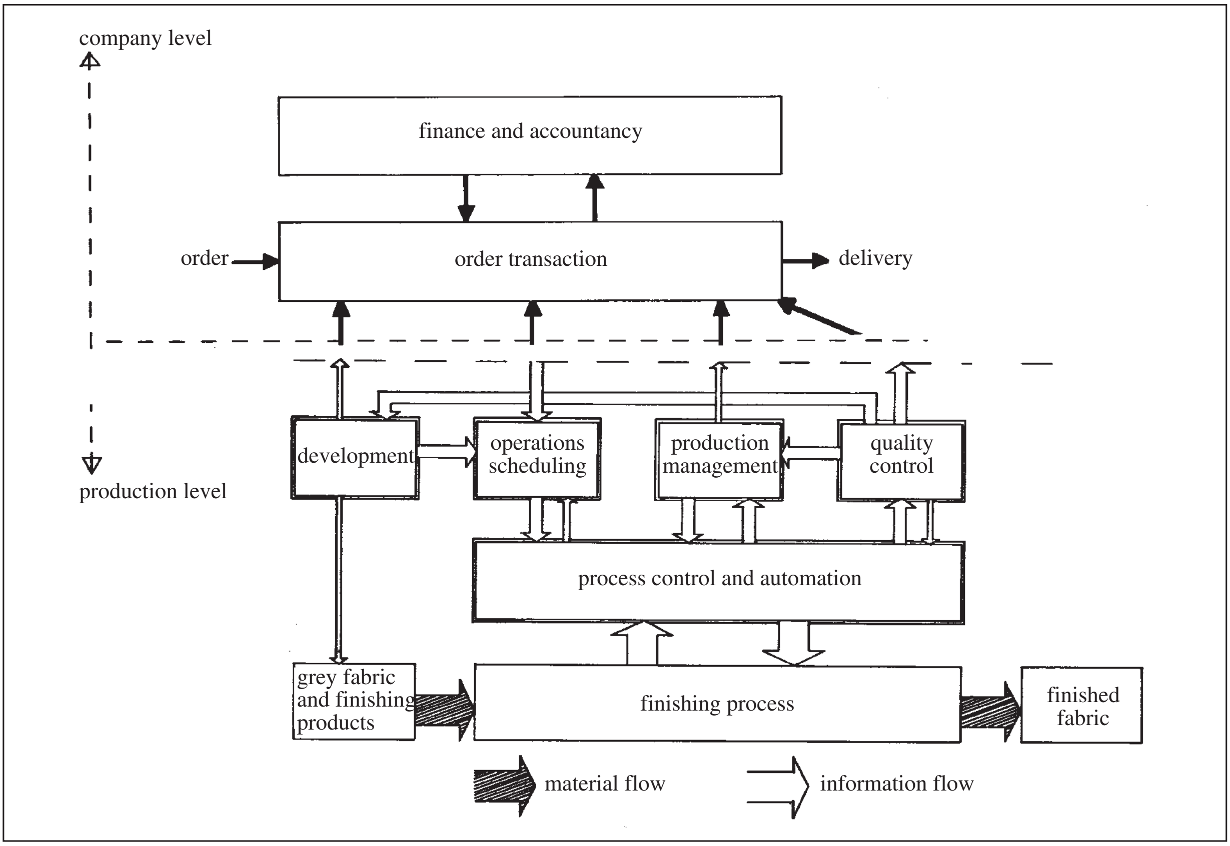


Fig. 1: Information flow (vertical) and material flow (horizontal) in the textile finishing operation.

Information flow in textile finishing

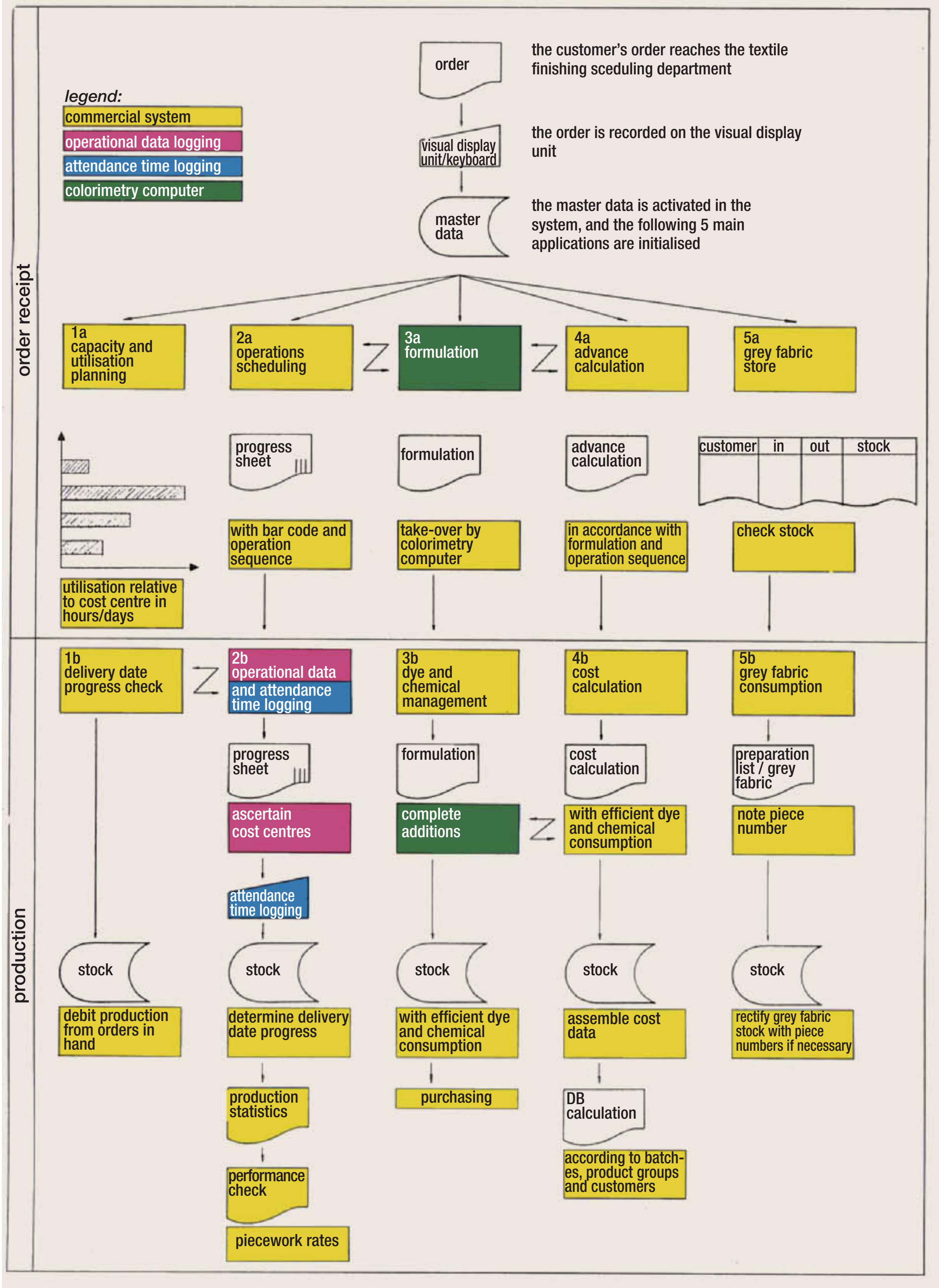


Fig. 2: Data processing in textile finishing.

entire processes can be carried out much more efficiently by computer. The necessary forms and process documents are produced easily, quickly and error-free by this means.
- Computerized data processing provides the most accurate possible information for planning capacity utilization and delivery deadlines, pre- and post-calculation of process costs, as well as the optimized storage of greige fabrics, dyes and chemicals. The computer-aided logging of operational data monitors the progress of each individual batch through all stages of finishing and provides accurate figures on machine times, consumption data and quality characteristics.

It is clear that the smoothest possible interlocking of the sub-domains of such a comprehensive information concept (Fig. 2) should be aimed for by carefully matching one to another.

Information systems Information or communications systems are generally available when information is acquired by the exchange of data. In the IT sector, an information system refers to an underlying database system which has been expanded to include a query system which enables the user to access the data interactively. The database system is the part of the information system which deals with the description of the data available, the data management, and handling of and access to this data. It consists of the database, which includes all of the relevant data, and the database software, which organises the management of and access to the data. In order to carry out specific requirements of a database system, in particular physical and logical independence, it is necessary to view the data in 3 different levels (Fig. 1):
- The conceptual level comprises the logical overview of the data,
- The internal level is concerned with the physical organisation of data,
- The external level deals with the view of individual user groups or application programmes.

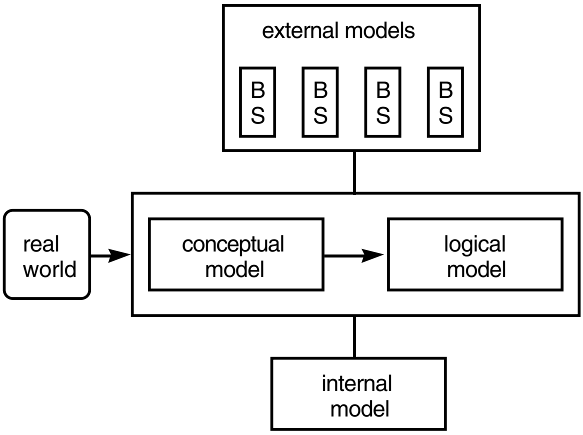


Fig. 1: Architecture of a databank system (BS = user viewpoints).

These 3 levels form the so-called architecture of a database system. The essential components are the conceptual, internal and external models.

The conceptual model describes the data of a system to be represented on a logical level, independent of the data processing perspective. For this purpose, the real world must be mapped on a suitable model by abstraction and grouping. The model is formed as follows: Certain things from the real world are described as objects, so-called entities, between which there are specific relationships (Fig. 2). Such entities can be any real and abstract things which are of interest when describing the area to be analysed. In order to reduce the actual complexity of the subject area in the model, entities are examined for certain similitude criteria in order to summarise them into categories. Entities are of one type within each group. Certain features, so-called attributes, are required to describe entities. In turn, each attribute may be assigned values from a specific range of values. The formation of categories is also characterised in that each entity type or category has a combination of attributes, i.e. each entity type is associated with a corresponding combination of attribute values. Concrete relationships between entities can be classified, in that quantifiable relationships, so-called relationship types, arise between entity types. Entities and their abstract relationships can be shown as an E-R diagram (entity-relationship diagram). Entity and relationship types are defined with the conceptual model and attributes and their values are specified.

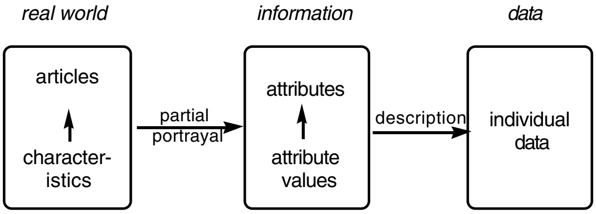


Fig. 2: Portrayal and description of the real world by data and information.

The external model describes the user groups' view of the logical overview of the data. Different user views are necessary as each user (or each user group) has his own view of the data stored in the database, adapted to the individual problems. This means e.g. that someone who only wants a general overview has a different view to someone who is looking for specific information within the database. Each user group therefore has their own external model. The external model must be derived from the overview of the logical data, the conceptual model. An external model is described by a data manipulation language (DML). A DML can either be an extended programming language or a specific query language. The external model is not only created by the actual user, but by someone with a knowledge of both the conceptual model and the user's field of application who is therefore aware of what data is relevant for the user.

The internal model comprises the physical data organisation, i.e. the structure of the stored data, its memory organisation and its access capabilities. An entity type describes a category of objects (entities) with similar features. Each entity type, E, is assigned a specific attribute quantity, A, with a finite number of elements, a.

$$E: < A >$$

$$A = \{a_1, a_2, ..., a_n\}$$

Each attribute $a \in A$ possesses attribute values w_a of a specific range of values. Each entity e of type $E: < A >$ is uniquely defined by its combination of attribute values, i.e. A is an identifier for E. This characteristic may however already apply to a subset of A. If no attribute may be omitted from the identifier subset in order to identify E, then the subset is described as a key for E. In general, there are several keys for each entity type. The primary key, which characterises a specific object using an attribute value, is differentiated. If the value is altered, this would signify a change in the object. (The attributes of the primary key can be identified by underscoring). Each combination of attributes except for the primary key functions as a secondary key. This enables a number of entities of type E with specific properties to be selected.

Entities which are actually available are connected together by concrete relationships, which in turn can be classified as abstract relationships between entity types. A relationship type can have attributes, the concrete relationships between entities have relevant attribute values. Entities and relationships are stipulated by an observer of the real world and can be totally different for different observers. It is possible when displaying the same facts to regard a relationship also as an entity or to define an attribute of an entity type as an independent entity, with a specific relationship arising between these two entity types. If the entity types have been selected, however, attributes and relationship types are also stipulated. In addition to relationships between two entities, relationships between three or more entities of the same type are possible: a relationship type, f, is characterised by the number, e, of entity types involved; the number of entity types corresponds to the size of f.

$$f: \{ E_1, E_2, ..., E_n\}$$

$$\text{size}(f) = n.$$

Where relationships have the same entity type, these must be given so-called role names so they can be identified within the associated entity types. The complexity of relationships gives information on how many other entities can, may or must be concretely related to an entity of a specific type. This is expressed by the degree of complexity (f). There are various notations available to represent the degree of complexity, which will not be detailed further here.

In view of the typologising of information systems, databases can be classified from various perspectives. The typology used to classify databases in one of the best known database managers "Directory of Online Databases" of Cuadra Associates, works on the basis of functional features (Fig. 3). In contrast, the databases are organised from structural perspectives. The different views affect the classification of databases.

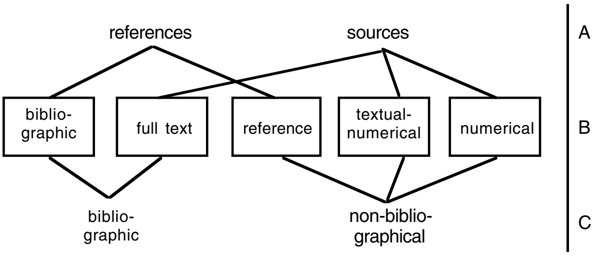


Fig. 3: Classification of information systems under different aspects.
A = functional feature; B = databank types; C = structural feature.

Reference databases are characterised by secondary knowledge, i.e. the data stored refers to sources of information such as literature, organisations, companies etc. Bibliographical databases, also commonly referred to as literature databases, such as BIBLIODATA, include bibliographical data concerning books, dissertations, congress reports, reports and periodicals from all subject areas which have been published in German language literature both at home and abroad since 1945. There are however literature databases such as the textile technology database, TITUS, which consists primarily of articles in periodicals, which are also structured following bibliographical criteria. The individual documents are generally available in the form of abstracts which convey the contents of the document in a concise and succinct manner thus expanding the significance of the literary reference.

Infotex International Abbrev. for Information Textile International. A cooperation between 7 leading international technical journals in Germany, France, Spain, USA, Switzerland and Hong Kong. Purpose: support in market observation, sharing of experience and reciprocal representation. German representation: Melliand Textilberichte International.

Infrared (Lat.: *infra* = below, beneath). Infrared (IR) radiation is long-wave radiation which is not visible to the human eye. The entire IR-spectrum extends from 780–400 000 nm of which only the smaller component of the vibration spectrum between 780–3000 nm is of most interest (see Fig.).

The transition zone between red in the visible spectrum and infrared lies within the range 700–860 nm. All bodies emit IR-radiation, even in the cold, although the radiation becomes more intense the hotter the body. Infrared radiation produces the sensation of warmth from non-glowing hot bodies which is why IR-radiation is also called heat radiation. In order to produce artificial IR-radiation of adequate intensity (e.g. for infrared drying), temperatures above 500°C are necessary. At such temperatures visible radiation is also produced to a notable extent although this can be eliminated by IR-filters in locations where it is not desired.

Effect: as in the visible spectrum, IR-rays are also subject to absorption to a greater or lesser degree. The spectral IR-absorption is greatly dependent on the atom groupings and chemical bond characteristics of the irradiated substance. According to this, most organic compounds have an absorption maximum in the wavelength region between 2500 and 15 000 nm (by comparison the absorption maxima of thin films of water are approx. 3000 and approx. 6000 nm). IR-radiation is capable of setting the atomic nucleus in motion, i.e. vibrating, positively-charged atomic particles in molecular association (dipole moment in cis-form) are formed as charge carriers (not electrons in the shells of the atom as is the case with visible light) which transfer the absorbed radiation energy to neighbouring atoms as so-called collision energy thus having the practical effect of causing bodies to heat up by thermal conduction. Chemical changes can only be caused indirectly by this heating. Only the short-wave IR-radiation can be made use of photochemically by the blackening of previously sensitized plates or films where radiation up to 850–900 nm is mainly involved in practice. IR-radiation is furthermore able to excite phosphors to accelerated phosphorescence which rapidly subsides again, and cause some metal alloys to emit electrons (similar to photocells in visible light). The latter opens up the possibility for direct detection of IR-radiation as well as reflection. The so-called image converter works according to a somewhat modified principle, whereby invisible IR-radiations or images are made visible indirectly. Lightproof IR glasses, which use an appropriate barrier filter, limit IR-visibility to the near IR-transition spectrum. IR-photography and highly sensitive temperature-measuring instruments of the thermoelement and bolometer type, etc., offer further detection possibilities.

Infrared-absorbing dyeings Such dyeings are particularly suitable for heat-retaining winter clothing. Since approx. 50% of sunlight is made up of infrared radiation, dyes which have a pronounced absorption capacity for infrared (IR) offer the possibility to convert absorbed radiant energy into heat. According to findings by the Philadelphia Section of the AATCC, increases in temperature of 14°C were measured on dyeings produced with such dyes on the same textile fabric with shades of similar appearance to those produced with ordinary dyes. Dyes of this kind are also described as “warm dyes”. Such dyes with over 70% absorption

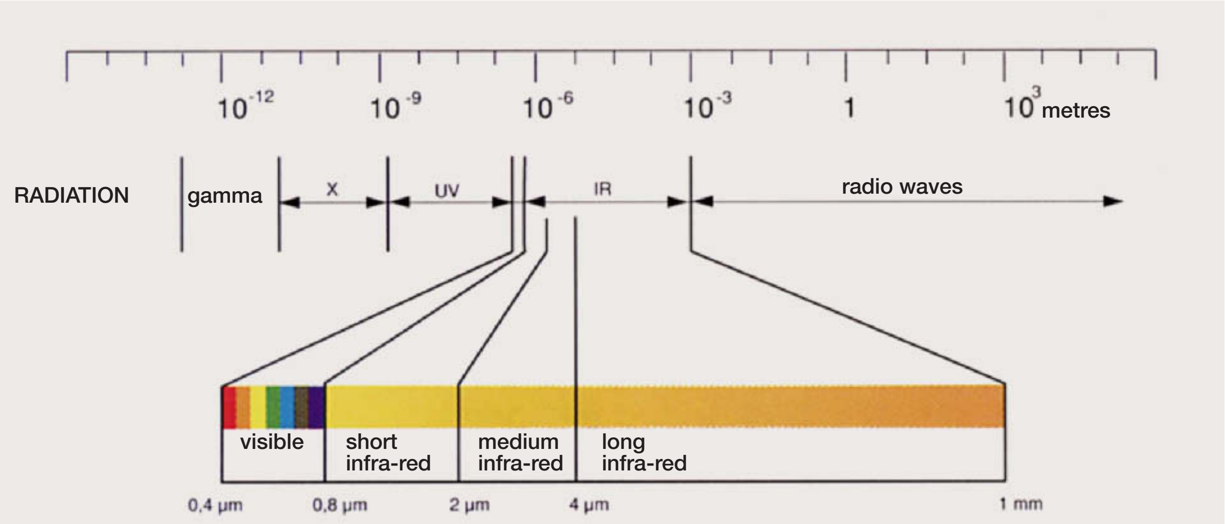


Fig.: Wavelength spectrum of visible and IR-radiation.

(monochromatic energy at the 1000 nm line) mainly include sulphur dyes as well as some vat, acid and chrome dyes where selected blue, navy blue and black dyes have predominated. In the nature of things, it is the chemical constitution of the dye, and not the visible colour, which is decisive here. Where lower demands are placed on absorption (approx. 40%), brown (40%) and green (45%) may also be included among sulphur dyes as well as brown (45–47%) in the case of chrome dyes. The above-mentioned dye classes also contain some other blue and black representatives with considerably lower absorption values. If necessary, reliable information on these properties can only be obtained from the dyestuffs industry. All other dye classes and the shades obtainable from them yield absorption values below 30%. The absorption capacity may be greatly increased by metal salts. By means of simple absorption determinations based on photographic exposures of dyeings irradiated with 300 watt incandescent bulbs (with the interposition of appropriate filters if necessary), inferences can be drawn from the density of prints taken from plates which are especially sensitive to IR regarding the extent to which total IR-absorption (black prints) or total reflection (white prints) is approached, or on which side the predominant intermediate values lie (grey prints). This method can be further refined by taking into account the time factor of exposure to IR radiation, and by measurement of the white or black content (grey standard) quantitative evaluations can also be made.

Infrared drying In drying technology, the invisible IR-radiation from electromagnetic wave radiation, referred to by physicists as infrared radiation, is used by preference. In terms of drying technology, the most significant spectral range is 700–3000 nm. In this range, the particles are displaced in more rapid, random vibrations, thus warming the product. The radiation emitted is referred to as the emission, and the radiation, converted into another form of energy when the material is penetrated, is referred to as absorption. The radiators or radiation receivers which emit the greatest possible flow of energy at a given temperature are referred to as "black bodies". Their radiation has a continuous spectrum and follows "Planck's radiation formula". According to the Stefan Boltzmann law, the following applies to the heat exchange between two large parallel surfaces of different temperatures:

$$Q = \frac{C_s}{\frac{1}{\varepsilon_1} + \left(\frac{1}{\varepsilon_2} - 1\right)} \cdot \left[\left(\frac{T_1}{100}\right)^4 - \left(\frac{T_2}{100}\right)^4\right]$$

C_s is the radiation constant of the "black body" (5.67 W/m^2K^4); ε_1 and ε_2 are the so-called emission ratios of the bodies involved in the radiation exchange; T_1 and T_2 are the absolute temperatures of the bodies. If the so-called radiation exchange coefficient C_{12} is formed from the expression outside the brackets in the above equation for bodies with known emission ratios (material constants) and a defined temperature factor

$$a = \frac{\left(\frac{T_1}{100}\right)^4 - \left(\frac{T_2}{100}\right)^4}{T_1 - T_2}$$

and a heat transmission coefficient of the radiation is defined using $C_{12} \cdot a = \alpha_{radiation}$, then the heat transmission during radiation can be represented in the form

$$Q = \alpha_{radiation} \cdot (t_{radiator} - t_{fabric})$$

and the evaporative capacity via radiant heat can be calculated using

$$G_D = \frac{Q}{r}$$

The radiation exchange coefficient C_{12} is formed from the radiation coefficients C_1 and C_2 of the bodies 1 and 2 as follows:

$$C_{12} = \frac{1}{\frac{1}{C_1} + \frac{A_1}{A_2}\left(\frac{1}{C_2} - \frac{1}{C_S}\right)}$$

The radiator coefficients can be read off from the emission ratio:

$$\varepsilon = \frac{C}{C_s}$$

In practice in textile drying, C_{12} can be set at 4.0. The temperature factor (for $t_{goods} = 100°C$) for various common radiator temperatures is:

T_{STR} (°C)	400	500	600	700	800
a (grd³)	6.19	8.44	11.3	14.62	18.66
$\alpha_{STR} = a \cdot C_{12}$	~25	~34	~45	~58	~74

It should be noted that in this definition, $\alpha_{radiator}$ is particularly temperature-dependent. Thus for a radiation pre-drier with a radiator temperature of e.g. 700°C (radiation on both sides and with an area ratio of $A_1/A_2 = 1$) for the quantity of heat exchanged the following applies:

$$Q = 58 \cdot (700 - 100) \cdot 2 = 69\,600 \text{ kcal/m}^2 \cdot \text{h}$$

and for the evaporative capacity per hour:

$$G_D = \frac{Q}{r} = 128.8 \text{ kg/h} \cdot \text{m}^2$$

The pure radiation exchange is counteracted here by convective influences which arise in particular with gas-operated IR-predriers as a result of the warm flue gases. This also causes a further convective heat exchange. Radiation driers are generally only used in the first stage of drying. As they have a high power density and achieve a high spec. evaporative capacity with well balanced emission and absorption ratios, there is a risk of surface damage to the goods if the wet bulb temperature is not adhered to. This depends on both the emissivity and the “correct” spectral range. In order to achieve a high level of profitability when heating materials, IR radiators with emissions essentially within the area around 3000 nm must be used. As the absorption ratios of textile fabrics (Fig. 1) and water (Fig. 2) are also very favourable in the order of 3000 nm (virtually 100%), radiation temperatures of 500–800°C are preferred.

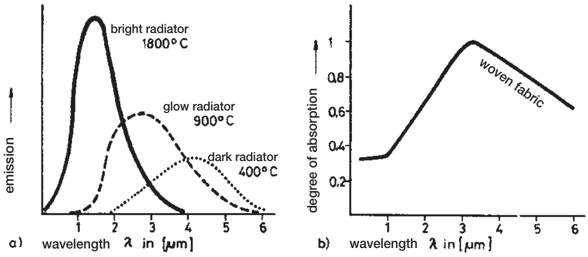


Fig. 1: a) Spectral emission distribution; b) Spectral absorption distribution on infrared radiation driers (1 μm = 1000 nm).

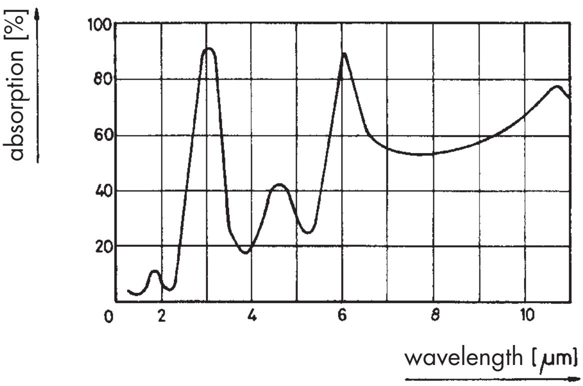


Fig. 2: Absorption spectrum (water 0.01 μm).

The radiator, the most important component of the IR-radiation drier, can be categorised (Fig. 3):

1. depending on the type of energy used to heat the radiator. Electrical and gas-heated radiators are most common.
2. depending on the portion of visible light; radiators which emit light, which noticeably illuminates the surrounding area in addition to invisible rays, are known as bright radiator driers. Invisible rays are emitted from dark radiators. Emission of light starts at temperatures above 500°C.
3. depending on the temperature of the radiator.
4. depending on the composition of the radiation.

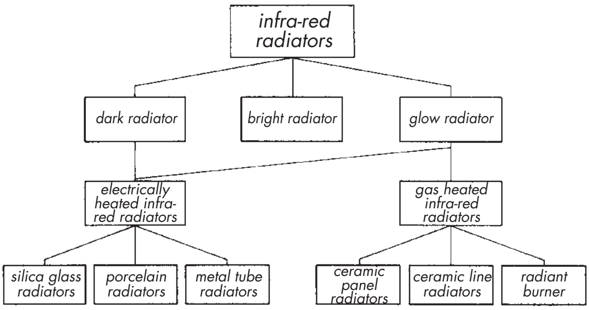


Fig. 3: Infrared radiator classification (Monforts).

Dark radiators
T = 200–500°C, max. emission 3700–6100 nm
Incandescent radiators
T = 500–1200°C, max. emission 1900–3700 nm
Bright radiator driers
T = 1200–2500°C, max. emission 1000–1900 nm

The electrically heated IR-radiators most commonly found in the textile industry are:

- Flat top IR-radiators made from porcelain
- Quartz glass twin pipe IR-radiators.

Flat top IR-radiators (Fig. 4) are integrated ceramic radiators with a heating spiral which has been firmly fired on, and are manufactured using a special process. The heating spiral is made from high temperature resistant nickel-chromium alloy. The glazed surface of the radiator protects the heat conductor from attack by atmospheric oxygen and thereby prevents premature oxidation and corrosion. The wires are arranged in such a way that it is only possible to have a slight temperature difference between the wires and the surface and that heating only takes a few minutes (Fig. 5). Radiating elements at 650–1000 W are used for textile IR-predriers. These radiators absorb surface temperatures of 300–750°C and radiate over a range of between 3000–10 000 nm.

Setting on a clamping fixture (tenter) is advantageous in that it is possible to control shrinkage of both the warp and the weft. On the other hand, these ma-

Infrared fixation

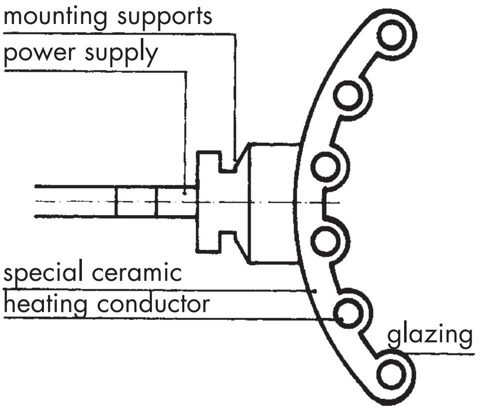


Fig. 4: Infrared panel radiator (Monforts).

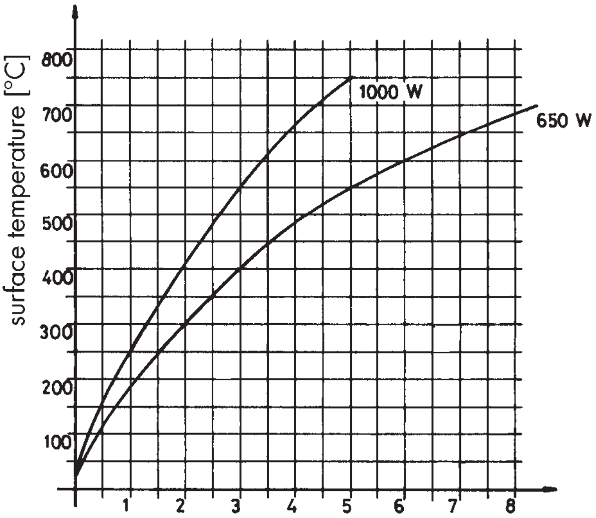


Fig. 5: Heating-up curves for infrared panel radiators (Monforts); abscissa = time [min].

chines require a large amount of space as sufficient production is only possible with long frames. Where short frames are used, the setting time can be reduced and production increased by integrating IR radiators with short-wave radiators (tungsten quartz burners). Electric and gas heated IR-predriers are known. Gas heated systems have heat recovery (Figs. 6 and 7). IR-driers can also be used before steaming machines.

Infrared fixation, e.g. the two-phase infrared process (Hoechst): printed fabric is padded and rapidly heated up without steam. No condensation occurs so there is less tendency for the printed fabric to mark-off or bleed. The recommended wavelength is 1300 nm at which a maximum radiation absorption of 80–85% is achieved.

Infrared laboratory dyeing machines The use of a liquid heat transfer medium (e.g. glycol) in laboratory dyeing machines can be substituted by heating the rotating dye beakers with infrared radiation; a particu-

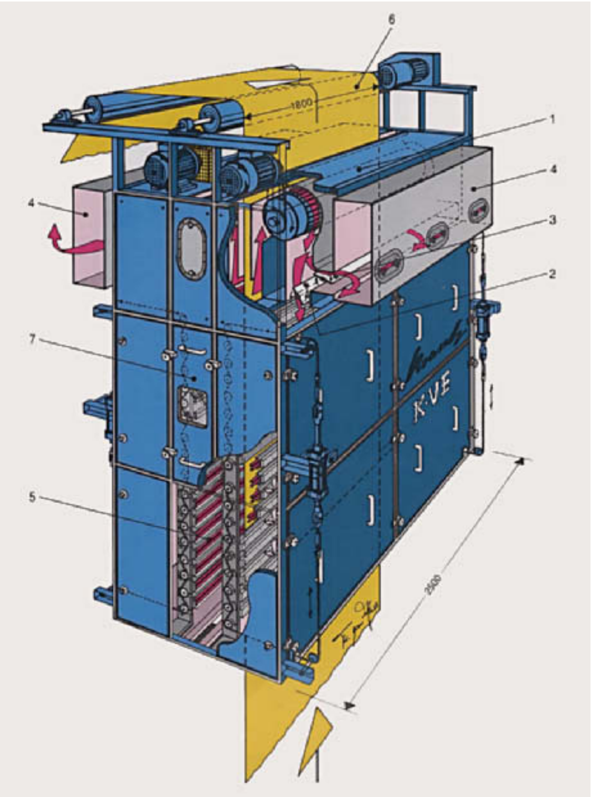


Fig. 6: Electrically heated infrared predrier (Krantz). 1 = circulating/exhaust air fans; 2 = circulating air regulating flaps; 3 = exhaust air regulating flaps; 4 = exhaust air ducts; 5 = gold vaporised IR-radiators, tiltable; 6 = driven deflecting rollers; 7 = flap with viewing window.

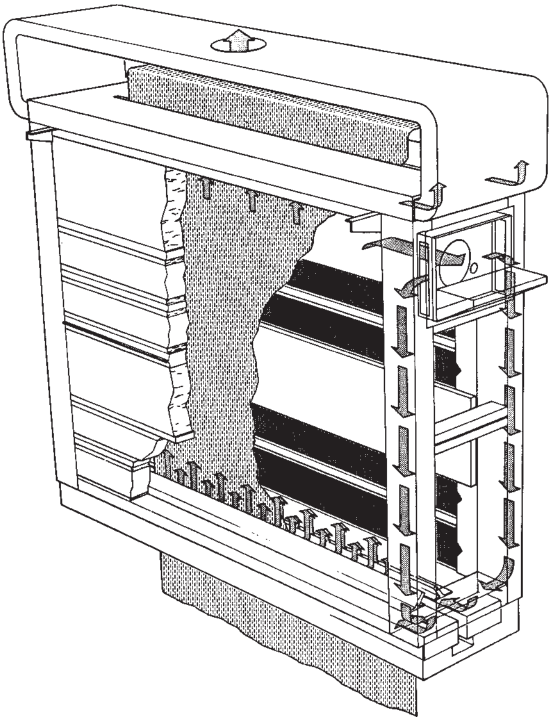


Fig. 7: Gas heated infrared predrier (Babcock).

larly intense absorption of heat is achieved with black beakers by this means.

Infrared moisture measurement Infrared light (IR) is absorbed to a different extent by various surfaces depending on wavelength. Water also absorbs IR energy of a certain frequency. If monochromatic IR light of one wavelength, at which moisture is particularly intensively vaporised, and another wavelength where there is virtually no absorption, is alternately irradiated onto a measuring device and the energy reflected in each case is compared, this will give the amount of moisture in the goods being tested. The so-called differential light process, i.e. alternately emitting a measuring beam and a comparative beam through the same beam entry point, is characterised by the fact that influences which affect both signals equally, i.e. structure of the goods to be tested, density, degree of reflection, ambient light, are largely insignificant.

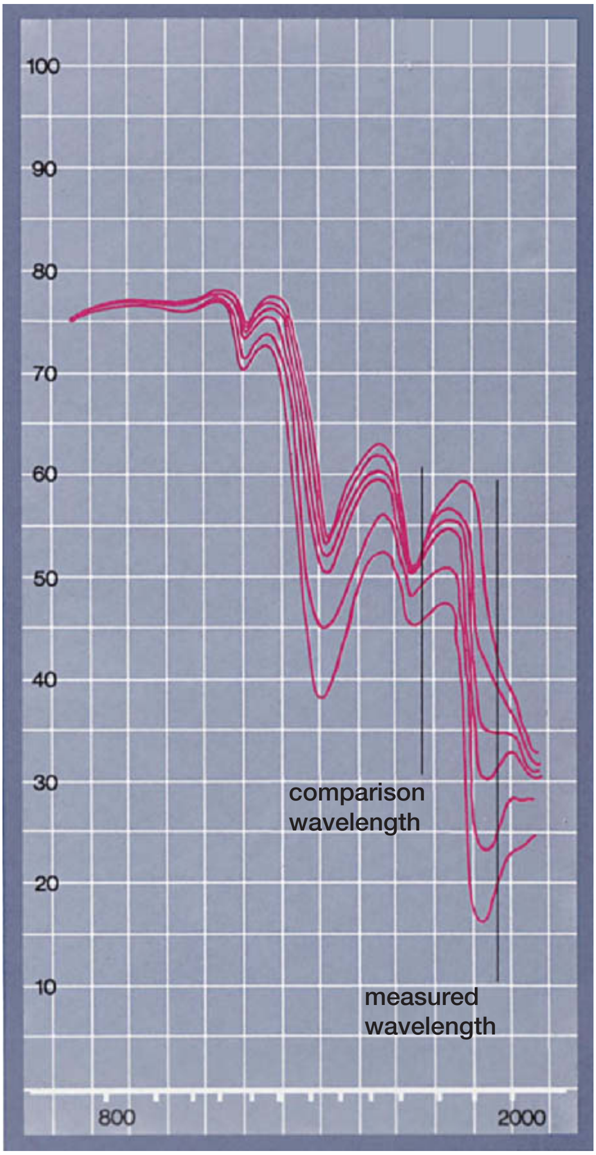


Fig. 1: Wool spectral curves in the infrared range.

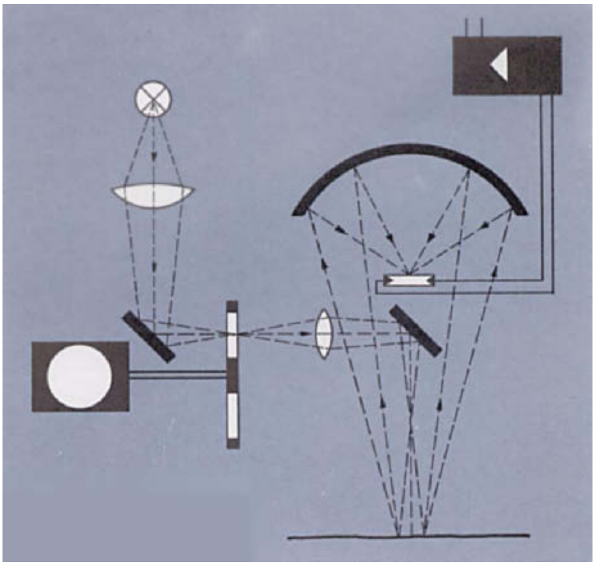


Fig. 2: Path of infrared radiation from light source to material to be tested and back (Mahlo).

The various wavelengths (Fig. 1) are obtained by two optical filters which are directed successively on a rotating filter wheel in the path of the rays. Monochromatic filters only transmit a very narrow section of the overall width of the infrared light. Different moisture measuring ranges may use different filters if preferred (exchanging the filter wheel). The distance of the reflective sensor to the goods to be tested is typically 100 ± 10 mm and is therefore relatively not critical. The ray of light should impinge both vertically and obliquely. The measuring point has a diameter of approx. 25 mm; in spec. cases it is thus possible to achieve an extremely well-defined reading (Fig. 2).

Infrared predriers Watertight infrared radiation fields in working widths up to 6 m are employed especially as predriers in printing, dyeing and finishing applications (Fig. 1).

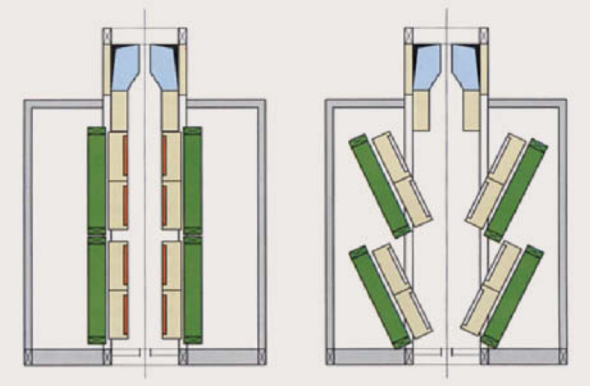


Fig. 2: Tilting electric infrared predrier (Matherm).

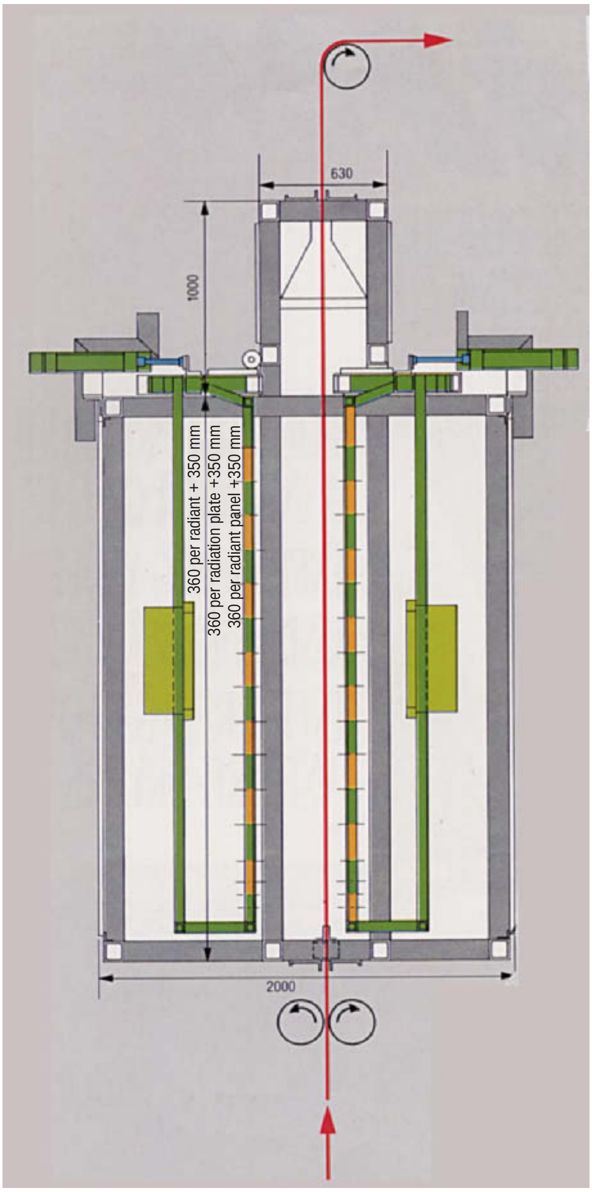


Fig. 1: Infrared-based AGT predrier.

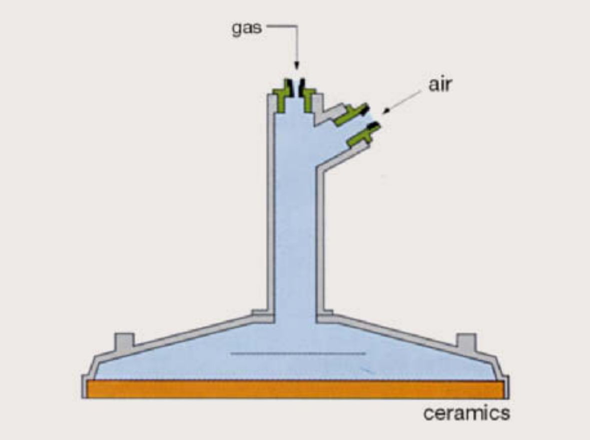


Fig. 3: Gas-heated infrared predrier (Matherm).

Both electrically-heated and gas-heated radiators (Figs. 2 and 3) are available.

Infrared reflectance As far as textiles are concerned, infrared reflectance is, in general, the diffuse reflection of light rays with wavelengths between 700–1200 nm. Infrared reflectance plays an important role in → Camouflage dyeings and prints.

Infrared-reflecting dyeings These dyeings represent the opposite of → Infrared-absorbing dyeings. Such dyeings are particularly suitable for cooling summer or tropical wear. Selected dyes with a pronounced reflecting capacity for IR-radiation, which are also described as “cold dyes”, are used for this purpose. A very extensive colour range, including almost all shades, is available for which most dye classes contain a relatively wide selection of individual representatives with over 70% reflection (monochromatic energy at the 1000 nm line). The IR-reflection of dyes used in the production of camouflage dyeings and prints for military purposes is of greatest importance here.

Infrared sensor Entry device for contact-free and mechanical sensing fitted to stenter driers, especially for sensitive fabrics and the detection of uneven edge migration with fine fabric qualities.

Infrared spectroscopy (IR-spectroscopy). An optical technique for measuring the absorption spectra of solid, liquid or gaseous organic compounds in the IR-region. The technique is also used for the determination of isomers and homologues. The IR-absorption curve obtained is compared with the known curves in a catalogue (e.g. Landolt-Börnstein) which permits a rapid identification of constitution. In IR-spectroscopy, transitions between molecular states, especially the vibrational and rotational states, are recorded. In order to record the absorption continuously, a beam of IR-light in the spectral region of 200–4000 nm is passed through the sample. From the resultant absorption peaks functional groups such as ketones, esters, etc., can be easily and precisely identified.

It is possible to carry out both qualitative as well as quantitative analysis by means of IR-spectroscopy. The “fingerprint” region of the spectrum in the range from 650–1 450 nm is particularly suitable for qualitative analysis. With very few exceptions, molecules have characteristic vibrations (skeletal vibrations) in this range which enable the analyzed substance to be identified. The Fourier-transform IR spectrometer (FT-IR) is particularly important for the quantitative analysis of low concentrations. In contrast to conventional IR-spectrometers, the IR-ray is not resolved spectrally at different angles in FT-IR instruments, a stream-splitter as well as a fixed and movable mirror are used for interference. Mirror movement is controlled by a helium/neon laser. The interference signal is digitally recorded and subjected to Fourier transformation. The FT-IR spectrometer is not only capable of recording IR-spectra, the investigation of material surfaces is also possible with appropriate accessories.

Besides the analysis of environmentally-relevant substances, the qualitative and quantitative analysis of textiles, with regard to their fibre composition, is also possible by means of IR-spectroscopy. IR-spectroscopy also offers the possibility to determine weaving and spinning assistants, e.g. sizes, quantitatively after extraction and the preparation of a calibration curve.

Infusorial earth → Kieselguhr.

Ingrain dyes An imprecise description formerly used for all colorants which were produced *in situ* on the fibre by the development or coupling of one or more intermediate compounds.

Inhibitors (Lat.: *inhibere* = to restrain). Substances which retard or stop specific chemical reactions or processes, e.g. →: Antioxidants and Corrosion inhibitors. In the so-called swelling treatment (→ Inoculation) of water conditioning, use is made of the inhibiting action of small amounts of sodium metaphosphate (0.5–2 g/m3) which amounts to only a fraction of the required quantity to prevent the formation of calcium carbonate crystals.

Initiator A reaction accelerator or promoter, e.g as in radical polymerization. Its action is similar to that of a → Catalyst, except that it is usually consumed in the reaction whilst a catalyst remains free.

Injector A device used in the colour kitchen of a printing plant for the preparation of e.g. thickeners. The substance to be dissolved is sucked into the injector by low pressure. The low pressure is produced by spraying water through nozzles with an overpressure. By this means, the substance is wetted out at the same time. The concentrate thus formed then passes from the injector into a mixer turbine.

Ink Coloured inks are aqueous solutions of coal-tar dyes with suitable additives. Both cationic dyes (e.g. rhodamine, fuchsin, methylene blue) and acid dyes (e.g. eosin, ponceau, nigrosine, acid blue) are used. Black inks consist mainly of a mixture of gallic acid, tannic acid and an iron (III) salt (iron gall ink). Uses: dyeing, drycleaning, varnishes.

Inking couple Dye paste trough with transfer roller and printing roller in the roller printing machine.

Ink jet A stream of liquid in the form of a dye solution produced by a spray nozzle.

Ink jet colorant application A contact-free application system for colorant solutions. → Ink jet colorant application.

Ink jet printing In the ink jet process (Fig. 1) there is no contact between a dye applicator (e.g. engraved roller or screen) and the material being printed as in conventional methods of printing. Rather, dye liquors (inks) are squirted through fine microprocessor-controlled jet nozzles. This operation is carried out almost silently at high speed on surfaces which can be in any form: e.g. eggs, wadding, metal cans, etc. Special requirements are placed on the inks and their additives both for the ink jet techology itself as well as for the various media to be printed. The inks must be of low viscosity, have adequate fastness to light and water, and a pH as close as possible to neutral. They must also be rapid-drying without, at the same time, drying-out in the printer head, and must also be non-corroding and possess a certain surface tension.

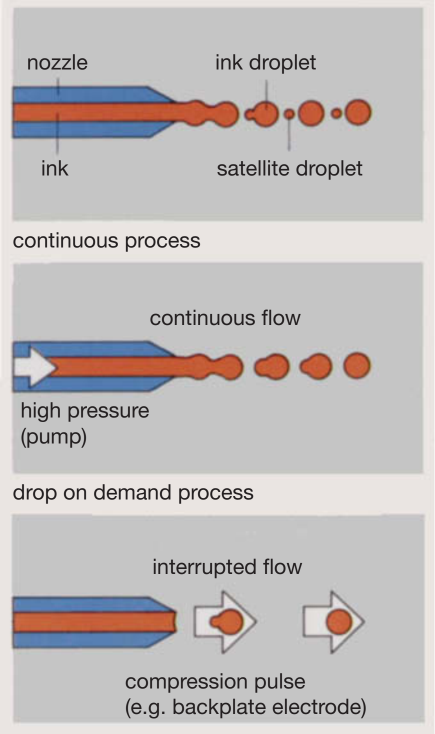


Fig. 1: Ink jet process functional principle.

The first functionally-reliable apparatus for ink jet application was an oscillograph. In this apparatus the rotary magnet of a galvanometer system is located on a fine glass capillary which functions simultaneously as a torsion thread. The upper end of the capillary is bent at an angle of 90° so that the flow of ink from the end of the capillary produces an ink stream in the direction of the substrate. The stream is deflected in rhythm with the galvanometer current. Modulation is achieved by rotation of the jet nozzle opening and continuous translation of the substrate. This apparatus, named “Oszillomink”, was developed in 1948/51 by Elmquist.The upper operating frequency is 1000 Hz.

By using special inks, formed into ink droplets (according to either the piezo-electric or the thermal “bubble-jet” principle), substrates with appropriate reactive groups (protein or cellulosic fibres) can be “printed” or better, patterned, with chlorotriazine reactive dyes by the ink jet process if the fabric has been pretreated with a colour intensifying auxiliary.

Ink jet printing may be conveniently subdivided into two types, continuous and drop-on-demand. The

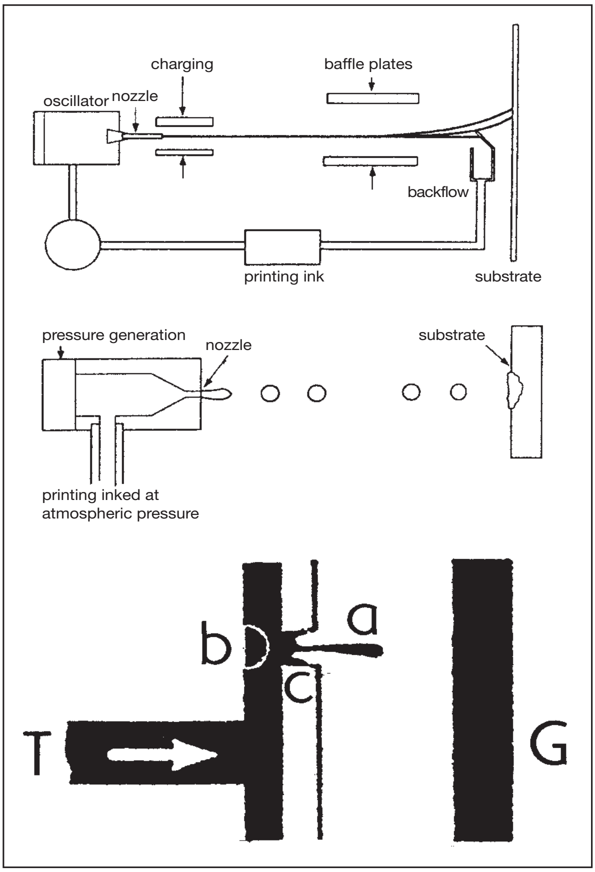


Fig. 2: Continuous ink jet process (top) in comparison with the periodic drop on demand piezo process (centre) and in comparison with the periodic drop on demand bubble jet process (T = ink feed; a = ink droplet; b = evaporating ink; c = nozzle; G = substrate).

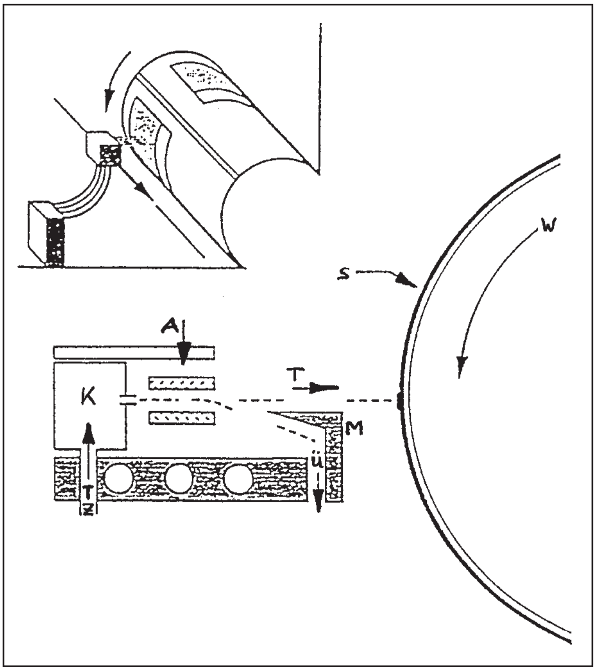


Fig. 3: Principle of IRIS-Graphics and Stork ink jet printing. Ü = diverted excess ink (is discarded); M = knife; W = roller; TZ = ink feed; A = cover plates; T = sprayed ink; S = substrate.

main difference between the two lies in the means by which the ink droplets are formed. In the continuous process (Fig. 2) ink is accelerated at moderate pressure through a jet nozzle and formed into droplets by a piezo-electric head which oscillates at high frequency. The droplets are electrically charged and deflected on to the substrate electrostatically.

In the drop-on-demand (DOD) method, a distinction is made between the piezo-electric and the bubble-jet process. The first process also uses a piezo-electric element but without a control mechanism. The speed of the droplets is slower and only sufficient droplets are formed as are actually required. The bubble-jet process (developed by Canon) uses a computer signal to produce an electric current on a non-conducting layer within the jet nozzle which reaches a temperature of around 400°C in 5 µs. This causes local vaporization of the ink and the shock wave from the expanding bubble ejects a drop of ink from the jet orifice at high velocity.

Stork has been particularly concerned with developing the application of ink jet technology as a printing alternative for cotton fabrics with reactive dyes (Fig. 3). Stork Screens BV has developed the TruColor Jetprinter 2500 (TCP-2500), based on Hertz technology, for the rapid production of colour-fast samples on textile fabrics. The conventional sample printing machine and sample table can be largely substituted by this system. The TCP-2500 works according to the Hertz continuous stream technology. A special valve for textile dyes as well as the necessary software (to control the printer from a CAD station and allow design information to be printed) have been developed for the practical application of this technology.

In continuous jet printing, a continuous stream of dye droplets is formed which is directed on to a substrate by a jet nozzle. This is achieved at a frequency of 625 kHz (625 000 droplets per second per colour). These droplets are selectively charged with a negative electric charge. The charged droplets are deflected in an electrostatic field and returned to a dye storage tank. The uncharged droplets are directed on to the substrate where the design is built up in the desired colour way. The system is based on four-colour printing (i.e. cyan, magenta, yellow and black).

A special type of reactive dye had to be developed in order to achieve optimum colour reproduction on the textile substrate since all the printing colours formerly used for the jet printer were unable to meet the requirements of the textile market. In collaboration with Zeneca Colours UK, therefore, new reactive dyes, based on the Procion P range, have been developed.

Ink jet printing technology,

I. Continuous ink jet printing. In this form of ink jet printing, the continuous stream of dye liquor forced out of a fine jet nozzle is controlled either by deflection or superimposition of a deflector plate (Electrocolor process) or deflection by means of compressed air (Millitron process). The excess dye liquor is collected and returned to the storage tank.

II. Drop on demand ink jet printing. In this case, discrete drops of dye liquor are jetted by switchable electromagnetic valves located in the dye liquor feed tubes in a predetermined sequence determined by the pattern being printed (Chromotronic process).

III. Quantitative control of the ink jet as in the Agfa ink jet process, etc. → Ink jet printing in the non-textile sector.

Inlet-controlled water heater In this type of water heater, stored water in a boiler is heated by excess steam which thus serves as a heat accumulator for the plant. The accumulator temperature can reach up to approx. 95°C. Heating of the stored water is entirely dependent on times when excess steam is available. The lower boiler is provided with a steam damper. The upper boiler functions as an instantaneous water heater, i.e. incoming cold water absorbs heat and is then supplied as hot water to the point of use. The boiler works without pressure and is in constant balance with the outside air. Even when used with high pressure steam there is no risk of explosion. Boiler scale and corrosion are hardly a matter for concern since the stored water is reused without interruption. With appropriate heat insulation there are practically no heat losses. This flow-through heating system for the production of hot water represents an economical process at a low investment cost and is much more advantageous than storage tanks and boilers which function solely as hot water accumulators.

Inlet material, bed ticking Inlet material is a thick cotton or viscose fabric in a 3-shaft twill weave which has a down-proof (feather-proof) weave and finish; generally red, but is also available in other colours. Use: for bed ticking.

In-line measurement This refers to the measurement of values without taking a sample, e.g. in the production system. → On-line.

Inner drum Rotating cylindrical drum of the → Double drum machine serving as repository for the treatment of items in washing, cleaning or dyeing and having agitator ribs, a segmented drum and perforations in its periphery. The inner drum is mounted axially either on one side with the loading door in the front face (front loading washing machine) or on both sides (for capacities exceeding 50 kg) with a top loading door (tangential). There is also a free axis inner drum which is suspended from stainless steel chains which are themselves actuated by a reduction gear drive. Every type of inner drum is enclosed within the robust → Outer drum. Washing machine inner drums of up to 90 cm diameter are usually not segmented but may have vertical dividing walls. Drum segmentation usual if the diameter exceeds 90 cm.

Innovation Conversion to forward-looking solutions, e.g. to technical production or processing problems. Perfection of existing, and the introduction of new, technologies, methods, experiences, new markets, etc.

Innovation time The time span required for the → Innovation of a product or process from the beginning of development to the commencement of industrial production or introduction to the market.

Inoculation Minimum dosage process for the prevention of boiler scale in boiler feed water by the complexing of hard water salts. The process is also commonly used for the removal of already-precipitated scale sediment in cooling water. A distinction is made between:

1. Acid addition, preferably with sulphurous acid which is less corrosive and also binds atmospheric oxygen at the same time.
2. Phosphate addition: 2–5 g/m^3 (e.g.) for the prevention of scale in cold and hot water piping systems.

Inorganic chemistry A term for the branch of chemistry concerned with the chemical behaviour of all elements and their compounds with the exception of those carbon compounds which fall within the province of → Organic chemistry. Today approx. 50 000 compounds are known.

Inorganic fibres Also described as → Mineral fibres. More exacting requirements in the field of environmental protection, the performance of materials, or the productivity of existing systems also calls for the development and use of newer types of fibres. The importance of inorganic fibres of oxide or non-oxide basis is due, above all, to the extremely high temperature resistance of various physical or chemical properties up to temperatures greater than 1100°C. Due to this outstanding property, this important generation of fibres will be of interest in the future for the solution of problems where resistance to high temperatures in processing or application is demanded. Yarns produced from mineral fibres are suitable, e.g. in the form of woven fabrics or braids, for heat insulation purposes as well as the reinforcement of specific electrical and thermal composites.

An increased environmental awareness, especially in the field of energy conservation and exhaust gas filtration, the higher requirements placed on material properties such as strength or stiffness even at high temperatures (the future-oriented development in the field of fibre-reinforced metals and ceramics is a striking example here), and the higher performance of e.g. fabric-reinforced printed circuit boards (for the electronics industry), are examples of tasks which will be solved by the use of special inorganic fibres in future.

Inorganic fibres are characterized especially by their high temperature resistance combined with higher specific strength and stiffness or their special physical or chemical properties. Complex requirements in various fields of application make the careful selection of appropriate types of fibres or yarns essential. Amongst the special inorganic fibres, products based on silica yarns have aroused particular interest as well as the extremely temperature-resistant Al_2O_3 and SiC fibres and yarns which are also used for the reinforcement of metals and ceramics.

INRA (Fr.), abbrev. for : Institut National de la Recherche Agronomique (National Institute for Agronomic Research). A French textile research institute. → Technical and professional organizations.

Insecticide A substance used to kill or destroy insects in the form of:

a) an oral poison (acts as a stomach poison provided it is taken with the insect's food),
b) a contact poison (which acts on the nervous system),
c) a respiratory poison (which acts on the respiratory organs). → Mothproofing.

Insecticide chemicals Chemicals which provide protection against insect infestation and are able to protect textiles from destruction by insects such as moths (→ Mothproofing), termites, silverfish, etc. Such products are based on e.g. fluorides, organic phosphonium, ammonium and sulphonium compounds as well as triphenylmethane and urea derivatives.

Insect repellent An odoriferous substance (repellent) for insects which is particularly effective against flying insects (insect protection). Insect repellents are used to produce → Insect repellent finishes on textiles which are effective for a limited period of time. Not to be confused with → Insecticide.

Insect repellent finishes In contrast to the use of → Insecticide (oral or contact poisons, etc.), special odoriferous substances (repellents) are employed for the purpose of repelling insects. These substances are unpleasant or unbearable to insects and therefore have a repellent effect as far as insect bites are concerned whilst, for humans, they have only a slight or even a pleasant odour. Repellents of this kind find widespread use as skin creams, body oils, etc. Experience has revealed that such insect repellency is rather non-specific and a relationship between chemical constitution, physical data and insect repellency appears questionable. Useable repellents are, as a rule, neutral, viscous oils of low volatility or crystals with low melting points and, almost without exception, a bitter taste. In order to maintain the longest possible activity, such substances must, in addition, not give rise to skin irritations or cause damage to textiles. Suitable products for textile impregnations include, e.g. indalone, undecenoic acid, mandelic acid hexyl ester, N-cyclohexyl-2-(butoxyethoxy)acetamide, etc. A patent for the production of insect repellent hosiery recommends saturation with quaternary ammonium compounds followed by subsequent drying and heating to approx. 100–150°C.

Insible interlinings → Interlinings.

In-situ reactive dyeing In order to shift the reaction equilibrium of a reactive dyeing on cotton to the right (see equation)

$$\mathrm{CellOH + ClRBF} \rightleftharpoons \mathrm{CellORBF + HCl}$$

to achieve a reduction in the pollutant load of the effluent (with unbound reactive dye), attempts can be made to increase the fixation yields on dyed cellulose , e.g. in the cold pad-batch method by appropriate process technology. Better yields are thus achieved in the Babcotherm drier (by the Ecoflash process or with Remazol dyes; Fig. 1). In the case of in-situ reactive dyeing, however, an entirely different approach is also possible by synthesizing the azo dye step by step on the fibre.

Under suitable conditions, reactive dyes will react with the hydroxyl groups of the cellulose fibre. As is well-known, however, this reaction does not proceed quantitatively since a certain proportion of the dye reacts to form the dye hydrolysate. In order to achieve high colour fastness, therefore, this hydrolysate must be removed from the completed dyeing as completely as possible. In some cases, a considerable amount of washing is required in order to achieve satisfactory removal of the dye hydrolysate. The amount of washing required depends, amongst other things, on the particular shade and the depth of dyeing and is also greatly influenced by the substantivity of the dye; ease of hydrolysate removal in washing is much more difficult with dyes of high substantivity than those with low substantivity. The alternative idea for a "two-stage" formation of dye on the substrate is not a completely new concept and has already been discussed in a publication by B. Bröcker and D. Fiola, where a reference by H. Rath in his Textbook on Textile Chemistry (*Lehrbuch für Textilchemie, 1st edition 1952, published by Springer-Verlag*) describes the reactive bonding of naphthols to cellulose in order to improve colour fastness. The present idea for a new, unconventional method of reactive dyeing without the undesirable generation of coloured effluents is based on the following procedure (according to Hilden, Grütze and H. K. Rouette: a colourless reactive component of small molecular size is applied to the cellulose fibre and covalently bonded to it by means of a reactive anchor under customary textile reaction conditions. After this reaction is complete, the unfixed hydrolysate of low substantivity (due to its small molecular size) is washed off. Then, in order to form the final dye (i.e. the chromophore system), a colourless diazonium salt (e.g. diazo-

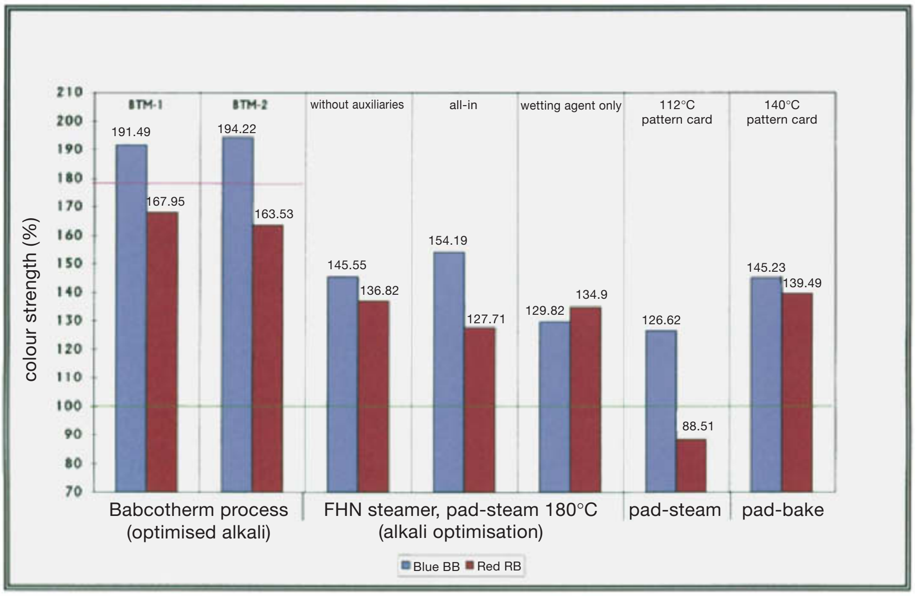


Fig. 1: Comparison of colour strengths (Remazol dyes) achieved in different processes. Reference = cold pad-batch process, washed/ pattern card = 100% colour strength. (source: Voth, Krix and Rouette).

tised o-sulphanilic acid) is coupled to the covalently-bonded reactive component during a so-called "illumination" stage. The sole function of the final short wash-off treatment is to remove excess o-sulphanilic acid. This procedure is described as the "ISR method", (i.e. in-situ reactive dyeing). Because of the large number of possible reactive components known, and the use of a single illumination compound, the colour range which can be achieved by this means covers over 80% of textile shades. In addition, a wide variety of reactive anchors may be employed. The outstanding feature of the new "ISR process" is the use of small molecular size reactive components of low substantivity which gives excellent levelness, good covering of structural differences in the fibre, as well as high rates of reaction. Of prime importance, however, is the relative ease with which the small molecular size hydrolysate can be removed during washing-off and the associated savings of water, energy and time (Fig. 2).

Because of the low substantivity of the individual components already mentioned, preference is given to applications on the pad. If a horizontal padder (with liquor application in the wedge between the padder bowls) is used for the cold pad-batch process in order to bond the reactive anchor to a cotton twill fabric during subsequent batch rotation then, after an appropriate dwell time, illumination can be carried out subsequently in the jigger. The build-up capacity of a typical red colour with this dyeing method (compared to a corresponding conventional reactive dye) of 453% at 0.05 mol/kg is good compared to a 100% colour strength at 0.01 mol. If the cold pad-batch fixation yields of these red dyeings after washing-off are compared with one another by means of reflectance measurements at 20 mmol/l in each case, then maximum fixation yields are already achieved with the "ISR method" after dwell times of 10 hours (Fig. 3). Based on the respective reactive content, fixation yields for the ISR components and the conventional dyes achieved in cold pad-batch dyeing are well over 90% (Fig. 4).

A more rapid reaction is achieved in the pad-thermofix-wash process. In this case, maximum colour

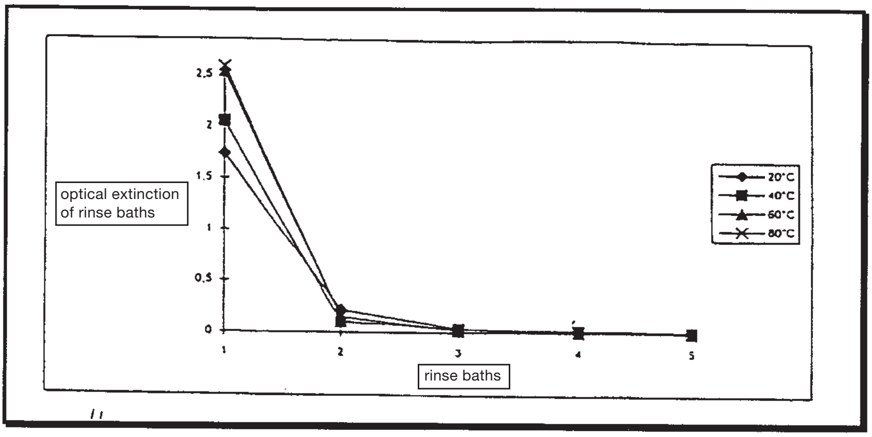


Fig. 2: Ease of washing out the reactive hydrolysate.

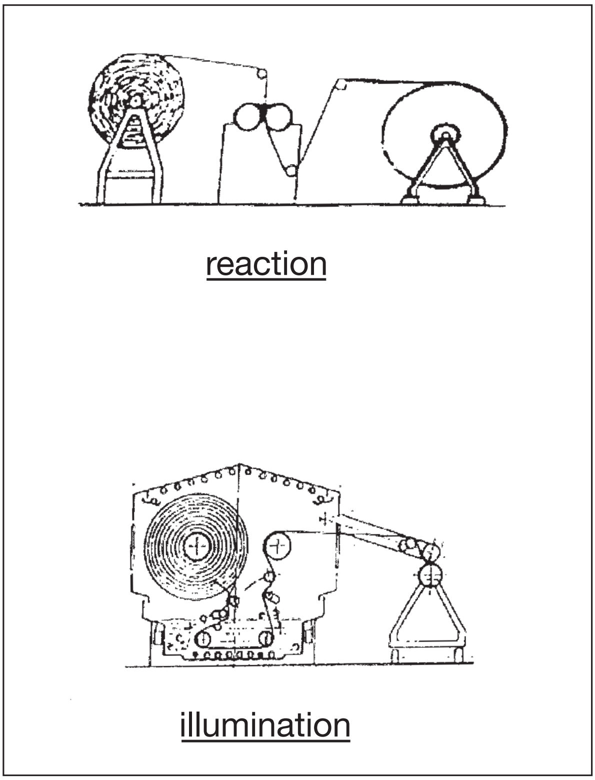


Fig. 3: Reaction and illumination.

strengths are already obtained after a reaction time of 1 minute at 150°C (Figs. 5 and 6).

For the diazotization reaction in the illumination stage, an approx. quadruple molar excess of activated o-anthranilic acid is required with deep dyeings when coupling is carried out in an alkaline liquor for only 5 minutes (LR = 10 : 1) (Fig. 7).

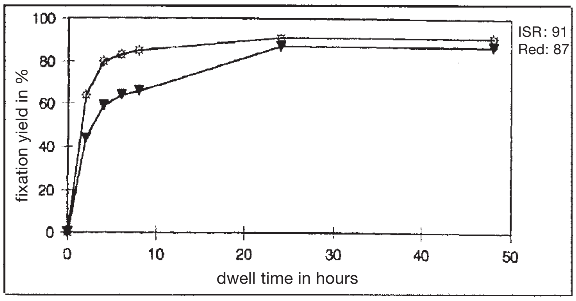


Fig. 4: Fixation yields in the cold pad-batch method ("ISR method" = 91%, conventional = 87%).

If four different cold pad-batch reactions are treated in a jet dyeing machine as a single batch and illuminated with a maximum of 2 mol (1 mol excess) of o-sulphanilic acid, then four colours are developed in-situ

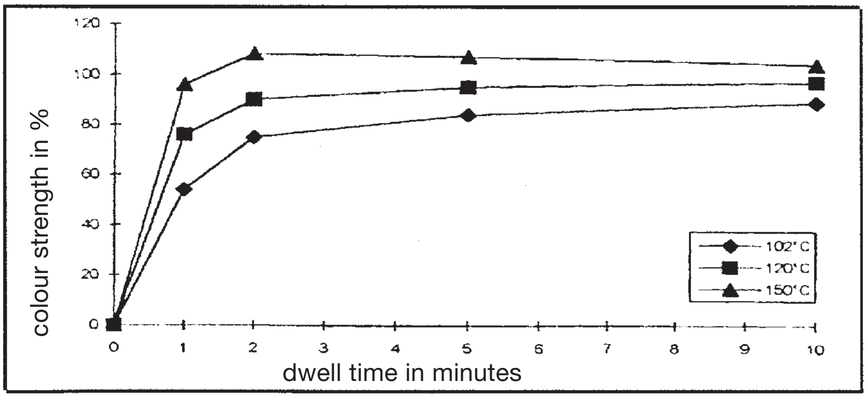


Fig. 5: Fixation yields in the pad-thermofix-wash method by the "in-situ reactive method".

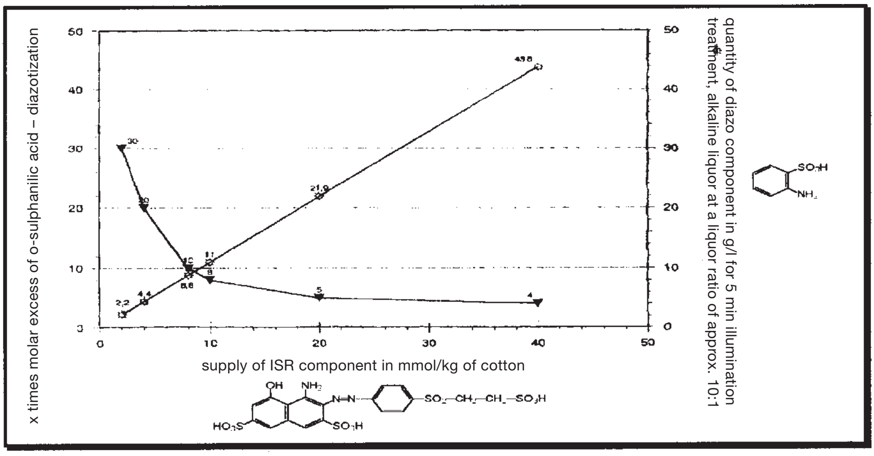


Fig. 7: Coupling ratios.

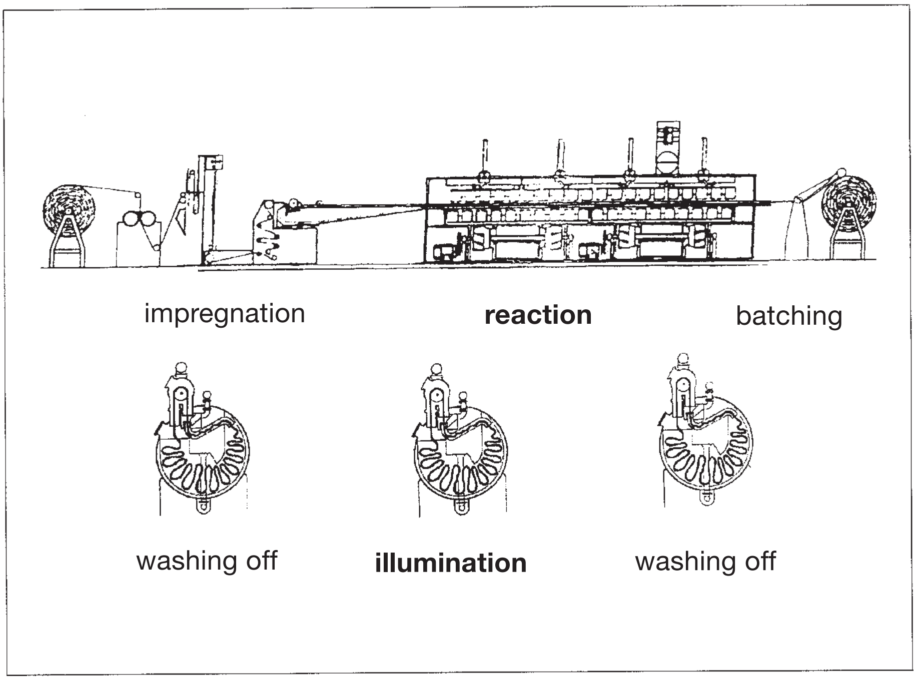


Fig. 6: Process stages involved in the "in-situ reactive" dyeing method.

simultaneously in the jet (Fig. 8). The rinsing and illumination stages take about an hour. The COD values of the effluent from overflow rinsing after 25 minutes are practically zero mg O_2/l for the 4 reaction fabrics; these values rise again during the illumination stage to a maximum of 500 mg O_2/l since the system has been dosed with 2 mol of activated o-sulphanilic acid, but the values fall again to around 100 mg O_2/l after 60 minutes and after the 1st rinse.

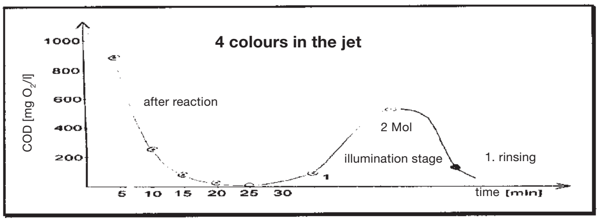


Fig. 8: "In-situ reactive" effluent COD values.

The essential characteristics of the "ISR method" derived from the foregoing can be summarized as follows:

1. the method is limited to applications on the padder,
2. it involves a 2-stage process, i.e. padding/exhaust process,
3. diazotization is carried out "in-situ",
4. the chemical process stages have been transferred from the dye maker to the customer.

The low substantivity of the reactive cold pad-batch/or pad-thermofix components already described above, which is the underlying principle of this method, limits their application to cold pad-batch and pad-thermofix processes only due to the fact that fixation yields in exhaust processes are unsatisfactory since the necessary substantivity for such processes is lacking. This means that "in-situ reactive dyeing" must be concentrated on certain important market sectors of reactive dye application: 20 000 tonnes/annum for cold pad-batch and 18 000 tonnes/annum for continuous processes, compared to 70 000 tonnes/annum for the exhaust process. The stability data for the particular diazonium salt of the o-benzene sulphonic acid used here, which has been precisely investigated, requires that the diazotization stage has to be undertaken immediately before dyeing, which means that the active chemical procedure is now carried out by the customer which is not very popular nowadays. In connection with these chemical limitations of the "ISR process", it is important to realize that brilliant yellow, golden yellow, orange and red shades are actually achieved from colourless reactive components, which is the basic precept of the process, i.e. the conversion of colourless dye precursors on the fibre into coloured dyes. The necessary change in wavelength required to produce a blue shade from two colourless dye precursors by means of an azo bond has unfortunately not proved successful; rather, the shade range requires a coloured reactive component which would unavoidably result in coloured rinsing water. Trichromatic dyeings produced from the individual components of yellow, red and blue are too reddish. The colouristic sectors of the market for brilliant blue, light-fast combination blue, turquoise and brilliant green are unfortunately not covered by the "ISR process". An innovative dye manufacturer has placed a wide spectrum of customer-oriented products and an innovative process at the disposal of the textile industry. The results are being tested by DyStar for market relevance and customer benefit in collaboration with various partners. At the present time, therefore, the example given in the foregoing report on the "ISR process" does not appear to justify further active development under the current technical and economic conditions relating to textile wet processing in the reactive dyeing of cellulose.

Inspection and mending The repetition of a previously carried out material treatment (i.e. as an aftertreatment). In the case of hosiery, the repair of defects such as ladders, small holes, etc.

Inspection machine Textile fabrics are examined on inspection machines after completion of the final finishing process. The fabric inspector carries out the following tasks: quality inspection, detection and recording of faults, defect marking. The fabric runs at full width over an inspection table, an inclined table top which, under certain circumstances, is illuminated from below towards the fabric inspector (matt glass plate). In some cases, defects detected visually can be manually entered direct into a fault marking and recording system. For many articles, such defects can be marked and recorded in this way whilst the goods are running which considerably increases the efficiency of the machines. Inspection machines are adapted to handle all forms of textile fabrics, i.e. from plaited goods on to rolls, rolls into plaited goods, and roll to roll. For tubular knitgoods, inspection machines are available for checking both sides of the fabric in a single operation.

Inspection tables → Inspection machine.

INSTA, abbrev. for: Inter-Nordiske Standardiseringsarbejde, Denmark (Scandinavian Standards Association); → Technical and professional organizations.

Intaglio A method of printing in which the design is engraved beneath the surface of a printing plate or cylinder, e.g. as in roller printing.

Integrated finishing A form of textile finishing in which textile material purchased by the finisher is finished and then re-sold, in contrast to → Commission finishing.

Integrated heat recovery A system in which heat recovery elements are integrated into the doors of stenter driers. Heated exhaust air is already cooled down in the drying chamber via a countercurrent heat exchanger thereby heating up the incoming fresh air which is then mixed with the circulating air.

Integrated pollution control In addition to downstream pollution control measures, "production-integrated" pollution control has assumed increasing importance. This involves the operation of plants in which environmentally-polluting emissions are reduced on a decentralized basis and, in ideal cases, prevented or in which the residual products can be re-used within the production processes. With the utilization of residual products as feedstocks in another process within the production plant or even in another plant, the term production-integrated pollution control has taken on a wider importance. The objectives of research and development in process technology will in future be particularly aimed at:

- the optimization of reaction conditions with regard to yields,
- the recycling of unreacted starting products and assistants within the plant,
- the separation of by-products and their use in another process,
- the reprocessing and cleaning of exhaust air and waste water.

An example of integrated pollution control in which the recovery of starting products and the cleaning of exhaust air and waste water are combined is the process employed for manufacturing polyester. In this process, environmental pollution has been almost entirely avoided. For the synthesis of polyester, para-xylene, ethylene glycol, atmospheric oxygen and methanol are required. The methanol used in the process can be recovered and recirculated. The formation of by-products results in slight losses of methanol. Only these quantities of methanol need to be freshly added in the process. The catalyst used in the process is likewise separated off and recycled. Only a small quantity of catalyst therefore needs to be freshly added. In addition to the desired polyester chips, only carbon dioxide and small amounts of carbon monoxide are formed as waste materials from the raw materials used, due to skilful process control and waste water/exhaust air combustion. In this process, therefore, it appears that apart from negligible amounts of pollutants, only the desired end-product leaves the manufacturing plant in practice.

Integrated pollution control solutions In an ideal situation, textile processing takes place in a closed system, i.e. the production material, "water", which is loaded with additives in the form of chemicals, is fed in a cycle without the sludge having to be disposed of externally. The energy required for waste water treatment is used as the middle stage of an exergy-cascade in the form of exhaust air combustion energy after the energy supplied to the plant has been optimally used for production purposes. Where surplus heat is produced in the closed operating system, the integrated concept should be extended to external consumers by using the excess for local heating. The intention is therefore to achieve textile finishing operations orientated towards recycling the working materials - water, dyestuffs and textile auxiliaries - at the same time as optimally utilising the process energy used without externalising ongoing costs related to removing by-products in a way which is detrimental to the economy as a whole. As the necessary internal electricity is produced using a gas turbine, $^2/_3$ of the energy converted in this should be used as process heat (in the form of steam for dyeing and finishing processes for textiles and to dry these at high-frequency current). The residual energy in the form of steam ensures the distillation of all waste water concentrates. The resultant distillate is reused as process water.

A plant may have sufficient energy in the form of heat from high temperature exhaust gases from the combustion of textile exhaust air.

a) to clean critical exhaust gases in a combined heat and power generation system by cleansing the NO_x content from after combustion products with catalysts using ammonia dosing; these are incorporated via a recuperation system;
b) to concentrate critical process heat in cascades after it has been usefully separated into partial streams and concentrations so that harmless ash can be dumped after the following processes have been carried out: evaporation by excess waste heat, partial recovery of potential recyclable dyestuffs and textile auxiliaries from the sludge formed, the biological degradation of the sludge in putrefaction basins in order to produce methane as a combustible gas and combustion of non-recyclable residual substances. Attempts are also being made to isolate surfactants with a new type of Cavitand technique and to process residual dyestuffs to form synthetics;
c) to convert the environmentally harmful carbon emissions into an environmentally-friendly energy carrier by releasing excess waste heat which is transferred during condensation of the evaporated distillate via recuperators to a local heating cooperative.

The integrated concept is comprised of the following:

1. The focus on the primary energy, gas (and to a limited extent the exhaust gas, methane, produced from the putrefaction basins when refuse is processed) which is used in gas turbines to produce internal electricity and to utilise the waste heat converted in the form of steam in the waste water distillation process (by using the waste heat in a waste heat boiler to produce steam). Gas is also used to provide vapour for production. Although the use of the primary energy, gas, increases the CO_2 emissions from the plant, the concept reduces the CO_2 production seen as a whole, if the production of external power (using coal, oil and atomic energy) is taken into account when assessing the overall CO_2 emissions. The entire old boiler house system used to produce steam by burning primary energy is no longer required.
2. Combustion plants in production (particularly certain dyeing and drying plants) are, in the long term; being converted to high-frequency drying. These operate on the basis of “power” without CO_2 emissions, thus reducing the emissions of critical waste gas, which affects decomposition products of chemicals evaporated during drying.
3. External electricity is used when the plant is overloaded. If excess electricity is produced, electricity is supplied to the general electricity grid.

Integrated process The combination of several elements in a system, e.g. the combination of individual finishing machines in a continuous processing plant.

Integration dyeing The method involves maintaining the concentration of dyestuff in the dye bath at the lowest possible level throughout the dyeing process. This is achieved by gradually introducing a dyestuff to the dye bath in accordance with the known diffusion rate of the dyestuff or dyestuffs in question. Integration dyeing is of particular advantage when dyeing using dyestuffs which have a high affinity to the fibre but a low diffusion rate, which makes possible the use of direct and vat dyes with which level dyeing is difficult. Diffusion measurements have confirmed that the aggregation is dependent upon concentration and (more significantly) the temperature, these therefore being factors which underlie integration dyeing (from Vickerstaff).

Integration of CAD systems CAD and drafting systems must be capable of integration into the production stages of textile manufacture. In order to follow market trends as quickly as possible (quick response), CAD systems used in the plant (e.g. for textile printing) must be integrated into a network. A designer does not have the technical expertise of the dyer just as a dyer does not have the experience necessary for the creation of new products. Both should be able to extract the data for their work from the same database, i.e. the designer obtains the exact colours for the creation of his product and the dyer/printer obtains exact data for dye recipe generation and the coloration process.

When systems for designers and colourists are installed on different computers and these are integrated with one another via a network, a common database can be accessed from any work station, i.e. using the same data source. Depending on the particular manufacturing stages in the plant, individual systems can be connected to this network so that any combinations of individual systems are possible (Fig. 1).

I. Colour system (CS): with this system it is possible to represent all popular colour specifier systems, and use them to produce electronic collection portfolios for subsequent product simulation. The advantage of this procedure lies in the fact that the colour coordinates of all colours defined in this way are known. These values can then be transferred to the CAD system for colour mixing or to calculate dyeing or printing recipes by computer colour matching (CCM). With this system it is also possible to generate in-house colour systems. The possibility also exists to determine particular shades by interpolation whereby the respective colour coordinates are also calculated each time.

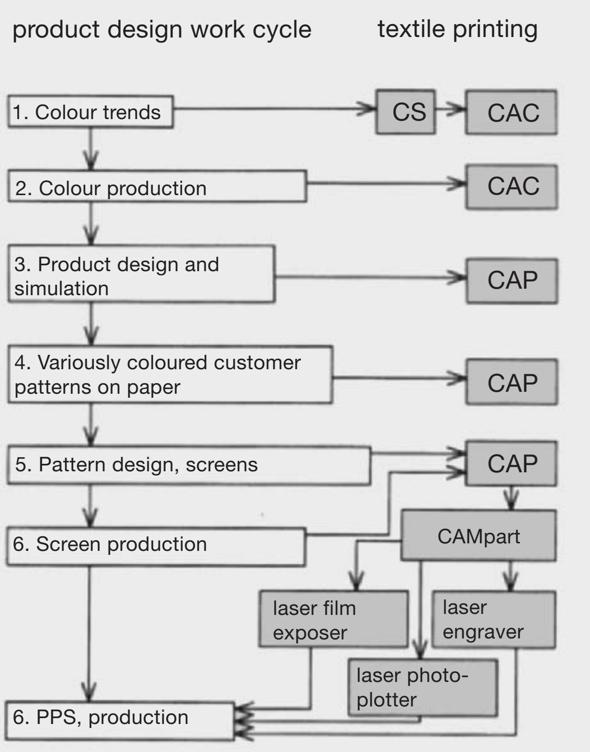


Fig. 1: Integration of textile industry CAD systems.

II. Computer Aided Colouring (CAC): in this system, colours are mixed with the aid of actual calibration dyeings. In compiling the range for these calibration dyeings, all product-specific conditions can be taken into account at the outset, e.g. so that only those dyes are selected which

- are actually suitable for application on the dyeing machines in the particular plant;
- are capable of meeting the required colour fastness to light or washing for the product in question;
- lie within the cost limits for the particular product.

By means of this procedure, it is possible to ensure that the colours selected to match a particular product can actually be produced subsequently under the given conditions already at the initial colour matching stage. A further significant advantage of this system is the fact that it can be integrated with Datacolor's "Osiris" computer colour matching system. Thus, CAC colour suggestions can be established first, followed by dye recipe generation with Osiris, and subsequent visualization of the recipes again on the CAC system under a wide range of conditions, all on the same computer.

The function of the CS and CAC systems is to establish colour collections for subsequent product design.

By building on the results of these colour collections, products can be designed on the display screen up to the actual simulation of a finished product depending on the particular textile manufacturing process. With all three systems, therefore, the data necessary for the product is automatically reproduced.

III. Computer Aided Textile Printing (CAP) is a system which enables all the processing stages as far as production of the final textile print to be carried out with computer assistance.

IV. Computer Aided Weaving (CAW) is a system which enables all the design work involved in dobby weaving to be carried out with computer assistance. In this case also, all the production stages, provided they can be connected to the computer, are linked to the system.

V. Computer Aided Jacquard Weaving (CAJ) is a system which covers all the various operations from designing through figure drafting, weave, construction pattern drafting to fabric simulation as well as machine control in jacquard weaving.

All these systems can be interlinked with one another and exchange information. This is achieved physically via a network (LAN = local area network) based on Ethernet hardware for PC networking and a common database. Various experts often carry out specific tasks at individual work stations since only a part of the information for the next manufacturing stage is necessary. All these systems are linked to the production (Fig. 2).

In Fig. 2, the work flow involved in product design for textile printing is represented schematically. Consideration of the six work stations involved in this

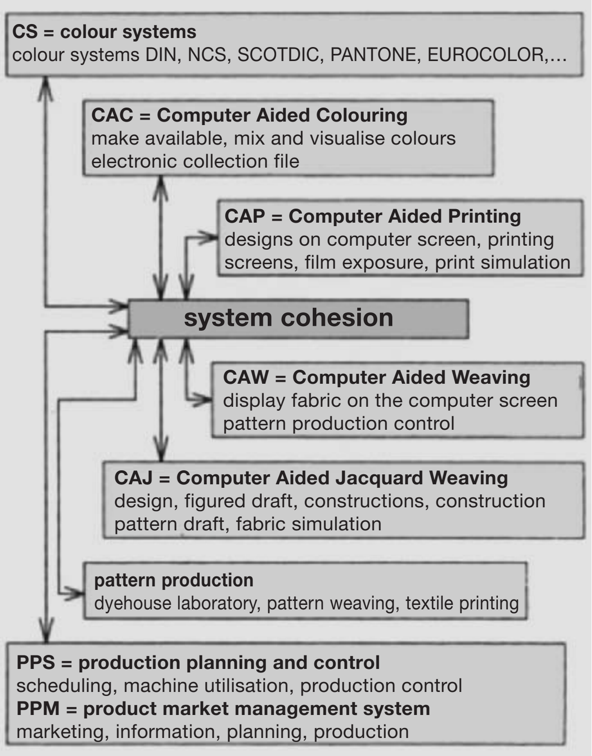


Fig. 2: Production stages and integration.

scheme immediately reveals that all these operations are not carried out by one and the same person. Even in this specific sector of textile manufacturing, it is also necessary for a variety of experts to make their own contribution to the success of the entire operation. The networking possibilities resp. the individual work stations of the system must therefore be made available to all the various functions involved in textile print production such as coloration, product design, product planning, engraving, sampling, film and screen making, and the colour kitchen (source: Fieles-Kahl).

Interactions Interactions between polymer chains (in fibres) are based on hydrogen bonds, salt linkages, hydrophobic bonds or chemical crosslinkages (see Fig.). Interactions also occur between polymers and compounds of low molecular weight (e.g. dyes).

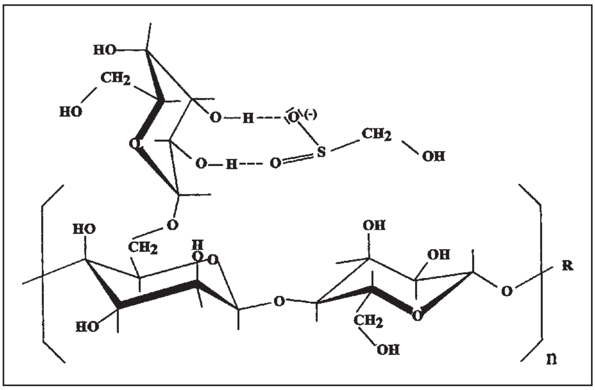


Fig.: Schematic diagram of possible interactions between alginate and formaldehyde sulphoxylate.

Intercellular A term meaning between cells, and refers to the non-crystalline (amorphous) regions, e.g. in fibres (→ Crystallites).

Intercellular cement An intercellular binding material which holds the cortical cells together in → Wool structure. It is analogous to sericin in → Silk structure.

Interchange impregnation Interchange impregnation refers to the impregnation of wet fabric on a padder or in a roller vat (see Fig.). During this process, there is a partial exchange between the water introduced by the fabric and the impregnating solution. Contrast → Additive pick-up.

Interface The surface of e.g. fibres, soil particles, etc., in contact with water, auxiliary solutions and wash liquors (→ Surface tension). In the case of porous solid substances especially, the (micellar) surface with its numerous macroscopic and submicroscopic channels must also be taken into account, besides the externally visible surface, which presents (with its air occlusions) a considerable interface for internally diffusing substances (dyes, auxiliaries). Thus, the micellar surface of 1 g cotton cellulose, for example, is approx. 5000 m^2.

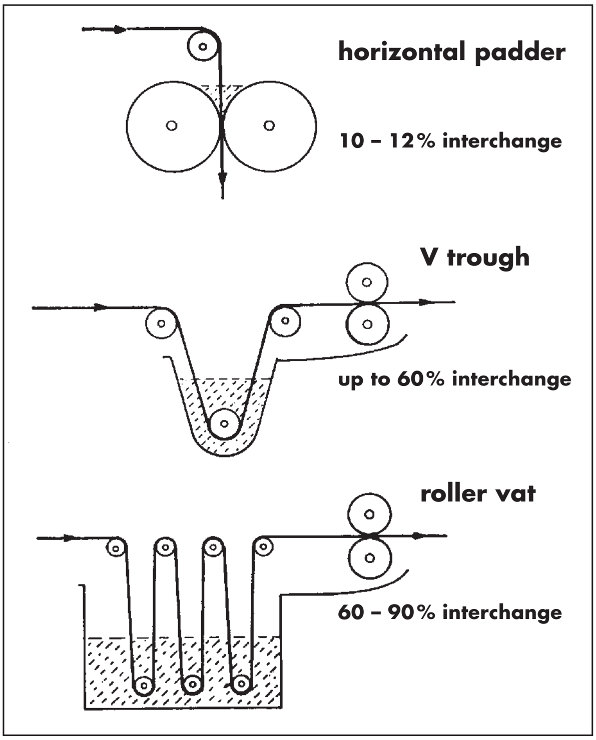


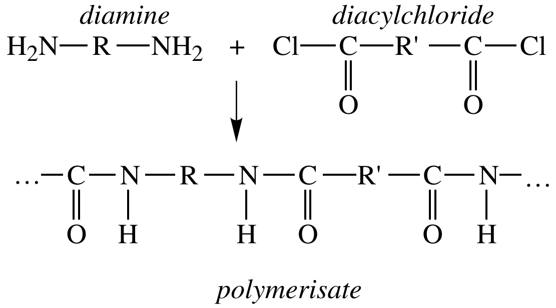
Fig.: Interchange effects of different impregnation processes.

Interfacial layer in tenside solutions This is the layer which extends across an → Interface. The thickness of this layer is determined by the fact that the concentration of the adsorbed substance is higher in this layer than in either of the two adjacent phases.

Interfacial phenomena Phenomena in the form of mechanical, electrical, optical effects, etc., which occur at the → Interface between two phases (liquid/gaseous).

Interfacial polymerization (IFP). Polymerization in which two reactive monomers, each dissolved in different solvents that are mutually immiscible, react at the interface between the two solutions. As applied to the antifelting shrink-resist finishing of wool, interfacial polymerization occurs at the contact zone between an aqueous alkaline solution of a diamine and an inert solvent (e.g. 1,1,1-trichloroethane, carbon tetrachloride or toluene) containing an acid chloride. In semi- or fully-continuous processing, an ultra-thin film of polyamide is formed on the fibre surface. In the Bancora process, for example, 1,6-diaminohexane and sebacic acid dichloride are used for this purpose. The process can be combined with mothproof and crease-resist finishes thereby improving serviceability properties. Neither the dyed shades nor the colour fastness of the dyeings are affected by the treatment.

The principle of this interfacial polymerization is as follows:



$$H_2N-R-NH_2 + Cl-\underset{\underset{O}{\|}}{C}-R'-\underset{\underset{O}{\|}}{C}-Cl \longrightarrow \ldots-\underset{\underset{O}{\|}}{C}-\underset{\underset{H}{|}}{N}-R-\underset{\underset{H}{|}}{N}-\underset{\underset{O}{\|}}{C}-R'-\underset{\underset{O}{\|}}{C}-\underset{\underset{H}{|}}{N}-\ldots$$

Interfacial tensiometer (according to Lecomte du Noäy and Seelich). An instrument for measuring the surface tension between two liquids. Applications: for testing the effectiveness of wetting agents, emulsifiers, soaps, etc.

Interference (Lat.: *inter* = between, *ferire* = to strike). Superimposition. A term used in physics for superimposition phenomena caused by the coincidence of waves (radiation) having a certain phase relationship to one another which can be observed in the region of overlap.

Interference filters These are composed of a suitable combination of thin films having different properties in which specific wavelength regions of light are supressed or allowed to pass through by interference (superimposition). The most common are metal interference filters produced by successively evaporating e.g. semi-transparent silvered films of suitable thickness on glass plates between which is a thin film of magnesium fluoride.

Interionic bonding forces → Ionic bond.

Interior lighting The aim is to create an environment which contributes to the well-being of the workers, prevents both accidents and fatigue, improves quality and minimizes waste. Several quality features directed at lighting in the various areas of the product process are significant in order to optimally fulfil these conditions.

The nature of the visual task to be carried out determines the level of illumination used. Minimum values as prescribed in DIN 5035 must be adhered to. These values refer to the relevant working planes. Compliance with the minimum values is monitored and required by the employer's liability insurance association and industrial supervisors during plant inspections.

Interlace Interlace is a mechanical yarn cohesion of (carpet) yarns which are manufactured with zero twist and formed by the interlacing of the individual filaments. → Intermingling.

Interlining More or less heavily finished → Interlinings such as →: Buckram; Linen interlining; Horsehair cloth; Nonwoven material, etc. as well as →: Wadding; Shoulder padding, etc. which is fused or sewn inside specific parts of a garment (i.e. between the inner and outer layers) to improve shape retention, strength, warmth or bulk.

Interlinings (linings). Interlinings are the "skeleton of clothing" which ensure a lasting fit. They are sewn to the outer fabric in the form of fabrics, knitwear or nonwovens or combined directly with these (fixed). Natural and man-made fibres, animal fibres and blends are processed. Sophisticated finishing methods provide the interlinings with specific properties depending on their intended purpose. Types of coating, adhesive compounds and add-ons in particular make it possible to adapt the various interlinings appropriately to all outer fabrics, from the finest batiste to silky jerseys, poplin, carded and worsted yarns to fleecy coating, leather and fur. Interlinings correspond to the outer fabrics in terms of their tendencies to shrink, wear comfort and care characteristics. They support and enhance these characteristics.

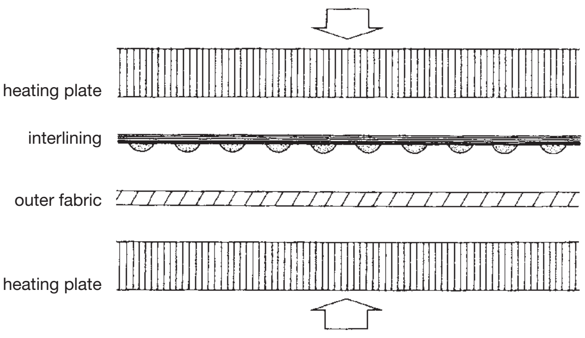


Fig.: Interlining heat setting operation.

In the past, interlinings were laboriously sewn into items of clothing in single or multiple layers as wadding, but today, the processing of fixable interlinings is predominant. These can be permanently bound to the outer fabric rationally using setting machines and pressing. This bonding, which is resistant to washing and dry-cleaning, is achieved by the influence of temperature, time and pressure.

A number of fixing points (meltable polymer applied to the interlining as a dot coating in mesh = number of setting points per inch) are used to bind the interlining and outer fabric (see Fig.) in the steam press (fusing temperature) between two steam platens. This is also referred to as front fusing.

Classification:

1. Elastic interlinings (the weft material is decisive for wrinkle recovery): hair linings, nonwovens, woollen wadding.
2. → Stiffened fabrics including hot melt adhesives.
3. → Interlining.

Some basic requirements: weight and ability to hold shape should be tailored to the outer fabric and intended purpose (no losses during wear), characteristic elastic recovery, no undesired deformations when sitting, good air permeability (no heat build-up or bothersome perspiration), total shrink resistance and resistance to repeated moisture and heat (during tensionless drying and pressing) and resistance to dry cleaning. The quality of the interlining has a significant impact on the serviceability of the garment. A high level of resistance to washing is required for shirt interlinings. High and low pressure polyethylene are suitable for this. These interlinings can be applied using the powder dot, dot or scatter coating method; the dots have an aqueous base. Interlinings display shrinkage conformity if any residual shrinkage alterations mirror those of the outer fabric.

Interlock materials Interlock materials are fine-meshed knitgoods produced on the circular knitting machine which are used for close-fitting undergarments etc. An alternative form of this is referred to as cross tubular goods. Interlock is the combination of two 1/1 rib knits. Only plain stitches are visible on either side of the fabric as the reverse stitches are found inside the knitted fabric.

Intermacrofibrillar cement Intercellular cement in → Wool structure.

Intermediate drying in textile printing Intermediate drying is carried out between the printing of each colour in a multicolour design in hand screen printing in order to prevent marking off during printing with the individual screens. In mechanized flat and rotary screen printing, as well as roller printing, intermediate drying is carried out between printing and steaming in order to preserve the sharpness of the print and avoid marking off. Intermediate drying is omitted in carpet printing.

Intermediate filament According to current nomenclature in protein chemistry, the microfibrils in the → Wool structure are formed from a type of low-sulphur proteins which are referred to as intermediate filament (IF) proteins. The matrix consists of proteins containing glycine and tyrosine, as well as proteins containing sulphur, known as intermediate filament associated proteins (IFAP).

The smallest link in the hierarchy of the wool structure is the α-helix (see Table). These combine to form protofibrils. These in turn combine to form microfibrils, which then result in macrofibrils, surrounded by the matrix. The α-keratins, as the main chemical constituent of wool are insoluble, hard substances which are highly elastic. They are present in the macrofibril in the form of two components, the microfibril and the matrix. The matrix consists of tyrosine and sulphur proteins, whereas the low-sulphur proteins are assigned to the microfibrils. The macrofibrils on the other hand form the cortex cell, embedded in the intermacrofibrillar cement. Chemically, the intermacrofibrillar cement is a non-keratin protein consisting of cytoplasm and residual nuclei.

Fibril type	Build-up in cross-section	Diameter (nm)	Length (nm)
Macrofibril	approx. 700 microfibrils	300	10 000
Microfibril (intermediate filaments)	8 Protofibrils	10	1 000
Protofibrils	4 Polypeptide chains	2	1 000
Individual intermediate molecule	2 Polypeptide chains		50
Polypeptide chain α-helical	1 Polypeptide chains	1	50

Tab.: Build-up and dimensions of fibrils in wool (all figures are approximate values).

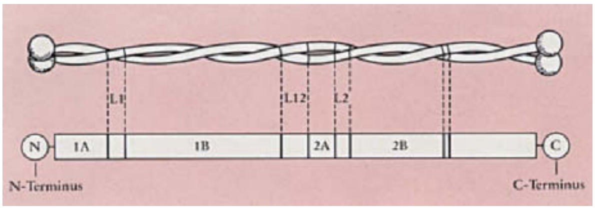


Fig. 1: Two entwined intermediate filaments.

During biosynthesis, dimers (Fig. 1) are formed as a result of parallel pair generation from a basic and an acid keratin (intermediate filament). The individual keratin has a rod domain consisting of α-helices. There is a double-strand super helix or coil in the dimer. The stability of the dimers depends on this particular double-twist quaternary structure which involves hydrophobic interactions. The next intermediate product is the “four-chain complex” which consists of 2 antiparallel dimers and represents the structural component of the protofilaments. It has been assumed for some time that there are protofilaments with a diameter of 2–3 nm in wool and hairs from microscopic electron tests. Earlier hypotheses on the number of protein chains in the cross-section of a protofilament have now been outdated, and the current theory is that tetramers supply a protofilament by means of longitudinal associations. Another theory is that 8 (as opposed to 9 + 2, as quoted in earlier literature) protofilaments combine to form one complete intermediate filament (Fig. 2). A filament is therefore made up of 8 tetramers (16 dimers or 32 single skeins) in cross-section. The length of a subunit is 50 nm and the length of an intermediate filament in wool and hair is 50 µm. 32 000 individual monomer keratin molecules, including 16 000 each of type I and type II form a nucleated filament. The details of how this occurs are not completely clear.

The intermediate filament associated proteins (IFAP) together with the filaments form the macrofibril. In hair, these proteins have long been known as a

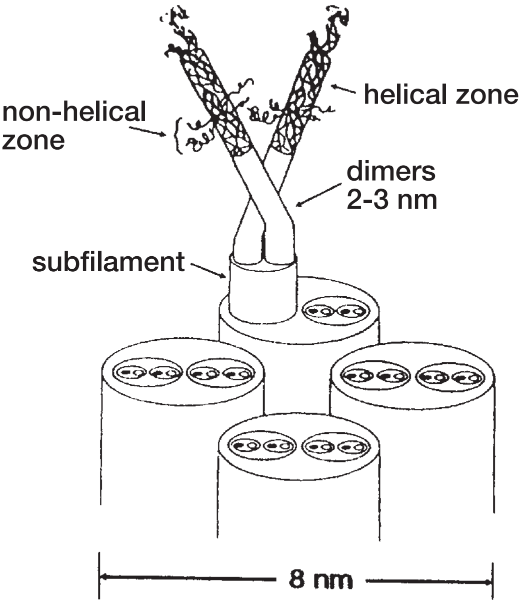


Fig. 2: Diagrammatic view of the intermediate filament from 8 protofilaments.

group of proteins containing on average 30 molar percent of cystine and have been isolated from the hair as soluble fractions by mercaptolysis, generally in the form of s-carboxymethyl derivatives or recently also as s-sulphates. There are however no generally recognised values either concerning the number of individual members of this family of sulphurous hair proteins nor the molecular masses. Even the ordered state is disputed. Some regard the entire "matrix" as amorphous, others as orientated at least in the fibre direction, and others even regard these proteins as paracrystalline, although by no means helical like the intermediate filament. One problem is the low yield of keratin and IFAP with reductive hair extraction of approx. 20% weight (source: Zahn).

Intermediate membrane in → Wool structure between the cortical layer and the scale-cell layer.

Intermediate reduction clear A reductive clear process to remove staining of the natural fibre component with disperse dyes in the dyeing of blends with synthetic fibres.

Intermediate solvent A solvent miscible in two different types of media such as methyl acetate (soluble in benzene and also miscible with 3 times its weight of water) and ethyl ether (soluble in benzene and also up to approx. 7% in water) etc. → Hydrotrope.

Intermediate support frame A frame containing fabric guiding elements installed between individual machines in a continuous production line to ensure trouble-free fabric feed from one machine to the next.

Intermicellar regions → Crystallites.

Intermingling (entanglement, interlacing). Intermingling involves the use of air jets to create turbulence in order to entangle the filaments of continuous filament yarns, without forming loops, after extrusion. Provides dimensional stability and cohesion for further processing without the need for a twisting process. If an intermingled yarn is produced from two varieties of differential-dyeing filaments, e.g. 50% deep-dyeing and 50% basic-dyeable types, effects from an intensive melange to a heather appearance are obtained after dyeing depending on the intermingling and mixing of the filaments, instead of the marl effects obtained with twisted yarns.

By comparison, intermingled yarns with four-sided cross-sections and hollow spaces are superior to all other forms by having an optimum combination of light-refracting and light-reflecting properties with minimal soil adhesion; the effect is most clearly observed in pile fabrics with a sideways-tilting pile.

Intermingling of filament yarns (→ Intermingling). Aerodynamic cohesion (produced by an air-jet) which, depending on the type and end-use of the particular synthetic filaments, may entirely or partially replace twisting and/or sizing. Excessive intermingling is undesirable since it can easily spoil the effect of the finished fabric. A high intermingling density is, however, desirable, i.e. a large number of interlacing points and their uniform distribution throughout the length of the filaments.

The intermingling process involves passing one or several filament yarns through the turbulent zone of an air-jet at right angles to the direction of the air stream. As a result, some or all the filament yarns are intermingled at localized points, i.e. they are intermingled with one another to achieve cohesion. A continuous jet of air produces a discontinuous quasi-periodic effect. Interlacing points (interlaces) alternating with open, non-interlaced areas of yarn are created by this means. Intermingling is often regarded as equivalent to air texturing. There are, however, considerable differences between the two processes (see Fig.). In air texturing,

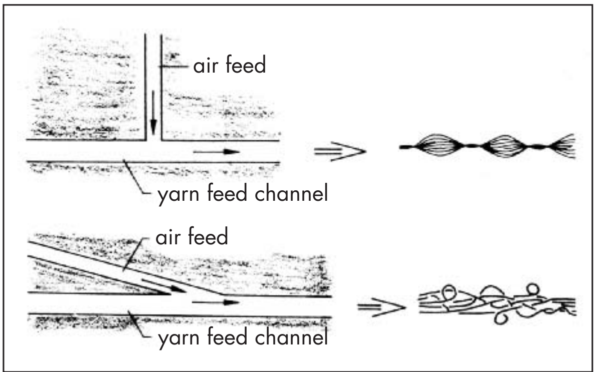


Fig.: Comparison of the principles of intermingling (top) and air texturing (below).

the filament yarn is over-fed at a rate of up to 30% through a turbulent air stream at an oblique angle so that the filaments are displaced relative to one another in a longitudinal direction thereby achieving a much higher level of entanglement by forming entangled loops in the filaments which imparts a hairy, staple yarn like character with the objective of producing texture or bulk. It is precisely this effect which should be avoided in the intermingling process (source: Weinsdörfer).

Intermittent (Lat.: *intermittere* = to leave off). To be suspended temporarily or at regular or irregular intervals; periodic.

Intermittent printing Printing on rotary screen printing machines whereby the printing operation of the screens is interrupted for a predetermined interval. By this means, larger repeats can be added to the normal rotary screen circumference during printing and design combinations are obtained which could not otherwise be realized on a printing machine.

Intermittent roller printing machine (“Jumper” printing machine). In this machine two sets of engraved printing rollers are employed, each set being brought in turn into contact with the fabric being printed on the pressure cylinder of the printing machine. As soon as the printing of one set, say that of the cross-border, is completed, its rollers are withdrawn or „jump away“ from contact with the pressure cylinder and the other set (“filling” rollers) simultaneously comes into action which is likewise withdrawn after printing a predetermined length of fabric. Intermittent machines are used for the printing of saris, sarongs, and certain types of Africa prints.

Intermolecular attraction forces → Secondary valency forces.

Internal A term which means within or centrally located. Used, for example, to indicate the position of typical groups in the long-chain thread molecules of textile auxiliaries. See also → External.

International Fabricare Institute (IFI). Founded in 1972 by the merger of two former leading American institutes of laundering (AIL) and drycleaning (NID). It is today the largest organization of its kind in the world concerned with the textile care sector (research, specialized courses, advisory service, information); → Technical and professional organizations.

International Federation of Associations of Textile Chemists and Colourists (IFATCC). Also known as the “Internationale Föderation der Vereine der Textilchemiker und Coloristen” (IFVTCC); → Technical and professional organizations.

International Grey Scale → Grey scales for fastness testing.

International Organization for Standardization → ISO.

International System of Units → SI System of Units.

International Textile Club (ITC). International professional organization of leading specialists from all branches of the textile industry; → Technical and professional organizations.

International Textile Service (ITS). A Swiss publishing house providing information on textile production. Publishes the quarterly technical journal “International Textile Bulletin” in several languages.

International Wool Secretariat (IWS). Independent organization for publicity and research service in the entire wool economy. Founded in 1937. Supported by the wool producers of Australia, New Zealand and South Africa with headquarters in London and branches in almost all textile countries. →: Woolmark; Technical and professional organizations.

International Wool Textile Organization (IWTO). Head organization of the world wool economy, resident in the U.K. → Technical and professional organizations.

Interpenetrating polymer networks → IPN.

Interweaving → Contraction.

Intimate blend A technique of mixing two or more dissimilar fibres in a very uniform mixture usually by mixing the fibres in loose stock form before or at the picker, in contrast to normal mixtures of warp and weft (e.g. polyester warp wool weft, and vice versa).

Intracellular A term describing processes within the cell (→ Crystallite), e.g. the further penetration of intracellular reactions from the intercellular spaces through the crystalline surface of the cell causing changes in the structure of the cellular building blocks. Of importance in severe fibre damage (acids: cellulose, caustic alkalis: wool).

Intramicellar Identical to → Intracellular.

Intramolecular salt A zwitterion molecule, e.g. betaine and the types of salt linkages in wool keratin. Attempts are also being made to describe intramolecular complexes as intramolecular salts.

Intrinsic error limit → Error limit.

Intrinsic viscosity → Viscosity index.

Intussusception dyeing (Lat.: *intus* = within, *susceptio* = deposition). A deposition dyeing in which new dye is progressively inserted into the thickness of an existing fibre wall. The cross-section of an intussusception dyeing is fully penetrated by dye, i.e. homogeneously dyed throughout, e.g. acetate acid wool and cationic dyeing. Compare → Apposition dyeing.

Inversion (Lat.: *invertere* = to invert),

I. A chemical reaction involving a change from one optically active configuration to the opposite configuration. The term inversion refers to the effect of a solution on the rotational direction of polarized light, e.g. the formation of a laevorotatory solution of glucose and fructose (→ Mutarotation) by the hydrolytic break down of a dextrorotatory solution of sucrose (cane-sugar). Glucose is dextrorotatory but fructose is more strongly laevorotatory which is the reason for the mixture formed (invert sugar) being laevorotatory.

II. Inversion is also used in the sense of an inversion of electrical charge, e.g. in so-called → Invert soaps, i.e. cationic textile auxiliaries in comparison with anionic ones.

Invert soaps Cationic textile auxiliaries including disinfectants and preservatives. The term invert soaps is used because their surface active effect is due to the large molecular cation, i.e. the opposite of common (anionic) soaps.

Invisible marking An example of invisible marking is the invisible labelling of finished fabric samples which are to be assessed by a third party against rival samples and where it appears justifiable to test the factual evidence experimentally where assessment was inconclusive. Principle: local print or lettering covered with a colourless solution which is later "developed" to reveal the colour after drying. "Developers" and corresponding dyeings are suitable for this purpose, e.g. sodium carbonate/phenolphthalein solution = red, lead acetate/sodium sulphide solution = black, salicylic acid solution/iron (III) chloride = bluish-violet, potassium tetroxalate/iron (III) chloride = bluish red, cobaltous (II) chloride solution when heated = deep blue. In all cases, samples can also be illuminated beneath the quartz lamp used for analysis for "rapid developing" (→ Fluorescence).

Invisible mending (Interweaving). The invisible mending of areas of fabric (clothing, home textiles, etc.) using a take-up needle. This is a needlework service provided by mending companies and dry cleaners. For small defects such as tears and holes, threads are pulled from the hem of the item and the needle is used to replace the damaged area thread by thread. The needle is woven through the fabric, the thread is drawn through and inserted (first the warp, and then the weft). For larger defects, a rectangular piece of the same material is taken (from a concealed area), this is frayed by 1–1.5 cm at all four ends and pinned to the damaged area to match the pattern. The frayed edges are then "woven into" the surrounding material using a latch needle.

Iodine (Gr.: *iodes* = violet-coloured: so named because of the colour of the vapour). Nonmetallic element of atomic number 53 and atomic weight 126.85. Valencies: mostly 1 and more seldom 3, 5, and 7. Iodine forms compounds which are mostly colourless. The element belongs to group VII of the periodic table under the → halogens. Pure iodine forms greyish-black graphite-like rhombic crystalline plates with a density of 4.93, m.p. 113.5°C and b.p. 184.4°C.

Iodine sublimes gradually even at room temperature (often causing a browning of the close surroundings). On heating to the boiling point, bluish-violet coloured toxic vapours are formed with a characteristic odour which cause severe catarrh-like reactions in the mucous membranes of the nose and eyes ("iodine cold"); TLV: ceiling 0.1 ppm in air. The violet colour of the vapours is caused by free I2 molecules whilst the brown colour of iodine solutions is, by contrast, caused by the formation of labile addition compounds between the iodine molecules and the solvent (charge transfer complexes).

Iodine azide reaction The reaction is used to distinguish between cupro and viscose fibres. It is based on the fact that slight traces of sulphur in viscose liberate nitrogen from iodine azide which rise to the surface of the fibre as bubbles (microscope). Procedure: 2 g sodium azide is dissolved in 100 ml of 0.1 n iodine solution. The fibres, previously degreased in petroleum ether, are placed in the reagent on a concave microscope slide with tweezers (without hand contact) and observed under low magnification. The formation of small bubbles only occurs with viscose. Iodine azide IN3 must be handled with care since it is easily detonated and is very explosive in the dry state.

Iodine number (iodine value). A measure of the amount of unsaturated acids present in fats and oils (i.e. the number of double bonds). It is obtained by finding the percentage of iodine by weight absorbed by the sample in a given time under standard conditions, i.e. the number of grams of iodine absorbed by 100 g of a fat or oil. To the cleaved double bonds of unsaturated fatty acids, elemental iodine is added according to the following equation:

$$\text{–CH=CH–} + I_2 \rightarrow \text{–CHI–CHI–}$$

forming a colourless iodine compound. The size of the iodine number thus indicates the proportion of unsaturated (free and esterified) fatty acids. Drying oils (linseed oil, poppy-seed oil, wood oil) have high iodine numbers (120–200); semi-drying oils (sesame oil, cottonseed oil, rapeseed oil, maize or corn oil, whale oil) have medium iodine numbers (95–120); whilst all non-drying oils and fats, on the other hand, have low iodine numbers (groundnut or peanut oil 86–98, castor oil 82–88, olive oil approx. 82, lard 60–68, palm oil 50–58, beef tallow 35–44, palm-kernel oil 10–18, wool grease 15–20, Japan wax 4–13, beeswax 8–11, sperm oil 4).

Iodine-potassium iodide solution (iodine test). 2 g iodine in 10 ml saturated potassium iodide solution (or 3 parts potassium iodide and 2 parts iodine in 45 parts water). Iodine is so loosely bound that it is liberated immediately in reactions. Uses:

I. For the detection of starch products: starch paste = dark blue; "soluble starch" = blue; dextrine = bluish-violet, reddish-violet or reddish-brown; maltose and glucose = colourless.

II. For the detection of mercerized cotton = bluish-black colour.

III. For the detection of polyvinyl alcohol in aqueous solution = blue colour.

Iodine solution → Iodine-potassium iodide solution.

Iodine sorption by cellulosic fibres The iodine sorption method is attributed to Schwertassek who attempted, amongst other things, to find a relationship between the iodine sorption number (ISN) and the proportion of crystalline regions in a cellulose sample. For this purpose, he measured absolutely crystalline and completely amorphous samples and produced a nomogram which indicated the relationship between the ISN and the degree of crystallinity. As a reference value he chose a partially hydrolyzed cotton for crystalline cellulose (ISN = 0) and starch or acetyl cellulose for the amorphous state. The influencing parameters for iodine sorption are: temperature, kinetics up to the point of equilibrium, concentration, thorough mixing, and the quantity of weighed cellulose (the smaller the weighing the more the iodine sorption). The bonding of iodine to cellulose generally takes place via adsorption forces and inclusion compounds. The sorption of iodine does not involve surface coverage. A uniform covering of the fibre has not been detected from investigations with the electron microscope. It must therefore be assumed that both molecular iodine as well as the tri-iodide are present. The tri-iodide is sorbed preferentially. Electrostatic interactions are formed between the partially positively-charged hydrogen atoms of the cellulose hydroxyl groups and the negative charge on the tri-iodide. The colour of the iodine-treated fibre sample can be taken as a further example for sorption of the tri-iodide. The brownish-black colour is indicative of tri-iodide uptake. This involves the formation of inclusion compounds in large voids of the fibre which do not exist in a chain form. Schwertassek explained the state of iodine in the fibre on the basis that amorphous cellulose is able to form blue iodine adducts (iodine chains with at least 14 iodine atoms) if the amorphous cellulose is capable of being transformed at a higher temperature and in the swollen state into the crystalline form. As a result, elongated channels can be formed between the crystallite units for the uptake of iodine chains.

Iodine-starch reaction → Iodine-potassium iodide solution.

Iodine-starch test The normal concentration of an enzyme in a desizing bath has an activity in the range from 50–300 Kilo-Novo-Units per litre (KNU/l) depending on the quantity of enzyme preparation used. The activity of a desizing liquor can be determined by the following method. The alpha-amylase in the desizing liquor degrades starch substrates. An iodine solution is used as an indicator so that the course of the reaction can be followed, and the time required to complete the degradation process is a measure of the enzyme activity. Two determinations are carried out in parallel, i.e. a standard of known activity and the sample of desizing liquor to be tested.

1. Solutions:

a) Water: approx. 1l distilled water is boiled for approx. 10 min and used to prepare the reagents and the substrates.

b) Buffer solution: 1 g sodium chloride + 7 g potassium dihydrogen phosphate + 0.5 g disodium hydrogen phosphate are dissolved in water and made up to 100 ml.

c) Iodine solution: stock solution (0.1 n) + 1.3 g iodine + 1.8 g potassium iodide are dissolved in water and made up to 100 ml. For the analysis, 5 ml of this solution are diluted with water to 1500 ml.

d) Standard alpha-amylase solution, e.g. 1 ml Dezyme 140 in 1 l of water.

2. Starch substrate: sufficient starch substrate for 5 analyses is prepared. 4.0 g of potato starch is sufficient. Soluble starch can also be used (provided it is always based on potato starch).

The starch is mixed with 50 ml water and the suspension poured into a tared 1 l beaker containing approx. 400 ml water which has been heated to approx. 55°C. The starch residue is swilled with 50 ml water and added to the contents of the beaker. The substrate is then heated to the boil under constant stirring and kept at the boil for 5 min. After cooling to approx. 50°C, 20 ml of buffer solution are added and the total weight is brought to 500 g with water. The substrate prepared in this way should have a pH of 5.8. In each case, 100 g of this substrate are transferred to 5 containers in a heated water bath at 40°C.

3. Analysis: 10 ml of enzyme solution (desizing liquor or standard) are added to 100 g of substrate which has been preheated in the water bath at 40°C and the stopwatch is started at the same time. In order to ensure complete mixing, air is conducted through the mixture or the contents are stirred vigorously with a glass rod. After 2 min a sample of 0.1 ml is withdrawn (corresponding to 2 drops from a Pasteur pipette with a flat-ground tip and an external diameter of 3 mm) and immediately mixed thoroughly with 60 ml iodine solution in a measuring cylinder. Samples of 0.1 ml are withdrawn at appropriate intervals of time until the iodine solution shows the same yellow colour as a blank test consisting solely of 60 ml iodine solution. The time taken to reach this point is noted. The coloration is best observed against a white background and is even more distinct when viewed vertically through the top of the measuring cylinder.

4. Calculation of activity: the amylase activity, expressed in KNU/l of desizing liquor, may be determined with the aid of the following equation:

$$A = A_S \cdot \frac{t_S}{t}$$

A = activity of desizing liquor [KNU/l],
A_s = activity of the standard [KNU/l],
t_s = reaction time of the standard,
t = reaction time of the liquor.

Iodine test → Iodine-potassium iodide solution.

Iodometry → Titration.

Ion-exchange chromatography → Chromatography.

Ion-exchange processes Modern ion exchange processes must fulfil the following requirements: total exhaustion of the bed capacity, high availability, low pollution of effluent , low space requirement, fully automated processes, constant water quality, even when the water flow varies, and the option of backwashing in order to enable substances, germs and fine grains of sand which can be filtered out to be rinsed away.

A distinction can be made between the ion exchange processes used predominantly by means of the regenerative techniques used and whether work takes place on a fixed bed or fluidised bed. In recent years, particular attention has been paid to reducing the regenerants used and consequently the salt fraction in the effluent. It was also necessary to investigate the behaviour of ion exchangers with respect to rinsing out pollutants and abraded resin, bacteria, particles etc. It was clearly demonstrated that the above mentioned substances cause difficulties in operation of such plants to a certain degree when ion exchange processes are being carried out, and that greater attention should be paid to these problems. Various regenerative techniques have been developed to optimise this type of plant.

I. Co-current regeneration: In the conventional co-current process, the exchangers are loaded and regenerated in the same direction. In particular where strong acid and strong alkali exchange resins are used, this requires a surplus of regenerant of up to 350% of the theoretical value in order to completely regenerate the resinous layer situated at the outflow. Despite this extremely high surplus, the very critical layers which cause the ion leakage into the pure water cannot be completely used to capacity. Univalent ions (labelled “C” in Fig. 1) break through, although the overall exchanger bed is still not fully loaded. When this break through occurs, the filtering activity must be discontinued. As a result, the entire ion exchange system is inefficient due to insufficient use of the regenerant and an insufficiently high percentage purity. If the problem of environmental protection is taken seriously, co-current regeneration exchangers should no longer be used and existing plants consequently dismantled.

II. The counterflow technique in the fixed bed process: It is possible to eliminate the disadvantages of the high regenerant surplus if regeneration occurs in the opposite direction to operation. This allows as yet unused regeneration chemicals to impinge on the critical ion exchanger layers, thus reducing the chemical surplus significantly to approx. 120–150% of the theoretical value. When the lowest exchanger layer has been completely regenerated, the ion leakage at the end of the exchanger bed is considerably lower, and consequently, the capacity utilised, with approx. half of the regenerant quantities used is considerably better than in the co-current process. Fig. 2 shows that the column is loaded from the top to the bottom in the fixed bed technique, with the exchange material settling as a compact bed on the nozzle plate of the exchanger. Regeneration takes place upwards. The regenerant is discharged from the upper end of the exchanger layer via a drainage system. The exchanger bed is fixed by a dynamic compressed air blanket located in the upper clearance zone of the exchanger during the regeneration process. It is possible to backwash and separate the exchanger bed when necessary via the upper clearance zone. This is predominantly required where rinsing is necessary. Although this process offers good operating conditions, the investment costs are relatively high.

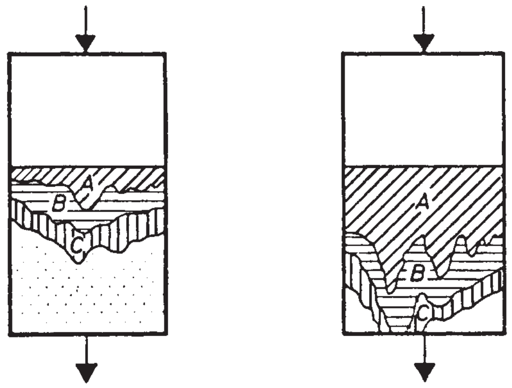


Fig. 1: Loading conditions of an ion exchange column in direct current regeneration (fixed bed).
Left = unloaded exchanger; right = loaded exchanger; A, B, C = variously highly adsorbed ions.

III. Counterflow technique using the fluidised bed process: This is a counterflow process where the sub-

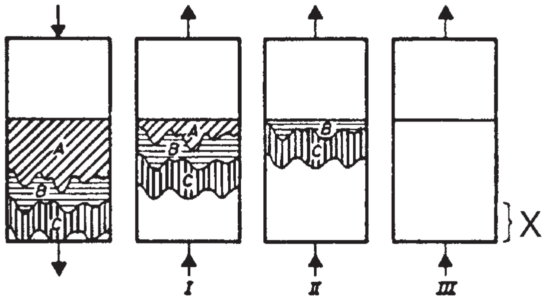


Fig. 2: Loading conditions of an ion exchanger column in alternating current regeneration with flow reversal possibility in the filter (fixed bed).
From left to right: loading; I.–III. regeneration phases; x = layer with best regeneration.

stance is loaded up-stream and a large proportion of the exchange bed is situated in the fluidised bed, whereas the smaller proportion settles as a fixed bed on the second upper nozzle plate. The fixed bed portion is essentially influenced by the rate of filtration. In order to maintain adequate water quality, a specific minimum fixed bed portion and an optimal exchanger rate is necessary. Regeneration occurs downwards, i.e. down-current. In the regeneration phase, the entire exchanger bed settles as the fixed bed on the nozzle plate. This prevents a rearrangement taking place during the regeneration phase with only negligible industrial or procedural outlay. This process is characterised by its simple construction and operating method. During recent years, this technique has extended into all areas of application. This has proved extremely worthwhile, although there are some disadvantages which can be seen repeatedly during operation. Essentially, the problem is backwashing where pollutants, abraded resin, germs etc. need to be rinsed out. It is not possible to avoid a rearrangement in the exchanger column where the process is more frequently interrupted, with the result that the water quality is affected by alternating loads or by turning off the water intake. Fig. 3 shows the various load situations of an ion exchange column using the fluidised bed process in countercurrent regeneration without internal backwashing. If the process has an external backwash tank, care must be taken that the resins are not mixed during backwashing (residual deposits in the backwash container) or that rinsing the resin is not linked to any extent with a particularly high outlay in terms of personnel and time.

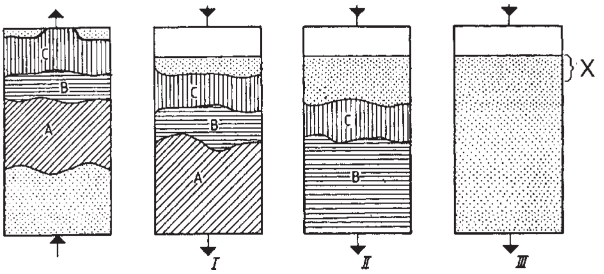


Fig. 3: Loading conditions of an ion exchanger column in alternating current regeneration (fluidised bed) with no internal flow reversal.
From left to right: loading; I.-III. regeneration phases; x = layer with best regeneration.

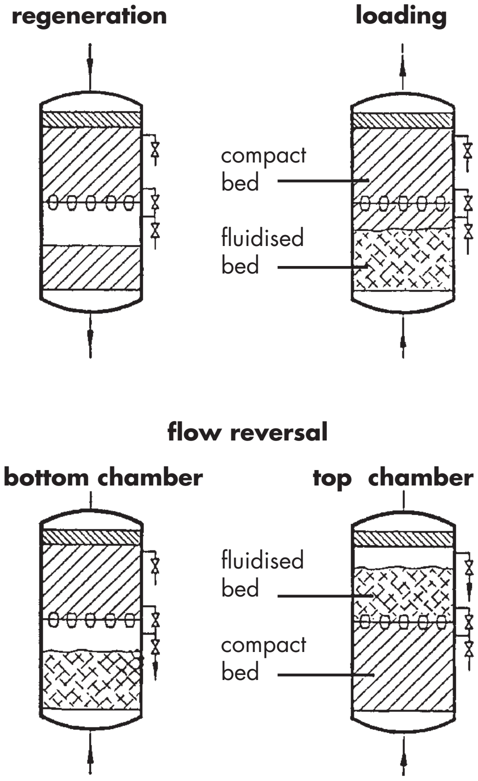


Fig. 4: Lift bed process stages.

IV. Liftbed countercurrent process: Optimisation and further development of the fluidised bed process results in the liftbed countercurrent process (Fig. 4). A third nozzle plate is fitted, thus separating the ion exchanger column into two chambers arranged above each other, both of which are filled with identical ion exchange material. The lower chamber of a liftbed exchanger is simply filled with up to 50% resin which is located in the middle nozzle plate during operation. This arrangement enables backwashing of the resin charge in the lower chamber. If necessary, resin in the upper chamber can be transported into the clearance space of the lower chamber enabling backwashing of the upper chamber. The resin is transported from the upper into the lower chamber and vice-versa by a simple pipe with fittings which is also referred to as a lift pipe. Another feature of the liftbed process is that it is possible to achieve a large exchanger layer height. This gives optimal exchanger capacities together with improved water quality. The fixed exchange bed in the upper chamber effectively prevents a rearrangement of the levels. This renders the system less sensitive in relation to load variations in the operating phase. This process can also be combined with the compound fluidised bed process, thus utilising the regenerant more efficiently. The higher installation costs and increased energy consumption due to the need for 3 nozzle plates to be installed should be taken into consideration.

V. Continuous ion exchange process: In this process, each exchange stage consists of an operating column, backwash column and regenerating and washing columns. The fully loaded exchange material is removed from the operating column, backwashed externally in the other columns, regenerated and washed before being transported back to the operating column. Only one exchange system is therefore required for continuous operation. The level of automation is higher than for other countercurrent and co-current plants. By controlling the resin transport from the load of the operating column, an optimal capacity utilisation is achieved (source: Marquardt).

Ion exchanger Granular, insoluble, inorganic or organic substances (e.g. crosslinked polystyrene) capable of interchanging accumulated → Ions (e.g. H^+, OH^- etc.) with other available ions in water, without affecting its structure and stability. A distinction is made between ion-exchangers according to the nature of the interchangeable ions:

I. Cationic exchangers (base exchangers). These are the most important ion-exchangers for water softening and are mainly high molecular weight polyvalent solid acids or their salts. They have acidic, positively charged exchange ions, i.e. acidic groups (SO_3H, COOH, OH) with mobile H^+ or Na^+, e.g. of the type $-SO_3Na^+$ or $-SO_3H^+$. The same compounds can function as

a) Sodium exchangers (Na exchangers, neutral exchangers): in this case the calcium and magnesium in water hardness salts are exchanged by sodium. Principle:
(A = exchanger)

$$Na_2\text{—}A + CaSO_4 \rightleftharpoons Ca\text{—}A + Na_2SO_4$$

The exhausted filter is regenerated with sodium chloride (5–10%) by the reverse reaction:

$$Ca\text{—}A + 2\,NaCl \rightleftharpoons Na_2\text{—}A + CaCl$$

b) Hydrogen exchangers (H exchangers); in this case hydrogen is exchanged by calcium, magnesium, sodium, etc. Principle:

$$H_2\text{—}A + CaSO_4 \rightleftharpoons Ca\text{—}A + H_2SO_4$$

This time, regeneration is carried out with hydrochloric acid:

$$Ca\text{—}A + HCl \rightleftharpoons H_2\text{—}A + CaCl_2$$

Cationic exchangers consist mainly of styrene and phenolic resins (water softening to 0°d is possible). The cation exchange is carried out either by co-current flow in which the water to be softened, and later the regenerating solution, flow downwards through the exchanger, or by counter-current flow in which the regenerating solution is passed through the resin in the opposite direction to the water being softened.

II. Anionic exchangers. These are high molecular weight, polyvalent bases or their salts which have basic, negatively-charged exchange ions, i.e. interchangeable OH groups against anions or end-groups suitable for the formation of acids. The principle of the exchange reaction is as follows:

$$A\text{—}OH + HCl \rightleftharpoons A\text{—}Cl + H_2O$$

Regeneration is carried out in this case with caustic soda solution (1–4%) or sodium carbonate (approx. 10%):

$$A\text{—}Cl + NaOH \rightleftharpoons A\text{—}OH + NaCl$$

By contrast, acid addition takes the following course:

$$A\text{—}NH_2 + HCl \rightleftharpoons A\text{—}NH_2\text{—}HCl$$

Regeneration is likewise effected with caustic soda solution:

$$A\text{—}NH_2\text{—}HCl + NaOH \rightleftharpoons A\text{—}NH_2 + NaCl + H_2O$$

Weak basic exchangers are suitable for the removal of high molecular weight organic compounds and amphoteric metal salts, and strong basic exchangers for weak acids, eg. carbonic acid, silicic acid, etc.

III. Mixed bed exchangers: i.e. a mixed bed or successive beds of anion and cation exchange resins results in complete water softening and the production of water qualities up to that of distilled water. In separate filters, the successive removal of bases with a hydrogen exchanger takes place in the first stage (as in I.b) and the removal of acids with an anion exchanger (or an anion accumulator) in the second stage (as in II.). Principle:

$$H_2\text{—}A + CaSO_4 \rightleftharpoons Ca\text{—}A + H_2SO_4$$

$$2\,A\text{—}OH + H_2SO_4 \rightleftharpoons A_2\text{—}SO_4 + 2\,H_2O$$

Ion-exchange resins Synthetic ion-exchange resins consist of various insoluble copolymers having a crosslinked three-dimensional structure to which ionic groups have been attached. An anionic resin has negative ions built into its structure and therefore exchanges positive ions. A cationic resin has positive ions built in and exchanges negative ions. Ion-exchange resins are synthetic organic polymers containing side-groups that can be ionized. → Organoliths.

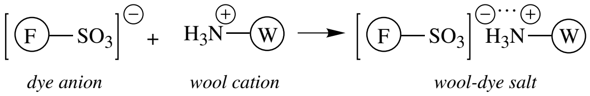
Ionic Relating to → Ions.

Ionic activity That property e.g. of textile auxiliaries to form → Ions in aqueous solution or dispersion by electrolytic dissociation. In this case the effectiveness of the textile auxiliary is due to its ability to carry an electric charge.

Ionic bond (electrostatic bond, polar bond, heteropolar bond, electrovalent bond). A → Chemical bonds which is based on the strong electrostatic attraction forces between cations and anions, and which owes its stability to the fact that certain atoms readily give up electrons and other atoms take up such electrons again. A typical example of this kind is the formation of sodium chloride (NaCl) from metallic sodium and gaseous chlorine. First of all each Na atom donates one electron which then becomes a Na ion: $Na \rightarrow Na^+$. For its part, the Cl atom accepts the donated electron and consequently becomes a Cl ion: $Cl \rightarrow Cl^-$. Due to the now actively charged state, the strongly electrostatic repulsion forces between ions with like charges and the attraction forces between oppositely charged ions, a regular arrangement of the ions takes place in the formation of the sodium chloride crystal:

$$2\,Na + Cl_2 \longrightarrow 2\,Na^+ + 2\,Cl^- \longrightarrow 2\,Na^+\,Cl^-$$

As the most well-known example in dyeing, mention can be made of the electrostatic dye bonding between the dye anion of an acid dye and the dissociated NH_3 groups of the wool fibre which then act as wool cations. The resultant reaction product represents a dyeing in the form of a wool-dye salt:



Ionic equation → Ionic reactions.

Ionic formula A type of formula which provides information on the composition of → Ions, their charge and charge sign, e.g. Na^+, Fe^{2+}, S^{2-}, SO_4^{2-}.

Ionic polarization → Polarization.

Ionic reactions Chemical reactions between → Electrolytes in solution always involve → Ions as reaction partners:

H^+ = acid reactions
OH^- = base reactions
SO_4^{2-} = sulphate reactions
Na^+ = sodium reactions

Such ionic reactions proceed (according to Pauling), almost without exception, in an extraordinarily short time because electrolytes of this kind are almost completely ionized or dissociated in solution. The neutralization reaction (see below) between acids and bases occurs instantly. In the ionic equation only the reaction which is actually proceeding is expressed, e.g. the combination of silver and chlorine ions to form silver chloride:

$$Ag^+ + Cl^- \rightarrow AgCl\downarrow$$

Neutralization is also a typical ionic reaction in which H ions of the acid and OH ions of the base combine to form undissociated H_2O releasing heat of neutralization. The neutralization of hydrochloric acid by caustic soda is written thus:

$$HCl + NaOH \rightarrow NaCl + HOH$$

and expressed as an ionic reaction:

$$H^+ + Cl^- + Na^+ + OH^- \rightarrow HOH + Na^+ + Cl^-$$

or, in the form of an ionic equation, simply as follows:

$$H^+ + OH^- \rightarrow HOH + 57{,}4\ kJ.$$

By contrast, the extremely numerous reactions between organic molecules mainly proceed as carrier functioning molecular reactions.

Ionization → Dissociation.

Ionizers Ionizers are devices which ionize the air by means of high voltage therefore removing the electrical charge on textiles. It is possible to use ionizers operating with high voltage where there is a risk of explosion. Explosion-proof peak-load ionizers do not have this disadvantage. They do not operate at high voltage. Ionization occurs via earthed peaks if the charge of the outgoing electrical field from the charged textile is sufficiently high. Ventilation can prevent explosive mixes accumulating on the peaks.

Ions (Gk.: *ienai* = to go, move). Atoms or groups of atoms carrying one or several positive or negative electrical charges. The ions present in an aqueous solution migrate to the oppositely charged electrodes when a direct current voltage is applied. Those ions which migrate to the cathode (positively charged ions) are cations and those which migrate to the anode (negatively charged ions) are anions. The transformation of an atom into an ion is called ionization. Cations are formed from neutral particles by losing, and anions by gaining, electrons. For these processes to occur, energy at least equal to the bonding energy of the electron (ionization energy, ionization potential) must be provided. This energy can be supplied in the form of chemical, thermal, light or electrical energy. The charge number of an ion is indicated at the top right of the atom symbol or the atom group in ionic formulae and the number of elementary charges precedes the sign. Examples: Cl^-, Li^+, Mg^{2+}, P^{3+}, S^{4+}, N^{3-}, OH^-, $HCOO^-$, $[CO(NO_2)_6]^{3-}$. In nature, the atoms of solid and liquid substances are mostly present as ions.

IONTEC Colombian standards organization; → Technical and professional organizations.

IOS, abbrev. for: Iraqi Organization for Standardization, Baghdad, Iraq; → Technical and professional organizations.

IPN, abbrev. for: interpenetrating polymer network. Mutually penetrating networks of polymers at the molecular level.

IR → Infrared.

Ir Chemical symbol for iridium (77).

IRAM (Sp.), abbrev. for: Instituto Argentino de Racionalización de Materiales, Buenos Aires, Argentina (Argentinian Standards Institute, including textile standards); → Technical and professional organizations.

IRCT (Fr.), abbrev. for: Institut de Recherches du Coton et des Textiles Exotiques, Paris, France (French Research Institute for Cotton and Exotic Fibres); → Technical and professional organizations.

Irish moss → Carragheen.

Iris print (rainbow, ombré and shadow hand block printing). This was once an important novelty print with multi-coloured effects blending into each other. This was achieved by a single print application using a device known as the iris block (approx. 30 small dye paste print compartments).

Iron (ferrum, Fe), I.1, atomic weight 56; soluble in diluted acids, hardly soluble in concentrated acids; moist air and water containing air cause the formation of hydroxide (rust). Chemically pure iron (grey iron) is a matt powder or (almost) silver-white and quite soft. Non-metallic compounds: iron is generally 2, 3 or 6-valent iron(II) hydroxide is quite a strong base, iron(III) hydroxide is a weak base (has the effect of an extremely weak acid against strong bases) iron(VI) hydroxide is a strong (ferric) acid (the same applies to sulphuric and chromic acid).

Iron(II), bivalent form of → Iron.

Iron(III), trivalent form of → Iron.

Iron bacteria The main iron bacteria are chlamydothrix, gallionella and crenothrix. They occur in untreated water containing iron and manganese, especially in pipes in the form of so-called iron-storing algae. They grow at a tremendous rate, causing pipe narrowing, silting-up, blockages, etc.

Iron buff (rust yellow, nankeen yellow). Rarely used mineral colour pigment for cotton discharge printing, military webbing, coloureds and washables, embroidery and knitting yarns. Especially in beige colouring for curtains and laces and associated yarns (to give an impression of ageing). This type of light shade does not fade, but tends to darken. Excellent fastness to light, air and atmospheric influences. Very good fastness to alkalis found in laundry soaps. Poor acid fastness. Low fastness to crocking (especially dark colours). Production: Impregnate with iron(II) sulphate, intermediate drying, reaction of weak alkali solution, pass through a calcium chloride solution (oxidation to form iron oxide). Organic acids give discharge effects (tartaric acid, citric acid).

Iron(III) chloride (ferric chloride), $FeCl_3 \cdot 6H_2O$. Molecular weight 270.41. Yellow-grey irregular crystals, deliquescent, easily soluble in water, alcohol and ether. Strong acid when dissolved (following hydrolysis). Use: only used very occasionally nowadays as a dye mordant in textile printing, used as an oxidising agent and for the detection of thioglycol.

Iron-contaminated process water This refers to process water containing iron (II) oxide (FeO). Encourages fibre damage by bleaching catalysts, rust stains, yellow muddy brown stains on white goods, change of shade where cationic and metal-sensitive dyestuffs are used.

Iron contamination of water This occurs e.g. when water is free from iron and is free from or has only low dissolved air content and the aggressive carbonic acid is present in iron pipes, especially after water has stagnated in them. The same occurs in water from which the iron has been removed. (Re-contamination with iron, often several mg/l iron content). Prevention: possibly by aerating the water.

Iron elimination If process water which is to be used for bleaching contains more than 0.1 mg/l of iron, this must be removed, i.e. the iron must be eliminated, in order to avoid the risk of yellowing the bleach goods. The iron is generally present as iron(II) hydrogencarbonate ($Fe[HCO_3]_2$) and is relatively easy to separate.

Ground water with a high iron content appears yellow to yellowish-brown and deposits a yellow, voluminous sediment consisting of ferrous hydrate on contact with air. This process can be accelerated by ventilating with atmospheric oxygen. Water containing iron is ventilated either in an open device while the water is allowed to flow across wooden racks or synthetic channels before being passed through a sand filter. In open devices, water containing iron can also be atomised, a process which also neutralises the water. In general, however, thorough aeration using a compressor in a sealed device is preferred. A piston compressor is required to ventilate large quantities of untreated water. The quantity of air should always be amply dimensioned; 1 g iron is required for approximately 5–10 l air. The iron flocculated during ventilation is removed from the layer of quartz chippings, stored in the device, by regular backwashing. According to experiments carried out in practice, the iron elimination process in open and sealed plants is simple to achieve with an average carbonate hardness and pH > 7, and is more difficult with low carbonate hardness. Where the iron content is above 4 mg/l, an open device must be added before the sealed device.

If the finishing company already has a waste water treatment plant which uses a precipitation process, or if the untreated water is industrially neutralised or decarbonised, the bivalent iron attached to the carbonic acid is also flocculated. If however, water containing iron is to be softened using a cation exchange process, a ventilation device must be added to avoid the exchange material being polluted or even totally obstructed by flocculated ferrous hydrate deposit. Manganese is a stable escort material for large quantities of iron and this is coprecipitated during ventilation if it is bound to carbonic acid. In other cases, a special treatment must be carried out in order to remove it (demanganization).

Ironing fastness Resistance of the shade to ironing. Test: duration 15 s, temperature 200°C (cotton), 150°C (wool, silk, viscose), 120°C (acetate, polyamide, polyester, acrylic);

I. Dry: The heated upper plate of the heating device is placed on the sample for 15 s.

II. Moist: Place a dry sample on dry cotton fabric, cover with cotton fabric which has been wetted to 100% moisture; 15 s as in I;

III. Wet: The sample and cotton fabric are saturated in water and squeezed off to 100% moisture. The wet sample is placed on a dry cotton fabric and covered with the wet cotton fabric; 15 s as in I.

Where methods II or III are used, bleeding is also assessed.

Ironing machines Ironing machines are used in making-up shops, laundries and dry-cleaning plants for rational shaping and finishing work in the press room. Ironing machines consist of an upper and lower plate. The article to be ironed is shaped between these two plates by means of pressure, heat and moisture (for underwear) or direct steam (for outerwear). It is then heat-set by a) contact drying in the case of underwear and b) drying and cooling extraction in the case of outerwear. The forms of the pressing surfaces (upper and lower plate) are adapted to the various spec. shaping requirements. The ironing covers which are elastic to a greater or lesser extent, must be totally permeable to air. Common combinations are as follows:

I. Upper and lower plate insulated; upper and under-steam; lower plate with extraction.

II. Upper plate uninsulated (metal), heated; lower plate insulated, with under-steam and extraction.

III. Upper plate uninsulated, heated; lower plate insulated, heated (contact drying). The high-performance pneumatic ironing machine which is activated via a hand switch and foot pedal with controllable pressure has replaced the manual model. In addition: automatic timing and function control of the individual operations by the programmer.

Ironing of garments Final treatment in drycleaning and the garment industry in the sense of shaping by smoothing using the combined effect of heat, moisture and pressure. A distinction is made between manual and machine ironing (→ Ironing machines). Manual ironing is preferred where machine ironing is not expected to give a satisfactory result. Manual ironing devices: ironing board, sleeve board, ironing pad, flat iron (if possible with electrically adjustable temperature control, with steam spray device), steam-heated piston shaping units. Manual ironing is generally carried out on the reverse of the fabric. Where this is not the case, a steam cloth is placed between the iron and the cloth face (this is not required for light fabrics which do not have a lustrous appearance after ironing). The ironing temperature must be adapted depending on the type of material being ironed, as certain damage caused by ironing is generally irreversible (e.g. on acetate, polyamide clothing).

Ironing presses → Ironing machines.

Ironing stains on acetate (fibre blends). Shiny areas, caused by ironing at too high a temperature or by contact with a heater during the dyeing process, i.e. temperatures of above 160°C. These are characterised by shrinkage and a harder handle or particularly lustrous areas, poss. a combination of the two. Removal: best results with liquor approx. 1 : 15, 15–20 min, 18–20°C (only 4–8% loss in tensile strength, higher temperatures give rise to greater losses) with 30% formic acid, stir and rinse. More pronounced ironing stains possible at 35–50°C. Dyed fabric is generally lightened and requires subsequent redyeing.

Ironing table Working surface for manual ironing in the garment industry and textile care available in various dimensions. Spec. ironing table with under-steam and suction, connected to electric steam flat iron with separate storage, available with spec. accessories such as water spray guns, pivotable narrow auxiliary ironing surfaces (sleeveboard), etc.

Ironing temperature The (highest) permissible temperature when ironing textiles before which damage occurs as a result of the fibres being softened or browned (see Tab.).

fibres	ironing temperature (°C)		beginning of softening or browning (°C)
	normal	max.	
cotton/ flax	180–200	200	215–220
wool/ silk	150–170	180	195–200
viskose/ cupro	150–170	180	195–200
acetate	150–170	180	210–220
polyamide	150–170	200	200–210
polyester	150–170	200	210–220
acrylic	150–170	220	230–240
polyvinyl-chloride	60– 70	80	90–100

Tab.: Ironing temperature of different fibres.

Ironing testers,

I. Ironing press, e.g. the Spuhrsche ironing press, is used for → Ironing test procedures in accordance with DIN 53 894 T1. It consists of a steam-permeable ironing table which is covered with a wool felt 15 mm thick of F2 hardness in accordance with DIN 61 200, and an ironing shoe of at least 600 x 200 mm which must exert a pressure of 0.4–0.5 N/cm^2 due to its weight onto the ironing table and be kept at temperatures of 120–200°C by electrical heating. Sections of a plain weave, absorbent cotton fabric (ironing cloth) with a fabric weight of 150–200 g/m^2 when air-dried are also required for the test.

II. Table ironing machine, e.g. the Hoffmann press is used for ironing samples in accordance with DIN 53 894 T2. It consists of a steam-heated ironing table and shoe with a working surface of 600 x 600 mm, 525 x 525 mm of which is perforated. Steam is only exhausted by the ironing shoe. This is in the form of saturated steam with a pressure of 5 bar. The suction air connection (0.10–0.12 bar) is located on the ironing table. The upholstering of the ironing shoe consists of one layer of tinned copper wire material in two-up-two-down weave and one layer of smooth, heat resistant textile fabric. The upholstering of the ironing table should consist of one layer of tinned copper wire material, 1 layer of wool felt and one layer of smooth, heat resistant textile fabric. Supporting surfaces can be found on all three sides of the ironing machine. These are used to support the areas of the goods to be tested which are not to be steamed when testing is to be carried out on the entire item.

Ironing test procedures In accordance with DIN 53 894:

I. Part 1: Determining the change in size (shrinkage or elongation) of textile fabrics when ironing with a moist ironing cloth on ironing presses. Method: Two (500 ± 5) mm long measuring ranges are marked 50 mm from the edges on a test sample of 200 x 600 mm, to enable the change of size both lengthwise and crosswise to be measured separately. A wool felt is placed on the ironing table of the ironing press, followed by a cotton cloth folded in two, then the test sample, which is covered by a moist ironing cloth. The residual moisture left in the fibre after ironing must not increase the weight of the sample by more than 8–10%: this can be achieved by varying the water content in the ironing cloth, the ironing temperature and the duration of ironing. After ironing, the sample is kept at standard atmosphere for 16 h and then the test results are calculated as a percentage from the change in length in comparison to the original length. From the two individual values, the arithmetical averages are calculated, together with the total average value for each direction tested from the various test samples. The relative surface change ΔF is calculated as a % using the formula:

$$\Delta F = \Delta K + \Delta S + \frac{\Delta K \cdot \Delta S}{100}$$

ΔK = relative change in length, lengthwise in %
ΔS = relative change in length, crosswise in %

II. Part 2: Determining the change in size (shrinkage or elongation) of textile fabrics (wovens and knitwear) following relaxation when steaming on ironing machines in a mobile state. Method: Testing can be carried out on test samples of 600 x 600 mm which have been cut out or on the item itself. Three (500 ± 5) mm long measuring ranges are marked both lengthwise and crosswise 250 mm apart on a test sample. Where the samples have been cut out, care should be taken that the outer measuring ranges are at least 50 mm from the edge of the sample. The test samples must be kept at standard atmosphere until immediately before steaming, as the change in size can depend to a large extent on the moisture of the fabric in steaming. The following treatment is carried out 5 times in succession (the 5th time only as far as step d):

a) lowering the ironing shoe to a distance of 10 mm;
b) 10 s steaming (only over-steam);
c) 10 s suction (through the ironing table);
d) lifting the ironing shoe;
e) gently shaking the test sample;
f) replacing centrally on the ironing table tension-free.

The samples are then left to dwell for 16 h in standard atmosphere and the arithmetical averages and the total average is calculated for each direction tested as described in part I. The values relating to change in length given when steaming on an ironing machine cannot generally be compared with the results of other shrink resistance tests; this applies e.g. to ironing under a moist cloth in accordance with DIN 53 894 T1 or immersing in warm water.

Ironing test reading → Formaldehyde release on ironing.

Iron mordant → Iron (III) sulphate.

Iron-on fabrics → Hot melt adhesives.

Iron oxidation Iron oxidation in plastic-lined iron pipes used for process water. Specific strains of bacteria, capable of corroding the protective plastic lining inside water pipelines, eat away the plastic layer so that the iron exposed in the water main can rust causing an irregular yellowish-brown discoloration of the water due to rust contamination.

Iron removal from water (A treatment frequently coupled with neutralization of acidic water). Hydrogen carbonates yield easily precipitated iron, whilst the sulphates yield iron in a form which is difficult to precipitate. Additions of caustic soda or caustic potash solution have an accelerating effect. Unwanted protective colloids are precipitated by aluminium sulphate or oxidative additives (permanganate, etc.). In general, 0.48 l of air is necessary for each 1 g of iron to be removed.

I. Open plants: by showering (through special nozzles) into a trickling installation (coke, broken lava, broken brick, concrete hurdles), especially useful for iron which is difficult to precipitate as well as in the presence of carbonic acid, followed by settling tanks (formation of insoluble hydroxides) and filtration or a second showering of the filter.

II. Closed plants: with compressed air (2–5% of the amount of water involved) and a filter backwashing system or, e.g. a manganese-permutite filter with simultaneous acid neutralization. Occupies less space, simple, contamination-proof. Small plants are also available for direct connection to boreholes or water mains with activated carbon filters. Principle of operation: oxidation of the bivalent to the trivalent form by atmospheric oxygen and formation of the colloidally dissolved hydroxide, slow flocculent precipitation followed by filtration.

III. Chemically: closed filtration (no contact with the outside air) over magnesite or dolomite for untreated water containing 3–5 mg/l of iron. Organically-bound iron (humate) can only be removed with aluminium sulphate, sodium aluminate or permanganate oxidation or, for small quantities of iron (0.1–0.3 mg/l of iron) with polyphosphate.

Iron(II)sulphate (ferrous sulphate, iron vitriol), $FeSO_4 \cdot 7\,H_2O$. Mol wt. 278; specific gravity 1.88. Greenish crystals, air exposure causes the formation of basic iron(III) sulphate, which is of low solubility. Use: to produce iron mordants, in vat dyeing (reducing agent) and as a precipitating agent in effluent treatment.

Iron(III)sulphate (ferric sulphate, sulphuric iron, iron mordant), $Fe_2(SO_4)_3$. Molecular weight 400. White/grey-white powder, deliquescent in air (brown solution), dissolves slowly in water. Basic iron(III) sulphate is only occasionally used today as an iron mordant for the weighting of silk.

Iron tests,

I. In dyeings: Incinerate goods to be tested, absorb using iron-free hydrochloric acid. Next oxidise with a few drops of hydrogen peroxide or concentrated nitric acid . Then either a) with ammonium or potassium thiocyanate solution = bluish red dyeing; or b) with potassium hexacyanoferrat II solution = blue precipitate (Prussian blue), in diluted solution = only bluish green dyeing. Limit concentration 1 : 500 000 in each instance.

II. In water: Generally present as iron (II) salts, then either a) with diluted hydrochloric acid + potassium hexacyanoferrat III solution = blue precipitate (Turbull blue); or b) first oxidise with hydrogen peroxide, then continue as in I a) or b).

Irradiation technology Since the capability of high-energy radiation to crosslink linear polymers and introduction of graft reactions has been known since a very early stage, it was a logical step to include textile fibres comprised of macromolecular materials in the radiochemical textile finishing processes, all the more so as the demand for diverse variation of properties in their articles is particularly pronounced in the textile industry. However, whereas in the plastics sector, processes such as the manufacturing of shrink film for packaging and heat-shrinkable sleeves for electrical insulation have been accepted in industrial production, irradiation technology has not as yet penetrated the textile industry. Of the various types of high-energy rays, only gamma or x-rays, consisting of high-energy photons, and electron beams, which are produced by acceleration in a high-voltage field, are used for technical and economic reasons. It is significant that the interaction between radiation and matter in the energy field in question is limited to the electrons, i.e. no radioactive decay occurs. A significant difference between the two forms of radiation is in their different adsorption behaviour. With electromagnetic gamma radiation, the adsorption is more or less proportional to the density of the material penetrated. This type of radiation displays good penetration capacity. With radiant energy of 1.2 MeV, as emitted from radioactive cobalt, the thickness of the half-value layer of a penetrated material of thickness 1 is approx. 10 cm, whereas the electron radiation is merely approx. 0.3 cm. Electron radiation is therefore well suited to thin layers such as textile webs, sheeting etc. In the case of gamma radiation, virtually all the energy is transferred to electrons, making the effects of both types of radiation at a comparable dose almost identical.

Irradiation technology can be seen in a simplified way as a method of producing free radicals. These can also be produced by peroxide or photochemically induced methods which generally give equivalent results in terms of quality. Given these circumstances, economic criteria are naturally particularly significant when choosing between the methods. As it is relatively expensive to produce irradiation energy per kWh, it is important that the best possible yield of irradiation energy is achieved. The quantity of product formed in a radiochemical process is directly proportional to the three values G, D and M, where G is the radiochemical energy yield, D is the dose of radiation and M the molecular weight of the product produced. The higher the value of G or the molecular weight of the quantum modified, the lower the energy costs. Chain processes are the most common systems with a high G-value, as found with graft-polymerisation or cross-linking using non-saturated bonds, whereas the high molecular weight of the polymers, as in the case e.g. in crosslinking polyethylene, also give a high yield. Another advantage of irradiation technology is that initiation and propagation phases are independent of one another, i.e. this type of process can e.g. be carried out at room temperature. Depending on whether disproportionation, recombination or propagation are to follow, the free radicals formed when irradiating textile fibres may cause 3 different reactions – decomposition or cross-linking of chain molecules, or, where monomers are present, graft polymerisation. The last reaction generally also results in larger quantities of homopolymers. As it is necessary to aim for as low a dose of radiation as possible both for economic reasons and as cross-linking is preferred to the decomposition reaction, suitable vinyl bonds which can carry out the appropriate chain reaction are generally added. There has been an increase in radiation-induced graft reactions, as the appropriate selection of various monomer systems can cause almost as many modifications to the properties of the substrate as desired. Two of the principal problems faced by the radiochemist who works with the fibres, are diffusion, which is becoming the determining factor concerning speed, especially with synthetic fibres, and the fact that due to the so-called "Trommsdorf" effect, only a few graft chains with very high molecular weights are formed, thus changing the properties of the fibre very little. On the other hand, there is an advantage in having graft reactions, in that they do not alter the basic properties of the substrate to any great extent and the properties of the graft polymers can be enhanced to a certain extent.

Irreversible Irreversible, as opposed to → Reversible. Term used to define the state of equilibrium of chemical reactions with equivalent properties, e.g. the formation of a precipitate which remains unchanged when a precipitate substance or a precipitable substance (or both) are exhausted. Example: Barium chloride and sodium sulphate = $BaCl_2 + Na_2SO_4 \rightarrow BaSO_4 + 2\ NaCl$.

Irrigated cotton Cotton which is cultivated under artificial irrigation (→ Rain-Grown-Cotton).

Irritant threshold concentration The weakest odour concentration of → Perfumes which can still be detected by the (human) olfactory system. Persons with a well developed sense of smell can achieve astonishing levels of agreement on these quantitative values which can be reproduced within narrow ranges as so-called → Odour threshold value. It has been authentically stated that the human nose is 100 times more sensitive than the best analytical apparatus currently available for the detection of threshold odour values.

IRS, abbrev. for: Irish Standard, ir. norm.

IRSFC (engl.), abbrev. for International Rayon and Synthetic Fibres Committee, analog. (french) → CIRFS, → Technical and professional organizations.

IS,

I. Indian Standard (ind. norm).

II. Irish Standard (→ IRS) (ir. norm).

Isfahan carpet Isfahan carpets are woven in the Iranian city of the same name as well as in the neighbouring villages. Isfahan, which is situated in the fertile plain of the Zaiandeh river in the centre of Iran, is the second largest city in the country. Isfahan carpets are woven on vertical looms. Backing in cotton; pile in very close cropped wool, some examples also having a silk pile. The Persian knot is used and the density is very high, i.e. approx. 400 000 knots per m^2. Isfahan carpets all have a floral design, usually with a central medallion on a field decorated by a motif of interlaced flowering branches. Some examples also have four corner decorations which have the same motifs and colours as those used for the central medallion. Carpets with scenes of flowers and animals are also quite common. Another decoration which is typical of this area is the one known as the "vase of flowers". A very wide colour range is used in Isfahan carpets to create a harmonious combination of ground and design with alternating light and dark colours.

ISI, abbrev. for ind. standard organization → Technical and professional organizations

ISIG, abbrev. for: ghan. standard organizations, → Technical and professional organizations.

Isinglass → Glue.

ISIRI, abbrev. for: Institute of Standards and Industrial Research of Iran, Teheran, Iran; →Technical and professional organizations.

"islands-in-the-sea" fibre A term used for a → Bicomponent fibres similar to the matrix/fibril type and described as a multiple interface or multicomponent fibre. The "islands" are fibrils of one or more polymers embedded in the "sea" (or matrix) consisting of a different polymer. The matrix is often dissolved away to leave ultra-fine filaments. The number and titre of these fine filaments is pre-programmed. Such fibres have been used in ion-exchange products as well as in imitation fur materials and in textile fabrics to achieve a different handle.

ISMIU Acronym for the "Institut por Standardizacia, Merki i Izmeritilni Uredi", i.e. the Bulgarian Institute for Standardization, Metrology and Measuring Instruments; → Technical and professional organizations.

ISO Acronym for the International Standards Organization, based in Geneva, Switzerland, founded in 1947. ISO is the international organization responsible for standardization and includes national standards bodies from numerous countries among its members. The working rules established by ISO committees are regarded as authoritative directives by member countries which helps to encourage the development of largely identical international and European standards, thereby promoting the international language of standardization and contributing to the improvement of international trade; → Technical and professional organizations.

iso- (Gk.: *isos* = equal). A prefix indicating:

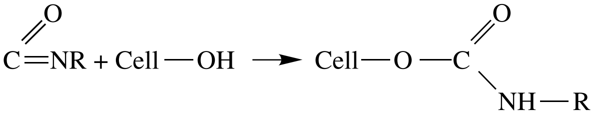
I. Equal or identical, e.g. isomagnetic.

II. An isomeric compound.

III. The presence of a branched carbon chain in the molecule.

Isobutanol (isobutyl alcohol), $(CH_3)_2CHCH_2OH$, → Alcohols.

Isocyanates Compounds containing the group –N=C=O. They are organic salts of isocyanuric acid. High molecular weight alkyl isocyanates or isothiocyanates form esters with cotton and regenerated cellulose resulting in cellulose alkyl urethanes with hydrophobic properties:



$$O{=}C{=}NR + \text{Cell}{-}OH \longrightarrow \text{Cell}{-}O{-}C({=}O){-}NH{-}R$$

Isocyanuric acids → Chloroisocyanuric acids.

Isocyclic compounds Compounds derived from → Cyclic hydrocarbons.

Isodiazotates → Antidiazotates.

Isoelectric point The pH of an aqueous solution at which dissolved amphoteric electrolytes appear to carry no charge. In the absence of other electrolytes, the isoelectric point at infinite dilution is identical with the point of zero charge where the sum of the actual charge on the particle (net charge) is zero. In amino acids, for example, both values are identical since they are not influenced by outside ions. For macromolecular ampholytes the isoelectric point and the point of zero charge do not necessarily coincide. In the case of proteins, for example, the characteristic location of the isoelectric point is influenced by the number of free acid and basic groups as well as their position in the molecule. The isoelectric point for wool lies at pH 4.9 and that for silk at pH 5.1, i.e. the neutral point for these fibres lies within the acidic range. At this neutral point the fibres exhibit their greatest internal strength, minimum swelling and reactivity as well as their lowest affinity for dyes.

Isoelectric wash → Acidic washing.

Isoionic point The pH of an aqueous solution, for example in which wool is immersed, which contains as many positive as negative ions. Also known as the ionic neutral point.

Isolines (isograms). Isolines are graphic representations in the form of lines along which the same value of a particular parameter prevails in the system represented (according to the designation of the abscissa and ordinate in a 2-dimensional graph or, in a 3-dimensional plot, the third axis), e.g. isobars: lines of identical pressure (p = a constant); isotherms: lines of identical temperature (T = a constant). One advantage of this statistical-mathematical modelling is the high degree of transparency provided by the opportunities for graphic representation.

Example of cold pad-batch reactive dyeing: both the depth of dyeing (Figs. 1 and 2) as well as the dye uptake (Figs. 3 and 4) exhibit the same fundamental behaviour. High dye uptakes and depths of dyeing are indeed achieved at pH 11 and a 12 h dwell time, but this set target cannot be fulfilled under these conditions. The reaction time, which should be completed after 4 h, must be emphasized in particular here since a constant rinsing-off time is not possible and the considerable change in target parameters is due to the high dependence of both target parameters on temperature over the entire temperature range investigated. Since both the temperature as well as the dwell time are now revealed as clear disturbance variables, the necessary reproduci-

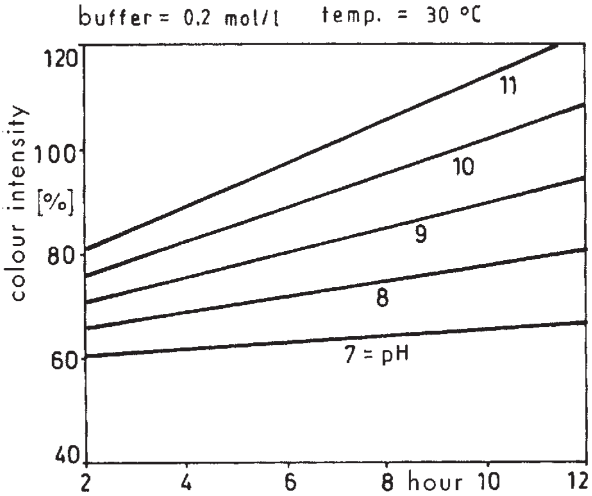


Fig. 1: Colour intensity as a function of storage time (C.I. Reactive Blue 19) in cold dwell reactive dyeing at various pH levels.

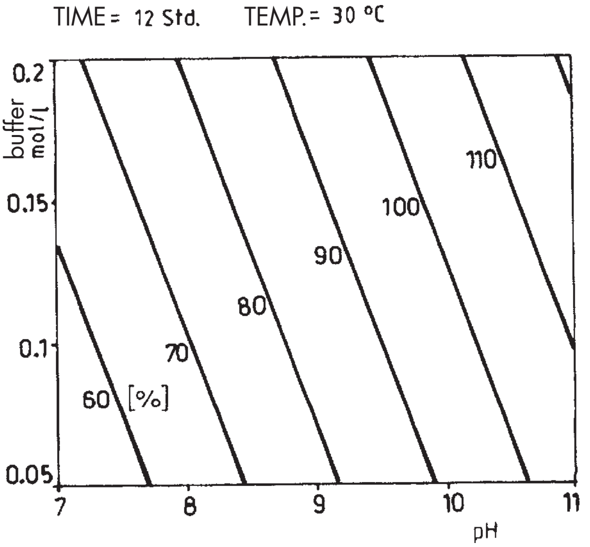


Fig. 2: Colour intensity isolines (C.I. Reactive Blue 19) in cold dwell reactive dyeing.

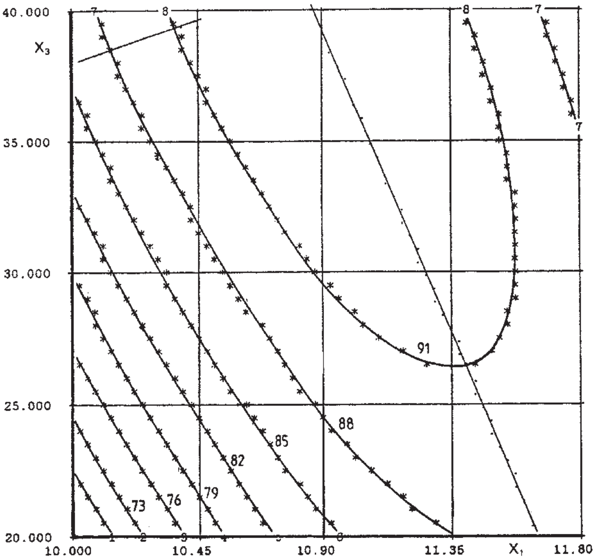


Fig. 3: Target dimension isolines: yield C.I. Reactive Orange 95 in warm dwell reactive dyeing.
time: 5h; X_1 = ph; X_3 = temperature

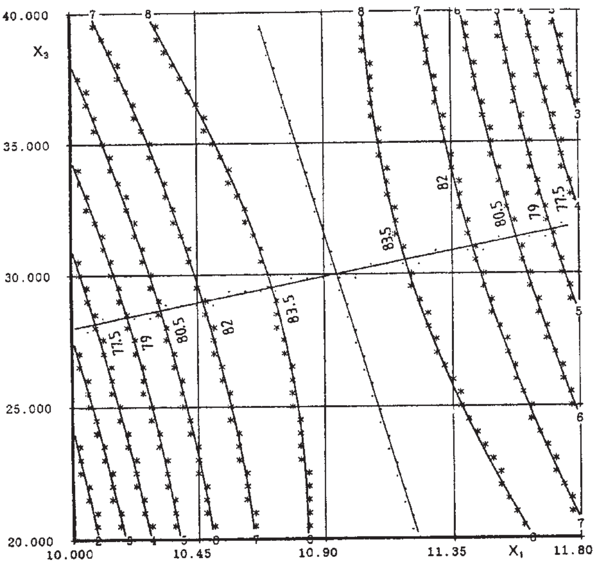


Fig. 4: Target dimension isolines: C.I. Reactive Orange 91 in warm dwell reactive dyeing.
time: 5h; X_1 = ph; X_3 = temperature

bility of the process is not possible and, consequently, any transfer of this process to production is out of the question. The creativity of the process developer is called upon once again here since he should now be in a position to deduce the causes of this result from the calculated model data in order (as in this case) to achieve the stated objectives by appropriate technical changes to the reaction technology.

The reaction behaviour of reactive dyes may therefore be clearly represented with the aid of isolines. C.I. Reactive Orange 95 (Fig. 3) exhibits high colour yields in the pH-range between 11 and 11.8 with stable process temperature conditions at the same time. In the case of C.I. Reactive Orange 91 (Fig. 4), a distinct colour yield maximum is apparent which is associated with narrow pH limits. At a pH > 11.3 and dwell conditions at temperatures > 25°C for dyeing, a fairly high degree of reverse hydrolysis occurs. An increase in the buffer concentration within the range investigated here only leads to a slight improvement in colour yield whilst the process reliability undergoes considerable improvement. This is especially noticeable when different amounts of residual alkali from fabric pretreatment are carried over into the dyebath. The influence of liquor storage time on colour yield is of no practical relevance under these particular test variations.

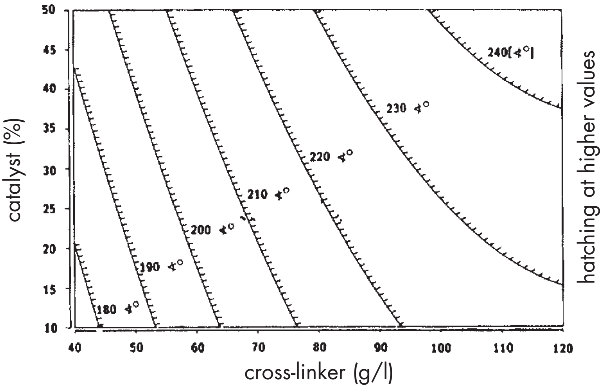


Fig. 5: Two-factor isoline diagram for dry crease recovery angle after washing in finishing with cross-linker C in combination with magnesium chloride hexahydrate.

An especially interesting relationship between the dry crease recovery angles and the ratios of crosslinking agent and quantities of catalyst in resin finishing may be represented with the aid of isolines. The isolines illustrated in Fig. 5 have been drawn up for various dry crease recovery angles dependent on the quantity of crosslinking agent and the ratio of catalyst for a curing temperature of 160°C and a curing time of 5 min. In order to obtain a dry crease recovery angle of 220°, for example, a 25% quantity of catalyst is required for the application of 100 g/l of a 45% solution of hydroxymethyl 4,5-dihydroxyethyleneurea, i.e. 25 g/l $MgCl_2 \cdot 6\,H_2O$. When 75 g/l of the crosslinker solution is used, the desired level is not reached with 25% of catalyst based on the crosslinker solution. With 75 g/l of crosslinker solution, 50% of catalyst already becomes necessary. In absolute terms, this is equivalent to 37.5 g/l of magnesium chloride hexahydrate.

In Fig. 6, dependence of the dry crease recovery angles after washing on the quantity of crosslinker and the ratio of catalyst for a curing temperature of 150°C and a curing time of 5 min is demonstrated by a 3-dimensional plot.

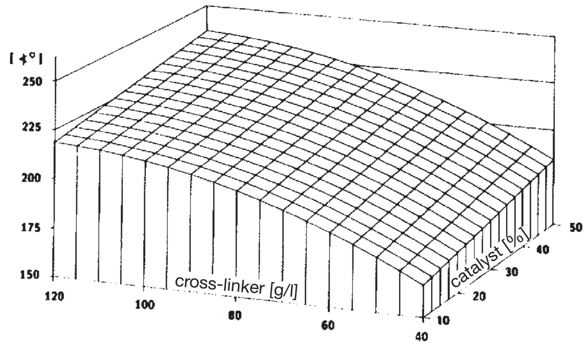


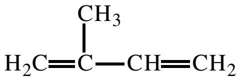
Fig. 6: 3D plot for dry crease recovery angle after washing for crosslinker C with magnesium chloride hexahydrate.

Isomeric (Gk.: *isos* = equal). As applied to compounds, a term which means of the same composition and the same molecular weight.

Isomeric compounds (isomers). Compounds possessing the same chemical composition (same molecuar weight, same empirical formula) but having different properties (e.g. with regard to their melting and boiling points, reactions and optical activity) which is usually due to different atomic arrangements within the molecule, i.e. they possess different structural formulae (→ cis-form; cis-trans isomerism). Some of the most well-known isomeric compounds are: ortho, meta and para compounds; monomers and polymers; mesomeric compounds; stereo isomers; tautomers; cis-trans isomers, etc.

Isomorphous (Gk.: isos = the same, and morphe = shape or form), to describe a substance with the same or similar crystal structure, e.g. the isomorphous (i) spherical form in contrast to the anisomorphous (a) fibrous form. The isomorphous property is based mainly on similar formulae and largely analogous arrangements of atoms, ions and molecules. Both states (a +i) are characteristic of, e.g. thermoplastic fibres: as a highly oriented, energy-rich form in the fibrous state (a), and in a low energy state as molten beads (i) = high temperature brings about a transformation into the molten state, i.e. by setting the molecules in motion through the introduction of heat energy, the a-state is destroyed and the a-fibre structure changes by shrinkage to the i-spherical structure (molten beads). By raising the order superimposed on the fibre molecules, the fibre becomes more receptive to dyes and a deeper dyeing results due to a reduction in the relative surface area of the shrunken fibre.

Isoprene (3-methyl-1,3-butadiene; 2-methyl-1,3-butadiene). The parent hydrocarbon of a homologous series which also includes → butadiene. It is a polymer unit in ethereal oils, terpenes, camphor, phytol and natural rubber. Due to reasons of cost, synthetic isoprene rubbers have had no technical importance hitherto.

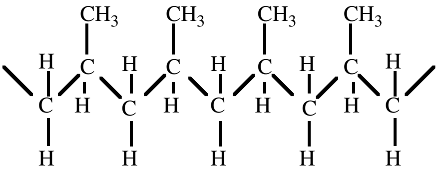


$$H_2C{=}\overset{CH_3}{\overset{|}{C}}{-}CH{=}CH_2$$

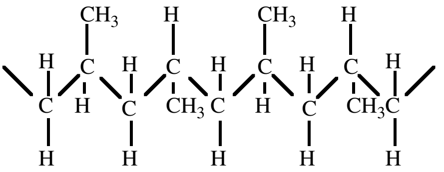
Isopropanol (2-propanol, isopropyl alcohol, dimethylcarbinol, IPA), $(CH_3)_2CHOH$. Colourless liquid with a pleasant alcoholic odour. Density 0.781; b.p. 82°C. Miscible with water in all proportions (solvent properties), soluble in alcohol, ether, etc. Chemically and physiologically similar to → Ethanol. Uses: extractions, spotting agent (tanning agent stains), component of soaps, polishes, etc.

Isotactic molecules Molecules having identical steric configurations of the groups on each asymmetric carbon atom on the chain. Catalysts with a stereotypical action are used to achieve this ordered molecular arrangement. → Syndiotactic molecules.

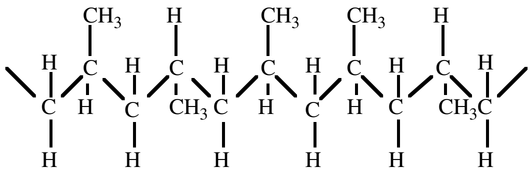
Isotactic polymers Synthetic macromolecules having a structure in which a regular spatial or stereo relationship exists between one repeat unit and the next and which have side chains ($-CH_3$, $-CH_2CH_3$, $-C_6H_5$, etc.) only on one side of the main chain, in contrast to polymers having side chains which alternate regularly on both sides (syndiotactic) or a random side chain configuration on all sides (atactic).



isotactic structure



syndiotactic structure



atactic structure

From the standpoint of fibre chemistry, isotactic polymers (e.g. polyolefin fibres) are of considerable importance because of the regularity of the chain structure by means of which, for example, favourable fibre-forming properties, high densities, high melting points, etc., can be specifically achieved. Isotactic polymers with the desired properties can be obtained in a controlled form by the addition polymerization of appropriate monomers with stereospecific catalysts.

Isothermal dyeing A rapid dyeing procedure carried out at constant temperature, e.g. for the HT-dyeing of disperse dyes on polyester.

Isotherms Lines (→ Isolines) connecting all points on a graph that correspond to the same temperature. For air and other gases, isotherms are used for heat, pressure, water vapour absorption (sorption isotherms), moisture vapour transmission (desorption isotherms) etc.

Isotopes All atomic nuclei are built up of protons and neutrons. An isotope is one of two or more atoms of the same element having the same number of protons (i.e. the same atomic number) in their nucleus but different numbers of neutrons. The presence of one or more extra neutrons in the nucleus means that different isotopes of the same element have different masses (atomic weights). Although isotopes have similar chemical properties, the slight difference in their masses is responsible for slight differences in their physical properties. All elements have several isotopes. Oxygen, for example exists principally as the isotope ^{16}O (i.e. with an atomic weight of 16) as well as very small amounts of ^{17}O and ^{18}O. There are relatively few naturally radioactive elements (e.g. radium) compared to the great number of radioactive elements produced synthetically (in nuclear reactors). Thus, one or more isotopes can be produced synthetically from any element in this way. These isotopes are, however, unstable and therefore emit radioactive radiation due to the fact that their composition differs from that of the natural number of protons and neutrons in the nucleus. This radiation can be detected easily and quickly with absolute certainty (even when localized). Such radioactive isotopes are important in textile research as well as in technological control systems of various kinds for the operation of control, indicating and regulating devices, etc. (an important isotope laboratory for textile research and teaching is located in Raleigh, NC, USA). For these applications, it is only necessary to have a substance (group) on which to carry out a series of measurements, linked to specific radioactive elements as indicators. Since even extremely small traces of radioactive substances can be readily detected, such isotopes may be used as radio indicators (RI) in practically minute quantities as they represent, in chemical terms, a chemically identical substance, selected at choice, which is chemically indistinguishable from the substance being monitored. Consequently, specific states of distribution and residues may be readily detected for control and investigation purposes by introducing such RI's as radioactive markers into textiles and application liquors of all types. Typical applications in the textile industry include, e.g.: the continuous control of dry or wet textiles in production processes, the monitoring of various finishing treatments, the distribution of synthetic resins on textile fabrics, the measurement and metering of dye concentrations in continuous dyeing processes, liquor circulation control, monitoring of dye migration in multicolour printing, determination of dye uptake capacity, quantities of finishes, coatings and print pastes applied to textiles, soil removal, detergent absorption, measurement and control of film thickness (fibres, yarns, slivers, foils, etc.), as well as to control the fill height in non-transparent containers, and control the extent of wear in bearings, etc. The most important RI in organic chemistry used up to now for textile applications is ^{14}C followed by ^{60}Co and ^{90}Sr, etc. Despite the well-known long-term damage to health caused by large doses of radiation, there is no direct danger to operatives using this type of equipment due to the very small amounts of radioactive isotope indicators employed, provided the substances are handled correctly. With the more penetrating gamma radiation, however, adequate precautions are essential.

Isotope radiation (isotope radiation emitters). The → Isotopes considered here include strontium 90, krypton 85 and promethium 147 which emit radiation of different intensities. When particles emitted by a radioactive isotope penetrate a material, the emission is attenuated in proportion to the mass of the substance. To determine the weight per unit area of textile webs by means of radioactive radiation, therefore, alternative isotopes are available to cover all ranges of weights encountered in the textile and allied industries. Krypton 85 is particularly suitable for all textile applications and is also the least problematic radioactive substance.

Isotropic (Gk.: *isos* = equal, *tropos* = direction). Having uniform physical properties in all directions in contrast to → anisotropic.

Isparta carpets Most of the carpets known by the name Isparta, or Sparta, have been woven at Smyrna (Izmir) in Turkey. The Persian knot is used. Sparta carpets are among the best from this particular area of Turkey. The decoration and techniques employed in Sparta carpets are very like those of the rough → Tabriz carpets, but they can be distinguished from the latter by the different feel of the fabric, i.e. they are more limp. The wool of the pile is somewhat lacking in lustre and the colours are usually pale, with ivory predominating in the ground and pink and light blue in the decoration.

ISTCL, abbrev. for: International Scientific and Technical Committee on Laundering. Secretariat: Krefeld, c/o wfk; → Technical and professional organizations.

Istle fibre → Ixtle fibre.

ITA (Sp.), abbrev. for: Instituto Textil Argentino, Buenos Aires, Argentina (Argentinian Textile Research Institute); → Technical and professional organizations.

Italian cloth Smooth, highly lustrous lining fabric (cotton, or cotton warp and worsted weft = half-wool Italian cloth) in satin weave.

ITC → International Textile Club.

ITCRA, abbrev. for: International Textile Care and Rental Association, U.K.; → Technical and professional organizations.

-ite A suffix used in chemistry to indicate an intermediate oxidation state of a metallic salt, analogous to -ous for the parent acid, e.g. sodium sulphite (Na_2SO_3), a salt of sulphurous acid, which contains one less oxygen atom than the sulphate (Na_2SO_4), i.e. a salt of sulphuric acid. → -ate.

ITF (Fr.), abbrev. for: Institut Textile de France (French Textile Research Institute); → Technical and professional organizations.

ItM (Ger.), abbrev. for: Institut für textile Meßtechnik, Mönchengladbach, Germany (German Institute for Textile Measuring Technology); → Technical and professional organizations.

ITMA (Ger.), abbrev. for: Internationale Textilmaschinen-Ausstellung (International Textile Machinery Exhibition). The largest and most important European exhibition of textile machinery held every 4 years at a different venue. Organized by: → CEMATEX.

ITMF, abbrev. for: International Textile Manufacturers' Federation, Headquarters: Zürich, Switzerland. Founded in 1978 as the successor to the IF-CATI. Umbrella organization of 32 textile associations in 38 countries on all continents; → Technical and professional organizations.

ITS → International Textile Service.

IUPAC, abbrev. for: International Union of Pure and Applied Chemistry. A voluntary non-profit association of national organizations representing chemists in 45 member countries. It was founded in 1919 for the standardization of nomenclature and coordination. Its headquarters are in Basle, Switzerland.

IUT (Fr.), abbrev. for: Institut Universitaire de Technologie de Lille (Technical Institute of the University of Lille), integrated with CREST; → Technical and professional organizations.

IVC (Ger.), abbrev. for: Industrie-Vereinigung Chemiefaser, Frankfurt, Germany (German Industrial Man-Made Fibres Association); → Technical and professional organizations.

IW dyeing method A method for dyeing those vat dyes (IW dyes) which have the maximum affinity for cotton at 40–50°C. → Vat dyeing.

IWS, abbrev. for: → International Wool Secretariat. → Technical and professional organizations.

IWS cold-dwell printing process for wool A printing process for the production of fast and brilliant shades on wool with reactive dyes of high reactivity which are stable to sodium bisulphite. The print pastes contain approx. 300 g/kg urea and 0–20 g/kg sodium bisulphite depending on the dye concentration. After printing, the fabric is allowed to stand in the wet state for approx. 24 h. Shorter dwell times are sufficient on chlorinated or Hercosett-treated wool. Finally, the goods are washed in dilute ammonia liquor.

IWS finish A process for the setting of wool fabrics. The fabric is moistened with Si-Ro-Set solution (MEAC/MEAS) by padding and squeezing. The fabric is permanently set by wet steam or gloss decatizing in the still moist state for 3–5 min. Finally the fabric is dried without tension.

IWS flame-retardant finish for wool Wool is treated with potassium hexafluorozirconate (K_2ZrF_6) or potassium hexafluorotitanate (K_2TiF_6) from a long liquor at 60°C or also from short liquors in various combinations with dyeing processes and/or antifelting crease-resist finishes.

IWS Superwash process → Superwash.

IWTO, abbrev. for: → International Wool Textile Organization; → Technical and professional organizations.

IWV (Ger.), abbrev. for: Internationale Wollvereinigung (analagous to → IWTO); → Technical and professional organizations.

Ixtle fibre (istle fibre, Tampico fibre). A fibre obtained from various tropical Central American agave and yucca trees (also palm fibres). Ixtle fibre belongs to the group of → Hard fibres and is similar to → Sisal although not a hemp variety. The fibres, of variable length, are stiffer and coarser than sisal. Uses: cords, ropes, brushes, flat carpets and coarse fabrics.

J

J symbol for → Joule.

J-acid (2-amino-5-naphthol-7-sulphonic acid). Organic intermediate used in the manufacture of azo dyes.

Jacquard fabric Collective term for a figured fabric woven with a design produced by lifting individual warp threads. Finely drawn, large repeat designs of great variety are obtained by this method which cannot be reproduced by dobby weaving. Typical jacquard fabrics include: damask, brocade, matelassé, and tapestries.

Jacquard mechanism A shedding mechanism on a weaving machine which controls the lifting of the warp threads via a harness with healds. Lifting of the ends is controlled by a data carrier, e.g. a chain of punched cards or by a loop of punched paper. The warp threads are lifted individually corresponding to the required design (analogous to jacquard mechanisms on knitting machines). Whilst shed formation with heald shafts (→ Dobby mechanism) involves the lifting of several warp threads in large groups, the number of groups of combined warp threads in the jacquard mechanism is small; in extreme cases each jacquard lifting hook can be supplied with a single thread so that separate control of every single warp thread is possible, e.g. as required in tapestries, figured gobelin and carpet weaving. As a consequence, the warp and weft repeats are theoretically unlimited.

Jacquard technology Knitting and weaving technology for the production of large repeat designs in which each warp thread can be lifted or each loop-forming operation can be individually controlled via a → jacquard mechanism. Named after the inventor, Joseph Marie Jacquard (1752–1834). Compared to fabric printing and dobby weaving, jacquard weaving represents the most expensive method of producing large repeat designs on textiles since, for each design, the individual lifting of a number of warp threads corresponding to the size of the design must be predetermined for each weft insertion. The design paper which controls the jacquard mechanism must then be punched out. Jacquard warp-knit and jacquard jersey can be reverse-plated on one side and, in this case, the back side of the fabric contains linked loops without floats. Float-plated jacquard designs are lighter but not as elastic as jacquard designs produced with double threads in which the backward thread floats of float-plated fabrics are avoided and those threads which do not participate in the jacquard design are knitted into the material.

Jacquard wire weaving machine A weaving machine with a jacquard control mechanism for the production of multicoloured → Wire carpets, e.g. Wilton and → Brussels carpets.

Japan silk (Japanese silk). A fine slub-free natural silk fabric with a satin weave produced from absolutely uniform yarns reeled from mulberry silk (warp and weft: raw silk). Also a collective term for fine natural silk fabrics without slubs for apparel use and lampshades. Specific constructions include pongé, Habutai, Helvetia silk, and Ningai. Japanese silk fabrics are sold in specific widths and lengths for export (22,8 x 3,8 m). The quality is indicated by an official quality stamp on the piece ends: red = first quality, blue = second quality and black = reject quality. The fabric weight is given in Japanese momme units per square yard (1 momme = 3,75 g). The lightest Japanese silks weigh 3–4 momme units, which corresponds to 13–18 g/m^2.

Japan wax (Japan tallow, sumac wax). A vegetable fat obtained from the fruits of a species of sumac (not a real wax). Available commercially in the form of small convex cakes or rectangular blocks, light grey in the raw state or yellowish-white (bleached). Water content up to 20%. At 10°C it is still a brittle solid but softens when held in the hand. Japan wax has a mp of 45–55°C. Soluble in benzene and naphtha, insoluble in water and cold alcohol. Readily saponified. Combustible. Uses: for textile sizes, finishes, etc.

Jaspé

I. A ply-like yarn produced from 2 differently coloured rovings lightly twisted together.

II. A filament yarn produced from two intermingled or air-jet textured strands of different chemical composition and cross-dyed to achieve 2 different colours.

III. Jaspé mouliné: a French term for a ply yarn produced from 2 jaspé threads (cotton and viscose) having a fine flammé appearance.

jato (Ger.) abbrev. for: Jahres-Tonne (tons/annum).

Java jute → Kenaf.

Java print A type of → Africa print with a particularly wide appeal among the indigenous populations of many African countries. The term “Java print” originates from the printed fabrics formerly produced in Indonesia with very characteristic designs although, nowadays, a modern “Java print” may be based on practically any multicoloured design having no connection with Java. A Java print generally consists of lemon yellow and gold resists on a green, blue (mostly phthalocyanine), dark red or brown ground. Procedure: cotton fabric, prepared with a naphthol, is printed with a resist agent (together with reactive dyes for coloured resists). The formation of diazo compounds in those parts of the design printed with the resists is inactivated in subsequent development more quickly than coupling with the naphtholate can take place.

Javelle water → Eau de Javelle.

J-box A large upright J-shaped vessel (which serves as a storage chamber) used in the continuous processing of textile fabrics mainly in rope form (seldom open-width) to provide the necessary reaction time for goods impregnated with chemical solutions, e.g. desizing, scouring or bleaching liquors (see Fig.). The impregnated fabric is plaited into the top of the long arm of the box from where it slides down and around the bottom before being withdrawn from the short arm. Duration of treatment depends on the process and may exceed 1 hour in some cases. Steam is used to heat up the fabric to the reaction temperature, either prior to entry in a steaming channel (Du Pont system) or in the J-box entry zone itself (Becco bleach system). Special J-boxes are also used for the treatment of tricot fabrics and as cold dwell units for cotton fabrics wetted with caustic soda liquor to induce stretch. J-boxes are usually constructed of stainless steel although, GRP (glass reinforced plastic) has been successfully employed for cold treatments, e.g. bleaching with sodium hypochlorite.

Jeans Originally an American term (now international) derived from Gênes (cloth from Genoa). The term was coined in the USA to describe tight-fitting trousers made of cotton twill, usually woven with a dark blue dyed warp and undyed weft (→ Denim), stitched on seams and pockets and having copper rivets here and there. As a rule, blue jeans are dyed with indigo and thus have limited colour fastness to rubbing and washing. At the beginning of the 1970’s, a casual and unconventional style of clothing based on blue jeans emerged which, from a wide variety of materials (brush denim, chambray, bullcord, cord velvet, brushed cord) and corduroy, spread to other garments and accessories such as skirts, jackets, shoes and bags that became the prototype of modern leisurewear.

The dyeing and finishing of ready-made jeans articles has gained increasing prominence in recent years. Originally used exclusively for workwear, jeans have gained a position of ever-increasing importance in the clothing market due to improvements in wearing comfort and their adoption by the fashion market. Designers soon learned how to make this original workwear material attractive to an ever increasing number of customers through innovative modifications and styling. As a result, it is impossible to imagine today’s clothing market without jeans in one form or another, e.g. “stone washed”, “moon washed” “used look” or “rodeo washed”.

The various processes used to obtain these different effects are not generally known in every detail. Consequently, the following example recipes can only serve as a general guide and are certainly subject to wide variations in practice. As a processing unit the drum washing machine is mainly used to achieve these effects.

I. Stone washed: a) the ready-made garment pieces are turned inside out and prewashed or desized; b) they

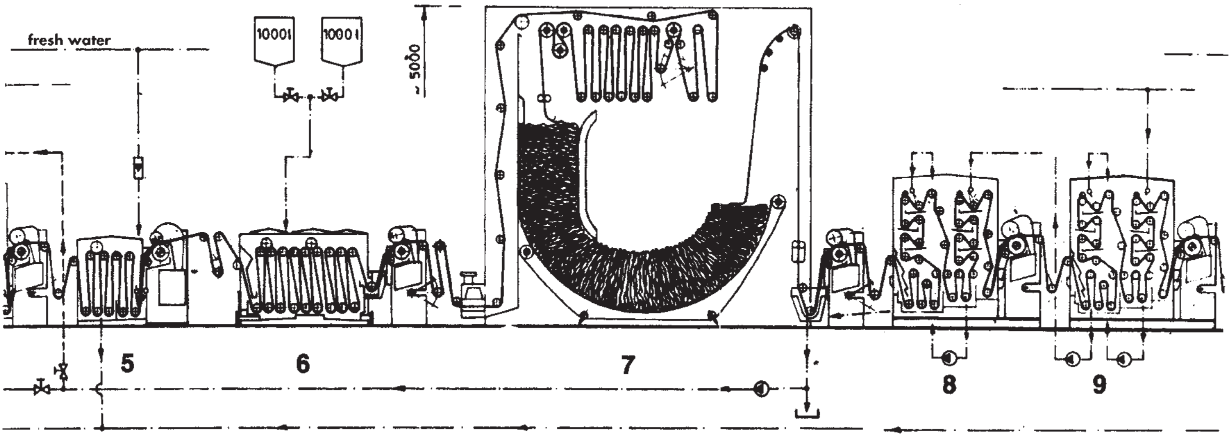


Fig.: Open-width bleaching stage with J-box (Küsters).
5 = roller vat with 10 m fabric content and high-efficiency squeezer with S-rolls for wet-on-wet pick-up; 6 = saturator compartment with 20 m fabric content for application of the bleaching agent; 7 = J-box with steaming zone in tight-strand passage, J-box storage section and pneumatic squeezer, nominal capacity: 600 kg/m fabric width; 8–9 = high-efficiency open-width washing machine meander type, fabric content 20 m per unit with pneumatic squeeze rolls.

are then taken out of the washing machine, turned face side out again and washed with chalky sandstone at a ratio of 1 : 3 (1 kg of garments: 3 kg stones; c) the garments are taken out of the machine, the stones removed, and bleaching is carried out with sodium hypochlorite (according to the desired shade). To minimise fibre damage, an alternative milder treatment can be given as follows:

1st bath: enzymatic desize followed by an intermediate rinse.
2nd bath: chemical stone wash treatment with enzymes followed by 2–3 rinses.
3rd bath: application of softener.

II. Snow washed: a) stones are soaked for 12 h in a solution of potassium permanganate; b) the wet stones are then hydro-extracted for 30–50 s in a centrifuge; c) the hydro extracted stones and garments are loaded into the washing machine for a cold treatment of 15–30 min; d) the stones are removed; e) the brown stains from the permanganate are washed off the garments with sulphurous acid followed by neutralization; f) a final application of softener is given. To minimise fibre damage, an alternative milder treatment can be given as follows:

1st bath: enzymatic desize followed by an intermediate rinse.
2nd bath: chemical stone wash followed by 2–3 rinses.
3rd bath: bleaching.
4th bath: application of softener.

Jelling machine → Gelling machine.

Jelly →: Gel; Colloid.

Jersey Originally the description for a milled wool fabric produced on the British island of Jersey, in the Channel Islands, and used for fishermen’s clothing. This fabric was produced on circular or supreme machines with a backing device. The elasticity of this knitted material was greatly reduced by the milling process so that it was also suitable for use in outerwear such as women’s jackets, dresses and quality goods. The single weft-knitted fabrics which alone qualify, on technical grounds, for the description “jersey” are nowadays often referred to as “single jersey” and the term is in no way limited to wool fabrics. Similar fabrics are thus produced on circular knitting machines (with and without a wevenit mechanism) in a variety of constructions. These knitted products, which have two face sides (double-knit) are described in the trade as “double jersey”. Textured crimp yarns produced from man-made fibres are mainly used for these fabrics. Today, even other materials produced on automatic circular knit, warp-knit and raschel machines in weave-knit constructions for women’s and mens’ outerwear garments are falsely described in the trade as jersey. Moreover, a “woven jersey” is produced from core-spun ply yarns as a matt, high quality, crêpe dress fabric with a surface similar to a knitted fabric. In summary, jersey is a collective term (generic name) for a range of outerwear fabrics (chiefly knitgoods) produced from a wide variety of yarns and production methods without any exact demarcation. Jersey articles are frequently encountered in the market with additional names such as, e.g. fine jersey, jean jersey, ripple jersey and silk jersey (produced from bright polyester yarns) having a completely different optical appearance.

Jersey finish on wool A milling treatment to reduce elasticity or stretch in order to make the fabric more suitable for e.g. outerwear.

JES abbrev. for: Japanese Export Standard.

Jet air circulation driers The most widely used driers of this type are stenter driers in which air flow is achieved by means of radial or axial fans via air ducts with round, oval or slit jets. The air is directed perpendicularly to both sides of the textile material (also tangentially in the case of swivelling jet nozzles) which is then deflected sideways and conducted back to the fans via heaters together with a controlled supply of fresh air. Since the textile material is supported on pins or clips along each edge, the width can be controlled within specific limits although this is not possible with the similarly constructed jet belt drier. In the latter type of drier, the material is transported on a conveyor belt (e.g. steel or textile fabric) through the drying chamber with separate air flows from above and below. In order to overcome the disadvantages of both systems in the finishing of sensitive knitgoods conveyor stenters, which represent a combination of stenter and belt drier, are now available. Further developments designed to eliminate damaging fabric tensions by a carrier effect with appropriately constructed jet nozzle systems and air flows include, e.g. swivelling jets, horizontal jets, carrier jets, air cushion stenters or driers, etc. which generally employ reduced rates of air flow.

Jet driers (steam jet driers). The principle on which these machines are based involves directing jets of a superheated steam/air mixture with a high steam content to both sides of the textile fabric without the introduction of fresh air. The high flow rate of the steam/air mixture generated in the jet nozzles by relaxation of pressure gives a high heat transfer and results in short drying times in the region of 10–20 s for normal fabrics of approx. 150 g/m^2. The high temperature of the drying medium (130–170°C) allows the application of a high proportion of superheated steam which is constantly drawn off with the water evaporated from the fabric. This steam/air mixture flows through suction channels over heating elements and is kept in circulation by fans via the heating elements, jets and the fabric. The steam atmosphere provides a high degree of protection against fabric damage since superheated steam largely displaces the air from the drier so that even low levels of residual atmospheric oxygen can no longer cause oxidative damage to the fabric. Provided they are used correctly, modern high-efficiency steam jet driers do not result in overdrying or other qualitative disadvantages in comparison to normal drying. Even with the heaviest wool materials no damaging influences are to be expected by rapid drying in superheated steam at 145°C – on the contrary improvements in handle are achieved. The use of jet driers in the finishing of fabrics with synthetic resins is generally superior to the older drying systems as far as uniformity of drying is concerned. In addition, they also offer the advantage of considerably shorter curing times and the risk of synthetic resin migration to the surface of the fabric is less.

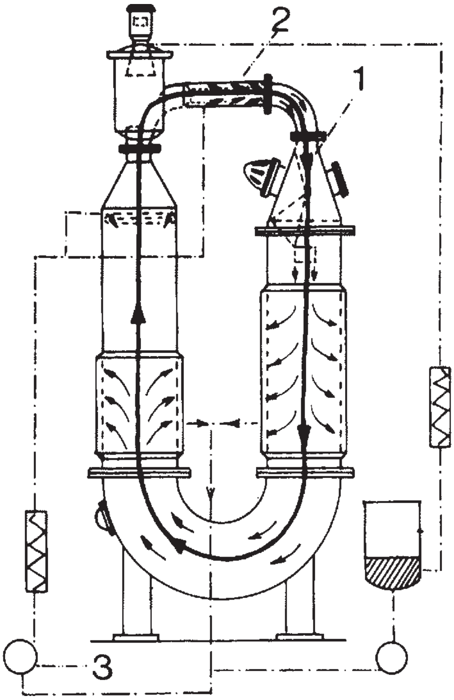


Fig. 2: Thies Jet Stream vertical fully-flooded machine (Jumbo Jet).
1 = fabric path; 2 = jet; 3 = pump.

Jet dyeing, development of The development of the jet dyeing machine closely parallels the introduction of synthetic fibre textiles to the fashion market. Although the so-called "Nyltest" shirting fabrics produced from polyamide warp-knits at the end of the 1950's were still being dyed in beam dyeing machines, the appearance of polyester circular-knits compelled machine makers to design a completely new type of dyeing machine. In dyeing this material, which first had to be slit into open-width and scoured, the loftiness (bulk) of the knitted fabric in particular had to be developed before the state of the material was heat set during the dyeing operation. The search for suitable dyeing methods culminated in the development of the → Jet dyeing machine. In these machines the fabric rope was not transported by a winch as in the HT winch dyeing machine, but by the dye liquor according to the jet principle via guiding and deflecting rollers or simply by a jet through a tube. Depending on the type of machine, the high fabric speeds of 120–160 m/min and the turbulence surrounding the fabric rope ensure a good shifting and opening of the rope so that the need for prior heat-setting is eliminated. Depending on requirements, fabric speed and lengthwise tension can be adjusted by regulating the liquor flow. Loading a jet dyeing machine with a relatively long run of fabric, depending on its weight per m^2 and construction, can be accomplished in a considerably shorter time than is possible in e.g. a HT-winch due to the higher fabric speed. For fabrics that do not require pre-setting, dyeing can be carried out by loading the fully-flooded horizontal (Fig. 1) or vertical (Fig. 2) jet dyeing machine with grey fabric and dyeing without a separate pre-scour. Occasionally, a short pre-scour is also given in the jet machine. The greatest problem with partially-flooded machines (Fig. 3) is foaming due mainly to the intense liquor movement. When foam development becomes excessive, constant fabric transport is no longer guaranteed and machine stoppages may even result. Although the addition of de-

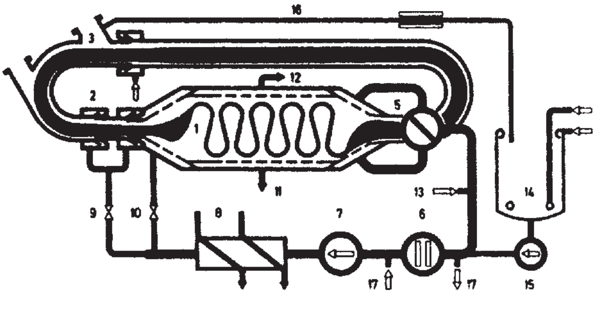


Fig. 1: Thenjet fully-flooded horizontal jet dyeing machine (Then).
1 = fabric rope; 2 = drive (venturi jet principle);
3 = fabric entry; 7 = dye liquor pump; 8 = heat exchanger;
11 = liquor discharge to drain; 13 = rinse water feed;
14 = preparation and expansion tank with water supply.

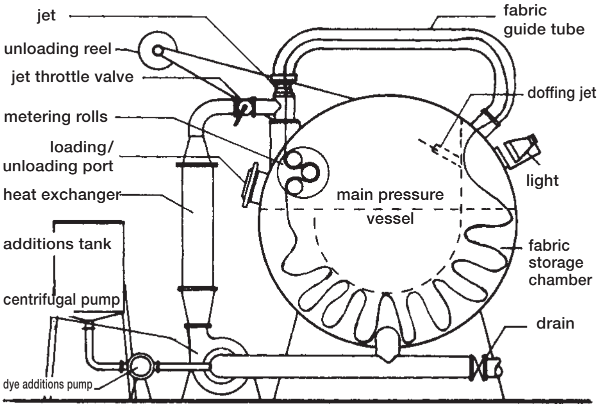


Fig. 3: Partially-flooded jet dyeing machine.

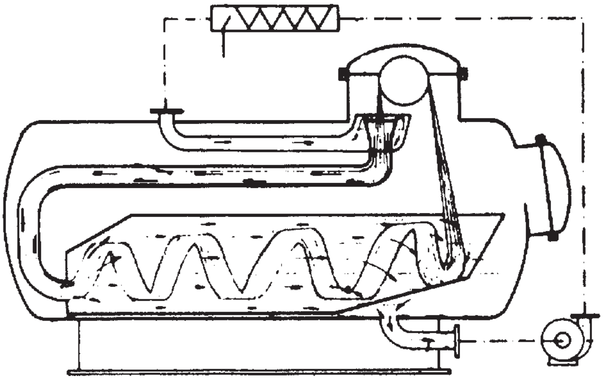


Fig. 4: Liloc overflow type HT dyeing machine (Jagri).

foamers is indeed helpful in such cases these products only serve to create other problems (e.g. waste water pollution).

Defoamers are not stable throughout the entire dyeing process and may lead to the formation of stains which can only be removed with great difficulty. Fully-flooded machines, on the other hand, represent the optimum solution for dyeing textured polyester materials under HT conditions. However, if the material being dyed contains certain blend yarns, e.g. polyester combined with cellulosic or animal fibres, fibre abrasion due to high turbulence and high running speeds can cause problems. For such materials, machines which operate on the overflow principle (Fig. 4) are regarded as more ideal (→ Overflow dyeing machines). In these machines the material to be dyed receives a much more gentle treatment due to the lower fabric transport and liquor speeds so that fibre abrasion and associated weight losses are not as great a problem as when dyeing is carried out strictly according to the jet principle.

The drive and deflecting reel in the dome (or in later machines also in the chamber) is typical for overflow rope-dyeing machines as well as later examples of jet dyeing machines. Fig. 5 illustrates the small non-driven deflecting roll in a Hisaka jet for fabric transport from above to below.

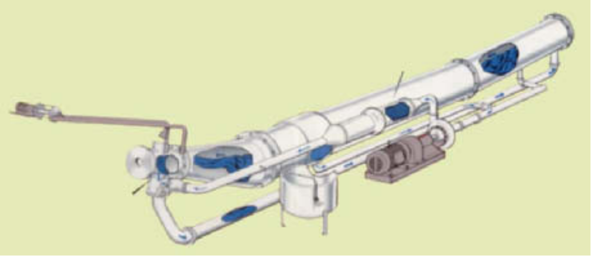


Fig. 5: Hisaka Circular Cut jet dyeing machine.

The "Fluido-Jet" was developed specifically for the rope dyeing of 100% silk fabrics (Fig. 6).

It is the result of a series of trials for dyeing all types of fabrics likely to suffer damage through contact with mechanical transport devices. The fabric rope moves horizontally in the open state without tangling. In the front part of the machine, the fabric rope is deflected by a guide bar immersed in the liquor thereby avoiding direct contact between fabric and metal bar. In the rear

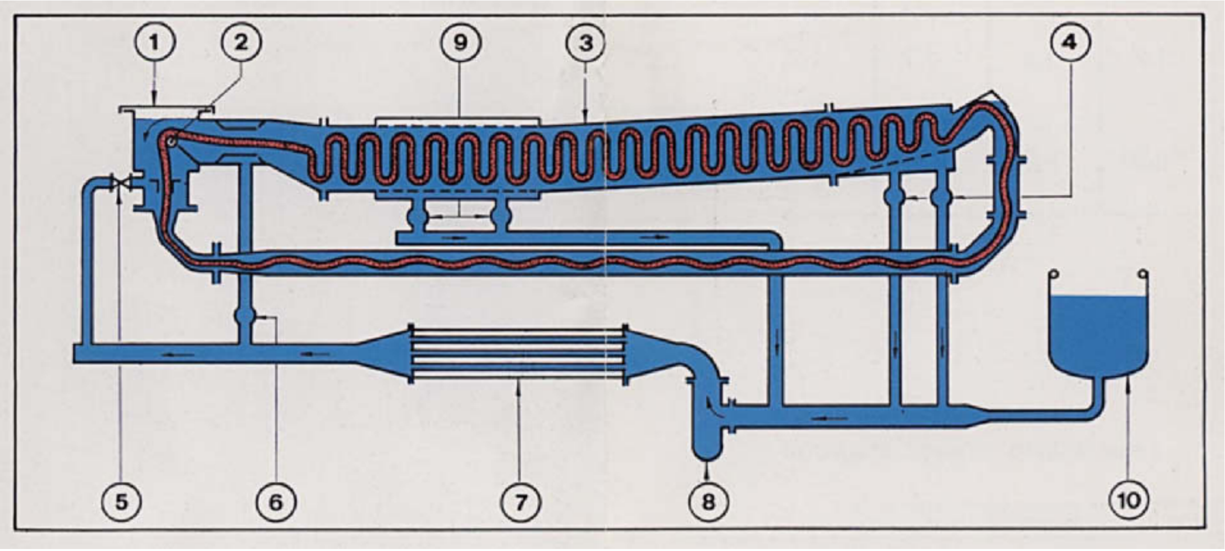


Fig. 6: Mezzera Fluido jet machine for the dyeing of silk fabrics.
1 = loading/unloading port; 2 = path deflecting bar; 3 = dyeing tube, 4 = regulating valve; 5 = jet pressure regulation; 6 = control valve; 7 = heat exchanger; 8 = liquor circulation pump; 9 = control valve; 10 = preparation tank for dyes and auxiliaries.

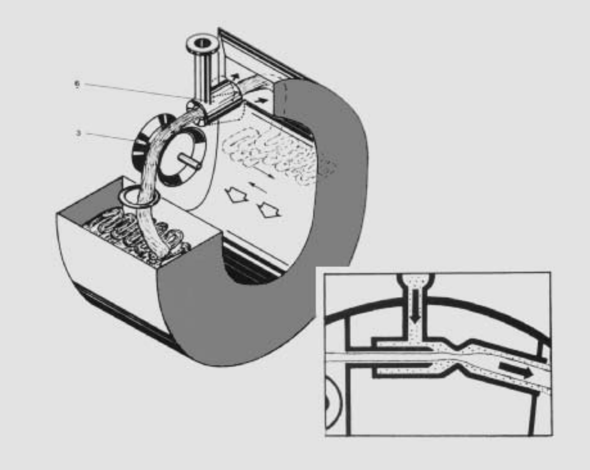


Fig. 7: Horizontal Jet Stream unit with driven winch in the Santana jet dyeing machine (Brückner).

section of the machine, the fabric is guided into the cylindrical dyeing tube via a specially shaped slide. The rinsing device and following channel have a special shape and location in order to prevent the extremely harmful twisting of the fabric rope.

The liquor ratio (10 : 1 to 15 : 1) and circulation speed (100–150 m/min) are particularly favourable for the type of fabric being treated. The average dyeing time and energy requirements (water and steam) have been reduced to about half that required in conventional machines. If required, a special parallel jet suitable for heavy fabrics can be supplied.

All models of jet dyeing machines can be used to dye two different batches of fabric or a single batch in double quantity when coupled one to another. All machines are fitted with a special safety device which automatically stops the circulation pump and triggers an alarm if fabric transport is brought to a standstill for any reason. The Jet-Stream machine is available in horizontal (Fig. 7) or vertical (Fig. 8) execution. Jet dyeing machines with non-driven winches (Fig. 9) are also available.

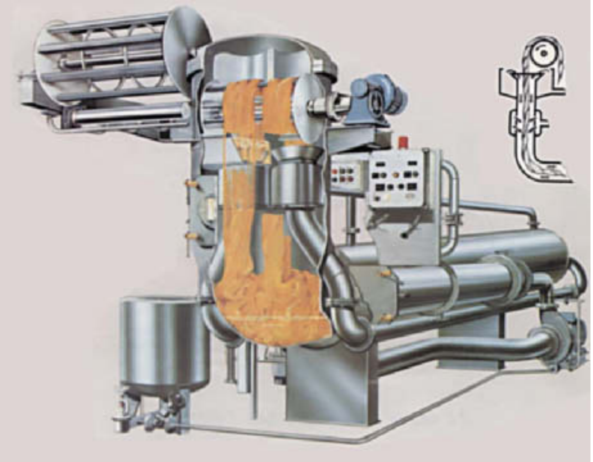


Fig. 8: Vertical Jet Stream unit with driven winch in the Rapidsuau jet (ATYC).

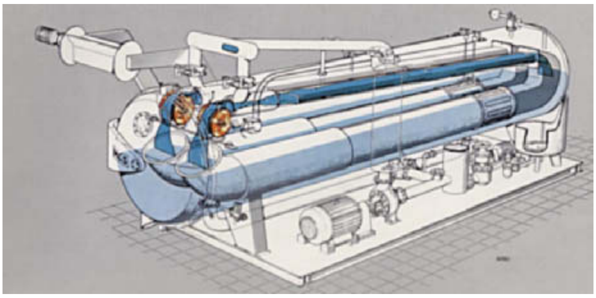


Fig. 9: Non-driven winch in the MCS Siluro jet.

The jet dyeing machine with a lower liquor level functions according to a two-phase principle, i.e. the jet is located in the gas phase above the liquor. When the liquor comes into contact with the rope of fabric in the jet, the air surrounding the rope is displaced without great loss of energy. Contact between liquor and rope is thus immediate and intense each time the rope passes through the jet. This is particularly important for the uniform distribution of dye, chemicals and temperature. There is no requirement to adapt the jet to suit different types of fabric. The same jet is used for lightweight as well as heavy materials, wovens, warp-knits or weft-knits. Rope speed is infinitely variable from 0 to more than 400 m/min. The choice of speed is determined by the dwell time; speed selection is thus dependent on the length of the fabric rope; a complete cycle should, as a rule, be less than 2 min or better still approx. 1 min.

Regulation of rope speed is achieved by means of the jet pressure and an infinitely variable driven reel. At these high speeds it is important for the rope to be well plaited after passing through the jet. For this purpose, the rope impinges on a baffle plate after leaving the jet so that the direction of movement is deflected and the rope opened out. The higher the speed the better the spread of the rope. Effective spreading of the rope has several advantages, e.g. lengthwise creases formed when the rope is drawn through the jet are smoothed out, and the fabric passes through the dwell chamber in an opened out state thereby preventing the formation of knots.

Rope transport:

a) Winch machine: the winch is driven in a clockwise direction (Fig. 10) and the rope has a much greater speed outside the dwell zone than within it. At the end of the dwell zone the rope, which is in a more or less uniform plaited condition, is then quite suddenly accelerated to the higher running speed. Inertial forces thus develop in this region which act on the fabric rope. In addition to these inertial forces, the static forces of the rope weight plus the weight of the liquor, before and after the winch, must also be added. These are designated as G_2 and G_1. According to Eytelwein, the following relationship exists between the forces acting on the rope at the winch:

$$P_2 \leq P_1 \cdot e^{\mu\alpha}$$

μ = coefficient of friction between rope and winch reel,
α = angle of wrap.

If,

$$P_2 = P_1 \cdot e^{\mu\alpha}$$

then P_2 is the max. rope force which, at given values of μ and α, can be transmitted without rope slippage on the winch reel.

However, if

$$P_2 < P_1 \cdot e^{\mu\alpha}$$

this means that the total angle of wrap available a is not necessary for the transfer of force but a smaller angle. This angle is called the transmission angle and may be assigned the symbol β; the following relationship is then obtained:

$$P_2 = P_1 \cdot e^{\mu\beta}$$

In the following considerations, it has been assumed that $\beta = \alpha$ and the max. rope force is

$$P_2 = P_1 \,.\, e^{\mu\alpha}$$

If the force

$$P_1 = G_1 = 0$$

then $P_2 = 0$, and rope slippage on the winch reel likewise occurs.

From equations (2) and (3) (Fig. 10a), it is apparent that undue stretching of the rope can be caused not only by a long length of free rope between the surface of the liquor and the winch reel, but also very probably by inertial forces acting on the rope at the end of the dwell zone.

b) Equation (1) under a) is also valid for the jet dyeing machine. The reel before the jet is not driven. Rope transport is effected by impulse exchange forces between the liquor and the rope. Equation (2b) expresses the same effect as (2a).

c) Softflow dyeing machine: as shown in Fig. 10 rope transport is achieved by a combination of the transport mechanisms described in a) and b). It is apparent from Fig. 10 that the risk of rope slippage on the winch reel is virtually eliminated by the force of the jet P_1 (equation 1). The action of the liquor impulse from the jet on the fabric rope is dependent on the nature of the fabric itself (open-structure fabric of low density or compact fabric of higher density). With denser fabrics, the liquor cannot penetrate the rope completely and runs off after a relatively short contact time. From the geometrical difference between the developing and dissipating impulse forces, a small force P results which moves the rope largely through surface forces acting on a relative small volume of the rope which can thus damage the material (the force per unit volume is great). In the case of fabrics with an open structure, the stream of liquor can penetrate the rope much more easily, the exit area of the liquor from the rope is greater, and the associated exit rate v2 is smaller which results in a greater impulse force P. However, this force acts on a larger rope volume and the force per unit volume is therefore lower which has the effect of transporting the fabric more gently. By installing a tube beneath the ring jet, the rope is penetrated more completely by the liquor, the exit rate v2 is even smaller as a consequence and the resulting impulse force is greater with a relatively small impulse force density giving a more "gentle" rope transport although a large transporting force is acting on the rope. The length of this tube installed beneath the jet is limited by the possibility of obstruction.

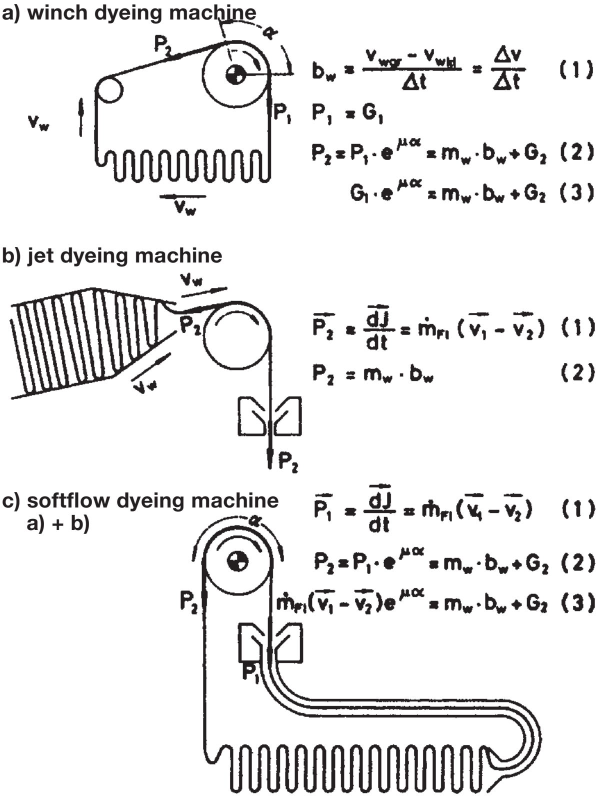
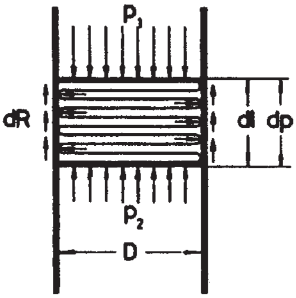


Fig. 10: Rope transport systems in the acceleration zone. m_w = mass of rope to be accelerated, b_w = rope acceleration, G_1 resp. G_2 = weight components of rope plus liquor, m_{Fl} = quantity of liquor entering/leaving the rope per unit time, v_1 resp. v_2 = flow rates of the liquor on entry/exit.

If a more “gentle” rope transport is required, which calls for a low impulse force density, then in order to avoid obstruction in the tube, the latter must have a greater diameter than the rope. The liquor is then able to penetrate the rope completely and also shift between the rope and the inner wall of the tube. The risk of obstructing this tube thus becomes much lower. The combination of a jet with an adjoining long tube is used in the soft-flow jet and is characterized by an extremely gentle rope transport. If, however, the ring jet is fed with a higher quantity of liquor the impulse force increases and less sensitive fabrics can be processed in a similar manner to a normal jet machine. The soft-flow machine described here can therefore be operated as a “soft-flow” or “less soft-flow” machine according to requirements. Because of this advantage, the machine is more universal in application than the other dyeing machines.



$$dp = p_1 - p_2$$

$$dP = dR$$

$$F = \frac{D^2}{4} \cdot \pi$$

$$dP = dp \cdot F = dp \cdot \frac{D^2}{4} \cdot \pi$$

$$dR = p \cdot D \cdot \pi \cdot k \cdot \mu \cdot dl$$

$$-dp \cdot \frac{D^2}{4} \cdot \pi = p \cdot D \cdot \pi \cdot k \cdot \mu \cdot dl$$

$$-\int_{p_1}^{p_2} \frac{dp}{p} = \frac{4 \cdot k \cdot \mu}{D} \int^{2} dl$$

$$\ln \frac{p_1}{p_2} = \frac{4 \cdot k \cdot \mu \cdot l}{D}$$

$$\frac{p_1}{p_2} = e^{\frac{4 \cdot k \cdot \mu \cdot l}{D}} \quad \text{resp.} \quad \frac{p_2}{p_1} = \frac{1}{e^{\frac{4 \cdot k \cdot \mu \cdot l}{D}}}$$

Fig. 11: Rope transport in the dwell zone and derivation of equation for rope movement.

The rope is moved forward in the dwell zone by differences in pressure forces. Even this process can be described mathematically by a model based on simplified assumptions. In Fig. 11 a schematic representation of the longitudinal section of a dwell zone assumed to be circular with a diameter D is given. In this tube the rope lies in a more or less ordered plaited state. This “rope packet” lies against the inner walls of the tube and a stream of liquor passes through it from above to below. From the section cut through the tube of length dl shown in Fig. 11, the pressure difference due to the liquor flow $dp = p_1 - p_2$ acts on the rope. The pressures p_1 and p_2 compress the rope so that it lies against the inner wall of the tube and during its liquor movement at this point a frictional force dR is produced which is dependent, among other things, on the friction factor m between rope/tube. The factor k is intended to take the transverse spread of the rope packet due to its longitudinal compression into account. This is dependent on, e.g. the amount of fabric in the tube, the character of the fabric, and the plaited condition of the rope (channeling), etc. $k < 1$ means that the transverse spread of the rope packet in the tube is less influenced by the longitudinal compression and vice versa. As can be seen from the equation, an exponential relationship exists between the pressure ratio of the pressures acting at the beginning and end of the tube length l and the other parameters (contributed by Vernazza).

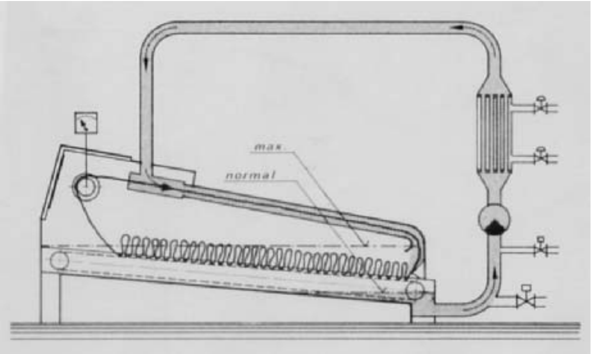


Fig. 12: Shorter liquor ratio by incorporation of a fabric support system in the form of a belt conveyor in the dwell chamber of the ESPA Miniflott-Jet (HT and atmospheric) of 100–2000 kg.

During the 1980’s, piece dyeing was given a new impetus by numerous new developments on the part of the machine maker. The liquor ratio, in particular, was considerably reduced by a variety of means (e.g. Fig. 12). Development led ultimately to the most modern derivatives of jet dyeing machines such as e.g. the Rotostream of Thies and the Then-Airflow machine.

The Rotostream dyeing machine is available in various executions with 1–6 storage chambers. Fabric transport is effected by means of a driven winch, a jet, and mechanically by rotation of the internal non-driven drum. Through modifications to the well-proven standard model, such as a lower position of the circulation pump, the heat exchanger and a shorter pipework system, a liquor ratio of 4 : 1 can be achieved. The fabric runs “dry” in a rotating storage chamber. Modification to the jet was also necessary in order to achieve adequate wetting of the fabric and secure fabric transport even with low volumes of liquor. A further advantage of this development is the elimination of time-consuming jet changes since, depending on the thickness of the rope, the jet nozzle itself adapts to the fabric. Speeds of up to 500 m/min are possible. Complete circulation of the liquor takes 2–6 min. In order to reduce mechanical stresses on the fabric surface, Thies have developed the Synchronized Dyeing System (SDS) in which the fabric flow, nozzle pressure and winch speed are synchronized. Cycle times during the individual phases of dyeing are variable. By this means, the times and dyeing phases critical for dyeing levelness are taken into account. The number of fabric cycles can be reduced by up to 60%. Programming of the control system is simple.

Compared to other jet dyeing machines, the most revolutionary development in fabric propulsion has been achieved in the Airflow. This system is based on an aerodynamic principle, i.e. fabric transport is not effected (as previously) by the dye or process liquor, but by a steam/air mixture. The product or dye preparations applied in this gas stream are finely distributed through several jet nozzles in a separate circulation and then sprayed or injected directly into the fabric. As a consequence, and depending on fabric quality, very low liquor ratios (2 : 1 to 4 : 1) with simultaneous high fabric speeds (up to 700 m/min) are achieved. In a 180 kg machine, complete turnover of the liquor takes approx. 8 min. The rate of turnover is 90 l/min. Programming is somewhat more complex since, for this machine system, the gas stream as well as the injection circuit must be programmed in relation to each other.

Savings in all liquor-dependent parameters such as steam, water and auxiliaries can be realized as a result of the liquor ratios achieved in short liquor jets, e.g. the quantities of salt can be reduced by more than 50 %. In conventional machines the costs of steam, water and electricity are approx. 0,40 DM/kg of fabric for a batch of polyester/viscose material. When the same batch is dyed in modern short liquor jets the costs lie between 0,075 and 0,10 DM/kg. Dyeings on synthetics result in small savings in dyes and a considerable reduction in dyeing times due to the quicker heating up and cooling down stages as well as the hot drop under HT conditions. On 100% cotton, a reduction of up to 10 % dye can be reckoned with although actual dyeing times cannot really be shortened.

Short-liquor jet dyeing systems have confronted the dyer with new problems: e.g. the distribution of dyes and auxiliaries on the fabric is only effected via the jet or the injection cycle since no dyebath, in the conventional sense, is available. The quantity of free liquor present in a single chamber machine (max. fabric capacity 180 kg) is approx. 200 l. Consequently, additions of dyes and fixation agents must be carefully metered. The distribution of dye and auxiliaries on the fabric is completed via a concentration migration process. This migration is dependent on a good capillary action which must be ensured by an optimum pretreatment. If the capillary effect is inadequate, i.e. the concentration gradient on the fibre cannot be balanced out, unlevel dyeings are inevitable.

Because of the waste water problems associated with dyeing, efforts have been made in the design of jet dyeing machines to achieve even shorter liquor ratios. Double rope systems are used for particularly lightweight knitgoods (see Figs. 13 and 14); special rope pilers for plaiting the fabric rope into the storage chamber are essential for running at low liquor ratios (see Figs. 15 and 16).

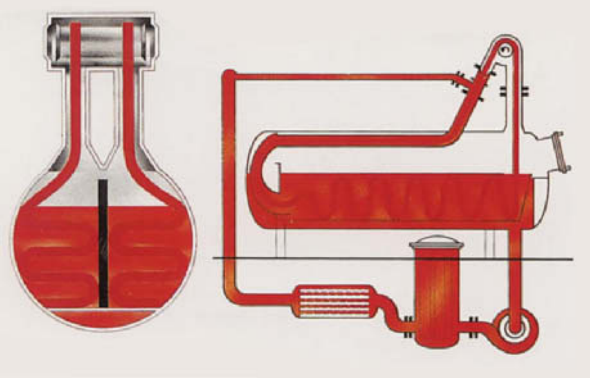


Fig. 13: Thies Soft-Stream with double rope.

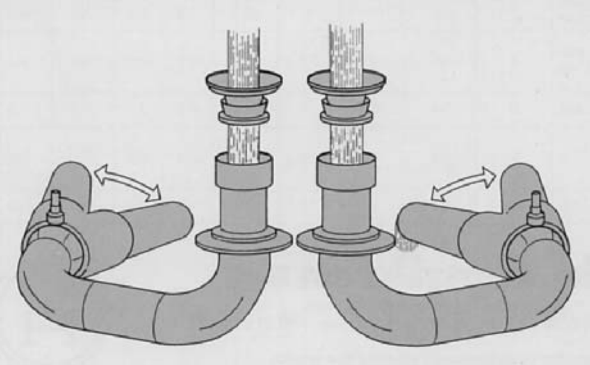


Fig. 14: Henriksen double rope system.

Taking the Colorstar jet dyeing system as an example, the great versatility of jet dyeing can be demonstrated (Fig. 17). The nominal capacity of the Colorstar machine is 180–200 kg per standard chamber. The capacity of approx. 180 kg is based on 100% cotton knit-

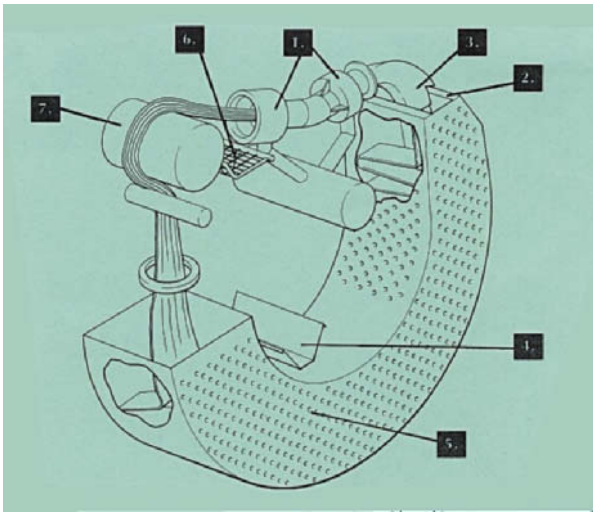


Fig. 15: Deposition tube in fabric container (Sclavos).
1 = jet system; 2 = bypass; 3 = deposition tube; 4 = rinsing trough; 5 = J-box; 6 = fabric speed regulation; 7 = winch.

goods and is approx. 200 kg for woven 100% cotton fabrics. On this basis, the smallest machine with only 2 chambers has a capacity to treat 360–400 kg of 100% cotton fabrics and the largest machine built up to now with 12 chambers can process 2160–2400 kg. For certain qualities, e.g. wool and wool blend woven fabrics or synthetic warp-knits, etc., the capacity is approx. 250 kg/standard chamber which thus corresponds to a capacity of 3000 kg for the largest machine with 12 storage chambers. For heavy, voluminous articles, larger storage chambers of even greater capacity may also be considered which have a positive influence on the price/performance ratio, liquor ratio and floor space requirements. For lightweight qualities, or articles for which shorter cycle times are desirable, even smaller

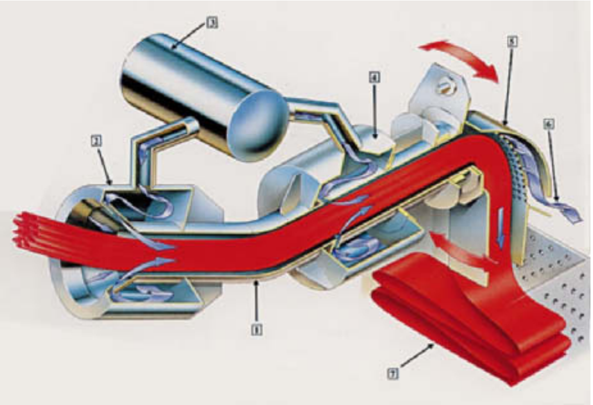


Fig. 16: Sclavos jet system.
1 = liquor/fabric guide tube as exchange zone;
3 = liquor distributor; 2 and 4 = jets; 5 = plaiter; 6 = bypass;
7 = plaited fabric.

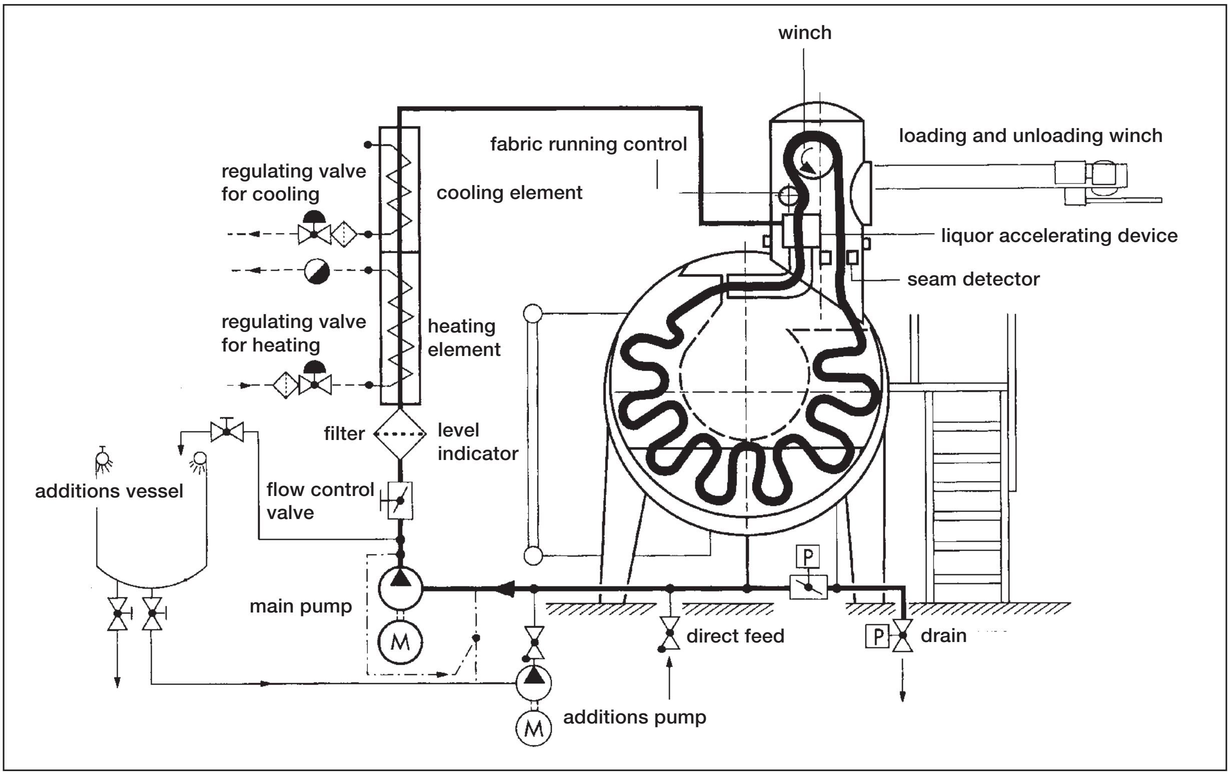


Fig. 17: Colorstar jet dyeing machine (Scholl).

chambers of lower capacity can also be used. Articles such as cotton interlock or single jersey are dyed at a liquor ratio of 5 : 1, woven fabrics containing a proportion of synthetic fibres at 4 : 1, and woven fabrics made entirely of synthetic fibres at 3 : 1. It is also possible to dye at higher liquor ratios on the Colorstar if necessary or desired.

Jet dyeing machines In a jet dyeing machine an endless rope of textile fabric, sewn end to end, is transported in a constant direction with the dye liquor in a narrow tube or chamber at temperatures up to approx. 142°C under pressure. Depending on machine design, the tube system is subdivided into a flow-through section and a dwell compartment (Fig. 1); several jet dyeing machines may be coupled together for high production. Liquor ratios from 5 : 1 to 10 : 1 are usual depending on fabric quality and type of machine. Considerable savings in time, dyes, textile auxiliaries and, above all, water, are achieved in jet dyeing machines. For crease-sensitive fabrics specially designed machines are also available.

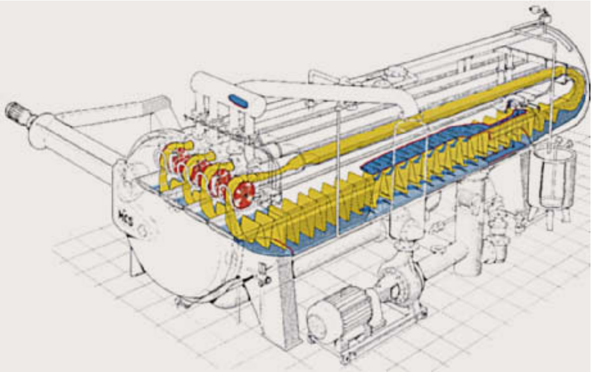


Fig. 1: MCS Siluro jet.

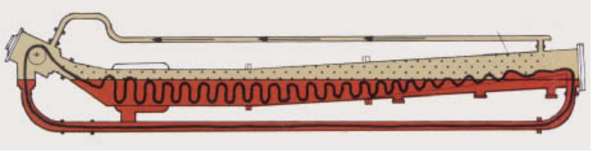


Fig. 2: Partially-flooded jet dyeing machine (Hisaka Jet) with separate circulation for air (above) and liquor (below).

Classification of jet dyeing machines according to functional principle:

1. Partially-flooded without transport jet.
2. With overflow principle.
3. With jet above the liquor surface.
4. With jet below the liquor surface (Fig. 2).
5. Fully-flooded with venturi jet.

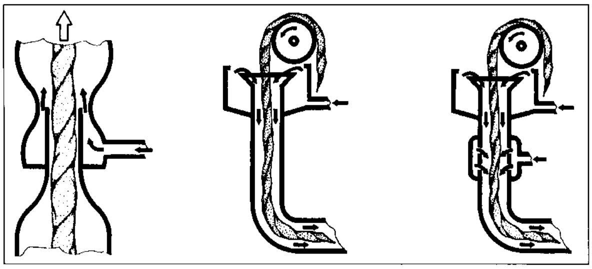


Fig. 3: Classic jet, overflow ATYC and Jet-Overflow "Rapidsuau" ATYC.

With the emergence of robust polyester knitgoods in the 1960's, fully-flooded jet dyeing machines were developed in which fabric transport was effected by means of a rapidly flowing liquor in the liquor exchange zone based on the venturi principle (Fig. 3). The trend in textile fabric development, however, has moved, and is moving, in the direction of lighter qualities which already contain "more air than fibres". Parallel to this development, greater consideration has been given to economic and ecological factors. Attempts have therefore been made to reduce the liquor-to-goods ratio so that savings could be realised not only in steam but water as well. Short liquor ratios also meant a reduction in the g/l of chemical and auxiliary additions which has been beneficial in terms of reduced waste water pollution.

From these considerations the first kier type machines with round storage chambers were developed. Due to the more stable flow of fabric, these machines offered advantages for very lightweight fabric qualities. Since the introduction of jet dyeing machines the advantages and disadvantages of jet or overflow systems have been the subject of continual discussion. The fundamental differences between the two systems are illustrated in Fig. 4.

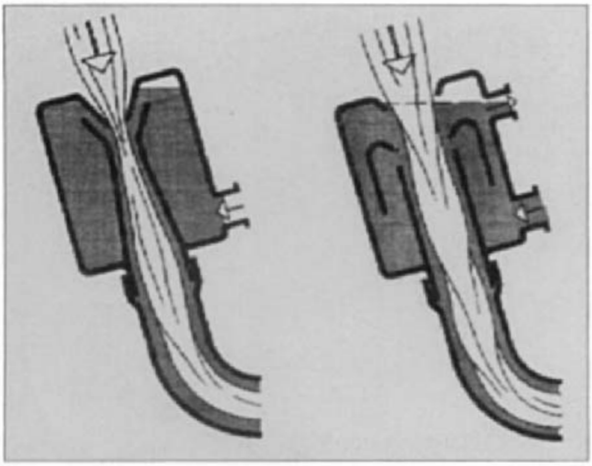


Fig. 4: Comparison between jet and overflow principle.

Jet dyeing machines

The initial development of jet dyeing machines began with pure jet systems derived from the so-called venturi jet. Here, the liquor passes through an orifice in the jet where it serves both to propel and shift the rope of fabric (Fig. 5).The effective force may be changed by the volume of liquor, the diameter of the jet and the jet orifice itself. This arrangement allows a relatively high fabric speed to be achieved. The German firm of Then has introduced a rectangular jet in the "Thenflow" machine (Fig. 6) which is claimed to offer the gentlest possible fabric treatment and allow a very wide range of fabric qualities to be dyed under gentle conditions without the need to change jet sizes.

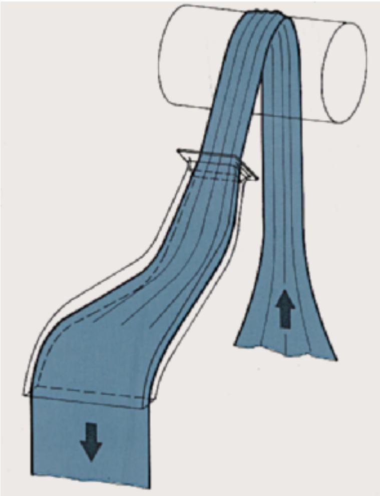


Fig. 5: Situation in the winch/jet region.

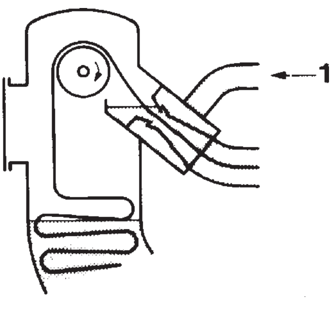


Fig. 6: Principle of the Thenflow.

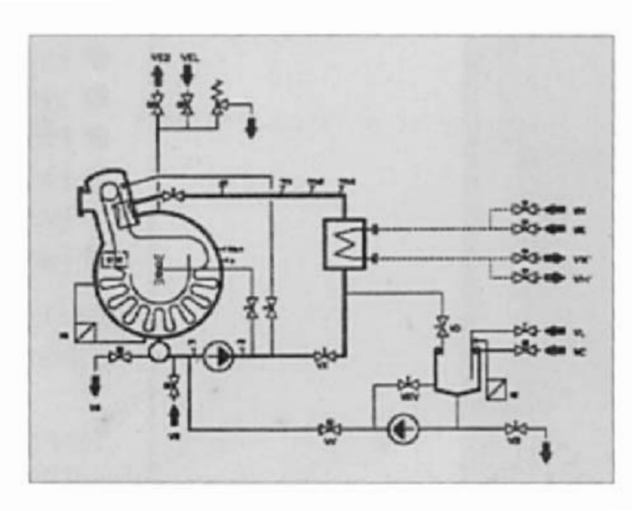


Fig. 7: Then Uniflow.

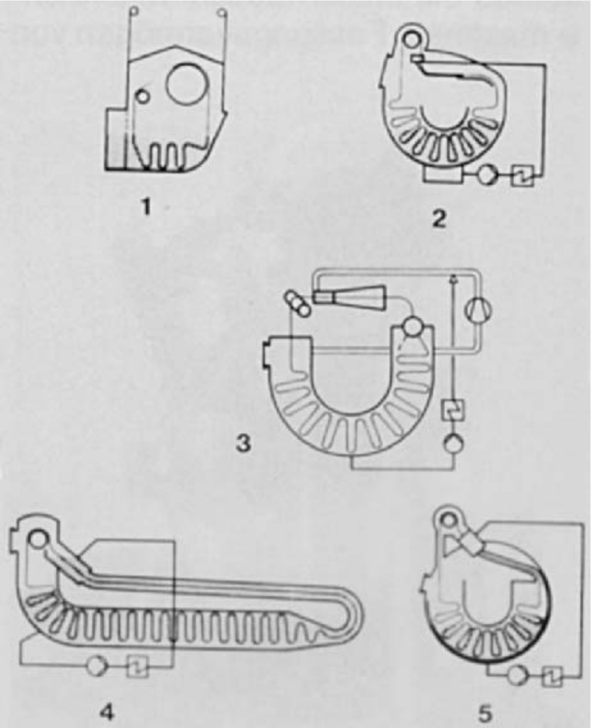


Fig. 8: Then piece dyeing machines.
1 = winch (liquor ratio 18 : 1); 2 = winch KFA (LR 10 : 1); 3 = Then Airflow HT (LR 2 : 1 to 4 : 1); 4 = Thenflow HT (LR 12 : 1); 5 = Economy Flow HT (LR 8 : 1).

The overflow system, in which the fabric rope is propelled by the liquor in an overflow condition, i.e. without dynamic pressure and dependent only on the height of fall, naturally provides the most gentle treatment as far as the fabric surface is concerned. High fabric speeds cannot be achieved because of the low dynamic force. However, the jet or overflow system is not solely responsible for the surface condition of the fabric. Other factors also play a part here such as the quality of the fabric itself. Moreover, factors such as fabric deposition in the storage chamber, fabric take up and friction on the reel, etc. all have a significant effect on the surface of the fabric.

The alternative to using either the jet or overflow system by means of a rapid change device has been realised in the "Uniflow" machine by Then (Fig. 7). Circulation of the fabric rope in the “Thenflow” is assisted by a driven reel. Fabric transport is effected by the liquor flow within the liquor exchange zone of the jet. The two jet dyeing machines “Thenflow” and “Economy Flow” differ in the form and arrangement of the fabric storage chamber, e.g. the “Thenflow” with a flooded horizontal storage chamber is more universal in application than the “Economy Flow” with a round storage chamber. In the latter, the fabric rope is transported above the liquor level to the side of the machine containing the reel and can therefore be used with a short liquor ratio at high fabric speeds as well.

The Then-Airflow (Fig. 8) has the shortest liquor ratio and requires no partial flooding of the storage chamber nor even a liquor sump due to the use of hot air as a fabric propulsion medium. Liquor ratios in this machine are determined by the nature of the fibre and the fabric construction and lie within the range of 2 : 1 to 4 : 1. The liquor ratio of 4 : 1 is only exceeded in the case of extremely heavy fabric qualities with high water retention (contributed by Quas).

Jet impingement Products and/or energy are applied via a carrier medium (water and/or air) to a textile fabric with the aid of jet nozzles. The action of thermal energy provides the necessary conditions for the activation of chemical reactions and/or the dynamic acceleration of physico-chemical processes in which the first part of the absorbed energy is mainly used to heat up the material. Since the reaction kinetics and diffusion processes are a function of the temperature, these processes only start to take place when the optimum temperature has been reached, i.e. the processes can only proceed to completion when the fibre and air or liquor have reached the treatment temperature. In practice, 2 important requirements must be observed in such processes:

1. The structure of the fabric must be uniformly penetrated.
2. Uniformity in the width and length must be constantly ensured.

In a jet application unit for liquors, products together with dynamic energy must be applied to a textile material simultaneously. Although the source of thermal energy can be selected at will, there are obvious advantages in choosing a suitable form of energy which is compatible with subsequent production processes. Steam is employed as a carrier of thermal energy in numerous textile finishing processes. The concept of an application unit with simultaneous action thus led to the idea of using mixing jet nozzles to spray a steam/chemical liquor mixture on to a textile fabric in a steam atmosphere (→ High wet pick-up). Although two-component mixing jet nozzles have been available for a long time, they were operated entirely with compressed air. An external mixture was selected as the mixing principle, which means that streams of steam and liquor exit the jet nozzle separately and mix in free space. Jet nozzles developed on this principle offer the following advantages (Raco Yet):

- liquor throughput can be adjusted over a wide range independently of the steam pressure to suit the fabric weight and running speed;
- the pressures in the liquor and steam on exiting the jet nozzle are of practice-relevant magnitudes;
- the most varied practical requirements are fulfilled by a simple exchange of jet nozzle components in a modular system;
- the essential jet nozzle characteristics required for uniform product application across the width of the fabric, e.g. optimum stream angle, are achieved.

Uniformity of application across the fabric width is achieved by overlapping the jet streams. For uniform application to the face and back sides of the fabric, a corresponding arrangement of jets is positioned on both sides of the fabric; here it is particularly advantageous if the two tapered air ducts containing the jet nozzles are staggered in relation to one another. The distance separating the jet nozzles from each other, the distance between the jet nozzles and the fabric and the angle of the air flow all interact in securing a uniform application across the width of the fabric. Process-dependent optimum distances thus need to be found which are compatible with the working limits of textile machines in a modular system.

In rope dyeing (jet dyeing machines), jet nozzles are required to perform a further task in addition to providing the means by which the fabric is impinged by a processing medium: i.e. the liquor stream from the jet nozzle is required to flow tangentially along the fabric rope and transport it along with it by taking advantage of the venturi principle. The flow characteristics of the jet nozzle must therefore be variable in order to provide suitable adjustment for fabrics and fabric surfaces of varying sensitivity (Fig. 1), i.e. the ratio between liquor

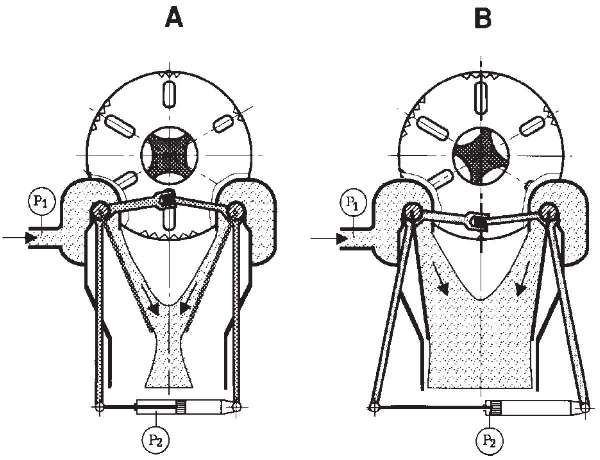


Fig. 1: Vario-nozzle (Thies) with approx. 5 jet sizes (A) from 50–120 mm and 1 overflow setting (B); no jet changing necessary.

flow rate and fabric speed must be variable (20 : 1 to 1 : 1).

For the treatment of open-width fabrics with hot air (e.g. drying, heat setting, thermosol process, curing, etc.), a high heat transfer in the region of air impact as well as a reduction in the impact stream during conversion into tangential flow is important. Formerly, only slit jets were used for this purpose.

In order to achieve a better packing density or concentration, round jets mounted in individual tapered air ducts were subsequently developed. The air flowing through round jets with a rotationally symmetrical heat transfer is able to find a way in the exhaust air spaces between the tapered air ducts without directly penetrating the jet streams. Despite this improvement, the 3 basic rules for an optimum geometry (by utilizing the total surface) are not fulfilled with this jet system either since, in the case of jet systems mounted in individual air ducts, there are always some zones with no air flow or zones which receive only a tangential stream with a low heat transfer (Figs. 2–4).

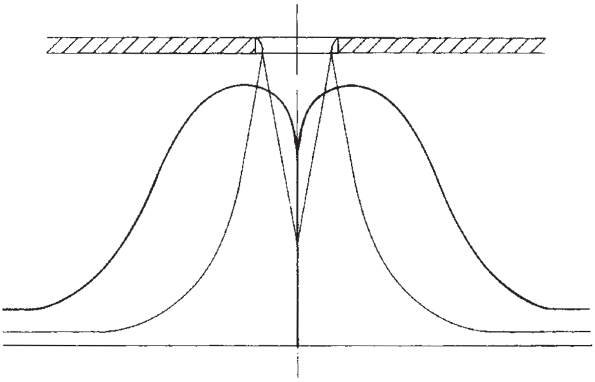


Fig. 2: Schematic representation of heat transfer from a single jet nozzle.

The optimum values for a favourable geometry with jet nozzle systems are as follows:

1. $$\frac{\text{distance nozzle/fabric (H)}}{\text{nozzle diameter (D)}} = 5$$

2. $$\frac{\text{area of nozzle}}{\text{area covered by air flow}} = 2\ \%$$

3. separation $= 1{,}4 \cdot H$

Optimum separation is not achieved in jet nozzle systems on individual air ducts. The Star-Jet system achieves an almost optimum utilization of the entire surface with large jet nozzles (Figs. 5 + 6). In this sys-

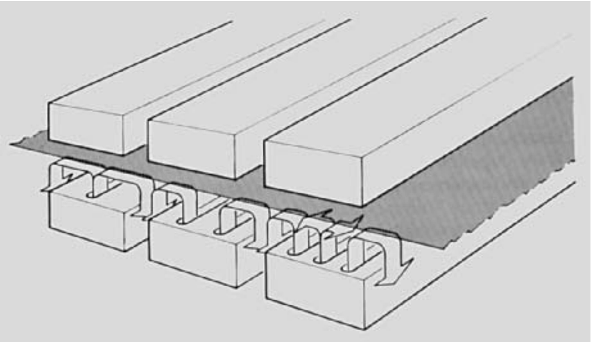


Fig. 3: Standard air ducts with different numbers of slit jets.

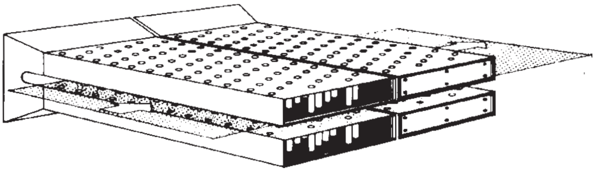


Fig. 5: Distribution of air ducts and nozzles in Star-Jet nozzle elements.

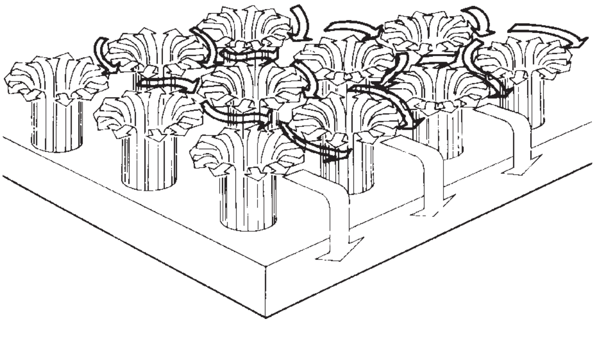


Fig. 4: Obstruction of impinging air by idealized representations of jet nozzle streams due solely to delayed air run-off in a standard round nozzle system (Babcock).

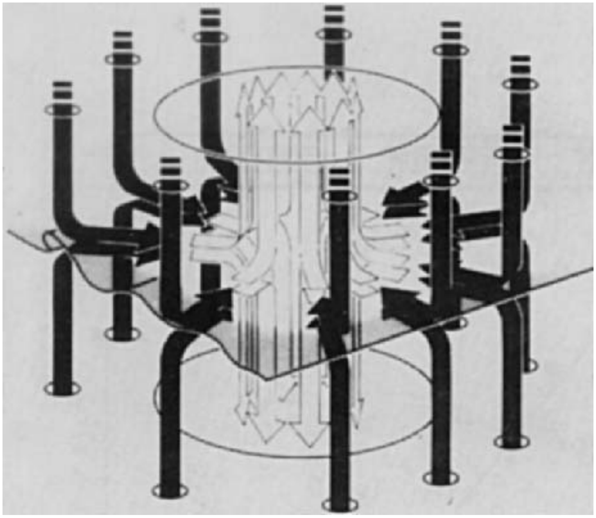


Fig. 6: Star-Jet nozzle (Babcock).

tem, several round jet streams have a discrete exhaust channel without disturbing the impinging air. As a consequence of these two measures, i.e. optimum distribution of air flow over the surface and no interruption of the individual round jet streams, heat transfer and therefore the evaporative capacity is increased by up to 12% (without any increase in fan capacity) in comparison to the usual round jets in individual air ducts. In the case of fabrics permeable to air, it is also recommended that the jets in the upper air ducts are staggered in relation to those in the lower air ducts. By this means, a certain degree of through-flow is also achieved in addition to the impinging air streams which further improves heat transfer (contributed by Carbonell, Farber and Gottschalk).

Jet nozzles Small nozzles used for the atomization of liquids into fine droplets or mist (mist projectors). In general, it can be said that a large bore produces coarse atomization and a small bore fine atomization. Increasing the pressure also results in finer atomization. Throughput is dependent on the bore of the jet and the pressure of the liquid, it changes roughly in proportion to the square root of the pressure.

Jet principle in textile driers In a jet drier, an impinging stream of hot air is directed through jet nozzles against both surfaces of the textile fabric being dried (at speeds up to 40 m/s). In this process the perpendicular component of the air flow is arrested on contact with the material and turned through 90° where it is present as a mixture of jet impingement air and deflected air thus forming a laminar boundary layer. As a consequence, not all surfaces of the individual capillaries in the interior of the fabric are reached by the impinging air flow (in contrast to through-flow drying). In principle, textile materials may be supported or unsupported for air jet drying (likewise in contrast to through-flow drying).

Jet printing → Ink jet printing.

Jet printing techniques In these methods of textile printing, liquid dye solutions are applied to a moving textile fabric with the aid of controlled jet nozzles (e.g. Chromotronic process, Electrocolor process, → Millitron process, → Ink jet printing, → Polychromatic dyeing, → TAK dyeing). → Jet impingement.

Jet rapid washer A washing machine for wool piece goods in rope form with an assembly of jet nozzles and perforated tunnel passages before the squeezer rolls. The fabric rope is sprayed with rinsing liquor from the jet nozzles which inflates the rope before the jet nozzle housing and between the jet nozzles and the squeezer rolls. This produces a very efficient washing and rinsing action at considerably higher running speeds than conventional washers. Manuf.: Hemmer.

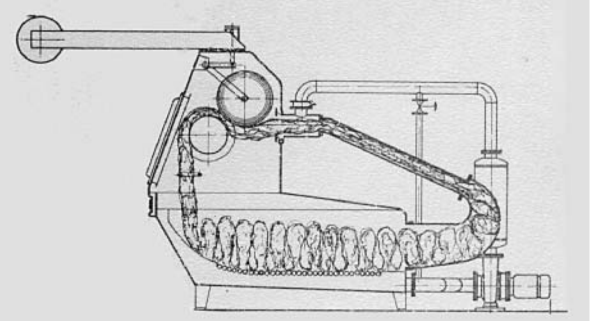


Fig. 1: MCS rope washing machine for continuous operation with jet liquor exchange system (side view).

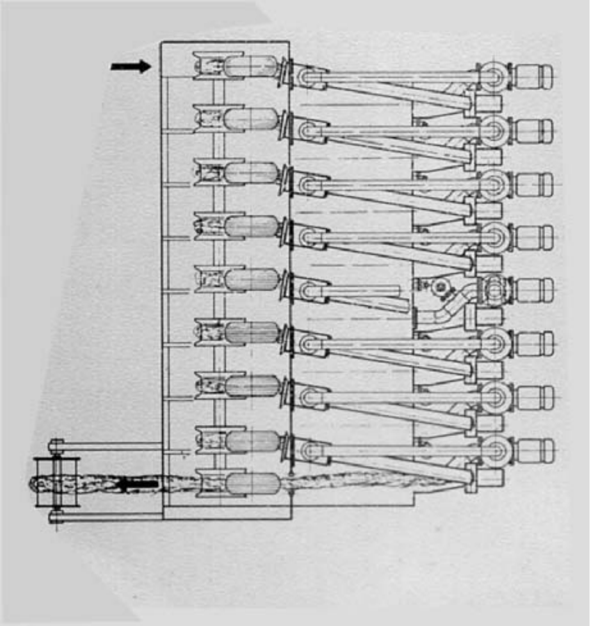


Fig. 2: MCS rope washing machine (top view).

Jet rope washing machines The continuous rope wash in jet rope washing machines takes advantage of the excellent liquor exchange of the jet system as well as the dwell time in the storage chambers (Fig. 1) so that both phases are incorporated into the washing process in an alternating rhythm:

- dissolution and detachment of soil by surfactant reaction with the impurities contained in the material (in the dwell zone)
- transport of detached soil (in the liquor exchange zone)

If necessary, different processes can be carried out successively in the individual compartments of a jet rope washing machine (Fig. 2).

Jet simulator A laboratory apparatus for pretesting the dispersion stability of disperse dye liquors, especially for use in rapid dyeing machines with large pump capacities and greatly increased rates of liquor circulation, e.g. 60 l/min/kg. From laboratory results obtained with a jet simulator system, the possibility exists to carry out preliminary evaluations of dispersion stability which are accurate to within approx. 90–95% of the behaviour under practical conditions. The test is carried out in a laboratory apparatus fitted with a flow recorder: instead of a yarn package with a perforated former, only a blank V4A tube (with 4–6 holes in the walls at the upper end, approx. 5 mm ∅) is placed in the material carrier and screwed tight. The filling height, quantity of liquor and working conditions correspond to the the jet or package dyeing machine being simulated. 250 ml of the cooled liquor on completion of the test is then filtered through a 7 cm ∅ special filter by suction and the filtration time measured by means of a stopwatch. Evaluation of the dried filter against a scale is then carried out (5 = very good, 1 = poor, 0 = thick filter cake or filtration time over 1 min).

Jet stenter The drying chamber in a typical jet stenter consists of a number of air ducts each of which has a type of closed air circulation and heating unit so that each drying chamber can be controlled to a specific temperature. The smallest unit of the counter type is the section with one fan. Each two constructively identical sections incorporate left and right handed ductings and fan and burner locations in alternate chambers so that any widthways variations in the velocity of one pair will be counterbalanced by the next. This two and two counter arrangement offers considerable advantages: 1) the completely symmetrical construction of the sections in relation to the centre of the machine and the fabric ensures uniform temperature and air distribution, 2) short air flows and minimum circulation losses ensure a high circulation efficiency as well as a high specific output and relatively low energy consumption. The paired arrangement of air ducts above and below the fabric are tapered towards the closed ends in order to achieve a more uniform distribution of air.

Jet washer

I. High efficiency open-width washing machine (Küsters) which works on the immersion-spray-suction principle, and is particularly suitable for long-staple carpet qualities. The machine employs slit washing jets with steplessly adjustable regulation of the minimum water quantity at speeds of 3–20 m/min (max. 100 l/min water for every 1 m working width) before the suction pipe. After deflection, the water flows downwards through the carpet pile into a sump (consisting of circulation becks, filter with automatic lint separator, pump and jet). The machine is suitable for working widths up to 500 cm and the quantity of water circulated is 2000 l/min for each 1 m working width (2 jets).

II. An element in continuous open-width treatment plants (Küsters) consisting of an immersion trough with liquor circulation pump and a cascade zone from the upper limit of which a coherent surge of water is released through slit jets and flows over the material.

Jig dyeing (jigger dyeing). The jigger is a short liquor dyeing machine for textile fabrics in open-width form. In jig dyeing, the fabric is transferred alternately from one batch roller to another through a bath of relatively low liquor capacity during each passage. The process, unlike many others, is economical and universally applicable if the actual running speeds can be individually adapted to the respective requirements of the dyeing process and the particular fabric quality, and the selected fabric speeds and fabric tensions remain constant throughout the entire fabric run from one batch roll to the other.

The trend to smaller dye lots has been incessant in recent years. This has been due to the adoption of more extended colour ranges and increased demands for flexibility as well as quicker response in dyeing. Although, in the meantime, dyeing in rope form has greatly increased in popularity due to current fashion trends, it is still true that no alternative exists to open-width processing for many woven fabrics during dyeing. The importance of jig dyeing has increased in recent years for this reason. Modern machines of improved efficiency are now supplied by various machine makers with the following features:

- bath circulation,
- several additions tanks and
- process automation by means of microprocessors (Fig. 1).

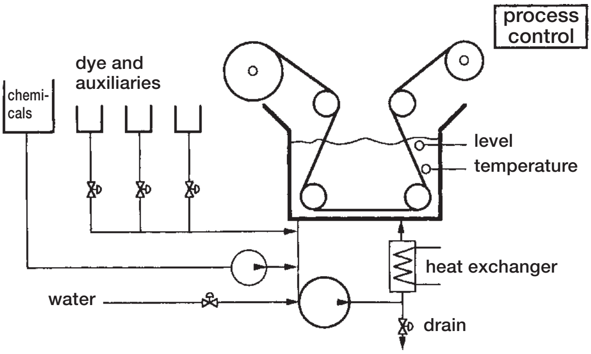


Fig. 1: Automation in jig dyeing.

In addition to their outstanding colour fastness, high dye yields are also a characteristic of Indanthren dyes which permits efficient dyeing with very low coloration of the dyehouse effluent. However, the high degree of fixation, plus the high rate of exhaustion, can result in unlevel dyeings. The addition of a levelling agent is therefore necessary if Indanthren dyes with a high rate of exhaustion are employed or pale to medium depth shades are to be dyed. During the application of vat dyes on the jigger very large quantities of sodium dithionite are required. This is due to the extremely large surface area of liquor that is exposed to the air and the turbulence caused by relatively high fabric speeds with consequent entrainment of air in the dye liquor.

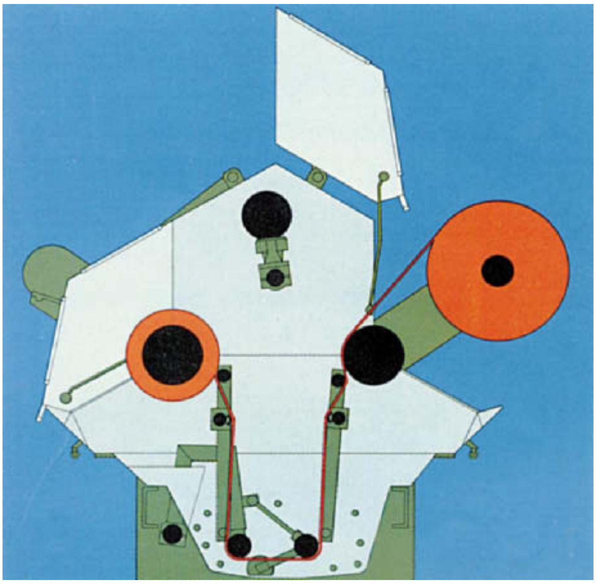


Fig. 2: Loading a Benninger jigger.

The jigger is less suitable for levelling out uneven dyeings since only a very small part of the entire batch is in contact with the dyebath at any one time. The probability that an unlevel dyeing will be obtained increases in the following order from top to bottom:

– pad-jig process with intermediate drying,
– pad-jig process without intermediate drying,
– jig pigmentation process,
– dyeing from the vat.

The pad-jig method with intermediate drying is certainly the most cost-intensive of the above methods but offers the advantage of better appearance in the dyeing of mercerized cotton besides providing greater flexibility in the dyehouse since the padded and dried fabrics can be stored for any length of time before development. In the case of polyester/cellulose fibre blends, intermediate drying is an absolute necessity for the subsequent thermosol process. The jig pigmentation method is employed when no dye padder is available. However, penetration and appearance (especially with tightly-woven fabrics) are not as good as in dyeings produced by the pad-jig process. Dyeing from the vat is hardly ever practised nowadays since it can be readily substituted by the more reliable jig pigmentation method without incurring additional costs.

In order to maintain the dye in a good vatted state in the dyebath and, above all, in the liquor retained within the fabric whilst on the roll, a certain minimum or base concentration of caustic soda and sodium dithionite must be available throughout the entire duration of dyeing. Moreover, at the beginning of each passage, the specific quantity of chemicals which will be consumed by atmospheric oxygen during that particular passage must already be present in the dyebath. In the jigger, the fabric wound on one roller is drawn by a second roller through the dyebath (Fig. 2). The machine stops when the end of the passage is reached, an operation carried out automatically on modern jiggers, the drive is then reversed and the fabric wound back on to the first roller again. In dyeing terminology each passage is referred to as an “end”. Depending on the particular process, dyeing is carried out over four to six ends and more. After two ends, all fabric qualities will have taken up approx. 85% of the max. possible amount of dye liquor. This is dependent on type of fabric, fabric speed and fabric tension. After four ends, an equilibrium is reached between dye on the cotton and dye in the bath. Various models of jiggers are designed to accomodate fabric widths up to 3,5 m and batch diameters up to 125 cm. Thus, batch sizes of up to 3000 m are possible. HT-jiggers are also available. In moder jiggers steplessly adjustable throughput speeds between 10–120 m/min can be preselected. Balanced drive systems ensure that the fabric speed remains constant despite the continually changing diameter of the batch during each end. Fabric speeds of 40–50 m/min are most commonly employed in jig dyeing. It is important that the fabric should run with minimum possible tension. Modern jiggers are equipped with tension control systems. Expanders of various types ensure crease-free running. The jigger is still an economically viable machine for dyeing batches up to 3000 m in particular, especially in automated dyehouses. The jigger is also compatible with the trend towards short liquor dyeing. However, the fact that level results in jig dyeing are dependent on many parameters and the risk of end-to-end and side-to-centre unlevelness increases with larger batch sizes must not be overlooked. Machine makers have made various attempts to reduce the likelihood of defective dyeings by offering additional features. In order to correct listing during dyeing some jiggers are provided with lateral traversing batch rollers. Attempts have also been made to heat the batch rollers to avoid end-to-end unlevelness caused by fabric cooling on the batch rollers and to overcome unlevelness at the edges of the batch due to inadequate liquor circulation by circulating the dye liquor. The fabric is batched off at the end of the dyeing process (Fig. 3).

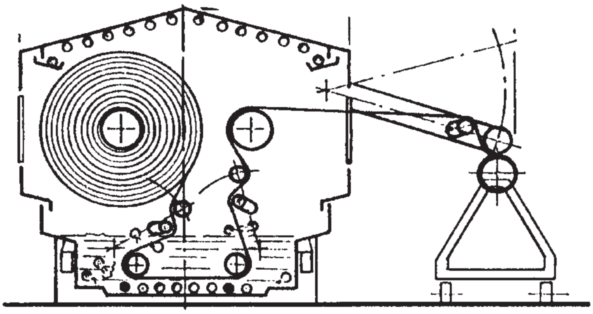


Fig. 3: Unloading a Caber jigger.

Jig dyeing

Most jiggers today are fitted with hoods. A combination jigger-beam washer is produced by Farmer Norton. In this machine the batch rollers are perforated and connected to a water supply so that the batch of fabric can be rinsed whilst still on the roll (to achieve savings in time). For good results in jig dyeing, the state of the fabric edges on the roll is particularly important, i.e. they should be neither too tight nor too slack and must not wander since otherwise creasing cannot be avoided. The problem can be minimized by batching the goods with perfectly straight edges before dyeing, preferably on a separate batching machine. Pile fabrics can also be dyed on the jigger provided the guide rollers have been suitably modified. Jiggers of this type are made by Mortensen. For woven and knitted fabrics which cannot tolerate lengthwise tension, tensionless open-width dyeing machines which operate on a “jigger” type principle (Jawatex) may also be employed.

If textile fabric is to be wound at an absolutely constant speed in the jigger, the rotational speed of both batch rollers must conform to the equation

$$\frac{1}{n_1^2} + \frac{1}{n_2^2} = \text{const.}$$

or, in other words, the sum of the squares of the effective diameters at any one time must remain constant. The manner in which this requirement is fulfilled in the unwinding drive of the CLA jigger is explained in Fig. 4. The diameter of the fabric batch changes continuously during the unwinding run. Therefore, both swivelling axes A–A of the spherical roller elements We, which are driven in parallel by connecting rods, must also be swung in such a way that their effective drive diameters correspond to the actual diameters of the fabric rolls. This task is performed by a hydraulic PI controller which receives its impulse from a pneumatically-loaded compensator roller. As a result, fabric tension is dependent entirely on the preselected pneumatic pressure. Even unbalanced batches cannot influence the fabric tension. The most important elements of this variable speed drive are the constantly excited DC motor and the control unit with silicon controlled rectifier. This drive system which is, in principle, very simple has a number of convincing advantages, e.g.:

- a wide infinitely variable speed range up to 1 : 10,
- simple speed adjustment by turning the knob of a potentiometer,
- good speed constancy and constant torque,
- smooth progression to the preselected running speed,
- smooth and, within certain limits, adjustable braking through braking resistance.

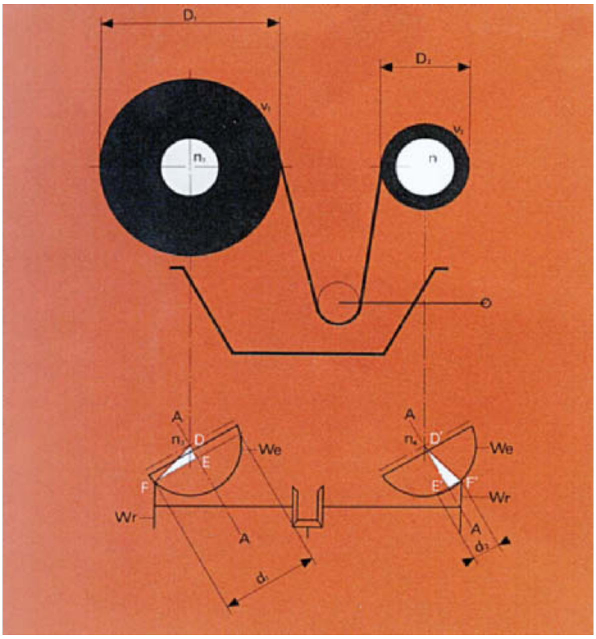


Fig. 4: Sketch illustrating the theoretical principle of the CLA unwinding drive.

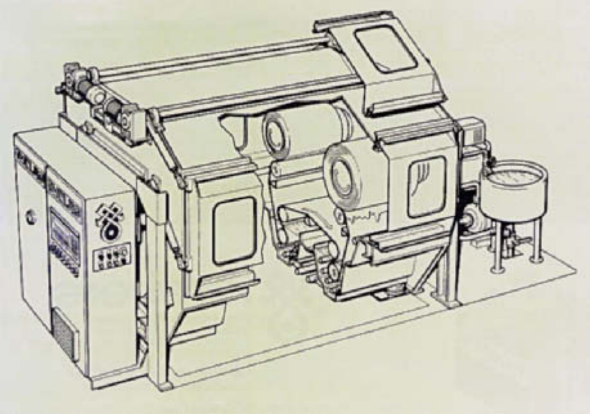


Fig. 5: Jigger based on short liquor technology (Küsters).

In jig dyeing, as already explained, the fabric runs back and forth between two rollers on which it is wound and unwound thereby passing through the dyebath (Fig. 5). The length of fabric actually immersed in the dyebath at any particular time is approx. 1 m. Since the running speed of the fabric can be 80–160 m/min, this means that any particular part of the running fabric has a dwell time of only approx. 0,5 s during its passage through the dyebath. As a consequence, only extremely small quantities of dye are absorbed substantively by the fibres during their short dwell time in the dyebath. Dye is transferred principally by the exchange of a specific volume of liquor from dyebath to fabric; the actual absorption of dye by the fibre takes place during the (much longer) period in which the fabric remains on the roll. If dye absorption does not occur rapidly, the fabric at both ends of the batch roll will be lighter in shade since, in these areas, dye is not absorbed before the next passage through the bath. This is in contrast to those areas lying deep within the batch roll where the "rest period" is considerably longer. If, on the other hand, the conditions for dye absorption are optimum, a risk of non-uniform dye distribution along the length of the fabric exists, since dye concentration in the dyebath varies exponentially from one end of the fabric roll to the other due to the dilution effect.

If jig dyeing is begun with the total quantity of dye in the bath, the dye concentration in the fabric K_v, may be calculated in relation to the initial concentration K_{bo} of the bath during the first passage as follows:

$$f = \frac{\text{total bath quantity}}{\text{dry weight of fabric}}$$

$$f_1 = \frac{\text{quantity of liquor in batched fabric}}{\text{dry weight of fabric}}$$

$$f - f_1 = \frac{\text{quantity of liquor in dye trough}}{\text{dry weight of fabric}}$$

$$F = \frac{f_1}{f - f_1}$$

$$= \frac{\text{quantity of liquor in batched fabric}}{\text{quantity of liquor in dye trough}}$$

M_v = weight of fabric
K_b = momentary dye concentration in dyebath
V_v = liquor in fabric = $f_1 \cdot M_v$
V_b = bath volume = $(f - f_1) \cdot M_v$

$$\frac{V_v}{V_b} = \frac{f_1}{f - f_1} = F$$

$$V_v = V_b \cdot F$$

p = degree of liquor exchange, i.e. that fraction of liquor contained in the fabric which is exchanged during the passage,
u = that part of the total fabric length which has just passed through the bath, so that at the beginning of the passage u = 0.

The exhaustion of dye from the bath is given by:

$$\begin{aligned} -V_b \cdot d\,K_b &= K_b \cdot p \cdot V_v \cdot du \\ &= K_b \cdot p \cdot F\,V_b \cdot du \end{aligned}$$

$$\frac{d\,K_b}{du} + p \cdot F \cdot K_b = 0$$

With the boundary condition $K_b = K_{b0}$ for $u = 0$, the solution to this differential equation is:

$$\frac{K_b}{K_{b0}} = e^{-p \cdot F \cdot u}$$

or, for the concentration on the fabric where $K_v = K_b \cdot p$

$$\frac{K_v}{K_{b0}} = p \cdot e^{-p \cdot F \cdot u}$$

In the following passage the uneven concentration distribution of the first passage is improved due to the opposing effect of the new exponential dye uptake. A complete balancing out is not possible, however. Thus, in order to prevent non-uniform dyeing, a practical procedure has been developed over the course of time whereby

- the total quantity of dye is divided into several portions (generally two) and each portion is added at the beginning of a new passage or "end";
- dyeing is begun at temperatures low enough to ensure that dye absorption in the fabric roll is only slight. During the course of a few ends, the dyebath is gradually heated up until the dyeing temperature is reached;
- the rate of dye absorption is controlled chemically, e.g. by progressively increasing the concentration of dyebath electrolyte (salt addition).

It is often common practice to combine the above three measures. From this example, however, it is clear that the procedure calls for much time and effort. The disadvantages of jig dyeing, as discussed in the foregoing text, are an inherent feature of the process itself and are equally applicable to atmospheric as well as HT-jiggers. The purchase of a HT-jigger, however, represents a considerably higher investment than a 100°C machine. For productivity in jig dyeing, therefore, it is essential that processing times are reduced to a minimum.

Jigger (jig dyeing machine) → Jig dyeing.

Jigger raising In order to achieve more efficient utilization of expensive raising machines with electronic fabric tension control systems and obviate the need to run textile fabrics over several raising machines in series, it is also possible to employ the jigger raising process (see Fig.) in which a batch of fabric is run back-

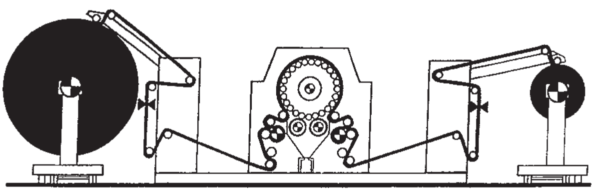


Fig.: Jigger raising principle of Menschner.

wards and forwards over the reversible raising cards. A particularly uniform raising effect can be achieved on knitted goods by this means.

Jigging stenter (jigging tenter). A type of stenter mainly used to "straighten" weft distortion in woven fabrics, e.g. bookbinder's calico. The two side chains are linked, one moving forward whilst the other moves back and vice versa which imparts an oscillating motion to the fabric. This diagonal or "to-and-fro" longitudinal movement helps to straighten the weft threads and reduce any inter yarn bonding between warp and weft thereby producing a softer fabric; → Mechanical breaking.

JIS abbrev. for: Japanese Industrial Standard, issued by the Japanese Industrial Standards Committee (JISC), Tokyo, Japan.

JIT abbrev. for: → Just in time.

Jobber An individual or firm that purchases large lots of textile fabric from producers or merchant converters for resale at wholesale prices in smaller quantities to other wholesale outlets.

Job dyeing A procedure formerly used for the redyeing of already worn garments or unattractive faded materials (for fashion studios, department stores, tailoring establishments). In contrast to conventional textile dyeing, this form of dyeing was nearly always concerned with defective goods or those having already suffered considerable wear and tear where no two pieces had the same background, composition or degree of wear. Despite these problems, the highest demands were often placed on dyed appearance, colour fastness, shape retention, quality, appearance, handle, strength, etc. The dyeing method (mainly carried out in dyeing kiers, winches, garment dyeing machines, paddle machines, etc.) was a correspondingly highly individualized operation. This form of garment dyeing was generally undertaken by departments affiliated to drycleaning and (less frequently) laundering establishments.

Joule (J). The derived SI unit of work for all forms of energy (mechanical, thermal and electrical) named after the English physicist James Prescott Joule (1818–1889). It is defined as the work done when the point of application of a force of 1 newton is displaced through a distance of 1 metre in the direction of the force. The joule is thus defined by the physical units energy x distance or work x time:

$$1\ \text{J} = 1\ \text{Nm (newton metre)}$$
$$= 1\ \text{Ws (watt second).}$$

The calorie, as the former unit of heat in use until 1977, has now been replaced by the joule.

Conversion: 1 J = 0,239 cal; 1 cal = 4,187 J.

Journal of the Society of Dyers and Colourists (JSDC). The leading British technical journal on textile coloration and finishing published by the → SDC, Bradford, U.K.

JPA abbrev. for: Japanese Standards Association; Japanese committee for technical standards; → Technical and professional organizations.

JR → Urena fibre, → Textile fibre symbols, according to DIN 60 001 T4/08.91.

JS → Rosella fibre (roselle), → Textile fibre symbols, according to DIN 60 001 T4/08.91.

J-scray A J-shaped trough used for short duration intermediate storage of textile fabric (usually in the open-width state) between one process and another. The long arm of the J takes the form of an inclined plane on to which the fabric accumulates before being withdrawn from the short arm after a short dwell period.

JSDC abbrev. for: → Journal of the Society of Dyers and Colourists.

JTN abbrev. for: Japan Textile News, a leading Japanese textile journal published in English.

JU → Jute, → Textile fibre symbols, according to DIN 60 001 T4/08.91.

Ju → Jute, → Textile fibre symbols, according to DIN 60 001 until 1988; from 1991 → JU.

Jumbo skin (jumbo hank) Hank of yarn of greatly increased weight, e.g. for wool = 2–5 kg per hank.

Jumper A knitted or crocheted garment similar to a pullover for covering the upper part of the body, usually made without fastenings at the front.

Just in time (JIT). A production management system of inventory keeping in which stocks are kept to a minimum and products delivered just before they are required. Likewise, finished goods are delivered to customers on demand. The system calls for a very high degree of cooperation between suppliers and customers throughout the entire chain of production. Advantages include a considerable release of "dead" capital which would otherwise be tied up in (often) slow-moving items of stock, improved cash-flow, reduced space requirements and reduced turnaround times between orders and delivery. A disadvantage is the greater vulnerability to production losses due to delays in delivery or defective components.

Jute A vegetable fibre belonging to the → Bast fibres. It is obtained from the stems of plants of the genus *Corchorus*, especially *Corchorus capsularis*. The jute plant is a herbaceous annual which grows to a height of 2–5 m and flourishes chiefly in tropical and sub-tropical countries (cultivated mainly in Bangladesh, India and China). The structure of the jute stem is similar to that of flax apart from the the position of the fibre bundles within the cortical layer. Jute fibre strands are polygonal in cross-section, usually with 5 or 6 sides. In a similar manner to hemp, primary fibres and, to strengthen the stem, secondary fibres develop between the primary fibres and the woody layer. In contrast to hemp, differentiation between the primary and secondary fibres in the mature state is no longer possible. From a chemical point of view, the jute fibre is similar to flax and is composed of: 63–75% cellulose, 9–10% water, 0,3–4% fats and waxes, 0,2–0,8% ash and 21–25% pectin and lignin. The lignin content of approx. 12% is the highest of all the vegetable fibres and explains the high lignification of this fibre. The structural build-up of the individual cell is similar to that of flax and hemp although, in the case of jute, lignin is present not only in the middle lamella but also in the cellulose layers of individual cells. Compared to other bast fibres, the individual jute cells have the shortest length (1–5 mm) and their thickness of only 15–25 µm is similar to flax and hemp. Commercial production of the fibre is carried out in a manner similar to that used for flax and hemp by freeing the fibres from the bast fibre bundles in retting and mechanical processes or by cottonizing. Properties: jute has relatively poor strength and durability. The fibres are soft and lustrous but lose strength when wet. Even the action of dilute acids causes a red coloration and destruction of the fibres; mineral acids have a more aggressive action on jute than on flax or hemp, and jute is readily dissolved by conc. acids. In contrast to other cellulosic fibres, the very high proportion of impurities in jute fibres, which cannot be removed without destroying the fibre itself, is responsible for its deviant affinity for dyes, i.e. the fibre also has an affinity for cationic, acid and disperse dyes besides the usual cellulosic dyes. Uses: tablecloths, curtains, wall-hangings, runners, carpet backings, sacks, ropes and cordage, etc.

Jute bagging (gunny) → Hessian.

Jute/hemp distinguishing test → Hemp/jute discrimination tests.

Jute line Fine yarn produced from long jute fibres after hackling.

Jute soiling Soiling which takes the form of brown stains on the polyamide pile in carpet dyeing due to the lignin and pectin impurities present in the jute ground fabric. Jute can severely reduce the light fastness of dyeings on polyamide carpets especially in light shades.

Jute stem structure → Flax stem structure.

Jute tow Coarse yarn produced from jute fibres.

JZS abbrev. for: Jugoslavenski Zavod za Standardizacija, Belgrade, Yugoslavia (Yugoslavian Standards Institute); → Technical and professional organizations.

K

K,

I. Element symbol for potassium (19).

II. → Twill weave DIN abbreviation.

III. → Kelvin (old unit symbol: °K).

k Unit symbol for → Kilo (one thousand times), factor 10^3.

KA → Casein fibres, → Textile fibre symbols, according to DIN 60 001.

Kagotsuko printing Typical Japanese resist printing process, comparable with paste resist printing (→ Resist printing).

Kalmuck (fries, swanboy). In general a 2-sided strongly raised soft cotton fabric, weight and roughened effect are even more marked than in → Melton; (cross) twill weave with back pick or as double cloth, striped or with a check pattern. Also long-haired, coarse, thick woollen fabrics. Application for heavy blankets, bed padding, table undercloths, backcloth materials, ironing board and mangle covers.

Kaloz process (lime and ozone), combined process for effluent cleaning, as a single stage or sequentially (= better results) by the precipitation of organic/inorganic impurities using calcium hydroxide. By the use of the correct techniques even fused and difficult to oxidise substances be made to oxidise more easily. Particularly suited for the cleaning of textile effluents due to its good decolorising effect. → Recalcination.

Kamdani Ancient Indian gold embroidery (silk thread wrapped in metal foil) of lighter style on fine fabric.

Kaolin (China clay, porcelain clay, terra alba), $Al_2O_3 \cdot 2\,SiO_2 \cdot 2\,H_2O$, density 2.1–2.6. White, loose powder, practically insoluble in water. Application: with starches and oils for filling and softening of finishes (bleached cotton goods, light coloured lining fabrics); pigment for viscose delustring (fixed in particular by sulphonated surfactants); also as spotting powder; as tailor's chalk, etc.

Kaolinite $[Al(OH)_2]_2[Si_2O_5]$. Predominant mineral in → Kaolin and clay, main component of bleaching earths and Fuller's earth.

Kapok → Vegetable hair fibres from the fruit pod of tropical cotton of the Bombaceen family (kapok, cotton or silk cotton; East and West Africa, India, Java, Sumatra, Mexico, Brazil). Single cell hollow fibres with large, air filled lumen. The cuticle is very thin and fatty. Length 10–40 mm, cross section round or oval. Width 20–30 µm. White or yellowy brown, soft, supply, lustrous. Microscopic: Smooth, pressed flat, typically many bends. Specifically extremely light, has a power to carry water of 20–30 times own weight, compressed 36 fold. Burns easily. Has 6–8 times the heat retention capacity of other fibres. Immune against moisture and all vermin (specific fat with toxin content). Consists primarily of cellulose, slightly lignified, therefore brittle and fragile. Difficult to wet, alkali sensitive (loss of lustre), less dye affinitive than cotton. Application: Preferred as cushion material (often faked); for swimming belts, bandages, hats; as kapok quilt lining. Less often spun: Pure after fat extraction; mixed with cotton, viscose, silk waste and wool.

Karabagh carpets Knotted carpets from the Southern Caucasus, patterning and colours similar to → Kazakh carpets, but shorter pile made of less lustrous wool. Approximately 150 000 Turkish knots per m^2.

Karl-Fischer method (KF process), simple, volumetric process for water determination, based upon the fact that iodine oxidizes sulphur dioxide to sulphuric acid in the presence of water. Particularly suitable in the presence of the smallest quantities of water in organic solvents, dyes, also in textiles. Available as stable, ready to use solution. When used carefully offers reliable, reproducible values.

Kashan carpets Knotted carpet from central Persia. Fine ornamentation on a matt red, violet or dark blue background. Around 350 000 Persian knots per m^2. Low, smooth pile made of fine wool.

Kasuri → Kasuri dyeing.

Kasuri dyeing (Kasuri-Resist), laborious, old Japanese dyeing technique of a white patterning on coloured ground by the partial resist of warp and weft threads and subsequent over-dyeing.

Katox-system An effluent treatment system that can be used together with other systems to create a complete effluent treatment plant for textile processes. It is based upon an activated carbon system that carries biologically active media in cyclone baths. The katox system for treating difficult effluents is based upon the use of high surface area substances (active carbon) as an exchange medium. The active carbon is used in a series of fluid beds in open baths (usually 3), through which the effluent is slowly passed (dwell time up to 9 h). The exchange media are fluidised over the cells located on the floor of the baths by aeration. The reaction baths are filled with different, but matched, media in a quantity up to 20 vol. % in relation to the bath volume. The downflow baffles keep the exchange media in the baths; only the finely dispersed carbon granules leave the system. These may be removed in a subsequent cleaning stage.

Active carbon, as a dispersion of fine particles, is characterised by a large specific surface area (external geometric factor); and a large internal surface area (internal geometric factor). Active carbon thus offers large surface area for exchange reactions. When specific active carbon grades are chosen, a synergistic effect is provided by the oxygen affinity of the surface.

The biological degradation of effluent constituents takes place on the expanded inner surface of the supporting medium, where chemical sorption ensures that activated oxygen is present in large quantities and is continuously supplemented by injected air. The supporting medium is not consumed, because it is not its adsorptive energy that is critical to the reaction, but rather the oxygen activated surfaces, which are continuously renewed. The bacteriological activity that occurs on the supporting medium, benefits from the high oxygen content, and high surface area of the supporting medium offers an artificially high concentrated form due to temporary adsorption. The fixation of the system onto the active carbon gives the chance for special biologically active systems to be included that multiply the effects as the microorganisms play an increasing role. The conditions are favourable to the microorganisms, and specific cultures develop that can assimilate the contents of the waste slurry as the generation cycle proceeds. There are differences between an hour (heterotropic bacteria) and days (autotropic nitrificants, specialists). Due to the retention of the microorganisms each type of bacteria is retained within the system regardless of the growth rate. Similarly, substances that are difficult to degrade are retained in the system longer due to temporary adsorption on the supporting material and are therefore subject to the effect of the colonised specialists for longer. The enzymes formed for the degradation of the organic effluent constituents of the microorganisms remain fixed on the supporting material as exoenzymes and when available they can accelerate the digestion of the pollutants. In addition it has been found that bound microorganisms and enzymes can bring about higher metabolic rates than those that are not fixed.

The linking of several fluid bed basins maximises the effectiveness of the plant as a whole by the exploitation of the plug flow. Plug flow means that there is a falling solids load gradient over the plant as a whole and a correspondingly varied digestion results. In the first bath the pollutants that can be easily biologically degraded are quickly degraded by a biological filter media. A “hard” effluent with altered composition flows into the second basin, whose BSB_5 content is lower, and therefore the $BSB_5 : CSB$ ratio is also lower. Corresponding to this situation, a changed, adapted biology forms on the supporting material of the second stage, with a high proportion of microbial specialists. The same applies for subsequent stages, which is why linking the stages together is so adaptable and efficient from the point of view of biological filter media.

The performance of the katox system can be increased still further by optimised reactor technology. Previously, the air intake was achieved by fans and porous aeration units located on the entire basin floor. Additional stirrers, together with the movement caused by the airflow, should ensure an intensive mixing of the effluent with atmospheric oxygen. The contact substances are fluidised in a rolling movement in the open basin, with the drive being provided by aeration cartridges on the basin floor. It is not necessary to keep the entire mass of base material suspended for a complete cleaning effect. So a solid forms at the bottom of the solution, which still allows material flow and which continuously participates in the circulating fluid bed / fixed bed (solid at the bottom of the solution), because aeration according to the rising air principle generates a partial draught. The contact substance is transported upwards to the surface by the air blown in from the deepest point, from where it sinks to the bottom of the basin in a wide arc. At the bottom of the basin the carrier speed is such that the contact substance is transported on to flow upwards again with the aerators. If this up-current made up of air bubbles, contact materials and waste water is passed over the aeration unit with the aid of a rising channel, there is a critical stabilisation of the flow and the contact mass transport and at the same time a consistent fluidisation over the entire volume of the basin.

Kawabata system System developed in Japan for handle evaluation (→ Kawabata system of handle evaluation). System developed to allow Japanese Technicians to use a single system of handle evaluation. Describes fabric handle in terms of 0 (slight) to 10 (very marked) with an overall rating scored as 0 (unacceptable) to 5 (excellent). The handle of a fabric is literally assessed by handling and recording the various sensations as e.g. hard, soft, full, thin, dry, greasy, granular, woolly, etc. These subjective assessments, common in the textile trade, are associated with problems. Any such assessment must be subjective and therefore directly dependent upon the assessor and will only have validity within their system of values. The lack of reproducible measurement results makes cooperation between different companies more difficult (weavers, finishers, dyers, clothing manufacturers); in addition the manufacture or finishing process is difficult to reproduce with regard to quality control. As the level of automation increases, objective, reproducible data is becoming more important. Therefore, attempts have been made in several countries to objectively describe cloth handle. The most successful work in this field is that conducted in Japan by Kawabata and his colleague which has yielded the KES-F system (Kawabata's Evaluation System for Fabrics). In this system various characteristics are used for handle evaluation:

Fukurami = fullness and softness
Hari = "non-drape" stiffness
Kishimi = scroopy handle
Koshimi = stiffness and elasticity
Numeri = flexible smoothness
Shinayakasa = suppleness with softness
Sofutosa = soft handle feel

These characteristics can be detected using four devices:

1. KES-F-1 for measuring fabric behaviour under tensile and shear loading.
2. KES-F-2 for measuring bending behaviour.
3. KES-F-3 for measuring fabric behaviour under compressive loading.
4. KES-F-4 for measuring surface characteristics of the fabric.

Method of deformation:	Measured and calculated (*) property:	Symbol:	Unit:
Traction	Ascending gradient (*)	LT	–
	Traction work	WT	J/m^2
	Recovery capacity	RT	%
	Extensibility	EM	%
Bending	Flexural strength	B	µNm
	Flexing hysteresis	2HB	mN
Shearing	Shear stability	G	N/m degrees
	Shear hysteresis at 0.5 degrees	2HG	N/m
	Shear hysteresis at 5 degrees	2HG5	N/m
Compression	Ascending gradient (*)	LC	–
	Compression work	WC	J/m^2
	Recovery capacity	RC	%
	Thickness at 0.5 g/cm^2	T	mm
Surface properties	Coefficient of friction	MIU	–
	Standard deviation of the coefficient of friction	MMD	–
	Surface roughness	SMD	µm
Deduced parameters	Shaping capability (*)	F	

Tab.: Kawabata measuring system for assessing textile fabric handle.

The Table lists the mechanical characteristics of the fabric, which can be measured using the KES-F system. If necessary these can be used to assess two characteristic properties of fabrics: The first is related to the handle and the other to the mouldability of the fabric, i.e. how this reacts to loading during shaping. The use and maintenance of the KES-F device requires a trained technical specialist, who is sufficiently competent to undertake the difficult, complex calibration. Another disadvantage is the time that is required for a test. A complete evaluation of a fabric can take 6–8 hours depending upon type. This disadvantage clearly represents a significant limitation to the application possibilities, in particular for the control of industrial process stages. In addition, the purchase price is very high.

The KES-F system has proved itself well as an instrument for research. Whether it can attain the same level of importance for routine handle determination in Europe as it already has in Japan depends not least upon whether quality requirements in the form of marks can be correlated with the European "handle culture".

Kawabata system of handle assessment The handle of a textile material is a very important quality feature because, together with the visual impression of the material, it often represents a decisive criterion for the sale or purchase of the textile item. In contrast to other fabric properties, which are evaluated in a consistent manner by the use of an objective test procedure, this significant quality criterion has up until now been assessed in a purely subjective manner, i.e. the finisher or manufacturer subjected the material to a tactile and visual evaluation, in which different experience and sensory values came into play depending upon the person performing the evaluation at the time. However, because handle is a complex phenomenon and is made up of numerous properties, it is clear that these subjective methods will bring indeterminable influences to bear during the evaluation. The associated lack of agreement and reproducibility of results is another reason why problems repeatedly cropped up in this connection between cloth manufacturers and clothing manufacturers. It is this lack of reproducible measuring results in particular which has made it necessary to develop a testing process which can yield an objective value for handle in relation to the human senses, and which thereby provides an optimal basis for comparison. The most successful work to date in the field of objective handle determination is that conducted in Japan by S. Kawabata and his colleagues. Their comprehensive investigations have led to a recognition of which mechanical-physical properties are critical for the handle of fabrics. On this basis they developed, in co-operation with the company Kato Tech. Co. LTD (Kyoto City), the so-called KES-F system (Kawabata's Evaluation System-Fabrics), which aims to facilitate the determination of the above-mentioned fabric properties. By means of the shear, tensile, bending, compression and surface property tests performed as part of the system, and taking into account the weight of the material, 16 characteristic parameters for the handle of a fabric are obtained. Kawabata and his colleague Niwa also correlated these properties with subjective handle expressions such as "stiffness" and "smoothness". However, this correlation is disputed outside Japan and it is very difficult to transfer to European conditions. Furthermore, the terms commonly used in Japan to describe handle can only be compared to Western measures by means of complicated paraphrasing, which means that it is impossible to make a precise and accurate translation. Nevertheless, the use of the KES-F system with regard to handle evaluation is of great importance, because even the consideration of the individual parameters can yield important insights into how handle is defined.

The principle of objective handle evaluation using the Kawabata system is based upon the determination of a number of mechanical-technological fabric properties, which have proved to be critical to the handle of a fabric. These are tensile and shear-elastic parameters, bending properties, compression, surface properties (friction and profile), weight and thickness of the textiles in question. The Kawabata procedure for the meaningful linking of the above-mentioned factors with regard to the objective evaluation of handle can be summarized as follows:

1. Cooperation with a range of Japanese textile experts first yielded the insight that there are two stages to the evaluation of handle in textiles, namely the so-called primary handle impression and a "total handle value" derived from this primary impression. A list of specific terminology is drawn up to describe the primary handle impressions (e.g. smoothness, stiffness).
2. Based upon this, the collection of 500 representative fabric samples was subjectively analysed by allocating marks between 0 (property not present) and 10 (property strongly marked).
3. Using pattern cards distributed within the industry showing samples marked between 0 and 10, it was now possible to make a numeric analysis (even though this was still only subjective).
4. The development of the KES-F system based upon 4 measuring devices then made it possible to determine 15 mechanical-technological fabric properties associated with handle. These 15 parameters were summarised in 6 "blocks", taking into account the fabric weight. The above-mentioned collection of 500 fabric samples was evaluated with the aid of this system.
5. Using a "progressive block regression" the standardized measured values were correlated with subjectively determined marks and a transformation equation was created for each handle impression. Using this transformation equation, the relevant mechanical-technological parameters for each new fabric sample could thus be expressed as a value between 0 and 10.
6. In a final stage the "total handle value" was determined from the primary handle impressions, which was itself correlated with a subjectively determined scale of 0 (= just acceptable) to 5 (= excellent). There are already transformation equations in existence for 5 different material classes, whereby these are characterized by the primary handle expressions currently in use (see Table).

MEN'S AND BOYS' WEAR winter	Koshi	-"stiffness and elasticity", flexural strength dominates, e.g. due to springiness, high woven fabric density, elastic resilient yarns;
	Numeri	-"pliable smoothness", smoothness, pliability, suppleness, softness, e.g. cashmere;
	Fukurami	-"fullness and softness", bulk, fullness, elastic, resilience, (warmth), e.g. rather thicker materials;
MEN'S AND BOYS' WEAR summer	Koshi	- as above;
	Fukurami	- as above;
	Shari	-"granularity", granular and rough surfaces (coolness), e.g. due to hard twist yarns;
	Hari	-"anti-drape (stiffness)", (≠ Koshi) independently of recovery capacity and elastic resilience;
WOMEN'S OUTERWEAR medium weight	Koshi	- as above;
	Numeri	- as above;
	Fukurami	- as above;
	Sofutosa	-"soft handle", softness, made up of Koshi, Numeri and Fukurami;
WOMEN'S OUTERWEAR thin	Koshi	- as above;
	Hari	- as above;
	Fukurami	- as above;
	Shari	- as above;
	Kishimi	-"scroopy handle", e.g. woven silk fabric
	Shinaya	-"suppleness with softness", made up of the other 5.

Tab.: Primary handle terms for different fabric classes according to Kawabata.

Kazakh carpets Tightly knotted, long pile carpets from the Caucasus. The large, bold, geometric patterning in bright dark red, blue, green, yellow and light ivory is typical. Dull silk sheen wool pile. 120 000–200 000 Turkish knots per m^2. The term Kazakh carpets is often wrongly used as a collective term for Caucasian carpets.

KD Ger. abbrev. for "Kräuseldehnung", → Crimp elongation.

KD-behaviour German expression for Load-Elongation behaviour (→ Stress-strain behaviour). Provides information about the interrelationship between tensile strength and extensibility behaviour of yarns.

KE → Kenaf, → Textile fibre symbols, according to DIN 60 001 T4/08.91 for certain jute fibres.

Kelvin (K), temperature scale of so-called absolute temperature values (→ Temperature), which begin at –273°C = 0 K. According to this scale, short wave radiation (light wavelength) has a high colour temperature and, conversely, blue light has a high colour temperature and red light a low colour temperature. In practice this means that direct sunlight is 5000–65 000 K, blue diffuse light is 5700–6600 K, white light with a completely overcast sky is 6400–6900 K and with a clear blue sky is 19 000–24 000 K. These differences naturally have an effect on colour matching. It should be noted that artificial light sources usually have a linear spectrum, whereas sunlight yields a band form spectrum.

Kemp,

I. Surface hairs, long, coarse animal hairs in the upper surface of the hair, usually medullated, strong, usually lustrous, rarely curled, low felting tendency. Problem as contaminant (soiling) in fine hairs, such as for example cashmere (as underside hairs).

II. Short, generally non-crimped hairs (e.g. rabbit hair), coarser filaments or slit (acetate, viscose) film yarn, white or coloured. Kemp is incorporated in spinning and produces a kempy fancy woven fabric with fibre tips and coarse fibres protruding from the face.

Kenaf (Bimli-jute, Gambo hemp, Ambari hemp, Bombay hemp, Mestha), similar to jute → Bast fibres (India, Soviet Union, China, Korea, Taiwan, Philippines, South Africa, Brazil, Cuba). The basic fibres have irregular wall thickness, an average length of 2 mm and a width of 20 µm. Kenaf has a lower lignin content (7.5–9.2%) than jute and is therefore less woody. It also differs from jute in its high sheen and increased strength. The stem fibres are separated in a similar way to jute. Application: As jute substitute and mixed with jute for the manufacture of packing material, rope goods and fabric. In addition to the fibre extraction the plant is also used for the production of oil.

Kendyr fibre (Turka fibre), of the → Bast fibres family. A winter resistant plant fibre from Turkestan. The stalk is cut annually; preparation takes place in a similar way to flax. The pure white, 80–120 cm long bast bundle with fibre strength up to 55 cN/tex can be processed by linen and tow spinning; by cottonising the kendyr fibre can also be used for fine spun yarn (mixing with cotton). The most important field of application is in the manufacture of highly rot-resistant fishing nets.

Keratin (Gk.: horn material), high molecular → Protein substance (scleroprotein) containing cystine. Basic substance of hair, nails, feathers and especially wool (wool keratin).

Keratin denaturing Keratin, which possesses a fibrous structure, is subject to a typical mechanism of reversible denaturing (the α-β-transition) when stretched. Discovered by Astbury. Fibre keratins such as wool and hair are multi-component fibres and fulfil the conditions of a compound structure. The three morphological main components are cuticle, cortex and cell membrane complex, which consist of further subcomponents. The cortex consists of individual cortex cells, which are themselves made up of macrofibrils (with intermacrofibrillated cement), microfibrils, protofibrils and α-helices. A particular importance is attributed to the microfibril matrix complex here, because it is one factor that determines the physical properties of the fibre keratin. This complex consists of part-helical, low sulphur microfibrils, which are stored in a non-helical, high sulphur matrix. The structure of the helices and the helix content are determined with the aid of the x-ray wide angle technique (Fig. 1).

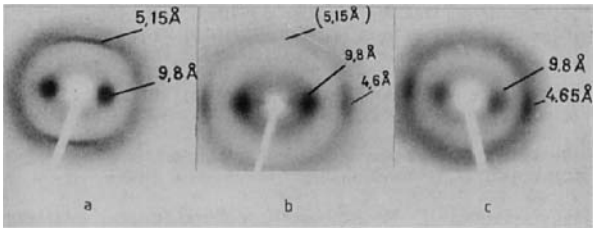


Fig. 1: X-ray panoramic diagrams of three different mohair test specimens (1 Å = 10^{-10} m) (Spei).
a = unstretched; b = 40% stretched; c = 60% stretched.

Under the assumption of a molecular mechanism of the α-β transition as postulated by Astbury, the α-content of the sample must decrease to the same degree that the β-content increases. However, this is not the case. After 40% extension of the fibre the 5.15-Å-meridian reflex (reflex intensity is a measure of the α-helix content of the sample) had entirely disappeared, but the 4.65 Å-equator reflex (reflex intensity is a measure for the β-content of the sample) is only relatively weakly marked and achieves a considerable gain in intensity at between 40–60%.

Combined thermoanalytic and X-ray examination (Figs. 2 and 3) of extended and tempered fibrous keratin have shown that the α-β transition follows a molecular mechanism up to expansion values of 60–80%: Structures that start out as crystalline α-helices are converted into extended β-pleated sheet structures. However, the possibility cannot be ruled out that the molecular α-β transition is overridden by a non-molecular transition, whereby previously extended amorphous keratin is converted into extended β structures by expansion crystallisation.

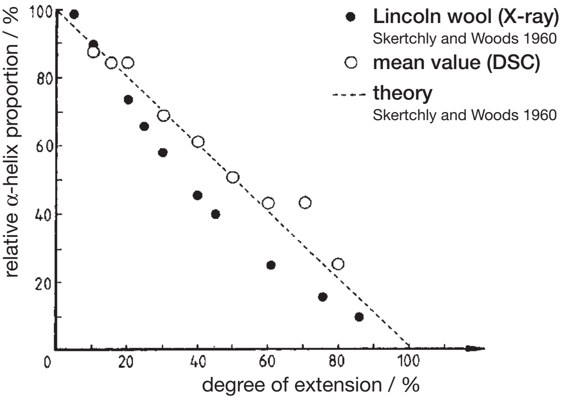


Fig. 2: Radiographically and thermoanalytically determined residual helix contents of stretched fibre keratins (Spei).

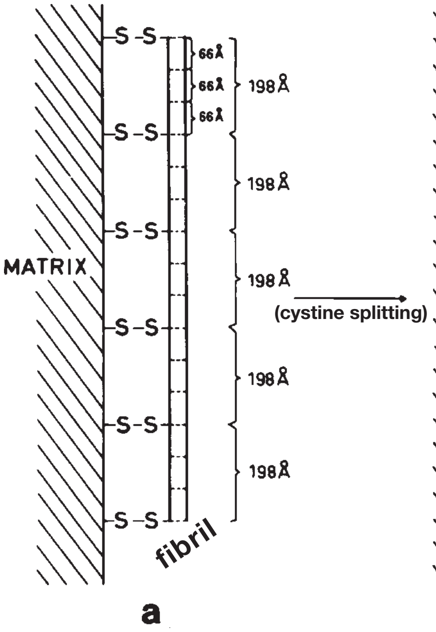


Fig. 3: Chemical grounds for a statistical bendig period of 198 Å ($1.98 \cdot 10^{-8}$ m) due to partial, uneven splitting of the cystine bridges between the microfibrils and the matrix (Spei).

Keratin parasites → Textile parasites.

Keratin sheet structure (polypeptide sheet structure, polypeptide lattice), consists of polypeptide main and side chains of wool keratin arranged in parallel in a plane. The stacking of keratin sheets, which are again cross connected by side chains, creates a multi-dimensionally elastically braced crystalline grid called →: Micelles or Crystallites.

Keratose High-molecular wool oxidation product, consisting of β-keratose (cuticula), α-keratose (microfibrils) and γ-keratose (matrix). Disulphide bonds are split by the oxidation of the wool keratin with peracetic acid and some of the side chains of the tryptophane (amino acids) are attacked. Such oxidized wool is easily soluble in diluted ammonia except for β-keratose; called α-keratose if precipitated by acidifying (the γ-keratose remains in the solution).

Kermes (scarlet), red → Natural dyes (a mordant dye). Is manufactured by the pulverisation of the female shield louse of the chestnut or kermes oak (Persia, Balkans, Spain). Active component: Carmine acid, related to → Cochineal. Mordant dyes for wool and silk. Light fastness and luminosity of equal value to the expensive → Purple.

KES-F-System (Kawabata's Evaluation System for Fabrics) → Kawabata system.

Keto-Enol tautomerism → Tautomerism.

Keto form → Ketones.

Keto group (carbonyl group), >C=O, characteristic group of → Ketones.

Ketohexamethylene → Cyclohexanone.

Ketone-aldehyde resins Condensation products of ketones and aldehydes, e.g. → Dimenthylolacetone. Application as reactant-type resin without chlorine retention.

Ketone resins Condensation products of → Ketones, such as → Methylcyclohexanone, also phenol modified.

Ketones Oxidation products of secondary alcohols with the typical keto group >C=O, e.g. in acetone $(CH_3)_2CO$. In chemical compounds we also talk of the keto form, which is typical of undissolved vat dyes, for example, unlike the (soluble) leuco compound, the so-called vat acids, which are called the enol form (enol leuco compound).

Ketoses → Sugars.

Key-lock principle In 1894 Emil Fischer developed the theory, to explain enzyme specificity, that the surface of an enzyme possesses a pocket (the "lock"), into which the substrate fits sterically like a "key", enabling the process of enzymatic catalysis to function. However, if certain neuronal distances are fulfilled in the sense of the key-lock principle, pseudo keys, i.e. similar substrates, can also lead to reactions of the enzyme. An example of this is provided by the recently developed silicon polyquats, which with increasing quat modification for the improvement of softness, bath extraction rates, water solubility, electrolyte stability etc. suddenly become highly toxic (Curare effect, see Fig.) if certain neuronal distances in the sense of the key-lock principle are fulfilled. There are equally good examples of modifications to a substrate, which is not converted by a certain enzyme, although the change in relation to the original substrate is only slight.

Although inhibitors fit in the lock as a key, they are not converted, but inhibit the enzyme. Thus the methyl group of acetic acids is linked to a certain enzyme. Mono fluoro acetic acid also fits sterically, but inhibits the enzyme. Mono chloro acetic acid, on the other hand, no longer fits sterically into the lock and there-

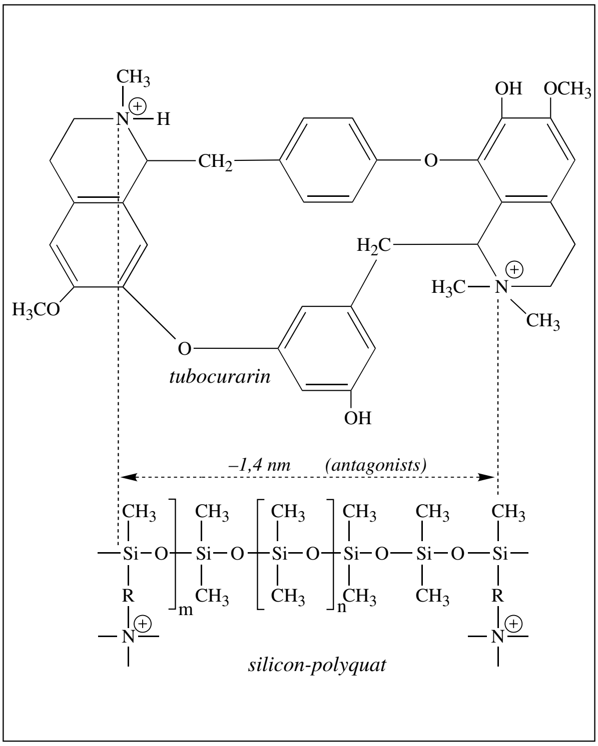


Fig.: Curare effect (from Stockhausen).

fore does not compete with acetic acid for the place in the enzyme pocket.

Kf → Kenaf, → Textile fibre symbols, according to DIN 60 001 till 1988, from 1991 → KE.

KF-dyeing process Short liquor ratio dyeing process on special dyeing equipment. In yarn equipment partial flooding with one-sided liquor circulation inner/outer and with minimum submerging of the yarn package and pressure pad (dyeing in liquor).

Kh, animal hair, → Textile fibre symbols, according to DIN 60 001 till 1988.

KH Standard abbrev. for temporary hardness; → Water hardness.

Kid leather → Leather.

Kidderminster carpets Double cloth carpets, in which two layers of cloth, manufactured from two warp and weft systems, lie on top of each other. The patterning is created by the threads of the cloth layers alternating, i.e. the wefts are inserted in tiers, which are sometimes formed by the warp threads of the upper cloth and sometimes by those of the lower cloth. This has the effect on the pattern that a red figure on a blue background on the front appears on the back as a blue figure on a red background (reversible carpet). It is woven without the use of heald shafts exclusively with Jacquard machines, with the depth of the harness being split according to the number of cloth layers. The Scottish or treeply carpet consists of three layers of cloth. These flat, but thick, carpets, usually made of wool yarn were first produced in the English town of Kidderminster.

Kier boil-chlorine bleach Combined process, consisting of → Kier-boiling with subsequent → Bleaching to achieve pure white, for cotton and cotton/viscose mixes with a fairly low viscose proportion. The disadvantage is that yellowing occurs over time and fibre loss occurs if viscose is present (approximately 8–10%, compared to approximately 5% for alkali scour-peroxide bleach and approximately 2% for oxidative bleaching). The kier boil-chlorine bleach has now been replaced by continuous bleaching processes.

Kier boil-chlorine-peroxide bleach Cotton bleach to achieve a non-yellowed white. If viscose is present 8–10% viscose losses occur, which can be reduced to approximately 3% by the transition to → Peroxide-hypochlorite-peroxide bleach. → Peroxide bleach.

Kier-boiling Alkaline scouring of cotton (in all processing stages) under pressure (1–4 bar) in the decatizing boiler to remove the natural impurities and increase the wetting out property.

Kier boiling aids (scouring aid), accelerate the cleaning process in the alkaline pretreatment of raw cotton, for example, by rapid wetting of the textile material. They promote the separation of wax and pectin substances, closed seed shells and prevent the re-extraction of dissolved impurities. Soaps have only limited use as kier boiling aids (water hardness); oil sulphonates act in a similar manner to soap, with highly sulphonated products being given preference. Fat solvent soaps aid the removal of wax to a certain degree, but are overrated. Soap-like synthetic products such as →: Fatty alcohol sulphates; Fatty acid condensation products etc. act as excellent emulsifiers and wetting promoters, depending upon their concentration.

Kier boiling assistant → Kier boiling aids.

Kier boiling fastness Resistance of the coloration of printing on textiles in all processing states during wet finishing with diluted NaOH under pressure. The test instructions apply primarily for natural cellulosic fibres. Two processes are used, one with and the other without the addition of an agent for the prevention of undesired reduction effects. Performance (DIN 54 032): Treat test piece wound in raw cotton fabric of 10 fold weight for 4 h at 120°C and 98 100 Pa in the kier boiling liquor with a liquor ratio of 1 : 50 in the pressure boiler. Solution I: 4 ml/l NaOH 35.5%; Solution II: 4 ml/l NaOH 35.5% + 4 g/l m-sodium m-nitrobenzene sulphonate. Evaluation with grey scale.

Kier boiling of coloured wovens Kier boiling of cotton fabrics with vat dyed effect threads. Because dissolved out fibre additives have a reduced effect, there is the danger that the vat dye will be dissolved, i.e. the dye will bleed out. In order to prevent this an alkaline liquor oxidation agent is added: Peroxide, persulphate, sodium m-nitrobenzene sulphonate.

Kier boil-peroxide bleach Full white bleach for easy to bleach cotton. Can be used in iron boiler (cement coating) without repacking.

Kier decatizing For achieving dimensional stability, voluminosity, handle and sheen in wool and wool mix fabrics. These are rolled up with backcloths (satin or molleton fabric) and treated in an evacuated boiler with saturated steam. Remaining shrinkage value below 1%.

→ Decatizing plays a particular role in the finishing of woollen fabrics, because it is generally the last stage in the finishing process and gives the product the most important properties that determine its quality. The most important of the classical decatizing processes, apart from kier decatizing, are finish decatizing and press lustre decatizing. Under normal finishing conditions, finish and press lustre decatizing, in which the fabric lengths are usually steamed for 3–5 min at 100–110°C (operating steam pressure 0.5–6 bar) and then cooled by aspirating for 2–5 min, generally do not provide permanent effects; in particular the desired dimensional stability is usually lost in garment manufacture, in which several intensive ironing processes are performed. As a result the shape of the fabric, which can be used to describe not only its dimensions in length and breadth, but also the smooth and level condition of the surface of the product or a crease or pleat, cannot be permanently fixed by these decatizing processes. The intensity of treatment is therefore only sufficient for cohesive and temporary fixing effects, which can be lost again by a subsequent steam treatment or by the treatment of the product in water. Kier decatizing employs much more intensive temperature, moisture and time conditions, however this can only be carried out discontinuously depending upon its design.

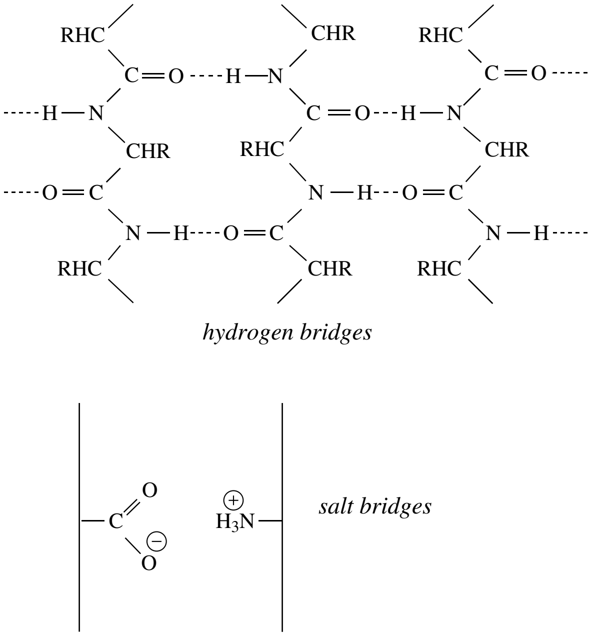


Fig. 1: Hydrogen and salt bridges re-oriented by steam decatizing.

Whereas only hydrogen bridges and salt bridges between the polypeptide chains of the wool are broken by the effect of the steam under the mild conditions of finish and press lustre decatizing (Fig. 1), it is assumed that in the harsher conditions of kier decatizing to a limited degree covalent cross bonds, the disulphide bonds of the cystine, will be hydrolytically split, thus achieving a permanent fixation.

$$\textcircled{W}-CH_2-S-S-CH_2-\textcircled{W} + H_2O$$

$$\longrightarrow \textcircled{W}-CH_2-SH + \textcircled{W}-CH_2-S-OH$$

According to the theory of the chemical mechanism of wool fixing, which is based upon the fundamental work of Speakman from 1936, it is precisely this breaking of the covalent disulphide bonds that represents the prerequisite for permanent fixing effects. Some subscribe to the opinion that the breaking of the covalent cross bond in the network of polypeptide chains merely makes it easier for deformation to occur, increases the mobility of the molecule chains and thus increases the number of hydrogen bridge bonds to be rearranged. An alternative theory is that the main contribution to dimensional stabilisation is the breaking and subsequent rearrangement of covalent cystine bonds (Fig. 2).

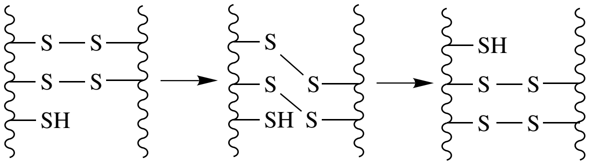


Fig. 2: Rearrangement of covalent cystine bridges by thiocatalysed disulphide exchange.

It is disadvantageous to the creation of a smooth production process that the kier decatizing stage must be inserted as a discontinuous intermediate stage in a series of continuous finishing processes. Commercial demands for higher production speeds, reduced personnel and energy costs and high quality products are resulting in efforts to invent new continuous decatizing machines that can be fully integrated into the production line, despite the favourable decatizing effects of discontinuous kier decatizing (Fig. 3).

The decatizing effects can be influenced by the following factors:

– pressure, which is generated by backcloth tension

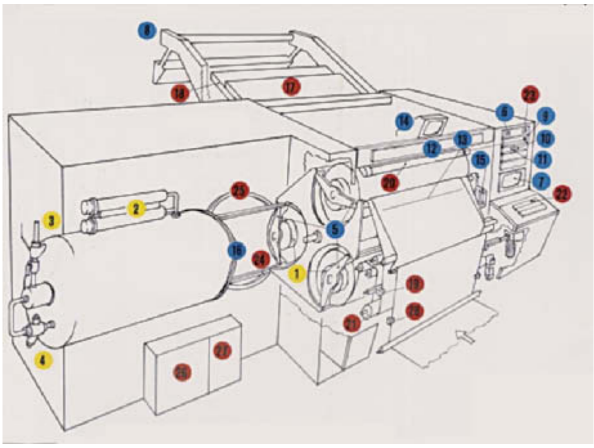


Fig. 3: Biela Shrunk "Suprema" kier decatizer.
1 = cylinder; 2 = steam control; 3 = cold cycle; 4 = starting cycle; 5 = truck; 6 + 7 + 9–14 = control and regulation functions; 8 = adjustable plaiting width; 15 + 16 = residual steam extraction; 17 = cold air blow-in; 18 = air extraction; 19 = automatic back grey guiding; 20 = presser roller; 21 = back grey drying calender; 22 = back grey tension control; 23 = presser roller control; 24 = automatic truck transport; 25 = door opening; 26 = electronic control panel; 27 = process control; 28 = automatic fabric guiding.

  and pressure from the pressure roller during the winding of the decatizing cylinder,
- steam pressure,
- treatment duration,
- fabric moisture during decatizing,
- cooling after decatizing,
- condition of the backcloth.

If these parameters act for an appropriate period they influence the surface pattern and the handle of the product according to the following rules:

a) Brilliant sheen (permanent) and solid handle: high steam pressure, medium steaming time, long cooling in tightly wound state, satin backcloth.
b) Brilliant sheen (permanent) and soft handle: high steam pressure, long steaming time, short cooling in less tightly wound state, satin backcloth.
c) Lower sheen (permanent) and solid handle: medium steam pressure, medium steaming time, long cooling in less tightly wound state, satin or molleton backcloth.
d) Low sheen (permanent) and soft handle: medium steam pressure, long steaming time, no cooling, winding with low tension, molleton backcloth.

Different manufacturers produce kier decatizing machines, the main differences being adjustable backcloth tension, diameter of the winding roller, winding system and boiler preparation, the possibility of changing the backcloth, capacity and steam flow direction. Structure and operation of a classical kier decatizing machine (Fig. 4): The undecatized material is passed via the high inlet, a material tensioner and several deflecting rollers via the run-in table and is wound on a tubular cylinder located in the decatizing boiler. After the boiler has been closed the programmed decatizing sequence begins. After treatment the boiler opens and the yarn package is aspirated. The material is fed to the delivery device via a conveyor belt. An additional cooling unit is installed under the conveyor belt.

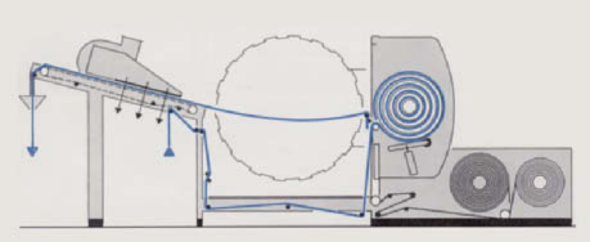


Fig. 4: Diagram of a Menschner/Kettling & Braun kier decatizing machine.

Lap formation (Fig. 5): Lap formation is critical for the quality of the decatized effect, because the fabric entering the lap is fixed in its existing state. The winding tension determines and alters the actual hardness of the lap, with pressure on the lower layers increasing as the number of layers increases; this creates a lap that is solid and hard at the bottom, whilst the outer layers are loose and soft. This gives rise to different decatizing effects at the start and end of the material. A variable pressure roller regulates the hardness of the batch, so that the pressure exerted rises as the diameter of the batch increases. This guarantees a constant winding hardness from the start to the end of the roll.

Decatizing boiler: The internal diameter of the boiler is in the range 900–1300 mm, as required. Automatic control of the decatizing programme promotes consistent material quality. Pressures of 1.5–3 bar are possible, the time can be set between 0–10 min. The steam flow direction can be set as outside to inside or inside to outside. The decatizing boiler can be filled via steam inlet valves. Saturated steam produces the best decatizing effect, superheated steam leads to the material drying out and yellowing and wet steam can lead to condensation marks. The deaeration of the boiler, i.e. filling with steam without the inclusion of air also takes place via steam inlet valves. After the decatizing process has finished the steam outlet valves open. The lid opens in two stages for pressure equalization. The decatizing boiler is surrounded by a pressure resistant wall, so that the intermediate area this creates acts as a steam storage container and heating jacket, and prevents steam from condensing on the inner walls of the boiler (condensation marks). At points where pipes or safety valves are welded on, draining of water is diverted via guiding plates to the lower part of the boiler. Steam should flow from outside to inside, because then the steam will already have expanded by the time it

Kier decatizing

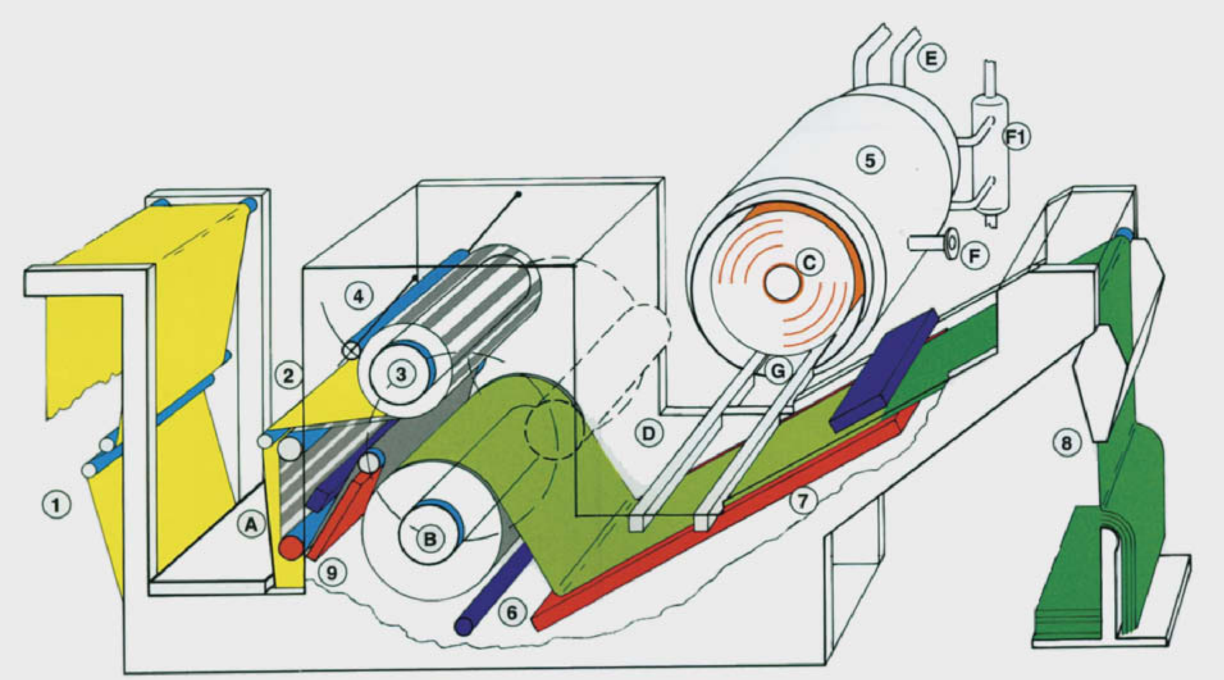


Fig. 5: TMT kier decatizer.
1 = automatic cloth centring device; 2 = perfect inspection of piece drawing-in; 3 = uniform winding of the cloth up to 100 m/min by means of d.c. motors with electronic speed and wrapper tension control; 4 = adjustable pressure roller; 5 = autoclave with innumerable vapour passages and types, Multiprogram System also with vacuum pump; 6 = automatic piece detaching and unloading at a synchronised velocity; 7 = thermal shock with a high stabilising power with multiple aspiration + blowing system; 8 = unloading of the batch on to a trestle or platform; 9 = satin moistening studied for high temperatures control of residual moist by means of a combined system aspirator + blower + calender roller; A = wrapper tension controlled by load cells (TMTSYS) and pressure of pressure roller are programmable and may be constant or variable during the winding-up phase. In the memory 100 different types of winding cycles may be stored; B = automatic wrapper centring by means of alternating axial movements (TMTSYS); C = special stainless anticondensate tube beams (TMTSYS) with min/max diameters studied for perfect quality and high production; D = only one trough carriage, less maintenance, no dripping from above, dirty and greasy parts are kept away from the cloth and the wrapper; E = autoclave, standard version, with 9 valves (inlet – relief – outlet – vacuum), all are configurable by means of Multiprogram system, adjustable vapour quantity, anticondensate labyrinth system (TMTSYS. In the memory 100 different vapour passages (xc), completely conceived by the user himself, may be stored; F = vapour treatment plant at the input with a series of containers, a reducing valve, collectors and by-passes (already fitted); F1 = vapour quality regulator; G = condensate aspiration from the beam by means of a vacuum pump; X = electric fittings centralised by PC and video terminal to supervise: – used programmes and parameters – illuminated diagram of autoclave cycle – a hundred messages for programmation and trouble locating Multiprogram System: basic and advanced software to use and programme (combining cycle xa and xc) over 100 programs to obtain permanent finish, PF 2000 effect; – data bank to record and certify every single treatment; – programmable meter counter, production counter, plaiter control monitor, winding levers and advanced feeding device are manufactured by TMT and can be fitted according to the requirements.

reaches the inner layers of the lap, which equalizes the differential pressure on the layers.

Extraction: The extraction of the steam trapped between the layers of the lap causes the steam to condense; the moisture produced is drawn into the material. Cooling the material once more on the conveyor belt prevents creases, breaks and folds during layering down. Extraction and cooling particularly influence the quality of material handle.

Backcloth: has several important functions:

- Separating the fabric layers to avoid imprinting,
- Transferring the surface pressure to decrease the thickness of the material,
- Leading the steam (heat and moisture) into and through the material,
- Gentle, fold free, low tension material transport during rolling and unrolling of the yarn package,
- Type and surface of the backcloth influence the handle and lustre (molleton for soft, voluminous handle and low lustre, satin for smooth handle and high lustre).

Problems: Faults may occur in the material during kier decatizing that are difficult or impossible to rectify. These include colour transition at the selvedge, caused by the backcloth being too narrow; thick areas of the material, foreign bodies or seams sewed with coarse thread, can press through the individual layers of the yarn package (regular imprints); differences in the decatizing effect may arise due to different yarn package pressure between inner and outer layers; decatizing folds caused by material entering the yarn package with folds. Excessive backcloth tension, excessive steam pressure and high residual acid content of carbonised material result in rapid wear to the backcloth (high operating costs). Other disadvantages are the discontinuous procedure and the use of direct steam, which can vary in quality.

History:

1960: Maschinenfabrik Gerhard Moers, Aachen, develops the first kier decatizing machine of the world (Fig. 6). This machine is delivered to Tuchfabrik Becker, Aachen-Soers.

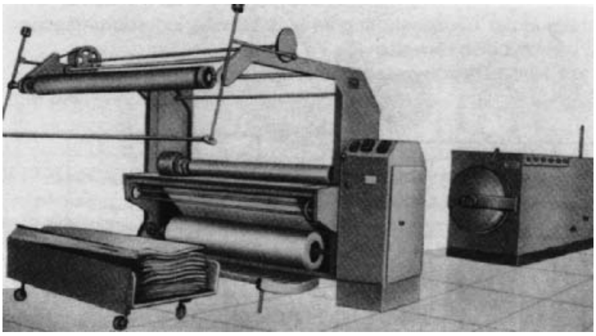


Fig. 6: First kier decatizer by Moers.

1961: A second similar machine is delivered to Textilingenieur-Schule, Aachen. In this machine with a diameter of 900 mm first experiments have been made with a cylinder diameter larger by 35% of the 100% vessel diameter (900 mm), i.e. cylinder diameter 315 mm.

From 1971 on: Vapermat 900 from Moers is successful (diameter 900 mm).

1973: Moers delivers the first machine with diameter 1000 mm and a cylinder diameter of 160 mm to Tuchfabrik Becker, where it is used for batches with 4 x 50 m wool fabric in molton wrapper. The machine is called Vapermat 1000 (Vapeur permanent automatique).

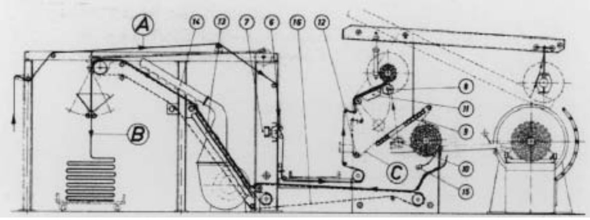


Fig. 7: Decoclav 1 from Kettling & Braun.

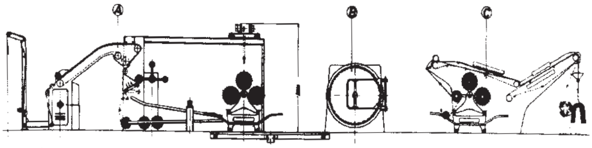


Fig. 8: Decoclav 3 from Kettling & Braun.

Mr Drabert develops on his way back from a visit to customers in South America in the plane back home the idea of Decoclav 1, built in the same year by Kettling & Braun (Fig. 7).

1975: Moers constructs a machine called Vapermat 1200 with a diameter of 1200 mm and a diameter of the cylinder of 160 mm. The machine is delivered to Tuchfabrik Becker, where it worked with batches of 6x50 m wool fabrics in molton wrapper.

At Kettling & Braun Mr Dieter Riedel constructs the Decoclav 3 (Fig. 8) which works with a star of three wound-up pieces being decatized at the same time in a vessel with a diameter of 1200 mm.

1979: At ITMA, Hannover, Moers shows the Vapermat 1200 with a cylinder of 450 mm diameter. At the same show Hemmer presents their first kier decatizer Permadec which works with a vessel diameter of 1000 mm and with vacuum inside the cylinder (diameter 300 mm) (Fig. 9).

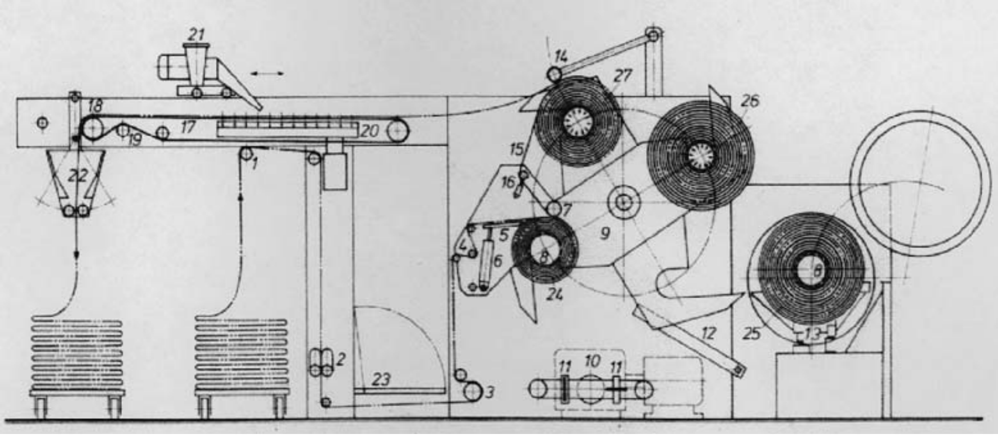


Fig. 9: Permadec (1979) from Hemmer.

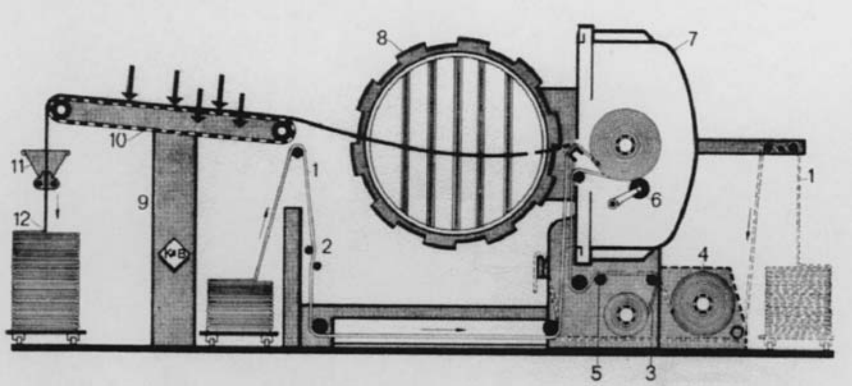


Fig. 10: Decoclav 2000 from Kettling & Braun.

1981: Mr Dieter Riedel at Drabert-Kettling & Braun, Minden, constructs the Decoclav 4 with a vessel diameter of 1300 mm. At the end of this year Draber, Kettling & Braun is sold to Menschner at Viersen-Dülken, where Decoclav 4 is built with a diameter of 1300 mm, but now called Decoclav - 8CL (from 1982 on).

Kettling & Braun presents the completely different system Decoclav 2000 (called "Bratpfanne") (Fig.10).

1982: Menschner built a very successful machine from 1982 on and sold it with 3 big versions to Tuchfabrik Becker as Decoclav 2200 (Fig. 11).

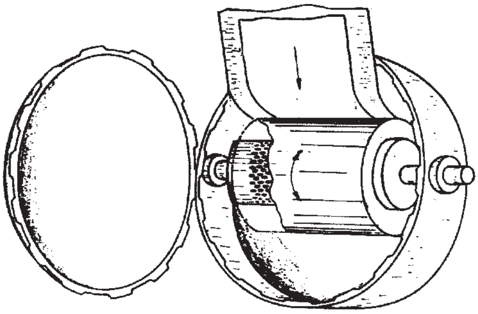


Fig. 11: Decoclav 2200 from Menschner.

Biella Shrunk presents the Cadet-System (Fig. 12) with

- autoclave diameter larger than 1000 mm,
- diameter of cylinder equal to 35% of vessel diameter,
- displacing element inside the cylinder.

Diameter of cylinder in Fig. 12:

type		diameter of cylinder (mm)	autoclav
I	(classic)	150	900
II		450	1040
III	(classic)	200	1040
IV		670	1300

Kier lining Treatment of pressure kiers and bleaching boilers with milk of lime, cement and water glass solution to prevent kier and bleach stains when the material touches unprotected boiler walls.

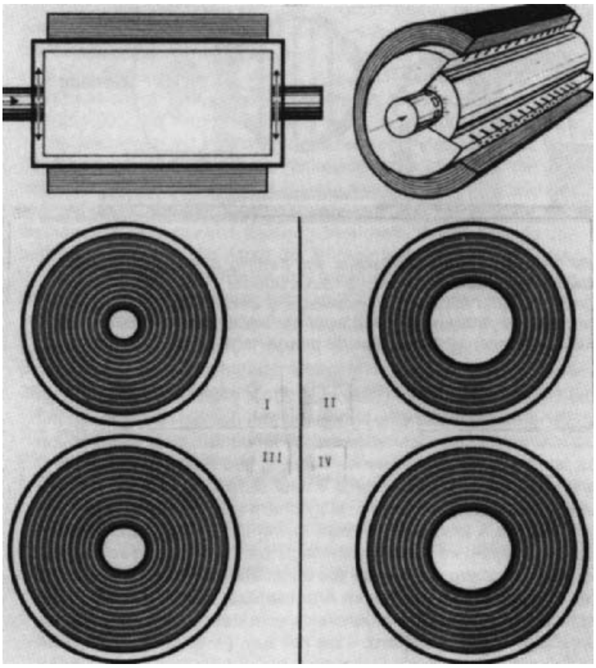


Fig. 12: Cadet-System from Biella Shrunk.

Kier stains arise due to unfavourable working conditions, such as hard, turbid water, poor, one-sided liquor circulation, inconsistent packing of the kier boiling material (channelling), wrong rinsing (cold instead of boiling hot), etc. This usually causes brownish deposits and uneven stains, which can only be removed by repeating the kier boiling or hot acid souring and boiling with sodium carbonate.

Kieselguhr (guhr, diatomaceous earth, infusorial earth, fossil meal, fossil dust), consists primarily of 70–90% amorphous silicic acid (SiO_2) and (raw kieselguhr) 3–12% water, is very fine grained, light (weight per litre 15–300 g) and usually light grey. Calcined kieselguhr is free from organic substances and water, a reddish (containing iron) or white powder; chemically very resistant, unburnable, heat and sound insulating, absorbent to fluids up to five times its weight. Consists of differently shaped, tiny silicic acid skeletons of prehistoric single cell algae (approx. 8000 types), extracted by open cast mining from large deposits (Lüneburg Heath; Lampoc/California, the largest deposit in the world). Individual frustules possess a huge number of very fine, normally air filled, grooves, hollows, capillaries etc., which explains their amazing lightness (1 cm^2 kieselguhr = over 1 billion diatomaceous shells). The unusually fine skeleton structure has an estimated diameter of just 0.1 μm. Such an extremely fine pored microstructure naturally favours the maximum possible filter activity in sewerage filters of contaminated organic solvents and in water filters. Even bacteria are retained (Berkefeld filter for water sterilization). To be suitable for use as a filter assistant, kieselguhr must possess a regular granulation and be fan sorted. Application: Heat (steam tubes, steam boilers) and sound insulation, packaging for irritating liquids (acid carboys, etc.); filter powder.

Kilim carpets Woven, bright, originally Turkish → Flat carpet with coarse wool weft. Sometimes with woven perforations, i.e. small open cracks on the border lines of the multi-coloured pattern. Used as floor carpet on thick felt underlay.

Kilo- (Gk.: chílioi = thousand), unit prefix for one thousand times = 10^3.

Kilogram (kg). 1 kg is the mass of the international kilogram prototype of a platinum-iridium body stored in the vicinity of Paris. → Mass.

K index,

I. Index in general use for characterizing a commercial grade of polyvinylchloride, calculated from its viscosity in solution and indicating its molecular weight. Polyvinylchloride with a K value of approximately 68–80 is usually used for coating.

II. Index used for the classification of basic (cationic) dyes with respect to their rate of strike (→ Association index K).

III. Index used in association with machines for measuring fabric length because of the effect on standardized length measurement due to the stretching of the material. The value is derived from the elastic characteristics of the fabric being measured (which are determined using prescribed apparatus) in combination with the effect of the tension applied during mechanical measurement (see also → K indices length measurement):

$$K = E \cdot G_A \left(1 + \frac{F'_M}{k\,G_A}\right)$$

E = extension of a sample of fabric subjected to a force of 10 N/m for every per metre width;
G_A = weight applied to the fabric per unit area expressed in N/m^2;
F'_M = force per metre width of fabric (N/m) exerted on the material by the machine during the measuring process;
k = proportional constant per unit length.

K indices length measurement For commercial purposes special machines are used to determine the length of textiles, cloth measuring machines which provide low-cost continuous measurement of material while the fabric remains in motion. In accordance with calibration regulation, such a machine must be calibrated so that the lengths it measures are accurate to within ± 0.3%. Up until the end of the fifties, during which time textiles were predominantly made from unyielding and thus low-stretch materials, this requirement could be met without difficulty by relatively simple machines. However, the development of elastic fibres and the increased prevalence of knitted goods has resulted in liability to error often exceeding the permitted calibration error range. The principle cause was the unintentional stretching of the textile fabric during measurement on account of the tension applied. In consequence, conventional measuring machines were no longer suitable for all types of material; new machines with tension compensating systems had to be developed appropriate to the → K index of stretch textiles. The K value was developed as an index for describing the elastic characteristics of material as displayed during the measuring process. By definition, the K index is an indicator of the dimensional error to be expected due to stretching during the measuring process, with K rising in proportion to the susceptibility to stretching of the material. As a result, the greater the K index of a material, the more extensive the technical requirement imposed on the machine with respect to tension compensating mechanisms which reduce the tension and thus the resulting extension at the point of measurement.

For this reason, machines for the measurement of textiles have, since 1978, been divided into four groups according to the K value of the materials which they may measure. The group code indicates which materials (K indices) may be measured using the machine. Machines of Group I, which are suitable for unyielding and low-stretch materials of low K value, possess limited tension compensating mechanisms, whereas Group IV machines must be equipped with a number of complex tension compensating mechanisms in order to accommodate high-stretch material with a high K value. The need for tension compensating mechanisms is independent of the method of measurement. However, it is of importance that the resistance to movement in the measuring device should not additionally stretch the material at the point of contact. Even in the case of newly developed techniques, the aim of which is to replace the inertia of the measuring wheel by a remote sensing device (e.g. laser Doppler effect, Correvit principle), the material being measured must at all times be transported past the point of measurement in a relaxed, i.e. in a minimally stretched state. In other words, remote measuring techniques cannot replace tension compensating mechanisms (source Mann and Zervos).

Kinetic equation in fibre loading Important process parameters regarding the mass transfer between textile and liquor can be determined by kinetic analyses. These parameters are the mass transfer constants and the adsorption isotherms in relation to process variables such as temperature, initial concentration, recipe and flow. For example, the diffusion of dispersion dyes in the fibre represents the slowest link in the reaction chain, and therefore determines the dyeing speed or the → Dyeing kinetics of the dyeing process. There is a formula based upon → Fick's equation which can be used to determine the → Diffusion coefficient during the initial phase of the dyeing process in the simplest manner:

$$\frac{c_t}{c_\infty} = 4\sqrt{\frac{D \cdot t}{\pi \cdot r^2}}$$

c_1 = dye on the fibre at time t,
c_∞ = dye on the fibre in the equilibrium state,
D = diffusion coefficient,
r = radius of the fibre.

The above formula simplifies to:

$$c_t = K \cdot \sqrt{t}$$

The mass transfer between the textile and the liquor can often be described in formal kinetic terms as a reaction of the first order, in which the transfer speed of the surface of the textile is proportional to the concentration of the mass to be transferred.

$$\frac{dc}{dt} = \beta\,(c_\infty - c)$$

$$\beta = \frac{D}{d}\,O$$

Solution within the boundaries t = 0, c = 0 and t, c:

$$\ln\left(1 - \frac{c}{c_\infty}\right) = -\beta\, t$$

c = momentary concentration on the fibre,
c_∞ = equilibrium concentration on the fibre,
β = mass transfer coefficient,
D = diffusion coefficient,
d = diffusion boundary layer thickness,
O = surface.

Kinetics Study of movement due to forces. Field of physical chemistry, which attempts to explain the macroscopically observed time variable properties and regularities of isolated or interacting substances based upon assumptions about the behaviour of free atoms and molecules. → Dyeing kinetics.

Kinetics in heterogeneous systems The kinetics of a process is related to the speed at which a process takes place, for example in solution, i.e. in a homogeneous system. A heterogeneous system is further complicated by phase limit problems and flow influences. Sizes, for example, demonstrate a characteristic, temperature dependent swelling behaviour, which can cause the thickness of the size film to multiply before the actual dissolution. This gives rise to the danger, particularly for starch sizes, of the fabric being loaded and thus the efficiency of the detergent being reduced. For a starch film to swell it is necessary for the intramolecular and intermolecular interactions of the amyloses and amylopectins to be dissolved until water absorption, and thus an increase in volume, is possible. If the swelling is a necessary step, which determines the speed of the dissolution process, then all structural units of the starch polymer must be solvated from the solvent, only then does solubility exist. Given a constant liquor flow rate a size film will be dissolved more quickly the thinner it is. The dissolution of the swollen size from the fabric can be described as a diffusion controlled process. In order to avoid long dissolution times for the polymers it is necessary to accelerate material transport in the diffusion boundary layer by turbulence. Intensively flowing past the fabric guarantees that the concentrated, highly viscose size solution is rapidly and completely mixed with the washing liquor on the fibre.

Desizing can be represented as a first order process, i.e. the reaction speed is not only dependent upon temperature, but also upon the concentration of the initial material. Because in this case, the speed v has a different magnitude at every point in time, this is a differential change. The differential quotient in general form is:

$$v = -\frac{d[A]}{d[t]} = k[A]$$

The quotient sign is positive if the concentration is decreasing and negative if it is increasing. The reaction speed is proportional to the concentration of the educt, the proportionality factor is termed speed constant k. For desizing kinetics the speed constant, the so-called mass transfer coefficient β, is determined from the change of the size mass m on the material over time:

$$-\frac{dm}{dt} = \beta \cdot O \cdot m \qquad \frac{dm}{dt} = -\beta^* \cdot m$$

Rearranging gives:

$$\frac{dm}{m} = -\beta^* \cdot dt$$

Solving the differential equation within the boundaries $t = 0$, $m = m_O$ and t, m:

$$\int_{m_O}^{m} \frac{dm}{m} = -\beta^* \int_{0}^{t} dt$$

$$\ln \frac{m}{m_O} = -\beta^* \cdot t$$

Where $m = m_O - m_B$ we get:

$$\ln \left(\frac{m_O - m_B}{m_O} \right) = -\beta^* \cdot t$$

$$\ln \left(1 - \frac{m_B}{m_O} \right) = -\beta^* \cdot t$$

t = time
β = mass transfer coefficient
O = surface of the fabric
β^* = the sum of β and O,
m = momentary size mass,
m_O = size mass on raw fabric,
m_B = size mass in the liquor.

On the assumption that the size mass in the bath reaches the initial size mass m_O at the time $t \rightarrow \infty$, we can also write the expression $m_{B\infty}$ for m_O. If we relate the size mass to a certain volume then we can replace m in the last equation with c.

$$\ln \left(1 - \frac{c_B}{c_O} \right) = -\beta^* \cdot t$$

If we plot the natural logarithm in the bracketed expression as a function of time then, under the condition of a first order reaction, this yields a straight line, the gradient of which is the mass transfer coefficient β^* (according to Heidemann).

Kinetics in homogeneous systems In order to find the speed constant of a reaction spectrophotometrically tracked in the UV or visible wavelength range, the extinction/time value pairs must be matched to a suitable function. The form of the function depends upon the order of the reaction being considered. The curve is based upon the "method of the least error squares". Extinction/time curves have a linear path,

a) if it is a reaction of zero order or
b) if a reaction of a higher order is being investigated using the "initial speed method".

The relationship between → Extinction and time can be described using an equation (Fig., a).

$$E = (E_A^0 - E_B^0)\frac{1 - kt}{c_A^0} + E_B^0$$

$$y = a \cdot x + b$$

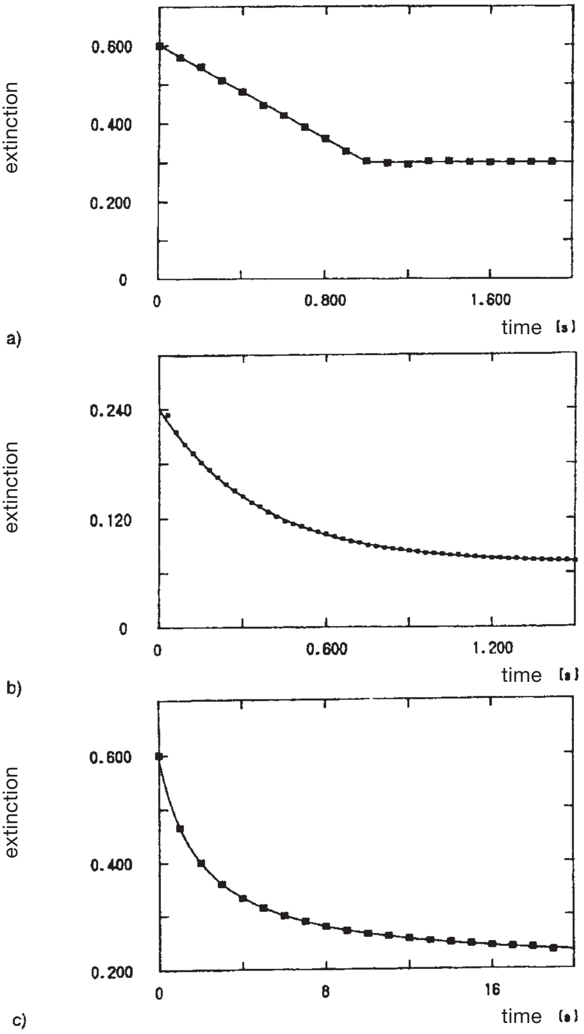


Fig.: Typical curve for a reaction a) zero order; b) 1st order; c) 2nd order, measured by extinction of the colour imparting component.

An exponential curve is obtained for a reaction of the 1st order or for a reaction that is being investigated under pseudo 1st order conditions (Fig., b).

$$E = (E_A^0 - E_B^0)\exp(-k_{obs}t) + E_B^0$$

$$y = a \cdot \exp(-cx) + b$$

A hyperbolic curve is obtained for a reaction of the 2nd order or for a reaction that is being investigated under stochiometric conditions (Fig., c).

$$E = \frac{(E_A^0 - E_B^0)}{1 + c_A^0\, kt} + E_B^0$$

$$y = \frac{a}{1 + cx} + b$$

The concept of keeping the reaction speed as low as possible, i.e. also obtaining as simple a measuring signal as possible (extinction/time curve) leads to the use of the "excess method". In this there is a deficit of the colour imparting reaction partner in comparison to all other reactands. This reduces the order of the reaction to that in the speed law with the deficit partners. In most cases this yields a reaction path of the 1st order. This is also known as a pseudo 1st order reaction. Getting a pseudo 0 order or a pseudo 2nd order is a major exception. If this method is not applicable, then the "initial reaction speed method" or the stochiometric conversion must be used. In the first case this yields a linear path of the extinction/time curve, in the second case a hyperbolic path generally results.

King bobbin One-sided → Conical packages with precision cross winding.

Kinking effect with textured yarns Tendency of a yarn textured using the torsion procedure to regain its original twist.

Kiss dyeing process Dyeing liquor application onto the fibre tips or on the back, often for carpet material.

Kiss print Special printing technique used in the rotary screen printing of carpets. Carpet transport on a needled backcloth which can be adjusted by electric push-button control. By controlling the height between back cloth and template a tunnel is formed, the height and thickness of which correspond with those of the carpet. Because this does not alter the position of the pile, a sharp printing edge is obtained. – Manuf.: P. Zimmer.

Kiss roll (lick roller) → Cover roller.

Km → Camel hair, → Textile fibre symbols, according to DIN 60 001 till 1988, from 1991 → WK.

Knife-coating principle The knife application unit (spreader) consists of the doctor blade holder, the doctor blade with lateral limit blocks and possibly a doctor blade liner. The coating substance is applied to the doctor blade, which is set at a defined distance between knife and fabric using the doctor blade holder. In continuous coating the base material moves under the fixed doctor blade. This movement exerts a shear force on the paste, forcing it to flow. The shear force applied can be varied by varying the working speed, the doctor blade profile and the tilt angle of the blade, which can also be varied by adjusting the doctor blade holder. Furthermore, the viscosity of the coating substance also has an effect. The paste is spread by the movement of the base material, and it should be noted that, when applied correctly, the paste rolls in front of the knife. The coating thickness is primarily determined by the distance from the knife to the fabric. Furthermore it is also determined by the tilt angle and the heel, which is the part of the coating knife, which is applied to the textile substrate. The higher the desired application quantity, the broader the knife heel selected and the lower the doctor blade, i.e. the greater the doctor blade angle, the lower the paste application.

Application is further varied by altering the working speed and tension of the base material. It is clear that numerous parameters interact during doctoring, so it is necessary to harmonize these parameters to achieve a satisfactory coating.

The coating thickness depends upon:

- doctoring speed,
- doctor blade tilt angle,
- doctor blade profile (heel),
- doctor blade distance,
- base material tension,
- paste viscosity.

For the application of the paste the spreader can be equipped with various doctor blade systems, depending upon the item. These differ in the shape of the coating knife and the type of support. In addition to the guiding of the textile during the coating process, i.e. the type of support, we differentiate between:

- air blade,
- knife on blanket coater,
- knife over roll coater.

The coaters of modern coating plants are generally variably equipped.

I. Air blade: In an air blade system the doctor blade acts directly onto the material without an underlay (Fig. 1). The carrier belt is drawn via two small tables or movable rollers. A supporting blade directly in front of the doctor blade aids even application in an air blade with roller guides.

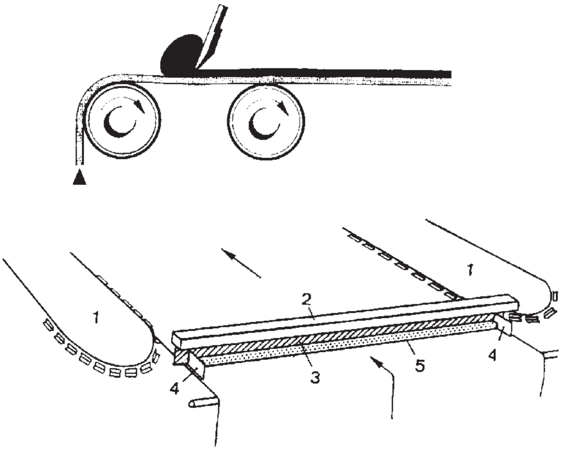


Fig. 1: Air knife principle.
Top: Air knife. Below: Air knife located at take-up on stenter frame (1 = stenter chains; 2 = knife mounting; 3 = air knife; 4 = cheek blades; 5 = coating paste).

The air blade makes it possible to achieve a low application quantity and is particularly suitable for dense, tightly stretched fabrics. It is often used for the preparation of light fabrics, when the coating substance should not penetrate too far into the fabric. These thin coatings are particularly favoured by the use of doctor blades without a marked heel. These are usually narrow, rounded off pointed knives with a width of 1–3 mm. The application weight is dependent upon the tension and speed of the carrier belt. It is 10–20 g/m^2. The air blade achieves satisfactory results in relatively low cost plants on stable, thin textile materials, but also has disadvantages. These are:

- limitation of the substrate used due to high material tension;
- shaving effect, which means that soiling is possible due to loose threads and fibres;
- tension in the substrate and flow characteristics of the paste cause inconsistent material quality, which is difficult to control by corrective machine settings.

II. Knife on blanket coater: The doctor blade works against a doctor blade underlay, which is an endless rubber belt that runs over driven rollers and is fitted with a support roller just in front of, behind or below the blade (Fig. 2).

The knife on blanket coater is suitable for thin or open carriers, which are to be coated without bleeding through and are unsuited for coating using the air blade system due to low stability. It is particularly commonly used for the coating of uneven substrates, e.g. roughened cotton fabric. Thin coats with a uniform thickness can be applied, particularly if the support roller is located under the blade, whilst the other positions permit a more elastic guidance.

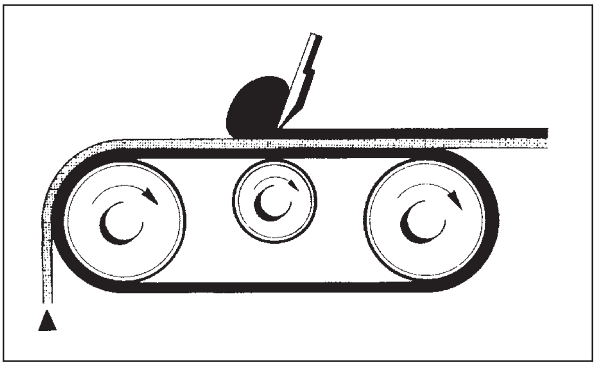


Fig. 2: Rubber sheet knife.

The paste application can also be varied by the pressure of the rubber blanket against the material and by the tilt angle of the doctor blade. For precoatings, narrow, rounded coating blades with a width of 1–3 mm are preferred. Otherwise for higher coats doctor blades with a wider, flatter heel of 3–20 mm are used. These shoe blades have a sharply angled undercut on the back, which is designed to prevent drops of coating material which have gathered on the back from being pushed off and spoiling the coating.

The drawback of this process lies in the rubber blanket condition. Firstly, intensive maintenance is necessary to control swelling or rubbing of the blanket. Secondly, the application method is difficult to control due to the varying forces on the rubber blanket, which result from unevenness of the substrate and the paste. Certain irregularities can be attributed to the varying hardness of the rubber blanket in places.

III. Knife over roll coater: A roller, over which the carrier is fed from below, serves as the doctor blade underlay in this method (Fig. 3). The knife over roll

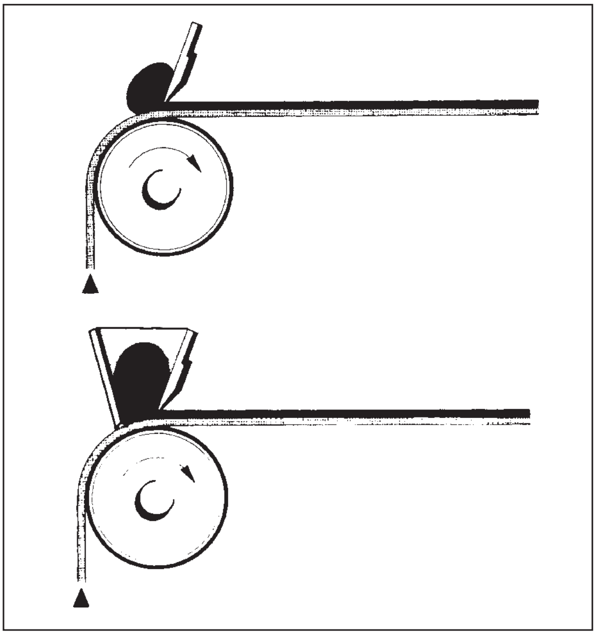


Fig. 3: Roller knife compared to trough knife.

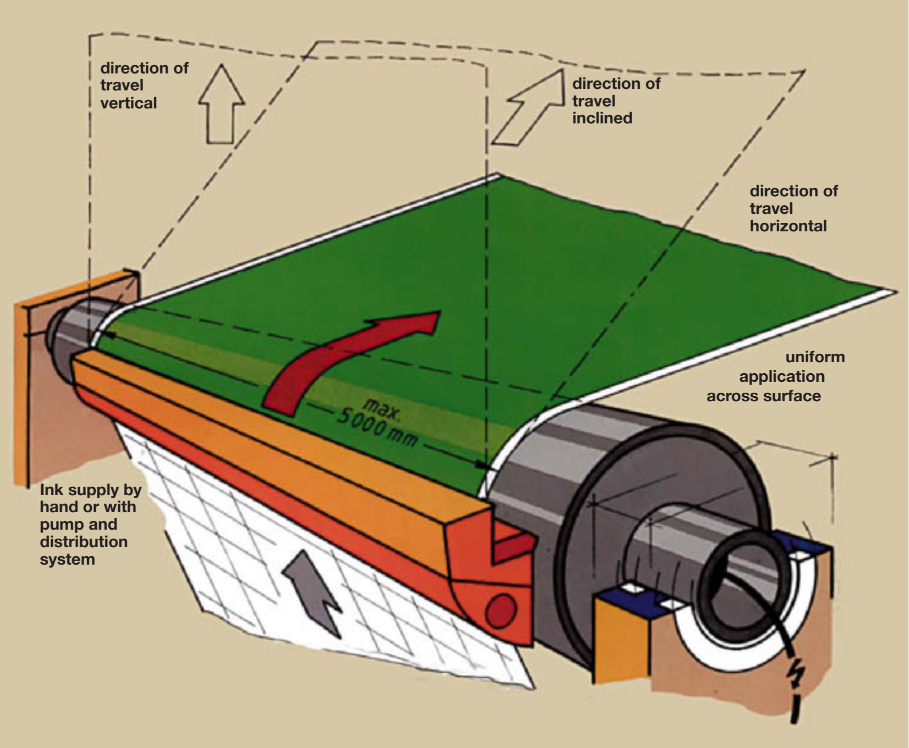


Fig. 4: Magnetic roller knife by Zimmer (Magnoroll '92).

coater is particularly suitable for high coating weights, as low coating quantities and less dense carriers lead to the paste bleeding through. High precision coatings can be achieved, as the material tension and paste viscosity have only a slight influence. The coating thickness is determined by the distance between roller and doctor blade. If necessary the penetration can be controlled by this doctor blade position. Furthermore, the application quantity is also dependent upon the width of the heel. Thick layers can be achieved with a wide heel.

Rubber or steel rollers are used with the knife over roll coater. Both achieve good results with low investment. The rubber roller is suited for uneven fabrics, but can also be used for smooth material. Depending upon the coating knife used and the hardness of the rubber roller, the coating effect is similar to that of the knife on blanket coater. In order to guarantee a uniform distance between substrate and heel, the knife is matched to the roller surface. If the doctor blade is precisely ground on the roller, great coating precision can be achieved with smooth, even surfaces. However, the roller encourages an undesired penetration of the coating substance, so preparation must take place. Thin coatings are difficult to control. Uneven points in the carrier lead to uncoated points or damage to the textile. The evenness of the coating can also be impaired by the doctor blade deflecting if high thrust forces are exerted by highly viscose pastes in front of the doctor blade. Therefore, magnet-roll doctor blades are recommended for full surface coatings over large working widths (Fig. 4).

Knife-coat machine → Coating machine.

Knife-on-blanket coating → Doctor blade for coating and laminating, which is supported on an endless rubber blanket.

Knifing Carpets with polyacrylonitrile or polyamide cut pile are drawn under a doctor blade to align the pile in warmed state.

Knit-deknit method (Whitaker process), a knit-pressure-fixation-rewinding process for the texturizing of yarns (similar crinkle). → Space dyeing.

Knitgoods finishing The trend towards continuous treatment is becoming more pronounced. Finishing lines for tubular knitgoods are made up of a squeezing device, horizontal dryer and high performance calender. The Fig. 1 shows typical wet finishing lines for knitgoods and Fig. 2 typical dry finishing.

Knitgoods, pretreatment A specialized technology has been created for the finishing of knitgoods, which takes into account the high two dimensional elasticity of knitgoods by appropriate modifications to existing machines. Knitgoods are finished in tubular (Figs. 1 and 2) or open-width (Fig. 3) form (piece goods) and as manufactured items of clothing. Pretreatments: Washing, bleaching, optical brightening, fixing, mercerizing, shrinking.

I. Cotton: Treatment of large batches discontinuously in hank form (pack system bleaching) or continuously in open-width form either using immersion aggregates or the impregnation steam method.

II. Synthetics: Most synthetic materials are sensitive

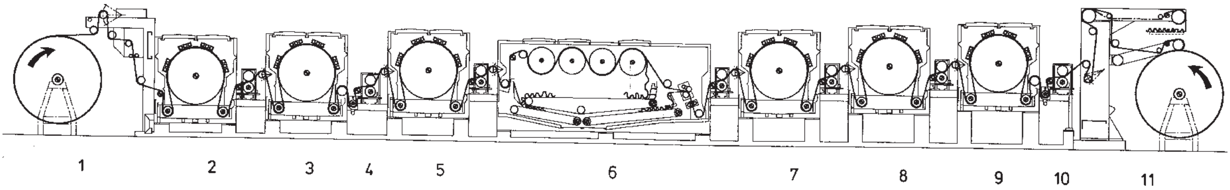


Fig. 1: Product line and functions schematic of the pre and post treatment Trikoflex 2000 facility (Kleinewefers KTM). 1, 11 = unrolling and rolling; 2, 3 = rinsing; 4, 10 = cooling; 5 = impregnating; 6 = immersion; 7, 8, 9 = rinsing.

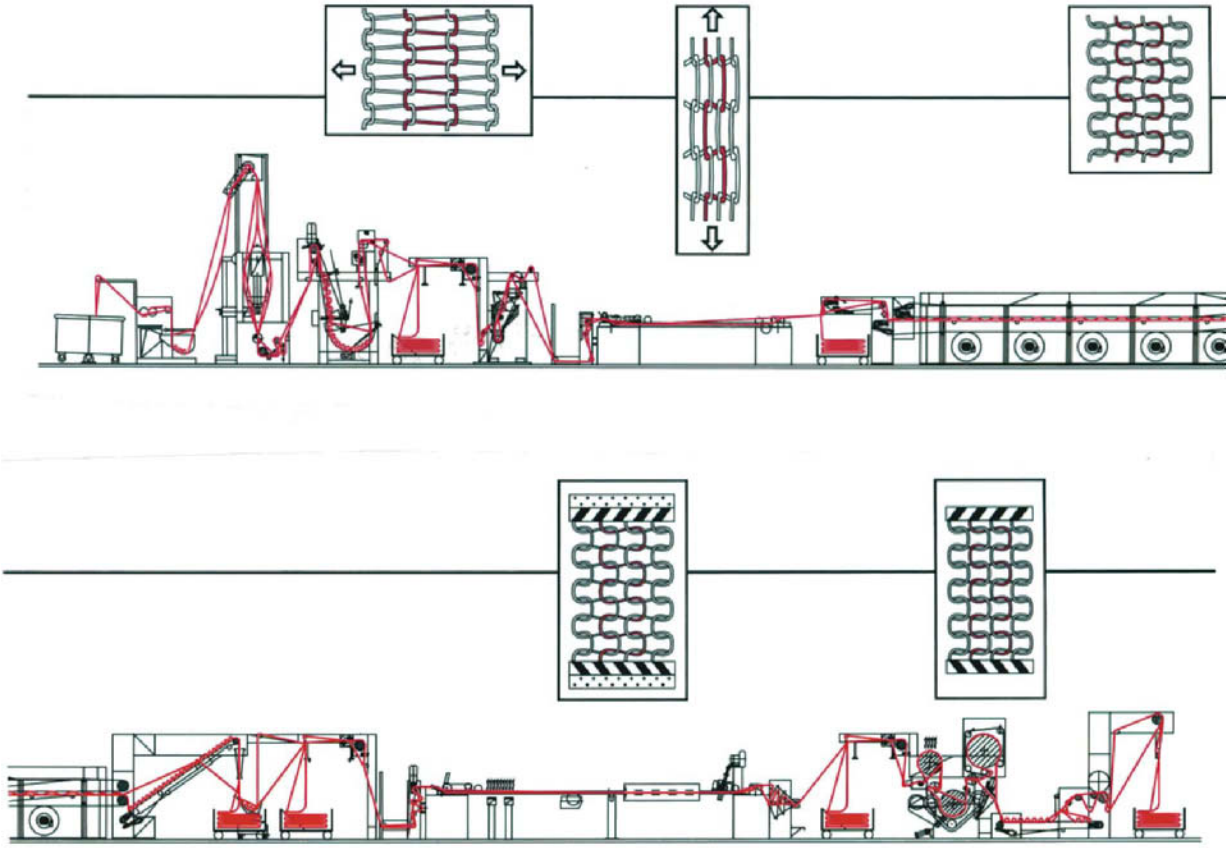


Fig. 2: Knitwear finishing line by Monforts.

to deformation. Raw material should therefore be stored rolled, and impact on the material must not be too high during finishing. Tubular knitgood qualities must be cut and rolled. Even less sensitive synthetics can only be cut after washing. Solvent washing is also used for the prewashing of knitgoods made of synthetic fibres.

a) Polyamide: Depending upon preparation, material can be fixed raw. However, if there is a danger of sticking, then washing takes place first. Some qualities can be cleaned in the dyebath; in this case thermofixation takes place after dyeing.

b) Polyacrylonitrile: Thermofixation not necessary. Washing at max. 60°C. For subsequent rinsing the temperature is reduced slowly, otherwise rope creases are fixed.

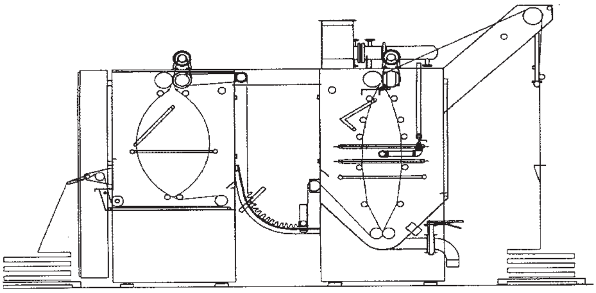


Fig. 1: Hydrosetting of Lycra-containing tubular cotton knitwear on an “Aquarius WEE 1.4” using Miltopan GB as abrasioning Zeolith-silicate.

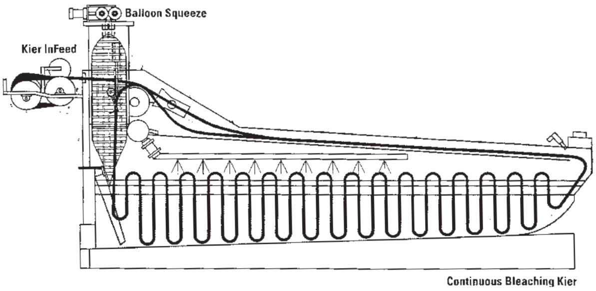


Fig. 2: Continuous bleaching kier from Jemco for tubular knit.

c) Polyester: These qualities are mainly produced from texturized yarns. Tubular knitgoods are cut, washed open-width, relaxed, dried and thermset.

d) Elastane: These qualities should not be stored for long periods (uneven shrinkage). Tubular knitgoods should be cut. First, complete deshrinking is necessary, which takes place on steaming tables or in hot water depending upon the material. Shrinking can also take place on carrying strap-stenter with max. advance. Then it is washed, dried and fixed on the stenter.

Knitgoods, problems in finishing Due to their constructive elements, knitgoods are characterized by high elasticity and always try to return to the most energetically favourable form. However, intermediate stages can also be temporarily fixed (Fig. 1), and thus the main problem of knitgood finishing is working without tension.

The concept of the relaxed structure can be described mathematically by rearranging the Munden's equations. Equations for the classical structure theory of knitgoods:

row density (rows/cm) $RD = u_{rd}/lz$

wale density (wales/cm) $SD = u_{sd}/lz$

stitch density (stitches/cm) $MD = RD \cdot SD$

fabric weight (g/m²) $Ag = (0.1 \cdot u_{md} \cdot T)\, lz$

knit width $$B = \frac{(N \cdot lz)}{(N_{ZB} \cdot u_{sd})} = \frac{N}{SD}$$

stitch form factor $$FF = \frac{RD}{SD} = \frac{u_{rd}}{u_{sd}}$$

density factor (tex $^{1}/2$/cm) $$K = N_Z \sqrt{\frac{T}{lz}}$$

u = weave independent correction factor, e.g. for a right-left material: $u_{rd} = 5.7$; $u_{sd} = 4.1$; $u_{md} = 23.5$;
N = total number of needles,
N_Z = number of needles of a structure cell,
N_{ZB} = number of needles of a structure cell width,
T = yarn fineness in tex,
lz = stitch length, thread length of the structure cell in cm.

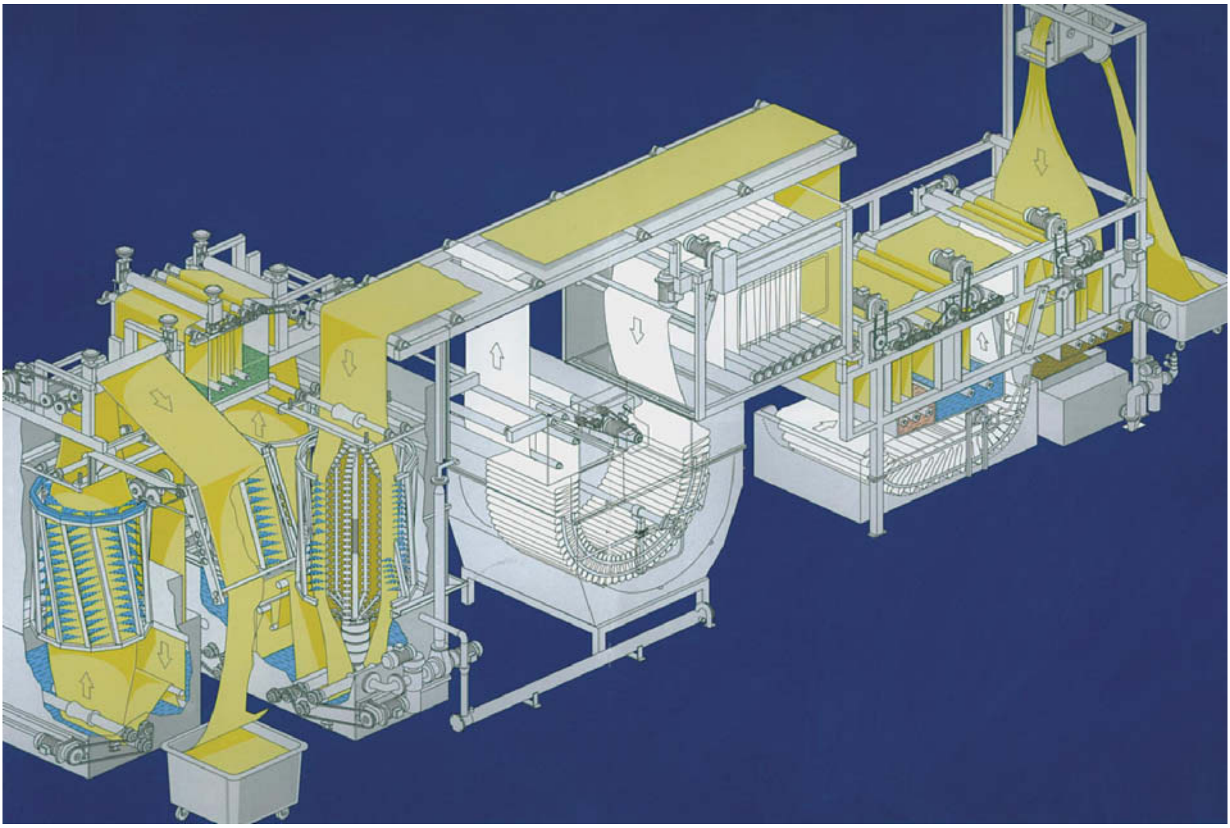


Fig. 3: Eco combine-pretreatment unit form Dornier for tubular cotton knitwear.

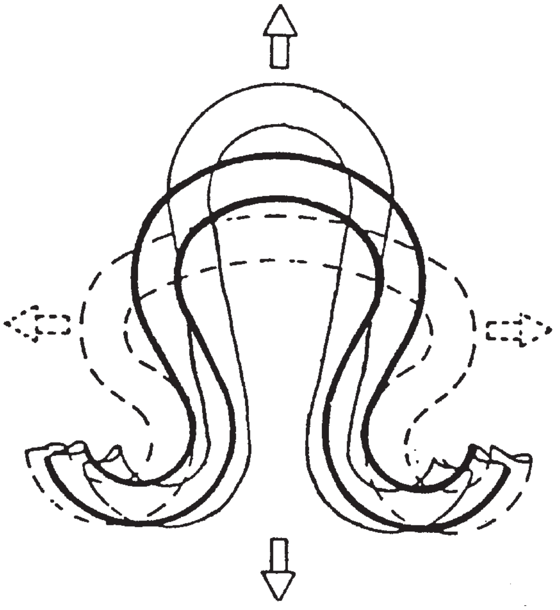


Fig. 1: *The configuration of a loop under differing conditions of tension.*

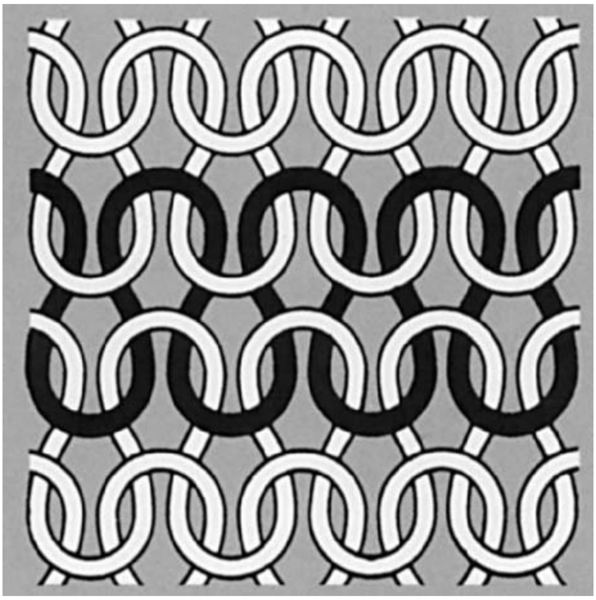


Fig. 2: *Knitgoods in a relaxed state.*

These equations include the following conclusions:

1. In the manufacture of knitgoods the relaxed stitch density MD is determined by the set stitch length.
2. The relaxed knitgood width B is determined by the distance of the stitch wale and then by the stitch length and the number of needles of the machine.
3. The relaxed fabric weight Ag is proportional to the ratio of yarn fineness and the stitch length.
4. The stitch form factor FF reflects the relationship between wale density and row density. The most stable RL material has a stitch form factor of 1.3.

$$FF = \frac{RD}{SD} = \frac{u_{rd}}{u_{sd}} = 1{,}3$$

It is clear that the basic dimensions of knitters are set.

Cotton has a small elastic range in comparison with other fibres. If a hosiery or knitted fabric made of cotton is loaded beyond its elastic range, then the knitgood is no longer able, despite constructively determined elasticity, to return to the stable state: it takes on a permanent expansion. If repeatedly stretched with incrementally increasing power, the value of permanent expansion increases. The more stretchable the knitting links, the more sensitive the material is to deformation (Fig. 2–4). Cotton knitgoods are not able to reverse a deformation by their own power. Knit dimensions are determined by the selected knit conditions, primarily the stitch length. It should always be ensured that the stitch length remains constant. This should be ensured:

a) by the use of row length measuring instruments;
b) with the aid of a suitable thread regulating wheel.

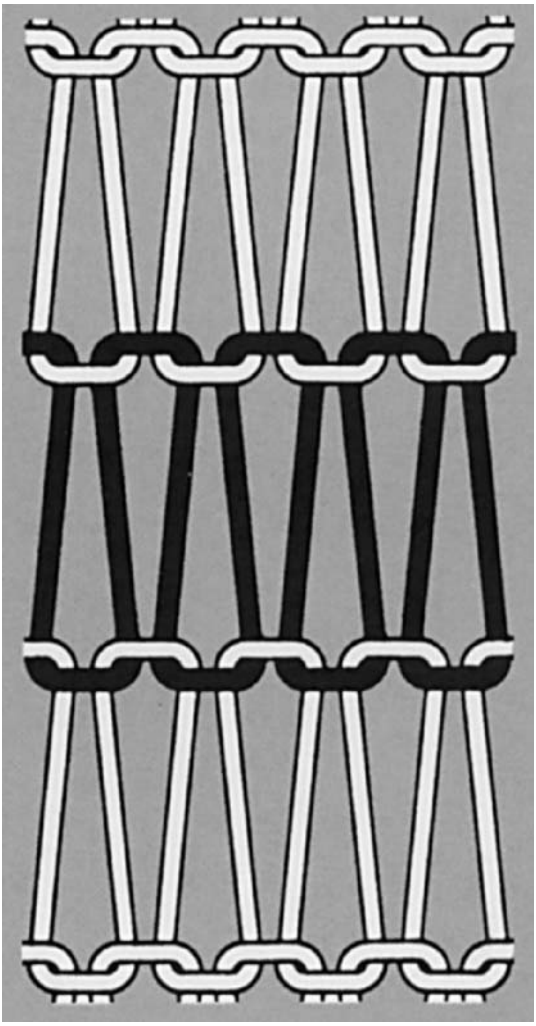


Fig. 3: *Knitgoods subjected to longitudinal tension.*

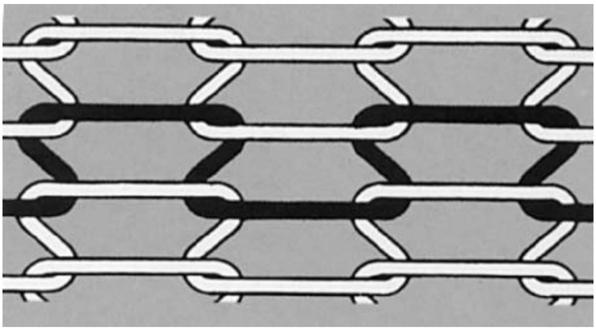


Fig. 4: Knitgoods subjected to lateral tension.

These thread applicators have the task of feeding the yarn to the needle, at an adjustable, constant speed, so that no irregularities occur in the knit pattern. The stitch length thus remains constant;

c) by consistent, constant setting of the feed section.

In order to facilitate a strike-off of the stitch, a certain draw off strength must be maintained. It is not possible to give the stitch its most energetically favourable form at this stage. However, the draw off strength must be increased

- the more systems are located around a knitting machine. Rows of stitches are produced in rapid succession and must be rapidly and safely transported downwards;
- by increasing production speeds, in association with increased centrifugal force,
- due to the processing of raw, poorly waxed yarn.

If hosiery that has been deformed by high draw off tension wound on a roll, then the material has no possibility of decreasing this shrinkage potential. To permit dry relaxation to take place, where possible the knitgoods should be taken off or left in an unwound state. If the knitgoods are subject to a tension free wet treatment in deformed state, then the stitches try to achieve their most energetically favourable state, i.e. the circular stitch. It tends towards the state of lowest bending energy; this means that the internal forces of the stitch do not bring about any change to the stitch shape. After the shrinking, the released volume around the fibre means that fibre movements are only possible if the frictional forces caused by mechanical effects, in particular tumbling or the addition of a lubricant can be reduced. If there is full swelling, the knitgood construction and thus the tension present is blocked, preventing full relaxation. Repeated swelling and shrinking or mechanical reversed loadings during wet treatment cause the latent tensions in dense yarn and hosiery areas continues to break down until all fibres have the opportunity to relax.

Fibre migration occurs due to the relaxed fibres interlocking and sliding into one another, which also increases the cross section of the yarn. The material shrinkage continues until the adjoining thread compounds are resting on each other. In theory the swelling shrinkage is fully reversible, however friction forces and the fibre migration that has already taken place impede the return of the material into the original dimension. The latter process is called progressive shrinkage and is evident after the release of the residual shrinkage. The material specific characteristic value of shrinkage must be carefully recorded and checked in the individual production stages. In the final finishing of cotton knitgoods the determination of the shrinkage potential is essential, because the finisher must know the values of dimensional change for the necessary shrinkage stabilisation and for machine settings.

The final check must incorporate a verification of whether the shrinkage present at the start has been compensated by the shrinking process. Basically, cotton knitgoods possess insufficient wet stability. During bleaching, dyeing and washing the following basic deformation problems occur:

- Due to its high water absorption capacity a cotton material is capable of increasing its own weight by several times. As a result it is clear that the material suffers stretching just by loose hanging.
- When the warp knitted fabric is in the dyeing or bleaching liquor then movement of the material and possibly also liquor circulation is necessary; the forces that occur have a negative effect on the dimensional stability of the knitgoods.

The dimensional changes that occur due to loading are dependent upon the method, but the order of magnitude of the stretching is not. There are various machines and methods, which can be termed low or high drawing. It is up to the finisher to decide which quality requirements he wants to meet and which techniques are to be used (discontinuous process in comparison to continuous systems, such as for example hydro-extraction by centrifuge instead of squeezing). Wet finishing is thus responsible for the increasing and decreasing of the shrinkage potential. In order to keep this to an acceptable level, the lowest possible tension and drawing should be used during bleaching and dyeing and in particular during work processes such as wet folding and expanding.

The drying process can contribute towards compensating for a proportion of the shrinkage potential. For this to occur the material must be given the opportunity of relaxing freely by tensionless material feed or dwelling. The factors of heat, moisture and mechanics are necessary for the shrinking of cotton knitgoods. If a swollen cotton material, which has an excess moisture of at least 30 %, has the moisture extracted by heat, as occurs during drying, then the deswelling gives rise to hollows in the knit structure. Friction at the binding points can be overcome by mechanical effects, e.g. by shaking devices or fans; the material is able to compact its stitch structure and thus to shrink. However, the principle still holds that a greater proportion of the shrinkage potential can be reduced, when this is also high. In principle it is important that the material has a uniform moisture content, because varying moisture contents cause the properties of the cotton fibre to vary.

The selected drier

- determines material quality,
- can cause structure development,
- can realise the reduction of a certain shrinkage potential,
- determines the machine output and thus the production speed (this aspect is of commercial importance to the finisher).

Stable stitch geometry for knitgoods made of non fixable fibre yarns is defined as follows. The fully relaxed state is characterized by the ideally shaped stitch, which is achieved if the forces from the bending of the yarn into stitch loops and the friction forces at the linkage points, which must have reached a minimum value, are in equilibrium. The stitch has achieved the status of the lowest bending energy, i.e. in the fully relaxed state the internal forces of the thread loop cannot bring about any change in the stitch shape. This stitch shape is largely independent of the yarn diameter and the fibre; it is primarily determined by the length of the stitch.

Knitgoods resin-finishing → Resin finishing of knitgoods.

Knitted carpet (knitted velvet pile carpet), created from knitted fabric bonded to a stabilising fabric. A backing is then attached to this composite material. The pile layer is usually roughened, creating the knitted velvet pile carpet. → Stitch bonding, Raschel and Raschel batt-on-base carpet.

Knitted composites → Bonded fabrics, bonded in the interweaving or cross stitch methods, similar to → Stitch bonded fabrics.

Knitted curtains The manufacture of knitted curtains (→ Warp-knitted fabrics) has developed into an important branch of knitting. There have been several reasons for this. One significant point is the development of the raschel machine into a highly versatile unit which can provide high production output and almost unlimited possibilities for the construction and patterning of the fabric. Secondly, the man-made fibre industry has been able to provide an ideally suited material in the form of filament yarns. Finally, the attractive pricing of knitted curtains has allowed a large group of consumers to improve the look of their home. Before the last war the construction of raschel machines was concentrated in the Apolda area of Thüringen. Curtain material was manufactured from cotton on these machines on a small scale. There were also crochetting machines. At the time, high quality curtains were woven, whether with gauze weave as marquisette or as voile. In comparison to the current situation, the market for curtains was significantly smaller then.

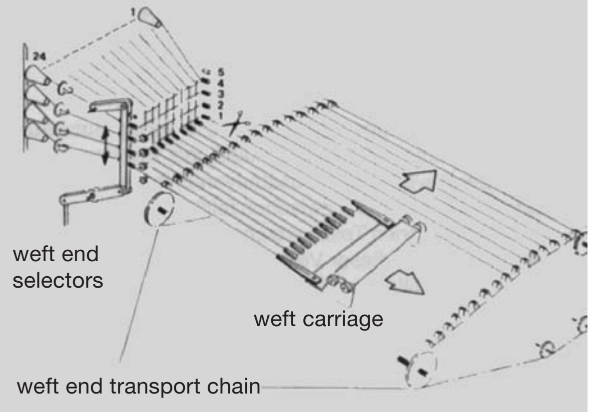


Fig.: Knitted curtain production.

A critical factor in the rapid rise of knitted curtains was the non-slip quality of the grid structure that forms the basis of the knitted curtain. An asymmetric weft layout, created by two parallel rows laid against each other, means that movement is no longer possible. Filament yarns made a significant contribution to the acceleration of production and increasing utility. Before polyester yarn was available, viscose filament yarn was often used. Large knitters perform warping themselves and draw the yarn on large cylindrical reels, whose diameter is matched to the reel distances in the frame. The reels, which are on the bobbin frame behind the jacquard raschel machines, must be particularly precise with regard to winding on and the unimpeded passage of thread. Stimulated by a trend towards greater structuring of curtains in the 1970s, the insertion of weft threads began to be used, initially on course yarns. These were the so-called single thread weft. In this reverse weft principle there was the option of using up to 6 threads alternately. When the market demanded finer curtain structures, the magazine weft entry system was developed. The principle of weft insertion over the whole working width is depicted in Fig. Nowadays weft thread selection takes place electronically. For this different and differently coloured, yarn attachments are available at the frame (according to Furkert).

Knitted fabrics Collective term for warp-knitted and knitted fabrics: Textile materials made of →: Stitches; Loop and Floating using single or multi-thread systems with a horizontal or vertical thread path. Unlike woven fabric, which consists of two thread systems crossing each other at right angles (Fig. 1), warp-knitted and knitted fabrics are textile materials, whose smallest unit is the stitch. The stitch consists of a thread loop, which is held by other stitches or stitch loops. The points of contact of two stitches above or below each other are termed linkage points (Fig. 2). Therefore, the

Knitted fabrics

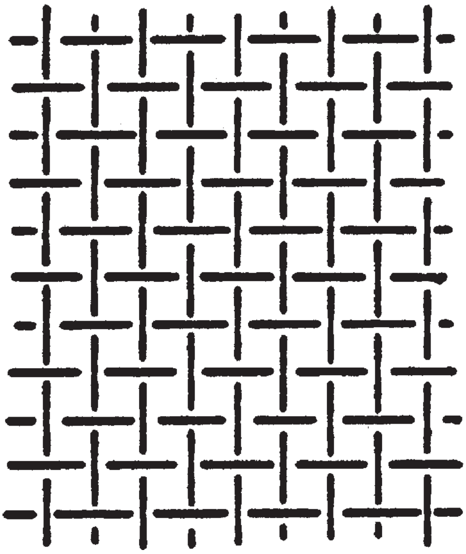


Fig. 1: Woven fabric.

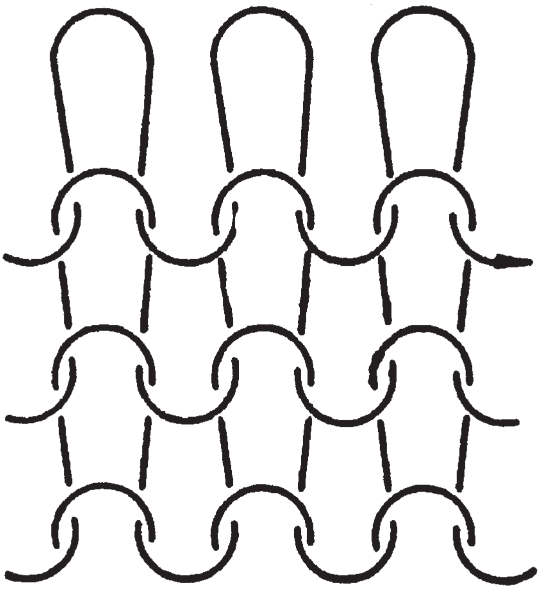


Fig. 2: Knitted fabric.

stitch has four linkage points. Due to their constructive elements, knitted fabrics are characterized by high elasticity, i.e. they always attempt to return to a state near the stable state, the round form of the stitch.

The euphoria of the 1960s, when attempts were made to replace the woven fabric of outer clothing with knitted fabric, which can be produced more quickly, has passed, giving way to a more rational way of thinking. Men's outer clothing is produced as knitgoods in the leisure sector, whereas in ladies' outer clothing the proportion of knitted articles is more widely dispersed.

Knitgoods have fully established themselves in the traditional underwear sector and in the sport and leisure clothing sector. In recent years there has been a move away from the simple T-shirt to high quality articles in this sector. However, increasing quality in this field has brought problems with it due to the use of ever finer and denser structures. The increase in sewing faults is directly related to this, plus the increase in manufacturing speed brought about by quicker sewing machines. For this reason, improving manufacturing ability is one of the primary goals of every item of knitgood manufacturing equipment.

Classification:

I. Weft-knitted goods (knitted fabrics): The threads run crosswise through the fabric. Produced on flat or round knitting machines or weft knitting machines. The threads can be separated out of knitgoods or weft-knitted goods (they form → Ladder/run).

II. Warp knit fabrics (→ Warp-knitted fabrics): Vertical warp-knitted fabrics made of as many threads as the number of stitches per unit width; the threads run lengthways through the fabric. The threads cannot be separated out.

During knitting, individual moving needles form the threads into stitch wales. In weaving, needles moving together (needle bars) form the row of stitches.

→ Knitgoods manufactured on knitting machines. Unlike → Warp-knitted fabrics the stitch formation takes place sequentially (Fig. 3), i.e., each stitch is formed and completed individually, whereas in knitting several stitches are always formed at the same time (according to Hofer).

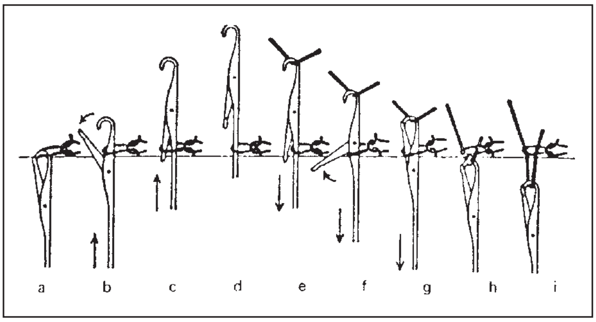


Fig. 3: Stages in the creation of a stitch during knitting.

The individual phases of stitch formation in knitting are illustrated in Fig. 3:

a) The old stitch is formed, the latch type needle begins to rise.
b) The old stitch opens the tongue until it
c) slides over it and
d) comes to lie behind the tongue on the shaft.
e) The new thread is positioned,
f) the needle slides downwards, the old stitch closes the tongue,
g) the old stitch slides over the tongue and closes the positioned thread,

h) the new stitch is pulled through the old.
i) The needle has reached the lowest point, the material is pulled away and when next raised the needle reaches position a).

Knitted plush → Plush cloth, (e.g. for imitation fur) manufactured knitgoods with cut plush loops that are firmly bonded to the knitted base. Manufactured on circular knitting machines and tubular hosing machines.

Knops (knots),

I. Symptom of a fault: Caused by knots or knot-like thickenings due to inextricably entwined fibres.

II. Yarn effect: In the form of dot-like or knot-like thickenings, fluffy places etc. in slub yarns.

III. Weaving effect: As the V- or W-weave loop formation in pile fabrics (pile loops); also similar in pile carpets.

IV. Denepping: Removal of unevenness in fabrics (knots, spun-in wool flock, curls, trapped pieces of thread etc.) using tweezers and fabric relaxation. The dyeing of undyed or off-shade dyed weaving points using so-called retouching pencils, this occurs after weaving or before or after wool scour.

Knops resistance (pile fixation), important durability property of pile fabrics. The force necessary to pull out individual loops/cut loops is measured with a tensile strength testing machine with a special holding device. Typical knop resistance in carpets is 2–6 (max. 10) N.

Knot density (slub or knot density), number of knots, or slubs in relation to 1 m^2 of an Oriental carpet. Top quality pieces contain up to 1 million, normal material 50 000–500 000, cheap pieces only approx. 15 000 knots or slubs.

Knot strength Used to evaluate the flexibility or (opposite) brittleness and bending strength, generally the transverse strength of yarns and ply-yarns. The knot breaking strength test is performed in accordance with DIN 53 842 in the same way as the simple → Tensile strength test. In the area of the free clamping length a knot is created with a defined preliminary tensile force. A knotted and an unknotted thread are tested alternately. The knot (maximum) tensile force is quoted in relation to the original (maximum) tensile force.

Knots Loops of threads, string, ropes etc. We differentiate between different types of knots, which either serve for the connection of two ends (e.g. in weaving) or for the creation of pile on carpets (see Fig.) (knotted carpets).

I. Knots in weaving: Single weaver's knots, double weaver's knots, tension knots (for the connection of threads coming from opposite directions, e.g. broken ends), cats head knots (connection of parallel threads).

II. Knots on knotted carpets: Persian knots, Smyrna knots (Ghiordes or Turkish knots).

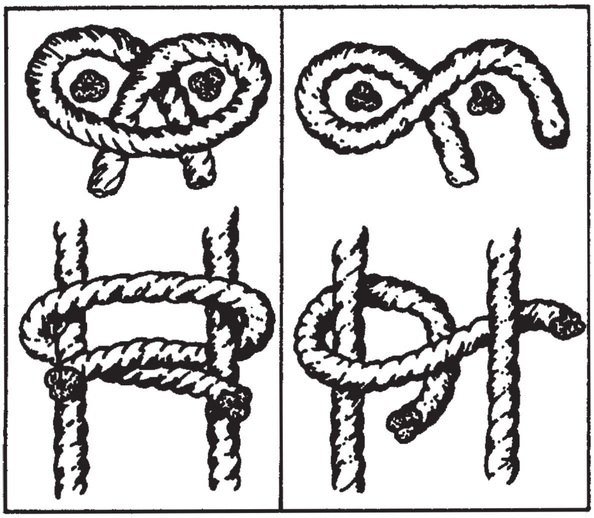


Fig.: Knots on knotted carpets.
Left: Smyrna knot, right: Persian knot.

Knotted carpets Pile carpets, created by the knotting of brightly coloured threads in a warp system. With the exception of weaving technology, the oldest and most common process for the manual production of carpets. We differentiate between Persian and Turkish → Knots. → Oriental carpets.

Ko → Coir fibres, → Textile fibre symbols, according to DIN 60 001 till 1988, from 1991 → CC.

KOB Abbrev. for children's outerwear.

Koch's contraction reaction → Contraction reaction.

Kogasin Aliphatic hydrocarbon, according to the Fischer-Tropsch method for the production of wash-active substances: Kogasin I boiling range 160–230°C (C_{10}–C_{13}); Kogasin II boiling range 230–320°C (C_{14}–C_{18}).

Kolloxan → Collodion cotton.

Konticrab machine This continuous boiling and fixing machine replaces the old, labour intensive and uneconomical boiling machine (crabbing jack) for the crabbing of wool and wool mix fabrics. It consists of an

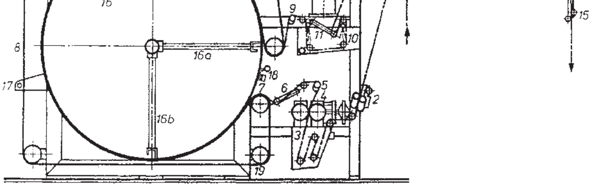


Fig. 1: Kontricrab (Hemmer).
1–7 = inlet trough with tension regulation and squeezing unit; 8 = rubber band; 9–15 = outlet with cooling trough and squeezing unit; 16 = heating drum.

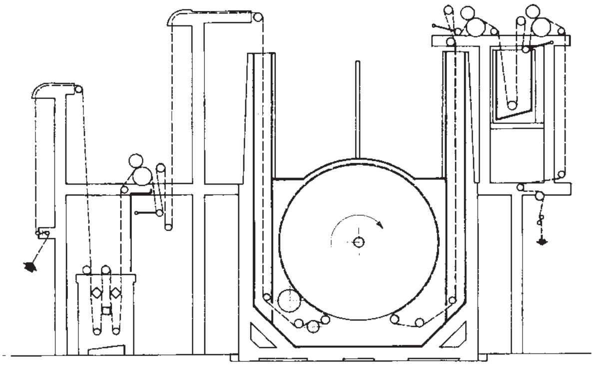


Fig. 2: Konticrab (MAT).

inlet for dry or wet material and a hot water trough with an adjoining pair of squeeze rollers. The material passes via a spreader roller between an endless rubber blanket above a heated drum and finally through a cooling trough (Figs. 1 and 2).

Kordofan gum→ Gum arabic.

Kotonin → Cottonized flax.

KP → Kapok, → Textile fibre symbols, according to DIN 60 001 T4/ 08.91.

Kp → Kapok, → Textile fibre symbols, according to DIN 60 001 till 1988, from 1991 → KP.

Kr Element symbol for Krypton (36).

Kracher Thick and knotty points in yarn.

Krafft point (t_K or T_K), of an ionic surfactant is the temperature of the triple point in the surfactant's phase diagram, at which equilibrium exists between the solid phase (crystal or gel), real saturated solution and saturated solution with micelles. Behaviour of the surfactant at high concentration: below the Krafft point = solid phase, above the Krafft point = solution with micelles. At low concentration the surfactant always forms real solutions. In the soap industry the temperature at which a transparent soap solution goes cloudy during the cooling process is called the Krafft point.

Krätzen More or less sharply limited points in hosiery after dyeing, at which hosiery stitches are more dense and irregular, presumably points which, due to bagginess during the fixing of the raw material, did not lie close to the hosiery form and therefore had inadequate tension. Removable by → Postboarding.

Kronos titanium white → Titanium dioxide (from Norwegian ilmenite) in different types with varying TiO_2 content (up to 98%). Chemically barely corrodible, unchanging white with maximum covering effect. Used for printing dyes, delustring, paints.

Kubelka Munk value (K/S). Describes the optical properties of a coloured sample as a double constant made up of K = light absorption (absorption constant of dyes) and S = light dispersal (determined by textile material). If K/S values for the maximum absorption wavelengths are displayed logarithmically as a function of the dyestuff concentration C, then in the ideal case this produces a straight line with a gradient of 45°, with dyeing or printing errors, for example, showing up as measuring points that deviate from the straight line. Calculated using

$$K/S = \frac{(1 - \beta)^2}{2\,\beta}$$

β = luminosity coefficient

Deviations also arise due to the concentration dependent absorptive capacity and different extraction, etc.

Kula rugs Prayer rugs from the Turkish city of Kula. Velvety smooth pile, approximately 150 000 knots per m^2. The large red or blue prayer niche is framed by a border with stylised, often tiny flowers. The masarli kula (cemetery kula carpet) is a special type.

Kurkuma → Natural dyes.

Kyanol Substance discovered by F.F. Runge in coaltar in 1833, which A.W. Hofmann recognized to be identical to → Aniline in 1843.

Kz → Cashmere, → Textile fibre symbols, according to DIN 60 001 until 1988, from 1991 → WS.

L

L DIN abbrev. for linen weave (→ Weave).

l Abbrev. for (→ Litre (volumetric measure).

LA → Rubber fibres (latex), and → Textile fibre symbols, according to DIN 60 001 T4/08.91.

La Symbol for the element Lanthanum (57).

Label printer Different types are used in a thermal print process, either single-coloured textile labels or multicolour, wash fast, printed on one or both sides.

Label printer machine A small flat-film printing machine for textile tapes or fabric patterns to be subsequently cut.

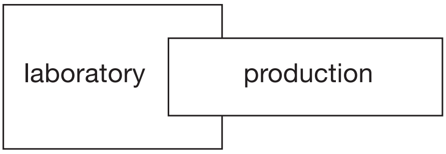
Laboratory In order to understand and assess the dyeing laboratory and its tasks and functions, it must not be regarded as a department on its own but in terms of its relationship to and interaction with the other areas in the textile finishing factory. The interaction between the laboratory and production is largely dependent on the distribution of tasks. These can be classified as follows:

- preparation of production,
- monitoring and correction during production,
- end-product control.

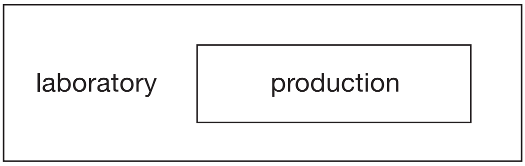
At the same time, it is possible to set up three models to illustrate the relationship between the laboratory and production.

1. The laboratory has a pure preparation function (control of raw materials, dyes, chemicals, textile goods and formulation).

2. In addition to the preparation function, the laboratory also has a correction function, i.e. due to its control tasks, the laboratory also carries some of the responsibility which would otherwise be solely the domain of production. Production is relieved but this presupposes a significant amount of collaboration.



3. The laboratory is also entrusted with quality control and therefore has the functions of preparation, correction and end control. In this case, the majority of the responsibility is held by the laboratory which leads to improved communication and a better assessment of laboratory-to-production reproducibility. A prerequisite for this is close collaboration between those responsible in the laboratory with those in charge of production.



Every textile factory decides differently in regard to the distribution of tasks depending on the production organization and company objectives. However, no factory can do without the services of a production laboratory. The following tasks must be taken care of:

- receiving inspection of textile goods, dyes, ancillary aids etc.,
- control of production water,
- laying down of quality criteria and development of appropriate test methods,
- selection of reasonable finishing methods and finishing products,
- making up of formulations for new articles and shades,
- production control,
- correction of off-standard dyeings and prints,
- testing of colour fastness and technological properties,
- determination of the cause of problems.

Depending on the size of the company, one laboratory takes over all the tasks or the tasks are shared between the test laboratory and dyeing laboratory. The question as to how much the importance of a dyeing laboratory is recognised by the company's management arises again and again, and this is reflected by the degree of investment made in this area. Investment is certainly adversely affected by the fact that the effectiveness of a laboratory cannot be described in terms of a clear relationship between costs and efficiency. The more accurate the work of a laboratory is, the better the results are which are achieved in production; in other words, a reduction in the number of dyeing defects and colour deviations produce savings in costs, in time, machine utilisation, energy and chemicals and dyes. Savings in cost can also be made by selecting more economic methods and optimising the process. There are numerous tests which can be used to define the viability of laboratory trials:

a) the cost of the dyed batch is equated to 100%,
b) in relation to the actual dyeing, additional costs arise from
  - samples 4–8%,
  - shading and patterns 12–49%,
  - redyeing 98–169%
  - pilot plant dyeing 19–31%,
c) the corresponding cost of the laboratory, on the other hand, amounts to a mere 2–4%.

It is easy to see that it is possible to carry out many adjustments in the laboratory before the costs reach those incurred by adding additional amounts of dye during production. Also to be taken into account is the number of batches: the more batches there are, the more the laboratory costs are spread out until their final impact on production becomes relatively minute.

The most important requirements in a laboratory context are laboratory reproducibility and laboratory-to-production reproducibility. A high level of laboratory reproducibility means that the laboratory values compare well with each other; the same results are only achieved by using the same conditions. This is essential for collaboration between production and the laboratory, for example, when converting laboratory formulations into production formulations. Laboratory reproducibility is crucially dependent on the accuracy of the work carried out in the laboratory. The following factors have an effect an the result and can impair the accuracy:

1. the starting materials, such as textile goods (homogeneity, preparation and conditioning), dyes and auxiliaries;
2. working procedure, such as weighing the starting materials and volumetric preparation of stock solutions;
3. laboratory equipment, such as the accuracy of the scales, pipettes and measuring cylinders and dyeing machines (the greater the number of parameters which can be programmed, the more accurate the result) or colour-measurement system;
4. dyeing conditions, such as liquor ratio, dyeing method, water quality, after-treatment and drying methods.

Reproducibility within the laboratory is also a prerequisite for a high level of laboratory-to-production reproducibility and, in addition to this, chemical and technological parameters are also important for the laboratory-to-production reproducibility. Not all parameters can be measured in the laboratory because, on the one hand, the technical facilities are limited and on the other hand, the production parameters themselves could be recorded better and more completely.

Chemical parameters:
- properties of the individual products,
- composition of the treatment liquor,
- temperature,
- pH,
- homogeneity and reactivity of the goods.

Technological parameters:
- period of treatment,
- type of agitation used for the goods and liquor,
- temperature distribution in the liquor,
- homogeneity of the liquor composition,
- distribution of liquor on the material,
- stress factors,
- pressure on the material,
- physical properties of the substrate.

In general, it can be stated that chemical parameters are easier to convey from the laboratory to production than technological parameters. These can be used to determine the demand according to production-oriented laboratory dyeing machines or pilot plants. In most cases, 100% laboratory-to-production is not achievable. For this reason, every factory operates with specific laboratory-to-production reproducibility factors based on years of experience in each case.

It is important to bear in mind that defects produced in the laboratory are amplified many times in production. A significant proportion of production defects have their origin in the laboratory. This is even more serious in the case of multi-step processes where defects which are within the range of tolerance for the individual steps become unacceptable due to the additive effect of the steps. A fundamental distinction can be made between systematic and coincidental defects. In the first case, for example, the inaccuracy of a temperature probe does not effect laboratory reproducibility but may affect the laboratory-to-production reproducibility. On the other hand, defects which are random also impair laboratory reproducibility. However, precise defect analysis and assignment is not always available. Examples of a few possible defects which can arise in the laboratory are listed below:

- different forms of pre-treatment and conditioning of goods,
- weighing errors in the case of goods, dye and ancillary aids,
- errors which may occur while preparing the stock solutions,
- volumetric errors during pipetting,
- fluctuations in the moisture content of the dyes.

The following steps must be taken to increase the accuracy:

- standardise the working methods,
- exclude human error,
- draw up exact specifications for transferring the laboratory results to production.

A critical factor in this connection is extensive automation of the working procedures. Even if the absolute accuracy is insignificantly greater than that of manual methods, reproducibility will be considerably improved by:

- automating the preparation of the formulation by means of colorimetry and colorimetric evaluation of the results;
- automating sample preparation and dye-liquor addition; errors which occur while adding the stock solutions, weighing the sample and pipetting can be avoided by using an automatic dispenser (Fig. 1);
- automating the dyeing process by using a large number of programmable parameters and controlling parameters such as the course of temperature w.r.t. time;
- automating the organisation of the working procedures via computer networking the individual operating areas to facilitate problem-free communication and data transmission.

Fig. 1: Dispenser (by datacolor) for dispensing standard solutions in the laboratory.

Automation mainly serves to improve quality and avoid errors. Savings in staff and direct profitability calculations are not of primary importance. However, by automating time-consuming routine work, more time is made available for development work, problem solving and process optimisation. The importance of the other equipment in the laboratory, such as analytical balances, colour measurement equipment, moisture meters, instruments for determining colour fastness, pH meters, pipettes, temperature measurement equipment, titration equipment and drying cabinets etc., must not be overlooked. The quality of the laboratory results is dependent on the interaction and additive effects of all steps in the working procedure. Visual contact with the dye liquors in the laboratory dyeing machine increases the accuracy of the dyeing results (Fig. 2).

Fig. 2: Ahiba Turbocolor with transparent walled dye containers.

Automatic equipment for dosing dyes and auxiliaries has been improved in the past in a number of respects but does not deviate in principle from automatic dosing equipment which is already well known. The same applied to the stock-solution dosing equipment where the emphasis was on improving the precision, accuracy of weighing and automation. In the meantime, vat dyes and disperse dyes are handled well by dosing units (Fig. 3). However, the equipment requires regular, careful maintenance so the impact on efficiency can only be calculated as being rather small.

Work hygiene is of particular importance, both in the laboratory and in production. The laboratory bench in Fig. 4 is equipped with a vertical pressure and exhaust stream and retains the dust at source, thus minimising the contamination of equipment and clothing. Preliminary filters with large retention capacities and absolute filters are fitted under the bench for safe and hygienic maintenance. Because the air stream is circulated, the laboratory bench stands on its own and can easily be switched between departments.

In the meantime, colorimetry has become an essential component in the textile finishing factory. However, opinion on the proficiency of colour-measurement

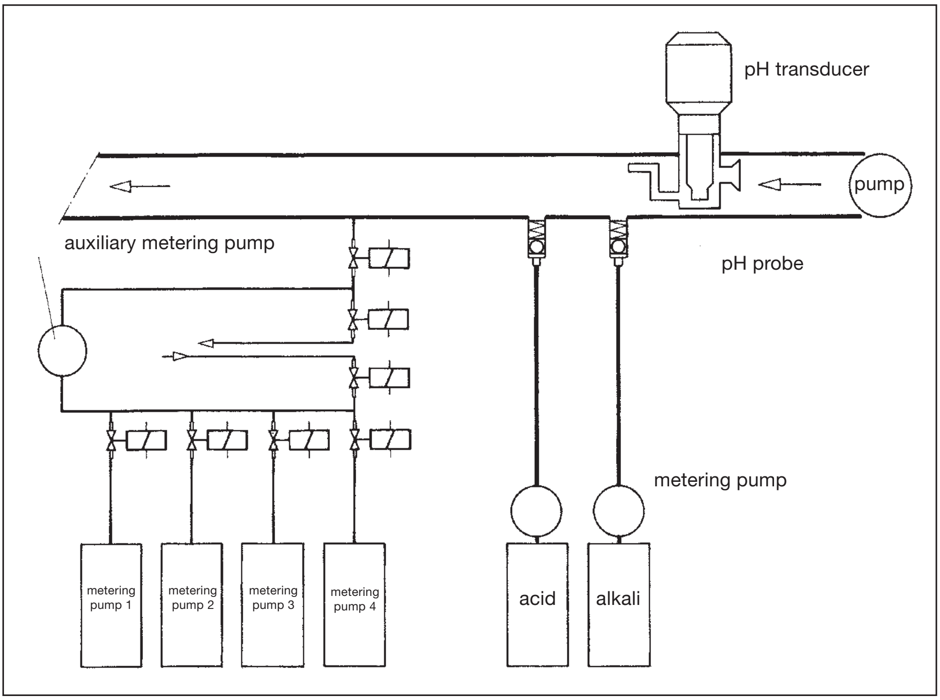


Fig. 3: Laboratory dye dose metering system (Benz).

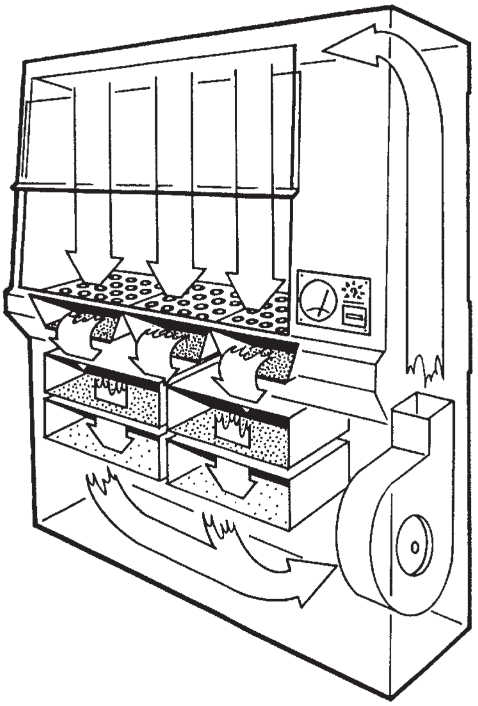


Fig. 4: Dust control bench for laboratory use (formerly ICS-Texikon, now datacolor international).

systems in regard to colour matching and the preparation of formulations is divided. Colorimetry can only be regarded as an aid, and the final decision has to be made on a visual basis or visual means alone have to be used as the only valid criteria. To start with, colorimetry was mainly used for establishing or calculating the formulation alone. The CAC (Computer-Aided Colouring) system opens new perspectives for creating new colours on the screen or colour print on paper or materials which are mainly used in the printing industry.

Colorimetry retains a central position in the area of automated design in particular. Thus, it is no longer a question of instruments but colour and formulation systems. Apart from the stand point of colorimetry, formulation print outs, networking with dye kitchens/weighing stations and process-control computers are required for production (Fig. 5). The colorimeter PC station is often the starting point for the computer networking of individual production areas. The original idea of automation designs is to network all departments and work stations taking part in production in order to increase the availability of the necessary information while, at the same time, pursuing the following goals:

- to reduce the sources of error, as data is no longer transferred manually,
- to increase quality in order to meet the ever higher requirements,
- to achieve “just in time” production in order to maintain short deadlines,
- to increase productivity,
- to avoid complaints,
- to reduce costs,
- to reduce the consumption of energy, water, air, dyes and chemicals.

The aim, therefore, is to optimise the process by linking the laboratory, production and administration via PC

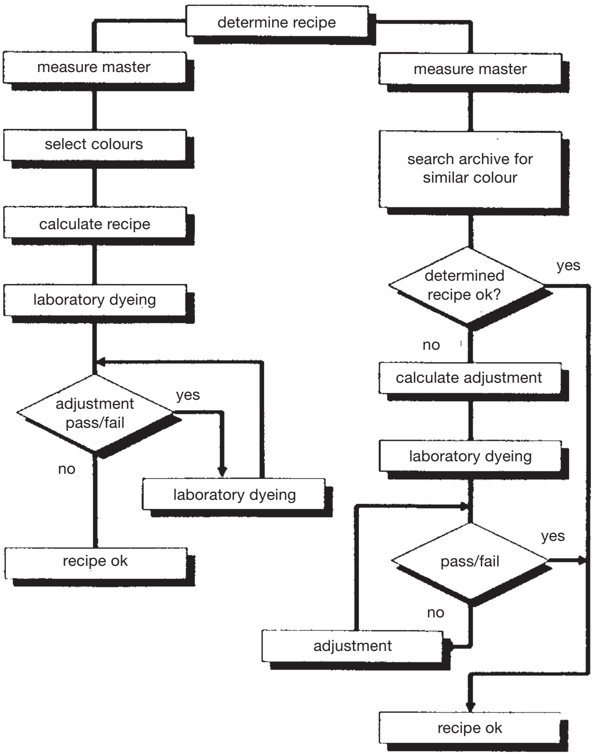


Fig. 5: Determining dye recipes using laboratory dyeing.

networking. Several companies are offering ready-made system solutions:

1. Datacolor produces the integrated Colour Network (ICN) (Fig. 6). This is an integrated network-based solution in industrial colorimetry. The core of the system is a database server, upon which are stored the company's own database. The data which is stored and managed centrally is available to all users at the ICN work stations. In addition to this, special software packages, such as Osiris for colour data processing, are provided for each application area. Apart from the PC-based work stations, various different units such as weighing systems, dispensers and dyeing machines can also be integrated into the ICN. It is also possible to set up links to the central PPS computer, host computers or machine controllers via file transfer.

2. Another supplier in the Total Colour Management area is ICS Texicon. In this case, the emphasis is on the colorimetric unit being used as the central control member as the "real-time multi-user". This is networked with other production systems and units. Software programs are available which are specifically used for the data recording and control and evaluation of, for example:

– colour strength,
– substrate routines,
– correlation,
– laboratory-to-production reproducibility
– formulation and top-up calculation for continuous and batch dyeing,
– batch preparation,
– storage and formulation archiving,
– machine programs,
– management programmes,
– dye kitchen software.

These layouts are available from suppliers but it may not necessarily be possible to use them in a textile finishing factory exactly in this form. Every factory has different specifications with regard to organisation and existing computer systems or satellite solutions. A decision to integrate individual departments into a high-level system involves a high level of investment and is mostly carried out in stages. Computer systems are basically classified into technical and business systems. Essential components of the business systems are order processing, disposition, establishing and pursuing deadlines and production planning. All important data relating to the batches to be processed are recorded and can be accessed as required. Batch data is also echoed during formulation preparation or after the finishing process is over. The industrial computer system deals with the laboratory and production areas. First of all, laboratory formulation is prepared either using colorimetric measurement or by accessing formulations saved beforehand. Dyeing is then carried out in the laboratory with the dosing stations and dyeing machine integrated into the network.

When assessing the future course of development for the laboratory, it is important to consider the general automation problems of the whole finishing factory and the economic position of textile finishing or the textile industry for the future as well as the specific technical conditions. Generally, the trend towards automation is

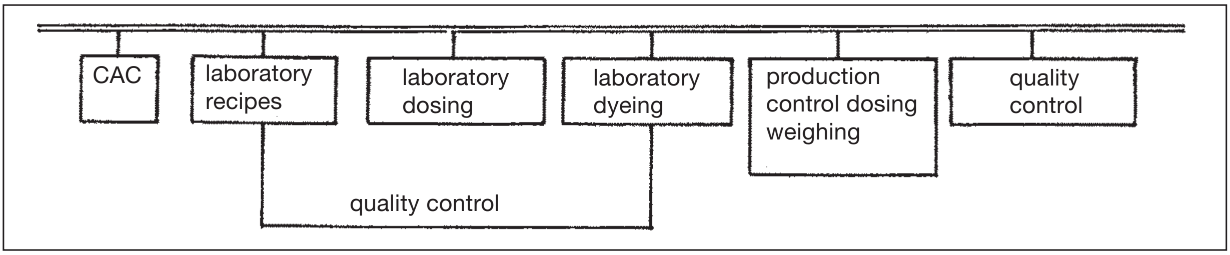


Fig. 6: Integrated Colour Network (datacolor).

clear to see. The important position occupied by the laboratory in this connection arises from the need for costs savings in production and a quality assurance system. The finishing laboratory is given further weight as part of increased efforts in the area of environmental protection: on the one hand, it can assist in reducing additions during production and on the other, the laboratory method can be optimised in regard to energy consumption and environmental loading.

As far as laboratory equipment is concerned, it can be assumed that it is the multi-position dyeing machine which will be of the greatest significance in the future. At the same time, the capacity for imitating air flow with liquor ratios down to 1 : 3 is also important. A further requirement for laboratory machines is a capacity for exact production-simulated dosing during the dyeing process. A trend for the future is, for example, heating the liquor directly by electrical means, heating the liquor using IR radiation or by using alternative heating media such as Bellatoni or aluminium blocks as a replacement for glycol heating medium.

High precision adjustable dyeing machines which simulate production conditions will be more widely used but will be restricted to high-quality, high-turnover finishing factories as the equipment demands high investment without offering high capacities in return. Modern SPC controllers also contribute to simulating the production process as much as possible. However, 100% laboratory-to-production reproducibility will not be a reality in the future either but it will, nevertheless, continue to improve. As a means of scaling up, pilot plants are one possibility in this direction but they are too expensive to procure and too costly to run. All the small components such as pipettes, small dispensers and balances etc. will contribute to optimising the laboratory results as much as possible. The question is, how the dyeing laboratory of the future will appear as a whole. It is still unknown whether European laboratories will follow what has already become reality in Japan, such as the one-man laboratory using robots, or whether it will be possible to create a laboratory without laboratory dyeing, i.e. by using Computer-Aided Colouring alone.

In quality control in the dye industry, approximately 50–80 parameters have to be checked for each dye and several thousand dye samples are tested every year (Fig. 8). This yields a flood of data which can only be overcome with the help of computer-supported data logging and evaluation. Here, laboratory robots can help during weighing out and dosing procedures and during sample taking (Fig. 7).

Examples of special pieces of equipment for the dyeing laboratory which are useful are listed below.

1. The dyeing laboratory is frequently given the task of investigating foaming during the dyeing processes and the effect of defoamers. Until now, the absence of suitable laboratory test methods has thrown into question the meaningfulness of the results; fre-

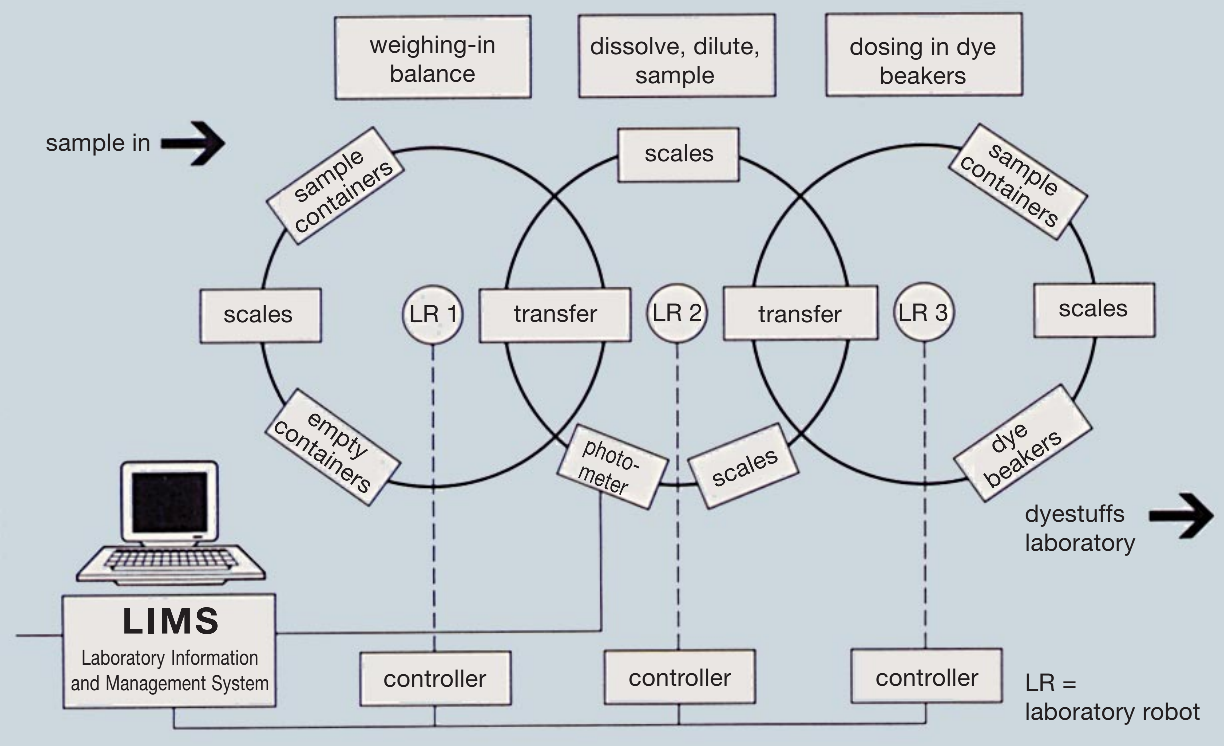


Fig. 7: Automated system.

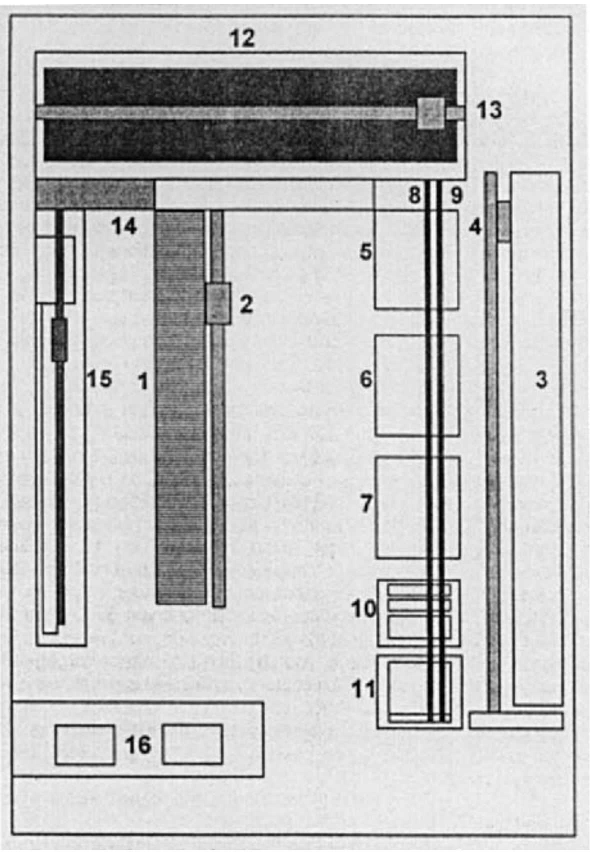


Fig. 8: Aladys (Ciba-Geigy); layout of the laboratory dye robot.
1 = store of various textiles; 2 = winding robot; 3 = dyestuffs and chemical products store with robot (4) serving the 6 dosing stations (5, 6, and 7); 8 and 9 = linear transfer lines; 10 = output device; 11 = waste water collection; 12 = dyeing station with 84 dyers; 13 = robot; 14 = drier; 15 = delivery belt for dyed samples; 16 = 2 computers.

quently, the result in production is not confirmed. Zeltex supplies a test instrument, the "Foamy", which can be connected to circulation dyeing machines with an external circulation system – the foam is generated via a nozzle. It includes a dosing unit for chemicals such as defoamers. The test area is heated or cooled as desired in order to provide constant temperature conditions for the test solution. Control is achieved via the dyeing machine. The height of the foam must be determined visually, although an automatic foam-height detector with PC interface is planned.

2. Officine Bisio s.a.s. manufactures a laboratory instrument for examining the change in colour and gloss in relation to pressure, vapour and temperature. A reproducible prediction about the dyed goods is given for finishing steps which follow within a short time (10 s).
3. The air-permeability test allows a prediction to be made on the beam dyeing of less permeable fabrics. Goodbrand-Jeffreys Ltd has developed a portable electrical acoustic air-permeability tester for quick on-site testing. The value for the air permeability is indicated directly on a digital display. It would be desirable to check whether there is a correlation between this method and the ISO/DIN method so that this instrument could also be used in the quality control of technical textiles outside the test laboratory.
4. Heraeus Instruments produce the Xenotest 1200 CPS (Fig. 9), a program-controlled rapid light-radiation device with radiation control which has been shown to be suitable for various different applications. In order to improve reproducibility, set-point

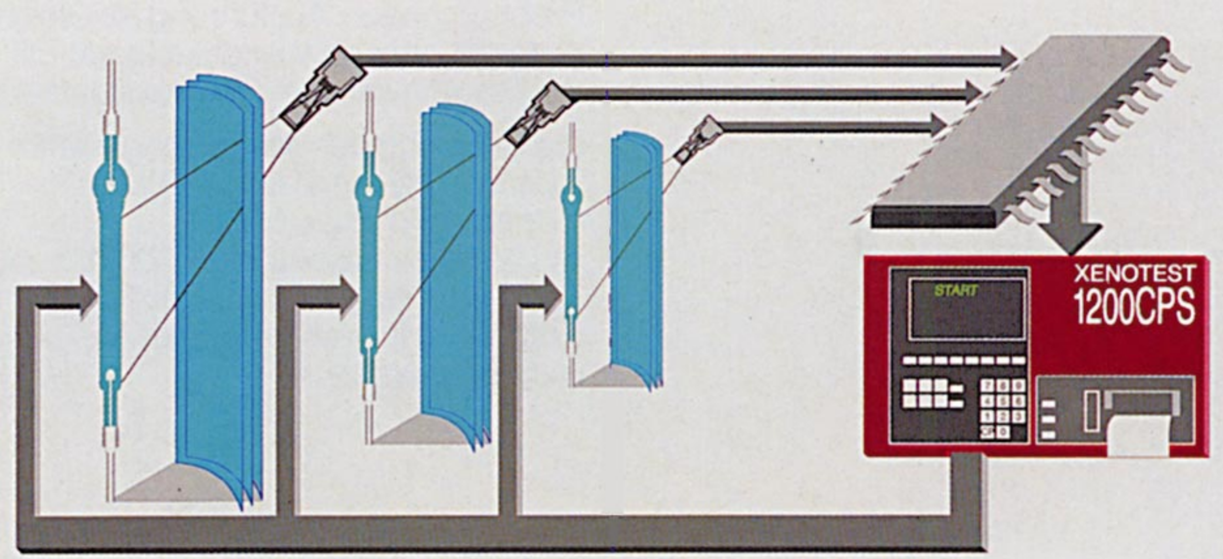


Fig. 9: Controlled irradiation intensity with the Xenotest 1200 CPS (Heraeus).

and actual values are constantly compared with all specified weather exposure parameters and corrected and documented where necessary. The values can be accessed at any time. After a period of weathering, the operating data are printed out as a log. The Xenotest was developed as a smaller but just as versatile and flexible unit for light-radiation and weathering testing. Heraeus Instruments recommend setting up all light-radiation instruments in air-conditioned rooms in order to avoid temperature fluctuations in the sample area. Xenoserv is a service package provided by Heraeus which is intended for the user who wants to procure monitoring equipment complying with DIN 9000.

5. Atlas SFTS has developed the Ci radiation unit series further. In addition to the Ci 35 A, which has made a name for itself in hot light-radiation testing, there is the smaller Ci 3000 model. The results and performance of this unit are comparable to those of the larger instruments, the Ci 35 A and Ci 65 A. For example, the sample temperature, black standard temperature and the radiation dose can be measured as well.

Laboratory coating unit This consists of a coating table and coating head, infrared field (optional) and drying box with a 20–250°C temperature controller. The sample size (coating area) is 45 x 100 cm max. This is also used as a laminator for polyurethane and a printing, calendering and schreinering device – Manuf.: Mathis.

Laboratory continuous dyeing machines The basic design is based on the requirement for setting up laboratory machines which simulate the plants and processes used in production as far as possible. The reproducibility of laboratory results in the production process must be ensured by maintaining certain established parameters. On the other hand, there is also the desire for flexibility which can be realised by assembling individual units according to a modular principle rather than, under certain circumstances, neglecting specific characteristics of the production plant such as the Shore hardness of the padder rollers and dwell times, etc.

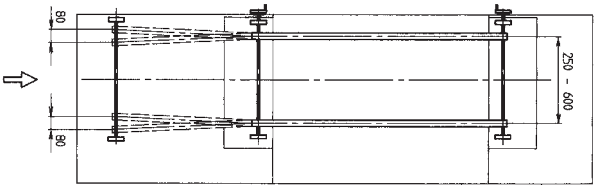


Fig. 2: Working width (in mm) of a continuous laboratory drier.

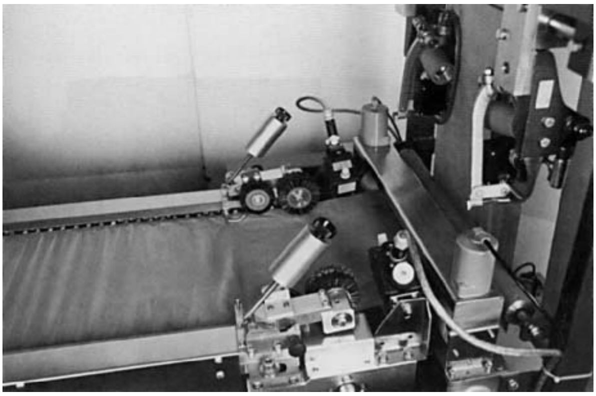


Fig. 3: Fabric feed on a laboratory drier (Mathis) with optical scanner.

The normal working widths are 250 or 600 mm (Fig. 2). The basic set-up for a laboratory continuous drying machine consists of a padder and drier (Fig. 1). Laboratory stenters can be of elaborate construction at the goods feed and may also have expanders and optical edge scanners for automatic pinning-down and adjustment facilities for under- and overfeed (10%) as well as 2 continuous needle chains (Fig. 3). Laboratory pad-steam plant may certainly be regarded as a more convenient set-up. This may be equipped, for example, with a vertical IR drier on the front end and a supplementary chemical trough as well as an air circulation system for the steam chamber and washers on the other end so the unit can be used both for the pad-steam process and the thermosol process.

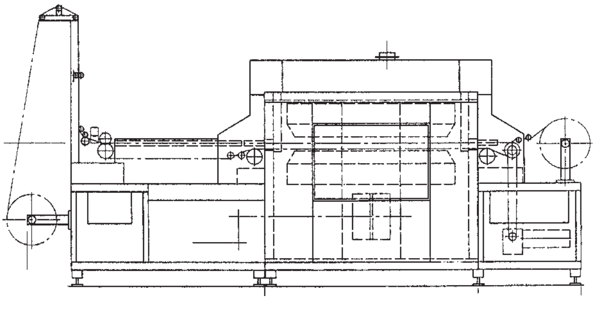


Fig. 1: Section of a continuous drier (Benz) for laboratory use.

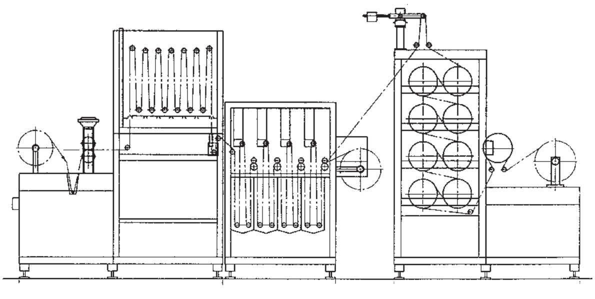


Fig. 4: Continuous laboratory system with pad, drier/steamer, wide washing roller vat and cylinder drier.

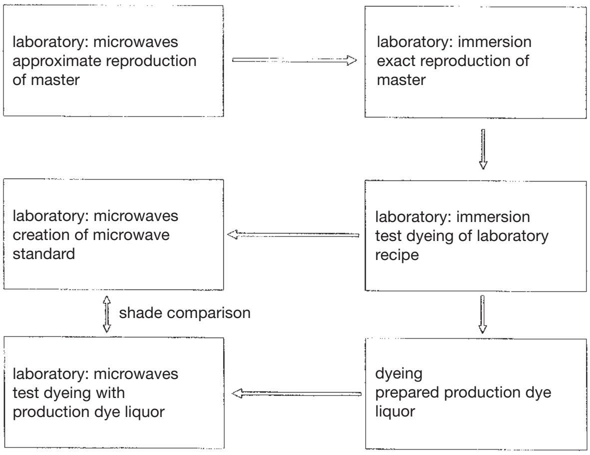


Fig. 5: Creation of laboratory recipes and testing production dye liquors using microwaves.

More complicated speciality plants can simulate whole production lines (for example, padding, steaming or drying, after washing and cylinder drying as in Fig. 4. With a little experience, a continuous dyeing process complete with padder and microwave drier can be reconstructed (Fig. 5). In this system, drying and steaming take place fairly rapidly in the microwave unit and merge seamlessly with each other. For example, the combined laboratory dyeing machine depicted in Fig. 6 is a very specific simulation of production plants for the continuous dyeing of tufted carpet goods - the coating and fixing of the dye liquor makes it possible to transfer a considerable amount of the process data determined in the laboratory to the production plant.

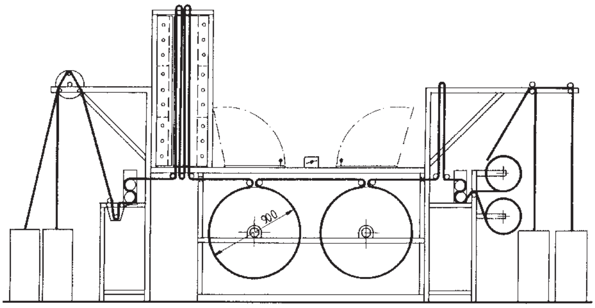


Fig. 6: Application of the sieve drum technique in a laboratory dyeing facility (Fleissner).

Laboratory dispensers for stock solutions These are suitable for large textile-finishing plants that have a high demand for dissolved dyes in different concentrations or require many different dyes. The dispensers relieve the laboratory technician in his daily routine work. A single or several concentrations of a dye must be prepared depending on the process and desired depth of shade. A dispenser operates with more precision so human errors are excluded and their consequences avoided. A lab dispenser (Fig.) is made up of single modules, i.e. a balance and a cabinet with water and chemical tank or a connection to the water supply. A hot plate and a rotating magnetic stirrer may be integrated to make up the dye solution with hot water. Multi-station dispensers are equipped with a conveyor system. The operating principle of the dispensers consists of accurately weighing out an approximate amount of the dye in accordance with the standardised concentration and, based on this value, determining and adding the amount of water required to make the solution up to the desired concentration.

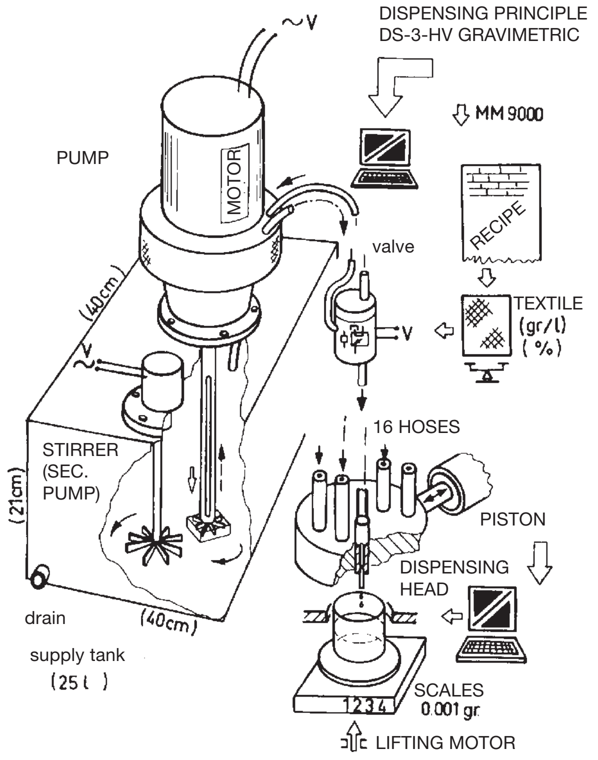


Fig.: DS-3 laboratory dispenser for textile printing ink by Gain.

The simplest system consists of a balance and a water and chemical tank. This can also be equipped with mixer plate and magnetic stirrer system for beakers. The weighing accuracy for the unit lies between 0.01 and 0.02 g. Designs with an accuracy of 0.001 g are supplied by various makers as an optional extra. Data may be stored by connecting the equipment to a computer; this is important, for example, for checking the age and quality of the stock solution. Thus, data can be recorded. All dispensers can be connected to a PC or computer and can operate in combination with metering units via a data connection.

Essentially, a separate stock system is advisable as this makes it possible for the dyer to automate the system in the laboratory in stages. The laboratory technicians can be introduced to a progressively automated technology in stages. Among other things, metering units may be integrated at a later date. Integrated dispensers, on the other hand, are sensible in a small laboratory as the number of liquors per day is smaller and the dispenser is not fully utilised. The advantage of separate units is that solutions can be made up independently while utilising the dispenser fully and when there is a technical fault with the dispenser.

Laboratory dye dispensing systems The first dosing systems for the dyehouse laboratory were presented at the ITMA ’87. Systems were developed in Japan and European producers followed suit later on. Many companies market equipment manufactured in Asia. Italian manufacturers build their own. The first units were run without software and were controlled via simple controllers. They were still relatively imprecise and involved a small number of containers – a maximum of 50–60 flasks.

Laboratory dosing systems (Fig. 1) have a role in:

1. Minimising errors by excluding the sources of human error during formulation and while dosing the dye by:
   - weighing the liquor and the sample with a precision of 0.01–0.001 g,
   - making an exact solution,
   - reducing the sources of error during pipetting.
2. Standardising the working procedures in order to guarantee reproducibility during the manufacturing process used for dye solutions and therefore the dyeing processes themselves.
3. Data management by:
   - storing all data associated with the dye liquors and
   - storing the formulations.
4. Cost saving, (which has an impact on production) by reducing the level of defective dyeing and 2nd quality dyeing, in terms of:
   - personnel and dyeing time during production,
   - dyes and ancillary aids for the production equipment,
   - reduction in effluent and effluent loading,
   - by improved quality,
   - optimum utilisation of the dye plant,
   - minimising the shut-down time and the running in of additional dye,
   - reducing the operating costs.

Fig. 1: Gain DS-3 dispenser (formerly ICS-Texikon).

Laboratory dye dosing systems operate according to the following principles:

- dosing automatically from stock solutions,
- storing all dyeing and dyestuff data,
- adopting the stored laboratory recipes and dyeing auxiliaries,
- weighing the dye and making batch calculations for all parameters,
- sending the formulations to the dosing unit,
- starting automatic dosing,
- pumping the stock solutions to the dyeing flasks through hoses and dosing them gravimetrically by means of high-precision balances,
- the technician removes the prepared flask from the equipment,
- special devices prevent stock solutions from sedimenting in pipes and containers.

Dye dosing systems are controlled via a PC in the laboratory from which all formulations are activated and passed on to the plant. In comparison to other systems, this type has a greater role than any other SPC controller. Integration into complete design solutions is important but it is still unknown whether Total Colour Management or INC Integrated Network Management will win through. Other factors contribute in this respect, such as capital available for investment, number of departments to be added and the company structure. Essentially, automation by means of laboratory dye dosing systems means more exact reproduction of dye liquors. The individual steps in the process, such as weighing, filling the containers and stirring the solutions etc., should be automated as much a possible in order to assist the laboratory. At the same time, it is not the time factor or saving in personnel which is of greater importance but improvement in reproducibility through higher precision and, above all, the avoidance of possible sources of error. The laboratory dye dosing equipment relieves the laboratory technicians but does not take over their work altogether.

When using the laboratory dye dosing systems, the following points must be taken into account.

Although dosing systems operate faster than a laboratory technician, there is a need for careful maintenance and a certain amount of time must be devoted to setting up and preparation and, for this reason, using equipment such as this does not always result in saving time. One advantage is that the operation of the dispenser is programmed automatically so that it can even work during the night and dye liquors are already available ready for use at the beginning of the early shift in

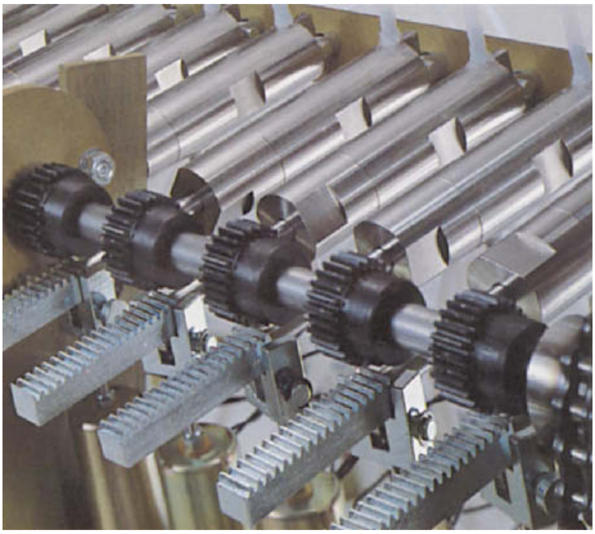


Fig. 2: Rack-and-pinion drive in a dispenser (Ishizaka).

the morning. Two or three concentrations of the dye being used are required to make optimum dosing possible across a wide range of formulations. This is catered for by using a large number of bottles of stock solution. Precipitation or dispersion of the dyes can be prevented using electrical stirrers or certain ancillary aids. A dosing system does not operate absolutely precisely but the results are significantly more reproducible than those produced by a laboratory technician carrying out routine manual laboratory operations. The automatic addition of stock solutions is around ten times more accurate than manual production. If errors or malfunctions do occur, these are indicated. Precision can be achieved, for example, by constant-flow pumping systems (Fig. 2) for liquid brands, the liquid dye solutions remaining in the hose connections being pumped back after weighing.

Laboratory dye dosing systems can also be used in the print-shop laboratory. Many units are equipped for the combined use of high- and low-viscosity dyes. There does not appear to be any great difference in the preparation of viscous dyes.

Laboratory dyeing machines These are classified according to the different dyeing principles upon which they are based as follows.

1. Liquor and goods circulate.
2. Liquor static but goods circulate.
3. Liquor circulates but goods static (flow processes).

Before the beginning of the twentieth century, textile finishing was a manual process. Process development was restricted to the dyes themselves and, in some cases, was a trade secret. However, this picture changed with the emergence of synthetic dyes and textile finishing increasingly developed into an industrial sector. Dye manufacturers invested in large research laboratories so the greater part of the development took place there. Another important change-around took place in the fifties with the production of synthetic fibres. As well as this, there came a plethora of new finishing processes, dyes and auxiliaries. The industrial range of application increased significantly and was supported partially by fibre manufacturers and machine builders. The results of this development work was for the main part legally protected by patents. There was no great need for the textile finishing factories themselves to invest much in production laboratories. Under external pressure from the customers, the laboratory was in many ways only directed towards matching the growing quality requirements of the customers by improving the quality control facilities. Since then, however, the laboratory has developed into an economic factor which cannot be ignored. Test and control functions as well as optimising the products and processes used were, for the most part, carried out in the textile laboratory, the development tasks predominantly falling into the domain of the chemical industry. The importance of the laboratory in the finishing process will grow, particularly where there is increased automation. The laboratory no longer plays a subordinate role to production but now occupies a position of equal importance where collaboration between the individual task areas is essential. The historical development took place as follows:

ca. 1870	Since the beginning of industrial dyeing, colour adjustment was carried out using simple laboratory equipment: – open beakers, heated using a heating surface and manual stirring, – heating surface replaced by a heating bath for even temperature distribution.
since 1950	Development of miniaturised production dyeing machines: pilot plants.
1960	Principle of closed, agitated dyeing beakers.
1963	Use of other methods to replace the manual movement of liquor, for example, moving the goods.
1967	Striving for greater production accuracy using flow systems.
1987	Since ITMA 1987: replacing glycol, the standard heating medium, with other heating media such as Bellatoni or infrared.

Under conventional laboratory conditions, working with beakers in motion in a glycol bath is still widespread. The development of “alternative” technologies for heating dye liquors has lead to the following procedures (Fig.).

- The IR method heats the dye liquor using long-wave radiation energy. The heating medium is no longer needed and work with the laboratory equipment is essentially cleaner and easier.
- Electrically heated systems heat the dye liquor directly and the need for a heating medium is fully

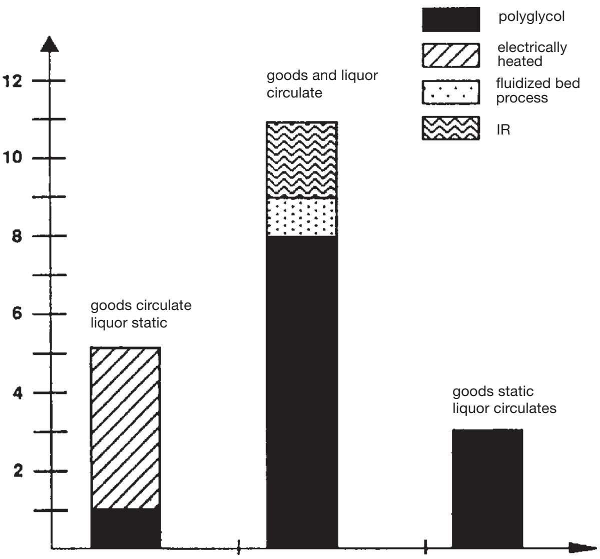


Fig.: Quantitative distribution of the different heating methods in laboratory dyeing machines.

redundant. However, the construction of the equipment is expensive.

- The fluidised bed or quartz-sand method involves the electrical heating of glass beads as fine as sand. This dry heating medium is easier to handle than liquid glycol.

The laboratory-to-production reproducibility is similar to that of glycol method. All alternative technologies are essentially simpler to handle.

For the most part, flow systems are fitted with electrical heaters. However, for dyeing principle with both goods and liquor in motion in beakers, electrical heating is not an option. Here, the tendency is to use radiation energy and dry heating media. In the case of the dyeing principle involving static liquor and goods in motion, no alternative technologies to glycol are available. There is a clear trend towards excluding sources of error through automation and greater accuracy. Using modern control systems, parameters can be recorded and controlled with a greater level of reproducibility and this leads to improved laboratory-to-production reproducibility. The exact simulation and recording of parameters crucial for production plants on a laboratory dyeing machine is problematic anyway. For this reason, it is more important to improve the technical capabilities of a laboratory dyeing machine by increasing the potential for logging, recording and controlling dyeing kinetics and process parameters. This means that increasing importance will continually be placed on the controllers on laboratory dyeing machines. Regulator controllers are being replaced by SPC or microprocessor controllers.

Control units, so-called multi-process controllers, are available through which all laboratory dyeing machines can be controlled. These can also be integrated into a factory-wide automation system such as the LACOS software supplied by Integrated Color Network.

On the one hand, it is possible to upgrade conventional laboratory dyeing machines with microprocessor controllers. On the other hand, a further alternative in regard to optimising the laboratory dyeing process is presented by installing HT circulation dyeing machines, supplied by Ahiba and Zeltex, which make it possible to control and regulate the process exactly. Dyeing parameters are not only set but regulated, i.e. controlled and readjusted during the whole dyeing process. These laboratory dyeing machines offer optimum laboratory-to-production reproducibility, particularly in regard to production dyeing machines used in cross-wound yarn package or beam dyeing as, in this case, the nature of liquor flow through the goods is directly comparable. Also to take into consideration in this connection is the type of makeup of the fibres during the dyeing process. The fabric appearance changes due to the different dyeing machines depending on whether the goods are dyed in a pressed or loose state. This influences the colour effect of the fibres. Whether the use of pilot plants for laboratory dyeing will win through is questionable. Because the principle of construction for these machines simulates that of full-scale plants (pilot plant suppliers also supply production plants) the dyeing parameters and control are in relative good agreement, thus ensuring good laboratory-to-production reproducibility. On the other hand, the high investment costs speak against it, i.e. high purchase price and high costs in terms of time, goods to be dyed, chemicals and dyes.

Laboratory dyeing principle – circulating liquid, static goods This dyeing principle is based on the flow system and is therefore directly comparable to the production machines of cross-wound yarn packages and beam dyehouses where the goods are subjected to a stream of liquor. The goods are made up on material carriers and are static during the dyeing process, whereas the liquor moves, flowing through the goods. In this method, many parameters may be controlled, defining the dyeing process and, therefore, increasing the laboratory-to-production reproducibility.

Praxitest and Multicolor (Fig. 1) are well known older systems. Where the highest demands in terms of levelness, dye penetration and reproducibility are required in a dyeing laboratory, it is necessary to resort to more expensive systems. Of course, demand and availability are lower in this sector than in the area where cheap machines are used for routine trials. Flow systems are by far the most gentle on the material to be dyed. The sample make-up is time consuming in the case of yarn or fabric where it is necessary to re-package or batch on to a perforated beam. Units with several

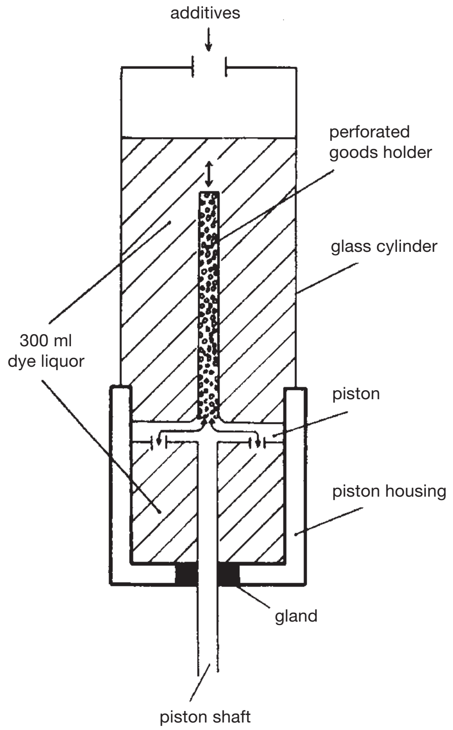


Fig. 1: Liquor circulation in the Pretema-Multicolor-System.

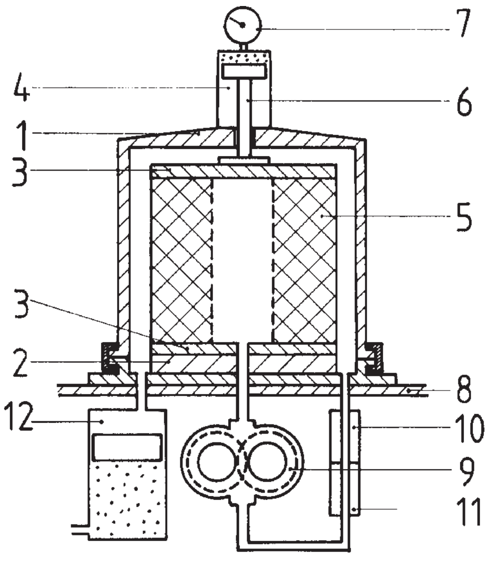


Fig. 2: Diagram of the Colorstar laboratory dyeing machine (Zeltex) with gear pump and computer.
1 = dyeing bell; 2 = impeller plates; 3 = cover plate;
4 = hydraulic press; 5 = package; 6 = piston shaft;
7 = manometer; 8 = work disk; 9 = gear pump; 10 = heater;
11 = water cooling; 12 = liquor reservoir.

dyeing positions offer the advantage that each dyeing position can be driven independently. In the case of Praxitest and Multicolor, both the liquor and the substrate can be observed during dyeing. Further additions to the dye liquor are possible at any time. When dyeing loose stock, a liquor ratio of 1 : 5 can be achieved.

While the Praxitest with a single dyeing position is exclusively used in research, machines such as the Pretema-Multicolor are use in the following areas: stability tests on dispersions, absorption behaviour of dyes, levelling tests for dark shades (end-to-end non-uniformity) and targeted adjustments. In terms of efficiency, the Praxitest pump system compares unfavourably to the Multicolor flow system which is based on a piston lift. The pump produces heat which is fed to the dyeing process in uncontrollable amounts. The uneven temperature distribution across the liquor causes problems. The streaming principle of the Praxitest and Multicolor systems is realised in an elaborate form in order to dye yarn packages or flanged bobbins. In this regard, the most elaborate is the Colorstar system which uses a gear pump (Fig. 2). Other units use a peripheral-wheel pump.

Fig. 3 shows that the delivery pressure of a gear pump is practically independent of the quantity of liquor delivered. The change in the speed of a gear pump results in a change in the flow of liquor which is proportional to the speed. In the case of a peripheral wheel pump, the quantity of liquor delivered decreases for the same pump speed with increasing pressure. On production machines, however, rotary pumps such as centrifugal or axial-flow pumps predominate. Each type of dyeing machine has different pump characteristics. These technological parameters have a great influence on the result. In the case of Colorstar, the delivery characteristics of the gear pump have now been incorporated in a computer program. At the same time, the performance characteristics of the pump on the production machines have been recorded, programmed and assigned to the parameters of the laboratory machine. With the help of a program such as this, it is possible to adjust the pump characteristics of the production machine and increase reproducibility from laboratory to production.

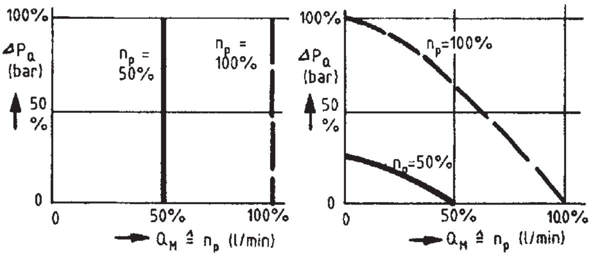


Fig. 3: Characteristic curves for a gear pump (left) and a centrifugal pump (right) at 100% and 50% of standard revolutions.

Laboratory dyeing principle – circulating liquor and goods The dye liquor and the goods are placed in

Laboratory dyeing principle – circulating liquor and goods

Fig. 1: Roller dye bath by Jagri.

a beaker and subjected to movement, e.g., via axial motion (Fig. 1), end-over-end tumbling (Fig. 2) or shaking movements. In this way, both liquor and goods are subjected to motion during the dyeing process and, technologically, this is the most simple and oldest method used and has relatively few controllable parameters. It is the most widely used in the world because it is uncomplicated, caters for large dyeing capacities and can be used under high-temperature conditions.

This dyeing principle is suitable for all types of samples. As a rule, no material carriers are required, but they are sometimes available as a special feature, for example, in the case of delicate yarns. The unit specifications differ in regard to the number of dyeing positions, capacity and temperature ranges. An important criterion is the possibility of dosing during the dyeing process. Sealing problems may occur depending on the type of closure used for the beaker. As a rule, these seals are made from Teflon which seal but, after a certain time, mould themselves to the beaker on which they are used. This means that, wherever possible, each beaker should only be sealed using the cover that belongs to it. The parameters relating to reproducibility reveal factors which can be regulated by controlling the unit in question.

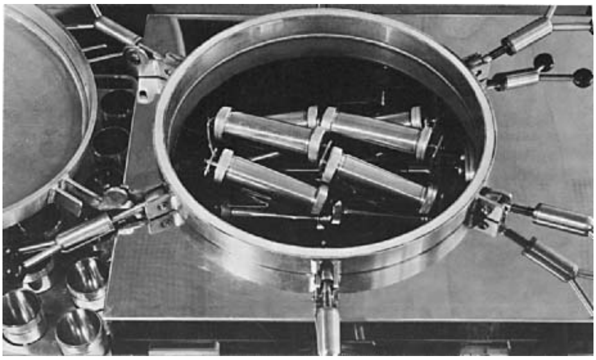


Fig. 2: Callebaut-De Blicquy (formerly distributed by Isal) with water bath in high temperature boiler.

Most units which are available are supplied with glycol as a heating medium. Roaches offers the IR and fluidised bed process and Mathis (Fig. 3) an IR unit for heating up the liquor as alternatives. The advantage of dyeing by agitating both the goods and liquor is that it is generally not necessary to make up samples on material carriers. High-temperature dyeing is possible with the exception of Osci-Color (Fig. 5) because the system is open. Dyeing and handling is simplest in the case of the beaker dyeing method (Fig. 4). It is the most wide spread method possible where a large number of colour adjustments can be rapidly carried out. The disadvantage is that the relative motion of liquor to goods is never monitored and this can have a detrimental effect on levelness and reproducibility. The goods are subject to relatively high levels of stress. Because the bath is heated indirectly, temperature control is inexact; only the temperature of the hot bath is measured. Aluminium

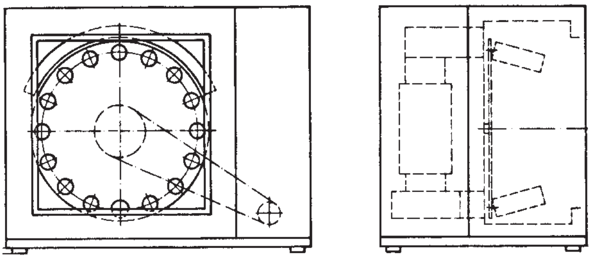


Fig. 3: Schematic drawing of the Labomat by Mathis.

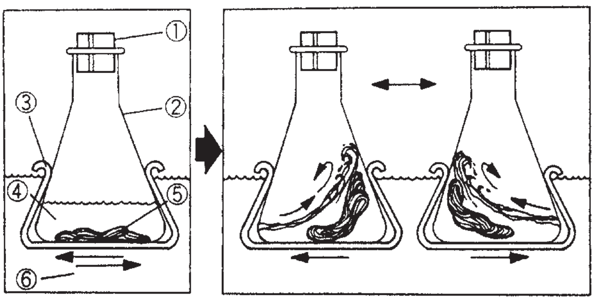


Fig. 5: The dyeing principle of the Osci-Color by Rapid.

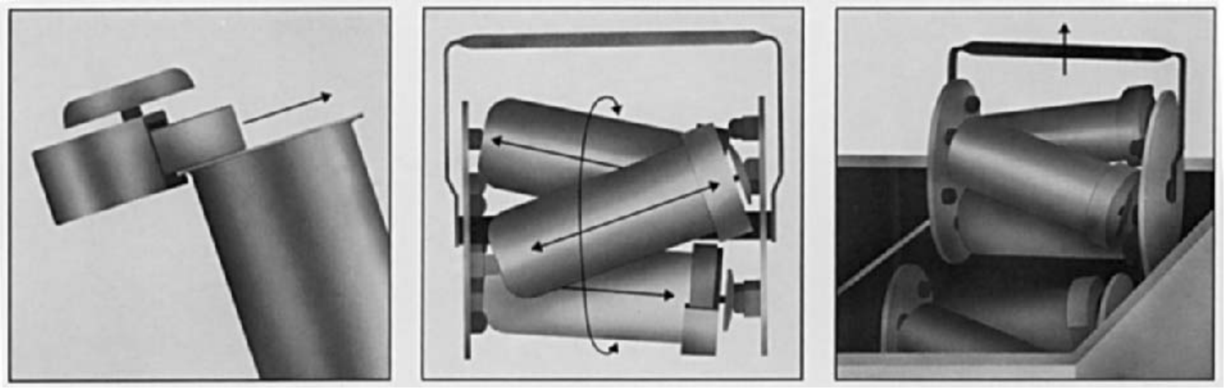


Fig. 4: The Polymat by Ahiba.
Quick-close cap with an O-ring seal and Teflon lining (left); the working principle (centre); simple loading and unloading of pots (right).

blocks or silicate fluids are presented as alternatives to the environmentally problematic glycol heating medium, but these are still too complicated to implement. The old high-temperature dyeing vessel using water as the heating medium and tumbling dye beakers (Callebaut de Blicquy, Fig. 2) is no longer available, although this is the best solution from an ecological point of view.

Laboratory dyeing principle - static liquor, circulating goods In a static beaker the liquor is moved more or less. (Figs. 1 and 2). The relative movement required between the substrate and the liquor is achieved by moving the goods (made up on material carriers). This is mainly a lifting movement which may sometimes be combined with rotational movement. The method is used in many dyehouses where all kinds of goods are dyed at temperatures below 100°C.

The Texomat (Fig. 3) can be converted for high-temperature conditions. However, this has not proved successful in practice: The arrangement produces mechanical difficulties, operates partly via solenoid systems and the seals are bad. As is the case for other machines, with this machine, the liquor is visible so the process can be monitored.

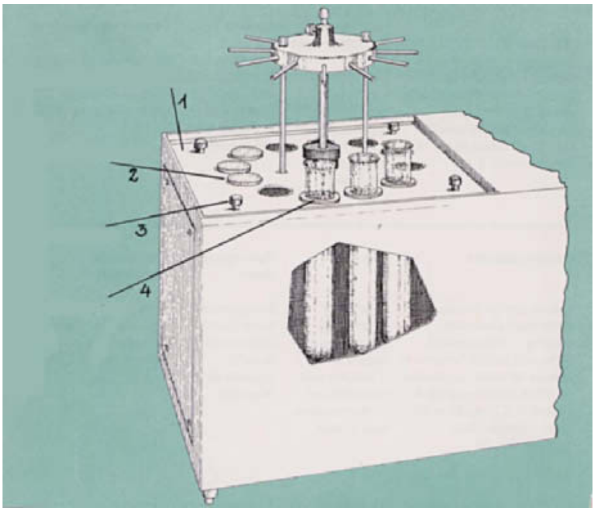


Fig. 2: Beaker dyeing apparatus (Roaches) with centrally located lifting mechanism.
1 = exchangeable cover plate; 2 = lids to avoid steaming; 3 = securing screw; 4 = dyeing beaker in mounting.

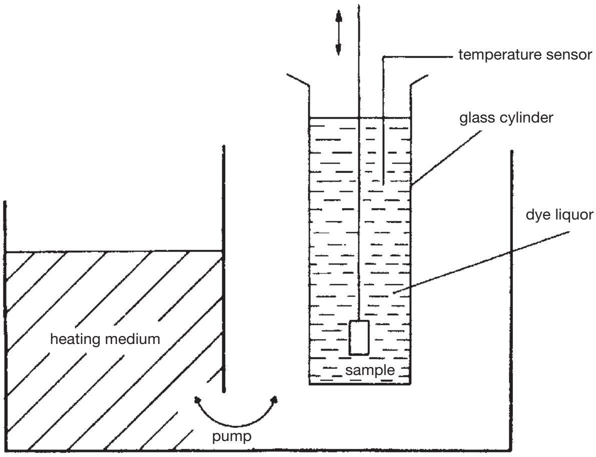


Fig. 1: Schematic of a beaker dyeing apparatus (static beaker, Multimat-Renigal system).

The advantage of laboratory dyeing with the goods in motion and static liquor is that dyeing on delicate goods can be carried out fast and reliably. If the liquor is visible, the exhaustion process in the bath can be observed and this can sometimes be informative. The disadvantage is that these machines can generally only be used for dyeing at temperature below 100°C and, because the system is open and the liquor is static, the temperature distribution and heat transfer are not optimised. This has a detrimental effect on the quality of the result. Glycol, which is used as the heating medium,

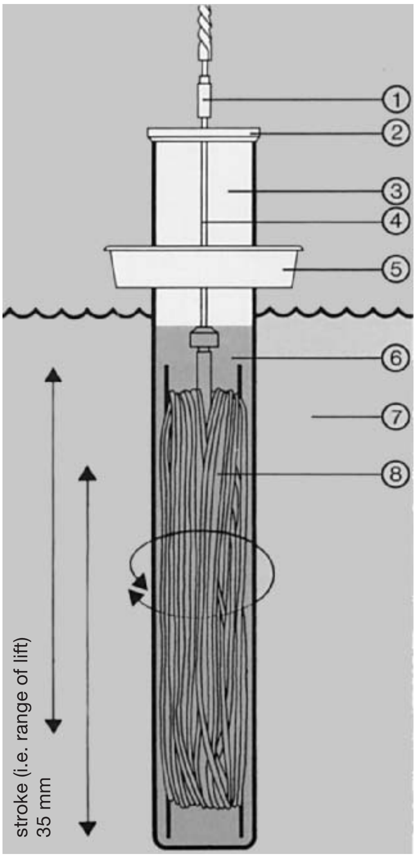


Fig. 3: Texomat GVII BT 412 by Ahiba with 4 beakers each holding 4 l.
1 = material holder connection; 2 = araldite lid; 3 = dyestuff container; 4 = material holder; 5 = rubber ring; 6 = dye liquor; 7 = heating liquor; 8 = material for dyeing (e.g. yarn).

manufacturer	type	capacity	minimum liquor ratio
Mathis	JFL	40 – 120 g	1 : 8
Benz	HT 140	1 – 3 kg	1 : 8
Then	OFHT 5	up to 5 kg	not given
Thies	micro soft	up to 10 kg	1 : 4
Thies	mini soft	up to 30 kg	1 : 4
Thies	midi soft	up to 60 kg	1 : 4

Tab.: Technical comparison of various laboratory pilot scale dyeing machines.

does not decrease in viscosity until high temperatures are reached and this can lead to a stagnation in heat transfer. It is therefore necessary to equip the bath with a mixing device. Dyeing can only be carried out at high liquor ratios (greater than 1 : 15) and it is also necessary to make up samples on material carriers and this takes time.

Laboratory pilot scale dyeing machines Reproducibility of formulations prepared in the laboratory using the available (→ Laboratory dyeing machines) is limited. On the one hand, they are based on experience in selecting the methods and the other, on the process-control capability via appropriate control systems for the laboratory dyeing machines. Frequently, when scaling up from laboratory to production, dyeing is still carried out on medium scale. This is used to prepare the patterns, optimise the process under practice conditions and investigate problems which could arise while dyeing on production scale but do not appear during the small scale laboratory dyeing of, e.g., 20 g material.

Laboratory pilot plants are modelled on full-scale production machines and represent a sort of "production in miniature". In contrast to the laboratory machines, not only can parameters which are determined by the dye formulation be readjusted, but features of the machine which have a decisive influence on result can also be simulated. For this reason, the trial-to-bulk reproducibility is usually significantly higher than is the case for laboratory dyeing machines. Pilot plants can be subdivided into smaller scale (1–3 kg) and larger scale units (10–50 kg), the demarcation being somewhat fluid (Tab.). Circulating liquor dyeing machines for dyeing packages are most frequently used for colour adjustments. (Fig. 1). For other processes, the advantage of the best possible way of scaling up must be weighed up against the high price which approaches that of a production machine. Because of the high costs, many finishers cannot afford to run this form of laboratory dyeing. The larger pilot plants are widely used in sampling dyehouses or used for dyeing special, small batches. They are only used for colour adjustment in the case of difficult shades or expensive raw materials.

1. Winches: these are used for economic dyeing and washing light to moderately heavy material which is

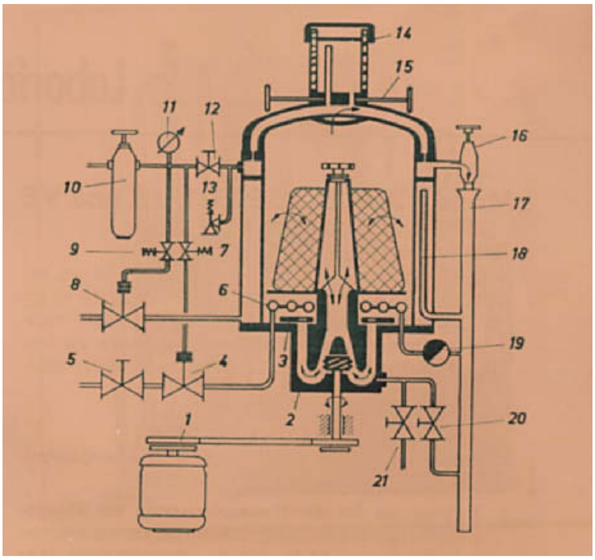


Fig. 1: MTM Obermaier circulation dyeing machine.

not sensitive to creasing. Process: the fabrics are sewn together in rope form, guided over a rotating winch, and plaited down in the dye liquor in the winch beck where they dwell for a short time. Dye exhaustion occurs during the repetition of this cycle. Dyeing is carried out in long liquor ratios. Winches for laboratory use are available from Roaches (50–100 l) and Mathis (10 l). They differ only in the liquor capacity. Both can only be used for the atmospheric range and have a dyeing drum as an optional extra. The winch vat supplied by Mathis also contains a paddle and a retainer for dyeing flasks.

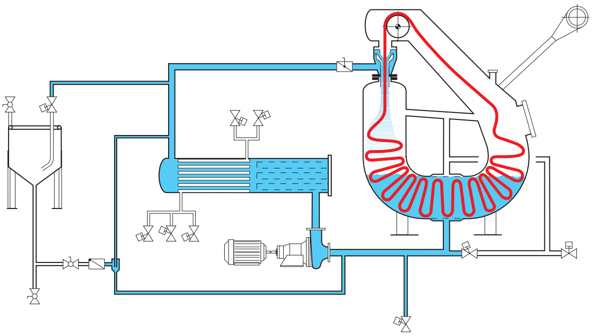


Fig. 2: Thies "mini-soft" piece dyeing machine.

2. Jet dyeing machines are used for goods which are not sensitive to creasing and are often used for polyester. Process: the aim is to reduce the liquor ratio. Dyeing can be carried out under high-temperature conditions. The fabric is circulated by the force of the jet and, in some cases, with a winch as well. The high rate of fabric and liquor interaction improves dye levelness at low liquor ratios. Jet dyeing machines are available from Mathis, Roaches, Benz and Thies (Fig. 2). Thies supply dyeing machines with capacities of up to 60 kg goods. The Mathis machines (Fig. 3) are designed for atmospheric use with goods of 100–1500 g and are suitable for high-temperature conditions for goods of 40–120 g and various different applications: jet dyeing using different jet diameters, dyeing drums, centrifuge, paddle, and high-temperature flasks (100,150 and 200 ml).

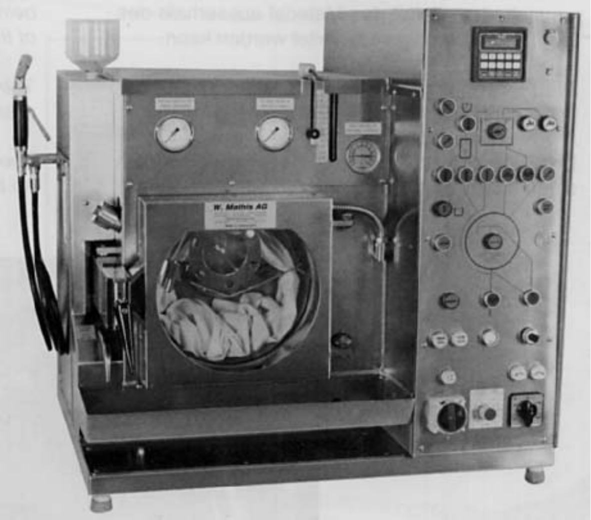


Fig. 3: IFL jet dyeing machine (Mathis).

3. Circulating liquor dyeing machines: for dyeing yarn and cones or tubes. Method: packages are placed in the machine on posts; dyes and auxiliaries are added using dosing tanks. The liquor is pumped through the packages while, in most cases, alternating the direction of flow (in-out and out-in). Circulating liquor dyeing machines are available from Jasper, Roaches, Isal, Then and Thies. MTM Obermaier supplied a high-temperature laboratory dyeing machine for 1–3 packages or with a dyeing bath for 7 packages which sits on top. It is also suitable for dyeing other material make-ups through different applications. The high-temperature pilot unit in Fig. 4 was developed from the high-temperature laboratory unit (mini-compact). With this, a unit is available by which all the following physical data of a treatment process can be measured and therefore reproduced:
- temperature,
- differential pressure,
- flow,
- pH,
- redox potential,
- conductivity,
- total water,
- rinsing water,
- exhaustion curve.

The dye bathe on the unit usually takes 3 packages with 6" lift. The bath has a glass mantle so that the behaviour of the yarn packages can also be monitored during the

Fig. 4: Laboratory dyeing machine for 3 packages in a dyeing column (Jasper).

treatment process (e.g., to see whether the system leaks and check the behaviour during the change in circulation etc.). The circulation pump is fitted with a variable-speed motor (frequency converter).

Jasper has also developed the 1-Plus-2 system to better utilise the capacity of the laboratory dyeing machine for the actual dyeing. Time-consuming pre- and after treatments, which are carried out under conditions of atmospheric pressure, are carried out in two treatment units next to the dyeing machine. An ancillary device is designed to draw the required chemicals from storage containers and another ancillary device is provided for pressing and unravelling press-cakes. The integrated chemical dosing unit is part of the standard design as much as the process controller (filling, time and temperature control, drain and rinse, etc.) is. In the case of Bellini and Bene Madinox, the yarn-dyeing machines are linked to a PC for controlling the process and recording the data so that important parameters such as pH control and flow rate can be worked out and established for production-scale process.

4. Jigger: for dyeing materials which are sensitive to creasing such as silk. Method: dyeing, bleaching, degumming and desizing piece goods in full width. The fabric is unwound from a roll, run through the liquor and wound on to a second roll. The fabric is run several times or “ends” through the liquor in this way. Laboratory jiggers for atmospheric dyeing are available from Mathis, Benz, Mezzera and Roaches.

5. Drum dyeing machines: for fully-fashioned goods dyehouses. Method: dyeing stockings, pullovers or sample pieces in a drum. The principle is similar to that of the household washing machine. Sufficient liquor exchange is achieved by the motion of the drum. Roaches supplies the Rotohose laboratory dyeing machine which has a perforated drum with partitions or blades.

Laboratory steamer Non-continuous saturated and high temperature steamer. Also used for adjusting formulations in carpet dyeing and fixing carpet prints. Used for a maximum pattern size of 70 x 150 cm, at temperatures up to 200°C and moisture control between 10 and 98%. Dwell times range from 10 s to 60 min – Manuf.: Mathis.

Laboratory to bulk reproducibility The dyeing laboratory plays an important part in optimising the costs of exhaust or continuous dyeing. In the laboratory, the colour shades are determined as recipes for particular dyeing methods. If the appearance in production is identical, i.e. without making further additions at the first attempt, and agrees reproducibly with the laboratory during all repeat dyeings, the reproducibility of the laboratory results in practice is good. Among the factors which affect the laboratory-to-bulk reproducibility are, for example, liquor ratio, temperature, flow mechanism in dyeing and liquor pick-up in the padder. (→ Laboratory).

Laboratory washing machines Laboratory washing machines are mainly used for testing wash-fastness and other fastness tests carried out in the laboratory.

Lace Lace is a more or less fine textile product with translucent base and dense pattern. Can be made by hand or machine. Genuine lace (hand made) is classified as follows: filet lace, crochet lace, bobbin lace, knotted lace. Knitted lace, (machine made): braided lace, weaver’s lace, bonded lace and embroidered lace. In the case of embroidered laces (for example Plauener laces) the base fabric is embroidered with a design and then removed as a piece process according to a pattern (→ Burn out style) or cut.

Lace effects → Burn out styles.

Lace galloon This is a fine, delicate copy of the genuine Valencienne lace on the weaver’s lace machine. Knitted ribbons of this type are called galloons. Chiefly made of cotton but also containing a small proportion of polyamide for strength.

Lace making Simultaneous braiding (interlacing) and twisting of threads (yarn, twist) in a diagonal direction for the manufacture of laces, small covers and similar items. These are classified into handmade lace (lace pillow), which in terms of quantity no longer has any significance, and machine-made on lace making machines. In the last case, the bobbins travel around each other in the warp sheet.

Lace Tweed Very light-weight Raschel-knitted fabrics made of natural silk, crêpe or polyamide warp. The bulky, roving or even wadding-type weft material is predominant and covers the warp (spun thread fine support structure). No qualitative requirements have developed.

Lacquer bases Film-forming component (such as natural or synthetic resin) in → Lacquers.

Lacquer-only screens Production of film-printing screens by the pre-lacquering or dissolving-out process using photochemical techniques. This method involves applying the lacquer to the screen, where the lacquer acquires better anchorage in the gauze than with post lacquering. Next, the photosensitive coating is applied and the copy made by laying a transparency on top and exposing it to light. The screens are developed as usual by dissolving out the non-illuminated areas. The lacquer is dissolved from the areas where no hardened copy coating remains and then special lacquers are used which, as a rule, are not suitable for post lacquering methods. → Photosensitive lacquer.

Lacquer printing Local gloss print chiefly produced in film printing using film(hole) screens, on thin fabrics and in Rouleaux printing (→ Chintz prints). Matt to high gloss effects are achieved with a certain degree of relief effect (depending on the thickness of the metal screen which ranges from approx. 0.3–1 mm).

Lacquers In most cases substances soluble in volatile solvents which form a thin, adherent, continuous film on the substrate by evaporation or physico-chemical processes. They are also important for the textile finisher, e.g., as different types of protective coatings, → Screen lacquers for film printing and for use in modern → Lacquer printing . Composition: in principle, lacquers consist of solvents and thinners (oil of turpentine, spirits, butyl or amyl acetate and toluene etc.) and so-called lacquer solids made from binders (substances such as natural and/or synthetic resin, cellulose products, chlorinated rubber and linseed oil), plasticisers and coloured pigments. Lacquers are classified according to their composition as follows:

I. Oil- (resin) lacquers: These are the oldest type of so-called “long-oil” varnishes with resin (e.g. copal + linseed oil + oil of turpentine) or without resin (e.g. so-called enamel lacquers for white internal and external coatings consisting of oil of turpentine + zinc white + boiled linseed oil + wood oil additive). Increasing the oil content prolongs the drying period but improves resistance to weathering. The use of oil-based lacquers is decreasing in favour of alkyd resin lacquers.

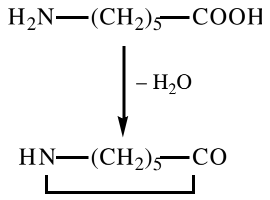
II. Cellulose lacquers: First among these are the different high-gloss collodium lacquers corresponding to the oldest type of so-called zapon varnishes (made from dissolved collodium wool or cheap film-formers or celluloid in amyl acetate) and pure nitro lacquers (nitro-cellulose dissolved in ethyl or butyl acetate etc. diluted with toluene etc.) used in lacquer printing and in pigment and bronze printing etc. Plasticisers are used as softeners. Pigmented lacquers of different types, such as fast lacquer dyes, are also used in the textile printing mentioned above and in leather dyeing. The nitro combination lacquers of complex composition contain either natural or synthetic resins as well, among these being combinations with alkyd resins which are customary in textile printing, and, to some extent, in rust-protection coatings. The acetate lacquers, made from cellulose acetate in solvents, such as acetone, ethyl acetate, butyl acetate, cyclohexanone and butyrolactone, are used in textile printing as fixers instead of these.

III. Synthetic resin lacquers: among these are, for example, phenolic resin lacquers made from phenolic plastic, spirits and another solvent, either as a so-called stove enamel (where infrared drying at 90–150°C follows curing) or “cold cure” lacquers with the later addition of very dilute acid (used as wood lacquers in particular). Pure phenolic resin lacquers are very hard, are of low elasticity, have excellent resistance to water, solvents and dilute acids, susceptible to alkalis and limited light fastness. Modified phenolic resins contain an integrated fatty acids, polyester or resin acids for improving elasticity. In the last case, significant amounts of linseed oil or similar substance can be solublised to produce oil-resinous lacquers (so-called synthetic copals) with high light fastness and high corrosion-protection properties for internal and external coatings. Although pure urea resin lacquers have high hardnesses, and a higher resistance to yellowing due to light or heat and are resistant to petrol, hydrocarbons and mineral oils, they are too brittle. For this reason, they are mostly only used in combination with nitro-cellulose for air-drying lacquers or with alkyd resins for stove enamels. Unlike the latter, urea lacquers modified with polyesters are characterised by significantly improved elasticity; they are suitable for acid-cured alkyd combinations and stove enamels which, in comparison to urea resin alkyd combinations, have the advantage of not yellowing even at very high temperatures. The different types of alkyd-resin lacquers have gained in significance in lacquer printing. In this case, the modified alkyd resins with condensed fatty acids (which can also be combined with nitro-cellulose) are of particular importance. They are soluble in hydrocarbons and tolerant to oils, harden in air during oxidation and polymerise in the final stage, which is insoluble. Chlorinated rubber lacquers (dissolved in solvents such as methyl acetate, butyl acetate, toluene and oil of turpentine) are also of interest and used in bronze, pigment and matt white printing.

Lacquer screen → Rotary screen printing machine.

Lacquer solids Solid components in → Lacquers.

Lactams Lactams are so-called internal amides made from amino acids or hydroxycarboxylic amides, produced from amino acids with the displacement of water (e.g., from 2-aminohexanoic acid (adipinic acid) → Caprolactam.



ε-aminocaprolactam

Lactates Salts of → Lactic acid $C_2H_4(OH)COOH$ (e.g., aluminium, chromium, titanic acid and tin lactate) which are used as dye mordants in dyeing and printing.

Lactic acid $CH_3CH(OH)COOH$; MW 90. The salts are called lactates. It is a viscous, pale yellow-to-brown hygroscopic liquid (miscible with alcohol or ether) or colourless crystals; high reducing power (gradual effect). Impurities (liquid): under certain circumstances, traces of heavy metals and calcium sulphate. Used as a wool mordant, in the manufacture of numerous dye mordants, as a substitute for tartaric acid and citric acid (leads to the softening of textiles to produce soft, silk handle without weakening the fibre or lustre), as a dye solvent (diphenyl and aniline-black pad dyes) and in aniline-black dyeing (aniline lactate), leather dyeing and finishing and for spotting agents, etc.

Lactones So-called internal ester of hydroxycarboxylic acids. These are classified into α, β, γ and δ higher lactones. The higher members of this group with 15–17 ring-links have a strong and, in most cases, pleasant smell.

Lactophenol cotton blue Substance used for revealing microscopic evidence of wool damage. Prepare a mixture from 50 ml chemically pure lactic acid, 20 g phenol, 40 ml glycerine and 20 ml water. Mix 50 ml of this with 10 ml aqueous blue solution, i.e. a 2% solution of soluble blue B (Hoechst), place a single drop on to a microscope slide with the test specimen, arrange and cover with a coverslip. Findings:

a) Mould fungus: after 30 min, the mould structure will turn blue and the spores blue or yellow to brown.
b) Fibre damage on the wool: after a few hours, the damaged fibres will be blue and undamaged fibres colourless.
c) Mould fungus on cotton: procedure and behaviour as for wool.

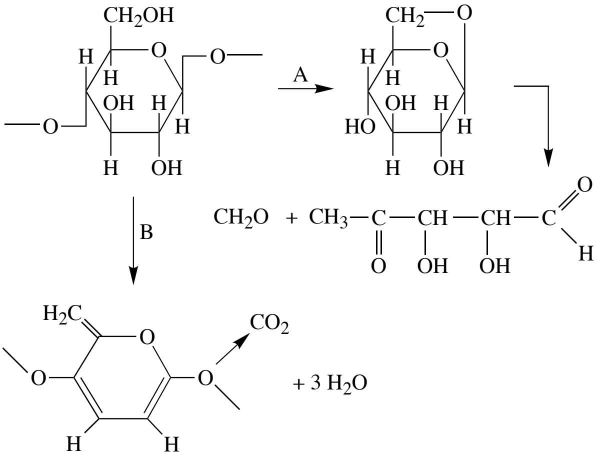
Ladder and snag-proof tester Instrument used for the testing of → Snag and laddering resistance, including the snagging of knitted goods.

Ladderproof finishes (snag and ladderproof and antisnag finishes). Treatment of knitted fabrics, usually made from fine yarns, and stockings against laddering and snags. Antisnag agents are used for this purpose. They are applied during exhaustion or spraying processes.

Ladder/run Appearance of a flaw in weft knit fabrics, especially women's hosiery. Arises as a result of a wale or wales having been mechanically undone or opened following thread breakage, where in addition to the stitch originally affected, those stitches connected to it also become undone in succession.

Ladik rugs Knotted prayer rugs from the Anatolian area of the same name. The separation of the pattern into middle, lower and upper sections is characteristic. Predominant colours are red, blue and yellow. Ornamentation is in the form of stylised flowers (tulips and carnations), short pile with around 200 000 Turkish knots per m^2.

Laevoglucosan Chemical compound produced during the initial pyrolysis of cellulose as the primary depolymerisation product by the breaking of the cellulosic glucoside bonds and in the next step with the formaldehyde cleaving forms a hydroxyketoaldehyde which then decomposes via various routes. In the case of flame-retardant finishing, it is assumed that the formation of laevoglucosan is suppressed, while H_2O cleavage becomes more significant during decomposition.



Laevo-rotary → Optical activity.

Lambert-Beer's Law The attenuation of electromagnetic radiation in a medium is termed → Extinction. In the case of solutions of dissolved molecules, the attenuation is essentially caused by absorption while that for dispersed particles also contains a scattering component.

extinction = adsorption + scattering

Where I_0 is the intensity of parallel electromagnetic radiation impinging on a layer of solution or dispersion of thickness b [cm] and concentration c [mol/l], under certain conditions, the following relationship applies to the intensity of radiation which emerges from the sample:

$$I = I_0 \cdot 10^{-\varepsilon(\lambda)\,c\,b}$$

where ε(λ) [l/mol/cm] is the decadic molar extinction coefficient which is concentration dependent within a defined range and is specific to the substance. ε(λ) is dependent on the wavelength λ, the polarisation of the incident rays and the solvent as well as the prevailing conditions in the solution or dispersion, such as pressure and temperature. In the case of dispersions, ε(λ) consists of the two components $\varepsilon_A(\lambda)$ for absorption and $\varepsilon_S(\lambda)$ for scattering. Thus,

$$\varepsilon(\lambda) = \varepsilon_A(\lambda) + \varepsilon_S(\lambda)$$

Among other things, $\varepsilon_S(\lambda)$ is dependent on the size, shape and orientation of the particles. Providing

$$\varepsilon_S(\lambda)\,c\,b << 1$$

multiple scattering plays a subordinate role and $\varepsilon_S(\lambda)$ may be regarded as being independent of concentration. Under these circumstances, dispersions can be measured by introducing the decadic extinction

$$A = \log (I_0/I)$$

to give the Lambert-Beer's law expressed by the following relationship:

$$A = \varepsilon(\lambda)\ c\ b$$

Its validity, i.e. the linear relationship between the extinction coefficient A and the concentration c within the range of the dye concentrations to be measured, is prerequisite for the quantitative photometric determination of dissolved and dispersed dyes where the effort to be put into calibration measurements must be small. Even for multi-component analysis, the applicability of the Lambert-Beer's law is crucial as, where this is not so, time consuming formulation-specific multi-point calibration curves will be necessary.

One of the most important effects in the case of dyes dissolved at molecular level is the concentration-dependent formation of associate structures. In the case of dispersed dyes, it is the scattered light which has the greatest influence on the extinction spectra. In practice, the conditions under which these effects have the least influence must be assessed. A proportion of dye may exist in its associated form in the solution (e.g., dimers and polyassociates) depending on the concentration. The extinction spectra of dissolved monomolecular dyes and their associate structures are different in most cases. Thus, for a certain dye concentration, the extinction spectrum for the solution represents the sum of the spectrum for the monomolecular dissolved dye and the spectrum of the different associate forms in the prevailing ratio. For this reason, it is advisable to carry out measurements on soluble dyes at the lowest possible concentrations. In order for the measurement error not to be too large, it must be ensured that the extinction values lie within the measurement range appropriate for the photometer. Measurements carried out at low concentrations are made considerably easier by relatively high specific absorptions, such as those for reactive dyes (source: Locher and Firmann).

Lambswool → Wool from the first shearing of young sheep.

Lamé,

I. A patterned fabric with → Metallized yarns woven in.

II. A generic name for → Metallized yarns.

Lamella,

I. A thin leaf or disc.

II. The term membrane lamella is used in fibre histology, for example, in the case of cellulose fibres and synthetic polymers. The two-dimensional system consisting of cellulose chains arranged in parallel and bonded to each other via hydrogen bonds represents the building block for the three-dimensional → Micelle (Fig. 1).

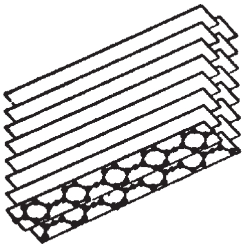


Fig. 1: Three-dimensional lamellae structure in cellulose.

Fig. 2 shows the macrostructure of a slow-cooled linear polyethylene. The (centro-symmetric) spherolites are produced by the radial growth of lamella packages. The crystalline and amorphous regions are clearly defined. If the polyethylene melt is cooled down rapidly, the spherolites are considerably smaller and poorly arranged.

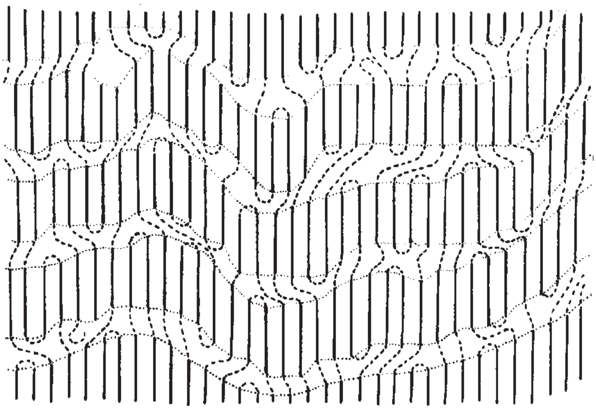


Fig. 2: Structure of lamellae packets (schematic).

III. The skin of blisters/bubbles such as those found in → Foam.

Lamellar macromolecule In crystalline areas (in the plane of the paper), the structure of two-dimensional or lamella macromolecules in the sense of so-called chain grids (→ Pleated sheet structure), for example, in the case of cellulose (lamella), wool (keratin grates), synthetics (crystallite) and silk.

Laminar Regular, sheet form, low friction.

Laminar boundary layer A layer consisting of gas or liquid that is carried along with the interface of a sold body in the direction of its motion as it moves in relation to the gas or liquid. If, for example, the surface of a textile fibre is regarded as the "river bank" and the surrounding liquor as the "river" then the flow profile may appear as illustrated in Fig. 1.

Zone 2 represents the fibre as the solid substrate. Zone I represents the bath, which is circulated by pumps, (dyebath with high initial dye concentration or washing liquor with initial soiling level at almost zero)

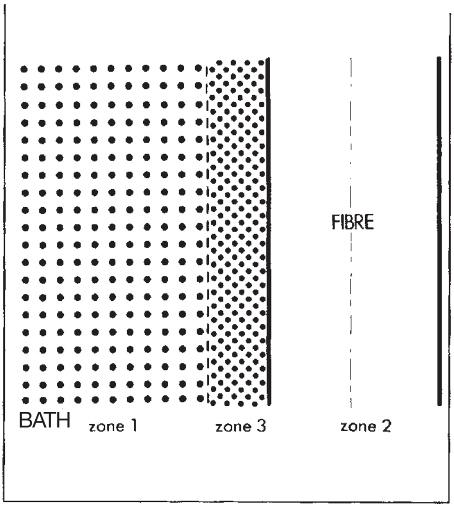


Fig. 1: Flow profile with three zones: turbulent (1), laminar (3), fibre body (static, 2).

where turbulent flow predominates. Zone 3 is the laminar boundary layer with a characteristic flow profile. If during dyeing the boundary layer is left undisturbed, the even distribution of dye found at the start of the dyeing process will gradually become uneven as the dye molecules are absorbed on the fibre surface and, because the liquor is “stationary”, the rate of replenishment within the layer is not as fast as the rate of depletion due to the adsorbtion process.

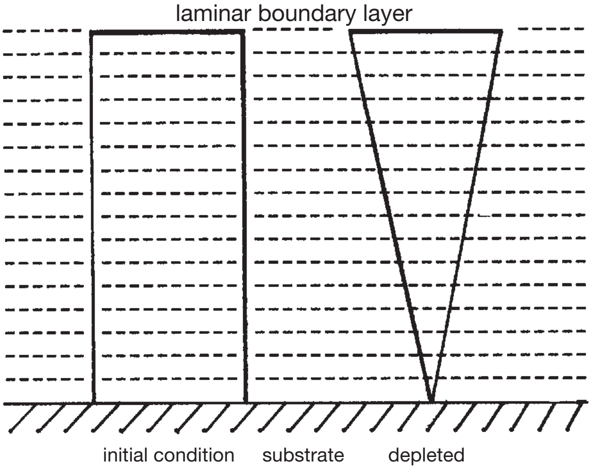


Fig. 2: Situation within a laminar boundary layer during dyeing of a substrate.

In Fig. 2, the even distribution of dye is shown on the left, and the depletion of dye at the substrate surface, caused by the diffusion of absorbed dye molecules on to the fibre while the concentration of dye is insufficiently replenished in the laminar boundary layer due to the lack of turbulence, is shown on the right.

Laminar flow Form of stationary liquids or gasses where their layers move past each other without turbulence, contrasts with → Turbulent flow.

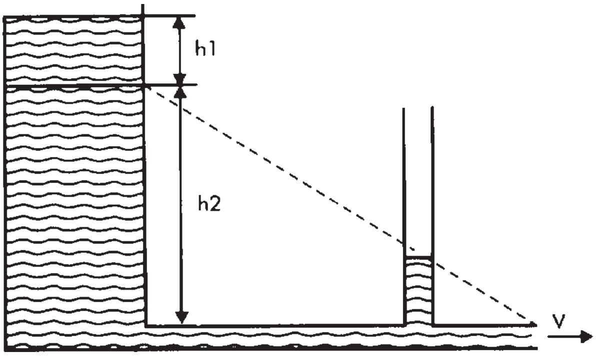


Fig.: Diagram explaining laminar flow.

If water is allowed to enter a vertical round tank with a horizontal drain at the bottom at the same speed at which it is allowed to escape through the outlet (Fig.), the velocity of flow at the outlet is given by:

$$v = \sqrt{2 g h_1}$$

From this, it can be seen that the proportion of flow corresponding to h_2 is reduced by losses due to friction. The losses due to friction are shown by a gradient of flow from the wall towards the centre (or in the case of flowing river water, from the banks towards the centre of the river) in the flow medium of the vertical tank. At the wall, the flow rate is almost zero whereas in the centre, the flow is at its maximum. This produces a flow profile with lamina flow at the boundary and turbulent flow in the centre of the pipe.

Laminated fabrics → Bonded fabrics made from at least two sheet materials of which at least one has textile character.

Laminated plastics Sheet form from paper, textile or wood, impregnated with synthetic resin (mostly phenoplasts) and then hot pressed. Hard semi-manufactured goods such as rods, pipes, profiles and slabs used for containers, apparatus or machine construction further machined for gear wheels and housings.

Laminates These are produced by bonding textiles and non-textile sheet materials using surface adhesives (→ Laminating). They fall into the following classifications:

1. Textile/foam laminates: two-layered sheet materials, produced by bonding a fabric (textile sheet material) or knitted fabric to a sheet of foam.
2. Sandwich laminates: three-layered flat materials, the two outer fabrics or knitted textile layers being

glued to either side of a sheet of foam as the middle layer.

Lamina thickness swelling This method, which has long been used in the paper industry, has been modified for textiles and developed further into a quick method for measuring the → Swelling of textiles, measurement of.

Laminating Bonding together of two or more layers of similar or differing flat textile materials (Figs. 1–4) such as wovens, knit goods, films, felt, paper, nonwovens, fleeces and foam films. If a foam or another non-textile flat material is bonded to a textile surface, this is termed laminating (e.g., by thermal bonding between the textile surface and the foam). If a textile surface (as the face fabric) is bonded to a lining fabric by a binder (foam), the term used is → Bonding.

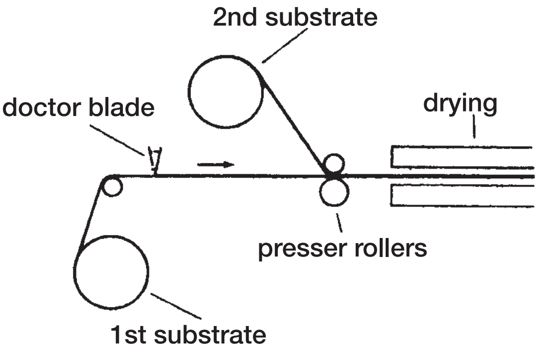


Fig. 1: Laminating principle.

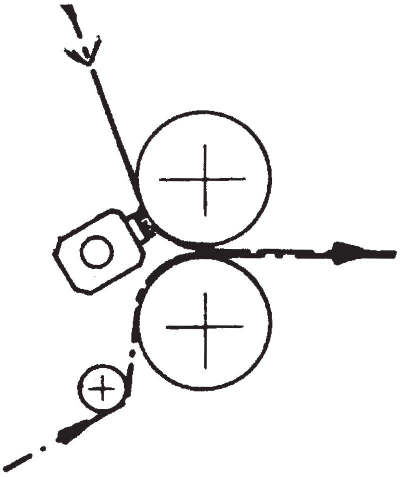


Fig. 2: Flame-lamination by the single-system.

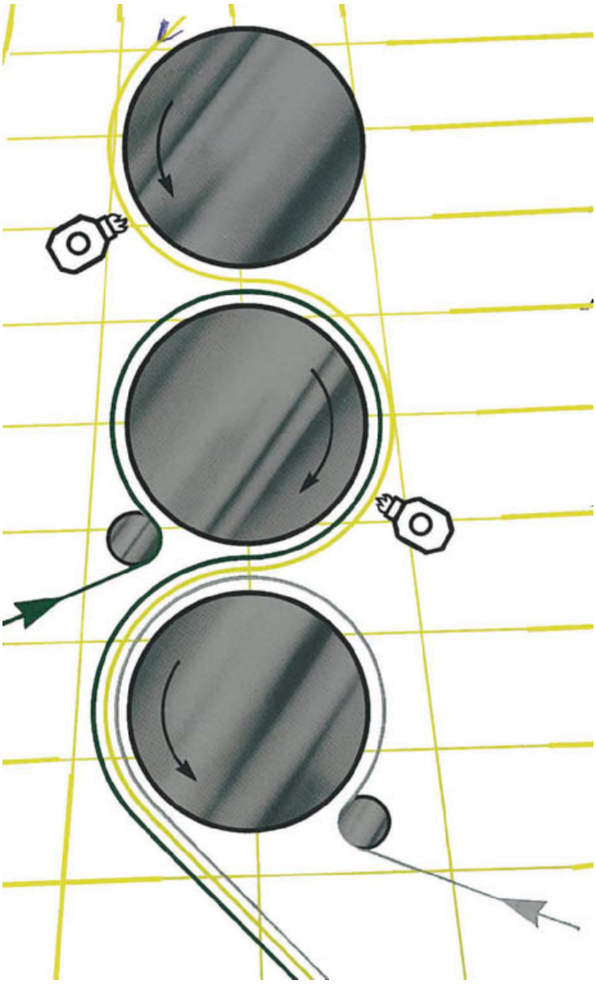


Fig. 3: Flame-lamination by the Sandwich-system

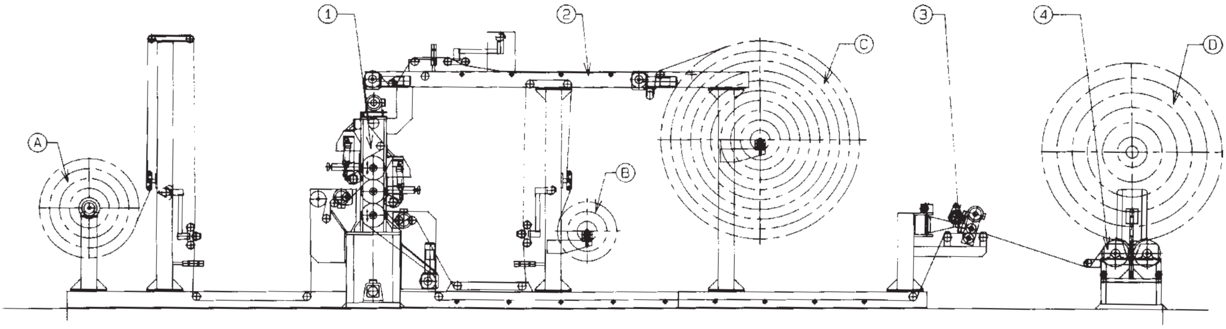


Fig. 4: Standard machine for non-continuous operation, consisting of: A = unwinding unit textile; B = unwinding unit backlining; C = unwinding unit foam; D = winding unit finished product; 1 = laminating machine; 2 = frame for the material flow; 3 = edge trimming unit; 4 = mandrel winding unit.

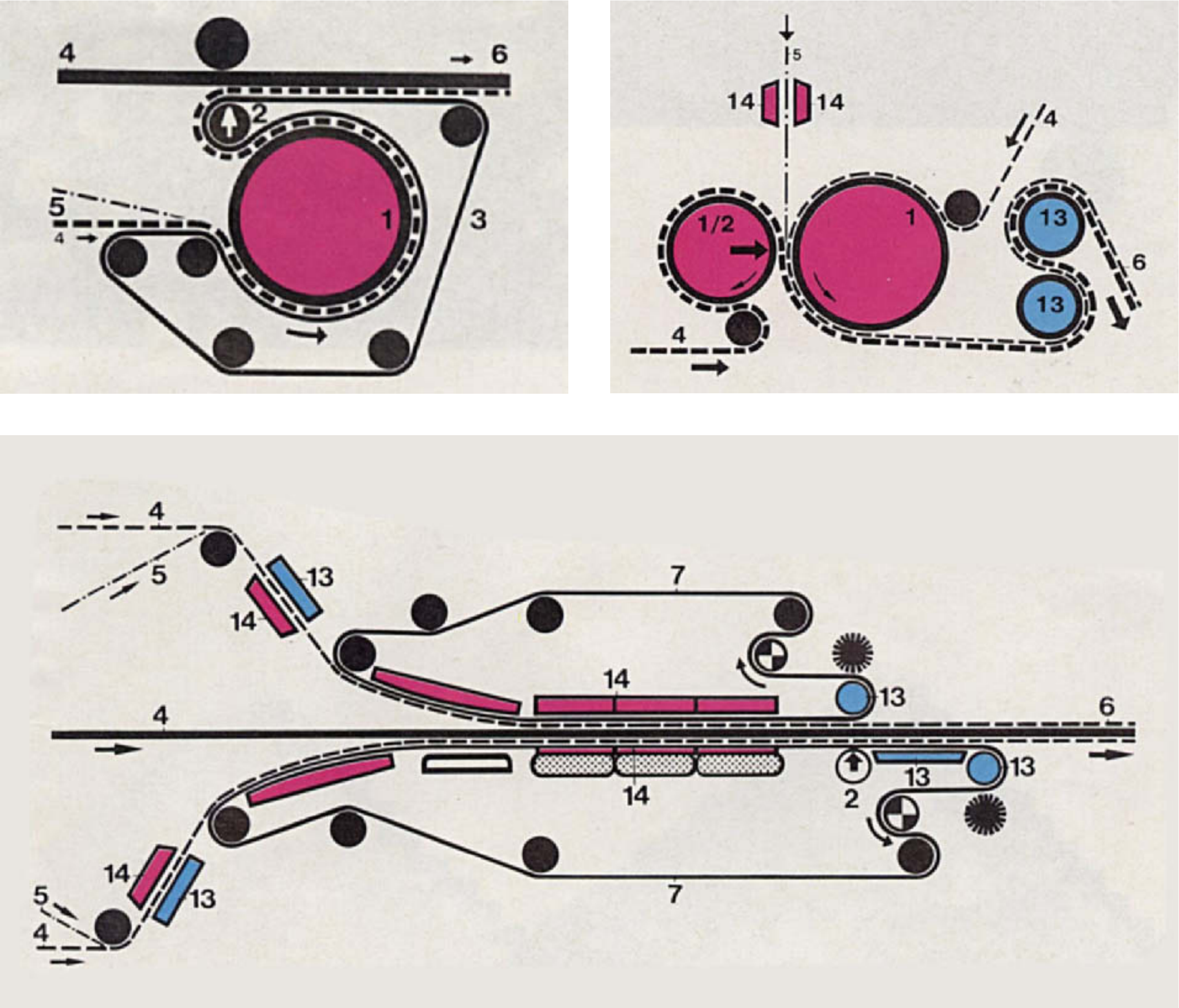


Fig. 5: Laminating possibilities with Stork systems.
1 = teflonized heating cylinder; 2 = presser rollers; 3 = siliconized rubber blanket back grey;
4 = substrate; 5 = thermoplastic film; 6 = laminate; 7 = teflonized back grey; 13 = cooling unit; 14 = heating zone.

With the inventation of the Swimming Roll in 1956, the first deflection controlled roll in the world, Küsters made today‘s production widths for the calendering process possible (Fig. 6). This experience in roll systems has been used for the development of the new ultrasonic calender (Figs. 7 + 8). Küsters have the know how to manufacture precision rolls. Together with the equipment of Hermann-Ultraschall, those precision rolls make an excellent combination. The high precision of the roll, the stable mounting of the welding heads combined with the accurate gap control system, guarantee a consistent, uniform bonding process across the complete roller width and throughout the complete time of operation. The optimized design of the vibration system enables the machine to achieve production speeds previously considered to be impossible.

In general, laminating is also used to bond preformed hard plastic films to another material using bonding agents or adhesives (Figs. 5 + 9 and 10 + 11). In this way e.g. bonded sheet materials from cellulosic and polyethylene are produced where the cellulose confers aroma sealing and the polyethylene is waterproof. Bonded films made from polyisobutylene (bond to steel) and polyethylene (corrosion protection) are used

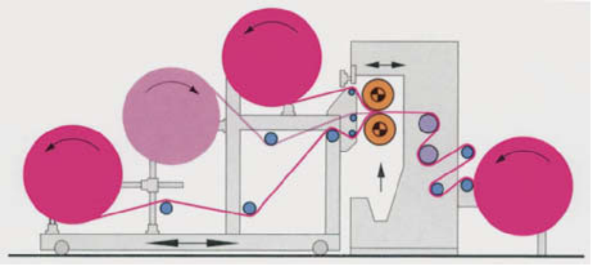


Fig. 6: Normal lamination.

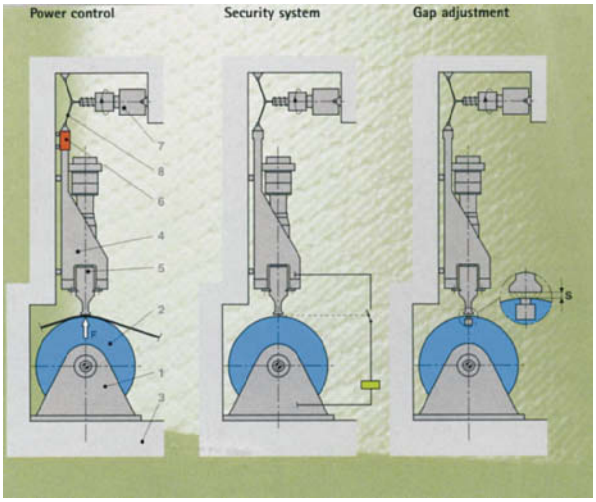


Fig. 7: Power control, security system and gap adjustment in an ultrasonic unit (Küsters).
1 = bearing; 2 = roll; 3 = frame; 4 = actuator; 5 = welding head; 6 = load cell; 7 = stepper motor; 8 = toggle lever.

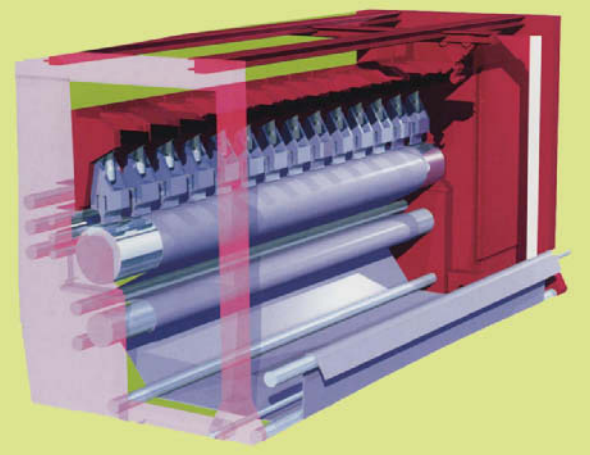


Fig. 8: Ultrasonic lamination.

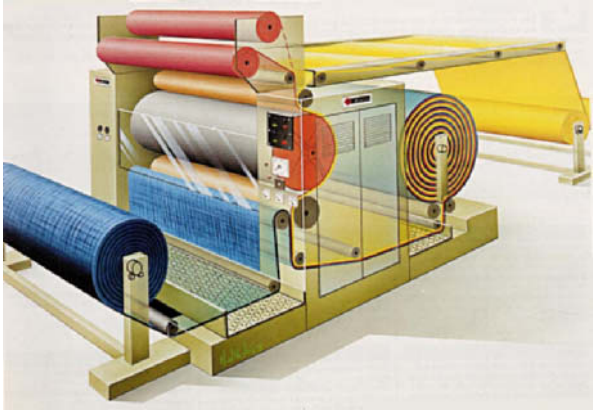


Fig. 9: Typical laminating process (Lemaire).

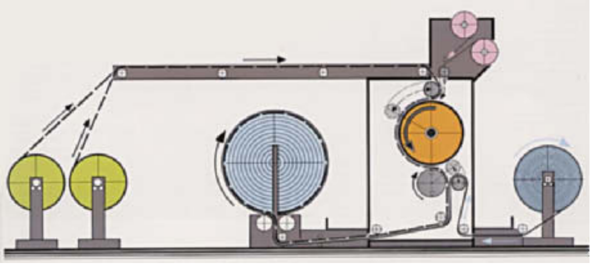


Fig. 10: Lemaire laminating calender.

in the construction of chemical apparatus. Sheet steel laminated with polyvinyl chloride can be worked like ordinary steel but is resistant to corrosion without further treatment. Polytetrafluoroethylene films are sometimes applied to aircraft so that it is difficult to wet and thus helps to reduce icing problems.

Bonded materials are often made using a process similar to laminating. In the case of synthetic leathers, layers of different synthetic materials are put together. For example, a product is manufactured consisting of an upper layer of polyurethane, a middle layer of mixed

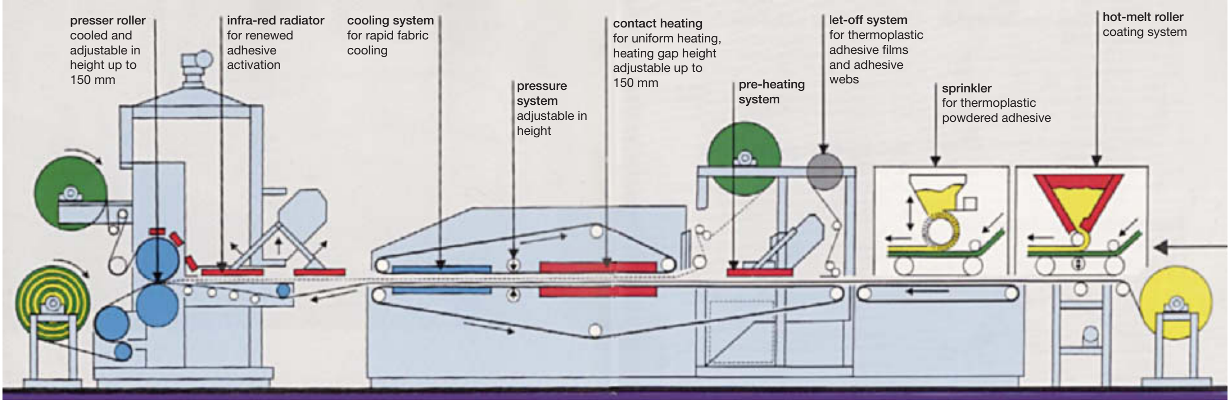


Fig. 11: Meyer flat bed laminating system.

textile made from 95% polyethyleneterephthalate and 5% cotton and a bottom layer made from polyethyleneterephthalate fleece. Bonded materials are mainly used as structural materials. → Coating.

Laminating calender This is used to bond textile or paper webs by hot-melt spray coating or with thermoplastic films (Figs. 1 and 2).

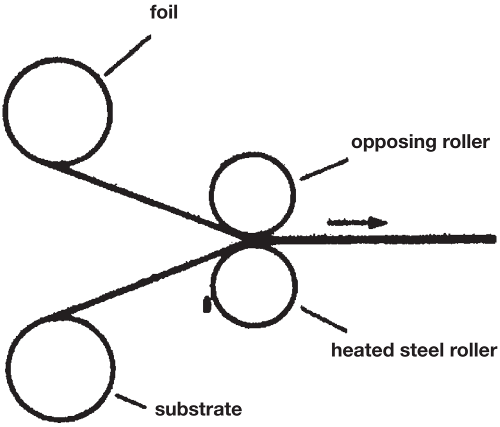


Fig. 1: Diagram showing principle of the laminating calender.

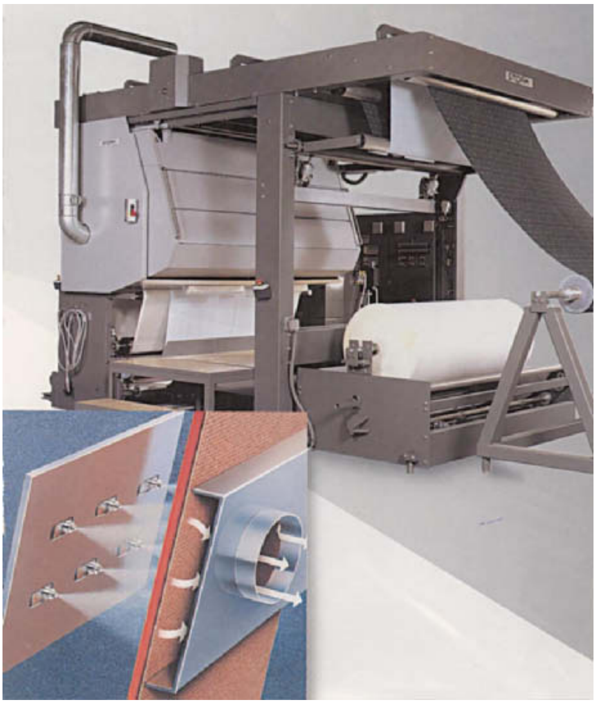


Fig. 2: Laminating calender with hot-melt spray coating (Stork).

Laminating carpet Term formerly used for → Bonded-pile carpets.

Laminating machines This section presents the technology on the use of the Primal acrylic emulsions as adhesives for bonding fabric to fabric, to foam, to nonwovens, to film and to fibrefill. These acrylic emulsions from Rohm and Haas Company are the backbone of a good laminate. Being water-based, they are easily formulated, applied and cleaned up, without objectionable odour or danger of fire hazard or air pollution. Fabric-to-fabric laminates based on the reactive Primal emulsions are durable to post-dyeings as well as to multiple washings and drycleanings. Their lack of discolouration on ageing and on exposure to light, allowing them to be used on light coloured fabrics, is yet a further advantage.

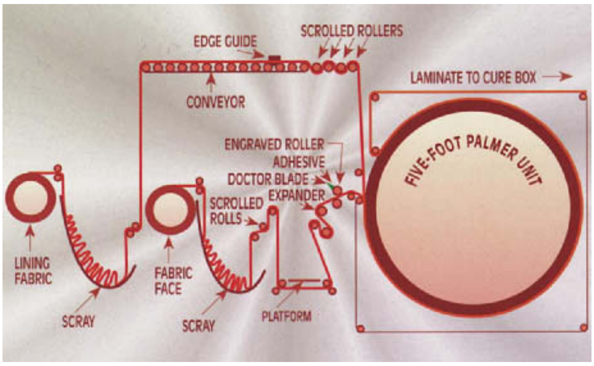


Fig. 1: Diagram of a typical textile laminating machine.

A diagram of a typical laminating machine is shown in Fig.1. Operating speeds on these machines are usually about 20 to 40 metres per minute. The maximum speed at which the machine can run is dependent not only on the time needed for properly curing the acrylic adhesive but also on the limits of fabric handling equipment such as straighteners. Adhesive is usually applied to the shell fabric or the film with one or more metal or metal and rubber rolls. Three of the most commonly used combinations are illustrated in Fig. 2. The kiss roll method (Fig. 2A) is preferred for applying adhesive to lace fabric which requires a continuous adhesive film because of its small surface area. The applicator roll is smooth and the amount of adhesive applied is regulated by the doctor blade.

Fig. 2B shows the “doctor blade reservoir” method, which is probably the most commonly used. In this method, the applicator roll is engraved. Fig. 2C depicts the use of a transfer roll which turns in the adhesive mix and contacts an engraved roll. A reverse transfer roll, where the engraved roll runs in the opposite direction to the fabric, can also be used.

The amount of adhesive applied is dependent on the fabric to be laminated. Fabric construction, its absorbency, hydrophobicity and surface characteristics will

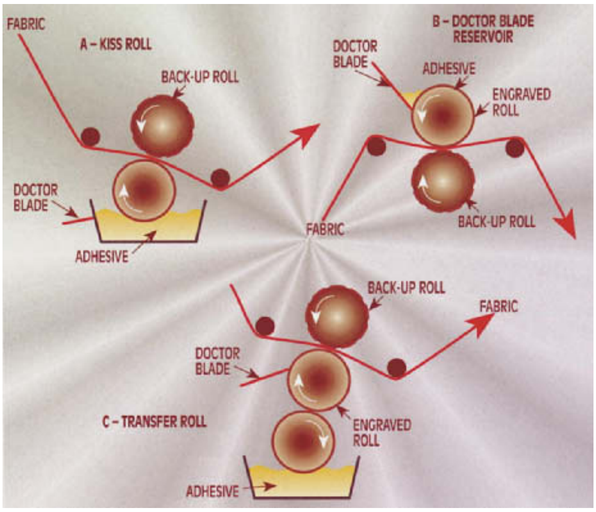


Fig. 2: Methods of adhesive application.

all influence the amount of adhesive needed as well as its penetration into the fabric. The adhesive should remain on the surface of the fabric to be available for contact with the backing fabric in order to form a good bond. Usually from 80 to 180 adhesive/m^2 fabric are applied. Probably the most important variable that affects the amount of adhesive applied is the engraved roll used. These rolls are available in a wide variety of types, including dot, quadrangular and lined patterns. Other factors which influence the amount of adhesive applied are: speed and direction of the engraved roll; coating viscosity; rheology; pressure from the backup roll; and where a backup roll is not employed, the amount of wrap-around.

Most of the factors mentioned that affect the applied solids also affect the penetration of the adhesive. Undue penetration can cause unsightly strike-through as well as stiffening of the hand of the fabric. The fabric should be married promptly after the application of the adhesive and dried immediately. Proper control of pressure is essential when a nip or pressure rolls are used to ensure that good contact is made but that there is not excessive penetration of the adhesive. Another method of marrying the fabrics is to use a large steam or oil-heated cylinder, a Palmer unit, which has an endless blanket wrapped around it. This method is the one illustrated in Fig. 1. The blanket presses the laminate lightly against the heated cylinder and prevents slippage of fabric during the early drying period. Laminates can also be dried over a series of heated small diameter cans. Heat is not applied uniformly, in this process, since the sides of the fabric receive heat alternately as the laminate travels from one drying can to the next. An endless blanket will reduce the tendency for the fabric layers to shift during the initial drying period. If strike-through is apparent, cutting the temperature of the initial drying cans can be effective in eliminating this problem, but it is not feasible if curing conditions are marginal.

The next processing step, curing, is one of the most important in laminating with acrylic adhesives. The bonded structure must be cured to make the adhesive durable to washing and drycleaning. The time and temperature necessary are dependent on the particular fabrics and adhesive formulation as well as whether curing is done on heated rolls or in a hor air range.

The ingredients in these typical formulations should be added slowly and in the order listed. Because of the final high viscosities of laminating adhesives, a power mixer is essential. The power requirements of the mixer will depend upon batch size and final viscosity, but a three to five horse power unit should be sufficient for drum-size batches at laminating viscosities of 40 000 to 80 000 cps. Mixers with a marine-type propeller are preferred, because paddle- and disc-type impellers will not provide adequate agitation. The blade should be about one-half the diameter of the mixing tank. When formulating in drums or larger containers, two blades, both directing the mix downward, should be used. The shaft should be off-centre and canted slightly for optimum liquid movement. Gear reducers are suggested to lower the speed of mixers to 300 to 500 rmp. without reducing power. These speeds ensure uniform mixing without whipping excess air into the adhesive. Lightning mixers and similar equipment are available in a variety of models and sizes. Drums are often used as mixing tanks. Larger tanks can be constructed of stainless steel, glass fibre-reinforced polyester or moulded polyethylene. The size of the tank should allow for adhesive depth to be about twice the tank diameter. The mixer should be mounted externally, not on the sides of the drum or tank. All mixer tanks should be covered to prevent adhesive contamination and skinning.

Laminating of dry bonding (principle of dry bonding). A thermofusible film placed between two materials is brought on a continuous basis to its melting temperature and permanently bonds the two materials (→ Bonding of textiles). The elements to be bonded can

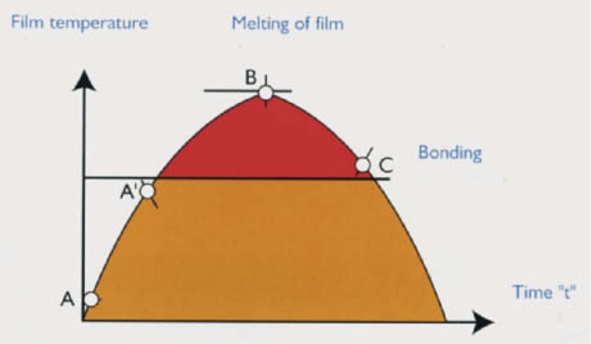


Fig. 1: Requirements of the dry bonding.

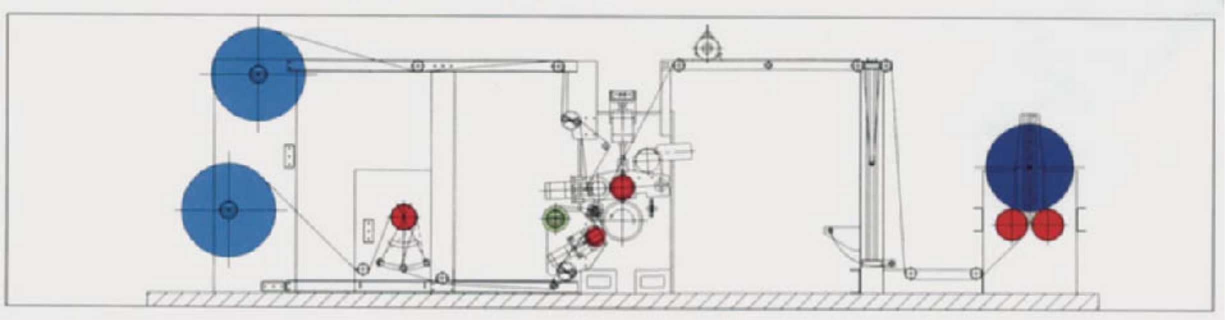


Fig. 2: Lemaire calender for dry laminating.

be either in roll form or in sheets. E.g., to perfectly bond foam to fabric, the film should first be in contact with the foam surface. This thermofusible film is heated to a temperature higher than its melting point, and immediately prior to its cooling, the fabric is compressed onto the foam to which the film is already adhered. The time needed do bond depends on the time of exposure to heat and the dimensions of the heating systems.

Fig. 1 illustrates the requirements on a practical basis: upon exiting from the heated surface where the film has been brought to its melting point, it is necessary to maintain this condition of the film for a given amount of time “t” after which time the second surface to be bonded will be pressed into the bonded assembly (B–C curve). A corresponding equipment is shwon in Fig. 2.

Laminating on rotary screen printing machines Rotary screen printing machines can be used for laminating all web-type materials. This may be a machine especially designed for dry laminating with extended facilities for wet laminating. Alternatively, a printing machine may be used before pressing (wet-in-wet) as a form of wet laminating or, particularly in the case of stretch-sensitive and low- or non-absorbent materials such as plastic and metal films, a printing machine may be used which facilitates laminating before or after the printing process, with intermediate drying after each print position.

Laminating technology Bonding textile materials with other non-textile flat materials such as paper and plastics. Techniques:

1. Adhesive is applied to one laminate component in the form of a paste (coating process), powder (powder point coating process) or melt (roller melt process) and this is pressed with a second or third component.
2. The surface of a foam is melted using a flame and pressed onto a textile material (→ Flame laminating, Fig. 1).
3. A (foamable) thermoplastic is first applied to a carrier such as paper (release paper) or continuous metal band and released at the moment of bonding (transfer or reverse process). This process can be used to produce very thin coatings.

The flame laminating process, using thermoplastic foams, is widely used, for example, in the manufacture of car upholstery. The surface of the foam is melted by heating it on one side. In the finished product, the foam layer has a clearly recognisable thickness of 0.5 mm which can be felt. In the case of the sandwich method, the laminate consists of two textile surfaces of different type which are bonded on both sides with foam sheet.

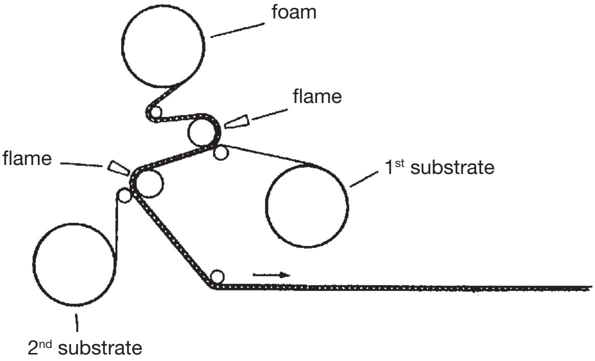


Fig. 1: Flame laminating machine.

The flame method is also used for double-sided laminating. The foam is melted on both sides from the heat of the flame. The procedure is to melt first one side by passing it near gas flames and pressing it with the first component material and then to melt the other side

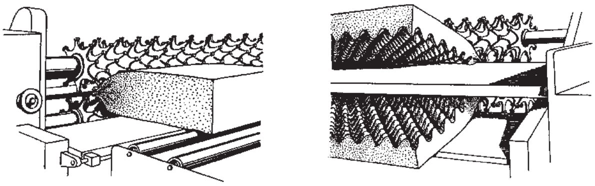


Fig. 2: Cutting a polyurethane foam in elastically deformed state to structure its surface.

with the gas flames and press the laminate with the second component material. With single side flame laminating, the foam can be structured on the side that is not laminated to the textile (Fig. 2).

Dot coating with powder or paste: Here we present a comparative report on two related techniques, namely dot coating with powder and with paste (Figs. 3 and 4). Both methods employ copolyester or copolyamide adhesives which, in the form of powder, are applied to the substrate by appropriately shaped rolls or wheels. The adhesive is then fused under an infrared radiation source.

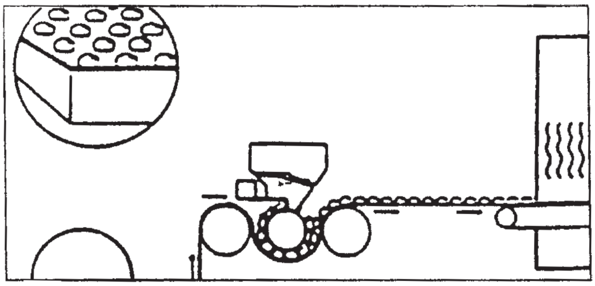


Fig. 3: Powder dot coating method.

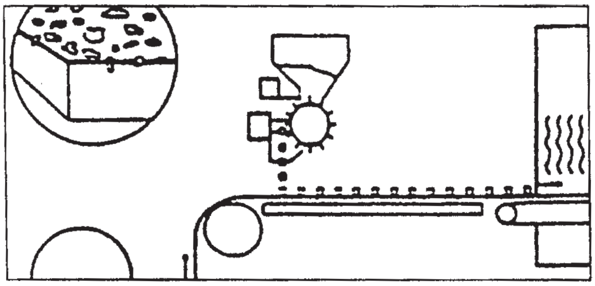


Fig. 4: Paste dot coating method.

A fundamentally different technique is to employ an adhesive that has already been melted or activated. Examples of this technique are:

- screen printing,
- roller printing,
- spray application,
- a new technology “Porous Coat”.

With both screen printing (Fig. 5) and roller printing, a squeegee roller produces discrete dot coating of adhesive on the substrate. In the spray method there is no direct contact and it is also possible to use reactive adhesives, for example polyurethane hot-melts. Customer requirements reveal a growing demand in end-uses involving long-term temperatures of around 120°C, for example in the car industry. It is difficult for these requirements to be met by conventional methods such as dot coating with powder or paste, screen printing or roller printing. Rather than copolyester or copolyamide, these methods employ reactive polyurethane adhesives which dissipate into the environmental atmosphere under the effects of heat.

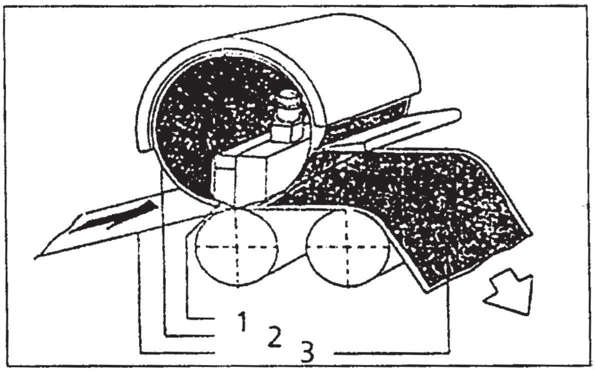


Fig. 5: Screen print method.
1 = snap-on nozzle; 2 = cylindrical screen; 3 = nonwoven.

Spray technology: This method combines the advantages of application without direct contact and uniform application using conventional polyamide/polyester or ethylene vinyl acetate adhesives and also reactive adhesives such as reactive polyurethane hot-melts. One of the principal distinctions between these two methods is that no contact is made with the substrate being coated with the adhesive. This non-contact application has its advantages for very thin or delicate materials as there is little or no influence of temperature on the laminate. Maximum precision of application is achieved in the spray method by using a gear pump in the spray head. Adhesive is applied by two independently controlled air jets which produce an elliptical ap-

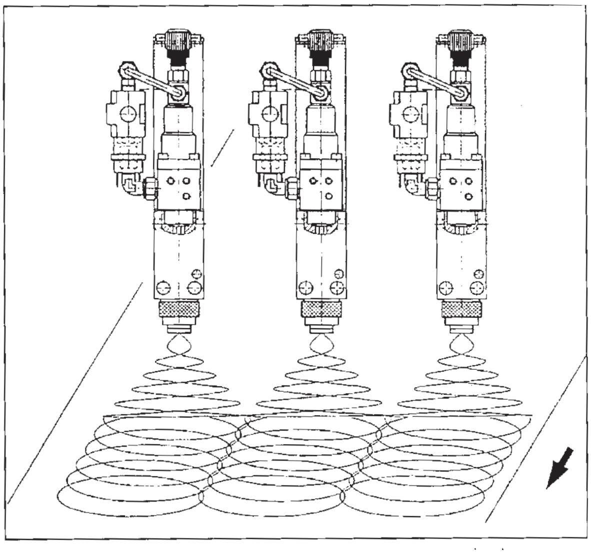


Fig. 6: Spray method. Adhesive application with two independently controlled heated air jets which produce an elliptical application of the string of adhesive.

plication of the string of adhesive (Fig. 6). These attributes make spray technology interesting for a large number of end-uses. The limitations of the process are evident when penetration of adhesive into the substrate is required, since the adhesive remains predominantly on the surface.

The “Porous Coat” method: A “Porous Coat” system consists of a variety of components (Fig. 7). The example illustrated is the configuration when using adhesives supplied in drums, for example reactive polyurethane hot-melts, or when using adhesives in granulate form, e.g. polyester or polyamides.

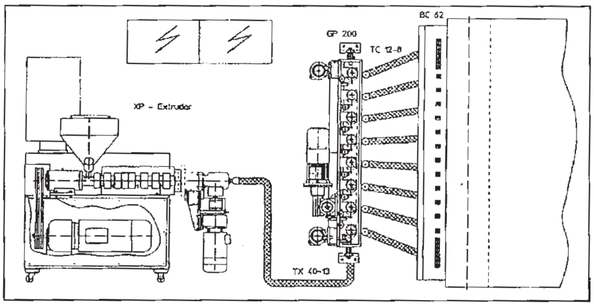


Fig. 7: Diagram of the “Porous Coat” system using polyester or polyamide in granulate form.

1. Adhesive supplied in drums: The adhesive is transferred into a reservoir by heated drum plunger fitted with a gear pump. From here it is pumped at controlled pressure into a central pressure pump unit by a gear pump, from where every feed hose and consequently every pressure zone of the “Porous Coat” applicator head is supplied with metered volumetric amounts of adhesive.

2. Adhesive supplied in granulate form: The adhesive is melted down in an extruder and, with a gear pump bolted on to the extruder, is metered volumetrically into the central pressure pump unit which then supplies the applicator head. This new technology permits positive application of unvarying amounts of adhesive from a special slit extrusion die. This type of dot application enables the amount of adhesive used to be reduced by as much as 30% compared with conventional methods of application. This prevents undesirable wastage due to adhesive penetrating too deeply into the substrate with consequent loss of pliability in the laminate. Thanks to its various automatic control systems the process is versatile and productive, for example its automatic width selection. This automatic system enables width changes to be implemented even whilst production is continuing, in adjustment increments of 3 cm. For instance, a slit extrusion die 1.70 m wide can be changed down to a coating width of 1.40 m or even narrower, with an electronic circuit automatically compensating the motor and/or pump speed and ensuring that the precise amount of adhesive applied is kept constant. Another option is to vary the position of the extrusion die in relation to the substrate. This enables the adhesive to be applied on the surface of the laminate or deep in the laminate as required. Using adhesive that is already in melted form also increases the production rate as there is no need to use an infrared heat source to heat the coating following application. Speeds as high as 100 m/min can be realistically attained.

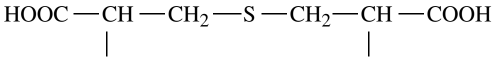
Lanameter An instrument used for measuring fibre fineness including that of chemical fibres. It consists of a desk-shaped housing which has a diagonally arranged measuring matt disc upon which the fibres magnified 500 times are projected. The thickness measurement is accurate to within 0.001 mm.

Lancé Fabrics with an associated group patterning (figuring) which is formed by a second warp and/or weft system. The patterning only appears in stripes even if the pattern itself shows no stripe arrangement. The threads not required for patterning on the face float or are woven in at points on the reverse (in contrast to → Broché).

Lanolin → Wool fat.

Lanometer (Rapid Lanometer) – instrument for testing the thickness of fibres, particularly wool. The total cross-section of 100 parallel bundled fibres is measured using a special calliper. Dividing the measurement by 100 gives the average fibre thickness (→ Lanameter).

Lanthionine Sulphur-containing → Amino acids as a thioester of cystine where the cystine sulphur has been replaced by a simple sulphur atom.



$$\mathrm{HOOC{-}\underset{\displaystyle NH_2}{\underset{|}{CH}}{-}CH_2{-}S{-}CH_2{-}\underset{\displaystyle NH_2}{\underset{|}{CH}}{-}COOH}$$

Lanthionine is non-reactive which explains the alkali resistance of the lanthionine sulphur. The lanthionine complex R–CH_2–S–CH_2–R plays a role as an intermediate in the alkaline treatment of wool. The mechanism of damage to the cystine in the wool caused by alkali has been thoroughly investigated. According to this work after the splitting of a proton from the α carbon atom, a β-elimination leads to the formation of a thiocysteine- and a dihydroalanine-residue (β-aminoacrylic acid):

$$\mathrm{{>}CH{-}CH_2{-}S{-}S{-}CH_2{<}} \xrightarrow{OH^-} \mathrm{\ominus{>}C{-}CH_2{-}S{-}S{-}CH_2{-}CH{<}}$$

$$\mathrm{\ominus{>}C{-}CH_2{-}S{-}S{-}CH_2{-}CH{<}} \rightarrow \mathrm{{>}C{=}CH_2 + {}^{\ominus}S{-}S{-}CH_2{-}CH{<}}$$

$$\mathrm{{}^{\ominus}S{-}S{-}CH_2{-}CH{<}} \rightarrow \mathrm{{>}CH{-}CH_2{-}S^{\ominus} + S}$$

$$\mathrm{{>}CH{-}CH_2{-}S^{\ominus}} \xrightarrow{OH^-} \mathrm{{>}CH{=}CH_2 + S^{2\ominus} + H_2O}$$

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The thiocysteine residues formed decompose into a cysteine residue and sulphur, the cysteine continuing to react due to the hydroxyl ions to form the dehydroalanine residue.

A second mechanism which has been postulated describes the formation of dehydroalanine directly from cysteine by cleavage of the H_2S group. The hydroxyamino acid, serine, reacts in a similar way.

$$>CH{-}CH_2{-}OH \rightarrow >C{=}CH_2$$

The reactive dehydroalanine residues thus generated can form the following products with the corresponding amino acids or other nucleophilic reactants present in the wool:

$$>C{=}CH_2 + >CH{-}CH_2{-}SH \rightarrow >CH{-}CH_2{-}S{-}CH_2{-}CH<$$

lanthionine

$$>C{=}CH_2 + >CH{-}(CH_2)_4{-}NH_2 \rightarrow >CH{-}CH_2{-}NH{-}(CH_2)_4{-}CH<$$

lysinoalanine

$$>C{=}CH_2 + >CH{-}(CH_2)_3{-}NH_3 \rightarrow >CH{-}CH_2{-}NH{-}(CH_2)_3{-}CH<$$

ornithinoalanine

$$>C{=}CH_2 + NH_3 \rightarrow >CH{-}CH_2{-}NH_2$$

β-aminoalanine

$$>C{=}CH_2 + H_2O \rightarrow >CH{-}CH_2{-}OH$$

serine

$$>C{=}CH_2 + H_2S \rightarrow >CH{-}CH_2{-}SH$$

cysteine

During the reaction with the nucleophilic amino acid side chains, new lanthionine, ornithinoalanine and lysinoalanine cross-links are produced in the wool fibre from the original disulphide links. It is generally accepted that the formation of lanthionine leads to a deterioration in the mechanical properties. This can be explained by the unzipping-like thiodisulphide exchange which takes place as the wool is stretched. With the formation of lanthionine and extension of the other links produced while damage caused by the alkali is taking place, this exchange is prevented, leading to a stiffening of the wool and worsening of the mechanical properties. Both in the case of alkali damage with the formation of lanthionine and in the case of the thiodisulphide exchange, Mechelbeck established in 1963 that the free H_2S formed from the cysteine acts as a catalyst. Thus, the following reactions may be considered conceivable:

$$>CH{-}CH_2{-}SH \rightarrow >C{=}CH_2 + H_2S$$

$$>CH{-}CH_2{-}OH \rightarrow >C{=}CH_2 + H_2O$$

$$>CH{-}CH_2{-}S{-}S{-}CH_2{-}HC< + H_2S \rightarrow >CH{-}CH_2{-}S{-}S{-}H + HS{-}CH_2{-}HC<$$

$$>CH{-}CH_2{-}S{-}SH + HC{=}C< \rightarrow >CH{-}CH_2{-}S{-}S{-}CH_2{-}HC<$$

This mechanism would explain the significant deterioration in mechanical properties seen to accompany alkali damage – the chain-segment mobility of the wool proteins is increased by cleavage and reforming of the cysteine links. This can produce a more pronounced change in the conformation than a change in pH alone. The newly formed cystine links may be formed at completely different sites to those before the bonds were broken and hold the wool protein chains in their new conformation. This would be possible, e.g., if the thiocysteine residue reacts with one of the dehydroalanine residues arising from the serine (source: Werkes).

Lapping,

I. Covering immersion rollers of a padder or impression cylinder (in the case of Rouleaux printing presses) with a fabric for the purpose of improving the liquor pickup or providing an even, elastic pressure pad. → Lappings; Tubular felt.

II. Difference in diameter between the centre and end of the roller in the case of the elastic rollers of calenders.

III. Lowest layers of the cover on decatising cylinders.

Lappings Used for iron printing cylinders in roller printing. These can be made from ramie or viscose in the warp and wool in the weft.

Large batch rolls Used to transport large quantities of goods and for storage for continuous processing machinery. Special winding machines are used to make large batch rolls (for example, Hyperbola-, surface and other winding devices). → Giant batch rolls.

Large repeat print styles Large repeat printed articles are on the one hand the → Sari and sarong of traditional Far-Eastern ladies' clothing and traditional clothing of the black African population and on the other, table cloths, bed linen, curtains, terry towels, ready-to-wear patterned ladies' outer clothing, flags and printed carpets.

Large repeat printing Printing on rotary printing machines with large circumference screens. These increase the design possibilities but at an extremely high cost. Screens are significantly more expensive and sometimes the components of the printing machinery have to be changed bring the circumference of the screen to 2 m. A further development is electronic controlled → Intermittent printing by two partially engraved complementary screens which lift and print in a reciprocating manner. Their use is of interest for large repeats for black-out curtains and shower curtains.

Large repeat rotary screens These combine the advantage of a high print speed offered by the rotary screen with that of a large format offered by the flat screen. For reasons of stability, the perimeter of the screen can only be increased to 2 m. They are used for printing table cloths, carpets, deco fabric and clothing materials with special patterns.

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LAS Linear → Alkyl benzene sulphonates.

Laser Abbreviation for “Light Amplification by Stimulated Emission of Radiation”, i.e. light amplification by excited emission of radiation. The laser is an instrument for producing very small, concentrated spots of high-intensity light. The possible areas of application in the textile industry are measurement and testing methods, photochemical processes and material processing:

a) heating threads,
b) patterning effects on textiles to change their dyeability,
c) producing surface roughness,
d) welding,
e) cutting textile webs whilst simultaneously sealing the raw edges,
f) cutting,
g) monitoring for surface defects.

On account of its high radiation density and controllable power, the laser has found a place in many areas of material processing where the advantages of laser radiation with its characteristic monochromatic and parallel nature, extreme power of convergence and power density are exploited. Infrared lasers such as CO_2 lasers, neodymium YAG lasers, neodymium-gas lasers and ultraviolet lasers such as excimer-lasers are used for material processing involving direct interaction between the laser and the material. Argon- and krypton-ion lasers and dye lasers on the other hand have a catalytic role in surface treatments (chemical processes). Used in industry for years, the IR lasers, predominantly CO_2 lasers with $\lambda = 10.6\ \mu m$, are utilised in metal processing. These generate continuous radiation of the highest energy with effective efficiencies of up to 20%. By exciting the rotational or oscillating states of the molecules, the radiation energy is made available almost completely in the form of thermal energy. Because of the high power of the lasers used today, enough energy is deposited in a given material volume to be used for industrial purposes, such as welding, in spite of the low absorption coefficient for IR radiation in the case of most materials. For textiles, the CO_2 laser can be used industrially as an intense, directional heat source which can be applied locally.

Radiation using IR lasers appears to be problematic for all surface treatments of polymers. The treatment is critical in regard to the experimental conditions and if the choice of laser intensity is unsuitable, the materials will be heated beyond their melting points. Controlled treatment of the surface alone is not possible in the case of the classical interaction because the absorption coefficients are low and plasma coupling analogous to metal processing has so far not been achieved. The use of excimer-lasers which operate within the ultraviolet range offer more possibilities. The advantages of using UV light are mainly to be found in the high extinction coefficients which range from about 10^3–10^4 for most organic polymers within the 400 nm wavelength range. The high absorption coefficients and the energy situation of the UV radiation offered by these lasers make possible the high-precision processing of sensitive polymer materials. Excimer-lasers are therefore used in the processing of polymer films made from polyester, polyamide and polymethylmethacrylate etc. where the controlled removal of material is of paramount importance. These are pulsed gas lasers containing noble-gas halogenide molecules which are stable in their excited state (excimer = excited dimer). The lasers can be operated at different wavelengths in the UV spectrum depending on the choice of excimer.

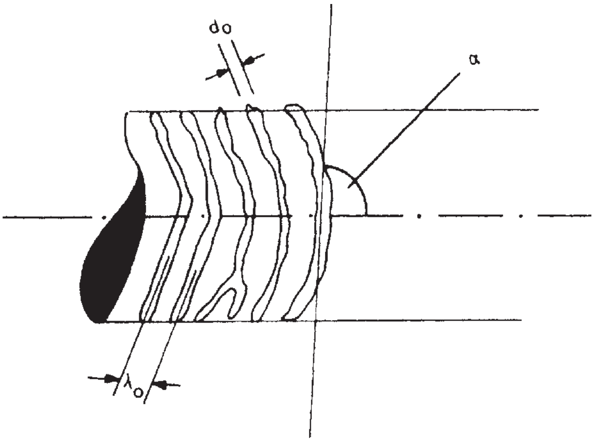


Fig.: Characteristics of the surface structure of polymers following irradiation by UV laser (according to Schollmeyer).

Examination of the irradiated surface yielded an interesting aspect of the UV laser radiation of polymers. On the one hand, the knowledge gained from experiments on polymer films relates to the chemical composition of the immediate surface. On the other, physical changes to the structure of the irradiated surfaces are described as well. Unlike the surface of plastic films which is smooth, the surface exposed by ablation shows a structure which can be described as a uniform arrangement of hills and valleys typically 1–2 µm apart (Fig.). A conclusive explanation for the appearance of such structures has so far not been forthcoming (source: Bahners and Schollmeyer).

Laser Doppler Effect Describes the frequency shift of monochromatic laser light when reflected from materials in motion. This effect can be used, for example, for contact-free length measurement on textile webs. The measurement set-up differs according to whether it is a difference or reference Doppler method. The reference method is also used in the textile industry for velocity measurement in association with large helium/neon lasers. For the purpose of miniaturisation

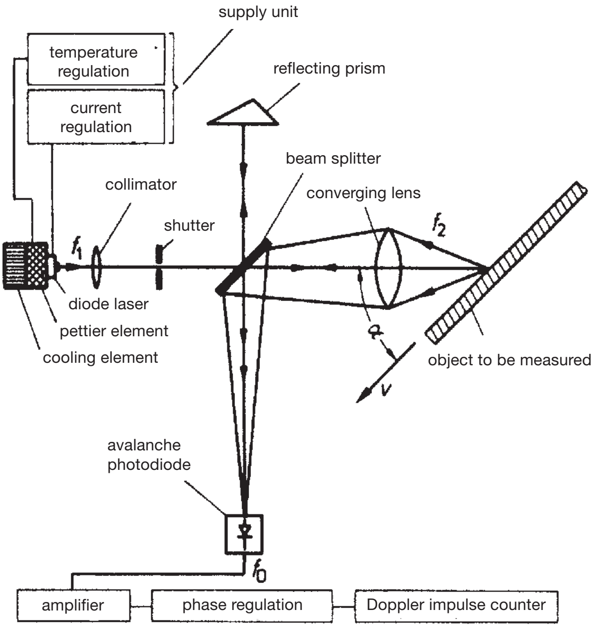


Fig.: Optical construction and electronic signal processing in the contact-free measurement of length using the reference Doppler process.

coupled with high radiation power, a compact laser diode is used as the light source with a stabilised wavelength of 784.580 nm.

An optical arrangement which is similar to a Michelson interferometer (see Fig.) is used for length measurement according to the reference Doppler method. The transmitted laser diode beam with frequency f_1 is split into a measurement and reference beam by means of a beam splitter. The measurement beam which passes straight through and forms the velocity vector v with an angle α, impinges on the moving goods to be measured and is reflected diffusely from the rough surface. Because of the Doppler effect, the frequency of the scattered light changes to f_2 and can be collected via a lens system and, via the beam splitter, is superimposed with the reference beam on its return path from the mirror prism. Superimposing the two light beams of neighbouring frequencies produces a frequency difference f_D, i.e. a beat frequency which represents a parameter related to the advance velocity v of the goods being measured. The intensity fluctuations of the laser light produced by the beat are converted into an electrical signal via an Avalanche Photodiode. The following equation applies to the beat of Doppler frequency f_D picked up from the output of the photodiode:

$$f_D = \frac{2\,v \cdot \cos\alpha}{\lambda}$$

where λ is the wavelength of the measurement beam emitted and the high order components can be neglected. The Doppler signal oscillations are continually counted for the length measurement. The number of Doppler oscillations counted within a measurement period t is n. The following relationship then applies to the distance l advanced by the goods being measured during the same period t:

$$l = v \cdot t = \frac{n \cdot \lambda}{2 \cdot \cos\alpha}$$

This equation shows that, providing λ and α are constant, the number of the recordable Doppler oscillations n is dependent on the distance advanced by the goods being measured alone and not on the speed. By counting the oscillations, it is possible to decide on the length of the measured goods sought for. However, a prerequisite for this is that the large fluctuations in the amplitude of the Doppler signal caused by the surface structure are compensated for electronically. The macrostructure of the surface, on the other hand, does not affect the Doppler frequency or the length measurement.

The Doppler signal at the avalanche diode output is processed by means of a special electronic circuit to give a continuous pulse count. The heart of the electronic unit is a phase-locking loop (PLL) covering several frequency ranges with automatic forward and back switching which is used to compensate for large fluctuations in the amplitude of the Doppler signal. At the same time, an internal oscillator is controlled so that its phase agrees with that of the Doppler signal or shows a constant phase difference, i.e. it in a synchronised state. In this synchronised state, the oscillator signal is used for the oscillation count instead of the original Doppler signal. If the synchronised state is momentarily interrupted due to extreme fluctuations in amplitude, then the oscillator frequency aims, in accordance with an exponential function, for the middle frequency of the prevailing PLL range where the fluctuations in measurement arise. These fluctuations are greater, the further the frequency just left lies below (positive sign) or above (negative sign) the middle frequency. Synchronisation starts again when a certain signal level has been reached. Due to the low advance speeds of the textile machines (approx. 1.65 m/s max.), the Doppler frequency range in question is relatively small, stretching from approx. 110 kHz to approx. 2.5 MHz and is divided up into 8 sub-domains (according to Zervos).

Laser light If a single wave of light is observed (Fig. 1), then this will appear as an electromagnetic transverse wave. The directions of oscillation of the electrical and magnetic vectors are at right angles to the direction of radiation and perpendicular to each other. The wavelength λ is found from two neighbouring maxima of the sine-wave oscillation. Visible light lies within the wavelength range of 400–700 nm which, in a

Laser positioning unit

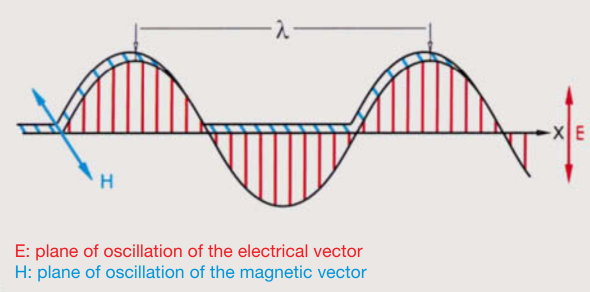


Fig. 1: Linear polarized light wave.

vacuum, corresponds to a frequency of 10^{14}–0^{15} Hz. Consequently, white light is composed of a spectrum of wavelengths and completely randomly emitted, i.e. out-of-phase wave chains.

In contrast to this, a laser can emit monochromatic light of one or several wavelengths which may be regarded as coherent. Waves which are emitted from a single source simultaneously are described as being coherent. The length of coherence is found from the line width of the laser light used and corresponds to the length of a wave chain oscillating in phase.

The resulting waves may be amplified, extinguished or shifted depending on the phase of the original wave chains. This phenomenon is called interference and is only found for coherent and, therefore, monochromatic light (Figs. 2 + 3).

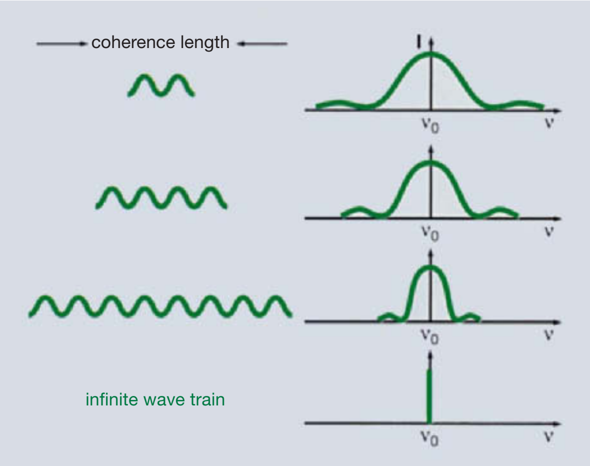


Fig. 2: Coherence length and frequency width of monochromatic laser light.

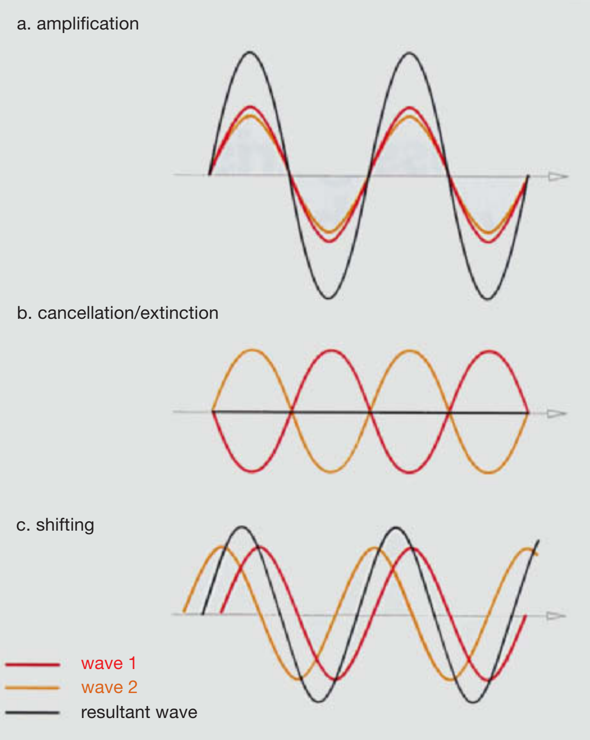


Fig. 3: Interference between two wave trains.

Laser positioning unit This device is used in rotary screen printing to position rotary screens during a pattern change. It enables precise adjustment to be made to the longitudinal, lateral and diagonal registers. Laser beams search for start marks on the screens to obtain the register (Figs. 1–3).

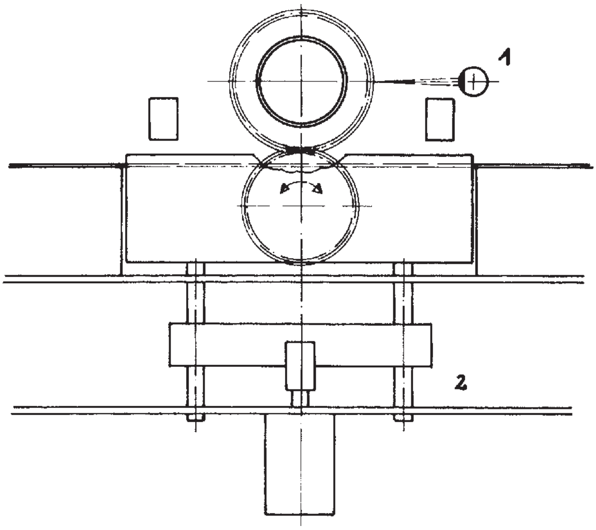


Fig. 1: Laser positioning unit for precise location of screen rollers.
1 = laser interrogation; 2 = step motor drive.

Laser Scanning Analyzer (LSA). These are used as a rapid high-resolution monitoring system for laser

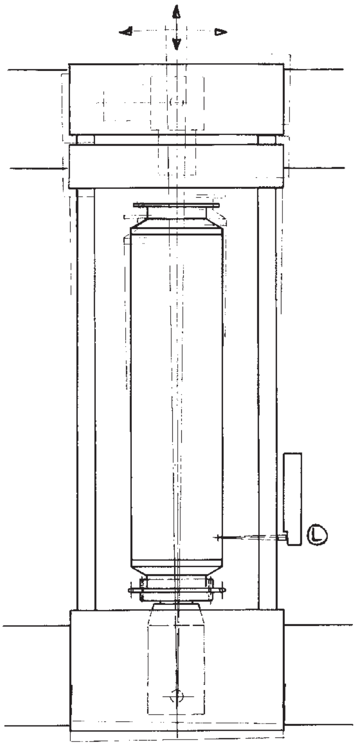


Fig. 2: Laser interrogation (L) of a screen roller in plan view.

Fig. 3: Laser positioning unit (STK).

control of optically detectable surface defects on material webs such as textiles, paper, rubber, plastic and non-wovens etc. whilst in motion. The LSA detects and analyses the surface defects. An integrated processor determines the size and number of defects, triggers the alarm signal and controls the marking and recording devices as well as other external monitoring equipment. Manuf.: Ferranti.

Laser screen engraving Various recording methods find use in the different colour separation processes and, on occasion, in direct engraving processes such as variable block mapping (non-continuous line location with offset) or continuous spiral recording and decoding (e.g., the Chromatograph CTX 330 from Hell).

In this case, an electronically controlled diamond-tipped engraving tool is used to engrave the copper cylinder directly. However, mechanical systems hit the upper limits of stability under load relatively quickly. In the case of classical systems, the speed of plot is limited by the speed of the controller and the necessity of the signal duration to achieve the desired effect (e.g., mechanical removal of copper by the diamond tip). It was for this reason that the use of lasers was considered but, what was being considered, was a “loosening” of a filled body e.g., a screen). However, from the amount of energy calculated to supply a laser of sufficient power it became apparent that a method such as this would not be economically viable. The following method has recently been developed: a laser beam that can be modulated is made to travel in a spiral across a classical nickel screen which had been completely blocked-off with lacquer. The CO_2 laser would be sufficiently powerful to burn the lacquer off in microseconds leaving the specified voids in the screen open. Theoretically, a laser flash such a this would last from 5–7 μs. Up to 27 000 spots could be picked off per second. A device has therefore been produced for this purpose and can apply the design to the screen directly at high speed and with high precision. The edges of the burnt out holes are sharply contoured and are sealed by the singeing and melting process. The lacquer used for this purpose is not related in any way to the original photosensitive lacquers and can be selected from an existing range of the most durable lacquers (even self cross-linking) thus offering the following advantages:

- lacquered nickel screens can be prepared and kept in stock,
- in the case of self cross-linking lacquers, drying alone and not stoving is required,
- the screen is ready after the laser treatment; no after-treatment is required,
- defects have so far hardly ever been observed because the data supplied by the computer merely controls a laser beam and nothing mechanical,
- the tracing speed depends on the mesh of the screen

as this determines the line density of the advance movement,

- the time used is shortened by the fact that the film no longer needs to be exposed, nor does the exposed screen need to be developed (washed out), dried, hardened or indeed re-lacquered with extraction or subjected to heat treatment a second time.

The screen is pushed on to a nickel/wood cylinder. The bearings are open on one side and the screen can be changed so that different repeat sizes from 640–1017 mm can be used. An elastic pneumatic support is used in fixing the screen to the cylinder, i.e. the nickel cylinder is pneumatically set under excess pressure which gives rise to the slight stretching which is enough to hold the precisely fitting screen in the exact position. The cylinder is now allowed to run in the two precision bearings which are centred exactly. From a mark on the screen, its exact circumference is calculated by a computer and, using this, the number of pulses from the laser impingeing on the surface during a single revolution is established. In regard to adjustment, avoidance of “seams” or having to work with adhesive stripes, this is better and simpler than the copying or exposure process using a film. Apart from this, the difficulties encountered in mounting the films on the circumferences which are not quite exact, in spite of high precision adopted in making the screens using electrodeposition, are excluded (according to Eibl).

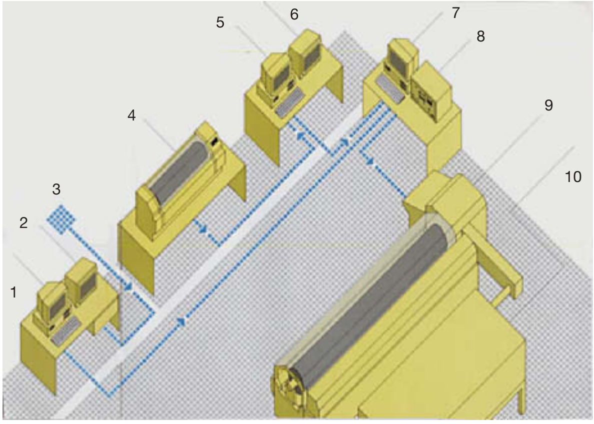


Fig. 1: Laser screen engraving department (Stork).
1 = computer: CAD input; 2 = control colour computer screen; 3 = design development system; 4 = drum scanner; 5 = computer: drum scanner; 6 = control colour computer screen; 7 = computer: laser engraver; 8 = control unit; 9 = laser engraver; 10 = laser unit.

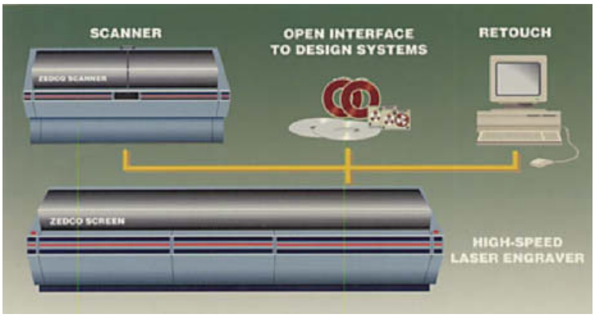


Fig. 2: Laser screen engraving (Zedco Screen System) with scanner, interface, retouch station and laser engraving machine.

Fig. 1 shows a laser screen-engraving department in which the design can be stored digitally during the operation and then transferred to the screen. The time-consuming and costly preparation of the films is thus made more economic and, in some cases, completely superfluous. The development and polymerization stages after engraving the screen are no longer necessary. The screens are immediately ready for use. The laser can be focused to a resolution of 50 µm; previously the resolution was limited to 100 µm. With this higher resolution, screens can be made, for example, for printing silk ties with cashmere patterns involving the highest detail. In addition to this, using laser engraving it is possible to engrave typical Rouleaux designs on the screens directly. All engraving methods in common use can be carried out both with and without tension roller and, in the last case, it is also possible to choose between screens with or without end rings. If engraving is to be carried out with end rings, these can be bonded in beforehand so that the screen can then be used immediately after engraving. If the design is selected without end rings or tension roller, the repeat can be changed immediately, quickly and without any intermediate steps.

Other components for a plant such as this could be:

a) MCD system (Manual Computer Design) for correcting or retouching designs or for preparing colour separations with overlappings based on a contour drawing. The MCD system can be used to mirror the design and prepare diagonal geometric patterns such as those of Zedco (Fig. 2).
b) An 800 W generator can be added to the plant for wide machines.
c) Automatic focus and repeat adjustment, for example, from Zedco (Fig. 3).
d) Through fine adjustment, suitable for engraving half-tone designs on screens with mesh sizes of 125 and 155.
e) TS 90 scanner (black and white) with high processing speeds and high resolution.
f) CS scanner for colour scanning, is capable of scanning half-tones and colours just as well as the usual black-and-white designs, with electronic point generator, speeds of 1000 r.p.m. and resolutions down to 12.5 µm (Fig. 4).
g) FP 89 film plotter with a maximum width of 1850 mm and maximum circumference of 1018 mm.

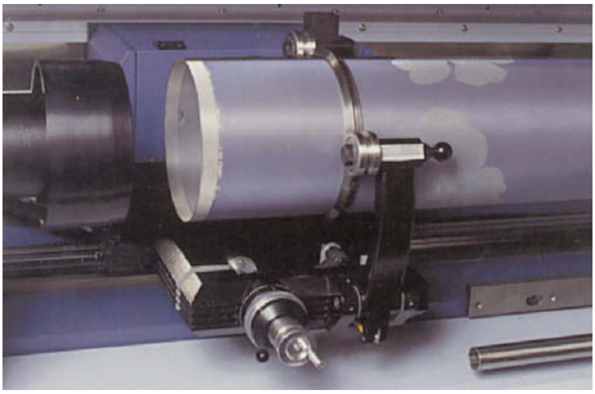


Fig. 3: Feeding the screen roller into the laser engraver (Zedco).

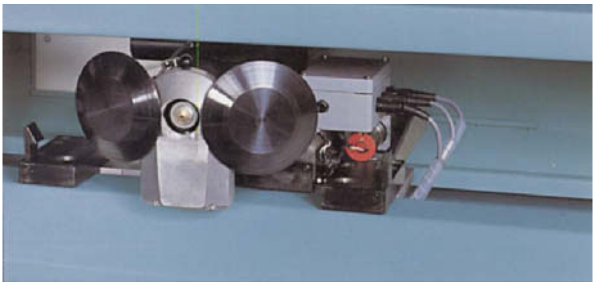


Fig. 4: Laser engraving machine (Stork LE-3000) with high-speed laser (max. speed 1000 rpm).

Fig. 5: Flat screen laser engraving (M. S.).

Since ITMA 1991, laser engraving tools have also been available for flat screens (from M.S.). (Fig. 5).

Latent crimp Crimp in a texturised yarn, produced by thermal treatment or by stretching and subsequent relaxation, can be released.

Lateral register in roller printing By shifting the bearing shells horizontally, it is possible to move the printing roller into the correct position so that the engraved figuring matches the whole pattern exactly in the repeat. However, the bearing shells can also be shifted sideways via threaded spindles so that the spindles and the printing cylinder are moved together to a different position. The bearing shells are then screwed back on one side. This device is referred to as the lateral register in Rouleaux printing.

Latex Basically, the liquid extract from the rubber tree (Hevea brasiliensis) and other plants including lianas (a.k.a. → Caoutchouc) that supply a liquid form of latex. Latex is used as the starting material for the manufacture of materials such as latex yarns. However, these days the natural product is only rarely used on its own and is more frequently used mixed with → Synthetic rubber. For this reason, latex now usually refers to mixed emulsions of natural rubber and vulcanisable synthetic rubber.

Emulsions of water-insoluble polymers are produced by emulsion polymerisation. They are used as latexes during the following process stages (in the manufacture of carpet backing, for example).

Typical parameters in an emulsion polymerisation process are (see Fig.):

1. Start:

a) One micelle consists of 50-100 surfactant molecules, each monomer micelle having a diameter of 4–5 nm. There are approx. 10^{18} empty emulsifier micelles at the beginning of the polymerisation and 10^{10} monomer droplets per ml (∅ 1000 nm).

2. Reaction (started by initiation):

b) At 50°C, approx. 10^{13} radicals per ml of emulsion are formed per second. 10–20% of the conversion soon takes place, there being approx. 10^{15} particles per ml present.

c) Next, all unused (empty) emulsifier micelles are consumed, achieving a conversion rate of 50–60%.

d) All monomer droplets are consumed by the end of the process.

e) The final diameter of the latex particles is from 50–300 nm.

Latex yarns Yarns extruded from latex, elastic rubber yarns (→ Rubber fibres) that are subsequently vulcanised.

Lattice-feed table A continuous roller-operated lattice conveyer made from wood, metal or plastic laths used to convey any type of goods. They often form the connection between two non-continuous processes.

Laundered articles → Laundry articles finished in a “cupboard dry” condition.

Laundering, clearing → Fabric clean washing agent.

Laundering, hydrodynamic process → Fabric clean flow wash process.

Laundering performance (washing perform-

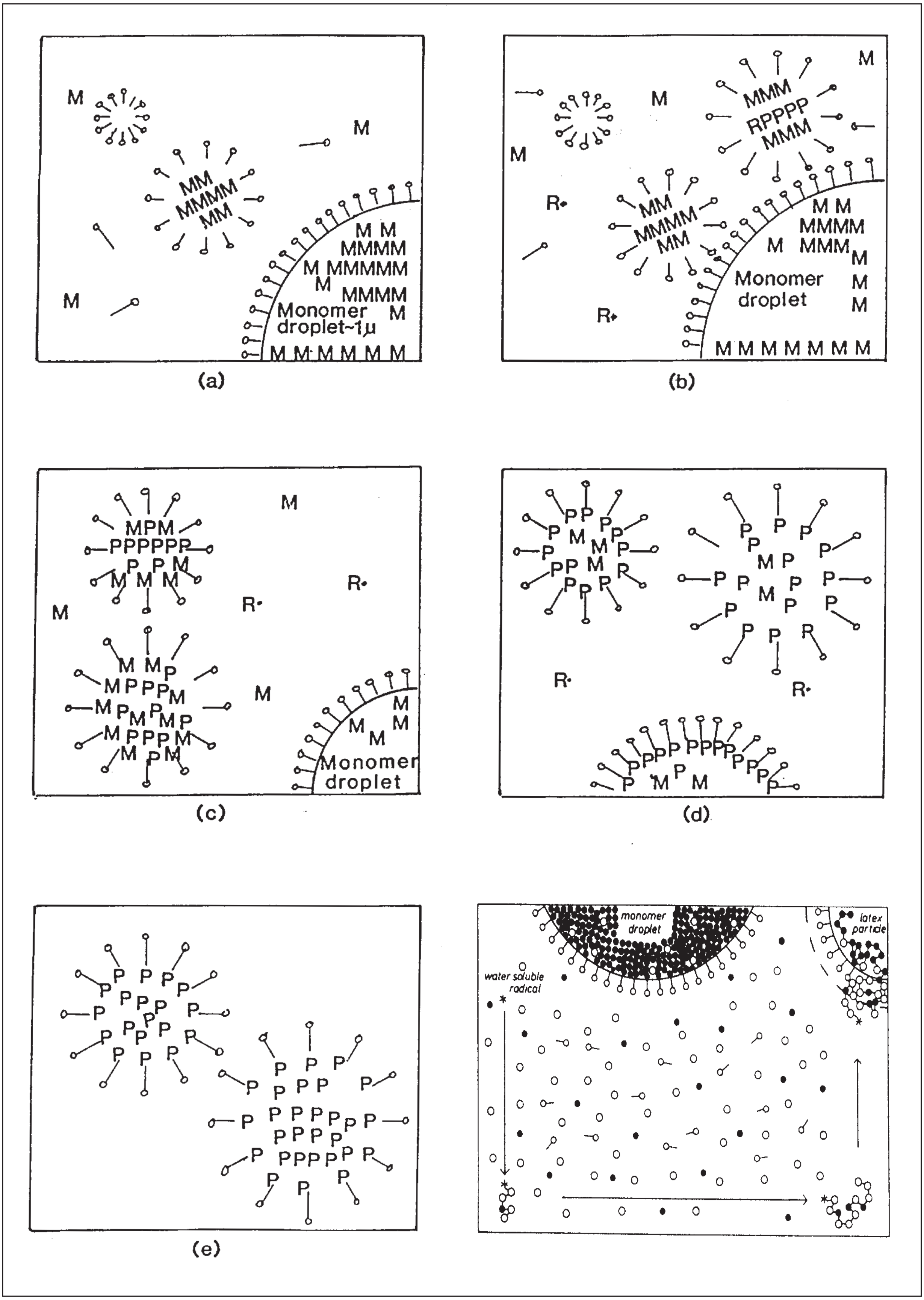


Fig.: The latex polymerisation process. M = monomer; P = polymer; R· = initiating radical.

ance). Laundry efficiency in terms of kg/hour processed. High laundering performance requires economy in processing. It is directly proportional to the loading ratio and inversely proportional to the required laundry time, i.e. the higher the loading ratio (in kg/l) and the shorter the time, the higher the performance, though only in relation to the laundry throughput.

Launder-O-meter (wash-O-meter) This is an American standard washing machine consisting of a heated boiler with motorised drive for using 10–20 screw-on bottles (500 ml capacity and 42 rpm) that contain 15 steels balls (∅ 6 mm) to mechanically manipulate the test samples during testing. This apparatus is especially recommended for laundering and milling durability testing but is also used as a wet fastness testing and HT dyeing machine. Manuf.: Atlas Electric.

Laundrinform Swiss information service based in Zurich for the laundry industry → Technical and professional organizations.

Laundry Industrial plant (large-scale plants are usually of industrial form) normally engaged in the → Washing of → Laundry.

Laundry articles Textile contract goods that are cleansed to remove soiling in → Washing machines.

Laundry for 100°C wash describes textiles that can withstand being laundered at the boil. Classified according to the Krefelder Wäschereiforschung (Krefeld Laundry Research Institute) as follows:

- underwear and bed linen etc.,
- intensive wash,
- pocket handkerchieves,
- kitchen laundry,
- workwear.

Laundry goods Classified as follows:

I. White goods: a) Raw calico and b) light resination finish (such as chiffon, cretonne and renforcé), glazed finish (such as lawn), heavy finish (such as shirting).

II. Clothing: a) underwear in smooth (such as batiste, chiffon, cretonne and renforcé) or brushed (such as beaver and flannel), b) outer clothing such as blouses and shirts, white (e.g. batiste, linen, poplin, and renforcé), yarn-dyed (e.g. bast silk, batiste, poplin and zephyr) printed (e.g. percale), brushed (flannel) and collars.

III. Batiste for blouses, lining, dresses, aprons and laundry etc.

IV. Bath-, hand-, kitchen-towels and pocket handkerchieves in grey/bleached, rope-dyed, linen-union and linen grey/bleached.

V. Bed linen and bedding: a) pillows slips and bed covers, white (plain smooth weave and patterned, either striped or figured) and coloured (yarn-dyed checks or floral prints), b) non-removable covers for feather filling, mattresses, quilts, in smooth weave (linen and twill), atlas weave, striped or figured.

VI. Table cloths and serviettes.

Laundry machines Machines for → Washing in the laundry including those for pre- and post-treatments. Differentiated as follows:

I. According to internal drum construction (→ Inner drum): a) single-sided: →: Front loading washing machine; Tub washing machine, b) double-sided: → Horizontal washing machines and long-drum washing machines, c) suspended without bearings.

II. According to the wash system: a) static liquor: multi-bath washing machines, b) flowing liquor: clear flow-, counter flow- and through flow- washing machines, c) according to batch separation: through flow-washing machines).

Laundry machines also include the →: Driers for textile materials; Centifruges; Mangle; Pressing in the laundry.

Laundry marker → Textile markers (inks, pencils, ball-point pens and marker pens) especially designed for the laundry and dry cleaning, with appropriate practical durability but easily removed in case of spotting.

Laundry quality control In laundries, for process and quality control, regular tests are carried out on fabric washed with the laundry, after 25 and 50 washes, to monitor →: Tensile strength loss; Damage factor; Ash content; Whiteness, degree of.

Laundry softeners → Fabric softeners.

Laundry wash,

I. → Raw wool scouring (as opposed to → Backwash).

II. Washing of soiled linen in the → Laundry (as opposed to → Domestic washing).

Lauric acid $C_{11}H_{25}COOH$. Component of coconut oil, laurel oil and sperm oil. Among other things, used for the manufacture of textile auxiliaries such as detergents.

Lawn Bleached linen, cotton or half linen fabrics with a linen finish. Mainly used for regularly washed articles.

Lay → Plaiting down.

Layered silicates From natural and synthetic sources, layered silicates have special structures that have shown interesting technical application properties. Used together with surfactants they have found many and varied applications so that an understanding of the interactions between layered silicates and surfactants has now become essential.

The different types of soils and their possible interactions with substances relevant to the environment are manifold. In order to provide a physico-chemical explanation for the contamination of soils due to environmentally problematic substances, the important components of the soil must be examined. Clay materials are laminated silicates of high reactivity. As can be seen in the case of kaolinite and montmorillonite in Fig. 1, for example, layered silicates consist of two or three

Layered silicates

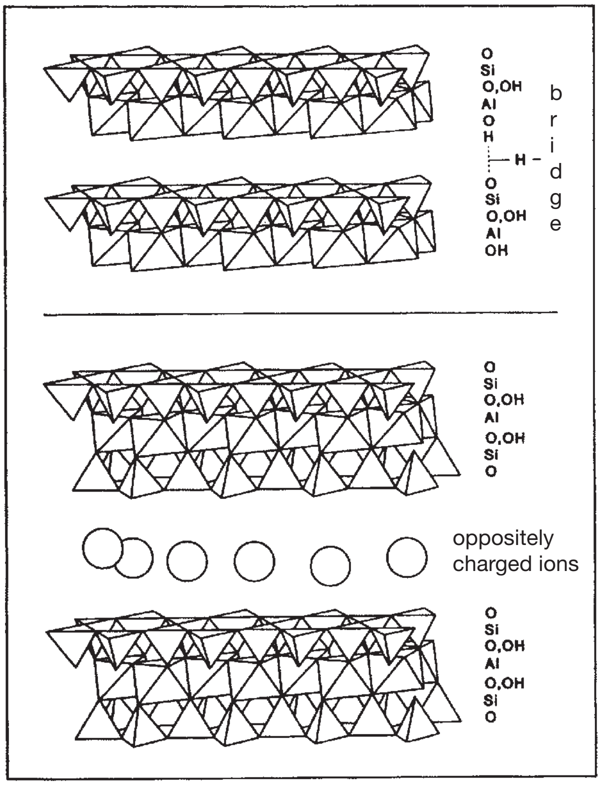


Fig. 1: Schematic representation of the structure of layered silicates as found in kaolinites (top) and montmorillonites (below).

layers with tetrahedral and octahedral structures. The co-ordinate silicon ions in the tetrahedral layers are surrounded by oxygen atoms and the co-ordinate aluminium ions in the octahedral layers are surrounded both by oxygen ions and hydroxyl groups. The charge in the layers occurs because co-ordinate metal ions have been substituted with atoms of lower valency (e.g., magnesium ions instead of aluminium ions). This fault in the lattice produces a negative excess charge in the layers which is compensated for by the positive charge of cations, such as calcium or sodium, located between the layers. The edges can carry positive charges of different magnitude depending on the pH.

Montmorillonite is a three-layered silicate with swelling properties, i.e. water can be absorbed between the layers and the cations there can be exchanged for others. The situation is different for kaolinite which does not have swelling properties because the hydrogen bonds between the two layers prevent swelling. As montmorillonite makes up the major proportion of naturally occurring bentonite, the natural occurrence of this clay is widespread. Kaolinite is correspondingly the main component of kaolin.

Within the layered lattice of this group of substances, the four oxygen atoms which surround the silicon atoms form a tetrahedral structure. However, three of these also represent the corners of neighbouring tetrahedra. The two tetrahedral layers are joined via the cor-

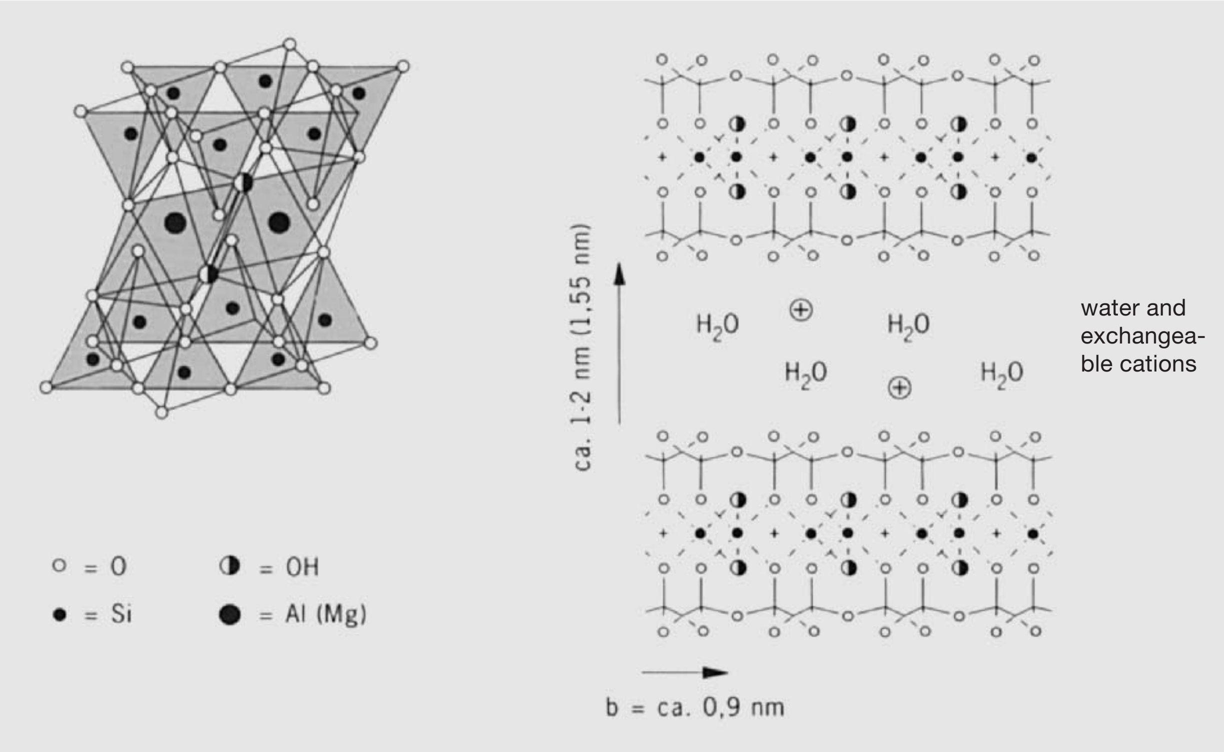


Fig. 2: Structure of layered silicates.

ners of the tetrahedra through metal ions such as Al^{3+}, Mg^{2+} or Li^{+}. At the same time, the cations which form the co-ordinate bonds are arrange octahedrally, the free valencies being satisfied by hydroxyl groups. Depending on the valency of the co-ordinating cations, the silicates are described as di-octahedral or tri-octahedral (Fig. 2). Cationic surfactants are absorbed on layered silicates of low charge in single, double or pseudo-triple layers. The amount of surfactant absorbed is determined by the swelling properties of the layered silicate and the structure of the cationic surfactant. The main points of possible interaction between cationic surfactants and layered silicates in the individual layers of soil, the soil levels, vary and depend on the physical properties of the soil.

Soil is a mineral, porous medium the pores of which contain air, water and organic and inorganic substances dissolved in water. The upper layer (the so-called top soil) is saturated with vegetation, humus, animal life (such as worms and lava, etc.) and micro-organisms. The oxygen content decreases with increasing depth, i.e. a transition exists from aerobic to increasingly anaerobic conditions. The proportion of biological material and humus also decreases as the percentage mineral content increases. The different layers of soil are identified as top soil, subsoil and bedrock, the subsoil and bedrock containing predominantly mineral components such as layered silicates (source: Schwurger).

Lay-on-air stenter An air control system for the fabric running in parallel to the fabric pathway and using a combination of slit and jets. Two fans in a vertical shaft with changeable direction of flow. These ventilators, in each field, allow an over and under-flow of air to be split through regulating flaps to control the air flow. The fabric is carried by the stream of hot air emerging from the jets without the aid of any additional guiding mechanisms.

L-calender To achieve the optimum calendering effect the parameters speed, temperature and pressure must be matched to the quality of fabric. Three- and multi-roller calenders define the pressure via a central pressure unit (Fig. 1). The changes in pressure act equally on all nips. In the three-roller Nipco L-calender according to the Kleinwefers KTM pattern, the working pressures are individually controlled at each nip, i.e. two effects, such as lustre and handle, can be achieved for the goods during a single run in one calender (Fig. 2).

Design characteristics:

- two calender nips where the working pressures can be adjusted individually,
- special rotating, wear-resistant, high elasticity cover,
- electrical motor-driven pressure-width control with angle measurement.
- steel roller with maintenance-free electrical hot water system.

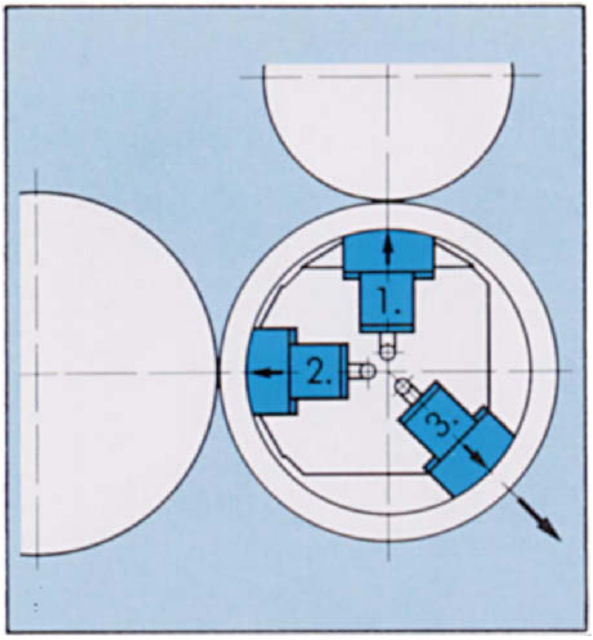


Fig. 1: Arrangement of the supports and of the three calender rollers in L-form.
1 = to steel roller; 2 = to cotton roller; 3 = as drawback element.

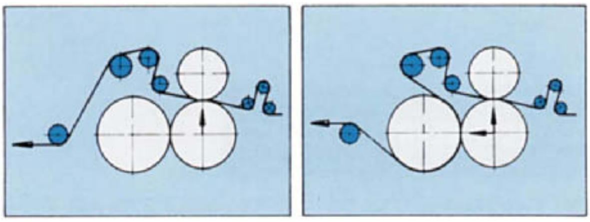


Fig. 2: Passage of fabric over Nipco roller.
Left: through one gap only for glazed and sheen effect; right: with the special cotton roller for a glazed and matt effect with a soft handle.

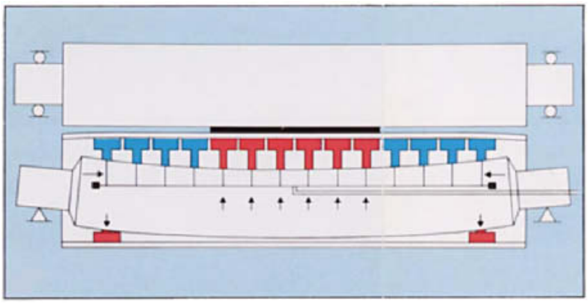


Fig. 3: Paired Nipco and steel rollers carrying a narrow fabric sheet.

The high-elasticity polyamide-based special cover rotates around a static yolk fitted with pressure elements arranged at 90° to each other. The cover is guided on a defined hydraulic fluid film and is not integrated with bearing forces in its dynamic components. Hydrostatic back-pressure stabilises the cover and guarantees a defined load contour in the individually controllable calender nips (Fig. 3). The contact surface of the cover for heating the steel roller is controlled simultaneously via the back-pressure in association with the motor-driven width adjustment.

LC-50 and LD-50 values These parameters are used to describe the lethal concentration (→ Lethal limit) of toxic substances. The acute toxicity is given as the average lethal dose (50% of tests) in mg/kg live body weight for oral toxicity (LD-50) and as the lethal concentration in mg/l for inhalation toxicity (LC-50).

LDPE Low-density polyethylene; → Polyethylene.

Lé French carpet-width measurement unit. 1 lé = approx. 70 cm.

Lea Non-metric unit in the English measurement system.

I. Lea yarn number for linen yarn (1 lea = 1 hank at 300 yards/lb; corresponds to the American Cut-system for carded yarns) and synthetic fibre yarns (1 lea = 1 hank at 120 yards/lb on 1.5 yards reels).

II. Lea strength: tensile strength giving the no. of lbs tensile load required to break 1 lea of a particular yarn.

III. Lea Test: Skein strength test (fibre-bundle tensile strength).

Lead (Pb). Atomic weight 206.9. Very soft, blue-grey metal (softest heavy metal) highly ductile, low strength and easily worked; surface oxidises on contact with moist air, strongly attacked by carbon-dioxide-free water (lead pipework), soluble in nitric, acetic and lactic acids but barely soluble in hydrochloric and sulphuric acids. Compounds: Lead is mainly bivalent, most of its salts are colourless and highly poisonous, its oxides are yellow to reddish. The dioxide hydrate $PbO_2 \cdot H_2O$ is a weak acid (lead acid, salts = plumbates). Lead nitrite and acetate are very soluble (lead sugar); lead chloride is easily soluble in hot water and low solubility in cold water; lead chromate (yellow) sulphate and sulphite (charcoal grey) are almost insoluble in neutral solutions, precipitation is caused by hydroxides and phosphorous and carbonic acids. Use: metal for metal sheeting, linings, pipes, lead-acid accumulators, alloys (+ Sb/Sn = cheaper bearing material), for colours and coatings, salts etching and waterproof impregnations, etc.

Leader cloth Cheap fabric which is used as the first layer on the jigger and also in drying and steaming and other continuous processes to lead the piece goods. Often made from polypropylene (low dyeability and economic). → Back grey.

Lead soap Lead soap is produced similarly to lime soaps by → Water hardening salts.

Lead, test for dyeings The sample is ashed and the ash dissolved in dilute nitric acid. The filtrate is mixed with some sodium acetate and potassium dichromate and gently heated. A yellow precipitate of lead chromate is produced which (unlike barium and mercury chromate) dissolves in caustic soda and ammoniacal tartaric acid.

Leaf fibres Sub-group of → Hard fibres in the form of woody fibres and vascular bundle components from the leaves or leaf sheaths of numerous sub-tropical plant species (such as sisal and manila). Fibre extraction by manual or mechanical methods; fibre preparation by rotting often produces poorer qualities.

Leasing The renting of capital commodities and long service items or industrial plant by lease financing or lease-purchase agreements. Used increasingly as an alternative means of finance in the textile and finishing industries.

Leather Skins or pelts prepared by → Tanning. Depending on the tanning process, a flexible (as in the case of chrome leather) to soft (e.g., chamois leather) material, resistant to humidity and hot water (except in the case of white leather). Lacquered leather is made by coating with (coloured) desiccant-containing linseed oil. Split leather is produced by splitting thicker bark-tanned leather which has been patterned using heated rollers to make grained leather. Depending on its surface texture, leather differs according to whether it is smooth (glazed from lamb or kid pelts) or rough, for example, in the case of soft glove leather with the flesh side of the gazelle hide or sheep pelt on the outside and with the grain removed (chair, Danish, suede leather) or (wild) leather from deer, fawn or antelope hides which are matt and velvety (Fig.).

Animal skin consists of collagen fibres in different layers as follows:

1. outer skin (epidermis),
2. corium (cutis),
3. adipose tissue (subcutis).

The outerskin is removed by the tanner using chemicals or by using enzymes and mechanical means. Only the corium is used for making leather and the adipose tissue is stripped off mechanically. Collagen has the following physical characteristics: it is water-insoluble, has pronounced swelling properties, a characteristic shrinking temperature and gluing ability via heat and aqueous alkalis. The skin can be preserved and stabilized.

The corium consists of a lattice structure of collagen and fibres of connective-tissue which branch and cross over each other without beginning or end and are linked in all directions. They are divided into papilla and reticular layers. The papilla layer has a particularly fine and dense fibre network on its surface and produces the so-called grain. This determines the appearance of the finished leather. The reticular layer, which is the most critical of the two in leather production, is thicker than the papilla layer and determines the mechanical properties. When the hide is removed from the carcass, it is con-

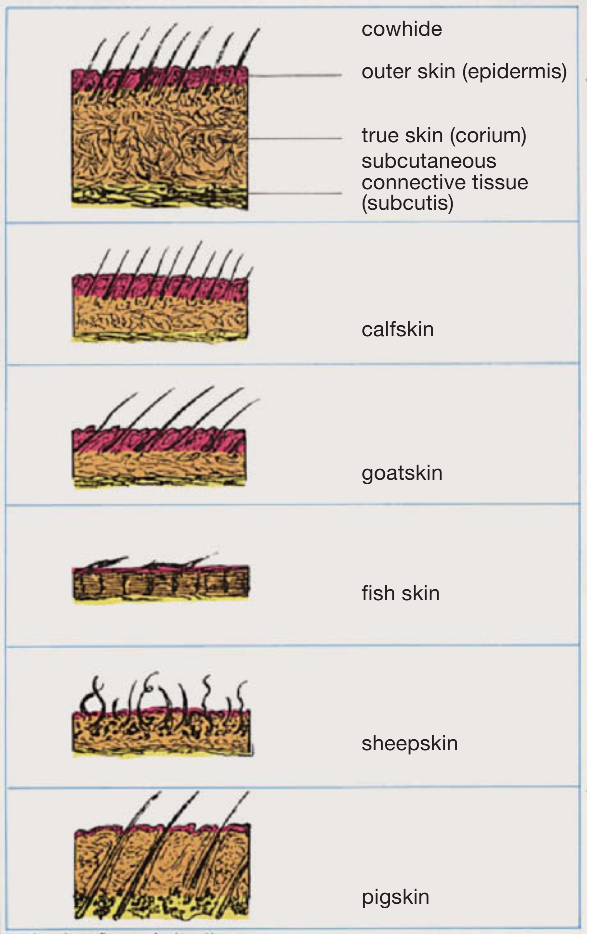


Fig.: Histological structure of different animal skins.

verted into leather by means of several chemical or chemi-mechanical treatments to prepare it for use as a starting material in the production of leather goods.

Leather after-treatment in dry cleaning Re-fatting with suitable → Re-oiling agents to compensate for the stiff handle of leather clothing after cleansing by coating or immersing in a fat liquoring bath to produce a natural soft handle. In the case of suede, it is sometimes necessary to re-dye the articles using a spray gun or dye dusting powders. The leather is restored to shape by careful steaming and evaporation and brushing with brass-wire brushes in the case of suede leather.

Leather cloth A coated, light calico cloth, elastic and waterproof for table cloths and the lining of hats, etc.

Leather dyeing,

I. Dyeing in drums: With drum dyeing the temperature must not exceed 48°C to avoid shrinkage of the leather. The drum is run at approx. 10 rpm in order to avoid abrasion and damage to the grain. The liquor volume is calculated on the dry weight of leather at ca. 500–700% or approx. 200–300% of the folded weight. Large amounts of similar types of leather can be dyed in the vat at the same time. The advantages of this method are its precision and gentle treatment of the leather.

II. Dyeing in dye winches: thin and sensitive leathers and split grain leather in particular are dyed on winches. Drum dyeing is less suitable for these sensitive leathers as the very thin skins tend to roll up, become knotted and even tear. The mechanical loading in the drum is too great. A longer liquor ratio is used on the winch. The advantages are a high degree of levelness, less handling and the gentle treatment of the leather. The disadvantages are low dyestuff exhaustion and the rapid cooling of the liquor.

III. Dyeing with brushes: brush dyeing is always used when the leather must be dyed on the grain side only, when the leather has already been partially dressed before dyeing or to avoid high dyestuff consumption. Dyeing is started with the grain side being moistened with warm water at 35°C. Small amounts of wetting agent are added when necessary. After this, acid dye solution at 35–40°C is applied to the surface with a brush three or four times. This process is repeated to obtain even coloration. A dye liquor containing 1–3 g/l acetic or formic acid is added while brush coating for the last time. This acidifies and fixes the dye. The brush liquor is thickened with alginate thickener to reduce penetration of the dye into the leather.

IV. Spray dyeing: spray dyeing is suitable for dry leather where a high level of uniformity and good penetration of the dye solution is achieved using solvents and penetration aids, especially in the case of vegetable-tanned leathers. Dyes with particularly high solubility are suitable for spray dyeing. Dyes with low solubility are not suitable as they partially crystallise out on the leather surface. The dye solution should be sprayed on to the leather using a spray gun at a temperature of 40°C and a pressure of 4–6 bar at a distance of 0.5–1 m from the surface. The concentration of the spray liquor in the case of acid dyes is 5–10 g/l and the concentration for cationic dyes is 2–5 g/l.

Leather dyes Term used by numerous companies for dyes (such as cationic, acid and direct etc.) used for dyeing leather. Unlike textiles, leather has a number of individual components resulting from structural differences which cannot be dyed uniformly. Another difference between leather and textile dyeing is that leather is not a flat material of uniform thickness but a three-dimensional structure up to 3 mm thick in which the dyes penetrate to different depths and at different strengths. A third characteristic is that while dyeing the leather, two different surfaces are dyed at the same time: the less reactive grain side and the strongly reactive flesh side. For a few dyes, the colour intensity on the flesh side can be seven times stronger than it is on the grain side. The same difficulties also limit the use of optical methods for measuring the dye strength and adjusting and re-adjusting the colour tone. When dyeing leather, different parameters must be taken into account. The theoretical consideration must include the chemical processes taking place during ionic bonding to the leather fibre as well as the diffusion processes within the leather, the equilibrium in the dye liquor and its influence via the parameters of the dyeing method, the effect of the ancillary aids and finally, the physico-chemical changes taking place in the leather which are caused by the conditions of the dyeing process.

The collagen is chiefly dyed in a tanned state, i.e. as leather. This can be done using any of the dyes also used for wool, silk, polyamide and cotton in the textile industry. These dyes must be carefully selected according to the tanning method used and type of leather. Typical leather dyes are metal-complex, acid and substantive dyes which develop “secondary valency forces” as they bond ionically with the collagen. Depending on the type of leather, the dyeing temperature used for leather dyeing lies between 40°C and 60°C and the pH used ranges from 3 to 8. Since the beginning of the seventies, the requirements in regard to the quantity and quality of leather dyeing has continuously increased. The quality of the leather dyeing depends on the raw hide, the chemi-mechanical treatment, the type or method of tanning, the dye, the dyeing method, the chemicals or auxiliary aids and the dressing. The dye and the dyeing method have a large influence on the quality of dyeing in the leather dyeing process.

There are numerous ranges of dye to select from. Some dyes have good light fastnesses but insufficient wet fastness. Other dyes have high fastnesses but the colour shades do not satisfy the requirements. These properties are determined by the chemical structure of the dye itself.

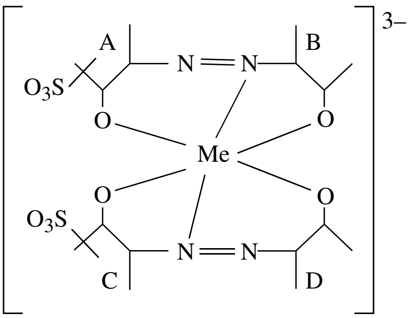
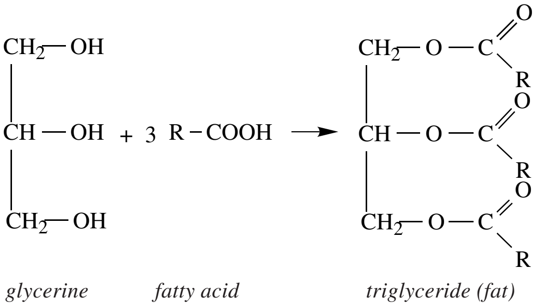


Fig.: Typical structure of a leather dye with 2 sulpho groups and 3 anionic charges. A, B, C, D are aromatic systems of the chromophore.

Although the typical metal-complex dye (Fig.) can be regarded as an anionic entity, basically it has amphoteric character because both cationic groups and anionic groups are actively present. The complex-forming ions can be those of iron, chrome, copper or cobalt. These metal ions bond with the hydroxyl, amino and carboxyl groups of the azo-dye molecule to form water-soluble metal complexes. Either one or two dye molecules bond to each metal ion to give 1 : 1 or 1 : 2 metal-complex dyes respectively.

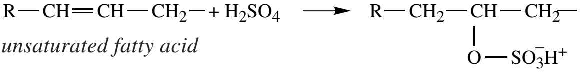
Leather fat-liquoring Water retention influences the softness of leather but the dehydrating effect of the tanning process can cause a drastic change. Leather becomes brittle, stiff and inflexible if it is over-dried. The purpose of fat-liquoring, by forming a fat film around the leather fibres, creates and increases the insulation effect. Maximum softness is achieved by the additional mechanical effects of staking. The breaking strength of leather is increased by the orientation of the fat-liquored fibres that takes place. The aim of every fat-liquoring process is to achieve the greatest possible penetration of fat into the leather.

Fat liquors are typically esters of the tri-functional alcohol glycerine and higher fatty acids.



The fats or oils which are mainly used in the leather industry may be from animal origin, such as tallow, fish oil and neatsfoot oil, or vegetable sources, such as olive oil, linseed oil, coconut oil and castor oil etc. The end characteristics of animal and vegetable fats and oils are developed during the formulation processes. When using emulsions of animal or vegetable fats and oils, in most cases, it is partially unsulphonated fats which are used, the sulphonated triglycerides acting as emulsifiers for the remaining non-sulphonated hydrophobic fats. By using formulated fats and oils, the so-called oil and fat liquors, it is possible to obtain an even distribution of the oil droplets on the surface and in the pores of the tanned leather, thus making the leather soft and semi-water resistant. The fat, oil and paraffin modification procedures most widely used are sulphonation (sulphiting), sulphation and chlorosulphonation.

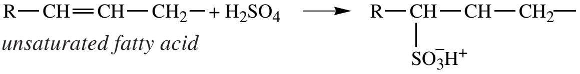
sulphation:



$$R-CH=CH-CH_2- + H_2SO_4 \longrightarrow R-CH_2-\underset{|}{CH}(O-SO_3^-H^+)-CH_2-$$

unsaturated fatty acid

sulphonation:



$$R-CH=CH-CH_2- + H_2SO_4 \longrightarrow R-CH(SO_3^-H^+)-CH-CH_2-$$

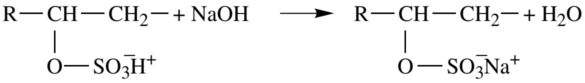
unsaturated fatty acid

sulphation:

$$R-\underset{\displaystyle OH}{\underset{|}{CH}}-CH_2- + H_2SO_4 \longrightarrow R-\underset{\displaystyle O-SO_3^-H^+}{\underset{|}{CH}}-CH_2- + H_2O$$

hydroxy fatty acid

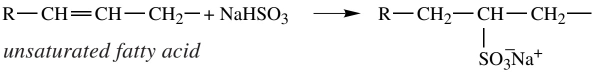
The water-soluble ester salts are produced by neutraliszing the ($-SO_3^-H^+$) groups with caustic soda, ammonia or organic bases.



$$R-\underset{\displaystyle O-SO_3^-H^+}{\underset{|}{CH}}-CH_2- + NaOH \longrightarrow R-\underset{\displaystyle O-SO_3^-Na^+}{\underset{|}{CH}}-CH_2- + H_2O$$

fatty acid sulphate

The water-soluble ester salts are produced directly via sodium hydrogen sulphite ($NaHSO_3$).

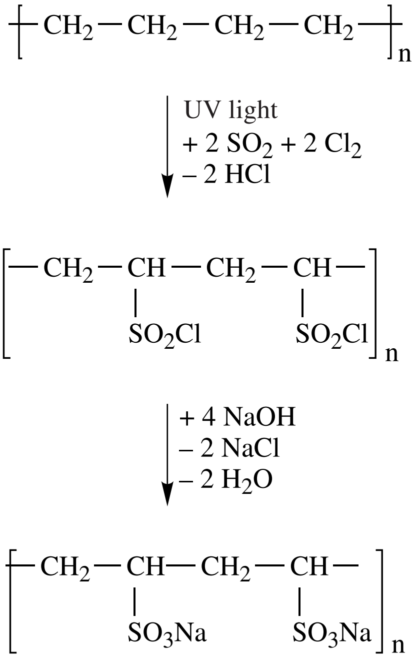


$$R-CH=CH-CH_2- + NaHSO_3 \longrightarrow R-CH_2-\underset{\displaystyle SO_3^-Na^+}{\underset{|}{CH}}-CH_2-$$

unsaturated fatty acid

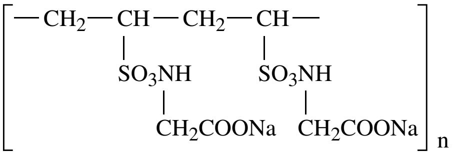
fatty acid sulphonate

Unsaturated fatty acids must be present for sulphonation to take place. The purpose of sulphonation is to make the fat or oil water-soluble. Good emulsions are obtained with 3% SO_3^- and transparent solutions are obtained on reaching 4%. In the case of synthetic fat-liquoring agents containing high-molecular, straight-chain hydrocarbons, the water-soluble sodium salt of the hydrocarbon sulphonic acid is produced via chlorosulphonation.



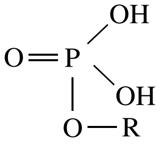
$$\left[-CH_2-CH_2-CH_2-CH_2-\right]_n \xrightarrow[\displaystyle -2\,HCl]{\displaystyle UV\ light,\ +2\,SO_2+2\,Cl_2} \left[-CH_2-\underset{\displaystyle SO_2Cl}{\underset{|}{CH}}-CH_2-\underset{\displaystyle SO_2Cl}{\underset{|}{CH}}-\right]_n \xrightarrow[\displaystyle -2\,NaCl,\ -2\,H_2O]{\displaystyle +4\,NaOH} \left[-CH_2-\underset{\displaystyle SO_3Na}{\underset{|}{CH}}-CH_2-\underset{\displaystyle SO_3Na}{\underset{|}{CH}}-\right]_n$$

Neutralization can also be achieved with ammonia followed by the sodium salt of chloroacetic acid which results in a better fat-liquoring effect and stronger bond to the substances in the hide.



$$\left[-CH_2-\underset{\displaystyle \underset{\displaystyle CH_2COONa}{\underset{|}{SO_3NH}}}{\underset{|}{CH}}-CH_2-\underset{\displaystyle \underset{\displaystyle CH_2COONa}{\underset{|}{SO_3NH}}}{\underset{|}{CH}}-\right]_n$$

In addition to the fat or oil components, there may be other emulsifiers with lipophilic and acido groups present in the fat mixture. Emulsifiers such as these may in general have the following constituents, as in the case of phosphoric acid esters.



R = lipophilic group

$= -C_nH_{2n-1}$

$= -C_nH_{2n-1}$

$= C_nH_{2n+1}(O-[CH_2]_2)_mOH$

In acid range, fat-liquoring agents in which the active group is an anion bond to the NH_3^- groups but in the alkaline range, cationic fat-liquoring agents bond to the COO^- groups of collagen. Bonding can also take place via secondary valence forces arising from groups containing oxygen or chlorine. Coordinate inclusion of acidic groups in the complex domain of chrome tanning agents is also possible. The non-extraction of fat from leather can be promoted by increasing the degree of sulphonation, using multi-bonded metal tanning agents and by using more emulsifier and unsaturated fatty acids in the fat-liquoring agent.

Leather glue → Glue.

Leather production The term leather applies to all products which are made from the different animal hides using one or more chemical or mechanical treatments to change their properties so that they no longer show the negative characteristics of raw hide. The treatments required are classified according to the nature of the raw hide, the method or type of tanning and the purpose for which the leather is to be used (e.g. Figs. 1 and 2).

Mechanical leather processing: Collected under this heading are all processes taking place at different stages during leather treatment and in most cases used to produce certain effects. They represent a supplementary function to the chemical processes.

1. Depilation and scraping: The hair is removed mechanically or manually and the epidermis destroyed.
2. Fleshing: The flesh and fat residues such as muscle and subcutaneous connective tissue are removed using a cutter block (knife roller) (Fig. 3).

Leather production

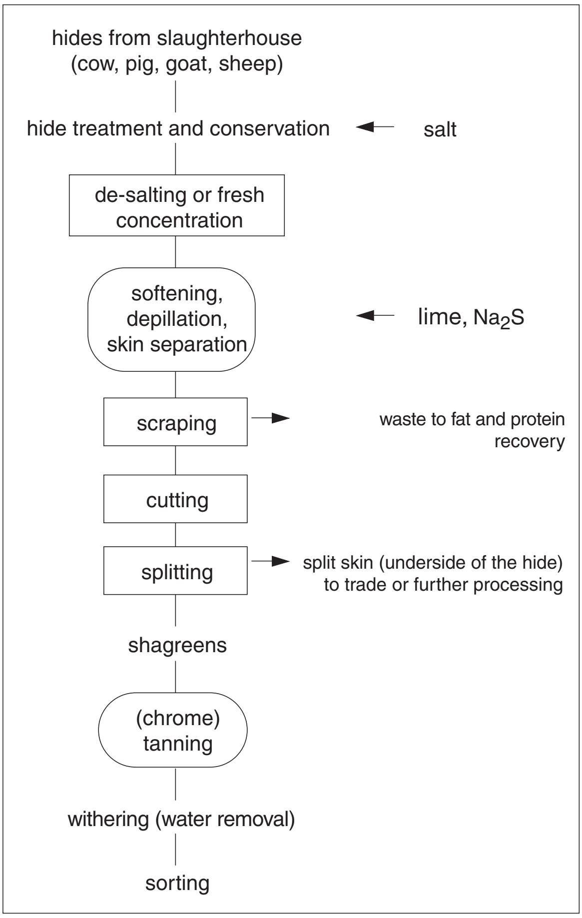


Fig. 1: Production cycle in leather manufacture (Wetblue).

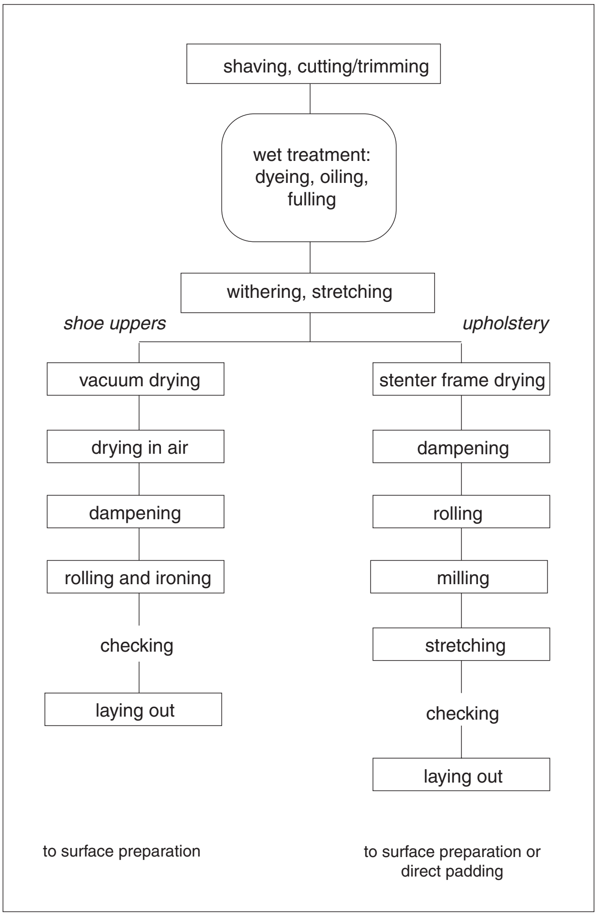


Fig. 2: Treatment processes for crust leather used as shoe or upholstery leather.

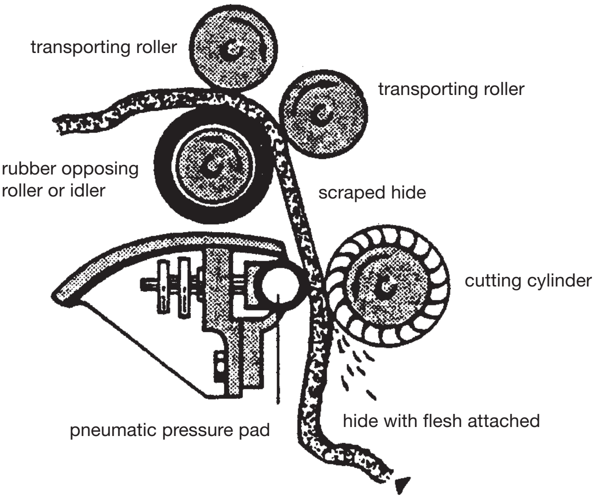


Fig. 3: Leather processing: fleshing on the scraping machine.

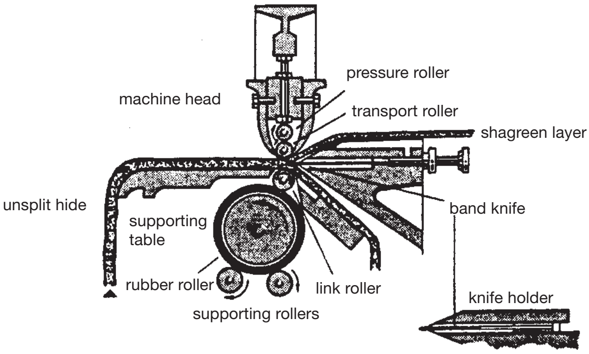


Fig. 4: Leather processing: splitting on a splitting machine.

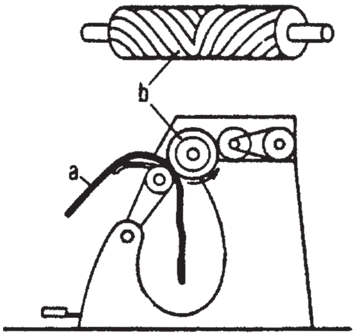


Fig. 5: Leather processing: shaving on a shaving machine.
a = leather; b = shaving roller.

3. Splitting: The lime-soaked hide is split into two or several layers: grain split, middle split and flesh split (Fig. 4).
4. Shaving: reducing the thick parts of a hide and producing a final thickness (Fig. 5).
5. Grinding: The grain and flesh splits are ground during dressing to produce the different effects.
6. Dewatering: Excess water is removed using blunt knife rollers before drying (Fig. 6).
7. Staking: The leather is softened by means of a vibrating metal-spiked plate (Fig. 7).
8. Drying: heat is used to evaporate off the water.
9. Grain stamping: The grain effect is embossed on to the leather using a grain-embossing machine.
10. Ironing and glazing: The surface is stabilized and glazed using heat and pressure.

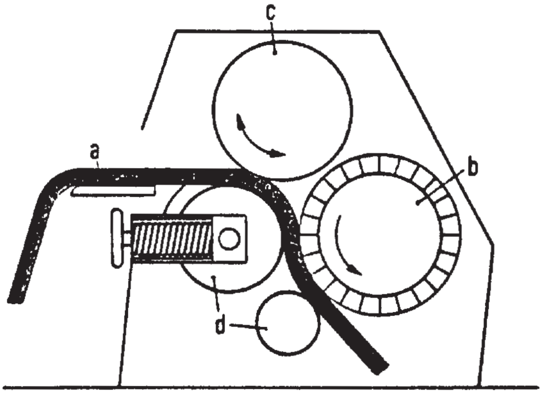


Fig. 6: Leather processing: withering press.
a = leather; b = stretching roller; c = transport roller;
d = pressure rollers.

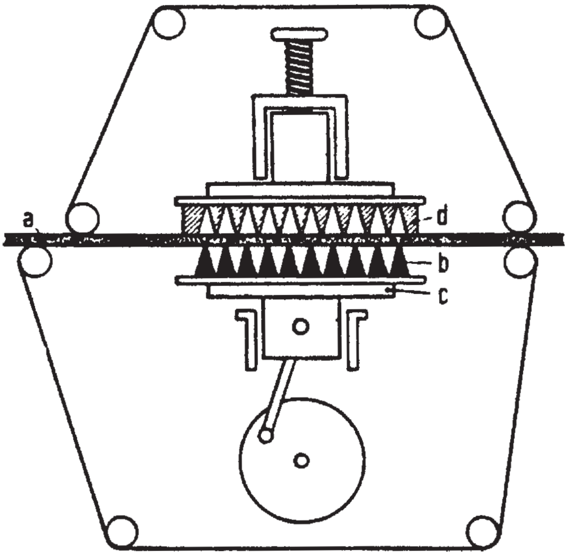


Fig. 7: Leather processing: vibration rolling machine.
a = leather; b = metal points; c = vibration plate; d = foam rubber plate.

Leather production, wet processing This collective term describes all the work and processes used to convert the preserved hide into a hide stripped of hair, i.e. hide prepared for the tanning process. The purpose of the softening process is to swell the hide and impart suppleness and flexibility to the individual fibres and to provide a cleaning effect. An exchange takes place between the salt solution stored in the collagen fibre structure and the soft water, ensuring diffusion of salt out of the hide and the absorption of water into the hide. The softening effect can by the addition of sharpener, acid and alkali be increased (attributed to the swelling of the collagen caused by acids and alkalis). Wetting agents can be used to reduce the interfacial surface tension between the water and the hide. A very important process carried out before tanning is liming. The purpose of lime-soaking is to loosen and remove the hair and relax the hide at the same time. The quick lime-sodium sulphide lime, a mixture of $Ca(OH)_2$ and Na_2S, loosens the structure by swelling the collagen, the sodium sulphide promotes the decomposition of the keratin, thus thoroughly loosening the hair as well as swelling the hide.

$$2\,Na_2S + 2\,H_2O \rightarrow 2\,NaOH + 2\,NaSH$$
$$2\,NaSH + Ca(OH)_2 \rightarrow 2\,NaOH + Ca(SH)_2$$

$$2\,Na_2S + 2\,H_2O + Ca(OH)_2 \rightarrow 4\,NaOH + Ca(SH)_2$$

In the presence of OH^- ions, the sulphur hydride has a powerful loosening effect on the hair and the caustic soda has a powerful swelling effect on the hide fibres while saponifying the hide fat as the same time. A lime soak can be used on its own as alkalis also break the disulphide links of the amino acid cystine in water.

$$>CH{-}CH_2{-}S{-}S{-}CH_2{-}CH< \xrightarrow{OH^-} >CH{-}CH_2{-}SOH + HS{-}CH_2{-}CH<$$

The mercapto (cystine-) sulphenic acid formed during the hydrolytic cleavage is very reactive and decomposes as follows:

$$>CH{-}CH_2{-}SOH \rightarrow >CH{-}CHO + H_2S$$

The aldehyde thus formed can bring about re-cross-linking with the cysteine which is produced:

$$>CH{-}CHO + HS{-}CH_2{-}CH< \rightarrow$$
$$>CH{-}CH_2{-}S{-}CHOH{-}CH<$$

Lanthionine-complex type cross-linkages may also be formed:

$$R{-}CH_2{-}S{-}CH_2{-}R$$

Re-cross-linking takes place during alkali treatment by incorporating calcium ions after the disulphide bonds have been broken, primarily through alkaline hydrolysis:

$$>CH{-}CH_2{-}SOH + HS{-}CH_2{-}CH< + Ca^{2+} \rightarrow$$
$$>CH{-}CH_2{-}SOCa{-}S{-}CH_2CH< + 2\,H^+$$

The lime-sodium sulphide lime soak combines the advantages of a hydroxyl lime soak, where the hairs are loosened due to hydrolysis of the protoplasmic proteins in the epidermis, with those of a sulphide lime soak, which accelerates keratin hydrolysis and loosens the hair while attacking it at the same time.

The de-liming acids have to compete with the "collagen acids" in removing and neutralising the lime bound to the collagen and only those with an acid dissociation constant greater than $2 \cdot 10^{-1}$ are used. The lime salts formed during the process are removed by rinsing. The hide is relaxed further during the pickling process due to a loosening up of the collagen structure by a tryptic pancrease proteolytic enzyme such as trypsin. Carbohydrate components, particularly neutral sugars and amino sugars "leucopolysaccharides" are broken down. The prepared, de-haired hides are treated with a solution of acids and salts before tanning. The purpose of the pickling solution is to retard the chrome tanning process by chemically converting the hide using acids. The free amino groups are ionised (charged) by saturating the hide with acid. The basicity of the chrome salt is reduced at the same time, leading to a reduction in hide shrinkage. The risk of the grain shrinking (surface tanning) is removed. The salt in the pickling solution reduces the undesirable swelling effect of the pickling acids on the surface by suppressing acid dissociation.

$$\text{collagen-}NH_3X \rightarrow \text{collagen-}NH_3^+ + X^- \ (X^- \text{ anion})$$

Sodium chloride ($NaCl \rightarrow Na^+ + Cl^-$) supplies excess anions to drive the reaction to the left. The charge on the acid groups can be suppressed again by adding more salt. However, this effect only occurs within certain limitations for the reasons mentioned above. Both inorganic and organic acids can be used.

Leather tanning A high degree of stabilisation of the leather structure is achieved through the bonding of chrome to carboxylic acid groups, thus forming so-called binuclear chrome complexes between two carboxylic acid groups of the amino acids in the collagen structure. The stability is so high that the collagen fibres are resistant to boiling (Fig.). The process is termed collagen tanning and it is this which turns hide into leather.

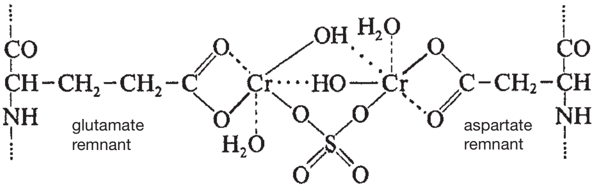


Fig.: Bi-nuclear chromium complex in a collagen fibre.

The chrome is integrated intramolecularly, i.e. from one part of a collagen molecule in the fibrils to another part of the same molecule. Where there are 0.8–0.92 milliequivealents of "chromable" carboxyl groups per gram collagen, between 3.63% and 6.22% chrome or between 5.30% and 6.22% chrome(III) oxide Cr_2O_3 may be bound to the leather, depending on the composition of the cross-links (Tab.) and assuming binuclear complexes are formed.

carboxyl groups m-equivalents	composition of cross-link	Cr	Cr_2O_3 % in leather
0,8	$Cr_2(OH)_2(H_2O)_2SO_4$	3,75	5,49
0,8	$Cr_2(OH)_2(H_2O)_2(SO_4)_2$	3,63	5,30
0,8	$Cr(OH)_4$	3,89	5,69
0,92	$Cr_2(OH)_2(H_2O)_2SO_4$	4,26	6,22

Tab.: Composition of cross-links in chromium leather.

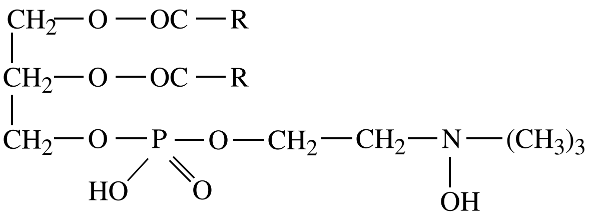
In leather manufacture, the pickled de-haired hide, in which the main substance is positively charged, is tanned using, for example, a 33% basic chrome(III) liquor. During the chrome-tanning process, multinuclear hydroxy compounds (so-called basic chrome salts) of chrome(III) sulphate are formed by the gradual addition of caustic soda, while the pH of the so-called liquor (containing the chrome) is raised from 3 to 4. At higher pH (between 5 and 6, depending on the chrome concentration) non-active insoluble chrome(III) hydroxide would precipitate out.

Chrome tanning produces a firm, flexible leather which is stable in both hot and cold water and is resistant to heat and bacteria. It is pale bluish green in its undried state, (termed “wetblue” as semi-manufactured goods). A mixture of potassium aluminium sulphate, sodium chloride, egg yolk and wheat flour is used as a mineral tanning agent in the production of kid leather (fine glossy goat or lamb leather). → Tanning; Vegetable tanning.

Leblanc soda Term from the oldest method of manufacture for → Sodium carbonate.

LECARIM French textile research organization in Mazamet; → Technical and professional organizations.

Lecithin The phosphoric acid ester of natural fats with a choline group. It is included among the lipoids.



Lecithin is obtained from soybean oil which contains up to 4%. It is a brownish yellow, hygroscopic, wax-like mass which is freely soluble in alcohol and ether, etc. In water, lecithin first swells, and later,forms a translucent colloidal solution. It is used as a lubricanting agent and softener for sizes and finishes, especially in polyamide hose finishing; also contained in softeners with accompanying stabilizing effect for oxidative bleaches.

Legal protection of designs Legal protection of tools and equipment or their components in so far as they are used to work with or used in a new form, arrangement or device. In the case of designs changes must be significant. Usually valid for 3 years but this can be extended by 3 years. → Registered design.

Legislation on environmental protection The concept of “integrated environmental protection”, i.e. production and finishing processes are applied that use the highest possible quantitative proportion of products and energy, is the correct basis for all parties with a commitment to environmental protection. In an age of strong global integration, the textile finisher must have a clear concept for controlling his environmental impact and that this will help to protect the future of his own working environment. This dependency is better understood as a shared environment rather than a surrounding environment. The sharpened public awareness of ecological matters has put much pressure on the legislators so that the textile finisher, as a significant consumer of water, air and energy as production media, is now confronted with a flood of environmental legislation, whose impact on the industrial sector is still not yet fully understood. The German Water Resources Law of 23.9.86 (Fig. 1), requires the textile processor to meet the following controls:

- the conditions of the Regulation on the limitation on emissions and their impact, e.g. Effluent Regulations (textile manufacture) of 5.9.84;
- environmental audit as an information- and early warning-system;
- application of “the polluter pays” principle.

Reetz has defined the environmental law in terms of three levels of legislation:

- Federal Law: BImSchG (Bundes-Immissionsschutzgesetz – Federal Immission Protection Law) with 4th BImSchV (Bundes-Immissionsschutzverordnung – Federal Immission Protection Regulation) and with TA Luft (Technische Anleitung zur Reinhaltung der Luft – Technical Instructions for Air Purity: → TI-air); WHG (Wasserhaushaltsgesetz – Wa-

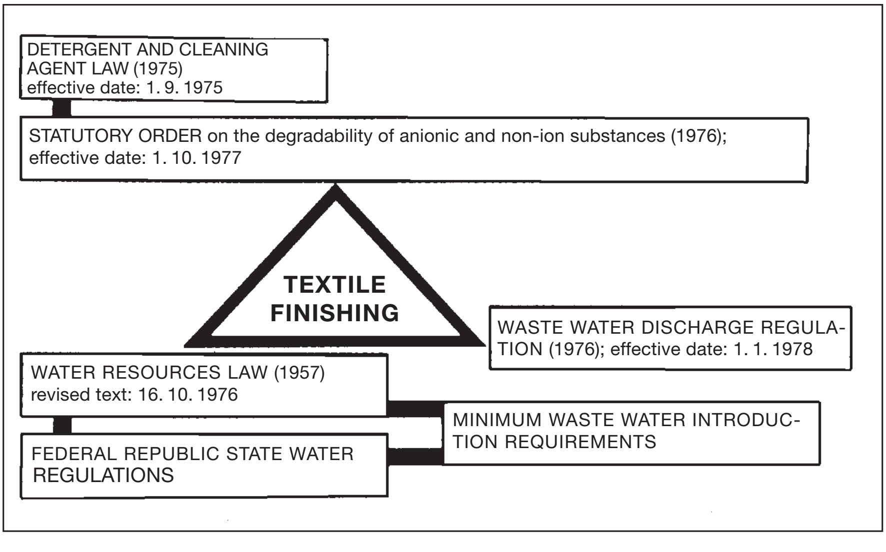


Fig. 1: Most important Federal German Republic water protection laws and regulations.

ter Resources Law); AbwAG (Abwasserabgabengesetz – Waste Water Discharge Regulation); AbfG (Gesetz über die Beiseitigung von Abfällen – Waste Disposal Law); GefStoffV (Gefahrstoffverordnung – Dangerous Substances Regulations); VwVfG (Verwaltungsverfassungsgesetz – Administration Constitution Law);
- State Law: LWG (Landeswassergesetz – State Water Law); IndEV (Industrielle Emissionsverordnung – Industrial Emmissions Regulations); EKVO (Eigenkontrollverordnung – Self-checking Act); VAwS (Verordnung über Anlagen zum Lagern, Abfüllen und Umschlagen wassergefährdender Stoffe – Regulation for the Handling of Substances Hazardous to Water); SmogV (Smog Verordnung – Smog Regulation); VLwF (Verordnung über das Lagern wassergefährdeter Flüssigkeiten – Regulations for the Storage of Liquids Harmful to Water); LBO (Landbewirtschaftungsordnung – Land Management Regulations);
- Local Government Law, bylaws such as AbwS (Abwasser-Satzung – Waste Water Statutes).

According to Reetz, the following areas are pertinent to environmental protection within the area of textile finishing:

1. Dangerous substances which are toxic, non-degrading, accumulate in the environment, carcinogenic, ovary damaging or mutagenic (WHG § 7a).
2. Substances which are harmful to water according to a constantly up-dated reference list (in accordance with § 19g WHG) regulates the storage, filling, manufacture, handling and application.
3. Dangerous substances (according to the GefStoffV – Dangerous Substances Regulations), which are toxic (T), slightly poisonous (Xn), corrosive (Z), irritating (Xi), highly flammable (F+) or combustible (O). Handling dangerous substances is regulated under § 17 (Common duty of protection); § 18 (Duty to monitor, MAK [Maximale Arbeitsplatzkonzentration – Threshold Limit Value]; TRK [Technische Richtkonzentration – Technical guideline concentration]; BAT [Biologischer Arbeitsstoff Toleranzwert - Tolerance Limit of Biological Substances]); § 20 (Operating Guidelines); § 21 (Duty of Care).

These areas are in the domain of environmental quality control so the textile finisher must determine which of his by-products fall within these controls and then further measure their impact. The Water Resources Law requires improvement in the aquatic environment and it is a stipulation that water must not contain any dangerous substances after use. The Origin of Waste Water Law states that textile finishing is a possible source of effluent containing dangerous substances so the textile finisher must remove any by-product before he can discharge effluent directly into open water systems (drainage water) or, if he discharges indirectly into the sewers, to treat the effluent to a condition that is acceptable to the local effluent treatment works.

Thus it can be seen that the textile finisher must pay for the cost of the volume and content of his effluent discharge, whether direct or indirect to the sewers, so he has a very strong incentive to reduce his effluent volumes and control any hazardous substances that it may contain (Effluent Cost Law). In the discussion between the authorities and those affected about interpreting the broad and blurred definition of § 7a of the Water Resources Law in regard to "dangerous substances", a distinction must be made between the desired standards (guidelines for effluent cleaning according to Code of Practice A 115 of January 1983) and the reality of the limits in the statutes governing regional sewage treatment plant operators. The practical guidelines of the national standard, which may vary from state to state, lie somewhere between the Federal Law and its regional interpretations. In the future, of course, increasing attention must be paid to developments in the European context. Basically, a distinction must be made between legislation controlling the handling of a certain environmental medium (media legislation in relation to water and air) and legislation controlling the handling of products such as detergents, tetrachloroethylene (perchloroethylene) or formaldehyde (product legislation controlling the storage and use of dangerous substances). At the same time, legal arguments frequently flare up between textile finishers and authorities as to what is to become the "the industrial standard" for restricting or monitoring exhaust gases and effluent from production or cleaning them.

Environmental legislation covering textile finishing:

1. Handling chemicals:
   a) Law on chemicals:
      - Dangerous Substances Regulations with Appendices I–VI,
      - Classification and identification of dangerous substances and preparations,
      - Dangerous substances which are carcinogenic, ovary damaging or mutagenic,
      - Dangerous substances which are poisonous, corrosive, irritating and chronically harmful,
      - Certain dangerous substances which are combustible, explosive and flammable,
      - Supply investigations,
      - Dangerous substances and preparations which are classified.

   b) List of TLVs (Threshold Limit Values).
   c) List of BATs (Tolerance Limit of Biological Substances).
   d) List of TRKs (Technical guideline concentration).
   e) Regulation on flammable liquids.
   f) Storage of chemicals and textile auxiliary aids.

2. Waste water hazard: Water Resources Management Law, Local Regulations, Register of Substances Harmful to Water, Detergent and Cleansing agent Law, Surfactant Regulation and Effluent Emission Law.
3. Exhaust loading and environmental pollution: Federal Immission Protection Law (Fig. 2) and associated legal regulations:
   – TI-air (Technical Instructions for Air),
   – TI-noise (Technical Instructions for Noise).
4. Disposal of waste liquors, waste products and effluent sludge: Waste Law, Procedure Regulation and Effluent Sludge Regulation.
5. Physiological effects of textile goods: Dangerous Substance Regulations including Appendices I–VI, allergic effects, smell, skin tolerance and prevention of poisons in the home (home furnishings).
6. Law relating to environmental issues (contamination liability): law on liability for environmental damage and amendment to the Water Resources Law and the Federal Immission Protection Law (1.1.1991).
7. Environmental Penalty Law: 2nd Law on controlling environmental criminality (1992 in process of legislation).

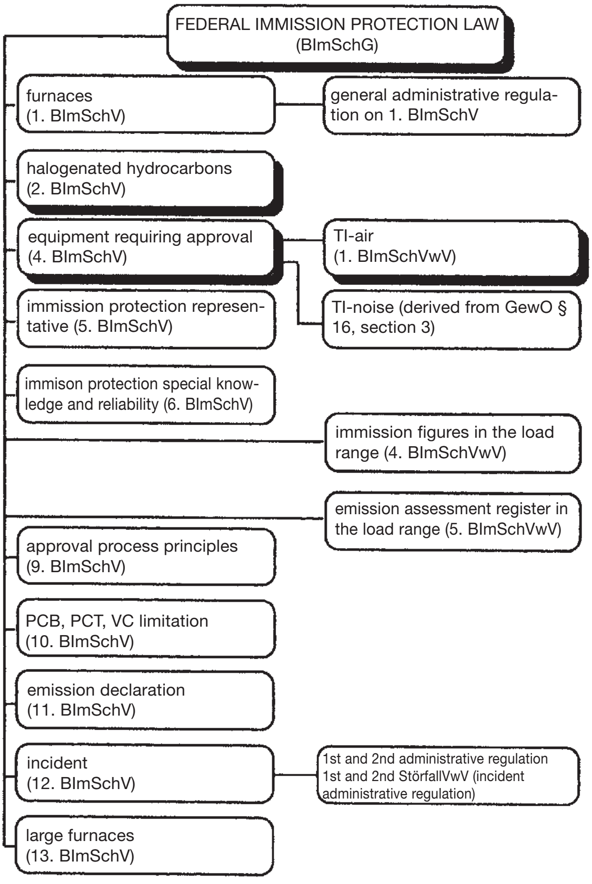


Fig. 2: Organigram of German Federal Immission Protection Law (Bundes-Immissionsschutzgesetz).

In regard to the disposal of effluent, in most case, textile finishing factories discharge "indirectly to the public sewage system". They must acquire official approval for discharging effluent into the public sewage treatment plant and this contains threshold values in regard to loading and concentration. Substances registered include seven heavy metals, four volatile chlorohydrocarbons, AOX (organic halogen X) and free chlorine. AOX is a sum parameter, i.e. the corresponding test methods express the total without differentiating between the different species. This is significantly cheaper than a qualitative and quantitative analysis of the individual substances. The sum parameters which are very often used in effluent analysis are TOC, COD, BOD and AOX.

If the textile finisher discharges his effluent into the sewer system after intensive cleaning in the factory's own treatment plant, then he is confronted with the Waste Water Discharge Regulation which, in this case, regulates more according to the quantity discharged to sewer than the harmful substances it contains. On the other hand, the effluent released into the sewer system must comply with a particular water-quality classification after the discharge point which takes into consideration the biological quality of the open water, i.e. the survival capacity of certain organisms in the mixture of flowing water and discharged water.

If the effluent is discharged into the public drains, then it must be ensured, for example, that the effluent will not attack concrete due to its sulphate content. The maximum sulphate concentration of, for example, 400 mg/l SO_4^{2-} seems reasonable as the corresponding requirements of the legislator protects the textile finisher from serious consequences which he may have to suffer according to the principle of causation if the effluent causes extensive damage to the drain system due to sulphate or damage to the effluent treatment plant (such as a collapse of the biological equilibrium) due to other substances harmful to water.

It is known that, in relation to eutrofication problems, there is intense activity in the search for substitutes for phosphates in detergents. Citric acid and nitrilotriacetic acid (NTA) have been introduced as substitutes for sodium polyphosphate or sodium aluminium sulphate as a detergent builder in detergents. However, as phosphates also come from agricultural sources, the construction of sewage treatment plants with a third purification stage was discussed some time ago. Such discussions in regard to phosphate affect the textile finisher if he softens hard water in the textile finishing process using water softeners or consciously uses phosphates as builders in the washing processes. The list of substances harmful to water is constantly growing and also affects both their storage in the factory and their handling. Surfactants are affected in particular but so are all substances which may release heavy metals.

According to the Dangerous Substances Regulation, the responsibility rests with the employer to provide operating guidelines for handling dangerous substances. The safety data sheets of all chemicals used in the chemical industry are, therefore, an important source of information in the matter of avoiding hazards. From these, the textile finisher can find out how the by-products of his work will affect the environment and what measures must be taken for assuring the quality of the environment. A typical example of conscientious behaviour is found in the way the manufacturers and users of the alkyphenolethoxylate (APEO)-based surfactants responded after recognising their damaging effect on the environment. The remaining test methods for determining the bio-degradability of APEO show that the products meet the requirements of these tests. The metabolites of APEO are, in fact, toxic to fish (Fig. 3).

Voluntary restriction in regard to these products has given rise to a successful search for APEO substitutes, of which the ones predominantly on the market are the fatty alcoholethoxylates which have a similar application range. Of course, the surfactant manufacturers are affected by the Chemical Law most of all. However, the example shows that the user, who also has some responsibility, can take action as well.

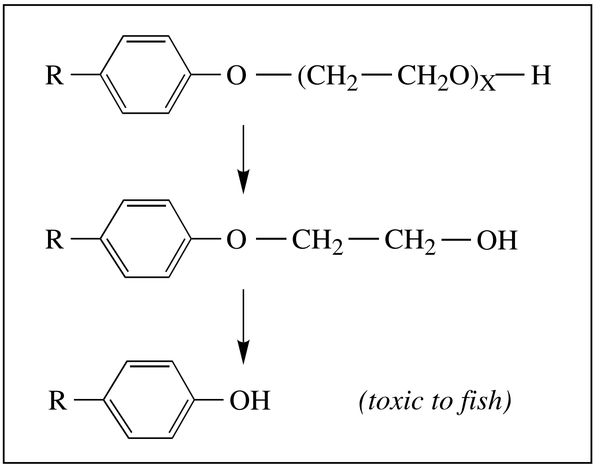


Fig. 3: Biological degradation of APEO to metabolites toxic to fish.

Apart from the solvent, water, and the solid or dissolved particles, the textile finisher must also direct his attention towards air pollution, which has been subject to regulation since 1985 under the 4th Federal Immission Protection Law. Indeed, this law also has something to say about the protection of certain areas from noise. However, textile finishing normally produces relatively little in the way of noise emission. Air pollution is defined in the TA-Luft (Federal Government Technical Instructions for Air, 1986). Of course, the threshold of interference is a point of contention between the authorities and textile finishing industry when existing plant is being evaluated. At a regional level, there is no opportunity for discussion when new plant is applied for. Of course, textile driers and furnaces (steam boilers) are particularly affected by the Federal Government Technical Instructions for Air. However, processes during which unknown by-products are produced also represent potential sources of exhaust-gas emission under certain circumstances during chemical or thermal conversion (resin finishing and heat setting). Finally, the textile finisher must come to terms with product-related environmental protection. Formaldehyde can be released from crease-free finished fabrics during storage and use due to partial hydrolysis of unconverted N methylol and N alkyloxymethyl compounds and, under certain circumstances, cross-linked cellulose. Of interest for the toxicological evaluation of formaldehyde in this application, is the amount released under the conditions of use and reabsorbed by the skin or reabsorbed from the respiratory air.

Leisure wear Style of clothing which, in comparison to the so-called conventional-classical clothing, is designed more to meet the user's requirements and place more emphasis on comfort with light fabrics and a casual style with the trend of fabric compositions towards synthetic mixtures and ease of care; used for shirts, ladies' suits, dresses, men's jackets, trousers, suits and trouser suits. Further developments in → Casual wear.

Length measurement Usually made on the running fabric by means of measuring wheels, i.e. a wheel with known circumference is pressed against the fabric under a defined pressure. The number of rotations is recorded via a mechanical or electronic counter (turning impulse generator) from which the corresponding length or speed is determined. One variant of this method is the determination of rotations at a guide roller and back calculating this to the running lengths. All these methods have the following disadvantages:

- the measurement wheel is subject to wear, i.e. changes in diameter;
- material specific slip between the measurement wheel and the goods;
- measurements frequently take place at a drive point, i.e. the fibre is not relaxed;
- pressure sensitive goods may be damaged;
- goods may be deformed if wet, moist or hot or fibres may be disturbed.

These problems demonstrate that sufficient measurement accuracy in production can only be achieved under favourable conditions.

With pile fabrics a more marked variation can occur due to the reaction between the wheel and the fabric pile. Mechanically driven goods move the measurement wheel by means of friction. The elastic fibres are moved out of their original position by the force exerted by the wheel which means that the speed of the goods base weave being measured V_{Mg} no longer agrees with the speed of the measurement wheel V_{Mr}. Fig. 1 is a schematic presentation of length measurement on knitted-type piled textiles. In the first case a), measurement is carried out with the nap, i.e. the pile is leaning in against the direction of the fabric movement. As a result of the force between the pile and the measurement wheel, the inclination of the pile increases and the outer casing of the measurement wheel lags behind the forward moving ground weave of the goods. Thus, $V_{Mr} < V_{Mg}$ and the measurement has a negative bias (under-reads). In the second case b), measurement is carried out against the nap, i.e. the pile is leaning in the same direction as the direction of advance. The relationship between the measurement wheel and the goods is reversed so giving rise to positive deviations in the length measurements (over reading). In both cases, the calibrated tolerance of ±0.3% allowed for textile measurement machines is exceeded many times over. Typical pile dependent deviations are of the order ± 2–4%.

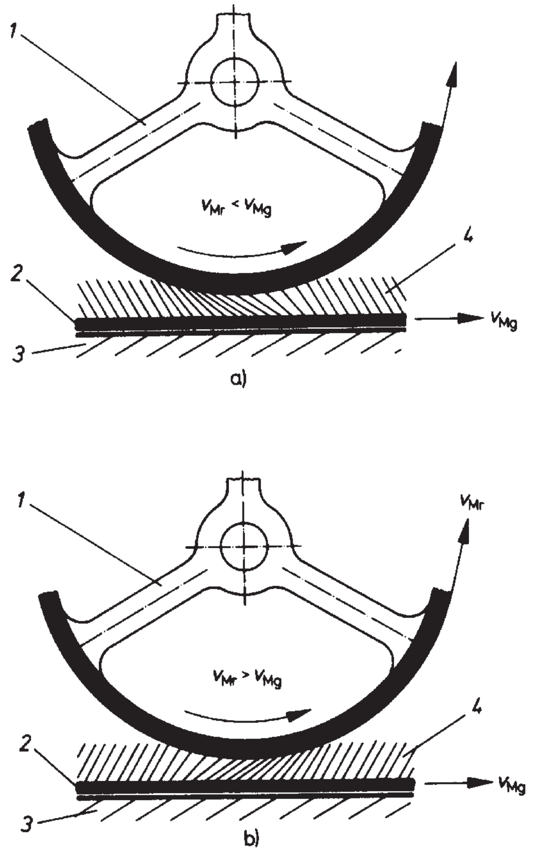


Fig. 1: Diagram of scanning textiles with pile: a) with the pile, b) against the pile.
1 = measuring wheel; 2 = sample material backing; 3 = straight feed; 4 = elastic pile fibres; v_{Mg} = velocity of sample backing material; v_{Mr} = circumferential velocity of measuring wheel.

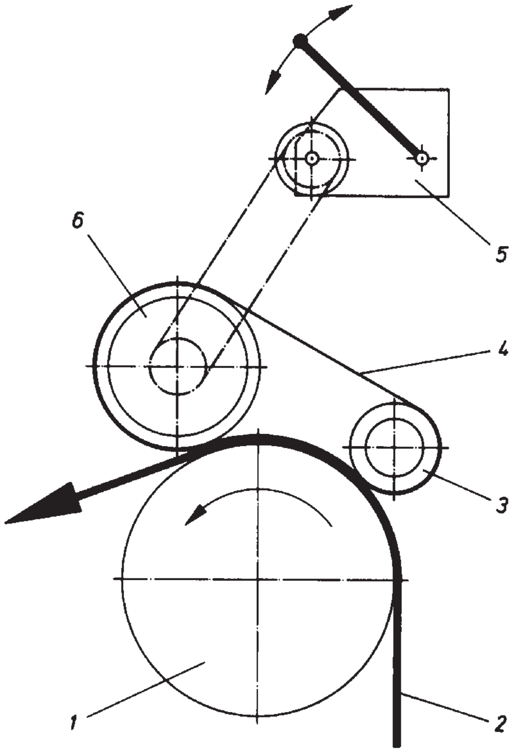


Fig. 2: Diagram of indirect mechanical length scanning.
1 = drive roller; 2 = sample; 3 = tail wheel; 4 = belt; 5 = counter; 6 = measuring wheel.

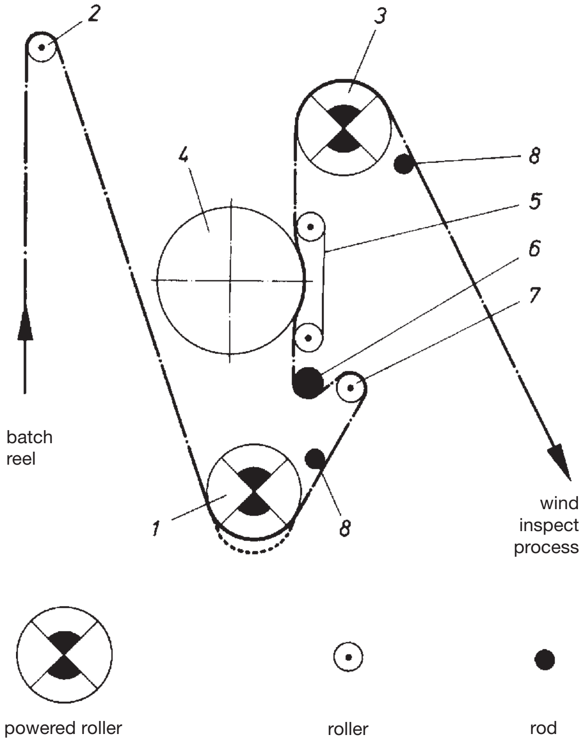


Fig. 3: Traction regulation using pressure belt (as proposed by the Physical-Technical Laboratory, Braunschweig).
1 + 3 = pull roller; 2 + 7 = roller; 4 = measuring wheel; 5 = pressure belt; 6 + 8 = rod.

The deviations just described can be reduced to the calibrated tolerances if, instead of the measurement wheel impinging on a straight run of material, the fabric to be measured is guided round the circumference of measurement wheel. The friction between the wheel in this arrangement is much higher so that, in the case of piled fabrics, deviations in the movement of the fibres has little effect on the circumferential velocity of the wheel. An even better arrangement is via indirect contact with the goods being measured using a belt, as shown in Figs. 2 and 3. The belt is used as a link between the goods being measured and the wheel and caters for a high transmission of surface-frictional force. Using this principle of length measurement, the deviations due to slip and similar problems can be reduced by a justifiable amount, but it is not suitable for goods which are sensitive to touch. Laser technology, for example, using the reference Doppler method can be used for contact-free measurement with these materials instead (→ Laser Doppler Effect) (source: Zervos).

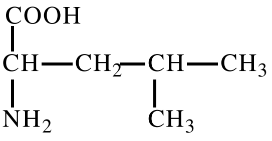
Leno fabrics (àjour fabrics, filigree work, gauzes), in most cases, transparent fabrics with → Gauze weave, leno weave such as ajour fabrics, etamine, net-curtain fabrics, gauzes, marquisette and similar weaves; also used for fashion effects in dress and blouse fabrics.

Lethal index Concentration of a → Poison in mg/m^3/min. required to lead to the death of an adult → ct Product.

Lethal limit Lethal limit for poisons: → LC-50 and LD-50 values; Death rate for fish in effluent.

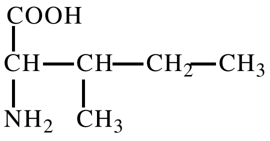
Letterpress printing (book printing). The ink is transferred from the raised printing areas of a roller or similar device.

Leucine, iso-leucine → Amino acids monoamino-monocarboxylic acids):



$$\begin{array}{llll} \mathrm{COOH} & & & \\ | & & & \\ \mathrm{CH} - & \mathrm{CH_2} - & \mathrm{CH} - & \mathrm{CH_3} \\ | & & | & \\ \mathrm{NH_2} & & \mathrm{CH_3} & \end{array}$$

leucine



$$\begin{array}{llll} \mathrm{COOH} & & & \\ | & & & \\ \mathrm{CH} - & \mathrm{CH} - & \mathrm{CH_2} - & \mathrm{CH_3} \\ | & | & & \\ \mathrm{NH_2} & \mathrm{CH_3} & & \end{array}$$

iso-leucine

found in wool (11.3%) and silk (0.8%).

Leuco- (Gk.), white, colourless.

Leuco compounds Water-soluble colourless reduction compounds, for example, vat and sulphur dyes, in aqueous and alkaline liquors (→ Vat) that are fibre substantive and are rendered insoluble through oxidation to become fixed in the fibre. In most cases, leuco compounds are a different colour to the final oxidized dyestuff. Originally, the term leuco compounds was only used for colourless reduced-dye compounds such as the reduced form of indigo which is completely colourless in acid solutions. Nowadays, the term is also used for the coloured reduction compounds of vat dyes and similar. An example of more or less colourless leuco compounds are the natural dyes which are "dissolved down" to this state during reduction bleaching.

Leuco-sulphur dyes Powder-form of (→ Sulphur dyes) which already contain the reducing chemicals necessary for solution and dyeing. Applied without the addition of sodium sulphide. No longer commercially available.

Levantine squeegee oil stone A natural stone of particular grain size (Levantine), soaked with oil; also known simply as an "oilstone". Used for sharpening or grinding the cutting blade to make it sharp and smooth.

Level controller An automatic measuring device for controlling the level of liquids and printing pastes etc., operates according to various principles. The level of aqueous liquids can be determined by closure of a d.c. circuit or by a pressure switch on the floor of the tank. Mechanical sensors based on a float detection principle are used. Level controllers are a series of measuring systems that use the sensing device to compare should/is values (microprocessor) and subsequently control an on/off device to adjust the actual level of the liquor. The level controller shown in Fig. is suitable for use on a dye padder. This is particularly suitable for strongly foaming, sticky and aggressive liquids. All components coming into contact with the liquid are made from acid-resistant steel so the controller can be used for dilute acids and alkalis.

The PRA 30 level controller monitors and controls liquid levels with an accuracy of ± 1 mm. It consists of a sensor (1), an electronic amplifier (2), solenoid valve (3), push button (4), indicator lamp (5) and an end

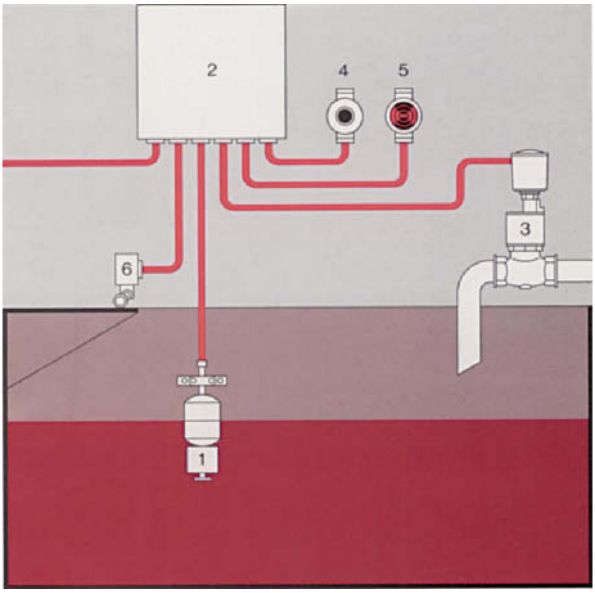


Fig.: Level controller PRA 30 (Erhardt and Leimer).

switch (6) which is only used for lowering and tipping troughs. Optical and acoustic alarms can also be linked into the system. A delivery pump for controlling the supply and discharge of liquid can be used instead of the solenoid valve.

Level dyeing test for package dyed polyester yarn → Shock dyeing test.

Levelling →: Levelling properties; Levelness.

Levelling agent Agents which are added to the dyebath or pad liquor. There is a difference between a) fibre-affinity levelling agents which absorb more quickly on to the fibre than the dye, temporarily block the fibre absorption sites and are then slowly replaced by the dye; and b) dye-affinity levelling agents which, due an interaction with the dye in the bath, increase the size of the dye molecule so that the complex takes longer to diffuse into the fibre. Under dyeing conditions they produce an even distribution of the dye within the textile material and on its surface. The product is based on surface active agents and preparations such as sulphonated oils, fatty acid esters and fatty acid amides, fatty acid condensation products, alkyl sulphates, alkylaryl sulphonates, alkyl and alkylaryl polyglycolethers and fatty acid polyglycolesters as well as amine derivatives. Also used as protective colloids, e.g., for fatty acid-protein condensation products.

The effectiveness of different levelling agents can compared using the Time-Step Levelling Test. On reaching boiling point (time 0), fabric samples of identical size (or 2.5 g wool felt samples) are placed in a dyebath after time intervals of 4, 16 and 32 minutes receptively. Dyeing continues for a further 30 minutes after the last piece has been placed in the bath. After removing the dyed material (4 samples), a 2.5 g fabric sample (or wool sample) is immersed in the bath until the remaining liquor is completely exhausted. Dyeing is continued for a further 30 minutes at boiling point. When the fabric samples are removed from the bath they are squeezed out while still hot and thoroughly rinsed in 250 ml cold water and then removed. In order to establish the drainage properties, a fabric sample is dyed in the same rinse liquor at boiling point.

The liquor ratio, for example during dyeing, is 1 : 50 in comparison to 10 g material. The dyebath contains 1% dye + 10% sodium sulphate calc. + 3% acetic acid (60%) at approx. pH 4.5, + x% levelling agent. The assessment is made by comparing the difference in depth of colour between the individual samples in comparison to the result using the comparison product.

Levelling capacity of dyes → Levelling properties; also the ability of a dyestuff to cover differences in exhaustion onto a substrate. The property of the dye, on the fibre, to migrate from a site of higher concentration to a site of lower concentration. The levelling capacity is dependent on time, temperature and additions of electrolyte and auxiliaries.

Levelling dyes General term for acid dyes with outstanding levelling properties for dyeing wool.

Levelling in finishing A distinction is made between levelling as a treatment on so-called → Fabric straightening machines and the masking of irregularities such as streaks and bands. These are treated with press-fast or ironing-fast stitch-colour corrections or colour pencils (also called retouching or tinting), particularly common for finished wool goods with deep dyed warp and white weft, and for carded-yarn goods before finishing.

Levelling index The five-step → Grey scale for fastness testing of the German Fastness Commission (DEK) corresponding steps for the evaluation of levelness/unlevelness produced according to the so-called Fransen method of dyeing. 5 on the scale represents uniform and 1 significantly non-uniform coloration.

Levelling phase in dyeing During normal dyeing cycles, the rate of exhaustion gives no dimension to a levelling phase. It is accepted that surface adsorbtion of dyestuff onto the fibre surface ocurrs more or less unevenly and experience has shown that this initial unlevelness will disappear after sufficient time during the levelling phase. Levelling (migration) rather than even exhaustion is regarded as the crucial characteristic of levelling dyestuffs (in this context, levelness refers to the uniform distribution of dye on the textile fibre).

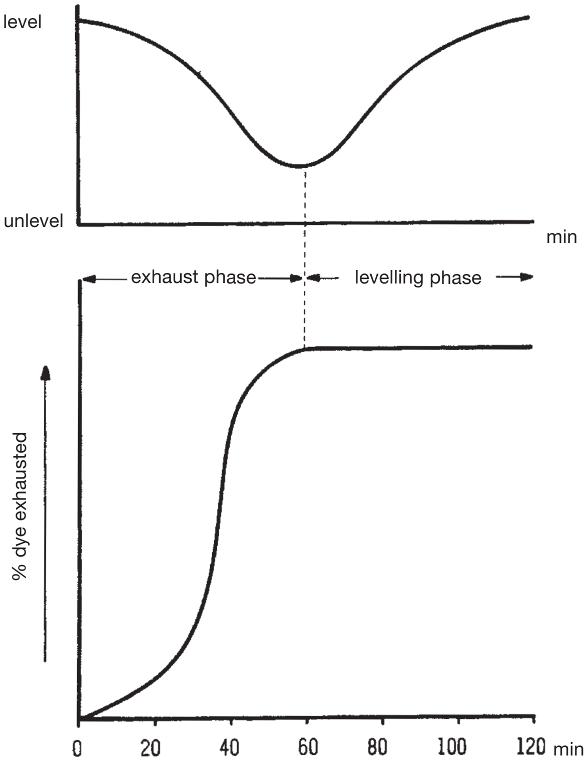


Fig. 1: Exhaust curve and levelness in the standard HT process.

Levelling properties

The lower part of Fig. 1 shows a typical absorption curve for a dispersion dye on polyester fibre during the course of a conventional HT process. The dyeing process consists of an adsorption phase and a levelling phase. A schematic presentation of the levelness of dyeing during the dyeing process is shown in the upper section. The initial state is the undyed textile which may be regarded as uniform. The dyeing increasingly becomes non-uniform during the adsorption phase; during the levelling phase, uniformity increases again. However, during this process, a considerable amount of the dyeing time is devoted to levelling the distribution of adsorbed dye which can be very uneven. The often relatively long levelling phase can be significantly reduced if the adsorption of dye at the start is as uniform as possible. The viability of this route has been proven in the case of cationic dyes and polyacrylonitryl fibres. This knowledge has contributed to process control in the case of polyester fibres, as taking suitable measures to increase the efficiency of the dyeing process has allowed the introduction of so-called rapid dyeing methods.

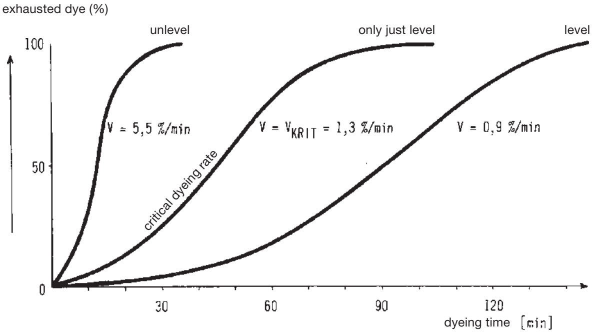


Fig. 2: Critical dyeing rate with a given system.

The critical rate of dyeing (Fig. 2) gives the limits for the production of level dyeings. If the curve is altogether too flat, then time is being wasted. If the curve is too steep, then the critical dyeing speed has been exceeded and dyeing during the adsorption phase is more or less non-uniform. Of course, a certain amount of non-uniformity at the start is acceptable when sufficient time is available for the levelling phase to give a uniform result by the end of the process. This corresponds to the term "acceptable adsorption non-uniformity".

The task of dyeing rapidly and uniformly, therefore, requires that the dye adsorption speed is matched to the critical or just allowable dyeing speed as determined by the machine and other conditions. This is most easily achieved by using a method involving temperature control. Within the temperature ranges in which the dye adsorbs slowly, or if the dyebath is already significantly exhausted, absorption is accelerated by rapid heating. For those cases where the dye has a particularly high adsorption rate, adsorption can be slowed down by heating slowly.

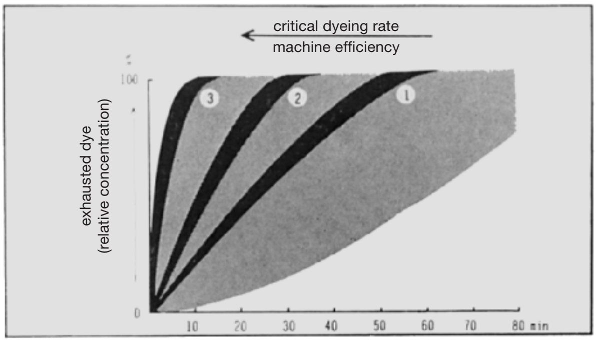


Fig. 3: Exhaust curve bunching due to process control in adjusting to the critical dyeing rate.

The starting position represents a great variety of possible adsorption curves which can lie within a wide range; this range is shown by the areas highlighted in grey in Fig. 3. Process control is used to bundle these adsorption curves into a narrow group. This process must be oriented to the critical dyeing speed if dyeing is to be uniform from the start. For any given substrate, the more efficient the machine is the higher is the critical dyeing speed. How much the rate of adsorption can be increased, therefore, depends greatly on whether an appropriately efficient machine is available. This relationship is represented by curve groups 1, 2 and 3 where 3 corresponds to the highest requirements.

Levelling properties Term used for the ability of a dye to exhaust evenly onto goods, i.e. the levelling out of different dye concentrations or amounts per unit area. Critical in achieving a level dyeing are → Exhaustion rate and migration properties of the dyestuff.

Levelling property test,

I. Roll test: Fabric is rolled on part of a glass rod and the half not on the rod is immersed in the dyebath. Dye according to the method usually used for the dye in question and then immerse the undyed portion and continue to dye. The levelness between the two halves of the fabric are assessed.

II. Migration test: Part of the sample is removed before the start of dyeing and immersed in the dyebath as mentioned under item I; in this also, an assessment of the colour difference is made between the sample and migration sample.

III. SDC migration test: a sample of fabric is dyed in a dyebath, while a second comparison sample is dyed in a "blind" dyebath, i.e. a bath without dye but containing auxiliary aids. After the treatment is over, the half of the "blind" sample is swapped for half of the "normal" sample and this is dyed in the "blind" bath for a further thirty minutes. The contrast between the two samples is assessed with the aid of a grey colour scale.

IV. → Strike migration test.

V. Felt chromatogram: The liquor is allowed to circulate through columns of felted fibre under certain conditions for a long period of time and the uniformity of the dyeing on the felt assessed.

Levelling risks The sum of all dyestuff and dye-process specific parameters which affect levelness in a dyeing process. Such parameters are, for example:

- constitution and finish of the dye,
- temperature-dependent exhaustion properties,
- reactivity,
- diffusion,
- migration properties,
- fabric preparation,
- temperature control,
- auxiliaries and electrolyte additions,
- dyeing time,
- machine-dependency of the dyeing process.

Levelness This term is used to describe the uniformity of distribution of a finishing substance on and within goods after treatment. It is frequently used as a parameter for the certainty and economy of a dyeing process. A dyeing is judged as level when the dyed goods have the same depth of colour and colour tone all over (optimum levelness). The levelness tolerance largely depends on the use to which the goods are later put. Basically, levelness can be controlled according to two strategies:

I. The principle of controlled adsorption, i.e., mainly uniform adsorption and relatively short migration phase for full penetration dyeing.

II. Migration method, i.e. rapid absorption and extended migration phase for levelling non-uniformity.

The choice of method depends on the dyeing machine system, the type and make up of the textile and the economic considerations. The process control is also dependent on the dye and dye auxiliary aids which are used.

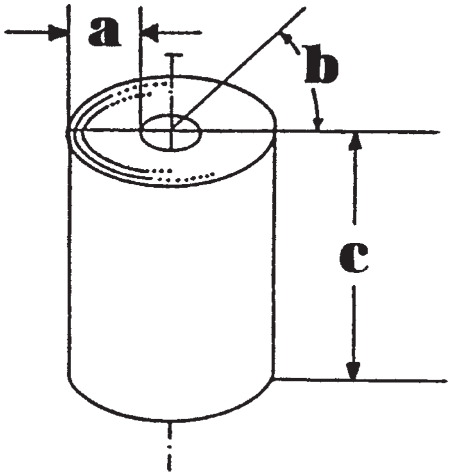


Fig. 1: Dye gradients in yarn packages.
a = radial; 2 = azimuthal; c = axial.

Package dyeing can be analysed for levelness, for example, by describing a package in three-dimensional terms, i.e. by a radial, axial and azimuthal dye distribution (Fig. 1). However, initially it is sufficient to illustrate the situation in terms of radial dye distribution.

Example: the levelness of dyeing is tested by taking a sample from the middle package on the press column in the dyeing system. Samples are taken from the inner and outer layers of the package at predetermined intervals. The distribution of sites from which the samples

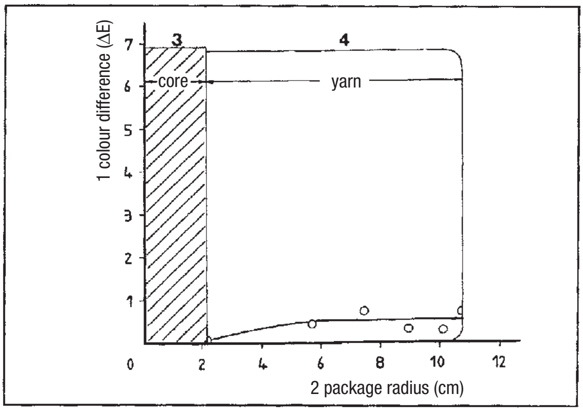


Fig. 2: Levelness testing: level dyeing, as ΔE < 0.5.

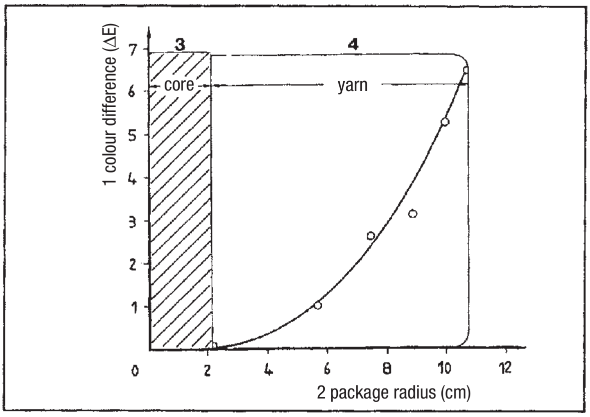


Fig. 3: Levelness testing: unlevel dyeing, as ΔE > 1.

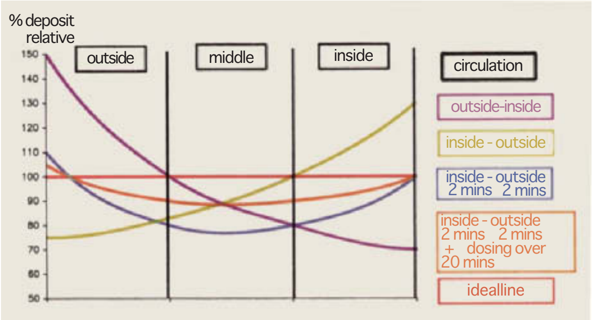


Fig. 4: Relation between levelness and liquor circulation.

are taken is selected to correspond to the package diameters; thus ensuring even distribution throughout the package in terms of its volume, i.e. the liquor must penetrate the same amount of yarn from one sample site to another. Knitted pieces are prepared from the samples of yarn (n = 5–6) and these are subjected to colorimetric measurement (Figs. 2 and 3). Fig. 4 shows the relationship between levelness and liquor circulation.

Leviathan (hebr. liwjathan = giant), continuously operating plant for washing loose wool which is sluiced through 5–7 wash vats (2500–4400 l capacity) by means of (fork, drag and shake) rakes in accordance with the pass-on principle. Mangle rollers are located between each vat and the liquor is controlled by the counter-flow principle. The liquor flows at approx. 40-50 l/min. The capacity is ca. 300–400 kg/h. Washing agent consumption for 1000 kg raw wool is approx. 20 kg soap, 1–2 kg hard water stable detergent and 12 kg sodium carbonate.

L-form → Optical activity.

L/H Abbrev. denoting an aqueous → Emulsion, for example an oil (Gk.: lipos) in water (Gk.: hydro) system.

LI → Flax (linen), → Textile fibre symbol, according to DIN 60 001 T4/08.91.

Li Symbol for the element lithium (3).

Liebemann's indophenol reaction Test for nitrosoamines or easily nitrosatable imidazolidones and pyrimidones in synthetic resin finishes (→ Nitrite reaction). Procedure: fuse 1 ml nitrosoamine containing solution with 0.5 g phenol, mix with 3 ml concentrated sulphuric acid and after 2 minutes pour over ice. Then add excess sodium hydroxide. In the presence of phenol, nitrosoamines yield violet to deep-blue indophenols.

Ligands (Lat: ligamen = band, bond), term used for inside a complexing molecule (→ Complex compounds) for atoms or atomic groups which surround a so-called central ion; for example, in potassium hexacyanoferrate (III) $K_3[Fe(CN)_6]$ the complex is $[Fe(CN)_6]$, the central ion is (Fe^{3+}) and the ligands are $(CN^-)_6$, i.e. the six cyanide groups are arranged around the Fe^{3+} ion.

Light → Light wavelengths.

Light barrier Opto-electronic safety or monitoring device used for machines; also used for the automated opening or closing of doors etc. Operates according to the → Photocell principle.

Light cabinet Colour-matching cabinet; → Colour matching of dyed/printed samples.

Light (colour),

I. → Lightness.

II. Term used for classification according to "white and pastel shades".

Light damage → Photochemical fibre degradation, yellowing of textiles.

Light edges → Edge-to-edge unevenness.

Light exposure damage The strength of textile fibres decreases with the time of exposure to sunlight (Fig.). The complex photochemical reactions vary dependent on the type of fibre. Polyamide 6, where the decrease can be 50% and more, is at particular risk, whereas natural fibres are affected less. (→ Photochemical fibre degradation).

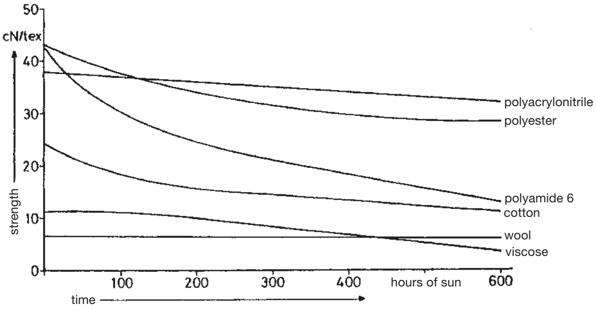


Fig.: Light exposure damage in the form of strength losses of various fibres.

Light fading Exposure to light, through photochemical reactions, causes damage to dyeings; recognisable as changes in the colour tone.

Light fastness When textiles are in use, typical quality characteristics such as colour fastness or strength parameters may change due to external factors. In this connection, the effect of long-term exposure to light in particular can give rise to changes. When wool is exposed to radiation from sunlight, for example, protein and possibly nuclein components absorb energy. This gives rise to photochemical reactions, such as the oxidation of amino acids, cleavage of peptide chains and cross-links, cross-link reactions and double bond formation. The mechanical strength of the irradiated goods is reduced. The effects can be clearly seen, e.g., in the case of car upholstery. Sunlight can cause a considerable rise in temperature in some cases, such as the inside of a car. Measurements have shown that, on the parcel shelf in particular, the temperature can reach 122°C. A light fastness test in accordance with DIN 54 004 is of little help. To some extent, car manufacturers require a different type of light fastness such as → High-temperature light fastness.

In the case of car upholstery, light-fastness testing at elevated temperatures is required to simulate the combined effect of long-term exposure to light and high fabric temperature. The type of long term solar radiation can alter the strength of the coated fabrics in different ways depending on the thickness of the coating (Fig.). At the same time, environmental effects on the different irradiated sites accelerate the decrease in tear strength by different amounts. This type of complex long-term behaviour (irradiation, temperature and rain etc.) in the

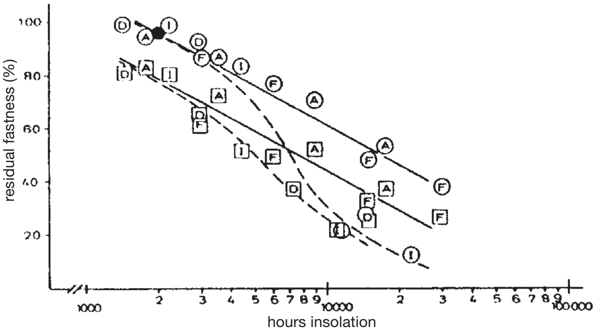


Fig.: Residual fastness in relation to insolation hours (practical weathering at 2000 hour Xeno test).
Coating thickness 20 µm (❑) or 50 µm (0).
D = Wuppertal; A = Ebnit; I = Dormeletto; F = Miami.

case of coated fabrics can in no way be predicted from artificial weathering, so it is necessary to use real weathering in various different climates for periods of 2–5 years in order to give a quality prognosis (Fig.).

The resistance of textiles to the effects of UV radiation is an important factor in the area of net-curtain fabrics, ready-made curtains, belts, carpets or geotextiles. On the one hand, the fibre producer is endeavouring to stabilize his products to UV radiation and on the other, test institutes are looking for a short duration test method to provide information on fabric behaviour in the presence of sunlight which is to some extent accurate. A short duration test to simulate the real conditions is always fraught with problems: while the processes in practice take place slowly and are caused by relatively weak effects, the short-duration test has to highlight these same effects quickly (in most cases without intermediate periods of recovery) and under the increased influence of a particular effect. In addition to this, several effects are always at work simultaneously in practice and these interact with each other. In the laboratory test, however, only one or at most two or three effects can be examined at the same time.

During outside weathering, the following factors are important in the case of textiles:

1. Due to radiation, the textile can be at a higher temperature than the surrounding air. This temperature may not be high enough to induce thermal decomposition processes. However, the reactions which are taking place are probably hydrolytic, oxidative and secondary photochemical processes which proceed faster the higher the temperature.
2. Moisture and rain in particular can cause physical damage (freezing) and swelling. Hydrolysis and catalysis can be initiated by rain and air and are aided by dirt.
3. Wind stresses textiles mechanically, especially by the impact of tiny particles.
4. The attack of air pollution can be extremely aggressive for textile fibres. Worth mentioning in particular are SO_2, SO_3, H_2S, $(NO)_x$ and O_3. Organic compounds (unsaturated alkyls and aromatic compounds) are catalysts for photo-oxidation.

The chemical bonds in textile fibres are mainly broken by the short UV wavelengths of the solar radiation. The UV component varies strongly with geographical location and altitude. Seasonal changes and changes throughout the day are significant and vary from year to year. These fluctuations are greater the shorter the wavelength. To some extent, all these effects have interactions, i.e. their effects on the textile may show some synergy. Outside weathering at different locations or different times cannot therefore be compared. If this is not possible, it will be hardly possible to develop artificial radiation or weathering which can be used to predict the general behaviour of textiles on exposure to the sun.

Light fastness testing The most significant factor in weathering is the effect of solar radiation. The sun radiates a continuous spectrum ranging from UV radiation (Wavelengths < 380 nm), through visible (wavelengths 380–780 nm) to infrared heat radiation (wavelengths > 780 nm). Radiation meeting the earth includes wavelengths ranging from approx. 300–3000 nm which corresponds to part direct solar radiation and part diffuse celestial radiation = solar and sky radiation. The last mentioned is not constant but varies according to position, time of day and time of year.

Artificial radiation sources, for colour measurement and testing, were developed by the Commission International de l'Eclairage (CIE) and standardised as a global radiation distribution in the standard illuminant D65 according to CIE Publications Nos. 15 and 20. When considering the effects of solar radiation, it must be remembered that it is the short wave UV radiation which is crucial in triggering photochemical decomposition reactions in fibres and dyes even though this represents only approx. 5% of global radiation. The UV radiation range is therefore very important when carrying out light-fastness tests; well simulated solar radiation is an essential requirement for radiation sources used in accelerated weathering devices. The combination of the type of radiation source and the optical filter system used is decisive for accelerated weathering equipment and the results it produces. The radiation emitted by xenon gas-discharge lamps represents the best possible technically realisable simulation of solar radiation. Since their initial use in the Xenotest 150 in the fifties (W.C. Heraeus GmbH Original Hanau product range) these radiation sources have been adopted across the world and have largely superseded the carbon-arc radiation sources introduced at the beginning of the twentieth century. The ISO standards and many national standards for the determination of light fastness in textiles exclusively require that filtered xenon-arc radiation sources be used in accelerated weathering equipment.

Light fastness testing

1. Illumination in Xenotest 450 in accordance with or in line with ISO 105-B02: the samples are arranged in a circle and rotated at a distance of approx. 25 cm around the xenon-arc lamp. UV and IR filters are placed between the sample carriers and the xenon-arc lamp. Illumination is carried out at air temperature of 35°C and air humidity of 65% rh.
2. Illumination by UV lamp: the samples are arranged in a circle around a high-pressure mercury-vapour lamp at a distance of approx. 28 cm. The samples are stationary. The temperature and humidity of the test room are not controlled.
3. Illumination in the Fadeometer - AATCC Test Method 16A – 1977: the samples are rotated in a circle around a carbon-arc lamp at a distance of approx. 25 cm.
4. Weathering in the Xenotest in accordance with ISO 105-B04: the samples are sprayed for 1 minute during illumination (demineralised water) and dried for 29 minutes (without additional heat or moisture).

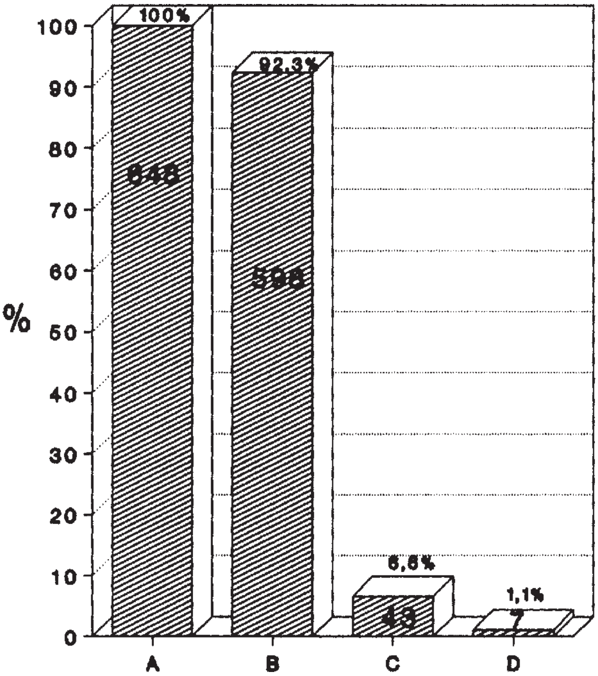


Fig.: Comparison of light fastness values obtained by colorimetry and by visual assessment.
A = overall evaluation; B = no deviation from visual assesment; C = deviation ± 0.5 points from visual assessment; D = deviation ± 1.0 points from visual assessment.

The measurement of intensity of radiation (radiation flux per unit area, expressed in W/m^2) or the radiation (radiation intensity integrated over time, expressed in Ws/m^2 or J/m^2) in accelerated weathering equipment places high demands on the long-term stability of the measurement equipment due to the conditions prevailing in the test room (high temperature and humidity). One radiation measurement instrument, for example, the Radialux (W.C.Heraeus GmbH Origin Hanau product range), is available for use in the Xenotest tester and in natural weathering tests. The Radialux consists of the processing units with LCD display for reading off the values and a UV and global sensor for measurement within the 300–400 nm and 300–800 nm wavelength ranges. The sensors are made of stainless steel and are cylindrical in shape in order to receive the optical and electronic units used for recording the measured values. They are inserted into the Xenotest tester instead of a sample carrier and are therefore subjected to the same conditions as the sample. The power is supplied via two special 7V lithium batteries. The incident ray passes through a scattering lens made of Teflon to a cosine recorder, through optical filters to establish the current measurement range and then strikes a photo diode. In order to read a sample value, the sensor is removed from the Xenotest tester and connected to a processor unit by means of a cable. After pressing the function keys, the radiation sample appears on the digital display in Wh/m^2. The average radiation intensity is calculated from the sample value divided by the time of exposure. Where the arrangement of the sensor is stationary, as is the case for the Suntest apparatus (also Heraeus) or a natural weathering test stand, the current radiation intensity can be read off in W/m^2 directly.

For illuminations in accordance with ISO 105/B01 and B02, the ISO light fastness scale (Blue scale) is used. This scale consists of a series of standard-depth dyeings using blue dyes on woollen fabric which are arranged in order of increasing light fastness labelled from 1 (very low) to 8 (very high). These standard-depth dyeings are known as blue types 1–8 or BT 1–8.

In the case of illumination in accordance with the AATCC method 16 the American light-fastness scale is used. In this case, graduation is achieved by an internal mixture of a worsted wool with very poor light fastness and a worsted wool with very good light fastness. The American scale is labelled L2–L9. In the case of both scales, each step should require double the illumination time to achieve the same colour as the step below.

Visual evaluation of the colour change is encumbered by a large amount of scatter. For this reason, efforts have been made to carry out the evaluation using colorimetric methods. When comparing a shade change in the sample against a grey scale (for example, in the case of wash fastness) the colorimetric method is clearly more reliable than the visual assessment. On average, the standard deviation to be expected when using colorimetry is around 0.3 against the 0.55 expected in the case of visual assessment. For light fastness, on the other hand, both the colour change in the illuminated sample and the illuminated different coloured wool-blue depths of the light fastness scale must be assessed. In the case of the visual assessment, this comparison is direct. When the colorimetric method is used, the points on the grey scale for the sample and wool-blue depth are determined independently. The light-fastness points determined using colorimetry compare well with values obtained visually (multi assessment) (Fig.). During the time of the colour change, nearly all of the seven cases with a deviation of ± 1.0 points resulted from the xenon-arc illumination (ISO 105/B02) and could be attributed to the Blue depths 4 and 5, between which there is relatively little difference, (source: Weber, Kübler and Ushöfer).

Light hardening of phosensitive coatings Found in coatings which rely on the use of → Light-sensitive films in which chemical reactions are triggered by light energy. These reactions lead to changes in the properties which can be used to produce patterns (→ Screen making). Normally, gelatine is used which, when mixed with chrome salts, forms an insoluble compound (→ Chrome gelatine) when exposed to light radiation for long periods. In most cases, the reaction of gelatine with certain chrome (III) compounds brought about by the photochemical reduction of chrome (VI) compounds (chiefly potassium and ammonium dichromate) are utilised to harden the carrier coats. Chrome salts do not show this effect until they are incorporated into colloidal organic substances. The sources of illumination used for light-hardening are mainly carbon-arc lamps, high-pressure mercury-vapour lamps or appropriate incandescent lamps. The threshold value is the degree of hardening during light hardening. For chrome-silver paper, this value is 0.5 and for compounds produced from gelatine and chrome salts this is $8 \cdot 10^6$.

Light-induced ageing, resistance to Fastness characteristic of pigment prints which appears as a change in wet fastness properties after the printed pattern has been exposed to light.

Light intensity Basic parameter of the SI system (→ SI units) with the candela as the fundamental unit (unit symbol: cd).

Light microscope Simple → Microscopes, consisting of two lens systems inside a tube: a) the objective consisting of several individual lenses which is placed directly over the object to be viewed (objective) and b) the eyepiece containing two lens systems (condensing and eyepiece lens) 2–4 cm apart which enlarges again the reversed image enlarged by (a), as through a magnifying glass. Corresponding enlargements and resolutions (ability to recognise the finest details) of the object are created by moving (a) in relation to (b) (Fig.). The resolution, of course, decreases with increasing magnification and is dependent on the wavelength of the light, i.e. if the fine structure is of the same magnitude as the wavelength, then this will produce diffraction effects (blurred, contourless microscopic image). Consequently, using a light microscope for magnifications above 2000 x is to no avail, so an → Electron microscope must be used instead.

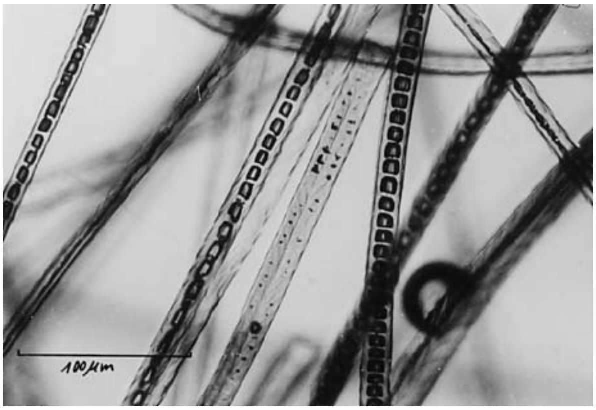


Fig.: Longitudinal view of angora fibres under the light microscope.

Lightness Used as a so-called blackness value integrated component of coloured and non-coloured light sensitivities (dependent on illumination). During → Colour measurement of coloured bodies it is identical to the luminosity coefficient β and can be clearly seen from the spectral remission curve. As measurement value (→ Colorimetric measure) this lightness is used in the so-called Standard Colour Value (Relative lightness, lightness value or lightness index) Y = 100%.

Light protective finishes for wool Treatments for wool textiles to protect fibres and dyes from the effects of light and in particular UV radiation, for example, so-called UV absorbers (Fig. 1). After exposure to light, wool in particular is subject to numerous changes. Initially, the wool is bleached (photo-bleaching or first break). As exposure continues, especially if there are other damaging influences such as temperature and a high proportion of UV in the light radiation (perhaps during the summer months in southern countries), the wool appears to yellow (→ Yellowing of wool). Apart from changes in colour, the wool is subject to changes in its chemical composition when exposed to light. These are in the form of amino acid decomposition, photo-oxidation of cystine and methionine and the aromatic amino acids, chiefly tryptophan and tyrosine. Photodegradation of histidine, lysine and other amino acids may also take place as a result of exposure to light. Photo-oxidation of wool also produces changes to its solubility properties, which can be in the form of increased alkali or

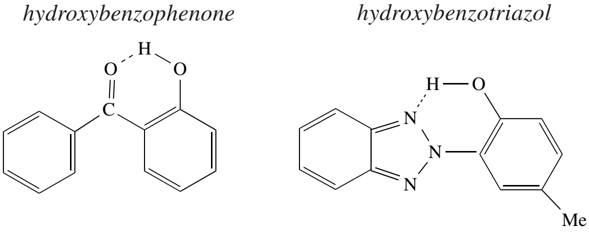


Fig. 1: Structures of UV absorbers.

pronase solubility. After short periods of exposure to light, new cross-links may also be formed which can, for example, lead to decreased urea-bisulphite solubility. Apart from the change in chemical composition of wool, light damage may cause a loss in mechanical stability.

Before now, sulphonated hydroxybenzophenones, hydroxybenzotriazols and hydroxyphenyltriazines have been used as UV absorbers on wool. Sulphonated UV absorbers have been found to be quite effective in reducing photo-yellowing.

Apart from UV absorbers which deactivate incident light and render it harmless, UV screeners used for stabilising polymers and cosmetics can also be exploited. These are able to reflect UV light, scatter it or absorb it on the surface of a polymer material and prevent it from reaching the interior of the material. Pigments such as titanium dioxide, barium sulphate, zinc oxide and iron oxide are used as UV screeners. Apart from UV absorbers, other light screening agents can be used as light-protective finishes for polymers. These are able to deactivate any photo-products which have formed (sec. stabilisation). They function as radical catchers, antioxidants or singlet oxygen quenchers (Fig. 2).

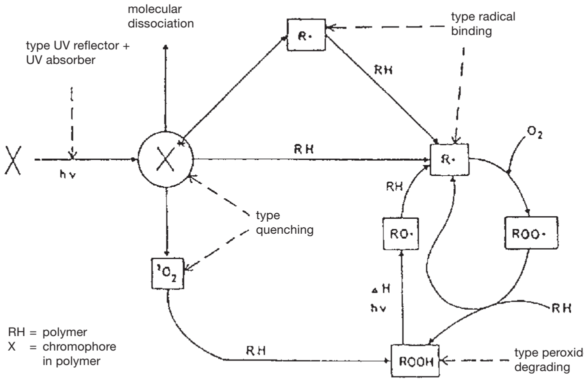


Fig. 2: Photodegradation and stabilisation mechanisms of polymers.

Sulphonated UV absorbers of the hydrobenzophenone and hydroxybenzotriazol type are able to protect wool from photo-yellowing and other light damage as the substituents in these substances have a significant influence on the effectiveness. Straight sulphonate hydroxybenzophenones have a characteristic yellow colour which on application to wool turns it yellow. Sulphonated hydroxybenzotriazoles do not have this effect. UV absorbers operate in many different ways. In general, they not only function as UV absorbers but also act as radical catchers or decompose hydroperoxides. It is assumed that UV absorbers based on the above-mentioned substances operate by de-activating radiation energy via intramolecular hydrogen bonds between hydroxyl groups and keto or triazol residues.

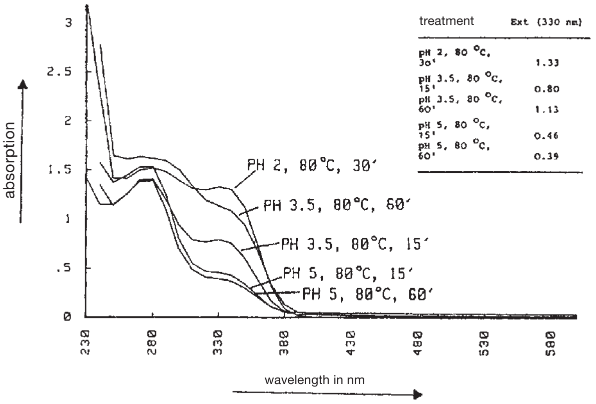


Fig. 3: UV absorption spectra of wool samples treated with Cibafest W under varying conditions.

In the case of sulphonated hydroxybenzophenones under strongly acidic conditions, the intramolecular hydrogen bonds are fully developed in wool (Fig. 3). Until now, application has been recommended under strongly acidic conditions (pH 2). The photo-stabilising effect of hydrobenzotriazole is not due to an energy transfer via the intramolecular hydrogen bonds. Stabilisation of these bonds is therefore not as important as it is for hydroxybenzophenones. However, in the case of the sulphonated hydroxybenzotriazol, Cibafast W (Ciba Geigy), effective stabilisation was found for wool after application under weaker acid conditions (up to pH 5), i.e. conditions which are normal for dyeing wool.

After application of Cibafast W at higher pH's, a light-protection finish can be obtained for the treated wool which is comparable to that produced by applications under strongly acid conditions. The effect of sulphonated hydroxybenzotriazol is seen in the delay in yellowing and improved chemical and mechanical stability. After application of Cibafast W at pH 5, good rates of bath exhaustion were found for the fibre but with low UV absorptions at 330 nm.

The radical catchers used were sterically hindered phenols or amines. Esters of the octadecyltertbutylhydroxyphenyl propionate type are characterised by poor water solubility. Their use as light-protection agents for wool is therefore limited. Although absorption of the light-protection agent is achieved for wool via application using hydrophobic solvent systems, this does not lead to photo-stabilisation. Sterically hindered phenol applied to wool together with sulphonated UV absorbers shows, at most, a synergistic effect. → Yellowing on storage is known and has been attributed to the migration of phenol-based antioxidants from the packaging materials. This means that problems could arise during the storage of wool which has been treated with antioxidants containing phenols. Sterically hindered amines of the piperidine type (Fig. 4) act as radical catchers. Radicals produced by photo-reactions (in *bis(1,2,2,6,6-pentamethyl-4-piperidyl)sebacate*

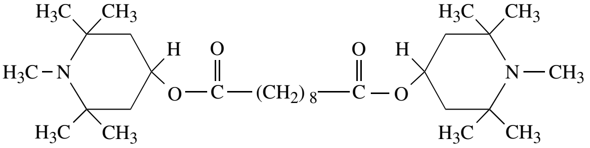


Fig. 4: Structure of the sterically inhibited amine tinuvine 292 (Ciba Geigy).

most cases, peroxides, hydroperoxides and CH radicals) are de-activated via circulation systems in which radicals are caught by the amine residues of the piperidine. Increased radical concentrations have been found for exposed wool. Sulphur radicals are formed in particular, but also those which are produced by the cleavage of NH or CH bonds. Thus, using radical catchers as light stabilisers for wool appears to be a reasonable route to take. The most well-known sterically hindered amines are of high-molecular type and, on solubility grounds, are therefore not suitable for use as stabilisers for wool via application from a dyebath.

The photo-degradation of wool is oxidative. Apart from the formation of cysteic acid from cystine, oxidation products of tryptophan are formed in particular. Antioxidants should therefore be appropriate for use in light-protection finishes for wool. As antioxidants, sterically hindered phenols and phosphite esters are used for stabilising polymers. Phosphite esters act as hydroperoxide decomposers. The calcium salt of sterically hindered phenol (Fig. 5) absorbs well on to wool (source: Schäfer and Gröger).

[calcium-bis-(3,5-di-ter.butyl-4-hydroxyl-benzyl-monoethyl-phosphanate]

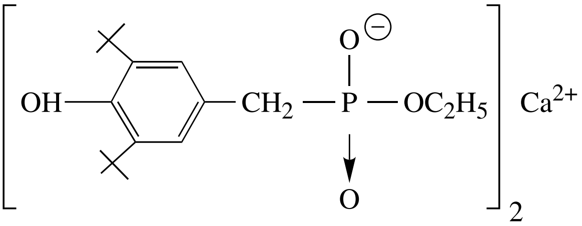


Fig. 5: Structure of the antioxidant Irganox 1425 (Ciba Geigy).

Light resistance testing of fibres and yarns Used to assess damage resulting from xenon arc light using a co-illuminated → Blue scale as a numerical value. Samples of similar thread- and fibre-titres and similar twist, in the case of yarns, are advisable for comparison exposures. Where necessary, agents which have been used for post-treatment must be removed. The samples are mounted stress-free in the case of fibres or under slight tension in the case of threads, and isolated from the effects of air from all sides. The start of discolouring from Step VI on the blue scale serves as the exposure unit. At least three exposure units are required to assess the course of damage. During exposure, the air temperature and the air humidity in the apparatus must be monitored. The light damage is assessed before and after each exposure by determining a) the wet strength and wet expansion and, if desired, b) the average degree of polymerization or damage factors.

Light sensitive coatings Used in the manufacture of print screens according to the photochemical method. The typical coatings are based on → Chrome gelatine and polyvinyl acetate. → Light hardening of photosensitive coatings.

Light sensitivity → Photochemical reactions.

Light sources → Standard illuminants.

Light table A glass plate which is illuminated from underneath and used for checking the opacity and register of diapositives. → Screen making.

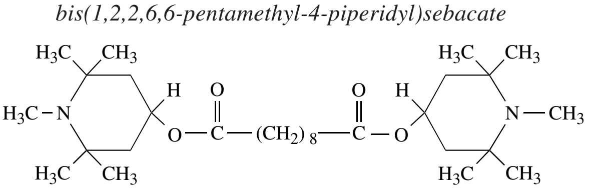
Light tenderer → Vat-dyes and fibre damage.

Light transmission measuring instrument Instrument for determining the degree of openness of printing screens. This facilitates precise photometric recording of the open printing areas and shows it directly on a digital display as a percentage of the total surface area. The value obtained, together with the mesh size and theoretical ink volume, gives the quantity of printing paste required per pattern and colour. Procedure: the negative film of each pattern or each printing ink paste is entered and the percentage printing area can be read off the display within a few seconds.

Light wavelengths Changes in the energy state of electrons within an atomic shell from a higher to a lower state are shown by the emission of energy in the form of an electromagnetic wave. Light is identified as a certain range of wavelengths of which the range of visible light waves represents only a part. Visible light contains wavelengths that give rise to reactions within the eye, i.e. trigger the process of seeing. Beyond this so-called visible spectrum, which is necessarily restricted by the sensitivity of the eye (→ Eye sensitivity to hue, chroma and brightness), are wavelengths of higher and lower energy that are of importance to the textile industry.

Optics is the science of light. It deals with phenomena perceived by a sense organ, the eye. The structure of its different branches developed through history has come about as follows:

Opinion about the nature of light has changed several times over the centuries. Newton had developed a particle theory by 1672. According to this, a light source sends out small particles which move in straight lines at enormous speed until they enter the eye where they trigger the sense stimulus either directly or after reflection from other objects. Using this theory, Newton was in a position to explain reflection and refraction of light. The phenomena of refraction and interfer-



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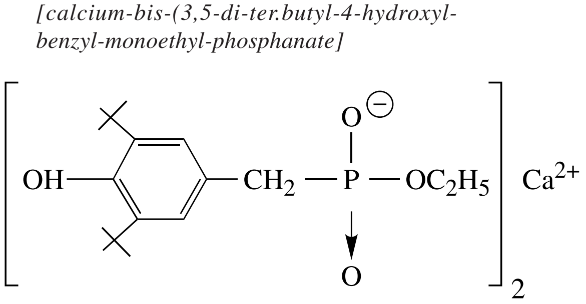

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Light tenderer → Vat-dyes and fibre damage.

Light transmission measuring instrument Instrument for determining the degree of openness of printing screens. This facilitates precise photometric recording of the open printing areas and shows it directly on a digital display as a percentage of the total surface area. The value obtained, together with the mesh size and theoretical ink volume, gives the quantity of printing paste required per pattern and colour. Procedure: the negative film of each pattern or each printing ink paste is entered and the percentage printing area can be read off the display within a few seconds.

Light wavelengths Changes in the energy state of electrons within an atomic shell from a higher to a lower state are shown by the emission of energy in the form of an electromagnetic wave. Light is identified as a certain range of wavelengths of which the range of visible light waves represents only a part. Visible light contains wavelengths that give rise to reactions within the eye, i.e. trigger the process of seeing. Beyond this so-called visible spectrum, which is necessarily restricted by the sensitivity of the eye (→ Eye sensitivity to hue, chroma and brightness), are wavelengths of higher and lower energy that are of importance to the textile industry.

Optics is the science of light. It deals with phenomena perceived by a sense organ, the eye. The structure of its different branches developed through history has come about as follows:

Opinion about the nature of light has changed several times over the centuries. Newton had developed a particle theory by 1672. According to this, a light source sends out small particles which move in straight lines at enormous speed until they enter the eye where they trigger the sense stimulus either directly or after reflection from other objects. Using this theory, Newton was in a position to explain reflection and refraction of light. The phenomena of refraction and interference of light could initially only be explained by the wave theory of light developed by Huygens (1678) which was later substantiated by the work of Young (1802). If at first the opinion was that these waves were elastic longitudinal waves in a universe filled with “ether”, then the conclusion drawn after the discovery of polarisation of light by Malus (1808) and Fresnel (1815) was that light was a transverse wave. The nature of light waves as electromagnetic transverse waves was finally recognised by Maxwell in 1865. The Maxwell equations have as their solution electromagnetic waves which spread out in a vacuum at the speed of light. As it was possible to derive all the laws of optics from the basic equations of electrodynamics, optics became a branch of electrodynamics.

Classification of visible light within the total spectrum of electromagnetic waves: the visible spectrum lies within the range of wavelengths $\lambda = 380–780$ nm. The wavelength is related to the frequency f and speed of light c via the equation $c = \lambda \cdot f$. With the speed of light in a vacuum at $c_0 = 299\,792.458$ km/s, the frequencies of visible light range from $f = 3.84 \cdot 10^{14}$ to $7.89 \cdot 10^{14}$ Hz. Accordingly, the human eye is sensitive to a frequency of one octave.

The wave theory of light had been established by the end of the nineteenth century but at the turn of the twentieth century, experiments were known that could not be interpreted by wave theory. Difficulties always arise when light interacts with materials, for example, in the case of absorption and emission of light. One way out was discovered by Einstein (1905) with the introduction of his quantum theory of light. According to this, light consists of individual light quanta which exchange energy with material in self-contained packets, i.e. in discrete quantities. Depending on the experiment, therefore, light was interpreted either in terms of streams of particles or as an electromagnetic wave. This twin function in the description was termed wave-particle dualism. A theoretical description which united both aspects was not available until the arrival of quantum optics or quantum electrodynamics.

Geometrical optics was based on the premise that, in a homogeneous medium, light rays radiate in straight lines. The term “rays” originated from particle theory, where the path of a particle was describes as a straight ray. Even in wave theory, the light ray has a meaningful place: it corresponds to the normal on the wavefront. In the case of point-shaped light source with concentric spherical-shaped wavefronts, the rays emitted by the light source are perpendicular to wavefronts. The sum of all rays which are restricted by the aperture is termed a ray beam or ray bundle. If the rays are emitted from a point source, or intersect at a point, the bundle is homocentric. In the case of plane waves, such as those transmitted by lasers or are found at large distances from the light source, the rays are parallel. Light rays which intersect have no effect on each other. Each ray continues to behave as if no others were present (source: Hering, Martin and Strohrer).

Lightweight coating Lightweight coating can be achieved using a blade in the run-in zone of a stenter. Coatings are usually very thin and are often applied as several coats (Fig.).

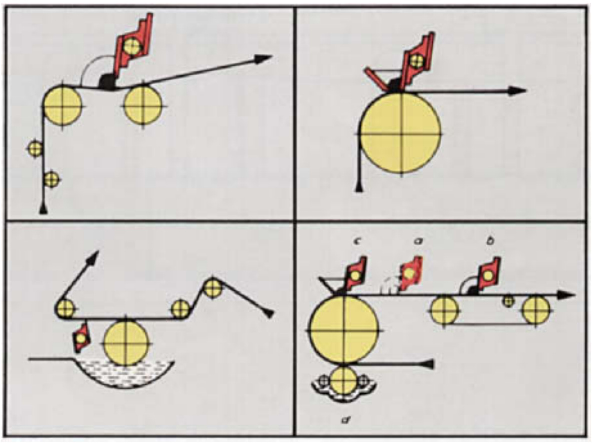
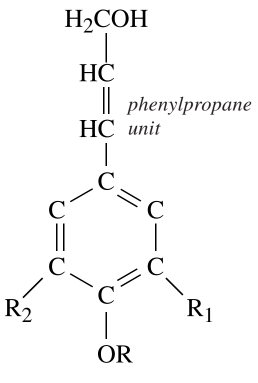


Fig.: Lightweight coating upstream of stenter frame (according to Brückner): from aqueous solution or from dissolvent (in microporous coating).

Lignin Found in the “woody” parts of → Cellulose that occur with the progressive maturing of a plant and as the cellulose cells thicken. A component, for example, of sulphite cellulose waste liquor. The name lignin was first coined by F. Schultz to describe that part of wood which dissolves when oxidized with potassium chlorate $KClO_3$ and nitric acid HNO_3 and then treated with dilute ammonia. It was later further defined by P. Klason to the calculated difference between wood and cellulose plus hemicelluloses. In general, lignin is defined as those polymeric, amorphous, encrusted substances in wood made up of methoxyl containing phenylpropane units which are not hydrolysed by acids. In terms of quantity, lignin is the most important component after cellulose of the woody cells of any plants. In herbaceous plants, there is less lignin and the content fluctuates greatly; grass contains 15–20% depending on the age, coniferous woods contain 26–30% and deciduous woods contain approx. 20–22% lignin. In wood it is associated with cellulose in the intercellular regions where it is found as a secondary substance in the interfibril capillary areas of the cellulose fibres forming the cellulose wall. This process of lignification produces a composite material, somewhat resembling steel-reinforced concrete, which is composed of lignin, which provides high compressive strength, and cellulose which provides high tensile strength. Within this close association with cellulose, a significant part or all of the lignin is bound to other polysaccharides but not to the cellulose. Characteristically, the lignin is unevenly distributed within the cell structure of the wood. Between the cell walls, i.e, the area of the middle lamella, the lignin content is high. The primary cell wall is also lignified while the secondary cell wall, especially in the case of deciduous trees, contains much less lignin. In general, the concentration of lignin in the fibre is at a maximum on the outside and decreases towards the lumen in the centre.

Various different types of vegetable matter also containing lignin are found in raw wool. Australian scoured wool is recognisable by the snail clovers (Lat. genus Medicago) which it typically contains. These may contain up to 30% lignin. The diameter lies between 3 and 8 mm depending on the species and their weight varies from 14 to 15 mg. The seed husk is covered with protective hairs which tangle with the coat of the animal. A second group is composed of the sandbur (lat. genus Cenchrus). Although they appear only occasionally, they are very difficult to remove from the wool due to their sharp thorns. They are 7–11 mm long and weigh 17 mg. The burweed (Xanthium spinosum) has a thick woody kernel. Because of their compact structure, they often fall out when the bales are opened. Straw and leaf remnants weigh less. However, they can impair the appearance of the fabric considerably. Due to their elastic properties, they move out of the way of all machinery. Some of the barley grasses (Hordeum leoprinum) also get into the raw material.

I. Monomers: there is always a degree of uncertainty when analysing the chemical structure of lignin. However, it has been shown that lignin has aromatic character and is a derivative of phenylpropane. The central unit of the molecule is a benzene ring carrying methoxyl and hydroxyl groups as active groups and a propane chain.



As well as the methoxyl group, each benzene nucleus has one aromatic oxygen to which can be assigned either a free or an alkoxylated phenolic hydroxyl group. The hydroxyl groups may appear on the benzene nucleus (phenol-) and on the propane chain. The phenylpropanes contain one or two methoxyl groups, depending on the type of wood. Only an extremely small number of free carboxyl groups occur in lignin. Carboxyl groups appear more frequently in the form of esters, particularly in the lignins of deciduous woods, bamboos and grasses. In coniferous woods, coniferols are found almost alone, whereas deciduous woods contain the sinapyl alcohols as well. The lower plants contain mixtures of both types or precursors. A third type appears in the case of grasses, cumaryl alcohol, which is formed together with the other two. Grasses are probably able to convert one form of the monomer into another.

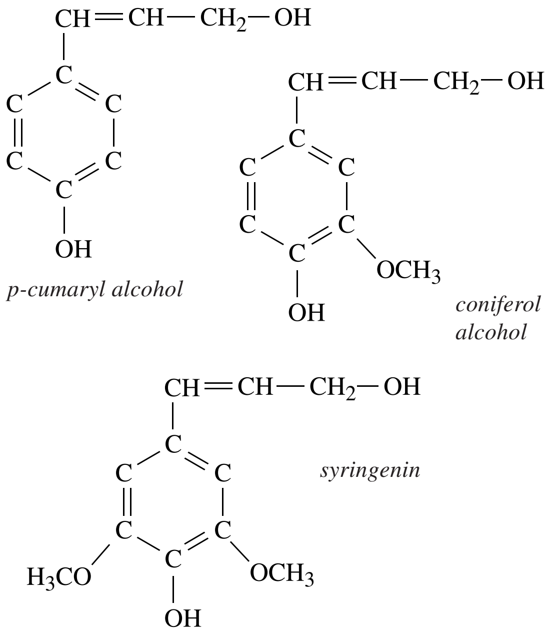


Fig. 1: Various monomers of lignin.

Indeed, different lignin monomers have been found in the same plant cell (Fig. 1). The elementary composition of milled wood lignin, a pale cream powder, corresponds to the coniferol minus 2 H; as well as this, each phenylpropane unit contains approximately 0.4 mol bound H_2O. As lignin consists completely or almost completely of phenylpropane units, the composition is frequently expressed in C_9 units. Spruce lignin, for example, corresponds to the empirical formula $C_9H_7O_2 \cdot H_2O_{0.4} \cdot OCH_{3\,0.94}$. As an auxiliary agent for analysis, the methoxyl content produces different values for the different types of lignin: deciduous lignins contain 20–22%, coniferous lignins contain 14–16% and the lignins of the grasses, among other monocotyledonous plants, also contain approx. 14–16% or less in terms of methoxyl groups. Lignins vary so much that the question arises as to how far this concept can be extended. A general boundary is provided by the fact that lignin is defined as an aromatic substance different from carbohydrates; lignins strengthen the polysaccharides in plants and convert the cell tissue into wood. However, this is not sufficient as a definition of lignin. In some areas, it is conceivable for these tasks to be fulfilled by silicic acid, tannic acids and other phenols and their polymerisation products. Indeed, they may even support lignin in this role in many trees.

II. Macromolecule: Based on the investigation into the structure of lignin, Freundenberg was able to define the structure of coniferous lignin more correctly and comprehensively than ever before. He was able to achieve this by examining the structural unit of a model lignin and carrying out biochemical experiments on lignin synthesis by dehydrogenation polymerisation of the p-cinnamyl alcohols. The structural units of the lignin are linked together via C–C or C–O bonds.

The C–C bonds are formed

- between two nuclei,
- between two side chains,
- between a nucleus and side chains.

Bonds such as these contain lignin at 25–35%, and are not broken during the delignification process. Approximately 65–75% of acrylopropane units are linked to neighbouring units via ether linkages. These break during delignification to varying degrees. The lignin model appears to be very complicated, as the starting radical has different mesomeric possibilities. This gives the molecule a variable and irregular structure which cannot be described by a general formula but only by a general structural principle. The molecular weight of lignins are found on average to be 10 000.

III. Biosynthesis: The process of lignification is irreversible; once the lignin has been produced by the living plasma and incorporated in the cell membrane, it is never metabolised by the plant again. The cell dies and with that, the lignin takes over the function of providing the plant with mechanical strength and protecting it from swelling. At room temperature, lignin is similar to a brittle thermoplastic and on heating, it becomes soft and malleable. Lignin sulphonates, as produced during the pulping of wood, have colloidal properties and are used as dispersants (Fig. 2).

IV. Chemical properties: Lignin is closely associated with the polysaccharides in the cell wall via various different linkages. For this reason, the time taken for and degree of completion of delignification is also significantly influenced by the chemical structure of the individual layers in the cell wall. Finally, a combination of chemical and morphological working methods is necessary for its elucidation. In the case of the chemical properties, it is necessary to include the history of the lignin while looking at it from the different points of view. Lignin can be established qualitatively using phloroglucine and hydrochloric acid, the so-called Wiesner reaction. This colorimetric reaction is attributed to the coniferal group. A dye is produced which has the structure presented in Fig. 3.

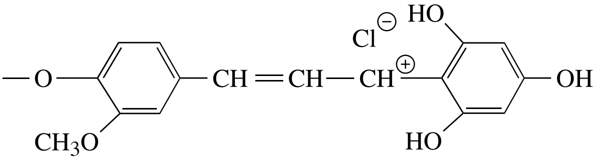


Fig. 3: Lignin pigment produced by phloroglucin-hydrochloric.

Liloc-Overflow HT piece-dye machine with goods conveyed through the liquor without jets. Jagri introduced the first type of overflow soft-dyeing machine from Japan in West Germany in 1971 under the name “Liloc”. With the Liloc- Overflow, the machine is divided into a reaction zone and liquor-exchange zone for the first time (Figs. 1 and 2). In this type of machine i.e, with a system in which the liquor was not moved much faster than the goods in the enclosed liquor-exchange zone, there was so little mechanical manipula-

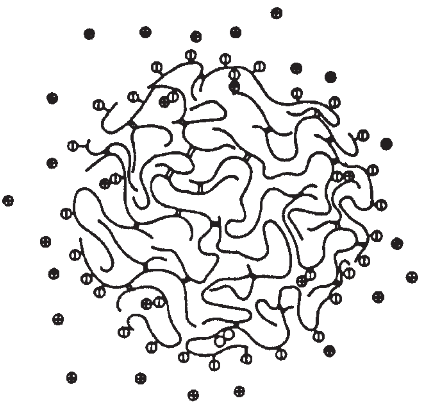


Fig. 2: Model of lignin sulphonate microgel dissolved in water and surrounded by oppositely charged positive ions.

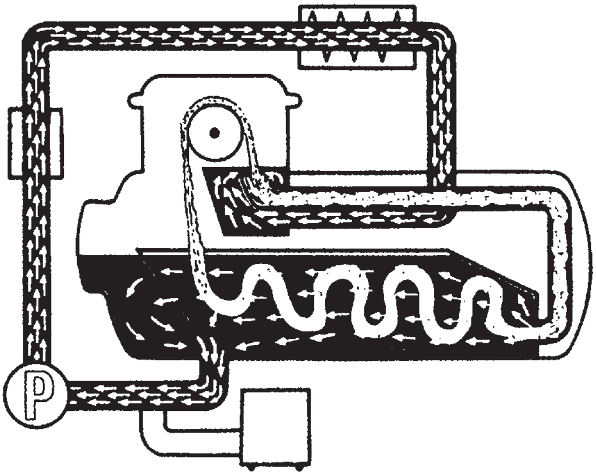


Fig. 1: Diagram of Liloc-Overflow process (Jagri).

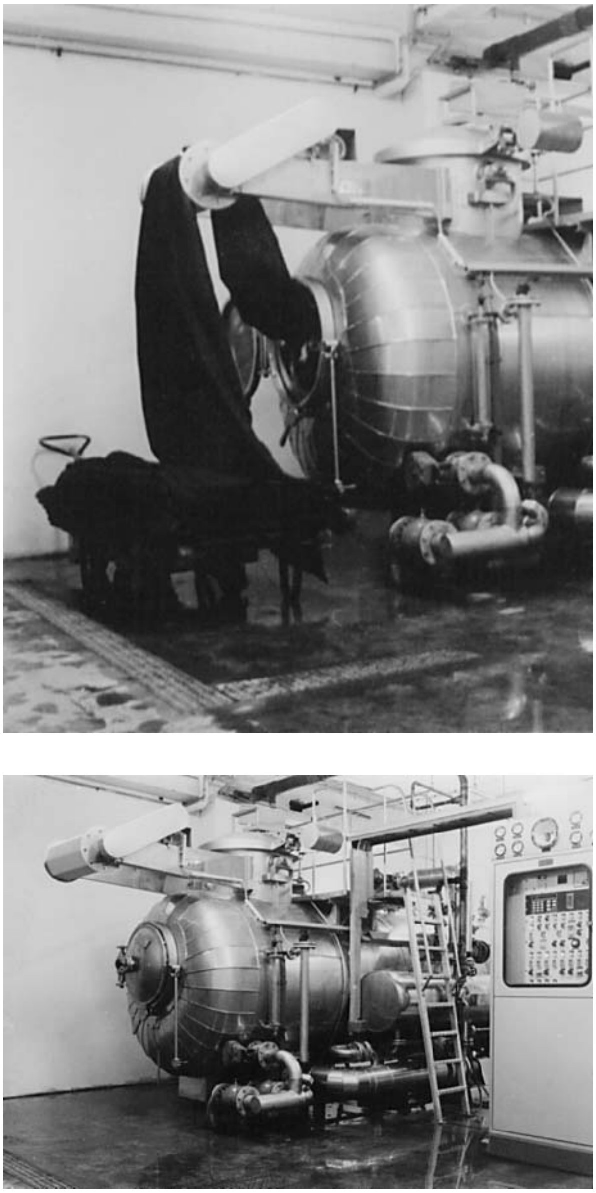


Fig. 2: Liloc-Overflow dyeing machine by Jagri.

tion of the goods that dye penetration into smooth worsted cloth was sufficient without having to sew it into tubes. For the Liloc-Overflow dome, which the winch operated in the air space above the liquor, was typical. The simple jet machines achieve the free movement of the conveyor winch by increasing the size of the vessel or by positioning the dye vessel at an angle. Former manuf.: Jagri.

Limbacher Artikel (simplex knit), suede-type finished knitted fabric made from cotton, used for gloves in particular. Strong alkali treatment is used to achieve a more compact structure.

Lime → Calcium carbonate.

Lime-baryta process Water softening process used where there is a high level of sulphate hardness and high permanent hardness. Degree of softening up to approx. 1–2°d.

Lime boil → Kier boiling.

Lime hardness → Water-hardness salts.

Lime soaking Initial treatment of hides or pelts before → Tanning, during which the scarfskin and adipose tissue are split from the corium before it is further processed.

Lime soap Lime soap is produced by the displacement principle converting soluble Na stearate soap into insoluble Ca stearate soap (lime soap) according to the following equation:

$$2\,C_{17}H_{35}COONa + Ca(OH)_2 \rightarrow \\ (C_{17}H_{35}COO)_2Ca + 2\,NaOH$$

109.3 g sodium stearate soap is converted into lime soap by 10 g CaO which corresponds to 1 m^3 water at 1°d. In Tab. 1 are shown the amounts of worthless lime soap precipitated by 1 m^3 water at 1–25°d.

degree of hardness °d	g of soap destroyed by 1 m³ of water	
	textile laundry soap cakes 60% fatty acid = approx. 56% pure soap	highly concentrated needle soap 82% fatty acid = approx. 88.5% pure soap
1	168,2	123,5
2	336,4	247,0
4	672,8	494,0
6	1009,2	741,0
8	1345,6	988,0
10	1682,0	1235,0
12	2018,4	1482,0
14	2354,8	1729,0
16	2691,2	1976,0
18	3027,6	2223,0
20	3364,0	2470,0
22	3700,4	2717,0
25	4205,0	3087,5

Tab. 1: Relationship between laundry soap precipitation and degree of hardness of water.

Tab. 2 shows the soap losses (sodium stearate textile hard soap in flakes, 60% fatty acid = approx. 65% pure soap) resulting from the different water hardnesses for a consumption of 5 g/l of the soap in question.

degree of hardness °d	residual soap of 5 g/l		% soap loss due to laundry soap
	g	%	
0	5,00	100	0,0
1	4,83	96,6	3,4
5	4,16	83,2	16,8
10	3,32	66,4	33,6
15	2,48	49,6	50,4
20	1,64	32,8	67,2
25	0,80	16,0	84,0
29	0,12	2,4	97,6

Tab. 2: Soap losses relative to degree of hardness of water.

Lime soap dispersant The name given to this group of substances is derived from the predominance of carbonate hardness (lime hardness). Unlike deactivating additives, lime soap dispersants prevent precipitation forming colloidal dispersions so that no precipitation of lime soaps or other similar substances can take place. The dispersant should be added before or with the soap because lime soap which has already been formed cannot in most cases be removed (Tab.). These dispersants also have wetting, washing and protective colloid properties.

Laundry soap dispersing capacity of surfactants	
Surfactant	Additive required as a % of soap
Fatty acid polyglycol ether	3
Alkyl phenol polyglycol ether	5
Sorbite-monolauryl polyglycol ether	7
Oleyl methyl tauride	7
Fatty acid amide condensate	22
Lauryl sulphate	35
Alkyl benzene sulphonate	45
Dioctyl sulphosuccinate	45
Castor oil sulphonate	50
Di-isopropyl naphthalene sulphonate	70
Quaternary ammonium salt	70
Secondary alkyl sulphate	70
Sodium laurate	70

Tab.: Laundry soap dispersing capacity of surfactants.

Lime soap stains In most cases, these are white deposits that can impair the colour of dyed textiles. The appearance varies, for example, appearing on both sides or as crusty whitish matting effect. Removal: fatty-alcohol sulphate solution (warm) then formic or citric acid 1 : 8–10 (warm).

Lime-soda water softening process This process is used for water with a high carbonate and non-carbonate hardness. Calcium carbonate (lime) and sodium carbonate (soda) are used concurrently, achieving water hardness of 1–2°d. The precipitation time can be reduced by preheating.

Lime water → Calcium oxide.

Lime water softening process Oldest method used for precipitating out hardness salts with calcium hydroxide; also used for de-acidifying water (stoichiometric amounts). Softening is possible up to around 2–4°d depending on the non-carbonate hardness. Not very suitable for water with a high chloride content as this increases the solubility of calcium carbonate.

Lime wool → Skin wool, (slipe wool) obtained by de-hairing, i.e. by separating the wool from the skin by hydrolysis using calcium carbonate, sodium sulphide. Results in wool which is generally damaged.

Limit concentration The concentration of a substance in solution at which a proof reaction can still be found. The limit concentration is stated in g/ml dilution; → Detection limit.

Limit controller A limit controller is a controller which prevents a set limit concentration of a specific variable being exceeded.

Limit strength → Tensile strength.

Limp handle value → Kawabata system.

Linear density of fibres and yarns The linear density of fibres, yarns etc. is a measure of the density of textile materials. Under the standardised system of units of measurement (→: Tex-system; SI units) the mass per unit length (Tex) is the only measure now permitted to express density. The length per unit mass which was formerly the standard (Nm = metric count) is still used in many areas, although the term is no longer permitted. Neither are any English or French designations and information in denier (den.) allowed. The Tex system has been internationally standardised and introduced in most countries (see Tab.). This system expresses: fibres in decitex (dtex), cable, tapes and roving yarn in kilotex (ktex), and yarns in tex.

$$1\ \text{tex} = \frac{1\ \text{g}}{1\,000\ \text{m}}$$

$$1\ \text{dtex} = \frac{0{,}1\ \text{g}}{1\,000\ \text{m}} = 10^{-1}\ \text{tex}$$

$$1\ \text{ktex} = \frac{1\ \text{kg}}{1\,000\ \text{m}} = 10^{3}\ \text{tex}$$

	dtex	den	Nm	Ne_B	Ne_L	Ne_K	Ne_W	Nf
dtex	x 1,0	x 0,9	$\frac{10000}{dtex}$	$\frac{5900}{dtex}$	$\frac{16500}{dtex}$	$\frac{8860}{dtex}$	$\frac{19400}{dtex}$	$\frac{5000}{dtex}$
den	x 1,1	x 1,0	$\frac{9000}{den}$	$\frac{5320}{den}$	$\frac{14880}{den}$	$\frac{7970}{den}$	$\frac{17440}{den}$	$\frac{4500}{den}$
Nm	$\frac{10000}{Nm}$	$\frac{9000}{Nm}$	x 1,0	x 0,59	x 1,65	x 0,89	x 1,94	x 0,50
Ne_B	$\frac{5900}{Ne_B}$	$\frac{5320}{Ne_B}$	x 1,69	x 1,0	x 2,80	x 1,50	x 3,28	x 0,85
Ne_L	$\frac{16500}{Ne_L}$	$\frac{14880}{Ne_L}$	x 0,60	x 0,36	x 1,0	x 0,54	x 1,17	x 0,30
Ne_K	$\frac{8860}{Ne_K}$	$\frac{7970}{Ne_K}$	x 1,13	x 0,67	x 1,87	x 1,0	x 2,19	x 0,56
Ne_W	$\frac{19400}{Ne_W}$	$\frac{17440}{Ne_W}$	x 0,52	x 0,30	x 0,85	x 0,46	x 1,0	x 0,26
Nf	$\frac{5000}{Nf}$	$\frac{4500}{Nf}$	x 2	x 1,18	x 3,30	x 1,78	x 3,88	x 1,0

Tab.: Count conversion table.

Linear pressure This refers to the pressure per cm of roller length in the nip of two press-rollers.

Line deposit (finishing),

I. Insoluble lime and magnesium soaps precipitated on textiles.

II. Term used for → Sodium hydroxide for soap boiling.

Linen This is a generic term for laundry, clothing, furnishing fabrics etc. made from → Flax. Various commercial terms based on a) the composition (pure linen, union linen); b) the origin (e.g. Bielefeld linen); c) the appearance (unbleached or bleached linen, blue linen); d) the weave (smooth fabrics in plain weave, drill linen in twill weave, linen damask with figuring); e) the quality (coarse linen, fine linen, linen batiste) and f) the use (e.g. linen sheeting, tailor's linen, linen interlining). Linen and linen union fabrics are important because of the sustainable raw material. About half of the content of linen union fabrics comes from linen. A min. linen content of 38% is prescribed for this designation, and one thread system, i.e. the warp or the weft, must consist of linen. The overwhelming majority consist of a cotton warp and a linen weft (predominantly tow yarn). The best known exception are the so-called Gminder linen union fabrics, which have a fibre blend of cotton and (cottonised) flax in both the warp and the weft and have an appearance similar to linen (these materials are no longer classed as linen unions under current RAL regulations). In order to reduce the crease sensitivity (very low elongation), linen is occasionally mixed with wool for the ladies' outerwear sector (so-called woollen linen). Pure and union linen are used for underwear fabric, batiste, table damask, hand-towel damask, face cloths, huckaback hand-towels, terry materials, kitchen towels, mattress materials and (high-quality) outerwear. → Flax processing.

Whereas pure linen is generally resin finished to a particular finish, in the case of blends, the aim is to achieve the linen look with the surface typical for the flax fibre, although a light final handle is preferred. An easy-care finish with a soft, smooth handle is therefore used. During resin finishing with low formaldehyde content, wash-and-wear behaviour and wrinkle recovery are of prime concern for cotton blends. With viscose blends, the emphasis is on the necessary dimensional stability.

Linen bleaching process cycle This is a classic process cycle in the → Bleaching of linen. Consists of boiling with sodium carbonate, hypochlorite bleach and anti-chlor. This takes approx. 8 h. The process is repeated until the desired whiteness is achieved. Two stages are used to achieve full-white on linen union fabric: the linen yarn is bleached and then further bleached as fabric using the standard process for bleaching cellulose.

Linen fibre → Flax.

Linen interlining (Tailor's canvas). Stiffening and interlining. A type of fine → Buckram, but more elastic, with a less stiff finish. Natural coloured linen tow yarn or linen union.

Linen pretreatment This is a complex and cost-intensive procedure. After the flax has been processed (retting and mechanical processing) and following a gentle alkali extraction treatment, oxidative bleaching generally takes place in several stages. A combination of peroxide and chlorite bleach is generally used for this. A pure peroxide bleach under standard conditions for cotton does not provide the required results with linen. As linen still contains approx. 20% hemicellulose, which is partially soluble in alkali, there is a high weight loss of material when strong alkali peroxide bleach is used. To obtain the characteristic linen handle, it is not generally recommended that the substance used on the fibre is completely removed. The chlorite bleach serves to oxidise the dark coloured lignins. From an ecological point of view, however, chlorite bleach should be avoided.

Linen, resin finishing This must be carried out extremely carefully. Processes which affect the abrasion resistance as little as possible are preferred. Wet cross-linking with DMDHEU (dimethyloldihydroxyethyleneurea) (furnishing fabrics, tablecloths) are particularly suitable. In classic dry cross-linking processes, highly reactive resin finishing agents such as urea-formaldehyde compounds and DMEU (dimethylolethyleneurea) are used. The shock-cure process with shock catalysts is also gaining in importance. Wet cross-linking systems are little used. Additives to increase strength should also be applied regardless of which method is used.

Linen union Linen union is smooth or figured fabrics (tablewear) made from flax (tow) and cotton yarn, in either warp or weft.

Line recorder This is the generic term for recording devices which reproduce the time history of measured variables in the form of a continuous curve. In contrast to: point recorders.

Line(yarn) Fine linen made from dressed flax or long-fibre flax.

Lining fabrics Lining fabrics are used for the lining of outerwear. Depending on the intended use (ladies' or men's suits, trousers, pockets, sleeves, coats, etc.), they are made from viscose, acetate, synthetic fibres, and also of cotton or wool. The quality of the lining fabric plays a crucial factor in determining the serviceability of the finished garment.

1. Inside linings for men's and ladies' suits and coats: these are partly visible and therefore must display a certain elegance in addition to their actual intended purpose. They should have good abrasion resistance and fastness to perspiration and be smooth to achieve a high non-cling effect.
   a) Serge: smooth, coloured fabric in twill weave: trade name depending on the appearance or use, e.g. artificial silk serge, cotton serge, serge-rayé, serge façonné, clothing or lining serge.
   b) Taffeta: smooth, coloured fabric in taffeta weave made from viscose or acetate; stiffer than a); predominantly single-coloured or taffeta warp/weft colouring.

   c) Rhadamé: heavy viscose coat lining in twill weave.
   d) Atlas: heavy men's winter-coat lining in atlas weave.
   e) Duchesse: very lustrous, light viscose or acetate lining material in atlas weave (satin duchesse); used for ladies' outerwear.
   f) Moroccan: sandy handle, supple drape; crimped viscose fabric with normal yarns in the warp and crepe (2 Z, 2 S) yarns in the weft; used for ladies' outerwear.
2. Sleeve linings: Printed with small figured effects or woven in stripes, yarn dyed; viscose or acetate in taffeta or warp satin weave; the smoothness is particularly important.
3. Waistcoat linings are divided into:
   a) Back linings: generally cotton or viscose serge.
   b) Inside linings: generally consisting of cotton printed with small figured effects or single colour viscose material.
4. Pocket linings: Cotton fabrics are used predominantly here; some have a filled finish to reduce soiling and increase wear resistance. A distinction is made between:
   a) Lining for sports jackets and waistcoats: generally in twill, dark-based, twilled cotton fabric.
   b) Lining for trouser pockets: tend to be light in colour (beige, grey); generally only particularly firm cotton fabrics such as pocketing, moleskin, nankeen, unfinished twill, and pocket drill.
   c) Lining for coat pockets: generally twill; for heavy coats mainly pocket velvet or pocket flannel .
5. Other:
   a) Glacé thread lining: warp satin weave, dark sleeve lining, often used for uniform coats; warp consists of shiny, lustrous cotton yarns (glacé thread).
   b) Jaconnet: plain weave, fine, smoothly finished cotton lining; generally grey or black. Used as knee lining and to line leather goods (handbags).
6. Knitted lining fabric: single-face, generally circular knitted cotton knitwear which also has an additional lining thread. A distinction is made between conventional in-laid fabric and fleece with building thread, where the binding thread is hidden by a face thread. Finished goods have plain stitches on one face and may be raised on the reverse.

Linitest Washfastness tester which can also be used as a laboratory dyeing machine; can also be used for HT-dyeing. – Manuf.: Heraeus/Original Hanau.

Linizing Permanent finish to make cotton fabrics look like linen e.g. with strong caustic and cuprammonium solutions whereby the fabric surface is partially dissolved and subsequently coagulated.

Links-links fabric, purl fabric → Knitted fabrics which only have purl stitches visible on both fabric faces. The purl stitch courses conceal the adjacent plain stitches, as can be seen in the crosswise extension of the fabric.

Linoxyn → Linseed oil is (air) oxidised and polymerised to form a thin, transparent, skin, e.g. by the oxidation of (linseed-) oil size.

Linseed oil A typical drying oil obtained from linseed or flax seed. Hot pressing gives a dark, strong smelling oil, cold pressing gives a lighter, milder oil, and extraction produces a non-sticking oil. When fresh, linseed oil is a sticky gold-yellow/brown with a typical mild odour. Poss. contamination by cotton, soya, rapeseed, hemp, corn, mineral, resin oil or hardened train oil. Used as oil-based size.

Linseed oil size → Oil size.

Linsey-wolsey (Linsey-woolsey). Hard-wearing material (cotton, viscose filament yarn, spun viscose, linen, wool, mostly multi- fibres) in plain weave and other constructions (incl. imitation knits), single- or multi-coloured, striped, checked, etc.; for garment fabrics, dirndl fabrics and decorative materials.

Lint Small hairs, fibrils, thread waste (twisted) etc. projecting from the surface of threads, yarns, fabrics, knitwear. Generally caused by material used and method of processing (error phenomena). Examples: dead cotton (→ Motes), fluffy silk (→ Floss), residue of broken retracted capillary threads (lint portion drawn above location of break, undrawn below) can be removed from yarns and fabrics, e.g. by singeing.

Lint doctor In roller printing, the → Doctor blade removes excess print paste, the lint doctor is located on the opposite side of the printing roller, behind the printing surface formed by the roller and printing cylinder, to remove excess print paste left on the roller after printing. This prevents the print paste from contaminating the following fabric.

Lint filter for textile effluents A common form of lint filter is a sieving device with no moving parts which has a self-cleaning curved mesh bottom plate and does not clog due to the particular form of the sieve bars, is corrosion-proof and free from parts subject to wear. Suitable for removing fibres from all types of liquids, even in difficult circumstances, e.g. waste water containing oil, solids loading and aggressivity.

Linters Linters are short fibres which remain on the seed husks after ginning the cotton, also short-staple waste from cotton fibres. Unsuitable for spinning due to their short length. Used in the production of regenerated synthetic fibres (acetate, cupro, viscose).

Lipases → Enzymes of the principal hydrolase group which act on fats and oils by water displacement to form fatty acids and glycerine. More rapid splitting of fats with a low melting point (larger proportion of unsaturated acids). In comparison to esterases, lipases act on water insoluble emulsified fats, and are therefore used in enzyme mixes (pectinases, proteases or amylases) for the gentle removal of grease spots or fatty substances as so-called soaking materials for particularly soiled laundry; also used for starch desizing agents with optimal action at 35–40°C. By adding lipases, the detergency efficiency of prewashing agents which do not contain anionic surfactants is improved. The effect is dependent on temperature, lipase concentration and the intensity of the fat contamination. Under practical conditions, however, the improvements achieved with lipases were low and were exceeded by adding a nonionic surfactant. The stability of commonly used commercial lipases under washing conditions is sufficient, but not ideal. Under a test arrangement, the grease removal by detergents containing lipases at 20°C is almost exclusively due to the lipase effect, at 30°C this is due to the additive effect of lipases and surfactant, at 40°C due more to the surfactant effect. The lipase effect at 30°C increases as the concentration is increased but decreases as the grease soiling increases.

Lipoids Lipoids are similar to fats (neutral fats, wax, fatty alcohol, etc.).

Lipophile (Gk.: lipo(id) = fatty; phil = loving, friendly). Lipophilic substances are “associated with grease”, “fond of grease”, i.e. they are easily soluble in fats, oils, hydrocarbons and organic solvents. The lilophilic molecular portion (nonpolar residue) corresponds in textile auxiliary structure to the hydrophobic hydrocarbon residue. The same applies to synthetic fibres with corresponding molecular structure. Involves metal abrasion with fats or oils which have a longer reaction time, graphite etc. adheres particularly well within the fibre and is difficult to remove. Contrast: → Lipophobe.

Lipophilic groups Lipophilic groups are molecular groups which have an → Endophilic reaction in an organic, non gaseous phase.

Lipophobe Exophile properties for an organic, non-gaseous phase, → Exophilic. Contrast: → Lipophile.

Lipophobic groups Lipophobic groups are molecular groups which have an → Exophilic reaction in an organic, non gaseous phase.

Lip seals These are heated slits at the fabric entry and exit zones (e.g. on a Krostewitz steamer) which are used for sealing during the passage of the cloth.

Liquefied gas Gas that is a liquid under pressure and reverts back to its gaseous phase when the pressure is released, e.g. the hydrocarbons propane, butane and (for petrochemistry) the associated gasolefines propene, butene and compounds. Propane is most commonly found as a bottled gas for domestic use, commercial purposes, welding non-ferrous metals and plastics. Butane is mainly found in commercial and industrial sectors; generally after premixing with air. Small quantities of liquefied gas are transported in compressed air cylinders (steel cylinders), and larger quantities in compressed air tankers (in the liquid phase). Storage of liquid gas: small quantities are stored in pressure flasks, medium-sized quantities in pressure cylinders and large quantities are stored in fixed pressure vessels. These type of storage facilities are subject to relevant safety regulations (pressurised gas regulations) and official monitoring (TÜV).

Liquid ammonia process Treatment of cotton textiles in a specially developed piece of equipment with liquid ammonia (–33°C). Finishing effects on textiles finished using liquid ammonia: good shrinkage stability, high smoothing capacity, good crease recovery, almost comparable mercerizing effects to those achieved with caustic soda mercerisation. Lustre is a secondary consideration. This finishing process dates back to the developmental work of the “Norwegian Textile Institute”, the Norwegian consortium, “TEDECO” and the “Sanforized Company” in the 1960s. The process was then introduced in the 1970s, originally in the USA, as a finishing treatment for denim fabric and other heavy cotton fabrics, as the treatment causes interesting effects on these articles, in particular an excellent dimensional stability to washing and tumble-drying, a pleasant soft handle and improved smooth-drying properties. The liquid ammonia process is increasingly being used as a pre-treatment for shirt, blouse and dress materials made from 100% cotton which are subsequently given an easy-care finish. It is also possible to use this process for fabrics made from other cellulose fibres, e.g. linen and regenerated fibres. The treatment takes place in such a way that the fabric is impregnated with liquid ammonia at its boiling temperature (–33°C), thus causing the cellulose fibres to swell rapidly. The ammonia is then volatilised by guiding the fabric over a heated drying cylinder and any residual traces are removed from the material in a subsequent steaming zone. The expelled ammonia is liquefied once again and reused. The fabric is treated in various finishing stages, e.g. boiling off (bleaching is carried out after the ammonia treatment), mercerising, solid-shade dyeing, or colour-woven.

The cellulose polymer chains can be regarded as stretched semi-rigid chains, whose conformation is stabilised by intramolecular hydrogen bridges. By forming intermolecular interactions (Van der Waals forces, hydrogen bridges), the chains arrange themselves into supramolecular ordered sectors, whereby the crystalline areas alternate with somewhat less distinct ordered areas in the fibre axis. The ordered states are arranged in fibrils which are separated from one another by long-chain interference zones (microvoids) along the fibre axis. When water is used on cellulose fibres, the water molecules are only able to split the hydrogen bridges in areas where the hydrogen bridges have a low density between the fibrils (interfibrillar swelling), whereas swelling in liquid ammonia also affects the ordered states in the fibrils themselves, including the crystal-

Liquid ammonia process

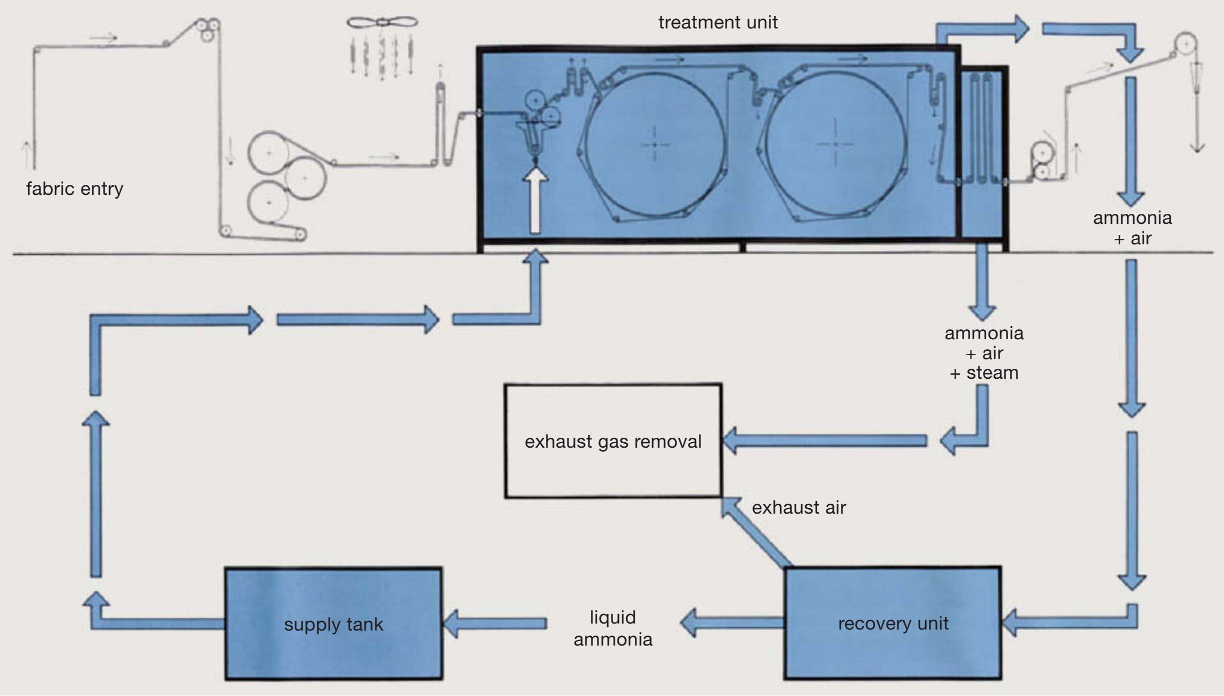


Fig. 1: Treatment of cotton piecegoods with liquid ammonia in accordance with the "duralized" process (Monforts).

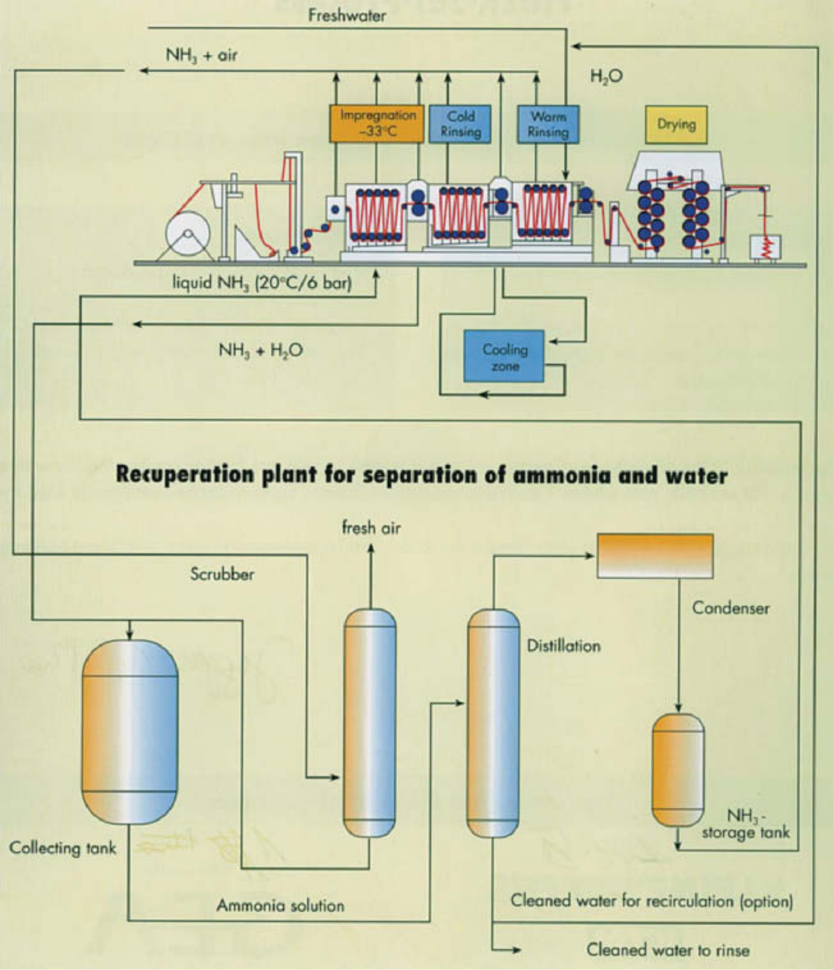


Fig. 2: HPA-system for finishing with liquid ammonia (Kleinewefers KTM).

lites (intrafibrillar and intracrystalline swelling). This is principally due to the higher basicity of the ammonia molecules in comparison to water, which makes it possible to split the dense hydrogen bridge network into crystalline zones. If inter- and intramolecular interactions are split in oriented cellulose fibres due to the effect of a swelling agent, the fibre can be shrunk to a greater or lesser degree. The main cause of this is the disorientation of fibrils and molecular chains during the swelling process. If the fibre is kept at a constant length during this process, a shrinking force develops. The extent of shrinkage and the shrinking force is dependent on both the orientation of the fibre structure and the fibrillar and crystal structure, as well as on the swelling conditions (swelling agent, temperature, tension). (Source: Bredereck).

It should be noted that it is just as expensive to purchase the treatment section as the recovery plant for liquid ammonia. Monforts produces a suitable plant (see Fig. 1) as well as Kleinewefers KTM (Fig. 2).

Liquid crystal display (LCD). This is a digital display which uses the optical behaviour of specific crystals in the electric field, rather than glow wires for the display (→ Liquid crystals).

Liquid crystals These are organic substances which are between plastic and liquid, possess indistinct boundary forms through to drop shapes and display double refraction or optical rotation.

If a molecule, such as a polymer chain, is sufficiently firm, the phenomenon of liquid crystallinity can arise beyond a specific concentration. This phenomenon is also referred to as mesomorphous or liquid anisotropy. This was predicted by Flory in as early as 1956 for polymers, and was confirmed experimentally by Herman in 1962. By increasing the concentration of rigid and semi-rigid macromolecules, a saturated solution with undissolved polymers can be formed, or alternatively, by placing more dissolved polymers in a specific area, the system is forced to form groupings with parallel polymer chains. By adding further polymers, the area of the ordered state is increased still further (Fig. 1).

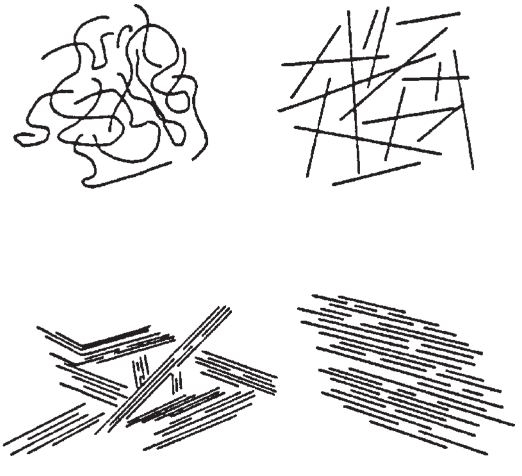


Fig. 1: Schematic diagram of polymer conditions in solutions.

The formation of a liquid crystal phase is accompanied by several specific phenomena, e.g. an opalescence when stirring and erratic changes to the viscosity of the solution. When the polymer concentration is increased in the isotropic area, the viscosity initially displays a normal increase up until a critical point at which the anisotropic liquid crystalline phase forms (Fig. 2); next the viscosity of the solution decreases as the polymer concentration increases. Above a specific concentration the viscosity then continues to rise. This behaviour is described for poly-γ-benzyl-L-glutamate in m-cresol and for an aromatic copolyamide in a mix of hexamethyl phosphorous triamide and N-methylpyrrolidone. The general progression of the viscosity curve is described in Fig. 2. This rheological behaviour is significant for practical application as it enables highly concentrated solutions to be spun.

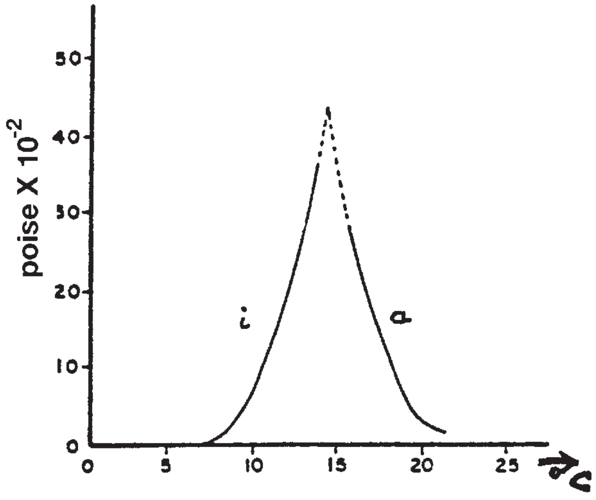


Fig. 2: Example of the development of the viscosity of a polymer solution with anisotropic (a) phase relative to concentration. i = isotrope phase.

Liquid dyes Liquid paste. Easy to handle, simple to measure, therefore well-suited for automated yarn dyeing and continuous plant. Formulation of → Dyestuff.

Liquid fast colour bases Fast colour bases for naphthols in liquid form. Advantages: Easily diazotisable with no residues, with virtually no pollution caused by nitrous fumes. Partly true solutions, partly dispersions.

Liquid fats These contain mainly → Oleic acids: e.g. olive oil, sesame oil, soya bean oil. Use: As a base for soaps with solutions of particularly low viscosity, for washing, soaping, degumming etc.

Liquid heating medium Polyglycol ether compound → Heat transfer medium. Density 1.12; Boiling range 260–310°C. M.p. 160°C. Waterwhite, odourless, not easily volatilized, non-corrosive, hygroscopic.

Liquid photometry by means of fibre optics The dyer requires the current visual depth of shade of the textile during the exhaustion stage of dyeing in order to project the final appearance of the shade (Fig. 1) or if the batch displays unlevelness. No suitable sensor is currently known for such measurements. It is conceivable that glass fibre sensors could be inserted into the dyeing packages and could then be used to track the spectral reflection and consequently the build up of colour on the fabric. In dyeing machines with fabric circulation, it would also be conceivable to convey the fabric past a window where a reflectance measurement could be taken. Next, the problem of evaluating reflectance measurements on wet goods in a liquor which partially absorbs the light, as opposed to clear water, would need to be solved. A further difficulty is that the reflectance measurement records the surface dyestuff addition to a much greater extent than the dyestuff portion in the fibres.

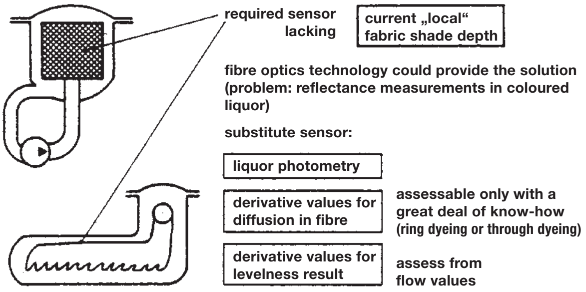


Fig. 1: Sensor for determining current fabric shade depth in the dyeing machine.

Liquid photometry is a possible solution to the problem of monitoring shade. In many cases, it should be possible to give information on the concentration of the individual non-exhausted dye residues, on whether the correct depth of shade can be expected, and if one dyestuff has been selectively blocked. The visual impression of a dye is determined by the dye penetration as well as the quantity of dyestuff absorbed. This correction would then have to be projected using experimental values and liquid photometry should be superimposed. The partial aspect of depth of colour and shade is insufficient however. The levelness of the batch must also be guaranteed. The measurement of the dyestuff concentration in the liquor does not give any direct useful information for this. Due to the natural connections between the absorption rate (significant rate of dyeing) and the risk of unlevel dyeings, it is possible to form an exhaust curve using liquid photometry. This can be used to calculate the significant rate of dyeing and introduce measures to prevent unlevel dyeing in good time. An essential prerequisite for this is that the “operating system” (i.e. the dyeing machine with its liquor circulation controller and the textile fabric in its standard form) remain constant. Whereas the liquor circulation can still be relatively well recorded using flow metering or alternatively using the pump speed, differential pressure, bypass and ring adjustment, there is still no real information concerning possible deformation of the fabric package during dyeing.

There are two basic methods of obtaining source data. Commercial systems such as “Colorex” (Barco) arrange the control equipment in the bypass. In the “Colorex” device, the elementary sensor is in the form of a movable cuvette. This enables adaptation to the Lambert-Beer’s law.

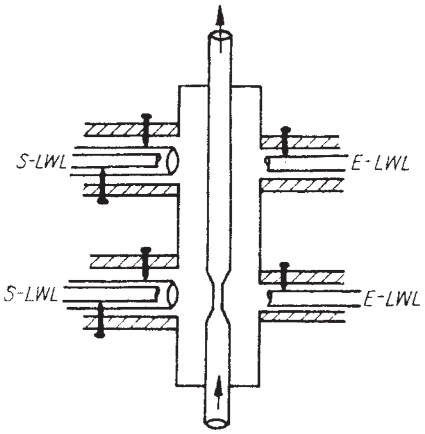


Fig. 2: Principle of a variable flow sensor for liquor photometry.
S-LWL = transmitter beam waveguide; E-LWL = receiver beam waveguide.

Glass tubes with irregular inner profile are adequate under simplified conditions (Fig. 2). When controlling waste water treatment plants, monitoring rinsing processes for dyes etc. it is not always possible to use a bypass. Spec. probes which are immersed into the medium are advantageous here (e.g. the dip sensor). A fibre optic receiver which is vertically displaceable enables variable gap widths to be adjusted. The reflex sensor also fulfils the same purpose (Fig. 3). In this case, a variable sensor length provides different intensities. The openings must be carefully sealed as the foreign ions that penetrate the optical fibre increase condensation, cause hydrolysis of the gas, and alter the colour and density of the optical resin used as an embedding medium, etc.

The obvious advantage provided by the possibilities of the fibre optic device is in the easy accessibility of

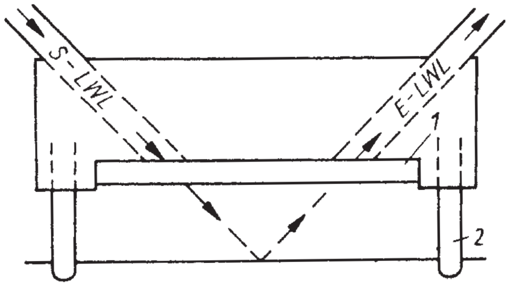


Fig. 3: Principle of a reflex sensor for liquor photometry.
1 = optical window; 2 = mirror.

the structural parts. The advantage of the continuous signal sequence (e.g. if the response time for photo-diodes is 10^{-7} s) can only be utilised if the information is adequately processed, however. It is not possible to manage the dyestuff and fibre characteristics which are required to control dyeing processes without the aid of a computer. Calculations relating to additions to the machines used to control the dyestuff extract are made using a computer from the very outset. The necessary software is not always generally accessible and system-compatible. However, there are also disadvantages: the cost of coupling and branching is increased; sources of error arise due to mechanical strain and curvatures occur when laying the fibre optic device. Lint and micro-bubbles cause the signal intensity to be altered. The material exchange is seen to lag behind in the gap when there is little liquor circulation. Soiling on the surface also results in further errors at the inlets and outlets in the medium.

Liquid ring vacuum pump A so-called displacement pump to transport extracted gases and vapours with the aid of a rotating liquid, the liquid ring. An eccentrically positioned impeller rotates within a cylindrical housing (see Fig.); a rotating fluid forms working areas with the impeller which vary periodically. Use: at large capacity ranges to evacuate equipment, pipes etc.; often as a water-ring vacuum pump (water is used as the operating liquid), e.g. when yarn steaming.

Liquor Liquid treatment medium (water, organic solvents) for textile finishing, laundry and dry-cleaning.

Liquor application This refers to the application of the treatment liquor on textile fabrics.

Liquor application systems A distinction is made between the following when applying dissolved products:

1. Low wet pick-up.
2. Standard wet pick-up.
3. High wet pick-up.

Low wet pick-up is suitable for
- spray application,
- foam application (Fig. 1),
- kiss roll padding.

Standard wet pick-up takes place in the padder (Fig. 2).

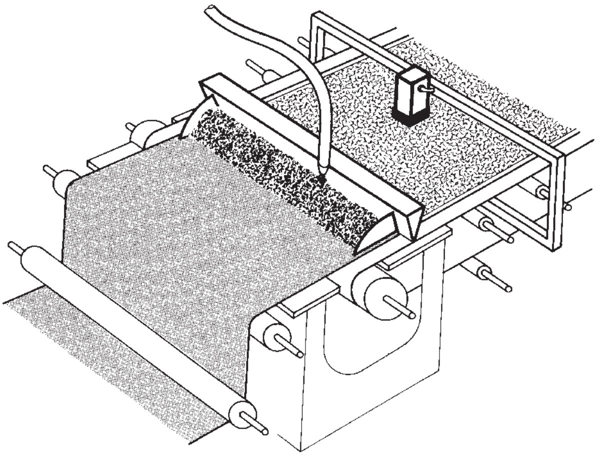


Fig. 1: Foam application.

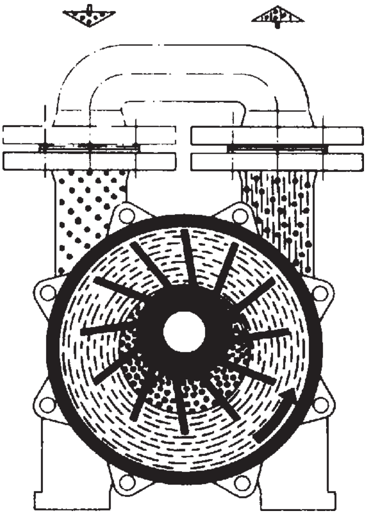


Fig.: Section through a 2-stage liquid vacuum pump (SIHI).

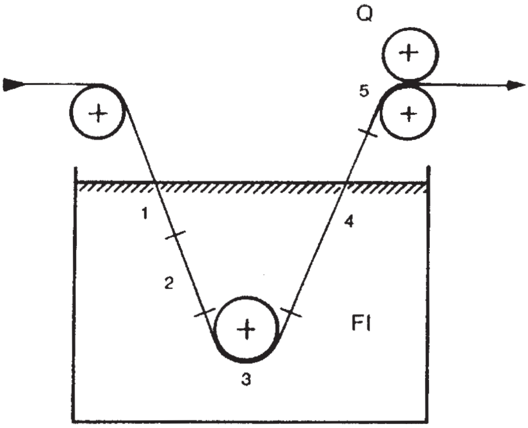


Fig. 2: Schematic padding diagram .
1 = wetting with liquor Fl; 2 = 1st immersion phase;
3 = deflection roller passage; 4 = 2nd immersion phase;
5 = water extraction by squeeze unit Q.

Liquor application systems

Fig. 3: Padder roller flexure.
L = bearing counterpressure; P = pressure.

In a standard padder, the liquor application is greater in the centre than at the edge as all the rollers deflect (Fig. 3).

There are therefore various systems to ensure an even distribution of pressure across the width of the rollers, e.g.

- Nipco roller with a pressure ram battery (Fig. 4). In extreme circumstances, it is (theoretically) possible to control each ram individually,
- Swimming roller (Küsters (Fig. 5)),
- Variflex (Babcock),
- CVC roller (Monforts),
- Bicoflex (Kleinewefers KTM).

The wetting process can be intensified by:

- immersed squeeze units (Fig. 6),
- steaming chambers arranged in front of the trough (Fig. 7),
- vacuum impregnation.

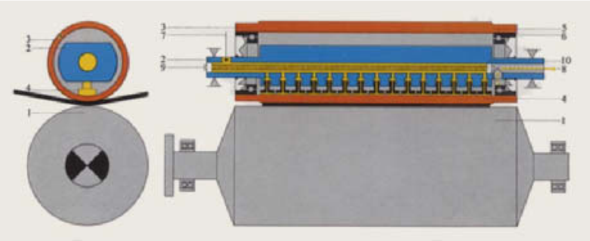


Fig. 4: Nipco roller pressure regulation (Kleinewefers KTM).

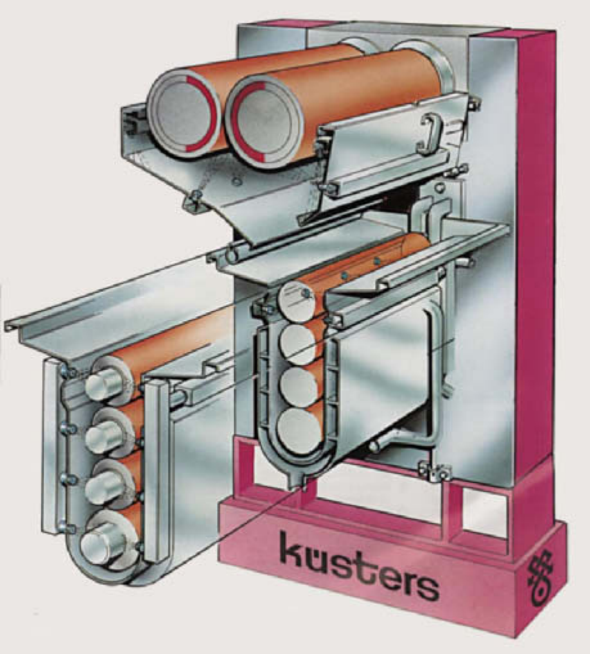


Fig. 5: Küsters "swimming roller".

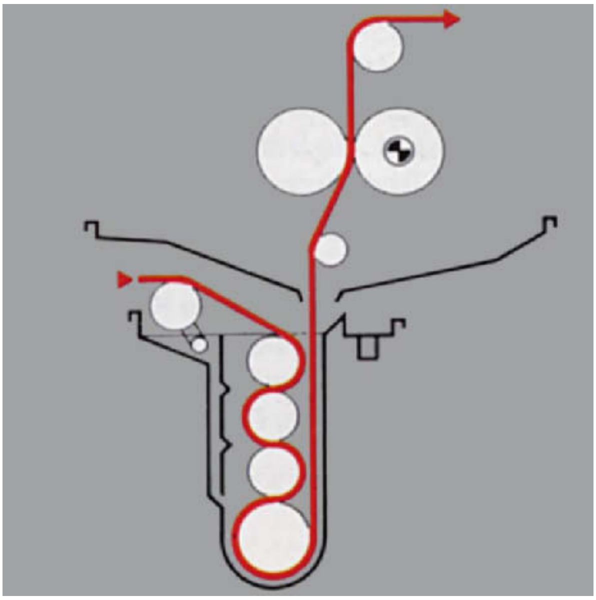


Fig. 6: Nip padder with submerged squeeze unit.

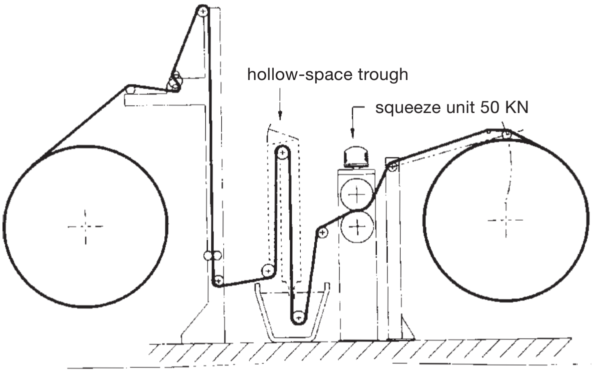


Fig. 7: Vertical padder with steam lock.

Different solutions that do not have long term stability are mixed shortly before the impregnation process. It is possible to control their use (Fig. 8).

High wet pick-up, e.g. more than 100% liquor application can be of interest:

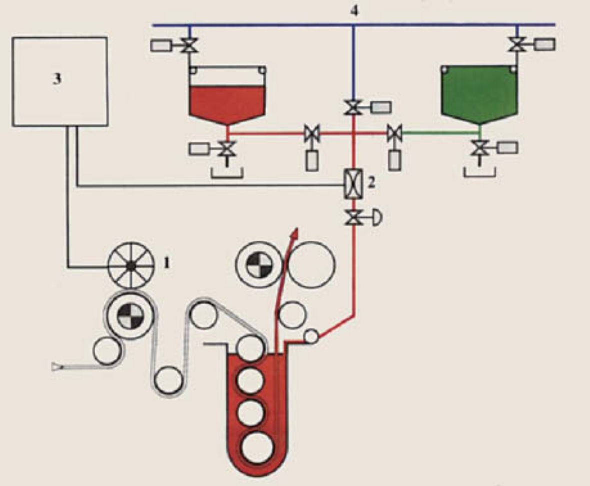


Fig. 8: Construction principle of dye liquor consumption analysis on a dye padder and software (Küsters processing technology).
1 = metre counter; 2 = flow measurement; 3 = processor; 4 = water connection for automatic rinsing.

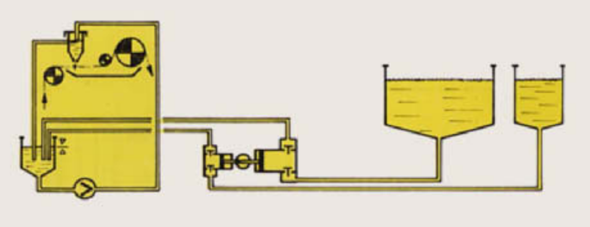


Fig. 9: Texo-Roll by Brückner.

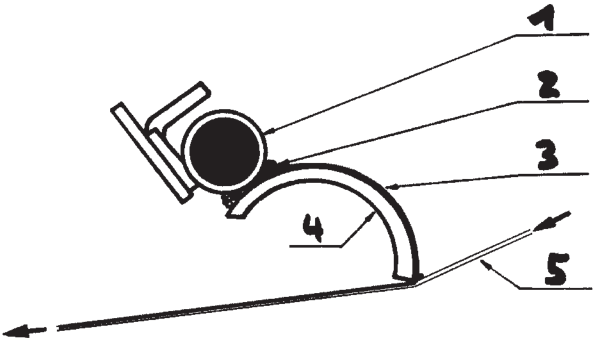


Fig. 10: Westpoint "Curved Blade".
1 = feed collector; 2 = plastic seal; 3 = finishing liquor film; 4 = curved feed plate; 5 = fabric.

- with Flexnip, a type of aquaplaning effect is used (Küsters).
- with Menzel's Optimax, the fabric passes upwards through an initial nip and then passes a second horizontal padder slightly removed from the first.

Flow coating processes also aim for high liquor applications (Figs. 9 and 10).

Liquor by-pass flow Designation for volume of liquor which e.g. flows past the cuff in a beam dyeing machine and which causes tailing or unlevelness.

Liquor calculations Correctly measured bath additives require knowledge of the liquor volume of dyeing machines. Unfortunately, in many companies, these are still often unknown, particularly as regards different bath heights for small batches. So-called constants are always calculated for each machine. It is only necessary to measure this once, as the bath height is found by multiplying the constants with the desired volume of the bath. All measurements are given in decimetres for breadth (B), diameter (D), height of bath (H), depth (T), maximum depth (T_1), minimum depth (T_2), volume (V).

I. Rectangular vats:

$$V = B \cdot T \cdot H$$

$$H = \frac{1}{B \cdot T} \cdot V$$

II. Cylindrical vats:

$$V = 3{,}14 \cdot \frac{D}{2} \cdot \frac{D}{2} \cdot H$$

$$H = \frac{1}{3{,}14 \cdot \frac{D}{2} \cdot \frac{D}{2}} \cdot V$$

III. Curved winch vats:

$$V = \frac{B \cdot H\,(T_1 + T_2)}{2}$$

$$H = \frac{2}{B\,(T_1 + T_2)}$$

IV. Complex dyeing machines: With respect to pipes, pumps and any divider inserts, not easy to define. Best to use titration. An accurately weighed quantity of pure sodium carbonate is added to the machine, mixed well and the concentration of the solution is defined with 1 n hydrochloric acid.

Liquor circulation This is the liquor throughput in l or kg/minute. The number of liquor rotations is inversely proportional to the heating-up time and to the liquor ratio. The heating-up time in the critical temperature range can therefore be reduced proportionally to the reduction in the liquor-to-goods ratio (→ Liquor flow reversal) where the conditions are unchanged (pumping capacity, substrate, hue, dyestuff, chemicals).

Liquor concentration Concentration of additives, taking into consideration the → Liquor-to-goods ratio.

Liquor cycle → Liquor circulation as a movement of the treatment bath through the material to be dyed with the aid of the circulation pump. The liquor cycle per unit of time is dependent on the pump capacity and the flow resistance of the dyeing machine. A high liquor cycle per unit of time is desired in order to avoid excessive differences in concentration arising on the substrate between the dye liquor entering and exiting. The dyestuff feed must therefore be larger than the absorptive capacity of the fibre.

Liquor exchange coefficient From a finishing liquor which contains 100 g/l of a substantive product, a squeezing effect of 80% gives a product application of 80 g/kg or 8%. If the squeezing effect deteriorates to 85% or 90%, the product application increases by 0.5% or 1%. Such deviations cannot be detected by differences in the finishing effects (e.g. handle, creasing behaviour). In pad-dyeing, the liquor exchange in the padding trough is influenced by several factors. In the past, the concentration of the feeding liquor was taken to be governed by the squeezing difference with the liquor exchange coefficient tacitly assumed to be $\alpha = 1$. As the liquor exchange coefficient is in practice actually 0.3–0.6 in the padding troughs, the bath concentration changes constantly and significantly where the concentration of the feeding liquor is the same.

Example: Based on the assumption that $\alpha = 1$ and a squeezing difference of 20%, the bath concentration of 100 g/l of a product with a feeding liquor concentration of 500 g/l can in theory be kept constant. If the fact that $\alpha < 1$ is taken into consideration, however, the bath concentration alters in line with the complex formula which makes the difficulty in recording the liquor exchange clear due to its differential nature:

$$C_B = C_0 \cdot e^{-\frac{m_F \cdot b \cdot v \cdot t}{V_0}} + \frac{X_2 - X_1}{X_2 - (1-\alpha) \cdot X_1} \cdot C_N \cdot \left(1 - e^{-\frac{m_F \cdot b \cdot v \cdot t}{V_0}}\right)$$

C_B = bath concentration in time t,
C_0 = bath concentration in the beginning,
m_f = mass of texiles,
b = fabric width,
v = throughput rate,
t = running time,
V_0 = liquor volume of trough
X_2 = squeezing effect after impregnation,
X_1 = moisture of fabrics at the beginning,
C_N = concentration of the feeding liquor.

Where the concentration of the feeding liquor is the same and the value of α varies, the bath concentration in the padder should have reached the following values after 1 h in each instance:

exchange coefficient	1.0	0.6	0.5	0.3
bath concentration g/l	100	147	166	227

This example demonstrates that it is not possible to guarantee any constant product application in the wet-on-wet process on the padder due to the fact that the exchange coefficients cannot be controlled in practice. In the case of slop-pad minimal application, there is no liquor exchange, i.e. $\alpha = 0$ and

$$\frac{X_2 - X_1}{X_2 - (1-\alpha) \cdot X_1} = 1$$

The concentration of the finishing liquor can be kept constant under these circumstances (Manuf.: Stenker).

Liquor flow The most important function of a dyeing machine is to achieve uniform dyeing in a defined and above all homogenous flow of liquor throughout the fibre mass from the volume elements of the yarn interstices through to the macroscopic dimensions of the textile fabric. The connection between the impinging flow and dyestuff absorption of a substrate is described in a considerably simplified form by the convective diffusion model. This model combines the flow profile of the liquor with the concentration gradient of the dyestuff across the substrate surface.

A distinction is made between:

a) m_s = dyestuff transmission via absorption from the liquor onto the substrate surface and
b) m_k = dyestuff transmission by convection in the flowing liquor.

The system can be characterised by approximation via the quotient q of these rates:

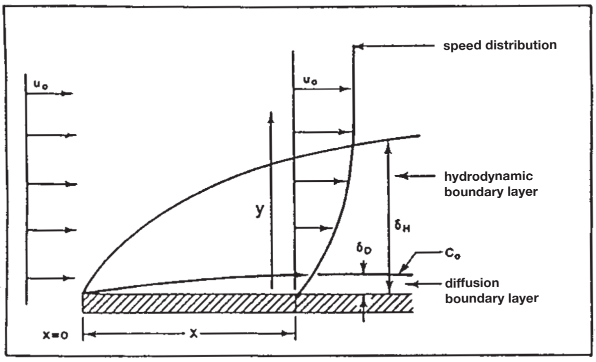


Fig. 1: Flow profile at substrate surfaces.
u_0 = liquor flow rate; c_0 = dye concentration in the liquor; The dimensions of the boundary layers s_H and s_D are defined for the 95% value of u_0 or c_0. The start section x_0 up to the formation of a constant profile is not taken into account.

$$q = \frac{m_k}{m_s}$$

In a stationary liquor, i.e. $q << 1$, the dyestuff is bound to the substrate surface by sorption. This process continues until the sorption equilibrium of the dyestuff on the surface of the substrate in question is reached (the sorption equilibrium should not be affected by diffusion of the dyestuff within the fibre). At the same time the liquor layer close to the surface is rapidly depleted of dyestuff, i.e. the dyestuff transmission takes place predominantly by means of controlled diffusion and $\sigma_D > \sigma_H$ applies. If the substrate is impinged with liquor, however, i.e. for $q >> 1$, when the dyeing rate is increased at the same time, the layer close to the surface which has been depleted in dyestuff can be cleared and replaced by fresh liquor high in dyestuff. Now $\sigma_H > \sigma_D$ applies. The model (Fig. 1) demonstrates how the liquor flow affects the dyeing rate by means of a simplified model. It also demonstrates that flows which differ locally on the substrate must result in unlevel dyeing. Level dyeing is therefore only possible in an homogenous liquor flow profile for $m_k >> m_s$. However, these conditions are not always possible for technical reasons. A practical solution is to adjust a quasi-stationary equilibrium between m_k and m_s. Level dyeing is only possible in a uniform flow profile which is constant over time.

The liquor flow therefore effects the dyestuff transmission (but also conversely the removal of soil e.g. when washing) as follows (Fig. 2):

1. Transmission of the dyestuff to the outer surface of the textile (e.g. surface of a package of a moving fabric). Takes place by convection (liquor flow and/or fabric movement) and free diffusion in the laminary boundary layer.
2. Transmission of the dyestuff through the textile (i.e. the interstices between the yarns and between the filaments or fibres in the yarn) to the fibre surface. This occurs by convection (with generally significantly lower liquor flow than outside the textile) and diffusion, whereby the liquor dyes the textile as it passes through it and consequently decreases in dyestuff content.

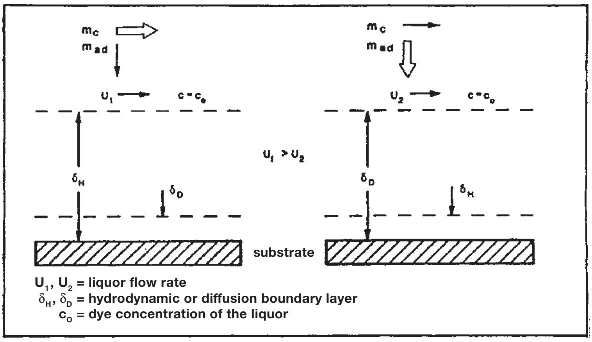


Fig. 2: Fabric transport at the substrate surface. The dilation of the boundary layers in the system is determined by the sorption and convection ratio.

Fick's law of diffusion for dyestuff in the fibre is based on diffusion of the dyestuff by a diffusion boundary layer in the liquor. The exhaust curves calculated for constant conditions shows a delayed exhaustion in comparison to the curves of the models without boundary layers. The effect on the flow by the parameters

$$l = \frac{D_L \cdot r_F}{k \cdot D_F \cdot \delta_D}$$

can be described using a Nernst adsorption equation. It characterises the ratio of the rates of diffusion to the fibre surface (diffusion coefficient D_L in the liquor, depth of the diffusion boundary layer δ_D) and the diffusion in the fibre (radius r_F, diffusion coefficient D_F and distribution coefficient k). The lower the value of l, the greater the effect of the flow.

The liquor flow is not uniform within the textile mass, however. In package dyeing (beam dyeing, crosswound yarn package dyeing) the situation is as follows:

1. The laminary boundary layer with decreasing liquor flow on the surface of the textile results in a somewhat slower exhaustion due to the effect of the diffusion boundary layer. This does not have a significant effect on the uniformity of the dyeing and only contributes to the lack of uniformity in less impinged areas to a small extent.
2. The low flow though the inside of the yarn or points of intersection: the denser a yarn in relation to the package density or the permeability of a surrounding textile fabric, the less it is impinged at the same average liquor throughput Q. This has an effect locally in yarn which is poorly penetrated or globally in packages with a significant difference between inside, centre and outside of the packages.
3. The uneven flow in the package: edges which have been poorly impinged or channelling in packages or insufficient liquor flow of a fabric accumulator in machines are the most common causes of unlevel dyeing. When assessing lack of uniformity, the local minimum Q_{min} is used in the place of the overall flow Q. Unfortunately, Q_{min} is not known more accurately under practical conditions.
4. The change of direction of the liquor flow in pack-dyeing machines: alternating the flow on packages reduces unlevelness. Frequent alternations, e.g. after each revolution, are not recommended. Changing the direction after every 2–4 revolutions is most favourable when the flow is approximately equal in

both directions and provides almost the same levelness as double flow with flow only from one direction. Where the flow occurs from outside to the inside, the yarn packages may become compressed with significant increase of the differential pressure, reduced flow or even deformation of the yarn package or the tube and channelling (according to Schollmeyer, Heidemann and Hoffmann).

Liquor flow direction The direction of the current within either a dye liquor or fastening liquor.

Liquor flow in packages The characteristics of flow within a yarn package (see Fig.) are an important parameter governing the even dyeing of yarn. As the temperature rises the viscosity of the liquor, and thus also the differential pressure, reduces. It follows so that the flow rate at the dyeing temperature can be controlled by means of the differential pressure (e.g. direct current motor, frequency converter, bypass). The differential pressure is a measure of fluid friction within the yarn winding and therefore of shear stress. Flow related characteristics, information concerning dyestuff transport or dyeing conditions, differences in winding density and methods for measuring and testing the distribution of winding density within yarn packages are all of great importance; due to the greater winding density in compressed packages and the greater surface area of yarn they contain, rapid wetting and venting is significant. Penetration enhancers and anti-foaming agents added in advance to the dyeing liquor have proved themselves in this application (according to Mosimann).

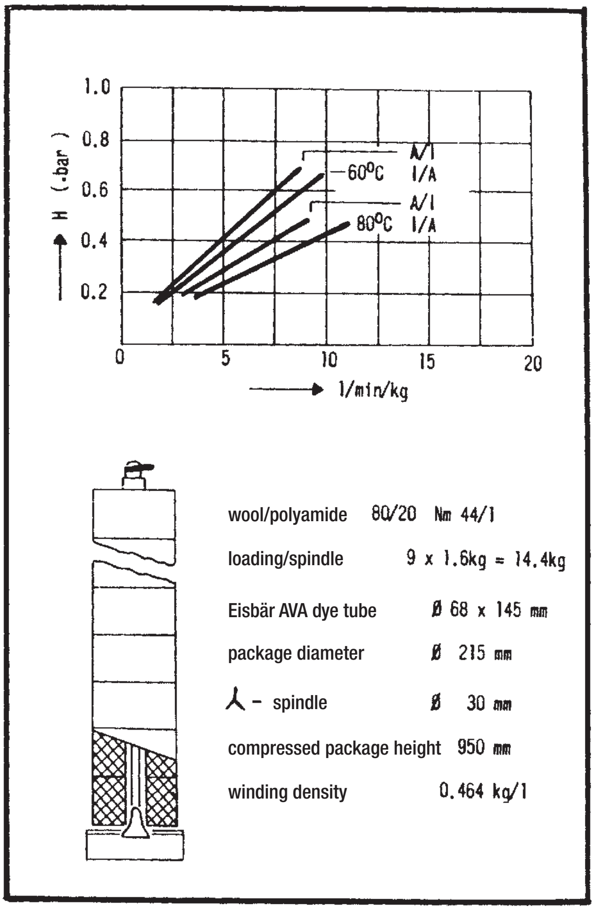


Fig.: Liquor flow and permeability relative to temperature and flow direction (wool/polyamide, Nm 44/1) (Mosimann).

Liquor flow reversal It has proved best to change the direction of liquor flow with every completed circulation of the bath volume (→ Liquor circulation) during through flow processes (see Fig.). However, in practice the liquor flow direction is changed after every two to three full circulations. For optimum results the liquor flow direction should be changed every 20–30 seconds, or at the least every 80–120 seconds, whereby the time allowed for outside-to-inside circulation should always be longer than that for the reverse direction in keeping with the reduced flow through rate of the liquor.

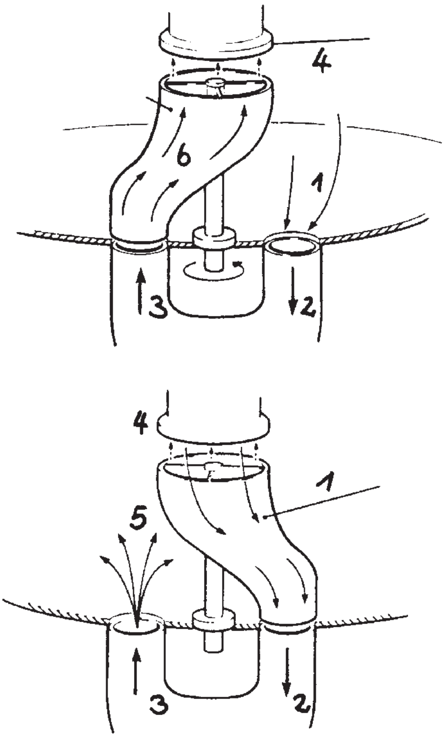


Fig.: Liquor direction change via a sort of "switch system" (Longclose) with the use of a unilaterally operating centrifugal pump.
1 = liquor return flow from material; 2 = suction side of pump; 3 = pressure side of pump; 4 = material carrier connecting piece; 5 = liquor flow out to in; 6 = liquor flow in to out.

Liquor heating by hot water This allows for good heat utilization. The process is possible for hot water temperatures up to 190°C; every steam boiler system can be used for hot water generation. The hot water generated, circulated by a pump, can be used immediately for heating purposes in indirect heating systems (loop: boiler – application – boiler). Advantages: best utilization of heat (unused residual heat is returned to the boiler, whereas steam operation leads to heat loss through water condensation), no change in liquor level or pH due to accumulation of condensate, only limited top-up feeding of the boiler required, no corrosion. Disadvantages: high cost of facility, direct heating not possible. Modern steam heating systems are able to compete with hot water heating systems.

Liquor level Either the level or the quantity of liquor contained within a dye bath, etc.

Liquor pick-up Also → Pick-up. The pick-up of liquor in the pad mangle is dependent upon:

- the squeezing pressure of the squeezer,
- the textile material,
- composition of the pad dyeing liquor,
- temperature of the dyeing liquor,
- throughput speed of the goods.

Liquor quantity → Liquor-to-goods ratio.

Liquor stability The physical and chemical resistance of dyeing and other treatment liquors.

Liquor throughput The relationship liquor to quantity of goods to time, e.g. 1 l of liquor flowing through 1 kg of goods per hour. → Liquor circulation.

Liquor volume calculation Fill the dyeing machinery with water and add 1000 g of dry, pure sodium carbonate then stir until dissolved. Extract 500 ml and titrate with hydrochloric acid until neutralized.

Liquor wedge arises in both horizontal and vertical broadloom washing machines between the guide roller serving as principal washing element (1) and the travelling sheet of fabric (2), i.e. shortly after the installed spray pipe (3) which constantly applies a film of liquor to the fabric (see Fig.). As a consequence hydrostatic pressure builds within the liquor wedge and forces liquor through the fabric.

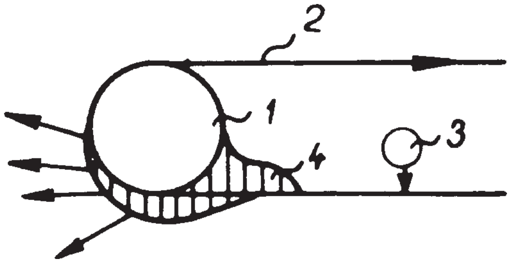


Fig.: Liquor wedge formation.
1 = deflection roller; 2 = fabric; 3 = liquor feed; 4 = liquor wedge.

Liquor-to-goods ratio The ratio of goods (kilograms) to liquor (litres), defined more precisely as: the ratio of the dry weight in kg of the goods, including all associated materials, measured immediately prior to the finishing process, to the volume in litres of the entire treatment liquor in the system at a temperature of 20°C at the time of the measurement. An essential factor when drawing up recipes (for dyeing, bleaching, etc.) is the establishment of freely reproducible values, and these play a deciding role when calculating the requirements for the heating steam. Every reduction in the liquor-to-goods ratio creates savings in time, water, waste water, energy and additional resources – within, of course, the bounds of technical and technological limitations (→ Liquor circulation). The following categorization is made according to liquor-to-goods ratio:

short liquor	1 : 10
standard liquor	1 : 20–30
long liquor	1 : 50–100

The liquor-to-goods ratio suitable for each type of dyeing apparatus is a decisive criterion in the selection of apparatus to be used:

jigger	1 : 1–8
apparatus	1 : 5–10
vat	1 : 20–30
paddle winch dyer	1 : 20–25
paddle machine	1 : 150
star wheel dyer	1 : 100–300

A reduction in the liquor-to-goods ratio may be aided by: a) making possible the maximum utilization of the space within an apparatus by suitable construction (Fig. 1) and b) exploiting this space by using optimum textile make-up and item size. Presupposing that the apparatus itself is ideally set up, it then rests largely in the hands of the finisher to achieve a lower liquor-to-goods ratio by ensuring a high packing density of the goods (Fig. 2). It is on account of this that presses are used in practice, also because of the increase in production which results. With the exception of special cases (sewing thread, filaments etc.), the following packing or winding densities may be attained:

loose material	300–500 kg/m³
strands in suspension system	80–130 kg/m³

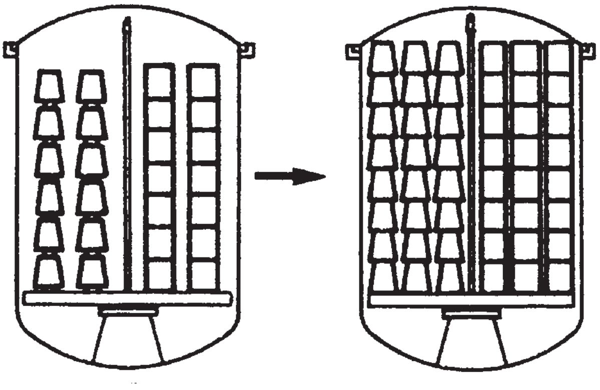


Fig. 1: Shortening liquor ratio by max. machine utilization.

soft winding	140–220 kg/m^3
crosswound yarn packages on rigid cores	300–450 kg/m^3
piece goods on beams	250–00 kg/m^3
piece goods in paddle winch vat	80–150 kg/m^3
piece goods in dyeing machine	150–200 kg/m^3

It is also possible to reduce the liquor-to-goods ratio by inserting displacement devices into locations which cannot be filled with material (Fig. 3). Their effectiveness should, however, not be exaggerated as it is less than generally assumed. Displacement devices for single packages or columns of packages do not achieve the desired effect, so that use is restricted to special cases in two-level apparatus when, for reasons of item size only, one material holder is used.

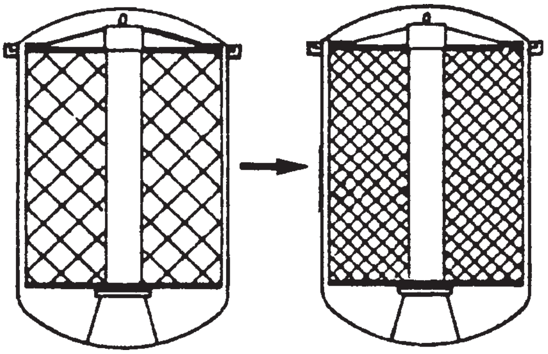


Fig. 2: Increasing packing density in order to achieve a shorter liquor ratio.

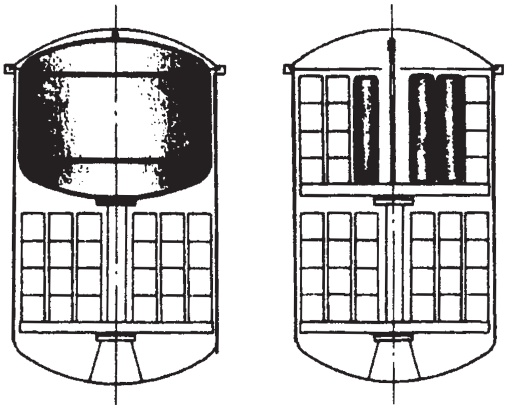


Fig. 3: Use of displacing elements with less than fully loaded machines.

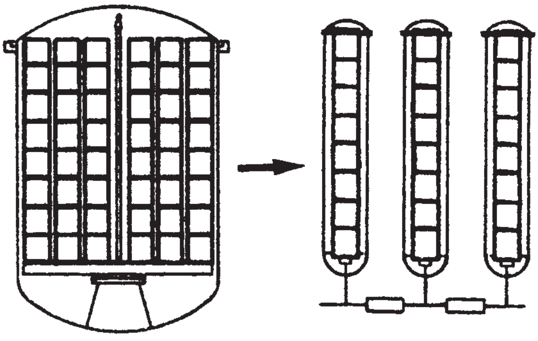


Fig. 4: Splitting up a large dyeing machine into small dyeing zones related to dye columns.

A further possibility is to adapt the form of the apparatus to match the make-up of the goods to be dyed (Fig. 4), in other words a purely machine technological measure which is particularly suited to dyeing apparatus for packages. A variety of such devices is on the market; they are more difficult to use and the facility takes up more space. A further disadvantage is the relatively narrow limitation imposed on package diameter since any reduction in diameter increases the liquor-to-goods ratio.

The liquor circulation pump and the heating and cooling systems may be built directly into the curved base of the autoclave, which cannot anyway be filled with material (Fig. 5). This does away with the piping otherwise needed for liquor circulation and as well as reducing the liquor-to-goods ratio, it also eliminates losses due to flow resistance. The measure has a favourable effect on drive efficiency and therefore on the consumption of electrical energy.

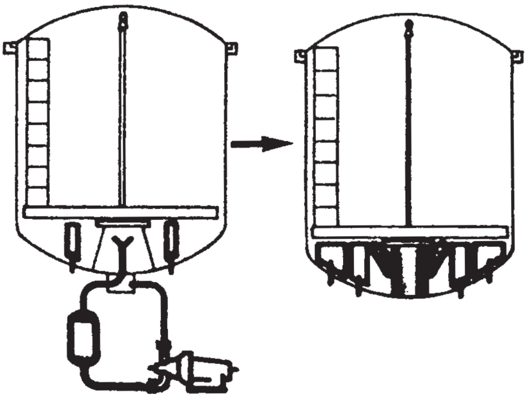


Fig. 5: Integrating the circulation pump into the dye vat.

Items with a make-up such as flocks, cross-wound packages, rocket spindles, muffs, warped beams and so on, which may be dyed from the inside to the outside, allow for processing in only partially flooded apparatus, which provides a simple and relatively effective way of reducing the liquor-to-goods ratio. In order to allow processing with as low a level of liquor as possible, the dyeing apparatus must be constructed so as to permit unhindered return of the liquor to the circulation pump while working at an adequate specific liquor flow rate. Compact systems, in which a multi-stage axial pump is integrated into the dye vat along with a heating coil, dispense with a secondary loop to an additional tank whose contents may be fed into the main loop by a an auxiliary pump. When used for well assembled compact columns composed of cylindrical packages with axially flexible cores, such a system can even dye "in sump", whereby the liquor is pumped from inside to outside and a small amount of liquor cascades down the package columns to the drain. Antifoaming agents are required to prevent frothing of the liquor. Maintaining pressure in the air space (air or inert gas), known as pressurized operation, assists maximum performance by the circulation pump even at the lowest of liquor levels.

In order to reduce the liquor-to-goods ratio in hank dyeing machines by taking account of the pipe and pump volumes, the heat exchanger can be placed within the reaction chamber (as in yarn dyeing machines), which allows for the shortest possible pipes connecting from the sump (which contains the heat exchanger pipe) via the pump to the overflow tank. In gentle dyeing machines the liquor film should be calculated at the minimum required to penetrate the goods. The liquor, which flows gently from the spray nozzles, not only aids the draining of the goods but also aids penetration on account of constant changes from laminar to turbulent flow.

The minimum application system for aqueous dye liquor requires only as much liquor as is taken up by the fabric sheet through capillary action and adhesion. Excess liquor must drain immediately from the lowest point of the treatment chamber and then flow into a collecting tank. Accordingly, there is no liquor surface level within the treatment chamber. The collecting tank is able to hold sufficient liquor reserve to enable problem free operation of the circulation pump. If one assumes that this system requires a significantly lower pump capacity, the collecting tank need only hold approximately 150 litres of free liquor in order to feed the pump. Goods of some qualities can take up liquor to a maximum of 300%; if the quantity of free liquor is added to this, then in the least favourable case a liquor-to-goods ratio of 1 : 5 is attained with a machine possessing only a single storage rack. Examples are:

– 1 rack, 80 kg goods, 300% liquor take-up

$$FV = \frac{(3 \cdot 80) + 150}{80} = 4{,}87 \cong 1:5$$

– 3 racks, 240 kg goods, 300% liquor take-up

$$FV = \frac{(3 \cdot 240) + 150}{240} = 3{,}62 \cong 1:4$$

– 3 racks, 240 kg goods, 250% liquor take-up

$$FV = \frac{(2{,}5 \cdot 240) + 150}{240} = 3{,}12 \cong 1:3$$

– 4 racks, 320 kg goods, 200% liquor take-up

$$FV = \frac{(2 \cdot 320) + 150}{320} = 2{,}46 \cong 1:2{,}5$$

Every liquor-to-goods ratio achievable on the basis of the characteristics of any specific fabric takes account of the total liquor volume required in order to dissolve the quantity of dyestuff and chemicals needed even for deep dyeing.

Listing → Tailing.

Lithium (Li) → Alkali metals atomic weight 6.94. Burns with a colourless flame, chemically related to → Sodium.

Lithium chloride (LiCl), density 2.968. Forms colourless crystals or a white powder (deliquescent). Strongly hygroscopic; poisonous. Uses: in air-conditioning systems as a water-retaining regeneratable substance; as conductivity measuring sensors for hygrometers.

Lithium chloride hygrometer In keeping with the principle of humidity detection, a suitable sensor comprises a wick soaked in → Lithium chloride and wrapped in a heating coil whose electrical heating effect depends precisely on the moisture content of the surrounding air. Operating on the definition of conductivity, so-called sensor platelets which are composed of a thin layer of lithium chloride embedded in a film of hygroscopic plastic are used to register humidity. Such platelets change electrical resistance logarithmically with increasing relative humidity, a characteristic which can be amplified to operate a regulator, pen recorder or similar device.

Lithography A flat printing (planography) process used in paper printing in which a polished and engraved stone was originally used as a printing plate (Gk.: lithos = stone).

Litmus A blue pigment obtained from lichen used as an indicator in solution or by colouration of paper. A distinction is made between red litmus paper, which reacts to an alkali by turning blue, and blue litmus paper, which reacts to an acid by turning red. Its neutral colour is violet. Its transition range (pH 5–8) is easily influenced by the presence of weak acids (e.g. carbon dioxide in air, therefore store litmus in a well-sealed brown bottle). Its sensitivity is approximately 1 : 20 000 for potassium hydroxide, 1 : 50 000 for hydrochloric acid (i.e. 1 g dissolved in 50 litres). Litmus is only used as a test for acidity and alkalinity; it is not used to measure pH value.

Litre Fluid measure, i.e. spatial or volumetric measurement equal to 1000 cm^3 of water at 4°C, which equals 1 l or 1000 ml.

Litre weight (L). The weight of a → Litre of gas expressed in grams, calculated by dividing the weight G by the volume V. Analogous to the varying weight of liquids (specific gravity, → Density), the litre weight varies between different gases occupying the same volume; e.g. litre weight in grams: acetylene 1.1708; ammonia 0.7713; chlorine 3.220; hydrogen chloride 1.6391; carbon dioxide 1.9768; air 1.2928; sulphur dioxide 2.9256; hydrogen 0.08987.

LL fabrics → Links-links fabric, purl fabric.

Llama hair South American ruminant, member of the camelidae (camel family); its wool is of various colours, having coarse guard hairs with a diameter up to 150 µm and fine underhair with a diameter of 20–35 µm; it has around 100 almost invisible scales per millimetre. → Animal hair fibres.

Lm → Llama hair, → Textile fibre symbols, according to DIN 60 001 until 1988; from 1991 changed to → WL.

lm Lumen, SI unit of luminous flux. → Lux.

Load ratio The ratio of the filling weight of goods in kg to the volume in litres of, e.g., the washing or dry cleaning drum. Frequently used ratios are:

a) Washing machines: drum washing machines 1 : 12–14; flow wash systems 1 : 16

b) Dry cleaning machines: long drum type 1 : 16–17; high-level drum type 1 : 18–22.

The guide value is the filling factor, calculated as the ratio between the volume of the drum in litres to the filling weight in kilograms of the goods. Example: for a high level drum type dry cleaning machine the filling factor is usually 18–22.

Locust bean flour (fine flour), the ground seeds of the fruit of the locust bean, or carob tree, a leguminous plant native to the Mediterranean, giving a very light, almost dusty whitish or light brown flour (the mechanically shelled beans are better than the chemically shelled; there are shell-rich and shell-free varieties, also bleached and unbleached). Active substance → Carob. To dissolve: disperse in glycerine, dilute with water. Thickened solutions are not considered smooth and have the disadvantage that they tend to liquefy and decay after being left to stand for several days: this may be prevented by adding proteins and preserving agents. A locust bean flour solution may be coagulated using alkaline lye, alkaline carbonate or perborate.

Loden,

I. Woven woollen goods in an unfinished state (unsized).

II. Predominantly woollen, coloured blended coarse material made from spun virgin wool and fleece (heavily milled and carded, not cropped), also with admixtures of camelhair, alpaca or mohair for higher quality. The name is derived from Old High German lodo = coarse cloth. It was originally a coarse hand made cloth among the upland peoples of Southern Germany. Loden now represents a general term for a relatively thick, usually olive green, red brown or dark grey material of tough character, often impregnated to make it waterproof. The most usual form of weave is twill. According to the finish or application a distinction is made between: a) melton-loden with a melton finish, primarily used for skirts, dresses, trousers and suits for hunters, farmers and foresters, and impregnated when used for coats: b) brushed loden with a long brushed finish is used solely for coats and cloaks, whereby the direction of combing serves to promote the water repellent effect.

Logarithm (log, Gk.: logos + arithmos), a ratio for the purpose of simplifying the calculation of mathematical equations, whereby natural multiplication is converted into addition and division is converted into subtraction. Negative logarithms play a role in textile finishing with respect to → pH. For example, pH 7 may be expressed as negative log "10^{-7}" which implies that 1 litre of water contains 10^{-7} grams of hydrogen ions.

Logistics The textile business is classically divided up in an organizational diagram into divisions, areas, responsibilities, departments etc. Conceptual thinking, or compartmentalized thought, lies behind this segmentation. These concepts are precisely segregated one from another; losses in effectiveness can arise at any interface due to an inadequate flow of information or because of unclear areas of competence. Integrated network thinking always considers a business as a logical system which exists to supply the market. Logistics encompasses the following technical and commercial specialities and may be divided into:

- disposition
- production planning, production control
- central purchasing
- despatching.

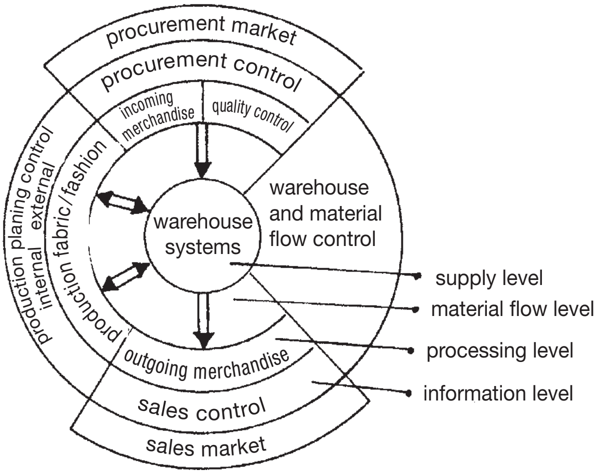


Fig.: Cybernetic logistics relationship diagram.

developmental stages of organisation	organisation by speciality, functional organisation	organisation by system, cybernetic organisation
applicability	when qualified specialists required in a slowly changing world	when coordination with no time lag required in a rapidly changing complicated world
models, focal point	the scientifically orientated speciality	the process orientated system
basic principle	unity of knowledge	unity of the control loop
key phrase	all substantive matters are to be dealt with by a suitably trained specialist	all control processes in the system are to be integrated
starting point	division of tasks and traditional disciplines, types of training and career path	system analysis, process interrelations, needs for agreement, types of mentality
prestige	number of subordinates	importance of the assigned subsystem to the success of the entire system
responsibility	responsible for fulfilling ones own tasks	jointly responsible for the working of the entire system
coordination	by agreement between managers of specialist areas	constant direct agreement among operatives
criteria (control)	observation of methodical rules, achieving isolated sub-optimums	realisation of models as desired effects upon the entire system. Maximum performance in isolation does not find approval.

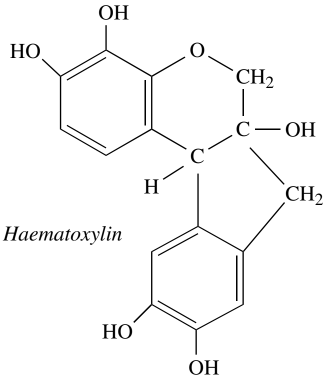
Tab.: Comparing "functional organization" with "cybernetic organization".

These different levels are seen as interacting intensively within a cybernetic logistics model (see Fig.).

Functional thinking (see Tab.) in traditional organizations is too rigid to be able to react quickly and flexibly to market requirements ("quick response") such as fashion changes, or to be able to deliver "just in time" (i.e. exactly at the moment when a customer is ready to further process goods) while tying up the minimum amount of capital in holding warehouses.

In order to realise the main goal of logistics (the supply of the market to be exploited by the marketing department) it is necessary that reliable data for prognoses are kept up to date and that real-time information concerning capacity, the state of production (at home and abroad) and warehouse stocks is available. This in turn requires that an integrated EDP system covering prognosis to delivery is available or at least in development. Only in a few instances will an EDP system actually be available to a newly installed logistics area. Instead, more or less group-constrained solutions will be in operation. It will initially be possible to make do with the available group-constrained solutions while still achieving success provided that the employees can substitute for the missing integration through high quality cooperation using communication and whole-system concepts.

Logwood The heartwood of the tropical logwood tree (heamatoxylon campechianum). Its active substance is colourless haematoxylin, which is extracted by oxidative fermentation, and from which the red derivative haematin is obtained through oxidation.



Haematoxylin

Fixing is done using metal mordant: tin = reddish violet; alum (potassium aluminium sulphate) = greyish violet; chrome = dark blue-black; iron = grey-black; copper = dull green-blue. Formerly an important mordant dye for silk (with simultaneous aggrevating action), logwood substances are nowadays used only as additives with certain synthetic dyes. Characteristics: excellently wear fastness with good wash fastness and satisfactory light fastness. Disadvantages are its fading to green in light and its colour change towards red when affected by strong acid.

Logwood black test → Hydrochloric acid test.

Logwood extract (noir reduit), extract of → Logwood, used in printing.

LOI (Limited Oxygen Index). LOI is the standard value for characterising combustion properties. The LOI test is a method devised by General Electric for testing the combustion behaviour of polymers and also textiles, and represents the minimum concentration of oxygen mixed with nitrogen at which a textile material no longer burns. The original term Limited Oxygen Index has in the meantime been shortened to Oxygen Index, i.e. to OI, and may also be described as limiting oxygen level (Fig. 1).

The test sample is stretched within a frame and suspended in an oxygen-nitrogen mixture, then ignited so that it burns from the top downwards. The minimum amount of oxygen which supports burning over a period of 3 minutes, or the burning of a 50 mm length of the sample, is determined. The test frame with the sample (40 x 100 mm) is placed in the testing column and the oxygen concentration is then set. The gas mixture is blown through the column for 30 seconds at a velocity of 4 ± 1 cm/s (at 760 bar and 273.15 K) and the sample is ignited using a special burner. The fabric must then either burn for at least 3 minutes or it must burn completely along a length of 50 mm. The LOI is read off from a scale (Fig. 2). Measurements are conducted ac-

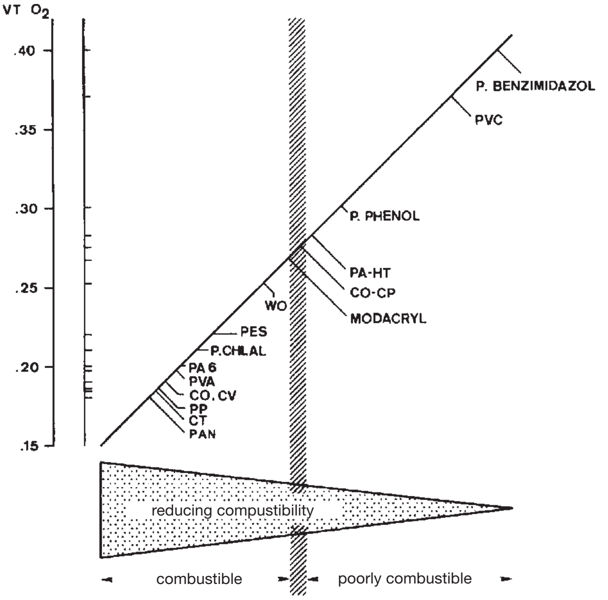


Fig. 1: The limited oxygen index of various fibres.
P = poly-; CO-CP = flame retardant treated cotton.

cording to ASTM D2863-76. The ignition source is a 25 mm propane/butane flame. The contact time between flame and fabric, i.e. the ignition time, is not specified under the standard. However, since the ignition time is important, the time for contact between flame and the environmentally conditioned fabric sample (standard conditions) is set at 5 seconds.

The LOI is determined primarily by the type of fibre in the sample and only to a small degree by the apparent fabric density or pore volume (see Tab.). The pore volume is determined by the density of both the fibre itself and the fabric weave. As the number of pores increases, the flame resistance of the fabric decreases.

The fact that almost the same LOI is measured for the same substrate when ignition from above is carried out at different ignition temperatures is a contributory reason for choosing ignition from above. Furthermore, the vertical test with ignition from above causes no additional warming of the substrate front, as would be the case with ignition from below. When testing woollen fabrics using ignition from below, the measured oxygen index is strongly influenced by the ignition temperature. Only small variations in ignition temperature may lead to false results. This finding also confirms the risk associated with the vertical test when igniting from below. At the same time, however, it must be made clear that the measurement of the oxygen requirement should be regarded neither as sole criterion nor sole method for assessing the combustion behaviour of various substrates, but is rather to be seen in a supporting capacity.

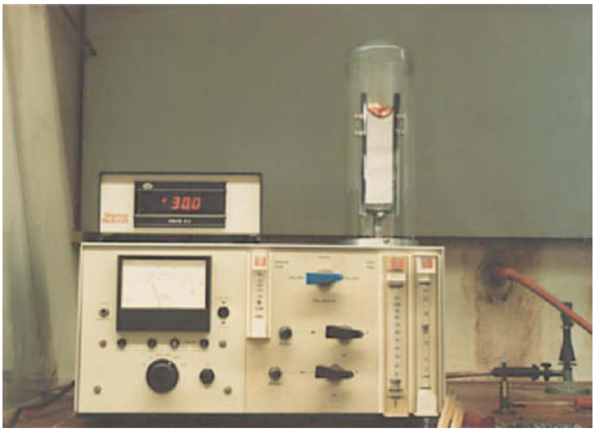


Fig. 2: LOI measuring apparatus.

material	apparent density (g/cm³)		index	LOI value	
	min.	max.		min.	max.
cotton	0,19	0,30	158	18,1	18,5
viscose	0,46	0,53	123	18,4	18,9
wool	0,31	0,34	109	25,1	27,0
PES	0,10	0,23	230	22,6	24,2
PA	0,22	0,67	305	27,0	31,0
PAN	0,18	0,27	150	19,8	20,9
PES/cotton	0,18	0,47	281	16,9	19,5
PES/wool	0,13	0,43	358	21,6	24,0

Tab.: The relationship between LOI and fibre density (according to Jeler).

When measuring the oxygen requirement, either a length of 50 mm of the sample must be burnt or else the burning process must persist for approximately 3 minutes at the minimum available oxygen concentration. At the same time any additional observation of melting, dripping, shrinking or blackening and so on is to be recorded. Care must be taken that the surrounding temperature remains low and that the pyrolysis gas can escape unhindered. Switching on an extractor fan above the glass bell is an advantage.

Experience to date shows that fibres with an LOI < 27–28 will not burn in air. Acrylic (polyacrylnitrile), triacetate, polypropylene and acetate still burn at the lowest concentration of oxygen in the oxygen-nitrogen mixture. Polyester and wool require a relatively high oxygen concentration. Fibres such as aramides, which are not combustible in air under normal conditions, have an extremely high LOI. In other words, combustibility may be deduced from the LOI.
The LOI values of various fibres are:

acrylic	18.0
triacetate	18.4
polypropylene	18.6
viscose	18.9

cotton	19.0
polyamide	20.0
polyester	22.0
wool	25.2
aramide	28.2
carbon fibre	35.0
polyvinylchloride	37.1
cotton/polyester 50/50	18.4

A very useful indication of the effectiveness of flame retardants on fibres is also given. For this test the sample is suspended vertically in an oxygen-nitrogen mixture and ignited, and the oxygen concentration adjusted until the sample burns for at least 5 minutes. The concentration of oxygen required for this is again an indication of combustibility, in other words the higher the LOI the less combustible is the substrate.

London forces Dispersion forces (→ Secondary valency forces) named in Anglo-Saxon literature after the physicist of the same name.

London shrinking process The purposeful restoration of the temporary stretching or tension arising in wool or wool-mix fabrics as a result of the production process by applying the principle of → Shrinkage. The fabric is laid in a tension-free state in damp decatizing wrappers for approximately 12 hours with subsequent slow and tension-free drying. In the process a cloth shrinks by approximately 5–10%.

London shrunk → Shrinking machine for wool and wool-mix fabrics. The fabric travels tension-free from the feed roller in a loose loop to the steam cylinder and then over a sloping, polished heating plate where weft and warp are allowed to relax entirely. The speed of the fabric and the steam intensity may be regulated to achieve any desired shrinkage effect suitable to any fabric. Uses: mainly following decatizing, or following pressing and before final decatizing. – Manuf.: Kettling & Braun.

Long-chain dye process Continuous indigo dyeing process for cotton warp yarns. The threads gathered together into strings (warps) are passed through several pre-wetting and dye baths. After each immersion in a dye bath the material is squeezed out and the indigo oxidized in air. There follows a final rinse or post-treatment, the continuous drying on a drum or cylinder drier, after which the dried strings are opened and wound onto warp beams.

Long cylinder The → Inner drum of a double drum machine, being mounted at both ends and with a ratio of drum height to drum depth (or length) > 1. The filling factor is 23–25.

Longitudinal (Lat.: longus = long) running or laid out lengthwise.

Long liquor Used for a liquor containing a large quantity of fluid, e.g. 1 : 40. Opposite: → Short liquor.

Long-steaming method Original steaming method in the two-stage printing process. The dried print is padded with reducing agent and, according to the thickening agent, with caustic soda, potassium carbonate, calcified sodium carbonate, sodium tetraborate or aluminium sulphate together with a wetting agent, and then steamed for 10–15 min. The process had the advantage that older types of steamer could also be used.

Look Term used to describe a fashion trend or style, e.g. the used look, safari look, etc.

Loomstate fabrics (loomstate plain weave, loomstate cloth), woven fabric coming from the weaving machine into the trade. The goods as such are not finished but usually merely brushed on a cleaning machine and if necessary steamed. Such loomstate fabrics may be raw fabric (e.g. untreated cotton, homespun etc. = loomstate cloth; hand woven linens = loomstate plain weave) or dyed fabrics (yarn dyed, printed, bleached) or patterned, etc.

Loop,

I. Any loop or swag of material, e.g. a loop of yarn, a loop of fabric (in a long loop drier or similar device). Loop fabrics are similar to Bouclé fabrics, except that while the latter's decorative threads possess only knot-like thickenings or small loops, loop fabrics have larger round loops which, in the case of strong patterns, may have a diameter equivalent to that of a pencil.

II. (pole stitch, plush stitch) a basic element of knitted fabric in combination with → Stitches appearing on the reverse side as regular long loops of thread (plush stitches) which are connected with plain stitches.

Loop-bonded composites → Fused bounded nonwoven.

Loop drier Piece goods are moved through the drier in long loops (long loop drier, suspended loop drier) or short loops (→ Short loop drier) with the reverse side suspended on the rail so that the right side of the goods may dry without contact or tension.→ Drying systems.

Loop-Dye 1 for 6 Warp dyeing facility for indigo; → Indigo dyeing.

Loop pile carpets Carpets made with closed → Pile loops. In the case of → Tufted carpets the loops of thread are stitched fast into the backing material. The loops, which are anchored in the backing material by a backing layer, provide the loop pile of the carpet.

Loop strength A means of assessing the suppleness or (the opposite) roughness and stiffness of yarns and twists, i.e. in general their transverse firmness. The loop pull test is carried out according to DIN 53843 analogous to the simple → Tensile strength test. Two threads are looped through each other so that they are held in the space between two clamps. The maximum loop tractive force is given as a ratio of the original maximum tractive force.

Loop transfer technique A minimal application process using indirect transfer of the treatment liquid. The liquid is first applied to an absorbent transfer medium by means of soaking, and the goods to be treated are then brought together with the transfer medium in a pair of squeezer rollers.

Loose stock A fine, light and loose structure composed of either smooth or tangled individual fibres (naturally washed, cut or torn). For example, loose viscose stock (or viscose flock) refers to piles of viscose fibres, usually cut to 30–150 mm, delivered for the purpose of yarn manufacture. Similarly, loose cotton is also referred to as loose cotton stock.

Loose stock dyeing Loose fibres, pressed into a cake in a suitable casing, may be dyed with through-flow liquor (Fig. 1). The case has both a perforated inner wall and a perforated outer wall. Reversal of the direction of rotation of the axial pump allows the flow direction of the liquor to be switched between inside-to-outside and outside-to-inside.

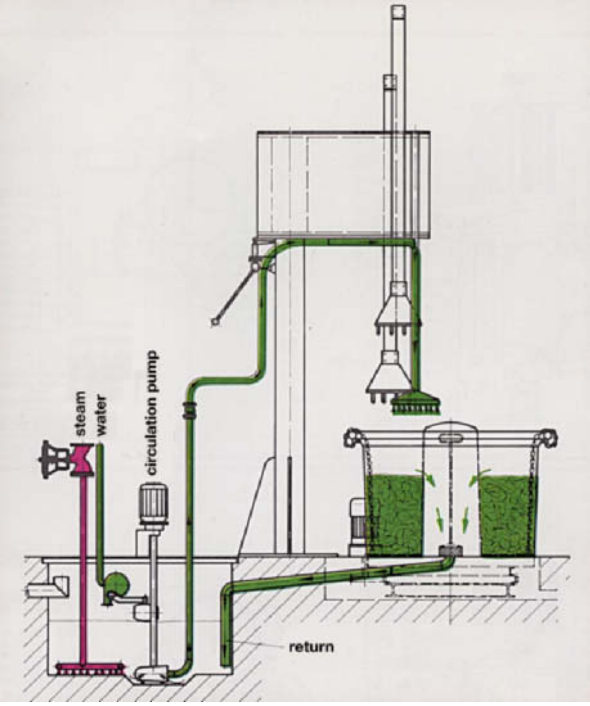


Fig. 1: Loose stock stamping machine.

The Krantz dyeing machine “OF/C1” is used primarily for the dyeing of loose material at temperatures up to 100°C (Fig. 2). The machine includes a built-in reversible axial pump capable of a change rotation and driven by a V-belt.

Loose stock packing device Used for the mechanical packing of loose material in apparatus pack cylinders.

Lot, batch (test batch) the number of items to be presented at a time for product testing. Also used in the sense of consignment in combination with other terms, e.g. production batch, delivery batch.

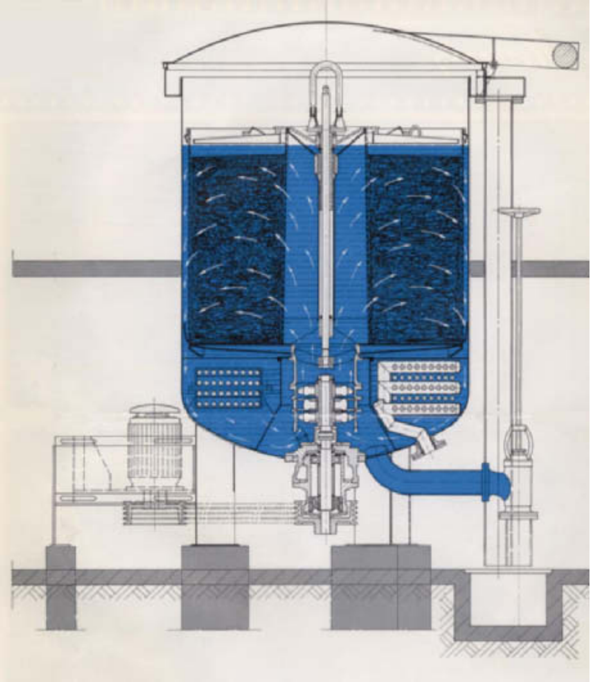


Fig. 2: Krantz loose stock dyeing machine.

Lot size The number of units in a → Lot, batch.

Lot system Dependent upon the organizational combining of all customer orders falling within a period of time so as to make a single large manufacturing order, which may then proceed as a unit through all manufacturing stages up to despatching (one-way throughput has time advantages, avoids leaving single items behind and improves production control).

Low add-on → Low wet pick-up

Low-density polyethylene (LDPE) → Polyethylene.

Low-Dyeing Polyamide → Differential dyeing polyamide fibres.

Low foaming The weak foaming characteristic of general purpose washing powders intended for use in a drum washing machine.

Low-formaldehyde finishing agents Finishing products with a low proportion of formaldehyde in the product (→ Low-formaldehyde resin finishing). From the range of N-methylol- and N-alkoxymethyl compounds, with which one can specifically keep below formaldehyde limit values without impairment of the known technological data. In resin finishing, it is predominantly compounds based on 4,5-di-hydroxyethene urea which are used, which demonstrably do not split off any formaldehyde in the finishing process, and which in the product itself are set to be low-formaldehyde.

Low-formaldehyde resin finishing Resin finishing of textiles with proportions of free formaldehyde on the finished goods being as low as possible. Measures for reduction:

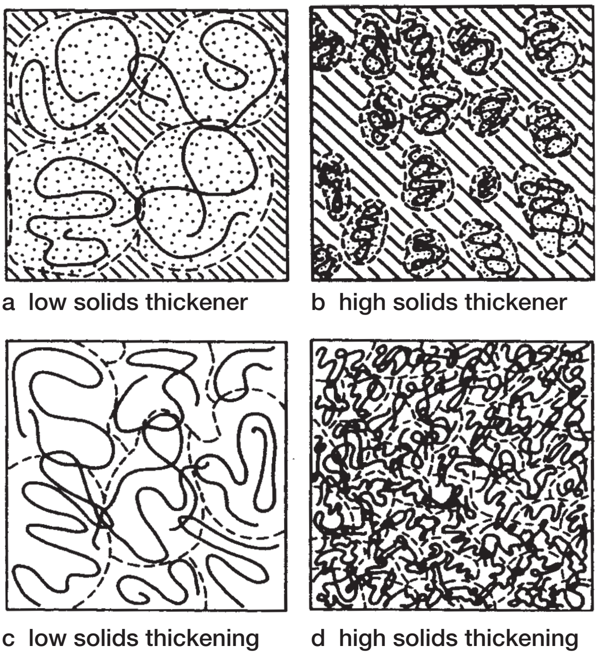
1. Choice of resin finishing products: products with a high resistance to hydrolysis, e.g. based on dimethoxymethyl-4,5-dimethoxyimidazolidone, are usual.
2. Process engineering: e.g. after-scouring of the finished textiles. Addition of formaldehyde acceptors to the finishing liquor, after-treatment with formaldehyde acceptors. When suitable resin finishing products are used, usually no process engineering measures are needed. Formaldehyde limit values on cotton 150 ppm, on polyester/cotton (65/35) 75 ppm.

Low/high solids thickeners Thickening with a small or large amount of → Solids content. Low solids thickeners = slow drying, soft elastic film. High solids thickeners = rapid drying, film more or less brittle/hard, contours standing sharply, but danger of splitting off.

Due to their high molecular weight, low solids thickeners form large gel bundles with a low bundle density. Even with low polymer concentrations, individual snags occur in the edge areas of these gel bundles, so that their freedom of movement is restricted. The viscosity curve shows the sharp rise in viscosity which is typical for the network solution after the critical concentration has been exceeded. The resistance which these polymer solutions demonstrate against a deformation is determined by the resistance which the linkage points of the network demonstrate in relation to mechanical stressing.

The situation with high solids thickeners is different. Initially, with a rise in thickening concentration one observes only a slight rise in the viscosity of the solution. The smaller, denser bundle packages of thickening agent can still move freely at these concentrations, and there is still sufficient free solvent available.

In this concentration range, the viscosity-raising effect of the high solids polymers is based not on the formation of a network, but on the fact that the gel bundles increase the frictional resistance of the flow layers, in that they act, so to speak, as flow breakers. If one increases the proportion of polymers, then with this thickening system too one finally reaches the critical concentration, and a steeper rise in viscosity is observed. The smaller gel molecules now likewise form a network. The figure shows a comparison of the two networks. Although they have a completely different appearance, nevertheless no differences can be established through viscosity measurement. (Manuf.: Schultz).



a low solids thickener b high solids thickener

c low solids thickening d high solids thickening

Fig.: Low and high solids thickener in diluted solution and in concentrated thickening (German Textile and Fibre Research Institute – Deutsche Institute für Textil- und Faserforschung, Denkendorf).

Low-liquor dyeing Dyeing process for yarn packages in circulating liquor machines (stacking system) with liquor reduced approx. 50%. Liquor direction exclusively from the inside to the outside (see Fig.).

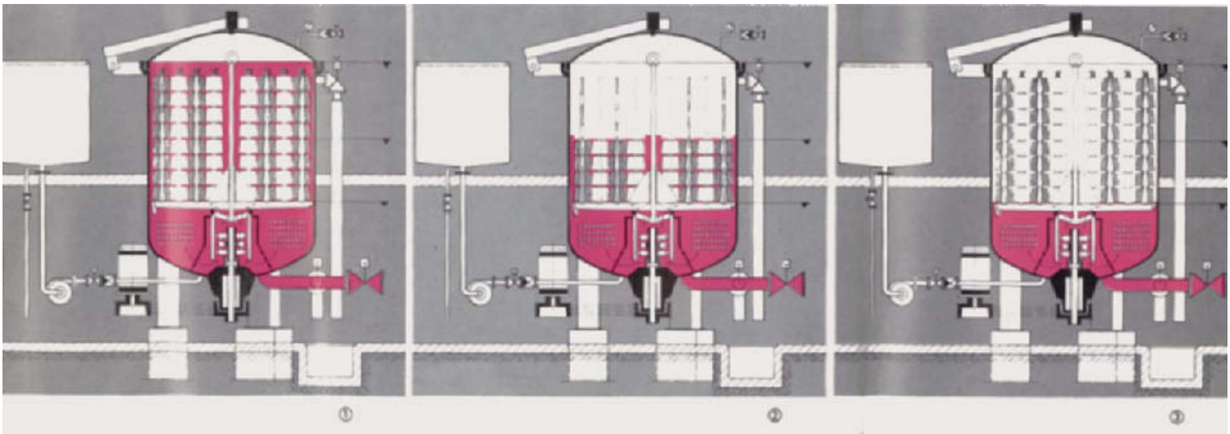


Fig.: Krantz yarn dyeing apparatus using the low-liquor dyeing technique.
1 = pressurized operation; 2 = partially flooded; 3 = low-liquor dyeing method.

Low pressure A low pressure (→ Air pressure). Not to be confused with negative pressure (→ Vacuum).

Low pressure dye winches Pressure winches for use at 103–105°C.

Low-pressure hank dyeing machine Vertical dyer for temperatures up to 110°C.

Low sulphurized oils → Sulphonated surfactants.

Low temperature dyeing Method of dyeing with direct dyes on cellulose fibres by exhaust method, at the lowest possible temperature (40–60°C). Whilst on the one hand there are savings to be made, on the other hand there are significant defects, e.g. lower dye penetration. Among reactive dyes, on the other hand, there is a range of dyes which can be dyed normally “cold”, i.e. at 40/50°C. When dyeing wool, temperatures of less than 80°C (also termed cold dyers) as possible only when larger amounts of solvent agents are used (e.g. formic acid). Actual advantages are yielded by the → Cold pad-batch process, above all when dyeing with reactive dyes on cellulose goods. Direct dyes can also be used when hydrotropic agents are used.

Low-temperature plasma LTP is used for modifying fibres and textiles, as an environmentally friendly and energy-saving alternative to some existing additive finishing processes. A suitable plasma for this is deemed to be a highly active mixture of ions, electrons and excited gas molecules, which can most easily be created through glow discharge at a pressure of ≤ 1330 Pa. For the modification of thermoplastic polymers, the use of LTP with relatively high electron energy together with low gas temperature is of particular interest. The depth of action of the LTP is limited to the surface of the fibre. The changes brought about in the polyester fibres by the action of plasma depend on the type of gas and gas pressure, the specific energy density and the treatment time, as well as on the type of energy supply. The treatment of fabrics of textured polyester fibres with air plasma over a period of 5–30 seconds, at a current density of 0.5-2.0 mA per cm^2 and a gas pressure of 133 Pa brings about considerable changes in the fabric characteristics: reduces the drop penetration time from ≥ 300 seconds to ≤ 1 second, raises the suction height from ≤ 20 mm to ≥ 200 mm; at the same time, the soil-release effect is comparable with the effects which can be achieved with additive soil-release finishing. These effects are wash-resistant. Quite different effects, e.g. hydrophobic, oleophobic or adhesion improvement, can be achieved by mixing inert gases with selected gases, e.g. halogens.

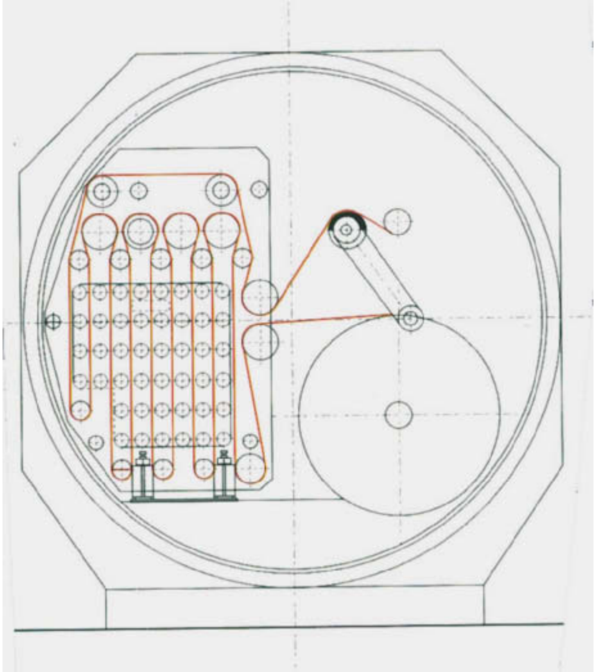


Fig.: Discontiuous plasma application.

Low-temperature plasma process in the textile sector For the modification of textile surfaces. In contrast to the → Corona treatment, in the plasma process the glow discharge takes place in a vacuum of approx. 1 mbar (see Fig). With this process, polymer films can be grafted on; where the wettability can be increased or reduced to hydrophobic effects, as desired. The dyeing affinity can also be altered. → Plasma treatment.

Low wet pick-up Minimum-liquor application; application of finishing liquors to textiles without excess liquor which would subsequently need to be removed. The principal aim is the capillary saturation of the material, e.g. cotton approx. 35% liquor loading, in general < 40% (Fig. 1). If, in the case of low wet pick-up, so little liquor is applied that complete distribution over the width of the goods is no longer possible, this is termed “deficit application”. In the field of textile finishing, low wet pick-up has gained in importance due to the increase in energy costs. However, the qualitative advantages of articles produced using low wet pick-up have also won this technology its place in the range of application methods. Thus the minimum application of

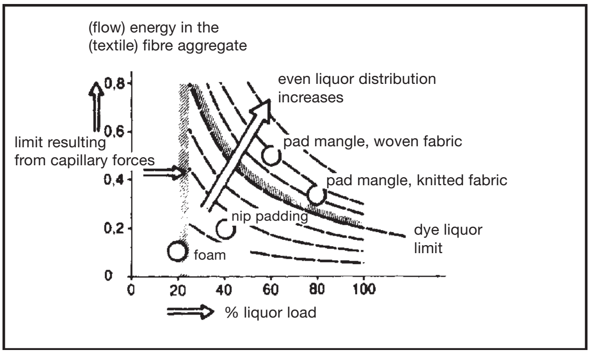


Fig. 1: Relationship of even liquor distribution to the liquor loading and the (flow) energy in low wet pick-up (after Kretschmer).

resin finishing chemicals, e.g. in the case of cotton fabrics, avoids the migration of the cross-linking agents in the water to the fabric surface, and the associated uneven cross-linking over the fabric cross section, since less water needs to be evaporated during drying. In this way, better strength values are achieved for the cross-linked cotton fabric. Besides qualitative aspects, in the case of one low wet pick-up variant, namely foam application, interest is focused on energy-saving efforts.

Low wet pick-up of alkalis for fixing reactive dyes of particularly high reactivity in the two-phase printing process takes place e.g. through spraying the fixing solution in the electrical field through which the printed goods pass.

The purpose of an applicator is to apply products with a carrier medium (usually water) to the goods. A check on the application amount carried out after the application requires that the residues of the mixture which are eliminated in the process can be fed back to the applicator. Ensuring that a precisely controlled amount is applied over the length of the goods is made more difficult by the left-over liquor being fed back and being mixed with the starting liquor, through so-called substantivity effects of individual products present in the liquor. This means that the recirculated liquor has a lower concentration of these products than the original liquor, through which – even if the amount of liquor applied is strictly monitored – the amount of the product received by the goods is progressively reduced. This problem is well known in continuous dyeing processes, but is of great importance in other finishing processes too, such as e.g. in the pre-treatment of cotton goods. The applicators can be divided up according to the criteria shown in the Tab.

1. Application of the liquor in excess amounts, with down-stream removal of the excess.
2. Application of a predetermined amount of liquor (with simultaneous monitoring of the amount of liquor applied).

	pick-up quantity		
	minimal	*normal*	*maximal*
with downstream removal of excess	F + C	F I	F I
with simultaneous control of pick-up	S C P	S	S M **A**

Tab.: Types of pick-up mechanism.
F = pad mangle; F+ = pad mangle with special quetsch system; I = impregnation vat; S = spray system; C = foam; P = pad; M = special pick-up mechanisms; A = addition pick-up.

To remove the excess, as a rule elements are used which simultaneously ensure a subsequent penetration of the liquor into the goods (pressure rollers, and suction extraction devices). In order to achieve the minimum application, attempts were made, using precision pressure rollers and suction extraction devices, to reduce the remaining liquor. The substantivity effects in the recirculated liquor could not, however, be eliminated. In the field of textile finishing, those applicators were considered which permit a one-sided application of the products (usually in the form of high-viscosity pastes). These applicators are among those which apply a controlled amount of the product/medium mixture to the goods, in practice at any rate amounts of less than 1 litre per kilogram.

I. Foam: The starting liquor is mixed with air, through which a slight foam is created. This foam is then applied to the goods, and usually passes through a down-stream doctor blade device or a suction device, in order to remove the excess foam. Main use: resin finishing/finishing.

II. Spraying devices: Jets or fast-rotating disks (WEKO) (onto which the liquor falls in droplet form) are used. Main use: resin finishing/finishing. With this application device, products have to be applied to the textile goods simultaneously with dynamic and thermal energy. The use of jets appears to be the most suitable element for fulfilling these requirements. Although the source of the thermal energy can be freely chosen, it is sensible to match the choice of energy form to the subsequent production processes. In a large number of textile finishing processes (an example of which would be continuous pre-treatment), steam is the medium for the thermal energy. The concept of a simultaneously acting application device therefore led to the idea of using steam/chemical liquor mixing jets for spraying the chemical liquor onto a run of textile goods in the steam box (Raco-Yet). Dual-substance mixing jets are well known in engineering, but they are operated exclusively with compressed air.

III. Slop-pad systems: A thin film of the liquor which is to be applied is created on a cylinder with a highly polished surface; this film is then transferred to the goods either via contact, or through an intermedi-

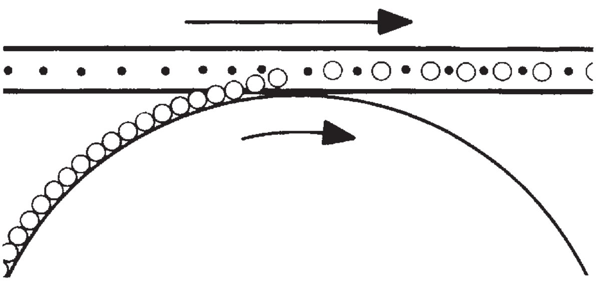


Fig. 2: Low wet pick-up concept.

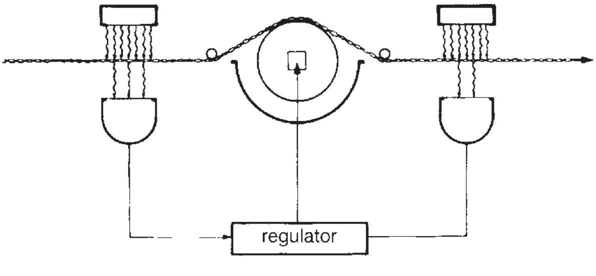


Fig. 3: Closed control loop in the Triatex-MA system.

ate carrier cylinder. Main use: resin finishing/finishing.

The speed ratio of fabric and application roller determines the application amount precisely and reproducibly. This low wet pick-up technology is made possible by a specially developed low wet pick-up plant with measurement and control technology (Fig. 2). The result is a continuously monitored minimum application, which can be set (Fig. 3). The low wet pick-up technique yields the minimum application necessary for capillary saturation without excess liquor. The treatment processes for applying finishing products are concluded by drying.

LP Abbrev. for Low Pressure (steam); → Steam.

LR Abbrev. for → Liquor-to-goods-ratio, in job specifications.

Lr Symbol for the element Lawrencium (103).

Lu Symbol for the element Lutetium (71).

Lubricants These serve to improve the ability of fibres to slide over one another in material processing, e.g. →: Scrooping agents; Sewing thread lubricants; Textile lubricants.

Lubricating felt Felt or leather soaked in oil, for cooling the top blade spirals on → Shearing machines.

Lubrication → Yarn lubrication.

Ludigol treatment Name given to the impregnation of printed goods with Ludigol (BASF), a weak oxidant (m-Nitrobenzol sulphonic acid sodium), which is used in order to render harmless any unwanted coatings on the goods left by printing pastes containing reducing agents. In coloured discharge printing (with vat dyes) on well-dischargeable ground coats, Ludigol can be dispensed with. Working method: usually on printing machines with a finely engraved roller, or by slop-padding of the background (see Fig.). Can take place before or after printing and drying. In flat screen printing, serves to intercept any splashing discharge agent by means of oxidation, and thus avoids unwanted discharge stains.

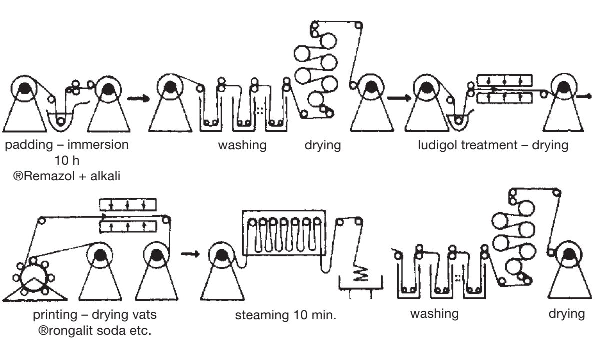


Fig.: Classic discharge-dye articles with impregnation based on ludigol.

Lukewarm, tepid Temperature of 30–35°C; in care instructions, 32–43°C.

Lumen,

I. Unit of → Luminous flux.

II. Cavity in the single-celled cotton fibre, which encloses the dead protoplasms. In turn, it is enclosed by the so-called tertiary, secondary and primary walls in the cotton structure.

Luminescence (Latin): Luminous light emitted by bodies below the normal incandescent temperature, in filtered UV light, with the colour and intensity depending on the chemical composition of the respective substance. Unfiltered, the invisible short-wave rays (→ Light wavelength) are absorbed; filtered, they are converted into visible, longer-wave light (complementary colour). Important use of luminescence in textile finishing through optical brighteners, i.e. products which themselves are non-coloured, but which when activated by the UV also present in daylight are stimulated to blue fluorescence, and thus increase the apparent whiteness. In a stricter sense, we talk of → Fluorescence and → Phosphorescence. The wavelength of the luminescent light is usually the same as or greater than that of the exciting light, but never smaller (Stokes' rule). In concrete terms, a distinction is made according to the origin of different types of luminescence:

I. Photo-luminescence: the luminous effect through absorbed light which is emitted immediately in another wavelength (fluorescence), which yields more or less after-glow after the light source has been switched off (phosphorescence).

II. Chemo-luminescence: the luminous effect caused by chemical reactions, where energy which is released does not convert into heat as it usually does, but directly into light (typical luminescence of phosphorous through air oxidation of the phosphorous vapours). Occurs as bio-luminescence in certain organisms (e.g. glow-worms).

III. Electro-luminescence: where luminous gases are electrically discharged (fluorescent lights).

Luminescence analysis Practical application for the filtered UV light which is produced by UV lamps, qualitative evaluation of any → Luminescence which occurs, whose appearance can vary depending on the chemical composition, through which numerous characteristics are revealed which would escape detection when observed in daylight. Influences which are to be taken into account here: light source, filter, object form (solid, powder, liquid), possible solvent, temperature, reaction, level of purity (constitution), particle size etc. Used for detection or differentiation in numerous textile-chemical investigations, e.g. of fibres, maturity of cotton, fibre damage (over-bleaching or oxycellulose, acid- or alkali damage etc.), dyeing (identity, differences in evenness), impurities or residues of warp glazes, sizing agents, textile lubricants, scrooping agents, numerous oils and greases, stains (mould, fungus, metal soap, oil stains, etc.; detection of blood), etc. The results can be assessed photographically.

Luminescent pigments, radioactive (→ Luminophores). Pigments which are made luminous by added radioactive elements. They are classified into 13 stages of brightness. When processed with binding agents, they form so-called radioactive luminous colours.

Luminophores A group of inorganic and organic substances which yield either → Luminescence (radioactive preparations), → Fluorescence (mostly organic, so-called fluorescent dyes), or → Phosphorescence (mostly inorganic, so-called phosphors).

Luminous colours → Phosphors.

Luminous control panel Orientation image in the control and regulation of automated technological processes. Individual symbols contain signal lamps which signal the operational status of the plant, e.g. with flashing and steady lights, or which with the aid of different colours enable faults to be spotted, together with their causes.

Luminous dyes → Fluorescent dyes.

Luminous flux The derived → SI unit is the lumen (unit symbol: lm).

Lunar caustic → Silver, silver nitrate.

Lustra fabrics (from "lustre"). For these goods, highly lustrous wools or hair are used; besides coarse wools, these include mohair and alpaca. In some cases the warp is of viscose and the weft of more lustrous material.

Lustre in textile finishing When a ray of light falls on a surface, it can be reflected or absorbed, or can pass through the material (Fig. 1). In many cases, these three phenomena occur alongside one another. Since lustre is mainly a surface phenomenon, in general the reflected light is accorded the greatest significance. However, the impression of lustre is often decisively influenced or modified accordingly by the light absorption (colour) and the transparency of the body. Two types of light reflection are distinguished: mirror reflection (complete mirror) and diffuse reflection (Fig. 2).

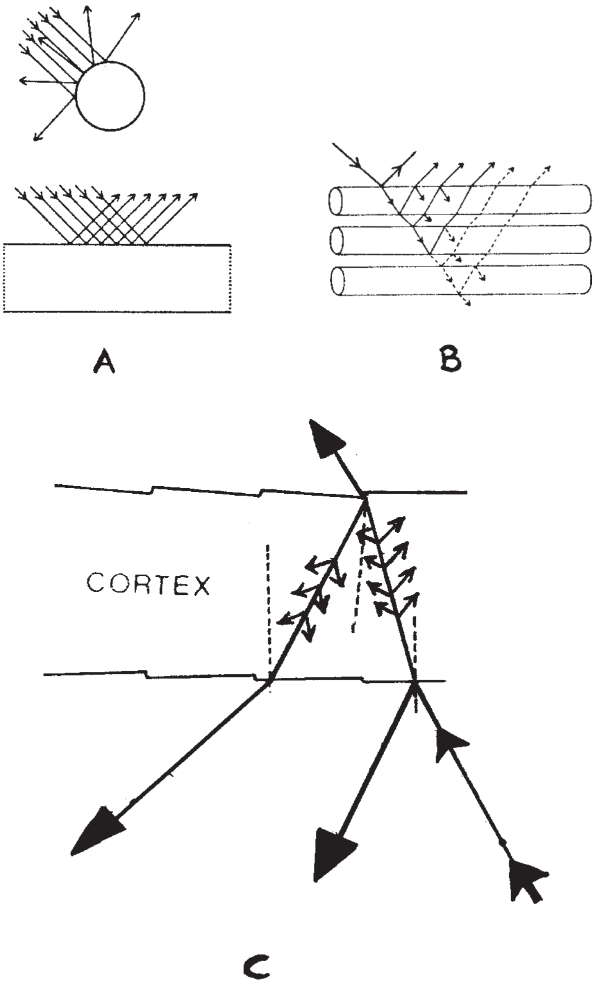


Fig. 1: Reflection (A), refraction (B) and absorption (C) of the impinging light.

The term "lustre" describes a subjectively perceptible optical impression of a surface. Lustre is defined as a "physiological-optical impression of contrast"; a surface is lustrous if its brightness appears to differ at different directions of observation or incident light. On the other hand, a surface is perceived to be matt if it conveys the same impression of brightness from all angles of observation and regardless of the direction of incident light. These optical impressions are based on the fact that in matt surfaces, the individual surface elements which reflect the incident light in a regular manner (which must be small enough not to be detected as an individual surface by the resolution capabilities of the eye) are oriented in such an irregular manner that on the statistical average no direction is preferred. In the case of lustrous surfaces, on the other hand, these surface elements are present in an orderly state. The nature of this order depends on the structure of the surface. In an item of fabric, the degree of order in the surface elements of the fibre material – which reflect the light in a regular manner – is determined by the following features of the fibre or elementary filaments:

- surface condition,
- cross-sectional shape,
- fineness (diameter),
- axial spatial curvature in the yarn and weave relationship.

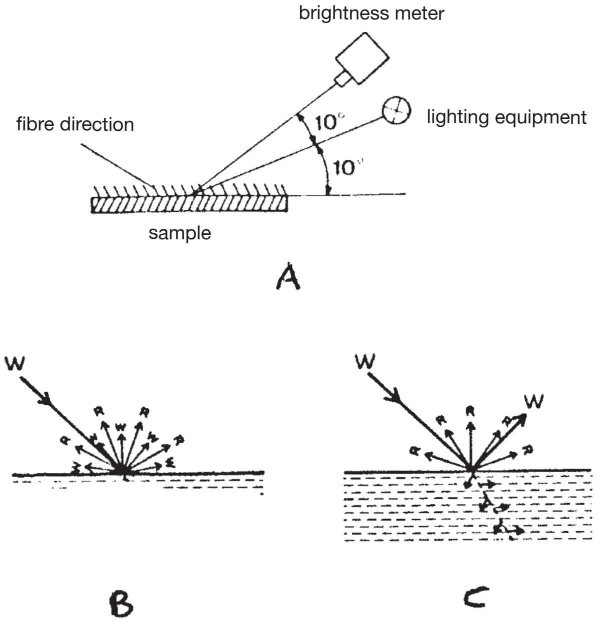


Fig. 2: Mirror reflection (A), diffuse reflection (B) and C: mixture of A and B.

Fibre materials whose surface elements are already of irregular orientation due to the first two features lead to matt fabric (regardless of their fineness and their axial spatial curvature). Fabrics made of fibre materials whose surface elements are present in an ordered state, due to their surface condition or their cross-sectional shape, have less lustre, the higher the fineness (the smaller the diameter) and the stronger the axial spatial curvature of the fibres or elementary filaments; in both cases the degree of ordering of the surface elements is reduced. The first three features are specific to the fibre substance. In the case of chemical fibre substances, these are determined by the spinning process. The axial spatial curvature can be influenced

- by crimping of the fibres, or through texturing of the filament yarns,
- by the yarn twist,
- by the thread- and fabric construction,
- through the formation or reinforcement of fibre ends or loops projecting from the fabric construction, e.g. through brushing or emerising.

These measures reach their limits where, for other reasons e.g. certain fabric constructions are required, smooth filament yarns with low twist have to be used, or the thread- and fabric construction excludes a roughening or emerising process. For fabrics of polyester and polyamide fibre substances, another possibility for reducing lustre, which is due to features specific to fibre substance, consists in equipping the surfaces of the fibres or elementary filaments with a micro-structure. This includes the alkalisation of polyester fabrics and the UV laser radiation of polyester fabrics and polyamide fabrics. In both cases, fibre substance is worn off, and the new surfaces are scarred or have a “hill and valley structure”. Through these methods, a surface condition of the fibre substance is created which is similar to that which natural fibres have, or to that which special polyester fibre substances acquire from the spinning process. Whilst the reinforcement of the axial spatial curvature of the fibres or elementary filaments in the yarn and the weave only indirectly leads to a reduced lustre, with micro-structuring of the fibre surface the actual cause of the lustre is eliminated.

In textile finishing, lustre (also termed sparkling effect) is created with pearlescent pigments as well as with spangles and sequins. Pearlescent pigment diameter 1–100 µm (in textile printing, predominantly 60 µm), spangle and sequin diameter 100–1000 µm. Pearlescent pigments are transparent, thin, plate-like pigments with high refractive indices, smooth surfaces and without any natural colour where possible. As the name suggests, pearlescent pigments are pigments which lend the objects on or in which they are located an appearance which is similar to mother of pearl. Furthermore, pearlescent pigments can be used to achieve effects which lend many objects a more pleasing or attractive and value-adding appearance. The most important pearlescent pigments are natural fish scale, basic lead carbonate, bismuth oxychloride and titanium dioxide mica. Of these, due to their mechanical, chemical and physiological characteristics, only titanium dioxide mica is considered for textile applications. Titanium dioxide mica pearlescent pigments (Fig. 3) are produced by applying a thin layer of titanium dioxide onto mica. The mica particles, with thicknesses of 200–500 nm and diameters of between 3–1500 µm serve as carriers for the titanium dioxide layers, which are around 50–150 nm thick.

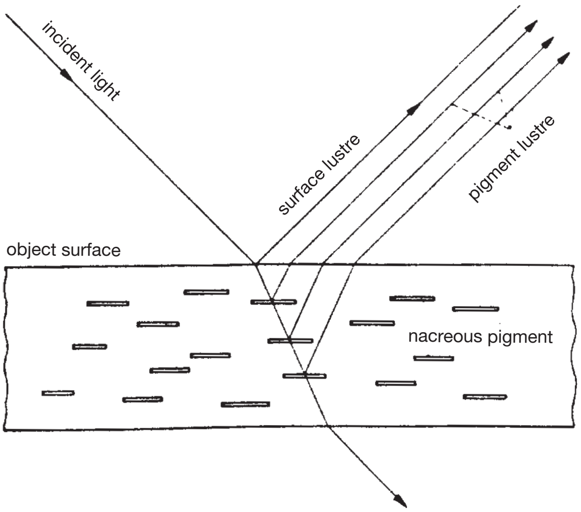


Fig. 3: Schematic diagram of the inter-reflection characteristic of nacreous pigment.

Pearlescent pigments owe their lustre, like the metal-effect pigments, to their lamellar form. However, unlike the latter, they consist of translucent, strongly refractive substances. In the case of parallel orientation, only a proportion of the incident light – which depends on the refractive index – is reflected, whilst the rest is let through and is divided up on further pigment lamellae in the same way. The lustre is said to come from deep down. Titanium dioxide micas are divided up by the manufacturers into areas of differing granulation. This classification runs from silk matt to glitter effects. Titanium dioxide mica pearlescent effects must be resistant to acids and alkalis, as well as to high temperatures and the solvents used in dry cleaning.

For the sake of completeness, bronze print should also be mentioned. Besides the silver-white pearlescent effects which dominate in textile printing, in the efforts to preserve lustre wherever it can be achieved, the so-called interference pearlescent pigments have become established in some print collections. In physical terms, an interference colour is defined as a colour which depends on the thickness and double refraction of a crystal, which arises when light passes through this crystal. Interference phenomena, also known as colours of thin lamellae, occur in the reflection of light on thin, permeable layers such as mica, soap bubbles or oil films. Interference pigments are produced in the same way and from the same raw materials as the corresponding colourless pearlescent pigments, from which they differ only in terms of dimension. The difficulty with their manufacture lies in the fact that all the lamellae must be exactly the same thickness as far as possible; deviations of the mean lamella thickness of just a few nm can be perceived by the naked eye as a colour displacement. Due to their unique physical nature, special effects are possible with interference pigments. In the case of parallel orientation in colourless media, they show complementary colours in the top view and through view, which vary with the angle of observation and lead to changing colour effects. This is particularly effective on goods which have previously been dyed dark. The application of pearlescent pigments in textile printing takes place largely in accordance with the same rules as are known for printing with bronze powder brands.

Glitter printing has been established for some years, particularly in motif printing. Through simple modification, lurex-like effects can be achieved via a whole-surface application; the diversity of the shape and colour of the glitter available opens up a wide colour range. A paste which contains 2–5 grams of polyester glitter and other additives is applied to the whole surface of the textile material, either similarly to a one-sided doctor finish, or by printing. The screen mesh size depends on the fineness of the mica. Work is carried out with a 60 mesh screen on a rotary printing machine. Afterwards, it is dried and fixed for 5 minutes at 150°C dry heat.

Lustre, measurement of Lustre, defined as the reflection of directional or specular rereflection, can be recorded subjectively by means of comparison measurements against normal white, or objectively with a photoelement. The measurement results which are found must not be confused with those of diffuse reflectivity, which is recorded e.g. in the case of coloured surfaces as the degree of remission via colour measurement with devices in the manner of the photoelectric universal colorimeter with reflector insert, or with devices for special technical purposes with simpler reflection measuring devices on a similar principle. In measuring lustre, the illumination should always be precisely at a certain angle (usually 45° in this case, non-standardised) to the surface of the goods to be measured. Colour measurement devices can also be used for measuring lustre. Usual lustre measuring devices are e.g. goniophotometers for static goods, whilst reflection spectrometers or laser scanners are used for measurements on moving goods. For all devices, the method is based on the recording of light energy by a detector. The difference is that in the latter, the goods move in the goods direction, and are thus scanned by the light beam. Through this, the detector detects differing energy values, which are dependent on the reflection; with the graphic or computational evaluation of these, one can draw conclusions about the thread density, surface structure and lustre. The fewer fluctuations the established light energy has, and the higher its intensity, the higher the lustre of the goods. The formula for calculating the lustre L in % is:

$$L = \frac{(Y_H - Y_L) \cdot 100}{Y_L}$$

where

Y_H = reflection maximum,

Y_L = reflection minimum.

The values depend on the device.

Lustring,

I. Constituent part of yarn finishing for the production of yarn with a high lustre and high level of smoothness. Takes place by means of solubilised bleach and waxes, paraffin, etc., as well as mechanical processing, which brings about adhesion of projecting fibre tips to the fibre core; e.g. through dry smoothing under stretching, rubbing, pressing and brushing treatment, between heated pairs of rollers etc. (lustring, glazing, polishing machines).

II. In the lustring of fabrics (pile fabrics), a combination of beating, brushing and waxing serves to achieve a standing, glossy pile.

Lux Unit of → Illumination.

Lyobipolarity If one compares this with the term tenside or surface-active agent, then in the latter the inter-granular activity and the surface tension-lowering characteristics which it can bring about are quite specifically highlighted, whereas the term lyobipolarity expresses the polar dimorphism of the molecule and the associated orientation tendency in the interface. Thus lyobipolarity is the characteristic, generally of higher-molecular chemical compounds, of simultaneously having affinity for two solvent media which cannot be dissolved in one another (e.g. water and inorganic solvents) (hydrophilic and lyophilic), due to their bipolar structure. One consequence is enrichment at interfaces, of which the case of emulsification of both solvent media with one another is an example. Typical examples include dry cleaning detergents, soluble in both organic solvents and water (fibre moisture, dirt/moisture) and enabled - through bipolarity - to form a clear solution with water (→ Solubilising power), which enables the cleaning-promoting activity in the first place. Lyobipolar compounds include e.g. sodium oleate $C_{17}H_{33}COONa$ (soluble to 10 parts in water, to 20 parts in alcohol), sodium dodecyl-benzol-sulphonate etc. On the other hand, we know of lyounipolar compounds which have affinity either only to water (hydrophilic) or only to oil (lyophilic). Lyobipolarity can be weakened or strengthened by the addition of adsorbable molecules.

Lyocell fibre finishing Cellulose is a natural polymer, a resource that can be regenerated at will, with reserves all over the world. The gross annual production of plant cellulose is 26 x 10^6 t, the potential is hundreds of millions of tons. Like natural cellulose fibre, regenerated cellulose fibre has many advantages: good moisture absorption, anti-static properties, good dyeing properties, easily made flame-retardant and produces comfortable clothing. On the other hand, regenerated cellulose fibre such as viscose, which can cause pollution problems in the spinning process, has many disadvantages: it has a lower wet tenacity, the production cycle is longer, etc. Lyocell fibre is a new solvent-spinning cellulose fibre with many advantages: higher tenacity, shorter production cycle and it causes no pollution.

By upgrading the plant capacities for lyocell fibres, which are spun from the solvent NMMO, the prerequisites have been created for the propagation of this novel fibre type. With its characteristic features, such as tendency to fibrillation, high wet tear resistance and environmentally friendly manufacturing process, this fibre is bound to conquer new territory. In particular in the field of highly fashionable garments, high-grade denim articles, underwear and technical textiles, this new fibre type is expected to partly edge out viscose, modal, polynosic and cupro fibres, but also cotton and synthetics. Economical and ecological aspects as well as the limited availability of cotton speak for this innovative fibre type.

If one compares the various regenerated cellulose fibres, one will notice that lyocell fibres differ from other fibres in two essential points (Figs. 1 + 2). Their distinct tendency to fibrillation and their high tear strength make it possible to create new fashionable articles using special process technologies. Due to their high wet tear strength lyocell yarns can, for instance, be used on special rope, slasher and loop dyeing ranges for warp dyeing with indigo.

The active group of amine oxides, which dissolve cellulose, was discovered sixty years ago. Since substances of this kind decompose easily, particularly at raised temperatures, in contact with reducing groups - i.e. with end groups of cellulose for example - or under the influence of metal ions, the former were only able to assert themselves roughly 30 years later when N-Methyl-morpholine-N-oxide, which is considerably more stable, was discovered. Now known as NMMO, the product haunts scientific journals (Fig. 3). Up until a few years ago, it was not possible to obtain NMMO in the quantities required for industry since no alternatve industrial application was known until then. The high costs of the solvent, for the reason just named, demanded the development of an almost closed circuit process. This can, however, only be accomplished when the manufacture of the solvent in particular is designed so as to prevent thermal decomposition of the NMMO apart from stabilising and recovery technologies.

Amine oxides are not new substances. They are practically ubiquitous, which means that they, for example, make up a considerable washing-active part of personal hygiene products which normally undergo intensive dermatological and toxicological examinations. It should, therefore, be possible to deduce toxicological

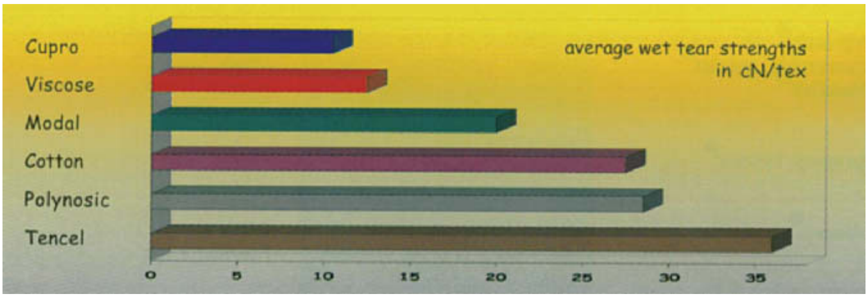


Fig. 1: Comparison of wet tear strengths in cN/tex.

fibre type	cotton	viscose	modal	polynosic	cupro	lyocell	lyocell LF
titre dtex	1.8	1–100	1.0–3.3	1.3–4.2	1.4–2.2	0.9–3.3	1.3
tear strength cond. cN/tex	24–28	20–24	34–36	35–40	15–20	40–44	34–36
elongation cond. %	7–9	20–25	13–15	10–15	7–23	14–16	10–12
wet tear strength cN/tex	25–30	10–15	19–21	27–30	9–12	34–38	28–31
rel. wet strength %	105	55	57	75	60	85	–
elongation wet %	12–14	25–30	13–15	10–15	16–43	16–18	13–15
degree of polymerization	2000–3000	250–350	300–600	500–600	450–550	550–600	–
loop strength cN/tex	–	10–14	12–16	8–12	–	18–20	15–17
fibrillation tendency	2	1	1	3	2–3	4–6	2
water retentivity %	45–55	90–100	75–80	55–70	100	65–70	63
crystallinity %	–	25	25	40	25	40	45

Fig. 2: Comparison of the properties of various cellulosic fibres.

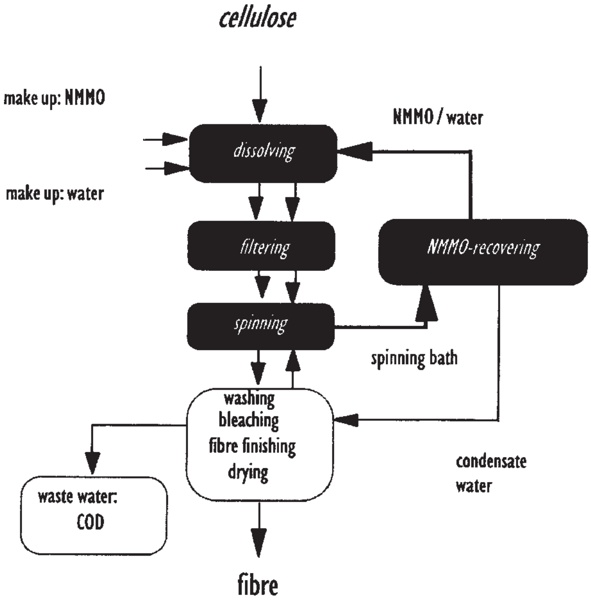


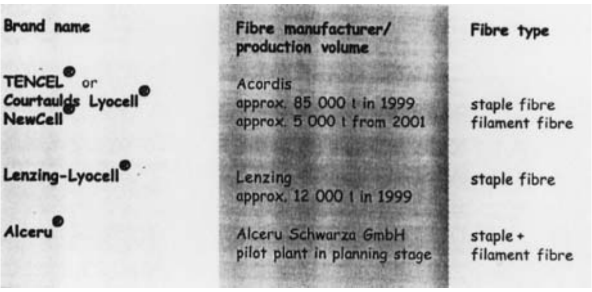
Fig. 3: NMMO.

safeness for industrial applications. Toxicological examinations were of course also carried out on NMMO itself. In the five examinations on hand carried out on various living organisms in the food chain, i.e. on rats - representing mammals - fish, small crayfish (Daphnia), algae and bacteria, it was apparent that NMMO is less toxic than ethanol. The discovery that the mutagenesis test according to AMES was negative was also of great significance since NMMO is considered toxicologically and clinically harmless.

The extremely high amount of water required for cotton immediately catches the eye. Compared to cotton, lyocell reveals lower consumption factors, and requires only half the amount of chemicals, which are not nearly as environmentally harmful, since cotton, for example, requires a share of those chemicals to protect it from pests - environmentally harmful and health-hazardous chemicals such as pesticides, insecticides and fertilisers are still necessary - which makes it necessary to test cotton prior to its use. Lyocell easily complies with the Eco-Tex 100 Standard.

During the preparation of the spinning solution and the spinning process, although lyocell fibre may come into contact with amine oxide, the crystal type of lyocell fibre still belongs to cellulose II, like viscose staple and viscose filament. The molecular weight distribution of lyocell fibre is narrower and the average molecular weight of lyocell fibre is larger than that of viscose fibre. Moreover, the microcosmic stucture of lyocell fibre is more compact and the degree of orientation is also larger than that of the common viscose fibre.

According to BISFA the generic name for these fibres is lyocell (symbol: CLY). This term comprises all cellulosic fibres spun from an organic solvent. Fig. 4 gives a survey of the various brands and manufacturers. In the clothing sector, the fibre is mainly available at a fineness of 1.3 or 1.7 decitex and as wool type at 3.3 decitex. Lyocell microfibres of around 0.9 decitex are in the trial stage. The worldwide production capacity of approx. 110 000 tons per year is expected to be achieved in 1999. In the group of regenerated cellulosic fibres, lyocell already ranks second after viscose and before cupro, modal and polynosic fibres.



Brand name	Fibre manufacturer/ production volume	Fibre type
TENCEL® or Courtaulds Lyocell® NewCell®	Acordis approx. 85 000 t in 1999 approx. 5 000 t from 2001	staple fibre filament fibre
Lenzing-Lyocell®	Lenzing approx. 12 000 t in 1999	staple fibre
Alceru®	Alceru Schwarza GmbH pilot plant in planning stage	staple + filament fibre

Fig. 4: Market survey.

Lyocell fibre finishing

There are two ways of processing lyocell that have asserted themselves in the market: About 40% of the fibre is processed conventionally in piece or hank form; the majority is, however, processed as made-up garments. Scarcely any other fibre imposes comparable requirements on process technology and textile chemical/finishing know-how on the way from the fibre to the ready-for-sale textile. With this fibre in particular, it is essential to realise that not only the finisher is responsible for a successful finish, but all those that are involved in the production of the textile. For this reason (Fig. 5), all members of the textile chain, from the fibre producer, spinner, weaver or knitter, finisher, machine constructor, dyestuff and auxiliary supplier, right through to the maker-up and garment washer, are dependent on close cooperation. Since the characteristics of a lyocell product are decisively determined by the yarn and fabric construction, standard processing routes or recipes can only be a guideline for the optimum process in each case.

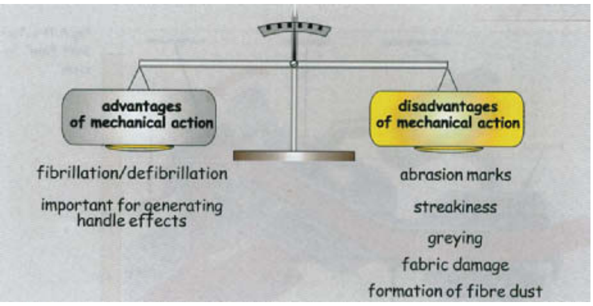


Fig. 5: Lyocell fibre advantages and disadvantages of mechanical action.

The two decisive machine-related factors that determine the possibilities and limits of a lyocell finish are mechanical energy input and a smooth running of the goods. Free movement of the goods is essential for a uniform fibrillation and largely depends on the machinery used. Due to the high swelling of the fibres (Fig. 7) the spaces between the fibres, especially when woven, are reduced and the textile becomes less flexible. Smooth running of the textile becomes more difficult. With rising square metre weight, the risk of abrasion marks and running creases grows. This undesired side effect can be controlled by blending lyocell with synthetic fibres, such as polyester or polyamide, that do not or only slightly swell. For 100% lyocell fabrics an open-width alkaline treatment is recommended.

Lyocell fibres differ in structure and several textile properties from conventional viscose fibres. The high fibrillation tendency, which is shown in wet state in mechanical stress, is characteristic of lyocell. This phenomenon is used to give textiles interesting surface effects. The fibrillation reduction can be realised by cross-linking the cellulose chains. In textile finishing mainly reactant cross-linking agents with low formaldehyde are used. The improved wet abrasion behaviour and the reduced wash greying of the lyocell textiles

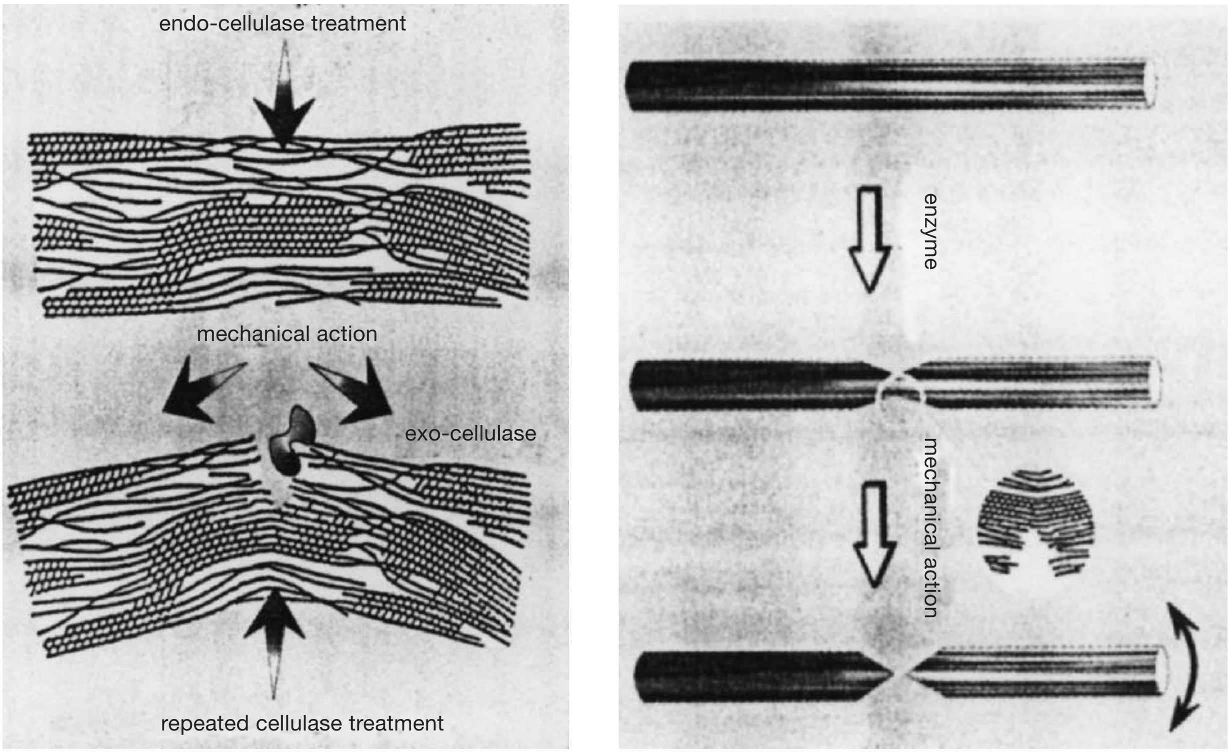


Fig. 6: Fibrillation mechanism.

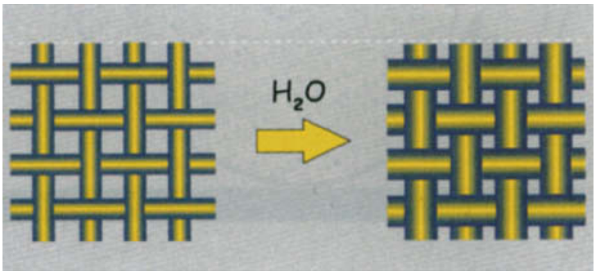


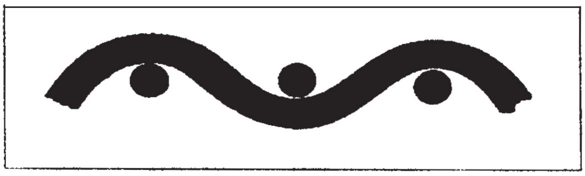
Fig. 7: Fibre swelling.

prove the positive influence of cross-linkers on the fibrillation behaviour. As resin finishing is not always desired, alternative cross-linker systems had to be investigated. One possibilty are the multifunctional reactive dyestuffs. High fixation yields and excellent colour fastness are reached by using these modern dyestuffs. The existence of more than one reactive group in the dyestuff molecule is a prerequisite to make cross-linkages between cellulosic hydroxyl groups possible.

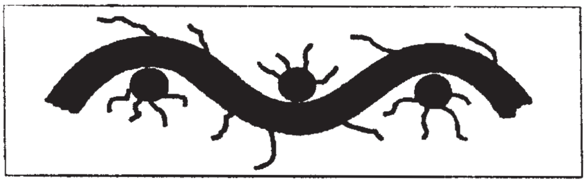
To get an objective assessment of the fibrillation of lyocell fabrics a modified wet abrasion test, according to Martindale, is suitable. This method includes the chafing of the wet fabric until holes are visible. The fibrillation tendency of lyocell fibres can be influenced by dyeing with multifunctional reactive dyestuffs, but not all bi- and polyfunctional reactive dyestuffs cause the same effect. The constitution of the dyestuff molecule and the application conditions also influence the wet abrasion resistance. Different reactive dyestuffs applied in the same initial concentration do not give the same results concerning wet fibrillation. Surprisingly there are even differences between two monofunctional dyestuffs. The higher wet fibrillation resistance using Reactive Red 158 is explainable by the bireactivity of the difluorodichloropyrimidine group. This group not only makes it possible to create covalent bindings, it possibly causes the creation of hydrogen bridges, which again might be the reason to make cross-linking feasible. Similar effects have been found by resin finishing with so-called self cross-linking agents. Just a minimum increase of the wet fibrillation resistance is reached using Reactive Blue 211. The reason is probably the relatively rigid arrangement of the two MCT-groups in the centre of the dyestuff molecules, which in the first place just leads to a one-sided fixation of the dyestuff. Compared to Reactive Blue 211 the symmetric and the lateral arrangement of the two VS-groups on the chromophore of Reactive Black 5 improves considerably the wet fibrillation behaviour. This is also valid for the bifunctional Reactive Blue 225 and the trifunctional Reactive Red 228. The hetero-bifunctional dyestuffs Reactive Red 198 and Blue 235 fit into a medium wet abrasion level.

Until now nothing was known about the changes of the wrinkle behaviour of lyocell fabrics by applying multifunctional reactive dyestuffs. The cross-linking reactivity of several dyestuffs gives reason to expect results even here. Even though the dry wrinkle recovery angle does not change much, the wet recovery angle depending on the dyestuff has increases between 24° and 52°. An exception is the dyestuff Reactive Blue 19. Having just one-functional binding, it causes only small changes of the wet wrinkle recovery behaviour of the lyocell fabric. The difference between the dry and wet wrinkle behaviour of reactive dyed fabrics is connected with the swelling state of the fibre during the cross-linking reaction. The fibres are swollen during dyeing. The incorporation of dyestuff cross-linking bridges in the wet state causes the self-flattening of the lyocell fabric only if the fabric itself is wet. The dry state of the fabric has hardly any effects because the cross-linking bridges are not tightly tensed any more. In

a) raw fabric – without fibrillation/hairiness

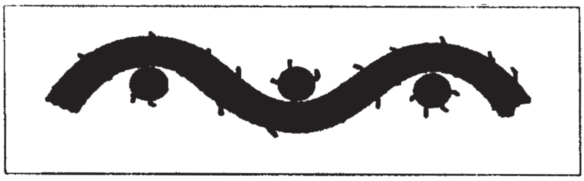


b) raw fabric – with yarn fibrillation



c) linty fibrils after primary fibrillation

d) fabric after cellulase treatment



e) secondary fibrillation (“Peach Skin” effect)

Fig. 8: Fibrillation mechanism.

cross-linking lyocell fabrics with reactive dyestuffs, a connection is found between wet abrasion resistance and wrinkle recovery behaviour.

Today's society expects both a good wash-and-wear behaviour and good wet and dry wrinkle recovery. Therefore the effects of the combination between reactive dyeing and resin finishing are important. Dyeing was carried out with a monofunctional and a bifunctional dyestuff. During the following dry cross-linking process the reactant cross-linking agent Fixapret ECO (BASF), containing low formaldehyde, was used. Wet fibrillation tests of the treated fabrics should give answers to the fibrillation behaviour. The fabrics which were only dyed confirmed experiences that the monofunctional dyestuff does not increase the wet fibrillation tendency. Only the following reactant resin finishing process causes a higher wet fibrillation level, depending on the amount of cross-linking agent used. The bifunctional dyeing process shows a definite dependence of the wet fibrillation resistance on the dyestuff concentration. These wet abrasion values are altogether on a higher level than with the monofunctional dyestuff. Using 40 g/l Fixapret ECO in a 2%-dyeing, wet abrasion values of more than 1000 are reached, which is at the same level as non-finished viscose fabrics and thus should not show any fibrillation problems. Similar to the wet abrasion behaviour the monofunctional reactive dyestuff influences wet wrinkle recovery angles to a smaller extent than the bifunctional dyestuff. Neither the monofunctional nor the bifunctional dyestuff improves the dry wrinkle recovery angle. By additional cross-linking with Fixapret ECO, 40 g/l cross-linker causes an average increase of the wet wrinkle recovery angles by 50° and the dry wrinkle recovery angles by 30°, compared to the raw fabric.

Besides the reactive dyestuffs, colourless textile auxiliaries exist, which possess reactive groups and are able to react with hydroxyl groups of cellulose. Examples of these are Sandospace R paste, which is a reserving agent of Clariant, and the test product AE 4425 (Ciba Spezialitätenchemie), which was developed for a controlled fibrillation of lyocell. Out of many tested Clariant products Sandospace R paste is a favourable product in the exhaust procedure concerning the increase of the wet abrasion resistance of the lyocell fabrics. Both with Sandospace R and with AE 4425 the results of the wet abrasion resistance of the lyocell fabrics are increased by using comparable amounts of pure substances depending on the concentration. With parallel tests with lyocell fibres treated the same way deficiencies in the textile features occurred, which is why the initial concentration should be under 6% related to a 100% pure cross-linking agent. The wrinkle behaviour of lyocell fabrics finished with the two products shows similarities with the bireactive dyed fabrics. This also seems to indicate that there is a cross-linking reaction.

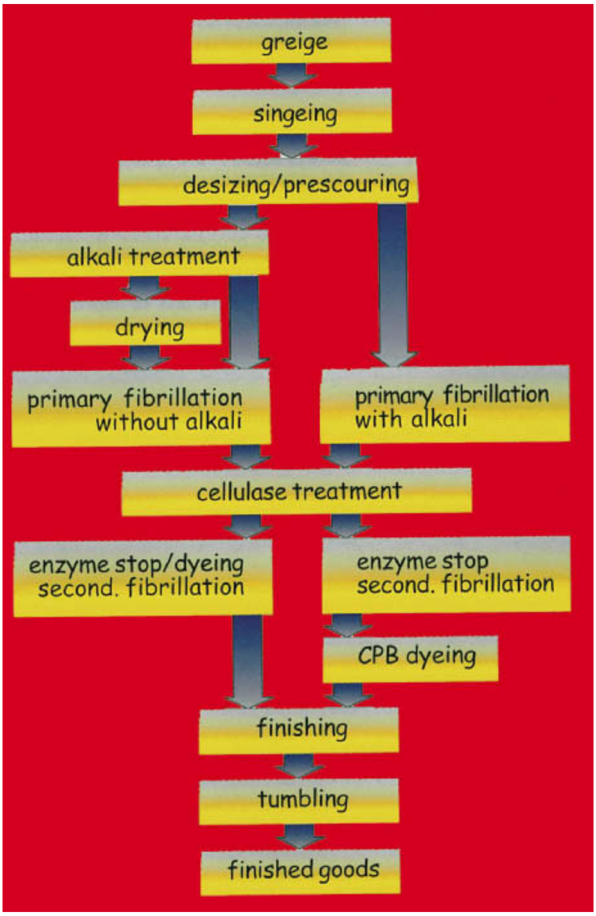


Fig. 9: Example: Combined open-width/rope treatment.

The swollen state of the fibre in the cross-linking reaction step is the reason for the large increase of the wet wrinkle recovery and for the fact that the dry wrinkle recovery angle does not change much.

A typical example for production of a peach skin effect on woven fabric contains the following finishing route (Fig. 9). After singeing and desizing in open-width, the fabric is treated open-width with alkali. The fibre swells substantially at this stage. Even when the alkali has been washed off, the fibre remains slightly swollen. This has a positive effect on subsequent wet finishing processes because it makes the goods more flexible and thus improves running properties. The risk of permanent crease marks is lower than if initial swelling occurs during treatment in rope form. During subsequent primary fibrillation, any fibrils that are not fully bonded are brought to the surface of the fabric. Primary fibrillation should preferably take place in an aerodynamic jet (Fig. 10), as this ensures uniform fibrillation. Since lyocell fabrics are prone to wet rigidity, temperatures < 60°C should generally be avoided and a suitable crease inhibitor should be added to all baths. This also minimises the risk of crease marks. If fibrillation is not uniform, there is a risk of streaks that cannot be levelled

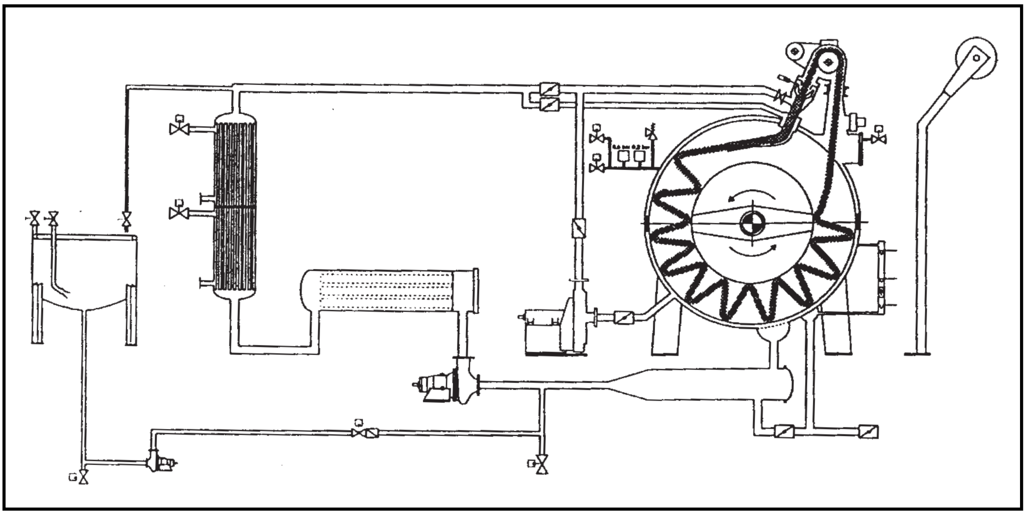


Fig. 10: Air-roto.

out at subsequent treatment stages. The linty fibrils loosened during primary fibrillation (Fig. 8) are then decomposed by cellulase during subsequent enzymatic defibrillation. The enzyme activity (Fig. 6) is stopped by raising the temperature and/or adding alkali.

Exhaust dyeings should preferably be carried out on aerodynamic jets. Secondary fibrillation occurs at this stage, creating a pile comprising short, extremely fine fibrils. Migration processes (80 (–90)°C → 60°C) improve levelness and trigger secondary fibrillation because elevated temperatures are used. Alternatively, the fabric can be dyed open-width using the cold pad-batch process. In this case, secondary fibrillation cannot take place during dyeing because the fabric is not exposed to any mechanical forces. To create peach-skin effects, secondary fibrillation can be carried out either before or after cold pad-batch dyeing.

High concentrations of some dyestuff chromophores with bi- or multifunctional reactive groups (e.g. Reactive Black 5) may impair fibrillation or cause cross-linking. In such cases, it is advisable to carry out secondary fibrillation before dyeing (e.g. during the enzyme stop process). Tumble-drying raises the fibrils and thus creates the desired peach-skin effect. To prevent continued fibrillation, frosting and formation of crease marks in domestic laundering, a resin finish should be applied. This is the only way to ensure that the handle and appearance of the goods is retained after repeated domestic laundering cycles.

Lyogel Fluid-rich → Gel of the jelly type. Opposite: → Xerogel.

Lyophilic Prevailing tendency, in a substance which is distributed in a liquid medium, towards endophilia. Solvent-affinity, solvent-attracting characteristic (similar to → Hydrophilic property). One also speaks of “lyophilic groups” in connection with textile auxiliaries. Opposite: → Lyophobic.

Lyophilic groups Molecular group which behaves in an → Endophilic manner in relation to a liquid phase.

Lyophobic Prevailing tendency, in a substance which is distributed in a liquid medium, towards exophilia. Solvent-fleeing, anti-solvent, solvent-repelling characteristic (similar to → Hydrophobic). Opposite: → Lyophilic.

Lyophobic groups Molecular group which behaves in an → Exophilic manner in relation to a liquid phase.

Lyopolarity → Lyobipolarity.

Lyotropic (Gk.) Phenomenon in which the solubility of a substance which is hard to dissolve in a solvent is increased by the addition of a third substance. This third substance is termed a “lyotropic agent”. Relates to characteristics of the coagulation of lyophilic colloids. Here, the flocculation power of salts depends on their attraction to solvents.

Lyounipolarity → Lyobipolarity.

Lysalbinic acid/protalbinic acid → Polypeptides with 6–10 peptide groups (molecules of lower → Amino acids) which have arisen through the alkaline decomposition (hydrolysis) of protein substances (leather waste, albumin, fish meal, etc.), and with an estimated molecular weight of around 450–800. Conventionally used term, but not strictly defined compounds of water-soluble protein decomposition products. They are of an amphoteric nature, belong to the group of surface-active protective colloids, and often serve to protect the fibre, as a levelling agent etc., especially for wool. Such products represent alkaline salts (lysalbinates, protalbinates) and contain further additives, e.g. oil sulphonates, fatty alcohol sulphates, etc.

-lysis (Gk.: lysis) Relates to the structural loosening, decomposition, splitting of a bond through e.g. → Hydrolysis, → Sulphitolysis.

M

M, symbol for → Mega (times a million); factor 10^6.

m,

I. Symbol for → Milli- (thousandth); factor 10^{-3}.

II. Symbol for → Metre, 1 m = 100 cm = 1000 mm.

μ, symbol for → Micro- (millionth); factor 10^{-6}.

m- → Meta-.

MA,

I. → Modacrylic fibres, symbol according to the → EDP key system → MAC.

II. → Low wet pick-up.

Ma → Manila fibre, → Textile fibre symbols, according to DIN 60 001 until 1988, from 1991 → AB.

ma, symbol for → Myria (ten thousand times), factor 10^4.

MAC → Modacrylic fibres, → Textile fibre symbols, according to DIN 60 001 T4/08.91.

MacAdam unit → Colour difference formulae.

Mace Snag Tester Testing device for checking the formation of snags in chain hosiery. Four rotating (60 rpm) aluminium cylinders are assigned to the samples. A sphere supplied with mandrels hangs loosely above each cylinder, whereby several mandrels are supported by the sample. The snags are pulled by rotating the cylinders. After 10 minutes of rotating the samples are compared under stipulated conditions using standard photos. Marking: 5 = no snags, 1 = considerable formation of snags. Samples are tested in longitudinal and transverse directions. For knitwear → Snagging Box (ICI).

Mach nozzle, Narrow slotted nozzle (0.025 mm), from which steam (5–7 bar) is blown right across the fabric width at a great flow velocity (ca. 450 m/s) to drain up to 25% of the residual moisture content. The steam thereby carries along a large part of the adhering water and is deposited in a special-purpose condenser (re-use of condensation). Substantial energy cost reduction. → Water extraction throughflow method.

Machine elements Machines alleviate and/or replace human labour. They increase the operating productivity and improve the quality of products. All machines consist of the same machine elements, which can be assembled into units depending on the function of the machine. Subdivisions are made between:

- unit for power production,
- unit for transmission of forces and movements,
- unit for the processing of a tool.

Machine elements include the machine parts which reappear in the building of all machines and so form the basic components of machines or driving gears. Three main focuses are purposely selected according to the areas of application:

- machine elements to connect machine parts,
- machine elements to transmit rotary motions,
- machine elements to convert movements.

Machine parts can be connected in a detachable or permanent way using machine elements.

a) Detachable connections: screws, pins, splines, featherkeys and bolts.

b) Permanent connections:
  - rivets: solid, dense and fixed connections, e.g. made of two steel plates through a compressed riveted shaft with riveted tops;
  - soldering: bonding of two metals using a molten, light, metallic solder, which flows into the “solder gap” and ingresses into the basic materials and so creates a connection;
  - welding: the combining of metal materials using the application of heat or pressure or both with and without adding materials of the same type is called welding according to DIN 1910. Similar or different types of thermoplastic materials can also be welded to these bonds;
  - adhesives: using adhesives different or similar materials are firmly bonded together with adhesive resins or double component adhesives (adhesive and hardening agent);
  - shrinking: materials are expanded using heat; they contract when cold. Shrinkage bonds are produced from these properties. Materials are intensely heated, pushed onto other materials and sit tightly after cooling down.

Machine-hour costs The costs relating to the normal annual number of hours, during which the one relevant machine (system) is in operation. Purpose: economic composition calculation for possible replacements as well as basis for prime cost calculation. Machine-hour costs consist of business loans for machine operation; the operating materials required for machines (power, light, etc.); repairs, insurance premiums, contribution of taxes, interest, write-offs, salaries, heating, public levies and costs of company's welfare facilities.

Machine-made carpets Machine produced carpets, in the narrower sense, term for machine woven or knotted carpets.

Machine time Component of → Useful life of working.

Machine utilisation planning The optimum sequences for given quality assessment (minimum throughput time as well) are determined from the technically possible sequences using the means of → Operational planning of individual finishing processes. → Processing sequence in textile finishing.

Machine-washable wool Woollen items, mostly knitted fabric, which are washable in domestic washing machines with a care cycle (ca. 40°C) according to particular → Antifelting finish without damaging the appearance of the fabric, handle or wearing characteristics. Antifelt finishing is generally carried out in the combed top. IWS standards for machine washable items (→ Superwash).

The washability of wool is increasingly important; the more easy-care wear properties are disappearing and chemical cleaning is problematic for ecological reasons. The antifelting finish of wool using chlorine or chlorine compounds will still only be feasible in a limited way using the legal AOX limit. This situation encouraged the development of new replacement products and for available ones to be revised, which produces improved effects and safer processes. Nevertheless →Antifelting finish remains technically superior and demands particular know-how, adaptation to customers' wishes, to wool material and available machines. New finishings for machine-washable wool items are (besides plasma) based on:

- peroxy-monosulphates,
- polymers such as polyethers, polysiloxanes, amongst others,
- and poly-quaternary compounds.

Machine-woven carpets Machine woven textile floor coverings. →: Pile wire; Double plush; Reversible; Axminster carpets.

Mackey test is used to test grease, which is based on heat accumulation from autoxidation (→ Oxidation of oils), for self-combustion. A previously scoured piece of cotton wool is impregnated with the oil or grease to be tested and exposed (in the Mackey device) to a temperature of 100°C (short test – test period up to 3 h) or 75°C (long test up to 48 h), in which the cotton wool temperature is checked. The latter rises very quickly for an oil with multiple unsaturated fatty acids through spontaneous oxidation. A non-combustible grease product withstands the Mackey test at 100°C (tolerance ±5°C).

Maco cotton (Maco), reddish/brownish/yellow, first-rate Egyptian cotton; very fine, longitudinally stapled fibres, uniform spun yarns.

Maco cotton test As a result of higher prices for genuine maco cotton there is interest in test methods for cheaper imitations. Such methods can be created using simple steaming or direct sulphur or iron buff coloration. Tests:

I. Staple length.

II. Boil sample with thinned nitric acid: real maco turns yellow; reddish tone disappears. If the colour shade becomes considerably, deeper however, simple steaming was carried out.

III. Effect of concentrated sulphuric acid: chromatic shades of colour are produced with direct dyeing.

IV. Boiling with tin salt and hydrochloric acid: decolorizing with sulphur dyeing. If you hold lead acetate paper over the reagent glass opening when boiling, dark brown/black dyeing appears with sulphur dyeing.

V. With potassium hexacyanoferrat(II) and hydrochloric acid: blue coloration with iron buff dyeing.

Macramé Precursor of pillow lace. Threads are elaborately knotted by hand from the warp threads which stick out of carpets. Can be used as a needlework technique with typical varied knottings, e.g. for flower garlands. The name has degenerated into coarse etched points worked on as a curtain base.

Macro- (Gk.: makrós = large), prefix with the meaning "long", "large".

Macroemulsions → Coalescence.

Macrofibrils Designation for cell units of the fibrillar type in → Wool structure, e.g. firstly in the sense of spindle cells and secondly where there is no direct connection with the actual fibrils (bundles). Integrated process of sulphur-rich keratin proteins, which show a variable affinity for heavy metals after reduction. Macrofibrils in intermacrofibrillar material are a biological unit in keratin fibrils.

Macromolecular bundle → Micelles.

Macromolecules Expression for polymers (coined by Staudinger), high molecular so-called "gigantic molecules" made of at least several hundred atoms with molecular weight > 10 000. Structure made of → Monomers, either thickly knotted or cross-linked (starch, aminoplasts, phenolic plastics) or more or less longitudinally stretched → Chain molecules (→ Polymers) as in cellulose, polypeptides, etc. Classification into a) natural macromolecules (e.g. starch; cellulose; pectins; caoutchouc; proteins; enzymes); b) converted (regenerated) natural macromolecules (e.g. viscose; vulcanized caoutchouc; leather) and c) synthetic macromolecules (e.g. polymerization-, polycondensation-, polyaddition products). Special natural macromolecules are mostly mixtures of macromolecules similar in construction, but different in size.

Macropolymers → High polymers.

Macroporous films The creation of these structures is possible by removing water-soluble fillers from a polymer matrix. Aqueous polyurethane dispersions have proven suitable. Films, which have a macroporous structure after substrates have been removed, can be produced through the deposit of salts amongst other substances, such as starch. As the polymer does not have any specific interactions with substances, which are deposited in the pores, it should be possible for water not only to be deposited in place of other substances, but also emitted again.

A microporous finishing of textiles is used to improve wearing comfort, as air and water vapour get through such textiles. Comparable effects, such as water vapour transmission, should not be expected from a macroporous finishing. There are also principle differences in polymers, which are in a position to absorb large quantites of water. Hydrogels or super absorbers do enable a multiple of their own weight to bind to water, but this does not become free again with mechanical stresses. Corresponding products are used in hygienic items and in the technology sector (according to Schollmeyer).

Macroscopic Visible with naked (so-called unarmed) eye; e.g. small individual fibres of a yarn, whose surface structure is however → Microscopic.

Madder (Turkey red), fiery red → Natural dyes (a mordant dye). Origin: ground root of the shrub-type madder plant (Orient, Mediterranean area, America). Effective component: alizarin (dioxyanthrachinon) from the Middle East. Lizari (alizari) and purpurin. Mordant dye for wool and cotton. Total fastness even surpasses indigo. Was already mentioned in the Bible (Egypt, Persia and India). Had its heyday during the 17th century.

Made-to-measure polymers It is possible to construct polymer molecules chemically using their chemical structure so that they are either extremely flexible and form irregular balls in melting or else are even in liquid crystal form even before solidifying into stiff rods in a strictly parallel packing. Two routes can be taken in order to approach these parallel molecular packings. In the first case one starts with existing polymers and develops specialised processing techniques, which force a parallelisation of the molecular chains. With polyester sheets, for example, a tear resistance is achieved increased by more than double using a threefold drawing (longitudinal/transverse/longitudinal). By gel spinning, manufactured polyethylene threads have a resistance close to the theoretical maximum value through parallelisation of the macromolecules. It is a multiple higher than for polyethylene threads produced in the normal way. In the second case, polymers have been sought, in which the chemical structure already produces a high stiffness in the macromolecules. This is the prerequisite for the individual macromolecules already being found voluntarily in a parallel arrangement in the molten state in microscopic dimensions, i.e. subjecting itself to self-organisation. This state of preferential orientation is expanded to macroscopic dimensions by the following processing step. The liquid crystal polyester Vectra from Hoechst Celanese (Fig. 1) displays such behaviour, for example.

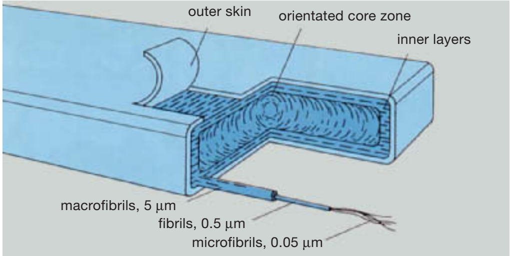


Fig. 1: Injection moulding from the liquid polymer Vectra.

The material spectrum of made-to-measure polymers ranges from polyethylene with flexible tangled molecules to polymers with noticeably restricted flexibility (polyester on polyethylene terephthalate base) and also the stiff-chained liquid crystal polyesters (LCP) or even to the extremely rigid structures of carbon polymers, which include, for example, carbon fibres, carbon glass and carbon-fibre-reinforced compos-

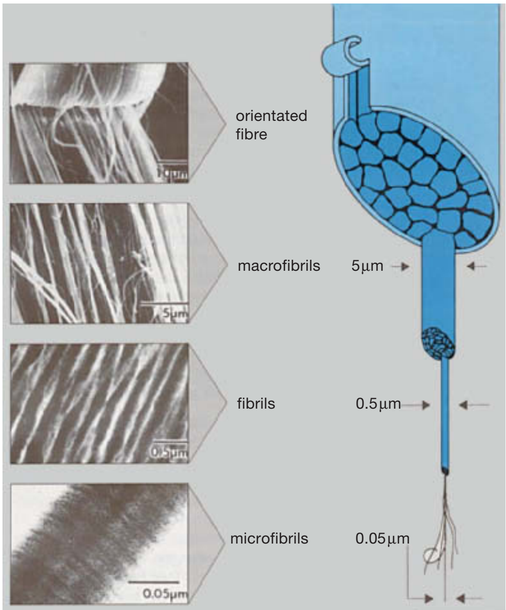


Fig. 2: Structure model of the liquid crystalline polymer Vectra (Hoechst).

ites (CFC). The resistance of the polymers to heat increases in parallel to the stiffness of the molecules.

The liquid crystal polymer Vectra from Hoechst Celanese (Fig. 2) is an example of one of the polymers, which are stable at high temperatures and fulfil high mechanical requirements. Liquid crystal polymers are a class of self-boosting high performance materials. They spontaneously assume an extremely complicated morphology when die-casting. The high resistance to heat of more than 240°C, chemical resistance as well as being flame retardant and electric strength allow the use of Vectra in electronics and space travel or even as a benzine supply lead in a car engine (according to Hoechst).

MAE → MacAdam unit.

Magazine screen printing machine Magazine screen printing machines were the first step towards full mechanization of screen printing. The development started from the fact that a machine with the smallest space required was requested for reasons of space. The printing table is only large enough to enable printing of a report and is equipped with moveable back grey printing in the form of an endless ribbon. The printing screens in question are accommodated in magazines of different design. A distinction is made between staple magazines and magazine screens. So-called “Carousel suspension” and “Serial magazines” are recognized in magazine screen design.

Magnesium Mg; atomic weight 24.36. Shiny, silvery white metal of low density. In air, an outer layer of almost transparent carbonate forms; with boiling water there is formation of magnesium oxide and hydrogen. When lit magnesium oxide is produced (formation of a very intensive white light). The magnesium cation (such as alkali and earth alkali ions) forms colourless salts with colourless anions. Magnesium chloride is water-soluble (even easily soluble in waterless alcohol); magnesium bromide, iodide, nitrate and sulphate are also water-soluble. Magnesium hydroxide is insoluble. Magnesium carbonate and phosphate are not easily dissoluble. Ammonium salts increase the water solubility of salts which are not easily dissoluble or are non-soluble. Application: powder or strip for the purposes of illumination; “lightning powder” (mixture of 1 part magnesium and 2 parts potassium chlorate), drying of alcohols.

Magnesium chloride (chlorinated magnesium), $MgCl_2 \cdot 6\,H_2O$; molecular weight 203. Melted and in crystals, very hygroscopic, water-soluble. Application: finishing additions (hygroscopes, binders and hardening agents), etc.

Magnesium hardness (MgH), unit per °d of magnesium oxide (MgO) 7.15 mg/l water. → Water hardness salts.

Magnesium silicate Agent for stabilising and controlling the oxygen output in bleaching agents; slightly alkaline to neutral, resistant to temperature and alkalines.

Magnesium soap Formation of similar → Lime soap, caused by water hardening salts.

Magnesium sulphate (epsom salt, sulphuric acid magnesium), $MgSO_4 \cdot 7\,H_2O$; molecular weight 246; density 1.68. Colourless crystals, often impure, resistant to damp air, weathered in dry air, water-soluble. Application: finishing addition (hardening and sealing agent in particular for cotton goods) in flame-retardant impregnation.

Magnetic-particle coupling or brake is in principle structured as an electromagnetic friction coupling or brake (Fig. 1). For torque transmission and/or braking, a friction-ended compound is produced between the radially arranged primary and secondary assembly. A special magnetic particle, which is in the system-dependant low radial air gap between the primary and secondary assembly, is used for this. These two assemblies are stored independently from each other. The outer assembly is also a field spool (magnetic part) and can be electrically switched using direct current via sliprings or fixed connections. Tapped holes fitted laterally on the magnetic part and the hole executed with the keyway on the secondary assembly facilitate a simple adaptation (magnetic flux in Fig. 2). The power is supplied to the couplings via axially contacting sliprings.

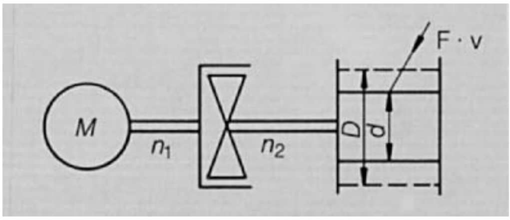


Fig. 1: Winding, unwinding, acceleration and braking of centrifugal masses.
v = discharge speed; D = max. diameter; d = minimum diameter; F = discharge force; M = motor torque; n_1 and n_2 = speeds, which the magnetic particle coupling matches to one another, i.e. equalizes.

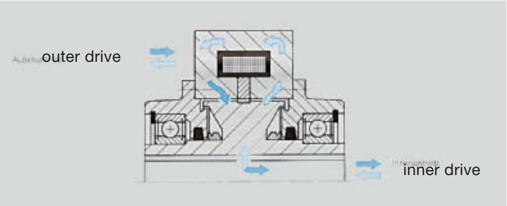


Fig. 2: Flow of forces in the magnetic particle coupling by Lenze.

The brakes are electrically connected to a flat reed connector installed on the end of the primary part. In cases where a magnetic-particle coupling is to be used as a safety or dry-fluid coupling, layout in accordance with the required torque is generally sufficient. A check of the performable quantity of heat must be carried out if there are frequent successive switching operations and in continuous operation. The safe slack time until a temperature limit is reached can be determined.

Magnet-roll systems Functional units of permanent or electromagnets as well as rollers of magnetizable material. Application as blade systems for flat and rotational film machines or as squeezing devices for magnetic drum foulard and for coating systems (Figs. 1 and 2). The permanent or electromagnet is shaped as a relocatable magnetic beam in screen printing and as a drum for foulard. The roller may consist of cylindrical iron bars, which are also covered with plastic if necessary, or a tube.

The magnetic pressure of rod squeegees has proved particularly suitable for precision coatings with great consistency of sheet thickness across the width of the cloth. Adhesive bonded coating, junction coating, lacquering or PVC coating in 2 strokes (Fig. 3) can be carried out as fully flat coatings or partial and/or sample coating shapes (e.g. powder point coating). Indirect glue coating can be achieved by dosing onto the magnetic roller and transmitting to the fabric guide (Fig. 4).

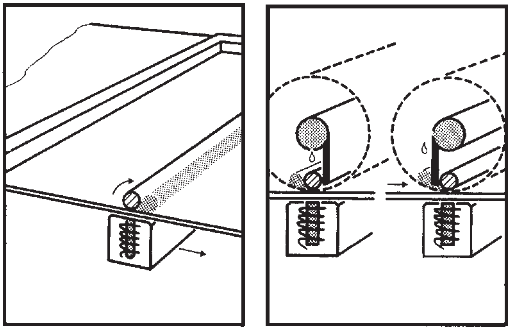


Fig. 1: Magnet squeegee by Zimmer for flat and rotation screen printing.

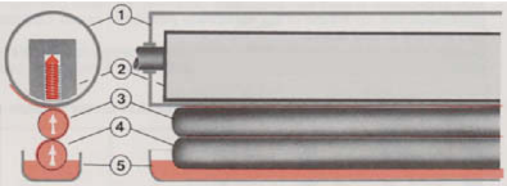


Fig. 2: Magnetic pressure system for product application (Roto-Stabil magnet roller by Zimmer).
1 = magnetic roller; 2 = magnet; 3 = application roller; 4 = immersion and metering roller; 5 = trough.

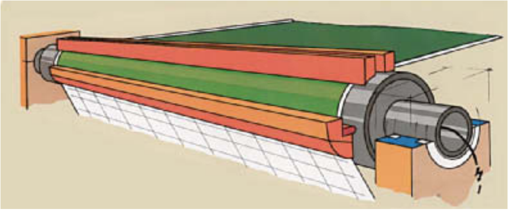


Fig. 3: Magnetic pressure used in the coating of canvas fabrics: 70 g/m^2 base coat (light green) plus 80 g/m^2 finishing coat (dark green); Magnoroll '92, Type s9+12 by Zimmer.

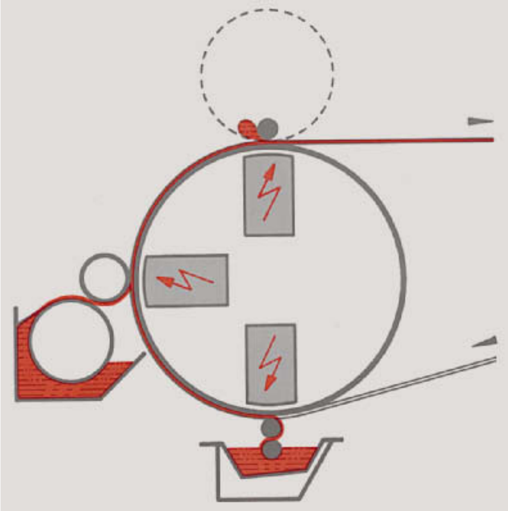


Fig. 4: Magnetic roller application in full-surface or partially-patterned rotary screen coating (Magnetic system "Plus" by Zimmer).

Cylindrical iron bars are inserted into clamped flat or round screens in automated flat screen printing. Their movement and printing pressure is a result of electromagnets running back and forth (controllable) under the back grey, whereby the fabric glued on the back grey in chain direction is contacted each time and pushed further by repeat length. Application also in rotary screen printing (Fig. 5).

Magnifying glasses chiefly consist of a composite lens (ocular), which should always be held directly in front of the eye. Allow linear magnifications up to 60 times. Very varied designs. Usually monocular (for one eye) as → Counting glass and similar, as well as binocular (for both eyes; bifocal magnifying glasses) for materials testing, etc.

Maguey fibre → Manila fibre.

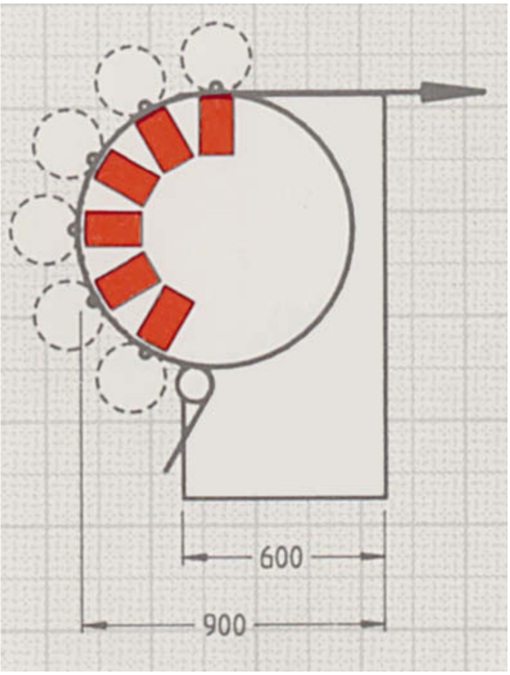


Fig. 5: Application of magnetic pressure as compact pressure zone in Magnoroll rotation screen printing (Zimmer).

Mahagony or Anacardia gum → Vegetable gums from Brazil, Martinique and Guadeloupe, which are very similar to gum arabic. Reddish colour. Besides mainly arabinose also contain bassorin and dextrin. They are not completely water-soluble.

Mahogany sulphonates In petroleum refining, besides the water-soluble “green acids”, the oil-soluble “petroleum sulphonates” which are produced. Application: esp. in USA as mineral oil emulsifiers for cheap lubricating and batch oils.

Maifoss process Dyeing to achieve “2 shades” on the same wool fibre or on different wool fibres in one dye bath. Particularly sought out dyestuffs are used for this; besides these you can use dyeing auxiliaries, which also increase the colour contrast. Colour blend imitations achieved in this way produce interesting effects, but have only found limited distribution, as effects largely depend on the wool quality used and are therefore hardly reproduceable from one batch to another. → Multi-colour process facilitates multi-colour effects in single-bath dyeing process.

Mains water (of towns), containing cloud matter from time to time, usually (to a greater or lesser extent) containing air from water return. Oxygen absorption seasonally temperature-dependent (tendency at 0°C = 14.56 mg/l, at 20°C = 9.09 mg/l); frequently nitrates as well (usually low, 0.01–1 mg/l), often chloride (frequently 30 mg/l; also in 1 mg/l for sterilizing), hardening salts, free chlorine (amongst others frequently iron and manganese, lead as well). For the textile finisher, mains water as industrial useful water is the most expensive and is therefore merely (if at all) used for sensitive products/processes. → Process water.

Maize starch Crystals, pieces, powder. White/ yellowish/red, a little more gloss than wheat starch. Handle as wheat starch (not so crunchy). Seldom distorted. Water content 12–14%. Heated bloating: swelling at 50°C, start at 55°C, end of glueing at 62.5°C. Paste: Greater adhesive and stiffening strength than wheat and potato starch, less than rice starch; acidic production thinner; alkaline thicker. Reaction against chemicals such as potato starch. Chemical finishing handle: very hard, but very pithy. Application → Starch.

Making up of finished textiles Textile form of making up, set to internal company purposes of finishing or packaging, distribution, marketing; e.g. the form, in which goods sold by the metre are presented on the counter ready for sale, i.e. folded, rolled or wound, the packaging of all kinds of products ready for trade, e.g. yarn make-up: to itself, wound up on cardboard, on paper board rolls, made up in a set, made up in an assortment, etc.; for piece goods: in a particular length, on rolls, layers (in the pile), fitted pieces, each simple or twisted (twice as wide), on drum or winding boards, slides, frames, in boxes, etc. Fabric inspection, making up and packaging are automated in large productions (see Fig.).

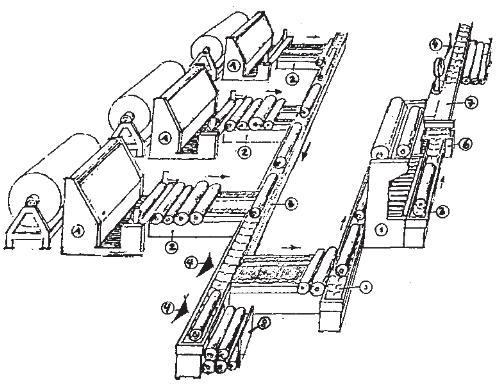


Fig.: Fully automatic packaging of rolled pieces after fabric inspection.
1 = fabric inspection with length measurement;
2 = transverse conveyance to making up; 3 = lengthwise conveyance; 4 = entry to film packaging (= 5) or sorted out as returns (= 9); 6 = labelling; 7 = scales; 8 = collection point for whole colour batches.

Maleate Salt and/or ester of → Maleic acid.

Maleic acid (cis-form), large white prisms, easily water-soluble. Application: for the production of synthetic resins (→ Maleic resin).

Maleic resin (colophony-) maleic acid resins, condensation resins, similar to → Alkyd resins.

Mostly in a modified form, e.g. esterified from colophony and/or abietic acid/maleic acid adduct with polyalcohols. These maleic resins have a high softening point, good resistance to water, lightness and good light fastness. Soluble in almost all organic solvents; partially soluble in alcohol. Application: for paint varnish, coatings (e.g. oilcloth production); addition for cellulose varnished bonds, etc.

Malifil process → Stitched-bonded composites from bonded threads, e.g. from an untwisted thread with polyamide threads "sewn in".

Malimo fabric → Stitched-bonded composites made from oversewn warp/weft thread layers, very similar to woven fabric; chiefly made from viscose staple fibre, cotton (for towels, sheets, etc.) and carded/worsted yarn (for clothing and interlinings).

Malipol fabric, → Stitch-bonded fabrics as a combined stitch-bonded yarn composite fabric type. Conventional textile fabrics (e.g. viscose staple fibre) with pile loops (1–7 mm) threaded to one side of the fabric using stitch bonding and the back of the fabric covered with stitches. I.e. chain plush fabric with pile threads bonded using stitch formation in contrast to tufted fabrics, where loops sewn in have to be bonded with adhesive on the back. Application for Terry fabric goods, duvets, furnishing fabrics, carpets, rugs, coat fabrics in types of fleece and velour, car upholstery and technical textiles.

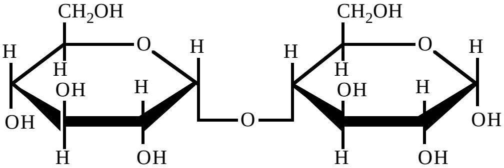
Maliwatt fabric → Stitch-bonded fabrics made out of oversewn nonwovens, with/without binding bonding; for interlinings, felts, upholstering fabrics, coating base for artificial leather, technical purposes; also layered agents for clothing fabrics, raised lining fabrics and artificial leather.

Malt Aqueous extract from germinated cereal grains (barley); contains amylase and maltase as diastatic, starch degrading (condensing via dextrines to maltose) enzymes (ferments). → Malt diastases.

Maltase A glucosidase as an enzyme of malt (malt diastases), which the starch decomposition (into maltose) already effected by the amylase continues to form glucose.

Malt diastases Obtained from germinating barley; consist of α- and β-amylases (→ Diastases). The effective malt diastatic enzyme decomposes starch into maltose. Effectiveness: pH of 4.5–6.2, 50–65°C and quantities of 3–20 g/l of sodium chloride addition have an active effect. Alkali, copper, tin and lead salts act as enzyme poisons. Malt diastases are very suitable for the production of sizing and chemical finishings, but also for desizing. When using diastases and surfactants, it should be considered that soaps and fatty alcohol sulphates are inhibitive. Ethylene oxide adducts have favourable compatibility.

Maltose (glucose, α-glucoside), $C_{12}H_{22}O_{11} \cdot H_2O$.



Easily water-soluble, sweet-tasting starch decomposition product, which is further decomposed by the enzyme of the malt (amylase) and by maltase into two molecules of α-glucose.

Management Intellectual leadership of a company with the aim of economic and ecological optimization of flows of energy, material and above all information in textile processing. The management develops programmes for market processing and controls a product policy geared to it. Production planning by the management comprises strategic and tactical methods. Logistics and quality assurance support management in the handling of application engineering. Management systems (e.g. Fig.) are chiefly supported by EDP for the optimization of the flow of information. Organigrams based on this help management to make decisions.

Manchester velvet → Genoa cord, named after the English city.

Mandrel Thread shaft for transmitting a rotary motion.

Mandrel jack Machine for fitting printing rollers on mandrels onto the steel shaft.

Mandrel removal from printing rollers Removal of steel mandrels from the tapered insides of engraved printing rollers after completion of printing is achieved in a hydraulic forcing machine (or forcing jack).

Manganese Mn; atomic weight 55; white, brittle metal; melting point 1240°C; tarnishing in rainbow colours during heating; rapidly evaporating at 1900°C; very soluble in thinned acids. Valuable component of chrome manganese steel (→ Stainless steel). Valency of 2, 3, 4, 6, and 7. Hydroxides of Mn(II) and Mn(III) have a quite strong alkaline effect, of Mn(IV) approaching neutral, of Mn (VI) and Mn(VII) pronounced acidic (permanagate acid $HMnO_4$, as the main substance of potassium permanagate, is a strong acid).

Manganese brown (manganese bistre, deep brown) → Mineral dyes. Significance: as a result of fastness and easy dischargability using reducing agents (tin salt, sulphuric acid) previously applied to wool, cotton fabrics, for travelling rugs and skin imitations.

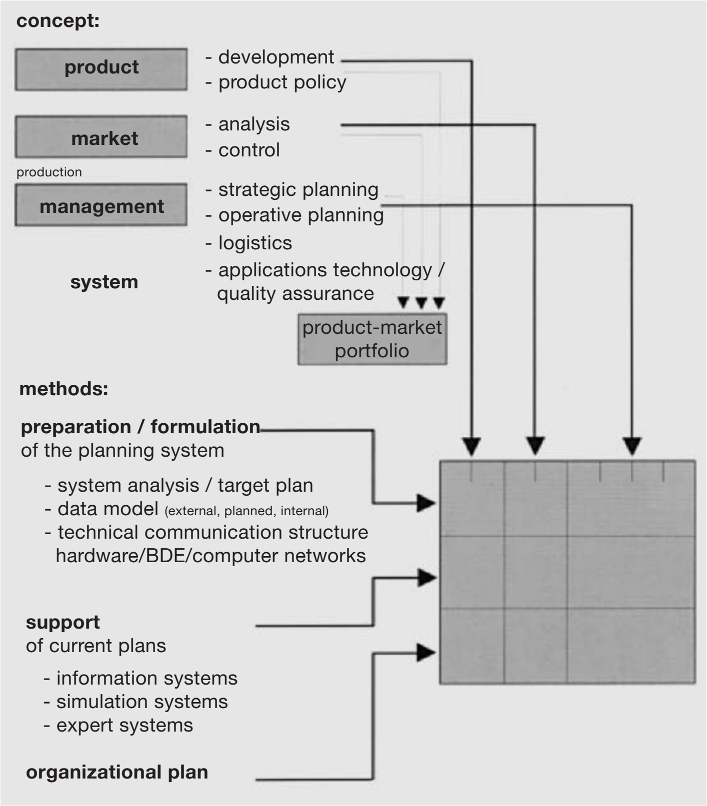


Fig.: Decision-making concept for the management in a production plant.

Production: Impregnate with extracted manganese salt, intermediate drying, caustic soda liquor passage (condensate of manganese hydoxide), oxidizing agent: bleaching powder solution (calcium chloride hypochlorite) or potassium dichromate (formation of managanese peroxide).

Manganese in water supply Encourages all kinds of catalytic fibre damage, unclear white fabrics, dull, cloudy, misdyeings, stains, etc. Nuisance even superior to iron. With 0.1 mg/l of manganese this water is ruled out for numerous finishing purposes. (→ Water demanganizing).

Manganese soap,

Formation similar to → Lime soap through water hardening salts.

Mangle Machines used for → Mangling. Basic types:

1. Bowl mangles: in the form of suction, single-bowl, double-bowl, multi-bowl and add-on mangles; constructed in small, medium and large units.
2. Steam chest mangles (smooth steel cylinder as smoothing body) for high volume industrial use.
3. Some multiple-bowl mangles have automatic feed and delivery units.

Mangle bowl (batch roll), fabric batching roller (made of wood or iron) for → Mangling (modular mangle).

Mangling,

I. Chemical finishing character work. Intended for the woven fabric (linen, less often cotton) to be treated with a simili gloss or handle improvement:

1. modular mangling, whereby the fabric wound on skeins is exposed to the pressure of a heavy module which goes to and fro. The effect is influenced by how tightly the fabric is wound on the skeins;
2. roller mangling, whereby the fabric continuously passes two or more heated rollers with adjustable pressure;
3. calender with 2 or more rollers, whereby mostly only elastic rollers are used.

A similar extensive finishing effect can also be achieved using the → Rotary cloth-press.

II. Mangling of washing as a combined smoothing and drying process in laundries, whereby washing is “mangle-dried”.

Manila fibre (abaca, banana, maguey, musa fibre), a → Bast fibres from the tropical fibre banana (Philippines, Central America). Yellowish-white, yellow to reddish. Specifically light. Fibre bundles 2–5 m long and 0.2–1 mm thick; individual cells 3–12 mm long and 0.016–0.032 mm Ø. Longitudinal strength 40–75 cN/dtex, transverse strength much weaker. Resistant to moisture and sea water. Structure: 63% cellulose, 10% water, 1.4% water-soluble, 0.2% fats and waxes, 25.4% pectin/hemicellulose/lignin, 1.2% ash (grey). Dyeable using cationic, vat, acid, sulphur and direct dyes. Application: for ropes, nets, strings; yarns for bags, mats, braids, etc. (→ Tagal); finer yarns with silk also for shirts, etc.

Man lock → Sampling lock.

Man-made fibre alloys → Polymer mixtures.

Man-made fibre generations,

I. Fibres of the 1st and 2nd generation: 1st view: fibres of the 1st generation: original fibres neither chemically nor physically modified in the first “year of their life” after discovery. Fibres of the 2nd generation: further development using physical and/or chemical modifications in the manufacturing process. 2nd view: only chemical modification (grafting and bicomponent structure) results in “fibres of the 2nd generation”, while physical modifications and depositing substances provide “made to measure chemical fibres”.

II. Chemical fibres of the 3rd and 4th generation: chemically or physically modified types of conventional chemical fibres, i.e. synthetic fibres created for a very specific requirement profile (→ Fibre engineering).

Man-made fibre manufacture From the melting or concentrated solutions of usually macromolecular substances and also from which some low molecular compounds (honey, soap solutions) can remove threads. So thread formation is not a special property of macromolecular substances. But the threads only have a low mechanical strength naturally. If the thread material consists of long molecule chains, these are partially oriented when drawing. The resulting fibres have a higher strength. But only some fibres show such high strengths that they are suitable for textile or industrial use. Chain-forming macromolecules are therefore the first prerequisite for fibre formation. Heavy branchings degrade the thread formation and mechanical properties, as fewer points of contact per unit length are possible between the chain molecules. A certain minimum degree of polymerisation should be available for thread formation for the same reason. The tear resistance is practically equal to zero with small degrees of polymerisation. This minimum degree of polymerisation is lower, the stronger the interactions between the chains are, i.e. the more polar the groupings are and/or the more easily the macromolecules can crystallise. But crystallisation is not an absolutely required prerequisite for the formation of fibres. For example, bristles for brushes, etc. are produced from the non-crystalline polystyrene. A cristallinity which is too high is even less desirable, as the fibre then becomes brittle.

The spinning jet nozzles for the spinning of man-made fibres are manufactured from metal plates with the finest bore holes (cross-sectional diameter of approximately 0.05–0.12 mm). These apertures were usually bored previously; now they are pierced without exception or produced using laser beams. With a spinning jet nozzle diameter of ca. 1–5 cm the number of apertures for viscose is between 16–120 and more; this number is considerably larger for synthetic fibres and is somewhere between 1000–5000 and more. Previously a gold/platinum alloy was mainly used for the nozzle base; now the silvery white precious metal tantalum, which is more mechanically robust and also more corrosion-resistant, is preferred.

Due to the considerable advances in nozzle manufacture, the fineness both of filament and staple fibre products can be as varied as you like. Fibres of the fineness of natural silk and finer (microfibres) and the thickness of the coarsest wool or animal hairs can be produced. The thickness of man-made fibres is geared to the purpose. It is given in dtex. The entire range, in which man-made fibres are produced today, is between ca. 1–45 dtex; for microfibres < 1 dtex. This produces a significant scope regarding the fineness and adaptability to natural fibres. Most products, which endlessly come on the market, are multi-thread or multifilament. Viscose filament, for example, consists of 16-120 individual filaments; the synthetic fibres, however, usually only have 6–18 individual threads. The fineness of multifilament man-made fibre yarns is given by two figures, e.g. 120/40; the first figure (here 120) signifies the total titre; the second figure (40) indicates the number of individual filaments. If you divide the total titre by the number of filaments, you get the individual titre. So in this case 120 : 40 = 3. The so-called B types (man-made fibres for the cotton sector) are normally in a fineness range from 1.1–2.75 dtex. The W types (wool types) start at about 2.75 dtex and reach up to about 33 dtex for particularly coarse products. Finenesses of more than 11 dtex are usually only used for the carpet industry (T types). A particularly popular fineness in the

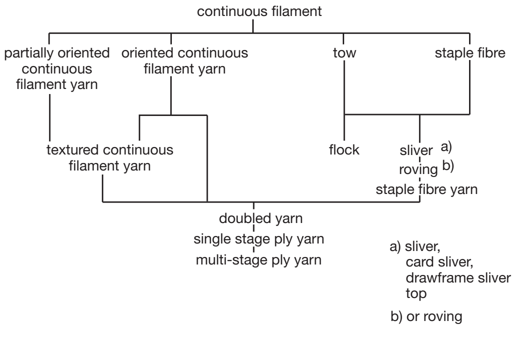


Fig.: Man-made fibre forms (according to BISFA).

outer clothing sector is 4.1 dtex. This corresponds approximately to a wool fineness of AA.

Just like the fineness, the length (staple) of the fibres is also adapted to fit further processing and/or the natural raw material in question. The fibres which firstly come out of the nozzles as filaments are cut to particular lengths using cutting machines. The length ranges from approximately 30–250 mm. A cut length of 30, 40 or max. 60 mm is usually selected for the B types. For the wool sector, the fibres are cut at 30–80 mm (usually 60 mm), if they are to be processed in the carded yarn process and at 100–150 mm (usually 120 mm) if they are to be processed in the worsted spinning process. Just as one frequently chooses the fineness somewhat finer than the natural product, one tends to use man-made fibres, which are somewhat longer than the natural products; this applies in particular when the natural raw material is relatively short (as e.g. for cotton or reclaimed wool). They can then be spun more easily.

With regard to purity, man-made fibres are an ideal spinning material, as they are not contaminated by shell or leaf remains, burrs, dust, etc. as are natural fibres.

The surface of man-made fibres may be smooth or rough, as it can be given a scarred effect. Highly glossy, glossy, matt and deeply matt threads can be produced. While a high gloss is regarded highly for certain fabrics, it is not to be desired in other cases and is felt to be chilly, greasy and cold. Instead of the previous, less resistant post-delustring the so-called delustring in spinning is used today. Finely distributed substances, e.g. titanium dioxide, are hereby mixed in the spinning solution before spinning out. So they are not on the fibre surface, but in the fibre substance. The most varied gloss levels, which are very natural, can be achieved with the corresponding dosage rate.

Spin dyeing is a similar process to delustring in spinning, i.e. coloured pigments are added to the spinning. So the spin dyed products already come out of the nozzle dyed. The particular advantage of this is that this type of dyeing is cheaper than all the others. Furthermore, it is possible to repeat these colours in a constantly even shade. Finally, these spin or nozzle-dyed products have unusually high colour fastnesses, especially friction, water, washing, sweat and light fastnesses.

The possibility of texturing exists in order to adapt fibres, which are used in the wool sector, as far as possible to natural wool. The appearance, handle and above all the thermal retention of the finished goods is determined to a high degree by the crimp. The artificially produced crimp is, however, not as resistant for all products as for natural wool, but considerably more durable for synthetic fibres than for the materials made from regenerated cellulose (the worst being acetate). Distinctions are made, e.g. between torsional crimp texturing (false twist texturing), stuffer-box crimp texturing, air bubble texturing or knitted setting texturing processes. A resistance to the mechanically produced crimp can be achieved for most thermoplastic synthetic fibres using thermal treatment.

While the moisture absorption of man-made fibres from natural raw materials (e.g. viscose 10–13%) is normal to good, practically all fully synthetic products characteristically only absorb very little moisture (→ Moisture absorption of fibres). With a moisture absorption of 4–4.5% in standard atmosphere, polyamide products are still relatively favourable, as polyester and polyacrylonitrile products only absorb approx. 1–2% moisture content in standard atmosphere. The low moisture absorption of synthetic fibres is, for example, also the reason why these products tend to be processed using wool, which is very attracted to moisture, in order to create compensation as regards this. The drying time of products naturally also depends on the moisture absorption. The low water retention is therefore the reason why materials made from synthetic fibres dry so quickly.

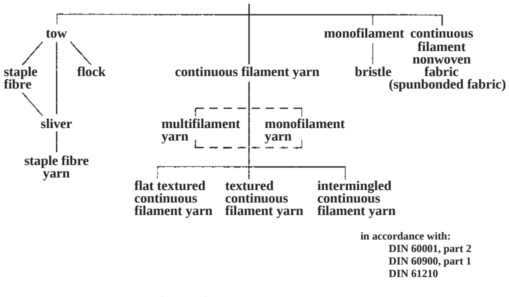
With the very considerable increase of man-made fibres in the textile industry amongst other sectors, technical terms, which give cause for uncertainities, were often used. The BISFA therefore considers it advisable to define in summary the names of the various manifestations of man-made fibres acknowledged as correct by experts (see Fig.).

Man-made fibres Generic term for chemically/ technically produced textile fibres:

I. Made from natural polymers: →:Regenerated cellulose; Man-made protein fibres; Mineral fibres.

II. Made from synthetic polymers (→ Synthetic fibres): →: Polycondensation fibres; Polymerization fibres; Addition polymers.

Man-made fibres (Fig. 1) are, as products of modern big industry, in contrast to natural fibre materials. They not only intrude upon the areas of application of natural products, but have also developed new areas and have been promoted to an indispensable factor of the economy and human life. Robert Hooke (London) had already referred to the exhaustion of lime-like materials for threads for the first time in 1665. The invention of nitrocellulose in 1845 by Schönbein, the artificial cel-



in accordance with:
DIN 60001, part 2
DIN 60900, part 1
DIN 61210

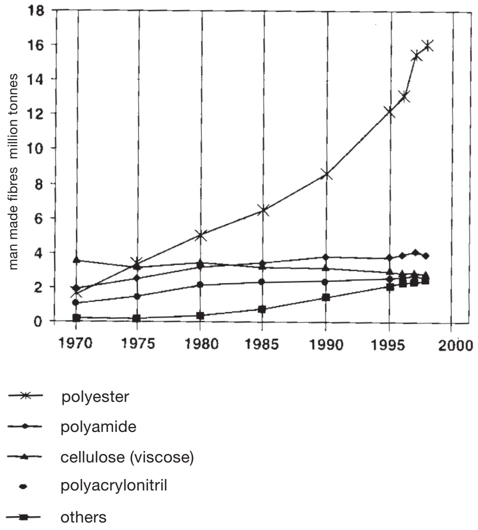
Fig. 1: Man-made fibre forms.

lulosic threads of the Frenchman Chardonnet and the proof of the solution of cellulose in cuprammonium hydroxide are milestones in historical development. But only through the introduction of long, chain-forming molecules were the scientific foundations created for a suitable theory. Staudinger coined the term of macromolecule, which is still valid throughout the world today. The years of origin for synthetic polymers are generally 1920 to 1930. The basic characteristics of a fibre-forming substance were found here: the availability of macromolecular chain molecules and the ability of these molecules to store themselves together in bundles, which guarantee a sufficient transverse strength from mutually effective attraction forces (secondary valency bonds). A synthetic fibre came onto the market for the first time in the middle of the 30s with polyvinylchloride fibres. The pioneering work of Carothers, USA (polyamide 6.6), Schlack, IG Farbenindustrie (polyamide 6), Whinfield and Dickson, England (polyester) and Rein, IG Farbenindustrie (polyacrylonitrile) formed the foundations for today's synthetic fibres. The construction of numerous manufacturing plants and the continual increase in the production opportunities available made the man-made fibre industry into an economic factor throughout the world (see Fig. 2) without which the provision of humanity with textiles and the considerable increase in consumption due to the growing world population is no longer conceivable. 4 main types (see Table) have developed amongst the large number of possible fibre raw materials. This includes the regenerated or transformed cellulose products, the polyamides, polyesters and polyacrilonitriles. Besides that, fibres made from polypropylenes have even taken a notable upturn. The remaining polymer systems have only achieved partial success in certain sectors due to very specific properties, such as the polyvinylchloride fibres, polyvinylalcohol fibres or elastomer filaments such as polyurethane, as well as some newly developed special fibres for technical textiles.

year	cotton	wool	synthetic fibres	cellulose derivatives	total
1980	14,0	1,6	10,7	3,6	29,9
1985	15,6	1,7	12,8	3,3	33,4
1990	16,5	1,7	14,5	3,3	36,0
2000	19,0	1,7	17,5	3,8	42,0

Tab.: Increased man-made fibre consumption in millions of tonnes (world-wide) compared with wool and cotton; silk production per year: 50 000 tonnes.

In nature, the organic molecules represent the essential ingredients of life. Amongst them the linear forms of the macromolecules of cellulose and man-made solids have a significant importance as a fibre substance. It it therefore understandable that empirical tests to manufacture artificial fibres began with these natural materials. Particular successes were, however, only achieved with cellulose, which still has great economic importance as a raw material today. The term man-made fibres was coined in 1950 for previously customary terms such as synthetic fibres, created fibres, industrial fibres, etc. This phrase thereby represents the new



	1997/98	1998/99	1999/2000
China	4.60	4.33	4.10
USA	4.09	3.05	3.70
India	2.69	2.73	2.70
Pacistan	1.56	1.50	1.62
Usbecistan	1.14	1.00	1.10
Turkey	0.83	0.86	0.87
others	5.11	5.08	5.11
total	20.02	18.55	19.19

million tonnes cotton production

Fig. 2: left-hand side: Economic importance of man-made fibres (1970–2000); right-hand side: cotton production (1997–2000), source: ICAC, Washington.

generic term for all types of fibre, which are created industrially, independent of whether they are manufactured as filament or cut, made of animal, plant or mineral raw materials. That is why they also include the synthetic fibres. Their number and importance has grown significantly since rayon staple fibre, as there are several hundred different types of man-made fibre throughout the world.

Cellulose is normally the starting material for the so-called man-made fibres made from natural polymers. It is, for example, found in the wood of beech and spruce trees, while the raw products for synthetic fibres are chemical substances such as phenol, benzene, acetylene, chlorine, hydrocyanic acid, etc. These materials do after all also derive from nature, namely petroleum, calcium carbonate, sodium chloride, etc., but they were obtained using chemical transition processes. All the products, so not only the filament threads, but also the cut fibres, are basically manufactured in a filament spinning process. While the filament, i.e. endless products, are left in this form and wound on cones, the staple fibres are tear-converted or cut to the desired length with the aid of trimming machines so that they can be spun together with wool, cotton, flax, etc. or also on their own.

Man-made protein fibres (protein man-made fibres, regenerated protein fibres), nozzle-spun man-made fibres made from natural polymers on base of protein solids:

I. Vegetable origin: vegetable protein fibres such as →: Zein; Arachin fibre; Glycine.

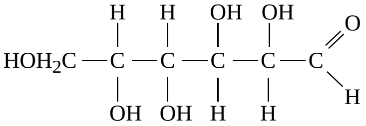
II. Animal origin: animal protein fibres such as →: Casein; Fibroin.

Man-made protein fibres are generally distinguished by heat, pleasant handle and elasticity. Depending on hardening they are remarkably resistant to rot and moth attack as well as not being inflammable. They are outstandingly suitable for mixtures with wool and viscose fibres (encourage richness, improve handle and wool-like character, reduce tendency for creasing). Generally very good resistance to diluted and weak acids strong acids have a damaging effect. Fairly resistant to weak alkalis, having a cold and short effect. Concentrated alkalis, particularly hot, have a swelling to destructive effect. Dyeing reaction: extensively like chlorinated wool. Bleaching is possible using sodium hypochlorite, peroxide or sodium hydrogen sulphite. As man-made protein fibres promote the felting process of wool, they were useful in the hat and felt industry, otherwise only as fibre blends.

Man-made protein fibres, distinguishing tests Boiled in 0.1% ninhydrin solution for 1–2 min fibres appear dyed as follows: groundnut protein fibres = greyish brown, zein fibres = grey-blue, milk casein fibres = faint purplish blue, soya fibres = undyed.

Man-made staple fibre Designation for staple fibres of the man-made fibre type. Opposite → Filament.

Mannose (D-mannose), $C_6H_{12}O_6$; molecular weight 180.16.



Belonging to the simplex sugar types. Occurring as a component of similar sugar polysaccharides, e.g. predominantly involved in the structure of → Locust bean flour (galactomannan, carob). In its pure state (commodity) white, sweet-tasting crystal powder, easily water-soluble.

Mannuronic acid →: Polymannuronic fibre; Alginic acid.

Manometer, pressure gauge Pressure gauge for gas, vapour and air pressure (also fluid pressure), which exceeds or falls below normal pressure.

I. Fluid manometer: Simplest type (similar to → Barometer) as an open U-tube filled with fluid (mercury, paraffin oil or coloured kerosene), connected on one side or (for differential pressures) on both sides, board-mounted, mm pitch, reading off the level stand above and below (rounded distance). Only for low excess pressures (often below 1 bar).

II. Diaphragm pressure gauge: oval housing, air-tight clamped diaphragm (corrugated sheet metal), one side with overpressure connection, another side with pushbutton, little gear wheels, pointer and calibrated measuring scale.

III. Tube spring manometer: tube spring bent in three-quarter circle (Bourdon tube) with oval cross-section made of brass or (for maximum pressure) bored steel tube, one side above with excess pressure connection, other side closed with lever-operated transmission, counting segment, gear wheel, pointer and calibrated measuring scale.

II. + III. for high-pressure measurements in autoclaves and similar also (remote) indicating as well as using a contacting device to control industrial machines or indicating devices; or also (tele)typing.

MA process Low wet pick-up process as an impregnation process with only low pick-up of finishing liquor, thereby shorter drying times. Fabric spreads across roller (applicator roller or inching roller), which dips into the liquor on the underside and possibly on the top side (see Fig.) and delivers this in a controlled manner to the fabric. Speed range of 0–150 m/min. For fabric finishing, knitgoods and application of chemicals in printing (2 phase vat printing). The MA technique can be used for very absorbent fabric; the liquid uptake is thereby only ca. 35%, compared with 60–70% for the padding. → Low wet pick-up.

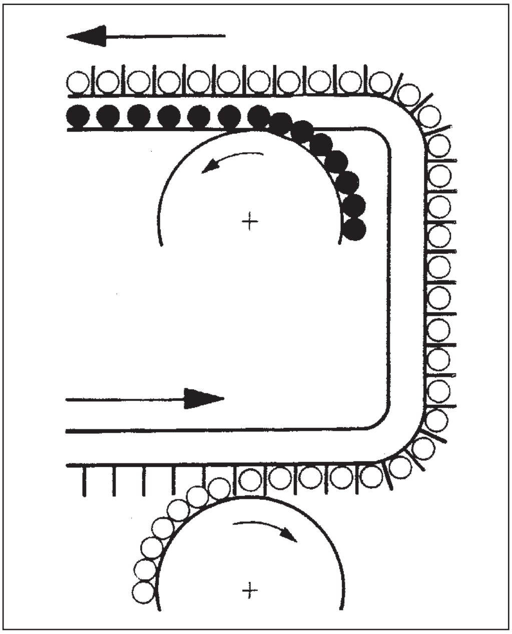


Fig.: Two-sided wet pick-up in the MA process (Triatex).

Marangoni effect According to the discoverer of the described "self-extension effect" of foam lamellae film damaged at one place, whereby a new film surface of higher surface tension and smaller area coverage with surfactant molecules develops there (see Fig.). This results in surfactant molecules immigrating from the environment with low surface tension and thereby carrying along the underlying fluid with their hydrophilic groups to fill the areas which have become thin (self-healing).

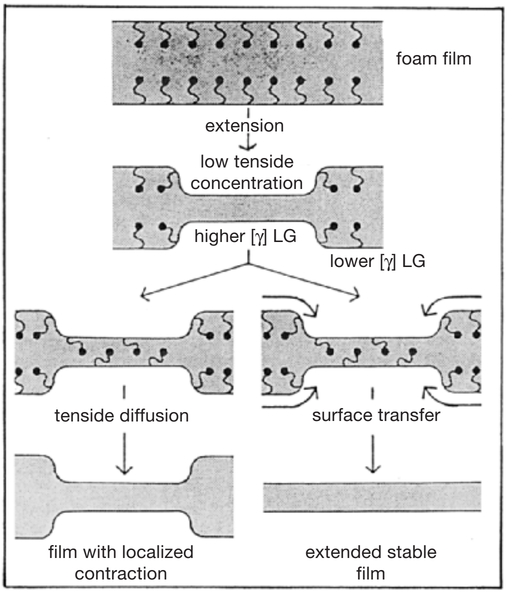


Fig.: Diagram showing surface elasticity and the Marangoni effect.

Marbled soap Soap, which is produced via the dilution taking place in the soap type (refined core-glued deposit) during cooling. This partial dilution gives rise to the formation of transparent or, with dye addition, coloured strands in the soap.

Marengo Suit and coat material (similar to fine → Loden), not a fabric quality, only a colour description. This concerns very dark-coloured, almost black materials, which are brightened up by a small white component of 1–4% (= radial-line colour). The four-weave symmetrical twill is almost exclusively found as a weave. There are marengos both in worsted yarn warp and weft and in carded spun yarn in both thread systems. There is therefore a distinction between worsted yarn and carded yarn marengos, the worsted yarn marengos are generally lighter and either barely finished or only lightly meltonated. The carded yarn marengos are practically in nearly every type of weight, above all for winter coats, and furthermore in all kinds of chemical finishing. The predominant marengos are qualities of merino-fine overcast wool, which are usually wool dyed. You can have part coloured marengos, but the white component must then either consist of resisted wool or synthetic fibres, which cannot be dyed when applying wool dyes.

Marengo yarn Black and white mottled yarn, e.g. made of wool or silk (worsted or carded yarn).

Marginal lye Electrolyte solution of a concentration above which soap is insoluble, below which it starts to dissolve. Its concentration depends on the nature of the solid matter used, the electrolytes and the temperature.

Mark Withstand capability of a print paste; perfect mark of a print paste when printing corresponds to a sharp vertical outline. → Print definition.

Market analysis Systematic/methodical examination of the position of individual companies in market events. A necessary prerequisite for the conception and business policy of a company, besides the monitoring of the market for the creation of market transparency. Implementation to a certain extent with own staff, but mostly with specialist institutes or market analysts/consultants. A product-oriented company management solely concerning optimisation of products and the technical manufacturing processes is no longer adequate today. The marketing area is gaining importance and so is the "buyers' market". The marketing idea is developed against this background. One definition is: market planning, a term for a sequence of functions, which consolidate all the efforts of the company to the one aim of serving the customers in order to guarantee that the customer receives:

- what he wants,
- where he wants it,
- how he wants it,
- when he wants it.

So in marketing the needs of the purchaser are the focal point, to be distinguished from the term "selling", which regards the needs of the seller as having priority. An effective marketing policy requires decisions in the marketing area. However, these are often related to the future and therefore tainted with a rather uncertain character. In order to make decisions as rationally as possible requires reliable information, which is used and/or interpreted, as well as corresponding methods. This information requirement is met by a partial function of marketing - market research. Market research is occupied with customers' wishes and modes of behaviour, competition measures, effect of own marketing policy measures, technological, legal and social trends.

Market research should be described as an interdisciplinary science, whose main sources are economics and social sciences. But other sciences are also included in order to do justice to the complexity and multi-layeredness of the task, which provides market research. This is how mathematical statistics and probability theories, for example, have become major industrial instruments of the market researcher. If any information is gathered for purely marketing policy purposes, one talks of marketing research. Market research, however, deals with the collection and processing of data gathered from the market for any purposes you like. The Figure clearly shows the delimitation, which is fluid, however.

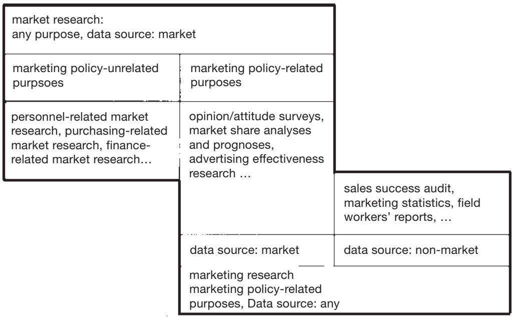


Fig.: Definition of market and marketing research.

Capital goods belong to producer goods - goods, whose purpose lies not in consumption, but in a longer-lasting use; so they wear out quickly and are not destroyed in use; a relatively high price should be supplied to the purchaser for their acquisition. Capital goods are, for example, furniture, machines and equipment, vehicles and similar. Consumer goods are, however, intended for consumption and are perishable; they are subject to consumption or destruction. The creation of the need for consumer goods applies to the human personality in all its levels of existence and in its social interconnections. The following sciences are therefore enlisted for the gathering and interpretation of data in consumer goods market research: biology, anthropology, psychology and sociology. The buying decision for investment goods is dependent on other criteria, which are of the technical/economic kind. This market is, however, not always as clear as the consumer goods market. It shows more market dependencies, as the national economic degree of integration is larger for capital goods. That is why it can be affected by more subsidiary economic developments and departmental economic trends. Another important distinguishing feature of capital and consumer goods is the structure of demand. While you almost exclusively find a polypolitical demand for consumer goods, complete market types such as buyer's monopoly, oligopoly and polypoly appear for capital goods. In contrast to capital goods, the circle of consumers for consumer goods can often be determined easily according to general characteristics such as gender, age, income, etc. You can usually form really homogeneous customer groups for marketing according to this. The circle of potential consumers for capital goods is, however, dependent on internal conditions, i.e. on specific functions of production. To this is added the fact that the capital goods themselves are distinguished by a great heterogeneity. Against this background it also turns out that the apparatus for the respective branches of market research can differ now and then. Secondary research dominates the field of capital goods market research, whereas primary research is of greater significance for consumer goods market research.

A specialist institute for technical market research, for example, offers ascertainment of the following data:

- total size of the market,
- regional marketing potential,
- own market share,
- market development tendencies,
- number of competitors,
- market share of competitors,
- advertising expenditure of competitors,
- distribution methods of competitors,
- prices and terms of competitors,
- structure of marketing channels,
- importance of marketing channels,
- description of purchaser circles (structure of customers),
- production methods and systems,
- design characteristics of rival products,

- marketing prerequisites for new developments and diversification,
- site selection criteria.

The marketing planning process demands help from market research for the following phases:

1. registration of the current market situation of the company (market diagnosis).
2. assessment of the probable market and sales development (market forecast).
3. determination of marketing aims.
4. decision on marketing strategies.

Research on demand, purchasing power and rivals are very significant for sales market research. Ecoscopic and demoscopic analyses are thereby applied. The competitive analysis is thereby essential for the assessment of the market and competitive position of the company concerned, unless this concerns a monopoly-type structured market. The following information is of importance for this: the number of competitors and their competitive intensity (market shares of competitors, market structure of rival firms and reactive competitive behaviour). Besides the competitive analysis, the analysis of your own operational market position is of importance for drawing up a complete picture of the market. It includes research into:

- the market shares,
- the consumer circles,
- the change of brand, the commitment to a brand,
- the consumer satisfaction,
- the product images,
- the degrees of information,
- the opinions and feelings,
- the trends,
- the potential market position.

Besides market diagnosis, the second task of market research consists in the market forecast. Forecasts show developments, which are the most probable according to the level of knowledge at the time of the forecast, i.e. currently effective influence factors are transferred to the future development. The following types are distinguished:

- national economic and business management forecasts,
- short-, medium-, and long-term forecasts,
- qualitative and quantitative forecasts,
- overall and partial forecasts,
- supply and demand forecasts.

The following procedures can be applied for this:

1. Extrapolation procedure, which is based on the tracking down of legal restraints.
2. Econometric procedure, whereby a relationship system is established between several explanatory sizes and their factors of influence.
3. Intuitive procedure: scenarios, i.e. presumable plots, are hereby drawn up on the basis of particular basic estimates.

Forecasts should have accuracy and reliability, which is, however, always in relation to coverage and detail. However, forecast errors, which can be characterised as data, modelling or assumption errors, may always occur.

The implementation of market research tasks can be carried out by the following institutions:

- operational market research,
- market research institutes,
- economic research institutes,
- advertising agencies,
- associations,
- marketing consultants.

In general it can be said that operational market research has the following advantages:

- better familiarity with the problem to be settled,
- better possibilities for co-ordinating market research activities,
- better exhaustion of information from the decision maker,
- often longer experience and specialist knowledge of the line of business,
- better information and data protection after conclusion of the project.

The following are considered as disadvantages:

- operational blindness,
- methodical backwardness,
- influence of results from internal authorities.

There are the following advantages for external research:

- use of specialists,
- greater objectivity in research,
- comparability with results from other investigations,
- better control and use of more recent research methods.

However, the danger hereby lies in the commercialisation and with that the setting of a goal operating on a profit basis.

Market research as such is a complex area. The objective of an individual market analysis is dependent on the customer. A businessman is, for example, interested in the behaviour of competitors, market shares, buying motives, differences in price and quality for the consumer. The instruments and methods of market research are therefore also very diverse and should always be selected against the background of the facts to be investigated. Key data of the market and/or market phenomena, often statistical, can usually be ascertained from already published sources. This is called secondary research or ecoscopic market research (desk research). On the other hand, behaviour of market participants must be directly investigated by the relevant persons. This concerns primary research or demoscopic market research (field research). Secondary research deals with collecting and evaluating information already available. Internal management data such as sales and order statistics, cost accounting, list of customers, customer correspondence, representatives' reports, after-sales service reports and purchasing reports are considered for this as well as external data such as official statistics for sales and prices, brochures, catalogues, annual reports, business newspapers, trade journals, directories and manuals, office addresses, trade fair catalogues and visits. Databases represent an important instrument in this connection, for example, complete register of all industrially active firms in Germany. Secondary research requires a far lower expenditure of money and time than primary research. Primary research is always carried out starting on the basis of the secondary data collected. One cannot usually do without a certain amount of primary research, as, for example, the existing sources do not go deep enough, one requires particular information immediately or else subject-related information about market participants in the real sense of demoscopic market research is required.

Marketing Concept of market-oriented business management, → Market analysis. The extensively small to medium-sized structured German textile and clothing industry sees itself exposed to dynamic changes in the market situation, which increasingly aggravates a monitoring of the market only using the traditional aids. The marginal conditions of marketing are essentially determined by the quicker fashionable change, the decline in established consumer groups. Information about the partners in the "textile chain" (raw material production, spinning, textile surface production, finishing, garment manufacture, trade, consumer and disposal) directly influence the distribution and marketing of a company. → Market analysis.

Marking → Sighting.

Marking chalks Are used for marking/sighting piece goods in the finishing phase. Consist of dye pigments stored in wash-active substances. Should not be decomposed during operating processes before the piece washing (e.g. steaming, burning at high temperature, etc.); otherwise risk of dye fixation on the fibres.

Marking colours Marking pencils, inks, → Textile markers.

Marking inks →: Chalk dyes; Laundry markers, but also dyes, which are applied to yarns for labelling without being fixed properly. Must therefore be easily washed out.

Marking machine,

I. For fabric faults, are used in combination with corresponding recording devices on inspection and measuring machines.

II. Are used for the labelling of individual pieces such as shirts, etc.

Marking of grey fabrics is used for marking/sighting as a grey material preparation in textile finishing using description or stamping (→: Textile markers; Stamping inks); also analogous to dry-cleaning and laundry (→ Laundry marker).

Marking off in wet goods Bleeding or destaining of colorations and printing in fabrics laying on top of each other in a wet or moist state.

Marl yarn (Fr.: twisted),

I. Marl ply-yarns: double or multi-thread tightly twisted ply-yarns, whose individual threads consist of contrasting colours, which gives a speckled appearance to the fabrics manufactured from them. The handle of these fabrics is usually somewhat harder due to the tight twisting. Marl ply-yarns are typically more often found in the following fabrics: cord, fresco and tropical, coat gabardines, whipcord and in particular in twists. Marl ply-yarns are manufactured in both worsted yarn and carded yarn techniques. Marl ply-yarn made from polyamide is important for carpets.

II. Woven fabric: no designation for a particular fabric quality, but only type of design. The name implies that marl ply-yarns have been used in the chain and in the weft, but only in the chain in many cases.

Marocain → Crêpe Marocain.

Marquisette Transparent net curtain fabric in gauze weave, fine thread, gauze-like; smooth, patterned, embroidered; mostly cotton (e.g. Swiss marquisette), cupro filament or synthetic fibres; for net curtains, curtains, furnishing and clothing fabrics (also made of silk).

Marseilles soap Fatty, mild → Soap made from olive oil, cotton oil, etc., white or green, bar or needle-shaped.

Marvel-Meter Instrument for the mechanical counting of stitch courses in any kind of stitch products, from the finest 75 g weight to coarsely knitted batch fabrics; fast and reliable, without special previous knowledge.

Masked fatty acid products → Fatty acid condensation products.

Mass (unit of measurement), basic dimension of → SI units using the base unit → Kilogram. The base unit 1 kg is the mass of the International Kilogram Prototype (original kilogram, mass kilogram). The unit already contains the prefix "kilo" so that no other prefixes may be used for multiples or fractions of the unit. The following are permitted as special names:

1 gram 1 g = 10^{-3} kg and

1 ton 1 t = 10^3 kg = 10^6 g = 1 Mg (megagram).

Mass action, law of puts pure, solid silver chloride (sediments) in equilibrium with its aqueous, saturated solution, so this heterogeneous equilibrium is described by the phase transition:

$$\mathrm{AgCl\ (solid)} \rightleftharpoons \mathrm{AgCl\ (aqueous)}$$

whereby the symbol AgCl (solid) resp. AgCl (aqueous) signify the neutral silver chloride in the pure solid phase resp. in the liquid mixed phase, which is made up of the electrolyte silver chloride and the solvent water. As silver chloride is only diluted in water to a small extent, it is called a not easily dissoluble salt. In the aqueous phase, the dissolved neutral silver chloride AgCl (aqueous) dissociates in accordance with the following chemical homogeneous reaction:

$$\mathrm{AgCl\ (aqueous)} \rightleftharpoons \mathrm{Ag^+ + Cl^-}$$

As this dissociation reaction is almost completely executed, the equilibrium is extensively at the end of the ions. If the concentration (molarity) of the undissociated silver chloride, the Ag^+ ions and the Cl^- ions in the aqueous solution is described using $c_{AgCl(aq)}$, c_{Ag^+} and c_{Cl^-}, the law of mass action for the reaction corresponding to the normal quotient notation for the equilibrium concentrations of the types of particle, which are left and right in the reaction equation, is as follows if the ideally displaced solution is assumed:

$$K_c = \frac{c_{Ag^+}\, c_{Cl^-}}{c_{AgCl(aqueous)}} \cdot \frac{1}{c^*}$$

K_c is the equilibrium constant for the reaction in the concentration scale and c^* a standard value of concentration, e.g. $c^* \equiv 1$ mol/l. The equilibrium constant for the given medium (e.g. water) generally depends on the temperature and (in condensed phases) slightly on the pressure. It is, however, independent of the presence of other electrolytes, even if these in turn contain types of particle, which participate in the reaction in question.

The concentration of dissolved complete electrolytes is constant for given solvents in saturated solutions at constant temperature (and constant pressure) – saturation concentration. The concentration of the undissociated silver chloride $c_{AgCl(aq)}$ consequently also represents a constant in this respect in the above example due to the equilibrium. With saturated solutions, the equilibrium constant and the concentration of undissociated electrolytes is therefore summarised by the definition:

$$s \equiv K_c \cdot c_{AgCl(aqueous)} \cdot \frac{1}{c^*}$$

The dimensional size s means solubility product. From the previous equations there follows:

$$s = c_{Ag^+} \cdot c_{Cl^-} \cdot \frac{1}{(c^*)^2}$$

Silver ions react in aqueous solution with ammonia under formation of a complex in accordance with:

$$\mathrm{Ag^+ + 2\ NH_3} \rightleftharpoons \left[\mathrm{Ag\ (NH_3)_2}\right]^+$$

For this equilibrium, which is extensively on the right end in the silver diamin complex, the law of mass action assuming an ideally displaced solution in the concentration scale is:

$$\left(K_c^{I}\right) = \frac{c_{[Ag(k)]^+}}{c_{Ag^+} \cdot (c_{NH_3})^2} \cdot (c^*)^2$$

whereby $c_{[Ag(k)]^+}$ and c_{NH_3} respectively signify the concentration of the silver diamin complex and the ammonia. The equilibrium constant KS_c^I of the reaction of silver ions with ammonia is called the stability constant of the complex or complex-forming constant. If ammonia is added to the saturated aqueous solution of silver chloride with sediment considered at the beginning, complex formation occurs. The silver ions used in this are subsequently delivered by the dissociation of the silver chloride. The undissociated silver chloride AgCl(aq) required for this is, for its part, made up of solid silver chloride. On the whole, the sediment is thereby fully or partially dissolved depending on its mass. Sum of the reactions results in the following for the gross reaction in the solution:

$$\mathrm{AgCl\ (aq) + 2\ NH_3} \rightleftharpoons \mathrm{Cl^-} + \left[\mathrm{Ag\ (NH_3)_2}\right]^+$$

The following applies for the equilibrium constant of this reaction under the conditions introduced above:

$$K_c^{II} = \frac{c_{Cl^-} \cdot c_{[Ag(k)]^+}}{c_{AgCl(aqueous)} \cdot (c_{NH_3})^2} \cdot c^*$$

The concentration of the undissociated silver chloride $c_{AgCl(aq)}$ now also represents a constant in the presence of the sediment silver chloride for a given solvent, at constant temperature (and constant pressure). For this reason the definition

$$K_c^{III} \equiv K_c^{II} \cdot c_{AgCl(aqueous)} \cdot \frac{1}{c^*}$$

is introduced. It results in

$$K_c^{III} = \frac{c_{Cl^-} \cdot c_{[Ag(k)]^+}}{(c_{NH_3})^2}$$

Use of the previous equations in this respect leads to:

$$K_c^{III} = K_c^{I} \cdot s$$

The correlation enables the equilibrium constant K_c^{III} to be calculated for the known concentration of chloride ions c_{Cl^-}, the silver ions in the diamin complex $c_{[Ag(k)]}^{+}$ and the ammonia c_{NH} in the solution mixed with ammonia with sediments made of silver chloride. The stability constant K_c^{II} of the silver diamin complex is available from this in accordance with the equation for the given solubility product s.

Mass coloration (spin dyeing). In this process (Fig.) also called jet dyeing, finely distributed dye pigments, which withstand the thermal and chemical demands of the spinning process, are added to the spinning solution/melting of synthetic fibres. Used, for example, in polyamide for upholstery fabrics, carpets, floor carpeting, automobile articles; in polyester for upholstery fabrics, menswear, work clothing.

1. Continuous process: dye is introduced to the already formed polymer (solid or molten state). Dye in powder or granule form is continuously distributed using dosage pumps and then mixed with polymer granules or chips, which supply the melting equipment (extruder or fixed melting furnace), or directly with molten polymer. Process is simple and flexible, but results in great variations in bright colours. Dyes (liquid or in paste form) are dispersed in binders (polymers of different molecular weights or polyethylene glycols of high molecular weight) and are injected into the molten polymer using additional extruder, which directly supplies the main extruder, in which polymer granules are melted.

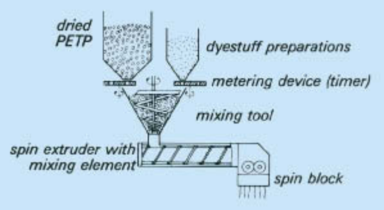


Fig.: Spin dyeing.

2. Discontinuous process for polyester: in a unit of production for the manufacture of polyester granules, the polyester chips are dried in a vacuum for several hours at 140–180°C in rotary driers or tumblers and at the end of this process specially selected dyes are added; they are fixed on polyester granules via thermodiffusion. Suitable process for the manufacture of small quantities of spin-dyed fibres/threads.

3. Discontinuous process for polyamide: Polyamide granules are simultaneously washed and dyed in the aqueous medium. After several hours drying at 180°C, it is melted under the same conditions as colourless granules. Granule dyeing is carried out in a machine with bath circulation.

It is indeed difficult to determine the cost difference between spin-dyeing and conventional dyeing even with only 10% accuracy; but it is estimated that the spin-dyeing of polyamide and polyester is 20–30% cheaper than dyeing according to normal processes. In addition, spin-dyeing has ecological advantages as well as simplicity and precision of technology. However, this type of dyeing cannot react to fashion trends in the short term and is therefore chiefly used for standard articles.

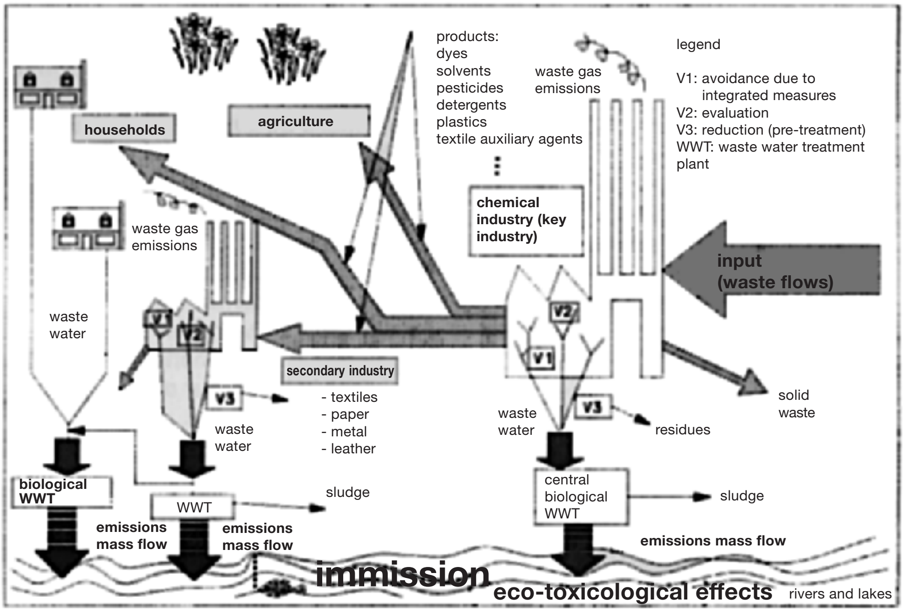


Fig. 1: Mass flows in the economic system (principal sketch diagram, according to Schönberger).

Mass flow In all areas, business with the associated process technology is linked to mass flows (material flows). The exhaust gas, solid waste and waste water accumulating from this are undesired mass flows. The wide use of raw materials and the application of products represent mass flows, which are normally desired or wanted (Fig. 1). Not only in the textile industry are undesired mass flows the subject of environmental protection efforts. It is necessary to avoid, exploit and reduce these and/or change these in the direction of better environmental compatibility. These aims can only be achieved cost-effectively and efficiently if the existing mass flow ratios are recorded and shown in detail. This should lead into a synchronisation of mass flow and associated flow of information (quantity and quality of the mass flow at the location x at the instant y) as is striven for and executed by the material flow logistics on the production side. In textile finishing, such an assessment and/or synchronisation can only be worked out relating to a procedure or process depending on the process stage due to the more or less strongly variable production processes. I.e. process-related emission factors should be established (in waste water quantity/kg of substrate, g of operating material in the waste water/kg of substrate, type of making up of finished textiles, application technique, etc.).

The initiative for recording the emission mass flows (environmental audit) should come from the individual textile finishing business itself with the aim of hurrying along the further reduction of the emission mass flows autonomously. This autonomy is legally supported by the self-monitoring regulation simply in Baden-Württemberg. The “general and production-specific self-monitoring” amongst others should be carried out in accordance with appendix 3 of this regulation (item 2.1 of appendix 3). According to this, the waste water-related materials used in production should be recorded at the internal waste water accumulation points according to type, quantity and composition (used material list). Self-monitoring also includes the following examinations at the waste water accumulation points from a drawn off waste water quantity of 50 m^3/day, in the field of textile finishing from 200 m^3/day:

– waste water accumulation according to type, composition, quantity, specific waste water load;
– the operating processes, in which specifically loaded waste water or cooling water accumulates;
– the possibility of improvement in waste water sepa-

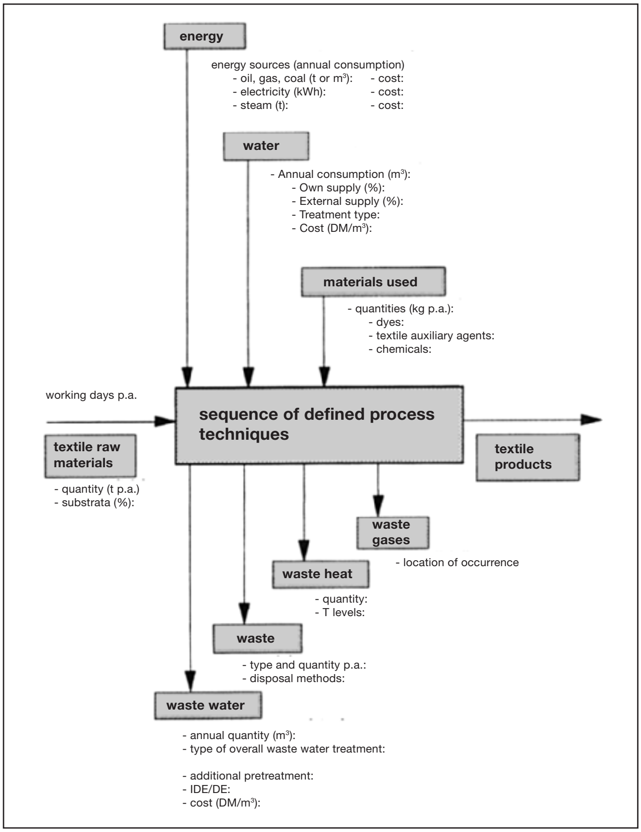


Fig. 2: Textile finishing operations: annual energy and mass flows (according to Schönberger).

ration (e.g. production waste water, waste water containing cyanide or chromate, rinse water, concentrates, etc.) and in segregated steam treatment;

- the possible measures for avoiding and reducing harmful pollutant loads within the meaning of § 7a WHG (Germany's → Water Resources Law);
- peculiarities, defects, possible remedial measures.

Waste water register is the synonym for the raising and representation of internal waste water/mass flow ratios. It should firstly be effectively drafted in a rough form, i.e. for the mass flows flowing within a year. As all energy and mass flows within the production flow together, this balance should be represented for all media (waste water and solid waste, exhaust gas and energy). While the annual survey of energy and mass flows shown in Fig. 2 is useful, this is only the case to a limited extent for considerably shorter periods of time (e.g. individual days). The reason lies in the continuous change in production (annual cycle, change of substrate, etc.). Finally a process-related stock-taking must be worked out as a very detailed plan concerning the determination of process- or procedure-related emissions factors, which are joined together to form a whole, the waste water register (multiplied with the respective substrate quantities and EDP supported).

So-called integral, all-media programmes for their avoidance, exploitation and reduction are possible on the basis of known mass and energy flow ratios. Unique solutions for the reduction of the emission mass flows associated with exhaust gases, solid waste and waste water are normally too uneconomic. Integral, all-media programmes also include energy flows. This will also be necessary in the future due to the Heat Utilization Ordinance (according to Schönberger).

Mass flow ratio in heat recovery (K), the ratio of the masses (m^2/m^1) indicates what proportion of fresh air (referring to the quantity of outgoing air) is supplied to the driers. K = 0.5 therefore means that 50% of the exhaust air filtered from the drier can be replaced by fresh air from the heat recovery plant.

Mass per unit length → Linear density of fibres and yarns.

Mass spectrometry Accelerated, positively charged particles are separated by a magnetic field proportional to their mass in the mass spectrometer. A mass spectrometer consists of the four functional areas of supplying samples, ionisation, mass separation and ionic detection. A fine molecular flow runs from the intake system into the ionic source and vertically meets an electron beam there, whose energy at 70 eV is:

$$M + e \longrightarrow M^+ + 2\,e$$

The molecular ions are accelerated and focused after abstraction of one or several electrons with 2–10 kV. The speed of the ions is thus:

$$z \cdot u = \frac{m \cdot v^2}{2}$$

$$v = \sqrt{\left(\frac{2 \cdot z \cdot u}{m}\right)}$$

z = ionic charge,
m = ionic mass,
v = ionic speed,
u = accelerating voltage.

The radical molecular ions which arise break into fragments, which are separated in the homogeneous field of approximately 1 teslar strong electron magnets based on their mass. The following applies for the deflection radius:

$$r = \frac{m \cdot v}{z \cdot B}$$

B = magnetic field strength.

The following results from this together with the first (speed) equation:

$$\frac{m}{z} = \frac{r^2\,B^2}{2\,u}$$

The masses of the fragments are determined by measurements of the deflection radii in the analyser part. Magnetic returns on the structure of the substance can be made from the fragments obtained in the analysis of the spectrum obtained, as this chiefly fragments at the weak bonded points.

Mass transfer kinetics Diffusion processes, whose mass transfer kinetics are associated with complex correlations, run both in dyeing (dye from liquor in fibres) and in washing (dirt from fibres in liquor) and in drying (water vapour from fibres in drying room). Dyeing processes in particular are extremely complicated procedures in their totality. In order to be able to understand them, you not only have to know the physical and chemical properties of the dyes and the substrates to be dyed; you also have to develop ideas as to how the diffusion and adsorption processes run physically and chemically. With the exception of pigment dyeing, all the other dyeing processes are based on sorption processes, whose transport processes are preset and which are often accompanied by chemical reactions. It is therefore difficult to describe these dyeing systems and the phenomena which arise in experiments accurately. Models, hypotheses and theories are needed for this. The more detailed such models are, the better the correspondence is between their statements and the experiment, but the more complicated are the formulae and equations necessary for their mathematical description as well. Finally, the mathematical terms are so complicated that approximation procedures (i.e. new hypotheses) are required to solve them, in which the model is however simplified again. There is no generally applicable dyeing theory where all the phenomena can be described clearly.

Interactions occur between the dye in the liquor and the dye on the fibre when dyeing cellulose fibres using direct dyes. In order to achieve a particular shade of colour, several dyes are normally needed, but the components influence each other mutually in such a combination. It is difficult to predict how a component of a mixture reacts in the equilibrium bath separation from the dye behaviour of the individual dyes. For prescribed calculations you can also recognise how these interactions should be included with the aid of colorimetry.

The affinity of the dye to the substrate is not only critical for the position of the equilibrium as a driving force in the dyeing process, but also for the kinetics of the dyeing process. The idea of Gouy-Chapman is used as the useful model for determining the dye equilibrium, in which the substrate is considered as an adsorbing surface. The following term is differentiated for the equilibrium distribution of a dye in a combination:

$$\ln (C_f/C_b) = A_0 - A_1 \cdot \frac{1}{\chi} - A_2 \cdot \frac{1}{\chi} \cdot \sum z_i \cdot C_{fi}$$

C_f, C_{fi}, C_b = equilibrium constants on the substrate and in the dyebath.

A_1, A_2 = constants to be determined in the experiment. They determine the electrostatic interaction between dye and dyed substrate. A_1 contains the charge-density, which should be considered as the parameter for the charge state of the substrate. A_2 contains the specific surface, which is accessible to the dye anions and represents another criterion for the dyeability of the substrate.

$\frac{1}{\chi}$ = Debye length, i.e. the distance from the surface according to which the potential is lowered to $^1/e$.

z_i = numbers of charges in the dye anions.

A_0 = standard affinity

This equation can be used for
- affinity tests,
- interpretations of diffusion coefficients,
- detection of interactions in the combination dyes using direct and reactive dyes,
- determination of the surface charge and internal dependence on the pre-treatment,
- computer colour matching of combination dyes.

The following material balance applies for the computer colour matching of any direct dye involved in a combination:

$$E = C_f + V \cdot C_b$$

E = dye application (g/kg),
V = liquor ratio (l/kg).

Using this equilibrium system, the applied dye C_f can be calculated according to an iteration principle. A high bath separation is not always desired due to the unfavourable levelling behaviour associated with it. In these cases the salt addition can be, which is required for a planned bath separation, calculating using the above equations.

Problems do not only arise when dyeing with dye mixtures, but also when dyeing with substrate mixtures (e.g. cotton/viscose). If both substrates are dyed in separate baths, the difference in the shade of colour is less pronounced than when dyeing out of a common bath, in which the viscose fibres really absorb a dye more deeply than cotton. If the substantivity characteristics A_0, A_1 and A_2 of both dyes are available on both substrates, this situation can be recorded arithmetically.

The following equation system applies for each dye involved in the combination:

for substrate 1:

$$\ln (C_{f1}/C_b) = (A_{01} - A_{11}) \cdot \frac{1}{\chi} - A_{21} \cdot \frac{1}{\chi} \cdot \sum z_i C_{fi1}$$

for substrate 2:

$$\ln (C_{f2}/C_b) = (A_{02} - A_{12}) \cdot \frac{1}{\chi} - A_{22} \cdot \frac{1}{\chi} \cdot \sum z_i C_{fi2}$$

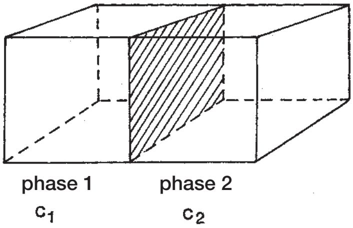
and the material balance:

$$E = m_1 C_{f1} + m_2 C_{f2} + V \cdot C_b$$

m_1, m_2 = percentages by weight of substrate 1 and 2 resp. (kg/kg); ($m_1 + m_2 = 1$),
C_{f1}, C_{f2} = dye absorbed by substrate 1 and 2 resp. (g/kg),
C_b = dye concentration in the dyebath (g/l).

The mass transfer between textiles and liquor is one of the most important process elements in textile finishing. In order to make the process kinetics controllable, adjustable and optimisable, it is necessary to know the transport mechanisms, the kinetic constants and the position of the exchange equilibria. In contrast to simple chemical reactions, which occur in the homogeneous phase, textile finishing processes take place in the heterogeneous phase. The phase surface between the fluid phase (liquor) and the solid phase (substrate) is a char-

Mass transfer kinetics



$$\dot{m} = \beta \cdot O \cdot (c_1 - c_2)$$

A

$\dot{m}$	mass flux	kg/s
β	mass transfer coefficient	m/s
O	surface	m^2
$c_{1.2}$	phase concentration	kg/m^3

Fig. 1: Formal description of the mass transfer system.

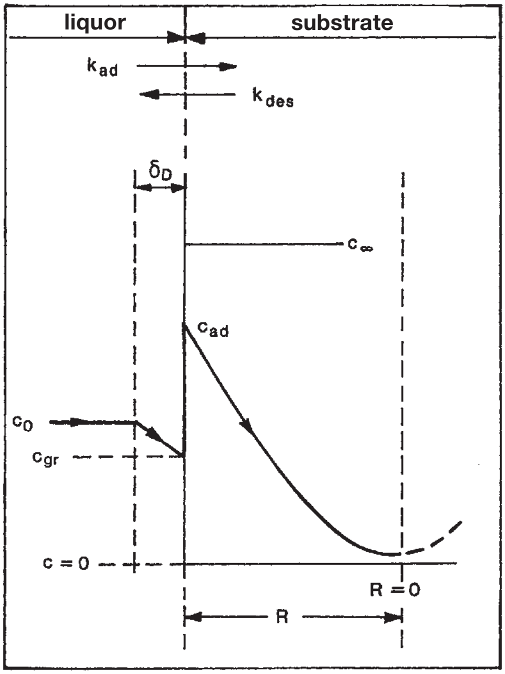


Fig. 2: Schematic diagram of the radial concentration profile on the substrate surface (Gerber).

acteristic feature. The mass transfer equation, which describes the mass flow from phase 1 into phase 2 (see Fig. 1), contains a kinetic term (the mass transfer coefficient β), a material-specific term (the surface range O) and a concentration term, which is also a measurement of the motive power of the mass transfer. The mass transfer causes a drop in dye concentration on the substrate surface range. This concentration deficit is in practice compensated for by the impinging flow of the substrate surface range. The strength of the hydrodynamic boundary layer is important in this connection (see Fig. 2).

A diffusion boundary layer forms into a transport resistance through mass transfer. The actual importance of liquor convection lies in the clearing away of this boundary layer and in the replacement with fresh, unspent liquor (liquor exchange). The strength of the diffusion boundary layer is critical for influencing the speed of this mass transfer. The hydrodynamic boundary layer is thick in laminar flow; thinner however in turbulent flow. Great impinging flow accelerates the finishing process. Unlevel dyeing may also be flow-dependent. The accuracy of test dyeings is therefore crucially determined by the adjustment of the flow profile in the laboratory.

Convective diffusion is the most efficient model for mass transfer in textile finishing processes: The competition between transport mechanics in the direction of convection (flowing liquor) and transport mechanics in the direction of diffusion (exhausting dye) represents the transport mechanics from the phase limit. The knowledge of the speed law of dye uptake under the current dye conditions in the fibre/liquor/degree of dye system is crucial for the optimised arrangement of dye processes. The test dyeings necessary for this, in particular for short dyeing times, require a defined sample packing and impinging flow of the fibre surface range.

Dyeings show that the integral dye uptake does not directly depend on the time in the form of R(t). The dyeing process can be treated from a formal, kinetic view as a dilution of two simultaneously accessible reservoirs for the dye. The integral dye uptake is described by:

$$\begin{aligned} c\ (t) &= c_1\ (t) + c_2\ (t) \\ c_1\ (t) &= c_1, \infty \cdot [1 - \exp(-k_1 \cdot t)] \\ c_2\ (t) &= c_2, \infty \cdot [1 - \exp(-k_2 \cdot t)] \\ c_F, \infty &= c_1, \infty + c_2, \infty \end{aligned}$$

c(t) = dye concentration on the fibre at the moment t,
c_1 (t), c_2 (t) = dye concentrations in reservoirs 1 and 2 at the moment t,
k_1, k_2 = speed constants in partial processes 1 and 2,
c_F, ∞ = dye concentration on the fibre in equilibrium,
c_1, ∞, c_2, ∞ = equilibrium concentrations in reservoirs 1 and 2.

The numerically determined speed and equilibrium constants represent characteristic properties of the liquor and the substrate. They give the access to the simulation of the dyeing system. The bath exhaustion of a separation dyehouse can be calculated in the same way as the exchange factor for continuous dyeing. Models of a cotton dyeing process derived from experiments can be explained by the morphological structures of fibres, whereby the quickly accessible reservoir represents the primary wall and the slower accessible the internal surface range of the secondary wall (Fig. 3).

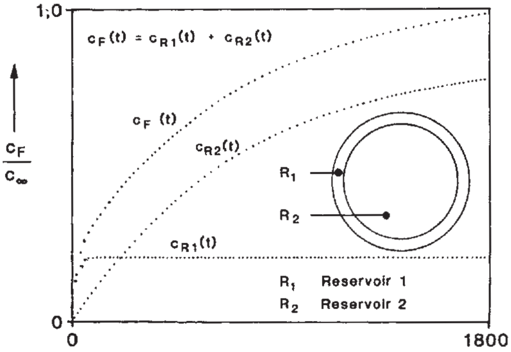


Fig. 3: Model of the substantive dyeing of cotton (according to Elgert).

The time/temperature programme is not predominant when simulating the dyeing process on the screen, but the exhaust curve. It clearly indicates the mass transfer between the liquor and the fibre material. In order to make it more clear, it is shown in time-lapse photography. So a process simulation tries to calculate an exhaust curve (i.e. “mass transfer”), which lies as closely as possible to the curves for control dyeings, from a few parameters for dye, fibre material and dyeing processes. The example of polyester bath dyeing using good combinable disperse dyes shows how you can construct a dyeing process simulation, how it works and for what you can use them. The prerequisites for the validity of the mathematical model are

– uniform fibre material,
– dyeing using disperse dyes according to the exhaustion process,
– finite bath,
– constant heating-up speed or constant (isothermal) temperature,
– process control in which no noticeable unlevel dyeings arise,
– constant liquor ratio.

A mathematical model for the transfer of the disperse dye between liquor and polyester material is the basis. It is based on the “dispersion depot” of dye in the initial dyeing range (DD range) and on the solubilised dye in the final dyeing range, which is exhausted (SE range). Building on a few functions, the DD/SE model, which assembles the dyeing process as made of two successive ranges, was constructed:

1. Disperse dye depot (DD range): the dye is available as a dispersion, turns into a solution from this monomolecular (at any rate low molecular) state and covers the fibres in this state. The concentration of monomolecular dye in the liquor remains roughly constant corresponding to an infinite bath due to rapid dye delivery from the “dispersed dye” depot. The rate of dyeing increases through constant heating up of the liquor. The course of the exhaust curve is either approached by a logarithmic function or by an ascending e-function (DD/SE model):

$$\mathrm{CTX}\ [\mathrm{g/kg}] = A \cdot (e^{-\mathrm{FSV} \cdot \mathrm{ZTM}} - 1)$$

CTX = dye concentration in textiles,
FSV = dye loss,
ZTM = (dyeing) time in min

2. Range of fully solvatised dye and the exhaustion of the bath (SE range): when the dispersed dye is used up by the exhaustion, only dissolved (solvatised, solubilised) dye remains and the bath is exhausted. The rate of dyeing continually decreases until it reaches equilibrium. The exhaustion can be described using an e-function, which approaches the final bath exhaustion as the threshold limit value:

$$\mathrm{CTX}\ [\mathrm{g/kg}] = C_\infty + (1 - e^{-k^* \mathrm{ZTM}})$$

The transmission point between both ranges (DD, SE) is macroscopically the turning point of the exhaust curve and microscopically the dissolving point (temperature, concentration) of the disperse dye, which indicates that the depot is used up.

The DD/SE model (Fig. 4) can be put to good use in numerous respects:

– time/temperature programmes can be constructed in order to produce exhaust curves;
– Knowledge about the mass transfer system can be extended;
– it is useful as an original test tool for detecting faults and for optimising practice dyeings;
– it illustrates representations of curves;
– Parameters are obtained, which bring extended knowledge, e.g. with regard to dye (diffusion constant and solubility), auxiliaries (dispersing effect and hydrotropic property) and fibre material (glass transition temperature range and accompanying activation energy).

Diffusion processes also operate in drying processes with characteristic mass and energy transfer kinetics. If a heating wire is centrally stretched out and heated in a

Mass transfer kinetics

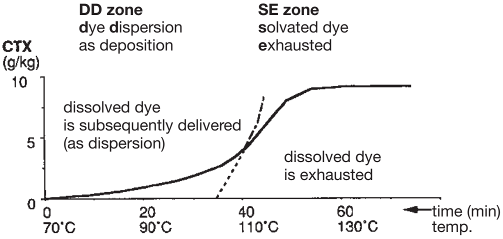


Fig. 4: Disperse dye deposition (DD) and bath solvation and exhaustion (SE) zones in the polyester process.

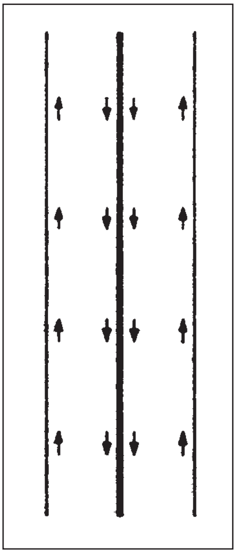


Fig. 5: Convection currents in the thermodiffusion pipe.

narrow, vertical tube with the aid of a weight, thermodiffusion takes place in the temperature difference between the cold wall and the hot wire (Fig. 5). This convectional flow is directed against gravity, i.e. upwards, near the hot wire; correspondingly downwards in the cold sheath of the tube. So, all in all, a flow of components, which endeavour to accumulate in the warmer part of the equipment in the thermodiffusion, continually takes place upwards and a flow of other components downwards until a more stationary state is reset.

Energy is consumed in the heating of air dry textiles through the heating up of fibres and through the volatilisation of the relatively low moisture content available. Instead of the specific heat c of the moist textiles, its reduced specific heat c_r is however authoritative for quantitative statements on the drying of a fibre. This should be interpreted as follows: the initial moisture content f_0 [kg/kg] is reduced to f [kg/kg] in air dry mass which occurs. The volatilisation and binding heat r' [kJ/kg] is the expended heat of volatilising: $(f_0 - f)\,r'$.

The heating-up time of the textile results from:

$$\frac{\vartheta(x,\tau)}{\vartheta_A} = f\left(Bi,\ Fo,\ \frac{x}{s/2}\right)$$

$\vartheta(x,\tau)$ = difference between the actual temperature t (x; τ) defined in place x and time τ and the constant ambient temperature t_U, so i.e.
$\vartheta(x,\tau) = t(x,\tau) - t_U$

a = temperature conductivity, represented by the term
$a = \frac{\lambda}{c\,\rho}$

λ = thermal conductivity of the material;

c = specific heat of the material;

ρ = material density;

ϑA = initial difference between fabric and ambient temperature, i.e.
$\vartheta_A = t_A - t_U$;

Bi = dimensionless number, characterised by the relation
$Bi = \frac{\alpha s}{2\lambda}$;

α = heat transmission number;

s = fabric thickness;

Fo = dimensionless criterion, defined by the relation
$Fo = \frac{a\,\tau}{(s/2)^2}$

τ = heating-up time sought for textile fabrics.

Thermal diffusion develops when temperature differences are balanced in gases. Convection is then the transfer of heat energy, which is accompanied by a flow. Exogenous forces may intensify the convection. Forced flow can appear as an exogenous force. So, for example, turbulence is a motion state (flow) of gas with statically unordered character of paths of gas molecules, which flow forming whirls. Flow through a tube is turbulent when the Reynolds number Re_{krit} becomes = 2320 with an irregular stenter. Turbulence develops from the laminar boundary layer (on an interface). The layers of a stationary moved gas phase slide past each other without whirl formation with pure laminar flow.

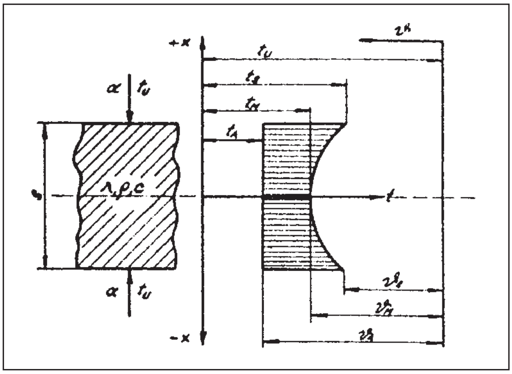


Fig. 6: The temperature profile in a textile fabric during heating.

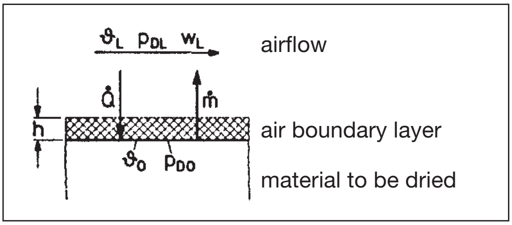


Fig. 7: Heat and fabric flow in the first drying section.

Two opposite flows flow through the laminar boundary layer of a moist textile which is heating up: the heat flow $\dot{Q}$ and the mass flow $\dot{m}$. In the 1st drying phase the volatilisation takes place on the surface area of the material (Fig. 7). This process is caused by heat transfer from the hot air via the boundary layer to the surface area and by transport of the vapour formed via the boundary layer to the air, whereby only the boundary layer appears as resistance. These processes can be described by the following equations:

$$\dot{Q} = A \cdot \alpha\,(\vartheta_L - \vartheta_O)$$

$$\dot{m} = A \cdot \frac{\beta}{R_D \cdot T}\,(p_{DO} - p_{DL})$$

$$\alpha = \frac{\lambda_L}{h}; \quad \beta = \frac{D}{h}$$

A = fabric involved in the transfer [m^2],
α = heat transfer coefficient [$W/m^2\,K$],
β = mass transmission coefficient [m/s],
ϑ_L, ϑ_O = temperatures of the drying air and the material surface area [^oC],
ρ_{DO}, ρ_{DL} = partial vapour pressure on the surface area and in the drying air resp. [N/m^2],
λ = thermal conductivity in the boundary layer [W/mK],
D = diffusion coefficient [m^2/s].

The state of the drying medium is described by the temperature ϑ_L and by the prevailing partial vapour pressure ρ_{DL}. The state of the drying material is determined by its temperature ϑ_O and the prevailing vapour pressure on its surface area ρ_{DO}. An equilibrium must exist between supplied heat and volatilised water quantity in the steady state, i.e.

$$\dot{Q} = \dot{m} \cdot r$$

and so

$$\dot{m} = \frac{A}{r} \cdot \alpha\,(\vartheta_L - \vartheta_O)$$

The scale of the heat transmission number α is chiefly determined by the intensity of the spray system, by the nozzle geometry as well as the distance between nozzle and fabric. So the heat transmission number is in the end a drying constant, as is the exchange area A (drier size), so that at constant spraying only the temperature difference (ϑ_L - ϑ_O) determines the transferable heat quantity and therefore the rate of evaporation. The heat and mass flow and/or the rate of drying may be determined from external conditions alone in this drying phase, i.e. independently from the material properties of the drying material. An increase in the rate of drying can therefore only be achieved by

1. increase in the temperature and partial vapour pressure difference between material surface area and air.
2. increase in the heat transmission and mass transmission values by increasing the speed of the drying air, which impinges the surface area, whereby the boundary layer thickness and therefore the resistance becomes smaller.
3. increase in the area involved in the heat and mass transmission.

(according to Dierkes and also to Gerber, Elgert and Rüttiger).

Mastic Greek tree resin; transparent drops, pea-size, pollinated outside, pale yellowish green (rarely reddish), malleable/sticking together when chewed. Bitter aromatic taste, glass gleaming break, softens at 80°C, melts at 105–120°C. Soluble in ether, benzene, xylene; partially soluble in alcohol, acetone, chloroform, turpentine. Distortions: often due to sandarac gum (never round drops, long stems, not softening when chewed, but powdery, only partially soluble in ethereal oils, much cheaper), colophony also powdered (solubility, high acid value), synthetic green dyeing using indigo. Easily soluble in ether, benzene ether and oils; up to approx. 90% in cold water. Application: dammar resin.

Matelassé Jacquard double cloth made from 2 chain and 3–4 weft systems, whose patterned fabrics emerge malleable, as if “padded”; resin finished. Application: coats, suits and garments, furniture covers.

Material,

I. (from Latin: materia = mother fabric), raw material, material, auxiliary, e.g. fibre material, dyeing material, sample material.

II. Generally, in the sense of → Woven fabric.

Material balance Concerns balancing of operational input and output values of dyes, chemicals, auxiliaries, work procedures, water (→ Waste water balance), etc. Intends to establish by product which substances accumulate in what quantity at which location. The resulting secondary products produced in the decomposition show how these react with the remaining constituents in the air and waste water. Helps to grasp

Material balance

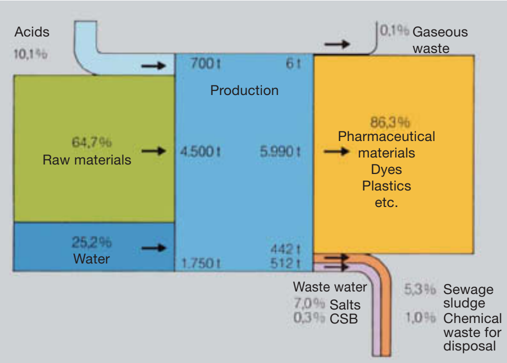


Fig. 1: Material balance in the Hoechst main factory in t per day (excl. fuels, cooling water, domestic-type waste, packaging and similar).

specific measures for the reduction of the waste water and exhaust air load and to prevent ecologically harmful waste materials from forming unchecked. In a dyeing recipe, for example, the kg input of dyes, chemicals, textile auxiliaries, water, etc. are balanced against the kg output of decay rate as waste water (salts, organic substances, water), exhaust gas (e.g. chlorine, ammonia) and any remains as solid waste (→ Ecological problems in textile dyeing, printing and finishing). In recent years, exhaust air cleaning plants, waste water treatment and waste incineration have been developed, which are connected to the production procedures. Pollution control does not however firstly start with the later disposal of exhaust air, waste water or solid waste, but already in the optimisation of production procedures. Only through this is it possible to consider all the factors such as also saving raw materials and energy. Though not all environmental problems can be solved by new procedure plans in accordance with the principle of reducing residues. You cannot completely do without connected measures. The following therefore applies:

- to develop and apply procedures, with which as little waste as possible is produced; waste is always lost raw material.
- reprocessing, recycling and reuse of waste; raw materials are also reclaimed here, but often at great expenditure.
- improvement in the processes for waste water treatment and cleaning exhaust air.

However each of these measures precedes a material flow absorption. The resulting product quantity diagram (Fig. 1) represents on the left all the output materials used in a process or in a finishing business; on the right all the finished products are listed together with the by-product level and as quantitatively as possible on both sides. Conclusions for suitable improvements can be drawn from the balance.

Zero values of emissions cannot be achieved thermodynamically. They still occur in the material flow of a large chemical plant even after pollution control measures

- in exhaust gas up to 0.1%,
- in waste water up to 7.0% as salts and 0.3% as organic added stabilisers,

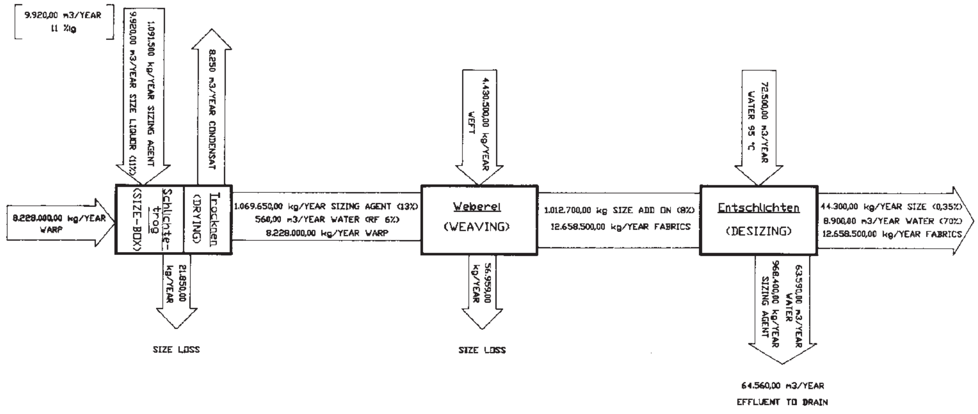


Fig. 2: Material balance without recycling of sizing polymers for a weekly production of 780 000 m fabric.

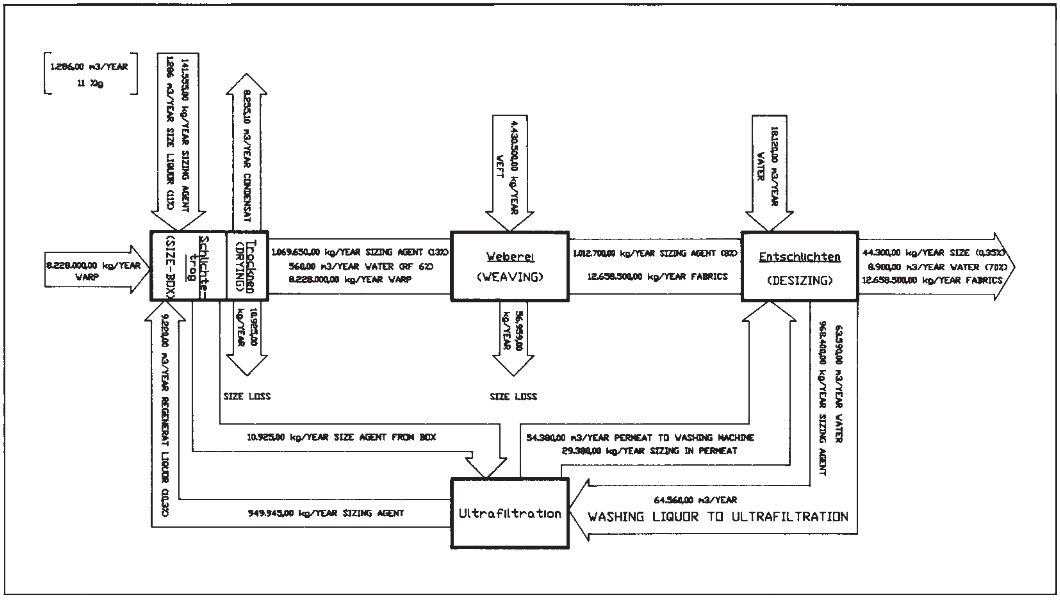


Fig. 3: Material balance with recycling (by GTV) for a weekly production of 780 000 m fabric.

– as waste, i.e. 5.3% sludge, 1.0% chemical waste to the waste disposal site.

In order to install size recycling between desizing and weaving preparation (Fig. 2), a material balance should be constructed beforehand, which can be compared with the success of the size recovery (Fig. 3).

Material carrier is used for the absorption of the dyeing material in the form of crosswound yarn packages, tubeless cross-wound yarn packages (bobbins), card slivers, spinning cake, loose material (loose stock), hank yarn and woven ribbons in circulating liquor machine dyeing.

Material ecology concerns the ecological aspect for materials, whose evaluation should in future no longer be restricted solely to its technical use in the completion of conventional material testing, but should also consider the damage to the environment. Production and products should be sustainably environmentally compatible.

Material flow The logistics in an industrial undertaking are the planning of demand, output, time and space as well as the monitoring and implementation of a planned material flow in view of the optimum cost. The term “quick response” is increasingly gaining in importance in the fashion-oriented market event and requires quick reaction to customers’ wishes exploiting logistic and economic material parameters of the sales market. Fig. 1 shows the material flow in a hypothetical textile operation from the order to the delivery, in a simplified form.

The production process in a yarn dyeing business is multistage and has different processing stages and times depending on yarn quality and requirements of the finished product. The path, which the raw yarn takes from delivery to the finished dyed package, is shown in Fig. 2: Material flow for a yarn dye works. Each package must be individually picked up at least twice, but in most cases 6–10 times, depending on the process. For a production of 10 000 packages per day, this results in more than 60 000 necessary operations. So, a total weight of more than 60 000 kg must be moved. Another 6–12 transport operations of pallets, boxes and dye carriers are added to this. These figures clearly show that transport and handling are labour-intensive and a considerable cost factor in high-wage countries. It is also physically hard and unattractive work.

The dyeing process lasting 4–8 hours operates fully automatically in many dyehouses on the basis of process control as well as automated chemical metering and a colour kitchen. The following manual operations are still required:

– monitoring of the process run on the PC usually centrally in the head dyeing office.
– loading and unloading of the equipment as well as designs by the operator.
– possible weighing up and release of dyes and chemicals according to the recipe in the colour kitchen, if this is not already automated as well.

Such an equipped dyehouse can be operated using 2–3

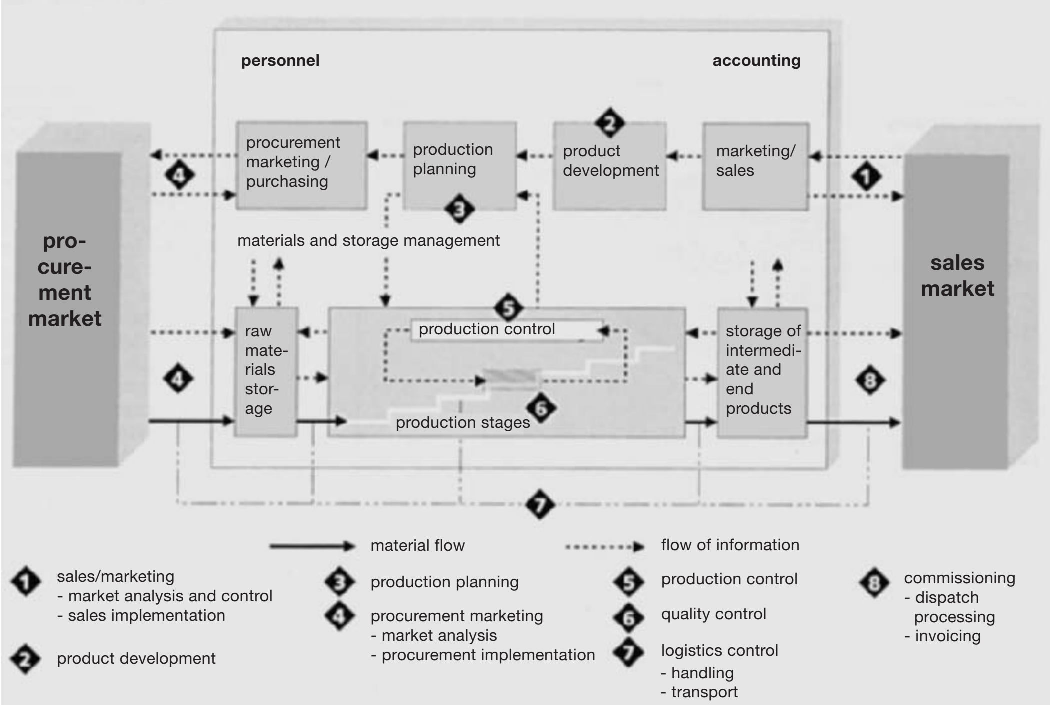


Fig. 1: Material flow in a hypothetical textile plant (according to Bug and Fischer).

persons, 10–15 machines and an ejection of approximately 3–4 tonnes per layer.

Materials Business and technology place ever more varied demands on materials. The areas of application and correspondingly material properties required are becoming more diverse with the increasing expansion of technology in the field of human life. Materials in their conventional form could not however or only incompletely satisfy these requirements. The resulting adaptation of materials to the altered conditions resulted in a multitude of previously unknown types of material: firstly completely new materials; secondly modifications of known materials; and finally combinations of materials with the purpose of uniting the properties of several materials in one. The so-called → Composites represent one section of the last group – combinations of a particular type of materials with the aim of the best possible adaptation of a material to its purpose.

There has not been a standardised and generally applicable definition of the term material until now; in general a material is understood to mean such which is used for the mechanical production of necessary items provided that it is an essential component of the end product. Material is a generic term for all material assets somehow used with regard to production in the manufacturing process, which are effective in the production process through the use of their material substance. In the broader sense, all material agents, which are also used outside the productive sphere to achieve some purpose or other, whereby the use of the material substance is not necessarily required, are thus summarised.

Each material holds a functional purpose; it is only useful due to its purpose. An absolute “material” is inconceivable without relation to a purpose. Nothing at all alters the fact that one and the same material may well serve several purposes. A material is therefore a technical processing material with at least one purpose. The concept of the quality of a material should correspondingly be tackled, namely as the degree of its suitability for the respective purpose. As a material may be good for one purpose, but unsuitable for another, an absolute definition of quality cannot be defined either. A strict relation to the purpose should be observed.

The properties inherent in a material stay together in a very particular proportion, which can only be modified in relatively restricted limits. The reason for this low modifiability mostly has its roots in the nature of the material; the range of modification is correspondingly of varying breadth for the different materials. The often mutually dependent material properties therefore stick together in a more or less fixed combination,

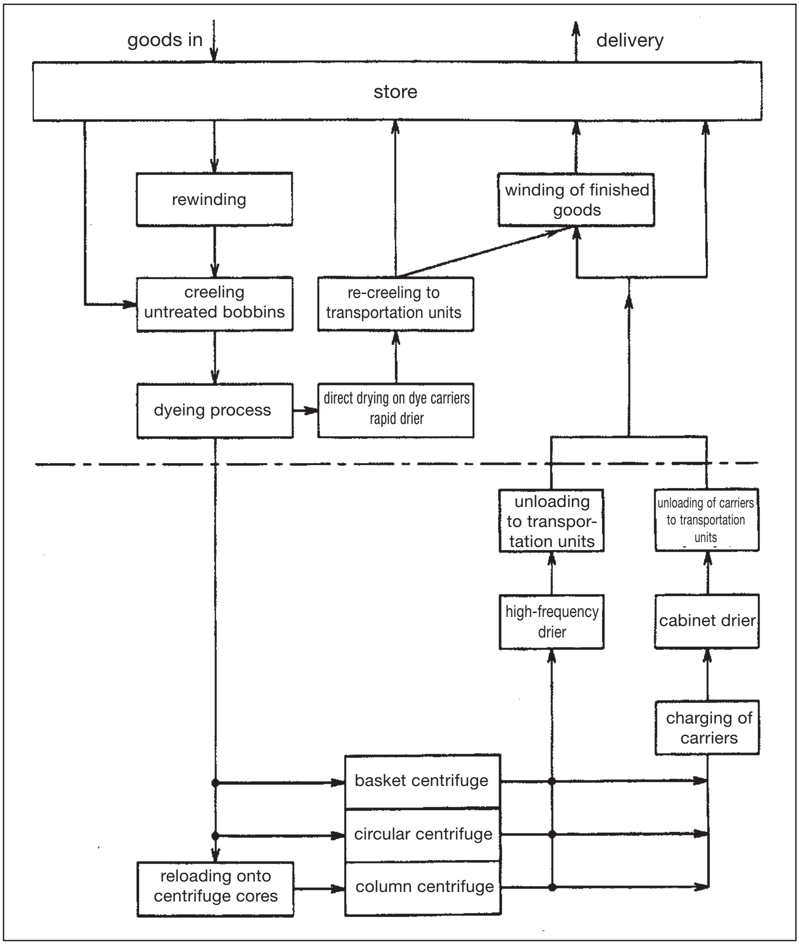


Fig. 2: Material flow for a yarn dye plant (Scholl).

which in its totality only corresponds exactly to the requirements of the purpose in exceptional cases. Rather deviations will appear in many points, which reduce the degree of suitability of the material. If these properties could be altered in isolation, it would be possible to achieve the most extensive adaptation to the purpose and thereby increase suitability through gradual modification of the original material. Partial alteration is hardly possible, however, due to the fixed combination of the properties to each other mentioned; the change of one property simultaneously also causes the alteration of others. In the manufacture and processing of some materials it is possible to achieve a partial preference of the properties regarded as particularly important by using particular technical processes. So growth of property is attempted: partial change of individual material data. As this concerns the attempt to improve the quality of a material, whereby the nature of the material extensively remains unchanged, the term “compensation” seems made for it. This term was previously almost exclusively used in the special treatment of steel; it has its alternative in the aimed property change of textile fibres in the term “textile finishing”.

The paramount importance of materials for the development of humanity is expressed in the names Stone Age, Bronze Age and Iron Age for the three great historical periods of development. Although it has become uncustomary amongst the people of the modern age to name periods of time after the most important materials, these have not lost any of their importance for the technical, civilisation and cultural progress. Not only the fact that they change the living and working habits as previously, more than ever they stimulate growth in many sectors of the economy and become breeding-grounds for new technologies and the starting point of a new quality of life.

Fundamental new discoveries and economic advances in the field of solid-state physics and chemistry were the prerequisite for the development of a multitude of new and improved materials. Newly developed, extremely sophisticated research methods have provided a very crucial contribution to this in the last 30 years. The most important contribution to science thereby consisted in the resolution of the correlations between the externally measurable properties of a material and its molecular structure, the inner structure. This structure is also often described as inner architecture. Science demonstrated that the inner architecture of materials consists of a hierarchy of structural levels constructed on top of each other. The big differences in the behaviour of the different materials could only be explained using the decoding of the detailed molecular structure and this highly complicated architecture.

The precise geometric arrangement of the atoms in the crystal lattice of crystalline materials including the exact atomic intervals even for the most complicated structure can, for example, be explained using the methods of solid-state research. The physical properties, which an ideally structured crystalline material might have, can be calculated in advance from this with the aid of computer programs. The pure research has also led to a better understanding of the correlations between the chemical structure and the spatial packing of molecules as well as the macroscopic properties in the field of polymers. This opened up new paths for the development of more innovative and improved materials. The conformation, i.e. the spatial arrangement of polymer molecules, can be determined with the aid of modern spectroscopic methods, such as the two dimensional nuclear magnetic resonance spectroscopy. The "molecular modelling" allows the motion processes within macromolecules to be studied and important characteristics to be derived from it. Shape and preferred mutual arrangement of macromolecules can be calculated and graphically shown as a bar or collar model using the "Computer-aided Molecular Design" (CAMD). Over and above that, motion processes in macromolecules, such as are triggered by an increase in temperature, can thereby also be tracked dynamically on a screen. The long-term goal of this still dawning development is to give valuable advice on the synthesis of new polymers to the chemist through continual dialogue with the theorist. It is important for the understanding of the behaviour of ceramic materials to clarify the influence of foreign matters in material molecules. They may appear as contaminants and lead to a reduction in quality or even unusability. Or they may be added to materials with the aim of improving certain properties. Just one foreign particle of a few thousandth millimetres in diameter may be a trigger for the breakage of a ceramic component with mechanical loading. When milling silicon nitride in a steel mill, e.g., contaminants with microscopically small iron particles may arise in the material powder due to abrasion. These in turn endanger the durability of the turbo-charged rotors made from silicon nitride. Conversely the specific adding of foreign, inert materials, i.e. those incapable of reacting, often leads to composite materials, whose positive properties are added. Another cause of changed properties in materials may be the exchange of existing atoms with foreign ones. The consequences here are sometimes beneficial, sometimes disadvantageous as well.

Materials handling technology In the clothing industry the automatic handling of individual parts through production and in intermediate storage is state-of-the-art. Semi-finished and finished products are also transported in spinning and additionally in weaving using suspension materials handling technology. In finishing plants materials handling technology is, however, rather unusual due to the multitude of finishing steps and the varying processing sequences.

Material, textile Fabric, material, e.g. dyeing material, cleaning material, textile material; should always be regarded as fibre loading in the technical finishing sense.

Matrix (Lat.: mother substance),

I. So-called cement substance in → Wool structure.

II. Ordered diagram of values for particular calculating rules, location diagram.

Matrix fibre → Bicomponent fibres, from M/F (matrix-fibril) type.

Matrix-fibril bicomponent fibre (ultra-bicomponent fibre, Island in the sea fibre), a real multi-component fibre in accordance with the matrix-fibril type. After the release of the matrix component, fibres with a fine titre, whose number and titre are pre-programmable, remain in a high yield.

Matrix-fibril fibres (→ Bicomponent fibres of the M/F type), several fine filaments (fibrils) are pressed out of a nozzle hole in the lattice, i.e. simultaneously and in a relatively large titre, and distributed into individual filaments (fibrils) in a subsequent step in the process. The individual filaments thereby consist of a matrix (e.g. polyamide) and fine fibrils (e.g. polyester). The matrix component selected is generally as small as possible. It amounts to 5–20% of the fibre depending on the titre and area of application. The matrix-fibril fibre can be separated relatively easily on the basis of the only low adhesion between polyester and polyamide. This takes place via shrinkage processes of one of the two partners with the aid of suitable solvents (Figs. 1–2) via treatment with alkaline solutions or via thermal-mechanical influences, e.g. on the hot plate of a texturizing machine. Combinations of several basic polymers are possible, in so far as the splitting up permits its mutual adhesion, i.e. if they are sufficiently incompatible with each other. The so-called orange profile type has proven to be particularly suitable in the polyester/polyamide 6 combination, amongst many cross-section and polymer options.

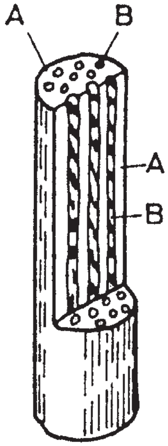


Fig. 1: Structure of the initial multi-component fibre. Multi-component fibre of polymers with varying solvent solubility (by Atzo).
A = embedding component (matrix) is soluble; B = capillary fibrils.

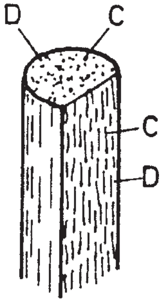


Fig. 2: Structure of the capillary fibrils B (from Fig. 1).
C = superfine fibrils (approx. 0.1 dtex); D = embedding matrix components, also soluble (usually with A).

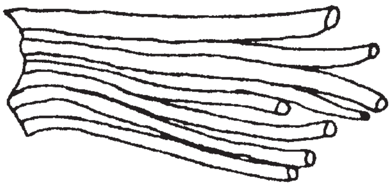


Fig. 3: Superfine fibril bundle after solution of the matrix (Akzo).

Yarns made from medium-sized bicomponent filaments can be texturized. The polyamide matrix melts locally using the correspondingly adjusted thermal treatment, whereby the direct compound of both polymers is transformed into a selective one (Fig. 3). The filament yarns can also still be processed without a coating as chains on all weaving machines, in this form. The selective connecting points between the matrix and the fine fibres are forced open in the finishing of woven fabric by triggering the different shrinkage behaviour of both polymers. Yarns then consequently exist with essentially more individual filaments than in yarn or fabric manufacture. In the case of a filament yarn of 50 dtex f 15, whereby the 15 individual filaments have a cross-section of a “6 orange”, there are 90 fine polyester filaments and 15 polyamide fibre-style fabrics (Figs. 4–5). Such filament yarns give fabrics new properties. Not only is the handle influenced, but the visual effect is also altered and the wearing comfort made of manufactured textiles. (→ Microfibres).

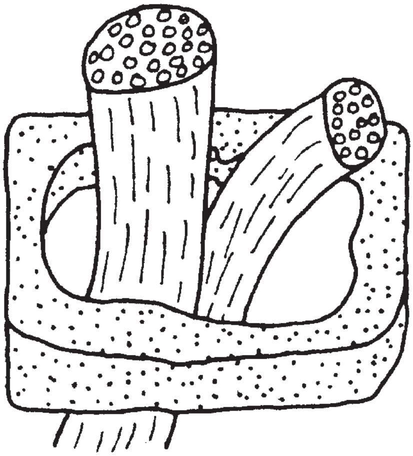


Fig. 4: Ultrafine fibres in bundle form before leaching out of the matrix (Akzo).

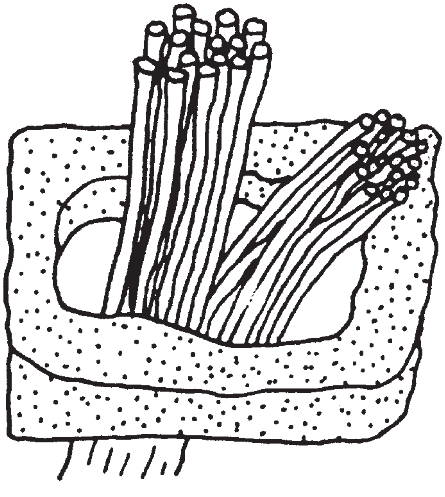


Fig. 5: Fibre following leaching out of the matrix (Akzo).

Matrix memory Magnetic structural memory. The rows and/or columns are represented by conducting or live circuits, for example, of a central memory. Exactly one memory cell of the matrix memory is activated by exciting a column or row circuit. It is also used as read-only memory.

Mats Pile-free, usually braided or woven underfloor coverings made of bast fibres. Also made of gum, plastic and fine metal filaments as door models.

Matting of wool The undesired → Felting of wool.

Matt printing → Pigment printing.

Mattress ticking Made of cotton, viscose, linen union and more rarely pure linen. Shank and Jacquard patterned fabrics are distinguished. The shank fabrics are self-coloured, coloured in stripes or they show a small figure design. The Jacquard materials have a large figure design. Markedly high strength values (mattress drill) are required from these materials. Twill and satin are considered as a weave. The Jacquard materials usually have a 5 or 8 shank chain satin in the base; the formation of figures takes place using the weft effect. Mattress ticking is difficult to obtain on the market as fabric by the meter, as these linings are usually sold in finished fitted form.

Matt white printing Printing using pastes, which contain white pigments and binders. Often used on dyed material.

Mauritius hemp (fibre), similar to sisal → Hard fibre, which is longer and more flexible than this, but has lower strength (approx. 10–20 cN/tex); not a type of hemp. Occurrence: Mauritius (aloe fibre), Brazil (pita fibre), Central America (fique fibre), West Indies and East Africa inter alia. Used for rope goods and sackcloth.

Mauveine (aniline purple), first synthetic (cationic) dye, which the then 18 year old Perkin discovered by chance in 1856 (called aniline purple, later mauveine, Perkin's mauve, Perkin violet) and a few years later industrially manufactured on a large scale, whereby he also thoroughly understood how to solve the application problems.

Max. International abbrev. for maximum, maximum peak value.

Maximum immission concentration Permitted immission concentration for air polluted substances, which may have an effect on the environment outside workplaces. These values apply to single appearance in the atmosphere. Maximum immission concentration k limits the permitted peak concentrations to 10–30 min. max., while maximum immission concentration d represents permitted average concentrations for 24 h in the atmosphere. (→ TLV values).

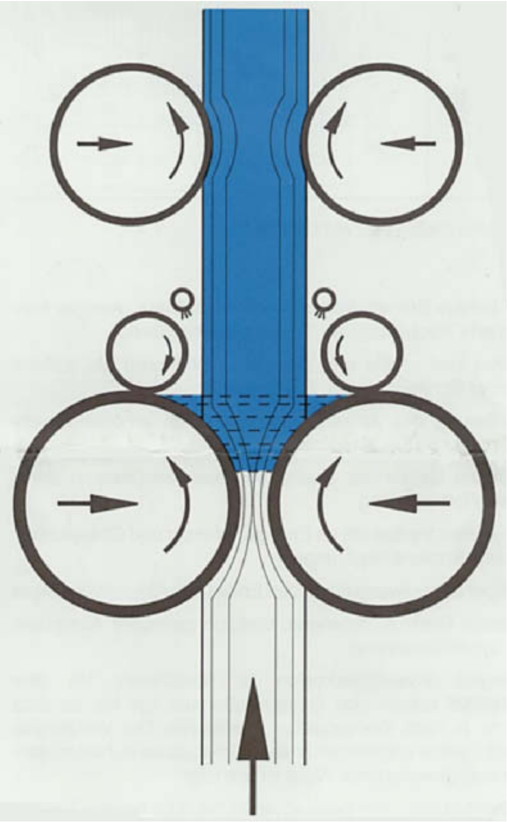


Fig.: Maximum liquor pick-up by a fabric in the Optimax unit by Menzel.

Maximum pick-up More than 100% of liquor application (compare →: Low wet pick-up; Addition high-wet pick-up). Using special machines (see Fig.), a fabric is loaded with as much liquor as it can just carry without dripping before it then, for example, goes into a steamer.

The classic wet-on-wet impregnation technique avoids intermediate drying, e.g. between the enzymatic desizing and the following peroxide bleaching. This thermal treatment is not only expensive, but detracts from the final quality of the pre-treated fabric by reducing the absorbency, the whiteness and by the insolubility of the remaining contaminant. Various measures are necessary in order to obtain uniform, reproducible effects in the classic wet-on-wet application (e.g. frequent checks of chemical concentrations). The continuous process requires the use of highly concentrated liquors in order to keep the concentration of the products in the saturator constant. The liquors are often at the limit of stability. At the end of the treatment, 500–2000 l of liquor are conducted into the waste water each time. Modern plants, on the other hand, work using a wet-on-wet maximum pick-up of 150% and a residual liquor of less than 101. The pre-treatment cycle is also simplified and the quality of the bleached fabric and the process safety are improved.

For each textile substrate, there is a limit of the application value dependence of the water of crystallization absorbed on the cellulose, the liquor withheld in the capillaries of the fibrils or in the holes of the textile structure as well as the liquid absorbed on the surface of the fabric through adhesion.

In classic liquor exchange, the cooled fabric is squeezed off up to 70% in the ca. 1000 l capacity saturator and is then padded using a liquor application of 90%. This produces a difference in the liquor pick-up of 20%. In order to prevent the dilution of the liquor as a result of the continuous throughput of the fabric the addition liquor must be increased by the factor 100 : 20, i.e. fivefold. In the maximum pick-up technique, however, the desized, washed and still warm (90°C) fabric runs into the ca. 10 l capacity applicator for a liquor pick-up of ca. 80%. This produces a final pick-up of 70% + 80% = 150%. The addition liquor is considerably less concentrated (100 : 80 = approx. 1.3-fold), so considerably more stable.

In the liquor exchange process, the NaOH and the hydrogen peroxide concentrations must unconditionally be monitored by titration in order to guarantee the reproducibility of the effects. The equilibrium is slowly adjusted and can be changed rapidly. No titration is necessary in the maximum pick-up technique because the system is very precise. The liquor pick-up corresponds to 70% water + 80% liquor = 150% liquor pick-up. The liquor is supplemented in fractions of a second. Finally this system leads to a better quality, but also to a better uniformity, reproducibility and safety in the continuous bleach.

Characteristics of a maximum pick-up bleach path: The contact time between fabric and liquor is between 0.2–0.4 s, so there is no risk of peroxide decomposition. The advantage lies in shrinking in the steamer in the warm state and starting the bleaching early. Dosing of the liquor application is possible, as the liquor can be changed easily. Thanks to the automatic dosing, the recipe can be aligned with the fabric in less than 5 s by varying all the concentrations of the products via a computer. The input in the steamer must be matched. In order to prevent the bleach liquor from dripping, it is necessary to fit the deflecting cylinder horizontally (close to the entrance of the steamer). This design prevents the loss of liquid. The small pools which develop promote the ingress of the bath into the heart of the fibre for a better bleaching. The fabric impregnated with 150% has no direct contact with the cylinders in the steamer. The chemical recipe is structured so that foam formation is prevented in the applicator, but it forms a fine foam layer between the textile materials and the rollers in the steamer. There is therefore no direct metal/fabric contact and the risk of rope creases and abrasion marks are thereby reduced. The first wash liquor after the output from the steamer is regarded as an extension of the steam chamber. The bleaching reaction continues on the basis of the active product residue still remaining on the fibre. Caustic soda liquor and washing agents ensure better hydrophilic properties, peroxide and stabiliser for a higher degree of whiteness.

In less than three years, six different systems have been developed and introduced into industrial production:
- Flexnip System (Küsters),
- Optimax System (Menzel),
- Booster System (Benninger),
- Super Sat System (Babcock),
- Dip Sat System (Max Goller engineering works),
- Raco Yet System (Kleinewefers KTM).

(according to Fornelli).

Maximum pressure → Air pressure.

Maximum workplace concentrations → TLV value.

Mazamet wool → Sweated wool from Southern French town of Mazamet, where most Australian sheepskins come to be processed.

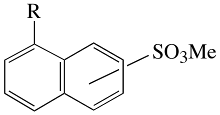
MBAS Methylene Blue active substance, so-called methylene blue test as a dye reaction for certain chemicals (e.g. anionic surfactants). Is used in the determination of biodegradability (→ Surfactant biodegradability, evaluation of). Restricted area of application. MBAS sludge degradation performance gives MBAS g, which are degraded per kg of activated sludge solids each day.

MD → Modal fibre, → Standard abbrev. for textile fibres, in accordance with the → EDP code; → CMD.

Md Elementary symbol for mendelevium (101).

ME → Metal fibres, → Standard abbrev. for textile fibres, in accordance with the → EDP code; → MTF.

Me Conventional abbrev. in standard chemical formula (similar to → R), whereby Me designates the cation each time; normally (alkali) metals, but also (for cationic) organic bases, e.g. RCOOMe type = soaps.



alkyl naphthalene sulphonate

Meander open-width scouring machine Multiple passage of textile layer via low gap saves liquor with a good liquor exchange. The principle: counter-current liquor from above, product from above; multiple squeezes, high liquor exchange, low water consumption.

Measurable variable regulator Regulator, in which measuring sensors and information processing section are united in one device and the information transfer between them does not take place using electrical signals. Typical for regulators for the processing of temperature, pressure, differential pressure and liquid level. A measurable variable regulator is a definite purpose regulator and only geared to a measured variable each time. Location is measuring point of the controlled variable.

Measurement and control Measuring instruments should provide information about the state of the finishing system via suitable sensors. They should put transmittable numerical values (process sizes) in the place of intuitive logging by human sense organs. Costs are not primarily caused by microprocessors or microcomputers, but chiefly due to the use of suitable sensors and control elements. The main emphasis is regarded as the purchase of regulating and control elements such as control valves, motors and variable speed, flowmeter for the recording of liquor circulation and liquor motion values, etc. The availability of the correct measuring probe for a finishing process decides as to whether the process is controlled or regulated using automation. In controlling (Fig. 1) a particular function is given between two variables (e.g. temperature/time). No degradation is, however, obtained about the success of the action (typical example: bath exhaustion due to heating-up rate). Only that sensor, which provides measuring information directly about the success of an action (e.g. transmission measurements of the dyebath), can reach the control unit (microprocessor) usefully amplified. A new action (→ Automatic control systems) takes place via the servo component after a variance comparison.

The degree of → Automation is clarified in the example of the stabilization of concentrations (NaOH, H_2O_2) in a pre-treatment path. The principle of control can be applied as the simplest action for the maintenance of the liquor concentration for liquor with a flat concentration profile, uniform movement and constantly remaining disturbances. An empirically determined quantity of liquor is thereby adjusted in proportion to the quantity of fabric put through. The speed of a driving roller on the bath can, for example, be selected as a measurement for the quantity of fabric. It can either be coupled mechanically via a gear drive directly to a dosage pump conveying the liquor addition or given “an electrical wave” to the pump via a pulse generator.

Actual values determined “off-line” (in the laboratory) or “in-line” are only used to control the proper sequence of the control system. Another step to increase the reliability of a process exists in the use of a manual regulation system. It is based on a comparison of the actual value with the desired values carried out periodically discontinuously on manual correction of the deviations which appear. The manual regulation system can be very usefully combined with a control system. The last stage in the automation of process control is the actual automatic control system. The actual values input in a control unit are continually compared with the likewise input desired values. Any difference arising (the control variation) is immediately and automatically removed using corrective action. Fig. 2 illustrates such a closed control circuit.

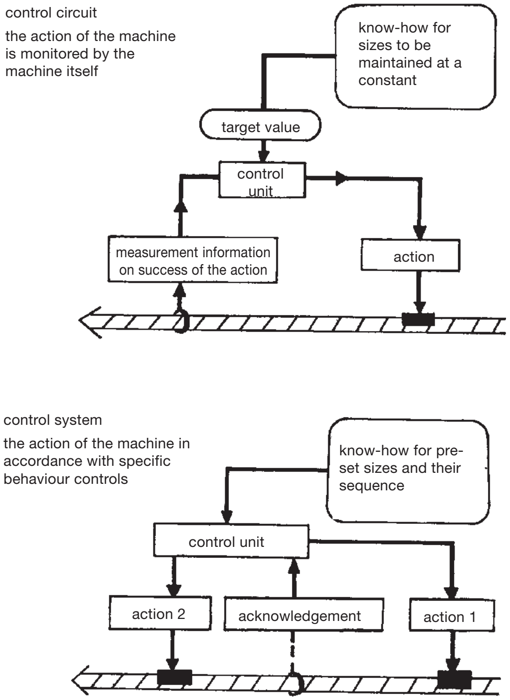


Fig. 1: Comparison of control circuit and control system as principal elements of automization.

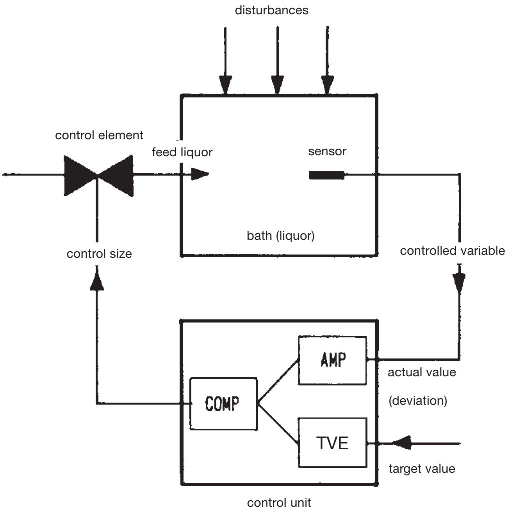


Fig. 2: Closed control circuit.
TVE = target value emitter; AMP = amplifier for the actual value detected by the sensor; COMP = comparator of target and actual values.

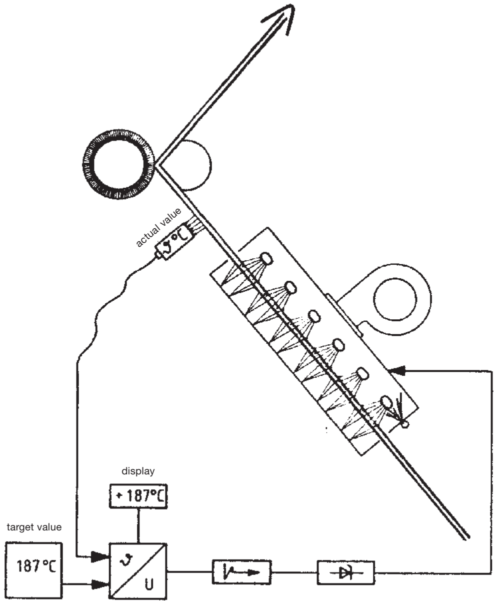


Fig. 3: Control of a thermal treatment process (pile brushing) by measurement of the effective surface temperature (Sistig).

These wet chemical explained principles can also be transmitted to physical dimensions, e.g. the temperature (see Fig. 3). This should be clarified by the example of the fabric humidity measuring device from Pleva. It is based on the principle of microwave adbsorption via water. A specialised oscillator on a semiconductor basis produces microwaves in the region of 10 GHz. This high frequency current of only low power (approx. 5 mW) is radiated via a transmitting head to the fabric to be measured. The accompanying reception head is fixed to the other side of the fabric. A part of the radiated microwave energy is absorbed on the metering pipe between transmitting and reception head depending on the quantity of water molecules. The absorption is thereby a measurement for the absolute water content of the fabric, which is given in scale divisions of 0–100 or via calibration in g H_2O/m^2. The percentage fabric humidity can easily be calculated using the known weight per square metre of the dry fabric.

Water molecules absorb microwave power due to its high permanent dipole moment, which originates from the spatial arrangement of the oxygen atom and the two hydrogen atoms. This dipole moment depends on the binding form of the water; it is different for different fabrics (cotton, viscose, synthetics, blends). Calibrations, which allocate the humidity values in g H_2O/m^2 in scale divisions to the humidity values displayed, are therefore required for the exact determination of humidity. In practice though, it has been shown that an optimum value of humidity is determined in scale divisions only once per batch. This optimum value is then the desired value of the humidity for every later production of this batch. The measurement is contact-free, non-destructive and also does not give rise to effects harmful to health. No kind of protective precautions are required.

An automatic control system for the dye padder dependence on the three measured values of the microwave measuring device requires three control circuits (Fig. 4). As these control circuits mutally influence each other via the dye padder rollers, an automatic con-

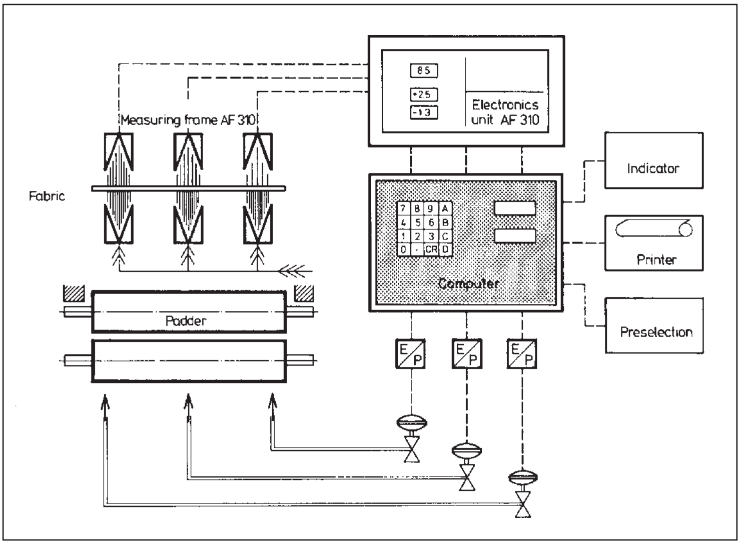


Fig. 4: Measurement and control with microwave measuring unit (AF 310 by Pleva) and computer for constant squeezing by a pad.

Measurement and control

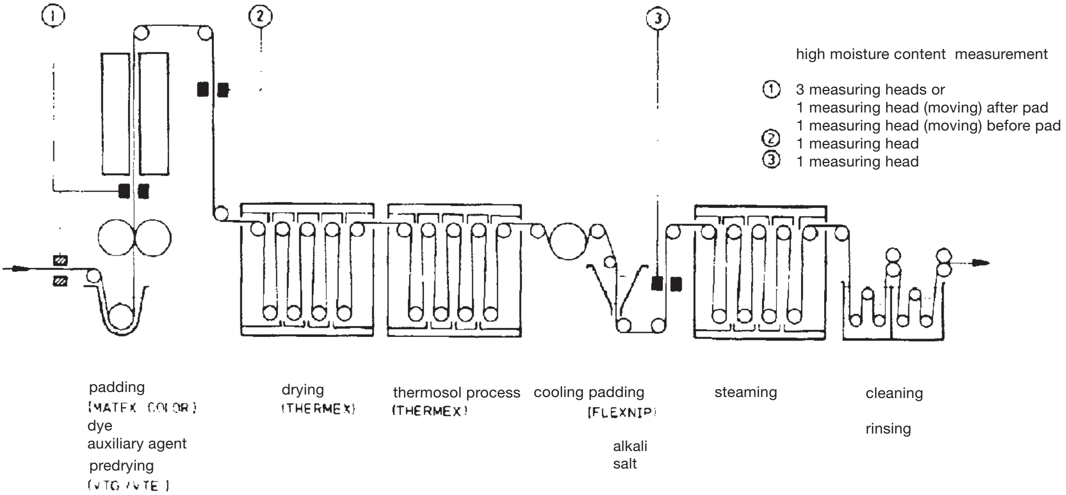


Fig. 5: Measuring device arrangement for the whole continuous process, controlling high moisture content in the Thermosol/ pad steam process.

trol system with three separate, conventional control units can only be realised with extreme difficulty. The automatic control system has proved to be favourable with the aid of a computer. The control diagram is valid in principle both for changes of the nip profile produced on the dye padder pneumatically, hydraulically or by shifting. Computers, which produce the connection from the AF 310 to the respective dye padder and regulate it, are offered on the market by Küsters, Kleinewefers KTM and Monforts, amongst others. Over and above that, Cintex offers a stand-alone, computer-aided automatic control system. Padders already available were automated for textile plants using this automatic control system together with the AF 310. The automatic control systems offer a choice of two control variants:

1. automatic control system for the humidity values centre, left difference and right difference edge dependence on the desired values stored per item.
2. adjustment of the padder to the normal squeeze pressure level (per item) and control of the edge deviation at given values. In most cases, it is controlled at the same pick-up on the edges or at a somewhat higher pick-up on the edges, always with reference to the centre.

The complexity of a continuous dyeing plant requires several control points (Fig. 5):

1. measurement and monitoring, if necessary, control of the liquor pick-up according to the padder either by microwave measuring instruments or by differential weight measuring instruments.
2. measurement, monitoring and control of the residual humidity in accordance with the IR pre-drying section using microwave measuring instrument or isotropic radiation measuring instrument.
3. measurement, monitoring and control of the liquor pick-up in accordance with the chemical pick-up before the steamer using microwave measuring instrument.

Each machine must receive the information about the machine setting to be corrected from a piece identification system. Batches to be processed differently can, for example, be clearly identified with the aid of a barcode applied to the fabric adjacent card in connection with a seam detector. Data required for the process (Fig. 6) is retrieved from the computer (1) or input via the terminal (2). The correct setting, for example, of the calender and control of the

– positioning of air coolant nozzles (3),

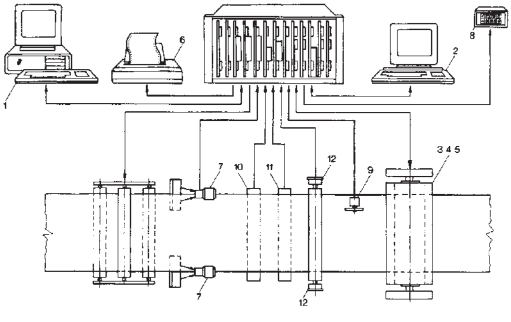


Fig. 6: Diagram of a calender with Elcom 18 (Mahlo).
3, 4 + 5 = control elements on the calender;
7, 9, 10, 11 + 12 = sensors.

- selection of the press width (4),
- roller temperature (5)

are then carried out automatically.

Operating conditions and actual values of the plant are continually displayed on the terminal. A matrix printer (6) creates a protocol of the measured values. In addition to this, the possibility exists of outputting the current fabric width determined using CCD cameras (7) via a digital remote indication (8) to any point of the machine desired. The fabric length is determined with the aid of an incremental probe (9). The active operator guidance using modern visual display units guarantees a real dialogue with the plant and thereby safer operation during the entire process. The Elcom 18 system also integrates the signal processing of the metal detecting device (19), the seam detector (11) and the fabric tension measuring instrument (10).

In order to achieve an optimum exhaust air moisture in drying machines, a control diagram has proven itself in most cases, as is shown in Fig. 7. The moisture content of the circulating air is measured in the first third of the drier, starting from the material infeed. The greatest water evaporation arises here due to drying technology reasons and thereby the highest humidity. The measuring instrument provides the control unit with the actual value. In order to achieve the desired value of humidity, the exhaust air quantity is controlled by means of a variable-speed exhaust air fan or by opening and closing operations of shutter butterfly control valves with the aid of stepping motors.

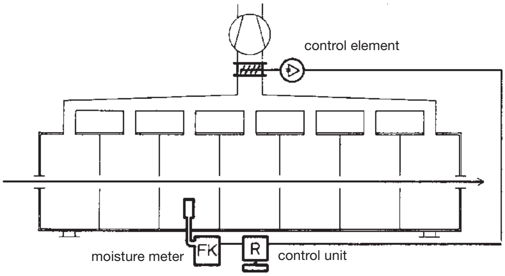


Fig. 7: Control diagram for circulating air moisture content.

The automatic positioning shown in Fig. 8 measures the temperature difference between supply air and return air and produces a thermal image of the process in the cage stenter from this. Control functions, which optimise the positioning process, are derived from this. The process is shown as a thermal balance in the screen display (top left), which correlates in the individual fields with the effective fabric temperature. The setting of the stenter chain running speed is directed accordingly so that the fabric to be dried does not run out of the frame overdried and the necessary contact time is satisfied at the heat setting temperature.

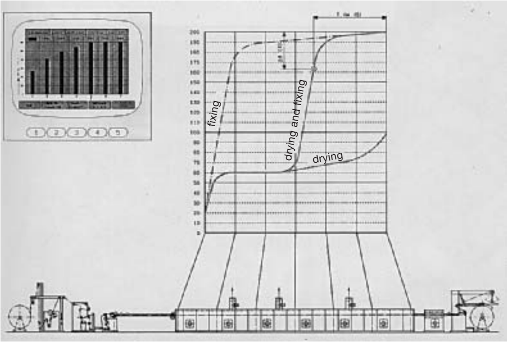


Fig. 8: Brückner automatic fixing unit Type BFM/CM.

Measuring cell Arrangement in which a property of a measured material is determined in a closed vessel. Flow measuring cell: the measured material hereby flows through the cells; thermal conductivity and conductivity measuring cells. Measuring cells with electrodes are → Measuring chain.

Measuring chain Combination of two electrodes, which are connected to each other electrolytically via a measuring medium either in the process flow or inside a → Measuring cell. It is used for the measurement of electrochemical concentrations and/or activity. There are: combined measuring chains, pH measuring chains, redox measuring chains and conductivity measuring chains.

Measuring geometry Term from the field of colorimetry; describes the type of illumination (diffuse or directed, e.g. at an angle of 45°) of the sample to be assessed colorimetrically (see Fig.: Measuring geometries in colorimetry) and the position of the measuring instrument to the illuminated sample. The measurement can be carried out perpendicular to the sample (0°) or minus 8°. The illumination and measuring directions can also be interchanged.

Measuring machine The → Length measurement of textiles is subject to legal provisions in many countries. In the territory of the FRG, fabric measuring machines must comply with the provisions of the “German calibration regulation”. The measurement determined by the machine may not exceed a difference of $\pm 2^0/_{00}$ for the new calibration or $\pm 4^0/_{00}$ for the recalibration compared with the value ascertained by hand according to the “German calibration regulation”. If you want to attain a precise measurement result for all types of fabric, the measured material must be brought over to the measuring device without any longitudinal stretching and carried out using it. The most important prerequisite for the calibration measurement is an off-circuit fabric guiding system. It is attained by the two reflection optics (R) in the infeed and exit of the machine. These cause the fabric to be relaxed between the

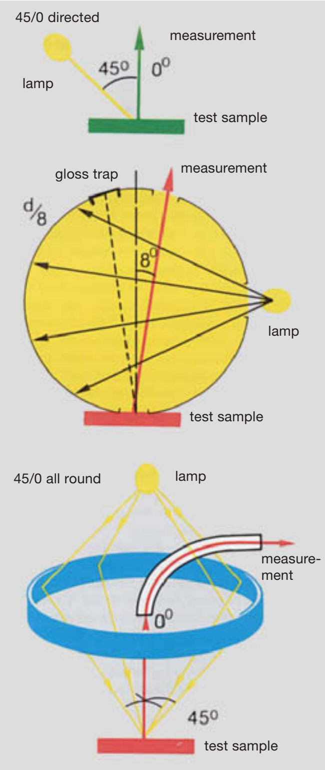


Fig.: Measuring geometries in colorimetry.

thread-up roller (A) and the measuring roller (B) contact-free. After the measuring, the fabric between the measuring roller (B) and the rolling device (C) can also be continued alternatively relaxed or under low tension depending on the application on the ready rolled bales. To avoid measuring errors an additional contact-free relaxation device can be provided for very strongly extendable hosiery goods using self-extension on the path from the thread-up roller (A) to the measuring roller (B), which works in the same way as the aforementioned relaxation and ensures a sag in the section of fabric (F) (see Fig.).

Processing of a reflection optic: A light signal with 2.4 kHz modulation frequency is thrown onto the fabric in a bundle. The fabric is moved below the focal point of the optics. The reflected quantity of light increases with the decreasing distance from the focal point until the operating point is reached. It is so low that a fabric sag is always secured. So if the operating point has been reached, the thread-up roller (A) is coupled around for a short time at a somewhat higher speed and the sag is enlarged again. A clock work mechanism accordingly opens the quick coupling again and the roller (A) is again turned more slowly than the measuring roller (B). As soon as the fabric sag is too low again, the

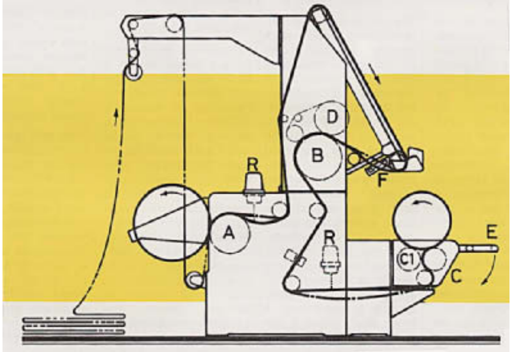


Fig.: Calibratable measuring machine (also used for synchronized rolling) for fabrics (Type MBW, formerly Monforts).

same operating sequence starts again. The reflection optics are independent of fabric colour and artificial light. The reflected signal is amplified in a narrow-band booster, which exclusively considers light impulses with the frequency of 2.4 kHz. The function described here correspondingly applies to the sag between (B) and (C) as well. If the machine runs in reverse operation, the clutches at (A) and (C) reverse their functions. So it is guaranteed that the fabric also reaches relaxed into the measuring device (D) in reverse and a precise length measurement is carried out in accordance with the regulations of the “German calibration regulation”. A transportable belt drives the measuring wheel (D) using fabric speed. The transportable belt lies on the fabric wrapped around the measuring roller (B). An electronic pulse generator, which gives a pulse per cm of transported fabric, is located on the measuring wheel axis. The meter is operated by a particular stepping motor, which absorbs the pulse and takes one step after each cm of fabric passed. The meter and measuring wheel drive are thereby separated from each other. There are no friction moments between the measuring wheel and the meter, which could result in a distortion of the result. Several meters can be arranged at any point you like in this separate type of drive.

Measuring sensors Measured quantity detectors, probes or sensors. The measuring sensor is a component in the signal flow path of a measuring device. It converts the characteristic of the measured quantity into the characteristic of another more favourable quantity to be processed. Measuring sensors, which provide a digital measuring signal, are particularly significant.

Measuring tapes Made of paper, are in exceptional cases inserted in the fabric batch in the batching process.

Mechanical breaking Finishing character work, which aims at mechanical loosening of the fabric structure, i.e. "breaking" the hardness caused by finishing application, tightening and drying, which consists of fixed thread and fibre bonds. Result: softer, fuller handle. The simplest mechanical breaking devices are blunt metal rails arranged perpendicular to the fabric run, which are used for very heavy linen and cotton fabric as well as tapes. The stud roller breaking machine (see Fig.) consists of two series of wooden rollers adjustable back to back and provided with round-headed nail mounting, which set the circulating fabric in revolution and this is thereby broken on all sides. The so-called patent finishing machine with needle rollers is similar. With the grooved roller breaking machine, the breaking effect is achieved by a number of driven grooved rollers, chiefly in the weft direction. The cylindrical blade breaking machine, however, only has up to three rollers with blunt steel blades arranged helically, which work against the fabric run using quick self-drive; particularly suitable for velvets. In all the devices described, the fabric throughput is repeated until the desired suppleness is reached. Similar effects are also possible on the jigging stenter.

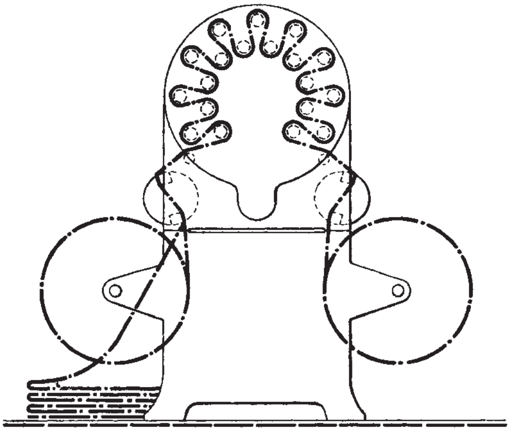


Fig.: Spiral roller mechanical breaking machine (Menscher).

Mechanical properties of fibres,

I. → Tensile strength: parallel orientation of polymer chains in the direction of the fibre axis causes the mechanical properties to be strongly anisotropic. The high axial strength is accompanied by relatively low knot and loop strengths in most fibres. The axial strength is routinely determined on fibres. The stress-strain diagrams (Fig. 1) result from the measurements. The tensile strengths refer to the cross-section; the titre (tex) should therefore be known. The ultimate load is divided by the titre and so the tensile strength or breaking strength is obtained in cN/dtex.

II. →: Loop strength and Knot strength: This is lower than the axial strength in most cases. The values are around 50–90% depending on morphology and stiffness.

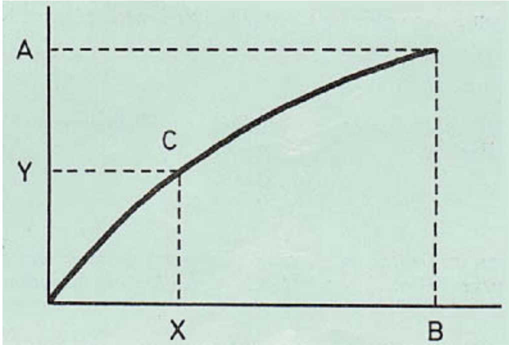


Fig. 1: Stress-strain curve of a fibre.
A = Force in cN/tex (stress at break); B = extension in % in relation t the original length (extension at break).

III. → Elongation: This describes the percentage ratio of length change during a tensile load to the original length without load.

IV. Initial module: The fibres are rarely loaded to breaking point in use. The initial part of the force/extensibility curve (Fig. 2) provides the important technologically significant initial module (M_i). The initial module is a measure of fibre stiffness and characterises the fibres in the field of Hooke's behaviour. The initially straight part of the force/extensibility diagram is small, but only here should a direct proportionality between force and extensibility be recorded. Tab. 1 compares several fibres with known materials.

V. Proportionality limit: The point in the force/extensibility diagram where the proportionality stops is described as proportionality limit (Fig. 3).

The deformation (extensibility) is elastic up to the proportionality limit. The fibres are capable of return-

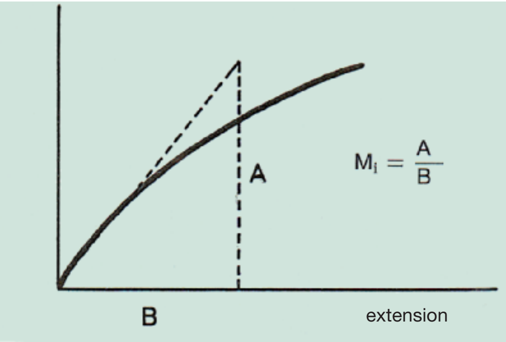


Fig. 2: Strength plotted on the ordinates (in cN/tex) against extension (in %) to explain the initial modulus (rise shown as dotted line = tangent to the curve through its origin).

	density kg/dm^3	modulus cN/tex	tenacity cN/tex	extension at break %
steel	7.8	0.3–1.5	0.7–3.0	variable
rubber	1.1	0.02	0.15	400–600
glass	2.5	280–320	6–12	2–5
polyamide	1.14	5–30	2.5–6.0	30–80
(TT)		60–90	6.0–9.0	15–25
polyester	1.35	25–40	2.5–6.5	15–40
(TT)		70–120	7.0–9.5	10–20
polypropylene	0.90–0.92	30–50	2.5–6	15–30
(TT)			22–55	
aramid	1.38	125	5.3 (–75)	20–25

Tab. 1: Comparison of the properties of certain fibres with materials (TT = textured with strong twisting tendency; according to Koch and Morawek).

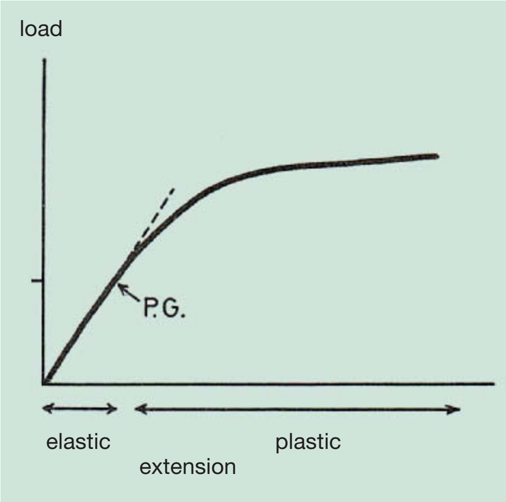


Fig. 3: Stress-strain diagram to explain the proportionality limit.

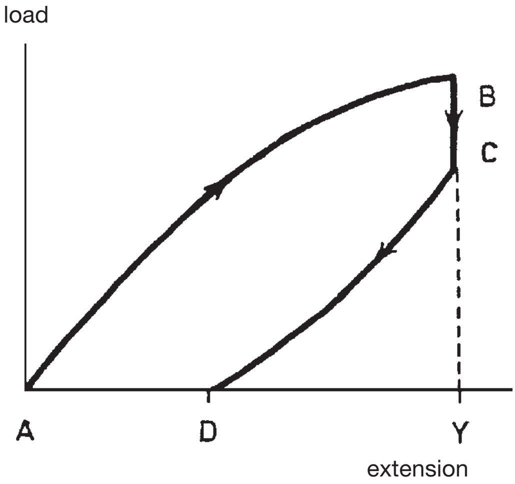


Fig. 4: Hysteresis diagram to explain the recovery property. A = starting point; B = specific extension (Y) achieved; B → C = during the rest period the tension drops; C → D = the test sample is freed from the load; A–D = permanent deformation.

	recovery %* of	
	3 % extension	15 % extension
polyamide	76	40
polyester	88	77
polyacrylonitrile	76	47
silk	67	32

Tab. 2: Recovery properties of fibres.
(24°C, 65% rel. moisture content, 30 s rest period, gauge length 5 cm; filament yarn).*

ing to their original length by unloading after a delay period. If the fibre is loaded (extended) beyond the proportionality limit, a deformation remains after the unloading.

VI. Energy capability: The surface under the force/extensibility diagram corresponds to the energy, which has to be applied in order to tear the sample. It is a measure of tenacity.

VII. Recovery capacity: If fibres are loaded beyond the proportionality limit and held there for a short time (e.g. 30 s), then unloaded, a deformation is produced. The tension decreases during the holding period and the polymer chains are displaced. The phenomenon is stress decay (tension drop). After unloading, the fibres have a permanent deformation, whose magnitude depends on the extensibility originally applied in the test. A so-called hysteresis curve develops (Fig. 4). The recovery capacity (just as ultimate load and module) varies with the speed of elongation, temperature, humidity, etc. Tab. 2 illustrates some values of the recovery capacity.

Mechanical resist → Resist printing.

Mechanization Creation and application of devices and methods to lighten heavy or tiring physical work and to increase productivity of labour. Mechanization is a preliminary stage towards → Automation serves rationalization and is used where considerable advantages can be achieved quickly using simple means, or automation at a given time appears possible for economic considerations, but not yet realisable.

Mechanochemistry According to Speakman concerns the derivation of mechanical properties of fibres from the chemical fibre structure. Mechanochemistry tests therefore provide insights into interactions between different influences, to which a fibre can be exposed, and changes to its textile behaviour.

Me-Complex dyes → Metal-complex dyes.

Medallion carpets have perfectly circular or elliptical motif on self-coloured primary backing in the centre of the carpet. Similar designs can be found along the edge of the carpet or in the corners.

Medical fibres →: Antimicrobial fibres; Antibacterial textiles.

Medio yarn Single cotton yarn of medium twist. Application as warp and weft yarn.

Medulla Medullary cord or medullary canal (in → Wool structure), inner central pores, filled with a network of cell walls. Unbroken (lattice medulla) and broken (fragmented, ladder medulla, the latter with one or several rows) occur.

Medullameter For testing wool samples for medullary cell content (→ Medulla). Wool impregnated with benzene or dichlorobenzenes is laid on non-reflecting plate, covered with glass plate and illuminated by two 100-watt lamps. Depending on wool quality the light reflected is released in a photocell current, which, increased by tubes, displays the test result on a specular galvanometer.

Medullary canal →: Medulla; Wool structure.

Medullary cord → Medulla.

Medullary rays are seen with the naked eye on decorticated trees as lens-shaped stains or short strokes (bands running horizontally), which continue in the direction of the centre of the tree (medulla). This applies as analogue for bast stems (→ Flax stem structure). Medullary rays aid the plant in the transport of carbohydrates from the so-called starch sheath (innermost cell layer of the bark) via the bast area to the cambium.

Medullation "Hairiness", in the sense of wool fibres with → Medulla, so-called hairlike fibres, hairs containing medullary cords.

Mega- (Gk.), unit auxiliary for a million times = 10^6; e.g. MJ.

MEK Max. permissible concentration of harmful emissions in the exhaust air. Can be determined on the basis of the → Maximum immission concentration, in view of the chimney height. So an MEK of ca. 40 kg/h of trichloroethylene or tetrachloroethane and 50 kg/h of benzine is produced from an exhaust gas conduction height of, e.g., 10 m.

Melafix process was used for the controlled chlorination of wool by adding chlorine acceptors to the chlorination bath. The chlorine was taken up by dispersed melamine compound and (controlled by temperature control) released. Thereby wool chlorination in the fibre-gentle acidic range. Effects: felting and shrink-resistant finish, increased dyeability with preservation of the wool fibre structure. – Manuf.: Ciba-Geigy.

Melamine (2, 4, 5-triamino-1, 3, 5-triazine, cyanuric acids, cyanurtriamide), product of polymerisation of → Dicyandiamide, from which 3 molecules are cyclically stored together as 2 molecules of melamine. White crystalline powder, water-soluble. With formaldehyde forms the chemically important finishing condensation products of → Melamine-formaldehyde compound.

Melamine-formaldehyde compound Condensation product made from melamine and formaldehyde (→ Methylol melamines). Melamine-formaldehyde compounds with methanol partially or completely etherified (→: Methoxymethylmelamines; Self-crosslinking resins) are important. Application as finishing agents, particularly for permanent calender effects, as binder of pigment colorants and finishing agents in hydrophobic finishing, in dry cross-linking (see Fig.).

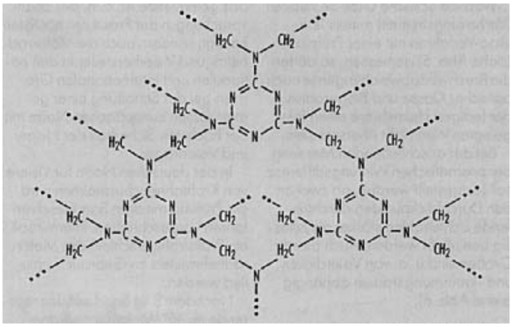


Fig.: Possible structure of a hardened melamine resin (part).

Melange flocking Flocking or flock printing using blended flock material.

Mélange yarn Mélange yarn made of bleached/unbleached or treated/untreated fibres, which only appears mottled after dyeing.

Melissic acid $C_{29}H_{59}COOH$; constituent of →: Beeswax and Carnauba wax (for chemical finishing, sizing, etc.).

Melt blowing process A filament spunbonded process, which allows the fine-titred filament (usually 0.07–0.40 dtex) to be directly converted into a fleece (see Fig.). Such fleeces are thereby most likely comparable with textile fabrics due to their pronounced soft handle with highly specific surface area, which are manufactured from microfilament yarns using conventional thread and fabric formation technologies. The prerequisite for a wide application is, however, that it manages to reduce drastically the high specific energy consumption, which is essentially caused by the firstly principle-conditioned application of > 200°C hotter and accelerated air for the filament drawing at a speed of 15 000–20 000 m/min. At any rate ca. 6 times as much energy is consumed solely for the production of the highly accelerated hot air streams with ca. 6 kWh/kg of fleece as is consumed for the conversion of the same melting into wound up threads in high-speed spinning at 6000 m/min. A quantitative comparison

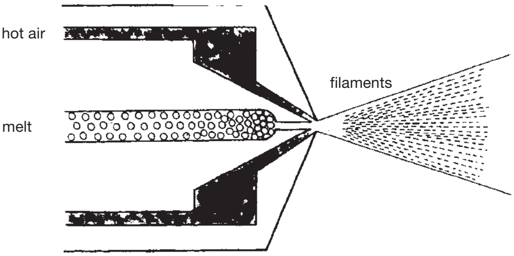


Fig.: Melt blown spinning nozzle.

naturally depends on concrete technological conditions (fleece fabric mass, filament fineness, plant formation, type of polymer), but in principle applies qualitatively in the mentioned order of magnitude.

Melt coating Process for the coating or laminating of fabrics, knitgoods, paper with high polymer thermoplastics (see Fig.), which are melted in granule form in a roller slot and so applied on the coating substrates.

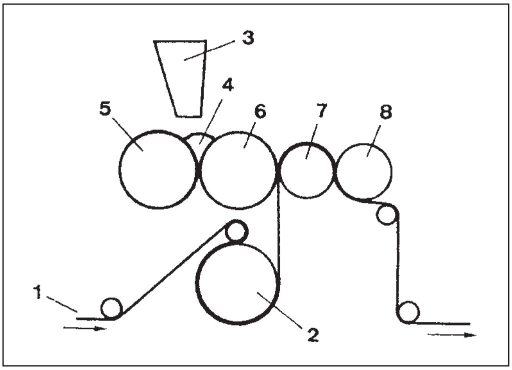


Fig.: Roller melt coating plant.
1 = fabric; 2 = preheater roller; 3 = granulate feed hopper with metering screw; 4 = thermoplast; 5 = melt roller (moveable); 6 = melt roller (fixed); 7 = take-up roller; 8 = embossing roller.

Melt-flow index (melt index), quantity in g of a condensed substance (e.g. thermoplastic) at a set temperature, which is squeezed through a nozzle per unit time using standard force. A high melt-flow index corresponds to low melt viscosity of the molten substance, in the case of a sealable polymer identical to good (hot)sealability: indicates quick penetration of the thermoplasticated coating material in fabric to be sealed, i.e. good adhesion.

Melting Transmission of a material from a solid to a fluid aggregate state. Opposite: → Freezing point.

Melting point Material-specific temperature of → Melting. The so-called → Softening range for thermoplastic fibres is found before the melting point.

Melton Named after the English town of Melton in the county of Leicestershire. Wool carded yarn fabric (occasionally also worsted yarn goods), which have a lightly matted surface on both sides due to milling. Depending on the strength of the milling process (lightly meltonated, semi-meltonated, fully meltonated), the fabric bond disappears more or less strongly under a tangled, flat fibre pile. Used for men's suits and costumes.

Melt-spinning process Spinning process for the manufacture of synthetic fibres by forcing out the viscous polymer melt under pressure from round or profiled nozzle channels, whereby the escaping fusible thread is stripped downwards at high speed, is firstly tapered, then becomes solid on a cooling system and finally reaches the vented organ (yarn package winding machine) (Fig. 1). The → Drawing of synthetic fibres, which can also be combined with the melt-spinning process or stretch texturizing using the texturizing process as drawing in spinning, mostly follows as the next processing stage.

The principle of the melt-spinning process for thermoplastic high polymers has been well-known for half a century. Its technological and technical development

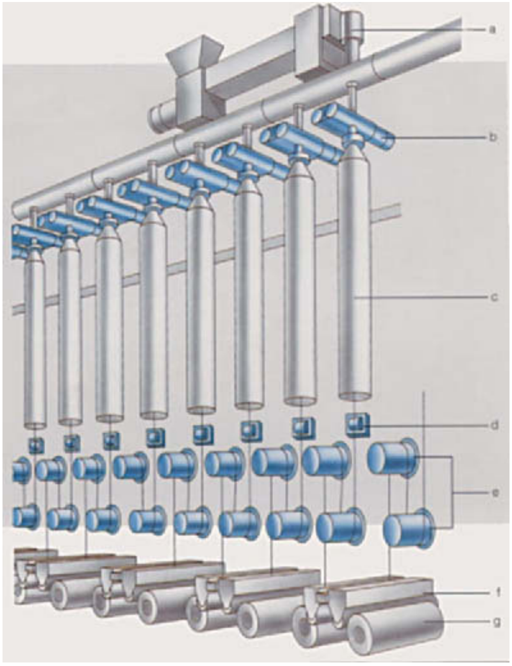


Fig. 1: Diagram showing a spinning-drawing-winding machine.
a = extruder; b = extrusion pump; c = cooling shaft; d = finishing rollers; e = godets; f = traversing; g = winder.

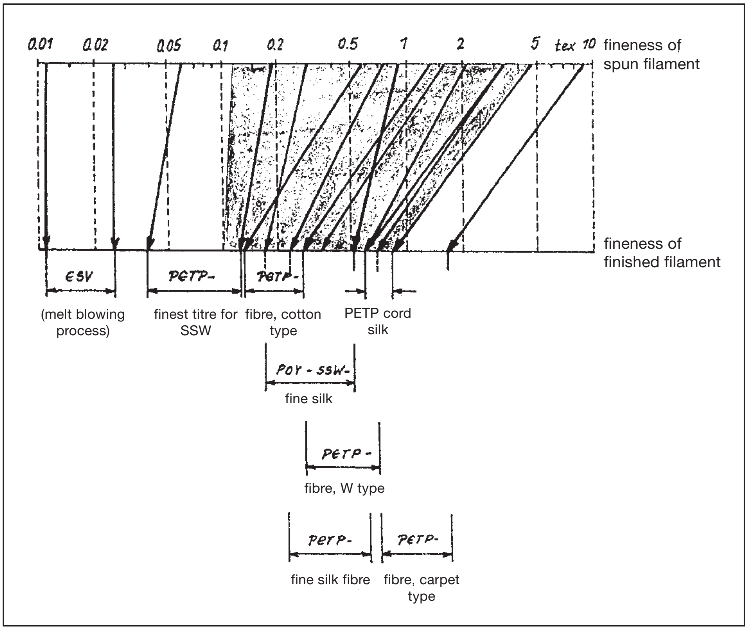


Fig. 2: Melt spinning of polyester; elementary filament fineness ranges.

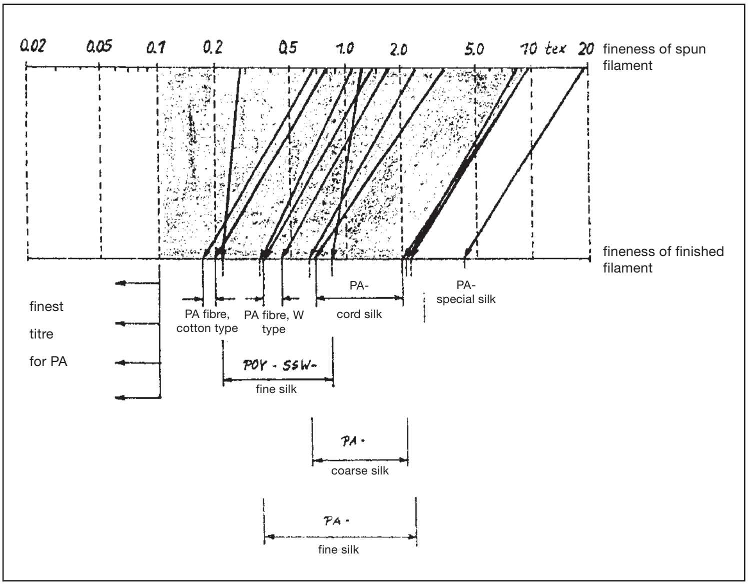


Fig. 3: Melt spinning of polyamide; elementary filament fineness ranges.

has lasted just as long, stemming from the first industrial origins of rust spinning up to today’s extruder spinning with its varied polymer-, technique- and range-specific production lines for fibre manufacture. The (provisional) last step in the current technology level is the different variants of high speed spinning process (→ High-speed spinning). If you include the fine filament, coarse (cord) filament and staple fibre spinning process or the variant of continuous filament spunbonded processes in the class of melt-spinning processes, different parameters result for each, which also determine the potential limits of continuous filament fineness in a specifically different way. In this connection, it is critical whether the demand for continuous and stable ability to wind up the filaments exists (indispensable for most spinning processes) or whether this does not completely apply (continuous spunbonded processes in accordance with the compressed air, suction-air or melt-blown principle).

The ranges of continuous filament finenesses of the threads are entered in Figs. 2 + 3 on the basis of the commercial range of polyamide and polyester fibres currently available. Each drawing contains two fineness co-ordinates. The continuous filament finenesses of the threads are applied on the top axis as they develop in the unstretched or partially stretched state in the spinning shaft, i.e. as they have to be manufacturable in the melt-spinning process. The continuous filament finenesses of the finished threads or fibres are applied on the bottom axis as they are presented for texturizing, yarn manufacture or surface formation or as they are merged directly into a textile surface (continuous filament spunbonded) in a more or less stretched out state.

The connecting arrows between the two fineness axes show which stretching ratio should be realised between the spinning and finished thread structure for the individual threads or fibre ranges. You can see whether this concerns a classic multi-stage spinning and stretching process or a high-speed spinning process from the angle. The figures show that threads, which are varied in their continuous finenesses by more than two powers of ten (> factor of 100), can be produced in melt-spinning processes realised today. The underneath hatching delimits the ranges, which are described in the thread formation catalogue. This range is somewhat larger for polyamide than for polyester, but for both fibres the fact that the extremely coarse and fine titres are not recorded first of all applies (according to Beyreuther).

Melt transfer printing → Transfer printing, in which all grades of dye are embedded in a fusible resin on the carrier (paper) and the dye is transmitted onto the textile via the phase of the molten resin under the effect of the temperature.

Melt viscosity → Viscosity characterised by the → Melt-flow index. Hot melt adhesives on a polyamide or polyester basis have a precisely definable melting point. But the melt viscosity curve (see Fig.) is more important for workability with laminates.

Membrane Taut skins or skin, permeable, impermeable or semi-permeable. One also talks of membrane in the radial layer structure of fibres. →: Intermediate membranes; Selectivity; Semi-permeable.

Membrane filtration, molecular filtration Increasing demands on product characteristics and the trend for ecologically compatible manufacturing processes necessitate a complex treatment of process flows in many sectors of the industry. The use of membrane filtration here proves to be a particularly promising solution approach. This process, also called ultrafiltration, is thereby understood to mean a technique for separating released or suspended substances from liquids, dependent on the size or the molecular weight. New ultrafiltration membranes and modules with high chemical and thermal stability are particularly suitable for sophisticated applications. The thin, asymmetric structure of the active membrane surface and the tangential flow facilitate a high flow rate (see Fig. 1). A surface layer formation normal in conventional filtration can consequently be reliably avoided by different methods (Fig. 2).

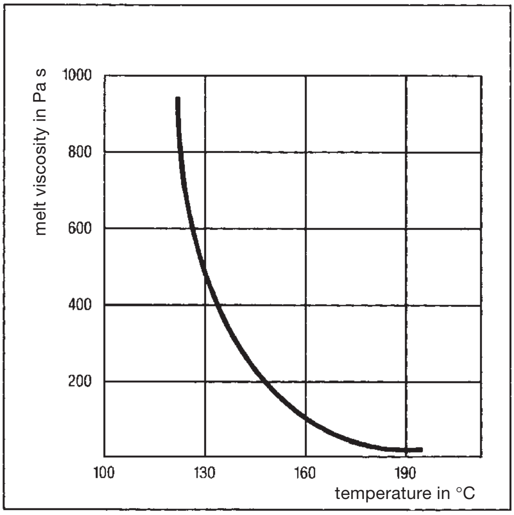


Fig.: Melt viscosity in relation to temperature.

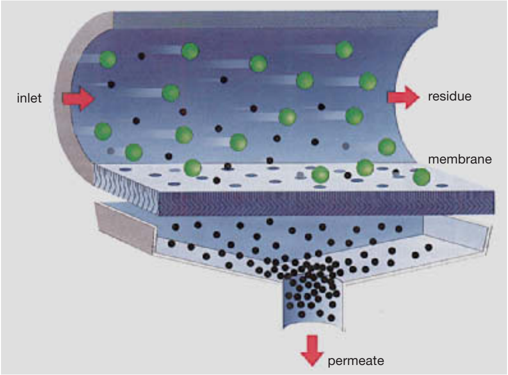


Fig. 1: Membrane filtration (according to Hoechst).

Membranometer Device for assessing the foam stability of detergent solutions by measuring the strength of surface skins.

Mepasin C_{13}–C_{16}; hydrogenated → Fischer-Tropsch waxes. Boiling range 220–280°C. Iodine number 10. Raw material for sulphonation products.

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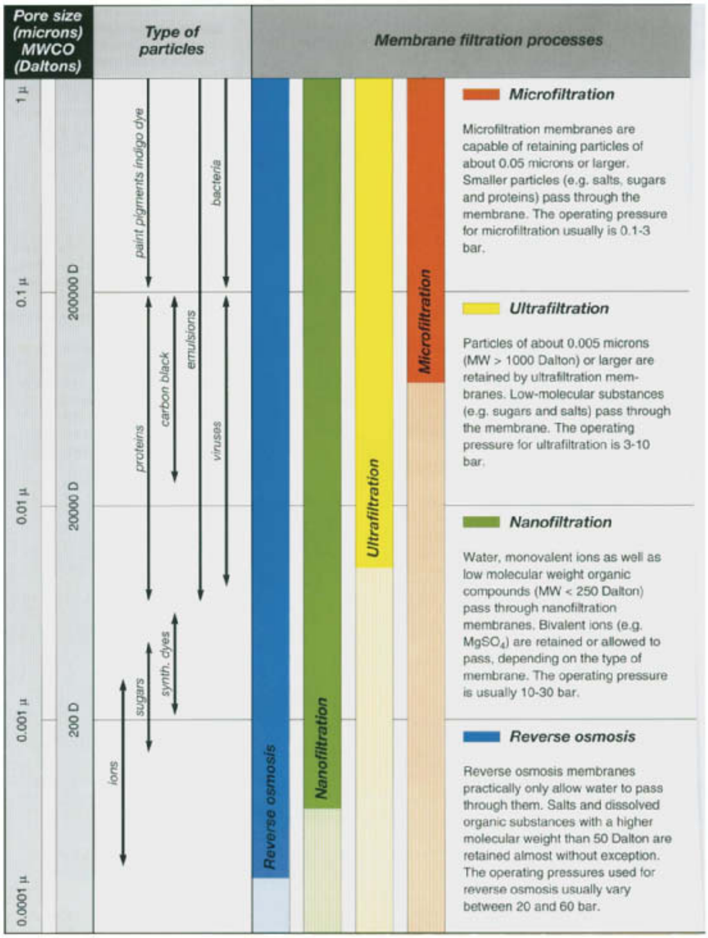


🟥 **Microfiltration**

Microfiltration membranes are capable of retaining particles of about 0.05 microns or larger. Smaller particles (e.g. salts, sugars and proteins) pass through the membrane. The operating pressure for microfiltration usually is 0.1-3 bar.

🟨 **Ultrafiltration**

Particles of about 0.005 microns (MW > 1000 Dalton) or larger are retained by ultrafiltration membranes. Low-molecular substances (e.g. sugars and salts) pass through the membrane. The operating pressure for ultrafiltration is 3-10 bar.

🟩 **Nanofiltration**

Water, monovalent ions as well as low molecular weight organic compounds (MW < 250 Dalton) pass through nanofiltration membranes. Bivalent ions (e.g. $MgSO_4$) are retained or allowed to pass, depending on the type of membrane. The operating pressure is usually 10-30 bar.

🟦 **Reverse osmosis**

Reverse osmosis membranes practically only allow water to pass through them. Salts and dissolved organic substances with a higher molecular weight than 50 Dalton are retained almost without exception. The operating pressures used for reverse osmosis usually vary between 20 and 60 bar.

Fig. 2: Waste water treatment by membrane filtration.

Mepuquat chloride 1.1-dimethyl-piperidinium chloride; bioregulator for the inhibition of unwelcome lush, vegetative growth functions of cotton plants.

Mercaptans (thiols), type R–SH; organic compounds corresponding to the alcohols in which S appears instead of O, e.g.:

CH_3–S–H	methylmercaptan
C_2H_5–S–H	ethylmercaptan
$C_{12}H_{25}$–S–H	dodecylmercaptan

Are highly volatile, have unpleasant odour and light acidic reaction. Mercaptan salts are called mercaptide (type R–SNa). Disulphide (type R–S–S–R_1) is produced from mild oxidation, which, e.g., includes the cystine of wool, while sulphonic acids (R–SO_3H) are formed from stronger oxidizing. Alkylated mercaptans are → Thioethers.

Mercaptoacetic acid → Thioglycolic acid.

2-mercaptoethanol HO–CH_2–CH_2–SH; seldom used reducing agent in water-soluble sulphur dye.

Mercaptophthalocyanines → Phthalocyanine dyes.

Mercerizing Treatment of cotton yarns, fabrics and knitgoods with cold, strong caustic soda liquor under tension. The process is based on the observation (Fig. 1) that cotton fabrics shrink under the influence of liquor, increase in density and strength and show an increased dye uptake ability. Mercerizing is an important

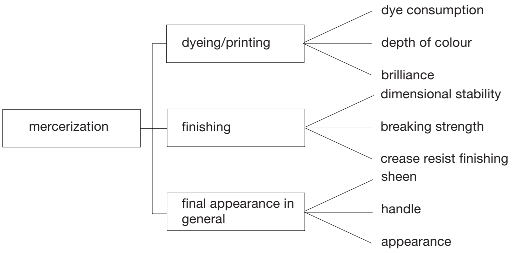
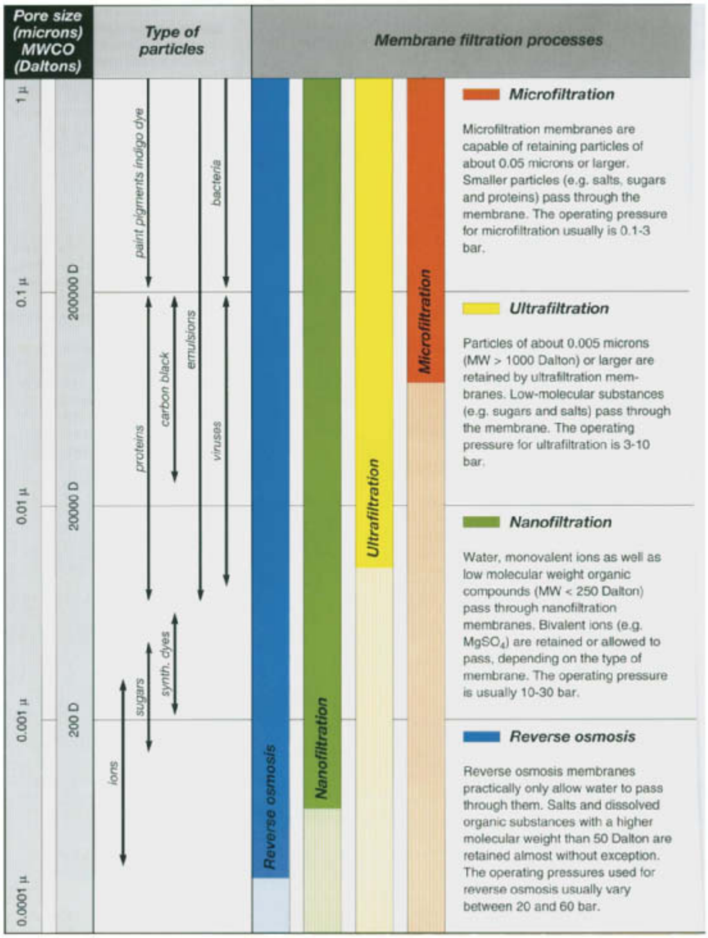


Fig. 1: Effects of mercerization.



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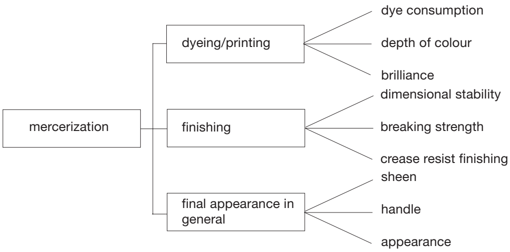

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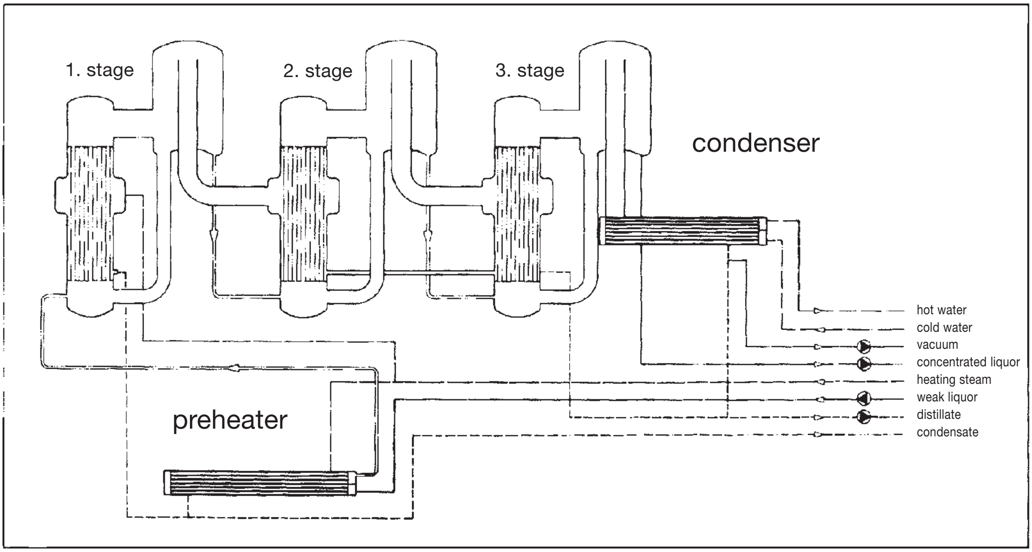


Fig. 2: Evaporation plant for recycling of mercerizing liquor (Kasag).

operation for cotton finishing to achieve a resistant silk shine and good handle without all the fundamental processes being understood. Yarn mercerizing is labour-intensive, self-dyeings on yarn mercerized knitgoods also usually break down somewhat fitfully and streakily. That is why the mercerizing of fabrics is better. Knitgoods can be mercerized both in an expanded state and in tubular form. Chain mercerizing machines can also be used for the expanded form as they are used for fabric. The mercerizing of tubular knitgoods is distinguished from cut or flat-knitted knitgoods.

Mercerizing is carried out in the following steps:
- impregnating with liquor (e.g. mercerizing of grey goods: 20 m/min, 20°Bé, air strake),
- stretching,
- scouring under tension (up to 7°Bé),
- souring off (1st section 80°C water and steam; 2nd section: 50°C acetic acid),
- rinsing (20°C).

If cotton is cold mercerized in its raw state, a liquor-resistant wetting agent must be added to the liquor. Products previously manufactured on a cresol basis have meanwhile been replaced by cresol-free ones (waste water pollution). The waste lye produced during scouring has a strength of up to 9°Bé when applying the counter current principle and is reused for scouring. In large-scale plants, the purchase of an evaporator system, amongst others, pays off (Fig. 2).

If an evaporator system is available for the washing water, non-foaming wetting agents should be used. The degree of mercerizing is expressed by the so-called “barytes number”. The more strongly the cotton is mercerized, the more it absorbs barium hydroxide. A shine which has a completely different intensity may however be detected at the same barytes number. For mercerization it is crucial that the scouring of the liquor is carried out under tension. The treatment of cotton fabrics in caustic soda liquor of mercerizing concentration, but without tension, also called “slack mercerization”, is more correctly described as → Causticizing. The properties of the cotton fibres are altered under the influence of strong caustic soda liquor as follows:
- the cuticle is destroyed,
- the cross-section becomes larger and assumes perfectly circular forms (Figs. 3–4),
- the lumen disappears,
- the spiral windings loosen,
- the fibre length is shortened by 20–25%,
- change in the macromolecular structure,
- orientation of the crystallites in the direction of the fibre axis,
- increase in the inner fibre surface,
- increased reactivity,
- improvement in the effect of resin finishings,
- higher resistance to attacks from chemicals, micro-organisms, sunlight and weathering,
- increased dye uptake ability (up to 25%),
- increase in the tear strength of individual fibres,
- better dimensional stability.

The chemical processes of mercerization have still not yet been clarified precisely. The following parameters are important:

1. Provenance: This has little influence on the mercerizing effect.

2. Caustic concentration: Caustic soda liquor of 28–32°Bé proves to be most effective, i.e. liquor with a

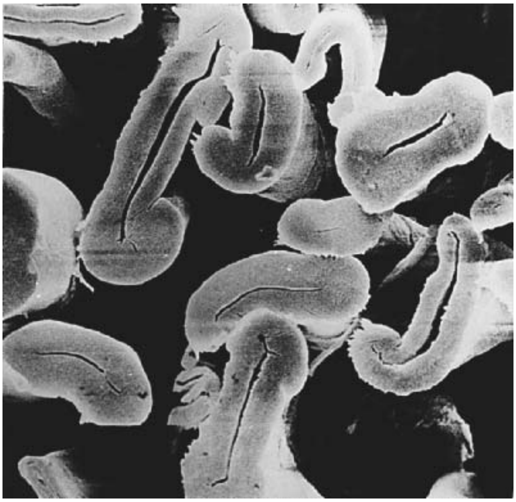


Fig. 3: Electron microscope image of natural (untreated) cotton fibres in section, magnified x 2200.

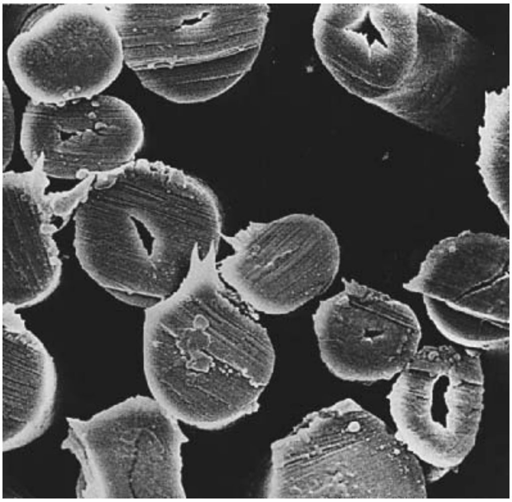


Fig. 4: Electron microscope image of mercerized cotton fibres in section, magnified x 2200, which are suitable for anticrease finishing.

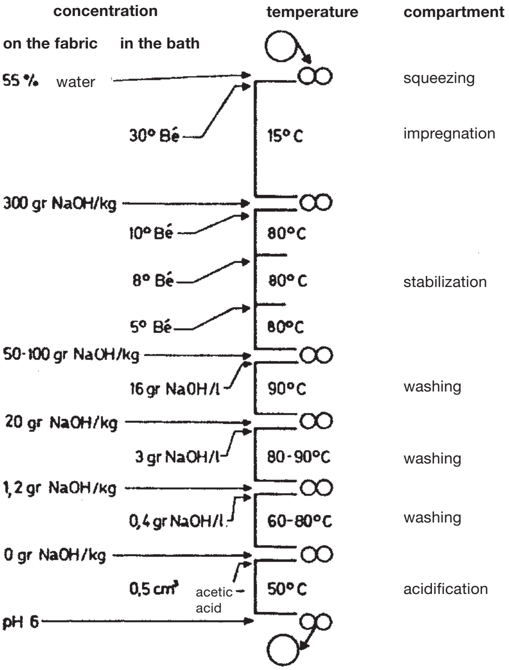


Fig. 5: Sequence of the classic mercerization process, diagram.

270–330 g/l sodium hydroxide content. This applies to the mercerization of dry fabrics. The cotton hereby absorbs more alkali than corresponds to the liquid quantity absorbed. The concentration decreases. Reinforcement under constant monitoring is required. There are fully automatic control devices for this. This advice should be observed to an even greater extent, if moist fabric is being mercerized.

3. Temperature: The principle that the lower the temperature, the higher the shine is not tenable in this form. It has been well established that the cotton swells to a maximum at 12–15°C. For this reason, mercerizing plants have often been provided with a liquor cooling unit. However, the heavy swelling of the wetting zones of the yarn then prevents a further ingress of the liquor so that the fibres remain more or less unchanged there. An increase in the liquor temperature to 50–60°C (hot mercerization) produces lower swelling, but complete penetration of the yarn, whereby optimum shine should be achieved. Fig. 5 shows the temperature profile in the individual steps of a classic mercerization of fabric.

4. Time: Normal values are 30–60 s of effect. The quicker the liquor penetrates into the fibre core, the shorter the time can be. One way of doing this is the addition of suitable wetting agents; another possibility exists in the use of heat (thermotex process), i.e. the fabric is highly heated shortly before admission into the liquor. High liquor temperature also results in quick penetration. As the penetration for dry fabric is also a matter of its air-containing capacity, one tries to carry out ventilation. Kleinewerfers has developed the vacuum method for this, by equipping the liquor padder with a suction cap (vacuum mercerization). Instead of the suction cap, Brugman ventilates the fabric by means of the “mach nozzle” (Fig. 6) and steam.

5. Tension: To achieve max. effects, the scouring of the liquor must firstly be carried out under tension. The

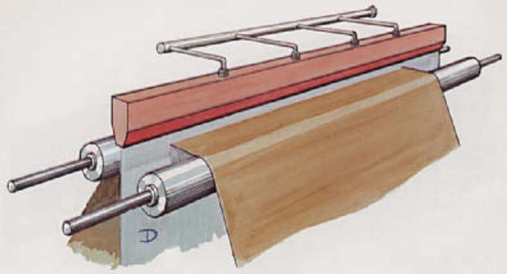


Fig. 6: Mach nozzle device by Brugman (Almelo): Steam (D) is blown at high speed through the fabric, which is then immediately impregnated with mercerizing liquor.

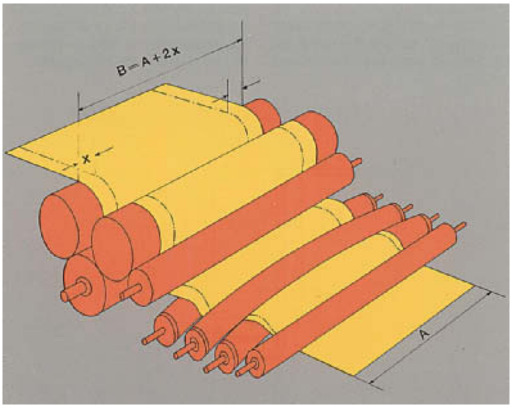


Fig. 7: Expanding rollers in the first rinsing bath (stabilization) of a roller mercerization plant by Kleinewefers KTM.

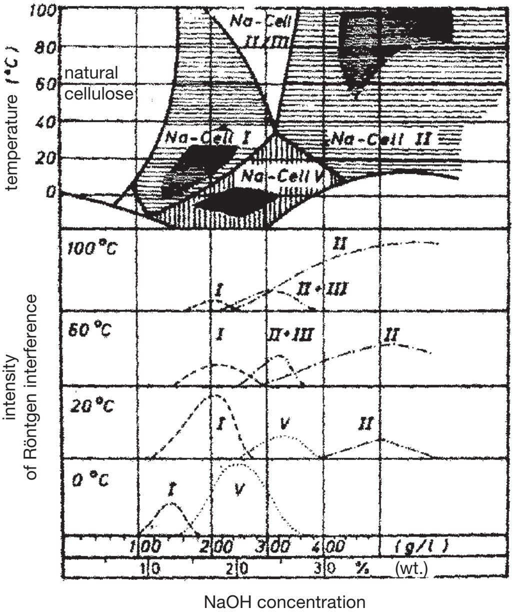


Fig. 8: Phase diagram for mercerization.

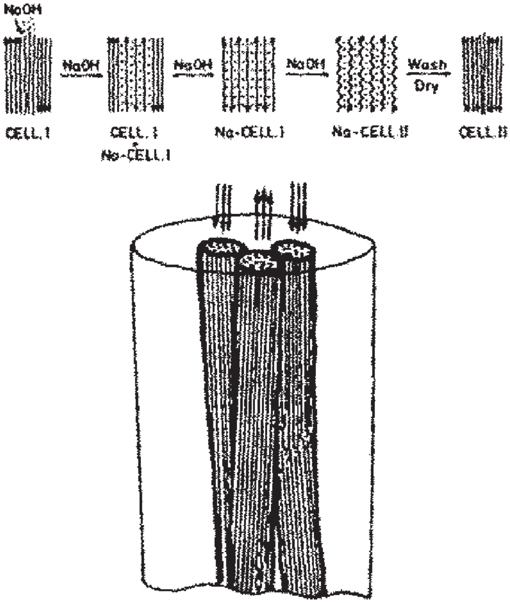


Fig. 9: Mercerization represented in model form.

installation of effective expander rollers in the first rinsing section (Fig. 7) (stabilization section) of chainless fabric mercerizing machines is therefore important. The fibre swelling of the cotton in caustic soda liquor is a fundamental prerequisite for successful mercerization. The swelling of the cotton fibre and its structural change during treatment with caustic soda liquor produce the far-reaching property changes that are striven for. Depending on the caustic soda liquor concentration and temperature, sodium cellulose is formed in the reaction between cotton cellulose and caustic soda liquor analogue to the phase diagram in the cotton fibre (Fig. 8). Alkali cellulose I is produced during causticizing with 16–18% NaOH, while the cotton cellulose reacts with 21% (and higher concentrations) of caustic soda liquor to form alkali cellulose II. Before these products, but after equilibrium adjustment can be recorded, complex preliminary stages, which determine the kinetics of the conversion, occur in the heterogeneous system of fibre/liquor.

The following knowledge is considered fundamental: Because the fibre is already heterogeneous in itself as a morphological structure, the different layers are variably sensitive to the reaction conditions of the caustic soda liquor effect. The spiral-shaped structure and the contra-rotating direction of rotation of the fibril bundles in particular (Fig. 9) make the cotton fibre considerably more resistant to a slip in the fibril bundles than, for example, comparatively regenerated cellulose fibres. The interfibrillar spaces between the microfibrils (consisting of crystallites and misordered areas), which represent the sub-units of the fibril bundles, play a particular role in the swelling of the cotton fibre.

An electric potential (the zeta potential) is formed on the fibre/liquor interface because water molecules from the liquor are orientated to the fibre surface due to their dipoles. Tied up functional OH groups may dissociate on the fibre surface. Dissolved ions are selectively adsorbed in the liquor: caustic soda liquor is present in the diluted solution (Fig. 10) dissociated as a hydrated ionic couple (below 100 g/l); due to their large diameter these elements cannot penetrate into the orientated areas of the fibre. The number of available water molecules is reduced with increasing NaOH concentration because, from 150 g/l of hydrated ionic couple, hydrates are formed by diminishing diameters. The swelling maximum is therefore reached at 180 g/l. From 200 g/l, an accumulation of hydrated dipole hydrates starts in the undissociated liquor and finally undissociated, non-hydrated NaOH molecules are produced via dipole hydrates without water, which would be mobile. These processes influence the electric transition work in the diffuse double layer. So a reduction of the negative zeta potential of the fibre results from the effect of caustic soda liquor on cotton until a limit is finally reached at 17% NaOH.

The increase in the fibre diameter (swelling) as well as the contraction in length to be observed clarify the anisotropic behaviour of the cotton fibre. An asymmetric pressure is built up in the fibre due to a Donnan equilibrium because the fibre surface (as a semi-permeable membrane) only allows the colloidal ions to diffuse through into the fibre and so it “inflates” itself. This behaviour of the cotton is irreversible, as a transition into hydrated cellulose and later into alkali cellulose is carried out by absorption of water. The resulting swelling is carried out intercrystalline from 5% NaOH effect. Higher caustic soda liquor concentrations produce lattice transitions in the cellulose.

The inner fibre surface, pore structure, hydrogen bonds bonding form, the degree of order (radiographically), or, in summary expressed in the sense of pretreatment and “the accessibility” of the cotton is altered by the respective alkali treatment. The increased dye uptake produced by the mercerizing, for example, is firstly based on this increased accessibility (e.g. at the same percentage, radiographical crystallinity in comparison to the untreated cotton due to a larger number of smaller crystallites). Secondly, the light from the rounder fibre after mercerizing is less diffuse, but reflected in a more bundled way (so with less light scatter), which supports the detection of increased dye uptake in the sensory impression of “colour”.

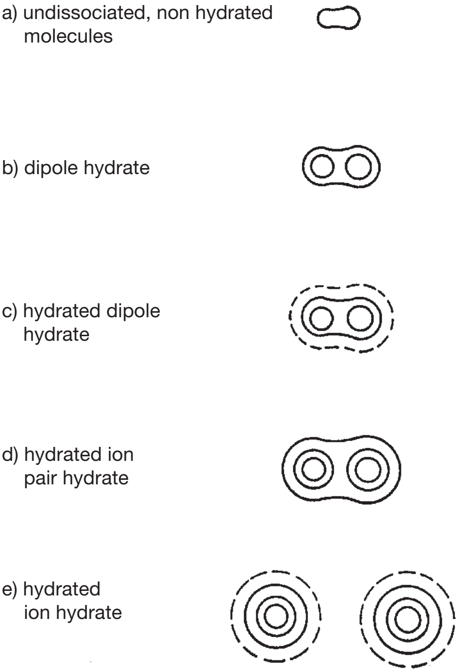


Fig. 10: Size of the caustic soda molecule in water, with decreasing concentration from a to e.
a = 0.1–0.5 nm; b = 0.5–0.8 nm; c = 0.8–1 nm (from 200 g/l); d = 1–1.5 nm (from 150 g/l); e = 1.5–2 nm (< 100 g/l).

Mercerizing can be carried out within different stages of finishing:

- as a grey good,
- after desizing,
- after desizing and scouring,
- after bleaching or between two bleach stages,
- after dyeing.

A double mercerization is sometimes also applied, i.e. a) mercerization of the raw fabric and b) mercerization after desizing, if necessary after desizing and kier-boiling. The decision depends on the requirements of the finished result of the fabric. Disadvantages of the mercerizing of grey goods: Complete penetration of the yarns rather difficult using liquor; soiled liquor, which can lead to discoloured fabric; reuse of the waste lye restricted. The increase in shine using mercerization should be greater the weaker alkaline the scouring was. Increase in shine produces a souring off between scouring and mercerization. If materials from unevenly spun yarns are to be mercerized, it is often advantageous to carry this out only after dyeing. The fabric pattern looks more even; the knops of dead cotton thereby also almost completely disappear. The dyeing must withstand the liquor and acid treatment. The latter should, if necessary, be left out.

Mercerizing

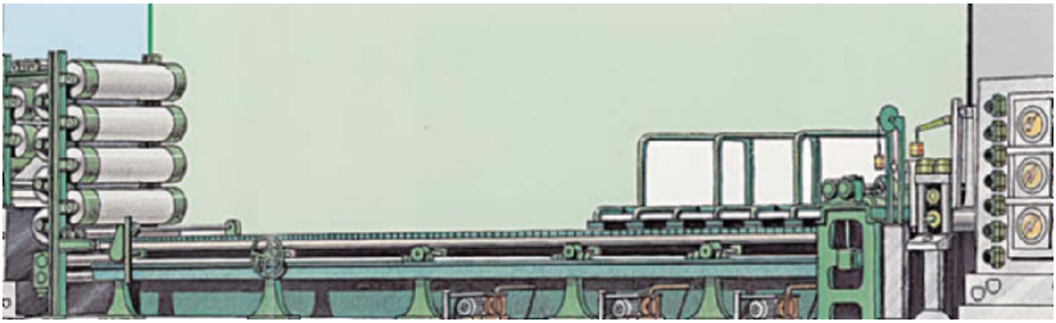


Fig. 11: Typical working line on a chain mercerizing machine (Morrison).
Left: lye impregnation zone with dwell time on cylinder rollers; centre: washing out on a stenter frame; right: start of rinsing.

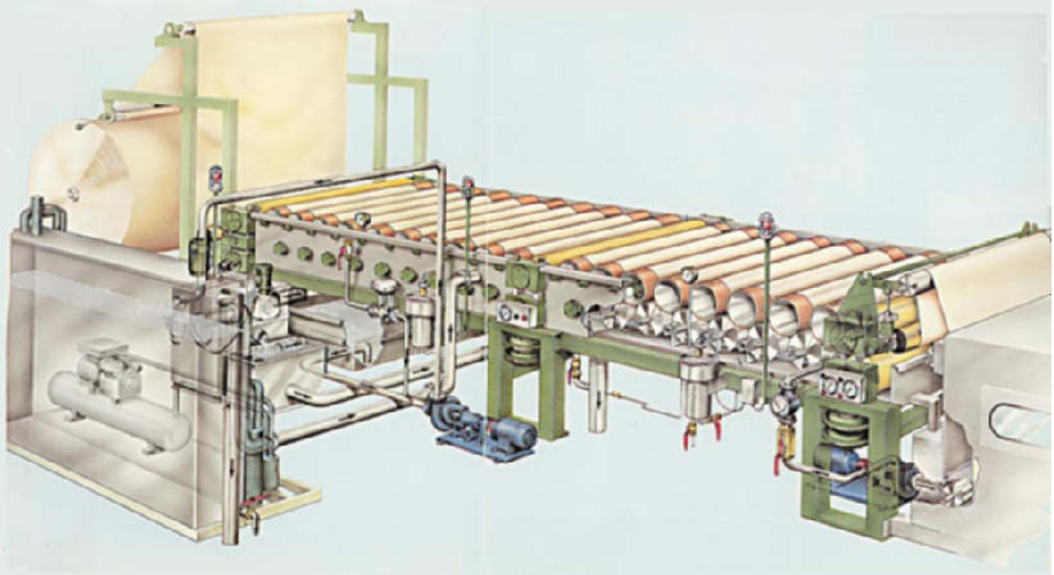


Fig. 12: Roller mercerizing machine by Brugman.

In some cases mercerization is carried out after dyeing and handle modifying finishes. This is the case when the tear strength and abrasion resistance of crease-resistant finished fabric is to be improved.

Two systems are in use for the mercerization of fabrics under tension:

- chain machines,
- chainless machines.

In less common chain machines (Fig. 11), the fabric is held on both corners by a clip chain after impregnation on a padder. The chains are brought closer to each other on the stenter infeed and then spread as far as the necessary width of the fabric requires. In the last third of the span, rinsing is carried out using hot water until no more shrinkage can occur after the tension has stopped. The rest of the liquor is removed in the following lye extractor. In this device, washing takes place in accordance with the counter current principle using hot water and an 8–10% strong waste lye is thereby obtained. After rinsing, it is soured off and the acid is washed out again. For economic reasons hydrochloric acid or sulphuric acid is used (the latter however only if soft water is available) or (with less risk during drying) acetic acid. For better impregnation with liquor, two padders are usually used, whereby a series of transition drums is connected between the two. The effective time is thereby extended. Chain mercerizing machines are chiefly suitable for the mercerization of knitgoods, if they are to be dyed evenly afterwards.

Chainless mercerization machines operate according to a different principle. The fabric runs across a system of rollers (Fig. 12) through the liquor and the so-called stabilizing section, in which so much liquor is rinsed away (Fig. 13) that it no longer shrinks in the subsequent lye extractor. The rollers lie closely next to each other or on top of each other so that the fabric has no possibility of shrinking. If need be, width losses can be compensated for by the installation of an overstretching field with expander rollers (Fig. 14) in the centre of the stabilizing field.

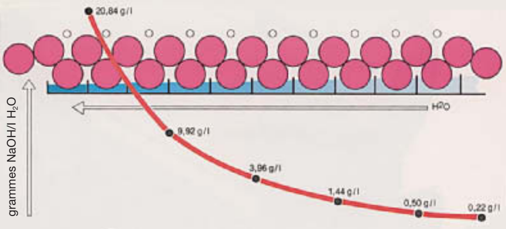


Fig. 13: Process of washing out the caustic soda in the stabilization section of a roller mercerizing machine by Goller.

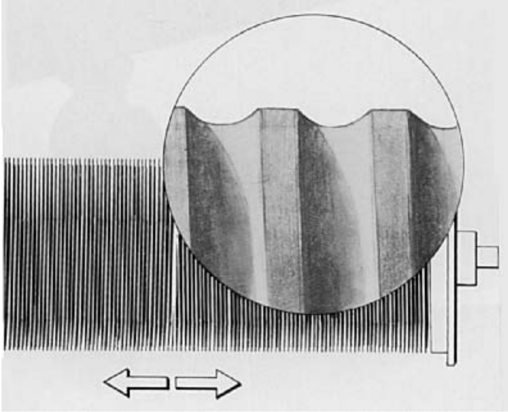


Fig. 14: Expander roller with ripples on the Goller roller mercerizing machine to ensure contact during fabric transport.

Benninger (Fig. 15) developed the two-stage process (1st stage hot impregnation, 2nd stage cold-swelling under stenter stretching, scouring on stenters and rollers). The result is the combined roller chain mercerizing machine "Dimensa", whose chain stenter part was developed in co-operation with Brückner. The "Dimensa" in principle consists of five modules:

1. In the impregnation zone, the fabric is brought into contact with 60°C hot caustic soda liquor (of mercerizing liquor concentration). The preparation of the liquor takes place in an under tub (the impregnating tub), i.e., only so much stock liquor and water is mixed as is consumed in the impregnating tub. Diluting heat is produced during the preparation of the hot liquor so that the liquor only has to be heated by 40°C to 60°C. The process of mercerizing liquor consumption is monitored and controlled in an extensive measuring and control system. Concentration measurements, level stage measurement and temperature measurements function for control circuits.
2. Subsequent to the hot impregnation, the fabric runs through a roller mercerizing section with two large cooling rollers. If good penetration of the fabric took place in the hot impregnation section (under simultaneous influence of the fabric shine), the fabric should now swell to a maximum at a lower temperature because swelling is an exothermic process. The mercerizing liquor concentration is not altered in this cooling and dwelling range.
3. The first part of the stabilizing zone, the span, which has 3 m long mobile arms, stored in a stiff, but adjustable in width in stentering, then follows. Hot weak liquor is applied in a spray box across the whole cloth width in order to start the stabilizing process.
4. The cloth then goes over into a normal roller mercerizing zone.
5. The process concludes with a roller vat.

The advantages of the "Dimensa" process are in the width constancy of the cloth; the untreated width can be fixed easily. It is debatable though whether with common material, which tries to engage up to 15% in width, an intensive stretching process does not stretch fabric sections on the selvedges more than in the middle of the fabric. The "Dimensa" process at least offers the possibility of pulling adjusted cloth correctly as in a loom to the untreated width and so save a drying operation.

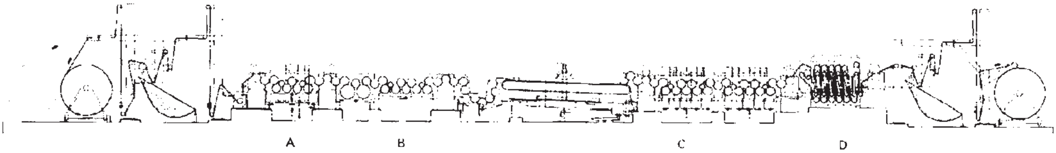


Fig. 15: Stenter frame and roller section of the "Dimensa" by Benninger (all elements with contact fabric transport). A = impregnation; B = cooling; C = stabilization on stenter frame; D = rinsing.

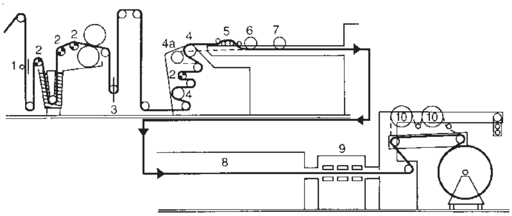


Fig. 16: Mercerization on the stenter frame by Sandoz. 1 = stretcher; 2 = expander roller; 3 = floating roller; 4 = drawing roller; 4a = drawing roller lowered for direct fabric feed; 5 = finger spacers; 6 = shrink roller; 7 = rotary brush; 8 = drier; 9 = cooling zone; 10 = cooling drum.

The purchase of a mercerizing machine is a financial problem in small production plants. Dornier built a special device for small batches. The fabric is impregnated with the liquor, rolled under pressure, then rewound on a second roller. After the rewinding, which is carried out from roller to roller in constant direct contact and consequently prevents a shrinkage in the weft direction, lye extraction takes place by spraying hot water under the same conditions. Another plant is the “Mercerizing centrifuge” of Kleinewefers-Jaeggli, in which the cloth impregnated with liquor is rolled up onto a perforated drum and washed in accordance with the principle of the Dokken washing machine and hydro-extracted by centrifuge.

In the Sandoz SM process, application is on the stenter (Fig. 16). As only a slight change is necessary, existing machines can be used without any problem. The infeed system, needle bonding or clips, all metal parts of the stenter, which come into contact with the alkaline impregnated textile, must consist of stainless steel. The brush trim in the punching may only contain polyamide brush hairs. The rubber in the squeeze rollers must have an alkali resistance of at least 23°Bé NaOH. The SM process is suitable both for flat knitgoods and cut circular knitted fabric and for fabric made from cotton and cotton fibre blends. The application technique includes padding at room temperature, stretching with controlled width, drying at 130°C and intensive scouring. The result is a very good dimensional stability with a high uniformity of fabric structure and high shine. As with all foulard processes, the conditions should be kept as constant as possible (liquor level, NaOH addition of 25°Bé, temperature). After the padding, chiefly the knitgoods shrink very considerably. The infeed phase (before the drying system) is carried out under stronger longitudinal tension. The width tension should be applied in such a way that the fabric is also pinned down in a heavily tensioned state, but without producing clip defects. When drying, the following rules of thumb should be observed for the dimensional stability and correct setting of the knitted geometry: width tension of 5–10% across the desired final width plus 3 cm for selvedge cutting (single jersey). The longitudinal tension is 20–30%. The adjustment of the width and longitudinal tension is a matter of experience and depends on the final dimensional stability, knitted geometry and final weight per square metre. A stenter with 4–5 drying sections is suitable for the application of the SM process. The drying takes place at max. 130°C in a stretched state; the tension is crucial for a good shine. You recognise the complete drying by the alkali-conditioned uniform yellow tone. The cloth is then rolled up in a cooled state; this can also be plaited down for knitgoods. The temporary low strength of alkali treated cloth in the dry state should thereby be considered. In the subsequent scouring, the cotton attains its original strength again, the yellow tone completely disappears, and the textile obtains the properties of a mercerized fabric. The adjustment of the knitted geometry runs uniformly in knitgoods, which helps to avoid listings when dyeing. The risk of selvedge condensing (Fig. 17) exists on conventional chainless mercerizing machines. This irreversible damage is based on the diverging shrinking behaviour of the centre and outside. The outside shrinks unevenly greater than the centre. A safe mercerizing of cut cloth is only possible on chain mercerizing machines or on stenters in accordance with the SM process.

A lot of interest exists in the true mercerizing of tubular knitgoods; if the stabilizing does not take place under tension (inflation of the tube), it is effectively only causticized. The Caber merceknit process (Fig. 18) acts as a pneumatic expander for the purpose of radical tension of the tube during stabilizing. Sperotto-Rimar is trying to achieve this effect by inflating with air (Fig. 20). But Dornier puts the most elegant solution into practice with a reworking of the Spreiz system: Dornier previously stretched the tube during stabilisation and rinsing with rings, which were expandable in the diameter. The cloth then stuck to the rings, especial-

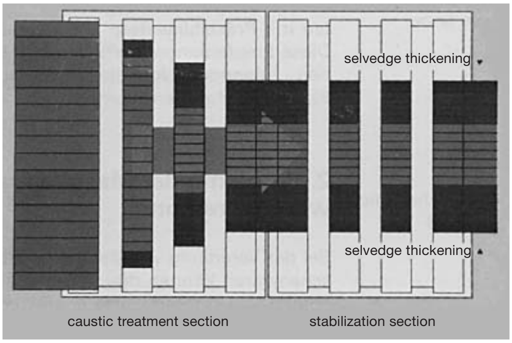


Fig. 17: Diagram of selvedge thickening in the case of a conventional, non-chain mercerizing machine.

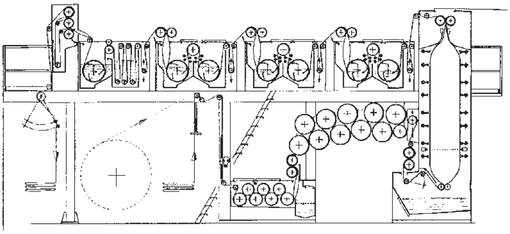


Fig. 18: Caber mercerization plant for tubular goods.

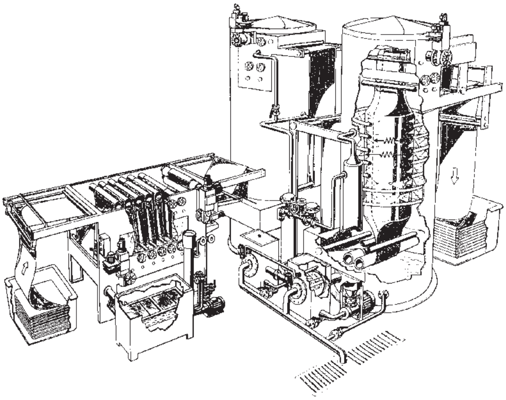


Fig. 20: Sperotto-Riemar mercerization plant for knitted goods in tubular form.

ly during rinsing, and a considerable longitudinal expansion was experienced. Dornier filled the extendable rings with a lot of rollers (Fig. 19).

It is said of the chainless machines that the knit formation between centre batch and lateral batch precipitates somewhat differently. This should be the case less often with chain machines. For this reason, the slitting of tubular knitgoods is dispensed with and a tubular fabric mercerizing machine is used.

The firm Coats firstly used liquid ammonia instead of caustic soda liquor for mercerizing cotton yarns. The Norwegian textile institute in Oslo developed the "Tedeco" process for fabric, also known by the registered designation "Duralized" in conjunction with permanent-press finishing. Liquid ammonia has a temperature of 33°C at normal pressure and penetrates cotton immediately. Up to more than 90% can be reclaimed. The equipment must be completely closed. Monforts also constructed systems for fabric. Before the fabric enters the ammonia, it must be cooled. After immersion a looping section follows, then the economiser, in which the greatest part of the ammonia vaporizes, a stretching wheel and finally a rinsing device with hot water. The effect should be just as good as in mercerization using caustic soda liquor. Caustic soda liquor should have more of an effect in the intermicellar region of cotton fibre and ammonia in the intramicellar region. With this system, it should be noted that the treatment part is just as expensive to purchase as the recovery system for the volatile ammonia. A schematic comparison of the mercerizing process might look as follows:

Decrease in shrinkage:
NaOH (20°C) → NaOH (90°C) → NH_3.
Increase in swelling speed:
NaOH (20°C) → NaOH (90°C) → NH_3.
Intensity of structural change:
NaOH (20°C) ← NaOH (90°C) ← NH_3.

A non-uniform mercerizing effect can be seen in non-uniform dyeing. Causes:

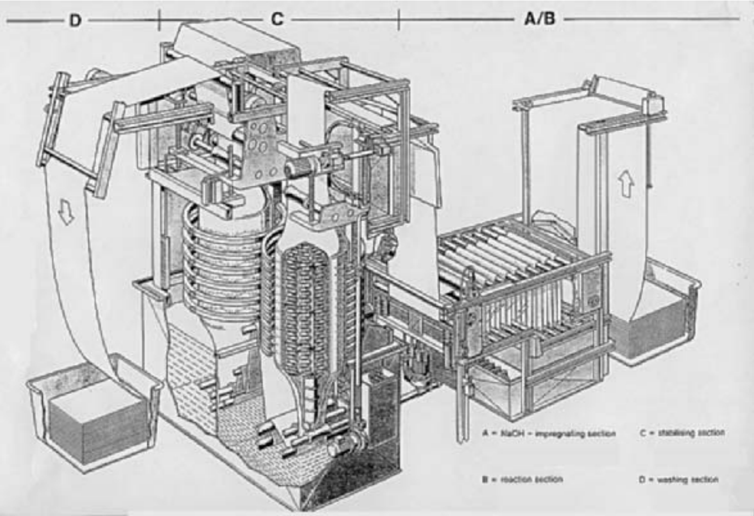


Fig. 19: Dornier mercerization plant for tubular goods with contact fabric transfer.

- non-uniform moisture content (water spotting stains);
- creases, which appear during mercerizing, cannot be removed;
- oxycellulose formation, if washed cloth is left not completely alkali-free;
- hydrocellulose formation, if acid is inadequately washed out and the cloth starts to dry.

Mercerizing of cotton blends: The sensitivity of most regenerated cellulose fibres (except HWM fibres) compared with higher alkali concentrations necessitates extreme caution when mercerizing mixed spun yarns of cotton and viscose. Mercerization incidentally only makes sense for this blend if the viscose fibre content does not considerably exceed 50%. The polishing effect of this treatment is hardly noticeable otherwise. But mercerization in these cases is accompanied by a much better tone-in-tone dyeing of both fibres. Viscose fibres have a solubility optimum in caustic soda liquor of 13°Bé at 20°C. The soluble component in viscose fibres is 5–45% depending on origin. The solubility is less in hotter liquors, greater in colder ones. If moist yarns or fabric are mercerized from cotton/viscose, these run through twice the dangerous concentration range of 13°Bé for viscose. That is why it is better to dry it beforehand. The rinsing process is altered compared with the treatment of pure cotton in that it is washed immediately with very hot water (50–80°C) in order to achieve a throughput of the danger zone as quickly as possible. Mercerization with caustic potash solution is less critical, as viscose fibres swell significantly less in that than in caustic soda liquor. However, as the effect on cotton is less, one works with mixtures of both liquors. Protection of the viscose fibres can be achieved by adding 40–50 g/l of sodium chloride to the caustic soda liquor. Mixed fabric made from cotton and polynosic fibres can be mercerized without special measures. Certain differences should though exist between polynosic and HWM fibres in their reaction to mercerizing liquors. Mixed fabrics made from cotton/polyester are also possible for mercerizing in a high proportion of cotton. There are no particular precautions to take for this. A partial mercerization of cotton takes place, if the cloth is impregnated with mercerizing liquor, dwells for 5–15 min without tension at 65°C and is then washed off. Simili mercerizing is merely a calender treatment on a grooved calender. The mercerizing of linen hardly alters it; however, it has been established that linen fabrics treated with crease-resistant resins and then mercerized obtain a better handle and better abrasion resistance (both in the treatment in caustic soda liquor and in liquid ammonia).

Mercerizing of grey goods → Mercerizing without prior kier boiling, scouring or other wet treatment; → Dry mercerizing.

Mercerizing plants Depending on which batch size you want to mercerize, you can fall back on small systems such as Minimerc from Menzel (Fig. 1) or on large systems such as Dimensa (Fig. 2) from Benninger (combined roller chain type), Flexnip addition pick-up from Küsters (Fig. 3) (roller type) or the classic chain mercerizing machine (Fig. 4) from Farmer Norton (with impregnating section, stretch stenter entry zone, stabilizing zone in the needle field and rinsing machines as horizontal and vertical width washing machines) (→ Mercerizing).

Both optimized chain mercerizing plants (Fig. 5) and roller mercerizing plants (Fig. 6) are in operation today. New types of roller arrangements (Fig. 7) have also become known in chainless mercerizing plants.

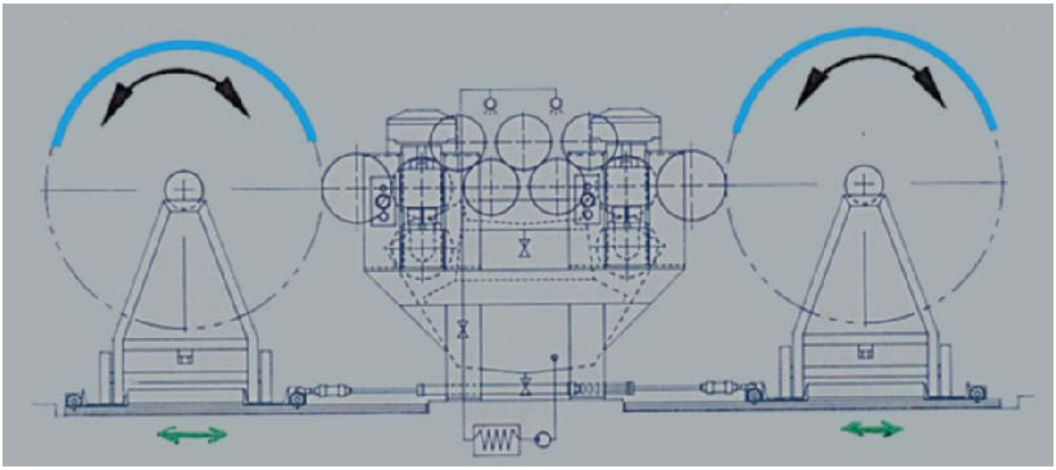


Fig. 1: Minimerc by Menzel.

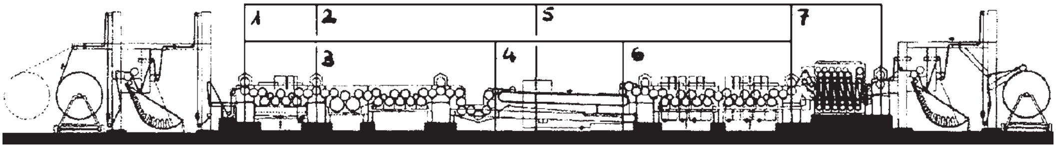


Fig. 2: Fabric transport diagram, Dimensa by Benninger.
1 = neutralizing and washing zone; 2 = stabilization zone; 3 = chainless principle; 4 chain principle (pin stenter frame); 5 = cooling and dwelling zone; 6 = chainless principle; 7 = impregnation zone.

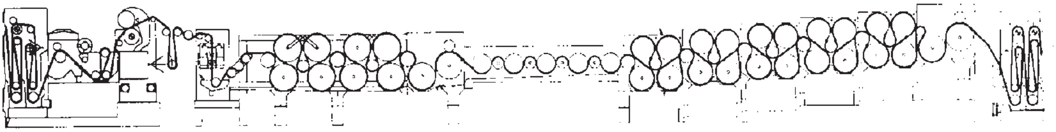


Fig. 3: Addition application with Flexnip using the Küster roller mercerizing plant.

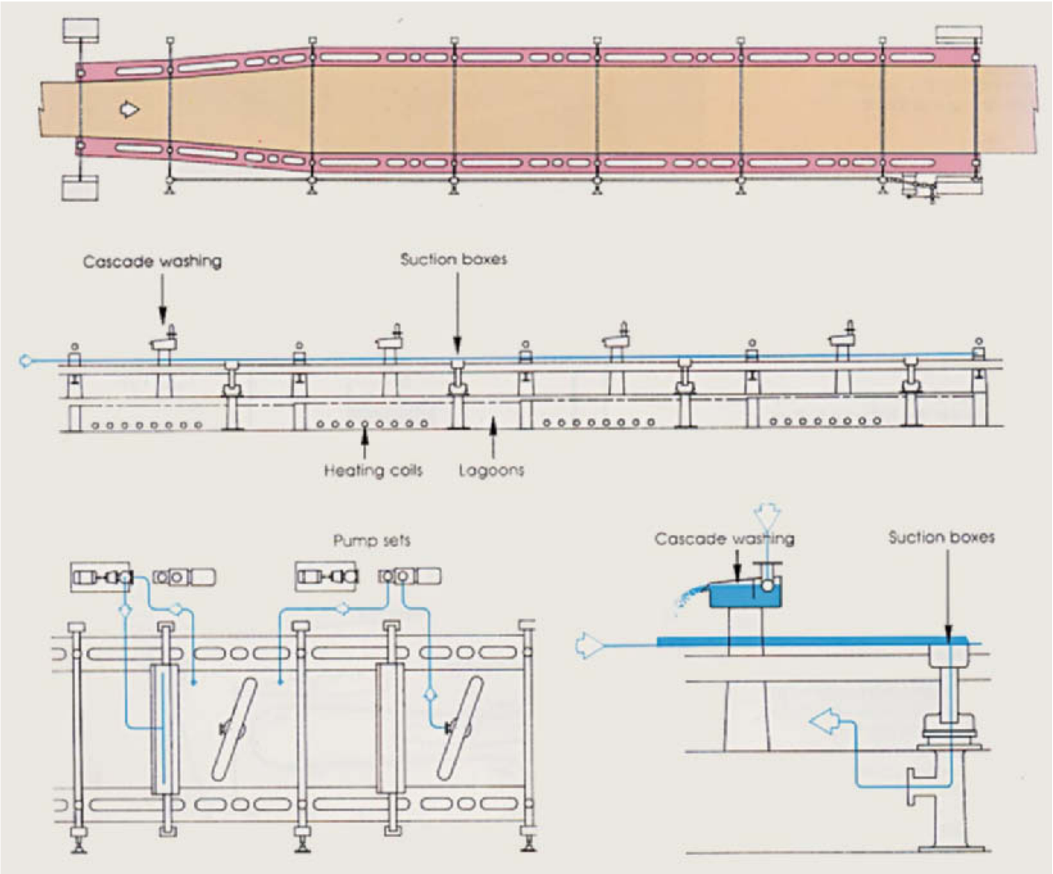


Fig. 4: Chain mercerizing machine by Farmer Norton.

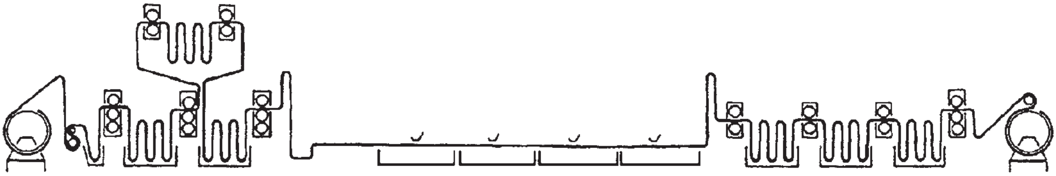


Fig. 5: Classic mercerizing plant, consisting of two impregnation sections with interconnected draw zones. Chain stabilization section with subsequent washing plant.

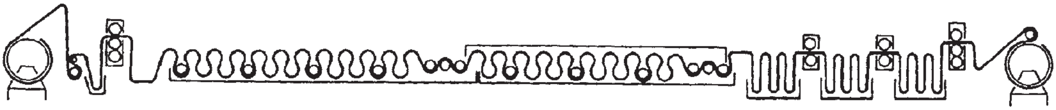


Fig. 6: Mercerizing plant, consisting of mercerizing section and stabilization section with connected cloth guide and subsequent washing plant.

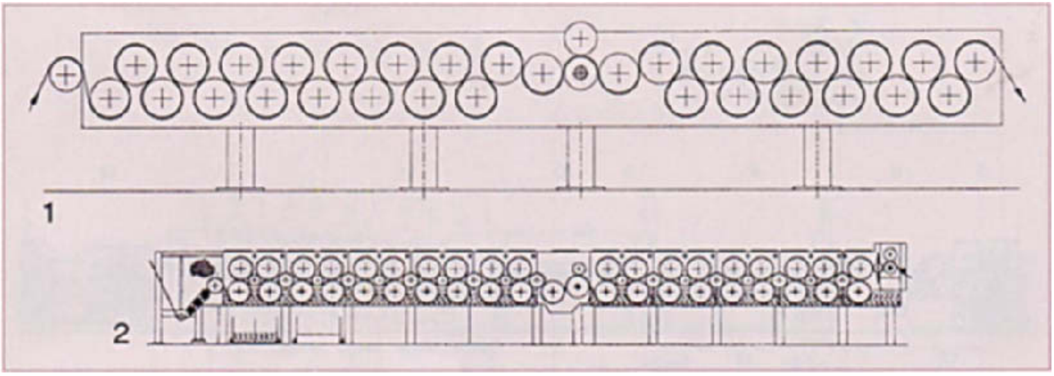


Fig. 7: Different types of chainless mercerizing plants.
1 = traditional roller arrangement; 2 = new type of roller arrangement by the Zittauer machine manufacturer.

Mercerizing position in cotton pretreatment → Mercer, John.

Mercerizing wetting agents The effectiveness of strong alkaline treatment baths used in mercerizing depends on how quickly the liquor impregnates the textile material, i.e. the fibre, the fibre lattice (yarn, ply-yarn), the textile fabric (woven fabric, hosiery goods), in which cellulose penetrates and due to whose swelling a shrinking process is triggered in the longitudinal direction of the fibre, which is transmitted to the textile material and by which more or less extensive prevention of the actual mercerizing effect is achieved. The shrinking process, i.e. the change in length over time, should therefore be regarded as a measurement of the effectiveness of a mercerizing wetting agent.

You cannot do without a wetting agent in raw cotton mercerizing. Lack of foam and shrinkage behaviour are important characteristics of the varied demands on such a wetting agent. The formulation of a mercerizing wetting agent using biologically degradable, end-group sealed non-ionic tensides as a defoamer has the following result:

- applicable in mercerizing and causticizing,
- good shrinkage wetting behaviour,
- low foam development,
- rapidly biologically degradable (OECD screening test: > 90% MBAS or BiAS acceptance; closed cylinder test: > 60% BOD_{30}/COD).

An automated method in accordance with Landolt is used to measure shrinkage wetting behaviour. The Landolt measuring tube (see Fig.) consists of a glass tube with a built-in guide rod, equipped with a double temperable sheath. The tube is filled with the mercerizing liquor, in which the yarn is given. A polished piece of metal is located at the bottom end of the yarn sample. This moves upwards when the yarn shrinks. A photocell tracks this movement; the data is processed in a

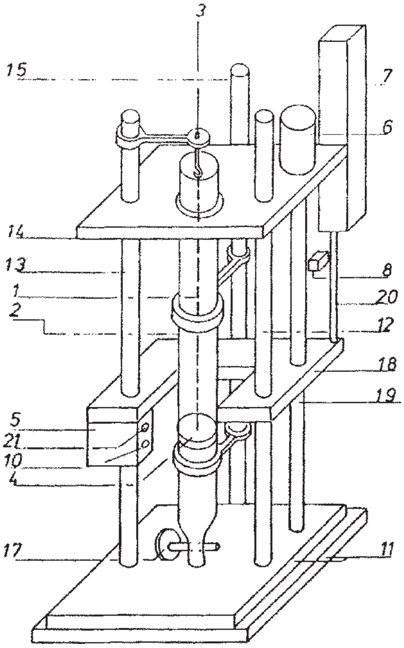


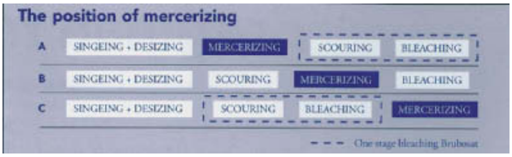
Fig.: Mercerization tester.
1 = yarn sample; 2 = measuring tube by Landolt; 3 = hook; 4 = weight; 5 = detector unit; 6 = drive; 7 = displacement transducer; 8 = stop switch; 10 = light source; 11 = base plate; 12 + 13 = guide poles; 14 = top plate; 15 = stand pole; 17 = drain cock; 18 = vertical sliding plate; 19 = threaded spindle; 20 = measuring rod; 21 = photocell.

computer and displayed on a screen via a displacement sensor and analogue/digital converter.

Mercer, John in 1844 observed the prerequisites, which led to → Mercerizing named after him. The first patent followed in 1850. The simultaneous tension required for polishing was only discovered in 1890 (Lowe) and technically utilised from 1895 (Thomas and Prevost in Krefeld).

Mercerizing can be carried out at various stages during pretreatment: After desizing, after scouring or after bleaching (Fig.). Each of these process sequences has its own merits.

A. After desizing: Pollution of the caustic can be caused by the continuous build up of size extracted from the fabric, thus causing lifetime reduction of the caustic liquor. However with this option maximum lustre is achieved.


The position of mercerizing

A	SINGEING + DESIZING	MERCERIZING	SCOURING	BLEACHING
B	SINGEING + DESIZING	SCOURING	MERCERIZING	BLEACHING
C	SINGEING + DESIZING	SCOURING	BLEACHING	MERCERIZING

- - - One stage bleaching Brubosat

Fig.: Mercerizing position in cotton pretreatment.

B. After scouring: After mercerization the washing off of the caustic has to be sufficient to obviate irregular bleaching. To prevent catalytic damage during the bleaching process extraction of iron has to be guaranteed.

C. After bleaching: When mercerizing after bleaching contamination of the mercerizing caustic is prevented, however, the whiteness as well as the absorbancy might suffer. Care should be taken to have sufficient washing capacity to prevent yellowing.

Wet on wet or wet on dry: Mercerizers are suitable for both wet on wet and wet on dry applications.

Hot or cold mercerizing: Between 12° and 15°C cotton fibres swell to their maximum which prevents deep penetration of caustic at these temperatures. Furthermore cold caustic also has a far higher viscosity than hot caustic therefore penetration of the fabric is much easier at higher temperatures. Cold mercerizing results in a higher degree of swelling but with the risk of uneveness, especially on heavier fabrics. Hot mercerizing gives deep penetration with quick uniform swelling without the need of wetting agents thereby reducing the required length of the mercerizing section. Overall dyestuff savings are comparable, dyestuff absorption is equal but dyestuff yield improves at lower temperatures. No differences in lustre are observed between 10° and 45°C but above 55°C lustre is significantly reduced. Stability of the cloth is not influenced by temperature but handle is much softer at higher temperatures.

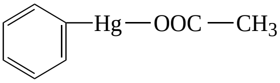
Merchant converter Commercial contractor, who purchases raw cloth or warp-knitted fabrics and has these dyed and printed by a commissioned finisher according to his instructions and then resells them; without his own production.

Mercury (Lat.: hydragyrum), Hg, atomic weight 200.6; density 13.6. Only fluid metal, with a silver glance, regularly expanding up to 100°C; freezing point –39°C; boiling point 360°C; low quantities already evaporate at room temperature; resistant to air. Soluble in diluted nitric acid and hot, concentrated sulphuric acid (mercury vapours are very toxic). Ion compounds: mercury valency of 1 (mercuro and/or oxydul salts), valency of 2 (mercuri and/or oxide salt); both highly toxic. Mercury iodide (yellow when heated) forms with potassium iodide in caustic soda liquor, releases Nessler's reagent (for the testing of ammonia and ammonium salts = blackish brown dye). Use as a metal: barometers, thermometers, mercury steam lamp (short-wave ultraviolet radiation) and artificial daylight (for the colour matching of dyed/printed samples) and analysis quartz lamp (quartz mercury burner for luminescence analysis). Alloys: amalgams. Powerful disinfectant; analytical reagents, etc.

Mercury column (QS), abbrev. for mercury column in units of measurement for pressure.

Mercury porosimetry A purely scientific method to determine the → Pore volume of textiles, pore diameter and pore volume distribution in the fibre due to the toxicity of mercury. Mercury can only be squeezed into the fibre by applying pressure due to the unwettability.

Mercury salts, organic The mercury phenolates and above all phenylmercury acetate were interesting for textile chemistry; but toxic.



All these compounds were important preservatives as well as products for microbisidal finishing.

Mercury vapour lamp → Ultraviolet lamp.

Merino fibre Fine crimped → Wool (see Fig.) from the Spanish merino sheep, yarns from this (also wool union knitted and hosiery knitted yarns) and fine worsted fabrics with a slight shine (also similar to cotton and wool union merinos). Structure → Hierarchical fibre structure.

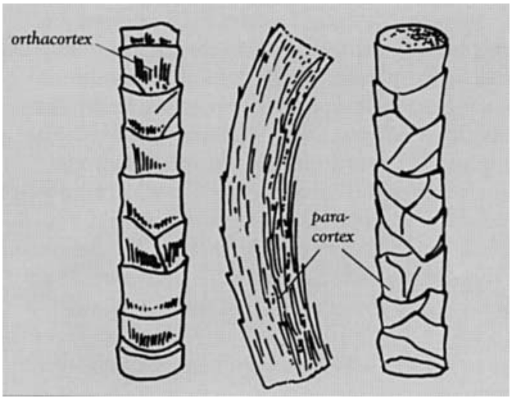


Fig.: Typical appearance of the merino fibre.

Mersolate → Sulphonic acids.

Mesh fineness For the labelling of the finenesses of → Screen mesh materials, are used for different systems depending on material: silk bolting cloth (screen silk): numbers 0–25 (8–16 for finenesses of 50–200 stitches per inch; 8–11 for normal design; 11–14 for sharp contours and 15–16 for the finest half-tone drawings). Phosphor bronze: mesh finenesses lie between 90 and 350 threads per inch (110–180 as normal fineness, 200–350 for the finest designs). Synthetic fibre threads: labelling according to threads/cm (12–200).

Mesh number Parameter for screen mesh, which indicates the number of openings/inch (= 2.55 cm), is however only meaningful using the diameter of the individual openings (see Fig.). As with constant mesh number the screen throughput is proportional to the opening diameter; besides the mesh number the screen manufacturer publishes a whole series of additional information, such as:

- hole diameter,
- number of holes per cm^2,
- throughput in %,
- type of hole distribution,
- vertical and horizontal hole geometry.

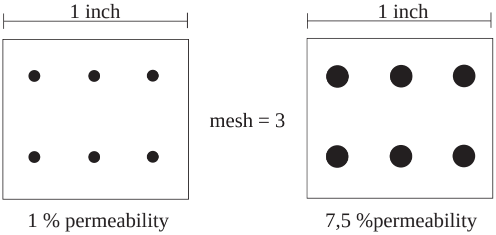
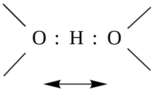


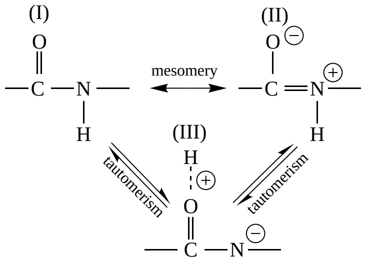
Fig.: Permeability (in % area) with the same mesh number, dependent on the diameter of the openings.

Meshtester Device for measuring rotary screens for screen printing with regard to manufacturing-related differences in the open area.

Mesomeric resonance is present in homogeneous molecules, which may have different chemical bonding structures. To an extent they form a bastard structure of atomic bond with a partial ionic character, which merges due to transfer of electrons flowing into each other, which however does not result in any change in the composition of the molecule. Mesomeric resonance is favoured for molecules from different atoms and also atoms lying particularly close to each other, whose unsymmetrical arrangement gives cause for a shift of developing dipole forces, as for example happens in hydrogen bonds, where the hydrogen (more precisely a hydrogen proton) swings to and fro between two oxygen atoms. [Distinction: mesomery = electrons migrate; → Tautomerism = atoms (usually hydrogen) migrate].



Mesomeric resonance occurs diversely in the interaction of fibres and dyes with conjugated double bonds. Hydrogen can be added to different molecule parts in tautomerism, which then easily leads to a transfer from the system of the alternating double and single bonds, whereby varied zwitterionic states can be observed and also correspondingly shifting electrical attraction forces are triggered between the fibre and dye. In the following example of another similar limit formula, attention is paid to the whereabouts of the hydrogen on the polyamide molecule and the load ratios conditioned by it, which are of course only effective at the shortest distance:

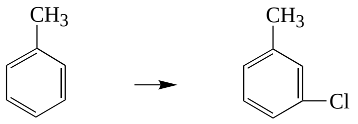


It should be understandable that such a delicate fibre system may have a strengthening effect with regard to dyes with similar resonance structures. This then easily leads to unpleasant differences in the shade of colour. So, shifting resonance structures are consulted for the plausible explanation of the phenomenon of some dispersion dyes, which dye different types of fibre in accordance with the same dyeing principle in varied shades of colour.

Meta- (Gk.),

I. prefix for inorganic compounds, which are produced via heating and release of a molecule of water from the aqueous ortho compound, e.g. metaphosphoric acid HPO_3 (from $P_2O_5 + H_2O \rightarrow 2\ HPO_3$).

II. as a designation for the isomeric status of substitution products in compounds of aromatic nuclei (compare →: Ortho-; Para-), e.g.:



toluene metachlorotoluene

Meta-acids/salts → Acid anhydrides.

Metabolites Living cell components for the reaction control of the metabolism, e.g. ferments and vitamins. Metabolites emerge as intermediate or finished products in the biodegradation of waste water contents.

Metabolite test As with surfactant degradation via those metabolites in → Waste water treatment plants, but also occurs in water under the influence of micro-organisms, the legal regulations (MBAS or BiAS analysis) in corresponding products found to be biologically soft and biodegradable must require an almost complete biodegradation (→ Surfactant biodegradability, evaluation of). The metabolite test looks into the phenomenon that the surfactant degradation does not necessarily have to be complete either; stable intermediate stages (metabolites) might remain. Waste water is led in circulation for several weeks in the waste water treatment plant simulation test for this (see Fig.) and each time new tensides and new waste water materials are added. Even the smallest quantities of stable metabolites have to be increased ever more in this way and become able to be tested. If a tenside passes this test, it is considered to be completely biodegradable. The limits of the evidence of this test are reached if the test compounds are not easily dissoluble or if intermediate products, which are not easily dissoluble or are strongly adsorbing, are formed in the degradation process. As a modification of the coupled units test, the metabolite test is a test system in which precipitation and/or adsorption of not easily dissoluble substances (on the activated sludge) might feign a degradation.

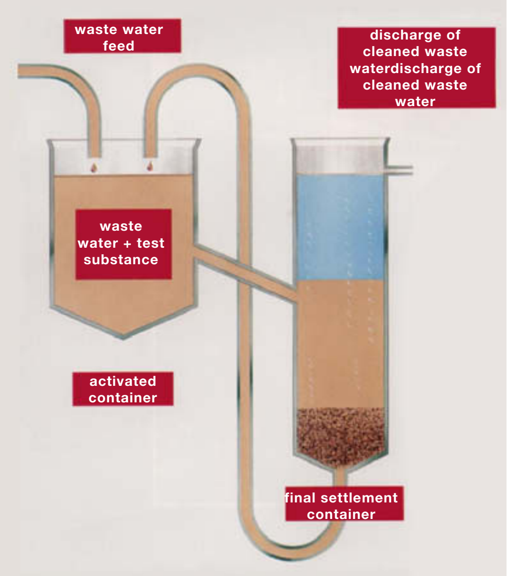
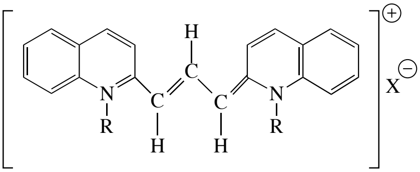


Fig.: Metabolite test as a laboratory-scale sewage treatment plant: the biological decomposition process of tensides in the course of operation of a communal sewage plant is successfully and realistically represented by the sewage plant simulation test (source: Henkel).

Metachromasy Property of certain dyes to show a different shade depending on concentration, aggregation, solvents and substrate. If, for example, you place an alcoholic solution of pinacyanol in sufficient concentration in a reagant glass here, this appears dark red in the inspection.



pinacyanol

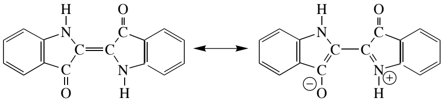
The thin layer, which flows down on the glass walls after the solution is tipped out, is, however, blue. This is a result of different strengths of absorption of different wavelengths of light by the dye. Red is not noticeably absorbed. The strongest absorption of the dye is in the orange parts of the spectrum at about 605 nm. The absorption subsides in the shorter wavelength range, but is still strong enough that with sufficiently large layer density or concentration the eye can no longer distinguish light let through here. So only red light is let through. By reducing the layer density, green and blue rays still have an effect on the eye as well, which results as the colour effect of blue.

By measuring the ratio of the noticeable (I_0) to the let through light intensity (I) for all the wavelengths of the spectrum, e.g. for the infra-red and ultraviolet area as well, the so-called extinction coefficient ε, which is defined as follows by Lambert-Beer's Law, can be determined:

$$\log \frac{I_0}{I} = \varepsilon \cdot c \cdot d$$

c = concentration in mol/l,
d = layer density in cm.

The graphical representation of the dependence on the extinction coefficient of the wavelength or wave number is called absorption curve. So this absorption curve is a material constant, with whose help the dye can be characterised and information on its structure can also be obtained. The absorption spectrum is only a constant in a diluted gas state. In solution or even in an adsorbed or crystallised state, the absorbing molecule is in interaction with neighbouring molecules and more or less alters its structure through this and thereby its absorption spectrum as well. This means that the colour of a dye is in no way invariable. So it has been known for a long time that dyes with asymmetric load distribution, so-called merocyanine, can sustain considerable colour changes in polar solvents. This is the cause of the change from blue to red in indigo: indigo can be recorded in different mesomeric formulae (polar and unpolar), whose weight is shifted depending on the polarity of the solvent, e.g.:



The absorption maximum is shifted between tetrachloride hydrocarbon and aniline by approx. 1000 cm^{-1}.

Water has a distinctive structure due to the hydrogen bridges, which are formed between the isolated electron pairs of oxygen and the hydrogen atoms of neighbouring water molecules. The order is certainly not complete so that it can be increased on surfaces, e.g. on the hydrophobic surface of dye molecules and macromolecules. But this means a degradation in the entropy. This system tries to balance this entropy degradation by reducing the surface, i.e. the addition of the dye is encouraged on the macromolecule. This effect is by far the greatest as a solvent in water. If you are dealing with even, two-dimensional molecules as with dyes, a reduction in the surface can also be carried out by stacking several dye molecules on top of each other, i.e. by an aggregation. In fact, a lot of dyes tend to form such aggregates just in water. Usually dimers appear as the first stage of aggregation. As the electron system of a dye molecule can be regarded as an electron oscillator, the splitting into two frequencies normal for such systems is carried out in the combination of two such oscillators with the same natural frequency, in a higher and a lower one than the one in the single oscillator. If the dimer molecule has a high symmetry, a transmission moment, corresponding to a strong light absorption, only remains for the higher frequency. The absorption band observed in the dimering is, compared with that of the monomer, shifted in accordance with short waves. A slight fault in the aggregate symmetry due to substitutents on the dye molecule also makes the long-wave shifted band appear weak.

The shift of the bands to the short-wave side of the spectrum is generally about 1000–1500 cm^{-1}, but increases, as with thiocarbocyanin, up to twice the amount by increasing the aggregate through further increase in concentration, whereby a limit is clearly reached. The dye molecules, which show such aggregations in aqueous solutions, are generally cations or anions with corresponding counter ions. It can be demonstrated that the dye ions are stored directly together even with the same charge. But through molecular weight measurements and measurements of the circular dichroism when using optically active counter ions it can be shown that the counter ions on the polyion are held in the aggregates and thereby extensively compensate the charges. The dye salt is completely dissociated in smaller concentrations of dye, for which there is still no aggregate formation, as the molecular weight measurement also shows (according to Scheibe).

Meta-formaldehyde → Trioxane.

Metal alcoholates Type R-Ome (→ Alcoholates). Conversion products between lower aliphatic → Alcohols and Alkali metals or polyvalent → Metals. The most well-known chemical textile auxiliaries are →Aluminium alcoholates as solvent impregnating agents. Metal alcoholates are normally easily decomposed via humidity, which is why a stabilising stage is carried out by means of conversion of the metal alcoholates (using acetylacetone, acetoacetic acid ethylester or higher fatty acids). The impregnating effect is thereby certainly worse the more absorbed alcoholate groups are converted to metal.

Metal-complex dyes Dyes of a different constitution with metal absorbed in the molecular complex, which gives the dye additional properties (light, wet fastnesses, bonding possibilities on the fibre).

I. Acid 1 : 1 metal-complex dyes: monoazo compounds with sulphonic acid groups, which contain one chromium atom per dye molecule (chromium complexes). Shades usually dull. They are chiefly dyed on wool, partly on silk and polyamides. They have to be dyed from a strongly acid bath and show very good levelling power under these dyeing conditions. Good to very good light fastness as well as good wet fastnesses. Well suited to carbonized piece goods. Quantity of sulphuric acid can be reduced by specific auxiliary products. Sensitive to metal-complexing agents.

II. 1 : 1 : 1 metal-complex dyes: mixed complexes made from one coloured, one colourless component and one metal central atom (variation from 1 : 2 complex).

III. Soluble 1 : 2 metal-complex dyes: Contain two-tone components and a metal central atom. With ionized, acid water-soluble groups or methylsulphone, alkylsulphone or sulphonamide groups. They are dyed onto wool, polyamides and silk. Excellent light fastness, very good wet fastnesses (better than I.). Potting fastness better than I., but not as good as after chrome dyes. Tendency to streaky dyeing on polyamides. Application on wool, neutral or weakly acid, together with levelling agents. Shades usually dull.

IV. Dispersed 1 : 2 metal-complex dyes: Do not contain any water-soluble groups and are applied as disperse dyes on polyamides. Good light and wet-fast, building up to the deepest tones. Tendency to streaky dyeing in brighter shades. Usually dull tones.

V. Pre-metallized direct dyes: Direct dyes, which contain one or several complex-dependent metal atoms in the molecule. Widely distributed in the highly fast to light direct dye ranges. Usually copper as the metal. In direct dyes capable of after coppering, which e.g. contain o.o-dioxyazo groups, the copper atom is not applied during the dye production, but only after the dyeing process, using after coppering.

VI. Phthalogen metal-complex dyes: Group of dyes, which are used with the blood dye haemin and the vegetable dye chlorophyll. They have a 16 element aromatic band and are usually present as metal complexes (copper, cobalt, nickel). Depending on additional groups, which are annexed to the phthalocyanine nucleus, pigment, direct, sulphur, vat and reactive dyes are produced. The → Phthalocyanine dyes synthesised on the fibre also belong to this group. Various phthalocyanine derivatives are subject to phototropism, especially if dyeings and prints are finished with synthetic resin.

Metal complex dyes 1 : 2 type Two dye molecules go onto a chrome atom, as is the case in weak acid attracting 1 : 2 metal-complex dyes. → Chromium-complex dyes.

Metal-complexing agent → Complexing agent.

Metal content of cotton Native cellulose fibres, such as cotton, contain different quantities of metal depending on their origin, absorbed as feldspars $K[AlSi_3O_8]$ and/or $Ca[A1_2Si_2O_8]$ (potassium and/or calcium aluminosilicate) as well as their weathering products, the aluminae with the general empirical formula $(K_2H_3O)_y\{Fe_2(OH)_2[Si_{4-y}A1_yO_{10}]\}$ (y = 0.7–0.9). Different quantities of metal cations: Mg, Ca, Ba, Fe,

Provenance	Year of harvest	mg metal ions/kg raw goods Ca	Mg	Fe	Cu	Mn
Brasil:						
– Paranah Conchal	1985	2 711	1 119	313	6	30
	1987	1 688	736	82	3	12
– Paranah Assai	1987	3 147	1 156	680	6	30
– Paranah Leme	1985	1 197	922	134	4	17
	1987	1 677	762	205	< 1	13
– Sao Paulo	1985	944	863	72	< 1	13
	1987	590	565	39	< 1	7
Peru	1989	700	440	13	< 1	< 1
Paraguay	1987	760	682	28	< 1	< 1
Columbia	1983	540	334	12	< 1	< 1
	1988	1 100	808	252	n. a.	10
USA:						
– Texas	1988	810	365	75	< 1	< 1
– El Paso	1988	683	715	24	n. a.	4
– California	1987	600	540	40	< 1	< 1
Mexico	1988	1 400	623	59	n. a.	11
Russia	1986	1 320	567	112	3	6
	1987	1 734	987	123	2	11
	1989	1 888	1 055	187	3	36
Egypt:						
– Makko	1989	640	452	11	< 1	< 1
Sudan (light)	1988	791	617	89	n. a.	9
(dark)	1988	947	912	300	n. a.	10

Tab.: Metal content of different raw cotton provenances (source: Wurster, Janssen and Rath).
n.a. = not available.

Mn, Cu are found absorbed in the aluminae. The table shows the metal content of different raw cotton origins.

Metal detecting device Device for the local monitoring (detecting) of the smallest particles of leading metals to prevent damage to calender bowls and shearing blades. Used at fabric speeds up to 400 m/min.

Metal detectors are metal detecting devices for the purpose of tracking down and removing metal parts dragged along (e.g. wire card teeth) in order to prevent damage to finishing machines. Tracking down metal even in heavily scutching, thin textile webs, already at 1 mm ∅ and at a speed of 2–360 m/min. Besides manual detecting devices, there are fixed installed detecting devices, which still respond to iron particles of 10 mg at fabric speeds of 400 m/min.

Metal fatty alcohol sulphates → Fatty sulphuric esters.

Metal fibres (MTF, ME), textile processed metal filament and staple fibres. Recently spinnable cut forms of metal filaments or → Metallized yarns, e.g. up to 5–15% compared with other long staple fibres in fashionable glitter effect yarns. Metal filaments are manufactured from high-grade steel filaments in the nozzle extraction process. Uniformity, high strength, abrasion resistance, electrical conductivity, temperature resistance, low extensibility. Chiefly used as an addition, e.g. in carpet yarns; prevents electrostatic charge. After sizing, 100% yarns can be processed in weaving and knitting. Steel filaments are, e.g., used for tyre cord.

Metal flock → Flock made from metal powders.

Metal foil printing Works according to the transfer printing technique. Fabrics are firstly pre-printed with adhesive and afterwards treated together with the metal foil in a transfer calender (see Fig.).

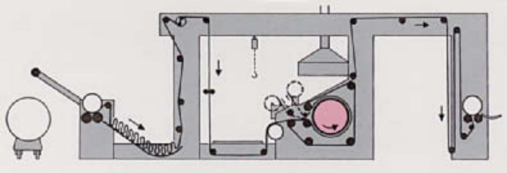


Fig.: Calender for metal foil printing (Stork).

Metal frames for screen printing have displaced wooden frames due to their dimensional stability. They are manufactured from tubes with different profiles. Besides square and circular profiles, above all A and W profiles have been established.

Metal indicators For complexometry using complex ions and similarly acting dioxy dyes, barbituric acid derivatives, etc. The metal complexes of these metal indicators are coloured differently from the free dye acids as a result of changes to the resonance system caused by complex formation. The metal complexes hereby usually behave in a somewhat less stable manner than the corresponding complexes with, e.g. Komplexon. From this, it is used in such a way that a trace of metal indicator is added to the metallic salt solution to be titred (buffered with ammonia and ammonium chloride to ca. pH 9–10), whereby the colour of the free dye acid is altered to the colour of the metal dye complex. This solution is then titred with a complexing agent solution.

Metallic contaminants in textiles Comparatively simpler identification by careful bleaching in a very short liquor with alizarin. Contaminated metals thereby act as a mordant. So, a fixed dyeing is produced on the relevant areas.

Metallic soaps Water-insoluble, fatty acid metallic salts, usually of aluminium for impregnating purposes or of magnesium for sealing and weighting agents; (with addition of fatty alcohol derivatives) as a bleaching stabilizer.

Metallic yarns From a textiles point of view, it is more correct to say → Metallized yarns.

Metallizable dyes Contained in the dye molecule → Mordant-attracting groups, which can form metal complexes (so-called colour lakes) with metals (metal mordants or metal salt aftertreatments). Examples: madder red, turkey red, logwood, alizarin red, mordant dyes, chrome dyes, aftercoppering dyes. The dye metal complex brings a colour change and has improved fastnesses in comparison with the original dye.

Metallized yarns (metal spun yarns, tinsel threads), products for textile purposes made from or with copper, brass, aluminium, silver, gold and similar, in different fineness, length and make-up.

I. Endless yarns: made from metal rods drawn through a narrowing bore hole made of steel or diamond. Are woven directly or with wool, silk and similar.

II. → Metal fibres.

III. Flat thread (tinsel, lametta, Plätt, Plätte, Plasch, Rausch): produced from endless yarns via band-type rolling out, possibly also imprinted or corrugated (frisé). Material description given by m/kg.

IV. Spiral filaments (purls, Kanetillen, Canetillen or helical tinsel yarn): pure metal filaments, produced by the helical re-winding of a needle, which is later pulled out.

V. Metallic yarns, wrapped in viscose, acetate or other plastic films and similar.

VI. Metallic spun yarns: different techniques, e.g. helically rewound textile yarns with tinsel (such as cotton, linen, viscose filament, etc.; or with coloured silk as so-called lustre yarn, with pearly ply-yarn base yarns as a flickering diamond yarn) or conversely tinsel gimped with e.g. finer viscose yarn or aluminium twist finely gimped with narrow little cellophane bands as an alucell, or tinsel lightly twisted and twisted into viscose yarn for example, also in variation with non-oxidizing metallic yarns.

VII. Metal yarn: Metallized textile yarns, e.g. galvanically produced (yarns previously made dominant) or with additives from atomised cathode metal in vacuum on acetate threads and similar, also similarly cut from films of polyesters with metallic vacuum, or impregnated with mixtures from metallic dust, acetate cellulose and similar. The content is guaranteed for real silver or gold twist respectively. Gold twist mostly consists of silver with gold plating. Fake gold threads (so-called simili or cement), for example, consist of copper with zinc coating (brass layer) and fake silver twist of copper with silver coating. Fineness given in nm diameter.

Application: variedly for party clothing, cocktail dresses, theatre clothing, effects in fashion clothing, deco furniture materials, in splendid knitting, hosiery goods, knits, trimmings, amongst others.

Metalloids → Non-metals.

Metal mordants for mordant and chrome dyes Chiefly chromium, aluminium and iron salts; for special cases (in alizarin indigo print) also nickel and zinc acetate as well as cobalt acetate (for nitrose beta-naphthol printing). Lacquer formation with mordant dyes generally takes place most easily using acetates, reduced using lactates, more or less incompletely using oxalates, tartrates and citrates.

Metal powder printing (→ Bronze printing), designing technique for the manufacture of gold, silver and graphite printing effects in hand block, screen, spray or roller printing. Precursor of → Pigment printing. Fixation of metal powder usually with aqueous plastic dispersions.

Metal powders (bronze colours), powdered metals of copper (alloys: gold bronze, bronze, German silver), aluminium (silicon alloys), also gold, amongst others. Usually coated with a fine layer of grease on the market. Shines metallically; in the most varied colours, either produced by heating, light-resistant tarnishing colours (yellow, red, orange, brown, violet, etc.), or dyed using cationic dye (so-called patent bronzes). Application: metal powder printing, amongst others. Fine powdered qualities, which are somewhat more matt in tone, but rather tend to be used less in film screens or added to roller engravings, are preferred for this.

Metals Chief representatives aluminium, barium, beryllium, lead, chrome, iron, gold, iridium, cadmium, calcium, potassium, cobalt, copper, lithium, magnesium, manganese, molybdenum, sodium, nickel, palladium, platinum, mercury, radium, silver, strontium, tantalum, uranium, bismuth, tungsten, zinc and tin. Heavy metals (density > 5): lead, iron, gold, cadmium, copper, manganese, nickel, platinum, mercury, silver, tungsten, zinc and tin. Light metals (density < 5): aluminium, barium, potassium, calcium, lithium, magnesium, sodium, strontium and titanium.Precious metals: gold, platinum and silver. Precious metals do not form any oxides in moist air or when heated. Properties: metals can be melted and thereby mutually dissolved into each other in any required ratio (alloys). Oxygen compounds: → Oxides (basic character). Hydroxide compounds: → Bases form (OH) ions; hydroxides are produced with acid salts. Exceptions: dependent on simultaneous presence of oxygen atoms and hydroxyl group, with increased number of oxygen atoms in aqueous solution. Tendency to weaker release of OH ions and stronger release of hydrogen ions. Hydroxides of metals with a valency of 1 and 2 therefore produce strong bases, metals with valency of 3 produce weak bases, and metals with an even higher valency produce acids.

Metal salt treat of dyes or dyeings This means treatments in the style of → Chroming (pre, single-bath, afterchroming) and aftercoppering (→ Aftercoppering dyes) in cellulose dyes.

Metal spangles → Glitter pigments.

Metal yarn → Metallized yarns.

Metameric index Two samples, which, for example, have the same colour in daylight, possibly have a different colour when the illumination is changed, if they have different spectrum reflection curves and are therefore metameric. A metameric index is used for the quantitative labelling of this undesirable property, e.g. in order to discover the sample which shows the smallest metamerism, when comparing several colour recipes for the post-dyeing of a pattern. If both samples do not have a colour difference in daylight D65 ($\Delta E = 0$), the metameric index of this sample pair for an illumination change from D65 to another light source is equal to the colour difference of the samples in this other light source. The metameric index is, for example, determined in the colour recipe calculation in this way, as the colour recipe of the post-dyeing is so determined that the colour in daylight D65 agrees with that in the pattern. In determining the metameric index for a washed out colour recipe in comparison to the pattern, even though perhaps only small, a colour difference will also always exist in D65.

Metamerism is based on the fact that two shades matching in daylight appear to be different in other light (e.g. artificial light) (→ Colour stimulus), e.g. exhibit a shade change from red to blue. Explanation: The summary of the colour effects determined by the reflectance curve is the function of the observer and the light energy coming into the eye, as long as the surfaces under the reflectance curve of both shades are equal, if not identical. If the observer or the light is changed, the areas are no longer offset and the shades are different. In order to prevent metamerism, the reflectance curves of both shades must be very similar, but preferably the same.

Metamerism can be explained colorimetrically with the aid of the tristimulus values X, Y and Z. Two patterns are the same at a particular illumination, if their tristimulus values are equal for this type of illumination. This condition is obviously met, if both patterns show identical reflectance curves. Equal tristimulus values may however also be reached with different reflectance curves for a particular light source, as this merely concerns cumulative values for the X, Y and Z values. It is well known from dyeing practice that a particular colour pattern can be set using different dye combinations. So orange/red/blue, for example, can be set so that both dyeings show the same shade in daylight, i.e. that the tristimulus values for daylight (D65) are equal. Because the reflectance curves of both dyeings are different, however, the tristimulus values are also different for the other light sources and both dyeings therefore show different colours with other light sources.

Metaphosates Condensate phosphate with ring structure. Do not have any complex-forming powers (potassium metaphosate and sodium hexametaphosate). Typical metaphosates of the $(NaPO_3)x$ type are cyclic polyphosphates, so not identical to the structure of the Graham's salt type of long chain polyphosphates, also called hexametaphosphate.

Metastable states Designation for pseudo-equilibrium systems, which do not decay in a particular temperature range, in which they are thermodynamically unstable, such as metastable foams.

Metering Metering is understood to mean the measurement of an amount of substance. A dose, which may be a substance, but also energy, is added to another amount of substance. Each measured amount of a dye or textile auxiliary in textile finishing should therefore be understood as a dose, which is supplied to a medium, serving the finishing of textiles in some way. If one talks of metering as finishing processes today, this is usually thought to mean a dose of liquids or solids distributed into a corresponding medium over a certain period of time, in non-observance of the full meaning of the origin of the word. Some meterings already practised are shown in the table, whereby the types of dose, their control size and, in so far as they are known, the processes are listed.

Dose	Control parameter	Dye system	Process
Energy	Temperature (K)	Disperse dyes	SDC system (Thies)
	Frequency (Hz)	All	
	Voltage (U)	All	
Salt	Quantity/time	Substantive and reactive dyes	MPI system (Thies)
	Conductivity (mS/cm)	Substantive and reactive dyes	
Alkali	Quantity/time	Reactive dyes	Levametering (Bayer AG)
	(Degressive, linear, progressive)		Remazol-Automet (Hoechst AG)
			Sypromatic (Sandoz AG)
			Dosacid (Ciba-Geigy AG)
			Ecosal (BASF AG)
	pH	Reactive dyes	
Acid	Quantity/time	Acid dyes	Dosacid (Ciba-Geigy AG)
	pH		

Tab.: Some examples of the use of metering processes and their application in the dyehouse.

Controlled addition of dyes or chemicals to finishing liquors is gaining ever more importance because manual metering is no longer suitable for the accuracy and cost demands of modern textile finishing. In the simplest case, substances are linearly metered (amount/time diagram); but dyes and scrooping agents are usually metered on a sliding scale, while salts, acids and alkalis tend to be progressively metered. The metering of chemicals and auxiliaries represents an important constituent of chemical engineering in continuous pre-treatment. The control and monitoring of a continuous chemical process is therefore more difficult compared with discontinuous processes in which the process conditions such as fabric speed, fabric throughput and liquor exchange may fluctuate widely in an impregnating dwell process. However, the quality and regularity of a pre-treatment is directly dependent on the control of the chemical process. Metering systems for pH regulation of the dyebath are important in the discontinuous type of dyeing. The solid metering of salt is also gaining in importance.

The classic system of chemical metering (Fig. 1) is the control of a continuous system via the decreasing liquor level in the impregnating section. Simple mechanical float switches or electrical level probes are chiefly used for detecting the liquor level. These level controllers operate a solenoid valve, metering pumps or other dosing systems, which is metered through the fabric proportional to the liquor abduction. The dosing should be increased as a function of the difference in squeezing in a wet-on-wet impregnation. The dosing

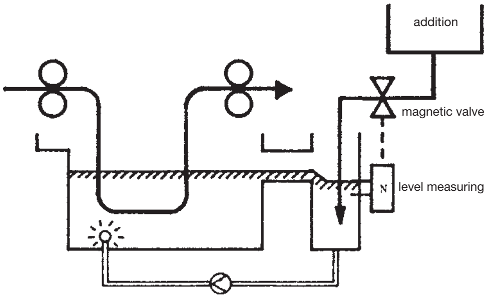


Fig. 1: Level controlled metering system.

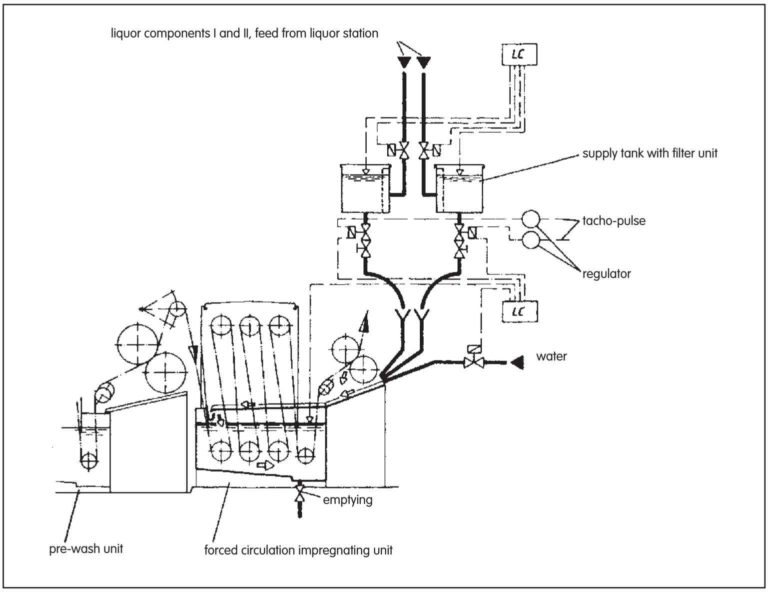


Fig. 2: Wet on wet impregnation with the Polykomat automatic metering unit as a speed-proportional metering system.

factor is only dependent on the difference in squeezing, but not on the liquor exchange factor.

The speed-proportional metering system is just as widely used. A pulse generator, which is normally fitted to a roller of the impregnating padder, sends a pulse to the metering pump in accordance with a particular meter number. This starts to operate within a set time interval, whereby the metering time should be adjusted via a pulse generator. The maximum metering time per pulse is generally 10 s. and the pulse spacing is 10–20 m. Speed-proportional metering systems such as the system from Texicon operate according to the same principle, except that measuring cylinders are used instead of metering pumps. Prescribed chemical volumes are prepared in these cylinders and called for by the pulse generator (Fig. 2).

The systems mentioned so far, in each case require a titrimetric control to determine the chemical content in the impregnating liquor. Metering systems with an automatic concentration measurement make these methods superfluous and facilitate an automatic control of the dosing. The chemical content in the impregnating section is detected by a measuring cell and a concentration meter. A measuring transducer then controls the dosing via valves or metering pumps. This involves an actual/set value comparison, i.e. true automatic control in the closed control circuit.

The concentration measurement is carried out by

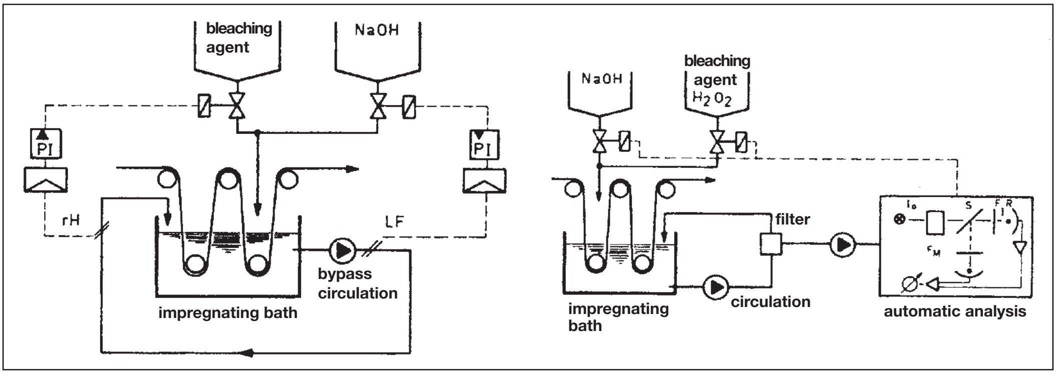


Fig. 3: Comparison of the in-line measurement of redox potential (rH) and conductivity (LF) for metering bleaching agent and caustic soda (left) with on-line measurement by thermometry (right).

devices, which automatically titre (on-line) liquor samples in given intervals of time or, for example, carry out heat-tone measurements by continuous flow of the liquor sample (on-line thermometry). Conductivity and pH devices are chiefly used for determining the concentration of caustic soda liquor (in-line measurement). This method can of course only be put into use if “titreable” chemicals are available in an impregnating liquor or the conductivity measurement is significant. Other recipe components such as stabilisers, complexing agents or washing agents need to be combined with the measurable chemicals, if the whole system is to be automatically controllable (Fig. 3).

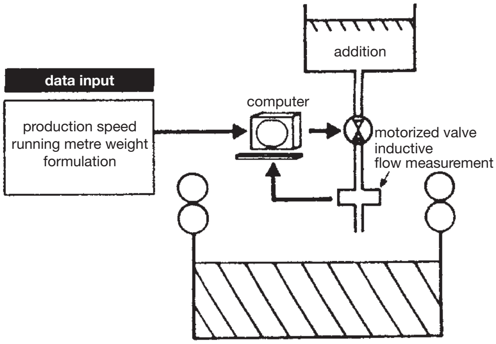


Fig. 4: Computer controlled quantity-proportional metering system.

Important new developments in metering technology are computer-controlled, quantity-proportional metering systems (Fig. 4). From the input data of production speed, running meter weight and recipe the computer calculates the chemical quantities/h required. The metering is carried out via motorised valves; the chemical flow is detected and re-registered by inductive flow measurement. Permanent control of the chemical quantities being added is possible using this system; the motorised valves are controlled by set/actual comparison by the computer. No mismetering can take place if the fabric data has not been input, as the computer will not let the system start.

Metering roller → Applicator roller.

Metering station Plant for the metering of particular quantities of dye and chemicals. Supplied as a ring main via mixing station or metering unit directly to the dyeing plant (see Fig.).

Metering systems for dyes and chemicals are used for mixing chemicals according to prescribed recipes. The mixture is intermittently or continuously dosed into the process. The term “metering” has become a term in wet finishing. In the following “metering” is understood to mean the addition of a given quantity of solid or liquid active material to a liquid treatment medium (dye or treatment liquor) over a period of time (metering time). According to this definition, the term “metering system” covers the metering volume, metering concentration, metering mechanics, metering curve as well as the type and composition of the metered substances.

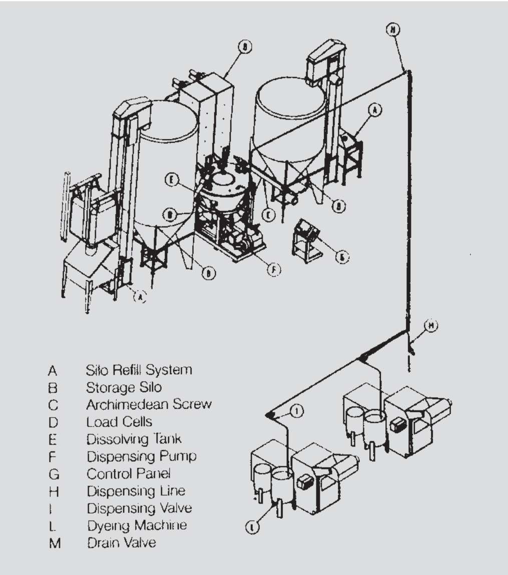


Fig.: Lawer Silos-Dos-System a typical metering station for dyestuffs.

Two types can in principle be distinguished:

1. metering systems for the stabilisation of a given active concentration in a treatment system in continuous use (continuous process).
2. metering systems for the control of a dye or reaction system with increasing treatment concentration (batch-wise treatment, exhaustion process).

The first case is used, e.g., in the bleaching and washing baths of continuous plants with automatic hydrogen peroxide, pH and surfactant control using metering pump systems. The second case, e.g., forms the basis of the metering dye process in the exhaust dyeing of cotton with reactive dyes or in the metering of acid for the dyeing of wool and polyamide or of silk with acid and metal-complex dyes. Over and above that, the metering principle can in general be used for the control of exhaust dyeings by means of electrolyte and dye metering. Both systems can be controlled, i.e. via monitoring points and feedback signals, or programmed. Programmed means metering according to a given volume/time-plan without feedback signals.

Apart from the weighing of dyes in dyeing, the weighing of print pastes (Fig. 1) (volumetrically or

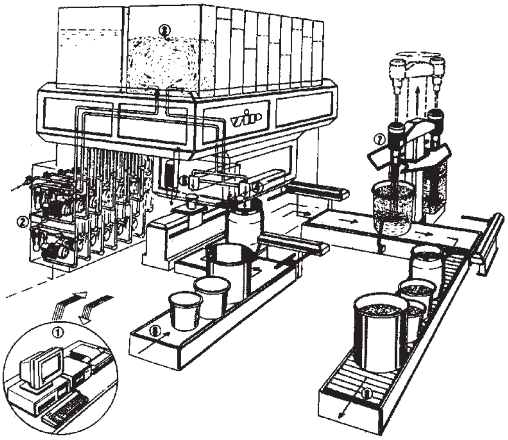


Fig. 1: Automatic dye kitchen for printing (according to ViP). 1 = computer control and monitoring; 2 = circulation and filtering system; 3 = storage tank for dyes and thickeners; 4 = compact metering block with steplessly controllable valves; 5 = automatic sample quantity metering and mixing system; 6 = bucket conveyor belt; 7 = Duplo-robot stirrer; 8 = bucket removal belt.

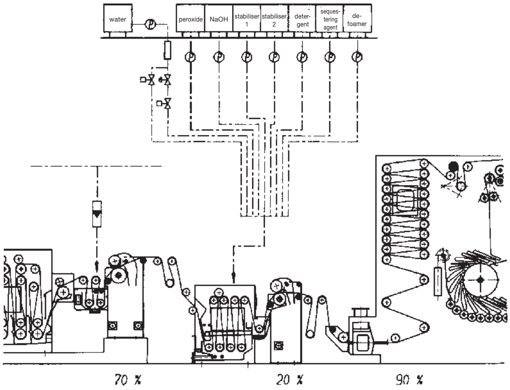


Fig. 3: Liquor application with the impregnation stage of Küsters cotton pretreatment.

gravimetrically) and the distribution of chemicals delivered to dye batches (Fig. 2) is also controlled by metering plants.

A wet-on-wet impregnation is, e.g., carried out in the vat impregnation in the roller vat (Fig. 3). 60–70% water is input, which must be exchanged with the chemical concentration of the impregnating bath. The mixing of both liquids and the additional liquor quantity of 10–20% applied onto the fabric via the squeezing unit of the impregnating vat require an injection of a liquor concentrated by about 4–5 times (concentration factor refers to 100% liquor pick-up, calculated on the dry weight of the fabric) to achieve the necessary quantity of chemicals. This liquor exchange requires expensive devices for metering. The high chemical concentrations necessitate a separation of chemical preparations in different vessels to avoid premature decomposition of the bleaching agent. The hydrogen peroxide on the one hand and the alkali with the stabilisers and surfactants on the other should be prepared separately. The selection of auxiliaries is however, restricted by this, for example, surfactants do not always show the high alkali resistance demanded or it has to be bought at the price of a loss of cleaning effect. The separated preparations have to be mixed via multicompo-

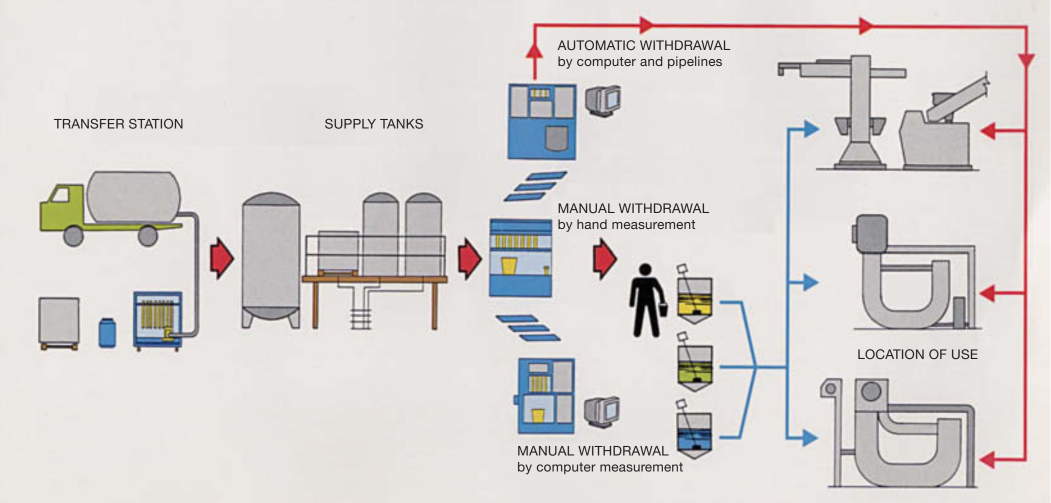


Fig. 2: Metering technology in a dyehouse (according to Meter).

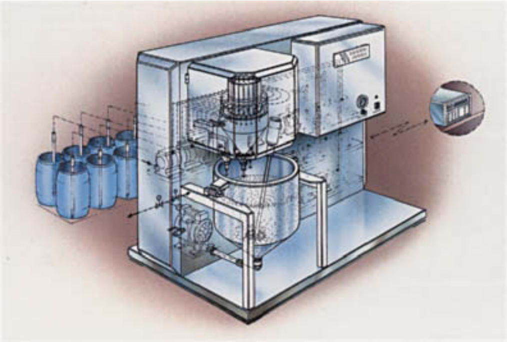


Fig. 4: OCD metering unit (van Wyk) for padder trough.

nent metering pumps shortly before being added. Quantity and mixture ratio can only be determined via costly, permanent bath control (titration).

If padders are to be charged with liquor before stretching, it is best to use fully automatic metering (Fig. 4) to reduce the residual liquor quantity. Fully automatic on-line metering systems for chemicals are based on the principle of gravimetric measurement in order to achieve a better measuring accuracy than in volumetric processes. With their aid, completely mixed preparations of 200 l can be prepared from a maximum of 20 chemicals and water. Each chemical is pumped directly from the vessel or the drum in which it was delivered by a pump. These quantities are directly delivered to the processing machines. The plant is controlled from a microprocessor terminal, which is set up close to the processing machine.

High wet pick-up plants, such as the Flexnip (Küsters), are most effectively charged with the aid of a continuous metering and mixing plant in continuous cotton pre-treatment (Fig. 5).

Metering system with proportioning cylinders A system for metering specific quantities of dyes and chemicals using proportioning cylinders with a content of e.g. 251 for each product. Sampling cylinders up to 500 ml are also available for very small quantities.

Metering technology for reactive dyeing The dyeing of cellulose fibres using reactive dyes can in principle be carried out according to two different types of process:

1. temperature controlled dyeing processes.
2. pH controlled dyeing processes.

In the temperature controlled dyeing process, exhaustion and dye fixation are controlled by the temperature and in the pH-controlled process by the alkali addition.

It is the purpose of the metering systems in reactive dyeing to systematize the alkali allowance and to programme the dyeing process as a preliminary stage to automation. Programming means replacement of the manual implementation of dyeing by a fixed programmed processing sequence, i.e. an industrial production principle instead of workmanship. Programming means adapting the most important process steps of dyeing, fabric quality and circulating time of the fabric to the dyeing machine The depth of shade, fixation efficiency in exhaust dyeing (substantivity), rate of reaction (reactivity) and the setting yield should also be considered.

That is why besides chemical and technical reasons, the development of metering technology in the plant also has economic and logistics grounds. The main argument is the improvement in reproducibility through

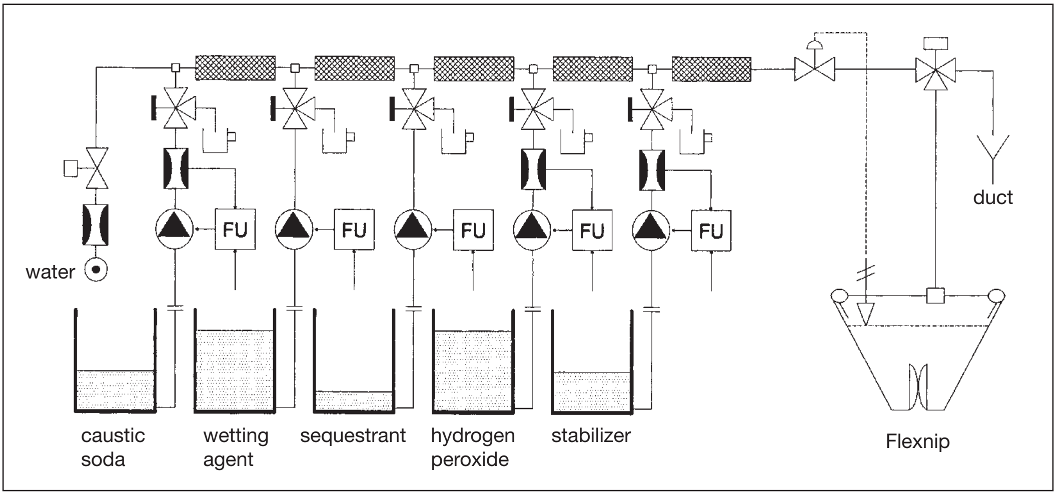


Fig. 5: Contidos continuous metering and mixing unit (Küsters).

reduction of the estimation margin by operating staff, simplification of the remaining manual operation, reduction of chemical and energy consumption and reduction of the proportionate labour costs per dyeing. The most important technical reason results from the better distribution of chemical additions to liquor and fabric, i.e. better mixing during introduction into the dye liquor and thus prevention of local over-concentrations, which may lead to precipitation and separation of dye and auxiliary. The kinetic task of alkali metering is the control of the rate of reaction using programmed pH build-up in the dyebath.

Metering processes in reactive dyeing can be subdivided into different groups:

1. dye metering.
2. salt metering.
3. alkali metering.

The individual metering steps can be carried out one after the other or simultaneously. Non-metered and metered allowances can also be combined. Attempts to improve the evenness via slow injection of dye solution to salt and alkali containing dye liquors has already been undertaken in the initial phase of reactive dye development, in particular in the field of yarn dyeing. The metering systems familiar today use different metering curves. A metering curve is thereby understood to mean the delivery rate of the metering pump as a function of the metering time. Progressive, linear and combined progressive/degressive curves were described for dyeing using reactive dyes and their suitability for dyeing cellulosic fibres and their blends with reactive dyes were investigated. Both stationary and mobile equipment were designed for solid metering. Solid metering, for example, permits the metering of sodium dithionite in vat dyeing and sodium chloride in reactive dyeing or in dyeing using direct dyes. The electrolyte to be dissolved is fed via a mixed head in a secondary circuit with a solvent channel, in closed machines, and by flexible delivery trunking to the heating panel in open machines. The same microprocessors are used for control as in liquid metering. Solid metering facilitates the automatically metered salt allowance during the dyeing processes in the dye run, a step which is otherwise difficult to implement.

Metering technology for solvent process machines is used for product blending, after treatment process and finishings by pre-selected addition of product quantities at the required moment. Automatic metering using dosing system (see Fig.) is the most efficient.

The fundamental part is a metal cylinder with moving pistons: piston stroke and delivery rate are precisely adjustable (scale with direction guide), check valves control the suction and metering process. The suction is achieved by spring or air pressure and the metering by air pressure. The air for the metering process is provided via a solenoid valve. The product to be metered gets to the operating cylinder via a suction pipe. Air pressure forces the piston down and forces the product through the metering pipe to the pump suction. By this method the product reaches the fabric mixed with the circulating solvent. There are dosing systems with different delivery rates which can be matched with the requirements of the machine depending on its size; varying with regard to requirements and any other required combinations.

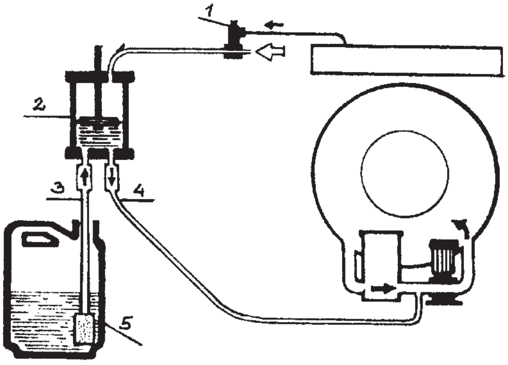
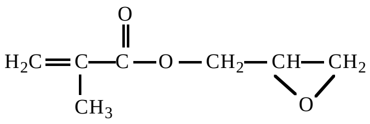


Fig.: Automatic chemicals metering for dry-cleaning.
1 = air magnetic valve; 2 = metering unit; 3 = suction line; 4 = metering line; 5 = product container.

Methacrylic acid → Polyvinyl derivatives.

Methacrylic acid glycidol ester (GMA, methacrylic acid glycidol ester, methacrylic acid-2 epoxypolypropylene ester, 2-propenoic acid oxyranylmethyl ester), monomer compound with 2 reactive groups, colourless liquid, almost odourless. Universal self-crosslinking agent for plastics (e.g. polyethylene, polyester, polypropylene), varnish resin on acrylate base, self-adhering adhesive substances; is used in fibre chemistry to modify wool, cotton, polyacrylonitrile, cellulosic fibres, e.g. by deesterification of methyl methacrylate using → Glycidol.



Methacrylic resins → Acrylate polymers.

Methanal → Formaldehyde.

Methanation in the biogas process Biogas is produced everywhere where organic material is microbiologically decomposed by the exclusion of air (anaerobic). This natural process has already been used on a commercial scale for several decades in sludge digestion towers for treating excess sludge from waste water treatment plants with the aim of disposing of the sludge. Anaerobic stimulation has gained increasing importance in recent years as a useful addition to the existing oxygen-supported activated sludge process in waste water treatment.

While the activated sludge process in principle concerns cold (biological) combustion, the biogas process can be understood as cold (biological) pyrolysis. The advantages of the anaerobic method lie in the fact that

- the energy intensive oxygen input can be dispensed with,
- less excess sludge is produced,
- instead of this, biogas is produced, the energy of which is usable,
- instead of an oxidative mobilisation of heavy metals, the result is their reductive precipitation as a sulphide.

The disadvantage of the anaerobic method lies in the high sensitivity to fluctuations in degradation conditions. The degradation chain requires balanced cooperation of the different microorganisms in order to avoid substrate limitation and product inhibition. Firstly, complex organic molecules are hydrolytically separated into soluble low molecular compounds. An acid (in particular, acetic acid) is added to them with simultaneous formation of hydrogen and carbon dioxide. The last step involves the actual methane formation. Besides the broad spectrum and the different generation periods of the micro-organisms involved, as well as the complex interactions between fermentative acid formation and methane recovery, the regulatory role of the hydrogen on the acetic acid formation by the acetogenic micro-organisms, dictated by thermodynamics should still be considered. While acetic acid degradation is independent of the partial hydrogen pressure, high partial hydrogen pressures encourage methane formation from hydrogen and carbon dioxide. The transition from propionic to acetic acid is, however, thermodynamically impossible under these conditions. If more propionic acid is formed by the series-connected materials in the microbiological food chain than can be degraded in further behaviour, this will lead to an accumulation of propionic acid (souring of digester doors). So what matters is that a narrow “thermodynamic window” is set regarding the hydrogen concentration, for which the methanation of hydrogen still functions on the one hand, while the propionic acid degradation is not yet inhibited. In practice, this can be implemented using a microbiological population as active as possible regarding hydrogen recycling (according to Aivasidis).

Methane → Saturated hydrocarbons.

Methane hydrocarbon → Saturated hydrocarbons, which are all derived from the first link in the methane series.

Methanoic acid → Formic acid.

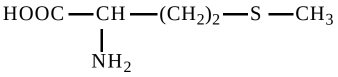
Methanol (carbinol, wood spirit, methyl alcohol), CH_3OH. Molecular weight 32; clear as water, easy and flexible liquid, boiling point 64.8°C; miscible with water, alcohol and ether; toxic; flammable with bluish flame. Wood spirit also contains acetone and methyl acetate. In liquids containing benzene, 20% addition removes the benzene odour. Different compared with → Ethanol: with sodium tetraborate addition and ignited, green flame colour is immediately produced (only after addition of concentrated sulphuric acid by ethanol). Application: added to the wet fabric in textile finishing during the rapid dry process (→ Remaflam process, Hoechst) and burned off for the purpose of shock-like evaporation of water, which should prevent the migration of the dyes.

Methanol/Water flashpoint Important for carrying out the → Remaflam process (Hoechst). Methanol combusts under certain physical conditions. Methanol vapour or the vapour escaping from the methanol/water mixture can, however, only be ignited if its temperature is above the flashpoint. A pad liquor with 35% volume of methanol must firstly be heated to approx. 35°C in order to achieve an ignition of the methanol vapour. As the pad liquor is submitted to the padder at max. 30°C, the temperature should be increased by IR radiators. These are medium-wave radiators, whose wavelength is chiefly tuned to substances containing OH groups. The ignition of the methanol vapours takes place for each batch to be dried and the flames are on the fabric guiding side, but the flame also effects the other side of the fabric. After passing the IR line, the fabric which is enclosed by flames enters the combustion chamber. The evaporation of the pad liquor from the fabric initiated by IR radiators is then continued by heat, which is released by combustion of methanol. The lower thermal value (= combustion heat minus condensation heat of the water component) of methanol is approx. 19 510 kJ/kg. The heat radiation from the steel duct walls is also added to the energy available from the combustion chamber of the Remaflam system. Hot air conducted in reverse by the principal of counter currents is used, which results in the energy released from combustion process being used most in the most efficient way.

Methenamine In the USA, normally in the → Pill test for the testing of flammability, especially of carpets.

Methine group (–CH=), hydrocarbon group with double bond; chromophor.

Methionine A sulphur-containing → Amino acid (monoamino-monocarbon acid), included in wool (0.71%), also identified in silk (2.59%).



$$HOOC-\underset{\displaystyle NH_2}{\underset{|}{CH}}-(CH_2)_2-S-CH_3$$

Methods engineering is used for work intensification and work rationalisation. Handles all the issues concerning time studies, job evaluation, work flow studies and technical workplace structuring. The transport technology in a company is a typical example of methods engineering, because, besides many other factors, time studies and workplace structuring are influenced.

Method study Economically useful application of the timing diagram (→ TMU) within the framework of the → MTM system. For example, the machine manufacturing industry today sells machines and automatic machines, whose machine basic times (t_G) are very low, which are, however, not always effective in business practice, i.e. in some cases, technical parameters, but not yet the desired reduction in working time. Manual times (t_H) may be too high as a result of poor workplace and method study or non-observed work study points already in the machine development. This makes a considerable proportion of the t_H times, minimised by high technical expenditure, economically ineffective.

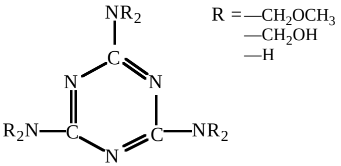
Rules for method study:

1. the most important point is the median plane (symmetry plane of the human body). Frequent or significant movements should be on or at this plane.
2. working methods should be organised rhythmically (countable phase time of a simple rhythm), advisably with slightly bent arm.
3. location of tasks so that good visual control is possible.
4. movements using the forearm as much as possible, for flexibility in change of direction and in the course of circular movement.
5. shape of movement (orientation of direction) and result of movement (structural orientation) should be in harmony with each other; a rational working method follows from this.
6. work tasks reaching behind should be avoided (costly body movements).

It can be seen from this that many work organisation aspects should be considered for optimisation of tasks.

Methoxyl content (methoxyl index), content of the methylcellulose in CH_3O groups. Plays a special role in the evaluation of solubility properties.

Methoxymethylmelamines Completely or partially etherified with methanol → Melamine-formaldehyde compounds; liquid, stable under storage conditions, depending on the degree of methylolation and etherification. Tri- to hexamethoxymethylmelamine used for finishing effects resistant to 100°C wash, no loss of strength from chlorine retention, however occasional yellowing tendency.



Methyl acetate (acetic acid methylester), formula: CH_3COOCH_3. Molecular weight 58. Density at 4°C = 0.9562; boiling point 57.5°C. Soluble in benzine and chlorinated hydrocarbons, also slightly in water. Application: carrier substance for water-soluble, non solvent-soluble substances in volatile organic solvents, for spotting agents, etc.

Methyl alcohol → Methanol.

Methylaminoacetic acid CH_3NHCH_2COOH. Belongs to the amino acids. Colourless crystals; easily soluble in water, less soluble in alcohol. Used for the pulping of vat dyes; as a stabiliser for diazoamino compounds; as a sodium salt for the purposes of wetting, dispersing and washing.

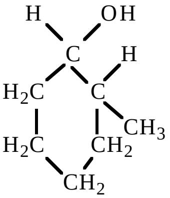
Methylanon → Methylcyclohexanone.

Methylcellulose (cellulose methyl ether), corresponding to the 3 OH groups existing in the cellulose molecule per glucose unit, the etherification using methoxy groups CH_3O can lead to mono-, di- and trimethyl celluloses. The products are water-soluble with a low methoxy content (approx. 5–13%), but insoluble in 5-12 % caustic soda liquor. The products are soluble in cold water with a medium content (approx. 15–25%), but are insoluble in a hot water and alkali solution. The products are soluble in solvents with a high organic content (more than 23%). Tri-methyl cellulose (approx. 45%) is soluble in many organic solvents. Used variably for permanent finishings, sizings, thickeners (especially for pigment printing), adhesives, etc.

Methylcellulose test on textiles Solution of 0.5 g of benzamide indigo blue RRLS to 1 l of distilled water. Load fabric sample, treat for 3 mins, rinse, perhaps dry. Methylcellulose contents are (on every fibre material) immediately dyed dark blue, which is clearly visible under a magnifying glass, but most certainly microscopically. Starch is stained to an extent by this, but not cellulose glycolate.

Methyl chloroform → Trichloroethane.

Methylcyclohexanol (methylhexalin, hexahydrocresol, heptalin), molecular weight 114; density 0.93; boiling point 160–195°C; flash point 68°C; evaporation number 807. Mixture of three isomeric hydrogenated cresols. Colourless liquid with a typical odour. Not very water-soluble, soap-soluble solvent for fats, resins, etc. Used for fat-solubilising soaps and spotting agents.



Methylcyclohexanone (methyl anon), formula as → Cyclohexanone, where hydrogen was replaced by CH_3. Is used as a solvent for fats, oils, resins, chlorinated rubber and polyvinyl chloride.

Boiling range 168–178°C; density 0.910–0.918, flash point 53–55°C; evaporation number 50. Primary product for synthetic resins and synthesis of polyamide 6.

Methyl dye Blue and violet cationic dyes.

Methylene blue active substance → MBAS.

Methylene blue method is used for the control and determination of the concentration of cleaning boosters in organic solvents in dry-cleaning. Most cleaning boosters are anionic compounds, either alone or mixed with non-ionic surface-active substances. These (e.g. alkyl sulphates and/or sulphonates or aralkyl sulphonates, etc.) react in aqueous solution with cationic compounds or pyridine (cetyl pyridinium chloride) as follows: a certain quantity of solution from a cationic substance is added to a mixture of several ml of liquor with anionic dry-cleaning detergents, chloroform and an aqueous acid solution of methylene blue. Two layers are obtained: an upper one containing water with a methylene blue colour and a lower chloroform layer, which should have the same blue colour as the upper layer at the end of the reaction. Pure chloroform, indicator solution (sulphuric acid solution of methylene blue) and titration solution (approx. 1% solution of cetyl pyridinium chloride) are required for titration. Depending on the concentration of dry-cleaning detergent in the liquor, e.g. 5 ml of liquor is added (at 0.5–1% dry-cleaning detergent content) or 1–2 ml (at 2–4% dry-cleaning detergent content).

Methylene blue number characterizes the content of the carboxyl groups in damaged cellulose (oxycellulose). Wash out sample in diluted methylene blue solution and determine the dye uptake using colorimetry of the dyebath before and after washing out. More accurate, but more awkward is the → Reversible methylene blue method.

Methylene blue test For the testing of:

I. Oxy- and photocellulose. Wash out using methylene blue (cationic dye), rinsing with hot water. With damaged material, a lasting blue dye occurs (not however to undamaged cellulose).

II. Acid, alkali and mechanically damaged wool. This has improved dye affinity (test by counting the darker and brighter fibres under a microscope).

III. Linen compared with cotton: after washing out and thorough washing, linen remains permanently dyed, cotton does not.

Methylene blue-potassium cyanide reaction For the testing of glyoxal and glyoxalmonourein, mix the test solution with 1 drop of 1% methylene blue solution and 10 drops of 1% potassium cyanide solution. Glyoxal decolours the solution at room temperature, glyoxalmonourein during heating and glucose only after addition of caustic soda liquor.

Methylene blue-sodium hydroxide test For the testing of reducing sugars. Mix test solution with 1 drop of 1% methylene blue solution and surplus liquor of concentrated caustic soda liquor, then heat carefully without shaking. Aldoses are available when the solution is dyed. Alternate shaking with air and heating makes the colour appear and disappear until the aldose has been consumed. Simple aldehydes do not give this reaction in practice.

Methylene chloride → Dichloromethane.

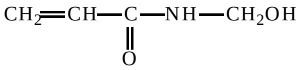
Methylene dyes Blue and green cationic dyes.

Methylethylcellulose Cellulose ethers of combination dyes (→ Cellulose derivatives).

Methyl green Green, cationic dye (heptamethyl-p-rosaniline chloride). Application: methyl green test; for the dyeing of bacteria (microscopy).

Methyl green test → Alkali traces in textiles.

Methylolacrylamide Besides the N-methylol group, also contains an acrylamide group, toxic. Used, amongst other things, as resin finishing agents in the so-called ambivalent crosslinking, usually together with cyclic N-methylol compounds. Finishings with moderate dry, but outstanding wet creasing angles, soft, smooth fabric handle. After-washing required.



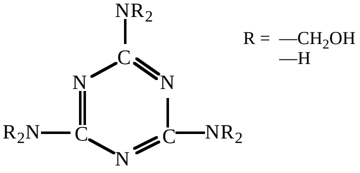
$$CH_2{=}CH{-}\underset{\displaystyle \overset{\|}{O}}{C}{-}NH{-}CH_2OH$$

Methylolamide group Reactive group of numerous self-crosslinking resins and reactive resins. → N-methylol compounds.

Methylolation Introduction of → Methylol group, e.g. conversion of NH-group containing compounds with formaldehyde to → N-methylol compounds.

Methylol group $-CH_2OH$. Component, of e.g. urea and melamine resins as well as numerous reactive types.

Methylol melamines → Melamine-formaldehyde compounds. Aqueous solutions of methylol melamines, less stable under storage conditions, self-polymerization in storage, therefore usually in powder form; only a few resin finishing products on a methylol melamine base (→ Methoxymethylmelamine).



Methylol ureas → Urea-formaldehyde compound.

Methyl orange (golden orange, helianthine, orange III, orange IV D), cationic orange dye; extremely sensitive to acid. Sodium salt of p-dimethylaminoazobenzene-p sulphonic acids. Soluble in water, insoluble in alcohol. Application: methyl orange test (change in colour at pH 4).

Methyl orange test is used (with 0.1 g to 100 ml of water) dissolved as an indicator. Reaction to alkali pale yellow; to mineral acid traces rose coloured. Neutralisation point: orange. Change to red/yellow at pH 3.1–4.4.

Methyloxyethylcellulose → Oxyethylated cellulose.

Methylphenyldiisocyanates Synonym for → Tolylene diisocyanates.

Methyl red Cationic red dye, p-dimethyl-aminoazobenzene-o-carboxylic acid. Soluble in alcohol and acetic acid, almost insoluble in water. Used as an indicator (0.5% alcoholic solution) in the titration of weak bases. Yellow in alkali solution, red in acid solution (change in colour at pH 4.2–6.3).

Methyl sulphinyl carbanions are produced in basic solution of → Dimethyl sulphoxide (DMSO) during action on, e.g., acid azo dyes. Cause increase in solubility and change in colour (halochromic effect), which is reversible and/or destructible through oxidation (air affect). Acceptance of a donor/acceptor complex formation.

Methyl violet Cationic violet dye. Mixture of salts containing hydrochloric acid from tetra, penta and hexamethylpararosaniline. Soluble in water; sensitive to acid. Used as cationic dye for dyeing and printing. Dye for inks, ink pads, typewriter ribbons, photocopy paper, etc. As an indicator (→ Methyl violet test).

Methyl violet test Indicator for traces of acids, which results in violet/greenish yellow change of colour occurs in the pH range 3.2–0.1. pH 3 violet; pH 2 blue; pH 1 green; pH 0 yellow.

Metre (m), unit of length; defined as the distance, through which the light in a vacuum passes during an interval of $^1/_{299792458}$ of a second.

Metre length Amount, e.g. of dyed or printed fabric in m.

Metric count (Nm) → Metric number.

Metric number (metric count, Nm), a mass-related length for the → Linear density of textile fibres and yarns. The designation Nm is permitted under the new law of units of measurement, as it derived from SI basic units such as mass and length. A larger Nm corresponds to a finer yarn. As this system is however contrary to the → Tex system (a large number indicates a thick yarn) and by using the designation Nm a risk of confusion exists with Nm = Newton · metres, the metric number should not be used any more as an indication of yarn fineness.

Metric system All metric systems, which are based on a metric basic unit. There have been various metric systems until now, such as the technical metric system, absolute metric system, etc. An international agreement describes the → SI System of Units. In contrast to this is the → Non-metric measuring systems from the Anglo-American and East Asian areas.

Mezzera continuous scouring machine (Mezzera/Hinnekens open width scouring machine), very common; is used (in warp and weft) for the untensioned continuous desizing, scouring and crêping of fabrics in the flat condition for a long period of immersion (see Fig.). Normal length 8 or 12 m for fabric widths of 1.2 and 1.6 m. A centrifugal pump provides continuous filtered liquor circulation from the main dyeing vat to the pre-wetting and guiding device (ventilation and drainage of the heavier liquids alleviate the formation of fabric loops). Separate after-flow tanks. Fabric inlet and outlet with centering device, outlet point with squeezing mangle. Two stainless steel chains with stainless steel bars move in the long main tank. The bars are led through a rack gear system so that they are, at times raised and then quickly drop and simultaneously move forward. In this way, besides the benefit of being washed, the fabric is removed from the bars and support points are avoided. – Manuf.: Mezzera.

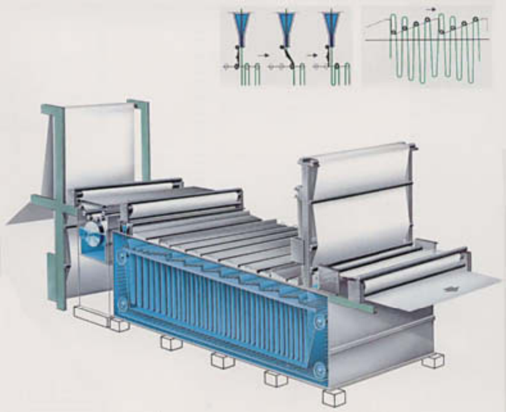


Fig.: Mezzera boil-off machine.

MFA Multifibre Agreement (MFA), refers to the World Textile Agreement (in 1974 by approx. 50 countries, in Geneva) on cotton, wool and synthetic fibres.

Mg Unit symbol for magnesium (12).

MgH magnesium hardness Standard short designation for → Magnesium hardness.

MH Abbrev. for Mohs' hardness scale, → Hardness scale.

Micellar bundle Bundled micelles, which consist of so-called fibrils, for example in → Wool structure. One talks of →: Micelles; Crystallites; Individual fibrils.

Micellar chain Designation in crystalline cotton structure for →: Micelle; Crystallites.

Micellar forces → Secondary valency forces.

Micellar network structure → Cellulose.

Micelles (→ Crystallites), smallest cell organisations of crystal lattice ordered ranges, like the three-dimensional order system.

I. In cellulose made from several → Lamella. (cellulose chain lattices), similar in wool structure (also silk structure) of → Keratin sheet structure grown in parallel on top of each other. Micelles form the next large organisational structures in individual fibrils, fibril bundles, spindle cells and individual fibres.

II. Tenside chemical: ordered aggregation of molecules (Fig. 1) and/or ions, which are formed above a certain critical concentration up to high molecular systems, e.g. with hexagonal rod packing (Fig. 2) (→ Critical micelle concentration).

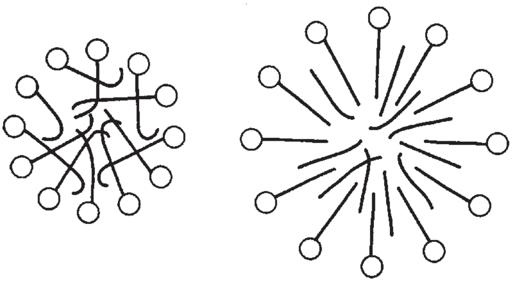


Fig. 1: Micelles of tenside molecules.

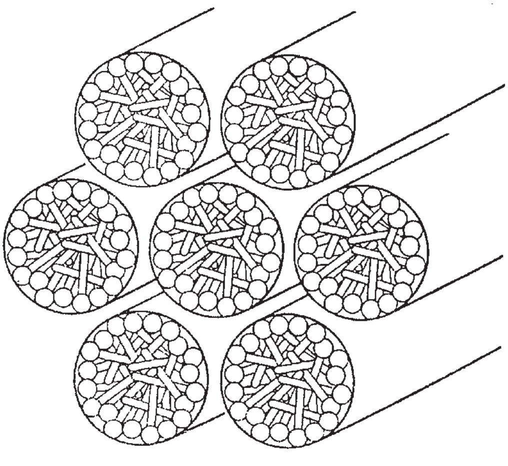


Fig. 2: Structural model of tensides. In dilute aqueous solution individual molecules are present, which form spherical or lamellar micelles as the concentration increases.

Micelle starches Starches reduced in their micellar size by steam, pressure, heating or mechanical measures. Particularly well suited to sizing purposes; therefore important for size boiling.

Micro- (Gk.: mikrós = small),

I. Prefix for compositions with the meaning “small”, “low”, “fine”; e.g. microfibres; microprocessor, etc.

II. Unit prefix for one millionth = 10^{-6}; e.g. µm.

Microbes Smallest micro-organisms. Appear in so-called colonies (→: Bacteria; Sarcina; Spores), which appear as worsted skin (→ Yeasts) or grass (→ Moulds), as fermentation, rot, disease exciters (→ Pathogenic bacteria) and textile parasites.

Microbial damage to textiles Generally promoted by a high moisture content, relatively high temperature, individual optimum pH (for bacteria pH 7–8.5; for fungi pH 4.5–7.5) and especially in a contaminated state. In principle, microbial damage from →Moulds (mildew stains) and → Bacteria may arise, contained by → Enzymes produced on both sides.

I. Protein fibres: wool is preferentially damaged by a group of so-called earth bacilli (aerobic and anaerobic, forming spores), but also by pathogenic types of bacteria (pus producers) also especially skin and hair fungi and by excreted proteolytic enzymes. Wool damage from fungi can, in fact take on the greatest proportions, however the predominant types of fungi only live by attacking fibre foreign substances and wool fat. Microbial damage goes beyond local or premature wear and tear to complete disintegration of the wool fibre (like splintered wood under the microscope, then complete splitting into individual fibrils). Alkaline washed, inadequately spun wool is particularly at risk. Alkaline oiling produces similar susceptibilities. Vat dyed wool is also considered as having increased susceptibility. Acid dyed wool is protected as long as there is still a relatively strong acid reaction. Chromed wool is particularly resistant however. Microbial damage to silk occurs more rarely.

II. Cellulose fibres: earth bacilli and numerous moulds as well as enzymes variedly excreted from both (especially cellulase and cellobiase) act as marked cellulose destroyers. There are also pectin-consuming bacteria, which destroy bast fibres. Usually cellulose fibres, which are in equilibrium with relative humidity of 100%, are chiefly attacked by fungi, but also some types at low humidity. Temperatures of 25–35°C encourage the growth of most cellulose destroyers. Water super-saturated fibres also increase the tendency of possible bacteria attack. The fungus resistance increases in cellulose with higher orientation and crystallinity towards

1. viscose
2. mercerized cotton
3. native cotton
4. ramie;

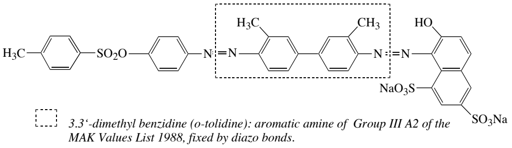
it also increases with increasing fibre lignification of cotton, hemp, jute, manila hemp and sisal hemp. The microbial damage which occurs can lead to complete fibre degradation in cellulose fabrics. It usually occurs in a locally restricted way and causes loss of weight and strength until the yarn breaks. Cellulose destroying and denitrifying waterborne bacteria and waste water fungi from the so-called sapropel together with cellulose degrading enzymes (cellulase, cellobiase) act on fishing nets, ropes and such, whereby considerable strength loss may occur. The so-called decomposability increases from flax, hemp, cotton and manila to sisal.

III. Synthetic fibres are generally considered to be microbe-resistant.

Microbiological degradation A substrate is biologically decomposed by biocatalysts (enzymes), which are produced by micro-organisms. This degradation may occur aerobically or anaerobically, but always takes place in the presence of water as a reaction and diffusion medium.

I. Degradation of fibres: protein fibres are easily microbiologically degraded by proteases. Cellulases microbiologically degrade fibres on a cellulose base, i.e. cotton or viscose. The main chain, the backbone of the polymer, should contain heteroatoms if a microbiological degradation of synthetic fibres is to take place. A conclusive reason for the resistance of many synthetic polymers to microbiological attack results from the theory of evolution: There is no selection print available for the degradation of such substances as long as they are missing in the environment of the corresponding micro-organisms. For polyamide, it has been proven in various works that the ease of microbiological degradation is controlled by the chemical structure of the environment of the amide bond and the hydrophobicity of the polymer. Polyamide is not generally degradable; nevertheless microorganisms, which, when growing cause corrosion to the surface of the polymer, have become well known.

II. Degradation of dyes: azo dyes have a high economic importance in the dyehouse and are currently indispensable with regard, for example, to light fastness and colour palette. Several primary products for the manufacture of these dyes as well as physical/chemical cleavage products, in particular, those on a benzidine base and microbiological degradation products in this substance class, may be carcinogenic. Although the waste water pollution caused by such dyes is comparatively low, the relevance of this problem is given on the basis of the toxicity which occurs (also bacterial toxicity amongst others). The microbiological degradation of azo dyes shows that the azo formation of these compounds can be split in this way (Figs. 1–2) and in addition complete mineralisation can be achieved with aerobic treatment. Such degradation is known to occur due to both bacteria and fungi.



3.3'-dimethyl benzidine (o-tolidine): aromatic amine of Group III A2 of the MAK Values List 1988, fixed by diazo bonds.

Fig. 1: Cleavage of tolidine dyes (Acid Red 114).

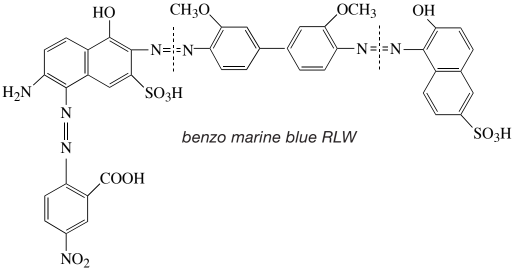


Fig. 2: Cleavage dianisidine dyes (Direct Blue 160).

III. Degradation of surfactants: due to their large scope of applications and their disposal via (predominantly municipal) waste water, surfactants are one of the important ecologically relevant substances, whose environmental compatibility must be guaranteed. The deciding criterion for the whereabouts and thereby, a possible harmful effect on the environment, is biological degradability as the chief mechanism of waste water treatment in waste water treatment plants and the self-cleaning processes in surface waters as well as possible toxicity in the metabolites produced. The degradability of anionic and non-anionic surfactants is regulated by the surfactant regulation. Accordingly, surfactants used in detergents and cleansing agents must on average be biologically degradable by at least 90%. This requirement is considered to be observed when a single test results in at least 80%. The corresponding test and analysis processes are stipulated precisely. The test is usually carried out in the OECD screening test, a static test with a mineral medium and the surfactant as a single organic source of nutrients; an 80% degradation must take place within 19 days after inoculation with waste water bacteria. If this limit is not clearly reached, the result is decided by identification of the surfactant degradation in a waste water treatment plant simulation test, the OECD confirmatory test. Here the surfactant is tested under continuous test conditions (the duration of stay of the test compound in the test system is 3 hours on average) in the presence of a high surplus of easily degradable compounds, i.e. under realistic competitive conditions. The biodegradation is measured each time with the aid of so-called substance group-specific analysis procedures, which permit a quantification of the a or n surfactant proportion still present. The property of anionic surfactants is hereby used with methylene blue, or non-ionic surfactants with Bismuth iodide, to form a complex so that the surfactant degradation is given as the acceptance of methylene blue active substance (MBAS) and bismuth active substance (BiAS) respectively. The so-called primary surfactant biodegradability is determined in the statutory degradation tests described using the MBAS or BiAS acceptance, as the surfactant molecule has already been altered by the first biological degradation steps so that essential properties of the initial compound, such as surface activity and, particularly important ecologically, aquatic toxicity, have disappeared or are drastically reduced. Commercially used surfactants normally consist of a multitude of homologous (in the C chain of different length) and possibly also isomeric (in different positions of the C chain, e.g. substituted by a phenyl ring) individual compounds. As a result of these different structures, the individual compounds also differ in their primary degradation and toxicity properties, whereby a contrarotation of both effects exists: The slower degradable individual compounds are less toxic than the quicker degradable ones.

The surfactant tetrapropylene benzene sulphonate (TPS) was a “hard” surfactant causing foam mountains on rivers at the start of the 60s, i.e. only inadequately degradable biologically due to its branched bulky structure (Fig. 3).

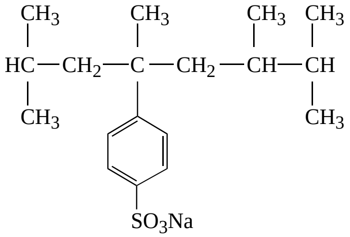


Fig. 3: Structural formula for the tenside tetra propyl benzene sulphonate (TPS).

It was replaced by a “soft” surfactant, a linear alkylbenzene sulphonate (LAS), which is very much more easily degradable due to its straight chain structure (Fig. 4).

In principle, tests on the total degradation of compounds were carried out in comparable tests as those described, i.e. in simple discontinuous screening tests (test of ready biodegradability) and in the waste water treatment plant simulation test (e.g. coupled units test). The fundamental difference however lies in the fact that the criteria for the final biological degradation are used as a set of criteria, i.e. the mineralisation of the test substance into carbon dioxide, water and possibly salts as well as the assimilation into biomass. The analytical apparatus for final degradation detection extends from the measurement of the mineralisation parameters “CO_2 production” and “biochemical oxygen demand” (BOD) to the complete determination of mineralisation and assimilation by measuring the acceptance of the dissolved organic carbon (DOC). The final degradability of the test substances is usually tested in one of five different tests of ready biodegradability recommended by the OECD and established in EC-wide chemical legislation. The test substance also represents the only source of carbon for the degrading bacteria stemming from environmental media (waste water, rivers and soils). According to the criteria of the OECD, compounds with a mineralisation rate (CO_2, BOD) of > 60% and a DOC acceptance of > 70% are considered as quickly and completely degradable under environmental conditions. If primary and final degradation data of surfactants are compared with each other, it can be established that an extensive degradation to the natural finished products also normally takes place in surfactants with a high primary degradation so that no durable degradation products can ultimately accumulate in the environment. The degradation reactions of a surfactant are shown in the example of the LAS already mentioned (Fig. 5).

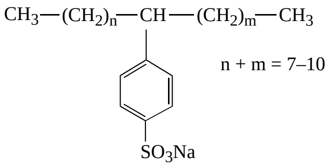


Fig. 4: Structural formula for the tenside alkyl benzene sulphonate (LAS).

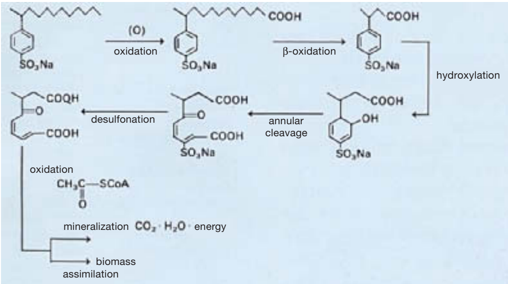


Fig. 5: Biological decomposition of a tenside.

The biochemical reaction proceeds in two sections and starts at the alkyl chain. Firstly, a terminal CH_3 group is oxidised to the carboxyl group and then the alkyl chain is shortened in C_2 steps into a branch (this reaction takes place quickly, partly in the sewerage system before the waste water treatment plant). The following opening circle starts with a hydroxylisation of the aromatic circle, which is simultaneously opened and desulphonated. The subsequent degradation of the now aliphatic compound happens quickly as in the alkyl chain, e.g. as β-oxidation and the compound is either completely mineralised or converted to cell substance by assimilation. The acute aquatic toxicity of surfactants, measured as LC_{50}/EC_{50} (concentration in which 50% of the organisms survive in the fish and daphnien test), is, apart from a few exceptions, above 1 mg/l. The use of highly toxic surfactants is, however, justifiable if their good primary and final degradation behaviour is warranted due to the crucial importance of biodegradation in the environmental compatibility assessment of surfactants.

Microbiological degradation in biological waste water treatment is tied to a particular $BOD_5 : COD$ ratio. The following should apply:

– approx. 0.5 in domestic sewage,
– < 0.5 in commercial sewage,
– > 0.5 in sewage from the food and drinks industry.

Small values of the ratio indicate that organic materials exist, which are barely degradable or degradable with difficulty. It should be considered that, in many cases, organically contaminated industrial sewage is concentrated. In order to create favourable conditions for biological cleaning, a dilution using purified water or operational waste water should be carried out. The oxygen consumption in the aerobic biodegradation of organic contents occurs in two stages (Fig. 6). The degradation firstly attacks in the carbon-containing compounds, which are finally converted into CO_2 and H_2O. This stage takes at least 20 days. In the second stage, the nitrification of nitrogen compounds occurs; this is carried on over several months. The oxygen absorption in aerobic degradation for urban waste water is shown for various temperatures in Fig. 7.

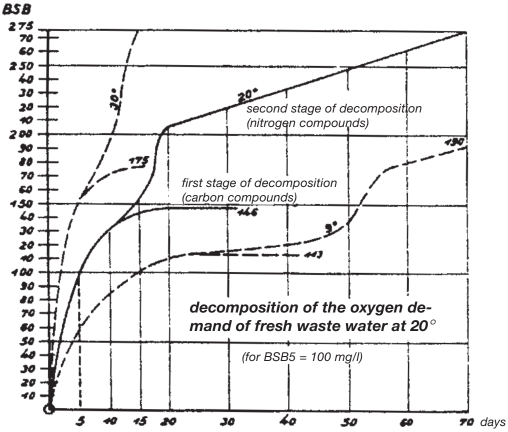


Fig. 6: Process of oxygen absorption during aerobic decomposition of municipal waste water (according to Meinck et. al.)

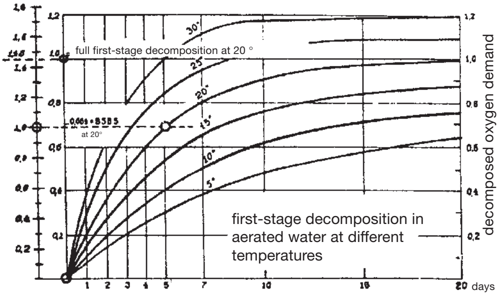


Fig. 7: Oxygen absorption during aerobic decomposition, dependent on temperature.

Furthermore, the oxygen consumption of 1 kg of activated sludge per hour at max. substrate breathing and endogenous breathing dependent on the temperature is shown in Fig. 8.

Only 5–15% of the oxygen in the air can be used bacteriologically so good ventilation must always be ensured if a high degradation performance is to be achieved. If a nutrient solution is produced without inflow and outflow, the following phases of growth can be established in the micro-organisms (Fig. 9):

1. Initial phase: The enzymes required for the degradation of the water contents are formed.
2. Exponential phase: Nutrient is amply available so that growth is determined by the max. division rate. This is known as “substrate breathing”.
3. Stationary phase: The number of cells remains, as the nutrient supply is restricted. The endogenous breathing (internal breathing of the separate cell substance) increases while the substrate breathing steadily decreases.
4. Dying phase: Nutrients are lacking. The microorganisms oxidise their own cell substance. Endogenous breathing chiefly exists.

The metabolism of the micro-organisms show coupled degradation (dissimilation) and construction (assimilation) processes. The metabolism processes are a branched and multiply coupled system of individual biochemical reactions. The conversion of waste water contents is thereby carried out in many small steps. The surmounting of an energy threshold is necessary for each such kinetic step, since the reacting substance must be transferred in a reaction-prepared state. This process is tied to the presence of enzymes, which are produced by the micro-organisms. A well-established theory on enzyme catalysed reaction, stems from Michaelis and Menten. The substrate S, contained in the waste water to be converted, enters into a complex with the enzyme E, wherein it is transferred in a reac-

Microbiological degradation

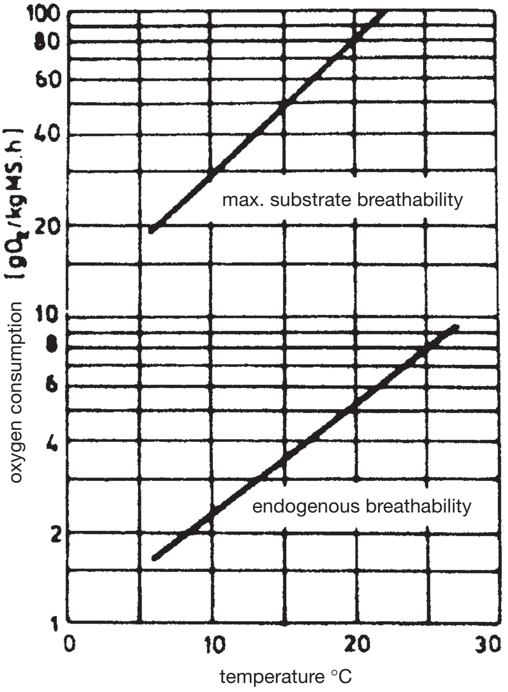


Fig. 8: Oxygen consumption (in relation to 1 kg activated sludge and one hour) for maximum substrate breathability and endogenous breathability in relation to the temperature.

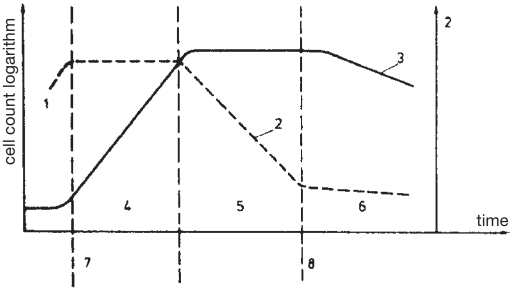


Fig. 9: Growth phases of the microorganisms and oxygen consumption.
1 = start-up phase; 2 = 0_2 consumption; 3 = cell count; 4 = exponential phase; 5 = stationary phase; 6 = slackening off phase; 7 = substrate breathability; 8 = endogenous breathability.

tion-prepared state. This facilitates the decay of the substrate. The enzyme is not consumed as a typical catalyst in the reaction. So the following can be formulated:

$$S + E \underset{k_2}{\overset{k_1}{\rightleftharpoons}} ES \overset{k_3}{\rightleftharpoons} E + P$$

P = product,
k_{1-3} = speed constants.

The transitory change of the substrate concentration can be written as the familiar Michaelis/Menten equation in the form:

$$v = \frac{dS}{dt} = V_{max} \frac{[S]}{K_m + [S]}$$

K_m = Michaelis/Menten constant,
t = reaction time,
V_{max} = theoretical max. degradation speed.

V_{max} is achieved when the total enzyme quantity available, saturated with substrate and known as ES. K_m and V_{max} characterise the substrate. It is recognised that a high S causes a high degradation speed for the substrate. So the biodegradation of waste water contents can be quantitatively formulated kinetically. The kinetics of the substrate degradation characterised by the BOD is particularly interesting. The equation of the BOD curve is known as Henry's equation. This can be written as follows:

$$S(t, y) = \frac{K_m}{V_{max}} \cdot \ln \frac{L}{L-y} + \frac{y}{V_{max}} - t = 0$$

L = BOD final value, referring to the zero point of the reaction,
y = oxygen consumption, referring to the zero point of the reaction.

It should be ensured that the pH remains in the 5–9 range in biological waste water treatment. It is of interest that the temperature dependency of the kinetics of biological waste water treatment is small so that no great differences occur in the degradation rate between summer and winter. There are several equilibrium ratios to calculate in biological waste water treatment, which are established within the framework of the nutrient substrate/substrate consumption relation of the organism. There is a "food chain" for the heterotrophic organisms, which leads from the nutrient substrate contained in the waste water to lower organisms (bacteria) and from them to ever more highly organised micro-organisms. Each type of microorganism, which is feeds on bacteria, is dependent for its reproduction rate on the bacteria.

These kinds of relationship in technical/biological cleaning are shown in Figs. 10 and 11. The technology of microbiological degradation in biological waste water treatment processes has meanwhile achieved a high level; these processes are chiefly used in municipal waste water technology. Endeavours are currently being made to use these degradation processes for undiluted industrial sewage as well. There are essentially three possibilities for the microbiological degradation of industrial sewage:

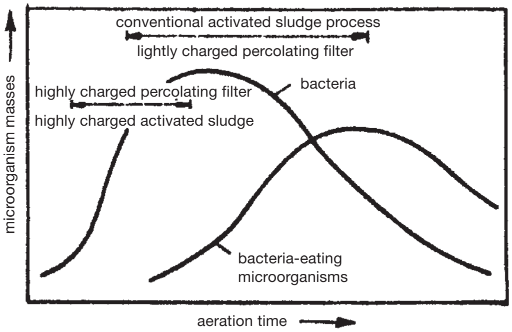


Fig. 10: Areas of growth phases of bacteria and bacteria-eating microorganisms in activated sludge plant and lightly charged percolating filters.

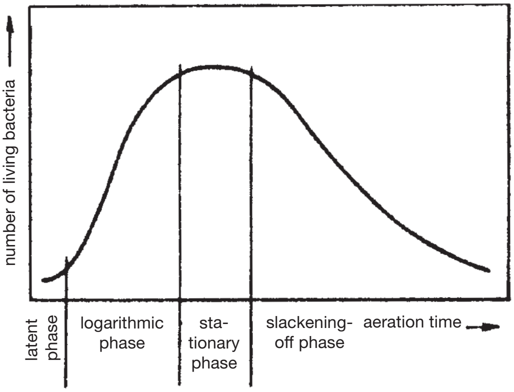


Fig. 11: Growth pattern of bacteria and bacteria-eating microorganisms in relation to the aeration time.

1. Natural processes, which are generally based on agricultural waste water exploitation and the use of sewage ponds. These processes are carried out in the natural habitat for economic use.
2. Technical processes, in which percolating filters and activated sludge plants are used.
3. Combination of these processes.

The country treatment of waste water has increasingly declined due to the increasing amounts of waste water and the steady fall in land areas available. A great cleaning effect is achieved by the festing technique, which accompanies mineralisation processes. It should, however, be noted that a large part of the bacteria dies in the upper soil layers, in which solar radiation plays a fundamental role. The draining of waste water, which is rich in E. coli, must be excluded from the harvest rhythm in order to avoid damage to foodstuffs. Not all waste water is suitable for agricultural use. The use of sewage in agriculture is standardised in the FRG. A much practised type of waste water treatment is the use of waste water ponds. They can absorb relatively large amounts of waste water over many days up to several weeks. A degradation of the organic contents also takes place on an aerobic basis as long as a sufficient oxygen absorption is guaranteed from the air across the water surface. Additional oxygen supply can be achieved through addition of oxygen-saturated surface water as well as algae multiplying under light irradiation. Several pond stages have been tried and tested. So-called refining ponds are occasionally connected. In special cases, waste water ponds can be used economically as fish ponds. Aerobically effective microorganisms from solid filling materials (e.g. mineral silicate, clinker, pumice, stone, etc.) are held as practically favourable in the percolation filter process; they are cleaned by rinsing with waste water. A mucilaginous lawn of microorganisms, nematodes and insect larvae is formed in the percolating filter material. So industrial sewage can be well treated (usually within the framework of a small waste water treatment plant).

Microcapsule Incorporation of dyeing auxiliaries. → Encapsulated dyes.

Microclimate,

I. Air moisture temperature and air moisture temperature ratios, which are employed in sections of a larger environment (e.g. in warp shed in comparison with warp barn).

II. Definitive for comfort. Not only important for clothing, but also for bed textiles. Concerns climate situation between textile (clothing) and human skin. Applies to the climate under the clothing, in contrast to the so-called ambient climate of the person, which does not correspond with the micro climate of the head and hands (normally unclothed), with regard to humidity and/or vapour pressure. → Clothing physiology.

Microcomputer A small computer, whose complete components are manufactured as integrated circuits, e.g. as control for machines and systems for fully automatic programming, especially temperature control. Can be connected by external data carriers.

Microcomputer process control Two main components: devices (hardware) and programs (software). It offers considerable advantages: e.g. supply of considerably more extensive and thereby more effective information on complete events in and on machines or systems. Cost advantages at switchgear cabinet level from saving the logic connections. Absence of auxiliary control relays and proportionate assembly costs. Many functions previously using individual electronic control can be monitored and/or controlled, combined in microcomputer process controls.

Microcosm The exploration of the world is carried out in two opposite directions and thereby also opposite dimensions. The macrocosm is the research aim of a large group of scientists and engineers. The greatest extent of the cosmos is the aim of the research of these researchers. They work in light year dimensions with gigantic telescopes and radio telescopes, whereby the inconceivable limits of their work is currently at about 10 billion light years. Spiral nebula, milky ways, quasars, pulsars, novas and supernovas are their research projects, amongst others. The other group of physicists and engineers is working in the field of pure physical research of the microcosm. The examination of the laws within the smallest dimension of the subatomic world is the research aim of these theorists and experimenters. The smaller these dimensions are, the larger and more expensive the measuring instruments. Gigantic microscopes, so-called particle accelerators and accumulator rings, facilitate advancement into inconceivably small, but measurable dimensions (Fig. 1).

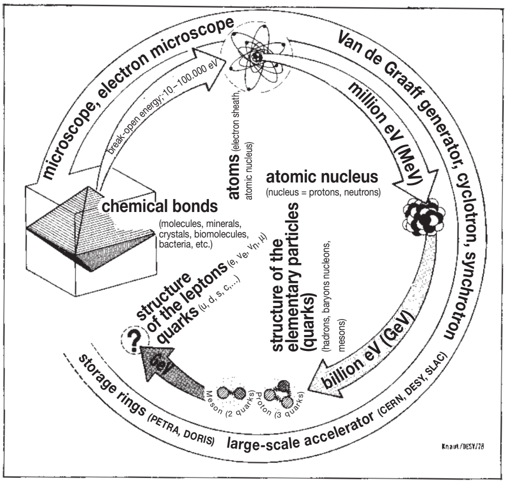


Fig. 1: Advancing through a microcosm.

In the course of the history of research, man has tried to analyse matter in ever smaller components in the search for the atomos, the indivisible. It has thereby been shown that larger forces and equipment are required for the "separation" of structures, the smaller the structures are. It was a long way from the magnifying glass to the accumulator ring. Breakage, fine grinding or crushing are sufficient to examine crystal structures or biological structures in the macroscopic area. In the atomic and sub-atomic area, however, an investigation of the structures only succeeds by bombarding these objects with very high energy particles. These particles must be accelerated at very high energy (almost at the speed of light). They thereby obtain a very high "breakage energy". They overcome the inner atomic forces, and can, for example, penetrate a proton or neutron, and "scan" these particles and analyse their structure.

Forces exist between the particles of an atom, whose examination, amongst others, is one of the main tasks of pure physical research. These four forces are:

- nuclear energy (powerful energy or powerful interaction),
- electromagnetic energy,
- weak energy (weak interaction),
- gravitational force (gravitation).

In elementary particle physics it can be estimated that, on the basis of theoretical and experimental results, a "combination" of the electromagnetic force and the weak force exists. An essential element of this combination lies in the fact that the effect of the forces is traced back to a homogeneous exchange mechanism. It seems that the forces can be traced back to the exchange of fixed particles [gluons (g) or photons (light particles)] and between two structural particles [e.g. electrons (e) or quarks (q)] (Fig. 2). Nuclear energy is distinguished from electromagnetic energy in that in nuclear energy the gluon is responsible for the effect of the force as a fixed particle and the photon (light particle, gamma particle) is responsible for the effect of the force in electromagnetic energy. The gravitation (mass attraction) has been known for the longest time of all the forces. But it is so weak compared with the other inner atomic forces that it does not play a role in elementary particle physics. It only appears in "large" masses, e.g. in the movement of celestial bodies.

The familiar Einstein equation $E = m \cdot c^2$ states that

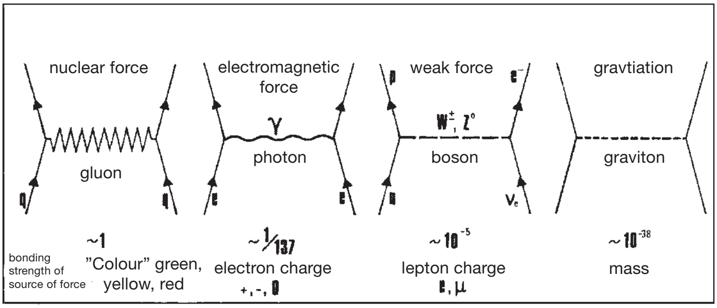


Fig. 2: Dynamic effect between two structural particles by exchanging a bond particle.

the energy of an accelerated particle is composed of the particle mass, multiplied by the square of the speed of light. The faster a projectile is accelerated, for example, the higher is its energy at impact. This acceleration is only possible in air up to a maximum speed. If, however, matter particles (e.g. electrons) are accelerated in a vacuum (maximum vacuum), they can be accelerated almost to the speed of light. The laws of “classical mechanics” no longer apply, however, but those of “relativity mechanics”. According to this law the particles do no not increase in velocity as they approach the speed of light, but instead become heavier, i.e. they increase in mass. Highly accelerated electrons have a high energy force based on their high energy (= mass), which is absolutely essential for the investigation of the structures of matter. After the Second World War, pure physical research became an important area of modern physics. The rapid development of ever larger particle accelerators and physical measuring instruments was a condition for penetration into the structures of the microcosm. Science and technology have pioneered new developments in recent decades and thereby for the first time facilitated the examination of this sub-atomic world. The particle accelerators thereby became gigantic microscopes for the examination of the laws within sub-atomic structures (according to Knaut).

Microcrystals → Crystallites.

Microdisperse (md.), range of vat dyes and disperse dyes as the fine dispersions of the standard size of 0.2 to a max. 1 µm.

Microemulsions Normal emulsions have a micelle particle size of > 300 nm (e.g. milk). Smaller particles < 100 nm lose their cloudy appearance and the resulting microemulsion is transparently bluish. There are even some with particle sizes < 10 nm. So you enter an area, in which the airborne form of the micellar microemulsion flows in a thermodynamically more favourable form, the so-called bicontinuum. The particle sizes of emulsions can be measured with the aid of photon scatter spectroscopy, also simply called laser measurement.

Particle sizes:

– normal, white	> 300 nm
– white to grey	300–100 nm
– transparent, bluish	100–10 nm
– as clear water	< 10 nm

The normal methods in practice for the manufacture of emulsions comprise a mechanical treatment with the addition of a corresponding emulsifier. Besides the simple mixer, high pressure homogenisation and shear emulsification are considered as mechanical treatment. High pressure homogenisation is, for example, used for the homogenisation of milk. Recently processes such as electrostatic or ultrasound emulsification have also increasingly been encountered. The manufacture of microemulsions proves to be considerably simpler: the emulsion is practically formed by itself in mixing the components together (the emulsifiers undertake the task of the mechanics and achieve the dividing work). One talks of so-called spontaneous emulsification. An increase in temperature produces an additional acceleration of the process. The essential manufacturing differences between micro- and macroemulsions are shown in the Table.

macroemulsions (more technical)	microemulsions (”high chem”)
less emulsifying agent	more emulsifying agent
a lot of energy	less energy
simple agitating mechanism	spontaneous emulsification, possibly with increased temperature
high-pressure homogenization	
shear emulsification	

Tab.: Differences in the production of macro- and micro-emulsions.

Clearly less energy has to be used for the manufacture of microemulsions than is customary for the manufacture of macroemulsions. The high stability of microemulsions can also be explained by this, which, compared with macroemulsions, are at a considerably lower energy level than the primary substances not yet emulsified, but already mixed together. The correlations are clarified by the energy diagram (see Fig. 1).

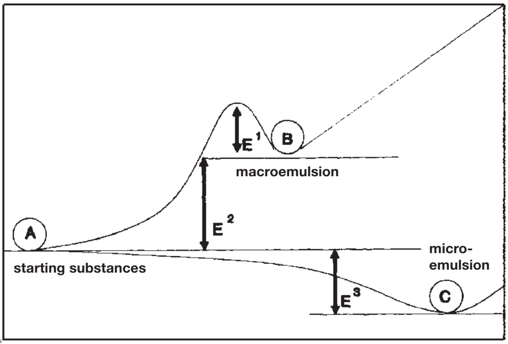


Fig. 1: Energy diagram of the emulsification process.

In Fig. 1 the primary substances already mixed together can be seen on the left. These substances can be transferred into a higher energy level by the addition of energy, where they are then relatively stable. The particles vibrate due to the inner energy available in the system. This vibration can be so strong that the emulsion again sinks to the old, lower energy level, which in practice means emulsion breakage. This is also called statistical fluctuation. It is a different situation for microemulsion: the primary substances move by themselves into a lower energy level almost without an external effect, where they then exist as a stable microemulsion. The emulsification takes place independently. Should the case then arise that the vibrations of the particles go beyond the normal framework, they always revert to the stable form of a microemulsion (according to Agster).

Microemulsions, for example, produce an outstanding soft handle, but the sewability is not noticeably improved. The fact that the particles can penetrate the centre of the yarn due to their size can be considered as an explanation for this, and has the effect that there is not the surface smoothness demanded, but rather an "inner softness" appears.

The soft and pliant surface handle and the excellent sewability of textile substrates finished with polydimethylsiloxanes (Fig. 2) made a significant contribution to their commercial use. Up to then, the novel handle could only approximately be achieved with any other class of chemicals. In the process chemicals sector too, the preparations of polydimethylsiloxane with colloidal silicic acid as highly active defoaming agent systems can no longer be dispensed with.

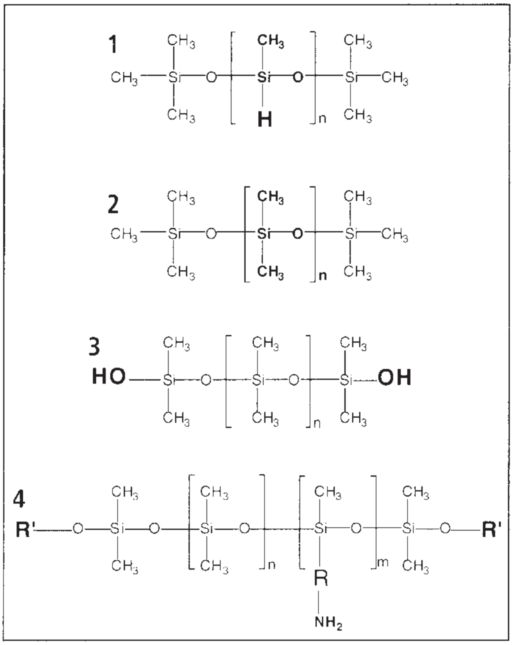


Fig. 2: Especially important silicone types.
1 = polymethyl-H-siloxane; 2 = polydimethylsiloxane;
3 = polydimethylsiloxane with end-positioned OH groups;
4 = aminofunctional polydimethylsiloxane.

New in the period which followed was the introduction of three-dimensional cross-linkable polydimethylsiloxanes with end-position OH groups (Fig. 2). In combination with organic tin catalysts and methylhydrogensiloxane as the cross-linker, highly elastic, wash-fast films could be produced, which became important in the rapidly growing market for leisure products and sportswear. In the coating field too, numerous application possibilities were developed from the solvent and aqueous phase based on OH end group-containing elastomeric silicones.

With the aminofunctional polydimethylsiloxanes, the large silicone producers' polymer chemists were able to improve the softening properties of the classic dimethylsiloxanes through the amino side groups. The familiar smooth, supersoft product handle can be achieved with the classic secondary emulsions produced from it. The same silicone oils, formulated into microemulsions, have a transparent to almost water-clear appearance, as the particle size lies – at > 40 nm – in the zone below the visible light wavelength.

On natural fibres, a filtration effect takes place during the application of classic, large particle macroemulsions. While the finishing liquor water penetrates into the fibre interior, the large silicone particles remain on the fibre and yarn surfaces, producing locally an increased silicone concentration in a kind of ring-shaped coating (Fig. 3). Due to their small size, the microemulsion silicone particles have much greater penetrating powers, and can therefore also penetrate the internal fibrillar structure of natural fibres. The resultant "inner softness" has a completely different handle.

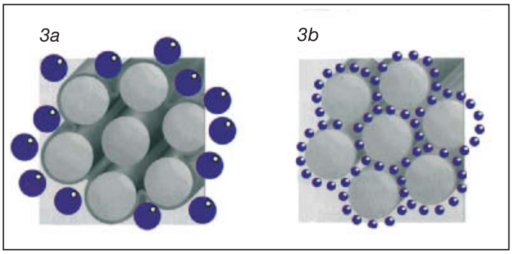


Fig. 3: Method of operation of macro and microemulsions on textiles.
3a = conventional, milky silicone emulsion, particle size > 120 nm, coats fibre/yarn = surface smoothness;
3b = fine particle, transparent silicone emulsion, particle size < 40 nm, penetrates fibre/yarn = inner softness.

Micro-encapsulation is a designation for the encapsulation of finely dispersed, fluid or solid phases by coating with film-forming polymers. With the aid of this micro-encapsulation technique, the most diverse substances can be converted into a dry mass, whose contents become free again as required using thermal, mechanical, chemical or enzymatic action. There are a variety of properties resulting from this, such as:

- conversion of fluids into solids,
- separation of substances reacting with each other,
- controlled release of active substances,
- reduction in the toxicity of products
- improvement in the processability of products,

permitting this technique to penetrate the most varied branches of industry, including the textile finishing industry (dyeing and printing) since its development in the 30s. The micro-encapsulation of water-soluble flame-retardant salts is called the typical application case, in which coating pastes can be added for roller blinds. The capsules only burst open and become active in case of fire and release the antimony- and halogen-free flame-retardant agents. The washing resistance of the finishing is the object of using micro-encapsulation in this case.

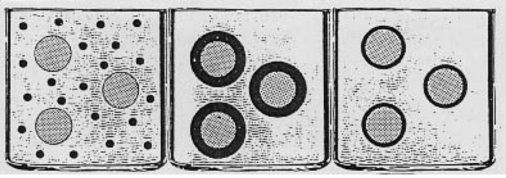


Fig.: Stages in the process of micro-encapsulation. Left: three-phase system; centre: deposit of the polymer protective coat on the raw material; right: fixing of the capsule.

Three non mixable substances are required for the manufacture of micro-capsules: a) the substance to be coated; b) a substance, which forms the coating, and c) a fluid medium, in which the coating takes place. Core material and coating material are found in the fluid substrate phase in a 1st process stage (see Fig.); water-insoluble substances are normally encapsulated in water and water-soluble substances in organic solvents. In the 2nd process stage, the coating material is deposited on the core material, i.e. it is adsorbed on its surface; there are a multitude of techniques covering this, such as emulsification, coacervation, interfacial polymerisation and additional polymerisation, etc. This adsorption is the necessary prerequisite for a technically applicable, effective encapsulation. In the last phase, the coating material should solidify by using thermal treatment, chemical cross-linking or water release.

Microfibres Finest fibrillar filament yarns (filaments) < 1 dtex (Fig. 1). In principle, three methods can be followed for titre refining:

1. Manufacture of microfibres in accordance with “conventional” spin technology and in a titre range from 0.3–1.0 dtex (main focus approx. 0.5–0.7 dtex in the West European market).
2. Manufacture of bicomponent fibres with a matrix/fibril arrangement. The basic aim with these yarns is suede or silk-like items (often also described as “supermicro” due to their fineness). They are still a speciality, due to their fineness, although they have already been on the market for two decades.
3. Titre refining via weight reduction of polyester fibres in the fibre surface. The alkali treatment of pol-

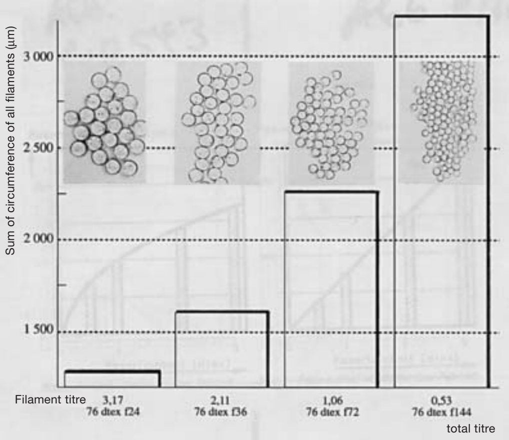


Fig. 1: Comparison in size of the individual filaments of a 76 dtex polyester filament yarn and the dependence of the filament circumference on the filament titres.

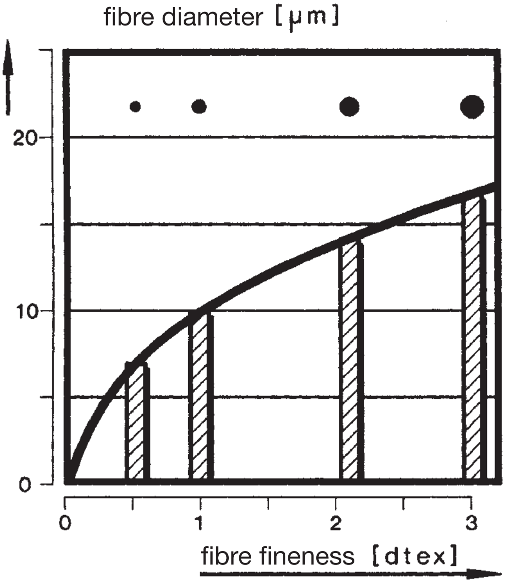


Fig. 2: Fibre diameter and fineness.

yester has been applied for the manufacture of silk-like crêpe fabric from wound up polyester filament yarns since the end of the 70s.

Finer titres increase the suppleness of the fibres, i.e. their flexing strength is extremely low. The size of the filament yarn is also strongly reduced, although the total titre remains the same. The diameter, the length of the fibres, their strength and modulus of elasticity as well as the size of the loading forces are important for mechanical stress and deformation of the fibres in processing. With reference to the fineness, the diameter shows a depressive curve (Fig. 2) corresponding to a root function, while the fibre cross-sectional area behaves linearly to the fibre fineness (Fig. 3).

Finenesses up to 1.0 dtex are recorded in the old and in the meantime withdrawn DIN 60 800. There has, however, not yet been success in establishing an exact definition for finenesses below this. The already prepared DIN 60 001 part 2 has not been published. For this reason, the following classification can only be viewed as a conventional classification for the practice, but not as the established standard.

Classification of man-made fibres according to fineness (see also Fig. 4):

fineness of the individual titre	conventional designation
> 7.0 dtex	coarse fibres
7.0–2.4 dtex	fine fibres (normal fibres)
2.4–1.0 dtex	very fine fibres
1.0–0.3 dtex	microfibres
< 0.3 dtex	supermicrofibres

Fabric made from microfibres: densely beaten microfibre fabrics are produced in parallel to membranes and coating systems. The high density of these fabrics is in particular realised by the fineness of the filament yarns. These fabrics can break down extremely hydrophobically due to a special treatment during the spinning out process. The water repellent effect is supported by application of the non-source synthetic filaments. This freedom from swelling inhibits the closing of the pores of the fabric by the effect of moisture, as is possible in hydrophilic textiles. Yarns made from the finest polyamide or polyester filaments permit fabric designs with up to 7000 filament threads/cm^2, whose superfine spacings allow the transport of water vapour, but prevent the penetration of water drops (Fig. 5). These fabrics are more suitable for the everyday, sport and leisure area, in which no specifically high demands are put on water-proofness and mechanical stability. Their water-proofness is attributed to that of laminates or coatings and diminishes again after care treatments and mechanical action. Application effects such as greasy contaminants, mechanical change, remains of wash-active substances and similar require regular care and additional impregnation, so a low product application, which does not bond the surface, should be carried out.

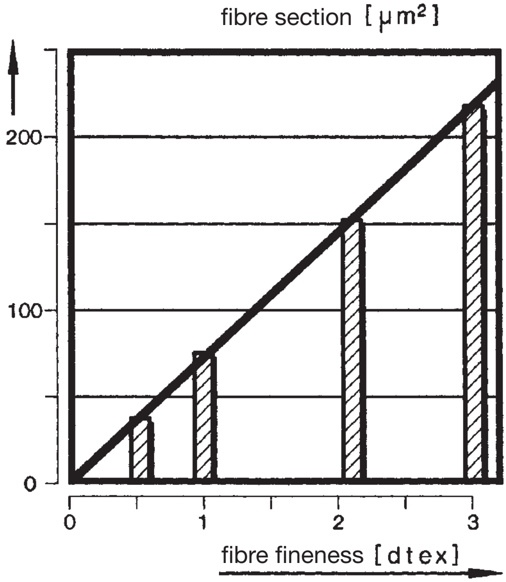


Fig. 3: Fibre section and fineness.

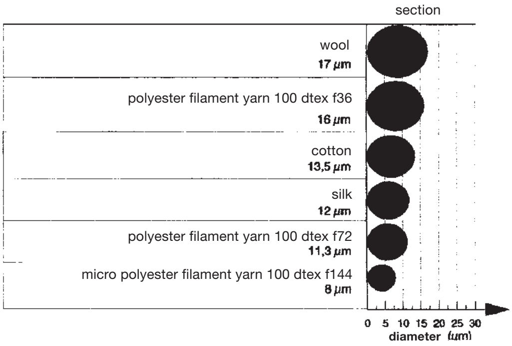


Fig. 4: Comparison of textile fibre diameters.

Microfibre fabrics are particularly suitable for sports clothing, for which functionality is relevant and four primary functions are demanded:

1. Good weatherproofing, e.g. wind-resistance (Fig. 6), is achieved using dense, but microporous fabrics; yarns with a large specific fibre surface area increase density and covering power, but at the same time produce a high porosity in the fabric, which even without coating achieves amazingly good serviceability.
2. Good thermal insulation, heat constancy and wearing comfort are determined by fine fibrillness, light

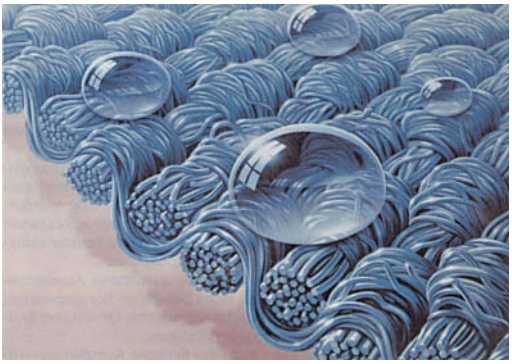


Fig. 5: The micro-fine fabric pores do not allow rain, mist and drizzle droplet, several times larger, to penetrate the fabric; cold bridges are eliminated (source: Hoechst).

Fig. 6: The large number of densely-layered microfilaments keep the wind away; cooling is thus avoided (source: Hoechst).

Fig. 7: Perspiration molecules quickly evaporate through the fabric pores which are thousands of times larger; the body temperature remains stable and the fabric stays dry inside (source: Hoechst).

weight, low moisture absorption, no swelling of fibres, good capillary moisture vapour transmission, softness and smoothness. Air pocket, material thickness and low moisture absorption play a key role in the effectiveness of insulation.

3. Good water vapour transmission (Fig. 7) is achieved using light, shape retaining, double flat knits made of texturized yarns with good capillary water transport capability on the inside and yarns made of water absorbing and water transporting fibres on the outside.
4. Optimum elasticity through selection of the correct yarn type and material design.

Microfibres, development history Microfibres have their origin in bicomponent microfibres. These fibres have a history going back as far as the 50s. The first group of bicomponent fibres appeared on the market around 1960. It had a simple compound structure similar to side-by-side and core/sheath compounds. Since then people have tried to duplicate the bicomponent structure in order to manufacture complicated fibres. Such “multi-layered bicomponent fibres” with more than 5 layers in one fibre had already been developed in 1965. They were split and so provided the first microfibres. Since the start of the 70s, microfibre technology has achieved five great innovations:

– imitation suede (Toray in 1970),
– silk-like materials (Kanebo in 1972),
– super high strength fabrics (Kuraray in 1981),
– 2nd generation artificial leather (Kuraray in 1981),
– high performance cleaning cloths (Kanebo in 1985).

Tab. 1 shows typical imitation suede made from microfibres. The most important and fundamental technologies for microfibres have been developed using these imitation suedes:

– spin technologies for multi-layered bicomponent fibres or spin technologies for fibres made of superfine titres,
– making (weaving, knitting, nonwoven technology),
– splitting techniques for multi-layered bicomponent fibres,

section	polymer	splitting	fineness (dtex)	structure
	PET/PS	dissolving	0,05–0,1	nonwoven fabric
	PET/PA 6	swelling	0,1–0,2	knitted fabric
	PA 6/PS	dissolving	0,005–0,01	nonwoven fabric
	PET/PA 6	mechanical deformation	0,24	loose-woven fabric, nonwoven

Tab. 1: Typical microfibres for imitation suede fabrics (according to Matsui).
PET = polyethylene terphthalate; PS = polystyrene

- surface raising,
- polyurethane impregnation,
- dyeing and finishing.

Imitation suedes are chiefly used for the manufacture of coats, jackets, gloves and upholstered furniture.

The 2nd development stage in the use of microfibres concerns silk-like materials for high-quality outerwear. The market has developed really slowly, but steadily. Tab. 2 shows typical microfibres for silk-like materials.

section	polymer	splitting	fineness (dtex)	remarks
	PET/PA 6	swelling	0,6	
	PET/llP	dissolving	0,2–0,3	mix with a common fibre
	PET/llP	dissolving	–	
	PET/PA 6	mechanical deformation	0,23	
	PET	–	0,1	mix with a common fibre

Tab. 2: Typical microfibres for silky products (according to Matsui).
llp = easily soluble polymer

The 3rd stage in the use of microfibres concerns super high density, water repellent fabrics. Tab. 3 shows microfibres for these fabrics from different manufacturers. They are used in a large selection of high-quality sport and leisure clothing such as coats, down jackets, ski clothing, wind jackets and clothing for anglers. Radial bicomponent fibres, for example, are split using a chemical process for the manufacture of these microfibre products. During this splitting process, the polyamide is strongly swollen and shrunk, while the polyester only shrinks a little.

The 4th development stage in the application of microfibres concerns the 2nd generation of artificial leather using soft surface nap (see Tab. 4).

section	polymer	splitting	fineness (dtex)	remarks
	PET/PA 6	swelling	0,1–0,2	mix with fine filaments
	PET/PA 6	swelling	0,1–0,2	micropile
	PET/PA 6	swelling	0,1–0,2	mix with silky yarn
	PET/PA 6	mechanical deformation	0,23	
	PET			
	PET/PA 6	mechanical deformation	0,2	

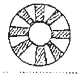
Tab. 3: Typical microfibres for super-high density fabrics (according to Matsui).

section	polymer	splitting	fineness (dtex)	remarks
	PA 6/PS	dissolving	0,001–0,003	for clothing
	PET/PS	dissolving	0,003–0,005	for shoes
	PA 6/PS	dissolving	0,01–0,001	for clothing
	PA 6/llP	dissolving	0,18	for shoes

Tab. 4: Typical microfibres for artificial leather (according to Matsui).

section	polymer	splitting	fineness (dtex)	remarks
	PET/PA 6	swelling	0,1–0,2	for industry and glass
	PET/PA 6	swelling	0,1–0,2	with encapsulated scent substances
	PET/PA 6	mechanical deformation	0,23	
	PET/PS	dissolving	0,05	

Tab. 5: Typical microfibres for high-quality cleaning cloths (according to Matsui).

fibre type	section
radial fibre	
Island in the sea (multi-core)	
radial and hollow fibre	
polymer blend	

Tab. 6: Typical microfibre composite structures (according to Matsui).

The 5th stage in the use of microfibres concerns high performance cleaning cloths. In 1981 Matsui found that microfibres have excellent wiping and cleaning properties. Tab. 5 shows typical microfibres for cleaning cloths from different manufacturers.

Splitting methods for composite fibres, which are used depending on the requirement profile of the microfibres, are chemical resolution, segmentation using mechanical deformation, chemical swelling methods as well as false twist processes (Table 6) (according to Matsui).

Microfibres, dyeing Compared with similar items made from polyester and polyamide yarns of normal finenesses, microfibres show a changed dyeing behaviour. The reason for this is mainly the enlarged fibre surface area. It produces an increased absorption and a greater exhaustion rate of the dyes at the start of the dyeing process, from which levelling problems result. In addition, the changed optics and the enlarged surface area result in an increased dye demand, which is 23 times the demand of classical fibres in microfibres made from polyester and twice the demand in microfibres made from polyamide (Fig. 1). The fastnesses of dyed microfibres can clearly differ from those of classic fibres. So the light fastness in particular may fail less depending on the depth of shade, material and finishing; a pH of the dyeing < 6 produces a deterioration in polyamide microfibres. The same applies for the wet fastnesses, chiefly caused by the increased dye demand and (in polyester fibres) the thermomigration.

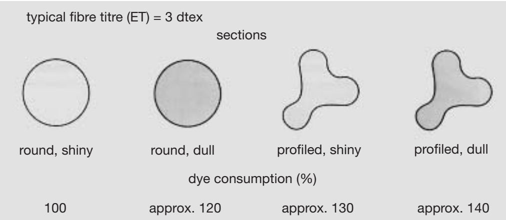


Fig. 1: Effect of the fibre section and the dulling on the dye consumption on polyester microfibres.

A calculation of the dye demand is possible according to Fothergill, if yarns from the same manufacturer or the same substrate are present (see Fig. 2):

$$C_2 = \sqrt{\frac{ET_1}{ET_2}} \cdot C_1$$

C = dye demand,
ET = individual titre.

The equation is only conditionally applicable, as fibre cross-section, delustring, spinning process, dye and similar also have an influence (according to Wiegner).

Microfibres, finishing A prewashing of the textile fabrics is required, as the warp ends are also sized in the field of microfibres. They are washed without tension in wide washing machines with vigorous liquor movement and sieve-drum systems. In special cases (e.g. for severely contaminated materials), the fabric should be treated and/or washed twice in accordance with the dwell process. After treatment, the material should be tested for remaining size residues. This can be carried out in accordance with a method using 1.4-dioxane iodine solution/boric acid. If size residues are established, 32.5% is post-washed before dyeing on the jet machine using 1.5–2 ml/l of caustic soda liquor (38°Bé), afterwards rinsed hot and cold and neutralised. Size residues may result in uneven dyeings, which can only be repaired with great difficulty or not at all. With perfect desizing, the material is dried at 140–150°C after washing. The free shrinking when dyeing the unfixed cloth attains the optimum density of the fabric. It is dyed on jet dyeing systems at high fabric speeds, which should be at least 250 m/min depending on machine type. In dyeings of microfibres, the light fastness of disperse dyes is partially degraded in comparison with normal textile polyester fibres so that a dye selection is required. If a setting process is carried out after dyeing, besides light fastness the dry heat setting fastness is also important.

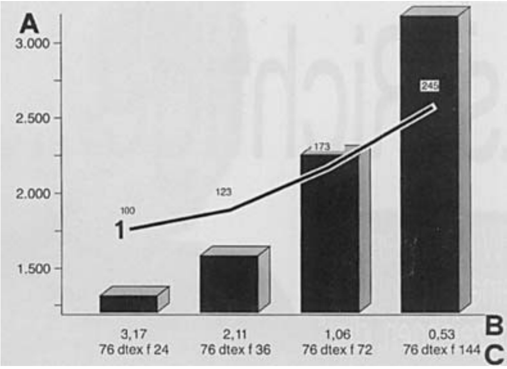


Fig. 2: Dependency of the filament circumference and the dye consumption on the fibre tire in the case of equal overall titre.
A = sum of the circumference of all filaments (mm); B = fibre titre (dtex); C = total titre; 1 = dye consumption (%).

In the re-adjustment of formulae, the dyer should also consider that, in comparison to normal polyester types, microfibres clearly require more dye. This may be between 30–60% depending on fineness. The main reason is the larger surface area of microfibres in comparison to normal coarser types.

A hydrophobic finishing may be carried out after drying. Afterwards it is calendered depending on the desired fabric result. Another post-condensing (post-shrinking) may be carried out on the stenters. The final finishing should be carried out so that the testing of the water impermeability is $\geq$ 500 mm water gauge in accordance with DIN 53 886 after the 5th wash, 3rd percolation.

Sports clothing and rainwear are to a large extent

windtightness, air penetration	10–20 l/m^2/s	0	0
watertightness	50–80 cm WS	up to 3 m WS	over 3 m WS
1st stage	high consumption of fluorene-based chemicals	medium consumption of fluorine-based chemicals	
2nd stage	–	micro-porous coating	film laminates

Tab.: Waterproofing options for microfibres.

manufactured from 100% microfibres (polyester or polyamide). Properties such as water vapour transmission, water impermeability, wind impermeability, but also soft handle and electrostatic properties are important. Fluorine chemicals are used for the water-repellent finishing, as normal silicones can reduce water impermeability via channel formation due to their gliding effect. The Tab. demonstrates the possibilities of water-repellent finishing. Besides the main functional focuses, surface structure is very important in today's fashion trend. Smooth or shifted (crusty, crêpe-like) surfaces may be determined by the pre-treatment and dyeing processes. Sanding and emerizing are either carried out before or after dyeing. The possible finishing operations are demonstrated in the Fig. Items made from or using microfibres are ideally suited to surface treatments due to their specific properties. It should, however, be observed that the fabric should meet certain requirements such as sufficiently high strength.

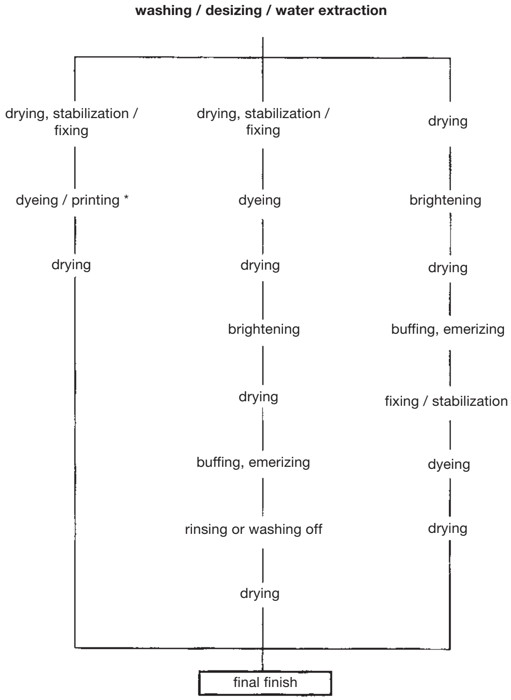


Fig.: Finishing sequence for microfibres (usual method depending on printing process).*

Leisure clothing and light coats are predominantly manufactured from blends of microfibres with cellulose fibres. The demands on wind and water impermeability are less high than for sports wear; softness, wearing comfort and functionality are however imperative. Surface treatments such as sanding or emerizing are the most widespread processes. With regard to the finishing operations, these operations differ only negligibly from those of sports wear. The sanding is normally carried out after dyeing, as the dyeing process may impair the effect on the cellulose part. Products, which do not have an influence on the water-repellent effect or can be washed out easily, should therefore be used as raising finishes.

Blends of microfibres with viscose (women's outerwear) or wool (men and boys' outerwear) are normal in the outerwear sector. Softness, wearing comfort and easy-care properties are the main requirements. While in women's outerwear the handle character should be "supersoft" to silky, soft and cosy is demanded in the men and boys' outerwear. The use of cellulose crosslinking agents cannot be avoided in most cases to achieve easy-care properties. Formaldehyde-free products should therefore be used with the ecology in mind and for wear properties. The quantities used comply with the respective fibre-blending ratio. Mechanical finishing is primarily important in wool blends. Chemical finishing thereby has a supporting effect for handle and volume variations.

In today's trend for casual combination fashion, trousers have a dual function: they are used as both leisure and business clothing. Trouser materials are offered in many blends. Cotton, viscose, linen and wool are the most popular components. The microfibre in the blend serves to improve the handle, wear properties and care properties of natural fibres without impairing their functionality. Emerizing effects are particularly fashionable in men's fashion. As dyeing chiefly takes place after emerizing, a mild "wash-out" effect corresponding to the trend in fashion results from this. Light, flowing qualities are to the fore in women's fashion.

Natural handle and wear comfort are the main qualities in using microfibres in shirts and blouses. Possible surface arrangements are sanding for "peachskin" or "angel's skin" and reduction of pilling and shaping for stylish effects. The finish should serve to emphasise the natural character. Silicon elastomer microemulsions are particularly suited to attaining a soft, dry and cool handle character. As shirts and blouses are manufactured in almost all possible blends, the final finishing should be matched with the blend component.

Napped knitgoods are another range of use for microfibres, which are used both in the leisure and sports sector due to their comfort and their good wearing properties. These fabrics are normally only napped after the dyeing process. While the requirements aim for a pleasant and soft, voluminous handle for leisure fabrics, water repellent properties are also demanded for sports items. This effect is normally produced using fluorine chemicals, as normal silicones result in an oily and less voluminous handle on these items. Easier care results as an additional effect (according to Gysin).

Microfibres, light reflection The total surface area of the fibre lattice or the textile fabric increases exponentially with the falling diameter of individual fibrils and/or with the decreasing titre, especially in finenesses < 1 dtex. A certain proportion of the incidental light is directly reflected by each fibre surface. The reflection of fibres of different finenesses is correspondingly different. This proportion is independent of a possible coloration, but depends on the specific expansion of the surface area. Only the light, which penetrates from the centre of the fibre outwards, is however determined by the light absorbing dyes. The relationship between the light reflected directly from the surface area and the light influenced by the dyeing coming from the centre of the fibre has a determining influence on the shade of colour and depth of shade. Fine fibres with a large reflection surface therefore appear brighter than the coarser fibres dyed with the same amount of dye. This relationship between the light reflected directly and the light returning from the centre of the fibre is altered with increasing depth of shade in favour of the surface reflection, as with increasing depth of shade less and less light is reflected back from the centre of the fibre. Conversely this means that it is more difficult to achieve deeper dyeings the finer the fibre and consequently the larger is the surface reflection.

Furthermore the optical impression of a textile fabric is strongly dependent on surface structure. If it is formed from fine fibres and is smooth, it has a rather mirror-like effect and reflects more light. Dyeing has a brighter effect, if a configuration is made from coarser fibres. The light is repeatedly absorbed in the larger spaces; the more open surface area has a darker effect. This effect also becomes greater with increasing depth of shade. So if textiles dyed with the same amount of dye appear brighter in finer fibres, a higher amount of dye is required in order to achieve equally deep dyeings.

Besides the diameter of a fibre, its cross-sectional form, its degree of delustring and its processing into fine or coarse threads and into smooth or textured yarns are also involved in the optical impression of a dyed textile material. These factors are not specific to microfibres. So a square cross-section, fibre pigmentation as well as crimping in the texturing process ensure higher light reflection, which likewise require higher amounts of dye for covering.

As a second phenomenon, the enlarged surface area produces a negative influence on the light fastness. Different yarn finenesses, degrees of delustring and cross-sectional forms have been known to be the cause of differences in light fastness for a long time. If the normal titres are shifted towards micro-finenesses, the quantity of outer fibre parts exposed to the light is increased by the denser, smoother fabric surface area. More surface is exposed to the light, which is interpreted as a bad light fastness mark because of dye destruction. The disperse dyes are however actually (provided they are the same polymer as the fibre) no less light fast in finer fibres than in coarser ones.

Microfibril composite fibre → Imitation suede.

Microfibril reconstitution Keratins consist of → Intermediate filaments, which are imbedded as a fraction lacking in sulphur in sulphur-rich surrounding proteins. This biological composite can only be fractionated by splitting (reducing) the cystine bridges beforehand and blocking the resulting cysteine. The protein structure denatures in this way because the higher protein structures (hierarchy) become lost. Both main fractions can be separated and are theoretically classified as follows:

a) microfibrils or intermediate filaments → SCMK-A fraction (s-carboxymethyl keratene A or B);
b) matrix → SCMK-B fraction.

A direct proof of this classification would exist if the fractions could be reaggregated individually, by recombining the disulphide bridges so that an analogy of the original components in untreated wool to the components obtained in vitro by reconstruction, would be possible via common morphological characteristics (comparison of electron microscopic photographs). The associated chemistry is designed for the separation operation and in the reconstitution as shown in the Figure.

The German Wool Research Institute has succeeded in reconstituting 10 nm of keratin intermediate filaments made of microfibrillar proteins lacking in sulphur, which exist in the unprotected thiol form. As the reaggregation tests were often carried out under the same conditions, the artefacts observed in the intermediate filaments by an electron microscope are of no concern. Furthermore it can be assumed that the intermediate filaments reconstituted in vitro are structurally identical to native intermediate filaments, as the primary material is pure microfibrillar protein, which was not isolated by partial enzymatic degradation of wool, but was chemically separated from the matrix proteins (according to van de Löcht).

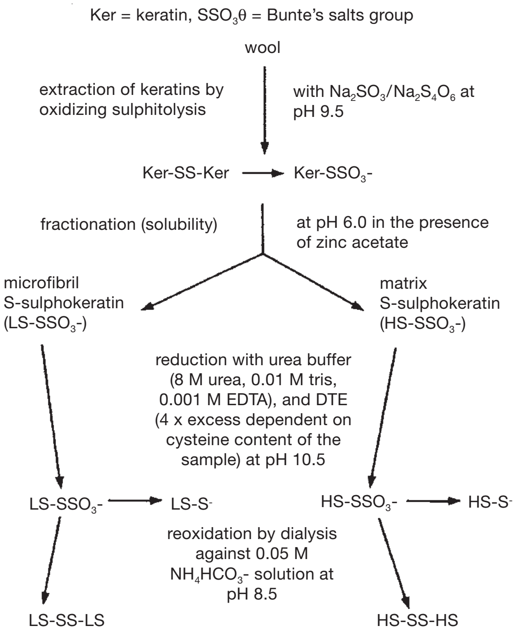


Fig.: Diagram showing the process for the isolation of low-sulphur (LS) and high-sulphur (HS) wool proteins in disulphide form (SS).

Microfibrils → Individual fibrils.

Microflotation Process for the cleaning of waste waters. Removes approx. 99% solids and clears away approx. 90% phosphates.

Micro-Length-Stretching (MLS, MS). → ML Process.

Micron (My, M), 1 M = 10^{-6}m. Unit of measurement previously used, normally for coarser inner and outer fibre structures, also for colloidal states, coarser emulsions, etc. Today replaced in the metric system by µm (micrometre).

Micronaire value A dimensionless number characterising the fineness of cotton fibre. Additionally dependent on the maturity index, i.e. cotton with the same fineness, but different maturity index shows a different micronaire value. The principle of the micronaire measurement is based on the resistance which a loose fibre stock offers to a defined air stream. The finer the fibres, the greater is their total surface area for the same weight, the greater the air resistance and the lower the associated micronaire value. The value is defined on the Sheffield 60 600 micronaire device (standard device). All different devices must be calibrated to it. The micronaire value scale ranges from 2.3–8.0 (corresponding air stream of 9.9 to 60.6 l/min).

Microorganisms (→ Microbes), microbiology is the field of knowledge of small organisms (microorganisms) and consequently a branch of biology. As an example of special working methods, microbiology applies the determination of the germ number, the growing of bacteria and fungal cultures, and microscopy. Microbiology can be subdivided according to organisms with which it deals: bacteriology (bacteria, actinomycetes), algology (algae) and mycology (fungi). Another division option exists in applied microbiology depending on topics: e.g. medical microbiology, technical microbiology, food microbiology, soil microbiology and waste water microbiology. The microbiologist in textile materials testing deals with textile products or (generally) with problems in the textiles industry from the raw material via the finished product and its transportation to its wanted or unwanted destruction. As a biologist he has to rely on cooperation with textile experts. The textile material can be integrated into the human/microorganism correlation (see Tab.) because both bacteria and textiles operate close to the skin.

Microorganisms do not absorb their food via an internal digestive tract like animals and humans. They release chemicals and enzymes in the substrate thereby decomposing potential food outside their cell and absorb certain materials (building and working materials). The metabolism of microorganisms is dependent on water. Every metabolic action, even the depositing of chemicals (excretory products) and enzymes (exoenzymes) to the environment, only occurs with sufficient moisture. There are some special moulds, with an equilibrium material moisture of 65% relative humidity which is sufficient for their growth. In practice, a humidity of more than 80% aggravates the mould problem. With the corresponding humidity, potential nutrients (e.g. natural textile fibres, textile auxiliaries) already sprout numerous moulds, existing as spores in the ambient air into visible colonies and result in mould marks. With even higher humidity, e.g. in aqueous emulsions, numerous yeasts and bacteria also find sufficient moisture for growth. If there is enough moisture, microorganisms still require building and working materials (energy) for mass reproduction. The important destroyers amongst microorganisms in the textile industry (fungi, certain bacteria, Fig. 1) exploit organic substances (e.g. cellulose, keratin, softeners, starch, dust, etc.) both as energy and as a source of building material. From this, it follows that microorganisms can also grow on materials which are not nutrients in themselves. Surface dust contains sufficient organic material for growth. If such growth appears, the excretory products formed from this can also influence and destroy non-nutrients.

Temperature plays an important role in the growth of microorganisms. It is slower at low temperatures than at slightly higher temperatures. While growth is also possible at refrigerator temperatures, there is an upper limit: most destroyers cannot grow above 50–

→	*Person (skin)*	*Microorganism*	*Textile (woven fabric, knitted fabric, fleece, fibre)*	*Antimicrobial active substance*
Person (skin)		*Defence (skin's acidic protection)*	*Wear, soiling, washing, dry cleaning*	*Selection of less toxic, more skin-friendly substances, decomposition*
Microorganism	*Infection, eczema formation, decomposition of perspiration*	*Equilibrium on healthy skin*	*Decomopsition of natural fibres, resistance of the most important synthetic fibres*	*Inactivation by enzymes of the microorganisms, resistance*
Textile (woven fabric, knitted fabric, fleece, fibre)	*Protection, properties, adsorption of perspiration, skin's oils*	*Nutiritive substratum: cellulosic fibres, polyvinyl alcohol fibres, wools*	*Alteration of the textile properties and the behaviour towards microbes due to fibre mixtures, contact infection*	*Adsorption, minimization of effect*
Antimicrobial active substance	*Allergy, skin-friendliness*	*Growth restriction, germicide*	*Alteration of antimicrobial properties, protection from rotting, handle effect, alteration of the absorption and other properties (creasing behaviour, strength), disinfection*	*Increase in effect, minimization of effect*

Tab.: Microorganic interactions in the person/textile fabric system.

60°C. Some archaebacteria in extreme habitats are exceptions. Far higher temperatures are necessary to destroy microorganisms: dry heat of 160°C with an exposure time of hours or wet heat (water vapour) of 120°C in approx. 150 minutes. Spores are particularly resistant to heat distribution in fungi and bacteria.

I. Hygiene: the → Antimicrobial finishes of textiles include mildew-resistant finish, decomposition protection, hygienic finish (hygiene related textile finishing), the impeding and temporary prevention of mould marks (storage protection). The corresponding antimicrobes and addition finishings should be selected dependent upon the requirements of the protected textile (operating area, use, etc.). The disinfection of clothing is important as protection against infection by destructive pathogenic microorganisms in dry-cleaning. In hospital laundries, the disinfectants used in wash liquor must make bacteria, fungi or viruses harmless. The proteins in the cell wall and the cytoplasmic membrane are denatured by disinfectants as well as by the effect of temperature, i.e. the protein coagulates (clots) irreversibly.

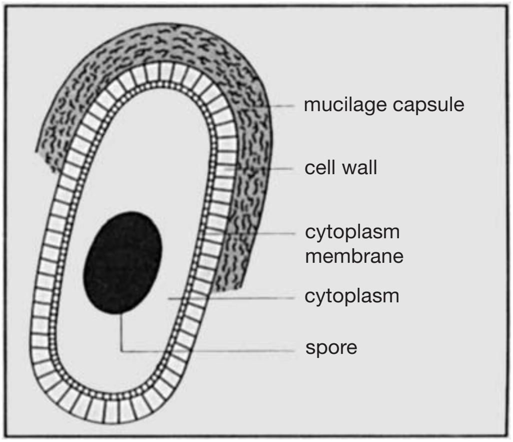


Fig. 1: Diagram showing bacterial structure.

II. Waste disposal: in working with microorganisms in activated sludge in →: Waste water treatment plants, it may be necessary to increase certain types of microorganisms. The search for microorganisms for the cleavage of compounds, which are difficult to decompose, may be carried out in accordance with two fundamentally different methods: continuous growing and vibration tests in charge operation. The latter concerns a sampling method with all its disadvantages: positive results are lucky, in which the chance of a hit with the number of tested microorganisms or the variety of inoculation materials used increases. It is, however, because of lack of available time not normally possible to exert selective pressure in the direction of the desired organism. Continuous growth can be cultivated (Fig. 2) to force a decomposition under aerobic conditions. A blend culture as complex as possible is thereby culti-

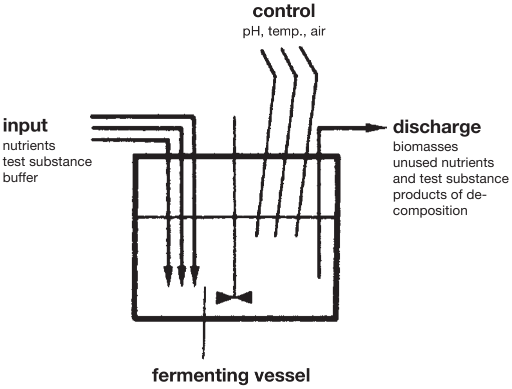


Fig. 2: Diagram showing continuous breeding of microorganisms.

vated over many generations and exposed to the compound to be decomposed. A compound is fed as a nutrient from which the culture can live. If this has a structural similarity to the test substance, the possibility exists that certain mutants can be adjusted to the decomposition of the latter. If the quantity of the nutrient is then reduced and limits growth, a selective pressure exists for mutants; i.e. those microorganisms, which may also decompose the test substance, have a growth advantage. There are also microorganisms, which live under oxygen expulsion, i.e. under anaerobic conditions. For denitrification, for example, reducing substances must be catalysed by enzymes, which come from bacteria. Finally microorganisms play an important role in waste dumps by causing decomposition. Certain types of finishing processes can thereby be toxins for the decomposing bacteria.

III. Fibre decomposition: the following are open to attack from microorganisms, if special preparations were not taken for their protection: wool, animal hairs, silk (somewhat more resistant), man-made fibres on a protein basis, vegetable fibres to a different degree, man-made fibres on a cellulose basis.

Man-made fibres on a synthetic basis such as polyamide, acrylic, polyester, polyvinyl and polyethylene fibres as well as copolymers made from these substances are more resistant to microorganisms. The following series was drawn up for the relative decomposition resistance of fishing tackle made from vegetable spun materials: flax → hemp → cotton → sisal → manila, whereby flax is decomposed most rapidly and sisal and manila most slowly.

The so-called skin and hair fungi mainly occur as wool-destroying fungi; there are predominantly such hyphomycetes in vegetable fibres, which are summarised by the trivial name “moulds”. They belong to a subdivision of the hyphomycetes, the so-called “eumycetes”. These microorganisms which cause the destruction of textiles can be found everywhere. Their spores can even be found in airborne dust. Their appearance is therefore described as “ubiquitous”. They are predominantly found in the earth’s crust and the bacterial content is therefore called “earth’s bacilli” or “earth’s bacteria”.

Even if microorganisms are not in a position to decompose man-made fibres, which are relatively resistant to bacteria and moulds, but does not prevent the bacteria and moulds and their spores from settling on these textiles and remaining viable. They can nevertheless proliferate substantially in the presence of a finish based on natural materials and mildew stains develop. Thus man-made fibres do not have any bactericidal or bacteriostatic and/or fungicidal or fungiostatic effect. They do not provide any culture media for bacteria either, if they are free of such finishes.

IV. Testing: in the → Soil burial enzyme test (decomposition test, mineral decay test) a test stripe of suitable size is used for the testing of tensile strength in germ-rich garden soil. The requirements of the soil mixture to be used is particularly variable. However, it is normal for all requirements that a finished test fabric made from a non decay resistant cotton should be totally decomposed in the burial period. It is more useful to standardise this control fabric than to stipulate a particular composition of the soil because the latter can only be maintained with difficulty. Therefore it pays to control of the activity of the test soil. The vessel, in which the test stripes are buried, should not be completely impermeable to air. According to all methods, a possible attack of the textiles by the microorganisms present in the soil should be retested by means of tearing tests and the designs new to the factory rechecked. If the drop in resistance is below 20% for a given period, the sample is normally regarded as sufficiently decay resistant (rot resistant or rotting resistant). It is customary in practice to extend the test to 4 or 6 weeks for textiles in particularly high demand (→ Rottability of textiles).

Good decomposition of cellulose fabric, which is demanded as a control material in various tests, cannot be considered as a comprehensive guarantee of good bacterial activity. The optimum humidities of the different destroyers present in the soil are too diverse for a defined humidity; both cellulose degradation caused by (aerobic) fungi and artificial leather degradation caused by bacteria require high humidity as an extreme substrate to be able to proceed equally optimally. For these reasons, the TEGEWA companies (loose interest cooperative of textile auxiliary competitors) is busy with two standard projects (as at August 1991):

- model standard to DIN 53 933 “determination of the resistance of cellulose containing textiles to microorganisms (soil burial test), part 1: test of a decay-

retardant finishing". After supplementary combined tests, the soil humidity was re-established and the implementation of the test altered, so that part 1 of the standard could be completed and is presently a yellow print. The "determination of the extended resistance of decay-retardant finishing" has been tackled in a combined test as part 2 of DIN 53 933.
- DIN 53 931 "determination of the resistance of textiles to moulds".

The microbiological textile test is an area with few internationally standardised methods due to the very specific form of the question. Numerous tests exist, which can be easily adapted to the current question. More extensive agreement in the acceptance of standard tests however exists in the degradability test of washing chemicals as well as other textile auxiliaries. The easy adaptability of methods is accompanied by the fact that results from different test cases may diverge as a result of small differences. Standardisation results in the fact that the differences are reduced and the degree of freedom in a test is reduced. Specialised microbiological knowledge also enables near-practice tests to be carried out for specific questions. In quality assurance tests, a selection should be made because of the wealth of possible tests. The support of several questions is thereby recommended: if both the bacteria and the mould and decay resistance are good, the forecast of microbial resistance can be made with greater certainty. In every discussion about preservation in the textile field it is important to know under which conditions microorganisms can grow. Dry storage is the safest preventive material protection against microbial destruction. If this cannot be implemented, an antimicrobial finishing as wash-resistant as possible can guarantee protection. A microbiological check of such measures, besides confirmation of existing protective agents, simultaneously allows the safeguarding of sufficient effect against test organisms or practice germs. In order not to use the antimicrobially effective materials in a way dangerous to the environment, besides clarifying compatibility for human health, the influence on the environment should also be given greater consideration (according to Nopitsch as well as Meyer, Raschle and Kuhlmann).

Micropore finishing Process in the finishing sequence to make films and coated textiles (artificial leather) additionally permeable to air and water vapour (sweat) but also keeps out heavy rain. Method of operation on layer starches of up to approx. 0.7 mm using electron beam bombardment, whereby up to 1 million micropores are produced per square metre. Polyacrylate, polybutadiene, polyurethane and certain polyvinyl chloride coatings and laminates are particularly suitable. Already manufactured textile materials are not suitable for this process.

Microporous coatings So-called "breathable" properties such as → Water vapour transmission and waterproofing should be achieved. This is possible using several processes:

I. Foam coating: porous structures were already being produced by foaming in 1950. Firstly, relatively stiff, non-breathing materials were developed, however. Foam coating in the fashionable, leather-like field achieved the breakthrough, where foam layers are provided with a top film. The foams can be manufactured in accordance with mechanical or chemical principles. The foaming process has a considerable effect on the foam structure and thereby on water vapour transmission. So, for example, thin films producable by the use of solvents are considerably "more breathable" than thicker ones made by mechanical foaming. Ecologically advantageous, purely aqueous systems have meanwhile also appeared. The foam layer produced when drying is usually condensed by the use of calenders and re-waterproofed or given a finishing lacquer (Fig. 1). This is absolutely essential, as the pores are somewhat larger than those of the remaining poromerics (15–50 μm) and therefore have relatively poor water impermeability. The number of pores is approx. 500 000 per cm^2.

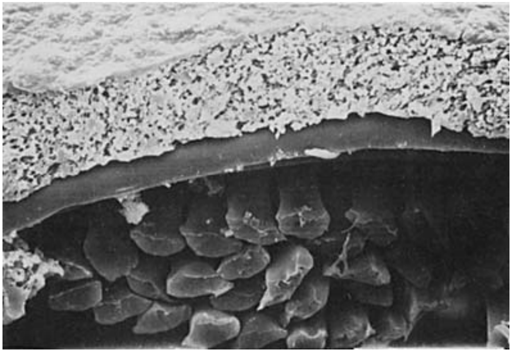


Fig. 1: Microporous fabric coating in section.

II. Coagulation process: microscopic pores are produced by controlled microphase separation, based on direct modification of polymer compatibility. Products manufactured by "coagulation" (precipitation, clotting) are distinguished by special softness and textile characteristics, unlike any other coating processes (Fig. 2). Three fundamental coagulation methods currently exist:
- DMF coagulation,
- thermo or evaporation coagulation,
- acid coagulation.

The sponge-like microporous coating film shows a structure connected with 0.2–0.3 μm pore sizes, which ensure water vapour transport as air conditioning channels. A "vapour starvation" of the coating paste should be prevented in the coating, as otherwise a more compact, non water vapour transmittable film is produced.

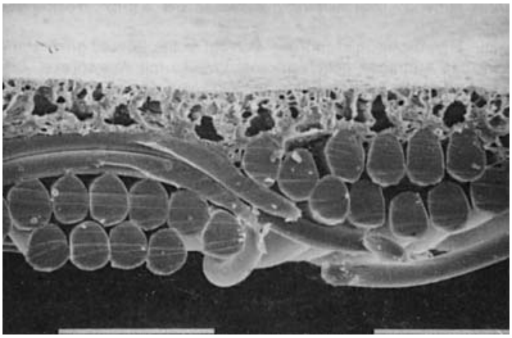


Fig. 2: Coating by the DMF coagulation process.

As a hydrophilic surface develops, using the polyurethanes normally applied, the coatings can be provided with a closed top film, which increases water impermeability. This top film thereby prevents the contamination of the coating from soiling and pore clogging.

a) DMF coagulation has been used since 1960 and is therefore the oldest process. Refined and transposable to other solvents, it is the most significant manufacturing method for microporous artificial leather (Fig. 2). Coagulation is based on the solubility of the polyurethane solvent DMF (dimethyl formamide) in water (Fig. 3), against which polyurethane is completely insoluble in water. The DMF is extracted in the coagulation bath by the water in the bath. A change in the solvent takes place by using the non-solvent, i.e. the solvent is successively extracted from the polyurethane while the polymer layer is increased by the use of water and the solubility of the polyurethane portion in the layer thereby diminishes. Finally precipitation and complete coagulation of the polymer occurs on the substrate. The plastic is combined to form a fluffy layer with a dense microporous structure. DMF residues should be removed in wash baths and rinsings, as otherwise they represent a risk to the cell structure during drying. Recovery of the DMF by means of a distillation plant is absolutely essential from an economic and ecological point of view. The process can be adapted to the desired targets using different solvent combinations or variations of the polymer system. The adjustment of the pore size and structure depends on:

- polyurethane concentration,
- solvent/precipitant ratio,
- temperature,
- other additives.

All parameters require extreme precision. It is a costly process, in which UV stabilisation and pigmentation of the polyurethane pastes are difficult. “Breathability” clearly exists in these materials, but the combination of water vapour transmission and absolute water impermeability demanded cannot be so easily achieved. The conflict is alleviated through the use of polyurethanes with hydrophobic elements. Another possibility is additional fluorocarbon finishing. Meanwhile polyamides from Japan capable of coagulating have also become well known.

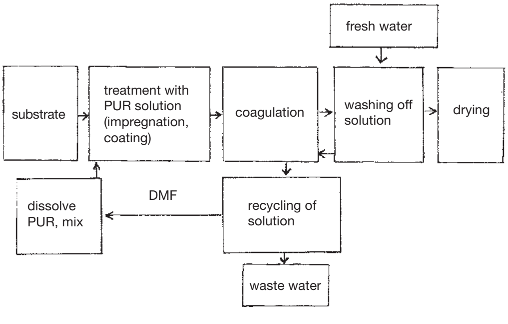


Fig. 3: DMF coagulation process.

b) Thermo and/or evaporation coagulation require lower machine investment than wet coagulation, as work can take place at the normal solvent coating plants and no DMF sewage is produced. Polyurethane is dissolved in an organic solvent and modified by a defined allowance of water and special additions so that a stable, easy to spread paste is produced in the form of a water-in-oil emulsion. The solvent is selected so that it firstly evaporates during drying. Through this selective evaporation, there is a steady decrease in concentration of the solvent and an increase in the concentration of the water. Finally the point is reached at which the polyurethane precipitates in a solid form under the formation of microporous structures from the aqueous medium. The water also only evaporates in the second drying phase. A partial temperature adjustment considerably alleviates the fractional evaporation. Long drying channels with at least three temperature zones allow the coagulation to be controlled by temperature and operational speed. As for all drying processes of polyurethane products, a temperature of 170°C should not be exceeded in order to prevent melting of the pores and thus their bonding. The structure of the dry coagulate ideally has finer cells than those of the wet coagulate. Individual item groups produce films of 25–50 μm thickness via different processes. The paste preparation, which requires the most meticulous care with regard to recipe, operational result and stirring intensity, needs special attention. An important parameter is the proportion of water in the formula, whose quantity is determined by microporosity. Referring to the polyurethane solution, the proportion of water is 40–70% so that the pore structure of such products varies greatly. By the increased addition of the non-dissolving proportion, the water vapour transmission can be increased by a certain amount. Further solvent addition does not however have an effect on porosity. Viscosity control of the coating paste is possible via water and/or solvent addition.

c) Acid polyurethane dispersions which can be coagulated, and which can be applied without solvent addition in accordance with conventional processes and which achieve similar results from the solvent coagulation, have existed since 1984. The polymers from these dispersions contain solubility switching groups, and have been converted into salts and lose their effect due to acidification. This acidification is the step, which triggers coagulation. It is not a gradual concentration shift as in DMF or evaporation systems, but a spontaneous coagulation based on the ion reaction. The products manufactured according to the acid coagulation process, show a remarkable water vapour transmission, but currently still unsatisfactory water impermeability, as coarse coagulation structures are produced. With increasing coating starch, water vapour transmission and water impermeability run contrary to each other This is the reason why a later water-repellent finishing is indispensable. This process is restricted to relatively open pore or voluminous substrates, which allow a satisfactory deposit of the coagulate. Furthermore no transparent films are produced. The relatively young acid coagulation process is still at the start of its development and can certainly be further consolidated.

III. Polymerisation accompanying pore structuring: According to this process of applied pastes, dispersions or solutions are applied, which first of all contain prepolymers and react to form microporous structures after application. The pore structure resembles coagulation porometrics. In this process, a solution of oligomers, monomers and photo initiators is applied. The relatively low molecular polymers, polymerise in seconds with their highly reactive functional groups using ultraviolet irradiation or electron beam bombardment. These are then no longer soluble in the solvent used and microporous structures are formed. The use of conventional apparatus, the versatile chemistry and high production speeds (approx. 100 times higher than in coagulation processes) allow the manufacture of inexpensive products. Another advantage is the usability of numerous plastics such as polyurethanes, polyacrylates and polyesters. The adhesion between substrate and monomer and/or polymer has a positive effect in the electron beam induced polymerisation reactions. A liquid monomer or oligomer surrounds the fibre better than a polymer dispersion, whereby the monomer can be adapted to the substrate more easily during the warp growth.

IV. Compact hydrophilic systems: new types of functional polymer systems with a sequential molecular structure combine the contrary requirements for water vapour transport and watert impermeability. In contrast to the microscopic dilution, in which microscopic pores are produced, a molecular dilution takes place in the polymer morphology. A polymer structure, e.g. in the form of a hydrophobic polymer matrix with hydrophilic channels, allows a high water vapour transmission, whereby the compact surface area guarantees water impermeability. The polymer chemistry opens up a broad spectrum through which the molecular combination of actually incompatible segments is possible. The principle of water vapour transport via complex molecular mechanisms has already been used for medical purposes, e.g. dialysis. As only certain hydrophilic polymers are in a position to transport water vapour in this way, only polyesters and polyurethanes are currently used. Their permeability is a fundamental material property and dependent on the diffusion coefficient and the solubility in water vapour. The diffusion coefficient is determined by the free volume of the polymer as a molecular parameter; the solubility is however dependent on the polarity, i.e. the functional groups. Polymers with different water absorption power and different swelling behaviour are available in the choice of suitable structural elements. The transport mechanism (Fig. 4) should be understood so that water vapour molecules landing on the hydrophilic surface are absorbed via hydrophilic polymer components. These may form weak bonds with the water vapour molecules and facilitate a diffusion along the molecule chain.

The direction of movement of the molecules is dependent on their concentration and speed. The higher the vapour pressure gradient, i.e. the moister and warmer one side is, the more the movement is promoted to the other side. Rising humidity increases the number of molecules which occur and increasing temperature increases their speed. The direction of move-

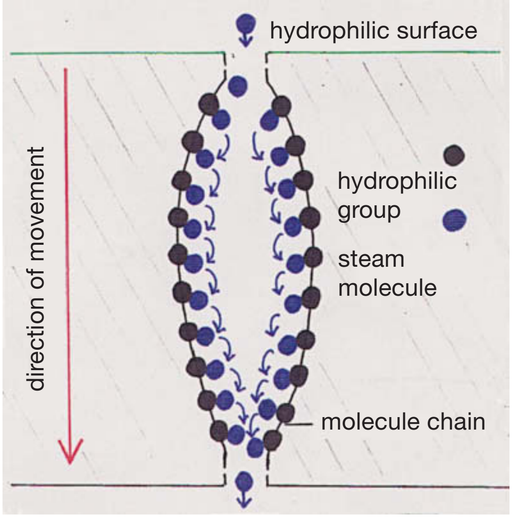


Fig. 4: Molecular steam transfer.

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ment can be promoted by a specific substrate structure; for example, coating strokes are structured so that their hydrophilic character is diminished from the absorbing to the emitting surface. The temperature mechanism does not allow any limitless use, as a reduction in operation may result from temperature and humidity ratios. The hydrophilic layers may be blocked by constant rain and prevent absorption of vapour or condensed liquid. This fall in the vapour pressure difference deteriorates the water vapour transmission on the one hand and increases the diffusion coefficient with the water content on the other. Swollen hydrophilic membranes transport more water vapour in a unit of time. The reduction in the partial pressure difference can therefore be compensated by the increase in diffusion speed.

a) Compact hydrophilic membranes: as with microporous membranes, the compact hydrophilic membranes can also be processed in a variety of ways. Laminates with top cloth, lining fabric or subcarriers permit numerous varieties of items. The polyester membrane from the firm of Akzo/Enka has been known in the market under the name Sympatex since 1984. Water vapour transport via the free hydrophilic groups of polyester molecule chains proceeds through the closed surface. The approx. 15 µm strong membrane is distinguished by an excellent watert impermeability of more than a 10 m water gauge due to its compact surface area and its functionality is not reduced by soiling to the extent as is the case for porous substrates. There are currently also hydrophilic compact membranes made from polyurethanes.

b) Compact hydrophilic coatings: the hydrophilic coating is the latest development in the field of “breathable” materials; it externally resembles the classic compact coating. Its hydrophilic molecule groups, e.g. polyvinyl alcohol or polyethylene oxide, facilitate water vapour transport through the intermolecular pores – the finest pores, which are set in the molecular structure. Dissolved polyurethane systems, which guarantee a good water impermeability in 30–45 g/m^2 of additive, are normally used. The water vapour transport of such systems is often inferior to that of the microporous coating, but individual manufacturers are already promising far better results. The polyurethane coating Witcoflex 971 from the firm Shirley-Baxenden promises a 50 times higher water vapour transmission than average microporous coatings. Other “breathable” polyurethane coatings are also possible with the Impraperm brands from Bayer AG, products from the Dutch company Stahl or the Belgian firm UCB. These compact films are often used as a top layer in a microporous coating in order to construct an absolute water permeability. Mostly thin films of 5–8 g/m^2 are applied. This strength should not be exceeded, as the water vapour transmission of the hydrophilic coating varies inversely proportional to the layer thickness. The layer thickness determines the density gradients of the material and thereby the rate of diffusion in these asymmetric coatings, i.e. a layer as thin as possible with molecular pores, which ensure water vapour diffusion and a porous substrate with macroscopic pores, permits rapid water vapour permeation. Surface dirt or detergents do not impair the strong, usually abrasion resistant coatings, as no pores can block up. Pump effects, as in macroporous systems, are not apparent and the hydrophilic polymers prevent an excessive formation of condensate through their “stepping stones”.

Microporous membranes The most well known is the Gore-Tex foil from the firm Gore, which has been known as an innovator in the field of “breathable” materials since the 70s. → Gore-Tex is produced by the drawing of partial crystalline polymer films made of polytetrafluoroethylene (PTFE), whose crystalline fibrils are separated in the stretching process under formation of microscopic pores. This thin membrane (approx. 25 µm) can be laminated on carrier textiles and used in the form of multi-layered laminates. The different designs may differ greatly in handle, case, function and area of application. The watertightness of such laminates is not problematic, though the laminate construction significantly determines water vapour transport. In particular the top cloth properties can, for example, reduce water vapour transmission by swelling and subsequent closing of the textile pores. The PTFE used, also known as teflon, provides a particularly hydrophobic surface, which supports water resistance and itself shows excellent water vapour transmission values. The evenly combined micropores (Ø approx. 0.2 µm) are approx. 500 times smaller than the finest mist droplets and 670 times larger than water vapour molecules. The proportion of pores is approx. 82%; that is approx. 1.4 billion pores per cm^2 so that active water vapour transport is guaranteed.

The use of membranes requires new operating processes, which give rise to additional costs. Strict guidelines, which are necessary to prevent damage to the membrane and subsequent leakage, should be observed especially in the seam processing. Their use permits high-tech functionality without influencing classic textile properties in an acceptable way.

The firm Gelman Sciences is promoting its microporous membrane Repel with properties similar to the Gore-Tex film, but at a considerably lower price. This “breathable” membrane (2 µm) contains approx. 1.7 billion pores per cm^2 and costs ca. a tenth compared with other membranes. This can be put down to low cost manufacturing. Other microporous membranes are the polyurethane membrane Porelle from the firm Porvair and Thintech, a membrane from the company 3M provided with an additional hydrophilic impregnation, as well as Sympatex (Akzo). → Microporous coatings.

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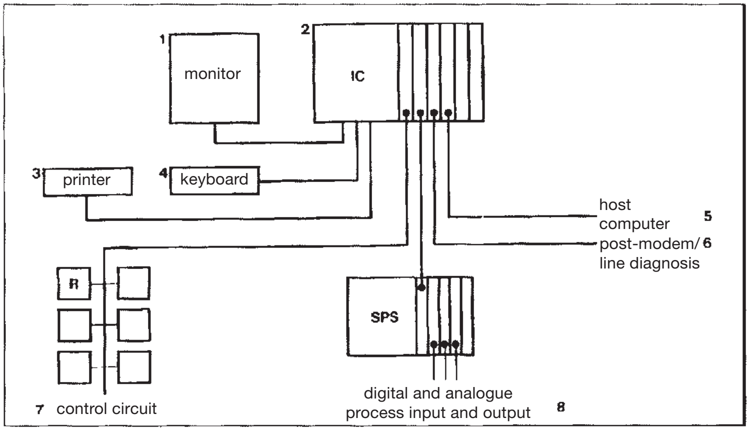


Fig. 1: Process automation of continuous plant, hardware system. 1 = monitor; 2 = industrial computer; 3 = printer; 4 = keyboard; 5 = host computer; 6 = post-modem/line diagnosis; 7 = control circuit; 8 = digital and analogue process input and output.

open or closed control circuit) important functions in the operation of a finishing plant or finishing machine. The hardware is divided into clearly defined modules (Fig. 1).

An industrial computer (IC) manages the process and fabric data, and exchanges data with other EDP systems. Storage Programmable Controls (SPC) are used at process measurement and control level. The regulating functions can be executed by software blocks or by interfacial controls. Stand-alone controls have the advantage that during computer malfunctions processing can continue using manually adjusted desired values. The SPC is equipped with digital and analogue cards in order to be able to issue the necessary control commands and receive process signals. The control information is generated in the IC from the fabric and process data and the operating mode (preparation/production) and handed over for implementation to the SPC and the controllers. The screens are connected to the computers, on which the machine operator observes the process and controls program execution. He/she inputs operator commands (Fig. 2) via the keyboard. The printer is used for the output of the production protocols and fault signals. This hardware must be supplied with appropriate software. A corresponding menu is set via function keys for the purpose of individual program execution. The process observer sees on the screen which tasks are available for the process and selects the next task in view of the information schedule and technological conditions. The data is automatically inserted in the mask “prepare next task”. The formulation of the process and the calculated liquor batch volume are printed out. Preparation processes are started and changes in process initiated from the mask “prepare next task”. The IC generates the control information from the fabric and process data and operator instruction (preparation/production/process change) and passes it for execution to the process measurement and control level.

Interactive programs lead the user in the interactive mode; he/she requires neither programming knowledge nor encoding lists. The consistent use of the menu technique alleviates the operation as well as the generation, management and running of the programs and permits adaptation of the control to the apparatus. By pressing

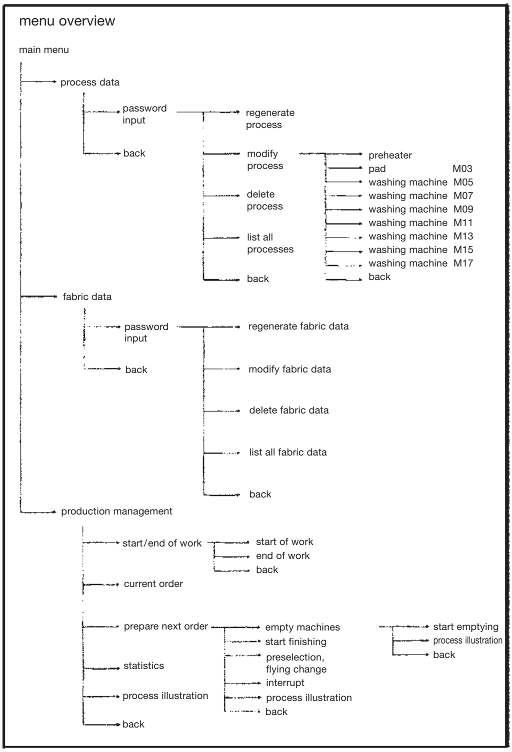


Fig. 2: Operating structure of a process-controlled continuous dyeing plant (Küsters process technology).

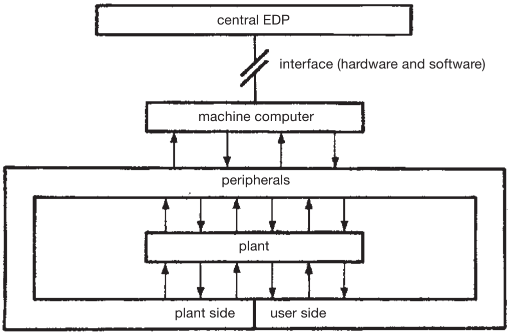


Fig. 3: Information flow system.

the corresponding function key, the control either splits into another menu or into a program routine. Distinctions are basically made between basic menus, program flow, program execution and service routine. The latter two are only accessible by inputting a password. An unauthorised change or correction of programs or machine settings is thereby prevented. All controllable functions appear in a logical sequence one after the other in plain text on the screen during the program generation, for example for a dyeing machine:

- fill dyeing kettle with water type 1,
- fill dyeing kettle with water type 2,
- fill secondary container with water type 1.

The person with authorised access compiles the required program steps via the function keys. The automatic system does not accept illogical steps; errors can be corrected immediately.

Systematic structuring and equipping with microprocessor systems as well as integration into the higher-level system is known as dyehouse management. After dyeing, the data is analysed and the batch data is fed back to the commercial EDP (Fig. 3). The dyehouse then also receives the necessary statistics. The provision of planning data for the commercial EDP is very important within the framework of batch preparation. The commercial EDP should know the need for dyes, chemicals, dyeing times per batch, etc. It asks for a planning recipe. This contains the quantity of fabric to be dyed, the colour and the possible pre- and aftertreament. The recipe with the necessary dyeing program, the demand for dyes and chemicals as well as the suitable type of machine and the time for the dyeing are then drawn in the technical EDP (Fig. 4). All this data (Fig. 5) is reported back to the commercial EDP, which works out the relevant dyeing tasks. As the commercial EDP usually also comprises the material management, the orders for dyes and chemicals can be initiated. Should this not be the case, the planning requirements and ordering can also be carried out by the technical EDP.

The dyeing tasks include all the important information for dyeing. Material, colours and possible pre- and aftertreatments then permit the selection of a suitable master recipe, which is transferred into a production recipe. The tasks for the weighing stations and the dyeing program are then gathered from the production recipe. The print-out of the necessary cards is carried out simultaneously. The respective operational progress status can be recognised by the commercial EDP at any time by feedback of the batch status. The production of the dyeing program from the recipe is optimum from this, if dyeing program modules parameterised at any time for individual treatment stages (such as the pretreatment, dyeing and aftertreatment) can be assigned. The recipe, which is organised into several treatment stages is on the left side. Parts of the necessary dyeing programs are shown on the right side. The dyeing program consists of the individual modules and the parameters with the data assigned from the recipe. So, in the example shown (Fig. 4), the gradient in the “colour” module is established at 1°C/min, the final temperature of 120°C and the retention time at 20 min.

The application of modules on the one hand and their parameterisation on the other permit very many recipes from the dyeing programs to be assembled from relatively few modules. The expense for the generation and maintenance of the dyeing programs is thereby considerably lowered and an optimum program can be produced each time without great expense.

Fig. 5 shows that the databases can be divided into three groups, which are product-specific, process-specific and machine-specific. The machine-specific data for example includes liquid level calibration curves for the machines to maintain definite liquor ratios, fabric

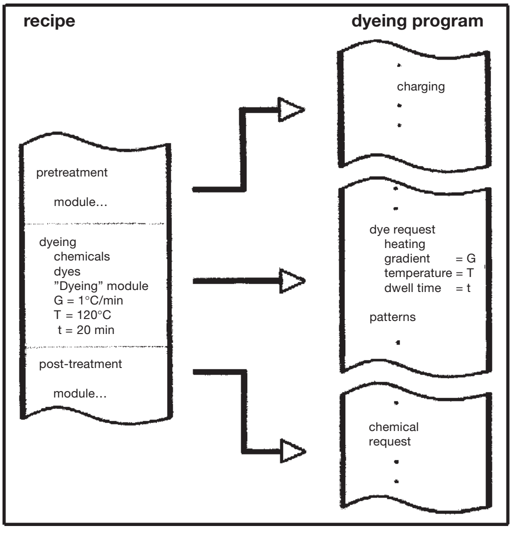


Fig. 4: Generation of the dyeing program for parametric modules (Then).

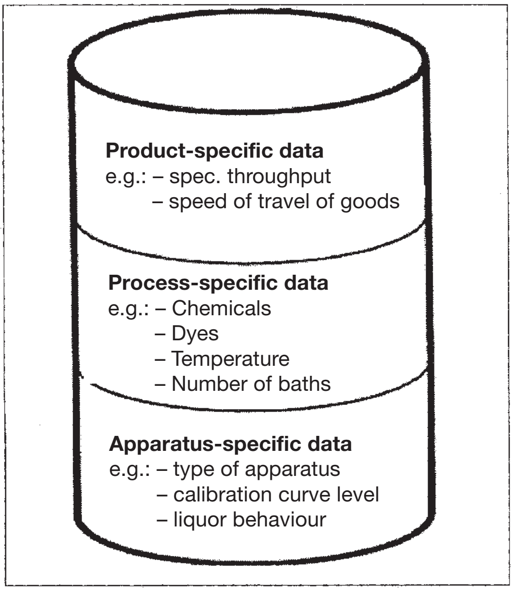


Fig. 5: Common database for recipe and dye program (Then).

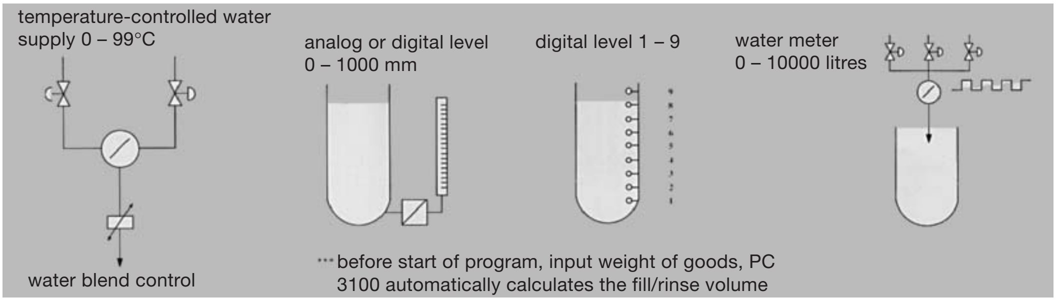
speeds, flow values in yarn dyeings, etc. A common and comprehensive database therefore appears to be an important requirement when integrating dyehouse management and process control. The next processing sequence is, for example, the patterns. If there is a pattern, this is firstly assessed colorimetrically. It is thereby split into three categories:

- The pattern is within the tolerance limit; the dyeing is good.
- The pattern is outside the tolerance limit; an addition is possible.
- The pattern is outside the tolerance limit; a colour correction is not possible.

The work to be carried out can be selected accordingly and triggered at the measuring station in the integrated system. If the pattern is good, the module for the after-treatment in the machine control is started; but if an addition is necessary, a suitable addition module can be selected depending on the colour variation, transmitted to the control and started . The weighing is done on the scales in the colour kitchen. A comment that this recipe should be revised can furthermore be input in the master recipe. The response of the batch within the dyehouse is recorded in a batch report. The time period, number of additions and machine control are documented and permit a check of the dye behaviour at any time. Layer and long-term reports not only verify the production success. A comparison of the production in the recent past with the long-term statistics also results in a trend report. This brings an influence to bear early on in the production. User-friendly data and inquiries give considerable help in the analysis of the events in the dyehouse. Not only are the machines controlled by the computer work station in the dyehouse (Figs. 6–7), but also a connection to the colorimetry, weighing stations and the recipe management can be produced. The BEE cards can also be produced by a minor hardware expansion for the programming of individual controls; in the case of control centre failure, work should be continued using individual control (Fig. 8).

The situation in the textile industry with continually increasing demands on quality and the obligation to maximum operational efficiency with simultaneous demand for just-in-time production can only be managed with practical process automation. As production processes are extremely complex, the information from individual process units must be connected to network systems in order to exhaust all the possibilities of modern data technology to form production planning systems.

The workplace in the dyehouse will change and dealing with the microprocessor will become routine for the staff. This also necessitates training and further education of staff in order to be able to use the continually growing possibilities of automation systems by means of EDP optimally as (according to Hartmann and Quas).



··· before start of program, input weight of goods, PC 3100 automatically calculates the fill/rinse volume

Fig. 6: Microprocessor applications: Filling/rinsing (Barco Sedo).

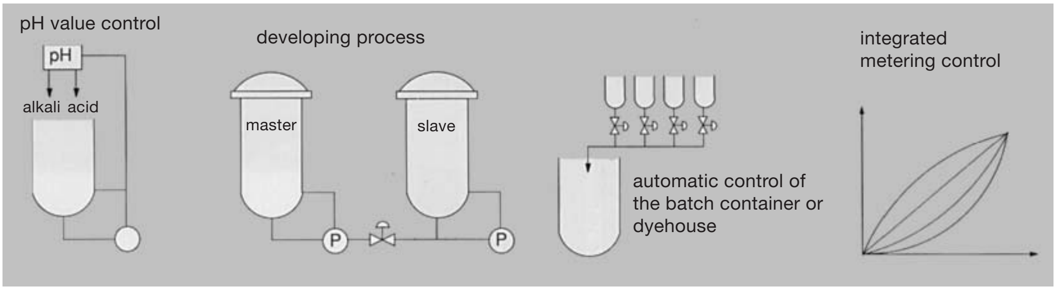
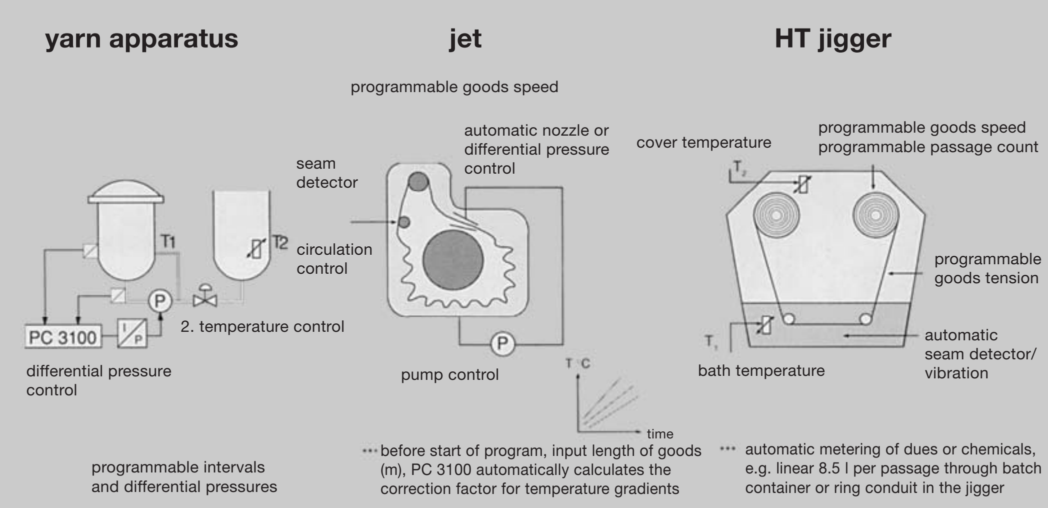


Fig. 7: Microprocessor applications: Dyeing (Barco Sedo).



before start of program, input length of goods (m), PC 3100 automatically calculates the correction factor for temperature gradients

automatic metering of dues or chemicals, e.g. linear 8.5 l per passage through batch container or ring conduit in the jigger

Fig. 8: Typical areas of application for microprocessor control systems (Barco Sedo).

Microscope A distinction is made between the → Light microscope and the → Electron microscope. Practical textile microscopy can be called on for clarifying numerous problems which occur in the manufacture and finishing of textiles. The identification of man-made fibre materials is becoming more and more complex with the increasing variety of new fibres and their processing into the most varied fibre blends. A differentiation in the various man-made fibres, especially in dyed items, is hardly possible any more without microscopic tests together with dissolving, swelling and dyeing reactions. In clarifying textile complaint and damage cases, extensive practical experience in all areas of textile manufacture are required in order to be able to evaluate the results of practical microscopic tests. Easy to operate working microscopes with a polarisation device are enough for practical textile microscopy, especially as these devices in many cases do not have to be operated by trained staff, but by semi-skilled technical assistants. An optical device with approx. 100–800 times magnification is adequate. But more important than the magnification is the resolution of the microscope. This is understood to mean the power of a lens system to make two object points lying close together separately visible. The resolution therefore depends on the strength of the lens systems, which depict a magnified, inverted image of the preparation. This image is made visible to the eye by the eyepiece, but no further resolution is carried out in detail by eyepiece magnification. A photo device is part of the basic equipment just as is a hot table microscope. This latter is necessary in order to be able to determine the melting range of synthetic fibres.

Microscopic Only recognisable under the → Microscope. Opposite → Macroscopic.

Microscopy In textiles, there is an indispensable specialist area of textile testing within the framework of identification, production (man-made fibres), item development, processing and damage information about fibres, yarns and fabrics. Technological tests provide information about textile physical characteristics, detect deviations from desired values, but are often only possible with the aid of the microscopy to allocate the causes. While the examination and description of vegetable and animal fibres were prominent in the beginning, textile microscopy set itself new tasks with the development and spreading of man-made fibres.

Clasification:

1. Light field microscopy with backlighting or front lighting for surface area tests and for the analysis of cross-sections.

2. Dark field microscopy, whereby the light, assuming the lens aperture is smaller than that of the condensing lens, passes the lens. The field of vision is dark. Only a part of the light scattered on structures and constructions reaches the lens and facilitates observation of the object. Structures on the surface, deposits of delustring agents, carbon black and dye dispersions as well as vacuum bubbles are very well reproduced.

3. Fluorescence microscopy is based on the phenomenon of photo luminescence. These tests are possible on preparations which contain substances which, with radiant exposure to high energy, short-wave UV light, convert this into long-wave, visible light. Devices for pick-up, of exciter and stop filters, as well as a light source (e.g. mercury high pressure lamp), which gives a high short-wave light content, are prerequisites.

4. Polarisation microscopy can detect the double refraction of man-made fibres and give information about the orientation of the chain molecules. The degree of orientation of man-made fibres can be influenced by the spinning speed and/or by the aftertreatment (drawing of synthetic fibres). Different tension or temperature ratios in subsequent processes (warp beam manufacture, sizing, fixation) also change the degree of orientation. Orientation differences in turn influence the dyeing behaviour and may consequently be cause for complaints. In addition, in polarised light, mechanically caused fibre deformations or filament breaks due to deformation zones in longitudinal fibre formation and texturizing processes can be detected with tension zones in the microtome cross-section. If an anisotropic object is brought into the optical path of the polarisation microscope at crossed polarisers, the ranges of the polarised light are shifted and appear coloured (interference colours) on a dark base.

5. Thermomicroscopy is used within the framework of the identification of man-made fibres for the analysis of substances adhering to fibres, e.g. oligomers/paraffin. Material-specific changes regarding shade transfer, softening and melting point caused by heat input are thereby also observed.

6. Scanning electron microscopy is being used to an ever greater extent. Besides research institutes, numerous laboratories work in the fibre industry using these devices. The high magnification in conjunction with high resolution at a depth of focus not attainable until now, facilitate representations of the topography of samples in their actual spatial form. The representations of → Scanning electron microscopes give insights into cross-sectional forms and surface composition of fibres and enable cause/effect correlations between process conditions to be recognised, from which, for example, measures for the yarn manufacture and/or aftertreatment can be derived.

Microscopy fibre cross-sections, preparation of Either (most effectively) by means of → Microtome or simplified in the following ways:

I. A carefully prepared fibre bundle (in which fibres are as parallel as possible) is pulled through a small pierced (0.5 mm diameter) supported metal sheet by means of a yarn loop so that the fibres fit tightly in the opening. Then the fibres are carefully cut off perpendicular to the fibre bundle on both sides of the small plate using a sharp razor blade. Cross-sections obtained in this way be assessed in the microscope at 250–400 times magnification. They can also be easily microphotographed.

II. In accordance with type I above, pull a fibre bundle through a stopper and then cut thin strips from the bundle. This method has the advantage of making several different cross-sectional forms in rapid succession from the same fibre material.

Micro-Stretching → ML Process.

Microtome Device for the manufacture of fibre cross-sections for microscopic work, e.g. without (manual microtome) or with mechanical blade guide (slide, pivot, automatic microtome).

Microwave moisture measurement is capable of measuring the moisture application behind the padder in continuous dyeing processes and of evaluating the measured values for the padder control. They can also be used to determine the residual moisture content be-

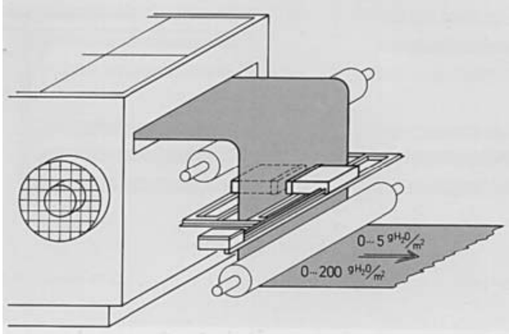


Fig. 1: Residual moisture measurement using the RF 110 microwave system by Pleva.

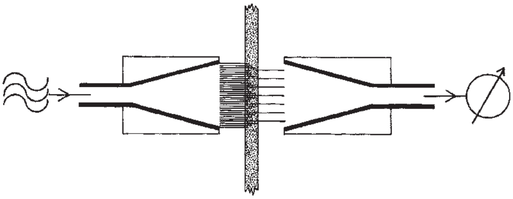


Fig. 2: Principle of moisture measurement using microwaves.

hind the stenter exit (Fig. 1). A defined microwave emission is thereby beamed onto the damp fabric. The proportion of microwaves not absorbed because of its density (Fig. 2) is measured and related to the humidity by calibration.

OH ions dampen radiated high frequency energy at microwave frequencies in proportion to the amount of radiation. In addition, they vibrate at a wavelength of approx. 1.7 cm in resonance with the excited energy and thereby consume a particularly large amount of energy as does every resonator. In this way it is possible to test humidity using microwaves and it is rather selective due to this resonance. These measurements are possible without contact; the cloth must be well controlled and maintained in a constant position. Humidity analyses can be carried out using different measuring arrangements both in the residual moisture range and with a high water content of approx. 20–400 g/m^2. The absolute water content is always indicated. So knowledge of the fabric weight is necessary for calculating the relative humidity. As the structure of the cloth and, to a certain extent also the type of textile material enter into the reading, item-specific calibration curves must be constructed (above all, in the residual moisture range, where only a little water is absorbed by the microwaves).

Different designs of device are on the market. One manufacturer allows the microwave energy to push repeatedly through the cloth when determining the residual moisture in order to increase the damping effect. Another guides the measuring instrument through a so-called pore resonator, in which the short waves vibrate as in a microwave oven. With high humidity, the waves are beamed onto the cloth from horn transmitters and again picked up behind by the similar elements. The measuring range limit is achieved, if so much water is found on the cloth surface area that it reflects like a sheet with high frequency energy. But if the deep humidity is distributed fairly evenly, the total amount of humidity can be measured using microwaves. The measuring accuracy is sufficiently good if measurements taken on the same cloth or different items are carefully calibrated. If extremely high accuracy is not required, a cloth-specific calibration can possibly also be dispensed with, at least for items similar to each other.

Microwave rapid laboratory method for CPB dye fixation The rapid laboratory method developed by Hoechst AG, in which the dwell time required in CPB dye fixation for the fixation of remazol dyes can be shortened to 4–6 min with the aid of normal microwave ovens. Reproducible recipe results, which are applicable to product batches, are thereby obtained.

Microwaves Electromagnetic radiation in the milli-, centi-, decimeter wave range (approx. 1 mm to 30 cm) and frequencies between 1–3000 GHz. → Radiation, comparison of different types.

Microwave treatment Fixation of dyes using microwave treatment. Continuous dyeing process for yarns, strips and fabric by means of microwaves. Dyes can be fixed in a continuous process using microwaves as a heat source (→ High frequency drying). A useful example of microwave treatment is its use in spinning. Honeydew in cotton fibres, amongst others, leads to stickiness owing to residue of plant sugars and insect secretions. The treatment process is based on the principle of evaporating the water on the adhesive particles by direct heating. The adhesive tendency is lost as a result of the drying out and/or embrittlement (see Fig.). As an energy source microwaves have the capacity of automatically having the greatest effect at the position of the highest water content. The heat takes effect chiefly in the adhesive particle and not in the fibre itself. The treatment system consists of a dissolving unit, the microwave element and an aperture cleaning unit.

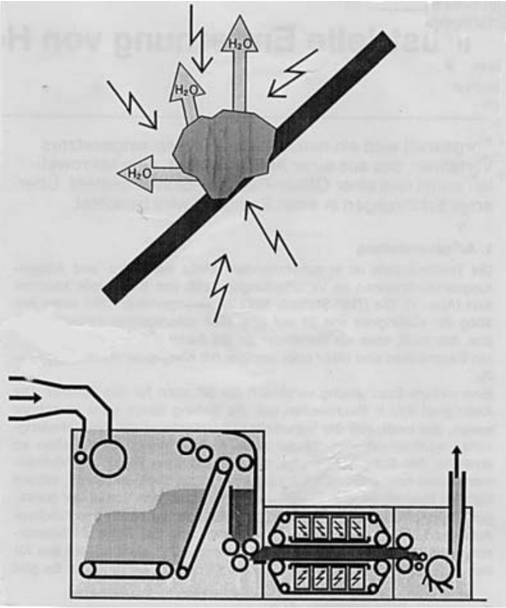


Fig.: Application of microwave drying for the removal of honeydew stickiness from raw cotton when opening bales.

The flocculent is formed into a wadding in the dissolving unit, which is led to the microwave tunnel and simultaneously compressed. A transport system consisting of two special-purpose strips continuously carries the compressed flocculent as wadding through the microwave tunnel. The microwave output is controlled at a given temperature profile. It is operated at a process temperature of 110–130°C. The released water vapour is dissipated via a ventilation system.

Microwax Shortened form for microcrystalline hydrocarbon wax made from de-paraffined products (paraffin gatch, petroleum gatch, etc.), obtained after de-oiling/cleaning. Colour black/brown/yellow/white; consistency sticky, soft malleable to hard. Has higher setting range/melting point of 55–90°C compared with commercial paraffins and a very fine crystal structure. Used for water-impermeable finishes.

Migration Migration power of a substance in or on the substrate from places of higher to places of lower concentration.

I. By levelling during the dyeing process (→ Levelling properties).

II. As a result of uneven drying in padding processes (→: Migration in intermediate drying; Dye migration in drying).

III. By contact with dyeings and/or prints with substrates, which have an affinity to the dyed and/or printed dye (e.g. with disperse dyes/prints in polyvinyl chloride coatings). Low wet pick-up processes avoid extensive migration compared with pad-dry condensation processes in resin finishing. A test of the migration of chemicals for resin finishing using a special-purpose staining technique (lattice test). The migration of dimethylol dihydroxyethyleneurea across the fabric cross-section and to the fabric surface area in the pad-dry condensation process was investigated by nitrogen and formaldehyde analysis as well as by colour measurement and was documented (resin migration). → Vertical migration.

Migration ghosting → Ghosting effects.

Migration in exhaust dyeing processes Controlled staining processes are mostly more economical through high standards and good reproducibility. They control the set up and/or fixation so that the cloth is almost equally dyed from the start. In migrating processes, however, a greater initial unevenness is accepted, which must be compensated for through migration. This requires good migrating dyes. Migrating processes may be more economical for unfavourable dyeing conditions (low liquor throughput, slow fabric run, etc.), as an almost identical staining would be time-consuming under these conditions. In many cases, migration processes are unavoidable, e.g. with fibre differences, temperature differences in the plant or with rapid filling dyes (such as vat dyes). The following applies for controlled staining processes: The filling only needs to be roughly controlled in order to avoid a filling which is considerably too fast (loss of time). The filling phase and the migrating phase are distinguished in a filling curve, as shown in Fig. 1. Uneven dyeings intentionally produced by migrating can be evened out in the too rapid filling phase.

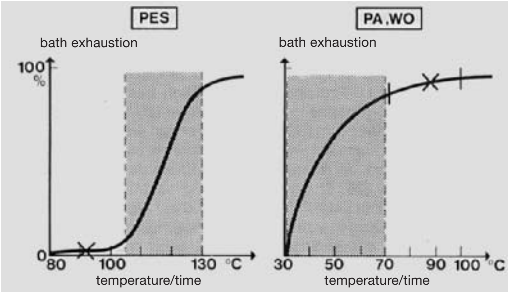


Fig. 1: Critical temperature ranges (dark) and idle times (x) in polyester or polyamide and wool dyeing.

Example: a dark yarn dyeing (100 parts = 2.5% dye made from yellow/bordeaux/grey) and a brighter yarn dyeing (70 parts of the same dye recipe) were wound on top of each other. This wound yarn package was then brightened on a blind dyebath boiling at pH 6 with the addition of 2% levelling agent and 10% sodium sulphate calcium. After cooling down to 60°C, the dyebath was adjusted to pH 4.5–5 using acetic acid and the wound yarn package washed out as normal (Fig. 2).

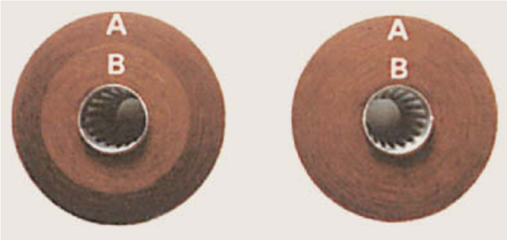


Fig. 2: Migration within a wound package.

Migration is understood as the evening out of inequalities, which are produced in fibres with the same dyeing properties through concentration or temperature differences in the liquor. The migrating power of dyes is normally tested by treating a (close to the equilibrium) pre-dyed fibre sample with an undyed one in the same bath and measuring the cross migration of the dye. Migrating curves are produced, as shown in Fig. 3.

The ratio of the quantity of dye $M_{F,2}$ on the previously undyed sample to that on the pre-dyed one $M_{F,1}$ according to a particular time t_M is described as the migrating power.

Migration in exhaust dyeing processes

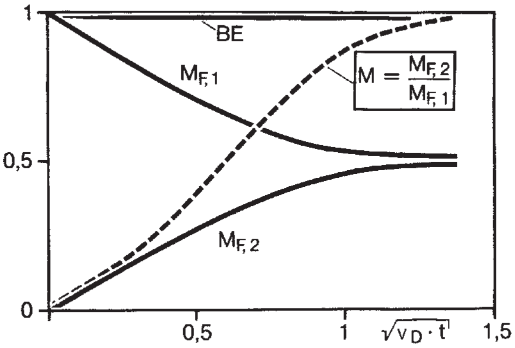


Fig. 3: Migration of a dye from the pre-dyed fibre 1 to the initially undyed fibre 2 in a fresh bath.
M = migration pattern; $M_{F,1}$ = Dye quantity in fibre 1; BE = bath exhaustion; V_D = diffusion speed; t = time.

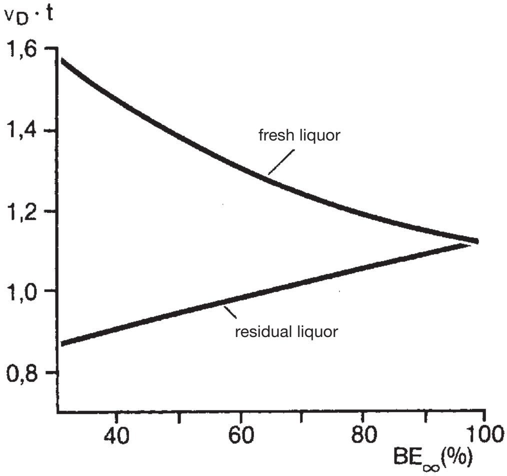


Fig. 4: Effect of the bath exhaustion BE_∞ on the time to 90% equalization through migration (i.e. until M = 0.9 is reached), expressed by the dimensionless parameters $V_D \cdot t$.

$$M = \frac{M_{F,2}(t_M)}{M_{F,1}(t_M)}$$

Some laws of the migrating process can be recognised by simple model calculations. With well-mixed liquor, the diffusion of the dye from the pre-dyed, into the initially undyed fibres, is determined by speed. Assuming Fick´s diffusion with the same constant diffusion coefficient D for both fibres and Nernt’s distribution equation, the following applies: the levelling time t_M is inversely proportional to diffusion speed v_D until a certain value of M is reached

$$t_M \approx \frac{1}{v_D}$$

and incidentally depends on the equilibrium bath exhaustion at the end of the migrating process BE_∞ and the liquor concentration at the start. The influence of BE is shown for two cases in Fig. 4.

A flat geometry (film) was assumed; but the same type of image is obtained for regular cylindrical fibres: with high bath exhaustion, BE t_M is almost independent of this. With migration in the residual liquor, t_M increases with increasing BE. With migration in a fresh bath, however, t_M is greater the lower is BE , i.e. more dye is desorbed in the bath. So migration tests in the fresh bath can be misleading. With uneven dyeings, evening out via migration is carried out considerably more slowly and is slower the lower the liquor flow. The cloth movement promotes migration to a different extent depending on dye and migrating conditions. The liquor may not be regarded as ideally mixed. Through the migration, inequalities to be evened out are produced by concentration or temperature differences in the liquor. This is also expressed in the fact that the measured migrating values of dyes do not only depend on the diffusion coefficients, but decrease much more strongly with increasing affinity (bath exhaustion) (Fig. 5).

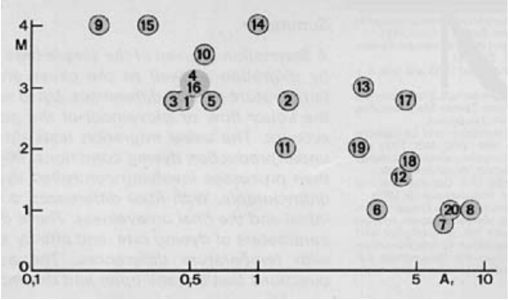


Fig. 5: Measured migration tendency M of acid dyes on polyamide against relative affinity A_r of the dye.

Three parameters are definitive:

- the diffusion speed v_D,
- the bath exhaustion parameter

$$b_M = \frac{RE_{outer,\infty}}{(BE_\infty)^{\frac{1}{n}}},$$

- the flow parameter

$$s_M = \frac{U}{v_D} \cdot b_M \cdot w.$$

(according to Hoffmann).

Migration inhibitors Substances, which are added to the pad liquor in order to prevent the migration of dyes when drying. The alkaline saponification of polyacrylonitrile facilitates the manufacture of water-soluble products, which can be used as migration inhibitors in the thermosol dyeing process. The molecular weight often results in a solution viscosity which does not satisfy technological standards. Control of the viscosity of these solutions using cross-linking agents is therefore recommended. It is possible to use water-soluble acrylic polymers modified with formaldehyde as migration inhibitors in thermosol dyeing. The structure of the polymer film, on which the fixation of the disperse dyes is carried out using heat treatment, considerably influences their yield. The opinion is thereby held that the fixation process is accelerated by the presence of a film with a porous structure. The use of crosslinked polymers can result in an increase of the fixation ratio of the disperse dyes, because of the existence of microgel particles. It is assumed that the volume of these particles is impervious to the disperse dyes, consequently their fixation takes place in practice from the phase with increased concentration.

Migration in intermediate drying is due to too little substantivity of the dyes under drying conditions and also to high moisture absorption. Migration tendency is greater in polyester/cellulose blend fabrics than in cotton and is encouraged by uneven drying. The smaller the particles of the dye the stronger the migration during drying. The coarser the yarn or the more densely beaten the fabric, the stronger the migration effect. Recommendations for avoidance: as little liquor pick-up as possible during padding. Resting of the damp fabric after padding or drying. Effective drying evenly across the whole width of the cloth. Avoid shock drying. Use products, which cause a change in the particle size under drying conditions. Only use wetting agents as far as necessary.

The pad liquor is more or less homogeneously distributed across the cloth after leaving the padder. Drying only starts on the top and/or bottom of the fabric. The liquor migrates from the fabric inner to the drier surface due to heat, whereby the substance is accumulated on the fabric surface. The migration ends when the fabric is so far dried that the coherence of the liquid phase is broken. As long as the liquid flow to the fabric surface is not interrupted in the first drying phase (70–30% humidity in the cloth), the so-called migration threshold will not be exceeded, i.e. the particles dissolved in the water (e.g. finishing chemicals) are borne along to the cloth surface and accumulate there (uneven distribution). This migration stops when the evaporation of the water transfers to the centre of the fibres, as through low wet pick-up or high squeezing effects (e.g. with the Roberto roll), no more surface water is available.

The types of migration can be subdivided in summary as follows:

1. Migration of the liquor to the fabric surface from less rapidly drying to rapidly drying places: “listing or centre run” (surface migration), or from one side of the fabric lagging behind in the drying through to the more rapidly drying side: “side uniformity” (fabric migration).
2. Migration of the particles dissolved in water on fabrics from the centre to the evaporation surface.
3. Liquid migrations as a result of concentration differences.

In all three cases migration is caused by the drying of the padded textiles. After impregnating the fabric with a solution, the liquid is held in capillary pores in the centre of the textile material. The evaporation of the water during drying firstly takes place on the fabric surface, then the liquid is further conveyed by capillary forces. The particles dissolved in water are rinsed onto the fabric surface together with the liquid. A back diffusion of the material particles is carried out by the concentration difference developing between inner and outer as long as one capillary is filled with liquid. But the back diffusion stops when either the liquid column breaks or when the particles dissolved in water become so large that they can no longer move due to lack of space. The migration is completed when the evaporation of the water only takes place from the centre of the material, i.e. the moisture content break point is reached, and the further conveyance of the liquid into the fine capillaries is completed.

Apart from migration from the fabric centre to the fabric surface, the types of migration shown in Fig. 1

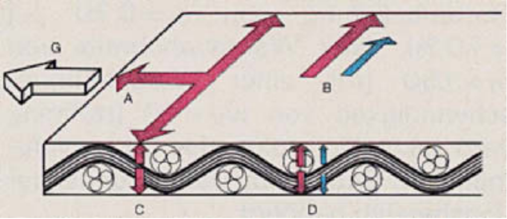


Fig. 1: Diagram showing the migration types during pad-dry processes (according to Somm).
G = fabric length (direction of travel); A = horizontal migration (cause of uneven fabric appearance); B = selective horizontal migration of the individual components of a dyeing (cause of dichroism and uneven fabric appearance); C = vertical migration (cause of listing and two-sided dyeing); D = selective vertical migration (cause of side-to-centre shading and shade differences).

are above all of interest to the dyer. A vertical migration can take place when more heat or earlier heat is supplied to the textile material from one side rather than from the other side. This then leads to “two-sided effects”. Stripes which occur during drying can be put down to the fact that front and/or back sides over the width of the textile material dry alternately stronger and weaker. A selective migration can take place, when in a dye combination the individual components of the dyeing are conveyed to the surface of the textile material length at different speeds. This uneven conveyance leads to shade shifts and an irregular cloth profile. In horizontal migration, the migration of the particles take place mainly on the surface of the textile material. In structured textiles, thin places dry sooner than thick ones, through moisture vapour transmission and dye conveyance which is effected from the thicker to the thinner places. The appearance of a so-called “wet” cloth profile can be put down to this reason.

Migration during drying can only occur when particles dissolved in water (e.g. finishing chemicals) are carried along in the liquid flow in the capillaries, which lead to the surface. The migration stops when the so-called migration threshold has been reached. The end of the migration varies greatly with respect to the material. In hydrophobic fibres, the proportion of surface moisture is considerably greater than in hydrophilic fibres, which have a large proportion of swelling moisture. The end of the migration or the migration threshold is an important criterion for the characteristics of the migration; several values are therefore given in the Table.

	end of migration (migration threshold)	water retention property
viscose	40 %	85 – 100 %
wool	36 %	42 %
cotton	21 %	45 %
polyamide	10 %	13 %

Tab.: Comparison of water retention properties and threshold value of the water content below which no further migration will take place on drying.

The drying conditions play a big role in all the possibilities. So it can be established that migration increases with growing evaporation performance, i.e. the more heat is carried over to the textile material to be dried, the more intensive the water evaporation is and therefore more particles can be transported to the surface of the textile material. A very large migration can be expected in the high performance convection dryers familiar today, also in the IR pre-dryers with a maximum drying performance of approximately 10 kg H_2O/m^2. Only low migration values can be expected with low air movement (circulating air distribution) and high relative humidity (i.e. with low drying performance). The migration drops off with falling moisture content of the material, i.e. the migration is at its greatest after the padding at the start of the drying process.

The migration decreases with an increasing degree of saturation of the drying air, caused by the reduction in the evaporation rate. It would be possible theoretically to control the evaporation rate via the saturation value. The more moisture there is in a drier, the higher the wet bulb temperature, which in turn can be equated to the fabric temperature. As this fundamentally concerns the reaction of hydrophobic and hydrophilic fibres to the migration, this factor can be classified under the physical factors. If a solution migrates in material not capable of swelling, an increase in concentration occurs on the surface of the fabric while a decrease in concentration takes place in the fabric core.

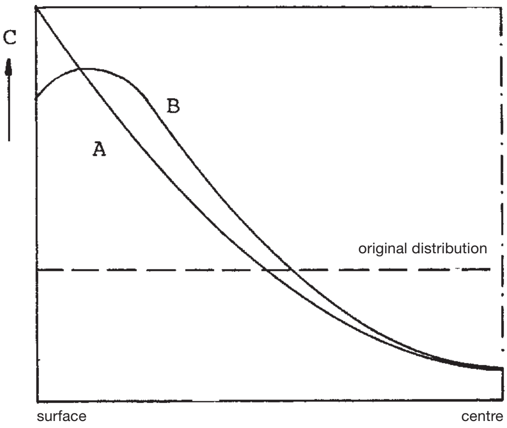


Fig. 2: Migration properties of a solution in non-swellable textiles (according to Junginger).
A = solution fully saturated; B = solution not fully saturated

Fig. 2 demonstrates the concentration profile of a completely saturated and a non completely saturated solution in the cross-section of the textile material not capable of swelling. In curve A, an efflorescence or precipitation of the super-saturated solution occurs in the second drying phase, which can only occur in the advanced drying stage in curve B. In a textile material capable of swelling such as wool, a capillary moisture movement is only possible up to the value of the swelling humidity. This humidity combined with swelling can only be removed in the vapour diffusion way, i.e. the substances dissolved in this swelling humidity cannot migrate, but result in a basic concentration value.

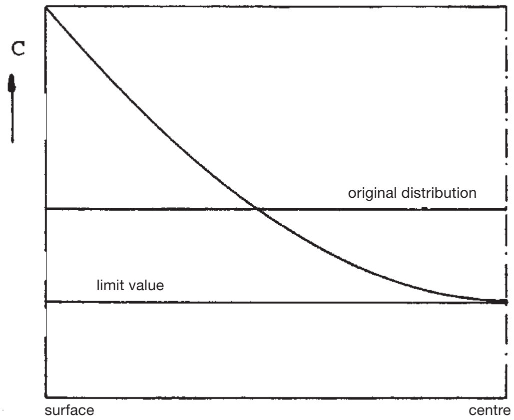


Fig. 3: Migration properties with a swellable textile (according to Junginger).

The distribution corresponds to the representation shown in Fig. 3.

A series of test methods, which can fundamentally be divided into two groups, is available to test the migration behaviour in a laboratory:

1. The migration takes place similar to the practical conditions in the hot air flow, such as: pocket and/or sandwich test, watch-glass test, hair-drier test.
2. Drying takes place at room temperature or given temperature without air movement in the drying cabinet, such as glass plate test, crease test, etc.

Migration in polyvinyl chloride Resistance of the colour of textiles to migration in polyvinyl chloride layers, which contain softeners. White pigmented polyvinyl chloride film is placed on a glass plate and the sample spread on it. A quantity of softener corresponding to the weight of the sample is evenly dripped on, the test specimen covered with a second glass plate, loaded and kept at 80°C in a hot cabinet for 3.5 hours. Then the sample is removed, the polyvinyl chloride film rinsed with petroleum benzine (petroleum ether) and dried. The staining is assessed using the grey scales.

Migration propensity of dyes Capacity for → Migration, in order to even out concentration differences. The levelling capacity of dyes is not only dependent on dye properties, but also on the textile material and dyeing process. The migration propensity of dyes is jointly responsible for their → Levelling behaviour. (→ Dye migration in drying).

Migration test The colour measurement should be partly consulted for an analysis of these tests, but colour measurement is a surface measurement and does not provide reliable evidence about dye distribution, other suitable methods are sought (→ Levelling property test).

I. Modified migration test in accordance with Baumgarte (Fig. 1): the fabric to be tested is laid in nine layers and crease-free samples, 5 x 10 cm, are punched out, so that it can be ensured that the layers have close contact with each other. Afterwards the sandwich samples are stored in a standard atmosphere over night. The air conditioned samples are then immersed in the liquor to be tested in the horizontal knuckle padder and immediately squeezed on the laboratory padder (80% squeezing effect). The pad liquor generally contains 20 g/l of dye. The sandwich is fixed between two Teflon sieves for intermediate drying in the laboratory drier in order to prevent flapping. The Teflon sieves are dimensioned so that they can be pinned down onto a stretching frame. The drying time is adjusted to the desired residual moisture, which can be ascertained gravimetrically.

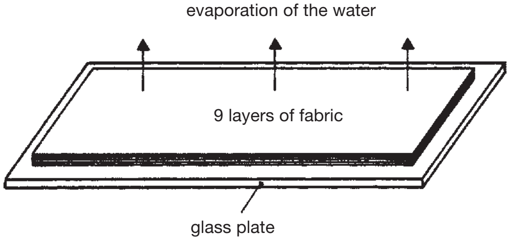


Fig. 1: Model test for dye migration (according to Baumgarte).

II. Sandwich test (Fig. 2): three fabric sections of 15 x 30 cm are padded and then closely fastened on top of each other on a pin frame. This is then dried in a hot air flow under precisely defined conditions. It is fixed, reductively cleaned or boiled with soap depending on the dye classification. The outside of the fabric (1, top or bottom), the middle fabric layer (2) as well as the inside of the fabric (3, top or bottom) are assessed.

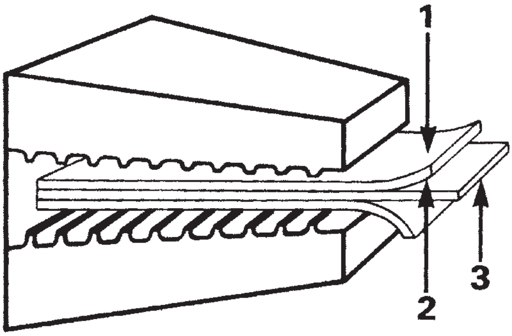


Fig. 2: Sandwich test for migration (according to Somm).

III. Clock-glass test (Fig. 3): a clock glass of approx. 10 cm in diameter is laid onto a padded fabric pattern run into the drier in a horizontal position. The drying is carried out similarly as in II. It is reductively

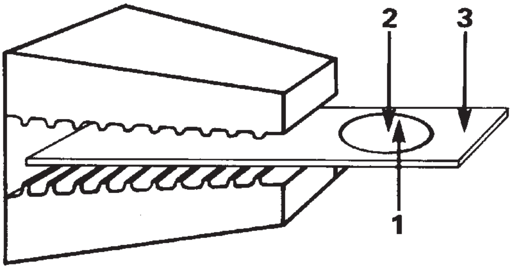


Fig. 3: Clock-glass test for migration (according to Somm).

cleaned or boiled with soap depending on the dye classification. The clock-glass underside (1), the clock-glass covering (2) as well as the top side of the fabric (3) are assessed.

IV. Hair-dryer test (Fig. 4): a padded fabric is laid onto a wire grid and dried from above using a hot air hair-dryer at a distance of 20 cm. The front and back of the fabric section are assessed with regard to difference in depth of colour or shade of colour after drying.

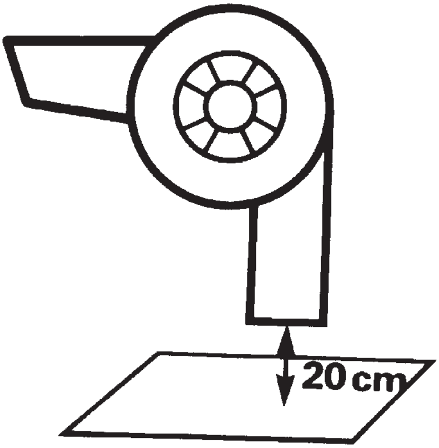


Fig. 4: Hair-drier test for migration (according to Somm).

V. Glass plate test: after padding, a fabric section of 9 x 9 cm is laid between two glass plates (A) of 10 x 10 cm, of which one has a hole with a diameter of 15 mm (B) in the centre. The edges of the glass plates are sealed with molten paraffin (C). After being stored at room temperature for 16 hours, the glass plates are separated and then the still damp fabric completely dried at room temperature. A fabric padded with the same liquor and likewise dried in the air at room temperature is used as the reference standard for the assessment. A comparison of the depth of colour between the reference standard and the “migrated” pattern on the covered places produces a dimension for the migration which has occurred.

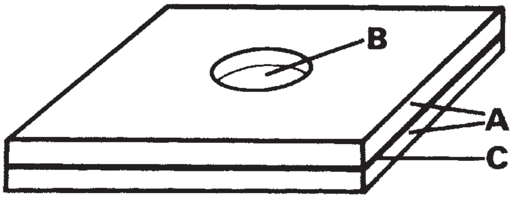


Fig. 5: Glass plate test for migration at room temperature (according to Somm).

VI. Crease test (“concertina test”): a fabric strip 75 cm long and 6 cm wide is padded and folded in book form. The small fabric staple length is dried between two glass plates in the drying cabinet at a given temperature.

Milas rugs One of the finest and most beautiful Anatolian → Prayer mats. Smoother, rather shorter pile with approx. 150 000 knots per m^2. Colourful, bright colours. Varied patterning varying from small flat stylised flowers to geometric shapes.

Mildew-resisting agent → Fungicidal finishes; Antimicrobial finishes.

Mild steel → Iron.

Mild washing agents Hard water resistant → Syndets for domestic washing. They are usually neutral.

Mild wash process for outerwear The protection of textiles against matting, shrinking, stretching and suchlike is hereby to the fore. These risks can be avoided by reducing the totality of the washing mechanics, but at the same time increasing the intensity of the mechanical effect. This can be achieved by using a washing drum with a large diameter for example, which operates with a pump speed corresponding to a transverse acceleration of 0.8–0.9 times gravitational acceleration at a reversing rhythm of 30–60 s interval and 2–5 s rotation (Miele Kreussler process). Outerwear, which had been reserved for dry-cleaning until now, can be washed using washing processes, which are carried out in washing machines using water with drum radius of 40–50 cm and are characterised by the fact that extremely long reversing pauses are used. These processes require completely new operating techniques and greater use of drying and ironing. In contrast to dry-cleaning, they have the advantage that water is used as a solvent. Even if still further optimisation is required, mainly in the field of drying, mild wash processes offer the possibility of completely re-structuring commercial textile cleaning (according to Hasenclever).

Milk of lime → Calcium oxide.

Milled composite fabrics → Bonded fabrics made from e.g. nonwoven wool (blends) bonded using felting and milling.

Mill engraving After producing the master pattern die (→ Pattern die) the actual mill engraving is carried out on the engraving mill (engraving machine). The hardened relief engraving is thereby pressed against a rotating copper printing roller with a thrust up to 7 tonnes until the required engraving depth has been reached. Mill engraving is precision work, as the repeats in height and width must turn into each other without any transition.

Milli- (Lat.), unit prefix for a thousandth = 10^{-3}; e.g. mg, ml.

Milling Matting and condensing (increased shrinkage in length and width) of wool piece goods (possibly also with a proportion of extraneous fibres) in the hot damp state, preferably of more open carded yarns. Milling is carried out in acid (→ Acid milling) and/or alkaline liquor. → Milling process.

Distinctions are made between the following:

I. Alkaline milling using excess sodium carbonate (+ olein fats + sodium carbonate = olein soap) or potassium carbonate and/or soap.

II. Neutral milling with as much sodium carbonate as is required for the saponification of the fatty acid content in the fats (fibre protection), milling auxiliaries. It is pre-washed for example (wool scoured) in "soap milling". In "fat milling, soil milling or soda milling" (raw fabric), fats capable of saponification must be removable in a maximum of 2–3 hours at approx. 3°Bé of sodium carbonate solution (otherwise fibre damage): milling in the "tanner". The latter always "fresh" (if too thin: soap addition; if too thick: no further soap). Grease milling requires special practical knowledge in order to prevent "burning of the dirt"; amongst prerequisites named for fabrics easy and difficult to mill. After 4 hours of milling using pH 10 sodium carbonate solution, approx. 30% area shrinkage; approx. 38% using potassium soap with same pH (→ Milling auxiliaries).

III. Acid milling of technical felting. Considerably higher densities of the felting are achieved than in alkaline milling.

IV. Milling in solvents (solvent milling, mixed phase milling, dry milling): finishing process carried out in tetrachloroethane, in which knitted, hosiery or woven textiles are milled with the addition of precisely metered quantities of emulsified water, i.e. shrunk, condensed and changed in their surface structure. The degree of milling can be precisely controlled by the quantity of water added and treatment time. Implementation in dry-cleaning machines of special design for knitted fabric finishing in a solvent. Milling in the solvent is also suitable for the matting of carpet yarns.

Milling auxiliaries (milling soaps) are used for the support of felt formation (thread end) in the milling of wool. This mostly concerns surfactants or preparations based on them. The action is based on an increase in wool suppleness and improvement of the sliding action at the same time. Suitable milling auxiliaries are milling soaps, triethanolamine soaps, further fatty acid condensation products and alkyl naphthalene sulphonates, possibly with inorganic or organic swelling compounds.

Milling calender Special calender for material pressing and milling to smooth fabric, in which e.g. needle bonded nonwovens and similar are pressed on the one hand, and on the other hand compact pores are converted into absorbent capillaries (handle improvement can also be analysed for fabrics/hosiery goods). Consists of a central cylinder (heated to a max. of 200°C) with several surface rollers (usually 8, heated/cooled), temperature and spacing are adjustable. As a laboratory and production machine (2–20 m/min) with/without batchers, also as part of a continuous plant assembly.

Milling dyes Colour fast for milling → Acid dyes.

Milling felt, Fulling felt Pressing felt → Felt.

Milling/felting theory The felting process was defined by Arnold for the first time in 1929. Felting is, therefore a "process for the connection of fibre materials and the formation of a homogeneous top layer from loose fibre materials by the use of friction, impact or pressure with the assistance of heat and moisture".

Witt had already put forward one of the first felting theories in 1888. He makes the flakey structure of wool solely responsible for the felting process in his so-called "mechanical sticking theory". This graphic model of the flakes mechanically sticking into each other is also still widely held today, although this theory is no longer valid. A short time later, Ditzel postulated that the flake structure of wool is a necessary prerequisite for the felting process because he had established that no felting of the wool could be observed if the flake structure is completely lacking. Wool has a direction-dependent coefficient of friction (Directional Frictional Effect, DFE, → Friction) due to its flake structure.

In contrast to Mercer, Speakman could not establish any better felting power using increasing DFE in his tests on the influence of elasticity in the felting process. From this he concluded that the DFE is not exclusively responsible for the felting process (→ Feltability of wool) The following three conditions should be fulfilled for the felting process according to Speakman:

- The wool fibres must have a flakey surface.
- The wool fibres must be easily elastic and easily deformable.
- The wool fibres must be able to return to the relaxed state from the extended state.

In contrast to Speakman, Martin holds the opinion that not only an extension of the wool fibres takes place during the felting process, but also a compression. The root ends are of great importance for the felting process in his theory. A clearly reduced felting tendency of the

Milling/felting theory

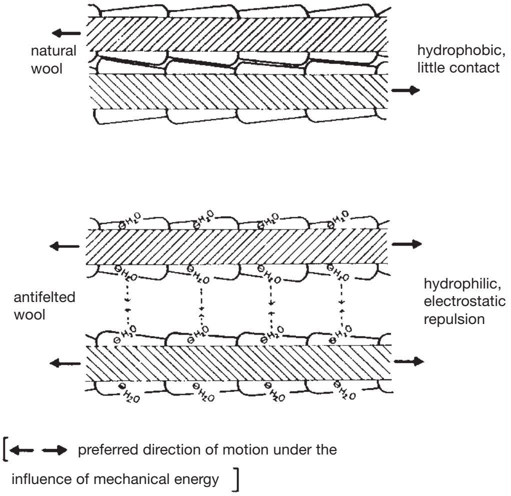


Fig. 1: Wool fibres are rendered hydrophilic through antifelt finishing, so that electrostatic repulsion in a fibre combination reduces compaction.

wool was observed by removing the flakes from the fibre roots. Speakman had already pointed out in his earlier works that a soaking of the wool fibre tips is necessary for the migration of the fibres in the course of the felting process. Rouette would also later confirm the influence of the soaked fibre tips on the milling process through treatment of wool fibre tips with H_2O_2. Speakman and Sun established a better feltability of the shorter wool fibres, while Sookne, Bogaty and Harris observed a better feltability of the longer fibres. Meichelbeck finally showed that the hydrophobic character of the flakes has influence on the milling process (Fig. 1).

The length milling process of a fabric is produced in the compression channel (Fig. 2), while the width milling process is realised through entré (Fig. 3). Laying the fabric hank (Fig. 4) prevents crease formation.

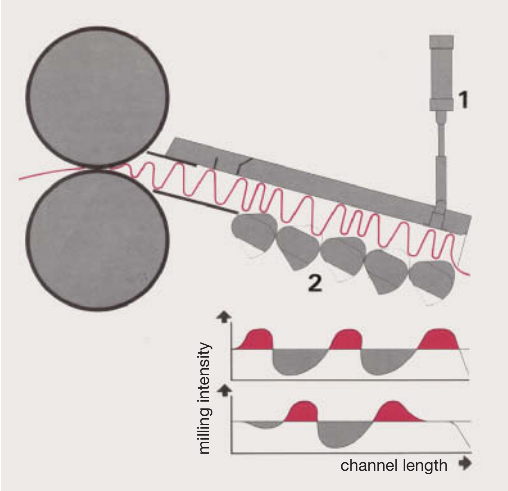


Fig. 2: Rhythmic compression and relaxation of the fabric to be milled in the compressing channel (Hemmer).
1 = pneumatic pressure cylinder; 2 = moveable elements for intensification of the rhythm of the movement.

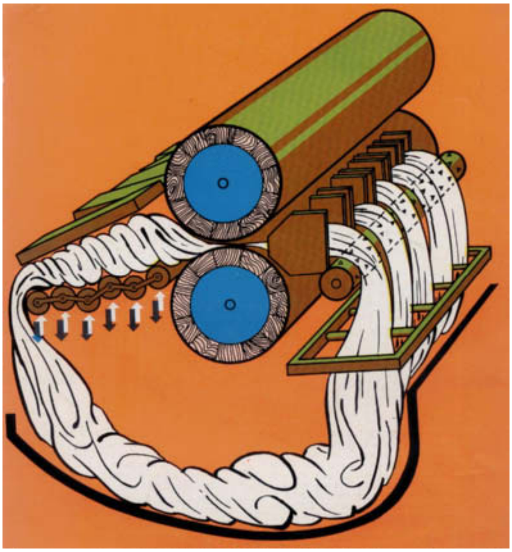


Fig. 3: Fabric hanks on entry into the feed systems of a mill (MAT).

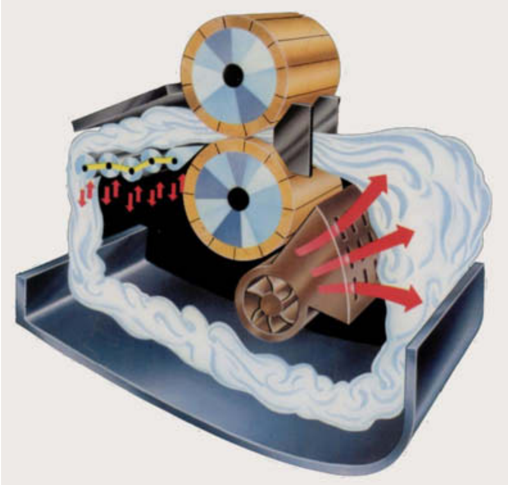


Fig. 4: Milling crease prevention by blowing the fabric hank with the objective of smoothing out creases (Turbomat).

Milling, light treatment,

I. Short → Milling (pre-milling): a) for the relaxation of wool (worsted yarn) fabrics; b) to achieve a particular fabric compacting and/or light felting of the fabric surface.

II. Addition of coloured fibre material (wool or foreign fibres) in the milling, which then stick superficially due to the felting power of the wool.

Milling lubricants → Textile lubricants.

Milling process includes the close connection of fibre material to a dense and hardwearing felt by the processing of loose fibrous materials by means of friction, shock and pressure assisted by moisture and heat. Felting is a specific property of wool, chiefly caused by its particular surface structure (→ Feltability of wool). As the flake cells overlap each other, as with roofing tiles, the friction resistance towards the fibre tip is lower than the reverse. The direction-dependent coefficient of friction (DFE) is obtained from this. The movement of a fibre swollen by moisture absorption under the effect of an external force, is steadily towards the root. In the opposite direction, the ratchet effect of the flakes hinders the migration of the fibre so that an irreversible shrinkage takes place.

Distinctions are made between the following:

1. Internal parameters of the felting:
   - flake structure,
   - hydrophobia of the cuticle,
   - longitudinal and transverse elasticity,
   - swelling,
   - fibre length,
   - fibre fineness,
   - grease content,
   - crimping,
   - yarn construction.
2. External parameters of the felting:
   - moisture content,
   - mechanics,
   - time,
   - pH,
   - temperature,
   - lubricants.

Untreated wool has a hydrophobic surface, in which the fibres tend to lie close to each other in water. This can be described as the start of the felting process. The longitudinal and transverse elastic properties of the wool fibre are causally related to the feltability. The fibres must be easily extendable and deformable since they are permanently extended during migration. While the root remains, due to the ratchet effect, the apical part (tip) must move up. This happens as a result of the fibre tangles being connected with the tip. Fineness, length, crimping and grease content have more influence on the quality of the felting than on the feltability. Fine fibres felt better with the same crimping. High felting speeds and high felting strengths are achieved at medium fibre lengths (25–50 mm). The felting power of completely de-greased fibres falls. Lubricants are used, which reduce the bending stiffness and so encourage felting. The fibre swelling indirectly influences the felting power because it has an effect on the elastic properties. The same applies to temperature. As regards the pH (Fig. 1) it is established that the felting power increases in the acid and alkaline range, while it is at its lowest at pH 5–7, i.e. in the isoelectric point range of the wool. The high densities, which are obtained in the acid medium, are no longer achieved in the alkaline one. Therefore fashionable woollen cloths are milled in an alkaline environment, while heavy technical felts are milled in the acid environment. Light furnishing felts made from nonwovens are produced using neutral milling.

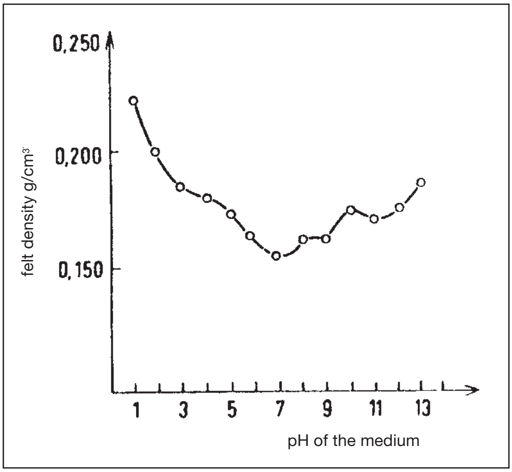


Fig. 1: Relationship of felting properties (Aachener shaking test) of loose wool to pH (according to Blankenburg).

Milling is understood to mean the processing of piece goods under extensively similar conditions such as in felting to increase the density and strength of the fabric (normally with a moisture content of 90–120% of the raw weight and at 30–35°C). The tasks of the milling process are character development of woollen items and preparation so that raw material strength is limited. Depending on the intensity of the milling process, a so-called pre-milled item is obtained, whose fabric weave can still be perfectly recognised, or a felt. In a core felt, the fabric is evenly felted in the cross-section; in a surface felt the top of the fabric only exhibits a random layer. In pre-milling the compression is achieved through relaxation and input of the piece goods in warp and weft direction. The number of warp and/or weft threads can be increased by a targeted compression to an extent, which cannot be achieved solely by fabric adjustment. Besides the compression of the fabric, a more or less strong matting is carried out by the milling. This further increases the mechanical union through the existing yarn and fabric bonds and so the fabric is made more resistant to wear.

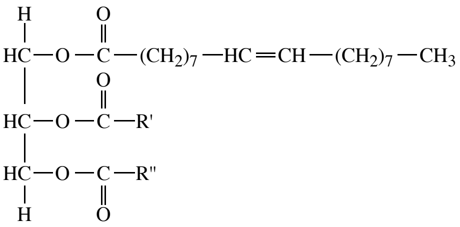
The area shrinkage, handle change (firstly soft due to relaxation, then firmer as a result of the increasing density) and air permeability, which decreases with the growing degree of felting, are standards for fabric compressing.

The milling processes are divided according to:

1. Dirt milling:
   - grease milling,
   - soap milling,
   - neutral milling,
   - acid milling,
   - special acid milling processes.
2. Milling of pre-washed fabrics:
   - soap milling,
   - neutral milling,
   - acid milling.

Natural wool chair fabric contains auxiliaries from the spinning and warp sizing in the weaving preparation, which must be removed in the washing and/or milling processes. The practical implementation of the milling process and the selection of milling method are therefore not only determined by the desired fabric result, but also by quantity and chemical structure of the spinning lubricants. Neutral oils, technical oleic acid (olein) and low-viscosity mineral oils are used as textile lubricants with and without the addition of emulsifiers.

Neutral oils, e.g. olive oils, contain a high percentage of dependent oleic acid.



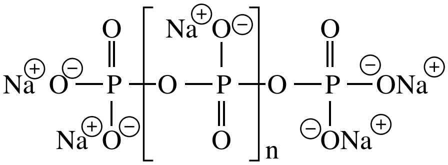
They have a good oiling property, but are not capable of saponification under normal washing conditions so they can only be removed with the aid of fat-solubilising soaps or emulsifiers. In order to facilitate their capability to be washed off , neutral oils are also available as emulsions.

- Technical oleic acid [$C_{17}H_{33}COOH$] has a satisfactory oiling property and can be saponified even in cold, alkaline liquor.
- Mineral oils [$CH_3(CH_2)_nCH_3$] can only be washed off in combination with emulsifiers. They are particularly valued as textile lubricants due to their good oiling property compared with metal and atmospheric oxygen.

Grease milling usually involves olein lubricated carded yarn fabric, whereby the spinning lubricant is saponified using sodium carbonate or ammonia. The soap formed by this is used for milling.

$$C_{17}H_{33}COOH + Na_2CO_3 \rightarrow C_{17}H_{33}COO^-Na^+ + NaHCO_3$$

Milling soap, sodium carbonate or ammonia and polyphosphates are used in soap milling. Through the formation of a lubricant layer on the fibre, the soap not only facilitates the throughput of the fabric through the milling instruments, but also reduces the fibre friction and so encourages the felting process. Alkali saponifies the olein present.



Polyphosphates are distinguished by:

- hardening and metal ion binding property,
- dispersing property,
- activation of wash-active substances,
- separate washing property,
- reduction of the turbidity point of soaps,
- emulsifying property,
- adsorption displacing activities (displacement of adsorbed soap residues on the fibre).

Chiefly mineral oiled or yarn dyed carded yarn fabrics and neutral oiled worsted yarn fabrics are treated in soap milling.

Neutral milling can be used should a non colourfast fabric be milled or only a low degree of felting is striven for. Carded yarn fabric, which contains an emulsifying spin oiling, can also be milled dirty at neutral pH. Synthetic surface-active substances are thereby used as milling agents. This, for example, includes fatty acid condensation products, fatty alcohol sulphates, alkyl naphthalene sulphonates, oil and sulphonated surfactants and/or sulphates (the long line in Fig. 2 symbolises a more or less long aliphatic hydrogen chain).

Acid milling is carried out at pH 2–4.5, adjusted by formic acid, with the addition of acid-resistant, synthetic milling agents. This milling process is chiefly used in felt manufacture (hats, technical felt), as particularly high degrees of felting can be achieved in the acid range; also in fabrics with a lack of colourfastness or with a large proportion of short fibres. Acid milling is the best method for mohair additions due to the low fibre loss.

– *fatty acid condensation products:*

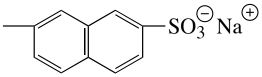
$——COO——SO_3^{\ominus}Na^{\oplus}$

$——CO—\underset{R}{N}——COO^{\ominus}Na^{\oplus}$

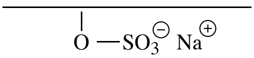
– *fatty alcohol sulphates:*

$——CH_2—O—SO_3^{\ominus}Na^{\oplus}$

– *alkyl naphthalene sulphonates:*



– *oil and sulphonated surfactants and/or sulphates:*



$\underset{O—SO_3^{\ominus}Na^{\oplus}}{\overline{\qquad\qquad}}$

Fig. 2: Surface-active agents for neutral milling.

Milling in is carried out in length and width one after the other by hammer milling (Fig. 3). Depending on how the piece has been laid in the tub, the impact of both hammers are either in weft or warp direction. Technical felts and felt slippers are milled in this way.

Width milling is effected by the pressure of the cylinders in cylinder milling (Fig. 4); length milling is however carried out by compressing the fabric together in the compression channel under the effect of the compression valve (Fig. 5).

Milling washing machines are fundamentally distinguished from cylinder mills only by the fact that the machine tank can be filled with liquor. The former were developed for reasons of efficiency in order to combine the processes of milling and washing in one type of

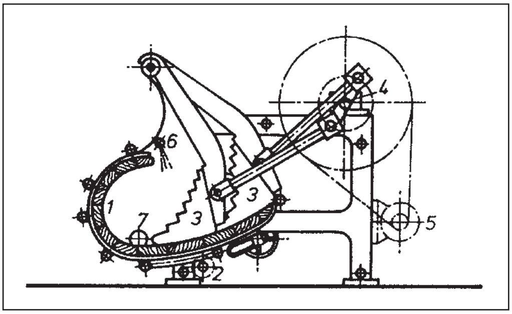


Fig. 3: Hammer milling machine, Model SHV (Hemmer).
1 = machine trough; 2 = trough adjustment device;
3 = milling hammer; 4 = crank; 5 = drive motor; 6 = spray tube; 7 = trough drain.

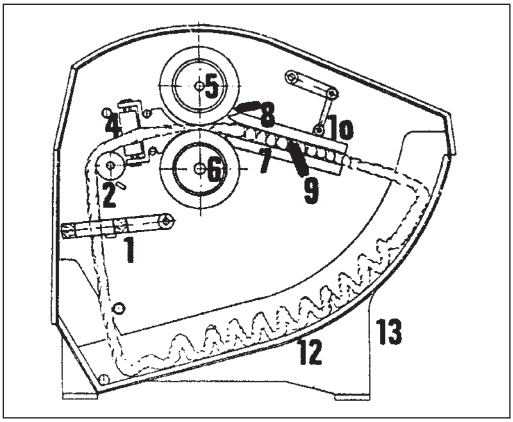


Fig. 4: Two-cylinder milling process Model E Type L
(W. Schiffers Maschinenfabrik).
1 = guide rake (collar plate); 2 = protective roller (antifriction); 4 = entry; 5 = upper cylinder; 6 = lower cylinder;
7 = lower tongue; 8 = upper tongue; 9 = milling channel;
10 = milling flap; 12 = machine trough; 13 = drive motor.

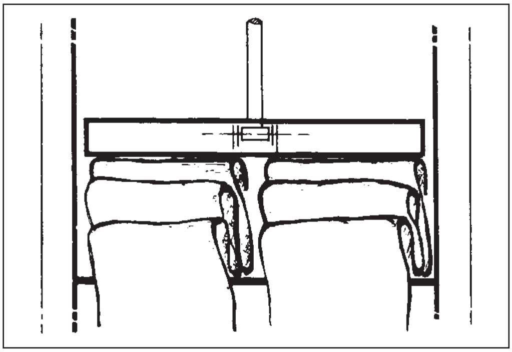


Fig. 5: Traditional milling box.

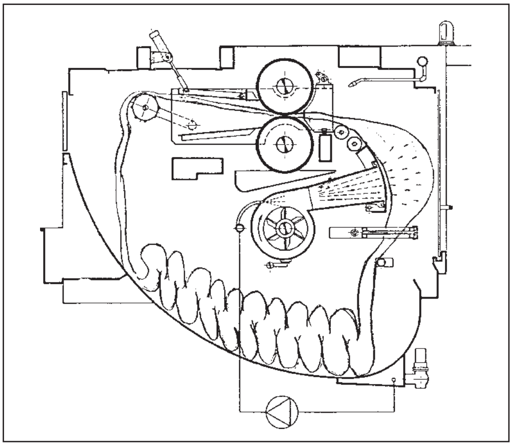


Fig. 6: "Turbomat 4 Stagioni" (MAT), diagram.

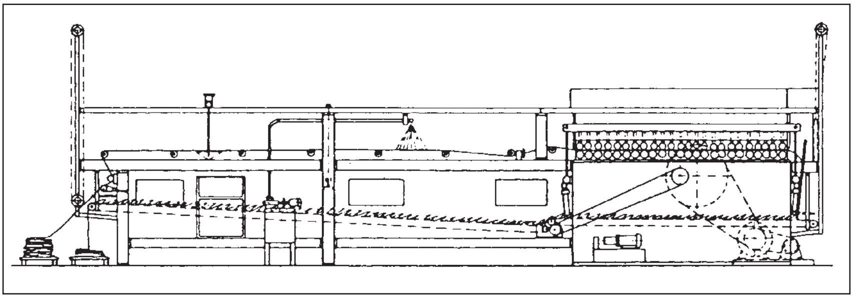


Fig. 7: Open-width milling machine.

machine, i.e. one operation. The models of different manufacturers are distinguished, amongst other things, by the cylinder coverings (plastic, wood, metal), the type of cylinder (continuous or disc cylinder) and the compression aggregates.

In order to guarantee a better hank layout for every hank revolution and to save sack sewing (sewing together of fabric selvedges into a tube), hot air at 40°C is blown by the turbomat (MAT) onto the fast running (600 m/min) hank, which is extensively unfurled by this before it again runs into the entrance. The name “Quatro Stagioni” (four seasons) expresses the widest possible application of this milling for all articles (light summer articles, heavy winter goods) (Fig. 6).

Furnishing felts made from wool fleeces are manufactured in a wide form on plate or roller mills (Fig. 7). Heavy carpet yarns can also be milled using peristalsis type movements in plastic tubes (periloc process, Fig. 8).

Additional elements in milling, such as the hank layout device from FAMIT (Fig. 9) or auxiliary elements in the compression channel (Fig. 10) support the milling process.

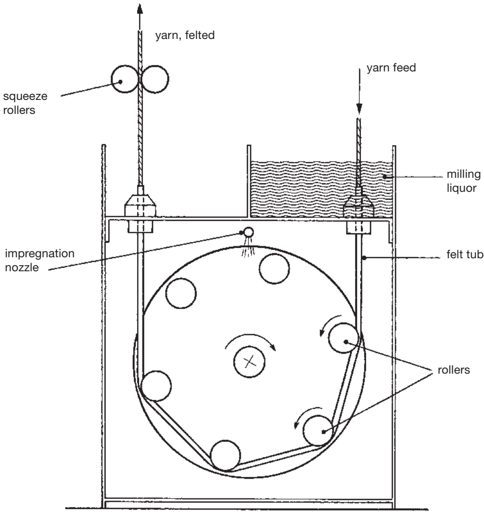


Fig. 8: Periloc process for the milling of yarn.

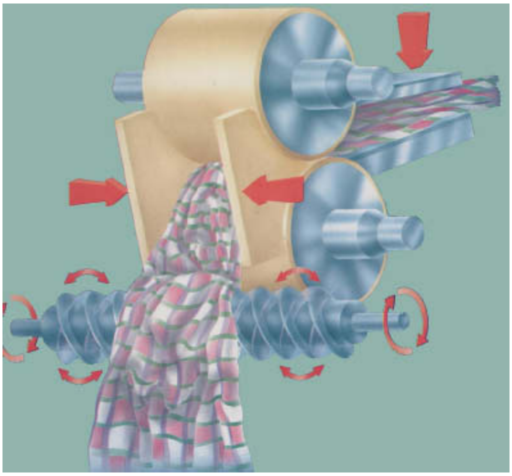


Fig. 9: FAMIT hank layout device.

Milling resist effects Milling of woollen items (woven or knitgoods) causes condensing of the textile fabric by felting. If you partially print on antifelting polymer fabric, the wool is resistant to milling at the printed places in the following milling. A fashionable surface structuring is obtained in this way. An antifelting paste is printed onto the untreated wool, as the application of oxidation processes, in particular the use of chlorine, is too problematic before printing. While it is customary to replace half of the resin proportions with a polyurethane polymer in the finishing of woven goods in order to achieve a softer handle, this is of little importance for knitgoods: the printed fabrics are then washed, which makes the handle soft again. To make the resin printable, it is prepared in the form of a print paste. The selection of the printing thickener is thereby important, as it should not interfere with the condensation of the resin and should be removed in the first washing and milling process. The market offers a broad selection of printing thickeners for the printing indus-

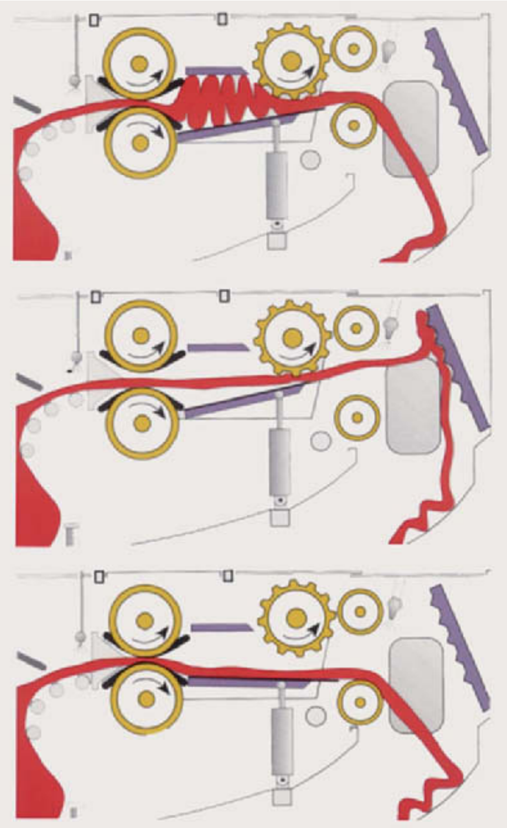


Fig. 10: CIMI auxiliary elements in the compression channel.

try, whereby "low solids/high viscosity" types with high profitability are preferred. Products on an alginate base are most suitable; others, which contain primary alcohols, may react with the resin and produce a hard handle in the fully finished part.

The preparation of the paste is carried out in steps; resolution of the thickener, addition of the diluted resin and the dissolved hydrogen carbonate shortly before printing, as the paste is only stable for approximately 12 hours after the hydrogen carbonate has been supplied.

Milling rig → Hole in milling.

Milling shrinkage,

1. Mark in a metre on grey goods in the sealing department. After milling, the difference between raw and finished length produces the felting shrinkage (in %, referring to the raw length).

2. Subtract percentage finishing loss (difference between raw and finished fabric weight) from the raw weight; divide the difference by the current finished weight per metre.

Millitron process Computer-controlled carpet spray printing, whereby dye solution is sprayed into the carpet pile from nozzles. As it is processed without screens, there is no contact with the carpet surface, therefore no deformation of the pile material and, when changing patterns, no machine stoppage. There are 100 nozzles on an area of 6.5 cm^2. The nozzles can be operated in a fixed or moving mode, continuously or intermittently. Operating speed: approx. 2–5 m/min.

Millon's reagent,

I. For the testing of protein substances (finishing analysis); reagent easily decomposable; always prepare freshly before use (consisting of 20 g of mercury and 40 g of nitric acid, heat in water bath until dissolved, leave for 24 hours, pour off precipitate; with protein, is turbid until precipitation, pink hue during heating); optimum pH range for reaction: neutral to weak acid.

II. For the testing of wool damage, i.e. degraded wool (reaction to the amino acid tyrosine). Boil sample with solution of mercury nitrate in nitric acid. This initially results in a white precipitate, which is then dyed reddish-brown (violet).

III. Testing of animal fibres (silk, animal hair fibres, casein) besides man-made fibres. It results in a red to reddish-brown hue when heated (animal fibres).

Mill scouring,

I. → Raw wool scouring (in contrast to → Backwash).

II. Washing of laundry in the → Laundry (in contrast to → Domestic washing).

Milnerised process Finishing process using application of resin finishing agents, catalysts and additives together with sizing agents and dyes on warp yarns made from polyester/cotton. Woven fabrics manufactured from this are firstly heat set and condensed at high temperatures (e.g. 185°C) and then washed. Final finishing with the same or other resin finishing agents (reduced amount of applications) concludes the finishing. Pigment colorant is used in this combination process for single-stage sizing, dyeing and after treatment. The process is for women's outerwear permanent-press items. After the weaving, it is rapidly processed on pin frames.

Mineral (Lat.: minera = ore mine), in German the term encompasses all natural constituents of the earth's crust, which are dug out. This not only includes materials of inorganic origin such as ores and the metals extracted from them, as well as rocks, salts, clay, mineral dyes, etc., but also organic decomposition products such as carbons, asphalt, mineral oils, peat, amber, etc. In languages other than German the term mineral is predominantly used for ore and rock.

Mineral acid hardness → Water hardness salts.

Mineral acids Inorganic, non-carbon containing acids such as →: Hydrochloric acid; Nitric acid; Sulphuric acid. Opposite: → Carboxylic acids.

Mineral dyes inorganic coloured pigments, known as so-called paints. Hardly used for textile dyeing and printing any more. The → Mineral khaki formed on the fibre is of some interest.

Mineral fibres (mineral and/or → Inorganic fibres),

I. From the group of natural fibres: → Asbestos fibres.

II. From the group of man-made fibres: other industrially produced fibres such as →: Glass fibres; Mineral silicate fibres (Rock wool); Slag wool; Metal fibres, etc.

Mineralization Biological degradation or biodegradation is understood to mean any transition of dissolved or solid substances by organisms into other compounds. Besides assimilation by means of photosynthesis, in which dissolved substances are absorbed in the biota, the biological degradation of organic compounds by micro-organisms such as bacteria and fungi is the most important process. Organic substrates are thereby oxidised, whereby the microorganisms use a part of the energy released for reproduction. This type of respiration is called mineralization. It consumes oxygen or, if this is not available, other oxidising agents such as nitrates, sulphates or already partially oxidised organic compounds. Simplified, these processes can be formulated as follows:

1. Aerobic respiration: Organic substances are oxidised; oxygen is reduced. Ideally the oxidation results in carbon dioxide and water:

$$<CH_2O> + O_2 \rightarrow CO_2 + H_2O$$

2. Anaerobic respiration: Organic substances are oxidised to carbon dioxide; carbon dioxide is reduced to methane (methane fermentation):

$$<CH_2O> + {}^1/_2\ CO_2 \rightarrow CO_2 + {}^1/_2\ CH_4 \text{ or}$$
$$<CH_2O> \rightarrow {}^1/_2\ CO_2 + {}^1/_2\ CH_4$$

with nitrate or sulphate:

$$2\ <CH_2O> + NO_3^- + 2\ H^+ \rightarrow 2\ CO_2 + NH_4^+ + 3\ H_2O$$

$$2\ <CH_2O> + SO_4^{2-} + 2\ H^+ \rightarrow 2\ CO_2 + H_2S + 2\ H_2O$$

These reaction sequences have been tested and are, for example, used for the biological treatment of waste water. Approx. 50% of the organic substrate is oxidised for the energy gain in aerobic respiration; the rest is converted into bacterial matter (sludge). However only approx. 10% of the substrate is converted into bacterial matter in methane fermentation (according to Kümmert and Stumm).

Mineralization of washed goods Appearance of a fault in cellulose fabrics (white washing) during washing in hard water with sodium carbonate addition, which converts sulphate hardness into calcium carbonate. The latter in particular is removed as coarse heat crystals and remains on the fabric. The sharp-edged crystals cause premature wear during use due to friction and abrasion. In the presence of soap, → Lime soap breaks down more rapidly, covers the calcium carbonate crystals and consequently reduces their cutting effect. Mineralization of washed goods is no longer a problem due to the increased use of softened water, addition of sequestering agents to the washing liquor and replacement of soap with synthetic detergents.

Mineral khaki Mineral coloured pigment. On cotton items in England, India and USA for tropical clothing, uniform materials, camouflage items, hunting shirts, tarpaulins and car covers, as extremely cheap, outstandingly light fast and good colour fast to washing (acids have a destructive effect though) as well as bacteriostatic, combined with a certain fullness and hard handle. An excellent camouflage dye for tropical uniforms and similar. Manufacture using blends of soluble chromium salts (higher quantity used results in greenish tone) and iron salts (higher quantity used results in brownish khaki). Process:

1. Impregnate on the 3 milling padder with the above blend (density 1.18).
2. Short steaming or drying (hotflue).
3. Passage through a) a bath (density 1.06) of 1 part caustic soda liquor 40°Bé and 3 parts sodium carbonate calc. (formation of chromium oxide and iron oxide on the fibre) or b) weak sodium carbonate solution and then diluted hypochlorite solution. Alternatively it is slowly heated to 80°C on the jigger using iron (II) sulphate and chromium salt; then follows rinsing, soaping, cold and hot final rinsing.

Mineral oil Usually carbon mixtures (benzine, benzene, petroleum, paraffin oil and vaseline oil), liquid, greasy or solid; insoluble in water, unsaponifiable. Application: benzine, benzene, oils: for lubricating purposes, oiling, etc.

Mineral silicate fibres Belonging to the group of mineral fibres; industrially manufactured fibres made from the melting of rocks. Only for industrial purposes.

Mineral wax → Ceresin wax.

Mineral weighting → Weighting of silk using inorganic salts (tin-phosphate-silicate weighting).

Mini-Fluid Doctor roll padder for energy-saving low wet pick-up of dyes, chemical and finishing liquors (see Fig.). Suitable for full immersion and roller application, consisting of colour box and kiss roll. Liquor quantity to the doctor roll is controlled by a magnetic beam. The liquor film is taken up by the continual material web and pressed into the fabric by the squeezing unit. A suction nozzle on the material edge accepts surplus liquor. Cleaning of the kiss roll by use of a cleaning device. Roller width 140–240 cm. Suitable for woven and knitted fabrics. Production speed up to 100 m/

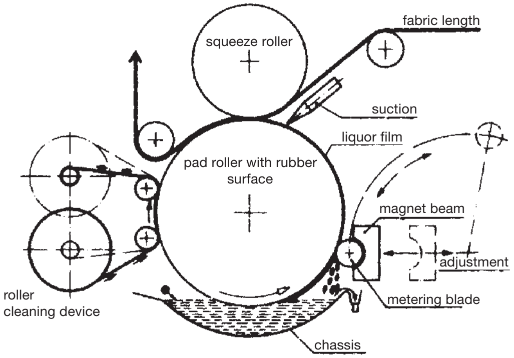


Fig.: Mini-Fluid product application by Goller.

min. Liquor application (using standard squeegee) 30–40%. – Manuf.: Goller.

Minimum film formation temperature (MFT, white point), below the typical temperature for the dispersion of a polymer, where only a white layer (white point) is formed during drying instead of a transparent/translucent, connected film. If, for example, a dispersion of white point (or MFT) is indicated at approximately 15°C, a clear, closed film is produced during drying at 16°C or above, against which a white, inhomogeneous layer is produced during drying at 15°C and below. The white point is always lower, the softer the film of a dispersion. The MFT is reduced by the addition of softeners, solvents, as well as acetic acid and similar. Field values of some important polymer dispersions are shown in the Table.

The respective particle sizes of protective colloid-containing dispersions (averagely or finely dispersed) play a role in this connection because particle sizes and their distribution decide jointly, with the emulsifier system, on the suitability of application of a dispersion (e.g. viscosity). The following processes take place in film formation during the drying of a latex application: very thin aqueous layers, so-called capillary layers, with a concave meniscus, are formed between the polymer globules (Fig. 1). The capillary forces squeeze out the water from the globular cluster and squeeze the globules even tighter together. If the polymer globules are too hard, nothing further happens. The water evaporates, but no film formation occurs. A densely packed globular cluster remains, macroscopically: a powder. If the globules are soft enough however, they are deformed under the influence of capillary forces. The contact areas become ever larger and many-faceted, geometric configurations, so-called polyhedrons, are formed from the globules, whose surfaces result from the geometric arrangement in the original globular cluster. The remaining water is thus completely displaced from the intermediate spaces and the polyhedrons themselves fuse with each other superficially. A polymer film is also produced: a matted globular cluster. A polymer globule, which consists of stretched, unsplit filamentary molecules, appears hard. If the macromolecules have lateral branches however, they

dispersion/ polymer of	iono-genicity	disper-sivity	film at room temperature	glass temperature (T_G) °C	min. film formation temperature °C
vinyl acetate	n	coarse	hard, brittle	+29	15
	a	fine	hard, brittle	+29	15
	n	medium	hard, brittle	+29	17
vinyl acetate/ ext. plasticizer	n	coarse	soft	– 3	0
	n	coarse	very soft,flexible	–21	0
vinyl acetate/ dibutyl maleinate	n	medium	firm, elastic	+16	12
	n	medium	stiffly elastic	+10	5
	n	medium	soft	+ 3	0
vinyl acetate/ ethylene	n	fine	soft, flexible	+ 7	10
	n	medium	soft, flexible	– 5	0
	a	fine	very soft, flexible	–20	2
	n	medium	very soft, strongly adhesive	–30	0
vinyl acetate/ acrylic ester	a	fine	hard, brittle	30	11
	a	fine	soft, very stiff	15	8
	a	fine	soft, flexible	– 9	9
	a	fine	very soft,flexible	–18	9
acrylic ester	a	fine	soft, stiff	13	10
	a	fine	soft, stiff	4	9
	a	fine	soft, flexible	–15	8
	a	fine	very soft,flexible	–25	8
acrylic ester/ styrene	a	fine	hard, brittle	+45	ca. 70*
	a	fine	soft, flexible	–12	0

Tab.: Glass and minimum film formation temperature (by Fischer).
** Even at room temperature a clear, transparent film occurs following heat treatment above 70°C.*

Minimum film formation temperature

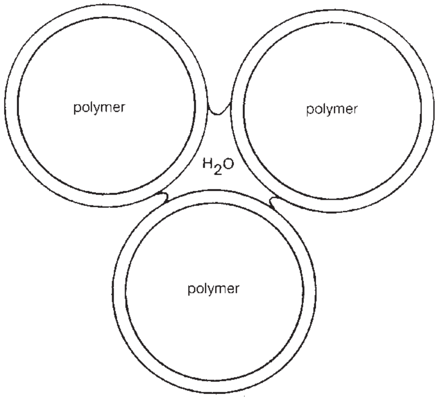


Fig. 1: Aqueous capillary layers with concave meniscus form between the polymer globules.

act as spacers. The polymer molecules can no longer lie so densely together, they remain mobile. Less energy is needed to push them apart. A latex particle, which consists of such well separated molecules, therefore normally appears soft.

Whether a polymer is in a state in which it can be described as hard or soft is also a question of the energy content. Only in the soft state are the small polymers mobile enough to felt with each other over the surface during close contact of two or several latex particles and so to weld the particles together. The temperature at which molecular mobility is only just sufficient for a film formation is the MFT. Only above the MFT does the welding of the latex particles into a relatively satisfactory polymer film take place. So much water is removed in the first stage of the drying process that a hexagonally compacted ball exists. In the second stage of the drying process, these balls should then fuse into a polymer film (Fig. 2). Three forces essentially work in this direction:

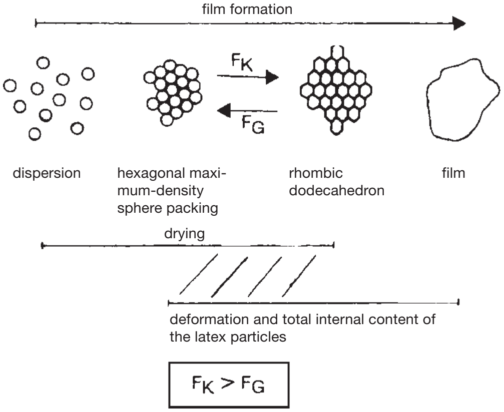


Fig. 2: Diagram showing film formation of latex particles. F_K = capillary pressure of the water; F_G = resistance of the polymer against deformation.

1. An internal pressure arises when two forces touch,

$$P_i = \frac{2\,\sigma}{r_k}$$

which tries to combine the balls into a larger ball. This internal pressure is higher the greater the surface tension σ and the smaller the ball radius r_k. The force F_i is equal to the product of pressure and area.

2. It can be seen in Fig. 1 that water capillaries with a concave meniscus are formed in the intermediate spaces of the globular cluster. The effective capillary pressure at the instant of contact of the balls is

$$P_k = \frac{2\,\sigma}{R}$$

So P_k is larger the higher the polymer/water surface tension σ is and the smaller the radius R of the capillaries. The capillary radius R can be converted into the ball radius r_k. The relation

$$R = r_k\left(\frac{2\sqrt{3}}{3} - 1\right) = 0.155\,r_k$$

for the same size balls is obtained, from which the above equation can be converted into

$$P_k = \frac{12.9 \cdot \sigma}{r_k}$$

So the capillary pressure is greater the smaller the latex particles are. If the polymer/water surface tension is approximately 35 dyne/cm (and the radius of the latex particles approx. 50 nm), the adjusted capillary pressure would be calculated at approx. 9 N/mm^2 under these conditions. In order to obtain the capillary force F_k, the capillary pressure must be multiplied by the area.

3. Intermediate molecular forces also work between the polymer particles. They may be dispersion forces, dipole forces, electrostatic forces, hydrogen bridges, etc. They all or some of them make a contribution, which supports the forces previously described. The quantitative recording of these forces is provided by the collective symbol F_{ZM}. The forces, which obstruct this process, certainly also hinder those forces, which encourage the coalescence of the latex particles. So the

polymer globules, as will any solid particle, also offer resistance to deformation. This resistance force is abbreviated to F_w. Finally the particles are given an electrostatic charge of the same denomination so that they can be generally stable as a dispersion. So Coulomb's repulsive forces

$$F_c = \frac{K \cdot e^2}{r^2}$$

counteract coalescence. These are greater the higher the particles are charged with a common denomination e and the smaller the distance apart of the centres of gravity of two particles r. So a coalescence of the particles into a polymer film only occurs, if

$$F_i + F_k + F_{ZM} > F_w + F_c$$

Only the capillary forces and deformation resistance are thought to play a leading role, so that the above unequal equation is reduced to

$$F_k > F_w$$

Accordingly, film formation is only possible if the capillary forces overcome deformation resistance. The deformation converts the hexagonally compacted ball into a complex of touching rhomboid dodecahedrons. Small particles in systems with a high surface tension are at an advantage.

Minimum ignition time → Ignition time.

Miscibility gap Components in solutions tend to be diluted at lower temperatures, while mutual solubility increases at higher temperatures, usually until complete miscibility (Fig. 1). Miscibility gaps frequently occur in compounds. These mixtures have a technical significance with regard to the equilibriums between the dissolved part and the non dissolved remainder. Restricted or varied solubility is exploited by separation via distillation.

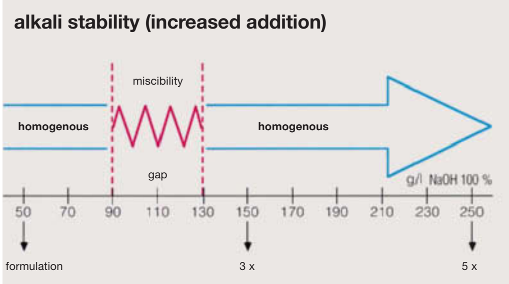


Fig. 1: Miscibility gap with increasing concentration of caustic soda.

The problem of restricted miscibility, which can assume varied forms, can be shown in the example of ternary mixtures. This is shown graphically in Figs. 2–5.

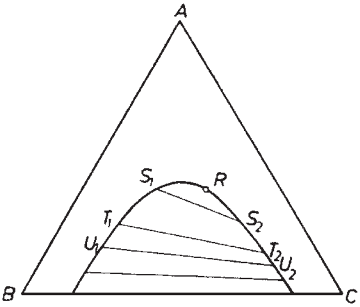


Fig. 2: Ternary mixture with a miscibility gap: the components B and C do not mix in every ratio. Phases belonging together (in equilibrium to one another) are linked by the connecting lines (tie lines) running through the miscibility gap zone.

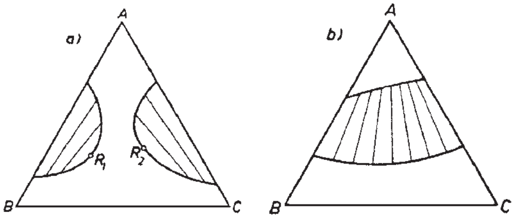


Fig. 3: Ternary mixture with two miscibility gaps: between A and B and between A and C. In a (left) the miscibility gaps are separated, in b (right) they have joined together. It is then no longer possible, starting with mixtures B + C, to achieve mixtures rich in A, or the other way round, unless (temporary) separation into two fluid phases takes place.

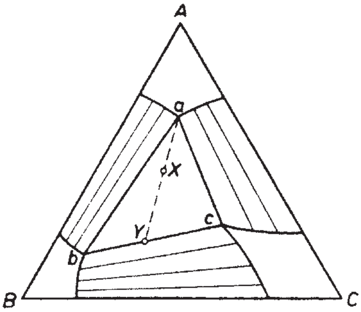
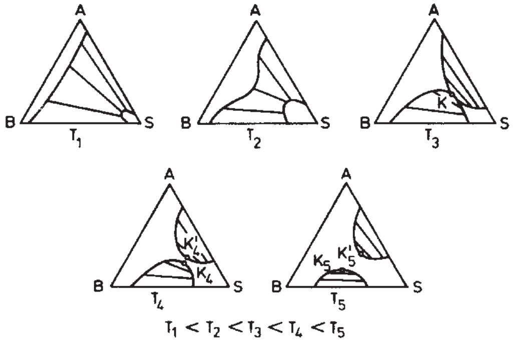


Fig. 4: Ternary mixture with three miscibility gaps: the miscibility gaps are so great that in inner zone abc, where the mixtures disintegrate into three coexistent phases according to the composition at points a, b, c. A mixture of composition X arises, which has a proportion at phase a, corresponding to line XY. The remainder, proportional by volume to Xa, disintegrates in relation to lines Yb and Yc in phases c and b.



Example:	A nitrobenzene	$C_6H_5 - NO_2$
	B methanol	$CH_3 - OH$
	S isooctane	C_8H_{18}

Fig. 5: System with two miscibility gaps at high temperatures, which grow together at low temperatures.

The representation of the phase behaviour of binary systems of water and surfactants is temperature and concentration dependent in the phase diagram. The phases formed are, however, subject to changes in state.

The binary phase systems go through several phases depending on the parameters, temperature and concentration mentioned above. Besides molecular, micellar and inverse micellar solutions, single and two-phase liquid crystalline zones are also observed. A large concentration range is passed through in a comparatively short period of time, in particular in the evaporation of diluted surfactant solutions. It is possible to identify surfactant structures under polarisation microscopes and so it is possible to classify the phases.

The liquid crystalline condition is the classification for organic substances produced from solutions, which are plastic to liquid. They are found in so-called liquo crystals or in the mesomorphic state. Most surfactants form crystals with a defined quantity of water, which is divided into thermotrope and lyotrope. This intermediate condition is also described as the 4th aggregate state. The division of the liquid crystalline phase is arranged as follows: thermotropic phases are composed of anisotropic molecules and occur between the liquid and crystalline phases. They alter their structure under the influence of the temperature. Lyotropic phases have considerably more complex behaviour. Their aggregates form a dynamic system, which continually exchanges surfactant molecules with the environment. The mobility of the molecular amalgamations is temperature-dependent and results in polymorphism. Lyotropic phases show characteristic liquid crystalline behaviour in the presence of polar and continuous media.

If the molecules are mobile in two spatial directions in the liquid state and can rotate around an axis, this is described as a smectic state (Gk.: gunk, glue). If the molecules move in all three spatial axes and turn around an axis, this characterises the nematic state (Gk.: thread). Both disk and rod micelles are distinguished in the nematic phase. Besides nematic phases, cubic, in particular hexagonal and lamellar structures occur in the aqueous medium. Steric reasons are responsible for the formation of the liquid crystalline phases. The spherical micelle is the energetically most favourable form of isotropic solutions at low surfactant concentrations. These become anisotropic micelles during growth. They show inverse structures; with high surfactant concentrations. The continuous phase is no longer the solvent, but the surfactant. Cylindrical (nematic) and hexagonal phases are produced from rod micelles for surfactants with a voluminous head and a short alkyl chain. Depending on the chemical constitution (hydrophilic property of the head group and chain length) hexagonal and cylindrical phases can be produced, and disc micelles and/or lamellar phases formed. If nematic phases occur in the system, these can always be found in the concentration range below the lamellar and/or hexagonal phase. If a system forms both hexagonal and lamellar phases, the hexagonal phase is always present at low surfactant concentrations. Cubic phases may occur both before the hexagonal and between the hexagonal and the lamellar phases.

The phase behaviour of non-ionic surfactants in aqueous solution is very complex in construction. A reason for this is that miscibility gaps appear in non-ionic surfactants in aqueous solution. A dilution into two liquid phases occurs when heating such isotropic solutions at a certain temperature (dependent on the surfactant concentration). The phenomenon described characterises the dilution point or cloud point, which plays a crucial role in the washing effect. Besides the single-phase lyotropic range, several two-phase regions are present in small surfactant concentrations: a diluted liquid phase and a phase consisting of inverse micelles. An isotropic region is also present. Single-phase liquid crystal regions are present at higher surfactant concentrations. Viscous hexagonal phases are found in many systems, which are constructed from rod micelles, and the essentially light lamellar phase, which consists of a surfactant double layer (according to Schollmeyer).

Miss pinning faults (stenter miss clipping). Appearance of fault on fabrics due to occasional non-gripping of the fabric edges on the part of the clips on the stenter.

Mist → Fog.

Mixed bed exchanger → Ion exchanger.

Mixed catalysts in resin finishing So-called self-crosslinkers and reactant crosslinkers are used in the resin finishing of cellulosic textiles. The self-crosslinkers are chemically unstable and therefore their liquors can only be used over a short period of time. This problem is extensively ruled out in the use of reactant crosslinkers, as their chemical stability in the liquor is considerably greater. On the other hand however, this results in the reaction of the self-crosslinkers with the cellulose having less catalytic acceleration than that of the reactant crosslinkers. The selection of catalysts in resin finishing depends on the reactant crosslinker used. It also influences the condensation time and temperature required. Mineral acids and strong organic acids are unsuitable as catalysts, as they considerably accelerate the crosslinking reaction and simultaneously considerably damage the cellulose. Various metal salts are used as latent acid catalysts for this reason. They should only become active in condensation conditions. The activity of the metal salts depends both on the cation and the anion. In practice, various → Catalysts are used for resin finishing.

From the point of view of carrying out the crosslinking under the most mild conditions possible, in order to keep the damage to the cellulose as low as possible, catalyst systems consisting of magnesium chloride and other metal salts have gained importance in dry cross-linking. This increases the catalytic effect of magnesium chloride, as the addition of organic acids, such as oxalic acid, was tested for an increase in catalytic activity. An optimisation of the process parameters, such as temperature, condensation time and catalyst concentration, was carried out for some small crosslinkers regarding the result of resin finishing. Independent of pH the presence of phosphate ions increases the stability of crosslinking liquors due to interaction with the crosslinking molecules. The metal salts used as resin finishing catalysts have little influence on the stability of the crosslinking liquors. They almost exclusively catalyse only the actual process of resin finishing (according to Buschmann and Schollmeyer).

Mixed felt → Felt.

Mixed red Mordant dye in cellulose dyeing.

Mixed shoddy yarn Pure mixed shoddy yarn: soft, silky shining, usually mottled 2–3 fold wool yarn (→ Carded yarn). Also mixed yarns e.g. made of wool/cotton. Artificial mixed shoddy yarn: less valuable cotton weft yarn in a type of carded yarn.

Mixers and stirrers → Metering systems for dyes and chemicals.

Mixing → Metering station.

MK,

I. German abbrev. for “Metallkomplex” (metal complex).

II. → Molar concentration.

ML Process (Micro-Length-Stretching = micro lengthening), drop in tearing strength in weft direction is prevented through mechanical drawstretching.

An even drawstretching going beyond elastic elongation (Fig. 1) is carried out across the entire surface of the fabric and along the whole length of the weft yarns and individual fibres. This results in the rectification and re-orientation of the structure of the individual fibres, the fibres in the yarn and the yarns in the fabric. Application, e.g. on wet fabric. In resin finishing, usually after application of the finishing liquor for a short time before drying and condensing. A typical machine for the ML process is the Memotex system from Küsters (Fig. 2).

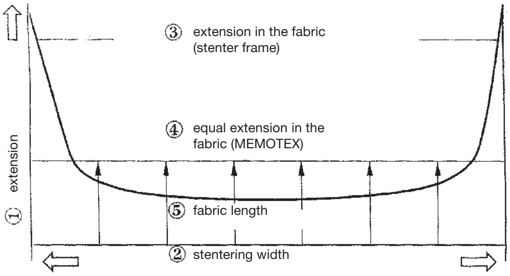


Fig. 1: Comparison of the tension in fabrics before and after ML treatment.

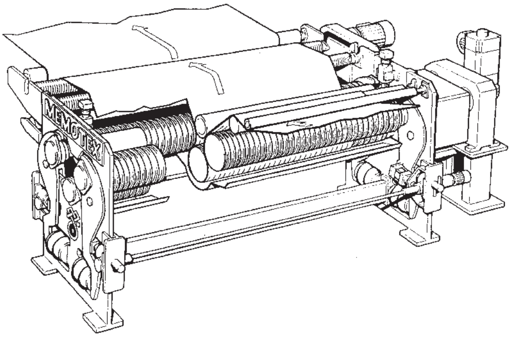


Fig. 2: Memotex plant by Küsters.

MLD Shortened form of minimum lethal dose (lethal limit), i.e. smallest known lethal basis for humans. In inhalation poisons, the criticality limit for gases, vapours and volatile suspended matter is usually given in ppm (cm^3 gas/m^3 air), for non-volatile suspended matter (dust, smoke, aerosol, etc.) in mg matter/m^3 air.

MLS → ML Process.

MM-co mercerising machine Mercerising machine operating continuously from spool to spool, especially for mercerisation, neutralisation and drying of cellulose ply-yarns (1000–2000 dtex). Useable fabric width of 480 mm, max. thread speed of 720 m/min. Chiefly consists of machine (with drive unit and spool feeding attachment in magazine design), two wet treatment chambers (yarn rollers, easily replaceable), electric hot air drier (circulating/exhaust air principle), winding head (also suitable for mock cake, with constant crossover angle) alternatively for conical or cylindrical spools (up to approx. 250 mm external diameter), electrical equipment (control equipment, thread monitoring, etc.). Central liquor treatment/distribution, extensive full automatic operation (processing sequence selection of shrinkage/stretching ratios, treatment time, etc.).

Mn Element symbol for manganese (25).

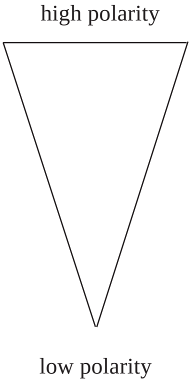
Mo,

I. → Mohair, → Textile fibre symbols, in accordance with DIN 60 001 until 1988, from 1991 → WM.

II. Element symbol for molybdenum (42).

Mobile solvents for thin layer chromatography are used as so-called → Eluents (mobile phase) for elution, whereby eluting effect of the mobile solvents increases with their increasing polarity. Selection of mobile solvents in accordance with the eluotropic series, thus for an unknown mixture, these mobile solvents are, to begin with, put in use one after the other (desired polarity can also be achieved by mixing):

bases
acids
water
methanol
ethanol
butanol
acetone
acetic ester
ether
chloroform
benzene
toluene
carbon tetrachloride
cyclohexane
benzine



Mock moiré effect → Moiring.

MOD Abbreviation for → Modacrylic fibres.

Modacrylic fibres (MA, MAC), modified polyacrylonitrile fibres made from 50–85% by weight acrylonitrile (copolymer fibres). Modified on the one hand for relaxing of the structure for improved dyeability or hydrophilic properties and on the other to also increases the flame retardant property. Other material properties are more or less affected because of this, and thus, advantages, such as reduced flammability, could also be connected with textile technology concessions.

Modal fibres (abbrev.: CMD, MD), regenerated → Cellulosic fibres with a high resistance and high wet modulus, manufactured by the addition of modifiers and by variable spinning speeds (wet elongation 15% at 2.25 cN/dtex load). This includes both → Polynosic fibres and → High wet modulus fibres. Modal fibres have a higher degree of polymerisation (DP 350–600), higher resistance, wet modulus, dimensional stability and alkaline resistance compared with normal viscose fibres. HWM fibres have lower alkaline resistance and lower brittleness compared with polynosic fibres (see Tab.).

The improved properties compared with the classic cellulose regenerated fibres are due to the clearly higher mole mass or chain length of the individual molecules and the more compact internal structure of the fibres, which come closer to the properties of cotton. A deceleration of the xanthate decomposition, caused by the addition of a modifier and the precipitation bath composition, results in an extension of the plastic state and in the possibility of a strengthened longitudinal orientation and the development of better internal structures. These developed structures play a crucial role in the finishing process. The deviating behaviour of classic regenerated and modal fibres is well known. One problem is the tendency for uneven dye uptake, which can often be recognised as colour streakiness. Local or temporary differences in the colloidal precipitation processes, delay and orientation processes, chemical decomposition of the xanthate as well as subsequent thermal effects, may constitute the cause of this.

Modal fibres, finishing In principle the same processes as for viscose and cupro fibres. Somewhat lower sensitivity to alkalis.

Models Scientific observations are often based on the idea of models or pictures, which exist in the human consciousness and help in thinking about the behaviour of nature. Model presentations of human behaviour are developed in psychology, and are used in thinking about the behaviour of a real human individual. A phys-

	breaking strength		extension at break		wet modulus	water retention properties	DP
	dry cN/tex	rel. wet strength %	dry %	wet %	%	%	
normal viscose staple fibre	18—27	40—65	19—27	24—35	45—90	90—125	300
HWM fibre	36—45	60—75	11—18	13—21	117—225	60—90	350—600
polynosic fibre	32—65	65—80	9—15	10—16	180—600	55—70	450—600
cotton for comparison	28—38	100—110	9—11	10—14	90—162	45—50	2000

Tab.: Comparison of the properties of modal fibres with viscose or cotton.

icist, who deals with high energy elementary particles, develops his own model presentations for the behaviour of these particles, whereby the concept that there are elementary particles forms one of these model presentations. With the aid of models for systematic scientific testing or for better understanding of reality, it should never be forgotten that this cannot be a complete picture of reality, but the models only agree with reality in a specific area concerning a particular question. The scientific experiment is assisted by a model in order to analyse complicated connections, to organise them into smaller problem fields and to understand them with the aid of these simplified structures. So model tests do not help in recognising complex connections, but are used to test a section systematically and to find answers to questions, which are concerned with area. A good model is, therefore, useful because it is simpler than a natural example. The disadvantage that models cannot convey everything about the real system is accepted.

The classic form of an experiment is the one of designing a system in which all the factors are comparatively carefully verifiable and for which particular types of results can be looked for. The scientific method would therefore look somewhat like this:

– observation of nature.
– search for a theory (model),
– testing of the general validity of the model through experiment.

I. Colour models: The technology as “applied science” comprises the alignment of the methods and facts of science to a particular objective. As varied, for example, as is the use of the colour, so are the problems in colour definition, reproduction and perception also varied. Each colour can be declared in different colour models using different parameters. That is why there are different colour models, which can in principle be subdivided into:

1. Colorimetric models: In order to define colours in the textile industry, and also in other industrial sectors and/or to nominate for dyeing purposes; the CIE or CIELAB colour model is chiefly used (colour difference in accordance with DIN 6174).

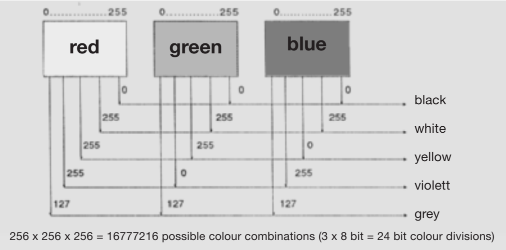


Fig. 1: Red, green and blue colour channels with 256 intensity gradations.

2. Technical/physical colour models: They describe a colour as a mixture of three primary colours (Fig. 1). The differences between the individual models lie in the selection of the primary colours and the type of colour mixture. The RGB basic cube and YIQ model are important for colour television.

3. Perception-oriented colour models: The technical/physical colour models are orientated to the requirements of output devices and transmission technology. But they are less suited to direct colour definition by the user. Colour models were therefore developed, which work with dimensions corresponding to human perception, namely shade of colour, lightness and saturation. Two groups can be differentiated depending on the description of these three dimensions:

– numerically symbolic colour description (HLS model),
– colloquial colour description (CNS model).

A model consequently gives a simplified picture of a complete set, leaving out many parameters. A danger in such simplifications lies in the fact that one begins to think monocausally or that conclusions are drawn, which would have looked different with a view of all the variables. For this reason, however, each model

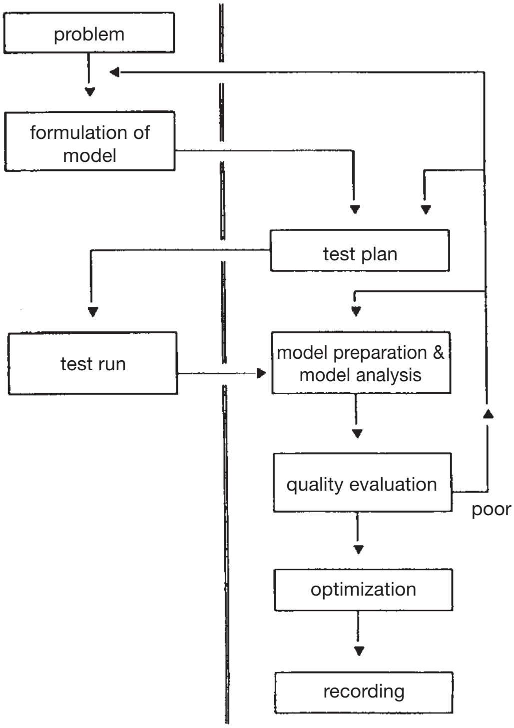


Fig. 2: Strategy diagram of a computer-controlled development process (left: data of the developer; right: the software [APO]).

presentation must be verified in the natural system, i.e. compared with measurements and experiments.

II. Process models: A process model is understood to mean a framework of technical correlations, which is more or less consistently capable of describing the behaviour of a process, e.g. a dyeing process. The mathematical description of a process is always the acknowledged aim in the natural scientific disciplines. In order to achieve this aim, a deterministically characterised solution strategy is required, which so to speak represents the tool, with which a mathematical process model is produced. Assuming that adequate practice-relevant measuring methods are available for the quantification of target demands, the question arises as to which statements are expected from the model to be constructed. Some essential ones are listed below:

- the behaviour of the target dimensions should be comprehensible in a mathematical equation in the technically relevant working area;
- the resulting model equation should reproduce the simplest possible correlation between influencing and target variables, objectively and comprehensively;
- the deviations between measured and design values must be minimal;
- the model equation should be numerically stable, which means that a slight change in the measured data does not result in a change to the model equation;
- the error existing in the measured data must be quantifiable so that a forecast for the process using a probability, adequate for the practice (e.g. 95 %) is possible.

The expectations for a general strategy can be formulated as follows (Fig. 2):

- the strategy must be independent of the technical problem to be dealt with at any one time;
- minimum expense for maximum information gain must also be guaranteed for multi-dimensional problems;
- the main variables of a process system should not only be recognisable, but also quantifiable;
- practical knowledge already available in the form of measured data should be capable of being transmitted into a new testing programme without loss of information.

The statistical planning of experiments and analysis is a solution strategy, which optimally meets all the demands previously made, but never replaces the problem engineering and the associated creativity of the developer. The more complex such process systems are, the more advantageously such methods are used, where the development of environment-oriented process conceptions are concerned. Therefore the objective demand here is in the position of having to be competitive with new process concepts within a few months with processes which have already been producing optimally for years (according to Marte).

Modified biochemical oxygen demand test (BODT, so-called closed bottle test), in which is indicated the measurability of the → Biochemical oxygen demand (BOD) utilised in the microbial oxidation of organic substances and the % measuring result of the theoretically necessary calculable oxygen demand for final oxidation, i.e. mineralisation of the test substances (% BODT). With this method, the BOD_5 value comes to hand incidentally as it were.

Modified cross-section fibres → Profiled fibres.

Modified fatty chain products E.g. → Soaps with modified fatty acid residues.

Modified fibres Viscose, high tenacity and high wet tenacity fibres with a particular structure caused by spinning in the presence of → Modifier (small additions of aliphatic amines, polyamines, quaternary ammonium compounds, polymers of ethylene and propylene oxide amongst others). These altered spinning conditions produce new valuable properties with suitable drawstretching: higher strength, higher working capacity, denser, homogeneous cross-sectional structure (all enveloping structure), lower swelling power and better wet tear strength.

Modified fibres and textiles Variously shaped group, which includes numerous industrially implemented new developments and new trends at the experimental stage. These can be differentiated between a) total or partially chemically modified fibres with lasting or almost permanently altered properties resulting in possible uses, for the latter, and b) causing various deposits and coatings.

Modified resins → Alkyd resins.

Modified starches All products for which only a gradual change of the characteristic properties is carried out for native → Starch (e.g. pregelatinised starches), and thus cleavage of the polymer chains or the reaction of functional groups should not take place to any determinable extent using chemical methods. The transition from a “modification” to starch decomposition is fluid. Decomposed starches are produced when principal valencies of native starch are split. This is carried out, for example, under the influence of oxidising agents so that the starch oxidation products are already attributed to the starch derivatives.

Modified starches, pregelatinized starches According to different processes broken down starches, which already swell more or less strongly when stirred with cold water and produce starch preparations with adhering properties. Usually short boiling is enough to obtain low-viscosity solutions for use in sizing and finishing. The ratio of modified starch : potato starch : dextrine approximately 1 : 3 : 2. The most widespread use of starch is based on its capacity for water absorption and its swellability. Air-dried starch particles rapidly swell in suspension in water, and its diameter increases by approximately 30–40% (Fig. 1).

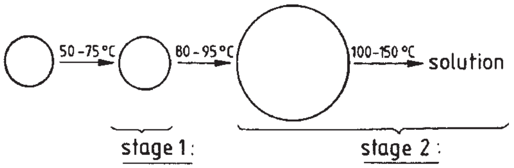


Fig. 1: Diagram showing the visible changes during swelling of the starch granule (van den Berg).
Stage 1 = from the natural granule to low swelling (reduction in refractive index); stage 2 = strong increase in swelling, poss. until solution is achieved.

During heating while carefully stirring, the shape and optical properties remain until suddenly irreversible changes set in at a specific temperature. The particles start to lose their double refraction and swell up considerably. This temperature range of approximately 10°C, in which all particles go through this process, is called the gelatinisation temperature. The swelling of the particles steadily increases with further heating, they lose their irregular morphology and look like a pair of bellows. The increase in the optical transparency, solubility and viscosity occurs simultaneously. The viscosity reaches a maximum when the entire space is filled with swollen particles. The diffusion of a part of the amylose from the particle starts in this stage. Before they burst, the particles can absorb 20–40 g of water per 1 g of starch. Above this critical point, the particles break up and the viscosity falls sharply. The second stage of gelatinisation, at which a true homogeneous solution is produced, is at more than 100°C, at approx. 120°C for potato starch and not until around 150°C for amylose-rich starch.

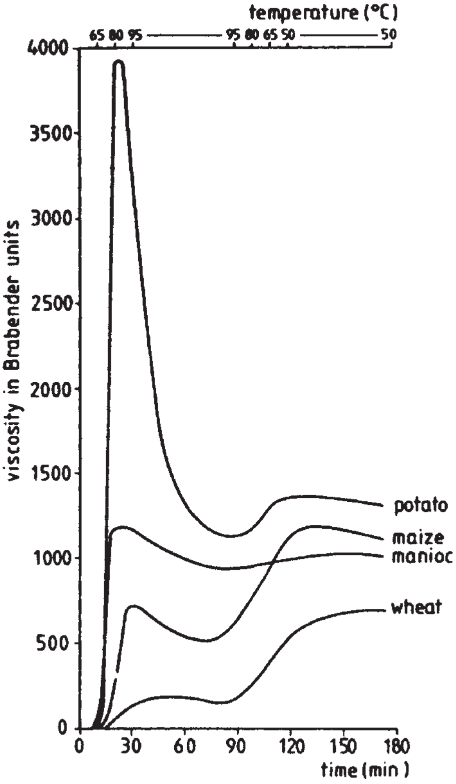


Fig. 2: Increase in viscosity of different starches during gelatinization (van den Berg).

Measurements on the Brabender viscoamylograph, which are carried out using a standardised time/temperature programme, are suitable for the characterisation of the gelatinisation process of different types of starch (Fig. 2). Potato starch shows a particularly high viscosity and swelling. This is possibly connected with its phosphate content. The association with regard to phosphate-free cereal starches would be lowered by the repulsion of the loaded groups.

The gelatinisation properties become lost by mechanical damage to the starch particles, e.g. in dry milling. Acid pretreatment results in lower swelling, presumably due to the increase in crystallinity. The transmission to gelatinisation is interpreted as a melting process. If the starch suspension is tempered, i.e. held for a longer time just below the gelatinisation temperature, the otherwise broad temperature range of the swelling (55–65°C or 62–72°C) is increased and shifted to the upper temperature limit. This observation is explained by a recrystallisation of defective crystalline. The actual melting point of the pure starch crystals in water is somewhat higher than the gelatinisation range reveals. In the first stage of gelatinisation,at 50–70°C, the starch crystallites melt and form a polymer network. At this temperature only amylose goes into solution, but a large part still remains. In the second stage, at approximately 100°C, the network is separated and a solution of amylose and amylopectin is finally obtained (according to Burchard).

Modified yarns → Textured yarns.

Modifier Modification agent, in → Modified fibres these assume important structural modifying functions as spinning auxiliaries, which result in the slowing down of the conversion on the spinning bath/thread surface and thereby encourage the formation of all cover fibres with improved dry and wet properties.

Modular construction principle Construction principle, in which systems are constructed from the smallest possible number of standardised machine elements assemblies.

Modulus (Latin: modulus = measure, scale), characteristic numerical measurement for particular property of a material (material constant), e.g. the ratio between loading/elongation as an elasticity modulus (→ Tensile elasticity).

Modulus of elasticity → Tensile elasticity.

Mogador gum → Gum arabic.

Moghan carpets → Knotted carpets from the South-East Caucasus. Moghan Steppe. Medium high wool pile with approximately 150 000 knots/m^2. Coloured design with a lot of bright yellow in the bright variation of geometric flourishes, flower and animal motifs.

Mohair (WM), one of the → Natural protein fibres, hair from the Angora goat (Turkey and South Africa). The microfibrils (keratin intermediate filaments KIF) are chiefly parallel to the fibre axis in the cortex of mammal hair. X-ray diffraction patterns were obtained from a large selection of mammal hair and all produced the A-keratin diagram. The quality of the diffraction pattern, which is obtained in the radiography of wool is not as good as that of mohair, which has an absolute helix proportion of 35%. This is one of the reasons for the fact that researchers, who deal with the molecular structure of wool and hair, readily study mohair fibres. Its wear resistance is a characteristic of mohair. That is why mohair fabric is always used when durability is the prime requirement. Mohair can be dyed easily and has a natural lustre. The surface of the fibre is covered in epidermal scales, which are much more tightly connected with the fibre stock than wool scales (→ Wool structure). There are only approximately half as many scales as on the wool fibre (see Fig.). The overlapping is slight so that the fibre has a soft handle. Light is easily reflected from the surface so that mohair has a characteristic lustre. Two typical textile properties of mohair are:

- lustre and soft handle as a result of the scale structure of the fibre surface,
- good breaking strength and wear resistance.

The scale edge height of mohair, in comparison to 1.07 µm for Australian wool, is 0.4 µm. The remarkable abrasion resistance and wear resistance of mohair items can be put down to the regular structure of the cortex. The individual cells consist of approximately 0.2 µm wide macrofibrils in the cross-section. The macrofibrils are in turn bundles of 10 nm fine microfibrils in a hexagonal pack. This structural arrangement is found in the low-sulphur keratin fibres, which supply highly informative radiographs with many radio reflexes. The microfibrils or keratin intermediate filaments (KIF) represent approximately 60–70% of the fibre mass. These KIF are mainly responsible for the stability of keratin fibres against elongation and drawstretching. The chemical sub-units of the individual KIF are 8 keratins with molecular weights of 40–70 Kilodalton. Each keratin consists of a central alphahelical rod domain of 311–314 amino acid residues. The central rod domain is flanked at both ends by regions, which vary both in their size and in their chemical character.

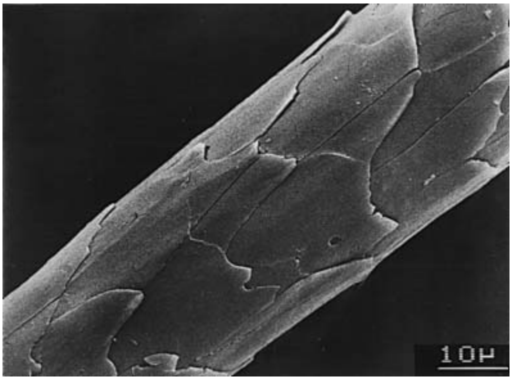


Fig.: SEM image of a mohair fibre under strong magnification.

Mohr bleach Combination bleach for cotton fabric in three stages:

1. pre-boil grey fabric in (used) peroxide bleach liquor.
2. chlorine bleach with sodium hypochlorite.
3. peroxide bleach (used liquor is used for each following batch).

Mohs' hardness scale (MH), → Hardness scale in accordance with Mohs.

Moiré effects are produced by interference from two linear systems. Moiré interferometry processes, which are used for the testing of surfaces, offer extensive detection. These processes are based on the fact that the overlay of the transmission functions of two equal, easily bent together, optical gratings produce characteristic intensity patterns in the form of light/dark stripes (see Fig.).

In screen printing, moiré effects can in particular be put down to the fact that the thread system of the mesh and the fabric to be printed knit into each other. A certain screen angle of the combining linear systems can prevent the appearance of moiré. Moiré is produced in roller printing if very fine longitudinal stripes are printed on coarser fabric qualities. In order to avoid this, the fabric is calendered before printing. In decatizing,

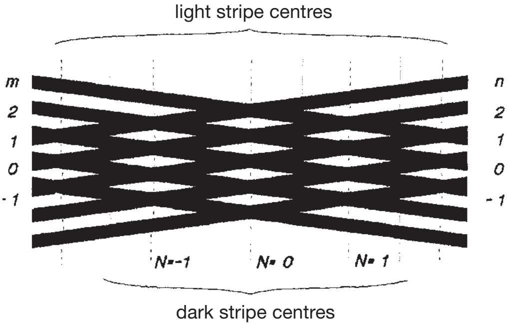


Fig.: The generation of moiré effects by inclined grid patterns.

moiré is produced in the interaction of the weft threads of wool fabrics and cotton back grey (worn out).

Moiré fabrics (from French: marmoire = marbled), most easily ribbed material (silk or viscose filament) with imprinted (lustrous) pattern effects, in plain, satin or twill weave, predominantly one colour and → Changeant. Antique moiré: with indefinite linear guidance, produced by pressing two material webs lying on top of each other. Renaissance moiré: with stronger “soaking”. Application: for garment, furnishing, upholstery fabrics and similar.

Moiring (watering), aims at production of wave-shaped → Moiré effects (so-called “soaking”), which occurs due to partial even printing of weft ribs on viscose and silk fabrics. Real moiré without repeat of figures is produced by calendering with ribbed rollers and possibly following outside passage of an irregularly perforated edge, whereby weft threads are shifted from their position and the moiré effect is increased. Work also takes place on the normal calender and/or the plate press by straining two material lengths lying on top of each other or a piece folded lengthwise. Designs running symmetrically to the centre of the material are produced in the latter case by unfolding. False moiré is produced on the embossing calender using moiré embossings. The pattern is repeated after each roller convolution. Embossing moiré (also washfast using synthetic resin application) can be produced in designs using impressive matt/lustre effects by fabric passage between steam-heated engraved steel roller (guide according to design size 1 : 2 or 1 : 3) and 2- or 3-times larger paper roller. If using ripple engraving (instead of correctly using circular or diagonal ripple) a rib fabric is processed using transverse ripple (parallel to the roller axis and thereby parallel to the ribbed fabric); a second, unwanted so-called mock moiré effect is produced as a fault within the embossed moiré. Ciré moiré: → Embossing. Besides desired production of the different moiré effects, moiré formation should still be referred to as a fault: This is produced, for example, by uneven setting of the fabric on the crabbing jack, on the dye beam, etc. generally appearing irregularly or even regularly as cloudy, more or less lustrous, pressure marks in the fabric. An unwanted moiré effect may also appear during combining or laminating if the type of weft and weft number meet unfavourably.

Moist-cure process → Wet crosslinking process.

Moist dwell process Fixation of compounds (e.g. resin finishing agents) by dwelling of the fabric in a moist state. →: Wet cross-linking process; Cross-linking.

Moisture (moisture content). Humidity, being moist, light dampness, water (vapour) content.

Moisture absorption and X-sectional swelling of fibres → Swelling.

Moisture absorption of fibres Approximated average values in % at 65% relative humidity and 20°C (→ Moisture behaviour of fibres and yarns).

alginate	20.5
natural silk, degummed	9.5
sheep’s wool	15.5
cotton	8.0
groundnut white	15.0
acetate filament yarn	6.0
casein fibre	14.0
polyamide	4.0
zein fibre	13.5
triacetate	3.0
viscose filament yarn	13.0
polyacrylonitrile	1.0
cupro filament yarn	12.5
polyester	0.5
jute	12.5
polyvinyl chloride	0.4
viscose HF	12.3
polyethylene	0
soybean fibre	11.5
glass fibres	0
cotton, mercerized	11.0
natural silk	10.5
flax, hemp	10.0

Moisture behaviour of fibres and yarns Besides → Moisture absorption of fibres and water retention (see Tab.), comprises the important values of the increasing depth in mm, as a dimension for the speed of the waste transport of liquid, which clarifies the fact

	F [%]	W [%]
Fibres:		
Cotton	7	40–45
Wool	13–18	20–30
Viscose	12–14	85–120
Polyacrylonitrile	1–2,5	5–10
Polyester	0,4–0,6	2–5
Polyamide	4–5	10–15
Polypropylene	0,7	8
Yarns:		
Cotton	7	38
Viscose	12–14	83
Polyacrylonitrile	1–2,5	8,3
Polyester	0,4–0,6	2,4
Polyamide	4–5	11
Blend:		
Polyester/ cotton		
35/65 %	3,5–4,0	29
65/35 %	2,8–3,0	14

Tab.: Moisture behaviour in different fibre materials.
F = moisture uptake in a standard climate (65/20) as a %;
W = water retention capacity as a %.

that in a growing proportion of man-made fibres the capacity to transport moisture also increases. This can essentially be put down to the fact that the capillaries existing in the yarn are not closed by swellable fibres. The moisture waste transport can be eased by construction; if, e.g., locally effective suction properties are required (such as in dusters), this can be adjusted by using cellulosic man-made fibres or cotton. The moisture waste transport is not, however, as frequently assumed, dependent on the higher moisture absorption in natural and cellulosic man-made fibres, but on the construction of suitable pores in the yarn or textile fabric.

The moisture waste transport mechanism is regarded as a function (individual and interaction) of chemical, physical and textile-mechanical factors. Moisture transmission and fibre swelling can have a contra-rotating effect in strongly swelling fibres (e.g. in regenerated cellulose): a strongly swollen fibre will delay the capillary moisture waste transport (= decelerated transport from the moist to the dry phase). In less swelling fibres, however, (e.g. man-made fibres) the actual moisture waste transport can be put down to the wicking along the smooth fibre surface area.

Moisture content control in drying occurs in accordance with the measured values determined in → Moisture content measurement; either alleviated by optical indicating devices, which report the crossing of the moisture vapour tolerance, by hand (speed and/or temperature regulation), semi-automatically (transfer or pushbutton operation of a servomotor in operating range) or fully automatically (change in speed via contact-released, gradual impulses). In control systems, the simplest impulsing is carried out via synchronous motor or via relay. Its constants and the respective operating conditions reveal whether manual control or a fully automatic system is more advantageous for a drier. The medium throughput time = medium fabric run speed is decisively divided by fabric length found in the drying zone. The inertia of all the control processes caused by the throughput time should thereby always be considered.

Moisture content in solvent vapour space is the relative humidity in the vapour space in closed systems above a solvent liquor, depending on the type of dry cleaning process according to experience in equilibrium with the humidity of the fabric and the solvent, so that one can practically directly infer the humidity in the vapour space from the fabric humidity (→ Moisture content measurement).

Moisture content measurement A distinction must be made between the determination of the moisture content of air and the substrate humidity.

I. The measurement of the humidity is carried out by means of →: Hygrometer and/or Psychrometer (thermohydrograph). The measurement of the relative humidity of air carried along in dried textile fabric and/or an air flow sucked through by the fabric can either be carried out mechanically by means of a micro-hygrometer or indirectly electrically, e.g. by means of resistance measurement of a cellophane strip.

II. The determination of the moisture content of textiles is carried out:

– Directly by drying out and according to differential weight determination (→ Conditioning).
– Directly by infra-red absorptive water determination with the aid of a special hygrometer.
– Indirectly by electrical measuring methods.

The indirect method has the greatest significance for production. Different variants are distinguished according to the following measuring principle:

a) Measurement of the electrostatic charge, whereby one makes use of the fact that when drying mobile material lengths (chains, fabrics, etc.) a static charge occurs dependent on the respective moisture content of the textile, which is lower in damp fabric and higher in dry fabric.
b) Measurement of the electrical conductivity (resistance measuring principle). Small changes in the textile moisture content hereby correspond in accordance with the order of magnitude of changes in the electrical resistance.
c) Capacitive measurement of the dielectric properties of the textile material (dielectric constant and/or dielectric losses), which also alter with the water content because the capacity of the continuous condenser field also increases with the textile moisture content, whereby dielectric losses are naturally also increased.
d) Microwave moisture measurement for water quantities between approx. 20 g and more than 30 g of water (of approx. 20–300% relative humidity for moderately heavy fabrics). Principle: coupled electromagnetic microwaves produced in a general reflex klystron (approximately 3 cm in size) are directed towards the damp fabric. The water present there absorbs a part of the waves. The re-

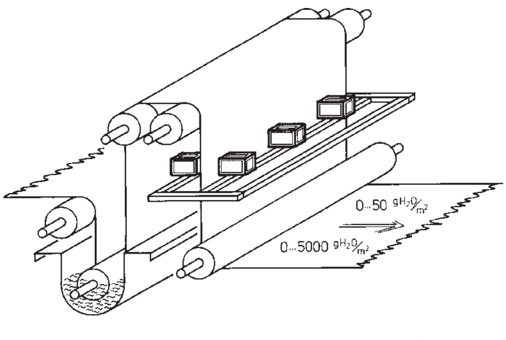


Fig.: Moisture content measurement on a running fabric by means of microwave absorption (Pleva).

mainder is reflected and absorbed in a receiving hollow conductor. The absorbed energy is a measure of the humidity (see Fig.).

Moisture content measurements have great importance in guaranteeing an optimum cleaning effect in dry cleaning, which (apart from dry-cleaning detergent) requires a variably optimum water content in the solvent depending on the type of fabric. The hair and special membrane hygrometer or electric conductivity measuring instruments are chiefly used for this, either to measure the liquor or the air in the vapour space above the solvent. The devices assume from experience that an equilibrium is formed between the water content of the fabric, that of the liquor as well as that of the vapour space above the solvent, during the cleaning. The balance between water content of the fabric and water content of the liquor is carried out relatively rapidly. Correspondingly lacking water can consequently also be rapidly replenished using a suitable device. Certainly the equilibrium between liquor and vapour space is adjusted somewhat more slowly so that work takes place with a certain delay. With small lithium chloride measuring plates, which are distinguished by quick reading, 10–15 s are required with sufficient ventilation in order to get close to the upper range value at 90%.

Moisture content measuring of circulating air in driers Control of the exhaust air damper position via measurement of the moisture content of the circulating air in the drying machine, comparison of the actual value with the given desired value in the microprocessor and instruction on the servo component (see Fig.). (→ Exhaust air moisture measuring systems).

Moisture content of air → Air humidity.

Moisture content of textiles is dependent on fibre hygroscopicity (→ Moisture absorption of fibres) and → Air humidity. The hygroscopicity varies according to fibre origin, can increase up to 40% in animal fibres and up to 32% moisture content in cellulosic fibres, without being noticeable by touch, and is normally approx. 4% (polyamide) to 0% (polyethylene) in synthetic fibres. Moist air thereby encourages a weight increase and dry air a weight decrease (air conditioning system). The determination of the actual moisture content (conditioning), i.e. referring to air dry “as-delivered” weight of the material, is therefore important in order to establish the actual dry weight at any one time and to guarantee the normal standard weight using agreed → Moisture regain. On the other hand, the moisture content determines the drying speed and is in a direct correlation with swelling processes, dye affinity, cleaning ability and the like.

Moisture regain (moisture percentage figure, regain), customary moisture percentage, as regain to the dry weight determined by → Conditioning in order to correspond approximately to the normal moisture content of the fibres at 65% relative humidity, which is, however, only partially accurate. The following regains in % are customary, for example:

18.25	wool combed top, worsted yarn
17.00	wool carded yarn
15.50	worsted yarn with 25% wool
14.00	reclaimed wool
13.75	jute

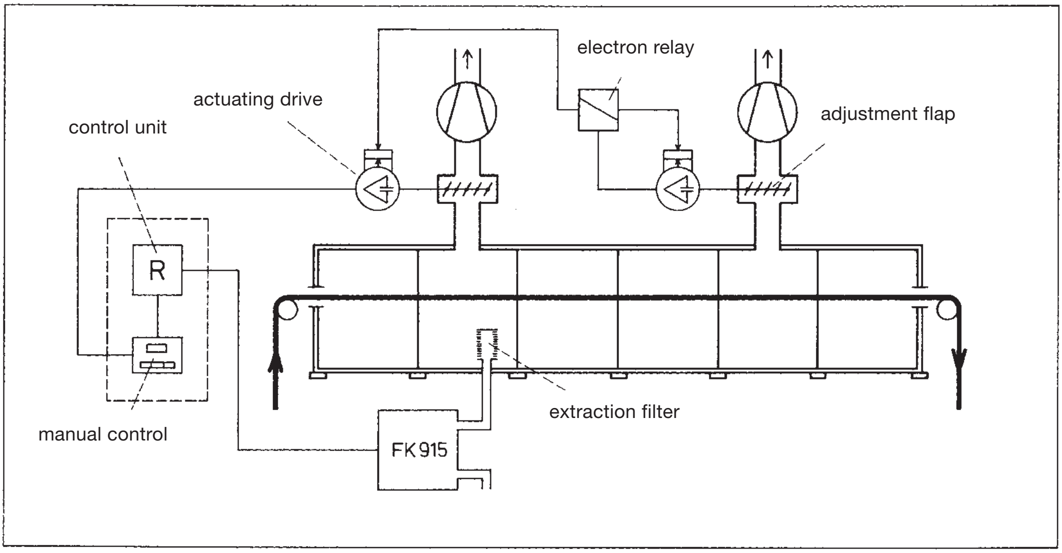


Fig.: Measurement and control of moisture content in circulating air (Pleva).

13.00	viscose and cupro
12.00	flax, hemp, ramie
11.00	natural silk
10.50	cotton, mercerised
9.00	acetate (de-oiled, desized)
8.50	cotton
6.25	polyamide 6 and 6.6 staple fibre
6.00	acetate (with 3% oil)
5.75	polyamide 6 and 6.6 filament
3.00	polyester filament
2.00	polyacrylonitrile
1.50	polyester staple fibre; polyethylene; elastane

Moisture-Register Device for electronic moisture content measurement.

Moisture transmission in bed textiles The view exists that man-made fibres with their low moisture absorption would be inferior to hygroscopic natural fibres and viscose regarding moisture transmission. This view is disputed by physical measurements. The moisture transmission via fibre material (depositing of the absorbed moisture) can practically be ignored on the basis of diffusion constants; however the water vapour diffusion is roughly 250 times faster through air than through a fibre material. The layer thickness and consequently the air volume are determining factors. Another moisture transmission is carried out via the fibre surface area. Electrical wicking measurements have shown that man-made fibres can transmit the moisture via the fibre surface due to their particular surface. This helps to achieve a true moisture concentration gradient from the bed core outwards to the ambient air containing less moisture.

Nonwovens weighing 200 and 600 g/m^2 with polyester proportions of 100, 50 and 0% (polyester/hygroscopic fibres) were tested regarding their water permeability. The thickness of the nonwovens (approx. 20 and 40 mm) is expressed; but the different moisture absorption of different types of fibre cannot be determined. The moisture transmission is dependent on particular physical factors and less on the moisture absorption of a fibre. Dry heat and dry skin are crucial for the "cosiness" of a sleeping person, i.e. a thermoregulation demanded by the sleeper without switching on the organism (indifference range for cosiness in the bed). This contemplation of the sensation of cosiness is valid in the heat generation for a normal person (no special meals or excessive taking of alcohol) and a draught-free dormitory of approx. 15°C.

Moisture transmission mechanisms of tent fabrics Without considering the area of application, it is the aim of many textiles to facilitate a moisture transmission through a solid substrate, which separates 2 climatic zones from each other (Fig. 1). The humidity of an interior (climatic zone 1) should diffuse outwards (climatic zone 2) and a moisture build-up should thereby be prevented and/or reduced by condensation. Water vapour permeability, water vapour absorption and water vapour depositing mechanisms should be considered for this. These mechanisms are controlled by different factors, which have a different effect. The following are decisive factors:

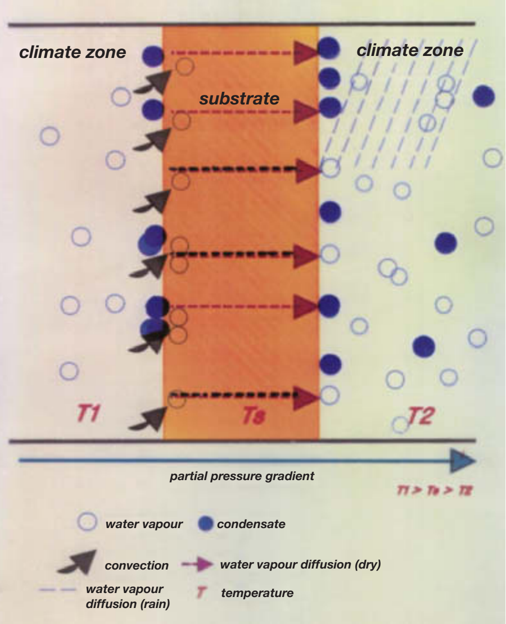


Fig. 1: Water vapour diffusion and condensation on a solid substrate.

- design of the transmission medium,
- temperature ratios,
- humidity ratios.

Each material has a characteristic water vapour transfer resistance (R_{et}), which is determined by thickness, type of polymer and structure. The higher R_{et} the lower the water vapour permeability in general applies. But the R_{et} is not solely responsible; the swelling behaviour of the textile material is also a crucial factor, as swelling closes the textile pores and the water vapour transmission is thereby reduced. Hydrophobic man-made fibres have proved to be advantageous, as they hardly have a swelling capacity. A textile simultaneously assumes a buffer effect in order to reduce condensate formation. In the buffer effect, a distinction should be made between liquid water and water vapour. Both properties can be described using constants. Water vapour transmission is only guaranteed via a sufficient vapour pressure gradient between both climatic zones. This vapour pressure gradient results from the relative humidity and temperature of the ambient air, which are at work in climatic zone 2, and the evaporation, sweat evaporation, water vapour convection, water vapour condensation, water vapour diffusion and core temperature, which predominate in climatic zone 1. The temperature difference is the driving force of water vapour transmission and determines the limit of the area of application depending on the external air humidity.

In a tropical climate, for example, "breathable" materials lose their advantages, as the temperature and humidity ratios of both climatic zones are reversed. Their use in extreme negative degrees is likewise dubious. Tests using tents at –17°C external temperature have shown that the early saturated external air and the large temperature difference encourage the condensation of the water vapour. Interior humidity arising excessively, e.g. due to heavy perspiration, cannot escape quickly enough so that a moisture build-up can hardly be avoided. Ice layers formed can additionally aggravate water vapour transmission. At the same humidity saturation in the climatic zones, the vapour pressure is adjusted corresponding to the temperature and can facilitate transmission at moderate temperatures. A temperature difference of approx. 15°C should be guaranteed for the moisture diffusion. Condensate is formed in just such a system, as the moist, warm air is abruptly cooled down on the colder substrate surface. However not only is the temperature gradient, but also R_{et}, responsible for the condensate formation. A loss of comfort cannot be absolutely determined at the start of the condensate formation. The condensate formation strongly increases only at a temperature difference of approx. 10°C. The substrate temperature is increased and the vapour pressure gradient falls due to the heat released in the condensation, but this shift does not have a significant effect on the cooling capacity of most materials. Fine condensate films can however increase the R_{et} as water vapour barriers. Only isolated materials improve their water vapour permeability with mounting condensation or wetting. Water films on the outside also represent an additional resistance. The surface character has an effect on water vapour permeability via the water repellency effect here. Different materials accordingly show different properties under water repellency. Some products, which show a good water vapour permeability in the dry state, still only show reduced results in rain. The water vapour permeability falls by 30–70% depending on the material, although the effectively driving force increases, if cooled by rain from outside. This phenomenon is different however in the various "breathable" materials. Distinctions are made in principle between two fundamental concepts, which can produce moisture transmission through solid substrate:

1. Controlled use of porosity (Fig. 2).
2. Permeability through functional polymer systems with defined molecular structures in compact systems.

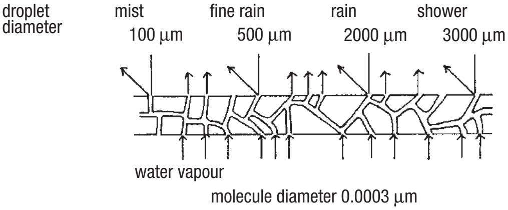


Fig. 2: Moisture transport through a porous system relative to molecule diameter.

The combination of water impermeability and water vapour permeability of porous systems is based on the possibility of using pore structures, whose open pores are larger than water vapour molecules, but smaller than drops of water. The following work according to this system

– microfibre fabric,
– laminates with microporous membranes,
– microporous coatings.

The capillary suction effect and the micropores allow adsorption and diffusion of the water vapour. The water vapour permeability of microporous systems is determined by the pore structure and is relatively independent of the layer thickness. The various porous systems are considerably differentiated in their pore structure, i.e. cell wall thickness, pore distribution, pore size and pore number. So, for example, thicker films usually have a heterogeneous pore structure with thin cell walls, while thinner films are constructed from smaller cells with a homogeneous structure. Fine pores with thin cell walls have a positive effect on water vapour permeability. In microporous systems the danger exists that water is pressed through the channels at high pressure. Rain can penetrate the outer fabric pores especially through friction points, thereby block them and cause a condensation of the incident vapour. The surface of microporous systems is sensitive to soiling, amongst other things residues, e.g. of washing agents, which cause a blockage of the pores and thereby restrict the diffusion. Residues remaining on the surface after salt water evaporation likewise make the water vapour permeability drop considerably.

Moisture vapour transmission →: Moisture behaviour of fibres and yarns; Diffusion mechanisms in dyeing; Migration.

Molality (kilogram molality, weight molality), → Mole/kg of solution (not per 1 solution as in → Molarity).

Molar % Molar percent = 100 x → Mole fraction.

Molar concentration (MK, molar solution), contains 1 → Mole (or one mole multiple or one mole fraction) of a substance dissolved in 1 l water. An example for sodium chloride (NaCl) is illustrated in the Table.

substance	atomic weight	mol	MK	semimolar 0.5 molar or m/2
Na	23.00	58.46 g	58.46 g/l	58.46 : 2
Cl	35.46			29.23 g/l

Tab.: Molar concentration of sodium chloride.

Molarity (litre molarity, volume molarity) →: Mole/l solution; Molar concentration.

Molar percent → Mole fraction.

Molar solution → Molar concentration.

Molar weight → Molecular weight.

Molded garments Textiles, which are brought out of the tubular form into the physically suitable form using mechanical/thermal deformation, e.g. for ladies' wear.

Mole (mol), → Molecular weight in grams. 1 mole of any material you like nonetheless contains individual molecules.

Molecular alignment of water repellent finishes It is typical in water-repellent finishings of textile fabrics that the hydrophilic residues of the finishing products (paraffin distillates, silicones, fluorocarbon polymers, etc.) are taken up by the surface of the fabric or knitgoods. The hydrophobic residues of the substances are then aligned so that they point towards the air (see Fig.).

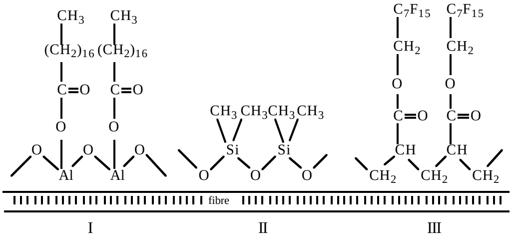


Fig.: Alignment of various water-repellent agents on the fibre surface.
I = aluminium salt/paraffin emulsion; II = dimethyl polysiloxane; III = fluorocarbon polymerisate.

Molecular dispersivity → Dispersivity.

Molecular engineering Production of → Fibre engineering using modified technical generation and chemical structure.

Molecular formula → Formula, chemical.

Molecular Modelling Became possible due to the development of theoretical chemistry, computer technology as well as screens capable of graphics. Complex calculations enable the spatial expansion of molecules, their surface area or their molecular volume, their electronic properties, such as chemical reactivity, distribution of atomic forces, electrostatic potentials, water-repelling properties amongst others or molecular dynamics to be determined. The chemical formulae are firstly depicted on the screen. The structures calculated by the computer are then shown three-dimensionally on the graphic terminal. These molecular images can be enlarged, reduced, shifted and rotated in all directions (Fig. 1). The most likely molecular geometries can be studied by minimising the molecular energies.

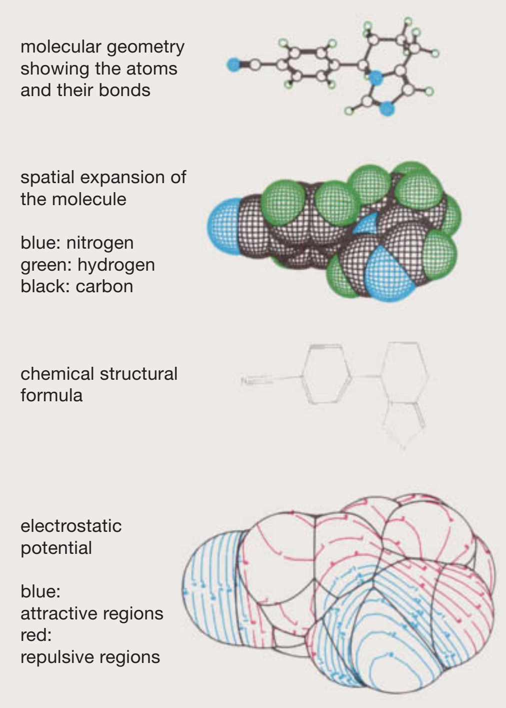


Fig. 1: Different methods of representing a molecule with the aid of "Molecular Modelling" (molecule CGS 16949A = active substance against tumours) (by Ciba-Geigy).

Molecular Modelling is therefore in simple terms a modern molecular modular construction, with which it is possible to reproduce realistic molecules. The use of such a program is not only limited to the mere view of one fact; with its aid you can additionally calculate the optimum geometry, binding intervals and binding angle in a molecule as well as electrostatic and Van der Waals forces. Information about how a molecule actually exists is obtained from this. The possibility of indicating or predicting particular properties of a molecule also exists. Such calculations are not only limited to individual molecules. Complete molecular bonds and their connections with each other can also be shown on the

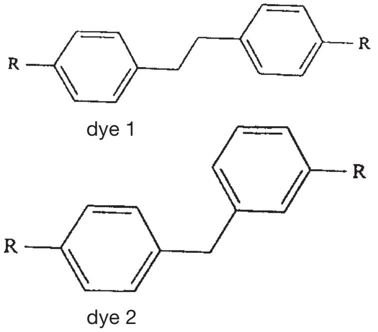


Fig. 2: Comparison of two dye molecules.

screen. An example from dye research should clarify this: Two dyes (Fig. 2), which only differ in their structure by one methyl group, behave completely differently in dyeing. While dye 1 uptakes well on cellulose, dye 2 almost completely remains in the liquor and hardly shows interaction with the substrate, although the residues R are the same in both cases. With the aid of molecular modelling it is clear that dye 1 is completely planar and can therefore enter optimum interaction with the planar cellulose, while dye 2 is angled and cannot therefore stick on the cellulose.

So the molecular dimensions of dyes can be deter-

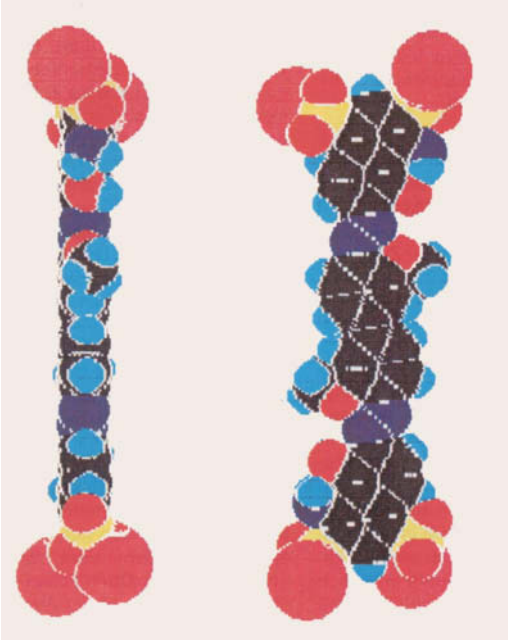


Fig. 3: Molecule conformation of C.I. Direct Blue 1. Red = oxygen; black = carbon; yellow = sulphur; violet = sodium; dark blue = nitrogen; blue = hydrogen (by Flath).

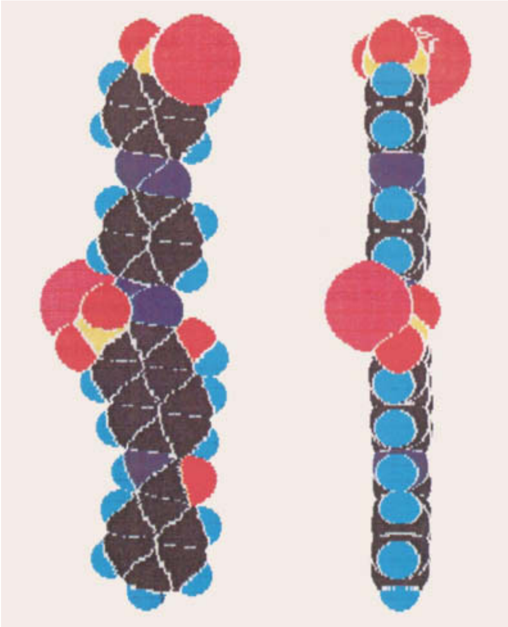


Fig. 4: Molecule conformation of C.I. Direct Red 81 (by Flath).

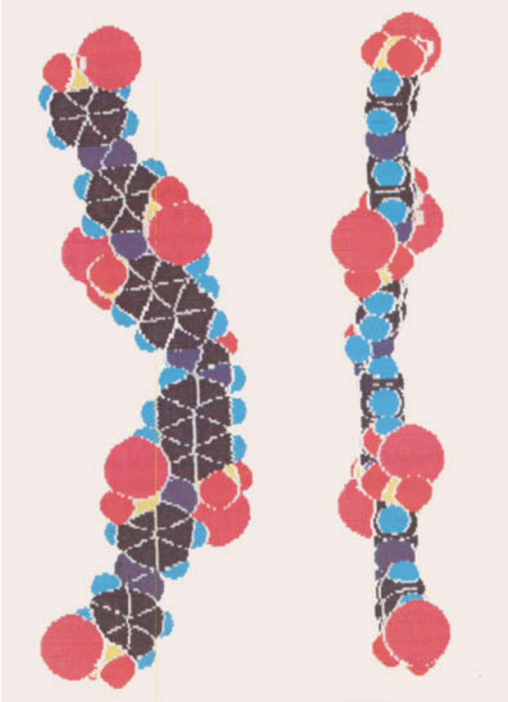


Fig. 5: Molecule conformation of C.I. Direct Red 80 (by Flath).

mined using computer simulation. The molecular conformation, which corresponds to an energy minimum (Figs. 3–5), is iteratively determined. The area of the dye molecules is calculated from the molecular dimensions. The proof that direct dye molecules exist as planar molecules, which was determined as the most favourable conformation energetically, could, for example, be produced by such calculations. They can be taken up in parallel by the cellulose chains and are then linked with secondary valency.

The planarity in the molecule C.I. Direct Red 81 (Fig. 4) is ideally shaped, for example. There are deviations from the ideal state in the larger molecules. While the phenyl and naphthalene rings are completely even, a bend in the molecule is caused by the azo group each time, as these groups only permit an arrangement bent at the side. The sulphonic group is a sterically demanding group, which always stands out from the molecule. This protrudes from the side elevations of the molecules (according to Cohen, Dörr and Flath).

Molecular weight (molar weight, mol. wt, MW), sum of the individual → Atomic weights of a → Molecule. Example: 1 molecule of water (H_2O) = 2 x 1 (atomic weight of the hydrogen) + 16 (atomic weight of the oxygen) = molecular weight of 18. In practice: 2 g of hydrogen + 16 g of oxygen = 18 g of water, or water consists of 11.1% hydrogen + 88.9% oxygen.

Molecular weight distribution of polymers Only molecular weight average values can be indicated for most man-made polymers due to their molecular irregularity (poly-dispersivity). The most important averages are:

$$\bar{M}_n = \frac{\Sigma\, n_i M_i}{\Sigma\, n_i} \qquad \text{(number average)}$$

$$\bar{M}_w = \frac{\Sigma\, m_i M_i}{\Sigma\, m_i} = \frac{\Sigma\, n_i M_i^2}{\Sigma\, n_i M_i} \qquad \text{(weight average)}$$

n_i = number of macromolecules with the molecular weight M_i,
m_i = mass of macromolecules with the molecular weight M_i.

Molecular weight average values say nothing about the distribution of individual molecular weights in the sample. The ratio of $\bar{M}_w$ and $\bar{M}_n$, which is described by

$$\frac{\bar{M}_w}{\bar{M}_n} = \quad \text{Q as a polymolecularity index or}$$

$$\frac{\bar{M}_w}{\bar{M}_n} - 1 = \quad \text{U as irregularity}$$

in contrast supplies a dimension for the width of the molecular weight distribution.

The polymolecularity index (or the irregularity) of macromolecular compounds depends on the mechanism of their synthesis and fluctuates to a great extent. For molecularly regular substances

$$\bar{M}_w = \bar{M}_n \text{ and with that Q = 1 and U = 0 resp.}$$

Q (and/or U) say nothing about the specific form of the molecular weight distribution though. To determine it, the polymer should be taken apart into fractions as molecularly uniform as possible, whose molecular weight averages are then determined. The following can be related to the fractionation:

- gel permeation chromatography,
- ultracentrifugation,
- extraction fractionation,
- precipitate fractionation.

Molecule (Lat.: molecula = small mass), smallest viable unit of a chemical substance, which consists of two or several → Atoms of the same or different type, e.g. hydrogen gas H_2, oxygen O_2, ozone O_3, water H_2O (made from 2 atoms of hydrogen and 1 atom of oxygen), sulphur dioxide SO_2 (made from 1 atom of sulphur and 2 atoms of oxygen), etc. → Macromolecules.

Mole fraction → Mol number of the component of a mixture and/or solution divided by the total mol number. The sum of the mole fractions is always equal to 1. If however you make them equal to 100, one talks of molar percentages.

Moleskin a weft atlas fabric made from cotton material; sometimes strengthened with an additional under-weft. The left side has a napped and/or emerized surface in the nature of a suede fabric.

Molisch's test For the testing of carbohydrates and/or their derivatives (e.g. methylcelluloses, cellulose glycolates, etc.). Two drops of a 10% solution of α naphthol in chloroform are added to the solution to be tested and carefully lowered using concentrated sulphuric acid; a reddish violet ring is produced on the interface of both liquids. This reaction also takes place in the presence of proteins. Distinction: leave solution with reddish violet ring for 10 mins, then shake it. Deep blue dyeing of the whole solution = carbohydrates and/or their derivatives. Faint purplish brown dyeing = protein.

Molleton Long-haired, soft wool material (lightly milled) with slightly visible weave under the hair surface; also in cotton, then thicker (e.g. →: Beaver cloth; Kalmuck). The cotton molleton materials in practice represent a heavier type of beaver; they are also occasionally described as heavy flannel. They are also found in plain fabric and twill; raw dyed, bleached white and piece-dyed, more rarely designed yarn dyed. Heavier qualities are produced using backing weft. Molleton materials are always raised on both sides.

Used as lighter duvets, padding materials, children's drawsheets, principally dyed as window display materials and for carnival costumes; in addition as decatizing fabrics for wool fabric kier decatizing.

Mollier diagram Gives information about steam conditions by means of isobars and isotherms. Describes the correlation between heat content (i) and entropy (s) of the → Steam.

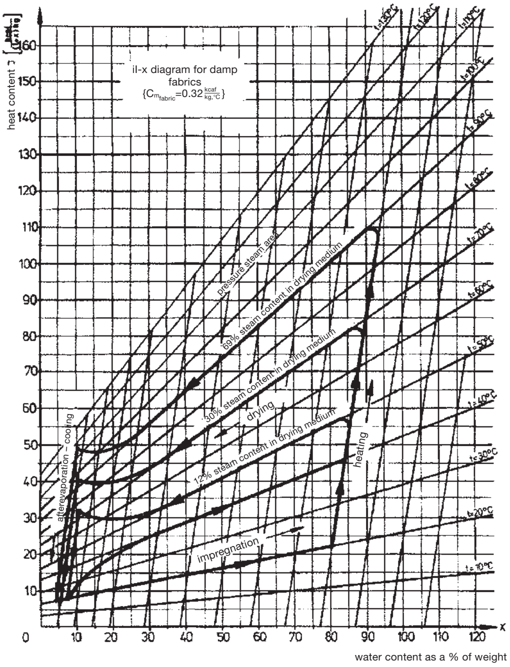


Fig. 1: Impregnation, heating and drying in i-x diagram for damp fabric lengths.

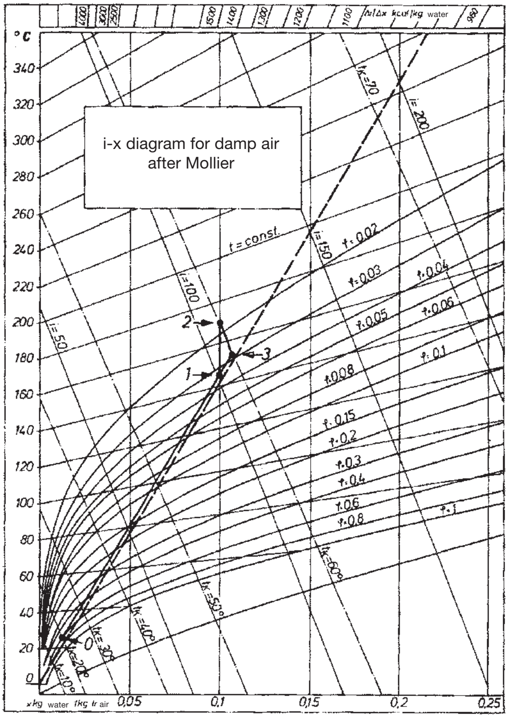


Fig. 2: Mollier i-x diagram for damp air.

With the aid of the Mollier diagram (Fig. 1) it can be shown how the heat content increases during impregnation with increasing water content in the system; heating-up when drying further increases the heat content of the system until this again decreases along the isotherms of the wet bulb temperature with decreasing water content when drying.

The heat content of the dry air (point 2, Fig. 2) is that which is blown from the nozzles of a stenter onto the fabric; this is connected to point 3 by a line of constant heat content (i = const.). The temperature of e.g. 170°C in point 2 can be directly measured easily: point 1 is exactly below point 2 on a line x = const. and in addition on the connecting line of point 0 and point 3. It describes the state of the air before admission into the heater in the drier and is produced by mixing the air streaming out of the fabric guide with fresh air from outside. If a parallel is drawn via the zero point of the diagram to the connecting line 0 → 3, this indicates the theoretical heat consumption on the edge scale when drying. The specific drying capacity increases and is reduced approximately proportionally to the difference between air temperature and wet bulb temperature in point 3.

Mol number Weight of a chemical, divided by its → Molecular weight.

Molten beads Drop-shaped end of thermoplastic fibres as a result of local heat effect, e.g. in burning tests, through singeing, ironing too hot or due to sparks flying. Compared with non-singed fibres, molten beads behave differently in dyeing and appear darker with the same dye content. Regarding this, particularly delicate polyamide and polyester fabrics are therefore singed after dyeing, frequently in fact not until after intermediate shearing.

Molten-metal dyeing machines First generation of continuous dyeing machines for piece goods, in which the heated metal was used as a divider and fixing section.

Molten metal dyeing process → Standfast molten metal dyeing process.

Molten Metal Process → Standfast molten metal dyeing process.

Molten metal, temperature effect on fibres Fibres are without exception not so strongly affected in molten metal as in water vapour treatment, as a result of a lack of water.

Mol. wt. → Molecular weight.

Molybdenum Mo, atomic weight 96, silvery white metal, melting point 1900°C. Forms numerous compounds less important for textile finishing. However particularly increases the acid resistance in steel alloys (molybdenum, chromium molybdenum, chromium nickel molybdenum, chromium nickel molybdenum copper steel, etc.; → Stainless steel).

Momme Japanese silk weight = 3.675 g. Momme number: weight of original Japanese silk for 1 yard length.

Monforizing Continuous mechanical shrinkproof finish on the monforizing system, consisting of padder as a damping system, nozzle dryer as a pre-drying system, palmer with overfeed device and felt calender for final drying. – Manuf.: Monforts.

Monfor-Matic Computer-controlled guidance system for heat treatment machines (e.g. stenters, hotflue, etc.) with processing sequence of measured values on screen in vertical arrangement (linearly indicating diode instrument); for central analysis and display stages of treatment sections. Mode of operation contactfree, maintenance-free. – Manuf.: Monforts.

Mono- (Gk.: mónos = alone), prefix with the meaning one, individual, single.

Monoacidic Designation for bases with an effective hydroxyl group, which can be ionised and replaced by acid residues, e.g. caustic soda liquor NaOH with hydrochloric acid produces sodium chloride NaCl.

Monobasic Acids with an effective acid hydrogen atom, which can be ionised and replaced by metal, e.g. hydrochloric acid HCl → NaCl Sodium chloride; Nitric acid HNO_3 → $NaNO_3$ Sodium nitrate.

Monocarbamates → Dimethyl-(mono-)carbamate.

Monochromatic Monochrome, light from a sole wavelength. Monochromatic microscope lens systems are only altered for a single light wavelength (usually 275 nm) and are particularly suitable for microphotography in short-wave UV light.

Monochromatic measuring arrangement → Polychromatic and monochromatic measuring arrangement.

Monochromatism → Colour blindness.

Monoethanolamine bisulphite (MEAS). Organic reducing agents for the permanent wool setting of surfaces and creases.

Monofilament Single-nozzled → Filament, i.e. single-nozzled capillary filament; single-threaded; individual thread. Artificial horsehair, bristles, tapes. Opposite →: Multifilament; Oligofilament.

Monofilament gauze Produced from monofilament polyamide or polyester fibres and usually calendered in accordance with particular processes. Monofilament gauzes have the advantage that they can be processed with less dye application. Thereby less “smearing” and sharper contours can be achieved. Advantages compared with multifilament fabrics:

- higher tear strength,
- greater abrasion resistance,
- greater open area,
- higher knit number possible,
- and lower squeegee printing pressure required.

Monofilament yarn In accordance with DIN 60 001 → Filament yarn made from only one filament. Monofilament yarns are spun by means of extruders, pressed through spinning heads and immediately drawstretched (Fig. 1). After the relaxation, the yarns are wound on a reel. Distinctions are made between homogeneous and heterogeneous monofilament yarns (bicomponent yarns, Fig. 2).

Monomer (Gk.: one-piece, one-part), basic chemical module (individual molecule) of the → Macromolecules. Opposite of → Polymer. Monomer units of polymers are e.g. glucose (cellulose), ethene (polyethylene) and caprolactam (polyamide).

Monomolecular layer consists of only one molecular layer. Under certain concentration conditions as

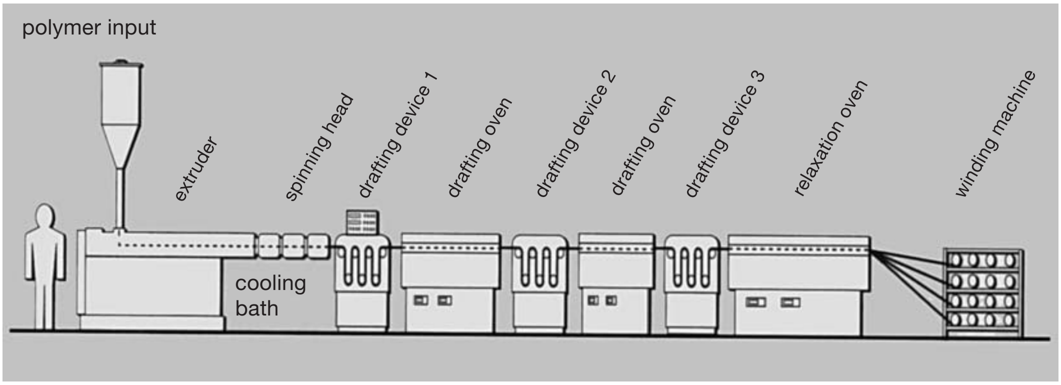


Fig. 1: Plant for the production of monofilament yarns of polyester or polyamide (by Reutter).

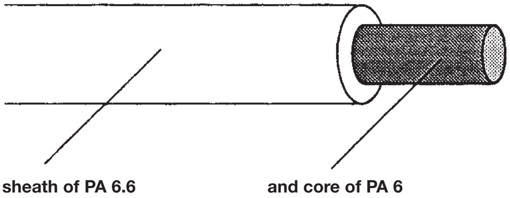


Fig. 2: Bicomponent monofilament yarn (by Reutter).

an adsorption layer is, for example, restricted to the "thickness" of a tenside molecule. In addition plays a large role in corrosion and in dyeing.

Monophosphates Salts of tribasic monophosphoric acid (orthophosphoric acid) H_3PO_4. The following, for example, are distinguished according to the number of H atoms replaced with monovalent metal.

1. Monosodium monophosphate (primary orthophosphate): NaH_2PO_4.
2. Disodium monophosphate (secondary orthophosphate): Na_2HPO_4.
3. Trisodium monophosphate (tertiary orthophosphate): Na_3PO_4.

Monsanto crease photographs → Photographic standards for fabric creasing.

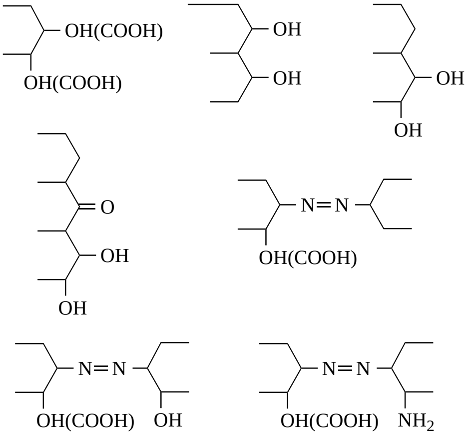
Mops (type of steaming table for napped fabrics). Designation for the steam table used particularly in the finishing of brushed fabrics, which is built on in many cases.

Moquette,

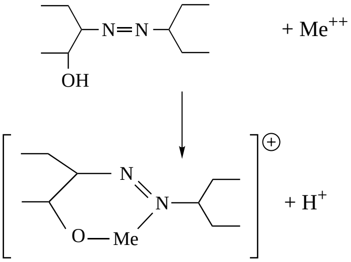
I. Colourfully patterned → Plush, manufactured using several pile warps or by printing (print moquette), then with smudged pattern contours; for upholstery covers, divan covers and similar.

II. Single-coloured, densely woven velour wire carpets. Designation also for carpets with corresponding appearance manufactured in a different way, e.g. flocked carpets.

Mordant-attracting groups in the dye molecule Molecular particles of dyes, which can have some influence on secondary valency bonds due to a particular configuration with metal ions so that insoluble colour lakes are produced. Chiefly "neighbouring" hydroxyl groups (–OH) and carboxyl groups (–COOH), which, for example, always appear in a neighbouring position in azo dyes in the –N = N group as the following overall view of the most important configurations shows schematically.



The metal mounting via e.g. chroming or aftercoppering takes place in accordance with the principle of salt formation in phenols, whereby a metal equivalent (Me) takes the place of hydrogen in the OH group each time, which is however connected to an inner complex salt here under formation of new ring systems with the dye. Simplified schematically this looks as follows in azo dyes:



Mordant dyes → Mordant-attracting groups in the dye molecule.

Mordanting Predominantly pretreatment, in some cases also aftertreatment, using mordanting agents (easily hydrolyzable acid or basic salts) in order to make fibres either susceptible to certain dyes or to fix such dyes more fastly (→ Colour lakes). Application for mordant dyes.

Mordants as resist agents in the dyebath → Retarding agent for fibres.

Mordants for animal fibres E.g. fur, pelts, goat hair such as mohair, hare hair and/or felting wool. Are used to increase the swelling capacity and alleviate milling in order to encourage the formation of felt.

Mordants for mordant dyes Fatty mordants and → Metal mordants for mordant and chrome dyes.

Morin Chief component of → Fustic; Flavone derivative. Crystal needles, colourless, shiny, difficult to dissolve (1 : 4000 in cold water), easier in hot water, alkalis, alcohol and acetic acid. Is used in alcoholic solution (1 knife point of morin + 50 ml of ethanol) as a specific aluminium test (still in dilution 1 : 10 000 000) = green fluorescence.

Morpholine (tetrahydro-1.4-oxazine), colourless liquid; density 0.998. Boiling point 128.9°C. Soluble in water and alcohol. Properties: solvent (for resins, waxes, shellac, many dyes, etc.), emulsifier, anti-corrosion agent, vulcanisation accelerator; intermediate product for fluorescent brightening agents, tensides, corrosion inhibitors, dyes and/or special reagent for zinc, copper, various man-made fibres (→ Morpholine Test).

Morpholine Test For the rapid identification of certain man-made fibres. The following characteristics result when immersing in morpholine (morpholine): polyvinylidene chloride fibres: slightly darker, after a few minutes morpholine becomes opaque and dyed almost black. Polyvinyl chloride fibres, post-chlorinated: dissolve clearly reddish brown. Polyvinyl chloride fibres, not post-chlorinated and vinyl chloride vinyl acetate copolymer fibres: no effect.

Morphology (Gk.: morphe = form/shape; logos = science), science of structure, shape formation and surface structure, e.g. of textile fibres. The morphology of a fibre loading is of particular importance to the finisher, i.e. for example the order structure and the clearance volume.

Fig.: Morphology of a fibre arrangement using the example of a rope.

The entropy of the fibre arrangement as well as the fibre distribution in the cross-section are substantial for the character and structure of a yarn. The yarn shape and the changes in this influence the physical properties and the technological characteristics of a textile. Besides such yarn structure parameters, the yarn diameter is an important parameter, which gives information about the proportion of air in the thread and/or about the packing density of the fibres in the thread in conjunction with the yarn count. Yarn finishing and completion processes often cause the fibres to compact as well as give an improved parallel layer of the fibres in the yarn as a result of post-drawstretching.

Mosaic printing → Roller printing.

Moss crêpe (mimosa), small patterned garment crêpe with mossy character made from viscose delustred in spinning.

Mote knife → Doctor blade.

Motes Appearance of fault in cotton in the form of fibre knots felted into each other as growth motes (skin residues, unripe and dead cotton, moisture effects, etc.) or processing motes (torn and spun together, chiefly ripe fibres, which are produced in the ginning and on the carding machine). This also includes the so-called small husk motes with fragments of outer husk and with them frequently complete bundles of → Cotton fibre tufts.

Mothproofing Mothproof finishing, is directed towards the garment, fur moth (and/or their larvae), the anthremus, attagenus beetle, etc., which live as → Textile parasites on keratin-containing substances (wool amongst other protein fibres, fur, duvet feathers, etc.). Countermeasures are (→ Insect repellent finishes):

I. Cold storage rooms: temperatures between 0–6°C do not cause any killing off, only a kind of “hibernation”.

II. Respiratory poisons: work very vigorously, e.g. ethylene oxide, hydrocyanic acid, carbon disulphide and similar. Less harmful odour poisons (camphor, naphthalene, and paradichlorobenzene) only work in a higher concentration, repel the larvae, but do not kill them off.

III. Contact poisons: neurotoxins, which enter through orifices of the body, paralysing and later have a deadly effect. Application in the organic solvent by spraying.

IV. Oral poisons: colourless compounds, which originate from a) aqueous, neutral or acid solution similar to dye, either combined in the dyeing and/or afterwards or in conjunction with wet aftercleaning; b) from organic solvents in the style of an impregnation.

Mothproofing agents should also protect against carpet beetles amongst other harmful insects. Insecticides are more or less poisonous. This applies in particular to the dieldrin banned in many countries. There is an intensive search for new, non-poisonous products. The synthetic pyrethroids also seem to be problematic. They are fish poisons as well, but can at least be removed from waste water. Pyrethroids have a satisfactory protective effect against moths, but only in high concentrations against carpet beetles.

Approx. 30 species of moth larvae and approx. 15 species of beetle larvae are counted as keratin-digesting insects. To combat these insects, contact poisons and products, which work on the digestive tract, are distinguished. The latter should be favoured because contact poisons can also be poisonous to other living things. The effect of the digestive enzymes of moths and beetles on a feed protection finishing of wool only shows to advantage in the consumption of the treated wool by the animal. A finishing is ineffective, if the bond between wool and product is not digestible. Digestion of the delicate group of the finishing by the insects however results in the release of the poisonous insecticide in the digestive tract of the insects. A mechanism of the digestion disrupting products should not only protect wool textiles against moths, but also against being eaten by carpet and fur beetles. A mothproofing agent is not necessarily also effective against the latter. The use of insecticides is prohibited due to their toxicity. So products based on DDT (dichlorodiphenyltrichloromethane), pentachlorophenol or dieldrin are ruled out.

Mothproofing fastness is chiefly based on biological tests with larvae from selected wool parasites. An extensively precise and clear definition of as many test details as possible (test animals, age, size, number, test climate, etc.) is desired. It should be shown whether a mothproof finishing has the effect of preventing feeding and if necessary also of killing off against the most important wool parasites and whether the protective agent is applied in sufficient quantity. In other cases, statements as to what extent the protective treatment shows particular fastnesses (e.g. wash, dry cleaning, ironing, water, light, perspiration fastness, etc.) are desired, or is not volatile, i.e. produces sufficient durability in normal storage.

Motif print Self-coloured or two-colour, if necessary, also multicoloured print of individual figures, emblems or strokes with the aid of printing screens of different sizes, usually in accordance with the pigment printing process. Predominantly made from tricot on semi-finished or finished products.

Motion study → Method study in accordance with → MTM system by means of → TMU units.

Motive power engineering The stepless adjustment of a motive power (rotational speed and torque) on the finishing machine can be carried out using several alternative motive power techniques:

- mechanical (adjustable gears),
- electrical (motor speed variation).

Distinctions are made in the following → Gear drives:

- gear drives with friction wheels,
- gear drives with V-belts (Fig. 1),
- ball-socket adjustable gears (up to 3 kW),
- contact gears (up to 150 kW).

Two kinds of current determine the types of electric drive with speed adjustment:

- d.c. shunt-wound motor with thyristor feed,
- three-phase induction motor with static frequency converter.

The output of the engine is achieved by resetting a reduction ratio in the coupled variant (Fig. 2).

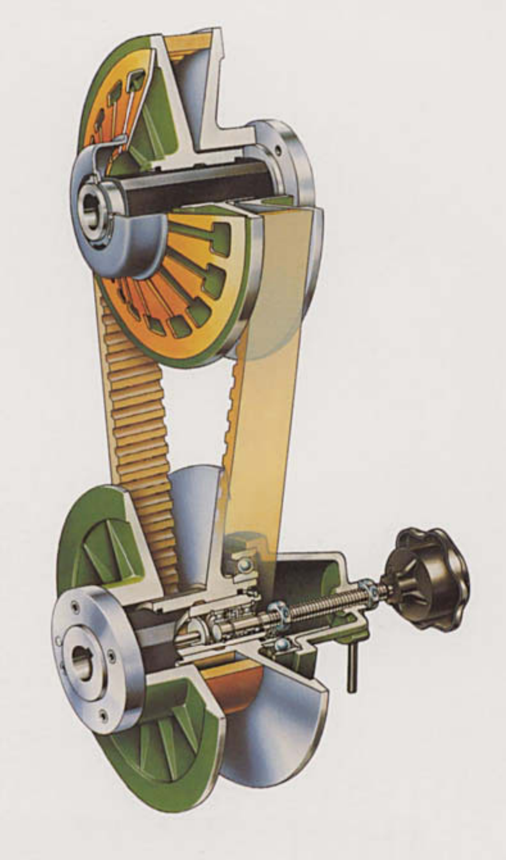


Fig. 1: V-belt adjusting mechanism (Lenze).

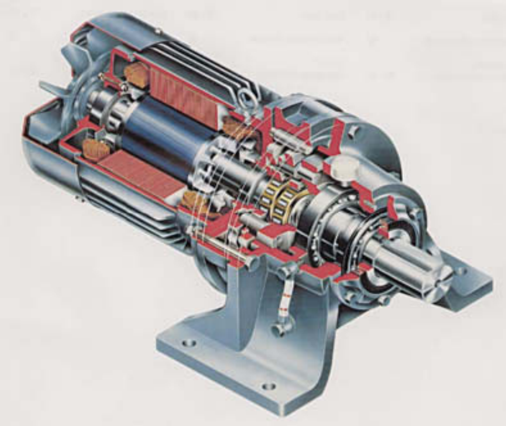


Fig. 2: Electric motor and transmission coupling (cyclic transmission) with transmission ratios of 6 : 1 to 119 : 1 in a single stage.

Mottled Mixed (bright/dark), speckled, checked. → Colour blend.

Moulding Seamless shaping of textiles made from thermoplastic man-made fibres.

Moulds (hyphomycetes) belong to the lowest group of plants. Hyphomycetes (eumycetes), those subordinated sprouting fungi and/or → Yeasts (saccharomycetes) and furthermore aquatic fungi (phycomycetes) are of particular interest to textiles. The fungus substance, in contrast to bacteria, consists of a connecting braiding (mycelium) of usually widely ramified fungal filaments (hyphae). Almost all moulds form → Spores, either in the hyphae inner (sporangia), on particular fruit bearers (conidia) or by hyphae decay (oidia). These fruit forms are already visible when enlarged by a magnifying glass and give affected textiles the most characteristic dyeing of mildew stains (→ Microbial damage to textiles). Moulds can

- live on textile finishings, i.e. a) destroy sizes and finishes (mucoraceae, individual fungi imperfecti) and b) additionally also destroy textiles through excretions (Aspergillaceae, penicillia, fungi imperfecti, etc.).
- attack textiles a) through excretion of cellulose splitting enzymes (→: Cellulase; Cellobiase); b) after caustic soda pretreatment of textiles; c) through pH pretreatment of textiles; d) through acid ↔ alkaline pH shift, in which possibilities of development arise for further types of fungi and bacteria.

Mountain flax → Asbestos fibres.

Mousseline → Muslin.

MP, abbrev. for → Melting point (floating point).

MPI (Multi Product Injection), liquid injection device for the programmed dye and chemical addition for dyeing and finishing processes (see Fig.). Funnel-shaped containers with measuring scale, rinsing ring and programmable quantity control, dosage pump with overload protection. Equipment made from rustproof stainless steel. Types for 100, 250, 500 l. Can be connected via threaded coupling to any dyeing machine. – Manuf.: Thies.

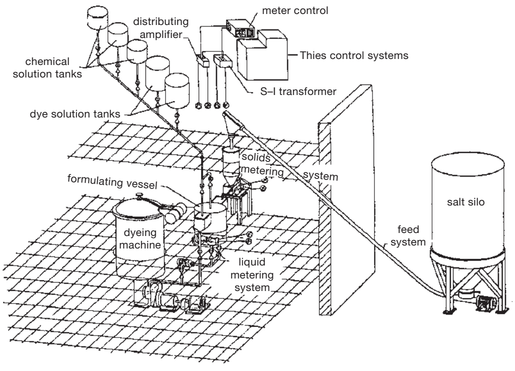


Fig.: Dyeing plant with stationary MPI installation (Thies).

MR Process (Menschner, Rotta), for wool fabric fixation. An enhancement in the quality of wool fabrics is possible in the MR process through the combination of physical treatment and chemical finishing. The MR stabiliser/MR finish finishing system is offered by the chemical factory Theodor Rotta under the name Rotta-Fix MR and Rotta-Finish MR. The use of these products facilitates the creation of the quality of wool items. The textile material obtains a shiny fabric surface. The handle is spring elastic. The process is adjusted into the normal finishing sequences. The fabric ready for fin-

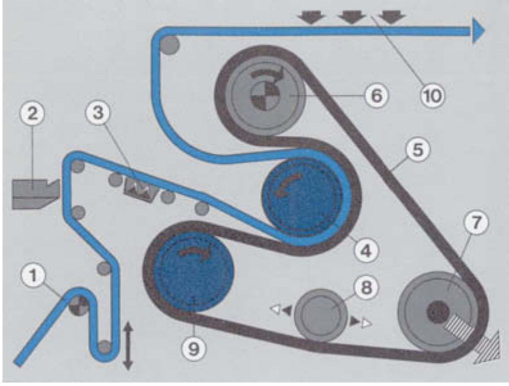


Fig. 1: Cloth passage diagram for the MR process in conjunction with the Contipress pressing and fixing machine (Menschner).
1 = pretreated cloth length; 2 = rotary dampening (WEKO); 3 = steaming table; 4 = heated effect roller; 5 = pressure belt; 6 = drive roller; 7 = tension roller; 8 = pressure belt control roller; 9 = heater roller for pressure belt; 10 = cooling zone.

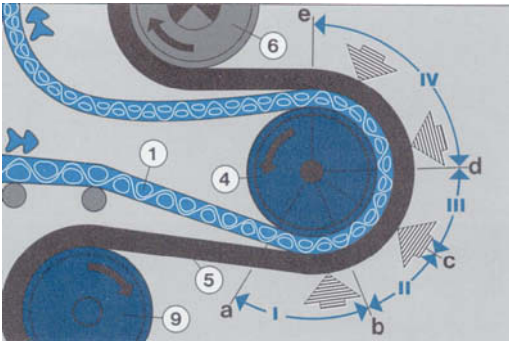


Fig. 2: Dimensional change during MR Process. Temperature differences in the cloth: I = pressing and heating phase; II = wet steam zone; III = saturated steam zone; IV = steam vapour zone (superheated zone).

ishing is padded with reducing agents and then dried. After shearing, it is sprayed with water by means of a special spraying device from WEKO (Fig. 1), and treated on the pressing and fixation machine Contipress (Menschner) using pressure and temperature (Fig. 2). In connection the fabric obtains a finish decatizing. The humidification of the fabric is necessary for the activation of the MR stabilisers. It is carried out directly before the Contipress with the aid of rotor moistening. The amount of humidity can be adjusted in a reproducible way. The application is carried out contactless and evenly. The rotor moistening takes place directly before the Contipress so that the moistened fabric side can enter into the core area of the Contipress in the shortest way.

Ms → Mulberry silk, → Textile fibre symbols, in accordance with DIN 60 001 until 1988, from 1991 → SE.

MSI Magyar Szabványügyi Intézet, Hungarian Standards Institute; → Technical and professional organizations.

MS Process (Micro-Stretching) → ML Process.

MST Labels for contaminant-tested textiles by the “Verein für verbraucher- und umweltfreundliche Textilien”. → Ecolabels.

MSZH Hungarian Standards Association; → Technical and professional oganizations.

MTF → Metal fibres, → Textile fibre symbols, according to DIN 60001 T4/08.91.

MTM (Am.: Methods-Time-Measurement), system of predetermined times in the → Method study in accordance with processes analytical to movement. Is assisted by the → TMU units (Time Measurement Units = 0.036 s). Organisation: German MTM Association, Hamburg.

Mucilages Plant products supplying mucilage, especially from → Algae, lichens and mosses, which in particular include →: Agar agar, Hai-Tao, Iceland moss or even carob extract and carragheen. Used for finishing purposes.

Mucoraceae (Lat.: mucor = mildew), genus of sizing and finishing destroying → Moulds.

Muff Loose → Tubeless cross-wound yarn package without batch centres for textured yarns. Can be dyed both in accordance with the packing system and in accordance with the creel system in the circulation machine. Short muff: height approx. 15 cm, 650–800 g; long muff: height approx. 25 cm, 1440–1700 g.

Muffle-Furnace Test Method for testing the burning properties of textiles, in which spontaneous combustion is determined in a hot furnace.

Muga silk → Wild silks from the muga or Moongaspinner (India). Quite similar to tussah silk, very tough. Colour depending on food greyish white, yellow and reddish.

Mukeka Mutono Special Special creasing and tying technique.

Mulberry cottonized bast fibre (cottonized mulberry bast fibres), cottonized fibre bast made from the bark of the mulberry bush (tree). White, silky sheeny, soft fibre of cotton-like staple length. Manufactured in Italy.

Mulberry silk (pure silk, natural silk). That → Silk, which is spun by the caterpillars of the silkworm (bombycidae, genus of scaled fliers, order of lepidoptera), also mulberry silkworms, in the form of threads, which form a cocoon. The mulberry silkworm runs through four stages during its development (Fig. 1): egg, larva (caterpillar), pupa, butterfly. After mating, the female lays 300–500 eggs, from which in the spring approx. 3 mm long and 0.45 mg heavy, black haired caterpillars hatch after a few months of hibernating. These so-called little darkies feed almost continuously. They live exclusively on the fresh leaves of the mulberry tree (monis alba). In the following 4–6 weeks, the caterpillar multiplies its net weight several times by absorbing food. Within 5 life stages, it firstly sheds its skin four times and develops into an 8–9 cm long and 4 g heavy caterpillar. Matured the caterpillar covers itself with a cocoon by spinning, which should protect the defenceless, immovable pupa against enemies and atmospheric influences. The caterpillar hereby excretes a sticky secretion solidifying in the air through two apertures located on the lower lip. It continually swings to and fro by its head and lays the thread in even, figure of 8 movements around itself. Within 3 days, the silk caterpillar fixes double threads hanging together in an average of 2000 m into a tight cocoon. After 3 days of rest in the finished cocoon the caterpillar sheds its skin for

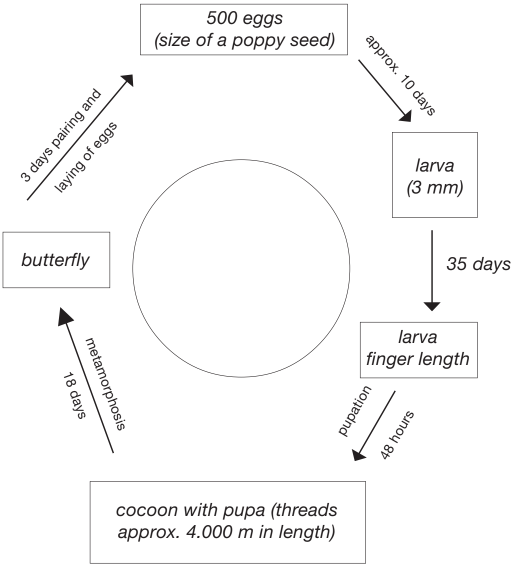


Fig. 1: The life cycle of Bombyx mori.

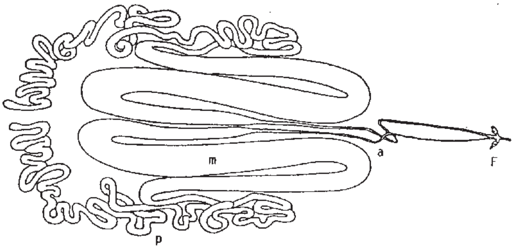


Fig. 2: Silk glands of the Bombyx mori larva.
F = Filippis gland; a = outer gland zone; m = middle gland zone; p = inner gland zone.

the last time. It thereby changes into the pupa, which already has the first signs of wings, legs and antennae of the later butterfly. After a further 2–3 weeks, the butterfly slips out of the cocoon, which was previously softened by the secretion of a proteolytic liquid and made accessible at one place.

The mulberry silkworm moth is an inconspicuous night butterfly. The animals are greyish white, ungainly with short wings; they can neither feed nor fly properly. Its lifespan is not more than 2–4 days and exclusively serves reproduction. The male dies immediately after mating. The female lays the eggs 10 hours after mating within 2 days and dies as well. The metamorphosis of the silkworm moth is concluded with the laying of the eggs.

The silk caterpillar has a pair of silk glands (Figs. 2 and 3), which are tubular shaped and consist of 2100 cells for the biosynthesis of fibroin and sericin. A back, middle and a front section are distinguished in each gland. The fibroin molecules are biosynthesised in the back section and sezerniert in the lumen. The silk fibroin exists there as 30% aqueous solution (liquid silk). This is transferred into the middle section and stays there until the moment of spinning (reservoir). Three kinds of sericin are biosynthesised and sezerniert in the middle section in order to wrap up the fibroin. The water gradually migrates into the sericin layer from the fibroin solution; the fibroin thereby becomes thicker and forms liquid crystals. Both flows from both glands meet near the spinning gland. That is why a raw silk thread consists of two fibroin threads. When the “thread” issues from the spinning gland it is stretched, whereby the chains are oriented in parallel so that the hydrogen bridges can then “click shut”. The hydrated hydrogen molecules are thus displaced and the resulting product is insoluble in water.

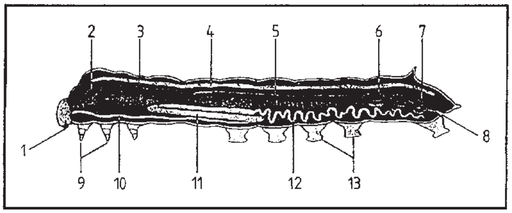


Fig. 3: Internal structure of the silk larva.
1 = mouth with spinning tubercle; 2 = pharynx; 3 = front intestine; 4 = heart; 5 = stomach; 6 = large intestine; 7 = rectum; 8 = anus; 9 = breat limbs; 10 = spin gland secretin segments; 11 = gland reservoir; 12 = gland ducts in pairs; 13 = prolegs.

The spinning speed is 1 cm/s over 2–3 days. The transformation of liquid silk into silk fibres is carried out using mechanical forces. Of the approx. 1000–3000 m long threads of the cocoon, only one part is regularly wound and unbonded; so it is only possible to unwind one part. The winding occurs in a way that, after killing the caterpillars using heat, the cocoons are soaked in hot water and lightly brushed. The origins of the threads thereby remain hanging on the bristles; the thread origins exposed by this are bundled and afterwards led to the reeling. The grège silk is obtained from reeling and twisting. As the fibre material of the sticky layers of the cocoon cannot be unwound, the sticking substances should only be removed in order to be able to obtain the silk described as floret or schappe.

Mule yarn Single, more or less (loose) twisted cotton weft yarn for soft materials, as a filling weft and similar.

Mull Soft, smooth, very light, thinly set (cotton, viscose or silk) fabric, similar to → Muslin (but denser and stiffer); also finer qualities than → Organdy, bleached, printed - brocaded - embroidered. Application: for blouse materials. Mull is also used for dressing material and nappies as a highly porous, plain woven cotton fabric (e.g. with 28 threads/cm^2). The thread density is from time to time so low that the total of warp and weft threads on a cm^2 is sufficient as the quality number. As a point and dot mull for curtains in broché design.

Multiaxial fabrics The structure results from several layers of monoaxial fabrics (fleeces, fabrics; see Fig.) arranged shifted together. The resulting physical properties such as strength and extensibility are clearly above those of monoaxial arrangements.

Multi-Bath process American description for multi-purpose baths, which facilitate various finishing stages in one bath.

Multi-bath washing for laundry The total standing liquor is drained for each individual washing/rinsing cycle and fresh water admitted for the next work operation. Processing in the single- or multi-bath process. Opposite → Flow washing process.

Multicellular Multicell, e.g. viscose fibres with a thin cell wall structure and triangular diameter.

Multi charge sewerage filter is used as a continuous → Sewerage filter. It is accumulated from charge

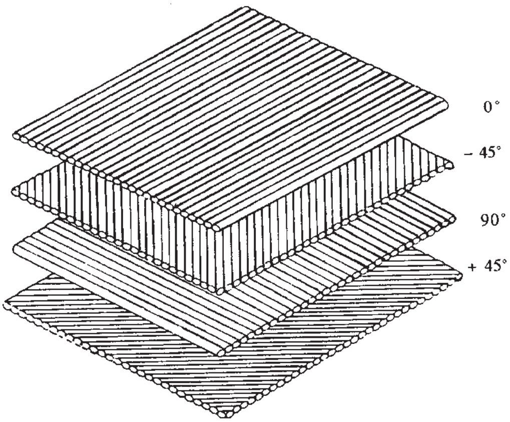


Fig.: Multiaxial composite material.

to charge as long as dirt together with filtering powder addition falls onto a basic layer until the flow output has reached a minimum value. The basic layer can also be repulsed mechanically by the filter elements for every charge in order to form a new filter layer together with other filtering powder additions during re-accumulation. As the flow output decreases with increasing number of charges, the multi charge sewerage filter must be dimensioned relatively large in order to obtain a satisfactory sewerage effect. So that the re-accumulated filter layer does not fall from the elements, low overpressure should always be present in the filter. Multi-charge sewerage filter cleaning and/or filter cake removal is in general carried out by mechanical devices or by rewinding.

Multicolour-Designer Device for the production of multicolour effects by means of 1–2 rotary screens. In the screen inner, scanned fully flat open or provided with patterns, a sealed print paste application part is located on the screen with specific apertures for the individual conducting of the print pastes across the whole fabric width. The print paste application part is axially pushed to and fro in the screen using a control mechanism. Stroke and stroke speed can be controlled steplessly. For the production of TAK and space effects (→ Space dyeing). – Manuf.: Mitter.

Multicoloured effect Achievement of heterochromatic marks using discharges, printing, fixation differences, resists, weaving and similar on textile fabrics.

Multicolour effects Multicolour effects on textile fabrics; e.g. →: Colourcraft process; Differential dyeing or also spray dyeing effects, e.g. on fabrics in special machines (Figs. 1 + 2).

Multicolour effects, space-dyeing Colour effects in various shades of colour, which are achieved by multicolour printing, by print paste application of different dyes, by exhaust dyeing processes on fibre blends, for which different types of dye are in one bath, or by → Space dyeing.

Fig. 1: Spray dyeing plant for multicolour effects.

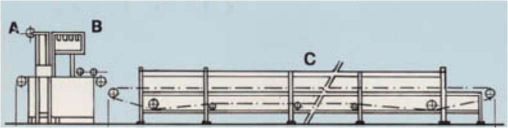


Fig. 2: Multicolour patterning plant.
A = material feed, poss. folded; B = Spray head for microprocessor-controlled application of five dye application liquors; C = steam tunnel.

Multicolour printing from one printing roller → Orbis printing.

Multicolour process Single-bath dyeing method for attaining multicolour effects on 100 % wool. Principle: simultaneous attainment of 2–3 tone-in-tone or contrast dyeings in one dyebath. Purpose of the process: processing of untreated compared with pretreated (prechromed and/or resisted wool) into yarns or fabrics/hosiery goods and subsequent dyeing. “Resisted” wool is only approximately half as deeply stained as “prechromed” wool. The multicolour process has found its way into the practice, but requires precise knowledge of the behaviour of the individual dyes. → Differential dyeing.

Multicolour Rapid-Printing machine for sample purposes can accept up to 8 printing rollers and produces application-oriented printing result. It is thereby not necessary to fit the printing rollers on mandrels. These are secured on the central cylinder by means of plug-in bearings. The doctor blade is shaped in such a way to save the print paste colour box that it can directly accept the print paste and dispenses using a colour furnisher roller. Approx. 75% of the print paste quantity otherwise required can thereby be saved.

Multicomponent fibre → Bicomponent fibre made from various synthetic fibre components of the matrix-fibril type.

Multienzyme complex Enzyme producers offer enzyme mixtures for the entire degradation of vegetable cell walls, which are manufactured from a chosen cultural root of the aspergillus group. This multienzyme complex has pectinase, cellulase, hemicellulase, protease and in low quantities amylase and lipase activity. It is used for the processing of cereal and for the production of beer, alcohol and starch.

Multi fibre Fibre blends, e.g. cotton/synthetic fibre blends.

Multifibre strip The wet fastness requirements of textiles were in a way carried to such extremes by Marks & Spencer that the position was selected as a model: A white textile gets into a large washing batch of coloured articles wash, which is subject to a 100°C wash. The white textile is simulated using a narrow textile carrier, on which all possible types of fibre are made up in a white form. This “multifibre strip” is suspended in the wash test of a dyeing, whose wet fastness should be tested. The dye migration conditions (diffusion ratios) are naturally optimum in that way so that this fastness to washing test represents an extremely rigorous test.

Multifilament (multifil), multi-nozzled → Filament, multi-threaded. Opposite: → Monofilament.

Multifilament gauze Polyamide or polyester gauze manufactured from multifilament fibres. Polyester gauze is preferred due to its good light resistance, low extensibility and good elasticity.

Multifilaments → Multifilament.

Multifilament yarn In accordance with DIN 60 001 B1. 2: → Filament yarn made from several → Filament.

Multifunctional clothing should, for example, protect against heat, cold, gases, colloid dusts, radiation, simultaneously being permeable to water vapour and body heat, and being electrically functional (cannot be found by radar and similar).

Multifunctional processes Multipurpose processes, which combine different finishing stages into one single process, e.g. bleach and dyeing combined or dyeing and finishing combined processes.

Multi-level drier In contrast to the horizontal or flat stenter, which needs a lot of space, the multi-level drier (see Fig.) has the advantage of carrying fabric in the stenter in several levels from top to bottom through the convective drier and consequently of being space-saving.

Multilobal Multi-lapped; e.g. cross-sectional forms of → Profiled fibres.

Multimetal machines Machines made from multimetal designs, e.g. older double drum machines, whose outer drum sheath consists of galvanised sheet steel and of copper in the inner drum.

Multi-Pass-System For the extension of rotary screen printing application using roller screens with standard diameter in order to produce designs with a large register (even more than 5 m). Is based on the draining of the print heads independent of each other corresponding to the preselected program, in which, depending on the pattern to be printed, the screen is disengaged after one or several roller revolutions and automatically stops. – Manuf.: Reggiani.

Multiplexer Circuit route, which selects a particular actuating signal from x actuating signals through default of an address and switches to the corresponding output terminal. Is used as an external measuring-circuit selector, forced value selector and power supply unit for connecting devices in the 2nd interface system to an EDP system.

Multipolymer fibres → Copolymer fibres.

Multipore fibre → Imitation suede.

Multi Product Injection → MPI.

Multiroller (dye multiroller), multi-roller milling and dyeing machine for hat bodies. Is used for simultaneous milling and dyeing in one operation. Slowly run-

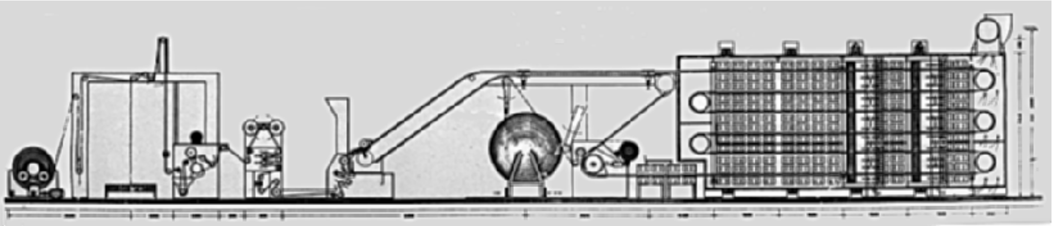


Fig.: Multi-level drier KM 15 (Krantz) as tenter frame.

ning roller aggregates, between which the hat bodies are continually sprayed with the dye-containing milling liquor. The squeezed off liquor flows across a collection tank, is reheated there and again is usedfor spraying, etc. Already $^2/_3$ ready milled fabric is advantageously used and starts with dyeing and weft milling at 50°C (max. attainable temperature approx. 85°C). Approx. 20% additional dye consumption should be considered. The dyeing should be completed after approx. 3 hours. Cost-efficient because the combined operation is feasible. Manufacturers of hat finishing machines have adopted the multiroller principle in multiple adapted form for their designs.

Multistage stenter For the stretching and treating of web shaped fabrics through the drying zone in repeated fabric forward and return stroke. Air supply parallel or vertical. Tension chains offset vertically (→ Tier drier).

Mungo Designation for class III (made from milled fabrics) sorted → Rags and → Reclaimed wool produced from them.

Mushroom Apparel Flammability Tester Flammability tester, developed by American National Bureau of Standards.

Mushroom reaction → Fibre damage (cellulosic fibres), tests for.

Muslin (Mousseline), named after the city in Iraq referred to as Mosul or Mossul. Only fine, single, softly twisted worsted yarns made from almost all fibres are considered for this type of fabric. The fabrics are fairly loosely adjusted and produce relatively light dress materials of soft, flowing drop in conjunction with the fabric weave. Bald finishing. They are typically printed, previously even printed by hand to some extent.

Mussel silk (byssus silk, sea silk, etc.), natural silk-like hair of different large ham mussels (Mediterranean, Normandy) belonging to the → Natural protein fibres, which are held tightly on the rocky ground with the fibre tuft produced and are torn off there. Reconditioning by kneading by hand using soap, carding, drying, washing using citric acid and hot platelets. Outer smooth, gold shimmering gloss, colour brown to olive-green. 2–3 threads of mussel silk are twisted with a thread of natural silk. Precious, rare material. Production barely 200 kg/year. Application: (Italy) for shawls, stockings, gloves, bags, etc.

Mustard gas protective finish Referred to as fabric impregnation against the poison gas, mustard gas (dichlorodiethyl sulphide), is 2.4-dichlorobenzylbenzoeacidchloramide (2.4-$Cl_2C_6H_3N(Cl)COC_6H_5$). Mustard gas protection with 35.5 % chlorine (23.5 % available chlorine); reacts with the poison gas into oxidised and chlorinated products, which should prevent the formation of skin blisters. Typical example from the field of use of technical textiles as protective textiles.

MUT (environmental-friendly textile label). Label for textiles kind to the environment, awarded by the Verein für verbraucher- und umweltfreundliche Textilien. → Ecolabels.

Mutagenic agents (Lat.), substances hazardous to health, which damage hereditary factors and trigger mutations, i.e. can cause changes in hereditary makeup. Mutagenic agents also partly act as → Carcinogens.

Mutarotation Is the optical change in rotation up to an upper range value occurring in the solvent state in sugars, in which e.g. the normal δ-glucose is produced from α-glucose and β-glucose (inversion).

MW Abbrev. for → Molecular weight.

MWS (metres head of water). Metre water column. Unit for → Pressure (-heights, liquid columns) no longer is use. 10 MWS = 9806.65 Pa.

Mycelium → Moulds.

Mycotoxins Collective description for infectious diseases caused by fungi. → Antimycotic finishing.

Myria- (Gk.), unit prefix for ten thousand times, factor of 10^4; e.g. myriagram of magnesium.

Myristic acid, $C_{13}H_{27}COOH$. Constituent of coconut oil. Application: for the manufacture of textile auxiliaries.

Myrobalans Tannin-containing, small rock hard fruits (Bengal, India) and/or fruit parts or their extract. Good myrobalans have a wrinkled exterior and contain 38–40% tannin; worse are smaller, unwrinkled with 25% tannin content. Stoned myrobalans have approx. 50–53% tannin content, 24–34% liquid and 65% solid extracts. Good myrobalans correspond approximately to $^1/_3$ tannin. Used as tannin for tanning.

N

N,

I. Chemical symbol for nitrogen (7).

II. Unit symbol for → Newton.

n Unit sign for → Nano- (billionth) factor 10^{-9}.

Na Chemical symbol for sodium (11).

Nacré (Fr.), nacré print, flowing print; like mother-of-pearl.

NALCC A leading American specialist textile cleaning organization; → Technical and professional organizations.

NALI English textile cleaning specialist organization; → Technical and professional organizations.

N-Alkoxymethyl-compounds Compounds with one or more N-Alkoxymethyl groups, $–N–CH_2–O–R$ (e.g. $R = CH_3$). Used inter alia as crease resist finish, e.g. → Dimethoxymethyl-4.5-dimethoxyimidazolidon.

Nanking yellow → Iron buff.

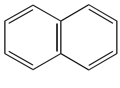
Nano- (Gk.), Unit sign for billionth = 10^{-9}, e.g., 1 nm = 10^{-9} m.

Nap cloth (floconné, Fr.: flocon = flock), the term used to describe thick, soft double fabrics (900–1000 g/m^2) made from carded yarns usually of high quality merino wool. The typical appearance is achieved by a separately-inserted 3rd weft thread, the nap weft, which is a long float thread, later napped (thus also called the "raised thread") giving rise to fluffy tufts of hair on the surface of the fabric. Depending on weave, comes in ribbed, diagonal or herringbone effect; wool-dyed or piece-dyed. Used for high-quality men's coats.

Nap finish machines Mainly → Brushing machines for the production of brushed or napped finishes on grey goods. In the widest sense they also include → Raising machines.

Naphtha The term for crude oil or certain crude oil fractions.

Naphthalene $C_{10}H_8$,



consisting of two contiguous benzene rings. A product of crude oil (rare) and coal tar. Small white laminations with a distinctive smell. Insoluble in water, soluble in organic solvents. Hydrogenation products →: Decahydronaphthalene; Tetrahydronaphthalene. Application: an essential base material (e.g. alkyl naphthalene sulphonic acid), as moth repellent, fire lighter, heating fuel, etc.

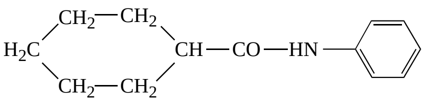
Naphthalene process A pad steam process for the continuous dyeing of loose wool, with the addition of emulsified naphthalene.

Naphthenes → Alicyclic hydrocarbons.

Naphthenic acids Light, saponifiable oils with an unpleasant odour, derived from mineral oils or the products of dry distillation of brown coals, bituminous shale etc., with the general composition:

$$C_nH_{2n-1}–COOH \text{ or } C_nH_{2n-3}–COOH$$

Goods (mercerizing), wetting, dispersion, emulsifying and washing agents are water-soluble alkaline (sodium salts = strongly foaming soaps), ammonium and particularly triethanol amine salts, whose unpleasant odour has prevented their widespread use in Germany. Good mercerizing wetting agents and emulsifiers also include the naphthamides, e.g.,



and their sulphonate products. Similarly, sulphonated wash-active substances are also obtained from oxyethylated naphthenic acids (e.g. ethanglycol naphthenate). Many metal naphthenates (containing copper, iron, aluminium, lead, zinc, etc.) are excellent antibacterial agents and are used as active substances against microorganisms, rot and decay in textile finishes. Naphthenic acid esters are also used as softeners for synthetic resins.

Naphthol dyeing process Naphthol dyeing is carried out on the fibre by combining (coupling) two soluble components, a naphtholate and a diazotized base. The base is either diazotized in the dye shop itself, a complicated process, or obtained from the dye manufacturer as a stabilized diazotized fast colour base, the dyeing salt. There is a large number of combinations, capable of achieving bright yellow, orange, scarlet and red shades which are not available in the vat-dyeing ranges, and more muted burgundy, brown, navy blue and black shades. Naphthols are characterized by good fastness, in particular fastness to boiling. Some combinations are also weather-resistant. The dyeing technique for naphthol dyeing requires promoting the main reaction to form an azo dye, and avoiding the secondary reaction of hydrolysis to a compound no longer suitable for coupling (Fig. 1).

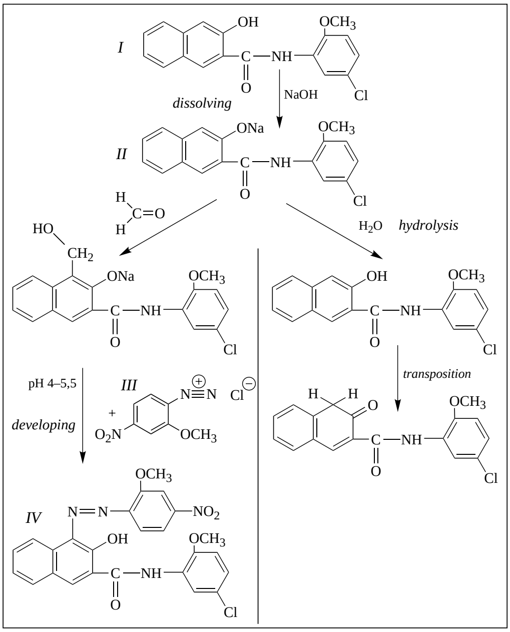


Fig. 1: Chemistry of naphthol dyeing using the example of Naphthol AS (Hoechst).
I = Naphthol AS-CA as grounding components;
II = dissolved naphtholate; III = fast red salt B in the developing bath; IV = dye pigment.

This is done by interim stabilization of the naphtholate with formaldehyde. Particular attention must be paid to the stoichiometric calculation of the developing components (also called diazo components, in the form of fast colour salts or fast colour bases) and the impregnating components (also called coupling components, Fig. 2), which join together to form depth of colour, given in grams of fixed naphthol per kilogram of goods. The dissolving instructions for naphtholates and for fast colour salts (or the solution and diazotization of the fast colour base) must be adhered to precisely. In the exhaust method on the jig or in yarn dyeing the selected liquor ratio must be adhered to precisely, in particular when impregnating, as the proportion of impregnating components absorbed by the fibre determines the depth of colour. As the relevant recipe preparation is complicated, special computer systems are available for naphthol dyeing.

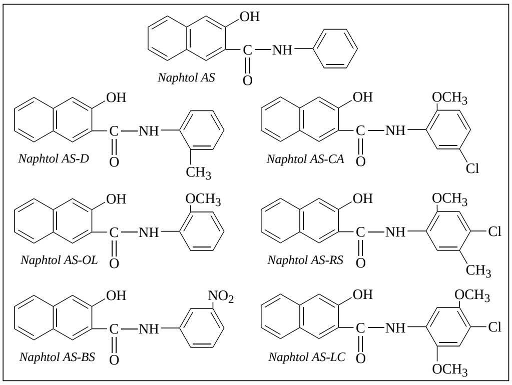


Fig. 2: Coupling components by Hoechst.

Naphthols can be applied using the exhaust method or padding, with the two-bath method, i.e. impregnation and developing carried out separately. In the exhaust method, in order to obtain a good abrasion resistance of the dyeing, the excess naphtholate must be removed after impregnation and before coupling. Depending on the equipment, this is done by squeezing, wringing or, even better, rinsing. This is possible due to the affinity of the majority of naphthols. Yarns to be dyed are on cross-wound package or warp beams. In certain cases, warp yarns are also dyed with naphtholene in the size, e.g. for denim articles. In yarn dyeing, the two-bath method is largely replaced by a single-bath method. By using specific recipes, it is possible to apply moderate- or high-affinity naphtholates and dyeing salts together in a bath containing dispersant, and promote coupling by the addition of an acid. There is also a semi-continuous process for knitted goods whereby pre-treatment and impregnation take place on hanks (e.g. in a winch beck). The goods require intermediate dwell time in watertight carriages, as they need to be completely covered by the impregnation liquor in order to exclude the hydrolyzing influence of atmospheric carbon dioxide. Wet-in-wet, following thorough hydroextraction, the developing bath is applied to the loop on the padder. A semi-continuous process is also used for impregnation on the jig with subsequent developing of the goods following intermediate drying in a continuous plant with developer bath section. In a fully continuous process (Fig. 3) the fabric is impregnated on a pad and developed following interim drying in a padding section with the diazotized fast colour base or fast colour salt. There is another classic process involving impregnation on the pad – hot-flue drying with cooling stage or airway as a wet-in-wet

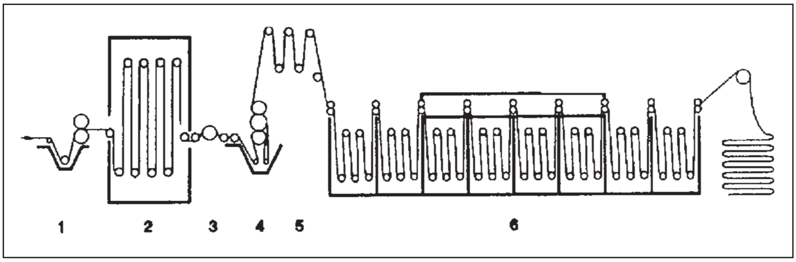


Fig. 3: Diagram showing the continuous process with naphthol dyes (with intermediate drying). 1 = pad for grounding; 2 = hot flue; 3 = cooling roller; 4 = 3-roller pad for developing; 5 = skying; 6 = full-width washer with eight compartments.

process – pad developing – airway – full-width washing machine. One type of single-bath process is discontinuous pad-batch dyeing. Naphtholate and fast colour salt are padded together and the goods left to dwell for 1 hour at 40–60°C. The coupling then takes place by means of passage through a bath containing acetic acid and sodium chloride at 80°C for 10–15 seconds. In all processes, following coupling a boiling bath with soap or a special dispersant is essential.

I. For wool: impregnation only in a sodium carbonate bath at 35-60°C, with the addition of formaldehyde, sodium chloride and protective colloid. Interim rinsing in cold sodium carbonate. Developing as described above, pH 5.5–6.5, temperature 20°C. Post-treatment at 40–50°C with detergent and ammonia, then a fresh bath at 80-85°C with detergent and acetic acid. Careful selection is essential, especially in the case of diazo components, as these are absorbed by damaged wool. As the process takes place in the alkaline region, the wool is likely to be damaged.

II. For silk: for boil-resistant, strong shades on yarns. Impregnation with naphtholate, protective colloid and sodium chloride at 20–25°C. Interim treatment: spinning. Cold developing with fast colour salts or diazotized fast colour base, with the addition of sodium chloride and acid. Warm post-treatment with hydrochloric acid, finally rinsed twice in a detergent bath, rinsing, finishing.

III. For acetate: for cross-dyeing-fast special-effect yarns. Limited selection of naphthols. Impregnation at 75°C with naphtholate and fast colour base in dispersed form. Interim treatment: rinsing. Developing: diazotizing with sodium nitrite and hydrochloric acid, cold. Post-treatment: rinsing, soaping, sodium hydrosulphite bath. Sodium nitrite may also be added to the impregnation bath, and after cooling to 45°C, diazotization may be carried out by the addition of formic acid. The disperse diazo dyes recommended for the dyeing of polyester may also be used for acetate. Dyeing temperature 105°C.

IV. For polyamide: of little significance. Procedure as for acetate, but with increased quantities of nitrite.

V. For polyester: the disperse diazo dye group is particularly suited to the dyeing of polyester loose stock, for later spinning together with other fibres. Deep dyeing with good fastness is achieved. The usual range of naphthols cannot be used for polyester. Special dyes are used, consisting of blends of naphthols with fast colour bases in disperse form. Impregnation is carried out under HT conditions or with the addition of a carrier, diazotized at temperatures of 80–100°C. Post-treatment: rinsing, reductive cleaning with caustic soda and hydrosulphide at 80–85°C.

Naphthol dyeing test in UV light Place a test dye sample in a 50 ml beaker, and fill with sufficient blank vat to cover the sample (36 g/l caustic soda, 35.5% and 24 g/l sodium hydrosulphite); boil until the original dye appears a dirty yellow; remove the sample with a glass rod, squeeze the sample out on the glass side of the beaker, place on a round filter paper (preferably on a glass base) and leave to dry. Examine the test samples under an analytic quartz lamp: strong luminescence indicates naphthol dyeing.

Naphthol preparation Firstly the necessary naphthol components are applied to the fabric, usually through padding. After drying, the second components, the fast colour base or the fast colour salt are applied together with the padded base.

Naphthols,

I. A designation of hydroxy-derivatives of naphthalene with one or more OH groups. They are used as intermediate products (α-naphthol, β-naphthol) in dye synthesis (→: Phenols; Cyclic hydrocarbons).

II. Developing dyes (obsolete ice colours), produced on the fibre, usually by means of a two-bath application, they are insoluble azo dyes from naphthols (primers) and fast colour bases or dyeing salts (developers), with around 2000 combinations possible. An essential class of dyes for cellulose fibres, especially for deepest red, scarlet and claret shades, which are not available in vat dyeing ranges. Can be used in exhaust dyeing and padding processes and also for “dyeing in the size”. Of lesser significance for wool, wool/cellulose, silk, acetate and polyamide. Dispersion diazo dyes have been specially developed as naphthol preparations for the dyeing of polyester. A range of special naphthol classes is used in printing.

Naphthols – colour scale Of greatest significance for red shades. Paranitraniline red has been superseded by naphthols. Naphthol dyes and prints (around 2000 different dye combinations: yellow, scarlet, red, claret, brown, blue, green, olive, violet, black) possess good properties to produce deep shades and often a high degree of brilliance.

Naphthols – fastness on cotton, wool, wool/cotton Largely dependent on the components (naphthols and fast colour bases/salts) which are used to produce the insoluble azo compounds. Naphthols achieve, to an extent, the highest levels of fastness and can then be labelled with the indanthren product designation.

Naphthols in direct printing,

I. Base printing: The goods are padded with naphthol (low affinity because of the subsequent removal of non-printed areas) and dried evenly (hotflue, drying cylinder). They are then printed with printing dye paste containing thickened dye salt (fast colour salt) or a dye base diazotized in the printing dye paste (fast colour base); they are then boiled with soap with an alkali additive.

II. Naphtholate print: Only suitable for patterns with very low cover. The fabric is printed with naphthol dissolved in caustic soda, thickened and as far as possible, dried, padded with dyeing salt or diazotized dye base, treated in a hot sodium disulphate bath, rinsed and boiled with soap.

III. Process without naphthol basis with steam or wet development:

a) Printing with a combination of naphtholate and antidiazotate: thickened dye, caustic soda and weak oxidizing agent are printed and then dried. The non-developed antidiazotate can be converted into a developable diazo compound by lengthy airing or steaming and subsequent passage through a hot electrolytic bath with the addition of organic acids (formic acid, acetic acid) or by steaming in acid ager, rinsing and boiling with soap.
b) Printing with a combination of naphtholate and diazoamino compound: thickened dye, wetting agent and caustic soda are printed, dried, with acid bath treatment (passage through a hot electrolytic bath with organic acid or steaming in acid ager). Conversion of the stable diazoamino compound into developable diazo compound. By using a developer in place of the caustic soda in the printing dye paste, fixing can also take place using neutral steam. Finally rinse, then boil with soap.
c) As b) with neutral, fissile diazoamino compounds. Fixing by neutral steaming.
d) Printing with a combination of naphtholate and antidiazosulphonate. Also fixed using neutral steam.

IV. Printing of prepared azo dye with alkaline fixing: only of historical interest. Splitting off of water-soluble components by saponification.

Naphthols in discharge printing Because of their chemical structure, naphthols are excellently suited to the dyeing of white and coloured dischargeable grounds. There are only a few exceptions where the dischargeability is insufficient or the dyes cannot be discharged at all. The special suitability of naphthol dyeing for discharge dyeing is a result of the high wet fastness properties and the ease of splitting of the azo pigments with the help of reducing agents. The advantages are also apparent in the discharge dyeing of deep dye shades, for which the colour fastness salts derived from aminoazobenzene are used.

Naphthols in resist printing Their significance has been substantially reduced by the application of modern discharge agents.

I. White resist: thickened aluminium sulphate, possibly with the addition of organic acids (e.g. tartaric acid).

II. Coloured resist: preferred with reactive dye in resist printing. The goods are printed, dried, briefly steamed, padded with slightly thickened variamin blue, ventilated, rinsed briefly, immersed in a boiling bath with sodium disulphite, rinsed, boiled with soap with sodium carbonate.

Further options: vat dye with potassium sulphite and zinc oxide added to the usual printing dye paste. Vat leuco ester, e.g. application of the ammonium chloride process with the addition of aluminium sulphate. Pigment dye with the addition of organic acid. Mordant dye with the addition of oxalic acid, potassium sulphite or sodium thiosuphate.

Nap velours A napped fabric, usually wool, in which the raised fibres all lie in a parallel direction. Opposite → Upright pile velvet.

Narrow fabric → Ribbon.

Narrow fabric accumulator A device for collecting the fabric by depositing it in transverse folds on a continuous conveyor belt.

Narrow fabric dyeing Narrow fabric lengths are wound into hanks and dyed in a circulating-liquor machine like yarns on sticks or wound directly onto bobbins. Wider narrow goods are dyed by the continuous process.

Narrow fabric finishing Narrow fabrics are woven in working widths of up to 300 warp threads, but usually as narrow textiles substantially less in width, on special looms, and it is in this form that they must be heat-set or crease resistant finished (possibly following pre-treatment and/or dyeing). This is carried out on cylindrical dryers, around which the narrow fabric passes several times (see Fig.).

NATA "National Association of Testing Authorities"; an Australian textile testing body based in Chatswood. → Technical and professional organizations.

National Cotton Council of America An information bureau for cotton processing based in Washington, USA, with branches in many countries. → Technical and professional organizations.

National Institute of Drycleaning (NID). An

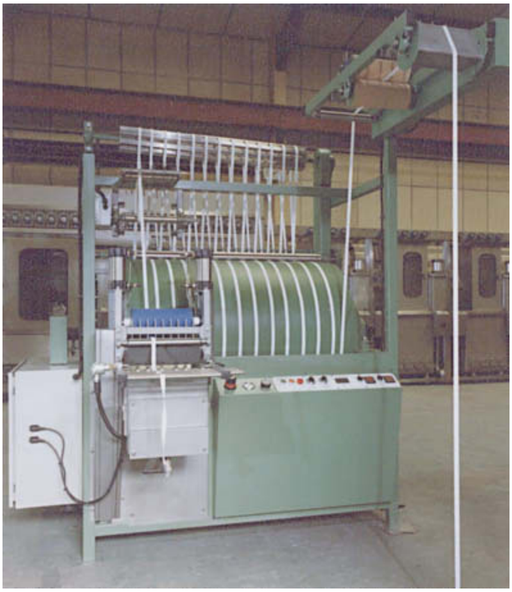


Fig.: Webtex narrow fabric finishing plant (left: entry; right: exit).

American dry-cleaning organization founded in 1972. → Technical and professional organizations.

Natural (Lat.), original, e.g. cotton can be called a natural cellulose fibre in contrast to regenerated cellulose fibres (viscose, acetate). Natural protein fibres are wool and silk, in contrast to man-made protein fibres such as casein fibres.

Natural cellulosic fibres belong to the group of natural → fibre materials of vegetable origin:

I. → Vegetable hair fibres: →: Cotton; Kapok.

II. → Bast fibres: →: Flax; Hemp; Jute; Kenaf; Kendyr fibre; Nettle fibres; Ramie; Rosella; Sunn fibre; Typha fibres; Urena fibres.

III. → Hard fibres: →: Agave fibres; Alfa grass; Bromelia fibres; Coir fibres; Henequen; Manila fibre; Mauritius hemp; Sea jute; New Zealand flax; Palm fibres; Panama; Pine apple fibre; Raffia bast; Sanseviera fibre; Sisal; Yucca fibres.

IV. others: → Paper yarns.

Natural colour The colour of undyed textile goods prior to dyeing, which needs to be taken into account when formulating the recipe. Sample dyeing is essential.

Natural dyes There is a vast number of plants whose extracts can be used for the dyeing of wool, silk cotton and linen; there are also a few examples of dyes of animal origin. Different parts are used depending on the plant, whether the whole plant, the bark, the heartwood, the leaves, the roots or the fruit. For various reasons, e.g. due to the dyeing behaviour, the fastness or the biological availability, only some of these have gained widespread acceptance as dyes. Some examples are given of the natural resources necessary for obtaining some dyes of plant and animal origin:

1. Cis-bixin (annato) from the seed pods of the fruit of the rocou tree, for food, oils, margarine, cheese rinds etc. One tree yields 1–3 kg seeds; 100 kg seeds yield 120–160 g pure cis-bixin. The annual harvest in Central and South America is approx. 500 t seeds.

2. Carminic acid (cochineal) is obtained from the female cochineal insect (coccus cacti) and is used as a wool, silk, food and cosmetics dye. 1 kg of dried female insects (approx. 140 000) equal to 50 g pure dye. Insects reared on plantations can be collected approx. 3 times per year; those living wild approx. 6 times per year. In opuntia plantations, still in use today, 1 ha yields approx. 300 kg cochineal per year.

3. Carotene is obtained mainly from carrots, red palm oil and pumpkin seeds, and is used primarily for food and pharmaceutical purposes. 1 t of carrots yields approx. 67 g pure carotene.

4. Carthamine is obtained at quantities of 0.2–0.3% from flowers of the safflower (carthamus tinctorius). The flowers also contain 30–36% worthless safflower yellow, which must initially be removed by extraction with water.

5. Curcumin occurs in the root tubers of the curcuma genus, native to east Asia. 30–50 g pure dye are obtained by extraction from 1 kg of the dried drug; this is used for dyeing wool, cotton and silk in yellow, in red to brownish-black shades.

6. Euxanthinic acid is obtained from the urine of cattle which have been fed on the leaves of the mango tree. The yield is 50 g per animal per day. The land of origin was India, although the practice was banned prior to 1930 on animal protection grounds. Euxanthinic acid was once a highly prized yellow artists' pigment.

7. Fustine and fisetine, obtained from young fustic (tanner's sumac). 1 kg wood dust yields approx. 40 g dye.

8. Haematin from logwood (campeachy), the heartwood of haematozylum campechianum. It is obtained from 10–12 year-old trees. The reduced form hematoxylin is present in the wood, so that in order to obtain the substance, the heartwood, cut into blocks, is left to season for approx. 1 year, or is artificially oxidized by fermentation. A faster oxidation is also possible using nitrites, chlorates or chromates. A consumption statistic from 1950 shows that approx. 30 000 t of logwood was shipped from Campeche (Mexico), representing worldwide consumption. At that time logwood was used in larger quantities in the textile industry to achieve fast blue and black shades on polyamide.

9. Hypericin is found in the ratio 1.2–1.5 g/kg in the dried, ground flowers of St John's wort. Depending on the mordant it produces yellow, pink or blue-black

shades, and without mordant reddish-purple shades on wool.

10. Indigo is obtained from East Asian Indigofera genus and European woad (isatis tinctoria) and dyes wool and cotton (principle dye used for jeans). 100 kg of the indigofera plants yield 1.5–2 kg raw dye, with a pure content of approx. 20%. The content is much less in woad.

11. Juglan is found in the ratio approx. 2 g/kg in fresh walnut shells. It give a brownish-yellow dye on wool, or pink if an aluminium mordant is used. It is also used for colouring in cosmetics (sun protection lotions).

12. Kermesic acid is a derivative of anthraquinone, which is obtained from the kermes insect (kermes ilicis or kermes vermilio). A dried kermes insect contains approx. 1% kermesic acid. The kermes insect lives on the kermes oak, quercus coccifera, native to the Mediterranean lands. Kermesic acid and carminic acid also occur in so-called St John’s blood, obtained from the Polish scale insect (prophyropus polonicus). The insects live on the roots of a type of carnation (scleranthus perennis), requiring the plants to be dug up, the insects collected and the plant replaced.

13. Madder dyes are hydroxyanthrachinones, obtained from the root rind of various plants of the Rubia genus, e.g. madder (rubia tinctorum). The roots contain approx. 1.9% dye, which occurs either free or in a glycoside compound.

14. Laccaic acid, consisting of at least 4 components, occurs at 0.5–0.75% in sticklac, the raw material of shellac, which is obtained from the Coccus laccae insect. It gives wool a red colour using aluminium or tin mordant.

15. Lawson is obtained from henna and is suitable for the dyeing of wool and silk, and as a hair colour. The dried leaves contain approx. 1% henna.

16. The example of archil, which is obtained from a slow-growing lichen native to southern lands, shows how excessive use and over-exploitation in the Middle Ages has led to an enduring shortage of the dye plant.

17. Phoenician purple (6,6’,-dibromic indigo) is obtained from the shell Murex brandaris, or other types, and is used to dye wool and silk. 10 000 of these molluscs would yield approx. 1.2 g pure dye. Excavations have shown where ancient dye shops would have been sited, from the quantities of broken shells found.

18. Rutin is contained in the leaves, flowers and fruits of numerous plants, e.g. types of buckwheat and Chinese yellow berries. The rutin content varies and can be as much as 27%. It give a citrus yellow colour to wool and silk with an alum mordant. It used to be used in China to dye the Mandarins’ robes.

19. Saffron is obtained from the stigmas of crocus plants and is used to dye silk as well as a food colouring. It takes 70 000–80 000 stigmas to yield 1 kg saffron, which contains approx. 10 g crocin and approx. 60 g crocetin, the actual dye. The city of Basle owes its status as a city to the saffron trade (Sewekow) (Tab. 1).

dye	name	occurs in/as	fibres	ecological/toxicological implications
red	purple	gland of the murex shell approx. 8 million shells for 1 kg dye	wool, silk	
	cochineal	cochineal insect approx. 2 million insects for 1 kg dye, 1 ha supplies 300 kg C	wool, silk, after preliminary mordant with metal salts	potential allergen, heavy metals
	kermes	kermes scale insects and other scale insects (1% in the dried insect)	the same, where necessary with preliminary mordant with metallic salts	heavy metals
	madder	outer root of the madder plant approx. 50 kg roots for 1 kg dye	wool, silk, cotton, linen after preliminary mordant with metal salts	metals
blue	indigo, woad	leaves and flowers of the indigofera or woad plants approx. 300 kg indigofera or 900 kg woad for 1 kg dye	wool, silk, cotton, linen after fermentation vat (urine, dung) and air oxidation	
yellow	saffron	stigmas of crocus plants approx. 1 million flowers for 1 kg dye	silk	
	weld	flowers and leaves of the mignonette plant	wool, silk	heavy metals
brown	redwood	as brazilin in Caesalpina species	wool, silk	heavy metals
black	logwood	heartwood of the Campeach tree	wool, silk	
	iron + tannin	gallnuts	wool, cotton, linen	

Tab. 1: Summary of some natural dyes.

	1	1 – 2	3	4 – 5	5 – 7
yellow and orange	fustic (Al) annatto saffron curcuma	yellow dyewood (Al, Sn) fustic (Sn) persian berries (Al, Sn)	weld (Al)	weld (Sn) laccainic acid (Al)	madder (Sn) laccainic acid (Sn) madder (Al) kermes (Sn)
red	archil sandalwood (Al)	redwood (Al) sandalwood (Sn)	cochineal (Al) kermes (Al)		
purple		logwood (Sn)			
blue		logwood (Al)			indigo
brown		redwood (Cu)	sandalwood (Cu, Fe)		cochineal (Cu, Fe) laccainic acid (Cu, Fe)
black		redwood (Fe)	logwood (Fe) cochineal (Fe)		

Tab. 2: Light fastness of some natural dyes (denoted in accordance with the blue scale) (according to Sewekow) with essential mordant metals.

The following dye categories are recognized:

I. Cationic dyes (barberry).

II. Direct dyes (curcuma, archil, safflower).

III. Mordant dyes (logwood, cochineal, fustic, catechu, kermes, madder, Persian berry, lacdye, quercitrin, redwood, sandalwood, weld).

IV. Vat dyes (indigo, Phoenician purple, woad).

Natural dyes only allow limited fastnesses and muted shades. The "old dyeing methods" were very well-developed, but usually extremely complicated. With the advent of synthetic dyes, their variety, consistent composition, greater purity, simpler, more reliable application and lower price, in addition to the necessary fastness, ensured their supremacy.

Naturally-occurring dyes display many disadvantages in comparison with their man-made successors; many of them have an adverse effect on the environment, either during manufacture or processing. The quality is variable and often insufficient. thus wash- and light-fastness can often be a problem (Tab. 2).

In addition there is not such a rich choice and they are unsuitable for many synthetic fabrics. They are also often substantially more expensive, and often cannot be produced in the quantities required due to insufficient natural resources (e.g. cultivation space or suitable environment).

Natural fibres Textile fibrous material of natural polymers of plant, animal and mineral origin. →: Fibres; Mineral fibres; Natural cellulosic fibres; Natural protein fibres.

Natural gas A substance obtained from the earth, consisting mainly of hydrocarbons, it is gaseous and flammable under normal pressure and temperature conditions. The composition is generally consistent within a natural gas field, but may vary from field to field. The main component of natural gas is usually methane, but may contain hydrocarbons of high molecular weight to a greater or lesser extent, capable of whole or partial separation by condensation. Natural gas is categorized as "dry" or "wet"; the latter is also known as petroleum gas. Natural gas may also contain: nitrogen, carbon dioxide, inert gases, and possibly also oxygen. It is mainly used as a source of primary energy for housing and industry, and in power stations for the generation of electricity.

Natural protein fibres Fibrous materials of animal origin belonging to the overall category of natural fibres. They are subdivided into the following groups:

I. Wools and hair: sheep's wool (→ Wool), camel wools (→: Alpaca; Llama hair; Vicuna; Guanaco), →: Camel hair; Hare and rabbit fibres; Angora rabbit hair; Goat hairs (→: Mohair; Cashmere; Cashgora; Tibetan cashmere), other hair (→: Dog hair; Human hair; Cattle hairs; Horse hair, Hog's bristles).

II. → Silks: →: Mulberry silk; Wild silks (→: Anaphe silk; Eri silk; Fagara silk; Muga silk; Tussah silk; Yamamai silk), other silks (→: Mussel silk; Spider silk).

Natural resins → Resins.

Natural rubber (polyisoprene). Typical properties: Shore hardness range 30–90 A, excellent fabric bonding strength and abrasion resistance, moderate to good resistance to acids, poor resistance to solvents (aliphatic, aromatic hydrocarbons), good against oxidation (ozone = poor), poor against the effects of sunlight and flammability.

Natural Sharling The designation for a fine, resistant but soft wool fibre obtained from a type of Merino sheep reared in Australia. The animals are kept in individual enclosures and receive a controlled daily amount of food. The fibres are particularly uniform. The fibre yield is 72%, compared with 65% from animals put out to pasture. The fibre is similar in appearance and handle to cashmere, although it has a different structure.

Natural silk → Silk.

Natural surfactants → Natural tensides.

Natural tensides Surfactants are necessary in nature (e.g. milk emulsifiers). Vegetable glycosides (sa-

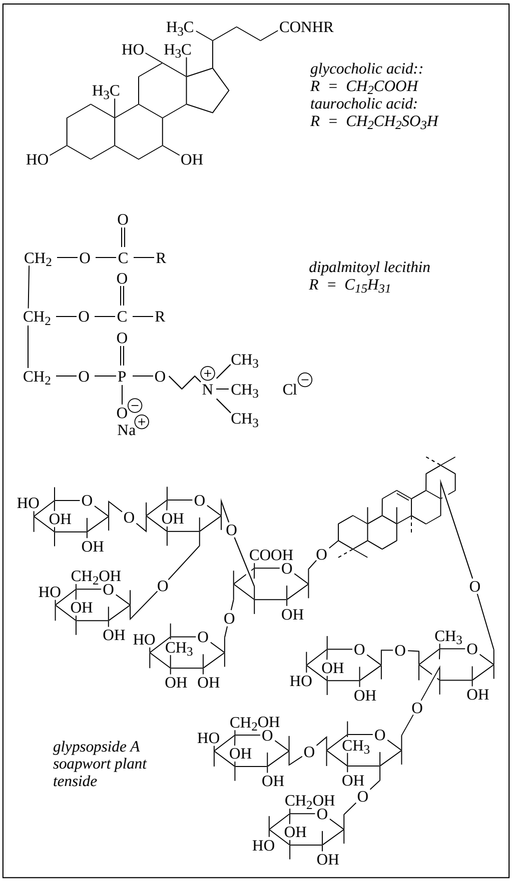


Fig.: Molecular structure of natural tensides.

ponines) occur in soapwort (Fuller's earth) and panama soap; they were formerly used for washing and cleaning because of their surface active, foam forming properties. Natural surfactants often have such a complicated molecular structure, in that hydrophilic and hydrophobic components are not obvious at first glance (Fig.).

Natural textiles Primarily a marketing term, but of genuine technical significance due to systematic awareness of ecological issues. Ecologically aware textile production seeks to label textiles which have been produced with minimum adverse impact on the environment. Thus natural textiles are defined as follows:

- Natural textiles: garments made from pure, untreated natural fibres, or those which have been dyed but without chemical treatment.
- Natural fibres: fibres of animal or plant origin (wool, silk, natural cellulose fibres, not mineral fibres or regenerated cellulose), preferably cultivated without the use of pesticides.
- Untreated natural fibres: neither resin finished nor chemically treated (from antifelt to silk weighting).
- Natural fibres without finish: unbleached, plant dyed, unadulterated fibre surfaces for skin contact, without the influence of chemicals, resin coating or toxic substances, on the properties of the natural fibre. Lubricants (paraffin lubricants) and sizes (modified potato starch) must be capable of washing out.
- Guaranteed free from residues: analytical inspections of each new yarn batch for raw material residues (pesticides, herbicides, formaldehyde etc.) by independent bodies.

Framework conditions:

- Obligation to declare: Textile labelling acts, declaration of any deviation.
- Quality development: influences on the production of raw materials such as good animal handling practices, ecological plant cultivation.
- Marketing methods: ecologically aware marketing and distribution (outlets dealing in natural fabrics and textiles).

Natural wax → Wax.

Nb, Cb The chemical symbol for niobium (41), also known as columbium (Cb).

NBS,

I. National Bureau of Standards, Washington, an American textile research body; → Technical and professional organizations.

II. New British Standards.

NBS Unit → Colour difference formulae.

NCH Standard abbrev. for non-carbonate hardness, permanent hardness.

Nd Chemical symbol for neodymium (60).

NE Dutch patent.

Ne,

I. Chemical symbol for neon (10).

II. English yarn count, → Linear density of fibres and yarns.

Neale process The use of sodium hydrosulphite in combination with sodium boron hydride in vat dyeing.

Near infrared reflection measurement (NIR). In contrast to the usual procedures involving analysis of wavelengths, in near infrared reflection measurement a continual optical spectrum is evaluated using statistical chemometric procedures, as even in the near infrared area the absorption of all relevant components overlaps to such a great extent that only by registering the whole spectral range can a clear statement be made on the components to be determined.

The PLS method is a statistical method based on Principal Component Regression (PCR) factor analysis, which is particularly suited to quantitative evaluation of the NIR spectra with heavily overlapping absorption bands. The bands are based on the molecular vibrations of the chemical components and can be identified as absorption bands in the infrared spectrum. The

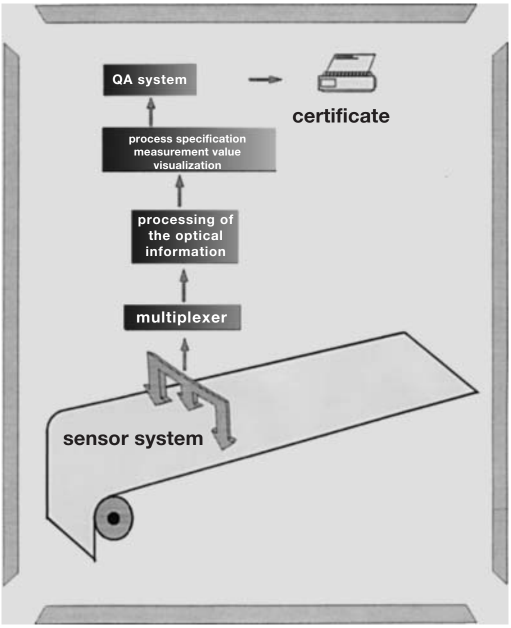


Fig. 1: Functional elements of near infrared reflection measurement (according to Schumacher-Hamedat) using a Qualimat 100i/3000i.

measuring process is based on the recording of a reflection spectrum in the near infrared range; this carries the relevant information for each process chemical. The basic principles of measurement value recording are shown in Fig. 1. The moving fabric lengths are exposed to radiation by special fibre optic bundles and the reflected radiation conducted to a spectrometer, where the optical information is split into its spectral components. An optical multiplexer means measurements can be taken at several points across the width of the cloth. It connects the optical fibres in sequence to the spectrometer.

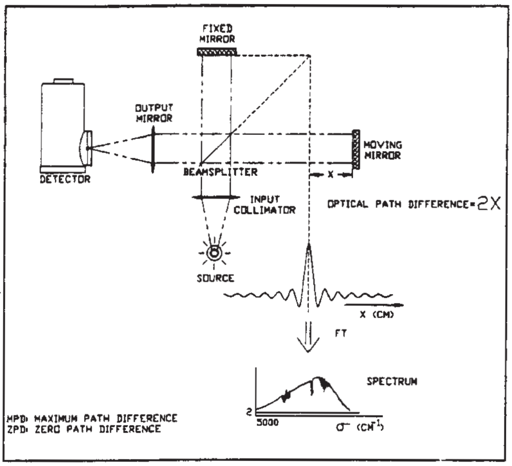


Fig. 2: Diagram showing the principles of a classic interferometer (according to Schumacher-Hamedat).

Possible spectrometers available include wishbone interferometer or grid monochromators. Unlike various other instruments, in the interferometer the optical frequencies are not separated.

The Fourier transformer-interferometer (Fig. 2) creates an interference effect by separating the primary radiation into two equal parts; a path difference between the two parts across a moving mirror with associated superposition produces in conjunction with the path difference what is called the “Interferogram”, which uses a mathematical algorithm, the Fourier transformation, to determine the spectral wavelength variation.

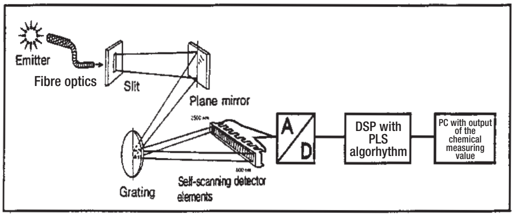


Fig. 3: Diagram showing the structure of a grating monochromator with detector elements (according to Schumacher-Hamedat).

The structural principle of a grid spectrometer with simultaneous array detection for the processing of optical signals is shown simplified in Fig. 3. The light captured by the fibre optic bundle is split into its spectral components (array) and transformed into electrical signals by a multi-channel detector.

Necked lamellar straight edge For napping the pile of fabrics with loose, slack and/or thickened selvedges, without these edges being cut by the blade (Figs. 1 and 2).

The straight edge is divided left and right for a length of 30 cm into 1 mm thick lamellae. At the point at which the fabric edges run over the shearing table, the lamella are automatically lowered. This gives rise to a greater distance between the lower blade and the surface of the fabric. It is not necessary to monitor the fabric edges or the shearing table. Loose, folded or thickened selvedges can slide beneath the blade without coming into contact with it. The lowering of the lamellae is controlled by two pneumatic fabric edge sensors placed immediately below the shearing table. The advantages over alternative systems include:

- the length of cloth does not have to be positioned precisely, and thus processing is safe even at high speeds;

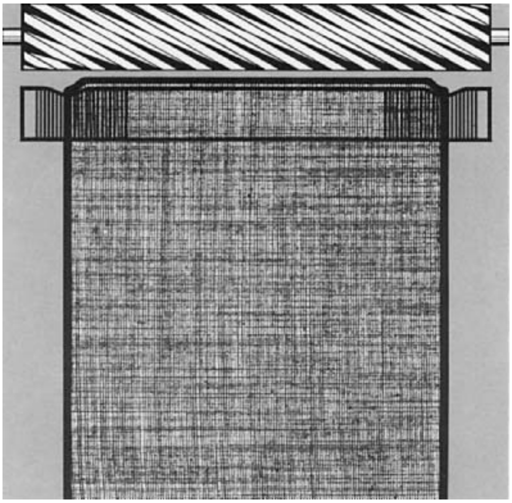


Fig. 1: Diagram of a necked lamellar straight edge.

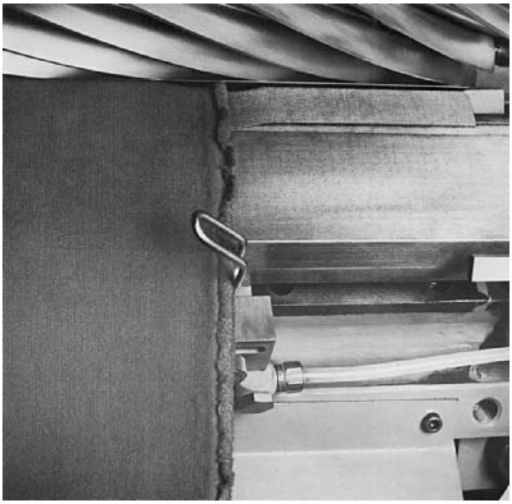


Fig. 2: Peerless selvedge automatism (Vollenweider) forming a necked lamellar straight edge for cutting machines.

- the length of cloth always runs centrally through the machine. It is not necessary to move it over to one side in order to keep the edge away from the cutting range of the blades;
- there is no need for the edges of two cloths of different widths to be sewn together precisely;
- the shearing table edge is not displaced to the side, therefore problems are less likely; particularly safe operation even at high speeds;
- the desired selvedge width which is not to be cropped, is adjustable.

Necking effect → Telescope effect.

Nederlandse Textielinstituut successor organization to the NVTC, member of the → IFVTCC. → Technical and professional organizations.

Needle bonding Fixing process for →: Tufted textiles; Needle punched nonwoven fabric, e.g. an alternate insertion and withdrawal of a number of needles in nonwoven fleeces, or similar in the case of napped needlefelt fabrics and batt-on-base woven felts.

Needlefelt fixing Following needling of folded fleece fabrics, which may be regarded as preliminary fixing, the fleece, in three-dimensional form as far as possible, must be fixed with binders. Fine fleeces (Fig. 1) are impregnated with foam, or by spraying the binder dispersion. Another form of fixing is bath impregnation with subsequent coagulation (Fig. 2). Less three-dimensional, i.e. smoother, needlefelt fabrics can also be fixed thermally (on calenders or by thermofixation).

Needle gauge The distance between the centres of two adjacent needles on knitting, needling tufting machines and similar. The number of needles in relation to a specific length (e.g. 10 cm) determines the gauge of the machine.

Needle pluck test A modified burning test for the detection of synthetic fibres spun from the melt (polyamide, polyester) which during the burning test can be drawn out by a needle to form a fine thread following melting, by a heated iron. The needle draw test does not work specifically with polyacrylonitrile, acetate and triacetate.

Needle punched carpets Textile floor coverings produced by the needling of bonded fibre fleeces (→

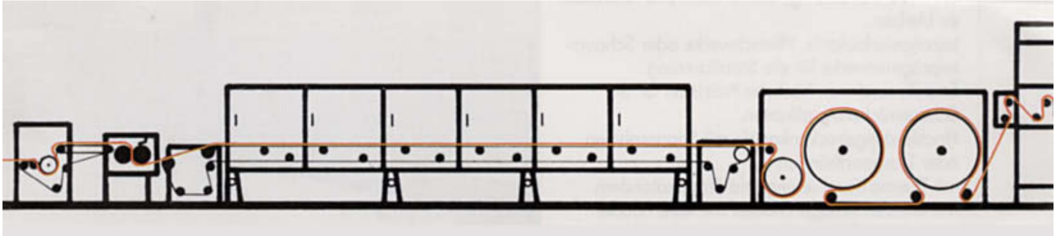


Fig. 1: Foam impregnation plant for needlefelt fixation of fine fleeces (Mohr).

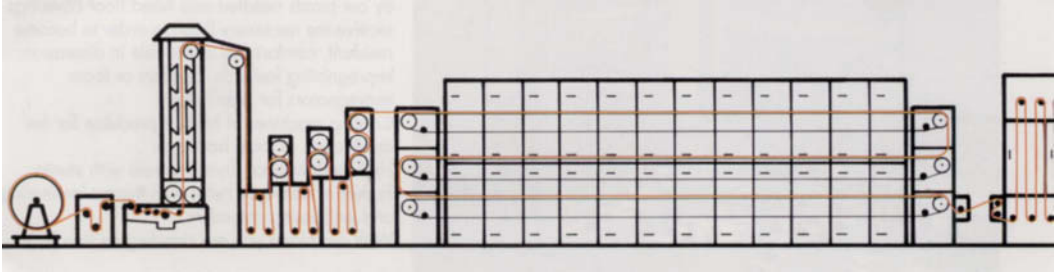


Fig. 2: Impregnation and coagulation plant for needlefelt fixation (Mohr).

Needle punched felt). May be composed of several different layers (top layer, lining, backing layer). The mechanical needle punching of the nonwoven fabric is known as pre-fixing. In post-fixing, binding agents are used. Nonwoven fabrics with a thermoplastic fibre content are fixed using heat treatment. The fixing needles penetrate the nonwoven fabric either vertically or at a slight angle. Special needles can be used to achieve special effects on the needle punched surface. In contrast to most other types of carpet the fibres are mainly horizontal. The backing is either embedded in the layers of the nonwoven fabric or forms the bottom layer for the needle punched felt. If embedded it is generally between one of the top layers and one of the lower layers, made from a combination of waste fibres. If the nonwoven fabric layers are to be needle punched onto the backing, a lining of cheaper material (e.g. nonwoven fabric made from waste fibres) can be inserted between the top layer and the backing, or stronger nonwoven fabrics or several nonwoven fabric layers of the same quality as the top layer can be bound together with the backing.

The top layer of needle punched felts mainly comprise different synthetic fibres, predominantly polyamide (sometimes up to 100%), which is particularly suitable due to its high wear resistance. In contrast to polyester, polyacrylonitrile and polyolefin fibres, polyamide fibres have a water retention value (10–12%), making floor coverings made from these fibres subject to stretching or shrinkage depending on the ambient humidity, which can lead to problems with regard to dimensional stability, particularly in the case of nonwoven fabrics. This problem can only be countered by full bonding. The biggest advantages of polyester and polyacrylonitrile fibres are their low moisture absorption rate (0.5–0.8 or 1.0–2.0%). Whilst they have been extensively used for tufting and weaving, they have to date, only rarely been used for the manufacture of needle punched felts, not least because of the dyeing costs. The polyolefins (especially polypropylene) are more widely used, either 100% or as a mixture with polyamide fibres for the top layer. Polyolefins absorb practically no moisture and have a water retention value of practically zero, which gives products made from these fibres an excellent stability regardless of ambient moisture conditions. The titre of the fibres usually lies between 17–20 dtex given a staple length between 40–100 mm. Hard-wearing needle punched felts may also be made from very coarse synthetics (up to 80 dtex). The lining and base layers are often composed of synthetic fibres, generally making use of waste fibres which can be obtained cheaply on the fibres market. Different processes variously make use of regenerated cellulose fibres and reclaimed wool. The backing used to be made from woven or nonwoven jute fabrics. For some time now increasing use has been made of woven or nonwoven polypropylene fabrics. Glass fibre backings are also used successfully for continuous and bonded fibre carpeting.

The nonwoven fabric may be produced either mechanically or by a pneumatic production plant. In the case of needle punched felts the proportion of pneumatically-produced goods is, for various reasons, very low, although they do have some advantages over nonwovens produced by carding. Thus, for example, there are no problems of substantial differences between longitudinal and transverse stability, as the fibres are applied by a flow of air and are thus laid down at random. On the contrary, in the case of a carded web the fibres are largely longitudinally arranged due to the carding process, resulting in a fabric which is substantially stronger in a transverse direction than in a longitudinal direction. This relationship can be enhanced even further by random carding. Special felting needles on the needling machine pass through specially-arranged holes or slits in the stripper plate into the base plate. The material to be needle punched passes between the stripper plate and base plate. The base plate takes the force and protects the material as the needle passes through, and the opposite forces as the needle is withdrawn are transferred to the stripper plate. The penetration depth of the felting needles is adjusted by raising or lowering the base plate. The fibres of the nonwoven material are captured by barbs on the felting needles and drawn through to the back of the fabric. A proportion of the fibres are thus reoriented from a horizontal to a vertical layer.

Standard needle punched carpets have a more or less open surface. Various attempts have therefore been made to improve the appearance of needle punched felts. This can be achieved by patterning using a further development of the needling technique. In order to achieve this pattern specially equipped needling machines are used in conjunction with specific types of needle. Loop, fork or side-hook needles are used to create looped, ribbed and velour surfaces. Needle-felt carpets are fixed mechanically and adhesively. It is the type of fixing which largely determines the use for which the floor covering is suited. The fibre bonding is generally achieved by means of polymeric dispersions based on polyacrylates or butadiene/styrol copolymers. In recent years carboxylized styrol-butadiene lattices (SBR lattices) have taken over in the market from the originally exclusively used polyacrylates. A further development of the SBR lattices is providing needle punched felt producers with products for finishing carpets which satisfy the most demanding requirements and are also sufficiently fade-resistant for most purposes.

Needle punched felt A nonwoven fabric, produced by needle punching transversely or diagonally → Bonded fibre fleeces with a backing layer or base fabric (Fig. 1). Needle punched felts are not considered → Felt in the usual sense, which represent textile fabrics whose composition and strength originate in the natural felting properties of wool and certain other animal hairs; rather they are fleeces compacted on needling machines and fixed with binding agents. They are made in a dry process by means of fleece carding. Fixing then carried out mechanically by means of alternating insertion and withdrawal of a number of suitable needles (Fig. 2) and then using an adhesive binding agent or a thermal process. Used for textile yarded or plate form goods as an underlay felt, padding felt, needle-felt carpet, etc.

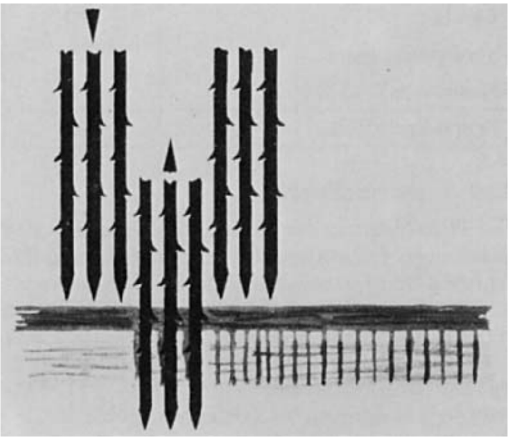


Fig. 2: Diagram showing the needle punching of fleece.

Needle punched nonwoven fabric → Bonded fabrics of the → Needle punched felt type and needle punched wadding. Fixed by needling with or without shrinkage or needling with thermoplastic bonding.

Needle roller bearing Miniature version of a roller bearing for the smallest rotating machine parts.

Negative process In contrast to other processes for the manufacture of screens for screen printing, the pattern section is projected onto the gauze in negative form. All those parts of the design which are to remain blank when applying the lacquer layer are fixed into the gauze in the form of exposed gelatine. Finally a specially selected lacquer is drawn over the gauze with an applicator. The lacquer penetrates all areas of the gauze; only the parts covered with the gelatine resist – the lacquer stays on the gelatine. Once the lacquer has dried the screen is immersed in water at 70°C and after a certain steeping time the lacquer layer on the gelatine can be removed. The same process is carried out for the back of the screen. Any residual gelatine is removed once the last of the lacquer has been cleared using an alkaline bath containing sodium carbonate or caustic soda, followed by thorough rinsing.

Neo-batiks A technically improved development of → Batik. Patterns in molten wax are applied to well-stretched textiles (usually natural silk), and aqueous or alcohol-based dye solutions applied with a cotton wool pad. It is then dried and the wax removed by dissolving in organic solvents, or by ironing between sheets of blotting paper. Then the fabric is steamed to fix the dye. In this way, combinations of wax resistance and different colour schemes can be used to produce unlimited effects.

Nephelometer → Turbidity meter.

Nernst's distribution law It is the case with all dissolved substances that the chemical potential in equilibrium must be equal in both solvents:

$$\mu_1 = \mu_1^* + RT \ln C_1 = \mu_2 = \mu_2^* + RT \cdot \ln C_2$$

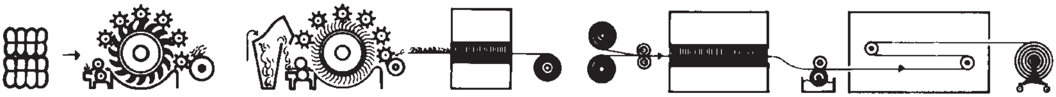


Fig. 1: Production of needle punched felt.

$$\ln \frac{C_1}{C_2} = \frac{\mu_2^* - \mu_1^*}{RT} = \text{const.}$$

and $$\frac{C_1}{C_2} = K$$ (Nernst's distribution law).

K = distribution coefficient,
C_1 = dye concentration in the fibre,
C_2 = dye concentration in the liquor,
μ^* = standard potential,
μ_1 = chemical potential solvent 1,
μ_2 = chemical potential solvent 2,
R = gas constant,
T = temperature.

Nessler's reagent For the detection of ammonia (in water) and for the detection of damaged cellulose (yellow to orange, later grey colouring).

NET (standard pressure increased temperature bleaching process). In contrast to HT bleaching this peroxide bleaching process does not require a pressure chamber steamer. The process is carried out using superheated steam without increased pressure, e.g. in a slightly modified Mather & Platt steamer (N = normal pressure, ET = elevated temperature).

Net curtain fabrics Fine, usually transparent fabrics made from suitable yarns. They must be washable and resistant to stretching and ironing; those made from synthetic yarns generally do not require stretching or ironing after washing. There are various different manufacturing methods for net curtain fabrics: looms (fine muslin, voile, etamine, marquisette, Madras), bobbinet machines, a form of bobbin lace machine (bobbinet, tulle and lace curtains), raschel knitting or crocheting machines (raschel or galloon curtains), knotted lacework machines or by hand (lace curtains), and embroidery machines (dotted muslin, burnt-out or air lace).

Net curtain finishing The finishing of these fabrics varies between extreme types. Net curtain fabrics are made, for example, on looms (voile, marquisette, etamine) or on special machines (tulle or raschel types). The former types are usually finished by separate finishing contractors, the tulles, however, by the manufacturers. Few specialist finishers have access to stenter frames up to 10 m in width and 100 m in length as is required for tulle finishing. Cotton has been widely replaced as a net curtain fabric by polyester or polyacrylonitrile. Polyamide is not sufficiently light-fast for this purpose. Raschel-type net curtains are made in widths up to 450 cm and in this width can be continuously washed, optically brightened or dyed in pastel tones with pigment dyes and fixed and finished on stenter frames. In the latter case, dyeing and finishing can be carried out in a single process. For heavily soiled grey goods or for the dyeing of fuller shades, beam dyeing equipment is used. The main finish to be applied is a dirt-repellent finish. Instead of flame-retardant finishes, flame-retardant fibres are used, e.g. Trevira CS (Hoechst), which also have the advantage of being easier to dye. The tulles, up to 10 m in width, are pre-cleaned, optically brightened or dyed using a deep winch beck. Fixing is carried out by saturated steam in autoclaves. The tulle is unwound to lie smoothly on a perforated cylinder. If the fabric is heavily soiled or needs to be bleached, it can be loaded into the circulation apparatus pack cylinder. Fuller shades can only be applied to polyester under HT conditions using beam dyeing apparatus. Finishes can only be applied to wide fabrics in hank form. The fabric is lightly squeezed, spun and stretched on the frame. For the finishing of cotton net curtain fabrics the usual cotton fabric finishing machinery is used.

Net textile weight A term in the German → Textile Labelling Regulations (TKG – Textilkennzeichnungsgesetz) for the overall weight of the textile raw materials used in the manufacture of a textile product, as the starting value for the weight proportions in percentages, where textile products made from different fibres are classified in decreasing sequence according to their proportional weight. Certain exclusions are made (cf. wording of Textile Labelling Regulations § 6, Sect. 1), e.g. components which are not part of the textile product, such as stiffeners, reinforcements, inserts and fillings, selvedges, facings, ornamentation, binder warp/weft for blankets, floor coverings, soft furnishing fabrics, the base layers of velvets, plush fabrics etc., and finishing agents (fatty compounds, binding agents, filling finishes) and similar.

Nets Generally wide-meshed fabrics which are produced by weaving, knitting, crocheting or on raschel looms.

Nettle fibres Bast fibres (stem fibres) obtained from the native stinging nettle or the Chinese nettle (→ Ramie); fine, strong, rough fibres.

Networking of CAD systems → Integration of CAD systems.

Network materials Due to their particular ductility, textile → Nets are well-suited to three-dimensional, structured materials, for example, impregnated with resin. After deep-drawing they are stabilized by curing (see Fig.: Three-dimensional, structured textile net fabric). Another production method involves the processing of fibres with different shrinkage rates.

Neutral affinity In connection with the dyeing of wool/polyamide blends, certain acid dyes possess a good neutral affinity, and are drawn into both fibres to a certain depth of colour from a neutral dye liquor, without the addition of acids or salts.

Neutral-exchanger → Ion exchanger.

Neutral exhaustion number As a term for neutral pick-up metal complex dyes, the expression is de-

Fig.: Three-dimensional, structured textile net fabric.

rived for what percentage is taken up of a dyebath developed to standard depth 1, at pH 7 and 90°C in 15 min on wool of a certain quality. The neutral exhaustion number characterizes very simply and precisely the homogenity in dyeing behaviour (→ Neutral affinity). (A better basis of evaluation is the ease of combination).

Neutral fats, neutral oils Fats in which all 3 OH groups of glycerine are always esterified with fatty acid esters, such as in liquid fats (olive oil and groundnut oil), which represent neutral oils.

Neutral(ization) A mutual saturation of acid and base until neutral reaction pH = 7 (equilibrium of H and OH ion concentrations). The result is a neutral salt. It is not substantially the latter, however, but in particular the H and OH ion combination “to water”, e.g.:

hydrochloric acid + caustic soda = sodium chloride + water

$$\mathrm{HCl} + \mathrm{NaOH} \rightarrow \mathrm{H}^+ + \mathrm{Cl}^- + \mathrm{Na}^+ + \mathrm{OH}^- = \mathrm{Na}^+ + \mathrm{Cl}^- + \mathrm{H_2O}$$

Neutralization of waste waters In textile finishing waste water is generated by a wide range of different process stages. Dyeing, printing and finishing cause different types of contamination of inorganic or organic origin. The degradation of organic substances can generally take place in biological treatment plant. In many cases the problem of waste water treatment in textiles can be solved by the factory neutralizing its own waste water and then discharging it into the public sewage system (see Fig.).

The Fig. shows a plan of a waste water neutralization plant. This example can be used to explain various problems and solutions which arise. The inflow (1) of waste water from various points during the works network passes first through a filtration plant (2) and then a grease trap. The pumping station (3) pumps the waste water into an equalizing and blending reservoir (4). Often, works generate acid and alkaline waste water at the same time or successively. In this case the tank not only has the function of an equalizing reservoir but this is also where the required self-neutralization of the water takes place. Depending on the local conditions, the water authority determines the permitted pH value for the water to be discharged into the public drainage network. In practically every case a pH adjustment is necessary to achieve this. This is the purpose of the reaction vessel (5) with agitator (6). For example, if the waste water pH value permitted by the local water authority lies within a range of pH 6–9, then in order to economize on acids and alkaline solutions this area will be fully utilized. The automation components are also

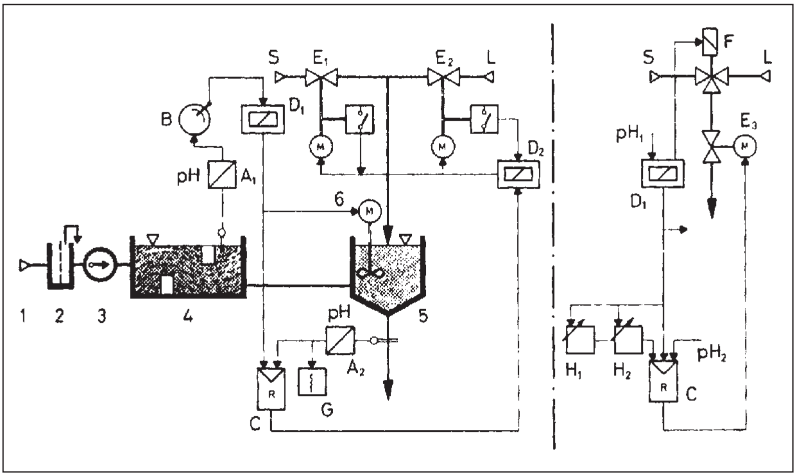


Fig.: Diagram showing a waste water neutralization system
1 = waste water feed;
2 = filtration plant/grease trap; 3 = pumping station;
4 = equalizing and blending reservoir; 5 = reaction vessel; 6 = agitator; A = pH value sensor; B = limit value warning; C = electrical control; D = auxiliary relay;
E = adjustment valve;
F = three-way magnetic valve; G = recorder;
H = target value adjuster;
L = caustic solution feed;
S = acid feed.

shown in the figure. In the equalization reservoir the pH is measured and the limiting value warning actuates auxiliary relay D_1 if the measured value is outside the permitted range. The agitator and controlller (C) are started by D_1. The control device works with a target value of pH 7 for the reaction vessel, for which the second pH value sensor is necessary. Additional substances for this controlled circuit are alkaline solutions or acids, which are added to the reaction vessel by control valves E_1 or E_2. These control valves are interlocked in such a way that only acid or alkaline solution may be metered (D_2). Once the pH tolerance range in the equalization reservoir is reached, the limit value warning (B) switches the control circuit off, both control valves are closed, and the agitator is switched off. The pH value is recorded by the recorder (G) for the purposes of plant monitoring and for the water authorities. The control circuit is therefore only operative if the pH exceeds or falls below the tolerance range. It controls the pH to a value of 7; the expected deviations from the target value do not, however, cover the full tolerance range. This automatic system can be improved even further, as shown in the right-hand section of the diagram: if, for example, the pH falls below pH 6, then the relay switch D_1 starts the control circuit and switches the control unit C to a target value of pH = 6. At the same time, the three-way magnetic valve F is actuated, so that only alkaline solution can be added to the reaction vessel through control valve E_3. By setting two target values, pH 6 or 9, it is possible to ensure that the permitted tolerance is fully utilized in the reaction vessel even during the control process. This concept also involves switching off the control circuit, as previously described, depending on the pH value of the equalizing reservoir, in connection with the closing of control valve E_3.

Neutralizing → Ion-exchange process.

Neutral milling → Milling.

Neutral point (→ Isoelectric point),

wool:	pH 4.9
silk:	pH 5.1
collagen:	pH 7.0

Neutral reaction Neither acidic nor alkaline, corresponds to pH = 7.

Neutral rinsing agent (neutral rinse), a neutralizing after treatment agent for washed items in the last rinsing bath.

Neutral steam process Neutral steam development for stabilized blends of naphthols and diazoamino compounds.

Neutrons → Atomic theory.

New tin A term (in the weighting of silk) for aluminium sulphate.

Newton In the → SI System of Units, the derived unit for force which imparts an acceleration of 1 m/s^2 to a body of mass 1 kg. 1 N = 1 kg · m/s^2.

Newtonian liquids The flow resistance defined by the Newtonian equation of proportionality between shear stress τ and shear rate (D)

$$\tau = \eta \cdot D \ (\eta = \text{const.})$$

is at a given temperature a material constant (Newtonian Flow) known as → Viscosity. For example: liquids of low molecular weight, thinned suspensions of spherical particles etc. Something approximating to Newtonian liquid properties are shown among thickeners, e.g. gum arabic. Newtonian behaviour is a rarity among solutions of high polymers, as most of these solutions are non-NF (non-Newtonian Flow, “apparent viscosity”, “intrinsic viscosity”) at higher concentrations; they do not fall within Newton’s Law. Here, η is not a material constant. Such liquids include, for example, colloidal solutions and suspensions at higher concentrations.

Newton’s Law of Viscosity → Rheological behaviour of solutions.

New Zealand flax or hemp (phormium fibre) → Hard fibres from various lily-type plants, most significantly Phormium tenax (New Zealand, Australia, South Africa, South America). Less valued when water retted. White, yellowish, brownish. Bast bundle 1–1.5 m long, fineness similar to flax. Bast cells 5–15 mm long, 8 – 19 µm wide. Strength 20–40 cN/tex. Applications: (often with manila or sisal hemp) binding twine, ropes, also for clothing, blankets, carpets and for the manufacture of core spun yarns with polyester/cotton.

NF,

I. → New Zealand flax or hemp (Phormium), → Textile fibre symbols, in accordance with DIN 60 001 T4/ 08.91.

II. → Non-ferrous metals.

III. French standard.

nf “Normal strength”, as opposed to hf “high strength”, additional designations for chemical fibres, which are significant when giving technical values.

Nf-metal → Non-ferrous metals.

NI Indonesian standard.

Ni Chemical symbol for nickel (28).

ni Abbrev. for → Non-ionic.

Nickel (Ni), atomic weight 58.7, silver-like → Metals; very ductile (can be hammered, rolled, welded); high strength; magnetic. Density 8.8; melting point 1452°C. Resistant to air, and to aqueous alkalis and acids. Easily soluble in nitric acid, more slowly in hydrochloric or sulphuric acid. Applications: as a metal, essential corrosion protection component in important steel alloys for equipment, machinery, linings, tanks, etc. Nickel salts as dye mordants, for analytical purposes, etc.

Nickel ammonium hydroxide Similar to → Cuprammonium hydroxide, but containing nickel sulphate instead of copper sulphate. Application: for dissolving or (quantitative) detection of pure silk among other fibres; wild silk and tussah silk remain undissolved.

Nickel screens are made for rotary printing using the discharge or rotary screen processes. Nickel screens cannot be recycled, i.e. cannot be re-used for other patterns. → Rotary screens for screen printing.

Night vision One of three components involved in the seeing process, in addition to the nerves and the brain, is the human eye. By multiplication of the spectral energy distribution of the light source with the spectral directional reflectance of the object being observed it can be calculated how much light of each wavelength is reflected and thus reaches the eye. If it is also known how the human eye reacts to light of different wavelengths, a statement can then be made on the perceived colour.

The light entering the eye through the pupil is bundled by the lens and generates on the retina an image of the object observed. The retina contains a large number of light-sensitive photoreceptor cells, called rods and cones. The conversion of the incoming light rays into nerve excitations is done by breaking down dyestuffs in the photoreceptor cells. All of the approx. 120 million rods have the same spectral sensitivity, which is many times higher than that of the approx. 7 million cones. It is therefore the rods which are responsible for night vision, i.e. for the perception of light/dark in low light conditions. In the case of higher light radiation, e.g. normal daylight, they are inactive and therefore of subsidiary colormetric significance. Because all rods have the same spectral sensitivity, → Colour vision is not possible. When the eye is adapted to bright light, e.g. in daylight, the less sensitive cones are responsible for transferring the visual impressions to the brain. There are three types of cone with a relatively broad but varied spectral sensitivity.

Nigraniline → Aniline black.

Nikki-plush → Circular-knit pile fabric (sheared plush). The grey cloth undergoes shearing during finishing, whereby the loops are cut to give a velvety look. The fabric has the elasticity of jersey. Used for outer clothing; also printed. → Circular-knit pile fabric finishing.

Ninhydrin reaction Triketohydrins, white crystals, soluble in boiling water. Only react with protein components and amino acids of low molecular weight. Identification:

I. Protein in a substance: dissolve as much of the substance as possible in a 10% caustic soda solution, boil for 10 min and adjust to pH 6–7 with acetic acid. Boil a few ml with 10–12 drops of a 1% ninhydrin solution for 1–2 min. Blue-purple colour after standing = protein.

II. Protein on the fibre: boil fibre in 1% caustic soda for 15 min, adjust to pH 6–7 with acetic acid and proceed as under I.

III. Triazone, primary amines and amino acids (e.g. in acid extracts of synthetic resin finishes): drop a few drops of solution onto filter paper, dry at moderate temperature, spray on both sides with ninhydrin solution (0.2 g ninhydrin in 120 ml n-butanol and 5 ml 10% acetic acid) and dry for 2 mins at 100°C. Triazone and primary amines (pale lilac), oxyalkylamine (reddish to violet-grey).

Niobium (Nb; columbium, Cb), atomic weight 92.91. Uses since World War II, includes use in German stainless steels as minor addition to stabilise the carbon content (known as carbide former), especially for equipment with working temperatures > 450°C.

NIOSH Abbrev. for National Institute for Occupational Safety and Health; → Technical and professional organizations.

Nip,

I. Passage of material (full-width piece goods) between two rollers, in pad dyeing, calendering and similar. The roller nip is the contact line between the two rollers which concentrates the pressure of the two rollers.

II. The gap between two nip rollers (Fig. 1). There are two types, hard nip rollers, as found in calenders (steel and flexible rollers) and elastic nips between two elastic rollers. An examination of nip formations (Fig. 2) shows a distinction between two limit cases of the elementary functions when padding:

1. Sufficient wetting in the chassis actually dispenses with the need for liquor to pass through the fabric in the nip, as the main role of the nipping process is the metering of the liquor in the goods.
2. If there is insufficient wetting the passage of liquor through the goods in the nip not only has the effect of metering the liquor, but also drives out the air (subsequent wetting).

The liquor pick-up (nip effect) in the nip is shown in the diagram (Fig. 3). The following basic functions are possible:

- compression of the textile goods in the gap between the rollers,

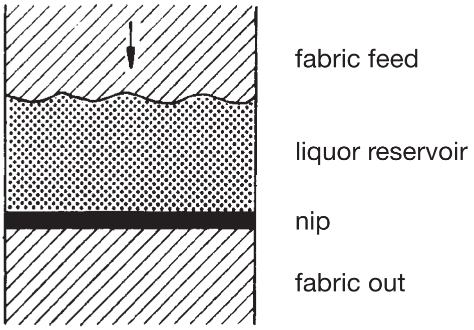


Fig. 1: Padding: nip structure.

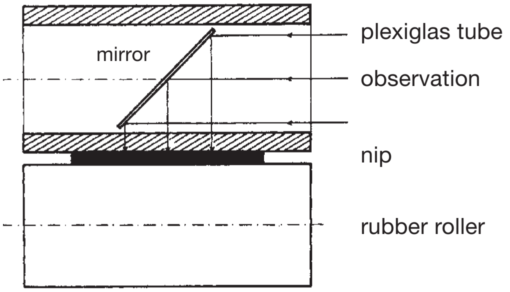


Fig. 2: Observation of the nip structure (according to Schollmeyer).

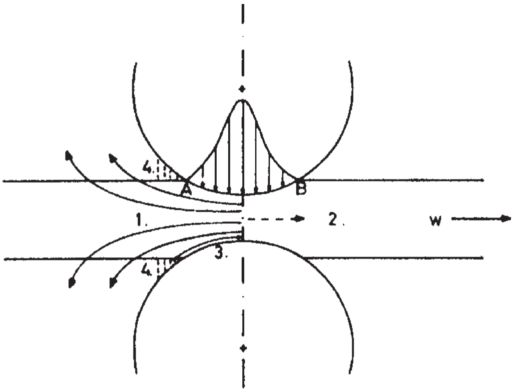


Fig. 3: Diagram showing the squeezing process in the nip. 1 = return flow of liquor; 2 = capillary transportation; 3 = return of liquor to be applied; 4 = liquor wrung out.

- return flow of liquor through the goods,
- capillary transfer in the direction of goods, velocity w,
- liquor adhesion return flow to the rollers,
- return flow of liquor squeezed out, etc.

During the transfer of the reaction mix after the nip, the basic functions take effect; these also play a part when dipping a roller:

- penetration of the fibre material by the water,
- penetration of the fibre material by the dye or the finish,
- evaporation of the water.

(according to Heidemann and Schollmeyer).

Nipco rollers Deflection-free (elastomer) rollers with hydraulic power transmission (see Fig.). Pressure generation with even pressure on outer mantle by means of individual hydraulic supports; load can be applied externally in groups, every 2000 mm, e.g. 5 zones. The Nipco calor roller can be precisely heated from the inside. Used for pads, calenders and other squeezing equipment.

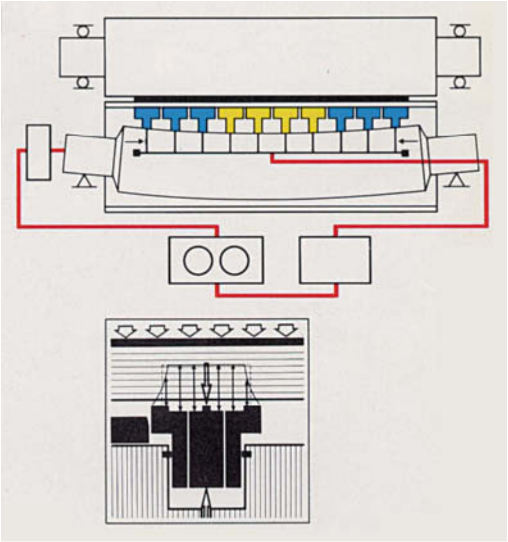


Fig.: Nipco roller system for the control of an individual preasure stamp (Kleinewefers KTM).

Nip padding A particular type of padding (see Fig., Krantz). With the two-roller pad the lower roller is wrapped with cloth and dips into the padding liquor; the fabric is passed between both rollers. Used especially in resist printing, as the short contact with the liquor prevents the resist from softening.

Nip pressure profile With the aid of, e.g. carbon paper, impressions can be obtained of the evenness of the squeezing pressure across the full width of the nip (see Fig., Kleinewefers KTM).

NIRC National Institute of Rug and Cleaning; until 1972 the American institute for carpet cleaning. Successor is → AIDS International. → Technical and professional organizations.

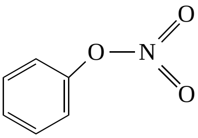
Nitrate discharges → Oxidation discharges for indigo ground.

Nitrate rayon → Nitro rayon.

Nitrates Contain the typical nitrate group $-NO_3$ or $-ONO_2$.

I. Inorganic salts of nitric acid of type $NaNO_3$; usually colourless (exceptions: iron, cobalt, copper and nickel nitrates, etc.); water soluble application as dye mordants.

II. Organic ester of nitric acid of type



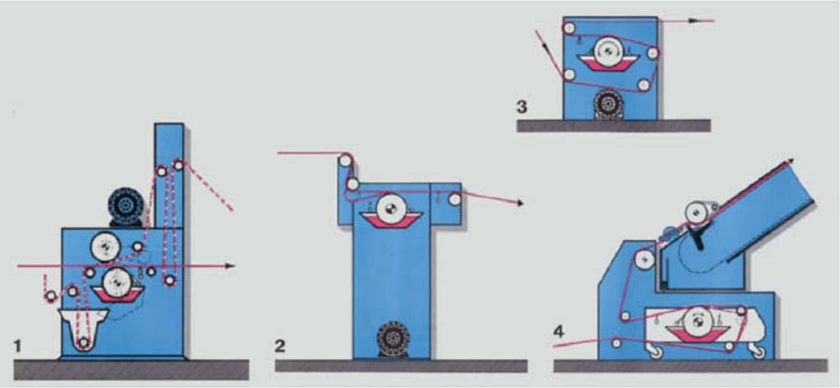


Fig.: Nip padding systems by Krantz. 1 = combined with two-bowl padding mangle; 2 = for the back of the fabric; 3 = for application on the top side of the fabric; 4 = in the fabric feed section of a tiered stenter frame.

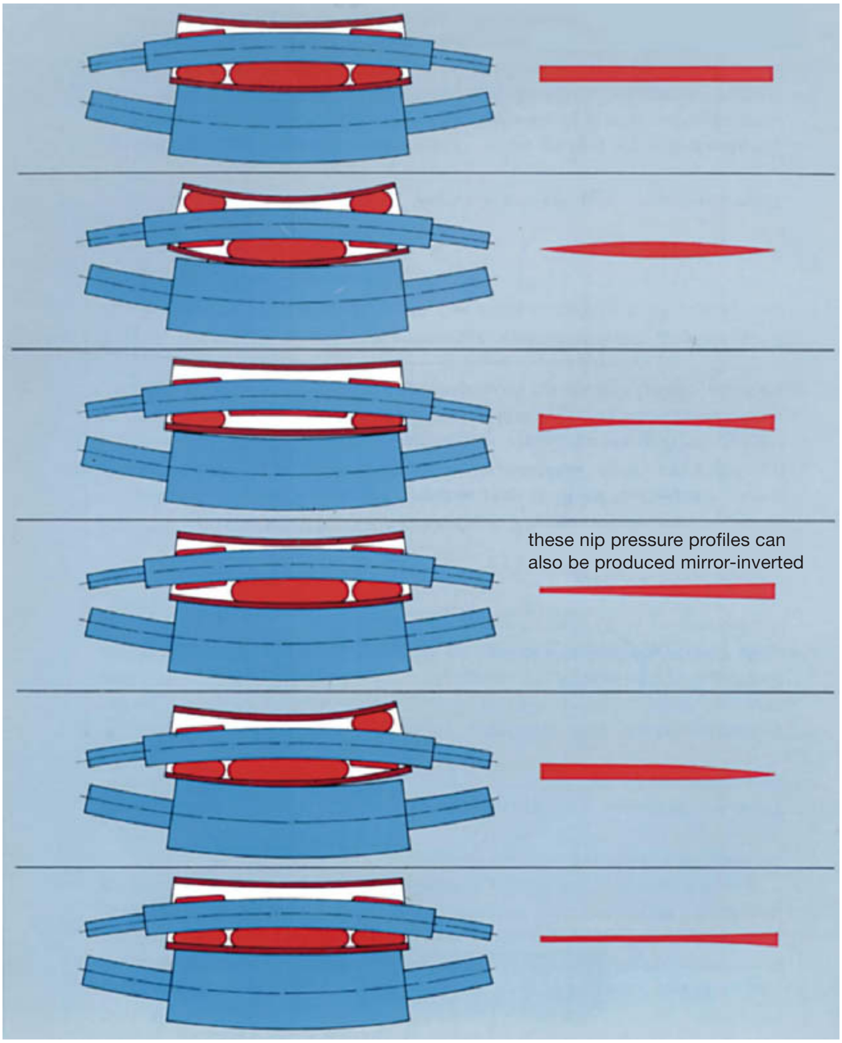


Fig.: Nip pressure profiles with a Bicoflex roller system (Kleinewefers KTM).

The presence of an oxygen (O) bridge is characteristic. In contrast to the → Nitro compounds, this compound as an ester is responsible for the fast decomposition of the nitrates when boiled with acids and alkaline solutions (phenol, nitric acid).

Nitric acid HNO_3. Molecular weight 63. Combines with water to form two hydrates: $HNO_3 \cdot H_2O$ (known as orthonitric acid, also written as H_3NO_4) and $HNO_3 \cdot 3\,H_2O$, the more stable, more important form (actual nitric acid). Salts: → Nitrates. Belongs to the strongest mineral acids. Dissolves most metals except gold (aqua fortis). Applications: the bleaching of silk, fibre identification.

Nitric acid/nitric oxide HNO: hyponitrous acid, salts = hyponitrites ($Na_2N_2O_2$). HNO_2: nitrous acid, salts = nitrites. HNO_3: nitric acid, salts = nitrates.

Nitric acid solubility test For the identification of synthetic fibres.

I. The following are insoluble in hot 10% nitric acid: viscose, casein, polyvinyl chloride, polyacrylonitrile, polyester and polyamide. Soluble: polyvinyl alcohol.

II. The following are insoluble in cold nitric acid: wool, silk, cellulose, casein, polyester, polycarbonate, polyvinyl chloride, polyvinylidene chloride, polyethylene, polypropylene, polytetrafluoroethylene, m-aramide. Soluble: acetate, polyamide, polyurea, polyvinyl alcohol, polyacrylonitrile.

III. The following are insoluble in boiling concentrated nitric acid: polycarbonate, polyvinyl chloride, polyvinylidene chloride, polyethylene, polypropylene, polytetrafluoroethylene. Soluble: wool, silk, cellulose, casein, triacetate and 2.5-acetate, polyamide, polyacrylonitrile, polyester, polyvinyl alcohol, polyurethane.

Nitrification Oxidation of ammonia released by decomposition of biological substances containing nitrogen to form a nitrate, which occurs through the action of aerobic, nitrogen-fixing bacteria (nitric bacteria) (→ Nitrogen elimination). Through aerobic and anaerobic decomposition organically linked nitrogen in waste water is transformed into ammonia ions. From this stage of oxidation, in the presence of specific bacteria (nitrosomonas, nitrobacter), the nitrogen is combined with oxygen from the air in higher degrees of oxidation. The following reactions thus take place:

nitrosomonas:
$NHS_4^+ + 1.5\,O_2 \rightarrow NOS_2^- + H_2O + 2\,H^+ + 230\ \text{kJ}$

nitrobacter:
$NOS_2^- + 0.5\,O_2 \rightarrow NO_3^- + 75\ \text{kJ}$

In good nitrifying plant nitrite is no longer detectable. Nitrite is produced, but is converted to nitrate almost immediately by nitrobacter. The same equations are produced by the whole reaction:

nitrosomonas + nitrobacter:
$NH_4^+ + 2\,O_2 \rightarrow NO_3^- + H_2O + 2\,H^+ + 305\ \text{kJ}$

Nitrite and nitrate are formed when the BOD_5 of the waste water falls to around 20 mg/l. Nitrosomonas and nitrobacter are autotrophic bacteria which assimilate carbon dioxide with the assistance of the energy obtained from the nitrogen oxidation. The prevailing opinion is that the named bacteria react sensitively to higher concentrations of the waste water contents, so that nitrification should only take place if the carbon compounds are largely decomposed, i.e. the nitrite or nitrate content only increases substantially in the case of low end BOD_5. During nitrification there are free protons, which correspond to an acidification of the waste water. Alkalis need to be added to neutralize.

Nitrile alloy American term for synthetic modacrylic fibres of a type in which the improvement of the dyeing behaviour of single-polymerizing compounds (approx. 10% N vinyl pyrrolidone) in the fibre molecule appears equally concentrated. Thus a more regular copolymer fibre is produced than is the case with irregularly modified polyacrylonitrile fibres. Thus a nitrile alloy has considerably more cross-linking hydrogen bridges, which in addition to notably good dyeing properties (also well-suited to anthraquinoid vat dyes) is particularly noted for its mechanical properties (see Tab.).

	Nitrile alloy	Unequally spaced copolymer (otherwise similar chemical composition)
density	1.19	1.17
moisture absorption	2.5 %	1.6 %
boiling water 6 min.	approx. 1 %	approx. 8 %
shrinkage 10 h	approx. 2 %	approx. 12 %
softening	254°C	> 253°C

Tab.: Properties of nitrile alloys.

Nitrilotriacetic acid (NTA), $N(CH_2COOH)_3$, used for complexometry and as a waste-water chelating agent. Iin the latter case at temperatures above 10°C full decomposition takes place both in sewage treatment plants and in river water, only partial decomposition at around 10°C, whilst at temperatures below 5°C it stops completely in river water and to a large extent in sewage plants. Nitrilotriacetic acid, as a potential phosphate substitute, possesses calcium compound-forming properties, but unsatisfactory biodegradability (after adaptation 3–74% BOD_{30}) and also negative toxicological effects through remobilization of mercury and cadmium compounds from sediments (redox potential ~ 100).

Nitrilotriacetic acid salts (aminotrimethylcarboxylic acid salts), salts from → Nitrilotriacetic acid, $N(CH_2COOH)_3$. This organic chelating agent, one of the → Aminopolycarboxylic acids is, in the form of sodium salts, resistant to boiling and alkalis. It displays maximum effectiveness at 70–100°C. Magnesium hardness only occurs with application of heat, but, not as calcium hardness, also in caustic alkaline solution.

Nitrite-containing untreated water Evident from traces of yellow staining of animal fibres. This in turn leads to divergent, dull dyeing (the effect of light can cause colour transformation to brown), dye alteration or destruction, general dyeing difficulties, difficulties with tone-in-tone dyeing of blends, changes in coupling dyeing, etc.

Nitrite reaction For the detection of urea, thiourea, dicyandiamidine, glyoxalureine in, e.g., synthetic resin finishes: approx. 5 ml of an acid resin extract is mixed with 1 ml conc. hydrochloric acid and 2–3 drops of approx. 0.1 n sodium nitrite solution. Every 3 min during the 15-minute process, a drop of the test solution is applied to potassium iodide paper. The blue colour is evaluated immediately thereafter. If the colour gets progressively fainter on each application until it fades away completely, the outcome is positive. In addition, if dropped onto a glass surface, nitrogen bubbles form. If the reaction is positive, but without nitrogen bubbles, this means the presence of nitrosamines, which are formed from imidazolidones and pyrimidones which react easily with nitrous acid. They are finally identified by the following reactions:

I. → Diphenylamine sulphuric acid (deep blue colour).

II. → Liebermann’s indophenol reaction (purple, deep blue colour).

III. Dimethylaniline test: add 1 drop dimethylaniline and a little conc. hydrochloric acid and warm. Yellowish-red nitrodimethylamiline hydrochloride.

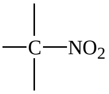
Nitrites Salts of nitric acid (HNO_2). A typical example is → Sodium nitrite, $NaNO_2$. Nitrites are usually colourless (exceptions: cobalt, copper, nickel nitrite, etc.) and easily soluble. Easily decomposed when heated. Application: for diazotizing.

Nitroaniline $C_6H_4NO_2NH_2$: (ortho-, meta-, para-) nitrified → Aniline. Crystalline intermediate products of dye synthesis.

Nitrobacteria Micro-organisms (e.g. bacterium coli commune, typhus bacillus) which oxidise organic nitrogen compounds (ammonia, nitrites, etc.) in the ground, ground water, etc., to nitrates. Nitrobacteria are of significance in connection with the water supply for textile processes.

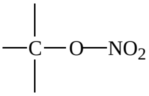
Nitrocellulose,

I. An erroneous term for → Cellulose nitrate. This is not a → Nitro compounds.



$$-\overset{|}{\underset{|}{C}}-NO_2$$

but a cellulose nitrate



$$-\overset{|}{\underset{|}{C}}-O-NO_2$$

A typical ester of cellulose, with characteristic sensitivity when boiling with acids and alkalis.

II. Not a homogeneous chemical compound, but a combination of various highly nitrified cellulose molecules. Cellulose dinitrate = collodion cotton, cellulose trinitrate = “gun cotton”. Nitrogen content 12.6–13.4%, in collodion around 10–11%. Fibrous, similar to cotton. Density 1.66. Easily flammable. Insoluble in cold and hot water. Further details → Collodion cotton. Solvent: esters, alcohols, ketones, oxyethers, very readily soluble in cyclohexylacetate. Thinner: benzene, benzine, toluol, carbon tetrachloride, ethanol. Application: fixing of the thickening agent for pigment, bronze and lacquer printing, and in large quantities for lacquer manufacture.

Nitrocellulose colours A sub-group of → Colour lake substance of colour pigments in collodion or nitrocellulose varnishes.

Nitro compounds contain the typical nitro-group $-NO_2$, e.g. nitro dyes, usually acid yellow or orange dyes. Other nitro compounds are nitrobenzene, nitrophenols, etc. In all nitro compounds the $-NO_2$ group is always immediately bonded to carbon (thus in contrast to organic → Nitrates), which results in good chemical stability. Thus nitrobenzene is absolutely stable, i.e. indestructible, in the presence of acids and alkalis.

Nitrogen Symbol N, atomic weight 14.04. → Non-metals, gases; colourless, odourless, tasteless; suffocating effect; non-flammable at normal temperatures, fairly slow to react. Combines with hydrogen, oxygen, carbon, boron, silicon, magnesium, calcium. Compounds: with hydrogen to give ammonia NH_3 (ammonium salts, ammonium bases = hydroxylamine, hydrazine, organic amides; amines, acid amides). With oxygen to give oxides or -ous oxides (nitrous oxide N_2O, nitrogen oxide NO, nitrogen trioxide N_2O_3, di- and tetroxide $2\ NO_2 \leftrightarrow N_2O_4$, pentoxide N_2O_5), which react with water to give → Nitric acid/nitric oxide.

Nitrogen elimination The government regulations for the discharge of waste water into water systems place strict requirements governing the residual concentration of the nitrogen, especially in the form of ammonia derivatives. The introduction of nitrogen must be limited in those places where communal sewage treatment plants are already overloaded with this form of pollutant. Nitrogen compounds in waste water

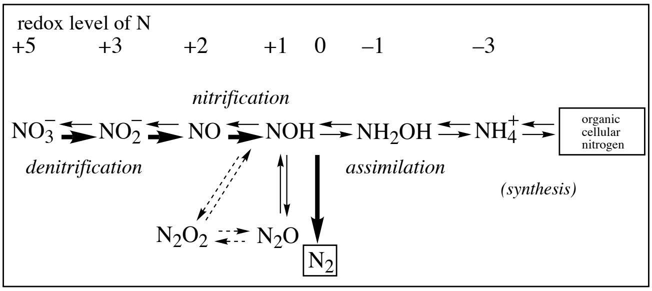


Fig. 1: Diagram showing the nitrogen compounds present during biochemical reaction in stagnant and flowing water.

arise from both organic and inorganic compounds, especially since nitrogen is one of the most important components of organic material. The total nitrogen content in unpolluted waters is practically always below 1 mg/l. If there is organic material in the water, this is ammonified by biochemical processes, e.g. in the case of protein:

proteins → peptones → polypeptides → amino acids → (urea) → ammonium.

Therefore prior to the introduction of the BOD$_5$ regulations, the ammonium-nitrogen content was used as the criterion for the evaluation of acute water pollution. In water systems and water treatment, nitrogen compounds constantly undergo biochemical transformation. The most important reaction stages of the chemical processes are nitrification, denitrification and assimilation (Fig. 1).

A range of adverse effects of the various nitrogen components includes:

1. Any ammonium nitrogen reaching the outfall is oxidized there to nitrate nitrogen; the necessary oxygen is drawn from the water, causing the oxygen content to sink below the necessary minimum in critical situations.
2. The increase in nitrogen can contribute to the growth of algae.
3. Depending on the pH, ammonia can be toxic to fish, and high concentrations of ammonia can also have a toxic effect on nitrifying bacteria.
4. High concentrations of nitrates, and in particular nitrites, in the drinking water pose a health risk to the public. Nitrates can lead to cyanosis in young babies. In addition nitrates and nitrites can contribute to the formation of carcinogenic nitrosamines.

Consequently nitrogen elimination is very important. As the chemical processes necessary for the removal of the dissolved nitrogen are not economical to implement due to the high solubility of the NH_4^+-, NO_2^-- and NO_3^--ions, nitrogen is eliminated using the self-cleaning biochemical processes of the water. The majority of nitrogen compounds are removed as a result of the nitrification and denitrification. The elimination of the ammonium nitrogen present in the pre-settled waste water therefore takes place in two stages. In the 1st stage of nitrification, the nitrogen is oxidized from the reduced form (oxidation number –3) to nitrate (oxidation number +5). This anaerobic process is followed in the 2nd stage by denitrification, which takes place under anoxic conditions, i.e. in the absence of free molecular oxygen, but in the presence of nitrate. The nitrate nitrogen is hereby partially reduced to molecular nitrogen (oxidation number 0), which as a free gas (N_2) can easily be removed from the water due to its low solubility. The high oxygen requirement of the 1st stage and the complete absence of oxygen in the 2nd phase require a separation of the process into two reaction areas. The microbial decomposition of the organic carbon compounds in the waste water, which is also required, can take place simultaneously with the nitrification, or in a prior biological cleaning process.

1st stage: the nitrification in the aerobic biological waste water treatment first takes place when the carbon-containing compounds have largely been decomposed. Nitrite and nitrate are only formed once the BOD$_5$ of the waste water has dropped to approx. 20 mg/l. The nitrification is linked to the metabolic processes of specific specialized types of bacteria; nitrosomonas (NM) and nitrobacter (NB). Both are autotrophic bacteria, which assimilate carbon dioxide using the energy obtained from nitrogen oxidation. The following reactions take place:

$$NH_4^+ + 1^1/_2\,O_2 \rightarrow NO_2^- + H_2O + 2\,H^+ + 230\,kJ$$

$$2\,H^+ + 2\,HCO_3^- \rightarrow 2\,CO_2 + 2\,H_2O$$

The protons formed by ammonium oxidation immediately undergo further reactions and destroy the carbonate-hydrogen carbonate buffer of the waste water, which can lead to a pH < 5.5. Alkali must be added for neutralization purposes. The further oxidation of the nitrite to nitrate can only be carried out by bacteria of the nitrobacter species:

$$NO_2 + {}^1/_2\,O_2 \rightarrow NO_3^- + 75\,kJ$$

Thus a total of 2 mol oxygen is needed for the full nitrification of 1 mol ammonium. In good nitrification plants, nitrite is not detectable, as it is immediately oxidized by nitrobacter. The high degree of specialization of the nitrifying bacteria requires a special environment, the maintenance of which is the defining influence on the degree of nitrification obtainable.

Nitrogen elimination

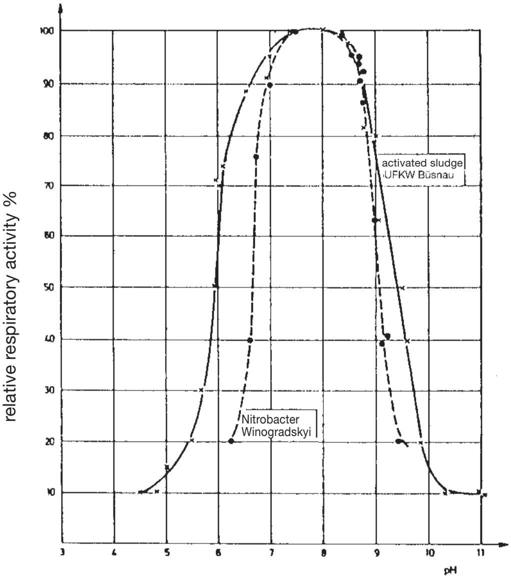


Fig. 2: Respiratory activity in relation to pH for a) activated sludge of the Büsnau training and research sewage treatment plant at Stuttgart University and b) Nitrobacter Winogradskyi.

Most microorganisms have a clear pH optimum, which is even more marked in the case of nitrifying bacteria. Fig. 2, shows the respiratory activity of activated sludge bacteria and nitrobacter, in relation to the pH. The optimum pH range is relatively narrow and in the case of activated sludge, bacteria and nitrobacter lie in the weak alkali range, for nitrobacter at approx. pH 7.5–8.3. Outside this range there is a sharp decline in the respiration activity. Therefore it is especially important to control the pH for the nitrification stage, particularly since the pH can fall due to nitrification because of insufficient hydrogen carbonate buffer; in certain circumstances optimum nitrification may only be maintained by the controlled addition of, e.g. sodium carbonate.

All nitrifiers are obligate aerobic bacteria, which makes it essential to ensure a sufficient oxygen supply to the system. The oxygen concentration of the water should, therefore, be constantly maintained above 2 mg O_2/l. The growth rates of the nitrifying bacteria lie well below those of the other waste water bacteria. At a temperature of 20°C nitrosomonas has a growth rate of $\mu = 0.34\ d^{-1}$ and nitrobacter of $\mu = 0.14\ d^{-1}$. The slow multiplication means that the bacteria are easily washed out of the system, which can only be compensated for by the age of the sludge. Nitrifying bacteria are limited in their biotic activity in the presence of organic, biodegradable substances in the water, so that nitrification can only take place in the case of low biological charging or residual charging. A range of heavy metal ions such as hydrogen sulphide, mercaptane, aliphatic amines and other toxic substances can upset the nitrification process even in very low concentrations. Sudden changes in temperature and other changes in the environmental conditions can also lead to an immediate reduction in the nitrification rate.

Technical nitrification may be carried out either by carbon oxidation in an aerobic, biological treatment plant, or as a separate process. The separation of carbon and nitrogen oxidation allows, above all, a separate control of the influential parameters of pH and oxygen content by intensity of aeration, which is significant for the optimization of the nitrification process. Fixed-bed reactors (e.g. percolating filters), which enable immobilization of the nitrifying bacteria, are particularly suited to separate nitrification. The good adhesive properties of the nitrifying bacteria types mean they can increase and multiply whilst fixed to the carrier without substantial losses by washing out. Also, in a fixed-bed reactor, a system with a longitudinal throughflow, they have more stable living conditions than in a fully mixed activated sludge suspension with free-floating micro-organisms. This is of great importance to bacteria as sensitive as nitrosomonas and nitrobacter.

2nd stage: The denitrification can be carried out by a number of heterotrophic activated sludge bacteria. Under anaerobic conditions the free molecular oxygen is substituted by nitrate or nitrite oxygen as the electron acceptor.

$$NO_3^- + 5\,H^+ \rightarrow 1/2\,N_2 + 2\,H_2O + OH^- - 360\ kJ$$

Many facultative heterotrophic bacteria may convert without difficulty to adaptation from oxygen breathing to nitrate respiration in an anaerobic environment. This respiration, termed denitrification, equates biochemically to oxygen respiration. It is effective to the extent that it reduces the proportion of free oxygen. Despite biochemical equivalence of the respiration systems, the enzymes formed need not be identical, as the tendency towards denitrification is linked to adaptive enzymes. Furthermore an electron donor is necessary to augment the redox processes. This may be made available in the form of organic carbon compounds, which are either present in the activated sludge or are added from outside. Due to its low cost and fast, full decomposition, methanol (CH_3OH) is often used for this purpose:

$$5\,CH_3OH + 6\,NO_3^- \rightarrow 3\,N_2 + 5\,CO_2$$

$$+ 6\,OH^- + 7\,H_2O - 750\ kJ$$

This reaction is slightly alkaline and leads to a slight increase in the buffer capacity in accordance with the following equation:

$$5\,CO_2 + 6\,OH^- \rightarrow 5\,HCO_3^- + OH^-$$

In contrast to nitrification, denitrification is not carried out by specialist bacteria and therefore does not require any special environmental conditions. The dependency of the respiration performance of denitrifiers corresponds in general to that of an activated sludge. As the affinity of the electrons to molecular oxygen is essentially higher than to nitrate oxygen, effective denitrification can only take place in the complete absence of free oxygen. As the denitrification tank has to be operated anaerobically, instead of by aeration, a slow agitator is installed which ensures thorough mixing and prevents the sludge from settling out. It is therefore possible to use fixed-bed reactors which through intensive bacterial growth give high volume-specific denitrification rates.

The ammonia desorption is a physical-chemical process for the elimination of nitrogen. Using this method, nitrogen can simply be removed from the waste water in the form of ammonium. Organic and oxidized inorganic nitrogen components are not included. It is therefore only usefully applicable for waste water which is already ammonified, or industrial waste water with high ammonium content. In the neutral range ammonium nitrogen is present in the form of the ammonium ion (NH^+_4). If the pH increases into the alkaline range, the dissociation equilibrium is shifted to free molecular ammonia (NH_3):

$$NH_4^+ + OH^- \rightarrow NH_3 + H_2O$$

Given a pH of 10–11 (Fig. 3) approx. 80–90% of the nitrogen components are present as ammonia. This is useful in ammonia desorption, in that the free ammonia is desorbed and released in the form of a gas. This process, described as “stripping” involves an internal contact between air and waste water, which enables the release of gaseous ammonia into the atmosphere.

Desorption plant is similar in construction to an industrial cooling tower. A strong fan provides the necessary air input, and an inbuilt grid system ensure the separation of the water flow into small droplets with a large surface area. Ammonia is very easily soluble in water, so that desorption requires a great expenditure of energy. The strong temperature dependency of the solubility of the ammonia requires, for example, for a 90% ammonia desorption at pH 11 and 0°C, almost 6000 m^3 air per m^3 waste water; at 20°C the requirement is still around 2200–3700 m^3 air per m^3 waste water. Ammonia desorption can be particularly economical if used in conjunction with lime phosphate precipitation, as this process gives a pH of practically 11. However limestone deposits can lead to problems of blockages.

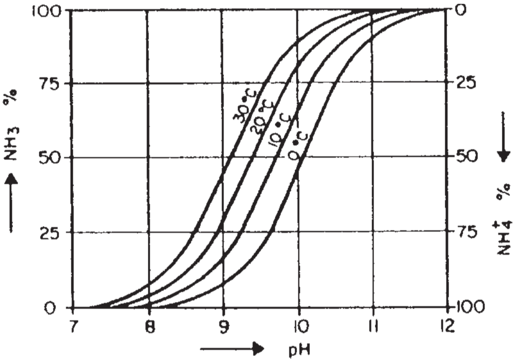


Fig. 3: Dissociation equilibrium for ammonia in relation to pH and temperature.

Nitrogen oxide gases (NO_x), gas combinations containing nitrogen oxide. Arise, e.g. when diazotizing and as gases from combustion (→ Exhaust gases). They are given the symbol NO_x, as their precise composition with relation to the proportions of NO and NO_2 is usually not known.

Nitrogen oxides Oxygen compounds of → Nitrogen, such as NO, NO_2, N_2O_3. Component of → Nitrogen oxide gases. Grouped in combustion gases under the designation $(NO)_x$, as the precise composition is generally unclear.

Nitrogen shock cooling If woollen fabrics which are overdried are treated with liquid nitrogen (see Fig.), the fabrics are shock cooled and when thawing are very moisture absorptive.

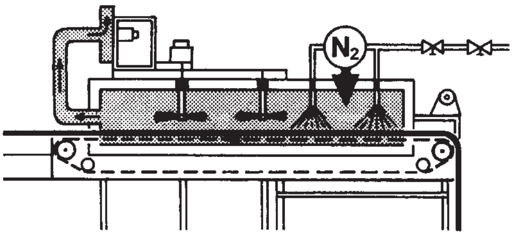


Fig.: Shock cooling with liquid nitrogen (N_2).

Nitrogen test in resin finishes,

I. Caustic soda test: boil a small fabric sample (approx. 3–4 cm^2) in a test tube with approx. 4 ml 32% caustic soda: released ammonia (positive nitrogen test) can be determined by the smell, with pH paper or by distillation with Nessler’s Reagent (yellowish-brown precipitation).

II. Thiocyanate test: finely grind a test sample in a mortar with sodium thiosulphate, then heat in a crucible on a sand bed until the solids start to burn, then boil off the residue with the addition of water; test the thiocyanate formed with ferric chloride: red coloration = positive indication of nitrogen. If nitrogen is indicated, the following could, for example, be present (without formaldehyde): polyamide and polyacrylonitrile and (if formaldehyde is also shown positive) amide resins; apart from any fibres which may upset the reaction such as cotton, polyamide, polyacrylonitrile.

Nitrogen test on damaged wool The usual methods for the detection of soluble nitrogen (sun-damaged, acid or alkali damaged wool) by the melting of the substance using sodium metal and the transfer of the sodium cyanide formed into Berlin blue, is often not appropriate in the case of dyed woollen materials. The process known as the micro-Kjeldahl process is acceptable.

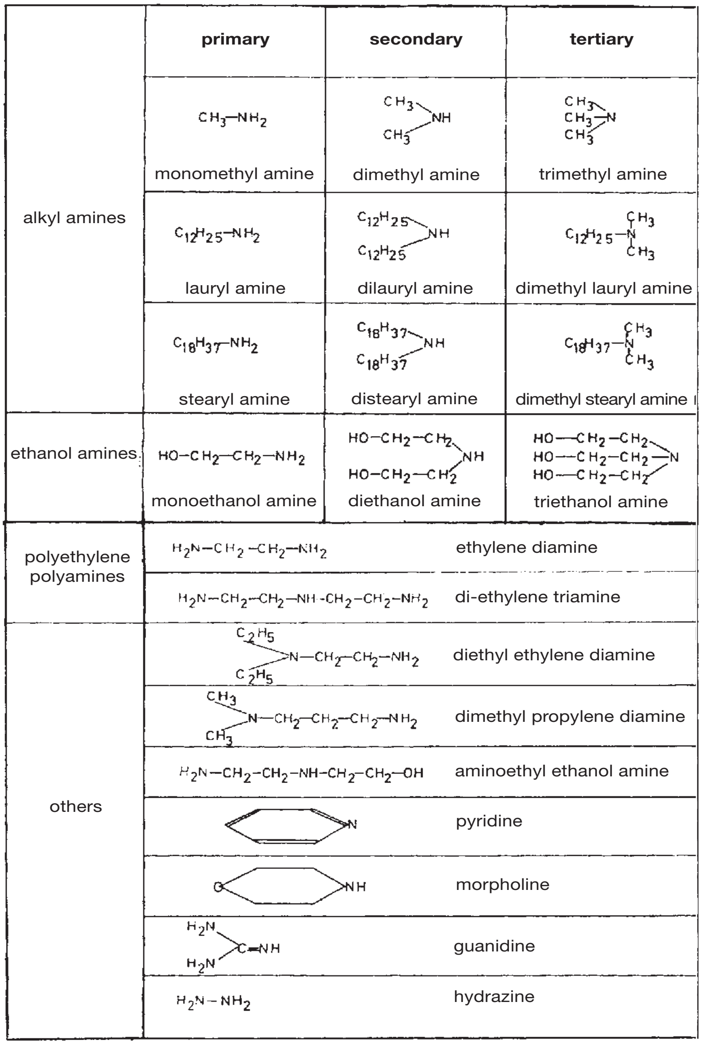
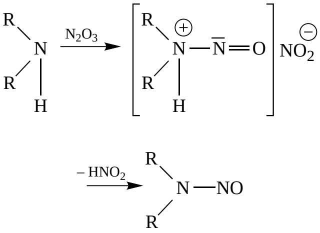


Fig.: Amino components in fabric softeners.

Nitro rayon (Chardonnet rayon), the first man made fibre (1884 by the Earl of Chardonnet). Produced from → Nitrocellulose, using ethanol and ether. → Man made fibres.

Nitrosamines Alkyl derivates of the type R–NH–NO, play a part, e.g. in the coupling of naphthol dyes. Softener on the basis of secondary and tertiary amines (see Fig.) may provide the chemical basis for the formation of nitrosamines during application.

Because of pronounced basic properties, high volatility, an intense smell and latent risk of formation of nitrosamines, effective measures during storage, transport, processing, operations and disposal are essential. Particular attention should be paid to the risk of nitrosamine formation of secondary amines with nitrous gases, as this is recognised as extremely carcinogenic in many animal species:



Nitrous acid treatment The introduction of the nitros group (NO) into an organic compound, e.g. through the effect of nitrous acid.

Nm,

I. → Metric number.

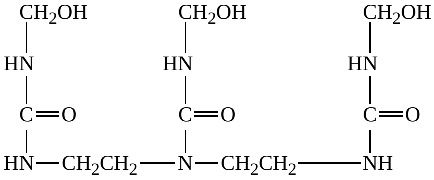
II. Unit of newton multiplied by metre, as a unit of torque.

N-Methylol compounds Compounds with one or more M-methylol groups $–N–CH_2OH$ (reactive group for crosslinking reaction). Produced by replacement of formaldehyde with appropriate compounds containing NH or NH_2 groups. There are two different types, linear (e.g. dimethylocarbamates) and cyclic N-methylol compounds (e.g. DMEU) with at least two functional groups, also etherified, $–N–CH_2–O–R$, (R usually CH_3). Applications include as crease-resist agent, of which it is the most important class of compound, e.g. →: Urea; Melamine-formaldehyde compound.

N-methylol group → N-Methylol compounds.

N-methylolacrylamide → Methylolacrylamide.

N-methylolpolyethyleneureas A crease-resistant finish; products of the reactions of polyethylene amines or imines, urea and formaldehyde, e.g. from diethylene triamine, urea and formaldehyde:



$$\begin{array}{ccccc} CH_2OH & & CH_2OH & & CH_2OH \\ | & & | & & | \\ HN & & HN & & HN \\ | & & | & & | \\ C{=}O & & C{=}O & & C{=}O \\ | & & | & & | \\ HN & -CH_2CH_2- & N & -CH_2CH_2- & NH \end{array}$$

NMMO-Cellulosic fibre The NMMO process is a solvent spinning process in which a Lyocell fibre is produced from cellulose in only a few stages, without the supplementary addition of chemicals (see Fig.). The technique represents a solution to the environmental problems caused by the usual methods (waste water and air emissions).

NMMO stands for N-methyl morpholine oxide, a cyclic amine oxide, in which cellulose is very soluble. The production of this solution with NMMO makes it

fibre types	NMMO	Giza 70*	viscose	Modal
FStr. (cN/tex) fibre strength, dry	45	34	26	35
FEI. (%) fibre elongation, dry	12	8	17	14
FStr. (cN/tex) fibre strength, wet	39	41	14	20
FEI. (%) fibre elongation, wet	19	21	7	8

Tab.: Comparison of fibre properties (Giza 70 = long-staple Egyptian cotton).*

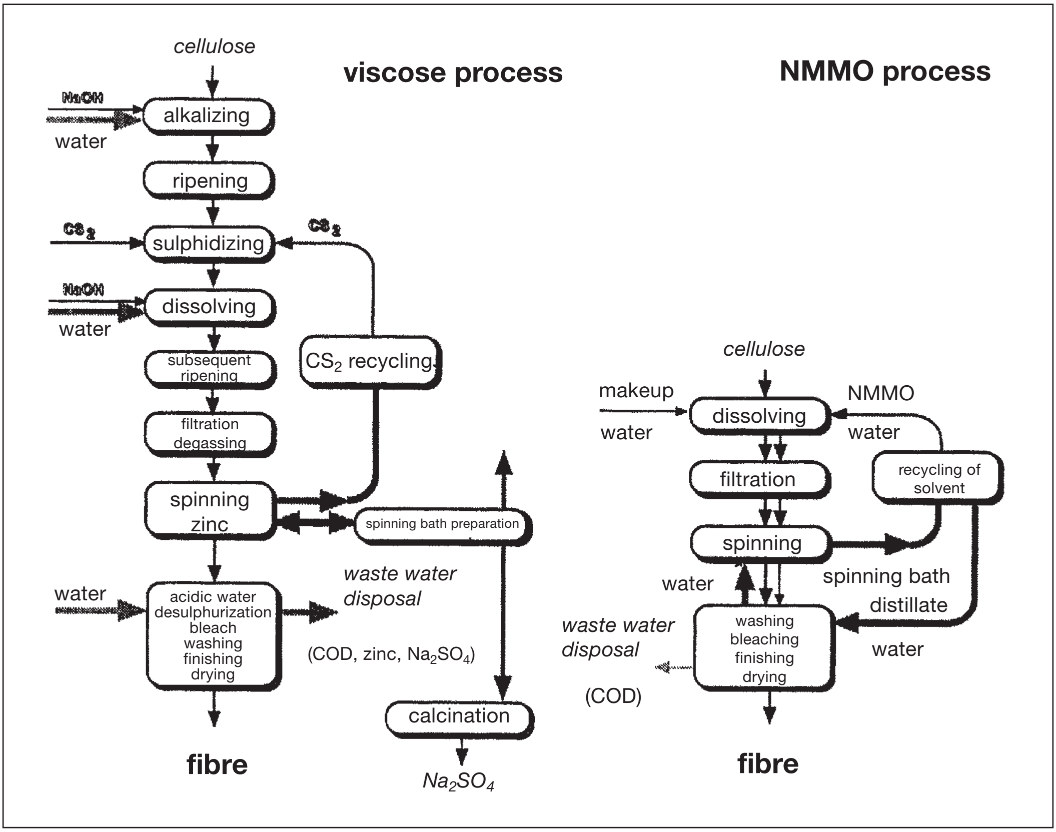


Fig.: Comparison of the viscose and NMMO (Lyocell) processes (Lenzing AG).

possible to regenerate the spun fibre in a precipitating bath of water without additional chemicals. Moreover, the aqueous NMMO solution can be re-used for the production of further solutions. This gives rise to a practically 100% closed circuit. The resulting Lyocell fiber properties are listed in the Tab.

NMR Spectroscopy (Nuclear Magnetic Resonance). This is used to determine the structure of substances. Pauli postulated isotopic spin to interpret the hyper-fine structure of atomic spectrums as early as 1924. In 1945, the first successful nuclear magnetic resonance tests were carried out on condensed matter. Bloch and colleagues observed proton resonance on a water sample in what was by today's standards a weak magnetic field as a small wide lobe on the oscillograph screen. In 1952, Bloch was awarded the Nobel Prize for Physics together with Purcell, who had observed the phenomena of nuclear magnetic resonance at the same time on solid paraffin.

Natural frequency is dependent on the chemical environment of the nucleus under observation, conditional upon the shielding of the electron shells. This chemical displacement, measured in ppm, is the basis for the use of NMR in chemistry. Several nuclei, e.g. protons, in a molecule also display a characteristic interaction which is expressed in the spectrum as a fine splitting of the resonance lines. The extent of this bonding and the multiplicity of the splitting provide a wealth of information on the number and type of adjacent nuclei as well as the number, type and geometry of the bonds between the nuclei within a molecule. The three values which can be extracted from a spectrum - position, intensity and bonding - are the corner stones of NMR spectroscopy structure analysis in solutions.

The actual sensor, isotopic spin, is a natural phenomena within the module. NMR spectroscopy can in principle be carried out on all nuclei which have a nuclear magnetic moment. In the classification of elements, there are 116 magnetically active nuclei, although only a few achieve the high sensitivity of protons. The strength of the magnetic moment and the natural frequency of the NMR-active isotopes are crucial here. In organic chemistry, C-13 NMR is of the greatest importance along with H-1 NMR. The natural frequency of the NMR-active carbon isotope C-13 is 1.1%. If the magnetic moment, which is smaller than that of protons, is taken into consideration, this means lower sensitivity by almost ten to the power of four. However, C-13 NMR has formed the basis of routine spectroscopy for a long time. Apart from the wide and increasing use of metal-NMR, F-19 NMR, P-31 NMR gained importance at an early stage and Si-29 NMR, N-15 NMR, O-17 NMR and H-2 NMR have only become significant with improved measuring technology. The introduction of the pulse Fourier transform technology (1966) had two consequences: NMR-spectroscopy of rarer nuclei was considerably extended and completely new measuring methods were developed.

With conventional pulse spectroscopy, a high-energy high frequency pulse is used to excite isotopic spin, the response of the released sample is detected inductively and registered on a time-dependent scale. The spectral information is obtained as a function of a frequency from the time function of the macroscopic magnetisation using Fourier transformation. If two or more pulses, which follow on from each other in a defined and gradually extended time interval, are adjusted for excitation, another frequency axis is created; the resulting range is therefore three-dimensional (intensity as a function of two frequencies) and is generally recorded as a contour line diagram (contour plotting). The bond relationships of the protons to each other or together with other nuclei can be made visible across the entire molecule, the spatial environment can be observed and dynamic processes can be detected and characterised. The three-dimensional structure of proteins can be clarified. This variety of methods and the resulting density of information on the molecular structure is unique to molecule spectroscopy. (according to Deusch).

NNI A Dutch standards body; → Technical and professional organizations.

NO Abbreviation for Norwegian patent.

No Chemical symbol for Nobelium (102).

No-Dip process in dry cleaning Based on the principle of cleaning drums which work without dipping (→ DIP process). As the dirt released is immediately removed from the machine to the filter, the risk of greying of the goods is substantially limited. As it operates without liquor and increased fall height, the no-dip process causes increases mechanical friction and thus an enhanced cleaning effect. In the case of chlorinated hydrocarbons is only recommended for particularly badly soiled goods, but not for delicate clothing.

NOEC (no-effect concentration). When surfactants are biologically degraded, for example, the first stage of the oxidation can be at the hydrophobic end of the chain:

The surfactant loses its effectiveness as a surface-active substance, i.e. if during biodegradation the surfactant concentration drops below a certain level,

– it is no longer detectable using the usual tests,
– it no longer foams,
– it is no longer toxic to fish.

No-Gel A foam carpet backing without gelling agent.

No-Gel-Foam A foam of natural or synthetic latex (for carpet backing, e.g. tufted pile), which is directly vulcanized in a single stage. The process is selected on the basis of the latex type and crosslinking system. All generally have high proportions of extenders from 150-220 parts per 100 parts latex solids and specific soap systems as foaming agent. In the case of no-gel foam based on cold latex, the foam system is derived from combinations of sodium sulphosuccinate and (particularly in the case of low litre loads) additional sodium lauryl sulphate. No-gel foams, of good foam structure, can also be produced on the basis of carboxyl latex, either sulphur or resin cross-linked.

No Iron Another term for crease resist finish. The literal expression of the purpose of this finish: no ironing is necessary after the washing process. The most frequently-used term is → Wash and Wear.

Noir reduit (steam black). Oxidized → Logwood extract for printing.

Noise emission Since the introduction of the German “Noise” Accident Prevention Regulation (Unfallverhütungsvorschrift “Lärm”; VGB 121) on 1.12.1974, ear protection must be provided for noise levels of over 85 dB(A), and ear protection must be worn from 90 dB(A) and above (→ Noise protection). Within a transition period of 3 years, i.e. by 1.12.1977, all employees working in noisy areas (levels assessed at ≥ 90 dB(A)) had to be given precautionary tests which would establish any hearing impairment caused in the past. In practice the wearing of personal ear protection does not guarantee freedom from the risk of hearing impairment.

Noise meter → Sound level measurement.

Noise protection Existing regulations require that machine manufacturers and operators increasingly reduce noise emissions from machines and noise immissions at the workplace (→ Industrial noise pollution). The EU Directive on protection against noise at the workplace, which has been implemented in Germany in the revised version of the Regulation for the Prevention of Accidents (UVV – Unfallverhütungsvorschrift), “Noise”, and the EU machine protection directive which was subject to national legislation up until the end of 1992, in particular give rise to considerable obligations relating to noise protection with which companies must comply. An example is the duty to declare noise immissions in the operating manual. Various methods of measuring noise levels are given in the applicable statutory regulations relating to industrial noise protection. A distinction can be made here between the following range of tasks:

– measurement of noise immissions,
– measurement of noise emissions,
– noise analysis for noise reduction.

Measurement of noise emissions and immissions should be clearly distinguished - noise emissions relate to the noise radiating from a machine, and noise immissions relate to the effect on the environment. A distinction can therefore be made between the two in terms of their objective: Measurement of noise emissions is used to assess a source of noise whereas measurement of noise immissions assesses the effect on humans. Both are directly related, thus it is possible to calculate e.g. the noise immission at a specific point (e.g. on a production line) if the noise emissions of all the machines together with the acoustics are known.

1. Measurement of noise immissions are necessary e.g.

– to recognise any potential risk to hearing at the workplace,
– to ascertain noise hazardous zones,
– to select suitable forms of ear protection,
– to test whether warning or danger signals can be detected sufficiently well in a noise hazardous zone,
– to check compliance with the limit values of 55, 70 and 85 dB (A), differentiated depending on activities and use of space as specified in the workplace directive (§ 15).

Procedure is described in DIN 45 645, Part 2.

2. Measurement of noise emissions is particularly significant for assessing new installations. According to the EU Directive 86/188 on the protection of employees against noise or the German Regulation for the Prevention of Accidents (UVV), “Noise”, the operator must find out about the anticipated noise emissions before purchasing a machine and must only purchase a machine which is in line with technical regulations. To support the operator, → VDI guidelines for certain groups of machines are available in Germany which give information on the status of noise reduction technology. For the textile machinery group, there is for example VDI guideline 2572, “Noises from textile machinery and in textile machinery halls and measures to reduce noise”. In Germany, it is also possible for a test institute approved under the Industrial Safety Act to assess whether a machine corresponds with the latest technology in terms of noise emissions. The test institute is also obliged to record and assess the noise emissions during the voluntary prototype test of a machine as stipulated by the law (GS-label = safety approved). Practical implementation of the measurement of noise emissions is described in Standard DIN 45 635. Parts 1–9 deal with different framework measuring methods, comparable with ISO 3740 to 3747 (according to Maue).

Nomad carpet → Oriental carpets, plush-like, with pile cropped to a greater or lesser extent, warp, weft and knotted sheep or goat wool pile (100 000–300 000 knots per m^2). Mainly narrow pieces (prayer mats, rugs, mats). Design (work of nomads) differs slightly in pattern, width, colour, often distorted and creased.

Nominal blending ratio (DIN 60 003), the given ratio of the fibre types used in a textile product.

Nominal diameter The approximate internal diameter of pipe connections, bracings, etc., in mm or inches. It is the determining dimension for the statement that parts of a specific nominal diameter fit together; whether they are functionally accurate is another matter.

Nominal pressure The maximum permissible → Working pressure in bars at 20°C. It is therefore sufficient when denoting the application range of a pipework component (piping, fittings) to give the nominal pressure.

Nominal temperature The temperature given on measuring instruments at which they should be used. If not given, it is 20°C. If two temperatures are quoted, this means the limits of the temperature range in which the appliance should be used.

Non-coagulating thickener Usually wheat starch or starch ether, which, depending on the printing process are mixed with various coagulating thickeners. Application in direct printing with vat dyestuffs following the 2-phase process.

Non-contact measurement → Temperature measurement.

Non-crystalline → Amorphous.

Nondrying oils These include e.g. olive oil and groundnut oil; mainly consist of → Oleic acid (linoleic acid in a few cases, probably never linolenic acid). Although unsaturated (fatty acid) compounds are also included, the oxidation capability (iodine number) of oleic acids is too low for them to be classed as drying at normal temperatures. → Oils, oxidation of oils.

Non-dyeing polyamide → Differential dyeing polyamide system.

Non-ferrous metals (NF metals), in particular chromium, copper, manganese, molybdenum, nickel, tungsten, vanadium. They are important as additives in the production of stainless steel or plated steel, in order to increase the corrosion resistance against atmospheric and chemical effects. Application: plant and machinery engineering.

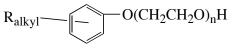
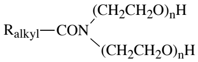
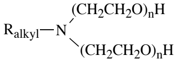
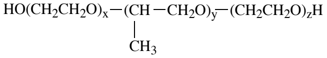
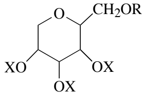
Non-flatspotting is achieved, e.g. by polyamide 6.6 cord yarns, which are used in vehicle tyres as cord lining. → Flat spotting is avoided or substantially reduced by modification of the polyamide by means of an increase in Young's modulus, yield point and increased structural stability at elevated temperatures. Measures of this kind include: treatment with di-isocyanate, blending of the polymer with polyester, co-polycondensation with specific aromatic dicarboxylic acids and possibly the development of new aromatic polyamides.

Non fuming spinning oils A slogan in the synthetic fibre industry for spinning oils which are not, or are only slightly volatile or fuming; e.g. based on sebacic acid ester.

Non-hardenable synthetic resins Such as → Phenolic plastics.

Non-ionic Does not form ions, e.g. nonionic surfactants.

Non-ionic surface-active compounds → Surface-active compounds, which do not form ions in aqueous solution. The water solubility is determined by functional groups which have strong affinity to water.

fatty alcohol ethoxylate	$R_{Alkyl}{-}O(CH_2CH_2O)_nH$
alkyl phenol ethoxylate APEO	
fatty acid ethoxylate	$R_{alkyl}{-}COO(CH_2CH_2O)_nH$
fatty acid alkylol amide	$R_{alkyl}{-}CONH{-}CH_2CH_2OH$
fatty acid alkylol amide ethoxylate	 $R_{alkyl}{-}CON{<}^{(CH_2CH_2O)_nH}_{(CH_2CH_2O)_nH}$
fatty amine ethoxylate	 $R_{alkyl}{-}N{<}^{(CH_2CH_2O)_nH}_{(CH_2CH_2O)_nH}$
polyalkylene oxide block polymer	 $HO(CH_2CH_2O)_x{-}(\underset{CH_3}{CH}{-}CH_2O)_y{-}(CH_2CH_2O)_zH$
fatty acid ester of sorbitol	

Tab. 1: Typical nonionic surfactants. (APEO is no more used.)

One of the most significant areas of application of non-ionic surfactants (Tab. 1) is as the raw material basis for washing and cleaning agents. In the case of constant hydrophobic chains, the pure surfactant properties, such as foaming behaviour, wetting action, emulsifying action, dispersing effect, and also solubility, etc., increase in their effect as the degree of ethoxylization increases, then either reaching a plateau or possibly falling away (e.g. washing effect). A special use for low-foam surfactants is as cleaning agents for automatic cleaning processes which operate under high pressure. In the case of industrial cleaning processes such conditions are often more marked, also, strongly alkaline liquors are often present. In addition to ethylene oxide-propylene oxide block polymerization, non-ionic surfactants also include closed end group fatty alcohol alkoxylates (the free OH group at the end of the alkoxylate chain is blocked by the relevant chemical reactions, so that low foaming properties and surfactant properties remain intact with small amounts of colour). Low-foam surfactants have a low cloud point, as they only possess low foaming properties above the cloud point. In the textile industry there are numerous examples of the application of non-ionic surfactants: in addition to their use as cleaning agents, they are used e.g. for the pre-treatment of wool, as a wetting agent, levelling agent, finishing agent, softener, lubricant and spinning oil; in every case because of their surface-active character. It is not always the cleaning effect which is of most importance. There are also many tasks in which non-ionic surfactants are absorbed in the substrate and thus do not enter the waste water. Such surfactants are also extremely useful for emulsifying processes. → Biodegradation is a prerequisite for their use. Among numerous analytical methods the Wickbold method has been developed to such an extent that a waste water analysis can detect 0.01 ppm, i.e. 1 millionth % (Tab. 2).

	BOD after 30 days (%)	degradation according to Wickbold (%)
fatty alcohol + 10 EO	80	98.5
fatty alcohol + 30 EO	57	98.1
nonyl phenol + 9 EO	1	33.7

Tab. 2: Biological degradability of nonionic surfactants.

Typical non-ionic surfactants with favourable ecological properties can be found in the following application examples:

When dyeing knitted cotton goods it is often essential to prewash the material to be dyed. Surfactant compounds based on hydroxy compound ether sulphates combine a wetting, emulsifying and dispersant effect. Dyeing processes can be carried out without the need for precleaning and bath changes. When mercerizing raw cotton the use of wetting agents is still necessary. Closed end group non-ionic surfactants represent biodegradable foaming agents which can be specially combined to form products for use as low-foam wetting agents in caustic treatment and mercerization. During production and processing of synthetic fibres, difficulties arise in the majority of cases due to electrostatic charges. A particular problem is the decreasing antistatic efficiency of antistatic finishes with time, especially in the case of polyamides. By using specific ether sulphonates it is possible to retain the antistatic effect on materials of polyamide fibres practically unchanged even after a storage times of several months.

Nonionic tensides → Non-ionic surface-active compounds.

Non-iron Textiles which, subject to compliance with certain care instructions, and following either dry cleaning or machine washing, fulfil specified minimum requirements for dimensional stability, colour fastness and smooth drying. Non-iron is a special feature of easy-care articles which applies exclusively to washable garments, signifying that no additional smoothing of the article after washing is necessary, provided the care label instructions are followed.

Non-iron finish → Resin finishing.

Non-metals (metalloids), Main examples: arsenic, boron, bromine, carbon, chlorine, fluorine, helium, hydrogen, iodine, nitrogen, oxygen, phosphorus, selenium, silicon, sulphur, tellurium. Oxygen compounds of non-metals have the character of → Acids. Hydrogen compounds are gaseous. Contrast → Metals.

Non-metric measuring system In contrast to the metric system (based on m, kg, s) the non-metric, or Imperial System is based on ft, lb, s. In order to achieve unity in measurement practice, the non-metric system should no longer exist, but only the SI system of measurement. However, the non-metric system is widely used in the USA, UK and East Asia. For conversions, see → SI System of Units.

Nonpolar bond → Atomic bond.

Nonpolar group An organic (surfactant) molecular component with electron distribution without appreciable dipole moment. Limited affinity to organic solvents of low polarity and thus lipophilic in character.

Nonpolar organic compounds → Dipoles.

Non-shrink finish Chemical and/or mechanical process for the dimensional and form stabilization of textiles, prevention of inability to retain size and shape (shrinkage) under conditions of heat, dampness and wetness.

Above all in the case of products of regenerated cellulose, repeated swelling and drying leads to shrinkage. To a lesser extent this also applies to natural cellulose products. Fabrics and knitted goods of synthetic fibres are given a non-shrink finish by heat-setting (thermosetting). Natural silk woven fabrics (with the exception of crêpes) do not tend to shrink due to the low swellability of the silk. Woollen woven fabrics are stabilized by crabbing, i.e. treatment with boiling water or steam and subsequent rapid cooling with cold water. The non-shrink finishing processes are principally divided into mechanical and chemical processes, with the combined process also of significance. These processes not only prevent shrinking, but also give other useful usage and care properties.

I. Chemical non-shrink finishes use chemical processes to limit or remove the fibre-specific causes of shrinkage.

a) In the case of cellulose textiles, shrinkage is most closely linked to the extreme swelling behaviour of the fibres. Reduction of swelling by → Resin finishing.
b) In the case of wool textiles the shrinkage is linked among other aspects to the felting of the wool. Reduction of the felting tendency of the wool hair is achieved by using enzymes, plasma, synthetic resins, oxidizing agents; → Antifelting finish.

II. Mechanical non-shrink finishing uses physical measures in the final finishing to equalize the tensions in the fibre material caused by the manufacturing process, and to remove the foreseeable normal shrinkage which may occur during making up or use.

a) For cellulose textiles, dryers are generally used which, to a great extent, enable pre-shrinkage by tensions in the fibres caused during manufacture (width shrinkage, overfeed). → Compressive shrinkage is largely limited to cotton (→ Compressive shrinkage processes). Size changes of ± 1% after boil washing can be achieved under optimum conditions.
b) For wool textiles compressive shrinkage processes are less common, usually only used as measures for tension compensation (→ Relaxation shrinkage).
c) For synthetic fibres → Heat setting.

Non-slip finishing of carpets Best achieved, e.g. with plastics, as backing finish (→ Backcoating of carpets) or by means of sprinkler, brushing machine or spray gun. Significant as a foam coating, with waffle backing as slip protection, etc.

Non-torque yarn (torque-free yarn), a practically torque-free textured yarn of the stretch type. Produced (→ Torque yarn) by high-twisting, fixing and twisting twice in S and Z twist in a discontinuous or continuous (i.e. false twist) process or stuffer box, or blast-drawing process.

Non-uniformity Deviations or irregularities in the properties of materials, the opposite of → Uniformity. Calculated (linear non-uniformity) as average percentage deviation of the → Average value; → Coefficient of variation.

Non-wetting agent The opposite of → Wetting agent. A textile processing agent without specific capillary activity.

Nonwoven pile fabrics Textile pile goods which are not counted in the narrower classification of → Nonwovens. They have a pile which stands up from the back cloth (nonwoven or individual fibre textile), tied into the back cloth (knit or raschel process), worked into the back cloth, or bonded to the back cloth. Nonwoven pile fabrics have good pile fastness, good resilience, abrasion and tread resistance, can be cleaned. They are used in the pile fabric, furnishing fabric and floor coverings sectors.

Nonwoven quilt Thick → Nonwovens fleece for waddings, bonded by spraying mainly of acrylic polymers.

Nonwovens,

I. Textile fabrics of textile fibres in more or less random layers, which are held together by the adhesion of the individual fibres. They are categorized according to the manufacturing processes (mechanical, aerodynamic or wet/hydrodynamically formed nonwoven fleeces, → Spunbonded fabrics), according to the type of fixing (→: Needle punched felt; Wadding; Felts; Stitch-bonded pile fabrics; Knitted composites) and according to the lay of the fibres (orientated fleeces → Cross-laid nonwovens; Random webs).

II. → Bonded fabrics. In the USA they differentiate between “pure nonwovens” (see III below), i.e. “bonded fabric”, “bonded web”, “fibre fabric”, “fiberized”, and “semi-nonwovens”, i.e. all the remaining bonded fabrics. Articles may also be disposable, short-life and durable nonwovens. The choice of fibres, binding agents and processing methods is made accordingly.

One of many new developments is “Vaporweb” lightweight, breathable nonwoven produced by Reifenhäuser/TBA Nonwovens. The two companies have developed a lightweight, soft and extensible, breathable composite for use as a wet barrier in hygiene products. This spunbonded/film laminate is produced by the following method (Fig.):

- spunbonded manufacture by the “Reicofil” system (PP);
- extrusion coating of the film on the surface of the spunbonded ($CaCO_3$ filled polyolefin);

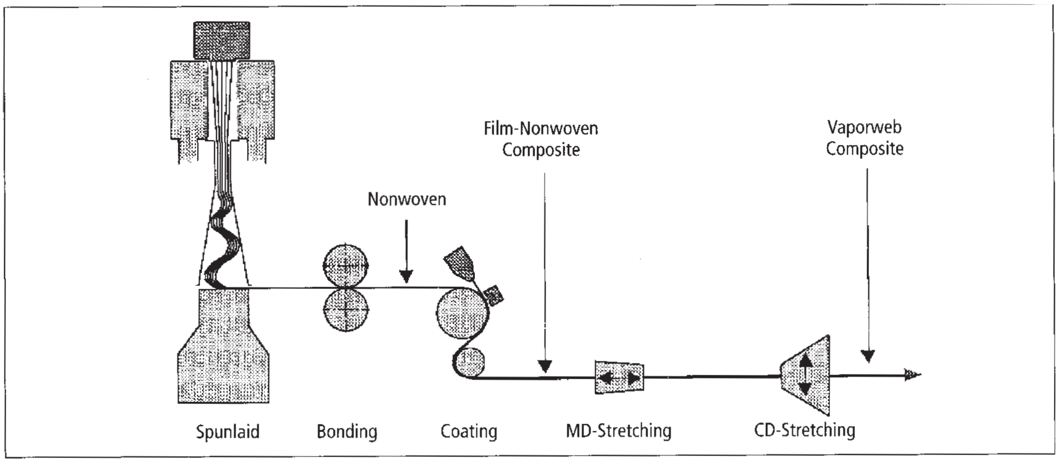


Fig.: Diagram of “Vaporweb” system design (Reifenhäuser).

- biaxial, longitudinal and lateral stretching of the composite.

The three-dimensional composite possesses the following functional characteristics:

- weight per unit area: below 30 g/m^2
- water impermeability: above 150 cm head of water
- vapour permeability: greater than 1000 g/m$^2 \cdot$ 24h.

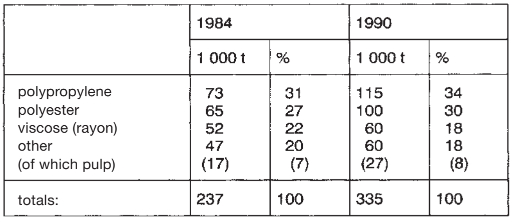
III. Textile nonwoven fabrics with additional mechanical or physical-chemical fixing (DIN 6210). From the material feed (fibre blend) to the finished product, all processes are carried out continuously on nonwoven manufacturing lines at speeds of around 120 m/min. Reinforced nonwovens contain, e.g. yarns, woven or knitted fabric or net inserts (stitch-bonded nonwovens, knit bonded nonwovens, pile nonwovens, etc.). Nonwovens which are too stiff are slit (Breveteam process). Applications (Tab. 1): interlinings, household articles, needle-punched carpets, hygiene nonwovens, technical articles, etc.

process	production article
mechanical formation	nonwoven coatings nonwoven linings filters and felts nonwoven padding floor coverings domestic goods hygienic nonwovens medival nonwovens
aerodynamic formation	nonwoven coatings nonwoven padding industrial wadding
hydrodynamic formation	nonwoven coatings disposable goods special papers
spun nonwovens	nonwoven coatings book covers nonwovens for decoration nonwoven linings backing for tufted piles nonwoven reinforcings technical nonwovens nonwovens for clothing hospital nonwovens

Tab. 1: Uses of nonwovens according to type of manufacture (according to Enka).

The type of fibre has a substantial influence on the properties of the nonwoven. It is evident that a long "average free fibre length" will lead to a more fibrous, textile nonwoven than a small one. In addition to the bonding points, the fibre itself is of importance in connection with the nonwoven bonding. In the case of smooth fibres the free fibre length is naturally less than crimped fibres. In high-density nonwovens it is also less than in lower-density ones. In the case of parallel nonwovens the free fibre length is also less than in the case of random-fibre nonwovens, as there are very few fibre crossover points; rather the fibres lie more or less parallel to one another for their full length, promoting the formation of more extended, thinner bonding films. The ratio of the average distance between two bonding points and the free fibre length affects the properties of the nonwoven. In the case of smooth fibres this ratio will approach 1:1; in the case of crimped fibres, depending on the intensity of the crimping, it will vary substantially. The greater this deviation, the more flexible the nonwoven will be, as the fabric has to undergo extensive stretching before the fibres are fully extended between the bonding points. This also means that the deformation only starts at an extremely late stage at the bonding point itself. If the fibres referred to have a fixed crimp, the stress-strain diagram has a high value of elasticity, independent of the elastic properties of the bonding agent.

The most significant fibres are polyamides, polyesters, bicomponent fibres and for special purposes also natural fibres (and blends) (Tab. 2).



	1984		1990	
	1 000 t	%	1 000 t	%
polypropylene	73	31	115	34
polyester	65	27	100	30
viscose (rayon)	52	22	60	18
other	47	20	60	18
(of which pulp)	(17)	(7)	(27)	(8)
totals:	237	100	335	100

Tab. 2: Fibres used in nonwovens (West Europe).

The basic difference between woven, knitted and braided fabrics, felts and other usual fabric types on the one hand, and nonwovens on the other, is the way they are held together. In the case of classic textile fabrics it is the friction between the individual fibre surfaces which ultimately holds the fabric together. The difference between the ways that classic textile fabrics and nonwovens are held together is the reason for the differences in mechanical behaviour between the two groups. So it can be said as a broad generalization that the flexibility of nonwovens is not as good as that of the woven, knitted, etc. fabrics. In the case of classic textile fabrics, in order to change the shape, e.g. creasing, a force is required which can overcome the friction between the fibres. Once the desired shape is achieved, the fabric remains in its new shape, as the individual fibres have been pushed against one another and now the same force has to be overcome to return them to their original shape.

In the case of nonwovens the force applied to change the shape must overcome the shear forces in the bonding agents and fibres. It is not possible to push the fibres against one another, as all the individual components of the nonwoven are held in their relative positions by the fixing process. A change in this arrangement would lead to destruction of the fabric. Because of the shear forces the "bent" fibres and bonding points caused by a change in shape seek to return to their original positions. Any change of shape to a nonwoven is therefore temporary, as it returns to its original shape with greater or lesser speed, as soon as the force causing the deformation is reduced or removed. A permanent deformation of the nonwoven is only possible by folding similar to the creasing in paper, which leads to a gradual deterioration of the nonwoven in the area around the crease.

Nonwovens manufacture Nonwovens are layered and mechanically or physico-chemically strengthened textile fabrics made of fibrous web. Using layering apparatus, the desired fabric weight is achieved by combining as many fibrous webs as necessary, which have been taken from several strippers (Fig. 1). This varies depending on the intended use between 15 g/m^2 (e.g. for so-called disposable textiles) to over 1000 g/m^2 (e.g. for floor coverings). Nonwovens manufactured from fibrous webs which are only combined lengthways have low lateral strength. Cross-laying is therefore used for articles subject to stress in all directions, i.e. strippers positioned diagonally to the direction of the web form other fibrous webs which are overlapped across the original web using layering devices as this moves past on a conveyor belt.

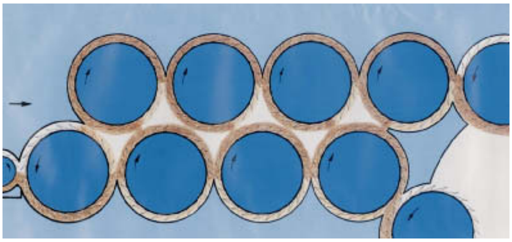


Fig. 1: Stripping the fibres for forming the nonwoven fabric (Turbo Lofter by Spinnbau Bremen).

The manufacture of fibrous webs therefore begins with the arrangement of the fibres being either flat or bulky. These may consist of staple fibres or filaments

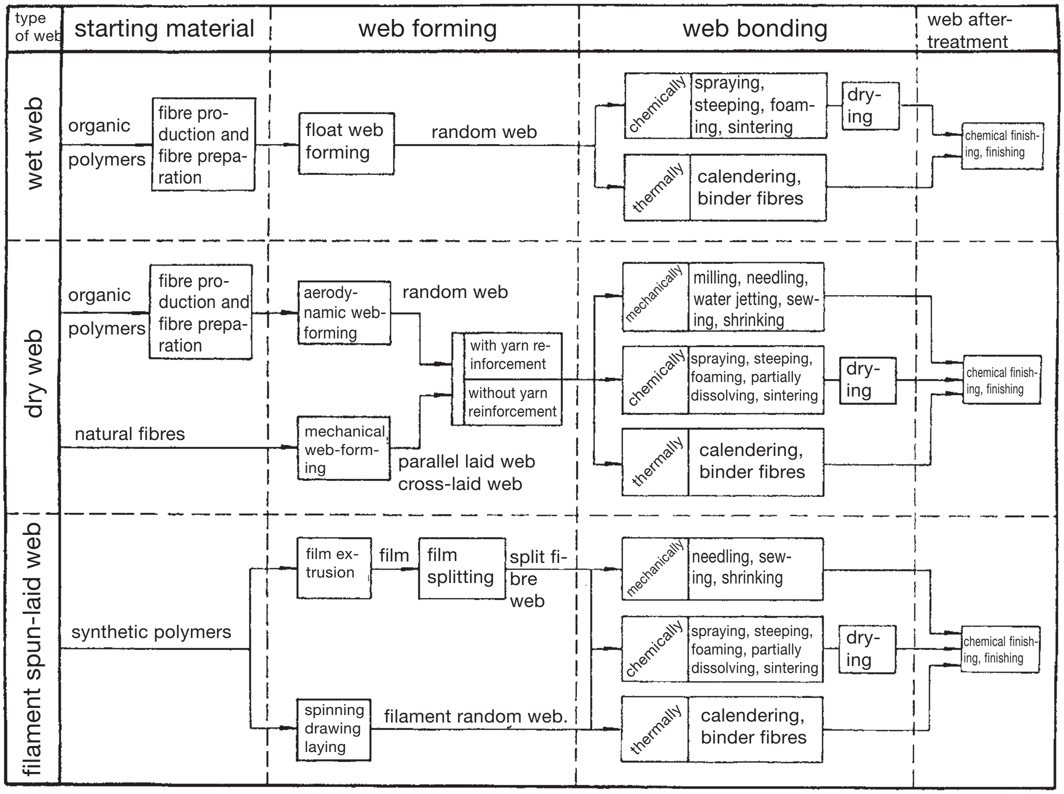


Fig. 2: Processing stages of various web forming processes (modified Bobeth diagram).

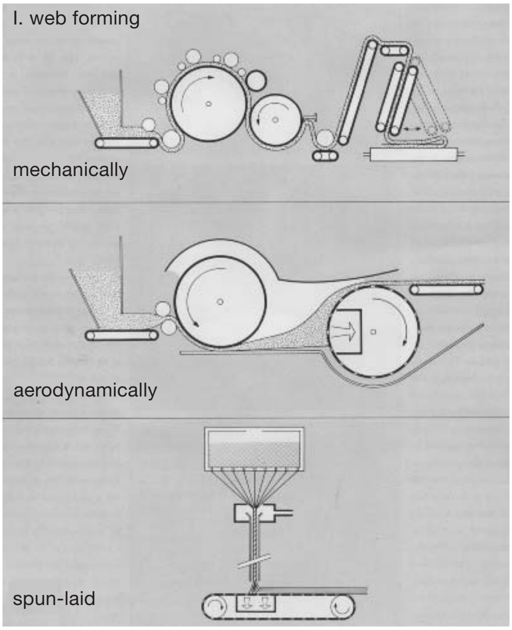


Fig. 3: Web-forming methods in accordance with the dry process (Groz-Beckert).

which are spun from melted polymer granulates. There are four different ways of forming a web (Fig. 2). Nonwovens are generally named after these methods (dry-laid manufacturing system, wet-laid manufacturing system, spunbonding method, other methods such as e.g. melt-blown); both aerodynamic web formation and the mechanical process are also important (Fig. 3). These processes, together with the formation of spun-bonded nonwovens, are classed as dry-lay processes, which should be distinguished from wet-lay processes (Fig. 4).

With nonwovens, the adhesion between the fibres or between the binder and the fibres is the base of the internal cohesion of the fabric. The smallest unit to determine the strength of nonwovens is the individual bonding point between two fibres (Fig. 5). A bond always signifies that the surfaces of two bodies have converged so closely that they form an interface. In order to enable this type of intensive contact, it is necessary for one of the bodies at least to be in a liquid state. The energy equation for this type of system is:

$$\Delta U_A = \Delta U_{S1} + \Delta U_{S2} - \Delta U_{S1S2}$$

U_A = adhesion energy,
S1 = solid,
S2 = bonded glue or melted, resolidified fibre,
S1S2 = interface.

The adhesion is independent of the surface properties of the substrate to be bonded and of the wetting angle of the liquid which wets them. As the adhesion between the binder and fibre or between melted and solid fibre during thermal strengthening is actually the basis for the inner cohesion of the nonwoven, the surface properties of the fibres are extremely significant. The larger the surface, the greater the adhesion. The fibre surface is not only significant for the bonding of the fibres in terms of its apparent size (round or x-shaped cross section), but also in terms of the capillary action which it may exercise on the bonding agent, thereby considerably increasing its actual effect. This type of effect occurs on substrates with a barky fibre sheath or a spongy surface.

Nonwovens are strengthened using the following methods:

1. bonding the fibres by printing, spraying, impregnating with binders (elastomers, bonding fibres, plastomers).
2. heat bonding (fusion) of thermoplastic fibres (binder fibres, e.g. made from copolymers) using the effect of heat.
3. heat bonding the fibres by spraying on binders using the effect of heat.
4. needle punching the nonwovens together (needle-punched felt).
5. fibre shrinking using the effect of heat and/or swelling agent.
6. effect of liquid jets.
7. etching, using admixes of soluble binding fibres, e.g. alginate fibres, bicomponent fibres, copolymer fibres, mixed polymer fibres, vinylal fibres.

Needle-punched nonwovens (also incorrectly referred to as needle felt) are obtained by inserting notched needles into the fibrous web (Figs. 6 and 7). If needles are used which are only effective for rehooking in one direction, fibres are also only pushed through the fibrous web in one direc-

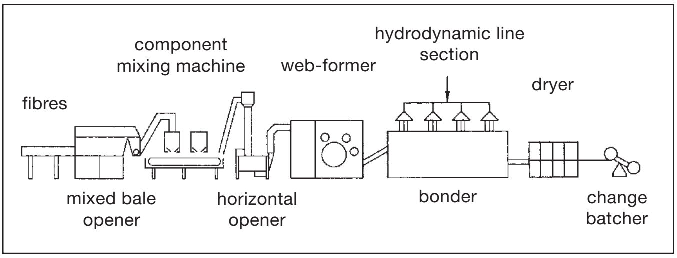


Fig. 4: Web-forming by the wet process (Wiesenbader).

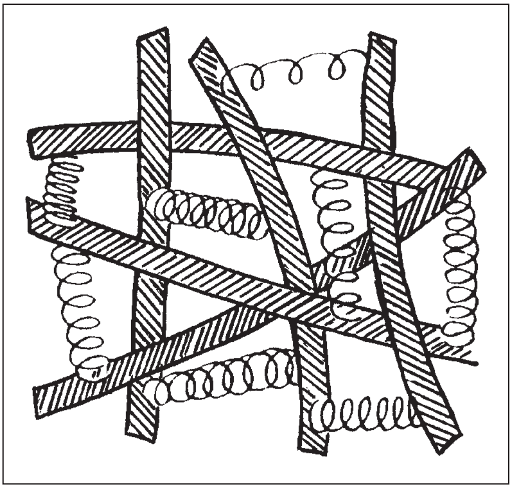


Fig. 5: Fibres in the ideal case with elastic bonds (by Enka).

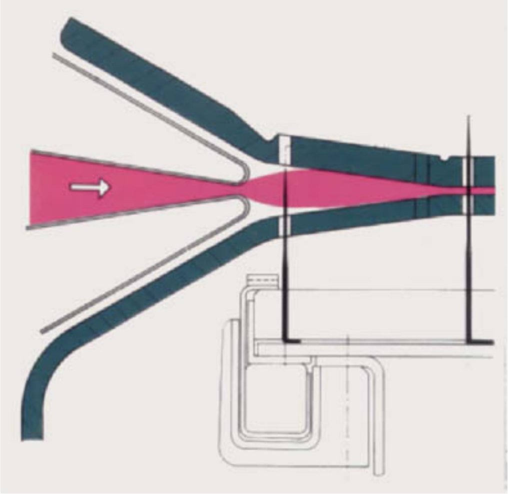


Fig. 6: Preneedling of the nonwoven fabric (by Asselin).

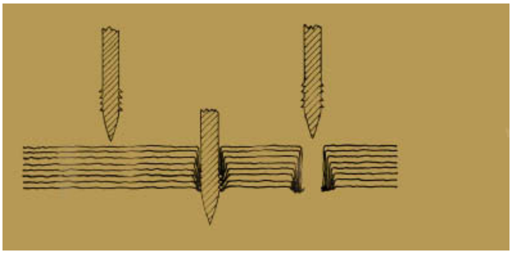


Fig. 7: Diagram showing the needle-punching of the fabric (by Bayer).

tion; the surfaces therefore have a non-uniform appearance. Strengthening is achieved as a portion of the fibres is pushed through the web itself and through the reinforcement fabric. Fibres from the fabric system are not incorporated into the web however, as this would cause a tendering of the reinforcement fabric (Fig. 8). The greater the number of needle holes per surface unit, the more intensive the strengthening achieved in this way. It must be noted that with a given fibre material, specific needles, constant nonwoven weight, etc. the strengthening can only be achieved up to a specific maximum. If this limit is exceeded, the effect is reversed: the nonwoven is “deneedled”, and this may in some circumstances result in the total disintegration of the nonwoven.

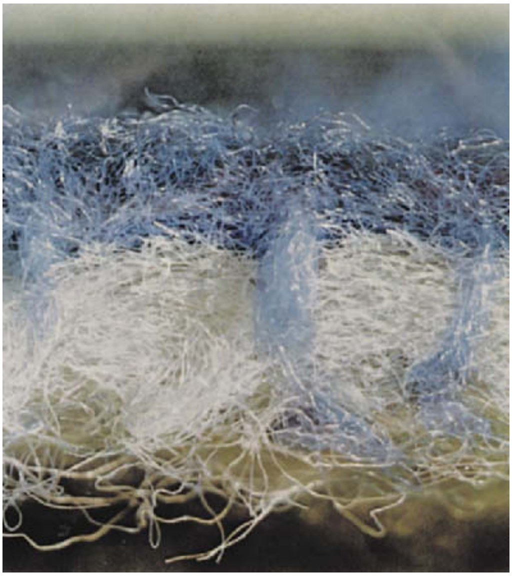


Fig. 8: Cross-section of a needle punched nonwoven fabric. Top layer Cuprama SK dyed. Base layer Dralon N (by Bayer).

The finer the needles and the fewer barbs they have, the higher the number of possible needle insertions per surface unit, if the maximum strengthening is to be achieved. The fineness of the needles also determines the character of the surfaces of the needle-punched nonwovens to a large extent. The selection of needles is dependent on the type of fibres to be needle punched. E.g. coir fibres are only strengthened with coarse, ultra-fine fibres using only very fine needles. Extremely hard needle-punched nonwovens or needle-punched felts are manufactured from ultra-fine fibres using extremely fine needles.

As it is impossible to achieve high-tenacity, hard and relatively dense products in this way in a single process, another method is used. The initial web is needle punched and an additional fibre web is needled onto this strengthened material. This process is continued until a product of the desired hardness, thickness and appropriate weight has been produced (Fig. 9). Where shrinkable fibres are used, additional compression can be achieved by a subsequent shrinkage process.

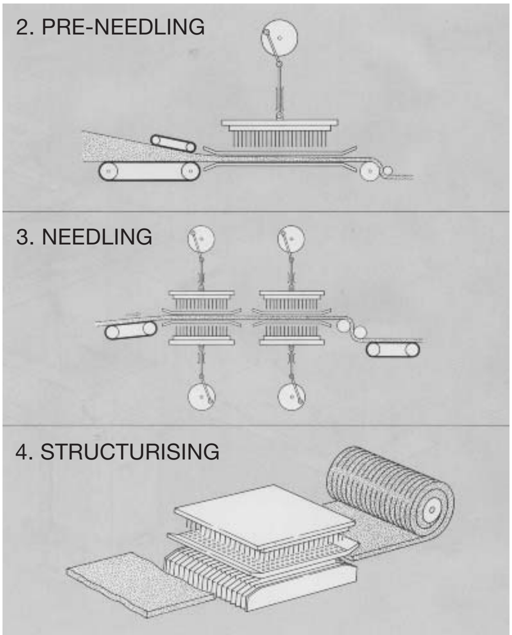


Fig. 9: Web needling for the purpose of mechanical bonding (Groz-Beckert).

Fibrous webs aligned in the machine direction can be better needle punched than those where the orientation runs transversely. The arrangement of the needles in the needle bed plays a crucial role here. In general, random webs cannot be needle punched as well as carded webs, as the proportion of fibres standing vertically in the web or the fibre lengths in the web which are required for strengthening using needling is not sufficient. It is difficult to catch these fibres with the barbed needles, and they therefore only form filling material in the finished needle-punched nonwoven.

Strengthening of the web is therefore an essential stage in the production of nonwovens. The choice of the web strengthening process is just as important in terms of the subsequent functional properties as the selection of fibres used. A distinction is made between three principal strengthening processes:

- chemical,
- thermal and
- mechanical strengthening.

It is possible to combine these types of strengthening. For nonwovens which are strengthened with thermoplastic fibres (thermal strengthening) or with chemical binders (binder strengthening), following carding and if nec. needling or other web formation techniques (wet, aerodynamic, spunbonded), synthetic fibres are mainly used.

Thermal strengthening takes place either on calendars or on sieve-drum driers as hot air fixation units, depending on the product. The type and proportion of thermoplastic fibres is set depending on the use (the proportion of thermoplastic fibres is generally in the region of 10–50%, 5–10% where prestrengthening occurs, and even up to 100% depending on the intended use of the nonwovens).

In addition to strengthening by heat bonding thermoplastic fibres, compressing swollen fibres is standard, as both of these manufacturing methods result in similar conditions in the finished nonwoven as fibrous webs strengthened using binders. Fibrous webs which consist entirely or partly of thermoplastic fibres can be strengthened using the effect of heat. The simplest method is formed by a passage between heated calendar rollers (Fig. 10). This method provides papery fabrics. Embossing rollers in a wide variety of sizes offer

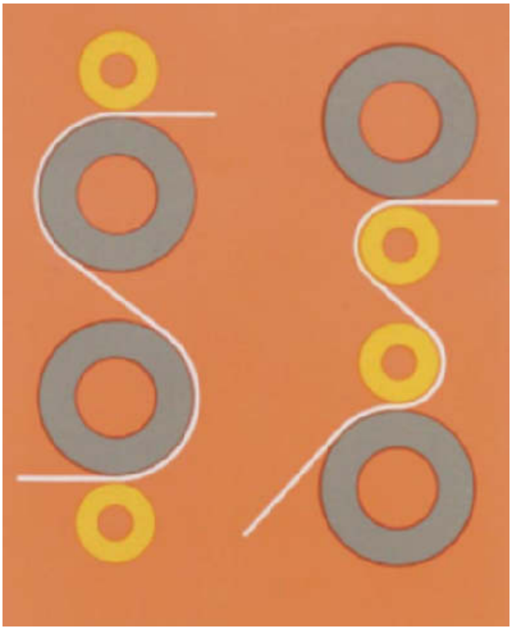


Fig. 10: Four-roller nonwoven calender by Kleinewefers KTM for thermal nonwoven bonding.

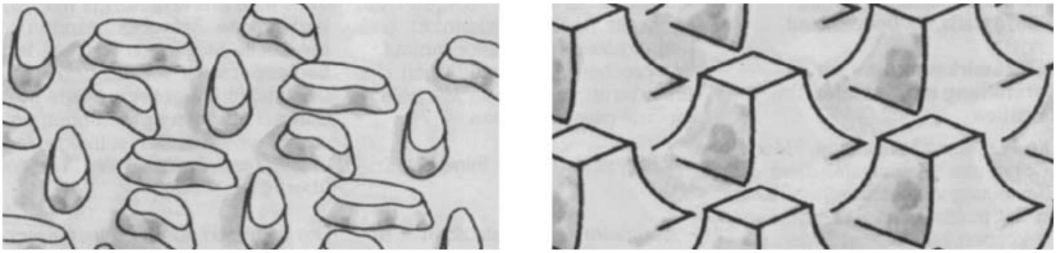


Fig. 11: Nonwoven bonding with embossing cylinders by Overbeck, Krefeld, Germany.

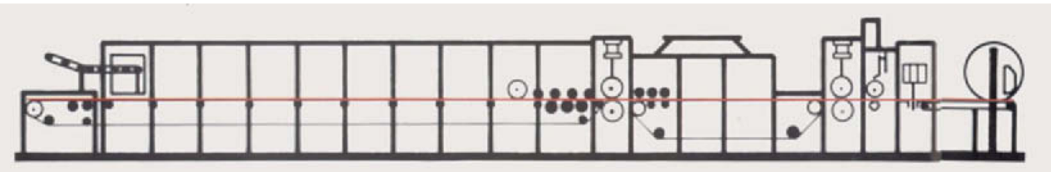


Fig. 12: Special thermobonding plant by Mohr set up as a perforated screen drier.

advantages in terms of web volume (Fig. 11) for all areas of application such as paper, nonwovens, cloth or leather.

If a felt calendar is used, where heat treatment occurs at extremely low pressure, a strengthened form is obtained without significantly reducing the volume of the finished product. There is also the possibility, in addition to the methods mentioned, of guiding preneedled nonwovens through a stenter frame at low tension. As only negligible pressure is exerted on the fibres during the heat treatment, a high volume nonwoven is obtained. The tension ensures that the fibres converge sufficiently closely together to guarantee good heat bonding between them. An alternative is the perforated conveyor drier (Fig. 12).

Compressing swollen fibres takes place in a similar way to heat bonding. The process simply takes place at lower temperatures, often at room temperature. Higher temperatures are used if the swelling agent or solvent is to be evaporated at the same time as compression. Often, the heat bonding and swelling process are combined, e.g. when compressing acetate fibres at higher temperatures following wetting with a small quantity of acetone. If cellulose which has been swollen in caustic soda liquor is used, a considerably higher degree of swelling is achieved below 20°C than at higher temperatures. The properties of the finished nonwoven are comparable to those of heat-bonded nonwovens.

Fibrous webs strengthened with binders are bicomponent systems. With heat-bonded or pressed nonwovens, the fibre acts as its own binder. However, it must not be forgotten that the swelling process or thermal treatment causes a modification of the fibre. It is always most likely that the degree of crystallinity of the fibres will be altered – reduced. The change to the fibre properties does not occur evenly – it is greater at the actual point of heat-bonding or bonding points than in the areas of the fibre which still retain their linear structure after the treatment. The term “bicomponent systems” can therefore also be applied to these nonwovens which are homogenous within themselves. The properties are extremely similar in the individual “components” (Tab. 1) and do not vary as much as fibrous webs strengthened using binders (Tab. 2).

high-pressure polyethylene	85–115˚C
low pressure polyethylene	126–135 ˚C
polypropylene	140–170 ˚C
polynitrilchloride	115–160 ˚C
copolyamide	110–140 ˚C
polyamide 6	170–225 ˚C
polyamide 6.6	220–260 ˚C
polyester	230–260 ˚C
Kodel 410 (Eastman)	85–170 ˚C
Dacron 927, 923, 920 (DuPont)	160–180 ˚C
Trevira 813 (Hoechst)	210–225 ˚C
bicompositional heterofil polyamide	220–230 ˚C
bicompositional heterofil polyester	170–230 ˚C

Tab. 1: Binding temperature zones for some important connecting fibres.

Special cases of the fibre/binder/fibre systems include: strengthening fibrous webs with binders polyacrylonitrile using polyamide 6, polyamide 6.6 using polyamide 6 or heat bonding using thermoplastics which are incorporated into the nonwoven in powder, sheet or flake form (Fig. 13). In line with the latest technology, however, fibrous webs are predominantly

Tab. 2: Influence of frequently used binding agents on the characteristics of nonwovens (by Enka).

binding agent	handle	elasticity	resistance to				other
			ageing	light	dry cleaning	laundering	
natural rubber [1]	soft	very good	moderate	moderate	moderate	very good	
nitrile-butadiene rubber [2]	soft	good	very good	very good	very good	very good	
styrene-butadiene rubber [2]	firmer	moderate	poorer than with nitril-butadiene rubber			very good	
acrylic acid ester copolymers [2]	dependent on construction		very good	very good	very good	very good	
polyvinylchloride [3]	firm	brittle/rough	good	good	swells	very good	can be HF welded and hot sealed, is flame retardant
polyvinylacetate [3]	firm	brittle/rough	good	good	not resistant	moderate	can be HF welded and hot sealed

[1] vulcanized [2] cross-linked

[3] requires combination with softeners or inner softening through copolymerization

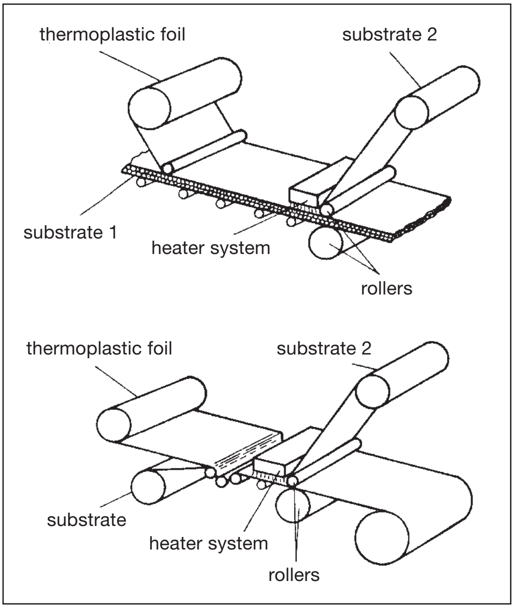


Fig. 13: Different methods of fastening nonwovens using melt foil (by Enka).

strengthened into nonwovens with binders which are available in the form of aqueous dispersions.

Nonwovens, shrunk Produced from nonwovens. Fixed by the effects of media which cause shrinkage (heat, chemicals).

Nonwovens with bilateral web Non-woven double-sided pile or loop fabrics of mechanically pre-fixed (needle punched) and additionally fixed nonwoven fleeces. The double-sided interweave of the fibres gives the substantially reduced fibre base layer relatively high strength, which can be increased even further by means of chemical or thermal binding agents. Up to 70% of the above fleece fabrics can be used for pile binding; pile height up to 18 mm per surface. Fibre tufts or loops then protrude vertically from the base layer in linear arrangement. Nonwoven fleeces of different colours can be used to produce interesting visual effects.

Nonwoven waddings For fills or waddings in all areas of clothing or textiles. Since the 1960s, synthetic fibre nonwoven waddings have replaced the grey wadding made from glued reprocessed yarns; moreover, they can be used for a far wider range of applications. Production: having formed a nonwoven fleece by carding, the fibres are pre-fixed by needles. The loose nonwoven fleece thus formed is sewed onto a textile base applied from below; in addition, the fibre stumps formed by the needle punches penetrate the textile fabric and it is usually “stitched”. It is easily observed that such nonwoven composite fabrics differ in their essential properties from nonwoven waddings (without backing material). This applies in particular with regard to the mechanical strength and the handle; however, it is sought to maintain the volume. The full bonding of the needled nonwoven fabrics is done using chemical or thermal bonding. The vast majority of the nonwoven fabric is bonded using binding agents, applied using aqueous dispersion. During production, first one side and then the other side of the fabric is sprayed and then dried. Condensation takes place immediately thereafter.

The chemical industry produces a range of binding systems suitable for nonwoven waddings, e.g. on the basis of (cross-linkable) butadiene styrenes, polyvinyl acetate, polyester or melamine resin. Those based on acrylic resin have proved particularly useful. There is a range of types of these to satisfy practically all requirements. Chemically, they are cross-linkable polymers on the basis of acrylic ethyl esters and butyl acrylates; they vary from extremely hard to very soft (adhesive). The binding agent strength (cohesive strength) is equal to the mechanical strength which the binding agent displays when subject to a particular load. This property is of particular importance in connection with the cleaning processes to which the nonwoven wadding may be subjected; it is in inverse proportion to the swelling capacity. In general it is the case that the harder binding agents show less marked swelling behaviour than the soft. Binding systems may be tested and evaluated for their specific swelling capacity, having regard to the optimum technology for the application. This is usually done using cast films which, using the parameters of temperature and time are subjected to simulated washing and cleaning processes. After drying the swelling subsides; however it must be assumed that binding agents which show marked swelling are not fully restored to their original cohesive strength or adhesion to the fibres.

With thinner nonwoven waddings, bonding fibres which provide an adhesive fibre-to-fibre bond are widely used. Bonding fibres (either in the form of fusible fibre or bicomponent fibres) provide thermal adhesion from their own substance. When heat is applied they become thermoplastically adhesive or melt. It is essential that whilst in this state they come into contact with one another and with the wadding, to ensure wetting. On cooling, they solidify, and an adhesive bond is produced. In the case of thin nonwovens, the contact is assisted by applying high mechanical pressure, e.g. by means of calanders. This method is not practical for nonwoven waddings, as the specific thickness needs to be maintained. In this case, the bonding fibres are used differently: the fibres are combined with approx. 10-30% bonding fibres. This is very expensive, as the mix must be absolutely homogeneous. After formation of the nonwoven fabric the material is lightly needled where appropriate and then subjected to thermofusion in a hot-air channel. The temperature applied here must be very precise, with a tolerance of ± 5°C, in order to avoid, for example, uneven shrinkage and to achieve an even bonding.

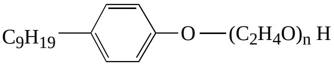
Thermofusion uses low-level forced convection of the air through the fabric from above. Factors are:

– the temperature used,
– the temperature generated in the nonwoven fabric,
– the dwell time.

At the exit to the channel, the final process is the calibration of the nonwoven, still thermoplastically malleable, under minimal pressure between cooled rollers (according to Eisele).

Nonwoven, wet-laid → Nonwovens of short-staple polymer fibres, produced by spraying from spinning nozzles (polymer solution or melt) onto, e.g. perforated conveyor belt. Used for filter mats, insulation purposes, etc.

Nonylphenolpolyglycolether,



A product of addition of ethylene oxide to nonylphenol (→ Polyglycol ethers). A washing and wetting agent.

Normal humidity → Air humidity.

Normality → Gram equivalent per l solution; → Normal solutions.

Normal pressure → Air pressure.

Normal solutions Solutions with precisely determined contents for titration. The 1/1 normal solution (1 n solution) contains the → Gram equivalent or val of a chemical substance dissolved in precisely 1 l distilled water. 1 gram equivalent or val hydrochloric acid thus equates to 36.47 HCl, 1 gram equivalent or val sodium carbonate to 53 g Na_2CO_3. Both these quantities by weight when mixed will lead to mutual neutralization and produce neutral reacting sodium chloride, NaCl.

$$2\ HCl + Na_2CO_3 \rightarrow 2\ NaCl + H_2O + CO_2$$

If 1 gram equivalent or val is dissolved in 1 l water, this gives the normal solution. For a given acid, it is always of the same acidity, as it will always be of the same acidity for a given alkali. It therefore follows that every unit of a normal solution of any acid must also correspond to the same unit of any alkali for neutralization. Used in → Titration. Titration with normal solutions determines the potential → Hydrogen-ion concentration (practically equal in all acids), in contrast to the pH measurement, which determines the actual hydrogen ion concentration (dependent on the relevant level of dissociation).

Norsk Tekstilforskningsinstitut Norwegian textile research organization; → Technical and professional organizations.

$(NO)_x$ Nitric oxides which are generated by combustion processes at high temperatures. 90% of the pollutant particles in the atmosphere derive equally from traffic emissions and large-scale furnaces in heavy industry. Only approx. 8% derives from direct chemical production. In addition to benzpyrene, $(NO)_x$ play a substantial part in the combustion of natural gas. Like SO_2, these compounds are significant in smog formation. Sunlight causes them to split off reactive oxygen, enabling the formation of dangerous oxidants. NO_2 can be oxidised in air to N_2O_5, which forms nitric acid with water vapour. Precipitation contaminated with this acid contributes to acidification of the soil and surface waters. Nitric oxides from nitric acid production with amine components can be converted into carcinogenic nitrosamine compounds. Above all the burning of fossil fuels leads to the oxidation of more carbon and sulphur as well as nitrogen, the last particularly in internal combustion engines and thermal power stations. The majority of the main and subsidiary components of the atmosphere (O_2, N_2, CO_2, CO, NO, NO_2, SO_2, CH_4) form part of cycles, which are controlled by biological reduction and oxidation processes (photosynthesis and respiration, and their secondary or consequent reactions). At present, however, in industrial countries, there is an increasing tendency for the civil energy flux to be higher than the biotic. The gas and aerosol components come from various photochemically catalyzed oxidation processes. The reaction times for the oxidation of SO_2 mean that the more significant sulphur compounds remain in the atmosphere for max. of a few days; this corresponds to travel distances of a few hundred to over a thousand kilometres. The oxidative formation of HNO_3 takes place somewhat faster.

$(NO)_x$ can be reduced to nitrogen within furnaces (see Fig.) by ammonia (conproportioning):

$$(NO)_x + NH_3 \rightleftharpoons N_2 + x\,H_2O$$

Noxious (Lat.: noxa = injury), a generic term for substances used in the workplace which have a harmful effect on humans, which are not toxic (→ Toxic substances), but which nevertheless have a harmful effect on health or may affect performance. Of particular interest to methods engineers are non-toxic dusts, e.g. textile dust and dirt.

Nozzle-Test Used for the evaluation of the handle of textiles, in which the test sample is drawn through an eyelet.

NP Norma Portuguesa Definitiva; Portuguese standard.

Np Chemical symbol of Neptumium (93).

NRC “National Research Council”, Canadian textile research organization; → Technical and professional organizations.

NS Norsk Standard, Norwegian standard.

NSO Norwegian standards organization; → Technical and professional organizations.

NT Nederlandse Textielinstituut, successor organization to the NVTC, member of the → IFVTCC. → Technical and professional organizations.

NTV-process (low-temperature dyeing process). The dyeing of polyamide carpet piece goods on a winch beck at temperatures below boiling point (e.g. 70–80°C).

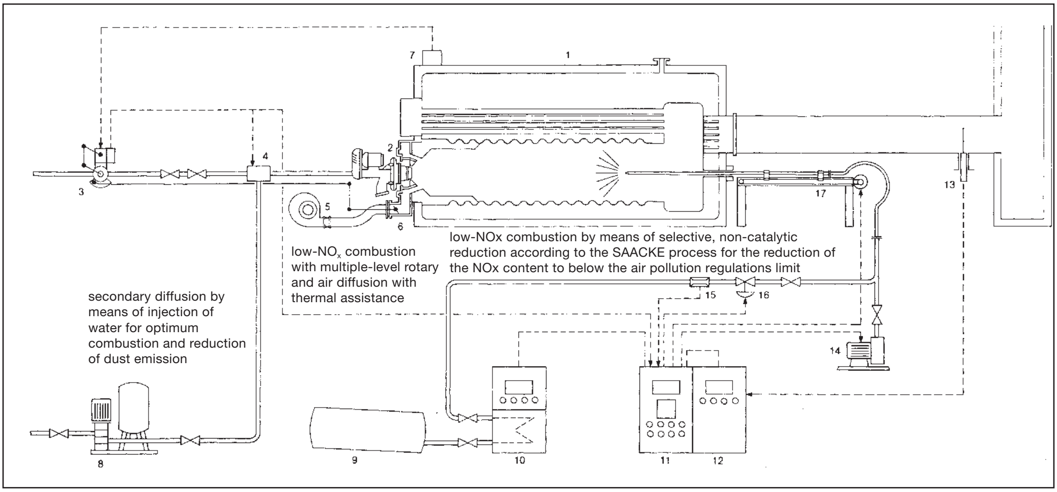
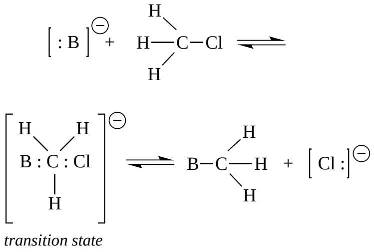


Fig.: Diagram showing a heavy oil rotary diffuser furnace with water injection and secondary measures for NO_x reduction (Saacke, Bremen).
1 = boiler; 2 = Saacke burner; 3 = compound control with servomotor and position indicator; 4 = fuel oil / water mixer; 5 = combustion air fan; 6 = combustion air flap; 7 = boiler control; 8 = water propulsion plant; 9 = ammonia storage container; 10 = Evaporator system; 11 = microprocessor-controlled ammonia control; NO analysis system; 13 = NO measurement sensor; 14 = air fan; 15 = ammonia volume measurement; 16 = ammonia control valve; 17 = ammonia jet lance with programme device.

Nucleophilic reagents

Nucleophilic reagents If an ion or a compound with electron donator properties is sterically able to approach a homeopolar bond weakened by polarization, displacement reactions are possible (see Fig.).



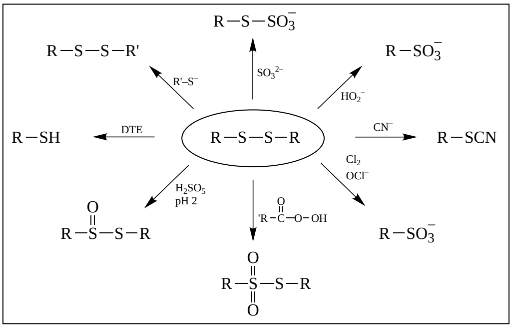


Fig.: Selection of different nucleophilic reactions of cystine sulphur.

Nuisance factor (NF). According to the waste water laws, the sum of the “nuisance proportion factors” for substances capable of precipitation (P), chemical oxygen demand (COD) and toxicity (T). The given quantity of waste water is multiplied by NF to obtain the value of the → Pollution index. → Waste water evaluation.

NZ → Sodium number.

NZSR New Zealand Standards Recommendation; the New Zealand standards mark.

O

O Symbol for the element oxygen (8).

o- → Ortho-.

Objectives of textile finishing In order to establish the sequence of operations for an article which is to be finished, first of all the target properties must be known. Depending on the use to which the finished article is to be put, different factors can determine the quality. The target properties can be divided into the following groups:

I. Visual appearance (eye)
II. Tactile appearance (hand)
III. Smell.
IV. Technological properties.
V. Environmental compatibility.

I to III belong in the subjective domain, and IV and V in the objective domain.

In the case of fashion articles, the emphasis is clearly on subjective visual appraisal (I). Usually one speaks of "attractive appearance, even finished quality, balanced design, level appearance, elegant drape", etc., i.e. evenness or unevenness in the sense of harmony or disharmony is a subjective measure of appearance. This evenness is the sum total of partial aspects, e.g. evenness of dyeing, of the fabric surface (geometrical structure), the thread distribution (thread structure), the surface structure (lustre), etc. All these partial factors thus form the totality of target characteristic I. Shade conformity (according to the reference specification) is a prerequisite; however, in connection with the appearance of the goods, it plays an important role in the overall impression.

The visual impression is followed by the handle (II). This characteristic is determined by the following factors:

- surface structure (lustre),
- stiffness (geometric structure, finish),
- thread distribution,
- thickness, etc.,

with the stiffness in turn also affecting the appearance (I), when one considers the suppleness, i.e. draping. Various factors thus influence the target characteristics I and II. If one orders the parameters and weights them with regard to target characteristics, a ranking results, depending on the article, e.g.:

1. geometric structure (incl. weak pleats, folds).
2. dyeing (cloudiness, skitteriness, etc.)
3. surface structure (lustre)
4. stiffness (finish)
5. thread distribution.

The ranking of factors can thus vary from article to article, since the target characteristic can only be evaluated subjectively, and people evaluate the influencing factors as an integrated target variable.

Furthermore, smell (III), e.g. the fish odour from resin finishing, and the technological data (IV), also play an important role. Usually, however, the technological data (IV) assume a secondary status, particularly in the fashion area, i.e. only when the first three areas have been fulfilled do they become co-determinants for the "quality" of the end result. A fabric with an uneven dyeing result (e.g. changes in shade from selvedge to centre) is generally not accepted, no matter how good the washing fastness of the dyeing. For the rest, the technological data such as tear strength, colourfastness, etc. depend predominantly on the substrate (material, dye) and on the process techniques of the individual operations, and therefore can be measured objectively. Increasingly, the environmental friendliness (V) of processes and products are the prime focus of interest. The aim should be to undertake ecological audits which attempt, viewed integrally, to weight all the influences in the overall production pipeline. (Source [in parts]: Loss).

Oblique-flow driers In conventional oblique-flow driers, after impinging on the goods in the space between the cloth and the nozzle boxes, the hot air emerging from the nozzles flows to the side, to the exhaust air ducts. The reversal of the direction of flow (Fig. 1) produces special aerodynamic conditions which affect the exchange of heat and substances. Heat exchange is accelerated, whilst substance exchange suffers under these conditions. For this reason, drier designers try to keep the route of the cross-flow exhaust air as short as possible by sub-dividing nozzle boxes, and to extract the heating medium directly after the cloth has been heated, via continuous extraction ducts (Fig. 2).

Connected nozzles of older driers, in which the hot air is supplied perpendicular to the run of cloth and the exhaust air is extracted laterally at the walls of the

Oblique-flow driers

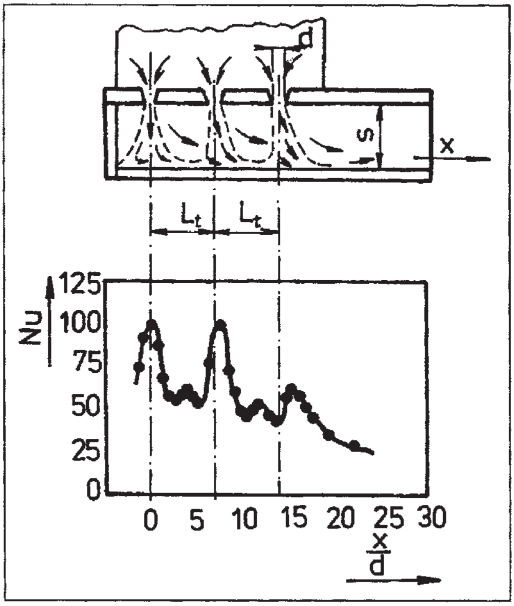


Fig. 1: Heat transfer caused by the crossflow in oblique-flow driers.

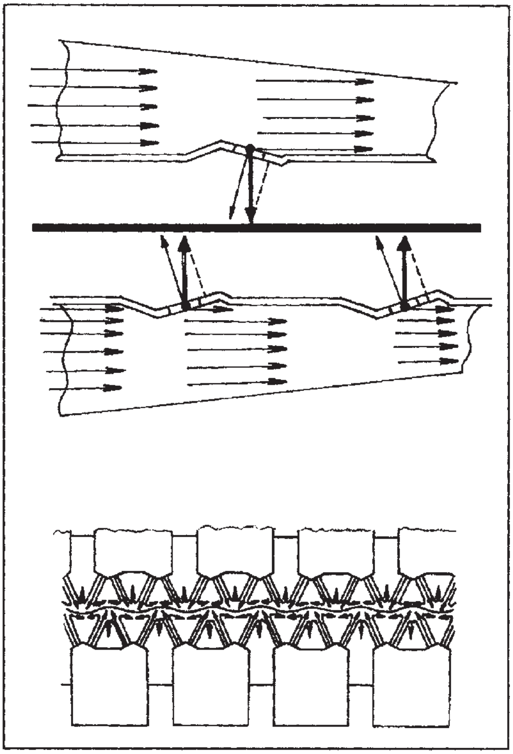


Fig. 2: Nozzle system with separate jet chambers (Krantz).

drying chambers, are no longer built. Compact nozzles still exist, but here too, the exhaust air is extracted directly in the blast zone.

The significance of turbulence lies in the following: the intensity of the substance exchange is influenced primarily by the transport coefficient in the flow field or in the zones subjected to the heating medium. The coefficient in turn is determined by the interaction of turbulence and flow rate of the impinging hot air. Alea (Italy) (Figs. 3 and 4) uses e.g. a parabolic profile of the hot air flow emerging from the nozzles, which is created with the aid of longer pipes in the nozzle system (Fig. 5).

Mixing the hot air flow with the ambient air increases turbulence, particularly at the walls of the drying chambers. This so-called “laminar” airflow system yields a considerable improvement in substance

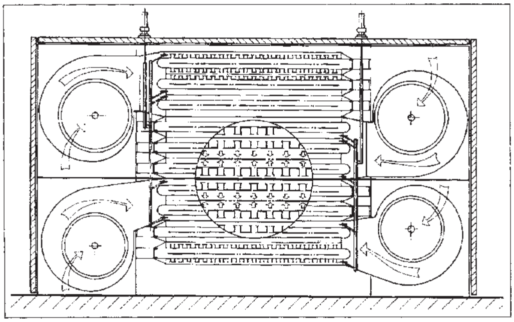


Fig. 3: Cross-section of a drier by Alea (Italy).

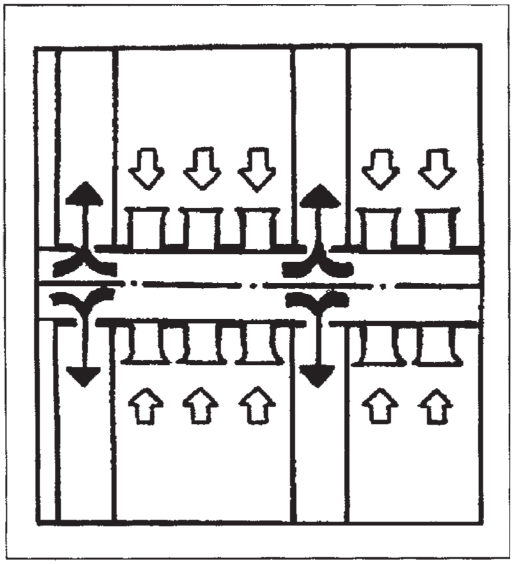


Fig. 4: A detail of the Alea system (Italy).

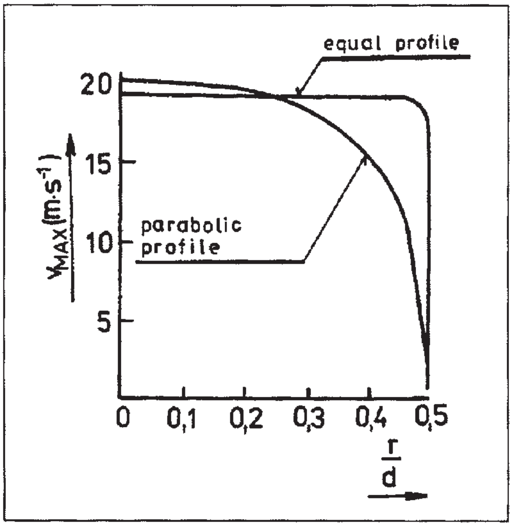


Fig. 5: Comparison of the flow velocities at the nozzle mouth for hot air streams having a parabolic and a cylindrical profile.

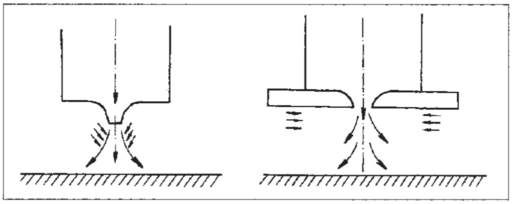


Fig. 6: Two types of nozzle.

exchange, i.e. by 30% in the slotted nozzles, and even up to 100% in the circular nozzles. The way in which the flow of hot air emerging from the nozzle outlets mixes with the ambient air is important. Mixing with the ambient air must take place directly at the nozzle outlet (Fig. 6, left). If this does not happen, i.e. if before impinging on the goods, the emerging hot air meets a barrier formed by the ambient air (Fig. 6, right), then inadequate mixing takes place, and substance exchange deteriorates.

The influence of turbulence and flow rate at various points in an oblique-flow nozzle system becomes particularly clear in relation to the effect of the so-called “inner” turbulences (Fig. 7).

Fig. 8 illustrates the system from Monforts: on the left is a universal system with circular nozzles for handling woven textiles and knits, in the centre, circular nozzles for suspended guidance of the goods to be dried. The system is particularly suitable for fine knits. For drying light woven textiles, Monforts offers a slotted orifice system (Fig. 8, right), which, thanks to the equilibrium between the individual aerodynamic fields, yields a level appearance of the goods after drying.

Good utilisation of aerodynamic conditions has been realised by Fleissner in the “Rotoswing” belt drier for knits. This is an oblique-flow drier characterised by movable slotted nozzles. The upper and lower jets periodically change their position relative to one another, thus effecting – by aerodynamic means – that the goods pass through the drier in a wave-like movement (Fig. 9). The result is evenly dried and shrunk knits. A pre-condition, however, is that the outflow speed out of the nozzle openings is uniform.

A tier belt drier from Monti (Italy) has been designed for handling tubular as well as open knit goods. Here too, the aerodynamics of the impinging air are used in order to give to the drying goods a wave-like movement. The slotted nozzle system with upper and lower nozzles offset relative to one another is shown in Fig. 10. In contrast to oblique-flow driers (with clip chains or needle chains, support rods or conveyor belts, etc.), in which the design of nozzle and air conveying systems for as great a drying output as possible, was the most important, in the case of tier driers the air circulation must be designed in such a way that floating and/or phase-shifted effects can be achieved.

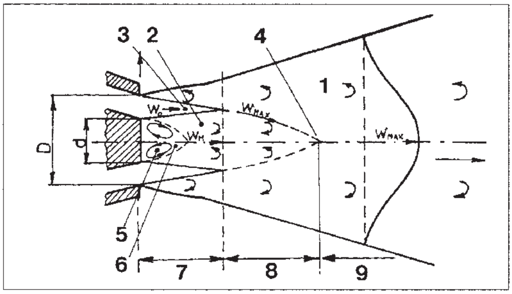


Fig. 7: Flow characteristics of a ring-shaped nozzle. 1 = outer mixing zone; 2 = inner mixing zone; 3 = active core; 4 = vertex; 5 = inner vortex; 6 = reverse flow zone; 7 = initial mixing zone; 8 = intermediate mixing zone; 9 = final mixing zone.

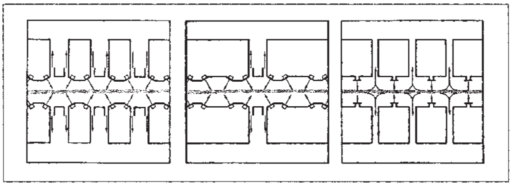


Fig. 8: Nozzle systems by Monforts: rim nozzles (left and centre), slit nozzles (right).

Oblique-flow driers

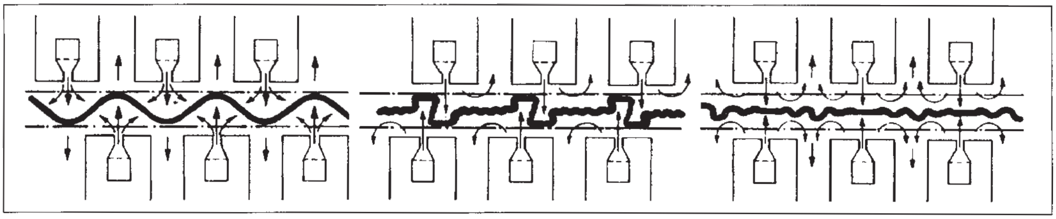


Fig. 9: Effect of the "Rotoswing" nozzle system by Fleissner.

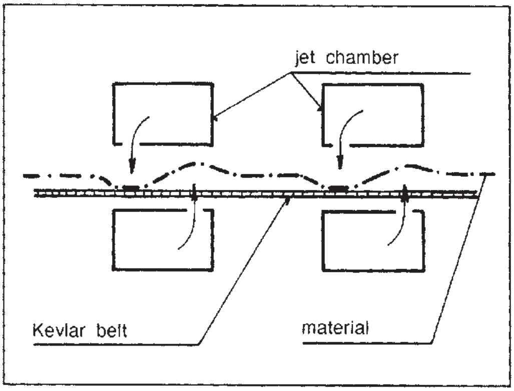


Fig. 10: Nozzle system by Monti (Italy).

In floating nozzle systems, both slotted and round nozzles are to be found. However, the nozzle outlets often have a special shape, by the use of flat plates or rollers (Fig. 11). Floating nozzle systems essentially differ from other systems through very precise control of the air circulation along the run of fabric. Included in this is a controlled quantity of exhaust air, through outlet air ducts equipped with slots and/or circular openings. In contrast to the circular jet fingers, in the Star-Jet system from Babcock (Fig. 12), after impinging on the goods each jet stream is led away by the shortest route, via the outlet tubes distributed on the jet body. The ratio between the jet supply and the outflow cross section is 1:18, compared with the usual ratio of approx. 1:5 in existing systems. The heating medium is supplied by means of special nozzle boxes of varied designs, which are assembled to form particular systems (Fig. 13). In this way, the uncontrolled flow of air above the run of goods perpendicular to the axis of the nozzle openings is eliminated.

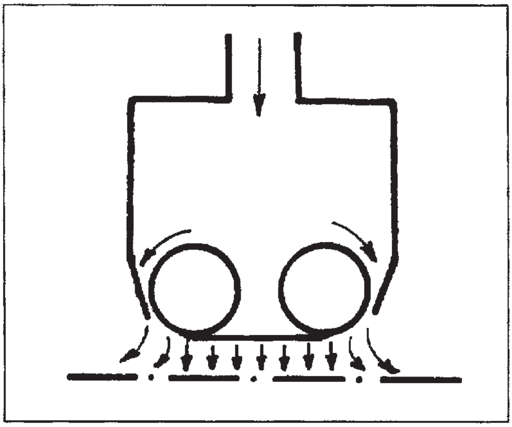


Fig. 11: Jet chamber with guide rollers.

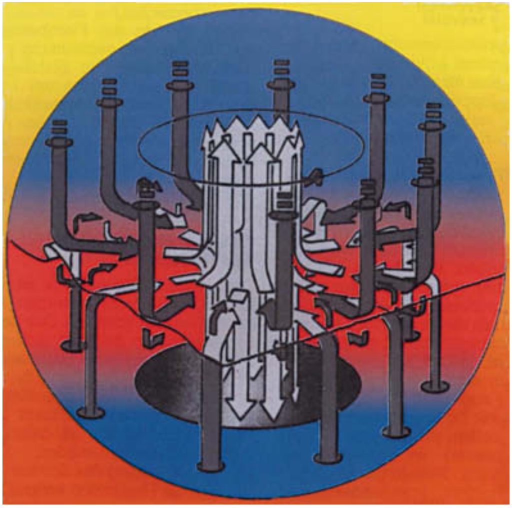


Fig. 12: Duett-1035 system by Babcock.

All floating jet systems use pressure or a pressure difference between the run of goods and the upper and lower jets in order to be able to guide the goods through the drier in a suspended state. The pressure difference can be achieved by various means; by casing the upper and lower nozzle chambers or with the aid of specially designed finger-like nozzle boxes which screen the two zones from one another, and thus create a partial pressure in the area of the run of goods. Particular attention

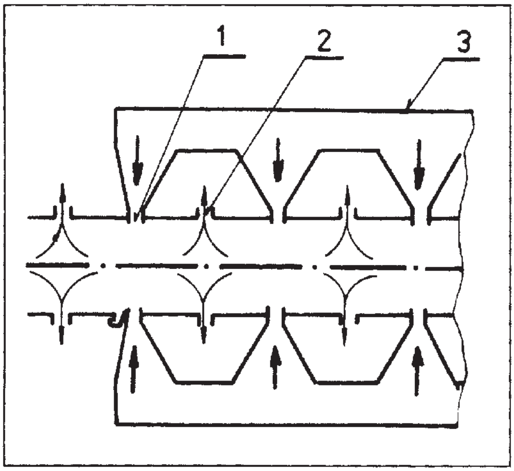


Fig. 13: Upper and lower jet chambers with facings.
1 = in; 2 = out; 3 = chamber.

is attracted by systems which use the “Coanda” effect to create the suspension (Fig. 14). In the drier from Elitex, rollers support the suspension, whilst circular nozzles yield a high drying output (Fig. 15). The Coanda effect is a phenomenon which can best be described as an adhesion of the run of fabric to the outflow of air (two-dimensional slotted nozzles). The fabric appears to be suspended on the jet system, lying above it.

Apart from the aim of creating state of suspension, other systems also aim at supporting the conveyance of goods by air flowing in the direction of the goods. This can be achieved either through suitable arrangement of the upper and lower jet systems, or through a special extraction system for exhaust air. In principle, the air conveying system of a floating drier barely differs from that of a regular oblique-flow drier. Only the control of the air circulation has been improved, via precise regulation of the drying medium flowing from the upper and/or lower jet systems, and through instruments for recording the total quantity of circulating air (Source: Krizek).

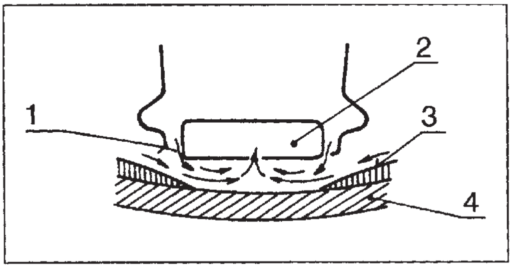


Fig. 14: Spooner TEC Coanda “air bar” system.
1 = in; 2 = out; 3 = guide; 4 = fabric.

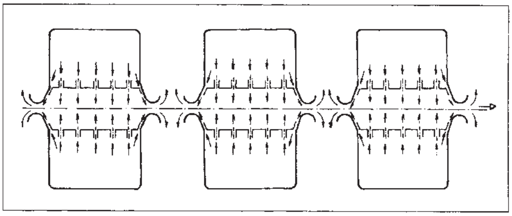
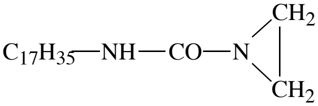


Fig. 15: Nozzle system by Elitex.

Occlusion (from the Latin occulus = “closed”). This relates to, for example, possibility of dirt adhesion for reasons of topography. Macro-occlusion: mechanical jamming of relatively large particles of dirt between the threads of a fabric and the fibres of the yarn. Micro-occlusion: jamming of the finest pigment particles (0.02–1 µm), which are nevertheless up-to-date in terms of washing technology, in the fine surface structure of the fibres. The existence of a micro-occlusion can be caused both by the core size distribution of pigment dirt, as well as by tears, cracks and pores appearing on the fibre surface. It can even be assumed that the micro-occlusion, in conjunction with the capacity of fine pigments to agglomerate, results in an adhesion which is extraordinarily resistant to surfactants, and which plays a not inconsiderable role in greying, particularly of cotton.

Occupational diseases in textile finishing →: Skin diseases; Solvent health hazards.

Octadecylethylene urea Textile auxiliary for soil-repellent finish and as a hydrophobic softener.



$$C_{17}H_{35}\text{—NH—CO—N}\begin{matrix}\diagup CH_2 \\ | \\ \diagdown CH_2\end{matrix}$$

Octet rule → Atomic bond.

Odorous substance complexes → Fragrant finishes.

Odour According to the present-day view, the receptor (= organ for receiving stimuli) appears to act in relation to the odour molecule like a key in a lock. Through the transportation of respiratory air, the odour molecules reach the upper nasal cavity (swirled by specially arranged cartilage laminae) to the smell receptors of the nasal mucous membrane (bearing around 20 million filament hairs), where they penetrate, are dissolved in the lipoid layer, and are passed to the brain as a physico-chemical (olfactory) stimulus through neuronal signals, for the purpose of transmitting odour-specific information. A wealth of theories are currently in existence, which do not satisfactorily explain the detailed sequence of perception of smell. → Osmophore.

Odour control Repellent or disabling effect achieved through odour, e.g. → Respiratory poisons for use against insects or microorganisms which damage textiles. Term is also used to describe a procedure to prevent the build-up of microbially induced odours by blocking microbial metabolism. → Hospital laundry.

Odour improvement Addition of odour modifiers to baths, e.g. in the case of sulphur dye baths, crease-resistant baths, etc. →: Deodorizing; Odour control.

Odour nuisance Environmental pollution is largely defined in the respective laws; these relate to the origin and action of pollutants in air, water and waste. The emission of pollutants can represent a nuisance even if, during emission, the source of pollution (introduction of pollutants into the environment) conforms to the law in respect of the amount introduced (e.g. in the case of emission of exhaust gases into the air which conforms to the Technical Instructions for Air [TI-air; TA-Luft] with regard to the permitted limit values). Odour nuisance in this sense is a cause for complaint. Typical odours are directly associated with textile finishing (e.g. in the vicinity of a wool finishing plant, due to the splitting of hydrogen sulphide derivatives in the wet-treatment of keratins; in carrier dyeing) or indirectly (e.g. in vehicles with a new interior trim which has been fixed with binding agents; evaporation in rooms with tufted, back-coated fitted carpets).

The human perception of smell is an extremely subjective matter. For a person to be able to perceive anything in the first place, the inhaled air must contain odour-forming components. For this, the concentration of these substances must be sufficiently high for the relative odour threshold to be exceeded. As a rule, even for intense-smelling substances, billions or even trillions of molecules are necessary. Despite this extremely high presumed figure, modern analytical chemistry has still not succeeded in making equipment to measure odours objectively. So we still have to assess odour by means of sensory test methods (olfactometry). There are three reasons for this:

1. The odour-forming components are often present in concentrations which lie well below the threshold at which they can be demonstrated. The nose is an extremely sensitive detector.
2. Many odours represent a combination of individual components.
3. It is extremely difficult to assign certain substances to a perceived odour.

The effect of scents on the area of the olfactory membrane is described by various theories, which differ in their views and nature:

- adsorption/desorption theory,
- enzymatic theory,
- oscillation theory,
- stereo-chemical theory,
- theory of functional groups.

Functional groups such as –OH, –OR, –CHO, –COR, –COOR, –CN, $–NO_2$ are → Osmophores with a pleasant smell, so-called euosmophores. –SH, –SR, –CHS, –CSR, –NC, $–NH_2$ on the other hand, are cacosmophores with an unpleasant odour. The threshold for a scent or a substance blend is that concentration which can just be perceived. A distinction is made between a non-specific threshold (an odour is registered) and a specific threshold (an odour quality is recognised). In the human sense of smell, the olfactory thresholds are subject to fluctuations which depend on various factors. Particularly important is the view that sensitivity to smell can be trained, but that on the other hand each act of smelling sets the threshold values higher for the one following immediately after. The olfactory thresholds for odour substances are subject to extreme variation; thus in the literature for ethanthiol, camphor, isoamyl alcohol, for example, $7 \cdot 10^{-6}$, $29 \cdot 10^{-4}$, and $11 \cdot 10^{-2}$ mol/l are given. Vanilla, whose threshold value is $33 \cdot 10^{-4}$ mol/l, is not infrequently used as a covering scent because it has an “empathetic” effect and in a subsequent act of smelling it pushes the specific value upwards considerably.

The organs of smell are localised in the nose. The olfactory region is an olfactory epithelium approx. 10 cm^2, which is equipped with $2 \cdot 10^7$ olfactory cells. It is located in the upper part of the nasal cavity, close to the brain. Even very weak external stimuli are thus directed there by the shortest route, and largely differentiated. In the case of corresponding olfactometric test methods, one must take account of the fact that molecules are only perceptible in terms of smell when they have a minimum vapour pressure; moreover, substances as gas must be water-soluble and fat-soluble, and contain osmophores. Sampling must be adapted to the application in question (ambient air of a textile finishing plant; the interior of a car; odour development of carpets in homes and offices). The evaluation by the persons doing the smelling must be independent of their mental or physical disposition. Grades of 1 to 6 are issued by 6 members of a team; the highest and lowest evaluations in each case are discounted, and the average is established from the remaining 4 grades. Grades are as follows:

1 = odourless
2 = perceptible, but not annoying
3 = bearable (limit value)
4 = annoying
5 = highly annoying
6 = unbearable

This elimination of the extreme values which have been found allows any possible temporary indisposition on the part of members of the smelling team to be taken into account. Up to the value of 3, grading is generally still tolerated, e.g. by the automobile firms, but “pungent” smells (such as those originating from HCHO)

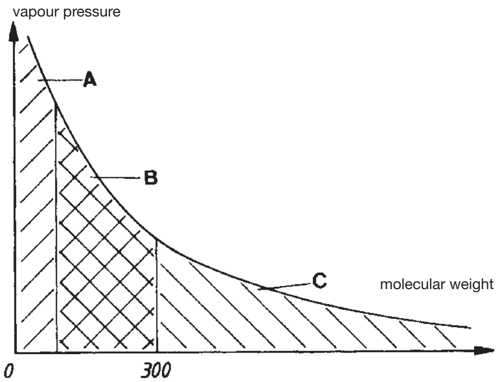


Fig. 1: Dependency of vapour pressure on molecular weight. A = odoriferous matter; B = condensable odoriferous matter, fogging relevant; C = fogging-significant substances.

would lead to rejection of textile furnishing materials. Odour development and → Fogging in furnishing materials for cars are, in the first instance, comparable processes in physical terms, since the relevant substances have to have a corresponding vapour pressure. The question of the transition range, namely concerning solids which are susceptible to both odour and fogging, is illustrated in Fig. 1 (source: Eisele).

When applying the preliminary coating of carpet backing, it was possible to determine the very intense-smelling 4-phenylcyclohexene (Fig. 2) by means of gas chromatography (imported into the process as an accompanying substance of styrene).

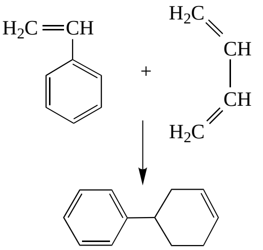
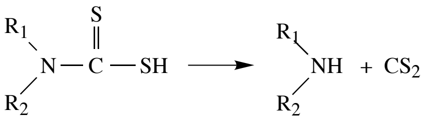


Fig. 2: Diels-Alder reaction during polymerisation of a carpet backing coating pre-coat.

Vulcanisation pastes of foam coating (as main coating in carpet backing) contain – besides carbon bisulphide and sulphur dioxide – above all amines, which are very odoriferous. These are reaction products of vulcanisation paste constituents which allow dithiocarbamine acid to arise from the dithiocarbamates when the pH is lowered; this then reacts further:



$$(R_1)(R_2)N-\overset{\overset{S}{\|}}{C}-SH \longrightarrow (R_1)(R_2)NH + CS_2$$

Odour poison → Respiratory poison.

Odour threshold value The smallest concentration of gases or vapours which can still be perceived by the nose (→ Odour nuisance).

Threshold values of some substances (in ppm):

Ozone	0.02
Sulphur dioxide	0.3–1
Phosgene	0.5
Phenol	0.5
Hydrocyanic acid	1
Carbon bisulphide	1–2
Formaldehyde	2
Chlorine	3.5
Ammonia	5.5
Ethyl ether	50
Tetrachloroethene	50
Toluo	50
Trichloroethene	50
Carbon tetrachloride	70
Benzol	100
1,1,1 trichloroethane	100
Chloroform	200
Benzene	300
Dichloromethane	600
Methanol	2000
Liquid gas	5000

OE-spinning process (Open End spinning process). Besides increased output in ring spinning, outspinning has been brought a decisive step forward with the realisation of open end spinning. These methods owe their existence to the long-held desire to maintain the ready-cleaned cross-wound bobbin directly after the control section, i.e. without the entire preparatory spinning, ring spinning and rinsing machine. Various solutions have been proposed. The basis of all OE spinning processes is the separation of a fibre tape feed into individual fibres, which are given a twist through various media, and are spun continuously into an "open end" stripping thread.

The most important process, and one which has been introduced in practice, is rotor spinning. The essential features of a rotor spinning machine can be described as follows: The fibre tape is fed to a high-speed cylinder, and split into individual fibres. Compared with conventional spinning processes, a "break" takes place in the work sequence, i.e. the fibres are conveyed individually into an air driven rotor, with the rotor running at speeds of between 30 000 and 60 000 r.p.m. Under the action of centrifugal force, the fibres collect in a groove on the rotor wall to form a multi-layered, sickle-shaped fibre ring. This ring is drawn axially out of the rotor, from a drawing point, whilst maintaining the necessary twist. The yarn which is thus created can be spooled directly onto any material carrier. The maximum fibre length which can be processed is determined by the rotor diameter and the system resolution.

The majority of the machine types are designed for the short-staple range of up to 40 mm (in exceptional cases, up to 60 mm). It is therefore often cotton which is spun on these machines. The area of application covers both normal cotton yarns (so-called 3-cylinder yarns) and the condenser cotton yarns (2-cylinder yarns). When using fibre of a particular provenance, it should be noted that a raw material which is difficult to process in the drafting zone, and which has a high proportion of short fibres or a high degree of staple variation, produces a better result on the OE machine compared with the ring spinning machine. One must also take into account the fact that dust and pieces of husk collect in the rotor groove, and can detrimentally alter its shape, leading to a drop in yarn quality (moiré) and increased thread breaks. For this reason, the feed for the OE process has to be as clean as possible, i.e. the cotton band should contain little dust and pieces of husk. As mentioned above, the band which is fed in is split up into individual fibres. In the course of this, impurities can be removed easily. Fine dust and poorly adhering preparations (chemical fibres) are, however, not detected by a cleaning device, and have to be removed by good cleaning and carding in the case of cotton, or by a suitable preparation in the case of chemical fibres. A favourable design of the spinning organs, including the rotor, can help to overcome these difficulties, and enable problem-free operation with constant yarn quality.

For the purposes of assessment, two different OE machine types are distinguished:

a) As soon as OE machines are used without a cleaning unit at the spinning location, a very good cleaning and carding room is the main condition for perfect running behaviour and good yarn quality, particularly in the case of cotton, even when it has been selected from relatively clean provenance, so that in difficult cases duo-carding machines, possibly with squeezing rollers, can offer advantages.

b) With dirt separation at every spinning location, it is possible to remove a proportion of between 50 and 95% of the dirt contained in the tape, according to the Shirley analysis. Through this, the majority of thread breaks, which are caused by larger dirt particles, are avoided.

(Source: Cripps). → Air jet spinning; DREF, false twisting method.

OE-yarn → Rotor-spun yarn.

Off-line lubrication → Yarn lubrication.

Off-line testing In this form of in-house quality control, three methods are distinguished:

- Off-line testing with sampling and evaluation of the sample in a (separate) laboratory, so that the measurement results are obtained relatively late (DIN 38404 pt. 1/92).
- On-line testing (e.g. as adapted laboratory colorimetry) with sampling; direct regulation of the process is possible with a relatively slight time delay (→ On-line Quality Assurance).
- In-line testing (non-destructive) with immediate control by comparison of target and actual values (see Fig.).

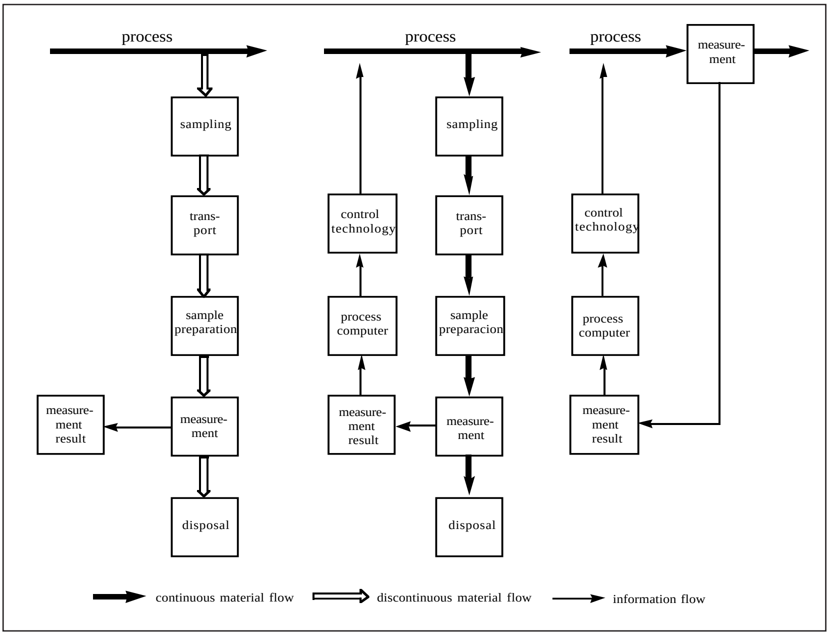


Fig.: Comparison of the material flows and information flows for off-line testing (left), on-line testing (centre) and in-line testing (right).

Offset printing The patterned coloration takes place indirectly via a rubber blanket, with printing colour paste being applied beforehand to the printing plate or roller, from the roller to the rubber blanket, and only then to the material which is to be printed. (see Fig.). During the printing process, the printing mould with the non-reversing image passes through the “moistening and dyeing unit”. Through moistening, the non-printing parts become dye-repellent, so that only the printing, water-repellent parts take up the dye paste. This dye paste is “deposited” on a rubber cylinder, which transfers the laterally reversed print image onto the running paper, with slight pressure.

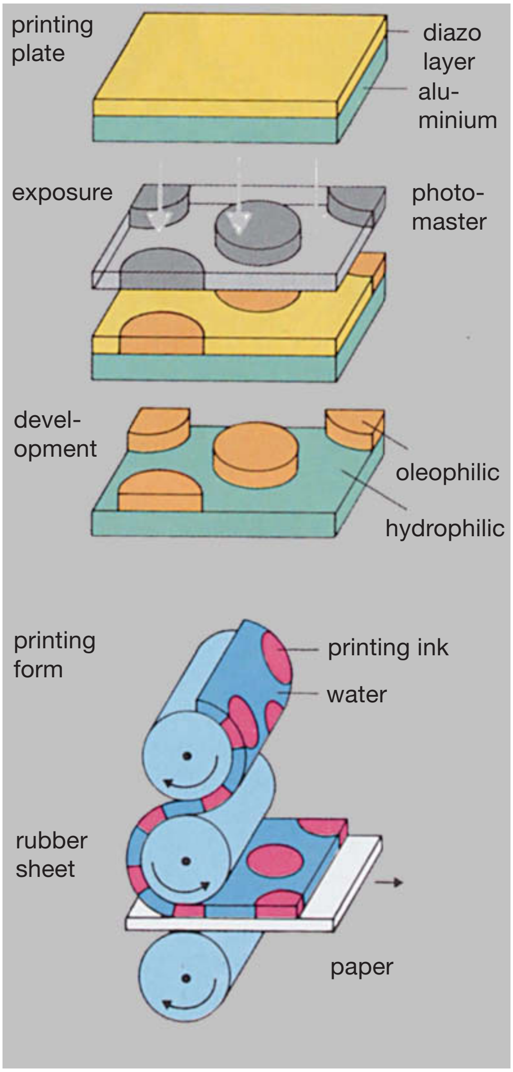


Fig.: Manufacture of an offset printing form and the principle of offset printing (source: Hoechst).

The process is begun by charging, which occurs as the printing plate is exposed in the automatic machine. Here, the surface of the photo-semiconductor layer is evenly charged electrostatically in the dark, under a high-voltage corona. In this state, the insulating photo-semiconductor layer acts like the dielectric of a charged capacitor. The next step is exposure. Here, the paper master of the printing side is illuminated. The reflected light reaches a photosensitive plate via a special lens. Through this, pairs of charge carriers are formed in the photo-semiconductor layer; under the influence of the electrostatic field they separate and migrate to the outer charges. These are neutralised, and the voltage of the capacitor collapses at the illuminated places, the “non-image places”. The charge image is developed with a toner which consists of resin particles with opposing electrical charges. Then follows a thermo-setting step, in which the resin particles are firmly anchored on the plate. Lastly, the photo-semiconductor layer is removed from those places not covered by the toner, by means of a de-sizing liquid, and the aluminium is exposed. The printing mould is thus ready for printing (duration approx. 3.5 – 7 min, depending on the type of automated device). With the largest types, 120 print plates in newspaper format can be produced per hour (source: Hoechst).

ÖFI Austrian research institute; → Technical and professional organizations.

Ohm (O or Ω) Unit of electrical resistance which yields a current strength of 1 A at a voltage of 1 volt; or the resistance of a mercury thread 106.3 cm long and a cross-section of 1 mm≤ at 0°C. The resistance is in direct proportion to the length, and in inverse proportion to the cross-section of a conductor. Resistance in ohms = length (m) multiplied by specific resistance in ohms (resistance of a substance of 1 m in length and 1 mm^2 cross-section) divided by the cross-section (mm^2).

Oil alkyds → Alkyd resins modified with → Fatty acids or → Resin acids.

Oil- and fat-soluble dyes These belong to the group of organic pigment dyes, usually (amino- and oxy-) azo dyes, but without a water-solubilising group. Soluble in fats, oils, waxes, lacquers, resins, (chloro-) hydrocarbons, alcohols, ethers, etc., but not in water. Oil- and fat-soluble dyes usually have a high yield (0.2 – 1 g is sufficient for dyeing 1 kg of wax). The dissolving process requires 30 minutes and more. Used for oil chalks, pigment and lacquer printing, fat dyeing in microscopy (Sudan Red test), dyeing leather fats, enhancing dyeings on coconut material, re-touching, etc.

Oil circulation heating (→ Circulating hot oil unit). In order to obtain a greater evenness of temperature in the stenter frame (Fig. 1), one can heat with hot oil, circulated by a pump, which has a flow temperature of around 40 – 50°C higher than the target temperature

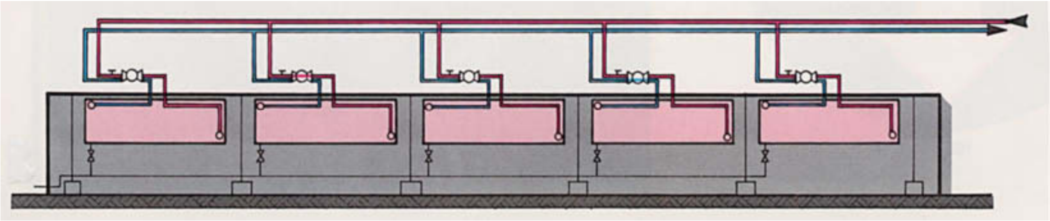


Fig. 1: Layout of heating pipes for the oil circulation heating of a horizontal stenter frame.

in the stenter frame, through separate heating (Fig. 2), i.e. where the frame temperature is 190°C, the oil temperature is approx. 240°C. Independent of boiler room.

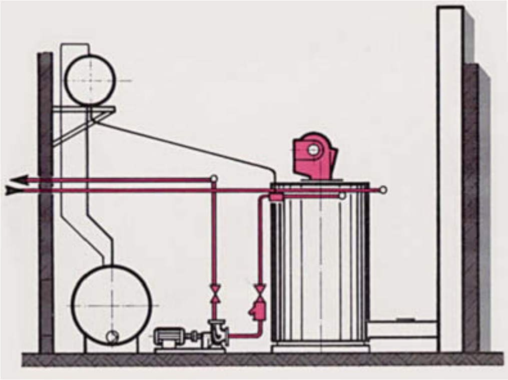


Fig. 2: Oil circulation heating boiler room.

Oil-colour solvent Special spot removers which can loosen even strongly resinified varnish stains, etc.

Oiled silk (insulating silk). Transparent, impregnated and printed fabric for raincoats, umbrellas, swimsuits, furnishing fabrics, etc. Manufactured according to a special process, such as elasticised urea resins. To avoid surface sticking, it is recommended that less elasticised urea resins are included, and that the mixture is thinned with alcohols or glycol ethers to immersion consistency. Usually dried at 80°C; this can also be accelerated by the addition of weak acids.

Oil emulsion → Emulsion system of water-in-oil (W/O).

Oil finish Finish with an oily, greasy handle, e.g. for anoraks. Originally, a non-permanent coating with vegetable oils. Permanent effects were only achieved through padding with → Silicone elastomers.

Oil-hydraulic batching drive Flexible drive for all winding operations with hydraulic motors, which guarantee the constant goods tensions for each winding size.

Oiling,

I. The preparation of man-made fibre continuous filament yarns, for the purpose of better processing in knitting (hosiery, warp knit and weft knit fabrics). Carried out on running threads, which pass through either oil-soaked wicks or rotating small rollers. The oiled thread is intended to preserve increased sliding properties and suppleness. Good removability by washing out is the main requirement. The oils used are mostly concentrated mineral oils with added emulsifier, for which oil sulphonates are suitable.

II. Preparation process for the willowing, carding and spinning of wool fibres or cellulose flocks or blends. Purpose: Increasing slding properties through → Textile lubricants with a film-forming characteristic which ensures an effective protective shell, lowers friction, and encourages stretching ability, flexibility, mouldability, etc. In the case of cellulose, there is in addition the elimination of electrostatic charges. Lubricant application for combed yarns 0.5 – 3%, carded yarns 8 – 15%, for reclaimed wool up to 30% (knits, etc. 6 – 7%, other used material mostly 8 – 10%). Oiling of synthetic fibres is neither customary nor necessary. In the case of wool blends, the wool is oiled separately beforehand, or – if this is not possible – the amount of oil is calculated only on the basis of the proportion of wool (according to experience, max. 4%). After dyeing or backwashing of combed tops, the preparations are washed out and have to be re-applied.

Oiling auxiliaries Added to → Textile lubricants, in order to facilitate the further processing of oiled fibres. Substances which are customarily used for this are mostly surfactants to promote the wetting, washing and milling characteristics, and to facilitate the removability by washing out. These include, amongst others, polyphosphates for easier washing out, reduced tendency to auto-ignition in the case of olein lubricants, and reduction of attack on metals.

Oil-in-water emulsion → Aqueous emulsion.

Oil repellence of textiles This is the capacity to withstand wetting and penetration by oily liquids. Oil is not absorbed, but is repelled in droplets. The effect is achieved by the application of oil-repellents in the oleophobic or oil-repellent finish. It is brought about by the fact that the forces acting between the oil-repellents and the oil droplet are weak in comparison with the forces acting within a drop of oil.

Oil-repellent → Oil-repellent finishing.

Oil-repellent finishing The textile auxiliaries used for → Water-repellent finishing are not sufficient to protect textiles against grease and oil stains. For this, special products are used, e.g. → Fluorocarbon polymers, which are used in the form of emulsion, sometimes in padding, sometimes in the exhaustion method. However, these products in turn do not provide a good water-repellent effect, which is why in practice oil-repellents and water-repellents are always used together. Some of the products available on the market provide effects which are resistant to washing and dry cleaning. Used with the → Soil release finish.

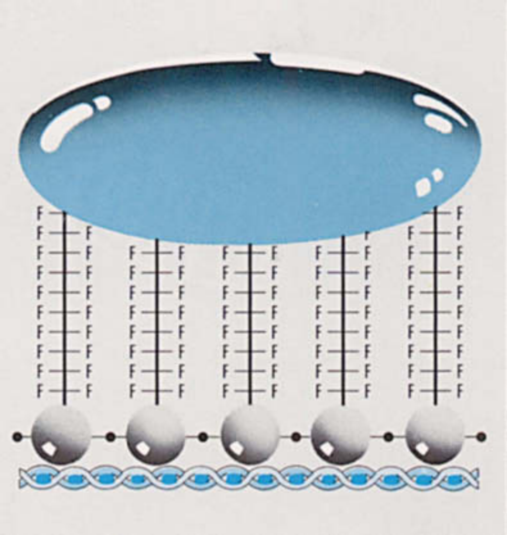


Fig.: The functional principle of an oil-repellant finish with hydro-fluorocarbon.

The synthesis technique of telomerisation used by DuPont provides access to perfluoropolymers. Sterically small base groups permit the arrangement of the fluoroalkyl chains close and parallel to one another, so that the result is oil repellence and water repellence (see Fig.). The high average chain length of 10–12 carbon atoms contributes to this.

Oils The composition and type of → Fats. There are (given corresponding presence of saturated or unsaturated → Fatty acids) →: Non-drying; Semi-drying and Drying oils. The drying property depends on the number of double bonds capable of oxidation in the fatty acids on which they are based (→: Oxidation of oils; Blown oils; Oil size). Chemical indices →: Iodine number, Acid value, Saponification number.

Oil separation from water Particularly from surface water and condensation.

I. Mechanical: (Preliminary removal of oil) Sedimentation basin (possibly introduction of compressed air, with addition of carbon dust, and subsequent filtration). Secondary removal of oil with special filters, e.g. filters with activated carbon. Principle and result: oil adsorption. Lowering of water velocity, constant change of direction, surface separation of the oil. Residual oil content approx. 1–5 mg/l.

II. Chemical: With sufficient alkalinity, e.g. with aluminium sulphate or iron salts; where alkalinity is too low, with added soda lye. Disadvantage: considerable enrichment of neutral salt. Principle and result: The precipitates which are created adsorb droplets of oil and drop out with them. Residual oil content approx. 1 mg/l.

III. Electrolytic: Condensation with soda lye slowly passes iron electrodes, and the oil precipitations which arise pass through gravel filters. Principle and result: destruction of the oil/water emulsion, separation, adsorption of basic iron salt separated at the anode, reduction of oil droplets. Residual oil content approx. 1 mg/l.

Oil separator Since oil has a lower specific gravity than water, it floats in an oil separator (see Fig.), if one leaves time for phase separation. If surfactants which have an emulsifying action are present in the oil/water mix, the emulsion separation is effected by means of colloidal chemistry; mechanical oil separation remains ineffective otherwise.

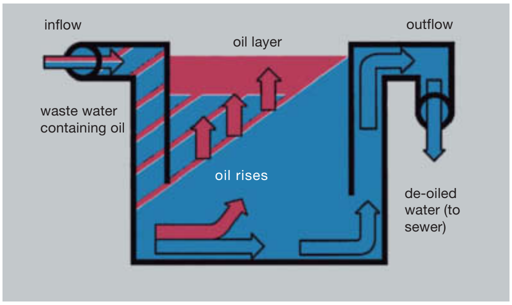


Fig.: The functional principle of an oil separator.

Oil size (linseed oil size). This was (and is) used for sizing viscose yarns with → Drying oils of the → Linseed oil type. This type of oil size is capable of oxidation, and polymerises, whilst absorbing oxygen, to form the characteristic “linoxyn skin”, which encloses the sized thread like a film. At the beginning of the 20th century, this oil size characteristic made a considerable contribution to the introduction of viscose yarns (highly twisted to non-twisted), which were prepared in this way for the warp stresses in the loom; it assumed particular importance for crepe articles and tightly woven fabrics (e.g. taffetas). The mills became independent of oil size, which had hitherto been indispensable, by the further development to full-width / warp beam size on special sizing machines, for they transferred the sizing of yarns from piece-work sizing shops directly to weaving preparation. Some disadvantages were eliminated, such as e.g. annoying oxidation risks and difficult de-sizing capability of the oxidised oil film. Oil size, these days is now barely of any significance. It is occasionally used for “end threads” or “selvedge threads”, as a substitute for highly twisted yarns, and in isolated cases as a viscose warp size for umbrella materials, with linseed oil size with paraffin and beeswax ensuring that a lasting water-repellent film is achieved.

In terms of the application technology, the following are distinguished:

I. Solution or dry oil size, type: Boyeux, Kress Special, Schetty, Swiss size. Principle: Linseed oil in organic solvent (benzene, trichloroethene, etc.), steep in the size centrifuge, spin, load in hanks, dry at 30–40°C in 48–60 hours, or according to method II.

II. Emulsion oil size (gamma size type): This served principally as a crepe yarn size, but did not become established as a general warp size. Principle: soak with emulsified linseed oil or similar in aqueous solution, centrifuge, spread, load in hanks, dry in 48–60 hours or (gamma method) in a shortened method according to the ozone oxidation method.

Oil size damage The main features of damage are e.g. the tendering of entire sections or localised areas, also differing strengths of outer/inner bobbin positions; auto-ignition through improper drying; warp streakiness through reduced stretching, sizing residues, yellowing, irregular crêpe effects in crêpe articles, etc.; brown spots, as local resin deposits through uneven drying, or residues or precipitations; sometimes considerably altered dyeing affinity.

Oil-soluble dyestuffs → Oil- and fat-soluble dyes.

Oil-solubler → Oil-colour solvent.

Oilstone (whetstone) → Levantine squeegee oil stone.

Oil tanning, chamois tannage → Tanning.

-ol Suffix in terms for → Alcohols and Phenols, usually appended to the name of the parent hydrocarbon in question; e.g. methane CH_4 = methanol (methyl alcohol) $CH_3\text{-}OH$; ethane C_2H_6 = ethanol (ethyl alcohol) $C_2H_5\text{-}OH$, etc.

Oleate Salt of → Oleic acid.

Olefin fibres → Polyolefin fibres.

Olefins (alkylenes, alkenes)**,** Unsaturated aliphatic → Hydrocarbons with a straight carbon chain and a double bond (type ethylene $H_2C{=}CH_2$). They contain 2 H less than the relevant saturated hydrocarbon, and thus correspond to the formula type C_nH_{2n}, and are characterised by the suffix “-ene” (formerly “-ylene”):

– derived from ethane $C_2H_6 \rightarrow$ Ethene C_2H_4;
– derived from propane $C_3H_8 \rightarrow$ Propene C_3H_6;
– derived from butane $C_4H_{10} \rightarrow$ Butene C_4H_8.

By splitting open the double bond, halogens are added:

$$H_2C = CH_2 \rightarrow CH_2Cl\text{-}CH_2Cl\ (C_2H_4Cl_2)$$

ethyl di-chloride

By contrast, unsaturated aliphatic hydrocarbons with so-called triple bonds are called → Acetylenes (alkines), and with 2 double bonds → Dienes (diolefins). Labelling of the C atom, on which the double bond is based, according to the following principle:

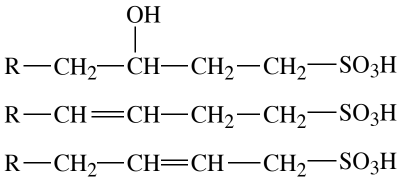
$$\overset{1}{CH_2}{=}\overset{2}{CH}{-}\overset{3}{CH_2}{-}\overset{4}{CH_3} \Longrightarrow \textit{1-butene, butene-1}$$

$$CH_3{-}CH{=}CH{-}CH_3 \Longrightarrow \textit{2-butene, butene-2}$$

$$CH_2{=}CH{-}CH{=}CH_2 \Longrightarrow \textit{1,3-butadiene}$$

1-configurations are also called α-olefins, etc.

Olefin sulphonate (α-olefin sulphonates, AOS, alkene sulphonates)



$$R{-}CH_2{-}\overset{OH}{\overset{|}{CH}}{-}CH_2{-}CH_2{-}SO_3H$$

$$R{-}CH{=}CH{-}CH_2{-}CH_2{-}SO_3H$$

$$R{-}CH_2{-}CH{=}CH{-}CH_2{-}SO_3H$$

Further development of washing agents based on → Olefins (α-olefins) through transformation with SO_3 and subsequent hydrolysis, where mixtures of hydroxy-/alkene sulphonates (among other formula types) arise. Designation as α-olefin sulphonates. Olefin sulphonates are among the most important detergent surfactants. The availability of the corresponding α-olefins is decisive for their introduction. Limited use of olefin sulphonate for detergents, flushing agents and scouring materials in the USA, Japan and Germany to date. Tests on the effective sulphonates of C_{14}-C_{18}-α-olefin mixtures yielded good washing power (low sensitivity to hardness, even at low concentrations); depending on the chain length, foaming problems can occur (foam inhibitor necessary). Olefin sulphonate mixtures with various other surfactants demonstrate synergistic effects and are particularly recommended (supplemented by other components) for well-foaming mild washing agents. Various olefin sulphonates no longer foam so strongly in the presence of sodium perborate in hard water at 60°C; the foam quickly collapses, which appears to be valuable for the manufacture of detergents for automatic washing machines. The ease of biodegrading of the olefin sulphonates must be emphasised: it is faster and more complete than for straight-chain alkyl sulphonic sulphonates.

Oleic acid (olein, $C_{17}H_{35}$–COOH) By-product of the manufacture of stearic acid. Colourless (pure state) to yellowish-brownish oil (unsaturated fatty acids; odourless; solidifies at 4°C, melts at 14°C; water-insoluble; forms easily soluble alkali salts (→ Soap). Used in: soap manufacture, lubricants for wool (absence of mineral oil, stearin, and similar substances which are difficult or impossible to saponify).

Olein (textile olein) Chemically non-uniform product. Main constituent: → Oleic acid and – depending on the raw material base (bone fat, tallow, train oil) – other (poly-) unsaturated (type: linoleic acid) and saturated fatty acids (palmitic acid, stearic acid). “Saponificate olein” (neutral fats and non-saponifiables) and “distillate olein” (more non-saponifiable, besides less neutral fat) are used for lubricants. The following is required for lubricant purposes: min. 99% total fat, flash point approx. 160°C, titre 10–17°C, acid value 175–195, saponification number190–205. Non-saponifiables 2–5%, ester number 2–5, neutral fat 2–5%. Iodine value 70–90, thiocyanogen value 75–85, metals less than 0.05%, Mackey test negative, discrepancy (difference between iodine and thiocyanogen values) 10.

Olein acid → Oleic acid.

Olein emulsions Commercially available lubricants in the form of compositions of olein soap.

Olein soap → Soap. Olein with special emulsifiers (mostly OE addition compounds), possibly with corrosion-preventing additives. With water, directly yields finely dispersed working emulsions.

Oleophilic Attracting oil; the opposite of → Oil-repellent (oleophobic). Some synthetic fibres, as well as cellulose and cotton which have been given a non-iron/crease-proof finish with synthetic resins, are strongly oleophilic, but also → Water-repellent (hydrophobic). Such materials are therefore easy to soil with oil, but difficult to wash with an aqueous liquor.

Oleum → Sulphuric acid.

Oleyl sulphate → Fatty alcohol sulphonates.

Olfactory (Latin: olfactorius = olfactory nerve; nerve for smelling). The characteristic of the olfactive (scent) which affects the olfactory nerve in the presence of → Odour.

Oligoester → Oligomers of polyester fibres.

Oligofilament Term used to describe a filament consisting of a few (2–16) continuous chemical fibres.

Oligomers (Greek: oligos = few, meros = part), few duplicated parts. Low-molecular attendants in → High polymers. Can be thought of as by-products not preventable by reaction kinetics (→ Pleionomers) in the synthesis of fibre polymers. Can be extracted using organic solvents. The structure is linear and cyclical.

A typical example is provided by oligomers contained at the level of 1–2% in polyester fibres, as e.g. dimeric and trimeric ethylene glycol terephthalate $(\mathrm{O(CH_2)_2O{-}CO{-}C_6H_4{-}CO})_{2-3}$. Cyclical oligomers have a strikingly high melting point (lowest members at approx. 70°C above that of polyester fibre), they sit firmly on or in the fibre, can be found frequently particularly after thermo-setting, cause annoyance through excessive dusting in re-spooling/twisting (abrasion products on thread guides and thread brakes) and – since they are specifically soluble at high temperature – as clouding deposits on dyed polyester fibres and at the edge of the dyeing machine, impair liquor circulation (Fig.) in wound package dyeing (filtered-off dye oligomer powder), reduce surface smoothness of yarns and the like. Remedy: dyeing time as limited as possible, carrier addition, relatively high use of dispersing agent (keeps oligomers in fine distribution); after dyeing has been concluded, drain the bath as hot as possible and rinse hot; after reductive washing off, conditions as intensive as possible; finish yarns before further processing; frequent cleansing (alkaline boiling) of dyeing machines, pipework, pumps, valves.

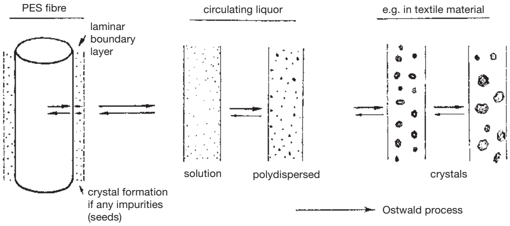


Fig.: Diagrammatic representation of the oligomer migration and crystallization process (source: Reinert).

Oligomer Test This test can be important for distinguishing oligomers as fibre abrasion products or as dyestuff dust. Demonstration is principally after extraction (see Fig.).

I. Cyclical oligomers show up in the polarising microscope as individual grains on a dark background.

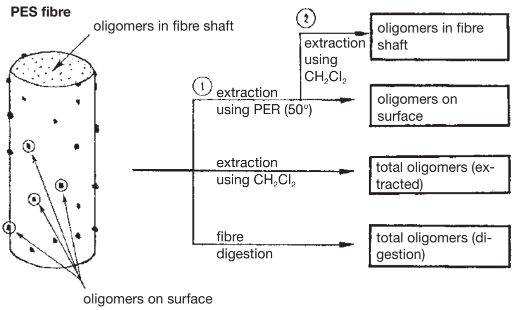


Fig.: Diagram of the process to obtain characteristic oligomer extracts.

Large amounts of oligomers on polyester satin which has been dyed black cause shadow-like patches, 100:1.

II. Oligomers in a mixture with 90 parts by weight of concentrated sulphuric acid and 10 parts by weight of water: polyester fibres are dissolved, cyclical oligomers simply swell.

III. Oligomers saponify in alcoholic potassium hydroxide solution to form terephthalic acid and glycol; separate terephthalic acid by precipitation with acid and cleansing through sublimation, dissolve the terephthalic acid obtained in diluted lye; with baryta water gives the specific crystalline form of barium terephthalate.

Oligosaccharides → Carbohydrates.

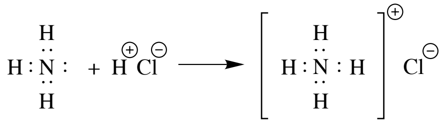
Olive oil lime soaps Mostly (more or less) thin-bodied special products, with a particularly softening or smoothing effect. Uses: (40%) as spool oil for viscose; finishing oil for silk, viscose etc. → Soap.

Ombré Colour effects yielded by continuous transition from light to dark and/or vice versa (shade, shadow), or from one colour (shade) to the next (variation shadow). They are achieved through → Dyeing of ombré or shaded effects, or also through special weave techniques (e.g. ombré weave).

O-Methylol compounds Compounds with one or more o-methylol groups ($–O–CH_2OH$), reactive group for cross-linking reactions (reactant resins), such as e.g. → Polyoxymethylenes (POM). Transformation products of aldehydes with alcohols, with at least two functional groups, also etherified, $–O–CH_2–O–R$, (R usually $–CH_3$). Used as resin finishing agents, e.g. dimethylol alkane diols; POM dimethyl ether.

Omnibus Short for omnibus designs: supply category for thermoprinting papers. Supplied to any number of firms, usually considerably cheaper. The opposite is exclusive designs: these are reserved for one firm or a certain small circle of firms, and are correspondingly more expensive; a minimum amount must be guaranteed.

Onium compounds (cation-active compounds), definition as → Complex compounds, in which the central atom effects one atom bond more than corresponds to the number of its valency electrons. The relevant anion is connected to the cationic complex via an ion bond. Ammonium compound derivation, e.g. of ammonium chloride $(NH_4)^+Cl^-$ in accordance with the following electron formula:



The proton thus pushes into the co-ordination gap of the nitrogen. Through this, via the free electron pair of the nitrogen, electrical resonance with the NH_3 group occurs, and an ammonium complex with a positive charge is created, i.e. a cation-active ammonium ion. Derivatives of this basic type are constructed analogously, and are generally referred to as onium compounds. Familiar ammonium compounds of this type are e.g. the cationic dyes. Since, in onium compounds, the cation represents the active constituent, the onium compounds used in textile finishing are termed cation-active (auxiliaries).

On-line Direct connection between data input and output (terminals) and the central computer which processes the data.

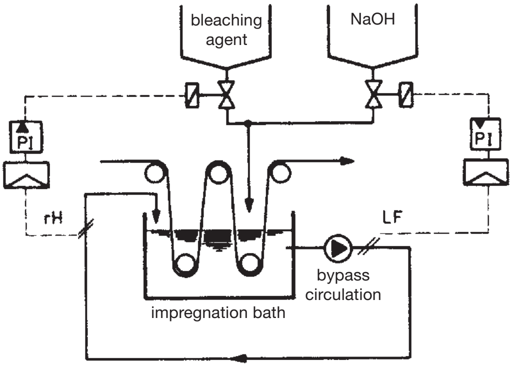
On-line controller Collective term for controllers on continuous runs of material. These include e.g. synchronous controllers, loop and tension controllers and band thickness controllers.

Online measuring probes Used in continuous processes for physical and chemical measurements (e.g. pH, redox, amperometry). As sensors, they have the task of bringing the measuring electrodes into contact with the liquid being monitored to obtain continuously reproducible measurements. Online measuring probes with an integrated mechanical cleaning system are designed to prevent soiling of the electrodes and are incorporated directly into the respective process cycle in either the main or the secondary flow.

On-line Quality Assurance → On-line quality control.

On-line quality control During the finishing process, on-line testing of the goods currently in production is used in order to prevent non-permitted variations in quality being produced at a production location (e.g. colour). On-line testing is thus an early warning system within quality assurance, to prevent “freak values”. If it consists of non-destructive measurement (i.e. without contact with the textile goods, or through direct measurement in the bath or in the bypass without liquor change), then this is in-line determination. The addition of soda lye and hydrogen peroxide in continuous pretreatment of cotton takes place e.g. after in-line measurement of the r_H value and the conductivity. The measurement of the so-called redox (oxidation reduction) potential takes place via a measuring chain, consisting of a precious metal electrode and a reference electrode (Fig. 1). The measuring chain potential is supplied to a measurement amplifier and a controller. The reference value of the controller is a redox potential based on practical experience. At the same time, the soda lye can be kept constant via conductivity measurement.

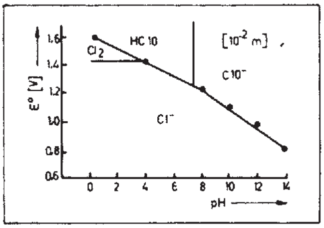
If in such a plant, a true concentration measurement – in each case during production – is to be the basis for the supplementation of chemicals used, then sampling of the liquor and its on-line titration with the loss of this liquor proportion must take place outside the plant, in its immediate vicinity, in a special analyser, in order to trigger the dosing via a control circuit (Fig. 2). The



$$E_{Rd} = E_0 + \frac{RT}{nF} \ln \frac{[Ox]}{[Red]}$$

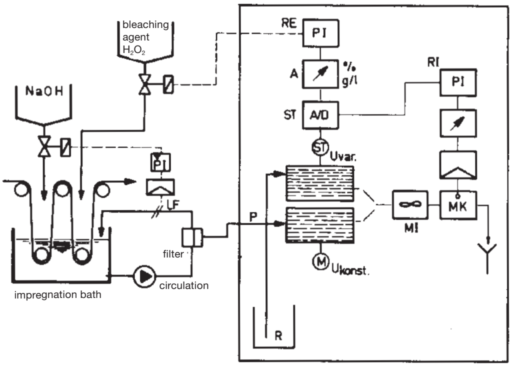
$$OCl^- + H_2O + 2e \rightleftharpoons Cl^- + 2OH^-$$

$$E = E^\circ + 0.028 \log \frac{[OCl^-]}{[Cl^-]} - 0.059pH$$



relationship of redox potential of hypochlorite to the pH value

Fig. 1: The principle of measuring redox potential for the purpose of controlling the concentration of bleaching agent during in-line operation.



automatic analyser Concentromat ® ACC

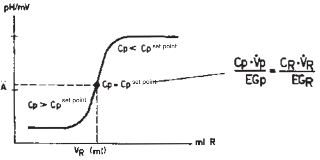


Fig. 2: The on-line principle for measuring and controlling the concentration of bleaching agent.
Cp = sample concentration (g/l); CR = reagent concentration (g/l); Vp = sample flow volume (l/h); VR = reagent flow volume (l/h); EGp = equivalent weight of sample; EGR = equivalent weight of reagent.

sample P is supplied in a constant amount to the mixer M1, via a pulse pump. The reagent R is likewise supplied to the mixer M1 via the variable output pump ST. The mixture now reaches the mixing cell MK, in which a pH or redox measuring loop is located. The measurement signal is supplied to an amplifier and a so-called internal controller R1. This controller R1 now regulates the reagent pump ST such that the mixture in the measurement cell MK is always at the neutral point. The reference value for the internal controller R1 is thus the neutral point of the corresponding titration. Under these conditions, the rotational speed of the reagent pump ST is proportional to the concentration sought. This signal is evaluated for the purpose of regulating the process concentration.

Off-line tests take place independently of the current process, in a laboratory separate from the process, on systematically-taken random samples which are not reusable. Its aims can include:

- detailed analysis of samples which were logged as defective during on-line testing;
- issuing of certificates for customers;
- production of internal statistics;
- establishing quality features which cannot be determined on the production machinery;
- checking the on-line system.

On-line control must take account of the respective inertia of the system. In the case of pH regulation, for example, the variables which influence the process control behaviour are the following:

- fabric characteristics, hydrophilic properties and the absorbency of the water/ethanoic acid mixture,
- placement of additives and the mixing process in the bath,
- measurement location,
- concentration of the added diluted ethanoic acid,
- pH of the water supplied,
- non-linearities (valve characteristics and pH curve).

Results obtained thus are shown in Fig. 3. Measurements are carried out every minute. It takes about 5–10 mins. to set the pH to a new value. Once the new value has been reached, there is stable control. The fairly long control time for a new value is due to the inertia of the system (determined by the ratio of bath content and the influx speed of the total liquids fed in, such as water, ethanoic acid). Trials with conventional PID controllers showed a slower or more fluctuating behaviour.

The problems with on-line colour measurement consist not just in how and with what scanning speed the measurement is to be made, but also in where the

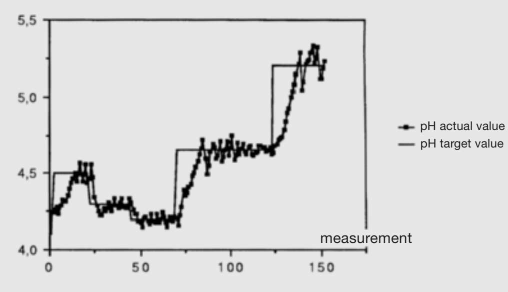


Fig. 3: On-line control of pH.

measurement is to be made. The industrial vat dye pad-steam process consists of the units illustrated in Fig. 4. The production sequence consists of pretreatment processes (washing, alkaline boiling off), which were carried out in the same plant before dyeing. After the fabric has been finished on this plant, it is then subjected to a thermal treatment (polymerisation or sanforisation machine). All that is of interest is the final colour. It makes sense to measure it after the last treatment and after a certain stabilisation time. Such measurements are carried out off-line, by the quality control staff.

These measurements provide information about the shade of the fabric, and are used in → Pass/fail tests or in corrections to recipes for the next dyeing. Since the number of such measurements is generally limited (they require the deployment of staff for cutting out samples for colour measurement), this leads to limited information about the causes of colour deviations. Moreover, they are not suitable for use in a control system for correcting colour deviations or for evaluating large amounts of data. The most suitable point in the dyeing process for predicting the colour which will finally result is the end of the continuous dyeing machine (point VII). Possible control corrections could be the liquor uptake (padder) or the addition of chemicals (reduction or oxidation agents). The reaction time between liquor uptake and colour measurement at the end of the machine is too great for effective control. Any change in liquor uptake which is necessary or which has been carried out is only registered at the end, after about 10 min. For this reason, additional measuring devices along the run of fabric can be useful for improving the overall control (e.g. measurement of the liquor uptake with the Mahlo or Pleva devices, air permeability, colour measurements in the wet state, pH or redox measurements). The colour measurements at the end of the plant are useful for correcting long-term deviations, for setting up reference values for critical control loops, or for setting up suitable control schematics.

When using colour measurement devices based on “reflectance measurement” in on-line operation, all efforts must be concentrated towards achieving the same dyeing conditions from the first to the last metre of the dye batch. This is particularly important for dyeing short lengths. Only when all these requirements have been met does it make sense to introduce the colour measurement device into the process, with the aim of measuring the current dyeing, and possibly of influencing the final dyeing result. Most colour measurement devices are concerned with evaluating quality in the final goods check, i.e. away from the production sites. Most measuring devices record the measurement value approx. 15–20 mm above the surface of the goods. If used on continuous dyeing plants, this would lead to the fear that problems could occur through heat radiation or re-evaporation from the goods. A measuring device which is suitable for this purpose should still be able to make measurements at a distance of 1.2–6 m from the goods.

A decisive factor for on-line colorimetry is the location at which the colour is measured. Depending on the measuring location, the run of fabric which is to be measured (e.g. polyester/cotton) in a continuous dyeing plant can be in the most variable conditions (Fig. 5).

– after the padder: wet (35–55% initial moisture content),
– after the IR pre-drier: damp (20–35% residual moisture),
– after the drier: residual dampness to absolutely dry (0–8%) and warm after the thermosol part: absolutely dry and warm,
– after the washing machine: wet (40–60% initial moisture content),
– after the drier: residual dampness to absolutely dry and warm,

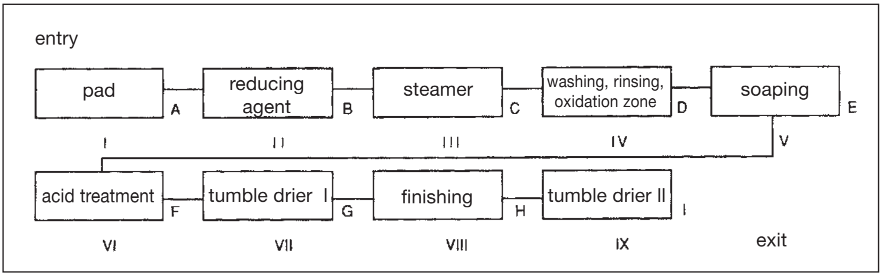


Fig. 4: Continuous dyeing facility.

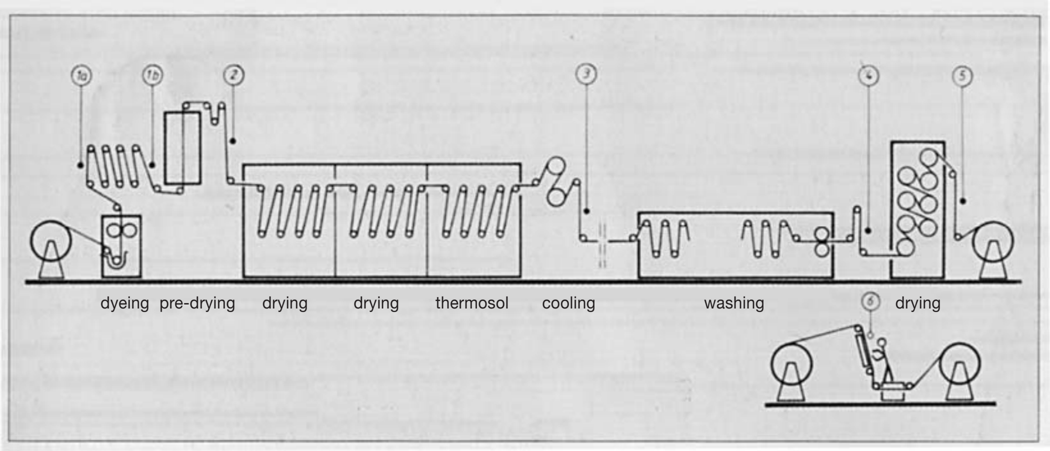


Fig. 5: Indication of possible dye measuring locations in a continuous dyeing facility (on-line) (Monforts).

– on the inspection table: cold (room temperature) and sometimes damp from storage.

Since the sample which is to be measured is compared with a standard, and this standard has to be prepared and worked out, it is to be expected that all the aforementioned states in which the goods might influence the colour appearance in comparison with a cold standard sample, damp from storage, to a greater or lesser degree. The use of on-line colour measurement devices in continuous dyeing makes sense where there exists a meaningful possibility of defining the standard clearly. Different levels of moisture and temperature influence the colour appearance so strongly that the measured values can be misinterpreted. Favourable measurement locations appear to be directly after the padder or in the finished goods inspection. With a perfectly-working drying and thermosol part, the colour evenness is preserved in respect of the edge/middle/edge difference. Any uneven colour result after the padder is partially alleviated by subsequent processes. The tendency of the dye liquor application appearance remains largely preserved right up until the finished goods stage. On-line colour measurement after passing through the padder can provide an early indication of defects or changes of shade from selvedge to centre.

Whilst pure on-line colour measurement technology is far advanced, and special pass/fail programmes for acceptance testing on dry runs of cloth are in the process of being developed, we still lack prospects of programmes which would put textile finishers in a position to provide the maker-up with information about the colour processability of a dye consignment. The maker-up must reckon with shade differences in the goods delivered, since in dyeing, for technical reasons it is not yet possible to avoid changes of shade within batches and colour deviations between batches to the desired extent. However, the processor would be well served with details of the bales of goods delivered which would tell him clearly which bales and bale sections can be processed together as one shade for making individual clothing items without the risk of visible colour differences appearing at the seams, and giving cause for complaint. This task must be taken on by colour sorting programs which, in the goods inspection system of the textile firm, are coupled with on-line colour measurement and pass/fail evaluation. For the textile finishing industry, this colour sorting would have the advantage that the time-consuming (visual or colorimetric) evaluation of the goods on the basis of sewing samples and their manufacture could be dispensed with (source: Jola, van Wersch, Rieker, D’Hulster).

ÖNORM Austrian standard.

Opal batiste Fine-filament, milky-looking cotton batiste, named after the semi-precious stone opal. Simple cotton yarns, usually maco yarns, are used for this. Finish: pre-mercerising, bleaching, acid treatment and final mercerising without tension. This creates a shrink effect which lends the fabric its milky appearance. Opal comes dyed, printed and embroidered in delicate colours, as well as in white. Used for summer clothing fabric, decorative aprons and in the cleaning industry.

Opal finishing → Transparent and opal finishes.

Opaline products → Pigment printing.

Opaque finish

I. In the case of thin knits, reduced transparency is often desirable, and this can be achieved through a calender process.

II. Black-out curtains are intended to prevent any light entering; this is achieved by coating.

Open area (printing screen) → Printing area.

Open-cell cellular material When → Foam lamellae (= closed-cell foam) are destroyed, or flow back into the cell webs at the end of foam formation, open-celled foam is obtained.

Open decatizing → Decatizing.

Open-end spinning → OE spinning process.

Opener (rope plaiting device) → Rope opener.

Opening, willowing In spinning technology, preparation on the → Plucker.

Open steam vulcanization → Vulcanize, to.

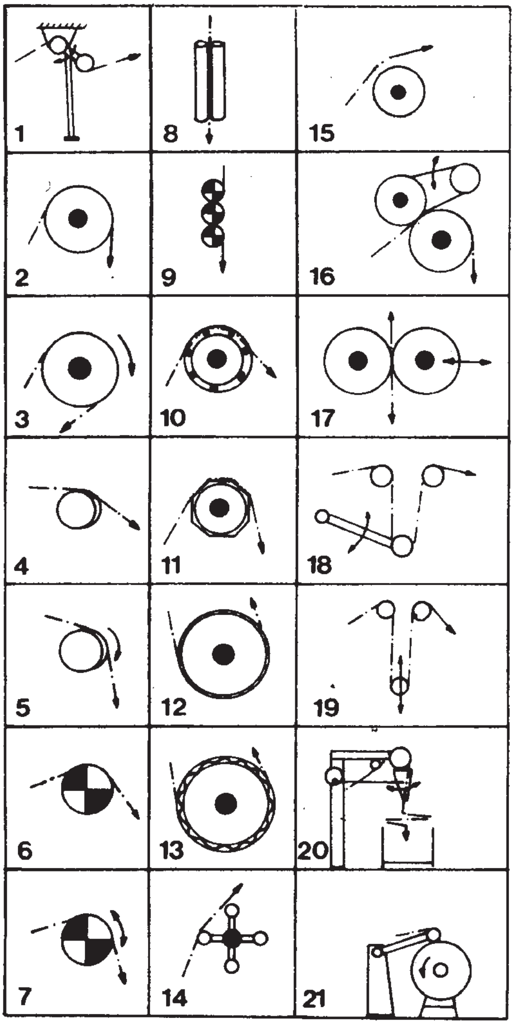


Fig. 1: Elements common to open-width washing machines. 1 = variable tension rollers; 2 = guide roller; 3 = driven draw roller; 4 = spreader; 5 = rubberized bow roller; 6 = expander bar; 7 = driven expander roller; 8 = fabric guider; 9 = three-finger selvedge uncurler; 10 = cage drum roller; 11 = contour roller; 12 = perforated drum roller; 13 = fluted drum; 14 = beater roller; 15 = brush roller; 16 = feed roller; 17 = squeeze roller; 18 = compensator roller; 19 = dancer roller; 20 = plaiter; 21 = large batcher.

Open-width centrifuge → Centrifuges for piece goods in their open-width state, also for warp- and weft tie beams.

Open-width dyeing machines →: Star frame; Padder; Jigger; Beam dyeing machines; Continuous dyeing ranges.

Open-width souring Soaking or impregnation of piece goods in the open-width state with carbonising liquor (sulphuric acid or hydrochloric acid or aluminium chloride) before carbonisation in impregnation machines or roller vats.

Open-width washing machine – elements There is probably no other group of textile machines for

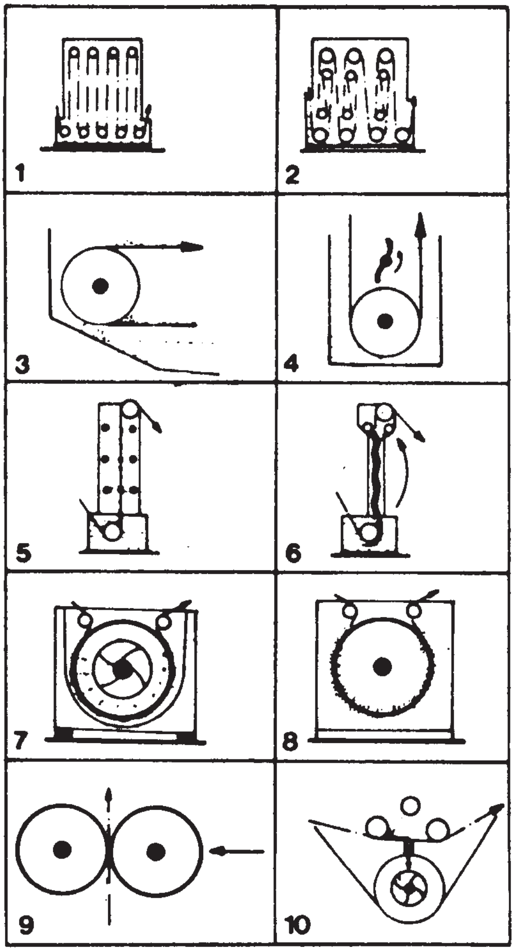


Fig. 2: Variants of washing sections in open-width washing machines.
1 = simple roller vat; 2 = roller vat with double fabric take-in; 3 = guide roller washing effect diagram; 4 = turbinator; 5 = spray section; 6 = circulation section; 7 = suction drum section; 8 = vibrating section; 9 = liquor separation by squeezing unit; 10 = suction rinse.

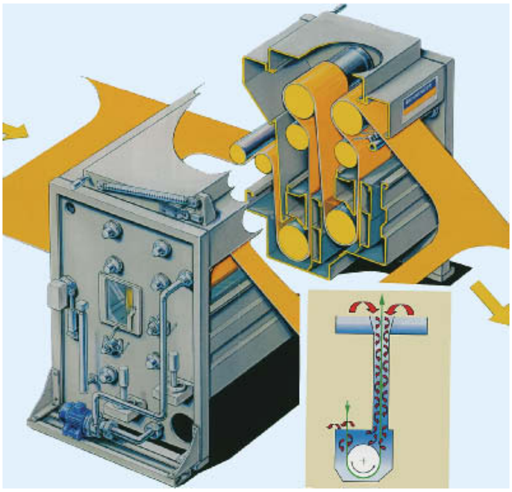


Fig. 3: *Open-width scouring Fortracta (Benninger).*

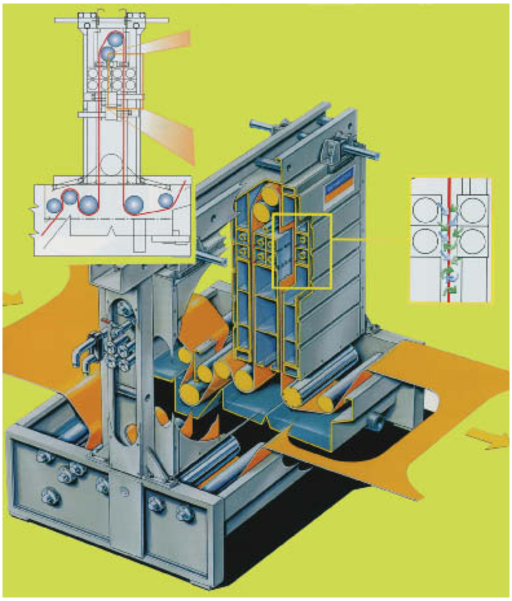


Fig. 4: Open-width scouring (Injecta).

which one can make such detailed divisions in design and application technological aspects. This is made more complicated by the fact that many manufacturing firms would like to develop their washing machines into universal machines, and to do this they combine several otherwise specific features. The distinction between pre-washing and final washing processes makes classification possibilities even more difficult. It may therefore be helpful to summarise briefly the design principles for open-width washing machines known to date. Fig. 1 shows customary construction elements for open-width washing machines.

There is a trend towards open-width washing and automation of the construction of the open-width washing machine. Loop guidance of the goods in roller vats is partly replaced by horizontal goods guidance, with the direction of the run of goods running equally from bottom to top and vice versa. Any longer contact time between the goods and the liquor can be obtained by dwelling immersion in an accumulator. To intensify the washing effect, vibrators and/or increased pump output for forced liquor circulation is used (Fig. 2 and 3).

Open-width washing ranges Machines for continuous open-width washing are constructed of individual washing units, which are modules within a plant which are capable of washing functions (Fig. 1). The

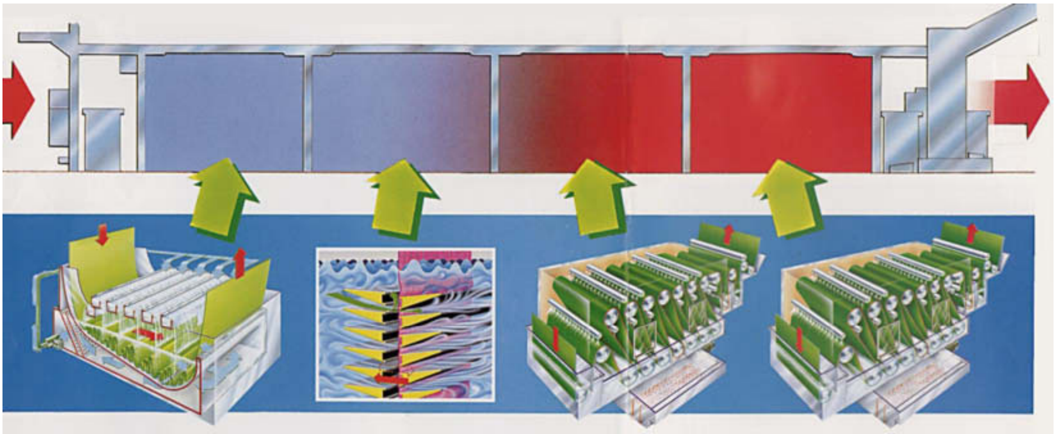


Fig. 1: Open-width washing line set-up (with CIMI elements).
Blue = steeping after impregnation; violet = mechanical loosening (by vibration); red = rinsing.

Open-width washing ranges

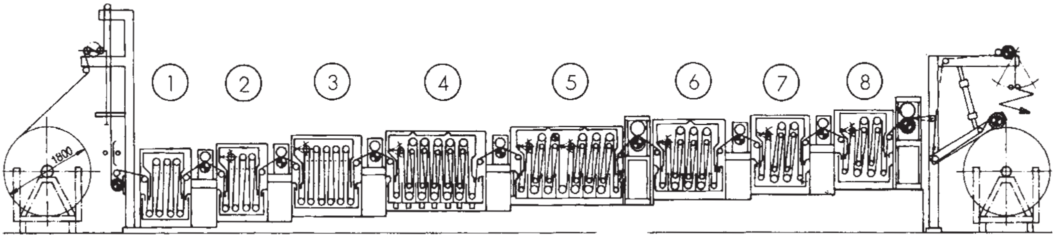


Fig. 2: Open-width washing line with various successive operations (1–8) and machine layout for wash liquor flow (from right to left) counter to the fabric flow (from left to right).

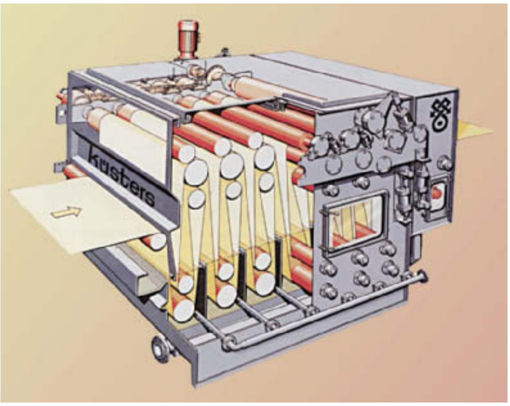


Fig. 3: Roller vat (Küsters).

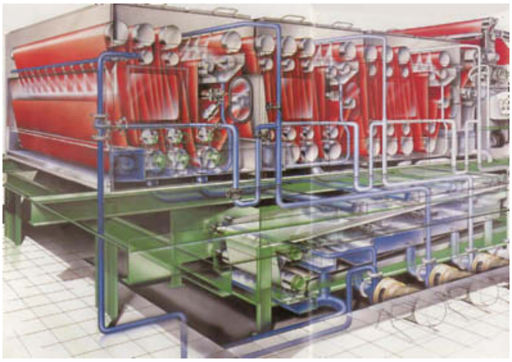


Fig. 4: Econ-Tex open-width washing machine (Babcock).

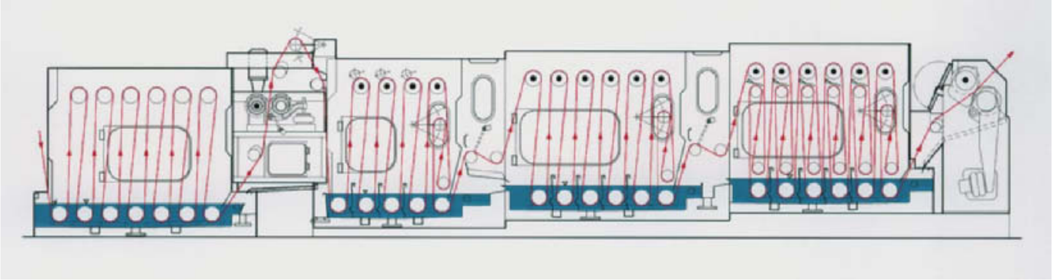


Fig. 5: Open-width scouring unit (Convi-Tex C from Babcokc).

sequencing of these units within a machine is variable. The individual units of a plant differ, to some extent, considerably, in terms of their guidance of goods and liquor, or else the same elements are used for each stage (Fig. 2). Large mechanical engineering firms include in their range, both horizontal and vertical open-width washing machines, as well as spray drum and perforated drum systems. In a conventional open-width washing range, the individual modules are set up from the back (goods exit) to the front, on modular foundations which rise step-like, so that the washing water flows against the goods step by step, with a natural fall (Fig. 5). The roller vats used in these open-width washing ranges (Fig. 3) represent the most important system of open-width washing machines. In the individual roller vat, also as a module in such a plant, the contraflow principle is realised by means of bulkheads and vari-directional liquor guidance.

The contraflow, which is regarded as essential, is created outside the liquor by means of laying-on rollers which lie on the upper guide rollers, loaded by their own weight. Through the laying-on roller's own

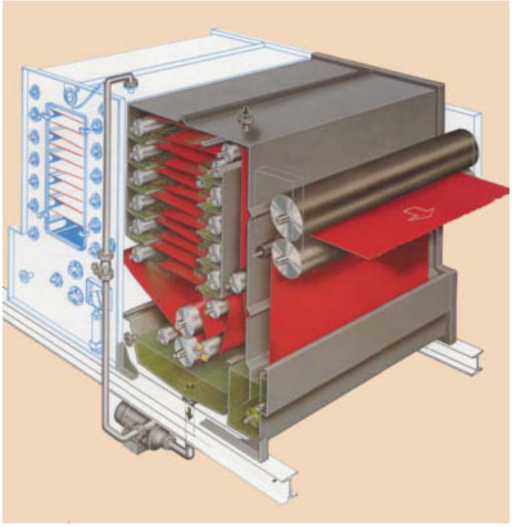


Fig. 7: Horizontal open-width washing machine (Kleinewefers KTM).

weight, excess liquor which is carried along by the goods is squeezed out and backed up to the extent that it flows down the ascending run of cloth in the form of a dense curtain of liquid. The high speed of the contraflow is calculated by adding the speed of the goods to the liquor which has been squeezed out. In the case of the “Econ-Tex” vertical open-width washing range from Babcock (Fig. 4), the goods run in a saturated steam atmosphere (virtually in a roller steamer). In relocating the standing baths of the roller vat from the goods compartment to below the machine, in order to carry out the contraflow and lint separation, the liquor is transferred by pumps from the liquor compartment into the respective goods compartment and back into the next liquor compartment. The overall contraflow liquor guidance thus has a strong liquor circulation superimposed on it. In each compartment, the liquor is brought directly into the nip between the goods and the rollers. The passage through the goods is effected at each deflection roller by the hydrodynamic print paste wedge and the effect of centrifugal force at each deflecting roller, particularly since there is no water back pressure (as in a roller vat on the lower deflecting rollers). Additional spraying tubes at the washing compartment exit support the washing action. Spraying tubes also support the liquor exchange at other points of the fabric passage (Fig. 6).

In horizontal open-width washing ranges (Fig. 7), which form the second most important group of open-width washing range types, the liquor flows down against the ascending goods under gravity. Here, the flow is forced through the goods in the nip at the deflecting rollers, which – in comparison with the passage through the goods in the areas between the deflecting rollers – leads to an increase of 0.2 l/m^2 per second (of a given fabric) to 1.2 l/m^2 per second. With raw cotton fabrics (not pretreated), problems can arise with this system, due to lack of through-flow, so that water pockets form.

In the third important group of open-width washing ranges, the perforated drum washing machines (Fig. 8), the liquor level in the interior of the drum is lowered

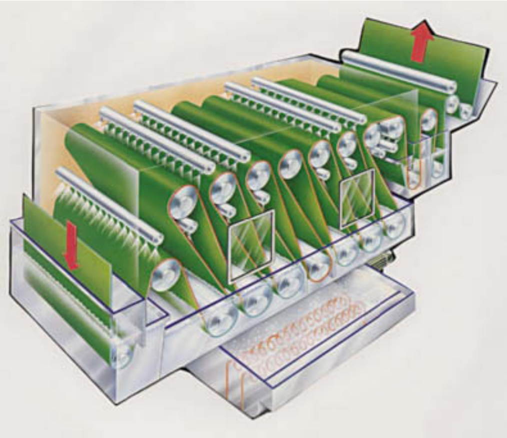


Fig. 6: Technoplus open-width washing machine (MAT).

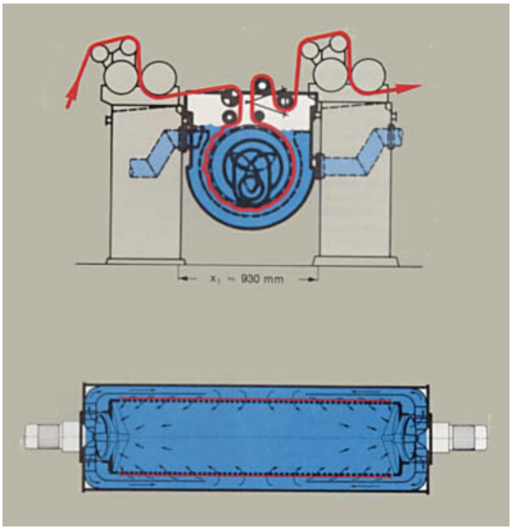


Fig. 8: Particular case of the perforated drum washing machine: suction drum (Babcock).

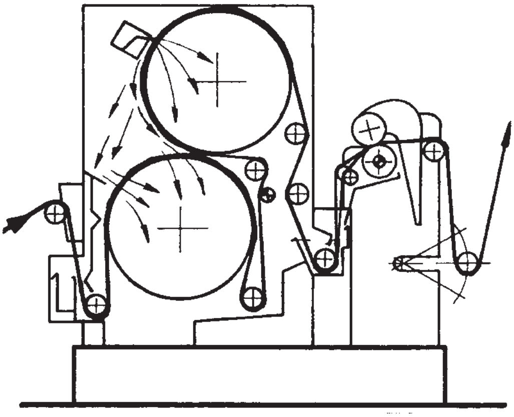


Fig. 9: Rotojet drum-type open-width washing machine (Küsters).

relative to the liquor level in the trough (outside), so that the liquor flows through the goods under gravity through the perforated drum. In contrast to perforated drum open-width washing ranges, in which the flow through the goods is effected by sucking the liquor out of the drum interior, in the fourth group of open-width washing ranges, (Fig. 9), the liquor is sprayed onto special drums around which the goods run. A special feature here is the grooved drum, since with this the liquor which is sprayed onto it runs through the fabric into the grooves, and then flows downwards and then through natural gradient, once again runs through the goods which have been conveyed by the drum. In today's washing units, the rules of liquor separation and substance exchange processes are realised consistently, i.e. liquor throughput with low-ballast liquor, early setting of washing equilibrium, washing temperatures close to boiling point of water, machine action deformation of the fabric fibre bulk, etc. A step in this direction is represented by the concept of an open-width washing unit in which the washing liquor is applied via a special liquor application device (bath-free), in which the liquor is separated and led away in the squeezer nip, and in which liquor throughputs of 5 l/kg are under discussion.

Open width wet pretreatment machines In the design and construction of washing machines, the trend has become established of ensuring as great a throughflow of liquor as possiblewith intensive substance exchange. Turbulence must be achieved on the one hand by the cloth itself, and on the other hand by mechanical devices. And not least, this task is performed automatically by the deflecting roller. Squeezing units and consistent use of the contraflow principle represent the state of the art. From these design concepts in machine technology, essentially four typical systems have developed: → Roller vat with horizontal passage of goods, perforated drum, cloth batch, and roller vat with vertical guidance of materials. Due to the number of large-sized baths, the result is, in part, relatively high in consumption of chemicals, corresponding high energy costs, and – under certain circumstances – a greater staffing requirement than for smaller compact plants; also considerable space requirement, since continuous washing ranges require space which is often not available. Open width wet pretreatment machines for open-width goods, in principle: pieces are wound onto a perforated tube, treatment liquor or rinsing water is introduced centrally whilst the roll rotates. In an ideal case, impregnation, dwelling, rinsing and spinning take place on the tube. In other cases, impregnation takes place on a padder, followed by winding onto the tube, dwelling and rinsing out. The fabric can also be sprayed with liquor whilst being wound on, and after winding on it can be pressed through the roll by means of a pump.

Operating costs (running costs) Pure, mostly fixed costs which result from those portions of the production costs accounted for by machinery and energy.

Operating point In a system (e.g. a pump) the actual operating status results from the intersection point of all the characteristic curves involved (e.g. in the pump diagram, see Fig.).

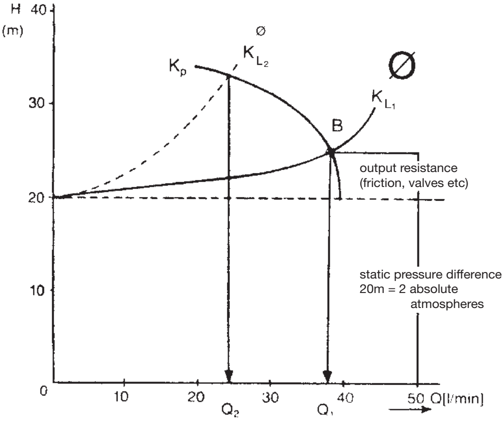


Fig.: Pump characteristic curve with operating point B with large pipe cross-section (K_{L1}) in comparison with pipe characteristic curve (K_{L2}) with small pipe cross-section.

Operating time Individual procedure within the → Processing sequence as a whole, time available to the worker for performance of the task within the period under observation. Divided into activity time and rest time (determined by the work sequence, interruptions, break times, other unavoidable activities).

Operational data logging In order to construct a realistic cost accounting system, operational data from meaningfully subdivided departments are necessary.

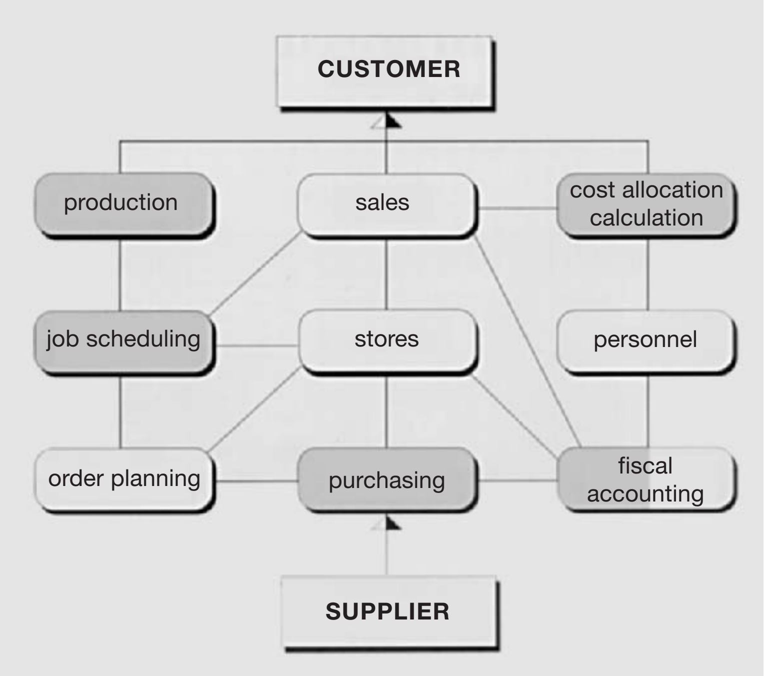
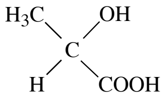


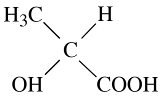
Fig.: Diagram showing the organisation of various operating spheres via an operational data logging system.

The firm (see Fig.) can be divided up according to technical considerations (organizational chart); for the purpose of operational data logging, the firm can also be divided up according to business management aspects. Here, production is a significant cost centre. Other costs centres include purchasing, distribution, operations planning and work preparation or warehousing.

Operational planning Predetermined sequence of individual processes or envisaged operations (→ Processing sequence in textile finishing). → Machine utilisation planning.

Optical Activity Characteristic feature of predominantly organic molecule bonds with spatial asymmetry. They match as the left hand and the right hand (mirror image isomerism), behave analogously in chemical and physical terms, have the same energy content, and yet are not identical, for → Polarised light in one case effects a laevo-gyration (l- or L- form, Latin: laevus = left), referred to as a negative rotation (–), and in another case a dextro-gyration (d- or D-form, Latin: dexter = right), here designated as a positive rotation (+). Such a pair of counter-rotating "optically active isomers", with the same structure otherwise, is called an antipodal pair. L and D forms of a molecule bond thus have optical activity. By contrast, a mixture of the same parts of both forms (D, L form) is optically inactive, since the L and D forms balance each other out (so-called racemic compound or racemate). Example: four different atoms or radicals adhering to the C atom, which take up different volumes, thus yield in space an irregularly distorted tetrahedron and thus lead one to expect optical isomerism, as e.g. lactic acid with asymmetrical C atoms can be laevo-gyratory (L-lactic acid) and dextro-gyratory (D-lactic acid):

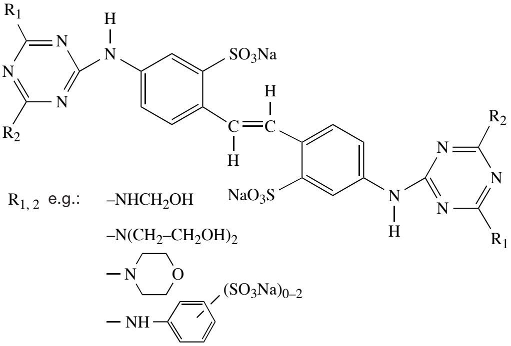




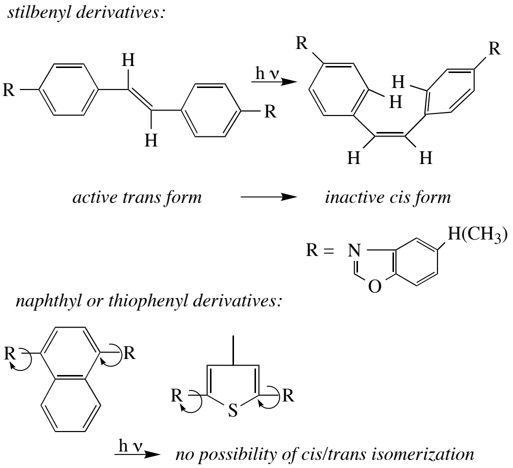
or non-rotating, optically inactive in the racemic mixture (D, L-lactic acid), as with commercially available fermentation lactic acid. Countless organic compounds exist in similar isomerism forms, such as optically active amyl alcohol, tartaric acid, glucose, fructose, sorbitol etc. Also included here are all proteins; they consist exclusively of L-amino acids, and are thus in their natural state only laevo-gyratory, i.e. optically active.

Optical brighteners (→ Fluorescent brightening agents). "Colour substances" which absorb light in the ultra-violet range and emit it again in the visible range. They therefore bring about an optical illusion on textiles, in that they raise the level of whiteness of the goods. This characteristic is associated with their chemical structure, as follows:

Cellulose fibre brighteners are derivatives of diamino stilbene di-sulfonic acid. What is effective here is only the trans-configuration, since only this form has a planar π-electron system enabling mesomerism in the excited state:



Above all in solution, stilbene derivatives suffer a light-induced de-activation of the optical brightener into the polymer matrix of the textile goods, but on the other hand there is a stabilization of the trans-stilbene form. Stabilisation of the trans-form of the optical brightener can also take place chemically, in that this configuration is sterically fixed, as in the naphthyl- or thiophenyl benzoxaolyl derivative:



Optical brightening agents → Fluorescent brightening agents.

Optical fibre Cladded core fibre made of inorganic or organic glass, whose core (diameter 5–100 μm) has a higher refractive index than the sheath. Through total reflection, light which enters at one end of the fibre and emerges at the other end transferred with as little loss as possible. Used for information transfer, lighting engineering, etc.

Optical Isomerism → Optical Activity.

Optics → Light wavelengths.

Optimization The organisation of technical and economic systems or processes in order to achieve a given aim in the best possible way, taking into account all secondary conditions. The optimization of finishing processes must be the aim in every firm. → Process control through measuring and control equipment represents the means for this. Many opportunities for reducing finishing costs remain unused, although the behaviour of most finishing products can be precisely described. Optimized process recommendations have been developed for, e.g., many classes of dyes or fibres. However, for the practical person it is often too costly to implement the knowledge available. Thus with changing finishing conditions (e.g. changes in the liquor ratio) or when transferring dyeing formulae from the laboratory and putting them into practise, it is frequently necessary to settle for wholesale corrections. Process recommendations are much simplified so that they can be applied easily and safely. Finally, in the selection of the most economical formulae, the process costs and the ecological effects are often ignored. With the current state of computer technology, computers and process controls can be successfully deployed in order to facilitate the selection of the most economical and ecologically optimized formulae, as well as to design the finishing process so that it is safer and simpler. In recent years, computers and process control systems have become considerably more powerful and cheaper. The question of their use for optimizing formulae and processes is therefore particularly topical. This is illustrated by two optimizations from the field of finishing:

1. Polyamide fibres take dye at relatively low temperatures. For this reason, energy-saving low temperature processes (e.g. at 55–75°C) have been proposed. However, to optimize, the low energy costs must set against the higher time costs, since in the case of polyester, a temperature which has been reduced by 10°C means that the necessary dyeing time is approximately doubled. The optimum maximum temperature, at which the overall costs (steam and time) are minimal, depends on the ratio of steam costs to time costs, as well as on the formula (rate of dyeing), the fibres (staining speed) and the heating rate (Fig. 1). The necessary dwell time in the case of this optimum maximum temperature is, by contrast, almost independent of the formula and fibres, and is essentially given by the cost ratio of steam/time. If the quality of the goods permits, it is consequently more economical to dye different formulae at different maximum temperatures but the same dwell time than (as has been more common to date) to dye for different lengths of time at the same temperature.

2. Some of the parameters which are characteristic for the quality of resin-finished textiles (e.g. crease

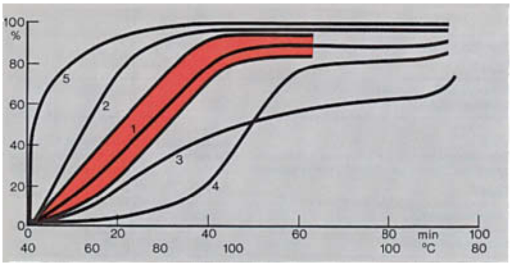


Fig. 1: Absorption curves for various dyestuffs applied to polyamide, whereby Curve 1 is approximately optimum. Curves 5 and 2 represent a rapid dyeing process with the accompanying risk of unevenness. Curves 3 and 4 guarantee even dyeing but require expensively long dyeing times. Curve 1 is the optimum compromise.

recovery ability and tear strength) change in opposite directions relative to one another, so that optimizing them simultaneously can be realised only by way of a compromise. The optimization process must be on the basis of process parameters which are typical for the crease-proof finishing of cotton fabric. In all three cases, the monomer is DMDHEU; the processes differ from one another in relation to the catalysts used and the condensation conditions. As an initial step in optimization, the mathematical relations which are characteristic for the individual processes were determined by means of test programming. The optimization parameters were dry and wet crease angles, decrease in tear strength, and releasable formaldehyde content. 20 tests were required to build up one database in each case. Of the so-called multi-purpose optimization methods, the method of loss reduction was used. It was thus possible to determine the compromise optimum values, with the aid of the loss reduction method. On the basis of all this, it was possible to work out a computer-controlled optimization program (Fig. 2). The program is constructed in the modular system, with one module corresponding to one finish in each case. The results obtained on the basis of test programming form the databases of the finishing technologies which are to be optimized. The databases can be compiled for each finishing agent which is used in practice within the firm, for each catalyst and its permitted concentration range. The databases and the system-description functions can be stored on diskette, so that the modules can be expanded, exchanged or put together in accordance with the finisher's requirements and capabilities. After selection of the databases for the finishing processes to be used, the characteristic data for the fabric to be finished, and also the requirements made of optimization parameters and optimization direction (minimum or maximum) must be fed in.

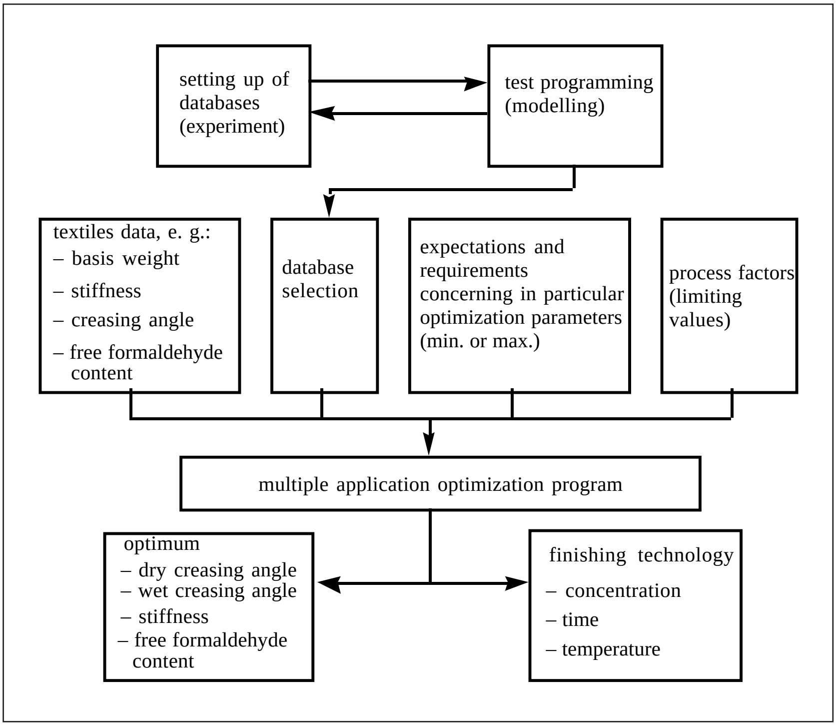


Fig. 2: Diagram showing computerized optimization.

According to the requirements, the following options can be selected: achievement of optimum crease recovery ability with

a) permitted max. tear strength reduction,
b) permitted max. amount of releasable formaldehyde content,
c) simultaneous permitted max. values for tear strength reduction and the releasable formaldehyde content.

(Source: Csanyi).

Optimum processing conditions

Optimum processing conditions Textile finishing methods which are associated with chemical processes often have optimum processing conditions, within the scope of which, they are applied (example: see Fig.).

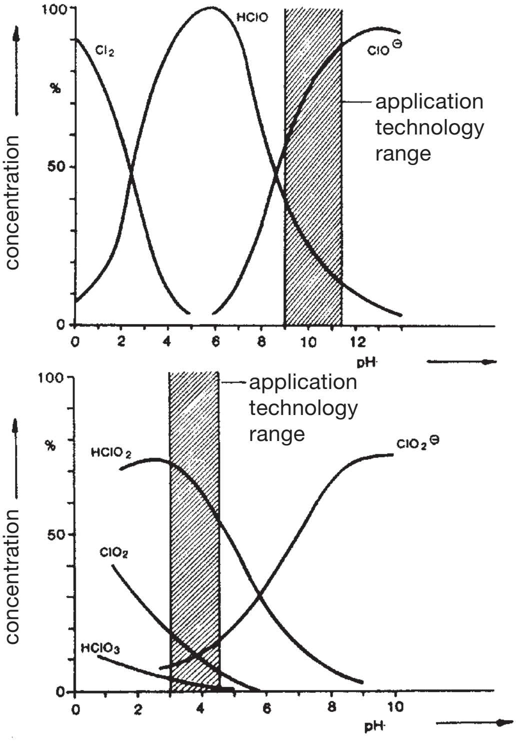


Fig.: Application technology range of activity with regard to the pH of the bleaching liquors of a hypochlorite bleach (top) and a chlorite bleach (bottom).

Optoelectronics For the transmission of information by optical wave guides through fibre-glass cables, using laser technology, the following principle applies: the shorter the wavelength, the more units of information can be transmitted. Since light has a considerably shorter wavelength than, e.g., radio waves, it can be used to convey considerably more information. A prerequisite for this, however, are the techniques and materials which can create and transmit the light signals, and where necessary amplify them, process them, store them, and appropriately decode and output them. Here, it is primarily the task of chemistry to smooth out new paths. By way of analogy to electronics, the technology based on light waves is called "optoelectronics" or "photonics" (see Fig.): tasks which were hitherto taken on by electrons are taken over by photons. When photonics was conceived in the late 1950s, the materials with which it could be achieved were not yet available.

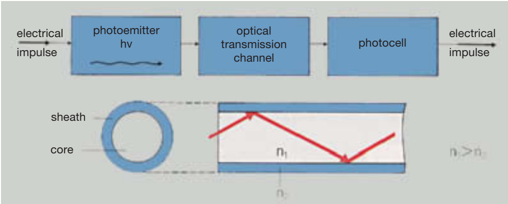


Fig.: The transmission of information by means of an optical waveguide (optical fibre).

The most obvious suitable material was undoubtedly glass. However, first of all the technical pre-conditions had to be created in order to produce glass which was as pure as possible. Although high quality optical glass was already very transparent around 1960, the residual absorption was still so great that it was not suitable as a light conductor for information transmission systems.

Due to the demands of the telecommunications industry, in 25 years the optical losses in glass have been reduced to one ten-thousandth of the 1960 value. A pane of the best optical waveguide glass which can be produced today, 3 km thick, would allow more light through than a conventional pane 3 mm thick. However, this does not exhaust the possibilities for optimizing materials suitable for optoelectronics by a long way. New perspectives are being opened up with polymer optical wave guides in particular. In optical waveguide technology, it is mostly quartz glass fibres which dominate. The transition from multi-mode to mono-mode fibres with a higher transition capacity has been achieved. Although initially the German post office preferred copper coaxial cables for extending the cable TV network, increased use of glass fibre cables in the extension and modernisation of the telephone and telecommunications network is becoming apparent.

Non-oxide optical waveguides are however already undergoing trials as alternatives to quartz glass. The high optical transparency of the non-oxide glasses predestines the fibres extracted from them for use in telecommunications. They should enable signal amplification ranges of up to 10 000 km. However, practical utilisation of these capabilities is countered by considerable implementation costs, which cast doubt on their economic viability. For applications in the close range area, interest is focused on optical waveguides made of organic polymers. Currently these are produced mostly from polymethylmethacrylate (PMMA) or polystyrene as the core material, and from fluorocarbon polymers as the sheath material. The purification stages (distillation, filtration, etc.) are carried out under clean room conditions at the monomer stage. Through melt spinning, a so-called step index fibre with a core/sheath structure is produced. Through the very low refractive index of the sheathing material, rays which impinge on this boundary surface at a flat angle are reflected back into the core, and are thus passed on. (Source: Hoechst).

Oral poison Pesticide for combating textile pests (→: Insecticide; Mothproofing) which is ingested with food. Potency is usually stated in mg/100 g (x mg have a fatal effect on living textile pests).

Orange peel effect Local shrinkages in two-layered fabrics such as e.g. synthetic leather; occurs particularly when non-woven fabrics are used as carriers. The cause is likely to be an uneven fibre distribution in the non-woven fabric.

Orbis printing (Tschekonin method). Patterning by means of a semi-solid coloured (mosaically composed) gelatine mass which has been applied to a metal roller, and which is produced beforehand and cut out in accordance with the pattern. Printing takes place with this, until the printing mass has been used up (i.e. similar to → Offset printing). A new roller can then be produced in the same way. Strong prints are produced by this method.

Orbitals (Latin: orbis = circuit, orbit). A term from quantum chemistry to describe the region around the nucleus of an atom, or around several nuclei in the case of a molecule, in which an electron is most likely to be found. In modern wave mechanics, atomic model for three-dimensional states of an electron, we have orbitals as so-called wave functions, in place of electron paths. This wave function of an electron is called the orbital wave function. We say that the electron has an orbital, not a path. The idea that when atoms and molecules are united, the bonding electrons come together and form chemical bonds, is expressed in the language of the molecule-orbital theory as follows: from the atomic orbitals (AO), the molecule orbitals (MO) follow, through linear combination. After that, a distinction is made between bonding, non-bonding and anti-bonding orbitals.

The term “orbita” originates from quantum theory. In 1925, the physicist W. Pauli showed that within an atom, two electrons can never have the same spin at the same time (Pauli’s exclusion principle). This rule allows the configuration of atoms to be determined, and the logic of the periodic system to be explained.

The shell configuration corresponds to definable energy states (Fig. 1):

Energy state	s	p	d	f
Max. no. of electrons	2	6	10	14

The energy states of atoms can be described thus:

Hydrogen: $Z = 1$ H: $1\,s^1$

Oxygen: $Z = 8$ O: $1\,s^2$, $2\,s^2$, $2\,p^4$

The orbital is a mathematical function whose spatial limits attempt to circumscribe the body within which the electrons of an atom move (Fig. 2). The square of this function gives the probability of the presence of the electron in the space. One cannot simultaneously determine the speed and position of the electron in the orbital. Moving from the atom to the molecule, the orbital is described as the linear combination of the atomic orbitals.

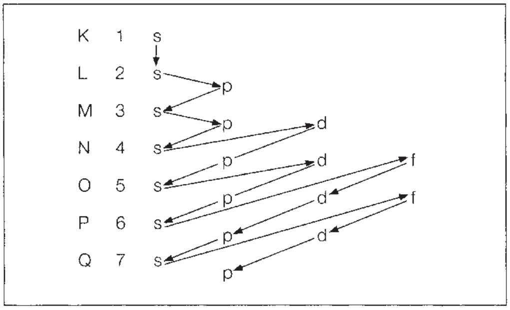


Fig. 1: Energy states according to shells, groups and sub-shells.

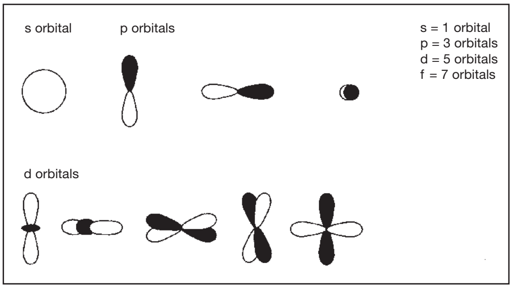
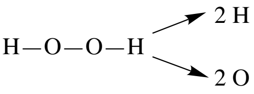


Fig. 2: Sketches of orbitals.

In peroxide bleach, the connection between orbitals and a stabiliser is shown. Hydrogen peroxide consists of a symmetrical molecule:



$$\mathrm{H{-}O{-}O{-}H}\ \begin{matrix}\nearrow 2\,\mathrm{H}\\ \searrow 2\,\mathrm{O}\end{matrix}$$

It is oxygen which is responsible for the bleaching effect. The oxygen atom OS^{16}_{8} belongs to the atoms with the neutron numbers 2, 8, 20, 50, 82, 126. Their nuclei are very stable, since they have the same number of protons and neutrons. The molecule structure of the stabiliser connects with the peroxide orbitals: synergy with an optical brightener. In the atom, as a rule the electrons are at the lowest energy level (Fig. 3). The UV radiation of the light excites the atoms and the electrons are brought to a higher energy level; since this higher energy level is unstable, the electrons change back to the lower level and in doing so, emit photons in the range of visible light. This also explains why, instead of 100% of the visible light falling on an optically brightened

Order planning

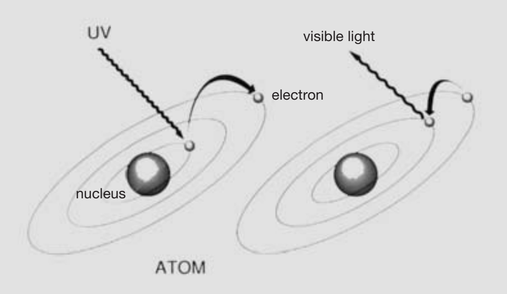


Fig. 3: Excitation states of an electron in an atom due to the absorption of electromagnetic energy.

substrate, there is a remission of 140%, thus giving rise to the impression of a high-white.

Order planning One application option for production control using computers is operations planning or order planning, and production tracking. Unfortunately, the arrangement of "Order planning – Planning" in spinning, weaving, finishing and garment manufacturing shops is variable. However, when the target is clear in

- the determination of the data for the start and end of manufacture of an order,
- the evaluation of machine utilisation over a unit of time,
- the checking of possible circumstances in connection with the delivery date for an order,

the restrictions in manufacture influence the method of order planning. To take an example from the mill: in view of the inertia of this type of manufacture and the existing difficulties in a change of article (tying, setting, etc.), continuous manufacture is out of the question (over-booking of the department for warp preparation, non-productive times, etc.). In the case of a finishing works, the waiting times between certain machines are associated with the maximum or minimum dwell times which have to be observed in order to prevent damage to the goods (through chemical reaction, wet goods, etc.). For this reason, planning which is suggested by an order planning software program, should be regarded as a representation of the operations which are to be carried out, in order of sequence. The solution must be permissible in respect of planning, and must be adapted to suit the technology. If one uses software for tracking production, the field surrounding production must be divided up into two large data groups: a) the machinery available within the firm; b) definition of the manufacturing sequence for each article. Machines equipped with the same features are grouped into operations planning points. This grouping allows e.g., one batch to be relocated if a machine is occupied and the manufacturing sequence is the same. This takes place in a manner which is transparent to the user. For an article, one determines a manufacturing area, which is ordered within the sequence of the work stages. Here, precise details of the manufacturing conditions and data belonging to the work stages (such as speed, response time, operations planning point, etc.) are established. Each work stage can be assigned an instruction for the staff entrusted with operating the machine (special requirements, etc.).

In its assembly, each article is clearly defined via the linking together of individual work steps (operational sequence). This assembly is carried out once, and stored in the computer master file. When planning a manufacturing order, the product plan is copied from the master file into the file of the internal order admin-

TIME PLANE	MARKETING (MIS) PLANE		PRODUCTION (CIM) PLANE
PLANNING PLANE season planning approx 160 – 220 days	sales planning	↔	production planning → supply planning → investment planing
ORDER PLANNING PLANE released working stock approx 10 – 30 days	order planning	↔	production order planning → personnel utilisation planning → machine load planning → ordering system/material reservation
EXECUTION PLANE throughput time approx 1 – 5 days	order monitoring ↕ order logging allocation/delivery note release	↔	production control ↕ operational data logging

Tab.: Integration requirement between MIS and CIM.

istration. Changes or supplements which specifically relate to the order can be made in the copied product plans. In the master file, on the other hand, all data remain in their original form. When a copy is produced, an order number is automatically issued, under which the product plan is stored in the system. This way, it is possible to check at any time how an order has passed through the works, even if modifications or supplements have been made in the master file in the same article, or if individual work steps have been deleted.

The algorithm is based on utilising each of the envisaged machines in accordance with the time required for the manufacture in question. This utilisation takes place based on several criteria, according to the level of intelligence of the software.

- Priority of calculation of the critical value: N = J/O; where J = number of days until the due date, and O = number of remaining work stages.
- Economic allocation, in order to increase the number of machines utilised at one operations planning point, with the aim of reducing the delay times during manufacture.
- Economic overlapping, which consists of starting a manufacturing process as soon as the material is available and before the current work cycle is concluded.

The planning which is thus achieved (see Table) can be altered manually if necessary, if certain regulations associated with the work cycle are to be taken into account. The modifications are made visible on graphic representations of the machine utilisation. At this stage of processing of the software programs, the user has at his disposal several printouts in the form of tables and lists. Usually these are manufacturing lists, monitoring lists, work tickets or operation lists. Confirmation that the work has been carried out is obtained via the recording of the data of the work sheet (length passed through, pass time). The system is then in a position to determine the dislocation in manufacture (orders not on time, room for play, etc.), and to supply the lists or screens with all the tasks necessary for the user (delays, etc.).

Order processing time (T). According to REFA, the association for time and motion studies, the time required by the worker from taking on the order to delivery of the finished goods. Dependent on the → Setting-up time and → Execution time.

Ordinates Vertical line in a system of co-ordinates. Horizontal: → Abscissa.

Organdy Fabric of cotton, viscose spun fibre and viscose filament woven fabric in taffeta weave construction, similar to → Mull or → Voile, with medium-strength finish, also figured and printed, transparent. Used for fine summer clothing materials; sometimes with stiffening finish.

Organdy finish → Transparent and opal finishes.

Organic chemistry Classification of chemical compounds of → Carbon, with the exception of carbon monoxide and carbonic acid, which for practical reasons belong to → Inorganic chemistry. Further sub-division of organic compounds into aliphatic and aromatic, which can often also be mixed (aliphatic-aromatic). Important organic compounds include, e.g. alcohols, esters, aldehydes, ketones, amines, carbohydrates, fatty acids, etc.

Organic glass By analogy to the term → Phosphate “glass”, this denotes colourless synthetics which are transparent like glass (e.g. aminoplasts, PVC, polyacrylics, melamine resins, the prototype → Plexiglas, etc.).

Organizational chart, organigram The classical textile finishing firm is divided into auxiliary establishments (e.g. laboratory), technical divisions (boiler house, repair departments, etc.) and production areas, as expressed in the organization chart (see Fig.).

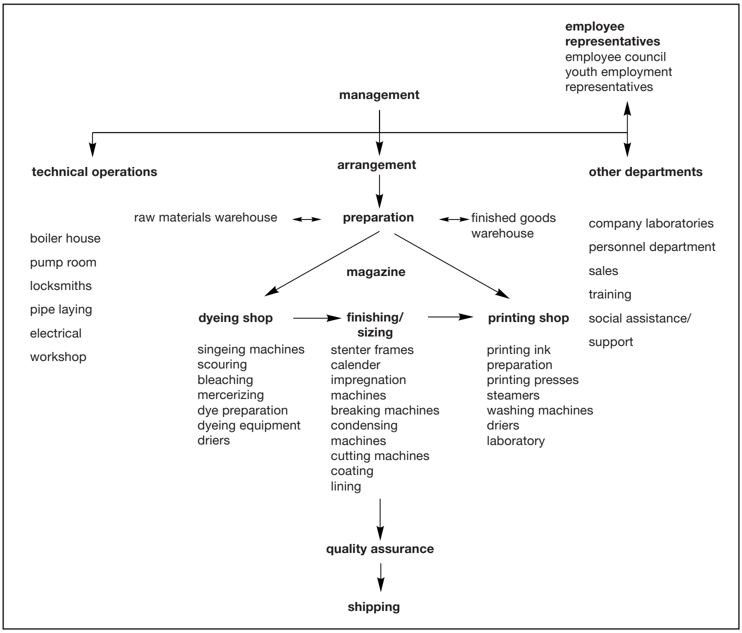


Fig.: Organigram of a finishing company.

Organizational structures in textile finishing

Organizational structures in textile finishing In textile finishing, as a rule a distinction is made between three different organizational structures (Fig. 1), which can be termed as follows:

- works finishing,
- integrated finishing,
- commission finishing.

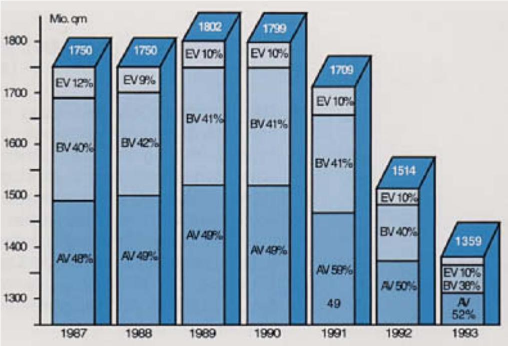


Fig. 1: Commercial finishing in the Länder of the original German Federal Republic according to the Central Association of the Textile Finishing Industry: contract finishing (AV), in-house finishing (BV), independent finishing (EV).

To clarify the different organizational structures, the relations between the mill, finishing shop and garment manufacture will be explained on the basis of structure models.

1. By works finishing, we mean finishing of raw goods produced in one's own works, on one's own account. Structure model 1 shows the classic vertical company. Finishing is a constituent part of the overall manufacture. This structure can provide ideal conditions of mutual communication. In vertical companies, efforts similar to those for other organizational structures are necessary for bringing the individual works, which are often set up relatively independently along the principle of divisions, to work together (Fig. 2).

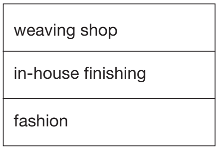


Fig. 2: Structural model no. 1 of in-house finishing.

Model 2 shows partial verticalisation, a common form which is a variant of model 1. The garment manufacturing shop is the customer, and the works' performance ends with the manufacture and sale of the run of fabric ready for making up (Fig. 3).

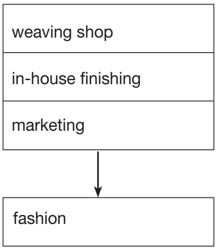


Fig. 3: Structural model no. 2 of in-house finishing.

2. By integrated finishing, we mean finishing of raw goods which one has bought in oneself, on one's own account. In this case, the finisher is one stage on the market, and is autonomous. The raw goods are bought, finished, and passed on at one's own risk. This possible organisational form is illustrated in Fig. 4.

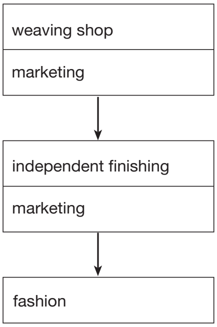


Fig. 4: Structural model no. 3 of independent finishing.

3. By commission finishing, we mean the finishing of outside raw material for the account of others. The finishing shop is practically turned into a service company, which exclusively offers its services for sale. The weaver is able to turn his entire attention to creativity and opening up markets, and to leave the extraneous finishing, which, due to its high requirements for energy, steam and water alone, also involves special environmental considerations and risks, to be dealt with by specialists.

The vertical "one-stop shop" type of firm with its own works finishing resorts to commission finishing if, due to good economic trends, it cannot cover certain production peaks, if its machines cannot deliver the required finishing effects, or if an article is particularly difficult and the finishing risks within one's own works are deemed to be too high.

The customer for the finishing cannot be either the weaver or the maker-up, but the textile intermediary, the manipulator. Experience shows that from this constellation, interesting tasks for textile finishing can result, but that partnership in the technical works is practically missing, which can have serious consequences. The manufacturing process of the fabric runs, the fibre material used, the texturing type in the case of filament yarns, and similar important details are mostly lost in the obscurity of the trade channels, so that often extensive checks on raw goods are necessary before corresponding batches can be worked on.

Organogens Those elements such as →: Carbon; Nitrogen; Sulphur which are predominantly involved in the construction of organic compounds.

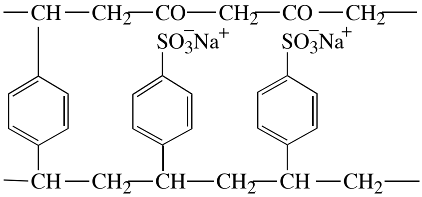
Organoleptic From the Greek, relating to perception by the senses. Organoleptic testing relates to the evaluation of appearance, handle, odour and taste; e.g. a purely visual assessment of a cleaning effect.

Organoliths Organic → Ion exchanger, subdivided into:

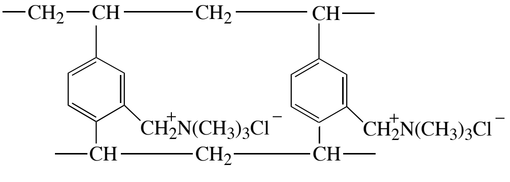
I. Artificial organoliths (carbon exchangers): sulphonated high molecular humus coals (brown coal, peat, wood), as acid-resistant ion exchangers.

II. Synthetic organoliths (exchanger resins, synthetic resin exchangers, resin exchangers): porous condensation and polymerisation synthetic resins with a large inner surface, with numerous reaction-capable, ion-forming acid or basic groups.

a) Cation exchangers are, e.g. condensation products of aromatic basic bodies of an acid nature, such as mono-valent or poly-valent phenols, aromatic and aliphatic sulphonic or carboxylic acids, with aldehydes, sulphonated phenol resin, sulphonated styrene, carboxylic acid resin, oxysulphonic acid resin, etc.; e.g. (in 3-dimensional terms):



b) Anionic exchangers are, e.g., condensation products of aromatic and aliphatic amines with aldehydes and related compounds of quaternary polyamines, etc.; e.g. (in 3-dimensional terms):



Organopolysiloxanes Organic silicon compounds of an oily or resin-like condition. Used for water-impermeable finishes.

Organosiloxanes (organopolysiloxanes) → Silicones.

Organosol Colloid solution in organic solvent.

Organosol process Hand dyeing process with dyes dissolved in solvents, for painting scarves, shawls, ladies' clothing fabrics and goods sold by the metre. Execution of partial plain dyeing, as well as all types of patterns. The latter is carried out with a cotton wool wad or brush, dipped in dye solution, onto the surface of the taut fabric.

Organotropic compounds,

I. These auxiliary solvents are organotropic compounds or polar, hydrophobic substances.

II. The solubility of strongly polar compounds in organic solvents is sometimes too low. The addition of organotropic compounds can increase solubility in that the hydrophobic proportion of micelles is increased in comparison with the hydrophilic ones (displacement of their → HLB value in favour of solubility in the organic non-polar medium). This requirement is fulfilled by polar hydrophobic substances. → Lyobipolarity.

Organotropy The capacity, especially of surfactants, to dissolve in organic media those compounds which are not soluble in solvents (→ Lyobipolarity).

Organzine Organzine (for warp ends, bolting cloth, etc.), twisted from 2–3 grège threads, given a corresponding preliminary twist, and twisted together counter-wise.

Oriental carpets Genuine, tightly-woven plush carpets, originating from the Orient: usually hand-knotted (typical → Knot density), always knotted through (each individual knot and each pattern discernable on the reverse), irregular pattern, often not quite uniform colour (slightly stripey in the background), fringed edge formed of warp threads. Main groups: →: Smyrna carpets; Persian carpets; Nomad carpet. Dyeing: previously with vegetable dye (usually good fastness to light, frequently not sufficiently fast to water and washing); European imitations of Oriental carpets are more resistant to washing and cleaning.

Orientation → Texture; Fibre texture.

Orientation forces → Secondary valency forces.

Original cost (prime cost) → Service life of textile plant and equipment.

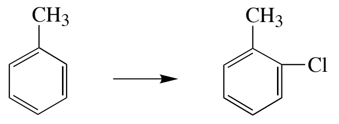
Orleans Smooth or patterned woven fabric (half-wool) in plain weave, twill weave and fancy weave (with figuring weft); also termed → Alpaca.

Orpiment Arsenic trisulphide, AsS_4. One of the oldest chemical reducing agents for indigo (orpiment vat). In the 18th century, generally known in Europe as "blue applied by brush onto calico" (orpiment brush blue), also known as orpiment English blue. Now found only in India (cottage industry).

Ortho- (Gk.),

I. Prefix for inorganic compounds which contain molecular linked water.

II. In the case of compounds of aromatic nuclei, term for the isomer (1,2-) position of substitution products, e.g.:



toluene *orthochlorotoluene*

Ortho acid → Acid anhydrides.

Orthocortex → Wool structure.

Orthokinetic coagulation Imperfection in the degree of dispersion of dispersion dyes in the dye bath, through strong mechanical influence, e.g. in pumps, conduits, etc. of circulation dyeing machines.

Orthophosphates Older term for → Monophosphates.

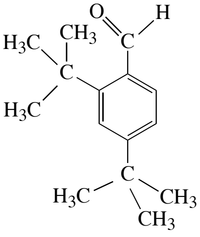
Os Symbol for the element Osmium (76).

Oscillation, oscillating (Lat.). Regular swinging to and fro.

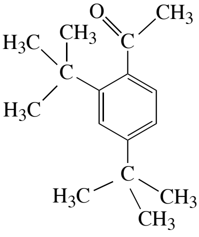
Oscilloscope → Stroboscope.

Osmometer Device for determining molecular weight.

Osmophore (odoriphore, Gk.: osme = odour, phorein = carry). Triggering sensations of smell. Relates to typical characteristics of so-called osmophoric chemical groups (such as carbonyl, hydroxyl, ether, nitro groups, or other groups containing nitrogen, sulphur or halogen, and unsaturated carbon compounds), which lend the odorous substance molecule a certain polarity and thus initiate the first step towards response contact with the specific receptor points of the olfactory nerves. They form an orientation factor, with the chemical condition generally having only a slight influence on the odour quality, for in many cases these groups are even interchangeable. For example, in the following molecule pair, exchanging the hydrogen in the carbonyl group for a CH$_3$ group alone is sufficient to change a strongly odorous substance into an odourless one:

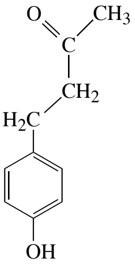


strong-smelling

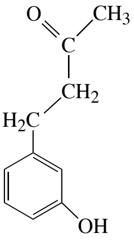


odourless

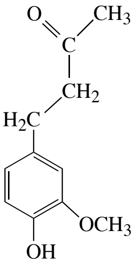
A strong shielding of the osmophore >C=O can prevent the interaction with the receptor system (olfactory nerves). On the other hand, the position of the osmophores also plays an important role, as the examples illustrate:



H = odour substance



odourless



odourless

Even the most minimal structural changes can alter the impression of odour completely: H is the olfactory principle of raspberries [so-called raspberry ketone (1-(p-hydroxyphenyl)-3-butanon)], with the osmophore -OH in para-position. By merely displacing the hydroxyl group into the meta-position, the molecule becomes odourless, likewise where the methoxyl groups (-OCH$_3$) are added in the m-position to the H-figuration. These examples show the complicated relation between chemical structure and → Odour, with osmophores only deciding together with their molecular environment whether an impression of odour arises, and in what differentiation. → Odour nuisance.

Osmosis (Greek: osmós = jolt, push) → Osmotic pressure.

Osmotic pressure Pressure exerted by dissolved molecules in their solvents, under → Brownian movement, to compensate density or concentration through → Diffusion (principle of tendency towards dilution). On the solution side of a semi-permeable membrane or dividing wall (→ Diaphragm), this pressure effects a drawing in of the solvent molecules, as a result of the higher mass concentration and thus the van der Waals attraction forces which have a stronger effect, until pressure equilibrium between the solution and the solvent is reached. Single-sided diffusion is called osmosis. The ability to diffuse through membranes fundamentally depends on the size of the molecule. Thus, for example, dissolved colloid-disperse Prussian blue cannot diffuse through a parchment membrane with water on one side (but water from outside inwards for the purpose of “dilution” of the concentration = osmotic pressure), whilst through this same membrane, in the case of dissolved molecular-disperse methylene blue, colour diffusion also takes place to the water side, through which a concentration dilution is effected on the one membrane side, and on the other side a concentration increase (→ Substantivity). Suitable membranes can thus also serve for separation (dialysis) of the two dispersivity systems. Associated with the osmotic pressure is the vapour pressure of solutions, which is small in comparison with the pure solvent medium, and which in turn, e.g. in relation to water is the cause of the aqueous solution boiling at a higher temperature (saturated sodium chloride solution at 108.7°C) and solidifying at a lower temperature (sea water only freezes at –2.6°C). Osmotic pressure is fundamentally involved in numerous textile finishing processes, particularly in all types of diffusion processes and swelling reactions.

Ossein, collagen A so-called scleroprotein or albuminoid, glue-providing substance with approx. 4% nitrogen, contained in bone cartilage. As a raw material, it is used for the production of animal protein chemical fibres (Ossein fibres), amongst other things.

Ostwald colorimetric measure → Colorimetric measures.

Ostwald colours → Colour circle.

Ostwald colour triangle → Chromaticity diagram.

Ostwald hue number The number allocated to each of the 24 hues in the → Chromatic circle.

Otting process Multicolour process for colouring carpets, with the work being done without thickening.

Ottoman cloth Light to heavy, stiff cloth with transverse ribbing, where the ribs are distinct and can be of even or different sizes (approx. 3–5 per cm). Worsted yarns are practically the only suitable type to use as warp yarn, and the weft can either be worsted yarn or carded yarn. Bonding: smooth or patterned ribs. If the weft yarn used is thick enough, cloth bonding can be used as well. These fabrics are either shorn or singed, to ensure that the threads are clearly defined. Use depends on the fabric and its weight. Woollen ottoman cloth is primarily used for ladies' suits and coats, upholstery and soft furnishings. Fabrics used for suits and coats are often raised on the reverse side to provide better heat insulation. Usually they are piece-dyed goods. Finely ribbed ottoman cloth in particular falls into the épinglé category, and is primarily used for covering upholstered furniture.

Outage time Interval of time between the point at which outage occurs (when one unit cannot be operated), until the system becomes functional again.

Outdoor textiles,

I. Textiles designed for open air use, such as synthetic lawns, sunshade fabric, marquees, etc.

II. Collective term for tarpaulins, tents, marquees and garden furniture with textile components. High-strength synthetic fibres, outstanding colour fastness, rot resistance, as well as a variety of designs are all essential qualities for outdoor textiles.

Outer drum Forms a large outer shell that encloses the → Inner drum and the "free liquor area" in → Double drum machine. The outer drum contains the necessary installed components and valve fittings, such as water supply and drainage, steam heating, condensate drain, chemical feed tanks, liquid level glass, remote thermometer, lid safety device for outer/inner drum, etc.

Outerwear Garments such as shirts, blouses, trousers, skirts, jackets, coats, as opposed to underwear. → DOB; HaKa; KOB.

Outline Thin, sketchy lines drawn around (print) patterns; contour, bordering. In print designing: Fine line printing. Clarity is mainly dependent on the thickeners used.

Outline printing with rotary screens Clear, fine outlines can be produced if the print paste channels are deepened: a) The nickel screen can be etched using iron (III) chloride solution after the lacquer layer has been cauterized (channel depth 0.04 mm); b) A thicker layer of lacquer can be applied using a special squeegee device (channel depth 0.08 mm).

Outward contract processing The German clothing industry is having more and more tailored fabric panels sewn ("finished") abroad, and the exported items are subsequently re-imported as finished garments (see Fig.). Typical countries that participate in outward contract processing (i.e. without any profit-sharing arrangement) are countries such as Greece, Portugal, Tunisia, Turkey and Morocco, where there is a backwards trend, causing the industry to turn to Eastern European countries like Russia, Poland, Hungary, the Czech Republic, Slovakia, Rumania and Bulgaria.

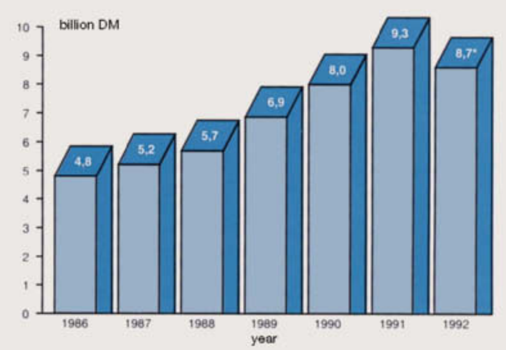


Fig.: Imports in the form of outward contract processing.

Oval winch → Winch beck.

Overall bonding Process for bonding nonwovens by means of coating with padding liquor containing binders, and using thermal induction to crosslink the binders (→ Print bonding).

Overboiling This can occur in situations such as boiling or protracted dyeing of cotton, wool or wool union goods. Causes: in cotton fabrics there are pectins present in the cellulose, which if they are not sufficiently removed before dyeing, will exert a dye reducing effect. In wool or wool union goods there are wool decomposition products that are produced as a result of a protracted dyeing process (possibly with a pH increase). Another cause of decomposition products is large quantities of sodium sulphate in the dye liquor (loss of molecular sulphur and nitrogen due to solubilization), which also exert a dye reducing effect. Effect: the dye is broken down or altered, causing incorrect shades, inconsistent surface appearance, difficult colour matching, extended dyeing period, and possibly a negative influence on fastness. Solution: do not use reduction-sensitive dyes and avoid addition of oxidants or salts that release acid when dyeing wool in a neutral dye liquor.

Overboiling inhibitor Auxiliary to help prevent → Overboiling of dyes and colourings. Lessens the reducing effect of alien substances on direct and wool union dyes, thereby reducing dye breakdown. The product is usually based on ammonium sulphate, urea, and possibly anionic active surfactants.

Overcoat (top coat) Dark, self-shaded or conservatively patterned (mottled) carded yarn cloths (e.g. Marengos); high-quality fabric in almost all types of finish. The fabric is used for smart, timeless coats of the same name.

Overdrying Excessive drying of fibre material, so that the capillary water content is removed. Heat and overdrying are damaging to a greater or lesser degree for any textile fibres, if allowed to take effect under uncontrolled conditions as opposed to controlled heating. It can result in thermal splitting of polymer chains. (→ Drying).

Overfeed devices Device particularly on pin stenters, to allow lengthways shrinkage during fabric tensioning (see Fig). Overfeed devices consist of two pairs of powered rollers located above the clip chains, which feed the fabric to the chains at a higher speed than the chains are capable of. This means that the fabric edges are fed onto pins while they are in a crimped position. Clip stenters have specially constructed clips with slits.

Overfeed system Fabric advancing devices for compression and crimping, e.g. on pin stenters, sanforizing machines, etc.

Overflow Dyeing Machines This rope dyeing machine system for woven cloth and knitgoods, is particularly suitable for delicate fabric types, and was designed on the basis of the overflow principle, which is easily manageable.

In Germany the “Liloc-Overflow”, an elongated, horizontal machine distributed by Jagri, can claim to have achieved success in 1971 as a non-winch beck rope dyeing machine for woven fabric (Fig. 1).

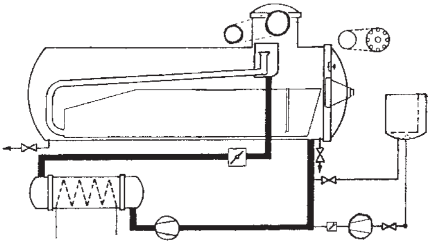


Fig. 1: Overflow principle (Liloc by Jagri).

Frauchinger launched a similar type of machine, the “Fastral”, in 1969 as a stationary version, which was developed into the “Fastex” in 1973. This type of machine, i.e. a system where the liquor contained within the sealed liquor exchange zone does not move much faster than the fabric (Figs. 2 + 3), has so little mechanical contact with the fabric that easily-creased fabrics can be dyed effectively in flat chambers without the need for tubular dyeing. The other advantage of horizontal dyeing machines is that they have two dwell chambers with a total capacity of approx. 300 kg of fabric, which means that two runs of fabric can be sewn together, resulting in shorter finishing times.

However, with thick cloth, a run-up time is required after feeding into the machine, which is stiff at first and thus must be monitored by the machine operators.

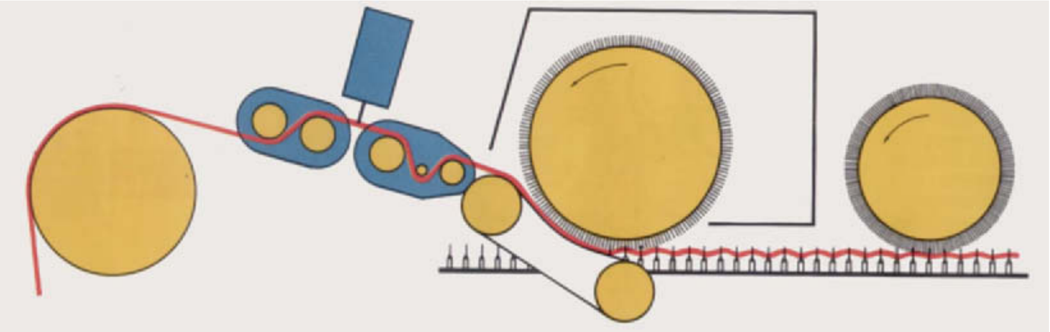


Fig.: Producing overfeed in a shrinking unit (Monforts).

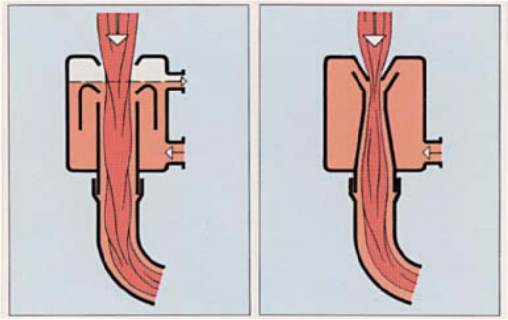


Fig. 2: Nozzle system (right) compared to the overflow principle (left).

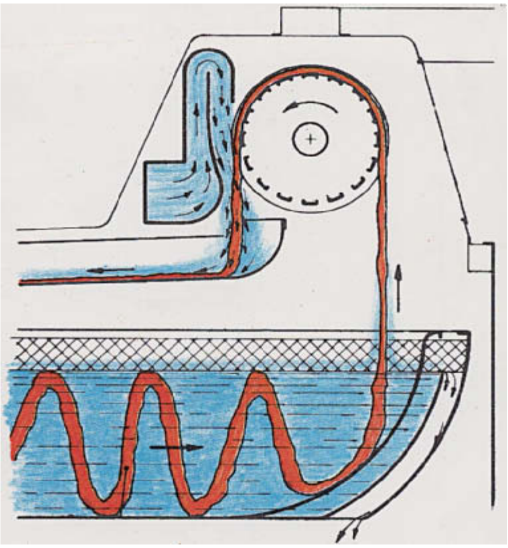


Fig. 3: Bellini fall-flow.

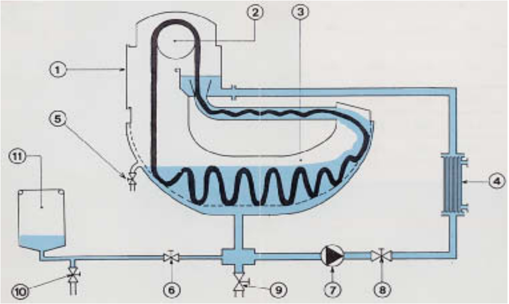


Fig 4: Mezzera atmospheric flow AF.
1 = door for unloading fabric; 2 = fabric transport winch;
3 = dye vat; 4 = heat exchanger; 5 = overflow valve;
6 = regulator valve; 7 = main pump for liquor circulation;
8 = output regulator valve; 9 = liquor drain valve;
10 = drain valve from chemicals intake tank; 11 = tank for dyestuff and chemical additives preparation.

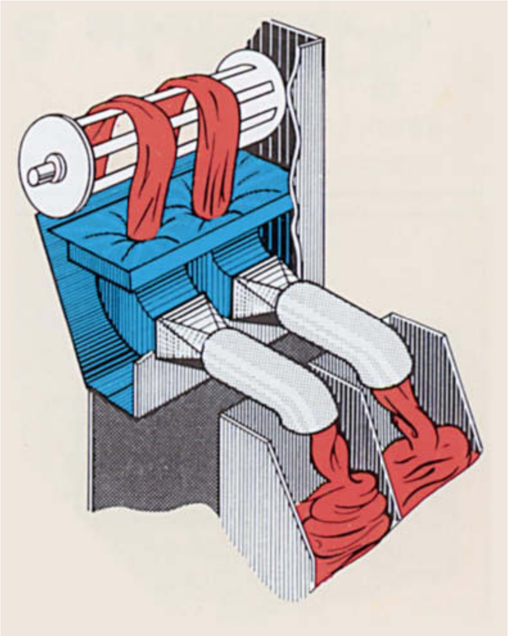


Fig. 5: Duplex ATYC with 125 kg chamber.

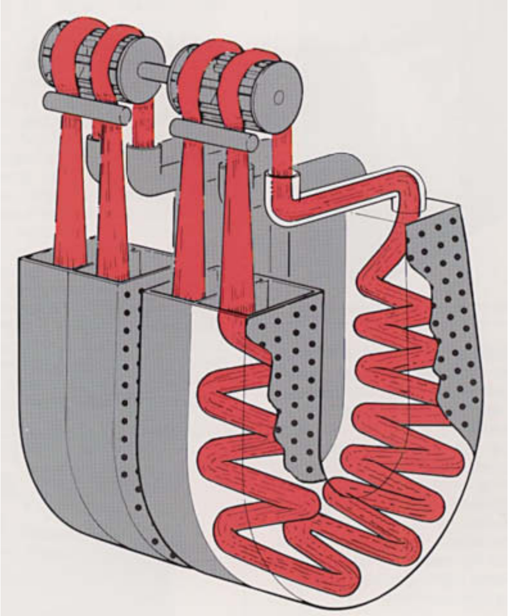


Fig. 6: Longclose with 125 kg chamber.

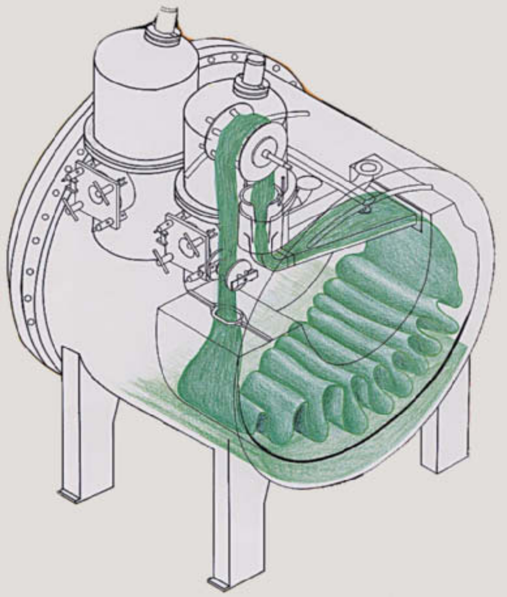


Fig. 7: MCS with 150 kg chamber.

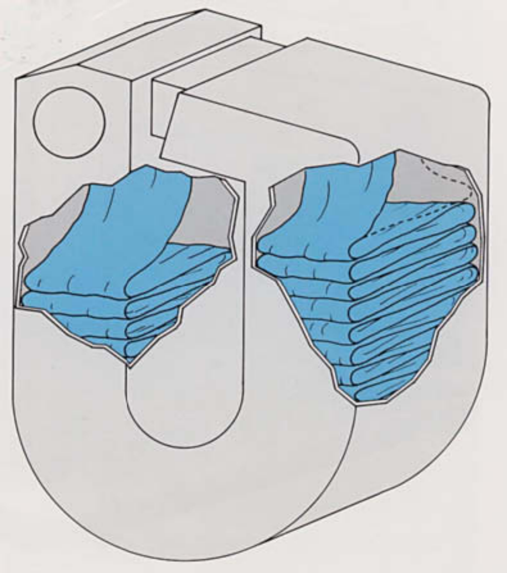


Fig. 8: Fong's with 200 kg chamber.

One definite disadvantage of semi-flooded overflow machines, which have become the standard type, is the liquor-to-goods ratio, which is still too high for practical use (Fig. 4).

Different overflow types offer different batch capacities depending on the fabric being dyed (Figs. 5–9).

→: Jet dyeing machines; Jet dyeing, development of.

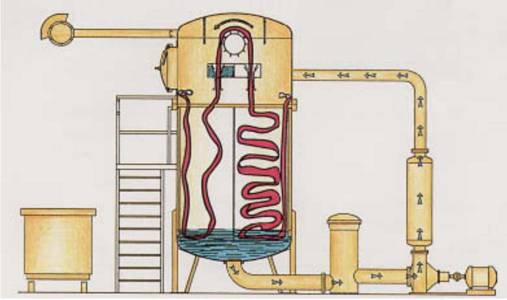


Fig. 9: Pandora (MCS) for 300 kg (type PA 300 HT).

Overflow system → Overflow Dyeing Machines.

Over maxing It is found (by using the → Waxing method) that the → Friction coefficient of jersey yarn reduces very rapidly as more lubricant is applied, in comparison with the friction coefficient for untreated fabric, until it reaches a minimum value known as the optimum friction coefficient. This optimum friction coefficient is usually half the value of the friction coefficient for untreated fabric. Based on this optimum state, if even more lubricant is applied, the friction coefficient will rise again. This phenomenon is referred to as over maxing, and is dependent on the lubricant used.

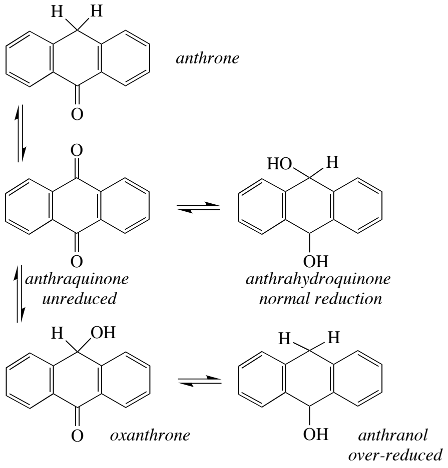
Overpressure → Air pressure.

Overprint In dyeing, a direct print covering lighter colour shades, not affecting the dye underneath.

Overprinted compound shades →: Half-tone resists; Half-tone screen; Half-tone printing on textiles.

Overprinted resists → Resist printing.

Over-reduction Undesirable characteristic of certain vat dyes, caused by factors such as an excessively high dyeing temperature, excessive levels of sodium dithionite in the dye liquor, extended dyeing periods, or a combination of these factors. Blue indanthren-type dyes are particularly sensitive to over-reduction:



Over-reduction leads to a loss in strength, significant dulling of colour shades, and sometimes causes reduced fastness to chlorine.

O/W Abbreviation for → Aqueous emulsion, i.e. an oil-in-water system.

Ox- Used as a prefix or suffix, or in the middle of a word; denotes the presence of oxygen in the molecule.

Oxacarbonic acids → Carboxylic acids with ether-type bonded oxygen atoms –C-O-C- in a continuous chain.

Oxalates Salts of dibasic → Oxalic acid; in the form of acidic, neutral, or double/complex salts. Alkaline salts are water-soluble, the rest are easily soluble in strong acids.

Oxalic acid (saccharic acid), $(COOH)_2$ or $C_2H_2O_4 \cdot 2H_2O$. Molecular weight 126.058; density 1.653; salts → Oxalates. Colourless crystals that are slowly eroded when exposed to air, mid-strength acid (one of the strongest organic acids), soluble in water, alcohol and ether. Strongly acidic solution (attacks cellulose fibres when in vapour form); toxic; powerful reducing properties; oxalic acid breaks down mineral-acidic alkaline salts. Potassium permanganate oxidizes oxalic acid to CO_2. Uses: reduction agent for dichromatic mordants (wool dyeing); discharge printing (indigo); bleaching agents (straw, etc.); detaching agents (for fruit, rust, ink stains); also used as a bleaching agent for leather.

Oxazine dyes Individual cationic, direct, acidic and benzidine dyes, deriving from phenoxazine.

Oxford Bi/multi-coloured woven cotton shirt fabric with a “sturdy” appearance; usually calico weave; occasionally also available as Panama or cotton twill weaves. Due to its soft, voluminous effect, it is also known as “non-raised flannel”. 2-thread warp and coarser weft, causing the Panama effect.

Ox gall → Gall extract.

Oxidation (oxidization), bonding of oxygen or release of hydrogen or electrons as a negative charge in chemical compounds. Typical example: Zinc + Oxygen = Zinc oxide ($Zn + O \rightarrow ZnO$). Opposite of → Reduction.

Oxidation bleach → Bleaching of man-made fibres using oxidizing agents, usually in an aqueous solution. This causes the natural dyes in the fibres to be broken down by means of oxidation and removed during subsequent rinsing, etc. There are different categories of product in common use:

I. Chlorine bleaching process (→: Sodium hypochlorite; Sodium chlorite).

II. Oxygen bleaching process (→ Hydrogen peroxide, less frequently →: Sodium peroxide; Peracetic acid; Potassium permanganate; Ozone).

Oxidation discharges → Discharging agents in printing resulting from oxidation.

Oxidation of metallic threads Tarnishing or colour change resulting from the action of oxygen in the air.

Oxidation of oils Dependent on the presence of one or several unsaturated fatty acids:

$$R-HC=CH-R-COOH$$

The principle behind oxidation of oils is that the double bond(s) break, and at the same time the free valency is saturated with oxygen. Double bonds, oxidation and drying properties are all directly proportional to one another. Examples of unsaturated fatty acids: oleic acid (1 double bond), linolic acid (2 double bonds), linolenic acid (3 double bonds).

Oxidation surge Term for rapid, immediate release of oxygen in large quantities, for example, if iron is present (as a catalyst) during peroxide bleaching of cellulose fibres. This reaction occurs primarily at high temperatures in an alkaline liquor at the iron/fabric interface, causing oxycellulose formation. It is assumed that continuous interaction is taking place as follows: iron with a valency of 3 is partially reduced by hydrogen peroxide ($Fe^{3+} + H_2O_2 \rightarrow Fe^{2+} + H_2O + {}^1/_2O_2\uparrow$) to valency 2 iron; however there are other possibilities currently under discussion.

Oxidative bleaching processes Oxidation bleaches for cellulose fibres (particularly viscose and viscose mixes) and protein fibres (wool, silk). Ammonium persulphate, potassium persulphate, sodium perborate, sodium percarbonate, sodium perpyrophosphate, sodium persulphate, sodium peroxide, hydrogen peroxide and potassium permanganate are the chemicals used most frequently for this type of bleaching process. Process is also known as → Peroxide bleach process. Neutral or non-dissociated hydrogen peroxide has no significant bleaching effect (minimal bleaching action at pH 7) but a strong danger of damage (maximum fibre damage at pH 7). Because of this, an alkaline additive is necessary as well as the oxygen carrier, to activate the bleaching energy and also to act as a cleaner. In excess of min. 20°d waterglass acts as a stabilizer, minimizing the damage factor. If the liquor is too alkaline (in excess of pH 12) and in hot concentrated baths, stabilizers no longer provide sufficient protection, preferably in the absence of extreme soiling. For this reason the two-bath process is frequently used: Pre-bleaching is carried out in a highly alkaline environment, and after-bleaching with a lower level of alkali (→ Bleaching of …). Uses: a level of pure white that is resistant to storage can be achieved, with a process that has a very mild effect on the fibre and excludes kier-boiling and chlorine; cleaning and bleaching is combined into a single process (→ Alkali scour-chlorine-peroxide), even suitable for raw cotton as a pure white single-bath bleaching process, for delicate textile mixes, dyed and printed fabric; also suitable for pre/after-bleaching using the standard chlorine-free two-bath process for fast, easy bleaching of cotton and viscose to pure white (also suitable for light wovens, jersey knits, coloured fabrics, etc.).

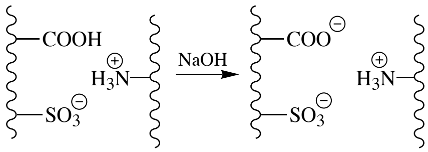
Oxidative bleaching with peroxide Oxidative bleaching process used mostly for natural fibres (wool, cotton, silk). The principal product used in this process is → Hydrogen peroxide. Alternative products of less importance are sodium peroxide, potassium permanganate, sodium perborate (only in detergents), peracetic acid. Of no significance: sodium percarbonate, ammonium and potassium persulphate, sodium perpyrophosphate. Neutral, non-dissociated hydrogen peroxide has no bleaching properties. It is only effective in an alkaline bath, at an ideal pH of approx. 11, achieved by adding sodium silicate (water glass), which also has stabilizing properties. Other stabilizers: sodium pyrophosphate, protein breakdown products, fatty alcohol sulphonate derivatives. → Bleaching of …; Peroxide bleach.

Oxidative washing agents This type of washing agent can consist of soap, alkali (sodium carbonate, phosphates, etc.), stabilizers (magnesium silicate) and a source of oxygen (sodium perborate, percarbonate, perpyrophosphate). Oxygen salts ensure that the alkali level is not too high and will therefore cause no damage. Modern oxidative washing agents contain appropriate synthetic surface active detergents instead of, or in addition to, soap (→ Syndets).

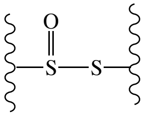
Oxides Oxygen combines with the elements. In situations where polyvalency arises, the valency is written in Roman numerals between the element and the oxide; for example the oxide of iron with valency 2: Iron (II) oxide (FeO); and of iron with valency 3 (also iron oxide) = Iron (III) oxide (Fe_2O_3).

Oxidimetrie → Titration.

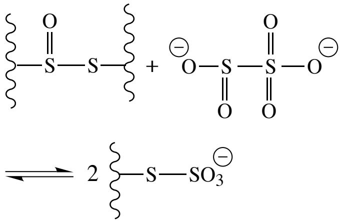
Oxidized wool In antifelt finishing processes on a subtractive basis, as well as during wool bleaching, the wool cystine is oxidized (a desirable effect for attacking scale, but unwanted when decolourizing melanin pigments). Oxidized wool is mechanically stable because wool keratin is electrostatically neutral in a model situation and therefore stable. In contrast to this, oxidized wool exhibits a high level of alkaline solubility because of osmotic pressure at pH 10, for example.



The complete oxidation of the cystine into cysteic acid occurs via various different oxides that are not immediately bonded when the crosslinking breaks down. If peroxomonosulphuric acid is used to oxidize wool, cysteic acid is not the primary product formed, as is the case with chlorination. The following structure shows the type of compound that is likely to form:



The process which is actually degenerative, but is essential for antifelting finishes, does not occur until subsequent sulphitolysis is carried out in a neutralization bath:



(The examples of wool used in these structures, by Zenko Stary, are highly simplified.)

Oxidize, to → Oxidation.

Oxidizing agent Either causes accumulation of oxygen or extraction of hydrogen. Oxidizing agents have practical uses, such as:

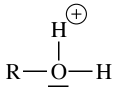
1. In oxidation bleach (chlorine products: calcium and sodium hypochlorite; products giving off oxygen: per compounds; sodium chlorite).
2. As oxidative products for unlocking starch.
3. For oxidizing/resoaping fast dyes (vat dyes, sulphur dyes and naphthol dyes) before setting (greater level of rub fastness, better general fastness, brighter colours).
4. → Stripping of dyeings.

Oxiranes Saturated three-section heterocyclical compounds with one oxygen atom, of the type ethylene oxide (C_2H_4O). Complicated and condensed ring systems of this type are → Epoxides.

Oxo acids (oxy-acids) Oxygen/hydrogen compounds with non-metals (e.g. chlorine, phosphor, nitrogen, sulphur) and metals with a valency higher than 2 (e.g. chrome, manganese, iron). Where there are polyvalent compound possibilities, the acidity level rises in proportion to the atomic number of oxygen (e.g. sulphurous acid H_2SO_3 and sulphuric acid H_2SO_4, etc.). Terminology of the salts: acids that are low in oxygen, or dithionic, hydro or hypo acids, have salt names ending in "ite" (→ Sodium sulphite, Sodium hypochlorite); salts from high-oxygen acids or → Per acids have the suffix "ate" (→ Sodium sulphate, Sodium perborate).

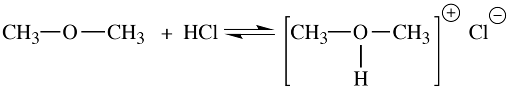
Oxo alcohols → Synthesis alcohols.

Oxonium compounds Chemical compounds with positively charged oxygen, e.g. in ethers with a weak basic character. They have oxygen-accumulating properties, analogous to ammoniac formation:



$R-\overset{H^{\oplus}}{\underline{O}}-H$

oxonium ion



$CH_3-O-CH_3 + HCl \rightleftharpoons \left[CH_3-\underset{H}{O}-CH_3\right]^{\oplus} Cl^{\ominus}$

Oxycarbonic acids Contain the hydroxy group (OH); e.g. (in castor oil in the form of) ricinoleic acid $C_{17}H_{32}OH\text{-}COOH$. → Fatty acids.

Oxycellulose → Cellulose damaged during oxidation (more or less broken down by oxidizing acids, bleaching agents, kier-boiling, etc.). The properties are analogous with those of photocellulose and → Hydrocellulose. Test: oxycellulose on its own →: Gold purple reaction; Nessler's reagent; Phloroglucinol reaction. In addition, as with hydrocellulose, with →: Prussian blue reaction; Fehling's solution; Methylene blue test; Vatting test, Turnbull's blue reaction.

Oxydiphenyls → Phenylphenols.

Oxyethylated cellulose (glycol cellulose, polyethylated cellulose),

$Cell\text{-}O\text{-}C_2H_4OH \rightarrow Cell\text{-}O(C_2H_4O)_x - C_2H_4OH$.

I. Cellulose ethers: produced as a result of ethylene oxide and a small amount of alkali acting on cellulose. In this way, fabric can be immediately oxyethylated, providing it with a stiff handle, transparent appearance and immunization. Synthetic fibres, monofilaments, films, etc. can also be produced from oxyethylated cellulose (synthetic fibres have almost as much wet strength as viscose filament yarns). Other uses are for glues, sizes, chemical finishing, etc., for which a degree of alkylation is of significance, i.e. the ratio of oxyethyl to glucose anhydride. If the alkylation level is between 0.2 and 0.9, there will be solubility in alkali and at min. 1.4 it will be water-soluble.

II. Methyloxyethylated cellulose: $Cell\text{-}OCH_3\text{-}OC_2H_4OH$. Produced from the action of ethylene oxide and dichloromethane on alkali cellulose, where there is usually approx. $^1/_4$ oxyethyl residue $O\text{-}C_2H_4OH$ and $^1/_4$ methoxyl residue $O\text{-}CH_3$ for each glucose residue. This type of product is used for sizes, chemical finishing, thickening agents, etc.

→ Cellulose derivatives.

Oxyethylation (ethoxylation, polyethoxylation, oxyalkylation), conversion of aliphatic, aromatic or aliphatic-aromatic compounds containing one or several reactive H atoms, using ethylene oxide, generating polyglycol ethers as a result. Oxyethylation can be explained as condensing polymerization, by means of the following equation:

$R\text{-}H + n\ C_2H_4O \rightarrow R\text{-}(C_2H_4O)_n\ H$.

The level of oxyethylation corresponds with the number n of oxyethyl groups. An increasing level of oxyethylation up to approx. n = 20 results in a constant increase in water solubility, lime soap dispersing properties and levelling effect (also in foaming properties up to n = 6). However surface activity is lowered, where the optimum value for fatty oils is in excess of n = 9, and for mineral oils the optimum value is as low as n = 5. For detergents the optimum is usually n = 5 – 12, but detergents acting on pigment soiling have a higher level of oxyethylation. Levelling agents for vat dyeing also have a group number of about n = 20.

Oxygen (O), atomic weight 16. Categorized under → Non-metals, gas, colourless, odourless and tasteless, non-flammable (but supports the combustion of other substances), liquefies (at approx. 100 bar) into a bluish substance, forms compounds with almost all elements (→ Oxidation). Extremely reactive. Combination of 3 oxygen atoms: → Ozone (O_3). Oxygen is water-soluble. Oxygen compounds: water, hydrogen peroxide (salts: peroxides), → Oxides (metallic oxides are alkaline, non-metallic oxides are acidic).

Oxygen carrier for bleaching → Bleaching catalysts.

Oxygen demand (waste water), The usual methods of analyzing waste water pollution are the → Chemical oxygen demand (COD), measured by the amount of potassium dichromate ($K_2Cr_2O_7$) used, or the → Biochemical oxygen demand (BOD).

Oxygen depletion Bacteria are responsible for the depletion of most organic impurities, consuming oxygen at the same time. It is essential that the micro-organism/waste water interface provides water-soluble conditions, and that the molecular weight is low, to ensure that penetration into the bacteria cell is possible. The bacteria cells do not absorb polymers.

$$\text{Organic substance} + O_2 \rightarrow CO_2 + H_2O + \text{new bacteria (biomass)}$$

Problems can occur with oxygen depletion if there is a low oxygen solubility level in the aqueous medium in which transfer into the cells takes place. To simplify, this is what happens during oxygen transfer: in anaerated nutrient solution containing micro-organisms, the micro-organisms absorb the dissolved oxygen, the concentration of dissolved oxygen becomes lower, and further oxygen diffuses from the air into the water. As the number of cells increases, both speeds become equal, at which point the dissolved oxygen content almost reaches its limit value. This is the point at which optimum

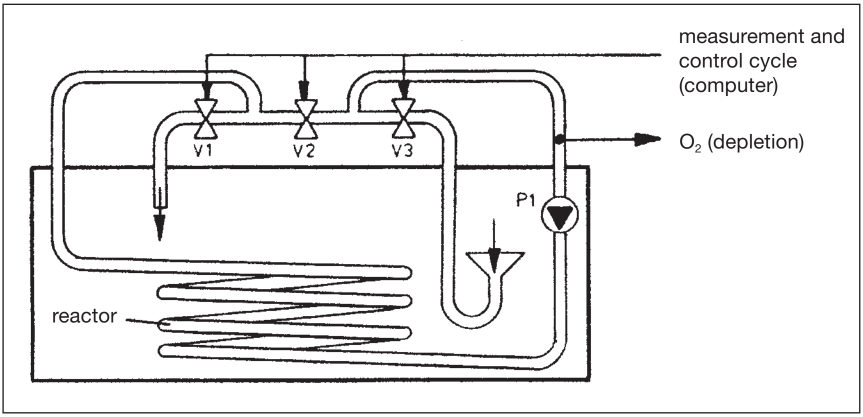


Fig.: Design and function of a depletion measuring device for determining the degree of oxygen depletion.

conditions are present for the process as a whole. Therefore there must always be sufficient oxygen diffusion occurring to meet the oxygen requirements of the cells.

BOD_5 specifications do not provide measurement values until five days have elapsed. For this reason, BOD_5 is just as unsuitable for running a biological purification plant as the COD or TOC specifications, because the specified values only apply to the level of impurities comparatively precisely in situations where the external conditions are constant. It seems more practical to measure depletion in relation to the level of impurities. The advantage of this method is that the measured values are available within 10 min, and the gauges, which are relatively easy to use (see Fig.), can be installed directly into the activation tank or the return sludge line. If the valve V2 is closed (V1,3 being open), the medium to be measured is transported from the tank in which it is immersed to the reactor. After only a few circuits V2 is opened (V1,3 closed). The medium is circulated through the reactor, where depletion measurement begins.

Oxygen fading → Ozone fading.

Oxygen-Index → LOI.

Oxygen measurement in steamers When dyes are set in a steamer, the steam needs to fulfil several functional requirements:

- It must supply heat and moisture.
- It must extract exothermic heat.
- It must extract reaction products.
- It must ensure that a constant level of fabric moisture is maintained.
- It must prevent oxygen in the air from causing redox reactions.

The influence exerted by oxygen in the air is of particular significance:

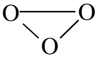
- setting vat prints or vat discharge prints,
- setting reduction-sensitive dyes (e.g. reactive dyes).

For the setting of vat discharge prints the oxygen content in the air must not exceed 0.06% by vol. O_2 (i.e. 0.3% by vol. air). However complete protection against oxygen in the air can lead to significant shade deviation during setting of reduction-sensitive reactive dyes. This is particularly apparent if sodium alginate thickeners are used in an alkaline environment, for instance.

It must be possible to measure and control the oxygen level in the steamer. Until now the state of the art method of measuring air/oxygen content was to extract the steam/air mix into a bottle filled with cold water, which provided qualitative and quantitative information. A direct analysis of the O_2 content is not possible using this method. In contrast, an oxygen measurement gauge measures the oxygen content directly in the textile steamer. The device consists of an oxygen sensor in direct connection with a pre-amplifier, and electronics for the purpose of analysis. The sensor is made from zirconium dioxide and has two electrodes. One of the electrodes is exposed to the air within the process, and the other is exposed to the external air in the room. Depending on the concentration difference between the two air sources, the sensor emits a certain voltage signal, which is processed in the electronic pre-amplifier. The analysis electronics compute the oxygen content in vol. % from the pre-amp signals, with the assistance of a microcomputer. The microcomputer has additional important tasks: It controls the function of the sensor and also calibrates it.

Oxy-sulphuric acid → Sulphur oxyacids.

Ozone (O_3), oxygen molecule with three atoms. Individual free oxygen atoms (known as “oxygen in status nascendi”, which have an extremely high level of oxidation energy → Ozone bleach) accumulate around O_2 molecules and combine with them to form ozone.



Ozone, action on fibres Ozone can react with aliphatic and aromatic bonds. For this reason it is possible to use ozone gas for antifelt finishing of wool, without the treatment becoming economically significant. Polyester is more easily damaged by ozone than polyamide, because polyester's aromatic ring system can be easily oxidized and destroyed by the ozone. The aromatic ring can be regarded as a double bonding system. When the dipolar ozone molecule attacks it, an epoxide is formed, in a defined rapid reaction sequence. Shortly afterwards the epoxide is broken down by the ozone, which at a higher temperature results in glyoxylic acid derivatives. As an example, the reaction for benzene is briefly sketched out in the Fig. below.

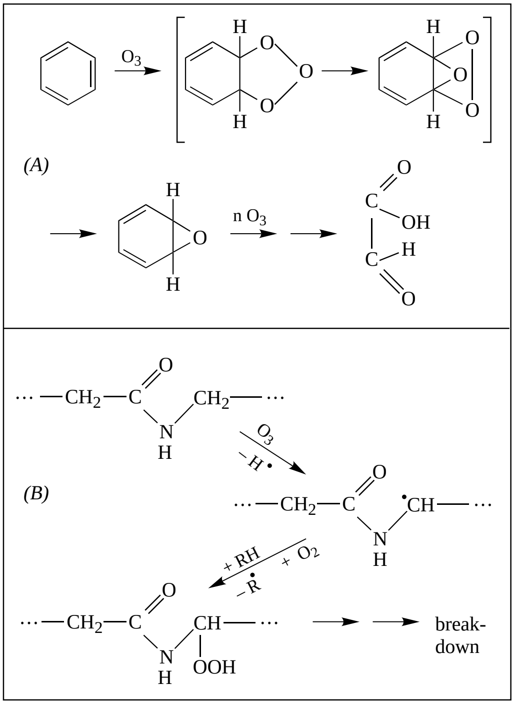


Fig.: Reaction pathway in the breakdown of aromatics and amides by ozone.

Aliphatic C-H bonds are much less readily attacked by ozone. This is why there is a lower level of damage in polyamide. It is only the CH_2 group adjacent to the nitrogen amide which is so unstable that it can be attacked. A radical is formed as a result of radical ozone reaction with this type of group (H abstraction), which reacts with the oxygen in ozone to form hydroperoxides. This reaction sequence is essentially the same as polyamide breakdown, which is influenced by atmospheric conditions (or xenon test conditions). The ozone treatment causes both materials to become more intense in colour, which is explained by the removal of a diffusion barrier. In the actual fibre structure, crystalline areas are bonded together by tie molecules (molecule chains that link one crystalline area to another, passing through the imperfect zones). Tie molecules of this type are under considerable tension, and are chemically more vulnerable to attack. For this reason, the oxidative breakdown process will remove these chains first. When the molecule chains are broken down, there is less resistance to prevent the diffusion of dye molecules into the imperfect areas of the fibre, so that the fibre can take up more dye during the dyeing process (Schollmeyer).

Ozone bleach Industrial development of an old type of bleach known as grass bleach, designed specifically for linen, less suitable for cotton. It has not been implemented on a large scale, both for cost reasons and also because it has no particular advantages over other bleaching processes.

Ozone fading (oxygen fading), the appearance of oxidative bleaching of blue, red and yellow dispersion dyes caused by the effect of atmospheric ozone, which is similar in appearance to gas fume fading. This effect is most common in acetate, triacetate and polyester dyes. Heat treatment of triacetate and polyester improves fastness to ozone fading. Penetration dyeing seems to be a significant factor (polyester dyes with a carrier are more resistant than those without). A maximum level of protection can be achieved by using an inhibitor and heat setting. Ozone fading can be prevented, by using anti-oxidation agents such as diphenylethylenediamine (also used as a gas fading inhibitor) and para-octylphenol (which has no gas fading inhibition properties), which means that using the methods detailed here, both gas and ozone fading can be prevented at the same time.

Ozone fastness Common in the USA, meaning the resistance of textile colour to the effects of atmospheric ozone in the following conditions: a) Air humidity below 65% at normal temperature; b) High air humidity of at least 80% at a raised temperature (40°C). Samples, and also control samples, are subjected to the effects of ozone in special chambers under the above conditions. The colour change is evaluated by means of a grey scale after a certain number of cycles.

Ozone layer depletion In the stratosphere there is a layer rich in ozone, which acts as a filter to block out UV rays (Fig. 1). At the Earth's poles (especially at the South Pole), a significant concentration of chlorofluorocarbons (CFC) has accumulated, generated by aerosol propellant chemicals, the production of synthetics, and refrigerator coolant.

UV radiation in the stratosphere causes chlorine atoms to break away from the CFCs, which react spontaneously with ozone (Fig. 2).

Ozone oxidation-drying process

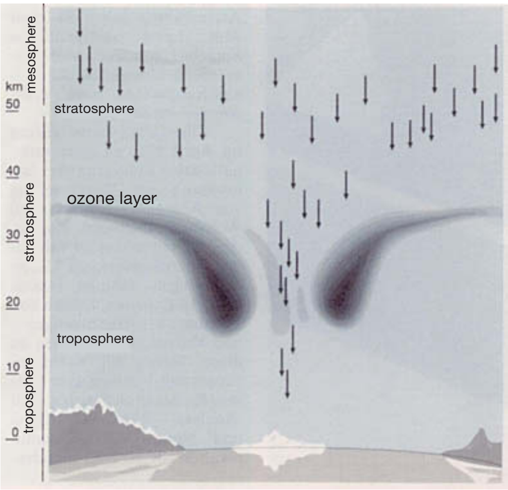


Fig. 1: Without the protective filter of the ozone layer damaging UV radiation passes unhindered through the atmosphere.

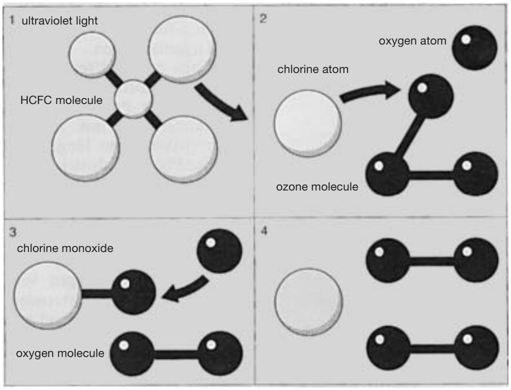


Fig. 2: Reaction of hydrochlorofluorocarbons with ozone.

The ozone is converted into oxygen, which has no UV light filtration properties. Excessive UV light radiation on the skin can cause pathological changes (skin cancer).

Ozone oxidation-drying process Drying process for → Oil size, in particular the gamma process (emulsion oil sizes) by ozonizing during the drying process, reducing the standard long drying times, which are sometimes in excess of 48 h, down to approx. 2 h.

Ozone treatment of waste water Treatment of waste water from dyeing with ozone can cause the dye molecules to break down (particularly in reactive dyes) into small fragments, causing the waste water to become decolourized (see Fig.).

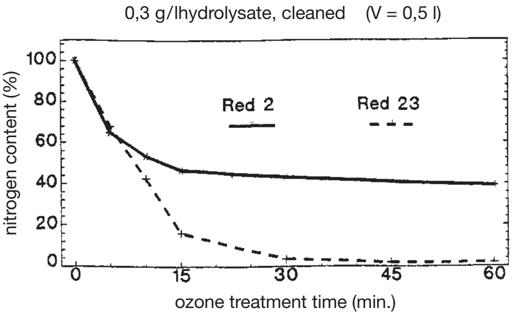


Fig.: The breakdown kinetics of two reactive dyestuffs (red C.1.2 and red C.1.23) during the ozone treatment of waste water from a dye works.

P

P,

I. Element symbol for phosphorus (15).

II. Textile care symbol for dry cleaning with tetrachloroethylene (perchloroethylene).

p → Para-.

PA → Polyamide fibres, → Textile fibre symbols, according to DIN 60 001 T4/08.91.

Pa,

I. Unit symbol for → Pascal.

II. Element symbol for protactinium (91).

PAC → Polyacrylonitrile fibres, → Textile fibre symbols, according to DIN 60 001 until 1988, from 1991 → PAN.

Package Wound package, consisting of a tube and winding, e.g. →: Pirn; Crosswound yarn package; Flanged bobbin; Hollow cop.

Package density Information in g/volume. Uniformity of package density is important. Based upon a liquor related flow equation, which is supplemented by taking into account the radial package density differences, the following equation is used for the determination of the yarn package flow resistance Δp_L [mbar]:

$$\Delta p_L = \rho_F/2 \cdot \upsilon \cdot \upsilon_{20^\circ} \cdot \frac{6{,}14 \cdot \rho_{TL}{}^{1{,}5} \cdot h_L \cdot 0{,}01}{d_S{}^3 \cdot \sqrt{\rho_S} \cdot (0{,}952 \cdot \sqrt{\rho_S/e_H} - \sqrt{\rho_{TL}})^2}$$
$$\left[\left(1 + \frac{Q_M}{F_L} \cdot \frac{d_S}{2{,}25 \cdot \upsilon_{20^\circ}}\right)^2 - 1\right] \text{ [mbar]}$$

Δp_L [mbar] = flow differential pressure of the yarn package,
$\rho_F/2$ [kg/m^3] = density of (ambient air) flow medium (0.60),
ν [m^2/s] = temperature dependent viscosity (at 20°C = $15.2 \cdot 10^{-6}$),
ν_{20° [m^2/s] = 20°C viscosity ($15.2 \cdot 10^{-6}$),
F_L [m^2] = (average) yarn package flow area,
h_L [m] = package height of the yarn package,
ρ_{TL} [kg/m^3] = (average) package density of the yarn package from G_T/V_T (G_T = textile weight; V_T = textile volume),
ρ_S [kg/m^3] = density of the textile substrate,
e_H [–] = (average) fibre form factor,
d_S [m] = (average) fibre diameter,
Q_M [m^3/s] = environmental air or liquor flow rate.

The representative characteristic values for 20°C ambient air and the yarn package textile meter are added in brackets after the formular symbols used in this equation..

For the arithmetic evaluation of environmental air flow experiments using the yarn package textile meter, the generally valid equation is rearranged so that the equation can be used to calculate the flow effective package density ρ_{TLX} of the yarn package through which flow occurs using the yarn package textile meter, whereby d_S is used in µm:

$$\frac{\rho_{TLX}{}^{1{,}5} \cdot h_L}{d_S{}^3 \cdot \sqrt{\rho_S} \cdot (0{,}952 \cdot \sqrt{\rho_S/e_H} - \sqrt{\rho_{TLX}})^2} = \frac{164\ 10^{-9}}{\left[\left(1 + \frac{0{,}051 \cdot 10^{-3}}{z_G \cdot F_L} \cdot d_S\right)^2 - 1\right]}$$

ρ_{TL} [kg/m^3] = flow effective package density,
z_G [s] = graduated time-calculated value of the textile meter, (graduated time display of the textile meter in 0.1 s).

(according to Kretschmer).

Package dislocation Deformation of crosswound yarn packages, yarn slides off the dyeing tube.

Package dyeing Advantages: Short liquor ratio, direct use of the yarn package for warping or warp yarns on the sizing machine. Disadvantages: Absolute evenness cannot be guaranteed in hard packages.

Package dyeing machines,

I. Yarn packages are packed and if necessary, compressed on material carriers (Fig. 1), which are transported by conveyors and craneways to the dyeing machine in question. In dyeing machines supplied with a centrifugal pump (Fig. 2) or an axial pump (Fig. 3) the dyeing liquor flows through the yarn package columns. → Dyeing machines, circulating liquor type.

II. → Dyeing machines for crosswound yarn packages, bottle package, combed top bobbins, card sliver and warp beams.

Package hardness testers The package hardness is an important criterion for faultless full penetration dyeing. A densiometer, which detects the → Shore hardness, is used for hardness testing.

Package hydro-extractor (package centrifuge) → Centrifuge hydro-extraction of yarn packages. These

Fig. 1: Crosswound yarn package dyehouse (Thies) with material transport by means of roller conveyer and craneway plus metering and automation units on each dyeing machine.

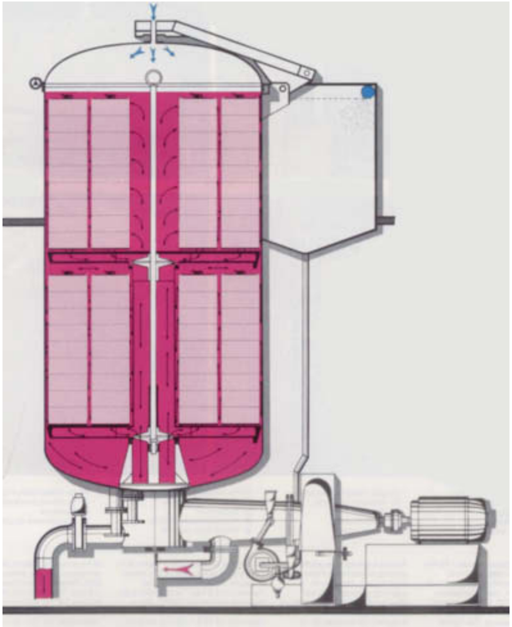


Fig. 2: High temperature crosswound yarn package dyeing machine (Krantz) with centrifugal pump and alternator.

are deformed in normal centrifugal baskets, which is why baskets with spool carriers or single spool centrifuges are used.

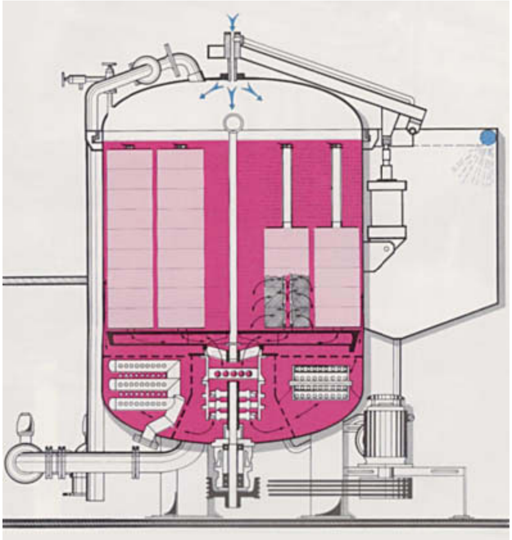


Fig. 3: High temperature crosswound yarn package dyeing machine (Krantz) with multi-stage axial pump and bypass unit.

Package width Width of the winding casing.

Package winding systems The winding of a → Package (→ Crosswound yarn package) determines its properties during further processing and thus the quality of the end product and the effectiveness of production. This has a critical influence on characteristics such as for example consistent package density or good run-off characteristics. Traditionally, there are two package winding systems: Random winding and precision winding (Fig. 1).

I. In random winding there is a fixed relationship between the package surface speed and the speed of traverse winding. This keeps the thread crossing constant, whereas the winding ratio, i.e. the number of package revolutions per cycle to-and-fro, falls with increasing diameter. The advantage of this winding system is that it creates solid packages, which have a uniform density. The disadvantage is that ribbon zones occur with this winding system, which lead to poor run-off characteristics and can cause irregularities after dyeing (→ Yarn packages in dyeing).

In random winding, the crosswound yarn package is driven by friction at its circumference (Fig. 2). The surface drive is mechanically linked with the thread changing device. Drive and thread changing devices are incorporated into one and the same machine element, namely the slotted drum. The surface speed of the yarn package has a fixed relationship to the thread lay. This ratio is expressed by the crossing angle of the threads on the package, which is constant, during the entire build up of the package regardless of the diame-

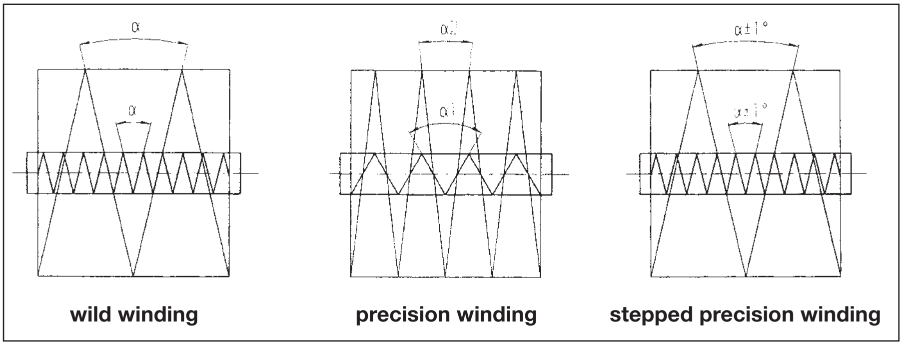


Fig. 1: Package winding systems.

ter of the package. This gives rise to a stable package construction with almost uniform density. The winding ratio, i.e. the number of package revolutions per cycle to-and-fro, alters in relation to the package diameter. For example it is 1 : 8.2 near to the dyeing tube and approx. 1 : 1.6 at a diameter of 280 mm.

If there is a whole numbered ratio of the diameter of the slotted drum and the diameter of the yarn package during winding, one thread is placed upon another, and ribbon winding occurs. Critical zones occur e.g. at 90 mm drum diameter and 90 or 180 mm package diameter. Ribbon winding is unfavourable for the run-off of the package in further processing. For this reason a ribbon breaker is used in yarn packages with random winding.

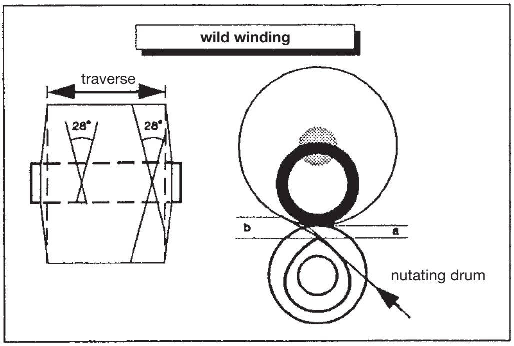


Fig. 2: Wild winding.

II. In precision winding the relationship between the package speed and the speed of the thread change is kept constant. Thus the winding ratio remains the same during the entire winding process. The thread crossing angle, however, decreases as the package diameter rises. No ribbon zones occur with this winding system. The package has good run-off characteristics, which means that high discharge speeds can be achieved. It also gives a high package density. The advantage: depending upon the yarn number up to 38% more running length for the same package volumes.

The stability of the yarn package is limited due to fact that the thread crossing angle decreases as the package diameter increases. The decreasing angle also causes an increase in package density towards the outside of the package, which can lead to inconsistent penetration by the dyeing liquor.

In precision winding (Fig. 3), the crosswound yarn package is usually axially driven. This drive is linked to the thread traverse mechanism. Therefore the crosswound yarn package always makes the same number of revolutions during one to-and-fro cycle of the thread guide. The winding ratio thus remains constant during the entire formation of the package and is independent of the package diameter.

If the speed of the crosswound yarn package is constant then the speed of the thread increases with the package diameter. However, constant package speed is a prerequisite for uniform package formation. Therefore, in order to keep the thread speed unchanged, it is necessary to control the package rotation speed. For this reason, precision traverse winding frames have a expensive adjustable drive.

Because the winding ratio remains constant, the thread crossing angle changes automatically as the di-

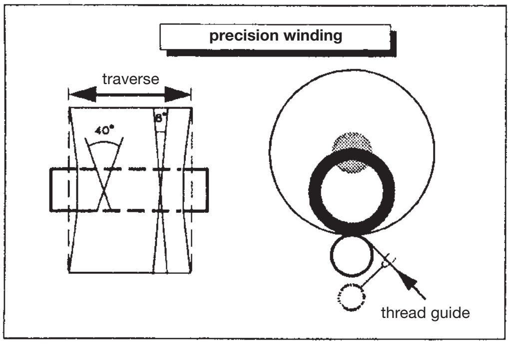


Fig. 3: Precision winding.

ameter of the crosswound package increases. So, for example at the start of winding, i.e. near to the tube, there is a crossing angle of 40°, whereas with a full package with a diameter of 280 mm only an angle of 8° remains. As a result of the varying thread crossing angle, the density of the crosswound package increases with its diameter.

III. Graduated precision winding: in order to combine the advantages of the two winding systems, and at the same time to eliminate their disadvantages, graduated precision winding was developed. This is a precision winding system in stages. After each stage the thread crossing angle is returned to the original number of degrees. The result is an almost constant angle, with the winding ratio being reduced in stages.

The benefits are clear. The almost constant thread crossing angle guarantees the stability of the yarn package and a uniform density. The defined thread distance of precision winding prevents ribbon zones and facilitates a high winding density. Because of this, the package has good run-off characteristics and running lengths are noticeably greater than those achieved with random winding.

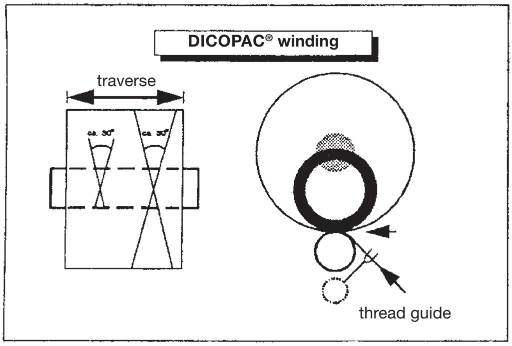


Fig. 4: Dicopac winding (Schlafhorst).

In the Dicopac system by Schlafhorst (Fig. 4) the placement of the thread is accomplished using a traverse mechanism. The crosswound package is driven on its surface by a driving cylinder. Because of the control of the thread guide movement, the winding ratio does not change continuously as in random winding, but in stages. This has the result that each thread layer is precisely wound.

Fig. 5 illustrates schematically the graduated change in the winding ratio with increasing diameter. The change is kept within narrow bounds due to continuous adjustment. Random winding with 20° crossing angle and precision winding are shown for comparison. This graduated adjustment results in the crossing angle remaining approximately equal on the package at all diameter ranges. This gives a uniformity of density similar to that of random winding, which cannot be achieved with precision winding.

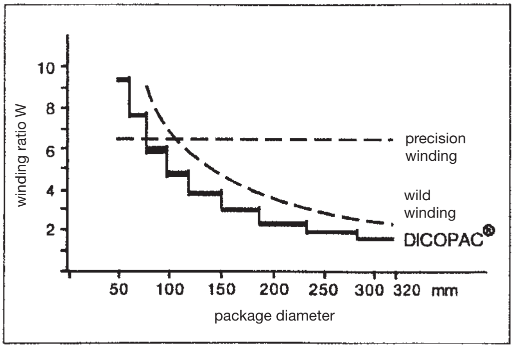


Fig. 5: Winding ratio related to package diameter.

Packaging For dyestuffs; should be practical, recyclable, standardized and environmentally friendly. Packaging cost/kg dye e.g. 45–55 g (see Fig.). A polyethylene bag can be loosely connected to the packing box, so that after complete emptying, separate disposal or full reuse is possible.

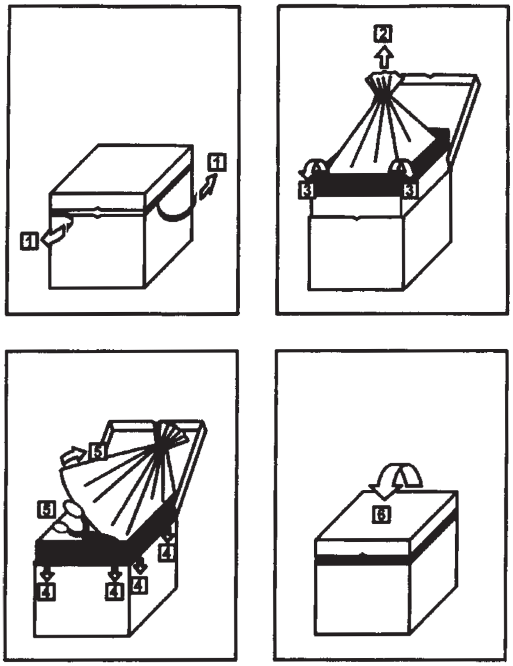


Fig.: Dyestuff packaging (source: Bezema, Gefatech and Mosburger AG): 1 = sealing strips; 2 = the PE inliner is provided with a gusseted base; 3 = holding tabs; 4 and 5 = opened around entire area of box; 6 = re-sealing.

Packaging of textile auxiliary chemicals In connection with the problem-free handling of dyestuffs and chemicals in the textile finishing industry, the packaging in which products are delivered to the textile company is particularly important. The criteria “efficient”, “customer friendly” and “easy to dispose of” are of primary importance in their development. Strict requirements are made of distribution, safety and protection of resources. There are still calls for a ban on non-reusable packaging. Self contained plastic packaging such as canisters and barrels could become less important. For every consignment (by rail, road, ship or air) the packaging must always fulfil the applicable safety requirements (UN legislation). It should also be noted that packaging (depending upon destination) will be subject to different storage conditions, which it must also conform to. Liquid and solid substances must be efficiently dispatched and stored. The following are used for this purpose:

a) less large barrels with 150–250 kg capacity, more packages with maximum 30–60 kg capacity;
b) packages for deliveries in palletised units, facilitating mechanized handling throughout the entire distribution chain,
c) large packaging of 500–750 kg in the form of returnable containers, which contain an easily disposable internal container,
d) bulk deliveries in tankers or silo vehicles.

Packing density Specification of textile goods in weight/volume (g/l).

Packing order (German legislation, VerpackVO, Verpackungsverordnung), a significant part of the packing order relates to the compulsory returning of sales packaging: As of 1.1.1993 industry is obliged to take back used sales packaging and reuse the material without public waste disposal. In § Section 3 VerpackVO the legislator permits a privately performed collection and sorting system for sales packaging, which frees the companies and all their suppliers from the obligation to take back material. By allowing an independent organisation to perform the collection and utilization of used sales packaging it strives to free companies from their obligation to take back packaging and charge a deposit. This system, which runs in parallel to the public waste disposal system is called the “dual system”. The dual system for sales packaging is run by a company called: “Duales System Deutschland GmbH (DSD)”, Bonn. DSD primarily performs monitoring and control functions in the dual system. The collection and sorting of valuable substances is performed by regional waste disposal companies under contract from DSD. Different collection systems are used to collect valuable substances, and after sorting and preparation these materials are transferred to the guarantors of material utilization as secondary raw materials so that they can be put back into the material cycle for utilization. The idea is that DSD will finance itself and the orders given to it by licensing the “Grüner Punkt” (green point). In order to participate in the dual system, the seller of sales packaging must purchase the “Grüner Punkt” for a licence fee. This “Grüner Punkt” signifies that licence payment has been made, which is used to finance the collection and sorting of the sales packaging. The “Grüner Punkt” also tells the consumer, that the packaging is a reusable material and he should return it to a collection system, which is also identified with the “Grüner Punkt”. The licence fee is calculated for each type of packaging, and differs depending upon the packaging volume. This flat rate classification was supplemented by a specific payment scale for flat and lightweight packaging.Recently, criticism of this type of reuse or recycling and of the DSD has increased.

Pack system dyeing Dyeing using the pack system (derived from package dyeing); pack dyeing of carpet yarns. The equipment in question must be carefully packed with the material to be dyed (loose stock, combed tops, yarn).

Pack system dyeing machines → Dyeing machines, circulating liquor type, in which the treatment liquor flows through the packed textile material. Circulation equipment without systematic liquor guidance, for universal application and for H_2O_2 bleach, made of special steel. Capacity 500–2000 kg.

Pad Impregnation on a padder. Differentiated according to procedure e.g. →: Pad-batch process; Pad-dry-process; Pad-jig-process; Pad-Roll-Process; Pad-Steam-Process.

Pad-batch process (→ Cold pad batch dyeing), performed on the padder (Fig.); high performance fabric opening and rolling machines guarantee crease-free material flow without edges rolling up from material entry to the nip. On the way from the nip to the rolling point the material is fed over additional rubberized rollers. The fixed material feed prevents the material from stretching lengthways and the edges from rolling up. This requirement to prevent rolling up on the batch roller is achieved by an adjustable hydraulic force on

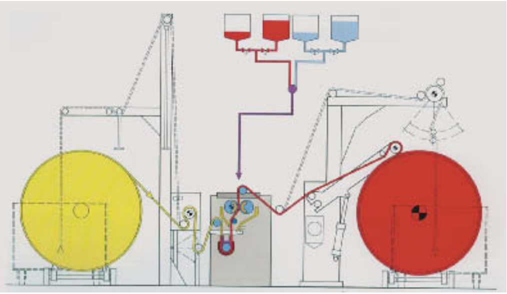


Fig.: Cold-batch-application (Küsters) with mini economy trough.

the last transfer roller. The material tension is modified to suit the process using a computer controlled centre roller. The following material qualities can be dyed economically, gently and with reproducible effects using the pad-batch process:

1. knitted fabrics: Single jersey, interlock, lining fabrics, nikki plusch,
2. woven fabrics: Mercerized and non-mercerized cotton fabric, inlet material, cord, terry fabric.

After the padding and cold dwelling the material must be washed in a suitable manner.

Pad-batch process control Padding the material with liquor in the padder, followed by a dwelling stage so that the applied liquor can be fixed or allowed to act. Padding can take place under controlled conditions (Fig.). The most important pad-batch-processes are:

→ Cold pad batch dyeing (CPB),
→ Cold pad batch dyeing with reactive dyes,
→ Pad-batch process,
→ Pad-Roll-Process.

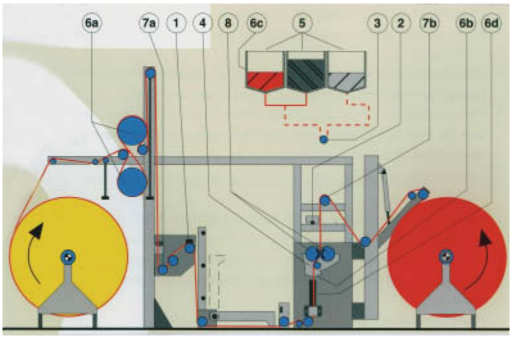


Fig.: Dyeing centre with new technology designed to control processes and to minimize defects and the volume of waste liquor in the cold pad-batch process.
1 = measuring of fabric moisture at entrance; 2 = measuring of dye liquor pick-up on the fabric; 3 = measuring of liquor colour at trough; 4 = rapid cleaning system; 5 = dye kitchen; 6 = central cooling station with: 6a = cooling of fabric; 6b = cooling of dye liquor; 6c = colling of liquor storage tanks; 6d = cooling of trough (Flex-shaft); 7 = load cells for winder control with: 7a = load cell for fabric tension control at entrance; 7b = load cell for fabric tension control at exit; 8 = Küsters' swimming rollers.

Pad-batch processes → Pad-batch process control.

Padder Open-width dyeing machine, padding machine for open-width treatment, padding, impregnating, (padder) delustring etc. of piece goods (loose material on special padders.) The task of the padder is to remove the excess liquor absorbed in the dyeing trough by uniform squeezing across the entire width of the fabric. Not every padder is suitable for this. We can differentiate between two types:

1. Relatively small, long trough with 1–3 guide rollers and 2–4 squeezing rollers mounted above and an elevated preparation vessel for the dyeing liquor, which is connected via a pipe with the trough to be continuously filled during dyeing. The 2 roller padder is selected specifically for absorbent material, the 3 roller padder is commonly used when frequent submerging is necessary for materials that are more difficult to wet, whilst the 4 roller padder is recommended for material that is easily stretched between submersions. The dry material passes through the roller system once or twice, whereby the dyeing liquor per pass is adjusted for the desired shade.
2. Colour box free high-performance padders are becoming ever more important, specifically for continuous dyeing techniques. There is a short padding liquor in the nip (therefore particular care should be taken, that the dye has actually dissolved, for dark dyes) between the 3–5 rollers, which both squeeze and move the material. Some typical examples are shown in Figs. 1–3 and 5–7.

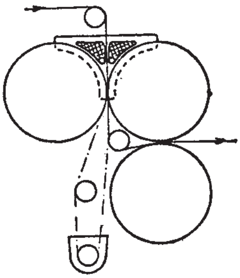


Fig. 1: Peter Econom with dividers (top at fabric entry).

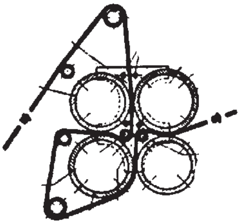


Fig. 2: Benninger Fibe.

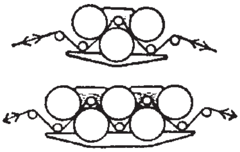


Fig. 3: Benteler 3- and 5-roller padder.

New designs strive to apply as little liquor as possible,

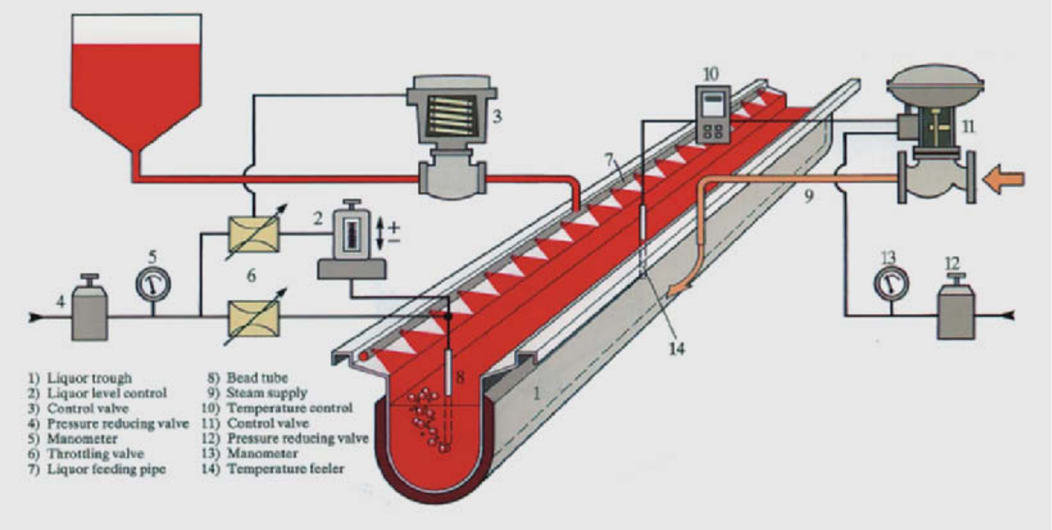


Fig. 4: Padding technique. Reproducible dyeing by liquor level control and precise liquor supply across the full width. Even distribution of temperature by means of indirect jacket heating of trough.

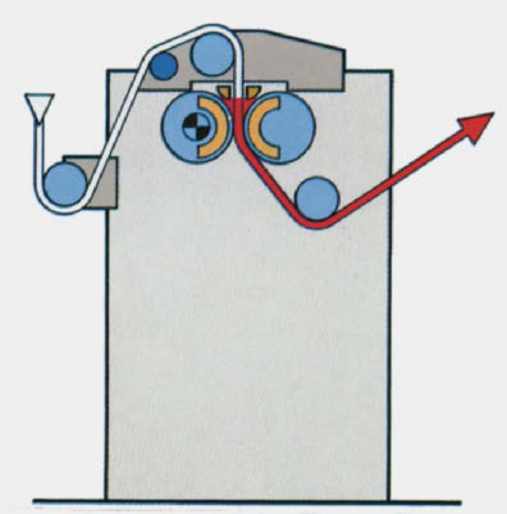


Fig. 5: Nip dyeing unit with plates pneumatically pressed against the lateral surfaces of the rollers, curved expander for woven fabrics (Küsters).

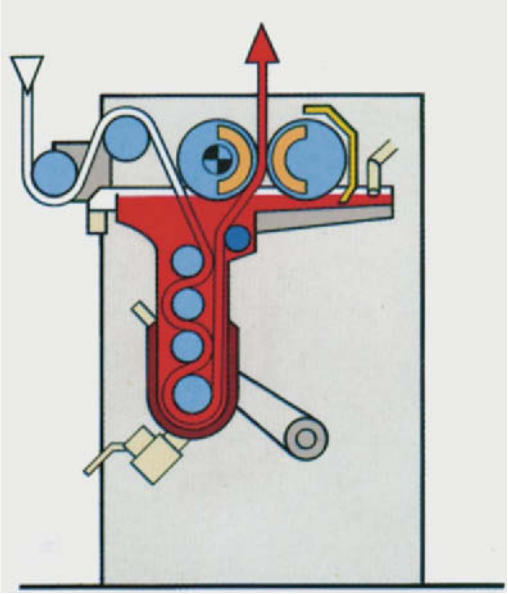


Fig. 6: Special "lapping-up" trough permitting squeezing rollers to dip into the liquor. Economic trough with pneumatic lifting device and 4 soft rubber covered rolls for underliquor squeezing serving simultaneously as displacer, indirect jacket heating, curved expander roller for woven fabrics (Küsters).

in order to firstly save dye, chemicals, assistants (Fig. 4), and secondly to reduce the problem of dye migration in the subsequent drying stage and to minimize the amount of water to be evaporated. The application of wet-on-wet application (Fig. 8) is an option that has recently become available. Pad-steam plants are used for the treatment of batches of virtually unlimited size, usually as continuous lines (padder, steamer, washing box). For knitted fabrics, continuous processes with in-

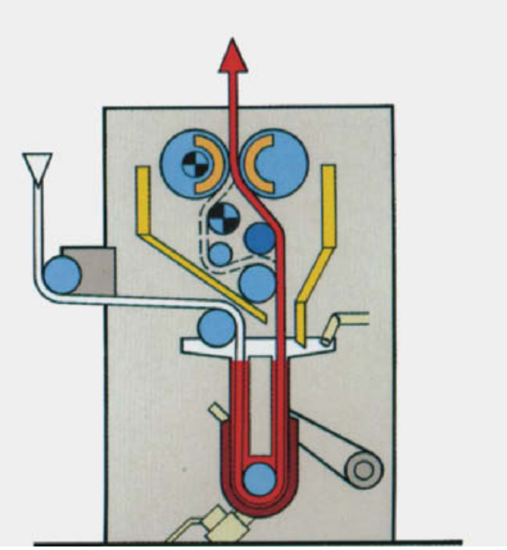


Fig. 7: Standard trough with pneumatic lifting device, displacer, guide roll and indirect jacket heating, curved expander for woven fabrics or alternatively counter-clockwise driven scroll roller for knitted fabrics (Küsters).

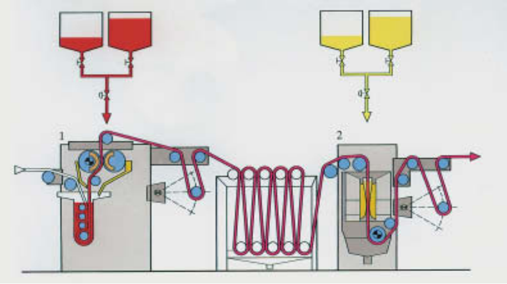


Fig. 8: Wet-on-wet application technique: dye padder (1) with Küsters' Flexnip (2).

termediate dryers give rise to particular difficulties, because the two layer tubular form causes dye migration problems that have yet to be solved.

Padder-jig Combination → Padder with → Jig dyeing, whereby the upper padder roller functions as a jigging roller. Used for discontinuous dyeing (→ Pad-jig-process) with vat, vat leuco ester, reactive dyes, etc.).

Pad-Develop-Thermosol-Process Pad-dyeing technique for polyester/cotton using vat leuco ester and disperse dyes.

Padding,

I. According to Rüttiger, the entire padding function can be divided into elementary functions:

1. Submersion of the textile material in the liquor for mixing.
2. Squeezing the loaded textile material for proportioning.
3. Transport of the reaction mixture (textile material with defined product application).

The elementary functions can be further subdivided into basic functions:

1. Basic functions during submersion:
   a) wetting,
   b) penetration of the liquor into the gaps in the textile material,
   c) removal of air from the textile material,
   d) diffusion of water into the fibre material,
   e) swelling of the fibre material,
   f) diffusing of the dye or finishing agent into the fibre material.
2. Basic functions during the squeezing process:
   a) compression of the textile material in the nip,
   b) liquor backflow as it flows through the textile material,
   c) capillary transport in the direction of the material movement,
   d) adhering liquor is returned to the rollers,
   e) squeezed out liquor flows back.
3. Basic functions during transport (similar to those during submersion):
   a) diffusion of the water into the fibre material,
   b) diffusion of the dye or finishing agent into the fibre material,
   c) evaporation of the water.

When considering the influence of the individual elementary functions during padding it is useful to consider extreme cases. So, for example, if wetting is merely adequate, squeezing is solely for proportioning, otherwise, depending upon the specific roller design and suitable padding conditions, air must be removed despite adequate wetting. If wetting is inadequate air is removed during the squeezing process by cross-flow and the inside of the material is wetted. Wetting is thus repeated by a mechanical effect in the nip (flow through the material). Therefore the squeezing process always becomes the dominant elementary function if there is inadequate wetting during submersion. The overall function of a system cannot be obtained by knowledge of the basic functions alone, because these are generally defined, i.e. without specifying the inputs and outputs of the system in question. Moreover, it is not just these basic functions that are decisive for the overall function, but also (and much more importantly) their interaction. In order to develop a padding procedure, the dominant relationships need to be found, rather than merely investigating them as individual functions. Options on offer are performing operational and laboratory experiments. Despite this fact, knowledge of the basic functions is of great value, because this knowledge can be applied to make predictions regarding the dominant influence variables of the system, particularly in certain extreme cases. In the case of padding, wetting, flowing through and compressing, these can be viewed as the dominant basic functions (according to Heidemann).

II. i.e. impregnation of piece material on the padder with dye or textile assistants. → Pad process.

Padding auxiliary (solvent), must fulfil the following requirements when used in the → Padding of woven fabrics and hosiery goods:

- increasing the wetting and penetration capacity as well as improving flow in the pigmenting process,
- little or no effect on the degree of distribution of pigments,
- prevention of pigment migration in the intermediate drying of pigmented material,
- low foaming in the padding liquor,
- adequate electrolyte or alkali resistance.

We differentiate between two padding auxiliary groups:

I. Padding auxiliary to increase the dye affinity of the fibre, preventing dye migration during intermediate drying or pigment separation. These padding auxiliaries are anionic surfactants.

II. Padding auxiliary to increase the padding liquor viscosity, increasing dye migration without influencing the degree of distribution of the dye. These padding auxiliaries are usually thickeners based upon alginate, carboxymethylcellulose, acrylates, etc.

Padding index Comparative dyeings are produced using absorption curves without adding salt. The depth of dyeing achieved after 10 min is set at 100, and the padding index is established as the depth of dyeing after 2 min. On this basis, direct dyes applied without using salt with high and steeply rising curve are particularly suitable for pad dyeing.

Padding machine → Padder.

Padding material Plain weave fabric made of linen and linen union, as roller covering material for finishing machines, for covering ironing presses, etc. with fabric.

Padding, stuffing (material). Inner material of outer clothing. Used for elastic shaping and shape retention.

Paddle machine Large, oval tub made from wood or stainless steel (vessel capacity up to several cubic metres), with the “island” in its centre containing the drive mechanism for the paddle, which consists of a paddle immersed in the liquor from the side, which can be rotated from top to bottom, ensuring continuous circulation of the liquor and material during operation. Application: Preferably with a high liquor ratio (approximately 1 : 150) for large batches (clothes dyeing), particularly for woollens for felt free finishing (see Fig.).

Paddles → Fallers.

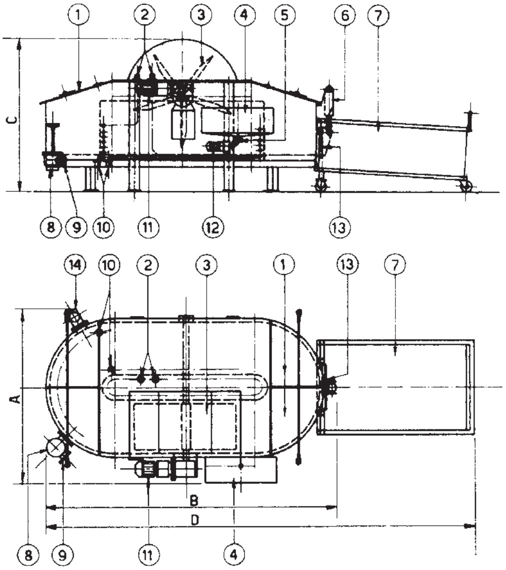


Fig.: Flainox paddle dyeing machine for finished items.
1 = lid; 2 = cooling; 3 = paddle; 4 = additives tank;
5 = cock; 6 = spigot; 7 = transport trolley; 8 = drain cock;
9 = water inlet; 10 = heating element; 11 = speed regulator;
12 = liquor circulating pump; 13 = liquor quick drain.

Pad-dry-process,

I. Variant of the heat setting process for reactive dyes (→ Reactive dyeing). Dye fixation on the fibre takes place after padding, during the drying process.

II. For antifelting finish of woollen piece goods and garment panels with a prepolymer made of polyether with reactive groups.

Pad-dyeing The → Pad process is replacing discontinuous dyeing methods for woven fabrics to an ever greater degree. Function mode of padder with swimming rolls (Figs. 1 and 2).

Pad-Fix-Process Pad-dyeing process for polyester spun tow. The tow, which is padded with the dye dispersion, is either packed into a packing cylinder or wound onto a perforated cylinder and dyed in the liquor in the HT circulation machine.

Pad-jig-process Garment panels are padded with dye solutions and developed or fixed on the jigger. The process is of particular practical interest in the dyeing of cotton and linen woven fabrics using vat dyes and also direct dyes to a lesser extent. Advantage: Better penetration and dyeing of larger batches. Disadvantage: The discontinuous vatting can sometimes cause lack of end-to-end uniformity in the full bath of the jigger, because some of the dye is transferred into the blank vat. These faults can be rectified by the addition of padding liquor to the bath at the start and end of the first passage.

Pad-jig-process for reactive dyes Discontinuous

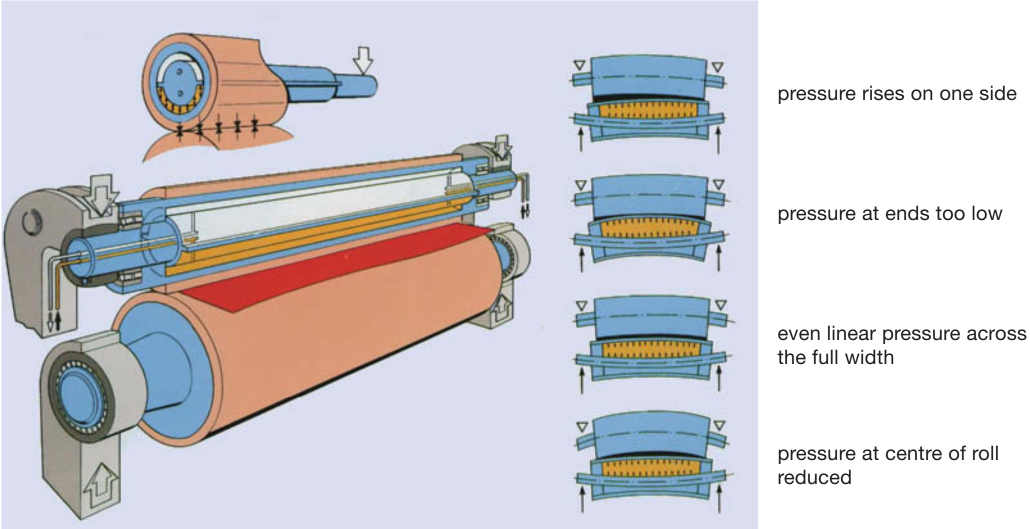


Fig. 1: Function mode of a padder with 1 swimming roll: controlled even and uneven linear pressure across the full width.

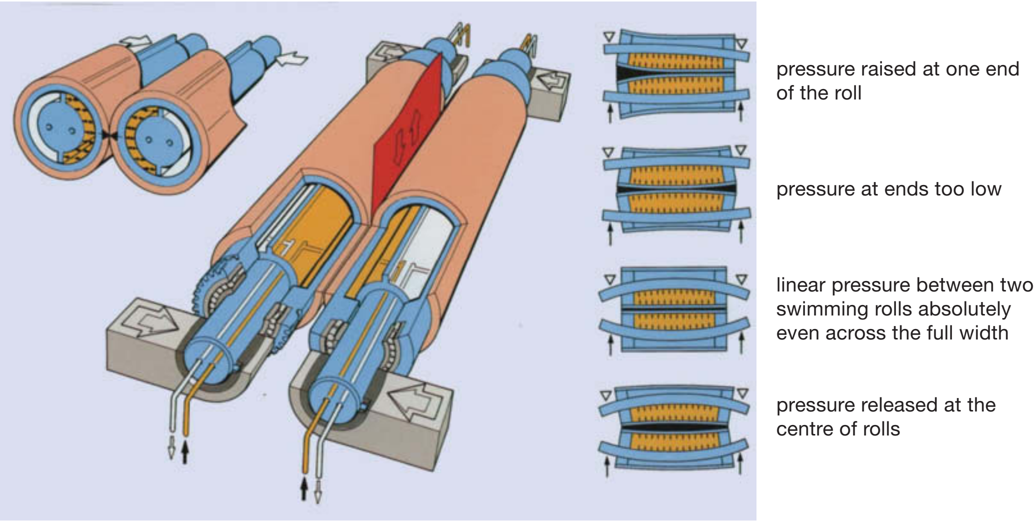


Fig. 2: Uses with a wider range of adjustment: function examples of a padder with 2 swimming rolls: controlled even and uneven linear pressure (Küsters).

principle: Padding with neutral dye solution, drying and treating on the jigger in a saline alkali solution.

Pador gum Lowest quality class of → Senegal gum.

Pad printing Complete printing of a material with the →: Kiss roll; Thousand-point roller or hatching roller.

Pad process Used for padding (→ Padding). The material is impregnated with liquor containing the dye or chemical on the padder, whereby the substantivity of the application product is almost eliminated due to shorter submersion time and shorter liquor ratio. Unlike the exhaustion processes, material flow is continuous, as the first work stage, if necessary followed by a second wet treatment (wet-on-wet-padding (Fig.).

Pad-rapid dry process Single bath continuous

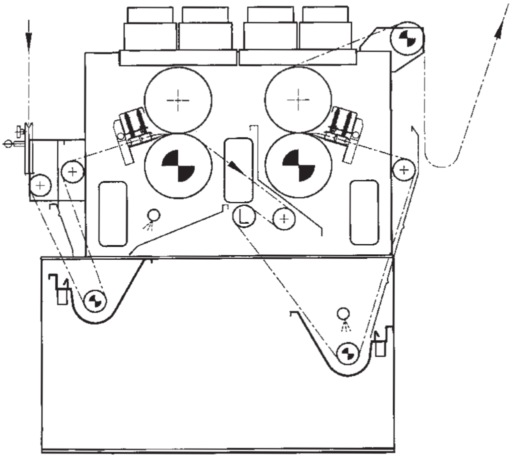


Fig.: Wet-on-wet-padding of knitwear (Küsters).

process for vinyl sulphone dyes using the caustic soda liquor/salt quantity required for the normal CPB process and a dosing pump. Machine requirement: Padder with economy trough and hotflue. Drying temperature 100–120°C. Urea generally not necessary. Yield as for the CPB process.

Pad-roll bleach Semi-continuous process for cotton, cotton/polyester mixes, reclaimed cellulose. Material is impregnated with bleaching liquor and batch rotated and dwelled in a heated chamber.

Pad-Roll-Process Discontinuous pad-dyeing process for dyeing cellulose fabrics with direct dyes, in batches of up to 5000 m. The woven fabric impregnated with the dye is heated up to approximately 100°C in a pre-chamber by IR emitters and wound in an adjoining travelling and heatable chamber. When winding is complete the chamber is connected to a steam line (direct and indirect), whilst the skein slowly turns (“roll”). Dwell time is dependent upon the colour depth. A plant always consists of several chambers. In principle, this process corresponds with dyeing using a 1 : 1 liquor ratio. Temperature and moisture variations in the chamber give rise to certain difficulties due to seam impressions and listing or ending. Reactive dyes can be successfully used in the pad-roll process. The plant is also suitable for desizing, scouring and bleaching according to the pad process.

Pad-Steam-Process With the exception of the jigger, the padder is the most important open-width dyeing machine for the application of liquor (pad). It is used in connection with a fixing facility (steam). Particularly strict requirements must be imposed on the dyeing padder: Each irregularity shows up as uneven dyeing. The quantity of dye applied to the fabric by the padder depends upon the dye concentration of the liquor, the liquid quantity absorbed (pick-up) and the ratio of “absorbed dye to absorbed liquid”. This ratio can vary during dyeing (lack of end-to-end uniformity), for example in exhaust dyeing using substantive dyes: The batch ends become lighter; or in vat pigmenting, by preferential take up of water: The batch ends become darker. A constant material speed is important, and the submersion path should be as long and constant as possible with as small a liquor volume as possible. It is better to work in a manner that allows fresh liquor to constantly flow into the trough during dyeing, than to allow the liquor to circulate continuously between trough and preparation vessel. For heavy or tightly woven fabrics it is beneficial to repeat the submersion and squeezing processes.

The material speed during padding is generally 40–50 m/min. As the speed increases the uniformity of the fabric appearance diminishes. The refinement of the padding design has now made it possible to pad not only woven fabrics, but also hosiery goods (including tubular tricot). These qualities pass through a fabric opening machine before entering the nip. However, good quality dyeing depends upon the tension along the fabric as well as across it. Irregular liquor application or turned over edges result in edge-to-edge unevenness. Shade inequalities across the width of he material can also be attributed to minor differences in the material structure. This can be detected by measuring air permeability. Dark edges occur due to drying out if the standing period before fixation is too long. Lack of end-to-end uniformity is the result if the material takes up a disproportionately large amount of dye from the liquor (tailing effect), or too much water, with the result that the dye concentration in the bath decreases (reversed tailing effect). The same can also occur with insoluble dyes (vat pigments). Non-uniform moisture content before padding can also result in inconsistencies in dyeing. If consistent padding is to be achieved it is important that the fabric swells completely. In cotton fabrics this requires 1–2 s submersion time, for fabrics made of regenerated cellulose fibres, 3–4 s. Therefore, very good pre-treatment of the material, with consequent absorbency, is important.

In the pad-dyeing process with intermediate drying, migration occurs if there is inconsistent air circulation; the points that dry first take dye from the surrounding fabric areas, thereby becoming darker (duplex dyeing). Excessively rapid drying at high temperatures causes dye migration from the inside of the fabric to the outside. The fabric then appears to be poorly penetrated. Migration is strongly dependent upon the fabric and its moisture content. Below around 30% moisture content, there is no migration. Additives that increase the viscosity of the liquor, agglomerating products and agents with “reversed” solubility, i.e. substances in which the solubility falls with increasing temperature, hinder migration.

Pad-Steam-Process

Critical factors for faultless pad dyeing can be summarized as follows:

Factors relating to the fabric:
- uniform width of the fabric batch,
- rolled up without creases,
- no curled selvedges,
- uniform absorbency,
- uniform temperature,
- uniform moisture content.

Factors relating to the padder:
- faultless roller covering,
- uniform roller pressure across the entire width of the material,
- uniform liquor temperature,
- uniform liquor feed,
- uniform liquor level in the colour box.

There are two alternative methods for the pad-steam process. During the steaming process attention should be paid to uniformity of the temperature throughout the whole of the steamer. If side-to-side deviations occur the material temperature should be checked to eliminate this fault. In saturated steam steamers temperature differences occur less often than is the case with superheated steam.

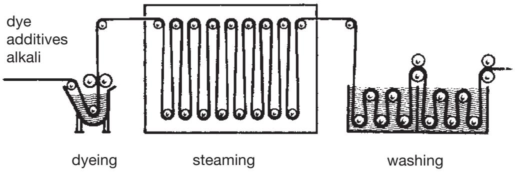


Fig. 1: Principle of the Pad-Steam-Process without intermediate drying (saturated steam process).

The pad-steam plant is a universal continuous dyeing plant (Fig. 1) for all dye groups and is the preferred equipment for vat dyeing. In order to be able to exploit the dyeing advantages of the process for small batches, various companies build so-called compact plants with smaller steamers (Fig. 2). Laboratory pad-steam equipment is available for patterning and experiments. The so-called “Williams unit” is used in some companies instead of the development (vat) padder. This is an open-width treatment dyeing vat with guide rollers at top and bottom. The area between the rise and fall of the material lengths is reduced to a minimum by inserted walls, so that it is possible to make do with a small liquor quantity, at the same time achieving a high bath turbulence. Bath and material feed is by the counter current method.

Soaping is a problem with all continuous dyeing plants for vat dyes. In order to achieve a sufficiently long soaping period, soaping must be performed in several compartments, depending upon the material speed. Kleinewefers KTM has found a solution by designing a “soap steamer”. The soaping effect is accelerated by steaming. The area above the soap tub is closed and fitted with direct steam feed pipes.

A large-scale pad-steam plant (Fig. 3) consists of a dyeing padder (2 or 3 rollers), hotflue, chemical padder (for sodium dithionite and lye), a small steamer (material capacity 40–50 m) and an open-width washing machine, if possible with several roller vats for oxidation, rinsing, soaping. For light shades the intermediate drying stage may be dispensed with (wet-on-wet, pad-wet process). The plant is also suitable for dyeing using reactive, vat, vat leuco ester, sulphur, naphthol and direct dyes.

All continuous dyeing processes for cotton fabrics

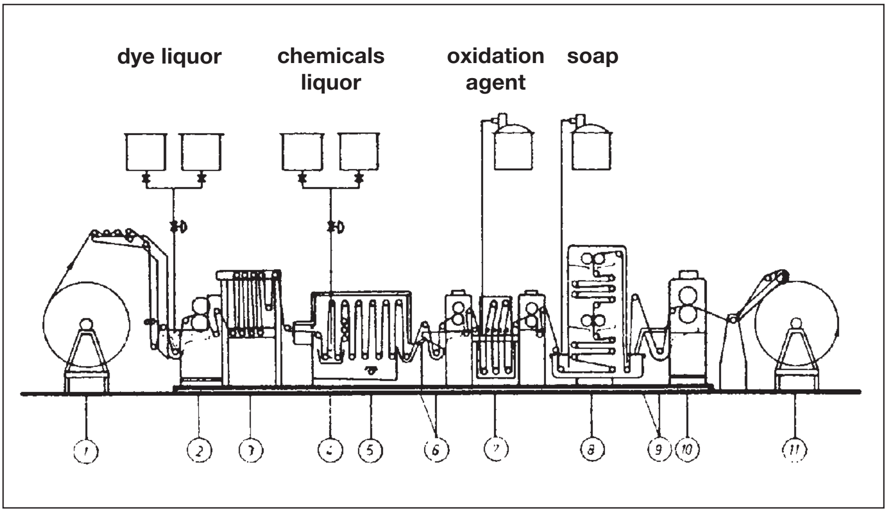


Fig. 2: Rapid curing facility for vat dyes (Menzel). 1 = undyed goods; 2 = pigmenting pad; 3 = open air section; 4 = booster; 5 = steamer; 6 = rinsing; 7 = oxidation unit; 8 = washer tower; 9 = rinsing; 10 = squeezer; 11 = dyed goods.

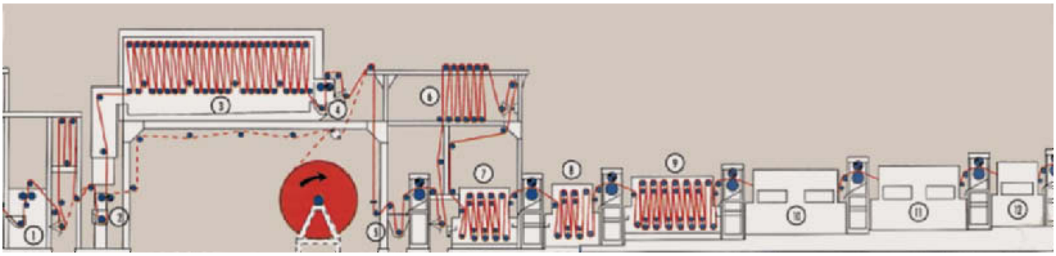
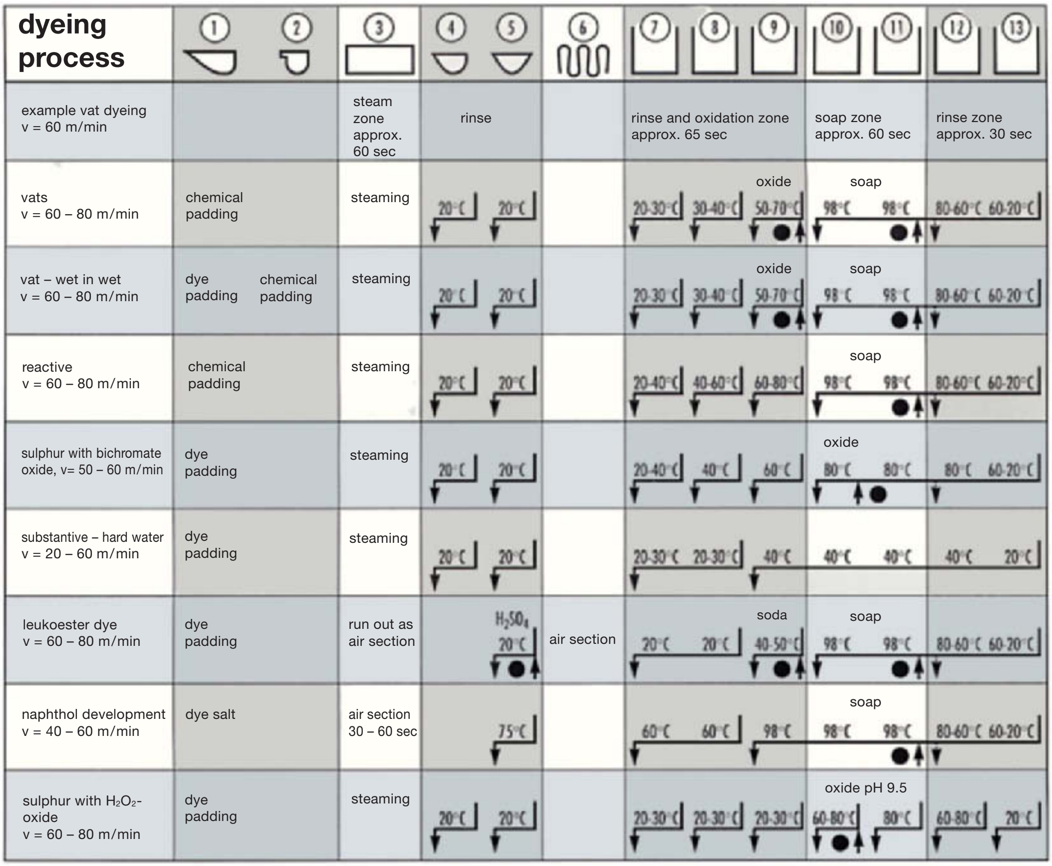


Fig. 3: Pad-steam facility by Kleinewefers KTM (material width 1800 mm, throughput 60–80 m/min, material weight up to 250 g/m^2, also for pile and cord fabrics). Key in Fig. 4.

(Fig. 4) have the following procedural stages in common:

1. Dye application: If the material to be dyed is a pure cellulose fabric the dye application always takes place in a single bath (for mixed fabrics made of cellulose and polyester fibres for example the dye can be applied in single or dual baths).
2. Fixation process: May differ for the different continuous dyeing processes. Options range from dry heat to wet steam fixation. It is the dye fixation stage that most clearly characterizes the individual process.
3. Aftertreatment: Dye and chemicals that have not been fixed are removed from the material. This



dyeing process	①	②	③	④	⑤	⑥	⑦	⑧	⑨	⑩	⑪	⑫	⑬
example vat dyeing v = 60 m/min			steam zone approx. 60 sec	rinse			rinse and oxidation zone approx. 65 sec			soap zone approx. 60 sec		rinse zone approx. 30 sec	
vats v = 60 – 80 m/min	chemical padding		steaming	20 °C	20 °C		20-30 °C	30-40 °C	oxide 50-70 °C ●	soap 98 °C	98 °C ●	80-60 °C	60-20 °C
vat – wet in wet v = 60 – 80 m/min	dye padding	chemical padding	steaming	20 °C	20 °C		20-30 °C	30-40 °C	oxide 50-70 °C ●	soap 98 °C	98 °C ●	80-60 °C	60-20 °C
reactive v = 60 – 80 m/min	chemical padding		steaming	20 °C	20 °C		20-40 °C	40-60 °C	60-80 °C	soap 98 °C	98 °C ●	80-60 °C	60-20 °C
sulphur with bichromate oxide, v= 50 – 60 m/min	dye padding		steaming	20 °C	20 °C		20-40 °C	40 °C	60 °C	oxide 80 °C ●	80 °C	80 °C	60-20 °C
substantive – hard water v = 20 – 60 m/min	dye padding		steaming	20 °C	20 °C		20-30 °C	20-30 °C	40 °C	40 °C	40 °C	40 °C	20 °C
leukoester dye v = 60 – 80 m/min	dye padding		run out as air section		H_2SO_4 20 °C ●	air section	20 °C	20 °C	soda 40-50 °C ●	soap 98 °C	98 °C ●	80-60 °C	60-20 °C
naphthol development v = 40 – 60 m/min	dye salt		air section 30 – 60 sec		75 °C		60 °C	60 °C	98 °C	soap 98 °C	98 °C ●	80-60 °C	60-20 °C
sulphur with H_2O_2-oxide v = 60 – 80 m/min	dye padding		steaming	20 °C	20 °C		20-30 °C	20-30 °C	20-30 °C	oxide pH 9.5 60-80 °C ●	80 °C	60-80 °C	20 °C

● chemical

Fig. 4: Technical comparison of cotton pad-steam dyeing processes (by Kleinewefers KTM).

washing out process can be carried out in the same way for all processes, e.g. in continuous washing lines on successive roller vats.

A significant procedural difference in continuous dyeing is in the application of chemicals: One option is to combine the chemicals and the dye in a pad liquor and apply them together. This is a single stage process. The other option is to put chemicals and dye in separate pad liquors and to pad them separately. This is called a two-bath process with liquor stabilization, which has the advantage that hydrolysis-sensitive residual liquor is stable for longer and is sometimes reusable.

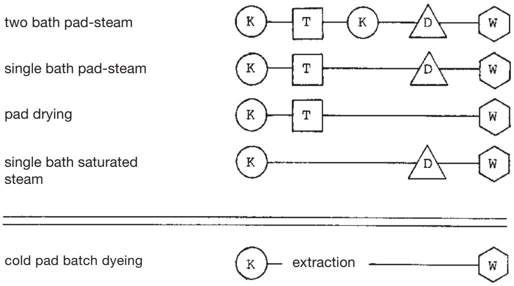


Fig. 5: Diagram comparing continuous dye processes using reactive dyes.
K = padding; T = drying; D = steaming; W = washing.

The pad-steam-processes include the two-bath pad-steam-process and the single-bath wet steam process. As can be seen from Fig. 5, padding takes place twice in the two-bath pad-steam-process; first the dye is applied and then the chemicals are applied after drying. The damp material then travels into the steamer, where the reactions between the dye/cellulose and dye/water (hydrolyzate) take place. Then the hydrolyzate and the chemicals are removed by washing. This process is also called the pad-steam-process with intermediate drying. The single-bath wet steam process (pad-steam-process without intermediate drying) only includes one padding process, in which both the dye and the chemicals are applied. The intermediate drying is dispensed with, which means that the damp material is steamed immediately after the first padding process. The washing off stage has the same purpose as in the other process.

Which of the two pad-steam-processes is preferred depends upon the material quality and quantity, the dye characteristics and the options open to the individual company. In general the pad-steam process with intermediate drying is recommended for companies with a complete continuous line and high production. The wet-steam process is of interest, due to the saving in drying costs, its high flexibility and high production. However, the process is only recommended for light to medium shades, because the build-up behaviour of dyes should be limited compared to the process with intermediate drying.

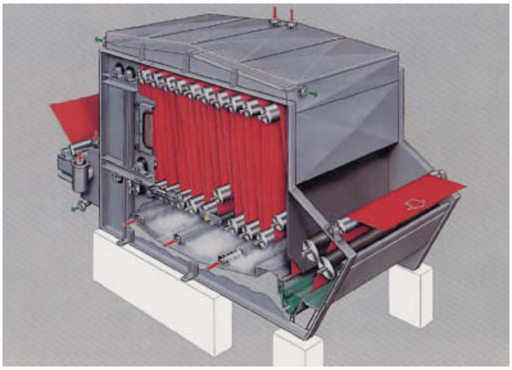


Fig. 6: Dye steamer for all pad-steam dye processes.

Steaming plays a decisive role in the fixation of dyes. The material is heated up rapidly in the steamer (Fig. 6) and wetted by the condensate. The dye migrates from the liquor into the fibre and is fixed. This process is an exhaust dyeing process with a short liquor ratio (1 : 0.7–1 : 1). Steam, an ideal heat conductor, supplies moisture and high temperature to the material soaked in liquor and thus takes on the function of the dyeing liquor. The main differences between saturated and superheated steam are as follows: If water is heated to its boiling point, steam is generated. Saturated steam can have a temperature of 101–103°C. If saturated steam is heated further, with the pressure remaining constant, then its volume increases; it is superheated. The steam condensation temperature is virtually the same as the fabric temperature. Because the steam will always condense where the textile fibre surface is “colder” than the steam condensation temperature, the fabric temperature is not influenced by differences in fabric weight or liquor application. The textile-dependent heating up time of approx. 3–10 s increases only slightly for damp padded material. The dye reactions during steaming are greatly accelerated; but it is not only the fixing of reactive dyes on the material that is improved, but also the hydrolysis reactions with the water. Moreover, the dye substantivity falls significantly as the temperature increases, which can result in yield losses depending upon the dye type. Because the steam condensate can increase the “liquor ratio”, i.e. the water quantity on the material, it is important to be able to calculate the amount of condensate. The damper the material when it enters the steamer, the greater the quantity of steam condensate. The condensate loading f_{TK} (kg condensate/kg textile) of the liquor-laden material, which is damp from padding, after heating is calculated using:

$$f_{TK} = \frac{C_T + e_F \cdot C_F}{C_D} \cdot (t_K - t_R) \quad [-]$$

C_T (kJ/kg °C) = specific heat of the textile,
C_F (kJ/kg °C) = specific heat of water,
C_D (kJ/kg) = specific heat of steam,
e_F (kg liquor/kg material) = liquor loading of the textile,
t_K (°C) = condensation temperature (= 100°C),
t_R (°C) = room and textile temperature (= 20°C).

For the entering material, damp from padding, with a liquor loading of $e_F = 0.70$ (= 70% by weight), then using the above values, we calculate a condensate loading of 0.148 = 14.8%. According to this worked example there is a condensate quantity of 14.8% on the material with 70% liquor loading, so that in total a moisture loading of 70% + 14.8% = 84.8% (by weight) is carried by the material during its passage through the saturated steam atmosphere. This example shows the increase of the liquor ratio. This results in a decrease in the yield for reactive dyes, which do not have a high enough substantivity to react with the material instead of hydrolyzing.

The hydrolyzate increases because the dye is too far away from the fibre due to the high moisture content and the excessively high substantivity. A better yield could be achieved when using reactive dyes with “poorer” substantivity, by selecting superheated steam for fixing instead of saturated steam, and possibly adjusting the steamer dwell times. The partial pressure of the steam is not altered by superheating; likewise the increase in the heat content of the condensate is so low that it can be disregarded. Therefore it is not possible to achieve an increase in the temperature of the material by the use of superheated steam. However, the dye yield can be improved by using superheated steam, because the increased energy content facilitates partial evaporation of the material moisture, so that dye concentration in the added liquor can again be increased. The same increase in effect due to partial evaporation can be realised if the steamer dwell times are increased. From the point of view of reproducibility, in this method a residual moisture meter must be installed after the steamer, so that the degree of partial evaporation can be measured.

The wet-warm dwell process represents an alternative to the wet steam process with regard to dye yield. The practical performance of this process is such that the wet, dye impregnated, material is heated by IR emitters as it enters the treatment chamber. In the chamber there is a steam/air mixture, in which the material dwells for approx. 40–60 s at a material temperature of 70–80°C. Because no further moisture can be added, as when fixing with saturated steam, a signficantly lower moisture content is achieved, thus obtaining a better yield when using less substantive dyes.

Pad-thermofix process General term for the pad-dyeing process using reactive and/or disperse dyes.

Pad transfer technique Low wet pick-up technique by transfer, e.g. → QS-process.

Pad-wet fixation process for reactive dyes (Hoechst), continuous process according to the principle: Padding with neutral dye solution, drying, passage through hot, saline, alkali solution.

Pad-Wet-Process Dyeing process, in which development or fixation of the dye after padding takes place without an intermediate drying stage.

Pad-Winch-Process (Pad-Winch beck), process for dyeing difficult to penetrate woven fabrics (above all those made of viscose staple fibres with direct dyes). Material is padded with the dye solution and then treated by boiling with a sodium sulphate or sodium chloride solution on the winch beck, whereby the dye is fixed.

Pailletine,

I. (Yarn) rice straw yarn for furnishing fabrics.

II. (material) Fine clothing material similar to → Paillette; 8 thread, reinforced satin.

Paillette,

I. Sequins, mica; thin perforated metal or glass plates for applying to clothes.

II. Light, shiny clothing, blouse or lining satin with a soft handle (Satin de Chine); 5 or 7 thread warp satin.

Palmer Open-width tensioning device on the felt calender for decatizing/drying open-width materials. Modern design → Pin wheel.

Palm fibres Vegetable fibres of numerous palm types belonging to the group of → Hard fibres, mainly in the form of so-called vegetable horse hair substitute, for brushes, braiding, upholstery material, etc. We differentiate between the dwarf palm fibre (Algeria, Morocco, Spain), the date palm fibre (similar to coir fibres) and further bassine, crin d’Afrique, kitul fibre, panama fibre, para fibres (the most important), piassava fibre, rafia bast, tecum fibre. They are all of regional importance only.

Palm wax → Carnauba wax.

PAM → Modacrylic fibres, → Textile fibre symbols, according to DIN 60 001 until 1988, from 1991 → MAC.

PAN → Polyacrylonitrile fibres, → Textile fibre symbols, according to DIN 60 001 T4/08.91.

Panama (hopsack),

I. Variant of plain weave (→ Weave), whereby at least 2 warp and weft threads are in the same setting (natté or dice weave).

II. Clothing material (wool) with dice-like surface (similar to the Panama hat) in multi-thread plain weave. It has a softer handle than plain weave material.

Panama soap (Quillaya bark, soapbark, wood soap), pieces of bark (from Quillaja saponaria, South America) a tree-like, evergreen rose bush. Dirty white to yellow, different shapes and long, approx. 1 cm thick, up to 10 cm wide. Contains 5–10% → Saponin, which strongly foams like soap when dissolved in water (boiling). Washing effect approx. three times greater than soft soap; fibres and colouring are not corrosive. Application: washing agent for sensitive textiles, for wool degreasing.

Pancreas diastase → Diastases. The active enzyme degrades starches, up to glucose, and also protein substances into easily water soluble products. Derived from the animal pancreas, which is otherwise unusable. Application quantity 0.5–3 g/l. High acidity and high temperature destroy the enzyme. Existing alkali sensitivity is reduced in special products. Temperature sensitivity is reduced by hydrochloric acid, with effectiveness being increased at the same time. It should be noted that heavy metal salts and some surfactants reduce its effectiveness.

Pancreatin (pancreas enzyme), protein degrading, so-called typical or proteolytic enzyme from the pancreas.

Pannonia process Lustring process for sheep skins; most commonly practised in USA, England, France, Italy, etc. Sheep skins with the softest wool possible are moistened with aqueous solution (with the addition of alcohol, organic acids, formaldehyde etc.) and drawn over heated, rotating cylinders (ironing machines). This uncurls the wool hairs and makes them take on a marked shiny character of precious furs (beaver, sea-lion), called Moutonderé, Beaver lamb, Hudson seal.

Panthenol An alcohol derived from pantothenic acid (group of B vitamins), which releases the vitamin in the organism. Promotes functions and regeneration of epithelial tissues, is particularly important for the local treatment of wounds. Used against burns and causticizations.

Pantograph (micrograph), drawing instrument used in pantograph engraving (→ Engraving) for the manufacture of calender rollers. The pattern is transferred from zinc plate onto a calender roller, which is painted with acid resistant paint, by a heated diamond pantograph, and the engraving is enhanced by etching.

Papain Enzyme (→ Proteinases) in the form of the dried milk of the so-called papaya fruit (American Carica papaya; melon or mamong tree). Similar → Trypsin. Acts on high molecular proteins in the presence of certain activators (hydrocyanic acid or thiophene compounds such as → Cysteine or reduced glutathione), whereby the latter function by reducing the enzyme disulphide to SH groups. Papain was proposed for antifelting finish of wool, either alone or in combination with the previous chlorine treatment (chlorzyme process) or hydrogen peroxide (enzyme + hydrogen peroxide treatment). This enzyme is used for the gentle degumming of silk when boiling soap baths are out of the question, e.g. when acetate is present in mixed fabrics.

Paper chromatography Capillary analysis for testing dye uniformity, based upon the different migration speeds of dye in solvents.

A drop of dye solution is applied to a strip of filter paper approx. 5–6 cm from the lower edge, allowed to dry and the lower end of the paper hung 1–2 cm in a suitable solvent. The “chromatogram” is evaluated by the heights of the different coloured zones. Paper chromatography is also successfully used as a separation process for the detection of different sugars, amino acids, etc. In the latter case, the initially invisible chromatogram is subsequently “developed” by spraying with ninhydrin solution and warming (red-violet colouring) or with diluted alkaline fluorescein solution. → Chromatography.

Paper nonwoven (paper fabric) → Nonwoven, manufactured on paper machines using a wet process, reinforced with long cut fibres (e.g. 7% polyamide or high wet strength rayon staple fibre), also without reinforcement, then preferably with loose polyamide long fibres and cellulose. As in paper manufacture, fibres are suspended and the nonwoven formed in a sieve-drum. The rinsing fluid contains an adhesive, which sticks the fibres to the paper nonwoven in the subsequent drying/pressing stage. Weight approx. 50 g/m^2, finishing as required. Application: In particular, disposable underwear, tissues, medical textiles.

Paper taffeta Paperlike taffeta with a thin paint-like layer of synthetic resin (preferably soluble in amyl acetate) applied to the back, which at the same time generates a rustling handle.

Paper textiles Fabrics made of → Paper yarns or products of → Paper nonwoven. Both can be very strong and finished.

Paper yarns,

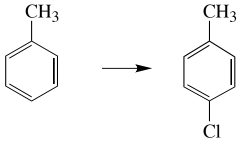
I. Made of cut narrow strips of spinning paper which (possibly after previous folding) are twisted together on a spinning machine in a moistened state (drilled). Sulphite paper or (tear resistant) sodium or sulphate paper or mixtures of these are used. Finenesses from 33–1000 tex, resistance to tearing from 4–7 cN/tex at 4.5–7% elongation at tear.

II. Wood pulp yarn is created by twisting together band shaped, wet strips of wood pulp, without previous processing into spinning paper. Finenesses from 33–2000 tex, resistance to tearing 7–9 cN/tex.

Application: For carpet underlays, carpet runners, wall coverings, bags, cord, hat braiding, etc.

PAR ISO abbreviation for → Polyaramides (aromatic polyamides).

Para- Prefix in compounds of aromatic cores as a term for isomer (1.4) position of substitution products, e.g. paratoluene derived from toluene (→: Meta-; Ortho-):



toluene *paratoluene*

Para-chloro-m-cresol Crystalline powder, white, cresol-like smell, slightly toxic. Virtually insoluble in water, easily soluble in alcohol, benzine, chloroform, soap solution. Application: Strong disinfectant and preservative for finishes, sizes, leather, woods, etc.

Paracortex → Wool structure.

Para-dichlorobenzene → Dichlorobenzenes.

Paraffin distillate Residue of petroleum and lignite distillation, from bituminous shale or synthetic products. Mixture of various aliphatic hydrocarbons. Solid at room temperature.

Paraffin lubrication → Wet paraffining.

Paraffin oil (vaseline oil), oily hydrocarbon mixture (mineral oil) made of liquid components of paraffin manufacture. Colourless, clear, density min. 0.88; does not rancidify or acidulate. Application: Fine lubricant for valuable machine parts; for lubricating wool (plus emulsifier) and in particular wool/viscose mixes.

Paraffins → Saturated hydrocarbons. Technically speaking, long chained, saturated → Hydrocarbons of waxy to solid consistency.

Paraffin test for dyeings on cellulose and protein fibres Used for → Dye class identification on fibres (on acetate, polyacrylonitrile, polyamide). Method: Soak some test threads with melted paraffin, place in glass tubes (2–4 mm long) which are hermetically closed at the bottom, heat carefully above a naked flame (without carbonizing), until paraffin melts and collects at the bottom. The colouring of this paraffin indicates the dye class: Vat leuco ester and vat dyes and naphthols.

Paraffin wax → Paraffin distillate.

Paraffin wax treatment → Wet paraffining.

Paraformaldehyde → Polyoxymethylenes.

Parallel ventilation in driers Takes place in parallel to material transport; e.g. as mixing component in jet ventilated stenters, because jet ventilation is arrested when it hits the material and reversed to form parallel ventilation.

Parallel winding Even or uneven, slightly helical thread winding, with threads lying side-by-side or one on top of each other. →: Yarn packages, preparation; Random winding.

Para-oxy-diphenylmethane Antifungal, antibacterial, sweat deodorizing and recommended for the permanent antifungal impregnation of hosiery; good material penetration, fibre preserving, relatively abrasion resistant, does not impair handle, darkens dye shades.

Parasite control in textiles →: Mothproofing; Antimicrobial finishes.

Parasites, textile → Textile parasites.

Paris blue, Prussian blue → Berlin blue.

Part by weight Mass relationship, weight of a part as a proportion of the entire weight.

Partially automatic Certain machine work stages are initiated manually but run automatically. Only part of the processes are automatic.

Partition chromatography → Chromatography.

Pascal (Pa), in the → SI system as derived unit for mechanical tension, strength and → Pressure. 1 Pa = 1 N/m^2 = 10^{-5} bar.

Passage application Squeezing process in water-impermeable finishing. Performed on an impregnating machine, jigger or squeezing padder, usually in 2–4 passes.

Passage counter So-called run time regulator, as reversing device (on jigger) for the control of forward and reverse, in connection with mechanical shutting down of the machine (after a predetermined number of passages). This device allows the drive motor for the jigger to be directly controlled or shut down.

Pass-Fail quality control Colorimetric Pass-Fail colour classification can be linked with the calculation of dye addition. This programme for colour quality control based upon objective colour tolerances determines whether a colour to be tested lies within or outside the tolerances set internally or agreed with the customer (Fig. 1). It determines whether a readjustment is too light or too dark, too clear or too cloudy, too red, too green, too yellow or too blue and immediately calculates the required addition, making the best possible use of the permissible colour tolerances (Fig. 2). Pass = can pass the colour check; Fail = fails the colour check.

Colorimetric matching is based upon the colour measurement of references and quality samples and the calculation of their colour differences (→ Colorimetry).

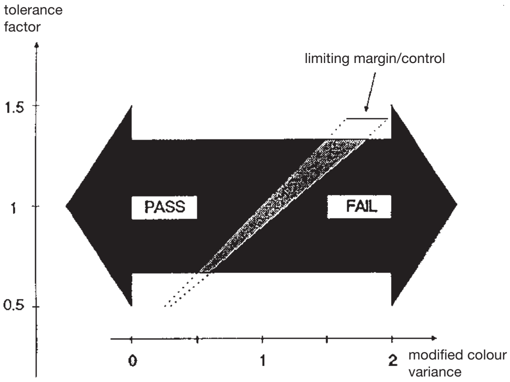


Fig. 1: Determining the size of tolerance margin using tolerance factors relating to the colour.

Pass-Fail quality control

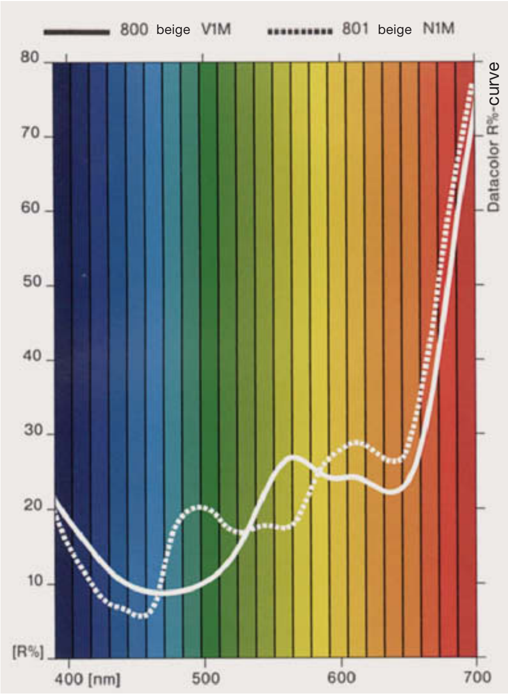


Fig. 2: Remission curves for two metamer dyeings whose standard colour values match for standard light type D_{65}.

Colorimetric detection and objectivication of the colour deviations between the two samples however is not in itself enough to permit colorimetric colour matching: For one thing the colour tolerances that must be satisfied are unknown. Determining these tolerances is hindered by the fact the CIELAB system, which forms the basis for the colour difference calculation, is not ideally sensitive according to the invention and tolerance limits. In CIELAB units take on different values depending upon the colour in question. The magnitude of the colour tolerance is therefore dependent upon the colour, i.e. the location of the colour in the CIELAB colour space. Secondly, the technical possibilities of the company must also be taken into account when determining colour tolerances.

Therefore, in the past empirical methods had to be used by the dyeing company to determine colour tolerances, e.g. for internal company use. As many repeat batches as possible were visually colour matched so that they could be accepted or rejected and the colour differences between reference and batch samples were determined by colorimetry. If we plot the colour differences of the known accepted and rejected sample on axes with the co-ordinates ΔC^*_{ab}, ΔH^*_{ab} and ΔL^* then the tolerance range is determined graphically based upon the boundary between accepted patterns. This process is illustrated based upon two examples (Figs. 3–4). The colours are defined according to DIN 6164.

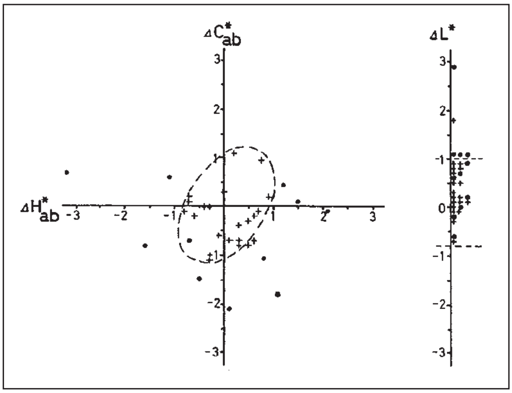


Fig. 3: Colour tolerances for the colour red 9 : 1 : 1.

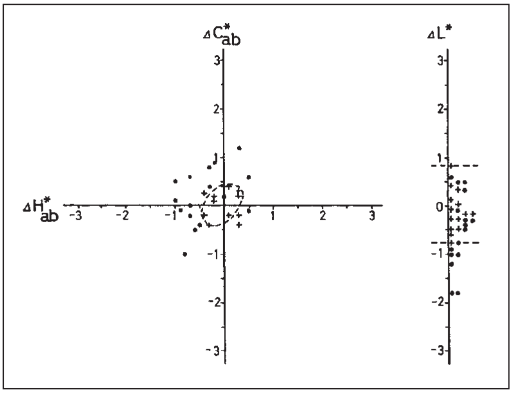


Fig. 4: Colour tolerances for the colour grey 1 : 1 : 7.

This process is expensive. However, there are programmes which can determine the tolerance limits automatically on the basis of the accepted sample. Secondly, a minimum number of samples from repeat batches are required for a certain colour, in order to achieve meaningful limits. This condition is however not fulfilled in many companies (e.g. in commission finishers). Therefore, colorimetric colour matching with the aid of pass-fail formulae represents a great step forward. These are colour difference formulae, which automatically account for the dependency of the tolerances on the colour by using factors for ΔL^*, ΔC^*_{ab} and ΔH^*_{ab}. They contain a mathematical transformation, which manages equidistance and weighting of the brightness, saturation and shade differences, so that a decision can be made whether to pass or fail a colour sample with just one number describing the colour tolerance (Fig. 5). This dispenses with the necessity of having a great many batch repeats available. Pass-Fail formulae are part of

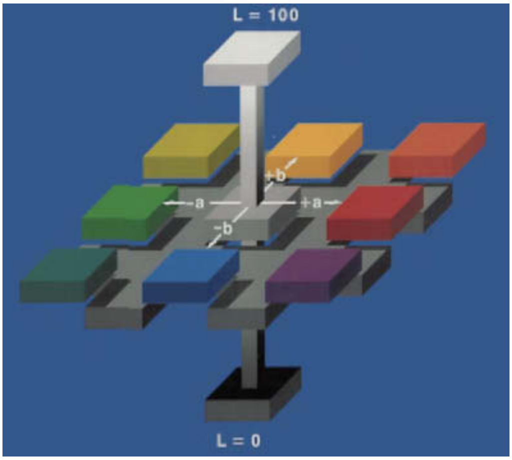


Fig. 5: Pass-Fail values for the colour specification and brightness of a sample to be matched.

the computer programme of some colorimetric systems (result e.g. as screen representation).

One problem is that depending upon the formula (DC; IPC; CMC; M & S) the same samples can lead to different Pass-Fail statements. This is understandable when we consider that the mathematics underlying the formulae is based upon colour matching with the following degrees of freedom:

- different distribution and different scope of the pattern in the colour space, as a result of the use of random and market determined batch samples;
- different make-up form (yarn or piece material) of the sample;
- different requirements of the personnel undertaking the evaluation;
- differences in the mathematics used for the description of the relationships.

Passive Transponder Can be used as a unit recognition system in fields of textile finishing, where pressing does not take place. Passive transponders can take the place of the barcode system, which is greatly limited due to the size of the bar code, the read distance, the read angle and the fact that it cannot be used in unfavourable environmental conditions and in many applications. The size of the passive transponder only needs to be a fraction of that of a single bar code stripe and can be read by a hand-held reader from distances of more than 20 cm (in some transponders more than 90 cm), regardless of read angle, light or environmental conditions. The system is based upon a hand-held reader or a stationary reader, which emits a low frequency magnetic field and activates the passive transponders within its range. The passive transponder does not have its own power source, because it draws the necessary power from the magnetic field of the reader. The transponder may be a unit encapsulated in plastic, which is available in different shapes and sizes. Each individual transponder is given a unique code during production. The code cannot thereafter be altered. The number of possible code combinations is approx. 500 billion and gives the user of the passive transponder system the possibility of identification.

Passive transponders function in liquids and can be read spherically (through most materials, with the exception of some metals) from every direction. The activated transponder sends its unique code to the reader. The code is then forwarded to a decoding logic where the code is analysed, simultaneously displayed on the LCD and stored in the memory of the reader for immediate or subsequent data processing. Hand-held readers, also called scanners, are a replacement for conventional keyboard data entry and other data collection methods. The main advantages of the use of a combination of hand-held readers and coded passive transponders are the reduction in the number of data capture errors, the reduction in work and administration costs involved in the processing of data, faster and more precise inventorisation and improved tracking and control of woven fabrics or knitted fabrics in finishing (according to Trovau).

Passive yarn → Immunization.

Paste resist printing Synonym of paste resists (→ Resist printing): Purely mechanical pre-printed resist made of many high solids thickeners, thickener containing a weighting agent (e.g. kaolin, zinc oxide, lead carbonate, etc.), preferably using indigo and vat dyeing.

Paste resists → Resist printing.

Paste transmission index Measure of print paste throughput in screen gauzes. The paste transmission index is determined by the stitch opening and the fabric thickness.

Paste up Term for the stirring of dyes, textile assistants, etc., usually with water, which precedes dissolving.

Pasting (chemical), transitions of fats into the state isotropic soap solution (→ soap paste), by → Saponification.

Patent application disclosure Patent disclosure of the patent application. Contains significant bibliographic data (name/address of the applicant, application date, priority, name of the innovation, etc.) in addition to the original application documents (description, claims, signatures). When access to the documents is granted (18 months after application or priority date), so that they can be viewed by anyone free of charge (in the patent office), even third parties have the option of conducting research or making an application for an examination. → Patent law.

Patent disclosure → Patent application disclosure.

Patent law The patent system is a subsector of the system for the protection of inventions. Every textile finisher (whether employee or company) should know his rights regarding the protection of his ideas. Possible commercial protective rights are:

- Patent law,
- Protection of inventions act,
- Trademark law,
- Design Patent law,
- Copyright,
- Utility model,
- Employee invention law,
- Peripheral subjects of the unfair competition act, cartel act, general contractual law, etc.

Prerequisites for applying employee invention law in Germany are:

1. There is a claim for a patentable invention;
2. which has been proven by the employee in the form of his invention.
3. It is significant whether the invention was solely part of the employee's duties or whether commercial experience was merely put into practice.

It is an employee invention if these three points apply. If none of the points apply, then it is a free invention. In the case of an employee invention the employer must first be immediately notified, who must make a written notification of his utilization of the invention within 4 months. He can make an unlimited claim for exclusive exploitation rights. Of course, the employer then has an obligation to make an appropriate remuneration to the inventor and employee. However, if the employer does not utilize the employee invention, his preferential claim lapses and the invention is free.

The rights of the inventor are regulated by the following acts depending upon the type of protective right:

– Patent:	ArbEG (Gesetz über Arbeitnehmererfindung – law relating to inventions of employees)
– Design:	ArbEG
– Protection of new plant varieties:	Compensation arrangement based upon ArbEG
– Copyright:	the artist
– Trademark:	–
– Design patent:	the employer or special contractual arrangement

For the granting of a patent the following must be made clear a) the objective of the inventor and b) his solution. The objects of this protective law for a patent are technical inventions, i.e. a guide to technical action, which consist of a task and solution. This covers patents for devices, procedures or applications.

The objects of other protective laws are:

Registered pattern: Implements of trade, artefacts, and parts thereof, that have a concrete physical form, e.g. sewing machines, rollers etc.

Trademark: Descriptions (word, picture, pictorial trademarks) of goods or services, e.g. Trevira®, crocodile pictorial trademark etc.

Design patent: Pattern and models with a certain aesthetic form or colour, whereby the shape or colour may not be exclusively technically determined.

Copyright: Artistic works, scientific works, musical works, etc.

The filing and patent application act is fullfilled by a patent attone.

The following protective conditions apply to the different protective laws:

Patent: Level of invention, commercially applicable: Registration at e.g. European Patent Office, test procedure.

Protection of inventions act: Innovation, invention progress, commercially applicable: Application at e.g. European Patent Office, official examination procedure.

Trademark: Differentiability, need to keep free, cannot be mistaken for other trademarks: Filing and application act at e.g. European Patent Office, testing procedure.

Design patent law: Innovation, ownership: Registration with e.g. European Patent Office.

Copyright: Artistic creation: No registration.

Protection of new plant varieties: Differentiability, homogeneity, stability, innovation, registrable type description: Registration at BSA (Bundessortenamt – Federal Office for protection of new plant varieties), testing procedure.

Protective scope and duration of protection differ depending upon the type of protective law.

Patent: Exclusive right to use the patented invention (use: manufacture, sale, trading, consumption, adoption, possession); 20 years from date of application in Germany.

Registered pattern: Exclusive right to use the object of the design 10 years.

Trademark: Exclusive right to identify goods and packaging: 10 years with the option of a 10 year extension each time.

Design patent: Imitation of the protected sample/model; 5 + 5 + 5 + 5 years (max. 20 years).

Copyright: Exclusive right to use the artistic work; 70 years after the death of the creator.

Patent letter → Description of the patent invention together with figures and drawings.

Paternoster batcher Batching device for the rapid changing of the yarn package. Consisting of axle drive to the winding spindle, by means of belts, and 2 changeover points at the sides for holding the yarn package while it is created.

Paternoster store For warp beams, roller printing rollers, dye packaging on moving chains; space saving (see Fig.).

Pathogenic bacteria Illness generating → Bacteria.

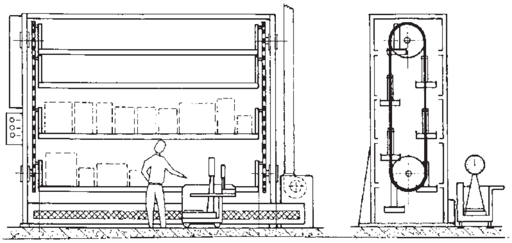


Fig.: Paternoster store for dye containers, with weighing facility.

Pattern brushing Patterns are brushed onto the surface of pile goods using a brush unit inside a round screen (Figs. 1 and 2) to brush the pile down.

Fig. 1: Circular brushes (not set) inside a circular screen for the pattern brushing of pile fabrics (Comet).

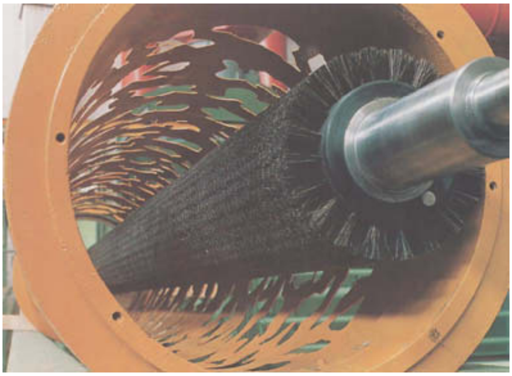


Fig. 2: A cylinder brush drum ready to brush a pile fabric article (Comet).

Pattern cards Patterned collections of coloured fabrics and dyeings relating to dyes or shades on offer in the form of standard depth dyeing, colour regulations, fastness data, etc.

Pattern cutting systems (making-up). Computer aided construction systems are used to graduate (Fig. 2) basic designs (Fig. 1) created using Computer Aided Design (CAD) and generate cutting patterns (Fig. 3)

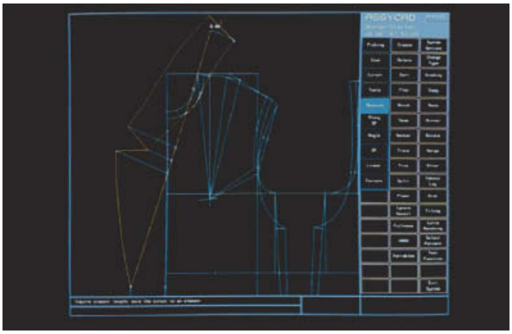


Fig. 1: Basic patterns using a pattern cutting system (assyst).

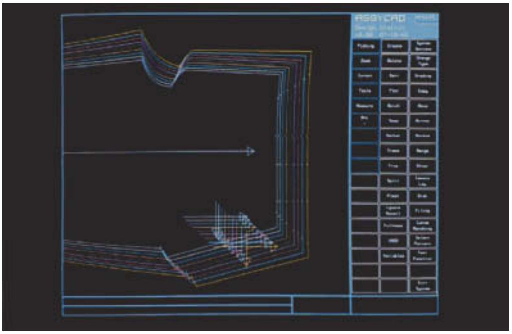


Fig. 2: Grading with the aid of a pattern cutting system (assyst).

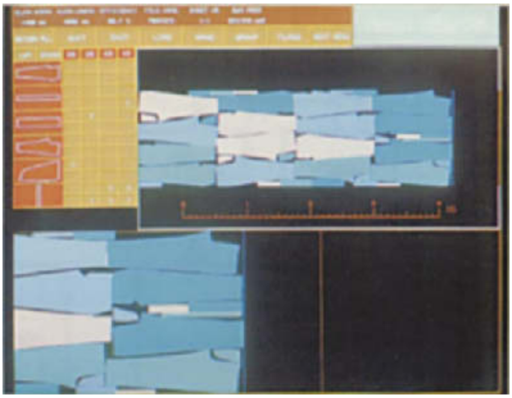


Fig. 3: Reference marker as pattern master (assyst).

which minimize material consumption. Using such a system, in order to minimize waste, it can be used to construct up to the material selvedges and thus keep tolerances for material widths below 1.5 m, equal to zero. If other EDP systems are available in a company (e.g. systems for production planning and control), the data from the pattern cutting system (dimensions, material consumption) can be transferred directly to these systems, and the systems thus linked together.

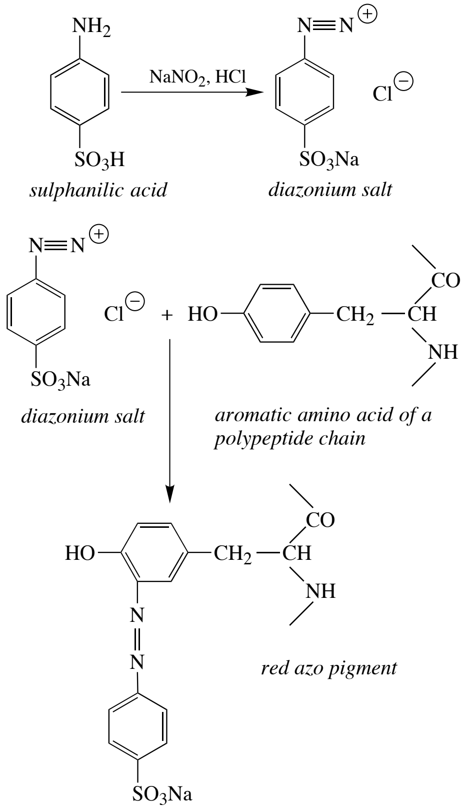
Pattern die Small roller with embossed “spur shaped” patterning. In practice the term pattern die is often mistakenly used instead of relief. In mill engraving (particularly for the creation of roller printing rollers), which is suitable for very small repeat and geometric designs, the design repeat is engraved in a small mild steel roller (→ Engraving). This takes place manually using graving tools or a stamping machine, or mechanically by an engraving machine. Photoengraving processes are also possible. The so-called parent pattern die or pattern die for short is created. Its patterning element is indented. The following usage applies: All manufacturing stages (in pattern die engraving) that generate indented patterning elements, fall under the term → Mill engraving. After hardening, the pattern die is rolled under high mechanical pressure on a wide mild steel roller, the relief pattern die, or relief for short. An impression of the pattern die is created in the relief. Its pattern elements are raised. All processes (in pattern die engraving) of this type, i.e. which generate raised patterning elements are called relief engraving.

Pattern flocking → Flock printing.

Patterning fault Faults in carpets (and textiles) made of multi-coloured (particularly space dye) yarns. Repeating pattern on the surface due to undesired regularities in the arrangement and size of the colour dots on yarn and loop sequence in carpets.

Patterning yarn trimming machine Long, floating weft threads (e.g. jacquard curtains) are mechanically cut and then sheared.

Pauly reagent (Pauly-Diazo reaction), has proved useful for detecting damaged wool. The reagent dyes damaged wool yellow, or orange to reddish brown depending upon the degree of damage; it being irrelevant whether the damage is chemical, biological or mechanical. The Pauly reagent is made of sulphanilic acid, which is diazotized. The diazobenzene sulfonic acid that forms is collected on a filter and dissolved by pouring 10% ice cold sodium carbonate solution over it. The fibre material, which has been thoroughly degreased by extraction with petroleum ether, is placed in the freshly dissolved, ice cold diazobenzene acid for 10–15 min. Then it is thoroughly rinsed with ice cold distilled water, the sample dried in air and the colouring evaluated. The Pauly reaction is based upon the fact that the amino acid building blocks with aromatic groups contained in the wool, form a red azo dye with the diazotised sulphanilic acid. The amino acid building blocks (with aromatic groups) are only found in the spindle-cell layer below the scale, i.e. colouring only occurs when the scale layer (cuticula) is attacked or destroyed. One such amino acid building block is tyrosine, for example, which has been detected both in wool and in silk. The dyeing reaction takes place according to the following diagram:



PB,

I. → Elastodiene fibres, → Standard abbrev. for textile fibres, according to DIN 60 001 until 1988, from 1991 → ED.

II. → Polyureas, symbol according to the → EDP key system.

Pb Element symbol for lead (82).

PBI fibres → Polybenzimidazole fibres.

PBTP → Polybuteneterephthalate.

PC,

I. → Polyacrylonitrile fibres, → Textile fibre symbols, according to the → EDP key system; → PAN.

II. Plastic abbrev. for → Polycarbonates.

III. Abbrev. for → Paper chromatography

PCB → Polychlorinated biphenyls.

PC Control In order to classify microelectronics projects according to their size, we differentiate between four device classes:

- Hardware replacement: The computer is "invisible".
- Small devices: They only contain one microcomputer.
- Large devices: They contain more than one microcomputer (this class includes PC).
- Systems: They contain several, different micro and minicomputers.

We talk of "hardware replacement" if the microelectronics system fulfils logical functions, which in principle could also be realised by conventional means (e.g. mechanical components, integrated circuits). The reason for the use of microelectronics is a reduction of space and power consumption. The microprocessor is not visible from outside. The user is usually not aware of its existence.

A system belongs to the class of "small devices" if a microprocessor is used because the desired function can only be realised by conventional means at excessive cost. A single processor usually suffices. However, it is more clearly visible than is the case of pure hardware replacement, i.e. the interested user is aware of its existence. Some small devices are fitted with several processors. Teleprinters for example have three processors: One is devoted to the keyboard and display, the second operates the printing equipment and the third takes care of communication with the remote station.

Small devices are limited, in that they have no loadable software, only permanently stored ROM software. External data carrying media (e.g. disk drives) are not involved.

The class of "large devices" includes all devices with loadable programmes or parameter lists. They often have several processors, of which one is usually evident to the user. There are often computers of different types. Examples: Word processing systems, checking machines, numerical controls for machine tools (NC control). The ability to load programmes is an important classification criterion for the following reason: The customer receives a device, the characteristics of which can change over the course of its useful life. This change can be made without modifications to the hardware. It is made by new software supplied at a later date or even by parameters that are changed by the customer himself. Parameter lists are often also called "programmes". The term "large" device should not be taken literally. Despite their small size, personal computers belong to exactly the same class of device as machine tools with numerical control.

If the product is assembled for each customer individually from elements (configured), then we talk of a system. The elements can be both hardware and software elements (programme components). Again, the individuality of each delivery is more decisive for classification than the physical size.

Simple temperature/time controllers for dyeing plants in companies and laboratories are based upon PCs with relatively low storage capacity (Fig. 1). Part machines for temperature/time regulation and control of partial processes such as filling finishes, rinsing, emptying, accessing storage containers require large PC storage capacities (Fig. 2). Interactive dialogue programming with a memory card to external programme storage and by interfaces for the connection of a central computer or controls again increases the required PC capacity.

Differentiated programming options and integrated dosing control (Fig. 3) are connected with comfortable PC storage.

→ Stored program control (SPC), which can control

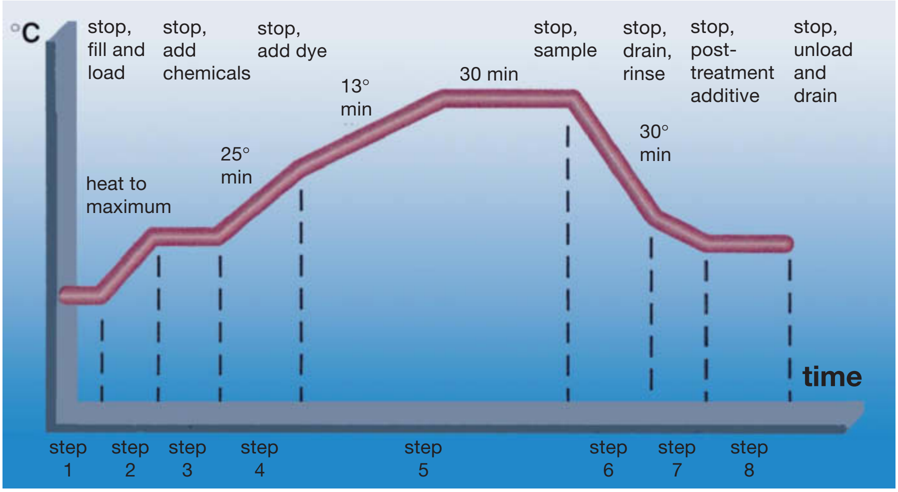


Fig. 1: Example of a program for a PC controlled dye process.

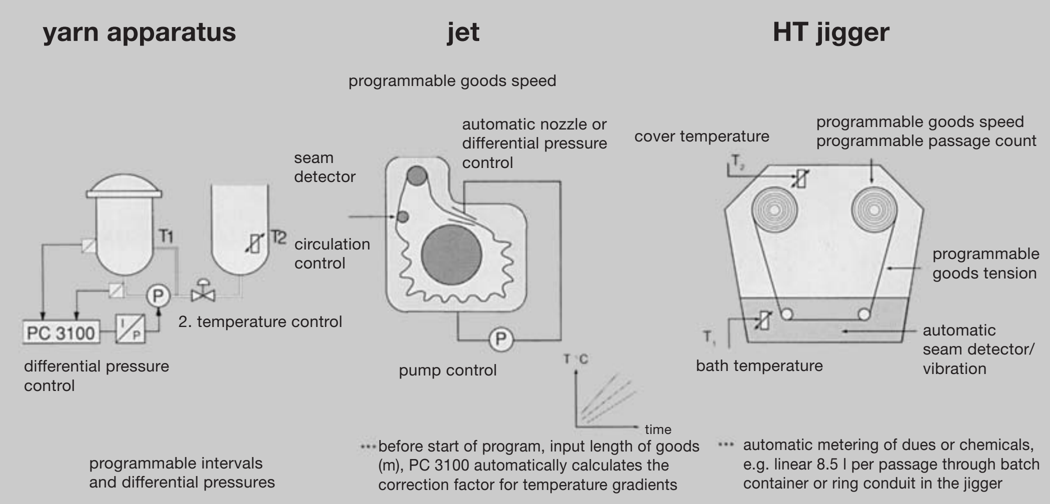


Fig. 2: Example of typical application for the PC based control of peripheral apparatus with suitably larger microprocessors (Barco-Sedo).

a large number of processes in dyeing equipment and in its periphery or provide a superior central control or fully automatic process control for "continuous plants", should be suitably large with regard to PC capacity used (partially according to Becker).

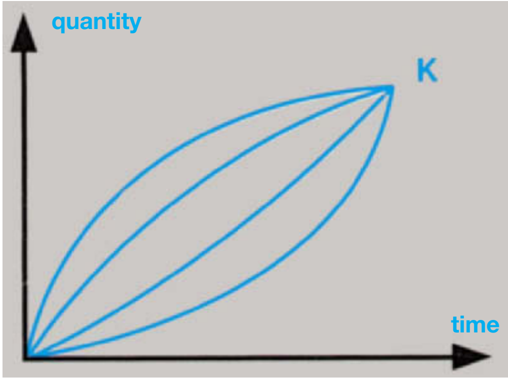


Fig. 3: Prescribed dosage curves for PC control systems.

PCL Abbrev. for protein contaminant layer, a layer surrounding the wool hair, which is dissolved during raw wool scouring.

pCl Concentration of Cl ions, similar to pH. Can be determined by → Potentiometric measurements using silver/silver chloride electrodes.

P Controller, Proportional action controller Continuous controller with proportional action. → Control equipment.

PCP → Pentachlorophenol.

Pd Element symbol for palladium (46).

PE → Polyethylene fibres, → Textile fibre symbols, according to DIN 60 001 T4/08.91.

Peachskin → Apricot skin.

Pearl printing Performed on the hank (→ Yarn printing) using a suitable yarn printing machine, in the form of point single colour illuminating dye.

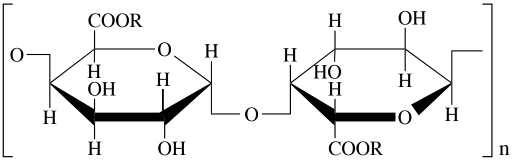
Pearl yarn (knitted yarn), pearl ply yarn made up of two different (heavily) twisted single threads (usually with opposing twist).

Peat fibres Peat contains residues of grass, swamp plants, mosses etc. that have decomposed in the absence of air. The dark brown or black strands it contains (approx. 15 cm long) consist of cellulose fibres, which provide a spinnable material. These fibres, which belong to the group of → Hard fibres, can be extracted mechanically or by boiling in lye with subsequent oily emulsion treatment (approx. 2%). The fibres are on average 30–40 mm long, the individual cells 1–3 mm long. Strength and elongation are low, absorbency on the other hand is high. They also have a certain antiseptic property. The fibres are similar to → Merino fibre.

Peat yarns Yarn made of → Peat fibres, either on their own or mixed with cotton or wool, etc., from which, covers, carpet runners, mats and carpets are manufactured.

Pectinases Specific → Enzymes (belonging to the hydrolases and carbohydrases), which gradually break down high molecular pectins (and hemicellulose) to single galacturonic acid. Pectinases play a decisive role in the biological retting of stalk bast fibres.

Pectins High molecular, carbohydrate-like vegetable substance, composed mainly of methylated polygalacturonic acid in a glucosidic bond:



R = $-CH_3$
$-H$

Pectin molecules are not stretched as tightly as cellulose molecules. It is thought that pectins represent a preliminary stage of vegetable lignin. Naturally occurring, dissolved in cell sap; as insoluble calcium pectates most commonly in the middle lamella of the cell wall of bast fibres; also insoluble, probably linked with cellulose, as proto-pectines in the primary cell membrane. Normal, soluble pectin is technically extracted from the latter by a type of hydrolysis (dry pectin by atomizing the solution or by reprecipitation with alcohol).

Pectins represent the majority of impurities in pure cotton. They absorb energetic dye and are split by kier boiling to form sodium and calcium pectate.

Peel adhesion Testing process for determining the adhesion of a matrix to the reinforcement material. The peel test is typically used for laminated or backed material, with the composite being pulled apart with a force x (with the two constituents of the compound at a defined angle). Alternatives are the shear test or a test in which the matrix is poured over a thread, and then a force x applied to try to separate the two (see Fig.).

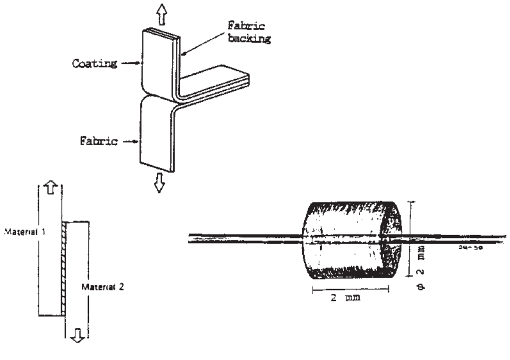


Fig.: Peel adhesion (centre) compared to other methods of testing (shear test left; micro-bonding test right), all with the same goal of determining the adhesion between matrix and hardener.

PEG → Polyethylene glycol.

Peg Small flakes falling through the grid during the → Opening of carbonized wool (waste).

Pelts Term for the hairy outer skin of smaller animals in particular, e.g. rabbits, goats, etc. →: Skins; Tanning.

Penetration,

I. Penetration of a fibrous mass with the applied liquor, which if possible must wet all surfaces if uniformity of product application is to be guaranteed before fixation. Good penetration can be worsened by subsequent migration as an overriding effect. If there is undesired print penetration through fabric or knitgoods, it can be rectified by the use of a suitable printing thickener. In padder pigment dyeing the penetration, as a time-dependent process, can be improved by air flow.

II. Characteristic feature of printed fabric (roughly comparable to full penetration dyeing), which is particularly dependent upon the type of fabric and thickener. A thick, dense fabric or a suitable filter paper is used to evaluate the penetration capacity of a thickener. Penetration percentages are best obtained by a comparatory whiteness measurement. Penetration is = 0% if the printing on a thick fabric remains invisible on the reverse side, i.e. the material still shows its original high, intrinsic degree of whiteness (for thinner fabrics 0% is never achievable, print with very high thickener concentrations is always visible on the reverse). Therefore: Penetration = 100%, the colouring is the same on the reverse and right sides. If the degree of whiteness of a the undyed fabric (W1), the printing (W2), and the penetration (W3) are measured, then the percentage penetration is calculated as follows:

$$\text{penetration} = \frac{W_1 - W_3}{W_1 - W_2} \cdot 100$$

Penta- (Gk.), determinative element for compounds, which means “five”, e.g. phosphorus pentachloride (containing five chloride atoms).

Pentachlorophenol (PCP), C_6Cl_5OH. Whitish to brownish needles, almost odourless (irritant to the mucus membrane), anhydrous, slightly acidic; almost insoluble in water. Soluble in lyes (salt formation) and organic solvents. Irritating to the skin (above 1% solution). Highly toxic to bacteria, fungi, yeasts, etc. Possesses high affinity to cellulose. Application: Preserves glue, casein, leather, wood, solvent impregnated textiles etc.; however, as a carcinogenic substance is not suitable for textile finishing. Usage and import ban.

Pentacholorophenol test Colorimetric procedure similar to → Hexachlorophene test.

Pentane C_5H_{12}, → Saturated hydrocarbons.

Pentanol (amyl alcohol), $C_5H_{11}OH$, → Alcohols.

Pentaoxane $(CH_2O)_5$; it is a → Polyoxymethylene. Applications include use as crosslinker in resin finishing.

Penta screens Second generation of → Rotary screens for screen printing with mesh values of 125–215. Finer designs can be achieved by using screens with higher mesh values (→ Mesh number). This is made possible by better mastery of the hole/web ratio by altering the cross-section of the engraving from the sawtooth type to drop-shape. Penta screens require a new special paint. Improved uniformity and higher printing speed and low doctor blade pressure at the same printing paste viscosity are further advantages.

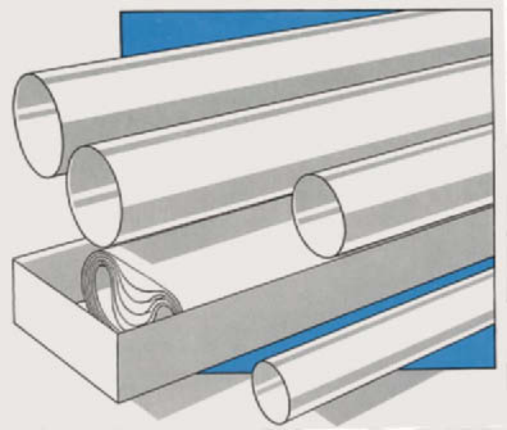


Fig. 1: Typical make-up of rotary serigraphy penta screens as delivered to the printer.

Standard screens have conical openings and a relatively high level of surface roughness. Penta screens have double cone openings and a much smoother surface, both on the inside and the outside (Figs. 1–2). This hole shape represents a significant improvement: The printing paste flows through the holes much more easily and the probability of blocking is reduced. Furthermore, the most important advantage is that penta screens have a much greater relative permeability, whereas a max. number of hole per cm^2 is achieved. For comparison: The most commonly used standard screen of 80 mesh has a permeability of 11% (Fig. 3); the finer penta screen of 125 mesh is 15% open (Fig. 4). There is also a difference in the number of holes: An 80 mesh standard screen has 1128 holes/cm^2, a 125 mesh penta screen has 2275 holes/cm^2. Fig. 5 shows possible differences in the patterning.

Fields of application of standard screens:

40 and 60 mesh: Suitable for blotch printing on heavy material qualities, excellently suited for penetration printing.

Fig. 2: Typical penta screen with end ring.

Fig. 3: Standard rotary screen by Stork.

80 mesh: For not too fine contours (up to 0.3 mm), blotch printing on normal material qualities, can also be used after penetration printing, 80 H specifically for half tone effects.

100 mesh: Surface printing, contours and details up to 0.25 mm.

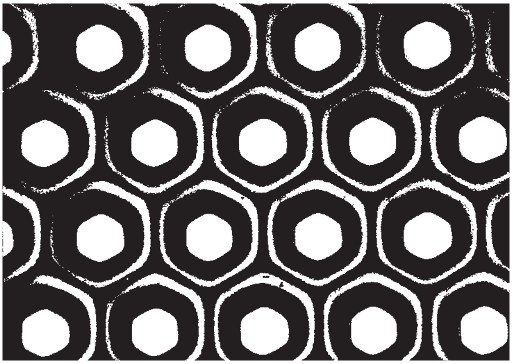
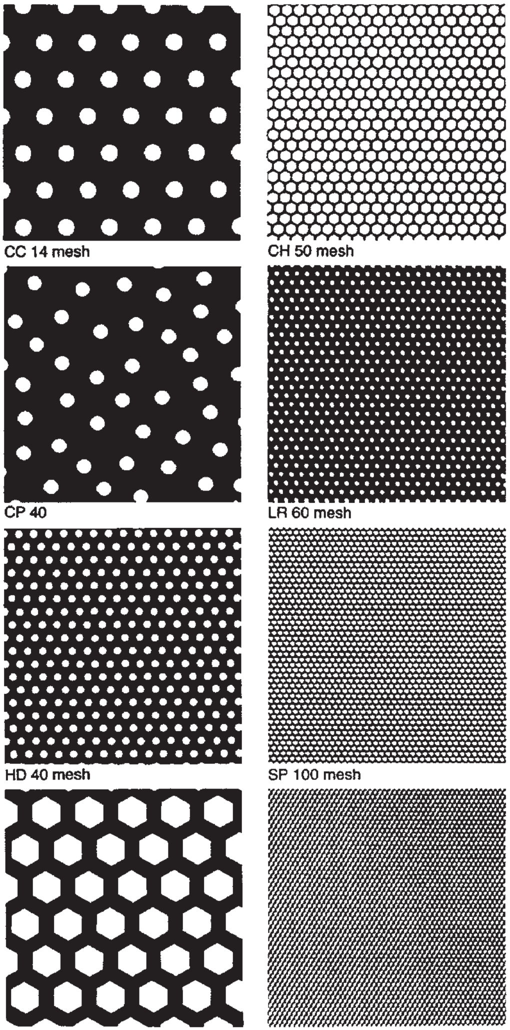


Fig. 4: Penta screen by Stork.



CC 14 mesh
CH 50 mesh
CP 40
LR 60 mesh
HD 40 mesh
SP 100 mesh
HX 14 mesh
LR 125 mesh

Fig. 5: Different rasters on Stork rotary screens.

Fields of application for penta screens.

Penta 125 mesh: Universally applicable, blotch printing is even more consistent, surface and penetration printing, contours and fine details up to 0.2 mm.

Penta 155 mesh: Suitable for blotch printing on light material qualities, contours up to 0.16 mm, half tone printing, discharge and resist printing, excellently suited for designs with horizontal and vertical lines, 155 DLH: Specifically for transfer printing and half tone printing with magenta pattern SCR 6480.

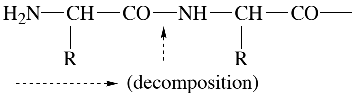
Penta 185 mesh: For extremely fine half-tone printing, contours up to 0.13 mm, designs with horizontal and vertical lines.

Penta 215 mesh: Half-tone printing with magenta pattern SCR 6480, contours up to 0.11 mm.

Pepper and salt Colour patterning effect, also known as thread by thread, in which a light thread alternates with a dark thread in warp and weft, giving rise to a diagonal stripe. Grey shades are typical, but beige-brown and other colour combinations are also possible. Weave primarily even-sided, 4-thread twill or panama 2/2. In German designs the so-called “staircase” in the finished material, runs from the top left to the bottom right (the twill ridge runs the other way); in English materials it is exactly the opposite. Finish generally bald. Application for ladies’ and gentlemen’s outerwear.

Peptidases Group of protein decomposing → Enzymes (belonging to the hydrolases and proteases), which however, only hydrolytically decompose (poly)peptides. In the polypeptidases one differentiates between:

I. Amino polypeptidase:

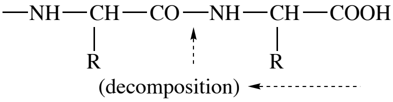


$$H_2N-\underset{\substack{|\\ R}}{CH}-CO\underset{\uparrow}{-}NH-\underset{\substack{|\\ R}}{CH}-CO-$$

$$\dashrightarrow \text{(decomposition)}$$

Decomposition in this case occurs from the side of the free amino groups.

II. Carboxy-polypeptidases, on the other hand, act from the free carboxyl groups.



$$-NH-\underset{\substack{|\\ R}}{CH}-CO\underset{\uparrow}{-}NH-\underset{\substack{|\\ R}}{CH}-COOH$$

$$\text{(decomposition)} \dashleftarrow$$

Peptide Condensation product made from → Amino acids, in which the amino group of one molecule links with the carboxyl group of another, discharging water:

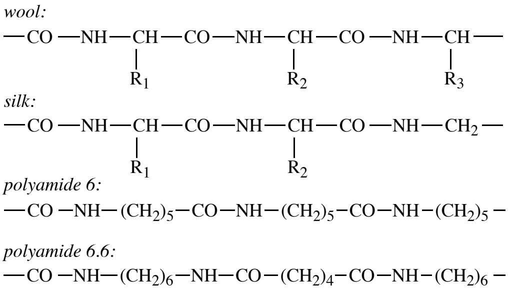
$$H_2N–CH_2–CO\boxed{OH + H}NH–CH_2–COOH$$

$$\downarrow$$

$$H_2N–CH_2–CO–NH–CH_2–COOH + H_2O$$

dipeptide

In the same way, any number of different amino acids can react with each other (polypeptides), whereby the acid amide group (COHN) represents the characteristic binding link (peptide bond). Wool and silk are chemical polypeptides made up of 12–20 different amino acids. The peptide bond determines the chemical properties and dyeing behaviour of the protein fibres (wool, silk) and also polyamide fibres:



wool:

$$—CO—NH—\underset{R_1}{CH}—CO—NH—\underset{R_2}{CH}—CO—NH—\underset{R_3}{CH}—$$

silk:

$$—CO—NH—\underset{R_1}{CH}—CO—NH—\underset{R_2}{CH}—CO—NH—CH_2—$$

polyamide 6:

$$—CO—NH—(CH_2)_5—CO—NH—(CH_2)_5—CO—NH—(CH_2)_5—$$

polyamide 6.6:

$$—CO—NH—(CH_2)_6—NH—CO—(CH_2)_4—CO—NH—(CH_2)_6—$$

Peptide bond → Peptide.

Peptization (eptize), formation of a stable dispersion of loose stock or aggregates, i.e. taking colloid particles (e.g. dirt) into a solution (as pepsin does with protein in the stomach), using small quantities of either acid or alkali (soap). Hereby H ions (acid) or OH ions (alkali) are strongly absorbed by colloid particles and the latter given a positive (acid) or negative (alkali) charge. Because particles with the same charge repel each other, → Colloidal solution (dirt-washing liquor) forms.

Peptones Protein-like, water soluble protein decomposition product, which is similar to high molecular synthetic → Polypeptide with regard to structure and molecular size. They form a transition stage between the latter and → Protein. No precipitation occurs as a result of ammonium sulphate (→ Albumoses). Peptones lack some typical protein reactions, such as coagulation when boiled or due to the action of diluted acids.

Per,

I. Abbrev. for → Tetrachloroethylene (perchloroethylene).

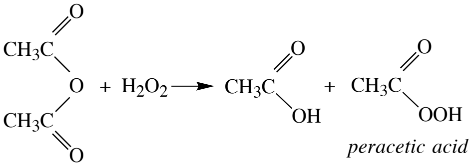
II. Prefix “over”, e.g. Permanganate, salt of permanganic acid $HMnO_4$.

Per acids Acids created by to the action of hydrogen peroxide (H_2O_2) on normal acids, which contain the –O–O–H group instead of –OH, e.g. caro’s acid H_2SO_5; Peroxy disulphuric acid $H_2S_2O_8$; peracetic acid CH_3COOOH; performic acid. Oxygen releasing principle:

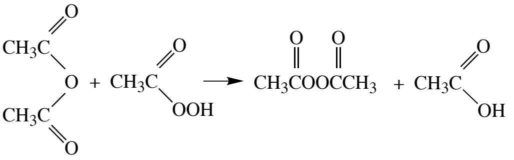
$$H_2SO_5 \rightarrow H_2SO_4 + {}^1/{}_2\, O_2$$

Peracetic acid Molecular weight 76. A 40% organic acid with 8.6% oxygen. Is classed as explosive; colourless; slightly ionized at pH 8.2. Commonly used as polyester and polyamide bleach, for the stripping of triacetate dyes and also as an oxidative bleaching and stripping agent for proteins and other alkali sensitive textiles, particularly for bright fabrics, for polyamide/cotton mixes (optimal 65–80°C; not damaging to fibres) and acetate materials (pH 6–8). Iron and copper vessels are unsuitable. No excessively unpleasant odours or noxious gases form in evaporated peracetic acid. Good ventilation is nevertheless recommended.

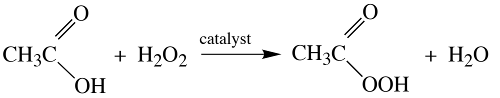
Peracetic acids can be manufactured from acetic anhydride or acetic acid with hydrogen peroxide. In the first method the acetic anhydride reacts with hydrogen peroxide to form one mole of peracetic acid and one mole of acetic acid.



It should be noted that a very dangerous sec. reaction may occur in the manufacture from acetic anhydride.



If excessive acetic anhydride is present, then it may react with the peracetic acid that has already been formed to create biacetyl peroxide and acetic acid. Biacetyl peroxide is a slightly soluble substance with a fixed point of 26.5°C. It is explosive upon impact or heating. By creating a chemical balance in a mixture of hydrogen peroxide, acetic acid and water, with the additional effect of catalysts and stabilizers, equilibrium peracetic acid is manufactured.



The sequence of processes for achieving the finishing objective is determined by a series of influencing factors:

- duration of bleaching,
- temperature,
- pH,
- oxygen concentration.

To fulfil this objective, the following recipe is used for a discontinuous peracetic acid bleaching:

quantity required: 1–3 ml/l peracetic acid (100%),
pH: 7–7.5,
temperature: 60°C,
duration: 30 min.

During the bleaching process acetic acid is released continuously. This must be captured by a suitable buffer, or balanced out by a pH control device with liquor dosing. The sequence in which bath components are added is also important. This sequence is water, peroxide, acetic anhydride, caustic-soda solution (for pH adjustment), and a buffer. When all chemicals are dosed via single, continuous, teflon coated dosing pumps the smell, which would otherwise increase in proportion to quantity, is completely inhibited. However stock pastes, like those used for other bleaching techniques, cannot be used due to their instability. Continuous processes including padding, dwelling on a dwelling belt, using a water lock before and after the dwelling to prevent odours, are possible. It is evident from the process conditions (pH and temperature) that the absorbency of the material and seed shell removal must be inferior to those of peroxide bleaching. However, this in no way rules out bleaching with peracetic acid, but rather predestines it for use as the 1st stage of a 2-stage combination bleaching process with subsequent peroxide treatment.

To greatly simplify, the bleaching effect of peracetic acid rests upon the breakdown of peracetic acid into atomic oxygen and acetic acid. The maximum bleaching effect is achieved at pH 8.2. This can be easily reproduced in laboratory experiments in catalyst-free systems. pH 8.2 corresponds with the pK_S value of peracetic acid and is the pH at which the same concentrations of peracetic acid and peracetateanion occur. As for every bleaching process, precise process conditions must be maintained to ensure that the reaction takes place in this manner. If the pH is too strongly alkaline (in this case pH > 9), then the peracetic acid breaks down at an incredibly high speed, resulting in an inadequate whitening effect and possible fibre damage. In the acid range, a balance between acetic acid and peroxide occurs that has almost no bleaching effect. Under practical conditions it has proved more expedient not to work in the range of maximum bleaching speed, which is 3–4 powers of ten faster than for hydrogen peroxide, but rather at pH 7–7.5.

Perborate → Sodium perborate.

Perborate activator → Bleach activators.

Percale Medium to fine threaded cotton or viscose material in linen weave, bleached or printed (stripes or small checker squares). Also called printed linen. The starting material is →: Cretonne, Chiffon or Renforcé. Fabric with thick ply threads at certain distances is called string percale. Application: For shirts, blouses, clothes and quilt covers.

Percarbonic acid → Carbon oxo-acids.

Percentage by weight (weight per cent), is a percentage mass relationship, i.e. grams in relation to 100 gram units, e.g. dye mass stated as a percentage of material weight. Where percentage figures are given in recipes, solvent concentrations etc., and no further information given, the percentage by weight is usually referred to, in solutions → Per cent by volume. Conversion:

$$\text{percentage by weight} = \frac{\text{per cent by volume}}{\text{density}}$$

Percentage set,

I. Proportion of orientated to non-orientated fibre components.

II. Proportion of actual to potential fibre stability.

A statement to the effect that following treatment a degree of setting of 90% has been achieved requires a reference quantity such that under defined conditions a measured surface shrinkage of, say, 20% of a textile to be treated has itself been reduced by 90% to 2%. With this definition the specifiable percentage set is as much dependent on the conditions of shrinkage measurement as the shrinkage of the original material itself. From this example it may clearly be seen that the set status is better defined independently of a standard reference sample, and that the best parameters are the thermal stability of the network formed on setting and the level of the strains frozen-in or locked-in at various temperatures. The terms effective temperature and effective tension as used here are determined by means of → Differential Thermal Analysis.

Per cent by volume (Vol.%), a certain quantity (e.g. mg, ml) of a substance is dissolved in a predetermined volume (e.g. 100 ml). In contrast to → Percentage by weight.

Perchloroethylene → Tetrachloroethylene.

Percolating filter Used in biological → Waste water treatment for enriching the waste water with air. → Biological filter media.

Perfluorocarbon compounds → Perfluoro compounds.

Perfluoro-carboxylic acids → Perfluoro compounds.

Perfluoro compounds Hydrogen fluoride serves as a fluorinating agent in manufacture. Many compounds, amines, ethers, esters, nitriles and fatty acids are suitable for fluorinating. Perfluoro carboxylic acids have a good wetting effect and excellent chemical stability. Perfluoro compounds have an oil-repellent effect and are used for → Oil-repellent finishing.

Perforated belt dryer Ventilation dryer (→ Conveyor drier), in which the perforated belt that serves as the transport mechanism (usually supported by rollers) has a low bending stability and is thus not suited to high loading, and is therefore only used for gentle drying at moderate air speeds. Dry air is sucked under the belt via a fan, transported via heaters, the jet housings of which are evenly spaced across the width, and thus passed over the material.

Perforated cage stenter Ventilation dryer consisting of sieve drum and revolving chain: Used for applications with defined end width, e.g. all fixation and curing processes and above all in the final drying of finished tufted carpets. Airflow (as for sieve-drum dryer) offers the most favourable conditions for the installation of a heat recovery plant, including preheating of outside air. The transport unit consists of the sieve drum inside the drying room and the transport chain which takes in material from outside and re-delivers it. – Manuf.: Fleissner.

Perforated disk beating process → Foam test methods.

Perforated nonwovens,

I. The often papery, non-textile handle of → Nonwovens can be improved by slit-like perforations. A hole-type perforation is also possible.

II. → Nonwovens with slits or incisions (e.g. perforations) to produce a softer handle (various different slit arrangements are possible). Amongst other things, this increases the permeability for gaseous and fluid media and creates better absorption characteristics. Have improved dimensional stability compared with un-slit non-wovens and lower strength depending on quality and slit arrangement.

Perforation Systematic perforation of materials in order to guarantee flow. For example, cheese centres (Fig. 1) or dyeing beams are perforated so that the dyeing liquor can achieve a good liquor exchange with the dyestuff. Nonwovens made of synthetic fibres (Fig. 2) are perforated with hot needles to guarantee air penetration or moisture exchange depending upon the field of application.

Performance, output Work performed, work yield.

Performance specification If a project is to be implemented, e.g. the purchase of a machine or an assembly line, a performance profile must be drawn up defining a list of priorities regarding the goals to be achieved. The performance specification created in this way must be continuously checked to establish whether the goals contained within it are being achieved.

Example: Development of a mercerizing machine.

Fig. 1: Perforated steel dyeing cores for the dyeing of cross-wound yarn packages (Fong's).

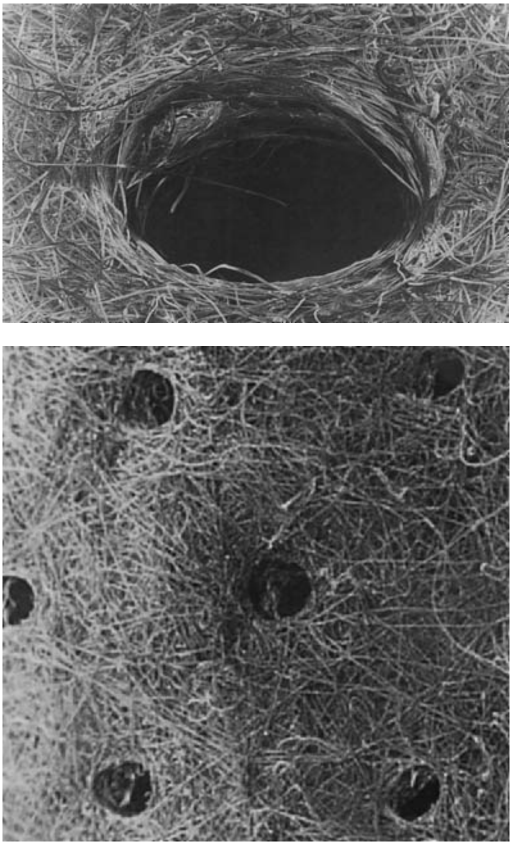


Fig. 2: Hot needle perforation of synthetic fibre mats (Kahnes).

The following performance specification was to be fulfilled:

1. Process technology:
   - intensive, complete and safe impregnation in a few seconds;
   - low liquor volume use;
   - automatic liquor management;
   - easy changing of the liquor concentration;
   - possibility of hot impregnation followed by cold mercerizing;
   - low liquor, water and steam consumption;
   - maintenance of preselected fabric length and width;
2. Textile material quality:
   - maximum dimensional stability in warp and weft;
   - optional, targeted influencing of the dimensional stability in warp and weft;
   - no edge-to-centre differences caused by the mercerizing;
   - quiet, even patterning in dyeing;
   - achievement of the normal mercerizing effects such as lustre, covering of dead cotton, increasing the dye affinity with good reproducibility.
3. Engineering:
   - set of modules for great flexibility with regard to customer’s wishes;
   - high degree of automation;
   - element construction method for short installation times;
   - use of rust and acid resistant material.

Performic acid CH_2O_3. A per compound of formic acids. Can be manufactured using special precautions (can be explosive) from formic acid, hydrogen peroxide (H_2O_2) and sulphuric acid (H_2SO_4). Colourless liquid and more volatile than formic acid. Decomposes readily when stored, forming H_2O_2, formic acid, carbon dioxide and oxygen. Is sometimes explosively decomposed by metals and metal oxides. Not available commercially due to its high instability. In finishing technology it serves as an oxidizing agent in the form of a reaction of formic acid and H_2O_2, whereby performic acid is created in an equilibrium reaction.

$$\text{H–CO–OH} + H_2O_2 \rightleftharpoons \text{H–CO–O–OH} + H_2O$$

Perfumes (scents). Precisely chemically defined natural or synthetic substances with → Osmophor groups, which, in combination with the molecular environment determine whether and in which differentiation an odour impression is created. → Odour nuisance.

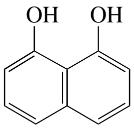
Perfume treatment of textiles Specifically of jersey knit goods, hosiery, etc. For removing, improving or covering the smell of oil, grease, dyes etc. Achieved using so-called → Fragrant finishes. Treatment stage in softening, rinsing, finishing, spray dampening, etc.

Perhydrates Addition compounds, which contain → Hydrogen peroxide (H_2O_2) in the form of crystal hydrogen peroxide (in addition to water of crystallization). Method of oxygen release: Slow decomposition of the H_2O_2 formed in the solution.

Periodic system Natural ordering system of → Elements in the order of their → Atomic weight, which permits inferences to be made by analogy regarding the behaviour of related element groups.

Periphery Environment of the actual work unit, i.e. control unit, power supply, electropneumatics, crane and other transport devices for the operation of the plant, EDP, recycling plants, exhaust and waste water disposal, waste collection. The periphery of a machine is usually at least as expensive as the work unit itself.

Peri-position In connection with chemical structure formulae. In the naphthalene nucleus this is the adjoining 1.8 or 4.5 position of certain substituents, e.g. mordant attracting groups in mordant dyeing:



Perkin, Sir William Henry (1838–1907), English chemist. In 1856, at the age of 18, discovered the first technically usable coal-tar dye (aniline purple or mauvine) when looking for a quinine synthesis. Founder of the dyestuffs industry.

Perlite Vulcanized stone with many small water voids (23% molecularly bound water). After fine milling and heating to over 1200°C perlite expands due to water vaporization to a swollen, feather light “foam stone” (approx. 20 times volume and more), which is used in the construction industry for temperature and sound insulation (rock wool). Repeated fine milling and subsequent separation treatment gives rise to a highly active filtration agent, which is excellently suited for application e.g. in chemical cleaning.

Permanent adhesive Water insoluble plasticized synthetic polymer used as a table adhesive for affixing material to be printed onto screen printing tables, sometimes also onto the back grey printing of screen printing machines.

Permanent emboss → Embossing.

Permanent finishing Applications or effects on textiles, which resist the stresses of use and care, e.g. washing, chemical cleaning.

Permanent hardness → Water hardness salts.

Permanent-press process Originally used exclusively as a collective term for → Resin finishing processes (dry cross-linking), in which the final fixing or stabilizing of the material takes place during garment manufacture. This produces items of clothing with excellent permanent dimensional stability, sharp ironing folds and pleats, nonshrink seams and particularly good smoothness after washing. Fixation is therefore not performed flat, but shaped. Also a common term for conventional resin finishing, however only for items with high-quality finishing effects.

Permanent-press process for wool Collective term for: → Antifelting finish and → Non-shrink finish.

Permanent white → Barium sulphate.

Permanganate → Potassium permanganate.

Permanganate number,

I. → Permangate number. For quantitative determination of fibre damage to cellulose. Oxycellulose and hydrocellulose are dissolved from the fibre by repeated boiling and detected using a potassium permanganate solution.

Permanganate number = number of millilitre 0.1 n $KMnO_4$ solution, consumed by 1 g fibre.

II. → Waste water permanganate consumption.

Permangate number (Kaufmann), → Permanganate number. Oxycellulose content of cotton bleached goods, which have not been alkaline-boiled before or after bleaching. Method: Boil 1 g material with NaOH and titrate dissolved organic products with 0.1n $KMnO_4$. $KMnO_4$ consumption up to 10 ml normal, 10–13 ml little damage, above this significant damage. When making the calculation, deduct the basic value for unbleached material. The permangate number can also be an important method of detecting cotton materials kier boiled in the presence of air.

Permeability (permeability to radiation, D), identical German term for → Transparency.

Permeability bag test Used for evaluating waterproof impregnation effects on textiles. Method: Fill clamped, sagging material trough with measured quantity of water (e.g. water level of 5, 7.5, 10, 15 cm, effect 24 h) and check the time it takes for water to start leaking through. Different water quantities are used depending upon the properties of the material. The permeability bag test usually does not accurately reflect the conditions in which the fabric is worn, but is still often used by finishing companies (particularly for tarpaulins, tent fabric, etc.).

Permeability determination In printing screens with a → Light transmission measuring instrument this permits the precise photometric determination of the open printing area.

Permeation Passage through a membrane. In membrane separation procedures this is a so-called pressure penetration. Permeation is the collective term for many different, yet fundamentally similar, and simply functioning membrane procedures: Micro, ultra and nano filtration as well as reverse osmosis (see Fig.). In all four procedures the waste water being treated flows turbulently across the filter element, the membrane,

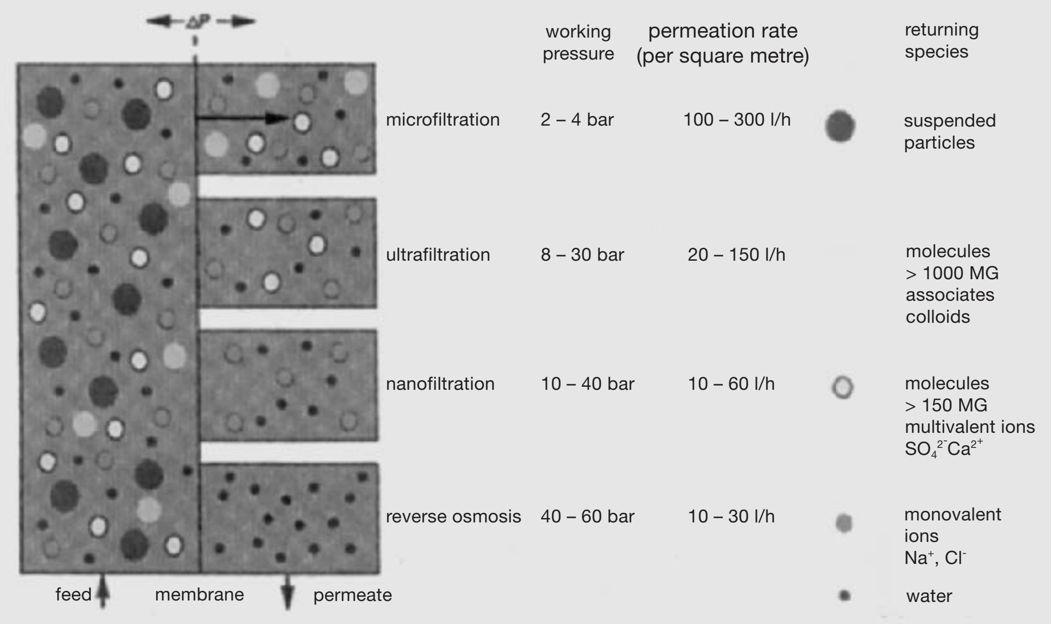


Fig.: Pressure permeation process (Bayer).

by the “cross-flow” technique. Under hydrostatic pressure a flow of water is forced through the semipermeable membrane at right angles to the direction of flow. Depending upon the membrane structure or the size of its pores, almost all the substances in the waste water, from large particles to small molecules and dissolved salts, can be concentrated.

Thus the pressure permeation process is nothing more than a filtration technique in the finely dispersed to molecular range, whereas the four individual processes differ according to the fineness at which the substance is separated out. Microfiltration membranes can only retain undissolved particles of a size of approx. 0.1 µm, whereas all dissolved substances flow through the pores of such a membrane. It is thus suitable, for example, for the clarification or prefiltration of solutions. The membranes used in → Ultrafiltration can retain larger organic molecules in dissolved form and separate these from small molecules and organic salts. As dyestuff molecules associate in aqueous systems and are thus not monomolecular, but are present as clusters, any dyestuff present in the solution will be almost completely (> 99%) retained by UF membranes with low separation limit. In this manner it is technically possible to largely decolorize waste water using ultrafiltration. However low molecular COD and AOX loads are not retained by this membrane or heavy metal salts, so that the permeate, although colourless, is only biologically capable to a limited degree. A nanofiltration membrane, on the other hand, has such fine pores that even small organic molecules with a molecular weight of > 300 g/mol and polyvalent ions are retained, although a sodium chloride solution, for example, would still pass through the membrane. The technical process of → Reverse osmosis is in principle, as the word appropriately describes it, the exact reverse of natural osmosis, which ensures a regulated balance of nutrients and fluids in every plant (Tegtmeyer).

Permutit Group of artificial → Ion exchanger. The strongly acidic permutit-cation exchanger in sodium form (insoluble in water → Sodium aluminosilicate) can absorb calcium and magnesium ions and release an equivalent quantity of sodium ions.

$$\text{permutit–Na}_2 + \text{CaCl}_2 \rightleftharpoons \text{permutit–Ca} + 2\,\text{NaCl}$$

$$\text{permutit–Na}_2 + \text{MgSO}_4 \rightleftharpoons \text{permutit–Mg} + \text{Na}_2\text{SO}_4$$

Permutoid,

I. Identical to →: Intracellular; Intramicellar.

II. Normally in the sense of “exchangeable”, e.g. ion exchanger property; so we talk of permutoid behaviour in textile fibres, permutoid conversion, etc.

Peroxide binding of fibres Fibres containing nitrogen (polypeptides) bind significant quantities (in mg/g fibre) even from 3% solution of H_2O_2 at 20°C (pH 8):

wool	9.8
polyamide 6.6	5.5
silk	4.5
cotton	0
glass fibres	0

Peroxide binding increases with concentration. In a reaction of 40% H_2O_2 solution a maximum of 2–3 mol peroxide/kg wool are bound. In the pH range 2.5–9 for wool (absorption falls below and above), and between pH 0–6 for silk and polyamide there is no dependency upon the hydrogen ion concentration. It is thought that peroxide binding is primarily determined by the amino groups (0.9 mol/kg wool, 0.1 mol/kg silk) and imimo groups (9 mol/kg wool, 12 mol/kg silk) present.

Peroxide bleach The oxidizing agent hydrogen peroxide (H_2O_2) has become prevalent in the pre-treatment of textiles made of cellulose fibres in the bleaching process. It is most convincing in the application technology and ecological field. Its competitors: → Sodium hypochlorite (NaOCl) and Sodium chlorite ($NaClO_2$), on the other hand, have significant ecological disadvantages; the ecological hazards consist of exhaust air pollution due to the formation of “poisonous” gases and waste water pollution (AOX).

Hydrogen peroxide dissociates only slightly in an aqueous medium.

$$H_2O_2 \rightleftharpoons H^+ + HO_2^-$$

If the hydrogen peroxide solution is activated with alkali, then the dissociation equilibrium is moved to the right and the concentration of perhydroxyanions is increased.

$$H_2O_2 + OH^- \rightleftharpoons H_2O + HO_2^-$$

The actual oxidation of the discolouring, i.e. the bleaching reaction probably occurs via a superoxide anion radical. In parallel to this a self-decay takes place in a secondary reaction that has no effect on the bleach. As the alkali concentration of the bleaching liquor increases the bleaching reaction and self-decay as a competing reaction decreases. Due to this fact, peroxide bleaching is usually carried out in the range of pH 10–12. Peroxide decay is accelerated by a number of substances or substance mixtures. The presence of such so-called catalysts in the bleaching liquor and/or in the textile material leads to a spontaneous breakdown of the bleaching agent. This is associated with fibre damage, which expresses itself by the oxidation of cellulose into familiar oxycellulose, and its subsequent depolymerization (→ Catalytic damage).

The permanganometric determination of the peroxide content takes place in a sulphuric acid solution by titration with potassium permanganate. Reaction process:

$$2\,KMnO_4 + 5\,H_2O_2 + 3\,H_2SO_4$$
$$\rightarrow H_2O_2 + 2\,MnSO_4 + 8\,H_2O + 5\,O_2$$

Titration takes place at 0.05 n $KMnO_4$. According to the equivalent ratios (34:2 = 17), this yields:

1 ml 0.1 n $KMnO_4$ = 1.70 mg H_2O_2
1 ml 0.05 n $KMnO_4$ = 0.85 mg H_2O_2

The quantity of peroxide (C_P) contained in the sample (5 ml) is found using the following equation:

$$C_P\ [mg] = \text{consumed ml } 0.05\ n\ KMnO_4 \cdot 0.85$$

If we relate this concentration at a volume of 1litre and use another conversion factor for the weight unit, then we find

$$C_P\ [g/l] = \frac{C_P\ [mg] \cdot 1\,000\ ml \cdot 10^{-3}}{5\ ml}$$

The peroxide breakdown can be calculated by the following equation:

$$\text{peroxide breakdown (\%)} =$$

$$\text{peroxide content} : \frac{\text{starting content}}{100} - 100$$

Determination of the max. titration error yields 0.1 ml 0.05 n potassium permanganate solution, so that the determination of the peroxide content with an absolute error of = 0.6% of the starting content: 2.9 g/l ± 0.1 H_2O_2 can be viewed as being sufficiently precise. However, a greater measuring error results if the sample is taken in deviation from the specified time (depending upon the decomposition speed of the bleach liquor). It is therefore vital that the specified time is adhered to. There is a functional dependency of the peroxide decay on the bleach breakdown. However, the bleaching result (i.e. the ratio of material quality to usability) is also influenced by other factors, which means that the reduction in peroxide content has no direct relationship with the bleaching result.

The catalysts contained in the impurities in the cotton in the form of compounds containing heavy metals can lead to fibre damage in the peroxide bleach, particularly where there are local concentrations in the yarn. The fibre damage can be attributed to the radical peroxide decay initiated by the catalysts. Radical decay should therefore be prevented under all circumstances. If possible, the heavy metal ions must also be removed in appropriate pre-treatment stages prior to bleaching, or the effectiveness of the catalysts must be repressed. Iron compounds make up the majority of potentially catalytically active escort substances in cotton. The point material damage (holes) depend partially upon the pre-treatment and bleaching conditions. The degree of fibre damage caused by catalysts is however, usually only recognisable in the subsequent treatment stages or during use, meaning that significant damage can occur. In an attempt to solve the problem of preventing catalytic damage, much effort has been expended to try to develop a procedure by which fibre damage is ruled out, despite the presence of catalytic compounds. The dissolution speed of the impurities containing heavy metal in the pre-treatment and bleaching liquor is a dominant influence factor for radical peroxide decay. Above all the dissolution speed of the iron hydroxide, i.e. the concentration of the dissolved iron ions in the bleach liquor, determines the catalysis of the peroxide decay.

Peroxide decay is, therefore, critically dependent upon the stabilisation of the system. Good stabilisation is characterised by a low H_2O_2 consumption, and the suppression of undesirable secondary reactions such as self-decay into water and oxygen and the formation of radicals. However, stabilisation using the classic regulator water glass is associated with disadvantages, which arise due to the deposits of only slightly soluble silicate on textiles and in the bleaching equipment. The suitability of most regulators can only be determined by practical stabilisation experiments. The determination of the H_2O_2 decay in empty baths should be sufficient for an evaluation of the stabilisation capacity. In this testing method the H_2O_2 content is titrated in the bleaching baths without the textile material and with the regulator being tested in relation to time. The decay curve obtained in this manner is compared with that of a known stabiliser, e.g. water glass.

Peroxide bleach fastness Resistance of dye to the effects of bleaching baths containing peroxide.

Peroxide bleach process Optimal stabilisation of the bleach bath consists of a balance between inorganic and organic stabilisation. Foaming and increasing liquor temperature (e.g. above 50°C) clearly indicate poor stabilisation of the bleach bath, and in parallel to this they also indicate a significant loss of peroxide. Addition liquors are often used in practice, if a modern dosing station for individual components is not available. The application conditions for the products used are strict. They require good alkali resistance and a good H_2O_2 stabilisation (e.g. 50–60 g/l NaOH and 200–250 ml/l H_2O_2 35%). When adding the liquor a very specific addition sequence must be adhered to:

1. water (stipulate maximum possible volumes),
2. magnesium salt,
3. organic stabiliser,

4. surfactant,
5. water glass (if required),
6. caustic soda liquor,
7. peroxide.

The addition of all products must take place slowly, whilst stirring. It should be borne in mind that the addition of the caustic soda liquor to water generates an exothermic reaction and warms the bath by 8–10°C prior to the addition of the peroxide. If the organic stabiliser is not effective enough or if it complexes the magnesium ions to an excessive degree, then sooner or later the liquor will destabilise, because the thermal reaction that is occurring can no longer be maintained. The increase in temperature occurs in parallel to the loss of peroxide. The liquor is controlled by titration with potassium permanganate. It is advantageous not to use too much liquor, but rather to renew the bath more often. If strengthened addition liquor is left to stand for too long then the peroxide concentration should be checked at predefined time periods from the start by titration.

The degree of whiteness and the waste of the polymerisation degree of the cellulose (s, according to Eisenhut) should be used to define a quality factor (Q) for the bleach. The damage factor of cellulose is based upon the difference between the polymerisation degree at the start and the end of the treatment. If the value s is less than 0.4 then the material is not considered to be damaged. The quality factor Q is defined as follows:

$$Q = f\,(W, s)$$

W = degree of whiteness,
s = damage factor of cellulose.

The Q value thus depends upon the material, the selected procedure, the selected recipe and the product selection of the bleach. Q values above 80 can be described as peak values (according to Fornelli).

Peroxide cold bleach Same process as →: Peroxide cold-pad-dwell process; Cold pad batch bleach; Cold dwell process. Very suitable as a pre-bleach. Only recommended for clean husk-free raw material.

Peroxide cold-pad-dwell process Bleaching process specifically for cotton circular goods. Method: a) Impregnate with bleaching and brightening solution on padder using expander for circular material; b) dwell in heat insulated vehicle; c) rinse on rope washing machine.

Peroxide decomposition kinetics During the bleaching process a decomposition process competes with the bleaching reaction, so that as the decomposition component increases the bleaching effect falls. Heavy metal compounds catalyse peroxide decomposition whilst forming radicals, whereby the latter statistically attack the cellulose, which leads to a reduction in the DP degree. It is also possible that the coloured accompanying material may be decomposed in the case of radical peroxide decomposition, so that an increase in the degree of whiteness is feasible. However, peroxide decomposition initiated by heavy metal compounds during bleaching is to be avoided due to the fact that this can be expected to minimize the DP degree. The peroxide decomposition in bleaching liquors can be described by a reaction of the 1st order in the case of the ionic mechanism. The reduction of the peroxide concentration at constant pH is proportional to the peroxide concentration itself.

$$-\frac{dc}{dt} = k \cdot c.$$

Integration between the limits c_0 and c_t according to the peroxide concentration at the beginning and at time t yields:

$$\ln \frac{c_0}{c_t} = k \cdot t.$$

Therefore plotting ln c_0/c_t against time t, yields straight lines, the gradients of which correspond with the speed constant k for peroxide decomposition. These conditions are illustrated in Fig. 1 for buffered systems.

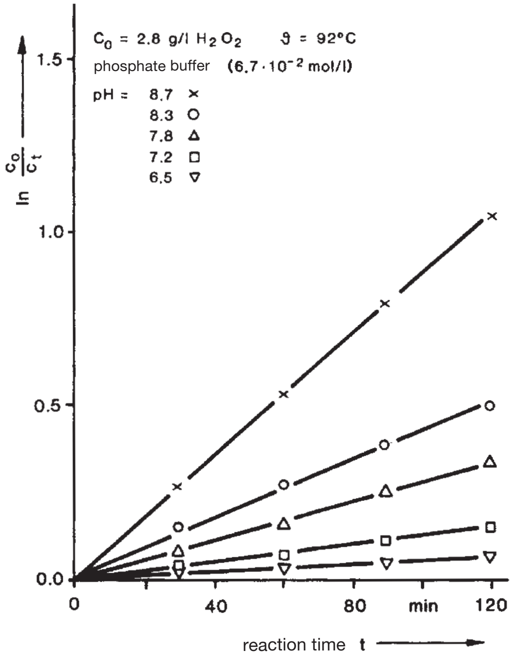


Fig. 1: Peroxide decomposition with changing pH in the absence of textile (according to Heidemann).

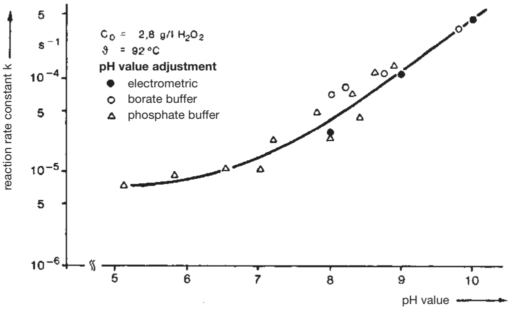


Fig. 2: Peroxide decomposition in the absence of textile (according to Heidemann).

Fig. 1 is based upon the marked dependency of peroxide decomposition on the pH of the medium. This fact is illustrated once again in Fig. 2, in which the speed constant of the peroxide decomposition is plotted against the pH of the liquor. Within the measuring accuracy, the decomposition constants are independent of the selected system, so that the interaction between the electrolytes used for adjustment and maintenance of the pH and the peroxide, e.g. in the sense of a stabilisation, are ruled out. The speed of the peroxide decomposition is, however, relatively high at a normal temperature even for bleaching processes in the weak alkaline range, which indicates the use of regulators (according to Heidemann).

Peroxide-hypochlorite-peroxide bleach Combination bleach for cotton and viscose items of all types, particularly for pure white without kier boiling on medium and heavy fabrics. In the case of mixed textiles or pure viscose items, high viscose losses can be expected, e.g. in the → Kier boil-chlorine bleach (losses approx. 3%) and → Alkali scour-chlorine-peroxide (losses approx. 7%). → Bleaching.

Peroxides (superoxide), compounds of type → Hydrogen peroxide H_2O_2, → Sodium peroxide Na_2O_2, magnesium peroxide Mg_2O_2. Principle of acid release:

$$H_2O_2 \rightarrow H_2O\ ^1/_2 + O_2$$

Peroxide wash, colour fastness to Washing in the presence of sodium perborate. Resistance of textile dyes, which are mechanically treated at high temperatures in washing liquors with bleaching agents that release oxygen. Guidelines particularly for cellulose fibres. Perfuse test piece plus two accompanying fabrics with 60°C warm washing solution (5 g/l soap; 2 g/l sodium carbonate calc.; 0.8 g/l sodium perborate ($NaBO_3 \cdot 4\,H_2O$); 0.15 g/l magnesium chloride ($MgCl_2 \cdot 6\,H_2O$); 1.2 g/l sodium silicate 35°Bé) in liquor ratio 1 : 50, then warm to 95°C within 10 min and treat at this temperature for 20 min. Rinse test piece, squeeze and dry open at max. 60°C. Evaluation according to colour change and bleeding with grey scale.

Per(oxy)carbonates (percarbonic acid sodium salt), salt of percarbonic acid (→ Carbon oxo-acids). Types: $Na_2CO_4 \cdot 1\,^1/_2\ H_2O$ and $Na_2C_2O_5$. Both decompose when dissolved in a) oxygen and sodium carbonate or in b) hydrogen peroxide and hydrogen carbonate:

$$Na_2C_2O_6 + 2\,H_2O \rightarrow H_2O_2 + 2\,NaHCO_3$$

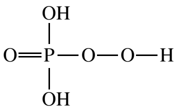
Peroxyformic acid → Performic acid.

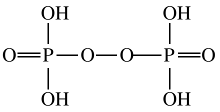
Peroxy group, –O–O group in peroxy compounds.

Peroxy-monosulphuric acid → Caro's acid.

Peroxysulphuric acid,
I. → Caro's acid.
II. → Sulphur oxyacids.

Perphosphates (peroxyphosphates), salts of genuine → Per acids, derived either from peroxymonophosphoric acid (H_3PO_5) or diphosphoric acid ($H_4P_2O_8$) (→ Phosphoric acids).





In the exchange of acid-hydrogen atoms by alkali metals (sodium, potassium) the salts in question are created as peroxymonophosphates or peroxydiphosphates (→ Perpyrophosphates).

Perpyrophosphates Salts of type $Me_4P_2O_7 \cdot 2\,H_2O_2$. Addition products of H_2O_2 on the carrier of → Pyrophosphates, thus not genuine → Per salts, like for example → Perphosphates. Perpyrophosphates are described in literature as those that have deposited approx. 20–50% H_2O_2. The sodium-perpyrophosphate, which is commonly used in practice, contains approx. 19.1% H_2O_2 and corresponds with approx. 9% active oxygen content. It decomposes into an aqueous solution in H_2O_2 and sodium pyrophosphate, has a low pH and excellent complex-forming characteristics. It dissolves hardness constituents and heavy metal salts or renders them inactive. The excellent stabilizing effect in comparison with bound oxygen also rests upon the latter characteristic. This useful combination of pyrophosphate and H_2O_2 is excellent for pre-bleaching in textile assistants and as an oxidizing agent or in the soaping aftertreatment of fast dyes.

Perrotine Printing machine named after its inventor, Perrot, which can be considered as the first stage in the mechanisation of block printing.

Per salts Genuine salts of → Per acids, such as for example ammonium persulphate or potassium persulphate. Principle of oxygen release:

$$K_2S_2O_8 + H_2O \rightarrow [K_2SO_4 + H_2SO_4 + {}^{1}/_{2}\ O_2]$$

Application: Oxidizing agent in dyeing and printing, kier boiling, desizing, bleaching agent; disinfectant.

Persian carpets → Oriental carpets of Persian origin. Usually dense knotting of 400 000 to 1 million knots per m^2 with fine patterning. Names such as →: Bakhtiari carpets; Bijar carpets; Hamadan carpets; Isfahan carpet; Kashan carpets; Shiraz carpets; Senneh carpets; Seraband carpets (Mir) describe the province of origin.

Persoz reagent Dissolves only silk from silk/wool mixes at 45°C. Consists of 10 g zinc chloride in 10 g water and 2 g zinc oxide.

Perspiration fastness Resistance of dyeing and printing to human sweat.

I. Determination according to DIN 54 020: one sample each is treated with an undyed accompanying fabric in an alkaline or acidic testing solution for 30 min (liquor ratio 1 : 50) at room temperature (slight mechanical action for better penetration). After the removal of excess testing solution the test pieces are individually exposed to a pressure of 12.5 kPa between two plates and are treated for 4 h in a warming cupboard at 37°C ± 2°C. After opening, the test pieces are hung to dry at max. 60°C. The change in colour and the bleeding are evaluated against the grey scale.

II. Perspiration fastness according to AATCC: a) Alkaline: 10 g/l sodium chloride, 4 g/l ammonium carbonate, 1 g/l disodium phosphate (Na_2HPO_4) and 0.25 g/l histidine monohydrochloride, pH of the solution = 8; b) acid: 10 g/l sodium chloride, 1 g/l lactic acid 85%, 1 g/l disodiumhydrogenphosphate and 0.25 g/l histidine monohydrochloride, pH of the solution = 3.5. Procedure: treat test piece for 15–30 minutes in the solutions a) and b) individually, squeeze (squeezing effect 250–300%) and load 10 kg for 6 h (or more) in perspirometer at 38°C.

Perspiration removal Thorough wet treatment, intensive steaming or stain removal by dry cleaning using → Deodorants.

Perspiration transport measurement Facilitates important test predictions regarding the serviceability value for items of clothing (→: Wesel triangle; Clothing physiology). Two adjacent drums are used with openings opposite each another, between which the material samples, which have been weighed, are clamped. In the first drum an air stream of 90% relative humidity circulates at 31°C, in the second drum air of 50% relative humidity circulates at 18°C. Under these conditions, with equal pressure in the two drums, the perspiration transport from drum one to drum two is measured with a hygrometer and the amount of condensation in the test piece is calculated by its increase in weight.

Perspirometer Am. device by AATCC for testing → Perspiration fastness. Sample is treated at a pressure of 4.5 kg between glass plates for at least 6 h at 38°C.

Persulphate desizing Procedures for the removal of starch sizes generally use enzymes because, unlike oxidizing agents, this rules out damage to the cotton. The latter are therefore only found in isolated cases, for example in cases where the size contains enzyme poisons. Persulphate desizing can be used both after the cold dwell process and after the steaming process. In order to avoid fibre damage, max. 0.5% sodium persulphate can be used in the cold dwell process, and no more than 0.2–0.35% (in relation to the material weight) in the steaming process. Application takes place in an alkaline medium. Without the alkali, complete desizing is impossible.

An oxidative desizing with persulphate destroys the carboxyl and fixed groups of polysaccharide into low molecular and water soluble size fragments (Fig. 1). Oxidative desizing is performed:

- If e.g. tapioca starch is present, which as a branched polysaccharide can only be broken down by enzymes with difficulty, depending upon the degree of ageing;
- If fungicides are used in the size recipe to prevent the formation of mildew (mould spots) (fungicides, which are mainly used in countries with high air humidity act as enzyme poison);
- For cost reasons, to save a separate work stage;
- If there is not enough space for the dwelling batch rolls.

Desizing with oxidizing agents involves a high risk of fibre damage. Unlike enzymes, persulphate does not differentiate between the chemically similar substances of cellulose and starch. If the starch is converted into a washable form by persulphate due to oxidative decomposition, then the cellulose will be damaged with possible remaining residual persulphate (recognisable by an excessive reduction in the DP value). The danger of oxidative damage can be minimized by using stabilised persulphate in place of pure persulphate (Fig. 2).

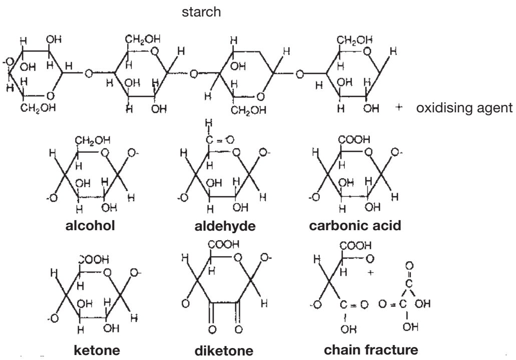


Fig. 1: Oxidative decomposition of starch by the action of persulphate or peroxide.

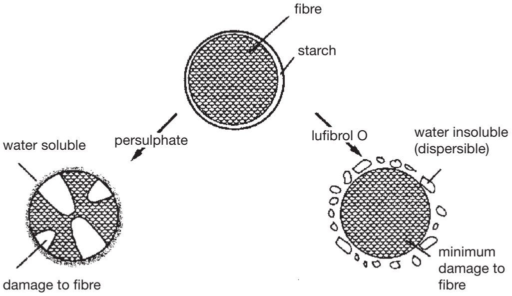


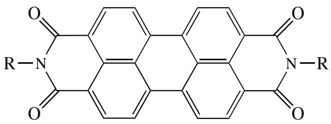
Fig. 2: Avoidance of oxidative damage.

Persulphates (peroxysulphates, dioxysulphates) Salts of peroxysulphuric acids ($H_2S_2O_8$ → Sulphur oxyacids), such as the highly water soluble ammonium, potassium or sodium persulphates. Application: Bleaching and strong oxidizing agent for vat dyeing and printing; desizing agent; bleaching agent for wool, waxes, fats and oils.

Persulphuric acid This is usually used to mean Caro's acid H_2SO_5; correctly persulphuric acid is the so-called peroxysulphuric acid $H_2S_2O_8$.

Perylene ($C_{20}H_{12}$) → Cyclic hydrocarbons.

Perylene tetracarboxylic acid derivatives → Perylene.



Representatives are particularly red and blue vat dyes, e.g. Indanthren red, Indanthren scarlet.

PES → Polyester, → Textile fibre symbols, according to DIN 60 001 T4/08.91.

Pesticides Means of pest control used in the cultivation of plants, e.g. in monocultures of cotton cultivation, to protect against weeds, fungi, bacteria and insects. Because of cultivation in the form of monocultures, the growing cultivation areas in half-dry areas generates a high pressure from pests, making it necessary to tackle this problem using pesticides (in cotton: approx. 20% herbicides; approx. 75% insecticides; approx. 5% fungicide) in order to increase harvest yields. The pest control strategy consists of spraying different types of pesticide (e.g. in three "windows", i.e. sections of the growth phase, each with different composition) intensively from aeroplanes. The use of substances such as DDT or Lindan is banned worldwide. It also appears, and this has been proven by analyses, that these persistent chlorinated hydrocarbons no longer play any role as a pesticide. Quantities used in plant feed fall well below the specified maximum quantities (1 ppm DDT; 0.5 ppm Lindan). Wool contains pesticides, if the sheep is driven through baths containing pesticides in order to fight parasites in the sheepskin.

Natural cotton ("green cotton"), which is not textile finished, brings its carrier into contact with the pesticides, the percentage of which can be 7–858 µg/kg cotton depending upon the cultivation area. Therefore efforts are made to bring "green cotton" onto the market from ecological cultivation without the use of pesticides.

Defoliants, which are sprayed over fields by aeroplanes before the mechanical cotton harvest, are particularly useful. They make their way into the cotton shrubs through the ground and cause the leaves to fall off, so that harvesting machines have easier access to the seed capsules.

PET Often used as an abbreviation for polyester in the Anglo-Saxon language area.

PETP → Polyethylene terephthalate, → Textile fibre symbols, according to DIN 60 001 until 1988.

Petroleum ether → Benzine.

Petroleum gas Wet → Natural gas.

Petroleum sulphonates → Mahogony sulphonates.

Petticoat finish In particular in polyamide and polyester items to achieve a permanent stiffening finish using aminoplasts and/or thermoplastic artificial resins.

Pfersee-testing instrument Simple test instrument for checking water-impermeable finishes on textiles in accordance with the American → Spray test. The stretched test piece is irrigated at an angle of 45° with 250 ml test water at 27°C by a funnel-shaped shower then, whilst still stretched, the table edge is struck to remove excess water in accordance with guidelines. Evaluation by comparison images (marks 0–100) : 100 = no clinging or wetting, 90 = slight, accidental clinging or wetting, 80 = wetting at irrigation points, 70 = partial wetting of the entire surface, 50 = complete wetting of the entire surface, 0 = complete wetting of the entire surface and back. Mild test method, which only shows up large differences. More precise evaluation by the → Water sprinkling apparatus Pfersee. – Manuf.: Erhardt & Leimer.

pH Describes the acidity or alkalinity of aqueous solutions. Water dissociates to a small degree according to

$$H_2O \rightleftharpoons H^+ + OH^-$$

According to the law of mass action the dissociation constants are found to be

$$K_{H_2O} = \frac{[H^+]\,[OH^-]}{[H_2O]}$$

A good approximation of the molar concentration of water is found by 1000 g (1 l water) divided by 18 (relative molar mass of water) as 55.6 mol/l, because water is virtually 100 % undissociated. Therefore we can consider $[H_2O]$ as a constant and rearrange the above equation as follows:

$$K_{H_2O} \cdot [H_2O] = [H^+] \cdot [OH^-]$$

We thus obtain a new constant, which is called the ionic product of water and the numeric value of which is determined as $1.00 \cdot 10^{-14}$ at 25°C.

$$H_2O_{dest} = 1.00 \cdot 10^{-14} \text{ mol/l} = \text{const. } 25°C.$$

Therefore, at 25°C in water $[H^+]$ and $[OH^-]$ each contribute 10^{-7} mol/l, which varies with temperature (Tab.). Because the H^+ and OH^- ionic concentration is clearly linked over the entire ionic product of 10^{-14} mol/l, it is sufficient to quote the concentration of one ion type, in order to be able to derive the concentration of the other.

$$[H^+] = \frac{10^{-14} \text{ mol/l}}{OH^- \text{ mol/l}}$$

or

$$[OH^-] = \frac{10^{-14} \text{ mol/l}}{H^+ \text{ mol/l}}$$

Therefore, if the H^+ ion concentration increases, the OH^- ion concentration falls and vice versa. For this purpose we quote the negative decimal logarithm of the molar H^+ ion concentration for the pH, i.e.

$$pH = -\log [H^+]$$

From this we find

$[H^+]$ mol/l	$[OH^-]$ mol/l	pH
10^{-0}	10^{-14}	0
10^{-1}	10^{-13}	1
10^{-2}	10^{-12}	2
10^{-3}	10^{-11}	3
10^{-4}	10^{-10}	4
10^{-5}	10^{-9}	5
10^{-6}	10^{-8}	6
10^{-7}	10^{-7}	7
10^{-8}	10^{-6}	8
10^{-9}	10^{-5}	9
10^{-10}	10^{-4}	10
10^{-11}	10^{-3}	11
10^{-12}	10^{-2}	12
10^{-13}	10^{-1}	13
10^{-14}	10^{-0}	14

A solution of pH 6 therefore contains 10 times more hydrogen ions than a solution of pH 7.

The pH plays a role not only in many chemical processes, which naturally include corrosion; biological processes too require an optimal pH, without which bacteria, for example, would not be capable of existence. This illustrates the importance of the pH for waste water and biological treatment plants. To measure pH a measuring electrode and a reference electrode are needed. If these electrodes are submerged in an aqueous solution, ions diffuse from or into the swelling layer, depending on whether the solution is acidic or alkaline. The inner wall of the electrode has a constant pH, so that a potential difference exists inside/outside, which is proportional to the hydrogen ion concentration. After calibration, the pH can be determined in this

temperature of distilled H_2O in °C	total ion production in $mol^2 \cdot l^{-2}$	H^+-ion production in $mol \cdot l^{-1}$	pH	conductivity in Ω^{-1}
0	$0{,}078 \cdot 10^{-14}$	$0{,}28 \cdot 10^{-7}$	7,55	$1{,}0 \cdot 10^{-8}$
18	$0{,}61 \cdot 10^{-14}$	$0{,}78 \cdot 10^{-7}$	7,11	$3{,}8 \cdot 10^{-8}$
25	$1{,}00 \cdot 10^{-14}$	$1{,}00 \cdot 10^{-7}$	7,00	$6{,}0 \cdot 10^{-8}$
35	$2{,}1 \cdot 10^{-14}$	$1{,}45 \cdot 10^{-7}$	6,84	$9{,}0 \cdot 10^{-8}$
50	$5{,}4 \cdot 10^{-14}$	$2{,}30 \cdot 10^{-7}$	6,64	$17{,}0 \cdot 10^{-8}$

Tab.: The influence of temperature on pH.

manner by a voltage measurement. The pH is a measured variable related to the concentration of hydrogen ions c_{H^+}. In normal notation this definition is

$$p_{cH} = -\log c_{H^+}$$

However, this relationship only holds as a first approximation, so a 10^{-2} normal hydrochloric acid with $c_{H^+} = 10^{-2}$ has a pH of around 2. Concentrations of alkaline solutions can also be estimated from the pH, because at room temperature the equation

$$c_{H^+} \cdot c_{OH^-} = 10^{-14}$$

is always true. It follows from this that a 10^{-3} normal alkaline solution with $c_{OH^-} = 10^{-3}$ and, according to this equation, $c_{H^+} = 10^{-11}$ has a pH of approx. 11. The pH is defined by a conventional pH scale with the aid of a range of precisely manufacturable buffer solutions. It is related more to the activity than the concentration of H^+ ions, but is normally an important indicator in various processes, including washing.

If the pH is measured during an acid/base titration (the simplest method uses a titration machine, which writes the titration curve), then a comparison of the titration of a strong and a weak acid, as shown in the Fig., shows a significant difference.

In a strong acid there is a precipitous change in the pH, and this is in the vicinity of the end of titration at pH 7. For a weak acid on the other hand this leap, which is still recognizable, is at a very different shaped 2nd area of the titration curve. The pH changes by only a relatively small amount with the addition of alkaline solution (or also opposing titration with acid). This means that in this area the solution is capable of collecting acid or alkaline additions, a relationship that is known as buffer characteristic. Depending upon the type of weak acid (its dissociation constant is decisive) the buffer area can be moved between pH 2 and 12 at will.

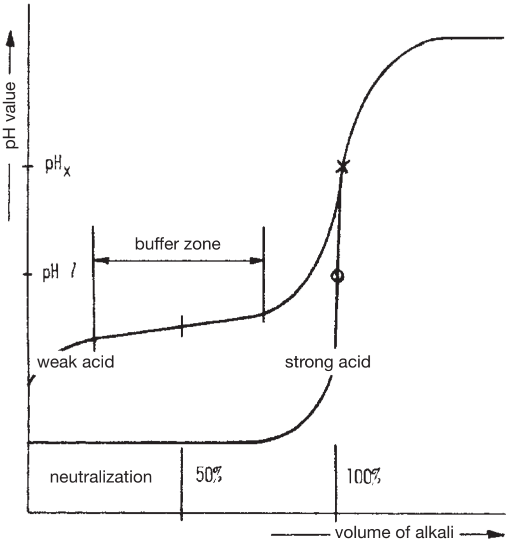


Fig.: Diagram comparing the titration curves of a strong and a weak acid.

It is significant that most washing agents are designed as buffered systems from their recipe. Thus they remain largely insensitive to pH changes, a reason why there is normally no need to make a → pH measurement for washing liquors.

Phase → Homogeneous material within a system which is separated from other components by physical boundaries. Each individual phase in a system encompasses all components with the same characteristics and the same composition. One example of a typical 3 phase system would be a closed tank, partially filled with water, in which ice is floating. Solid phase = ice, liquid phase = water, gaseous phase = air. According to the above definition, several pieces of ice do not represent several phases in this system, but rather just one, the ice phase.

Phase boundary → Interface.

Phase contrast microscopy Also known as microphase contrast. Makes finer structural details (thick/thin, high/low, convex/concave) of the micro-object and its environment more easily visible to the eye (photoplate) by phase differences in the illumination beam. In principle the zero order, i.e. the straight line beam, is changed by the addition of an annular phase plate (the condenser screen in the picture), which alters the phase of this zero bend (and only this one) by 90°. The micropicture created shows light differences in grey scale shades instead of the phase differences that are actually present (density and/or thickness differences). So the finest superpositions, textural changes, dispersions, cloudiness and layer thickness deviations can be recognised which are not picked up by bright field microscopy.

Phase diagrams of wash liquors The working mechanisms of surfactants are an important factor in the study of mass transfer in finishing processes. Surfactants act with water to form micelles, i.e. aggregates made up of a greater number of surfactant molecules or ions. However, these only form above a concentration limit called the → Critical micelle concentration. Nonionogenic surfactants make particularly good washing agents due to some advantages, such as:

– low critical micelle concentration, i.e. they produce a good washing effect at relatively low concentrations;
– high solubilization power for oils;
– low sensitivity to hardness;
– high adsorption power, even on negatively charged surfaces.

Binary mixtures of water and non-ionogenic surfactants pass through several phases in relation to temperature and concentration. In addition to these binary mixtures, ternary systems of the type “water/surfactant/oil” are also of interest (Fig. 1). They can form three-phase micro-emulsions, which offer advantages for washing practice. Microemulsions are optically isotropic, thermodynamically stable systems made up of water, oil and one or more amphiphilic surfactants.

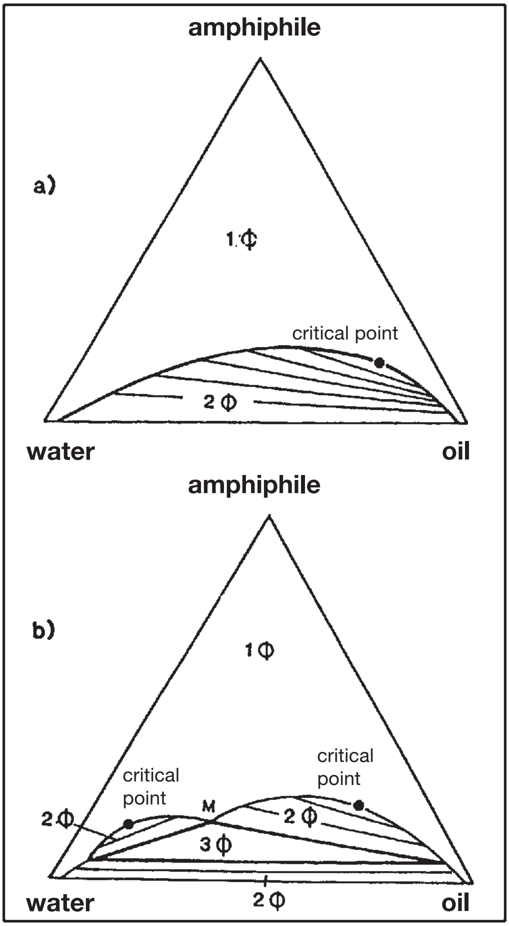


Fig. 1: Gibb’s phase triangle for a tenary system of water, oil and amphiphile (diagrammatic) (according to Kahlweit und Strey).

In a binary phase diagram of the Marlipal system 013/80/water (Fig. 2), the upper closed miscibility gap for surfactant concentrations lies between 0 and 30 percent by weight above 30°C. We can also see the area of the liquid crystalline phase above 45% surfactant by weight, which extends to temperatures equal to the upper closed miscibility gap. Liquid crystal phases however, lead to problems with regard to the kinetics of phase separation, because the surfactant-rich middle phase of such systems has a relatively high viscosity, which leads to a slow separation of the individual phases.

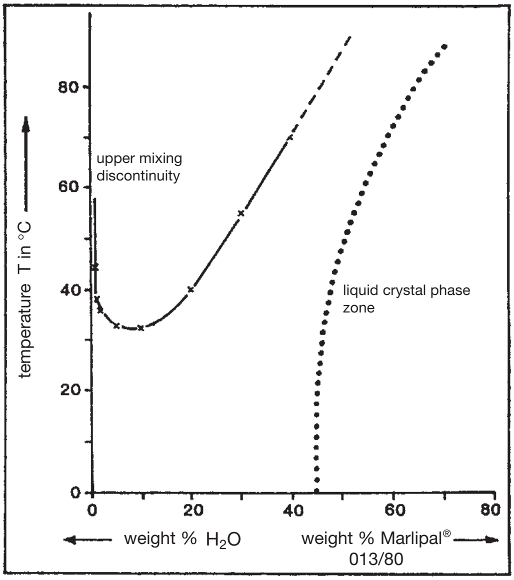


Fig. 2: Binary phase diagram (according to Schollmeyer and Knopf).

The characteristic sections through the Gibb’s phase triangle illustrated in Fig. 3 are worth studying for a suitable oil. These sections can lead to conclusions regarding the system being considered. The representation of the A section as a quasi binary system leads to a “fish-like” body. In the “tail” of this fish the three phase body deals with the surface of the central miscibility gap. The quasi binary representation of sections B and C supply predictions about the length of the coexistence point of the 3 phase area (B section) or about the areas of composition, in which the transition from an oil-in-water to a water-in-oil emulsion in the single phase area is possible. In practice, the temperature allocated to the washing process is an important parameter. The dependence of the superposition of oil on the temperature in the range between 50–80°C contains the transition from the two-phase area into the three-phase area and back into a two-phase area for the system being investigated. The best washing result under these conditions is to be found in the three-phase area. When a technical surfactant and a model oil (toluene) are used with such systems as a washing medium the best washing result is achieved in the single-phase area, if possible close to the transition to the three-phase area (according to Dierkes and also to Schollmeyer and Knopf).

Phase inversion temperature

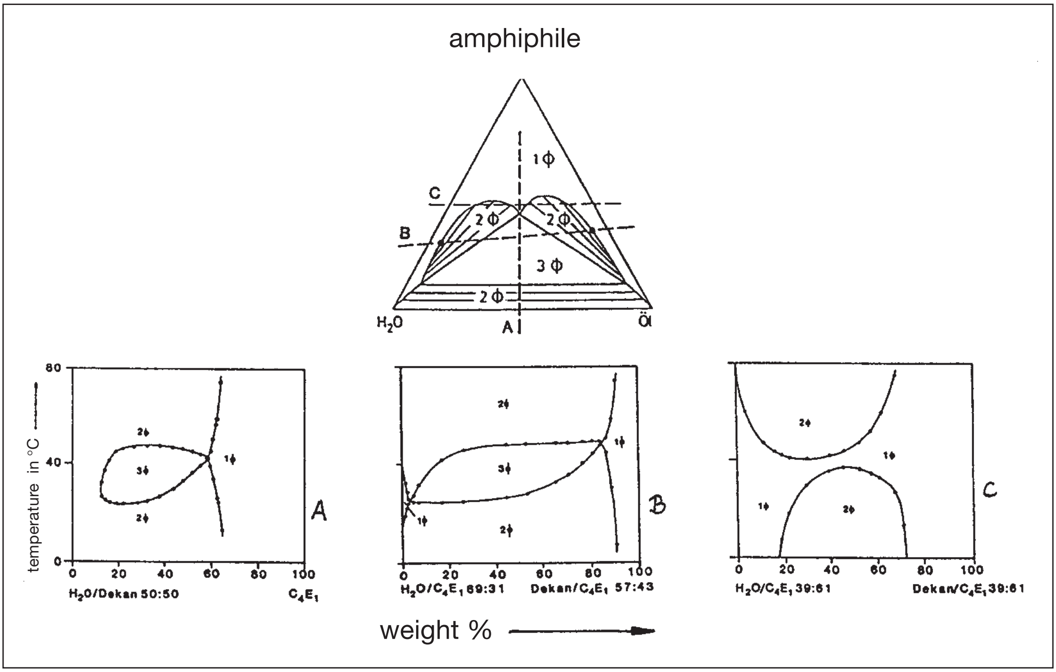


Fig. 3: Significant sections through the phase diagrams of tenary micro-emulsion systems (according to Kahlweit and Strey). n F = n-phase zone, C_iE_j ethoxylised linear alcohol of C-chain length i with j ethoxy units.

Phase inversion temperature (PIT). An emulsion can be made to change phase due to a temperature increase. The dispersed → Phase thus becomes the continuous phase, the continuous phase is dispersed. The Fig. showing the phase diagram of water/dodecane (as oil) with 20% pentaethylene glycol decyl ether by weight shows a micellar solution $M_{O/W}$ (oil is solubilized) at low temperatures and low concentration of oil-in-water. At constant emulsifier concentration, increasing the oil proportion brings us into the area of the O/W emulsion $E_{O/W}$. A great temperature increase and medium temperature brings us into the mesomorphic, liquid crystal phase FL, before a further temperature increase changes this into a W/O emulsion $E_{W/O}$. The FL phase (can be recognised visually by the clearing of the cloudy emulsion) is only stable within a narrow temperature range, because at a small reading below/above this temperature, oil or water coalesce quickly into large drops (the basis of the mechanism of de-emulsification due to temperature increase).

Because a phase reversal takes place in the transition through this temperature range, this critical temperature area is called the phase inversion temperature (PIT).

At the PIT (also known as the → HLB value) hydrophilic and lipophilic characteristics of the emulsifiers maintain the balance. PIT is thus a clear measured value for the emulsifier effect in a certain system. Within homologous rows the PIT increases with increasing hydrophilicity of the emulsifier. To generate stable

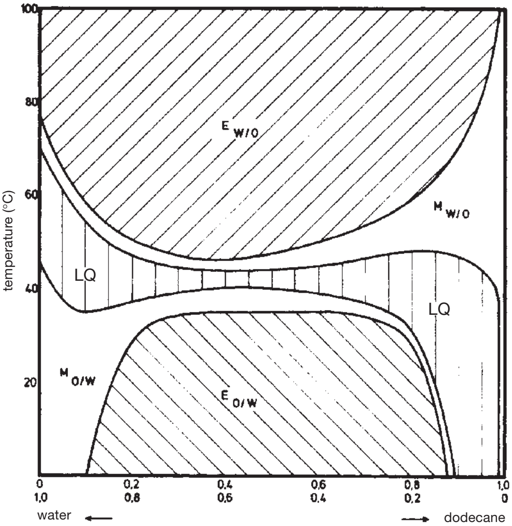


Fig.: Phase diagram of water and dodecane as oil with 20% pentaethylene glycol decyl ether by weight at various temperatures.

emulsions, emulsifiers are selected for which the PIT lies as far as possible from the temperature at which the emulsion is used. For O/W emulsions the PIT should be 20–65°C higher, for W/O emulsions it should be 10–40°C lower. It is recommended that non-ionogenic emulsions are manufactured at a temperature above the PIT and rapidly cooled.

Phase model for the structure of finishing processes One objective of process control technology is to describe and structure the information relating to production processes. The phase model of production is a tool in the structuring of the process and also of information. The results gained from the use of this semantic structuring tool have various applications, e.g. in quality assurance, safety and procedural analyses. The individual process elements can be viewed as operators, which transform the product characteristics from an input into an output state. This model facilitates, amongst other things, the representation of the information flows necessary to conduct the entire process so that the procedure is maintained in its current desired state. It also encourages consideration regarding the information that should be available in and after every individual process element for process control and quality assurance. In each process element monitoring, regulation and control tasks relating to certain product or process characteristics have to be performed.

A further characteristic of the phase model of production is the representation of a production process in varying depth. To achieve this the process is described hierarchically in several levels each with increasing level of detail. In this manner, detailed process information can be ascertained and incorporated into the structure of the phase model.

The application rules for the structuring of a process with the aid of a phase model of production are illustrated in the sample process “piece dyeing of cotton” in the Fig. The process, which is illustrated in three levels of detail, is structured so that it can be described with the aid of the process elements and the associated products which are allocated to the different levels.

The levels are defined by vertically structuring the processes into the levels “procedure”, “procedure step” (which is the specific term for “part process” in the case of a continuous production process) and “Procedure element”: The procedure supplies a textile with predetermined characteristics. Examples are desizing, dyeing, mercerizing etc. The procedure steps, which are part of the procedure, deliver a predetermined change of state in the textile in the sense of textile finishing. The procedure steps usually take place in a finishing group or are characterized by a certain recipe structure. Examples of procedure steps are impregnation, steaming and washing. A procedure element is the smallest indivisible

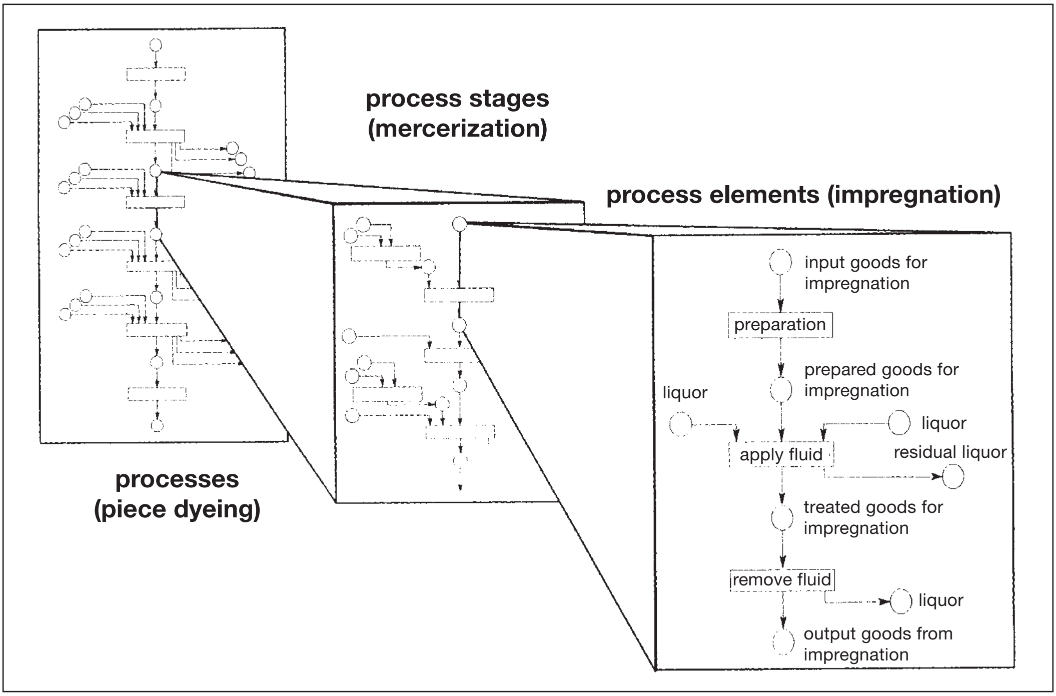


Fig.: Phase model of production in “processing of cotton piece goods” (according to Wulfhorst).

process in a procedure. It represents part of the treatment of a material that takes place in a single procedure element or a group of linked procedure elements, e.g. heating, cooling, extraction, squeezing, dipping, mechanical guidance of the material. The process elements of the first level are further detailed at the procedure step level, whereby the sample process is limited to the minimum possible number of procedure steps (washing, impregnation, reaction and drying). This incorporates products such as wetting agents, water and enzymes. At the procedure element level the procedure steps are described using standardized elements (preparation, application of liquor, liquor removal, dwelling, heating, cooling).

The process is structured in accordance with the classification of process and product characteristics. Process characteristics include state variables, process parameters, control variables, adjustment parameters and process indicators, and product characteristics include physical and chemical variables, technological characteristics and product indicators. In order to maintain an overview of the large amount of data, the characteristics are allocated to the following categories:
- organizational data,
- technological characteristics,
- physical characteristics,
- chemical characteristics.

The classification of the characteristics will become clear in the next step, the structuring and sorting of process and product characteristics in tabular form. This stage determines which characteristics can be measured "on-line". After the characteristics of the substances to be added or removed have been described, such as chemicals (type, quantity), water (quantity, hardness, purity) and exhaust (pollution, smell, temperature), the detailed procedure elements, such as dwelling, heating and cooling can be allocated specific characteristics, e.g.
- process form (continuous, discontinuous),
- type of material feed,
- voltage,
- temperature, etc.

If the sample process is structured using the phase model of production, then the results yielded can be interpreted with regard to a predetermined task formulation (according to Wulfhorst).

pH dependence of wool The relationships between the pH determined during manufacture and the change of the textile characteristics of the wool fibre was investigated by Elöd. He systematically deduced the relationships between pH (plus temperature) of a wet finishing bath and the chemical and physical characteristics of the wool keratin, and evaluated their implications for practical application. Wool can be finished at the → Isoelectric point in a manner that protects the fibres. The chemical and textile mechanical properties of the wool will be impaired in the event of deviation from this point (pH 4.6 at 90 °C) in both directions at boiling point. Dyeing takes place (except for 1 : 1 metal-complex or acidic levelling dyes) between pH 4 and 7.

In the wide range between pH 4 and 8 for wool neither acid nor base are bound (Fig.) and the charge remains zero (isoelectric zone). This is a result of the insolubility of wool and the formation of an electric double layer on the surface of the fibre. Hydrogen ions can only penetrate this with difficulty. The addition of salt reduces the electric double layer so that the wool behaves like a soluble protein and the curves for the acid and base absorption meet at the isoionic point.

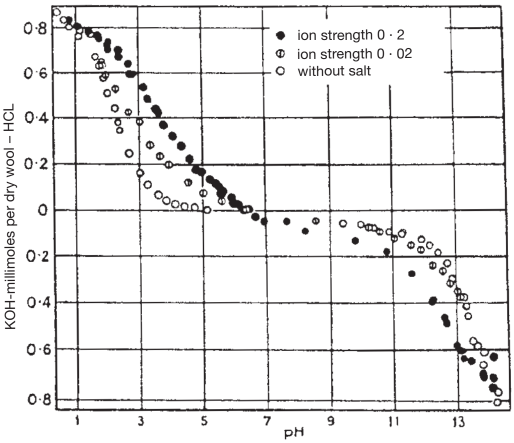


Fig.: Titration curve for wool (according to Steinhardt and Harris).

Phenol (carboxylic acids, C_6H_5OH), molecular weight 94.06; density 1.06; crystals or coarse crystalline mass, colourless to reddish, melting point 43°C, typical odour, (synthetic phenol up to 5% application odourless), water soluble (1 : 15), also soluble in alcohol, ether, benzene, chloroform etc.; aqueous solution slightly acidic, highly corrosive, toxic, volatile in combination with water vapour. Concentrated phenol solution dissolves acetate and polyamide fibres (fibre detection). Application: Antiseptic for chemical finishing (liquor ratios of 1 : 100 work reliably); solvent and saponification agent for acetate; good solvent for cationic dyestuffs (particularly for methyl blue); developer for substantive dyes; manufacture of synthetic resin, chemical finishing etc. Phenol and its derivatives are classed as → Co-carcinogen.

Phenolates Aromatic compounds originating from → Phenol in which the hydrogen atom of the hydroxyl group (OH) is replaced by metal.

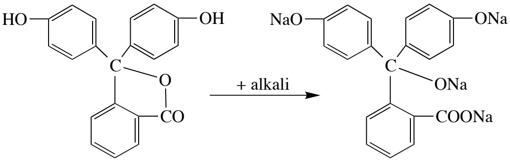
Phenol coefficient Comparative figure, comparing the effect of aromatic disinfectants and preservatives against bacteria with that of → Phenol, the effectiveness of which is equated to 1. The phenol coefficient varies considerably for different comparative products depending upon the chemical constitution, which is also almost always the case for the same product in relation to different bacteria cultures.

Phenol gential violet solution Micro colour reagency for → Gram stain made of 10 ml saturated alcohol solution of gential violet (mixture of methyl violet and crystal violet) + 1 ml phenol, topped up to 100 ml with distilled water.

Phenolic plastics → Synthetic resins made of phenol formaldehyde by polycondensation. A differentiation is normally made between a) non-hardenable (meltable) synthetic resins, soluble in solvents, e.g. as a shellac substitute, and b) hardenable synthetic resins of the bakelite type, temperature deviating and swellable in solvent or meltable and non-soluble in solvents. Latter are pure high grade synthetic resins (colourless, odourless, highly refractive, cannot be scratched with the fingernails, poor conductor of heat and electricity, temperature resistant up to 300°C, resistant to diluted acids and alkalis).

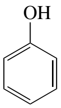
Phenolic resins → Phenolic plastics.

Phenolphthalein(paper) White powder, in solution of 1 g in 100 ml alcohol. Very sensitive indicator of alkali traces. Transition interval: pH 8.2–10. In the range pH 7–8.5 pink shade, above that crimson (recognisable at dilutions of 1 : 1 000 000). Even weak carbon dioxide acts on alkali reddened phenolphthalein paper.



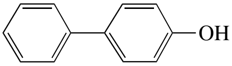
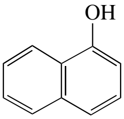
Colourless in the form of free acids, sodium salt red coloured. Application (solution or paper): Alkali detection on wool, for wash liquor, vat dyeing, etc.

Phenols Aromatic compound with hydroxyl groups directly attached to cyclic hydrocarbon(s).



phenol

Differ from aliphatic → Alcohols due to their stronger acidic properties (are also weak acids). Dissolve in weak aqueous alkalis, form → Phenolates and produce a deeply coloured co-ordination compound with iron(III) salts. Most important derivatives:

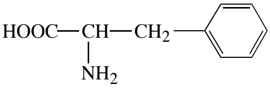
C_6H_5 OH	phenol (hydroxybenzene, phenylic acid)
C_6H_4 $(OH)_2$	resorcinol (meta-dioxybenzene)
C_6H_3 $(OH)_3$	phloroglucinol (1, 3, 5-tribenzene)
CH_3 C_6H_4 OH	cresol (methylphenol; o-, m-, p-isomers)
$(CH_3)_2$ C_6H_3 OH	xylenol (dimethylphenol, as disinfectant and mercerizing assistant)
CH_3 C_6H_3 Cl OH	para-chloro-m-cresol
C_6H_2 Cl_3 OH	trichlorophenol
C_6 Cl_5 OH	pentachlorophenol (hexachlorophene)
C_6 H_5 SH	thiophenol type (sulphur phenol)
	phenylphenol type
	naphthol type

Application: Phenoplasts, mercerizing assistant, disinfectant and preservative, carrier, developer for direct dyes, solvent for cationic dyes, acetate delustring, etc.

Phenothiazine → Heterocyclic compounds.

Phenoxazine → Heterocyclic compounds.

Phenylalanine A cyclic → Amino acid (monoamino monocarboxylic acid).



Contained in wool (3.75%) and silk (1.5%).

Phenylene group C_6H_4, bivalent radical, contains two hydrogen atoms less than → Benzene, from which it is derived.

Phenyl group C_6H_5, monovalent radical of the benzene residue, contains one hydrogen atom less than → Benzene.

Phenyl lithium test Unambiguous detection and differentiation of

1. Polyacrylonitrile and polymethacrylic acid ester. Based upon the conversion to lithium carbinols, from which free carbinols produce characteristic conversions and colour reactions.
2. Polyvinylchloride (also post-chlorinated), polyvinylether and polyvinylchloride co-polymerizate. Converted polyenes are used for the colour reaction.

Phenylphenols (oxydiphenyls, arylphenyls, hydroxydiphenyls) used as preservatives and carriers (swelling agent). No longer widely used in Europe for ecological reasons.

I. Ortho-phenylphenol: White, crystalline or scaly, melting point 58°C, boiling point 287°C. Usually used in the form of sodium salt. Application: Preservation of finishes, sizes, adhesives, textile assistants, textiles, leather; against rancidification of solid soaps and as the cheapest carrier in the dyeing of polyester and polyacrylonitrile.

II. Para-phenylphenol: Colourless, lustrous needles of flakes, melting point 164–165°C, very soluble in alcohol and ether or with caustic soda. Application: Antioxidant for greases and oils; wood preservative; carrier for polyamide, polyester (more difficult to wash out than I).

-philic (Gk.), loving, friendly, attractive, e.g. →: Amphiphilic; Hydrophilic; Lipophilic groups; Lyophilic. Opposite: → -phobic.

Phlobaphenes Anhydrides or oxidation products of → Tanning agents. Are particularly difficult to dissolve.

Phloem (Gk.), so-called “young soft bast”, e.g. in stalk bast fibres (→ Flax stem structure). Consists mainly of the still soft screen part (screen tube as conduction elements for the transport of sap), in which the forming cells of the young bast or phloem fibres are embedded.

Phloroglucinol (1,3,5 trioxybenzene), $C_6H_5(OH) \cdot 2\,H_2O$. White or yellowish crystals, soluble in water, easily soluble in alcohol and ether; reduced → Fehling’s solution in heat. Application: Detection of lignin and pentose (→ Phloroglucinol reaction).

Phloroglucinol method For the colorimetric formaldehyde detection of synthetic resin finished textiles with → Phloroglucinol according to Japanese specification (MITI test methods). The possibility of important secondary reactions must be taken into account.

Phloroglucinol reaction Solution of 10% → Phloroglucinol in alcohol and concentrated hydrochloric acid. Used for the detection of:

I. Wood pulp substances. The higher the lignin content, the stronger the colouring:

native protein substances	not coloured
regenerated protein fibres	not coloured
regenerated cellulose fibres	not coloured
cotton, flax	not coloured
ramie	not coloured
hemp	pink in places
jute	dark reddish violet

II. Protein viscose (reddish brown) next to wool or undyed silk.

III. Oxycellulose (red colouring) next to hydrocellulose (no red colouring).

pH measurement Used for determining the concentration of → Hydrogen ions (→ pH), using the following methods in particular:

I. Colorimetric measurement using pH indicators. When dissolved, the degree to which these indicators are present in a dissociated state depends upon the pH of the solution, and they therefore supply pH-specific colour changes. By arranging the indicators, which each represent 1.5–2 pH units by specific colour shade transitions, the entire pH scale can be detected colorimetrically. Due to certain temperature dependencies of the pH the reference temperature selected, unless stated otherwise, is 20°C.

Colorimetric measuring methods are usually cheap to use, simple and quick to perform, but are not all associated with maximum precision. They are however adequate for practical purposes. The method of application uses either a) indicator solution, in which individual indicators or a mixture in the form of so-called universal indicators are common (drop-by-drop application, comparative measurement with buffer solution of a known pH or more simply with artificial colour comparison standards, even for dark and dyed solutions. Error limit of pH ± 0.1); or b) pH paper, i.e. paper strips impregnated with an indicator, which is submerged for a few seconds and the shade that appears after 15–30 s compared with a colour scale to find the appropriate pH. Difficulties or inaccuracies are possible, particularly with high temperature bleaching liquors, dark coloured solutions, liquors with ionogenic textile assistant additives, protein compounds and colloids etc. Common as universal indicator paper (measuring range and accuracy vary depending upon origin), also as special indicator paper for greater accuracy. Measuring accuracy approx. pH ± 0.2; also suitable for coloured and cloudy solutions); or c) pH foil (similar to b), impregnated cellophane strips, commercially available as foil colorimeters, pH foils, etc. Application: Submerge for 1–2 min, possibly rinse briefly for coloured or cloudy solutions, accuracy approx. pH ± 0.1–0.2; colloidal dispersions and chloric and poorly buffered solutions between pH 5–8 cannot be measured.

II. Electrometric or potentiometric pH measurement is based upon the measurement of the voltage difference (potential difference) between two electrodes (so-called electrode chain) in mV, which serves as the measured variable for pH. The electrode chain consists of a reference electrode with a constant potential (usu-

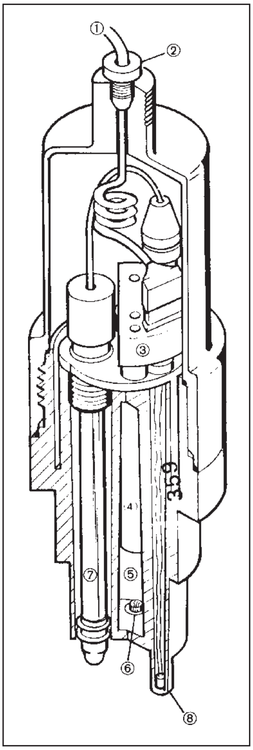


Fig.: Sketch showing the principle of the Type 381 pH/ ORP probe (Rosemount AG).
1 = connecting cable;
2 = cable holder;
3 = preamplifier or connecting plug;
4 = reference electrode;
5 = electrolyte chamber;
6 = diaphrams;
7 = glass electrode;
8 = temperature sensor.

ally in the form of a saturated potassium electrode) and a measuring electrode submerged in the solution being measured, the potential of which depends upon the current pH of the solution. The glass electrode (see Fig.) is the most important as a useful dip or flow measuring electrode. Universally applicable for pH 0–13, also for oxidation and reduction processes and for bleaching liquors of all types; however, it is attacked by caustic alkalines above pH 12 or, if the temperature is higher, at lower pH. Has a thin glass membrane diaphragm. The compensation potentiometer is used as a simpler instrument, and for higher demands, the high-ohmic tube potentiometer (almost unbreakable, accuracy around pH 0.1–0.01) is commonly used, which for operational purposes is also available with simplified operation, direct pH display, mains or battery operation, transportable, etc. In the so-called single rod measuring chain both electrodes are combined in a simple component (resistant to mechanical loads, always ready to measure, submersion length up to 1.2 m). Possibility of continuous monitoring, remote display, signalling, continuous registration, automatic control etc. There are also efficient devices for simple direct measurement on the surface of the wet textile material.

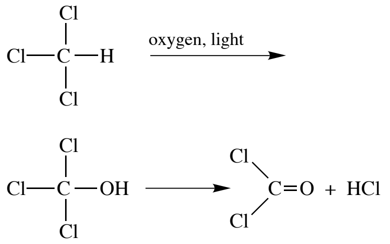
-phobic (Gk.), avoiding, hostile, fleeing, repellent; →: Hydrophobic; Lipophobe; Oil-repellent. Opposite: → -philic.

pH of fibre extracts Determination procedure: Fibre samples are leached for 60 min at room temperature in distilled water in a liquor ratio of 1 : 5, 1 : 10, 1 : 20 and 1 : 50 (in polyethylene bottles). The pH of the extracts is measured with a glass electrode and plotted against the associated liquor ratio in a co-ordinate system. The curve obtained is extended to intersect with the pH ordinate. This point is the pH (extrapolated) at a liquor ratio of 1 : 0 and corresponds with the pH of the fibre. It can be determined both graphically and by calculation and is applicable for all fibrous material (for wool only at pH < 3 or > 11).

Phormium fibre → New Zealand flax or → Hemp.

Phosgene (chlorocarbonic acid, carbonyl chloride), $COCl_2$, colourless, pungent smelling, highly toxic gas. In companies working with tetrachloroethylene it is, in some circumstances, a gas that occurs unchecked (by smoking or near a heating system) and is thus a “particularly dangerous substance” with a high inhalation toxicity (IT). Used e.g. for the synthesis of triphenylmethane dyes (→ Phosgene formation from chlorinated hydrocarbons). In order to protect against corrosion and damage to health, naked flames (e.g. from gas heated machines in the same room) and smoking should be avoided in working areas containing chemical cleaning plants or finishing operations that involve chlorinated hydrocarbon plants.

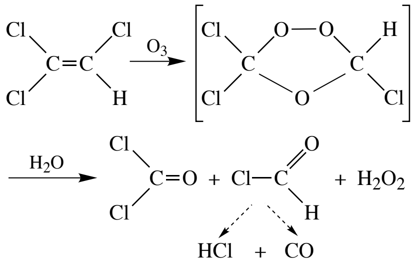
Phosgene formation from chlorinated hydrocarbons In chlorinated hydrocarbons from the methane series: In air and under the effect of sunlight, gradual oxidation occurs in chloroform accompanied by the formation of highly toxic phosgenes. The hydrogen in the triple chlorinated carbon atom can be compared with an oxidized carbon atom with regard to its sensitivity to oxidants. It is assumed that a hydroxylation takes place in the first stage.



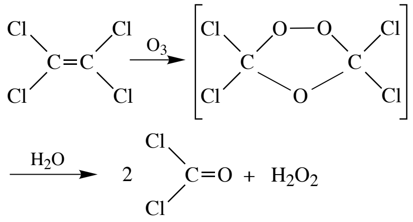
$$Cl_3C{-}H \xrightarrow{\text{oxygen, light}}$$

$$Cl_3C{-}OH \longrightarrow Cl_2C{=}O + HCl$$

In chlorinated hydrocarbons of the ethane series: If the chlorination production of ethylene is considered, even very pure trichloroethylene without a stabiliser is seen to be only resistant with the exclusion of light and air. Otherwise it decomposes, forming hydrogen chloride, carbon monoxide, phosgene and dichloroacetylene chloride after some time. After the addition of phenols, amines (most commonly triethylamine) or terpenes, it is stable in the presence of moisture. If the oxidation conditions are increased by ozonification, then the reaction may take place according to the following diagram:



This ozonification reaction is also feasible with tetrachloroethylene (perchloroethylene):



The ozone needed for the reaction can be created by static electricity, spark discharge onto hot iron and possibly by smoking in work areas.

Phosphatases → Esterases.

Phosphate, condensed (polymer phosphates), → Complex phosphates, are created by polycondensation of mono or dialkali monophosphates or their mixtures. Annular, chain-form and cross-linked products can be created. Basic types:

- diphosphates (pyrophosphates).
- triphosphates (tripolyphosphates).
- metaphosphates.

As the chain length increases the complex bonding capacity for water hardening salts increases, but the dispersing power decreases.

Properties include:

1. Buffering power: Due to metaphosphates = slightly acidic and neutral; due to polyphosphates = slightly alkaline; due to diphosphates = highly alkaline.
2. Complex bonding of alkaline earth and heavy metal ions. A differentiation must be made between stoichiometric and hypostoichiometric phosphate addition. Only in the first case does complex bonding of the multivalent metal ions occur. In the event of hypostoichiometric addition of condensed phosphates the precipiation of water hardening salts is prevented or delayed due to the physical effect of the added phosphate. Condensed phosphates in an aqueous solution are cation exchangers according to the equation

   $$n\ Alk^+(H_2O)_x(\text{phosphate})_n^-$$

   The alkali ions can be replaced by multivalent metal ions. If all the sodium ions are replaced by calcium, then water insoluble calcium polyphosphate is formed.
3. Suspending property and peptization property for pigment dirt.
4. Reduction of the titre of soap.
5. Supporting the washing effects of surfactants.
6. Adsorption suppressing effect, i.e. making it easier to rinse surfactants out of textiles.

Condensed phosphates tend to hydrolyse in neutral and alkaline solutions at temperatures above 60°C. Application: Softener for water, removal of iron, copper and manganese salts (rubber poison). Stabilizing effect for peroxide bleach, auxiliary in milling, degumming, washing, desizing, etc.

Phosphate “glass” Colourless, glass-like, non-crystalline → Polyphosphates. Phosphate “glass” is obtained under certain conditions by the heating of mixtures of mono and disodium monophosphate and the subsequent quenching of the melt. Such “glasses” are available commercially in the form of white powder and dissolve as a non-crystalline, glassy material. Depending upon their composition they possess good to excellent lime binding power, are much less temperature dependent and thus can be used equally well in the cold or at high temperatures.

Phosphate inoculum As the name suggests, phosphate inoculum is the water-soluble complex phosphate best suited for the phosphate inoculation process (→ Inoculation). Its specific protective mechanism is that it greatly reduces the precipitation of calcium carbonate and also, should calcium carbonate crystals in fact form, they are sufficiently modified in both size and physical shape that they are no longer capable of building a cohesive structure (scale).

Phosphate process for water softening and silicate removal The addition of → Trisodium phosphate (TSP) at temperatures above 50°C facilitates a quantitative reaction sequence without excess salt, quicker precipitation of hardness constituents, precipitation of silicates and colloids, easier filtration, simplified dosing and monitoring, reversal of elutriation losses, more uniform heat transfer, simplified boiler cleaning, etc. Principle: Conversion of hardness constituent to coarse flakes (completely insoluble) phosphates, with (sodium) sulphate, chloride, etc. remaining dissolved. Result: Virtually total softening and desilification.

Phosphates Derivative of → Phosphoric acid. To be differentiated between:

I. Inorganic phosphates in the form of salts of the tribasic monophosphoric acids H_3PO_4;

a) primary or monobasic type NaH_2PO_4 (monosodium monophosphate);

b) secondary or dibasic type Na_2HPO_4 (disodium monophosphate);

c) tertiary or tribasic type Na_3PO_4 (trisodium monophosphate).

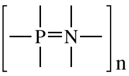
There are also condensed (polymer) phosphates; these include: metaphosphates (annular structure) and polyphosphates (chain structure), such as diphosphates, triphosphates, etc.; Graham's salt, and cross-linked phosphates (perphosphates, perpyrophosphates).

II. Organic phosphates in the form of esters of phosphoric acids.

Phosphate substitutes Relate to alternative efforts (since the start of the 1960s) to find substitutes for → Polyphosphates in order to achieve better ecological properties. Attempts aim to combine the positive washing agent properties of polyphosphates with toxicological and ecological harmlessness, plus faultless biological cleaning in sewerage plants. Well over 1000 substances have now been investigated, with the outcome that the performance of sodium triphosphate as a builder can be achieved by hardly any other phosphate substitute. Further phosphate substitutes are phosphoric acid derivatives, polyhydroxy compounds, polycarboxylic acid, hydroxy, oxo and oxacarboxylic acids, ester carboxylic acids, sulphor compounds and other compounds, including sodium-aluminium silicate.

Phosphating In the specific case of interface-active bodies this is a chemical reaction, in which phosphoric acid esters are created.

Phosphazenes Phosphor-nitrogen compounds of type

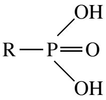


$$\left[-\overset{|}{\underset{|}{P}}=\overset{|}{\underset{|}{N}}- \right]_n$$

Spinning additive for the manufacture of flame retardant viscose fibres. Manufacture by esterification of a mainly trimeric chlorophosphazene (phosphorus chloronitrile). The best flame retardant finishes are achieved by alkyloxyphosphazene, chloralkyloxyphosphazene and alkylthiophosphazene compounds. Phosphane oligomers and polymers are also recommended. Approx. 20% should be spun in to achieve the desired effect. All these additives cause a certain reduction in the stability of the viscose.

Phosphines Similar to → Phosphonium compounds; alkyl substitution products of phosphorus hydride PH_3 of type R_2–PH or R_3–P; colourless bases, the basicity of which increases with the alkyl number.

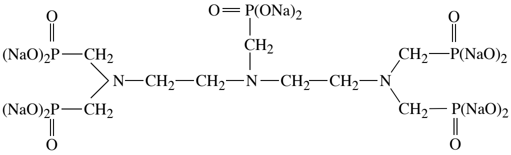
Phosphonates Types of the general formula



used for the stabilization of peroxide bleach, specifically

– amino phosphonates with nitrogen substituents;
– hydroxyphosponates;
– carboxyphosphonates.

The best results with regard to stabilisation are achieved with amino phosphonates that contain at least two phosphate groups. A phosphonate used as a stabiliser can be structured as follows:



This is a sodium salt of diethylene triamino pentamethylene phosphonic acid.

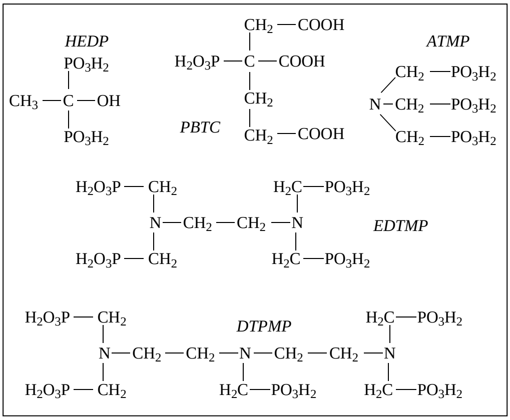


Fig.: Chemical structure of the important phosphonates.

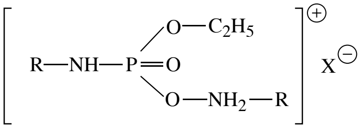
Phosphonates (see Fig.) in the quantities normally used in the finishing industry are assessed as follows:

– non-toxic to humans, animals and plants (at least not so far known);
– under aerobic conditions almost entirely non-biodegradable;
– degradable by photolysis;
– can be biologically eliminated by adsorption on different surfaces;

- chemical-physically eliminable by precipitation;
- low base mobility;
- its remobilisation power can be disregarded in relation to heavy metals.

Phosphonation Chemical reaction or reaction sequence, in which a molecule is introduced into one or more phosphoric acid groups with a direct phosphor/ carbon bond (→ Phosphonium compounds).

Phosphonium compounds Phosphor complexes of type (alkyl)$_4$P. Thus quaternary compounds, derived from co-ordinative pentavalent phosphorus and used as cationic-active products for improving fastness. However, the nitrogen-phosphor complex, also positively charged, is also of interest:



They represent cationic softeners and emulsifiers, which are oil-soluble and dispersible in water. Phosphonium compounds are important for flame-retardant finishes or as a mothproofing agent.

Phosphor bronze gauze → Screen mesh, screen gauze.

Phosphoramides → Phosphoric acid amides.

Phosphorescence Appearance of afterglow. A property possessed in particular by → Phosphors. The principle rests upon the retransmission of light energy accumulated (stored) previously during illumination. Procedure is thus not identical with the luminous phenomenon of phosphorus (→ Luminescence).

Phosphoric acid (monophosphoric acid), H_3PO_4, density 1.88. Salts → Phosphates. Rhombic, deliquescent crystals (melting point 41–42°C) or syrupy aqueous solution (70–89%, density 1.508–1.750), medium strength acids (less corrosive than sulphuric acid), tribasic (→ Phosphoric acids). Application: Dyeing of wool (with acid and chrome dyes); non-shrink finishing of wool; occasionally for silk softening; 89% phosphoric acid as cellulose solvent.

Phosphoric acid amides Compounds of phosphoric acid with amines or substituted amines for flame-retardant finishing. Nitrogen increases the flame retardant effect of organic phosphor compounds.

Phosphoric acid ester → Spinning preparations for friction texturizing.

Phosphoric acids,

$(HPO_3)_n$: Metaphosphoric acids, annular (n = 3 or 4); salts are genuine metaphosphates (e.g. sodium metaphosphate).

$(HPO_3)_n \cdot H_2O$: phosphoric acids; salt = polyphosphate (highly condensed, i.e. n is large).

H_3PO_2: hypophosphoric acid, monobasic; salt = hypophosphite (NaH_2PO_2), easily soluble in water, strong reducing agent.

$(H_2PO_3)_2$: corresponds with $H_4P_2O_6$.

H_3PO_3: phosphorous acid, dibasic; salt = phosphite (Na_2HOP_3 or NaH_2PO_3); more or less water soluble, weak reducing agent.

H_3PO_4: (mono) phosphoric acid, tribasic; salt = phosphate.

H_3PO_5: peroximonophosphoric acid; salt = peroximonophosphate.

$H_4P_2O_5$: diphosphorous acid.

$H_4P_2O_6$: per(di)phosphoric acid, strong acid, slightly reducing; salt = hypophosphate.

$H_4P_2O_7$: diphosphoric acid, tetrabasic; salt = diphosphates ($Na_4P_2O_7$), formation of phosphates in aqueous or particularly in acid solution.

$H_4P_2O_7 \cdot 2\,H_2O_2$: perpyrophosphoric acid; salt = perpyrophosphates.

$H_4P_2O_8$: peroxide phosphoric acid; salt = peroxide phosphate (polyphosphates)

Phosphoric acid trialkyl ester Used as → Wetting promotors.

Phosphors Light carriers, usually inorganic → Luminophores, which produce → Phosphorescence effects and consist of three different components depending upon the type of so-called Lenard phosphor:

1. light sensitive base substance (e.g. sulphide of cadmium, calcium, magnesium, strontium).
2. flux (e.g. sodium tetraborate, fluorite (calcium fluoride), sodium chloride, sodium phosphate).
3. traces of light generating heavy metal (e.g. copper, manganese, silver, thallium, bismuth).

In all cases daylight or artificial light previously accumulated in the phosphorus is re-emitted as a night-time illumination (8–24 h). This effect is easily recognized from several metres away.

Phosphorus (P). Chemical element, atomic mass 31; non-metal; crystalline mass (translucent rods), yellowy-white; waxy; smokes in air; slightly (self) ignitable (oxidation); glows in the dark (phosphorescent); very toxic; density 1.8; melting point 44.5°C; barely water soluble, but soluble in carbon disulphide, benzene, fatty oils. At 200°C red phosphorus is formed; insoluble in the above solvents, non-toxic. At 300°C black, metallic phosphorus. Compounds: Phosphorus hydride PH_3 (forms → Phosphines and → Phosphonium compounds), Phosphorus oxide (tri, tetra, pentoxide P_4O_6, P_2O_3, P_2O_4, P_2O_5). The latter and water yield → Phosphoric acids, halogen compounds, etc.

Phosphorus-containing polymers Whereas the flame-retardant effect of halogen compounds on fibres acts mainly in the gas phase and influences the burning mechanism by trapping radicals, the active mechanism in the pyrolysis of phosphorus compounds exists, but its function is unclear. Polymer phosphorus compounds

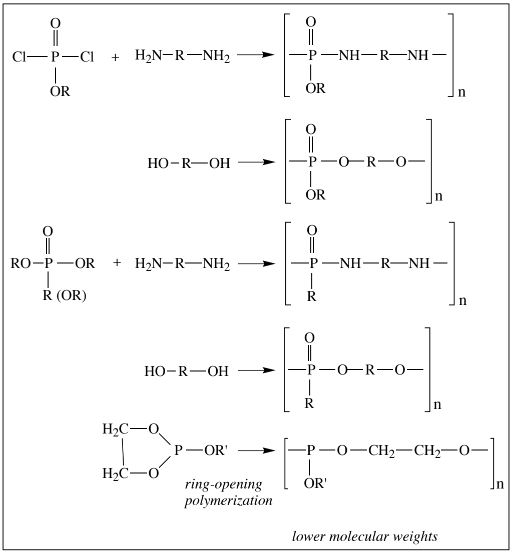


Fig. 1: Methods of representing macromolecular phosphorus compounds.

can be spun into polyacrylonitrile fibres if the phosphorus polymers are soluble in dimethyl formamide (DMF). The two polymers must be compatible with each other. The phosphorus can be anchored in the main chain or the side chain of the polymers. Cyclic phosphites can be converted into polyphosphites by ring-opening polymerization (Fig. 1).

Monomers with covalent bonds and phosphorus in the side chain can also be polymerized (Fig. 2).

Subsequent polymer-like attachment of the phosphorus to the side chain can also be realised (Figs. 3 and 4).

The washing fastness effects could be improved by the creation of copolymerisates from acrylonitrile and the phosphorus-containing acrylic acid esters. The spun phosphor-containing fibres show a surprisingly high degree of whiteness. The flame retardant effect is strongly dependent upon the chemical constitution of the phosphorus compounds. On the other hand, the same phosphorus content in the fibre leads to different flame retardant effects in different compounds (see Tab.). Copolyester also, which is obtained by the inclusion of phosphorus-containing comonomers in the polymer structure (Fig. 5), burns with difficulty. The comonomers are directly linked into the chain (according to Herlinger).

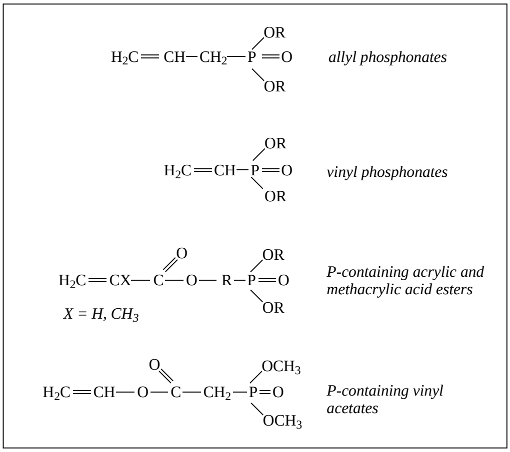


Fig. 2: Monomers in the production of polymer phosphorus compounds.

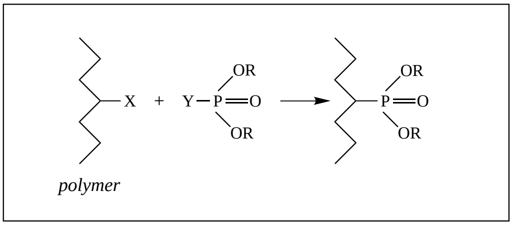


Fig. 3: Macromolecular phosphorus compounds by polymer-like conversion.

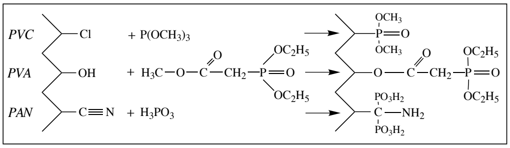


Fig. 4: Completed polymer-like conversions.

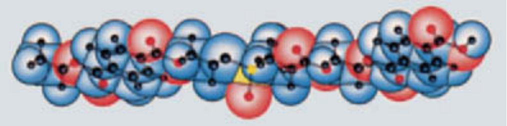
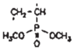
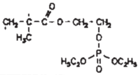
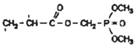
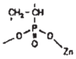
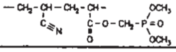
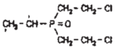


Fig. 5: Inclusion of a phosphorus-containing comonomer in the polymer structure of Trevira CS (Hoechst).

Phosphorus determination Determination according to DIN 38 405, Part 11; Phosphorus compounds are converted to o-phosphates by concentrated sulphuric acid and potassium peroxodisulphate ($K_2S_2O_8$) by boiling. The o-phosphate created in this manner is added to molybdate reagent, creating molybdenum blue. The intensity of the colour is determined photometrically and is proportional to the o-phosphate

compound type	formula	% P in polymer	% additive in PAC	% P in fibre	L O I	burning properties in vertical test
polyvinyl phosphonate		22,8	26,3	6,0	––	burns
polymethacrylic phosphonate D M P		11,55	32,2	3,71	24,1	burns
polyacrylic phosphonate D A P		15,87	22,7	3,61	28,1	self-extinguishing
polyvinyl phosphonic acid (Zn salt)		28,7 (18,4)	14,1	2,59	29,1	self-extinguishing
copolymerizate DAP/AN (16.8 %)		13,29 13,29	41,0 29,0	4,27 3,85	27,2 23,7	self-extinguishing burns
poly-bis-chlorethylvinyl phosphonate		13,30 + 30,47 Cl	30,0	6,0	21,0	continues to burn
red phosphorus	P_4	100	5,5	5,5	25	continues to burn

Tab.: Dependence of the flame retardant effect of various phosphorus compounds on chemical make-up in polyacrylnitrile fibres.

content of the sample. A calibration graph is necessary for evaluation.

Phosphorylase Ferment (magnesium adenylic acid protein), which splits starch into glucose (in test tube also artificial starch structure from glucose), whereby inorganic phosphate is inserted at the dissolved link point of the glucose molecule and splits glucose-I-phosphate.

Photoacoustic colour measurement Photometric spectroscopy encompasses numerous sensitive absorption spectroscopies, which are based upon the conversion of absorbed light energy into heat, whereby the induced temperature increase serves as the measured variable. A specific measuring arrangement is called photoacoustic spectroscopy and can be used for darker and more saturated dyes than colorimetry. A significant advantage of photoacoustic colour measurement, according to original theories, appeared to be its independence of the surface roughness of the sample. This would have meant that, unlike remission spectroscopy, no large databases need be stored to perform a colour analysis. However, investigations have shown a strong dependency on the fabric geometry. New theories indicate a relationship between the surface roughness or the porosity of the material and the photoacoustic signal. This means that appropriate corrections must also be made in photoacoustic colorimetry.

Photoacoustic spectroscopy Measuring procedures that facilitate on-line monitoring of dye concentration, or concentrations for mixed dyes and automatic after-dosing are desirable for a time-dependent monitoring of dye liquors. For current measuring procedures, for example, in transmitted light photometry, it is a great disadvantage, that in practice complex solutions exist, often with low transmission, which means that it is almost impossible to work with universal measuring cells, and drawn spectra are difficult to interpret or cannot be interpreted at all. Absorption spectroscopic measuring techniques, for example photoacoustic spectroscopy, have proved their worth as an effective procedure for determining material properties of solids. In such techniques the secondary effects (sample heating or expansion) of the energy absorbed is the origin of the measurement signal, so that unlike remission or transmission spectroscopy the absorption properties of the sample are determined directly.

For certain wavelength ranges the interaction of light with a coloured textile material leads to excited electronic states of the dye molecule. The deactivation of the applied light energy occurs partly without radiation (“internal conversion”) and is therefore converted into heat. Dyes undergo further competing processes such as fluorescence, phosphorescence and photochemical reactions, however it is assumed that the total light energy is converted into heat. These photo-physical excitation and relaxation processes are shown in a simplified manner in the Jablonski diagram in Fig. 1.

Photoacoustic spectroscopy is, in principle, a form of absorption spectroscopy. The sample is placed in a gas-tight cell of constant volume and is illuminated with an intensity-modulated Xe light (Fig. 2). The part of the absorbed light energy that is converted into heat

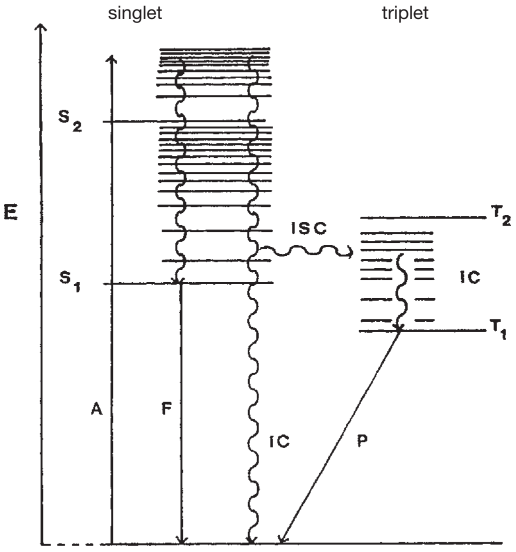


Fig. 1.: Jablonski diagram. Radiation emitting transfers involving the exchange of photons are indicated with straight arrows, non-emitting transfers with wavy arrows.
A = absorption; F = fluorescence; P = phosphorescence; ISC = inter-system conversion; IC = internal conversion.

causes pressure variations in the gas, which then dissipate as sound waves. The sound amplitude detected by the capacitor microphone is proportional to the light energy absorbed. Textiles differ according to their optical and thermal properties and are optically opaque and thermally dense solids. A sample is opaque if the optical penetration depth $l\beta$ is less than the investigated layer thickness l_p of the sample.

The optical penetration depth $l\beta$ is equal to the reciprocal of the absorption coefficient β:

$$l\beta = \frac{1}{\beta}$$

The thermal properties are defined using the thermal diffusion length μ:

$$\mu = \left(\frac{2\alpha}{\omega}\right)^{1/2}, \alpha = \frac{\kappa}{\rho\, C}$$

α = thermal diffusivity,
ω = modulation frequency ($\omega = 2\pi f$),
κ = heat conductivity,
ρ = density,
C = specific heat.

(according to Schollmeyer and Eickmeier).

Photocell, photoelement So-called photoelectric cell in the form of a → Photoelectric sensor. Basically consists of a light-sensitive layer acting as a cathode (e.g. grey selenium or alkali metal), which can be mirrored on the internal surface of a glass sphere that has been evacuated or filled with an inert gas and has inside it e.g. a platinum wire as an anode. When the photocell is illuminated, electrons migrate from the cathode to the anode. A so-called photocurrent occurs, which can be measured by a galvanometer (photometer) connected between the two. A number of photoelectric devices have been constructed according to this principle, which can be used for colorimetry, fluorometry, gloss testing, photometry, reflection measurement, spectrophotometry, turbidimetric measurement, whiteness measurement, etc. This also includes photoelectric operational control and monitoring. In more detail we differentiate between:

I. Photocells: Preferably made of alkali metal (alkali photocell) which, however, in the absence of a driving

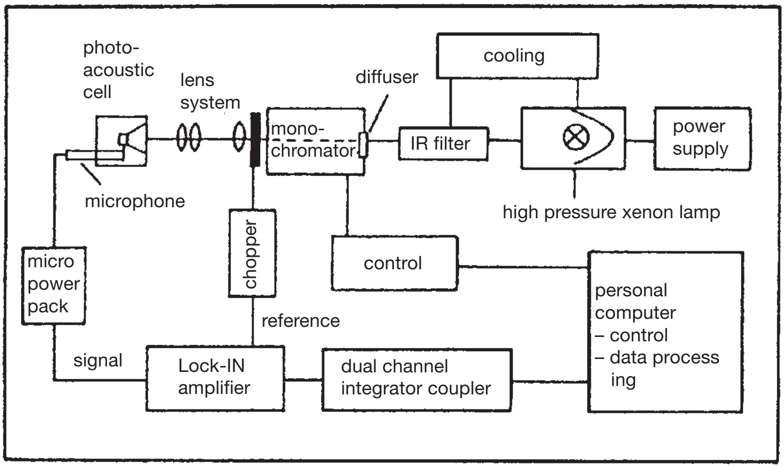


Fig. 2: Diagram of a photoacoustic spectrometer.

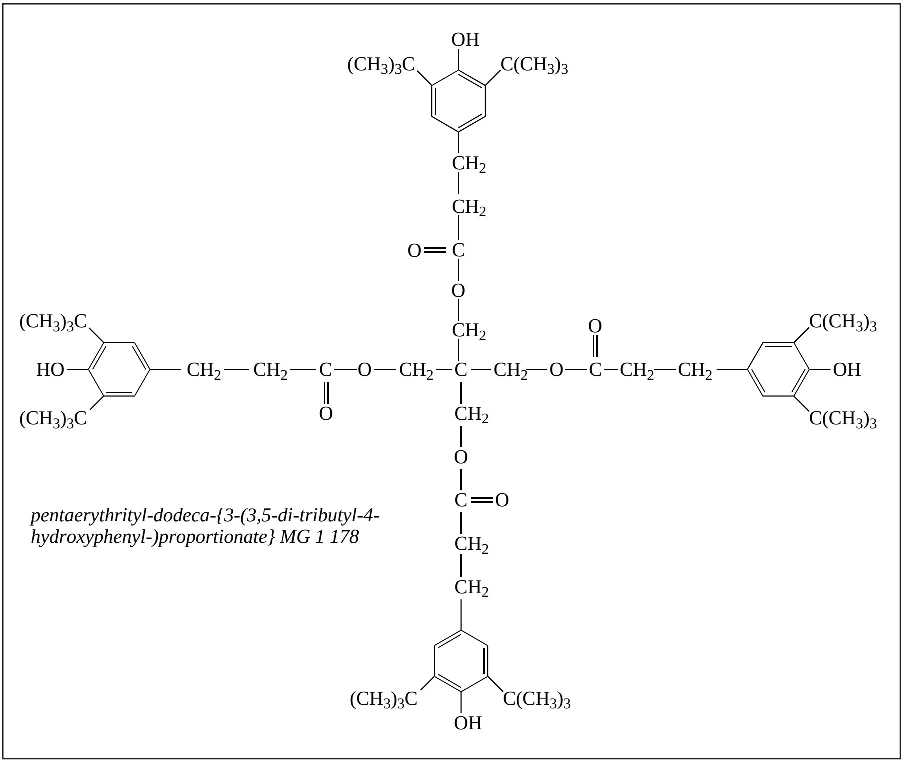
potential, only supply low photoelectric currents and therefore can only be used with an auxiliary voltage and then work in the same way as light sensitive resistors. So-called secondary electron multipliers are also used, in which auxiliary electrodes significantly increase the current generated in the photocell. Photocells are used, for example, for simple colorimetric measurements, where a significant increase in the photoelectric current is necessary. They are also used almost exclusively for → Spectroscopy due to their high light sensitivity over broad spectral ranges.

II. Photoelements: Consist of a so-called semiconductor layer between the metallic base area and the light permeable metallic front electrode. As soon as light falls on the latter, an electron movement over the front electrode and via an external conductive circuit to the base plate is triggered in the semiconductor. Unlike I., sufficiently strong measuring currents are created without an electric bias voltage. Selenium photoelements are used almost exclusively, e.g. for photocolorimetry. Germanium and silicon photoelements, which are used e.g. for the direct conversion of solar energy into electrical energy, are also worthy of mention.

Photochemical fibre degradation In nature, plant growth is based upon the principle of a photosensitive reaction, whereby carbon dioxide and water are converted into carbohydrates and oxygen by chlorophyll, also known as leaf green, as an activator. To protect the chlorophyll, β-carotene intervenes in the reaction mechanism and deactivates the singlet oxygen, which was created from the base-triplet-state by stimulation of the light by means of the activators, and which is reactive. If carotene production falls in the autumn, then chlorophyll is oxidatively broken down (also under the influence of hydrogen peroxide, which has been created by the reaction of the singlet oxygen with water), bringing about the characteristic autumn colouring of the leaves. This photolysis mechanism can be transferred to fibres and dyes.

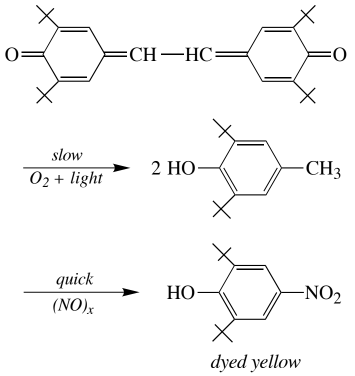
Pure fibres, above all polyacrylonitrile and cotton fibres, but also polyamide and polyester fibres that have not been delustred, are relatively stable against the effects of light. Wool needs a definite protection against photo yellowing (→ Light protective finishes for wool).

I. Polyester fibres: Dyes applied to carrier-free dyeable polyester fibres have poor light fastness due to the ether group content in modified polyester. Antioxidants in rubber, foam and other polymers (e.g. in coatings) react to the effects of light and also in the presence of nitrogen oxide and also in the presence of quat-based softeners:



pentaerythrityl-dodeca-{3-(3,5-di-tributyl-4-hydroxyphenyl-)proportionate} MG 1 178

Fig. 1: Antioxidant for polyester fibres.



There is an unmistakable chemical similarity between antioxidants for polyester fibres and substrate (Fig. 1).

II. Polyamide fibres: From the point of view of photochemistry, light falling onto material can be divided into two radiation strengths: Photoactivity in the ultraviolet range (280–400 nm) with an energy proportion of approx. 6% of all the radiation hitting the surface and heat radiation in the infra red range (720–2500 nm) with an energy proportion of approx. 52% (approx. 42% radiation strength in the visible range 400–720 nm). Accordingly, a differentiation is made regarding the effect of light on fibres (Fig. 2) between:

a) a physical mechanism of the interactions.
b) a chemical mechanism of the interactions.

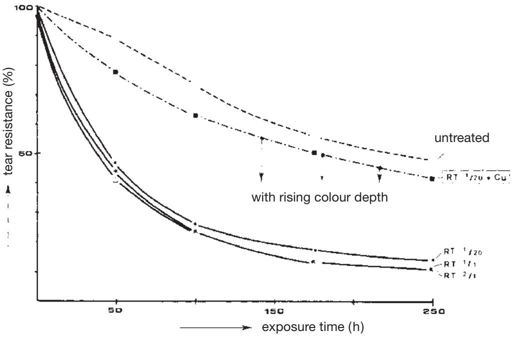


Fig. 2: Loss of tear resistance in dyeings of C. I. Acid Yellow 129 on polyamide filament yarn in relation to duration of exposure.
Exposure according to DIN 75202; copper content of the 1/20 RT-dye 83 mg Cu/g PA (RT = standard depth).

The kinetics of the photochemical decomposition of polyamide fibres (measured by the resistance to tearing) takes place in two phases: First chain decomposition, then stabilization (or slower decomposition) due to cross-linking reactions.

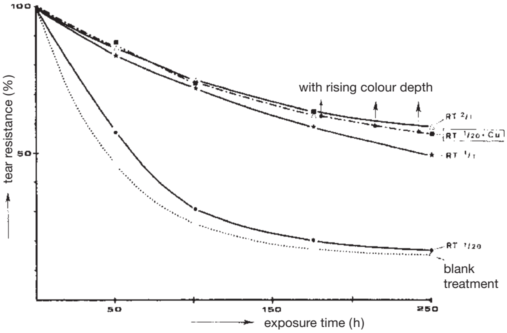


Fig. 3: Loss of tear resistance in dyeings of C. I. Acid Yellow 116 on polyamide filament yarn in relation to duration of exposure, with copper as optical protection.

In polyamide fibres, light stabilizers increase the resistance to tearing in relation to blank dyeing, e.g. C.I. Acid Yellow 116 (Fig. 3). Because the polyamide fibres are used as an additive in spinning, the absorption behaviour in sunlight changes erratically. Normal additives in polyamide fibres:

a) Delustring: 0.03–2.0% TiO_2 pigment, particle size 0.1–1 µm; preferred anastase modification; coated with aluminium oxide, silicon oxide, and manganese compounds to reduce photochemical activity.
b) Light stabilization: Up to 40 ppm manganese salts (phosphate, lactate, acetate) as an additive to the polymer, e.g. PA half-matt: 7–10 ppm; PA matt: 25–40 ppm manganese.

The titanium oxide delustring agent is the real cause of the light sensitivity of polyamide fibres.

Irradiation with short wave light causes an exciton (some electron holes) to form, which immediately reacts further with the surface hydroxyl groups, and Ti^{4+} ions. A hydroxyl radical splits, and the remaining Ti^{3+} ion gains an oxygen molecule, which is converted into O_2^- after the transition of an electron of Ti^{3+}. Finally a perhydroxyl radical HO forms with water (Fig. 4).

subreactions:

$$h\nu \xrightarrow{TiO_2} e' + p \text{ (exciton)}$$
$$HO^- + p \longrightarrow HO^\bullet$$
$$Ti^{4+} + e' \longrightarrow Ti^{3+}$$
$$Ti^{3+} + O_2 \longrightarrow [Ti^{4+}\,{}^\bullet O_2^- \text{ absorbed}]$$
$$[Ti^{4+}\,{}^\bullet O_2^-] + H_2O \longrightarrow Ti^{4+} + HO^- + HO_2^\bullet$$

overall reaction

$$H_2O + O_2 \xrightarrow[TiO_2]{h\nu} HO^\bullet + HO_2^\bullet$$

Fig. 4: Diagrammatic representation of the photochemical reaction at the surface of titanium oxide dye.

Photochemical fibre degradation

Type and quantity of polymer additives are in general not known; they vary according to provenance and can only be detected by costly analysis. Textile polyamide fibres always contain titanium oxide delustring agents (often coated with manganese salt) and/or manganese salt (increasing with a quantity of titanium oxide pigment). Copper salts are not contained in textile polyamide fibres. Limits are imposed on fibre manufacturers with regard to light stabilisation, the universal applicability of the fibres should be guaranteed. Material made of polyamide fibres can be exposed to aggressive processes during finishing, e.g. HT process, reductive and oxidative processes. Blind dyeing is problematic in relation to subsequent illumination, because under certain circumstances the manganese salt light protective finish dissolves out.

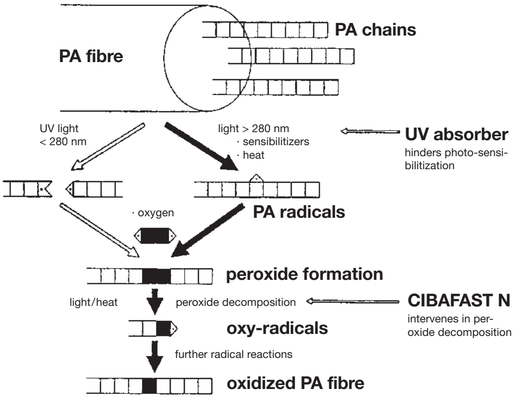
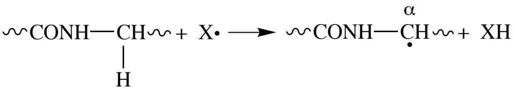


Fig. 5: Diagrammatic representation of the photochemical degredation of polyamide and the effect of UV absorbers and Cibafast N (Ciba Geigy).

The photochemical degradation of polyamide is a complicated process and can only be explained by modelling the relationships (Fig. 5). The primary reaction in the presence of sensitisers appears to be an attack by radicals (e.g. hydroxyl, perhydroxyl radical), splitting hydrogen into the amino group causes α-carbon.

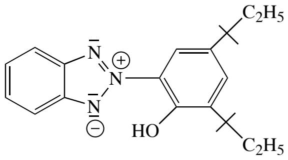


$$\sim\text{CONH}-\underset{\substack{|\\ \text{H}}}{\text{CH}}\sim + \text{X}\bullet \longrightarrow \sim\text{CONH}-\overset{\alpha}{\underset{\bullet}{\text{CH}}}\sim + \text{XH}$$

The main decomposition products of such reactions include aldehyde, carboxylic acids, peroxide, carbon monoxide, etc., in addition to chain fragments. Electromicrocopic pictures of non illuminated and illuminated fibre surfaces and cross-sections, which clearly show the fibre decomposition, show marked corrosion effects on their surfaces. There are cracks, channels, holes. Pictures of the fibre cross-section show cavities around the titanium dioxide pigment particles. These indicate on the one hand the photocatalytic action of the delustring and, on the other hand, the reason for the destruction of the fibre surface, caused by a pigment particle embedded in the fibre sheath. The obvious conclusion is therefore that the speed of photochemical fibre degradation depends to a significant degree upon the quantity (and quality) of the fibre pigmentation.

The formation of the radical along the polyamide chain is followed by the 2nd step of polyamide degradation: Atmospheric oxygen reacts with peroxides. Its decomposition due to further light and heat brings about a radical chain reaction. Oxidation products are the end product of broken down polyamide when the chain is broken due to traces of carboxylic acids, ketones, aldehydes or alcohols.

Light protective agents for polyamide fibres act firstly in the physical part of the mechanism; UV absorbers are used, which quickly convert light energy into heat. A differentiation is made here between a shielding effect (from 280–400 nm, a few sensitisers, such as, e.g., titanium dioxide can be excited) and the deactivation of the stimulated sensitiser molecules, by the transfer of energy, that has been taken in. Benzophenone and benzotriazole are UV absorbers, e.g.:



2-(2-hydroxy-3,5-di-tert.amylphenyl-) benzotriazole MG 351

Secondly, light protective agents are used to intervene in the chemical mechanism of photooxidation (Fig. 5) by destroying the peroxide and breaking up the radical reaction. Such stabilisers include copper salts (e.g. copper sulphate, an ecologically problematic substance) or copper complexes of a diazomethane derivative. Light protective agents should be applied in the dyehouse according to the profile of requirements for the final article (e.g. car upholstery, with hot illumination or carpets, with cold illumination) as a subsequent stabilisation process, and not non specifically exposed to the fibrous mass (with all the associated disadvantages).

III. Cellulose fibres: Cellulose fibres are also quite resistant to light; however, because cotton for example contains natural and artificial contaminants, these activators bring about light-related fibre damage by means of the following mechanisms (Fig. 6): The activator is stimulated by light; its reacts directly with the cellulose, which becomes a radical due to the removal of hydrogen. In the next step the cellulose radical forms a peroxide radical with atmospheric oxygen, which reacts with the original activator radical (AH) which has been created, whilst reforming the activator. The cellulose peroxide can also lead to decomposition products of the substrate. Unlike this hydrogen extraction mechanism, the attack on the cellulose due to the light stimulated activator can also occur directly (singlet oxygen theory). The energy of the stimulated activator is transferred to the air oxygen, whereby its triplet basic state is transformed into the stimulated, short-lived, reactive singlet state. Either the singlet oxygen extracts a hydrogen atom from the cellulose or hydrogen peroxide is formed.

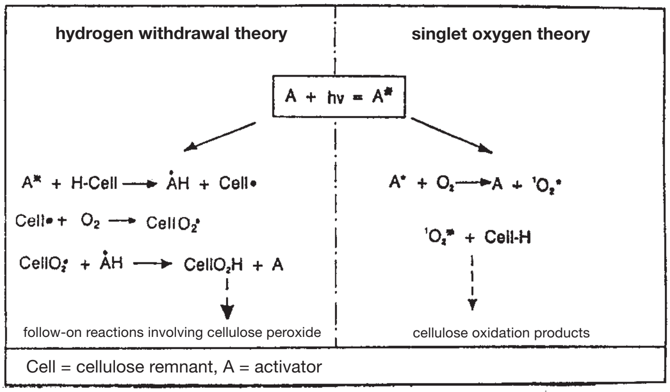


Fig. 6: Light damage to cellulose fibres in the presence of activators.

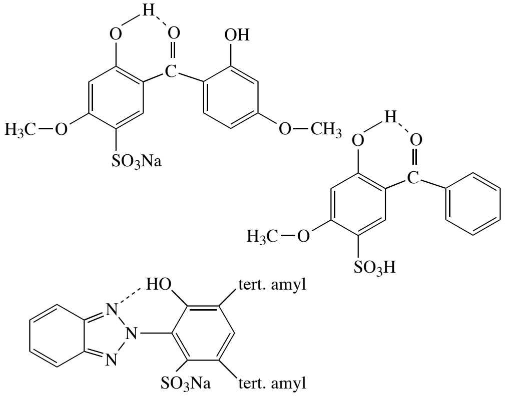
Fig. 7 shows possible cellulose degradation mechanisms with dyes as activators.

The primary step in the first mechanism is that a dye molecule D^* of cellulose stimulated by radiation extracts hydrogen (2). This creates free radicals. The degradation of the cellulose then proceeds by the destruction of cellulose peroxide. The accelerated effect of water occurs due to a 2nd reaction: The OH-radicals (6) created by the conversion of the stimulated dye with water extract further hydrogen atoms from the cellulose. This can also lead to the formation of hydrogen peroxide (7 and 8).

The mechanism illustrated in Fig. 8 is based upon the assumption that the triplet state of the dye D^* (2) stimulated by light will be deactivated by oxygen from the air. A stimulated oxygen molecule is created. It reacts with the substrate or with the water. The accelerating effect of moisture on fibre degradation is explained by the depicted hydrogen peroxide.

There are certain dyes, that not only cause no fibre damage when illuminated in the visible range (Fig. 9), but even have a significant protective effect (Fig. 10). This group includes e.g. vat green 3; vat blue 4, etc. It is possible to determine certain common features in the constitution of such dyes, which all possess an extremely high light fastness; they all contain NH functions, i.e. basic components, in the tetranuclear ring system.

IV. Wool: The main stabilisation mechanism of UV absorbers for the protection of wool (→ Yellowing of wool) is promoted by intramolecular hydrogen bridges. Three typical UV absorbers for wool:



The remaining polar molecular residues in the substrate influence the stability of these hydrogen bridges. The use of sulphonated UV absorbers on wool from aqueous liquor in the extraction process should there-

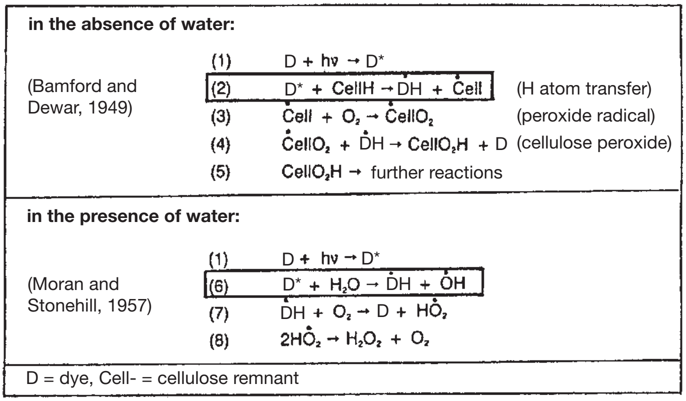


Fig. 7: Cellulose degradation (hydrogen withdrawal theory).

fore take place in a strongly acidic environment (pH 2) (60–80°C, 15–30 min). Although such UV absorbers for protection of wool against yellowing can actually at best dissipate the energy of light on the fibre surface, a ring "dyeing" is no better than a uniform distribution of the same amount of UV absorbers over the cross-section of the fibre. (according to Reinert, Schäfer, Baumgart and Wegerle, Krücker and Schmidt, Küster and Herlinger).

Photochemical reactions (photochemistry), chemical conversions triggered by the absorption of light (e.g. light damage to textiles and dyes, i.e. photodegradation, fading, light fading). Because the irradiated light wave consists of photons it can exert specific forces, and so-called electric fields, the strength of which increases with the intensity and frequency of the light. So, for example, in any absorbing molecule the increasing number of co-valent bonds effect an increase in the number of particularly mobile π electrons, and thus the molecule positions that can be excited by light energy, whereby the absorbed irradiated energy appears as a reaction triggering a burst of energy. According to Einstein the amount of energy is greater, the shorter the wavelength for each light quantum. The radiation energy is greatest in the entire UV range. The short wavelength UV range, at around 360 nm, alone suffices to split chemical bonds between fibre atoms and dye molecules, for example the splitting of cellulose C–C or C–O bonds with an energy of around 335 kJ/mol (photolysis). In the longer wavelength UV range, on the other hand, additional chemical energy (e.g. oxygen and easily splittable water) is

(1) $D + h\nu \longrightarrow D^*$

$\boxed{(2)\quad D^* + O_2 \longrightarrow D + O_2^*}$ (activated oxygen)

in water-free environment

(3) $O_2^* + \text{Cell-H} \rightarrow$ oxidation products

in moist environment

(4) $O_2^* + 2H_2O \rightarrow 2H_2O_2$

(5) $H_2O_2 + \text{Cell-H} \rightarrow$ oxidation products

D= dye, Cell- = cellulose remnant

Fig. 8: Cellulose degradation (singlet oxygen theory according to Egerton).

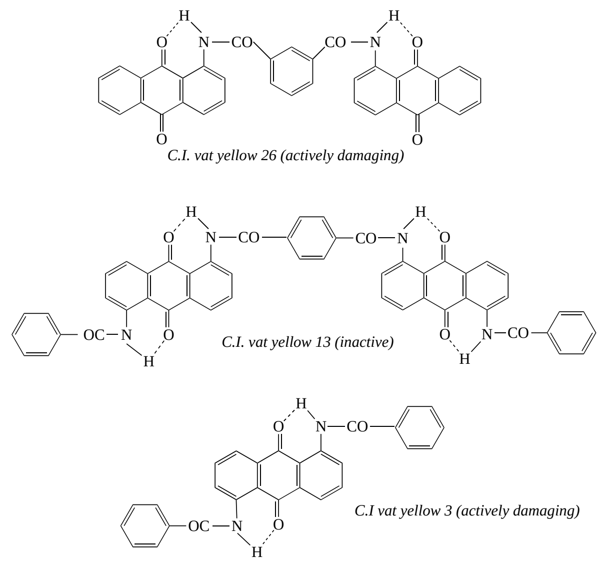
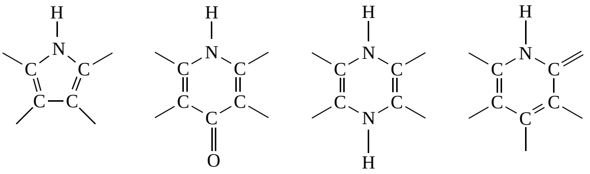


Fig. 9: Photochemical fibre damaging and non-damaging agents.



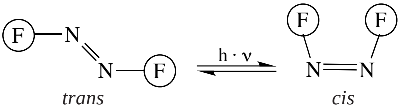
a'on-carbazole	*a'on-acridone*	*a'on-dihydro-pyrazine*	*benzanthronyl-amino-a'one*
e.g. C.I. *vat orange 11* *vat orange 15*	*e.g. C.I.* *vat orange 13*	*e.g. C.I.* *vat blue 4* *vat blue 6*	*e.g. C.I.* *vat green 3*

Fig. 10: Structural elements which have a protective effect on cellulose fibres.

required in addition to pure light energy for the splitting of chemical bonds (photooxidation). Therefore illumination using UV radiators brings about photolytic damage, whereas in sunlight, particularly behind window glass (wavelengths 320 nm with 35% penetration, 340 nm with 70% penetration and 360 nm with 90% penetration), we can expect photooxidation to be the main process. These photoreactions are the cause of → Light exposure damage.

Photochromism of dyes Also known as phototropism, however photochromism should be the preferred term. A time-limited colour change of coloured textiles under the influence of light. Determination: Sample is exposed to intensive illumination over a time period that is much too short to permanently change the shade. Evaluation takes place immediately after illumination and after 24 hour storage in darkness.

The effects of light on dyeings involving azo dyes on cellulose fibres can lead to reversible and irreversible changes to the dye molecules. Only in the first case do we talk of photochromism, i.e. of a shade change that is reversed in darkness. When illuminated in solution, azo dyes can change from the trans-form into the cis-form. The energy rich cis-form is unstable to some degree and returns to the stable trans-form in darkness. Because this effect is generally observed less often on cellulose fibres than on hydrophobic fibres, the phenomenon no longer represents a significant practical problem for the azo series.



Photochromism occurs in certain vat dyes and reactive anthraquinone dyes. In this the vat acid colour is observed. In vat yellow 1 (flavanthrone) on cellulose foil, it is caused by a reduction to the semiquinone radical (Fig.). Hydrogen is thereby extracted from the substrate. The semiquinone radical is coloured differently; the colour change is reversed in the dark because atmospheric oxygen oxidizes the reduction product to the initial dye. The intermediate radicals formed in the reduction of the dye by the cellulose can be detected with the aid of electron spin resonance methods. The dehydration of the cellulose is not associated with fibre damage.

Dyes also show the effect of photochromism in the presence of finishing agents, namely of the type N-methylol urea compounds. These agents take on the role of a hydrogen donor. This has the advantage that the effectiveness of these products on photochromism is in accordance with their tendency to form formaldehyde and free amino groups, which are easy to dehydrate. In addition, the reducibility of the dye is also important. The reduction of the dye could also come about due to an electron transition from the substrate. In addition to n-methylol compounds, hydrophobing agents, e.g. siloxane, also increase the tendency to photochromism; paraffin compounds, on the other hand, do not.

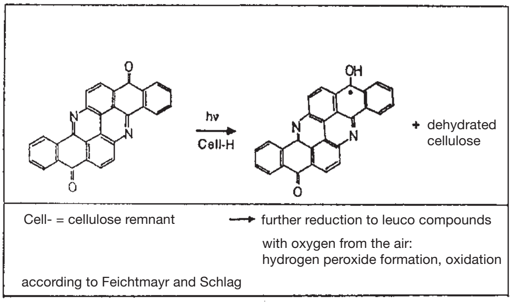


Fig.: Photochromism of C. I. vat yellow 1.

Whether photochromism occurs depends upon whether irreversible secondary reactions occur rapidly or slowly after the rapid primary step (the reduction of the dye). If they are very fast, then a poor light fastness is achieved, if they are slow then the possibility exists that in the presence of atmospheric oxygen the dye will be reformed in the dark, i.e. photochromism occurs. The greatest effect is observed naturally in the absence of oxygen, because a reversal reaction is not possible. In the presence of water the reversal reaction is accelerated due to the formation of hydrogen peroxide (according to Baumgarte and Wegerle).

Photodegradation Damage to dyeings caused by → Photochemical reactions.

Photoelectric sensors The optical techniques used in the textiles industry can be divided into three broad groups:

1. Monitoring
   a) of the textile material, its state during processing and after finishing: Photoelectric fuse fracture monitoring, lint monitors, thread cleaner, weft feeler, thread and seam monitor, error searching devices on stocking frames, pinhole detectors and devices for material presentation.
   b) of the processing machines, above all safety devices and photo-electric barriers on production lines, switching and control devices and needle monitoring on knitting machines, etc.
   c) of the treatment medium, i.e. flame monitor in gas heating of dryers, and indirectly also flue gas monitoring and turbidity meters.
2. Production using photoelectric output quantity indicator: Automatic weft aligning machines, synchronization control for the synchronisation of two machines; cutting devices; autolevellers with stored control parameters obtained by photoelectric meas-

urements of the belt thickness; material entry equipment.

3. Measuring and testing tasks that can be performed photoelectrically include all whiteness and colorimetric measurements, lustre measurements, liquor concentration measurements with the aid of the refraction index, extension measurements using a photoelectric transmitter, etc.

Photoelement → Photocell, photoelement.

Photographic colour separations Colour separations created using a reproduction camera from the pattern by the use of colour filters on panchromatic plates (for creating screens).

Photographic printing on textiles Phototype. It is possible to produce photographic pictures on textiles in rich patterns and all shades (→ Photone printing), e.g. washfast photographic printing with certain light sensitive vat leuco ester dyes. After illumination through a negative, clear, local prints on a prussian blue background are achieved. Locally reduced iron(III) salts and locally hardened points of chrome gelatine also serve for the local fixation of vat dyes under the influence of light. → Chrome photoprinting is based upon photochemical fixation of a chrome mordant with subsequent finish dyeing of the illuminated chromed pattern points with chrome mordant dye. Finally, coloured pattern prints can also be achieved by illuminating fabrics that have been impregnated with antidiazosulphonates, which thus rearrange to diazo compounds and link with phenols and napthols. Finally, there have also been proposals for multi-coloured prints, e.g. using three stage methods, the final effect of which represents a three-colour print produced by a mixture of vat, chrome mordant and insoluble azo dyes.

Photographic standards for fabric creasing Photographic fabric effect, which is creased by defined creasing methods and is used for the testing of resin finished textiles for their tendency to → Creasing (Monsanto crease photographs, random crease photographs). Evaluation uses a scale from 1 (very heavily creased) to 5 (no creasing).

Photoluminescence → Luminescence.

Photolysis of dyes The longer a molecule remains in the stimulated state, the greater the probability of it undergoing chemical changes. The reversible sec. reactions in dyes can take the form of intramolecular changes, e.g. in trans/cis conversions of azo dyes, or be caused by external influences, e.g. in the reductive attack on certain vat dyes and reoxidation due to atmospheric oxygen. In all cases a colour change occurs upon illumination, which reverses more or less slowly in the dark. This phenomenon is called → Photochromism of dyes. Irreversible secondary reactions express themselves by the bleaching of dyes or by shade changes, because colourless or coloured decomposition products can be created. There may also be damage to the substrate. Generally, the primary steps are oxidation or reduction reactions of the stimulated dye molecule with materials from the environment, whereby the latter may also have been previously transferred into the stimulated state.

Depending upon the substrate, there are dyes in the presence of hydrophilic or hydrophobic fibres. Water molecules and atmospheric oxygen are also present, and these can enter the fibres easily and quickly. Therefore, when illumination takes place, under certain circumstances an agent with a reducing action (cellulose) and an agent with an oxidating action (oxygen) are present in the system, in addition to the dye. In combination dyes, other dye molecules can also participate in the event. Many other influencing variables should also be taken into account, e.g. dye concentration, agglomeration, temperature, and the presence of other products, for example finishing agent. The complicated nature of the reaction mechanism should also be borne in mind.

In the photolysis of dyes that are present in the substrate, the following general rule applies: Dark dyes are more resistant to light than light colours. This is due to the state of the dye in the substrate. Dyes that are molecularly distributed are more quickly degraded by light than dyes are fixed in the fibre by aggregation (Fig. 1).

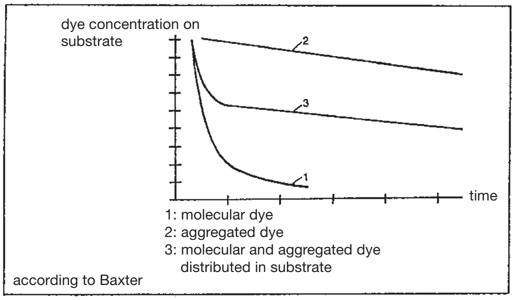


Fig. 1: Dye aggregation and kinetics of fading.

Not much is known about photo decomposition products of vat dyes. This is particularly true for the highly condensed aromatic ring systems. With regard to indigo, we know that although it is less light resistant on cellulose fibres than it is on wool, it is nevertheless amazingly stable. When illuminated, primarily the yellow oxidation product isatin is created, i.e. the dye becomes greener. If the article is washed, then the yellow product is removed and a colour is obtained that appears lighter, redder and more brilliant than the original dyeing.

It appears to be characteristic of indigo, that it is present in cellulose in the associated form, specifically in the trans form (Fig. 2). It is thought that the light stability of indigo is related to an intramolecular proton transition from nitrogen to oxygen in the stimulated

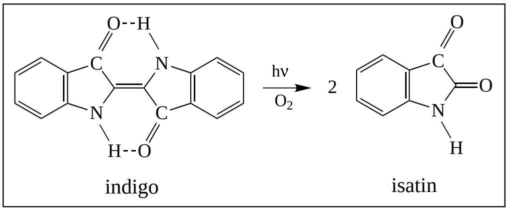


Fig. 2: Photodegradation of indigo.

singlet state. This stimulated state has only an extremely short lifespan, deactivation occurs without radiation.

Simple anthraquinone dyes are used for cellulose as reactive dyes and for cellulose acetate and polyester as disperse dyes. The photodegradation of 1 amino and 1.4 diaminoanthraquinone derivatives takes place in a polyester dyeing by oxidation processes with a number of degradation products.

If azo dyes are irradiated in solution and in the absence of oxygen, then reduction products are obtained. There are two reaction paths here (F = dye, RH = hydrogen donor, S = sensitiser):

direct reduction

$$F + h\nu \longrightarrow F^*$$
$$F^* + RH \longrightarrow \boxed{\dot{F}H} + \dot{R}$$

indirect reduction

$$S + h\nu \longrightarrow S^*$$
$$S^* + RH \longrightarrow \dot{S}H + \dot{R}$$
$$\dot{S}H + F \longrightarrow S + \boxed{\dot{F}H}$$

Unlike such model tests in the absence of oxygen, the photoreactions of dyes always take place in the presence of oxygen. For this reason it is not surprising that initial observations regarding the behaviour of azo dyes on cellulose fibres indicate oxidation reactions (Fig. 3). After illumination, oxidation products were detected. The dyes with a chemical bond between dye and fibre are more light resistant than the corresponding dye without a covalent bond. The “lightening conductor” theory is an attempt to explain this: Irradiated energy is taken from the dye to the substrate via the dye/fibre bond.

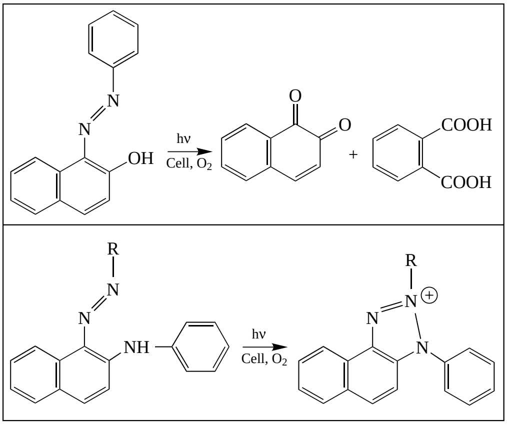


Fig. 3: Oxidation products following the exposure to light of cellulose dyeings with azo dyes.

Radical reactions are assumed to underlie the mechanism of photodegradation of reactive dyes. It is presumed that primarily the dye/fibre bond is split; only then is the molecularly distributed dye in the substrate destroyed. Particular problems can arise in certain reactive dyes after wet illumination (see Tab.). If a dyeing is illuminated in the xenotest device, and after 29 min it is sprayed with water for 1 min, then the fastness grades sometimes fall by up to 5 compared to dry illumination. Other dyes, on the other hand, show no significant effect. The type of reactive group plays no role.

C. I. reactive-	light fastness	
	dry	wet
yellow 2	6-7	5-6
yellow 6	6-7	5-6
yellow 22	6-7	5-6
yellow 35	6-7	5-6
yellow 14	6-7	4
yellow 1	6-7	1-2

according to Krallmann

Tab.: Wet and dry light fastness of reactive dyeings.

One attempt at an explanation assumes, that in dyes with poor wet light fastness the stimulated dye gives up an electron or splits a hydrogen atom particularly easily in an aqueous environment (Fig. 4). The radicals that

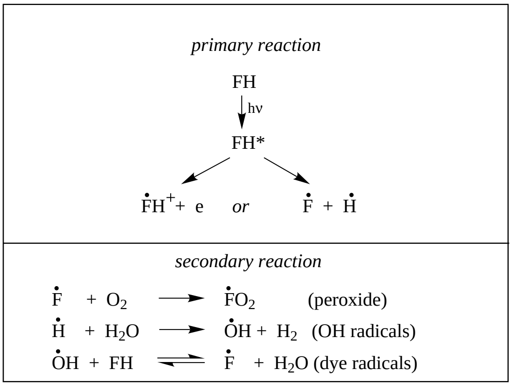


Fig. 4: Mechanism of the photolysis of reactive dyes in the presence of water.

are thus created suffer secondary reactions; the dye is destroyed. In dyes in which the wet light fastness is not reduced, fading occurs according to a different mechanism that is insensitive to water. Fibre plays no part in the reactions in these hypotheses.

Three reaction types have been found for the illumination of anthraquinone reactive dyes on cellulose foil or fibres and polyamide fibres (Fig. 5): A reversible photoreduction, a splitting of the bond between dye and cellulose and an irreversible dye degradation. Substrate and type of bond influence the kinetics and the mechanism of the photoconversion of the dye.

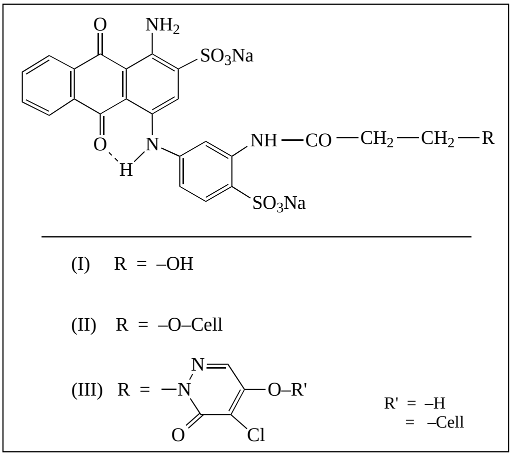


Fig. 5: Covalent bonding between dye and cellulose (anthraquinones).

Experiments with reactive 1.4 diaminoanthraquinone dyes showed that the fastness depends upon the type of illumination. Under artificial lighting, the fastness grades for the dye, regardless of whether the dye was covalently bonded in the substrate or not, were better than those for illumination in daylight. The fastness grades were better by 1–1.5 where there was a covalent bond between dye and substrate. As an alternative to the “lightening conductor” theory mentioned above, this could also be interpreted as meaning that where there is no covalent bond the dye agglomerates more in the substrate and is in closer contact to the cellulose molecules; in the chemically bonded state on the other hand the opposite is true: less aggregated and with poorer contact to the substrate (Baumgarte and Wegerle).

Photometer → Colour measuring instruments.

Photometer microscopy In a dyehouse, recipe variants are selected according to the criteria of price, metamerism and fastness. The dyeing behaviour of textiles is judged almost entirely by determining the exhaustion degree in the case of dyeing liquors (kinetic studies) and/or by the colorimetric evaluation of the substrate (CIELAB color standard values). On the other hand, a quantitative evaluation of dye distribution in fibre cross-sections is rarely performed due to experimental difficulties. The diffusion of dyes during a wool dyeing process initially takes place via the non-keratin between the wool scales, via the cell membrane complex and only then in the cortical areas of ortho, para and mesocortex, to varying degrees of intensity. One possibility for evaluating the quality of a dye is the degree of dye penetration; however there is no relationship between the visual impression of a dye, the standard dye values in inspection and the dye concentration profile in the fibre cross-section. The degree of dye penetration to which wool must be dyed to achieve the desired dye impression, on the one hand, and on the other hand to achieve an adequate fastness, is unknown.

When the photometer microscope was developed it became possible to determine the actual integral dye concentration taken up by means of transmission measurements across the cross-section of the fibre. The first measurements were made on polyamide fibres. There was a good correlation between the dye content determined by extraction and the integral dye concentration determined by photometer microscopy.

Using the λ-scan program (Zeiss), transmission spectra in the wavelength range 235–1050 nm can be taken from fibre cross-sections. In order to investigate the distribution of textile assistants in wool fibres, cross-sections must be prepared. Wool fibres are embedded in a shrinkable sleeve in a quick hardening two-component epoxy resin glue, whereby the wool fibres must be arranged so that they are as parallel as possible. After polymerization the tube is inserted into a wax block; cross sections are prepared with the aid of a hand microtome. Section thicknesses of 20–40 μm have proven themselves; the precise determination of the section thickness takes place by light-microscopy. Fibre cross-sections are scanned in a suitable embedding substance with the aid of the APAMOS program (Zeiss) in 2 μm steps (Fig. 1). At least 20 cross-sections of the average fibre diameter are analysed and this information is used to determine the transmission profile. The

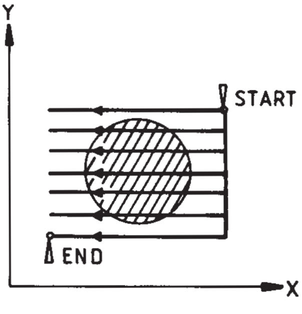


Fig. 1: APAMOS program for scanning fibre cross-sections (Zeiss).

migration of the textile finishing substance in the fibre is determined by evaluating the transmission profile.

The following method is used to determine the degree of dye penetration and the dye distribution over the fibre cross-section by photometer microscopy:

First, 40 µm thick fibre cross-sections are produced by using the traversing microtome on representative, dyed samples. The selection of the fibre cross-sections for analysis is made according to the unit distribution for the total sample, with a total of fifty fibres being measured. Then the transmission profiles are determined over the cross-section at the wavelengths λ_{max} red = 525 nm and λ_{max} blue = 630 nm.

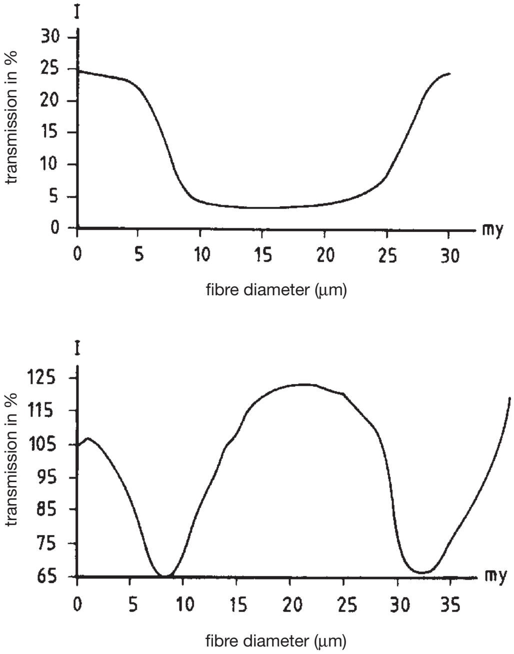


Fig. 2: Transmission profiles of woollen combed tops treated with UV absorber, measured at 350 nm (top = even dyeing; below = ring dyeing) (according to Blankenburg).

The transmission profile of a dyed wool fibre schematically represented in Fig. 2 is analysed according to the following aspects (whereby the definitions shown in Fig. 3 apply):

- the characteristic variable “relative dye penetration degree” is determined as a measure of the diffusion of the dye
- the characteristic variable “relative dye absorption” is determined as a measure of the dye concentration.

This procedure can be used for the evaluation of the photometric transmission measurement, because the absorption spectrum of the dye is known, the wavelength of the transmitted light and the thickness of the fibre cross-section (microtome section) are constant and thus diffusion and distribution of the dye can be determined (Blankenburg, Laugs and Souren, Schäfer).

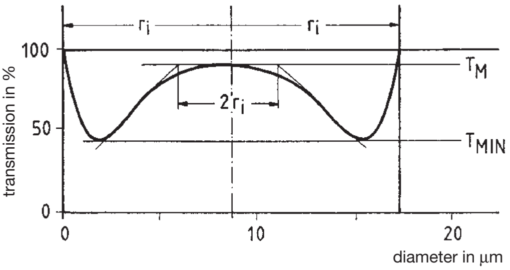


Fig. 3: Transmission profile of a dyed woollen fibre across its cross-section.

T_{min} = local minimum of the transmission value, preferably in the external area;
T_{max} = local maximum of the transmission value, preferably in the middle;
r = radius of the wool fibre;
r_F = radius of the transmission plateau in the range of T_{max};
A = transmission area of the undyed fibre = 2 · r · 100%;
A_F = loss of transmission area due to the dyeing =

$$A - \int_0^{2r} T \cdot dx$$

rel. dye penetration in %

$$= \left(\frac{\pi r^2 - \pi r_F^2}{\pi r^2}\right) \cdot 100\,\% = \left(1 - \frac{r_F^2}{r^2}\right) \cdot 100\,\%$$

rel. dye absorption in %

$$= \left(\frac{A_F}{A}\right) \cdot 100\,\%$$

Photometric measurements For the determination of the concentration c of a solution by determining the → Extinction E (Lambert-Beer law):

$$E = \log \frac{I_0}{I} = d \cdot \varepsilon \cdot c$$

I = light intensity behind the sample;
I_0 = light intensity in front of the sample;
d = layer thickness of the sample;
ε = extinction coefficient.

It is irrelevant whether the solution is an electrolyte or a non-electrolyte and whether it has natural colour or secondary colour (released by addition of certain rea-

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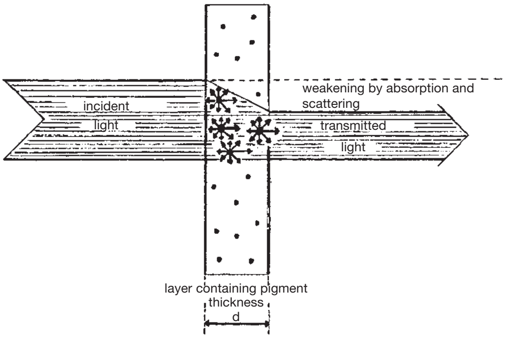

Fig.: Diagrammatic representation of light absorption and scattering by pigment particles in a true solution, e.g. dilute dye liquor containing dispersed vat dye and dissolved dispersion dye.

gents). Technically particularly well suited for low concentrations or substance traces. Diverse applicability.

As can be seen from the Fig., the dispersed particles bring about a scattering of the irradiated light. For the intensity of the scattered light, the theory of Tyndall scattering applies for particles that are smaller than the wavelength α of the irradiated light, whereby the intensity of the diffused light is proportional to the intensity of the irradiated light, the concentration of the scattering particles and the sixth power of its diameter and inversely proportional to α^4. Furthermore, the diffused light intensity in relation to the particle size is also influenced by the scattering angle from the primary beam.

Photone printing A negative is first developed as normal from the photographed pattern to be used in printing, and from this negative a transparent positive is produced. This is placed upon a glass roller, which contains a mercury vapour lamp, around which the fabric, which has been impregnated with light sensitive dye (→ Photographic printing) is allowed to run. After fixation, rinsing and drying the fabric has the transferred pattern, which although it is in a single colour has all pattern details.

Photoreproduction on aluminium oxide layers According to the following principle: Impregnation with light-sensitive silver salts, copying, developing, fixating, toning, rinsing. Whereas the so-called Seofoto procedure is tied to the manufacturing location of the aluminium plates, in the so-called Al-phot process the silver salt is stored at the depth of the oxide layer and can be stored for any desired time before use. Light sensitivity is only created after dipping into a simple sensitizing solution. Further processing takes place as for normal photographic paper. This requires only a few tanks, developing tray and a copying device. Picture reproductions can be kept for an unlimited period, and are corrosion and fire resistant. Subsequent dyeing of the aluminium layer is also possible.

Photoscreens → Screen making.

Photosensitive coatings Photosensitive coatings are increasingly competing with chrome gelatine in the manufacture of screen printing screens. These coatings mainly use → Polyvinyl alcohol which has been sensitized using chromium salts. Such photosensitive coatings have better adherence, contain no water soluble components when illuminated and always have sharp, unchanging contours. The screens are coated cold, in daylight. It should be noted that these coatings require slightly longer illumination times.

Photosensitive lacquer Forms the basis for the creation of printing screens, because once illuminated it takes on lacquer-like solidity and resistance, i.e. after illumination no further reinforcement is necessary (→ Positive process for screen making).

Photosensitive layers Used for → Screen making.

Photosensitive screen coating Layer of photosensitive lacquer applied to the gauze during the manufacture of screen printing templates, which hardens due to the effect of light.

Photostable Light resistant.

Photosynthesis The Fig. shows the first stages of photosynthesis in the inside of a cell. Sunlight strikes the reaction centre and triggers the release of one electron (e^-) after the other. So an electron circuit is kept in motion, which “pumps” a proton (H^*) from one side of the membrane to the other for each revolution. A charge gap, similar to that in a battery, is created. The plant uses this to convert low-energy molecules into high-energy molecules. The power of the sun is stored.

Photothermic The process temperature represents an important parameter in the stages of textile processing. It is responsible, amongst other things, for the accessibility of the fibrous material to dyes and its thermomechanical behaviour. Structural conversions at the glass transition point T_G and the effective temperature T_{eff} are critical for the thermic behaviour of the fibrous material. Whereas T_{eff} is set during thermofixation, T_G depends upon the process, e.g. heating rates. One analysis method that is available is → Differential Thermal Analyis (DTA). This method is however limited to laboratory analysis and is not suitable for measurement in inaccessible areas or atmospheres. One possibility for analysing the parameters in the process is the use of photothermic radiometry (PTR), a process for the determination of thermal properties of materials. The measuring principle largely consists of the generation of a temperature gradient by the irradiation of energy, e.g. by the light from a laser. The temperature increase created in this manner, which is characteristic of the thermal and optical properties of the material, can be detected by means of an infrared sensor. The signal can be used to make predictions regarding the thermal properties of a material. The advantage of this procedure is the fundamental possibility of non-contact

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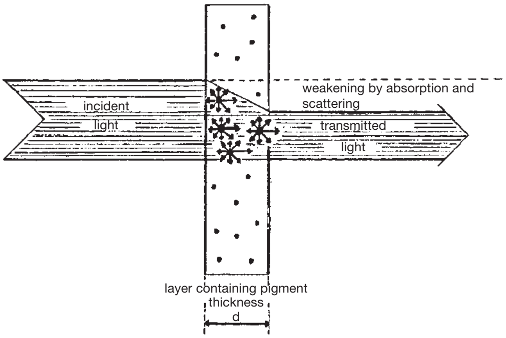

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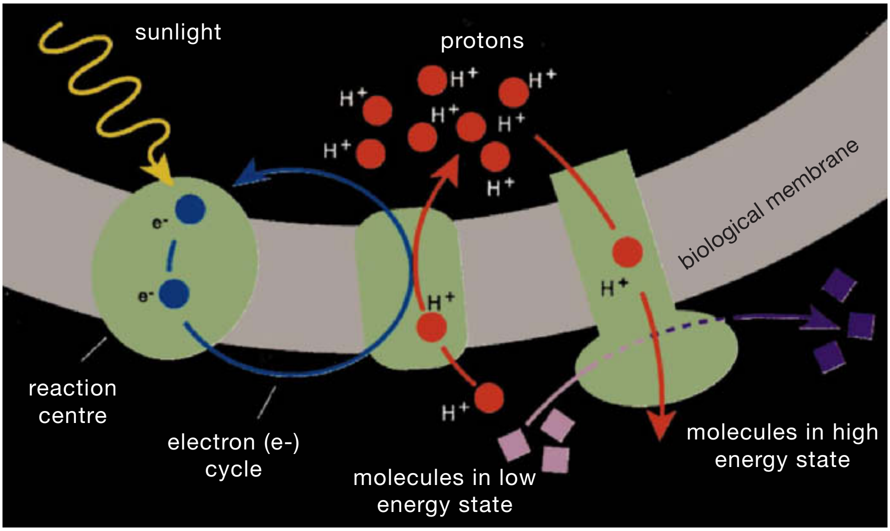


Fig.: Mechanism of photosynthesis within a cell.

and thus non-destructive measurement. In the use of the PTR in the textile industry, the influence of temperature on the expected measuring signal should be detected. Structural conversion points of macromolecules, such as glass transition points, premelting points (effective temperatures), are accompanied by a corresponding change in the thermal properties and therefore have a direct influence on the photothermic measuring signal (according to Schollmeyer).

Phototropism (Gk.), colour change due to UV light. Occurs if the dye reflects the UV part of daylight with longer wavelengths than that of visible light. This can be caused by after-treatments, such as anti-crease finishing, chintz finishing, etc. The normal shade generally only returns after long periods in the dark or when the material is irradiated with red light. → Photochromism.

pH paper Strips of indicator paper used for → pH measurement.

Phthalate resins (glycerol-phthalic acid resin, glyptal resins, glyceryl phthalate resins), group of → Alkyd resins, which are created by the esterification of → Phthalic acid and glycerol (therefore oil-free), are soluble in alcohol and are often used for the manufacture of paints; for water proof finishes, hat stiffeners, and in printing thickeners, coatings, etc. Also significant are so-called modified phthalate resins with condensed fatty acids, resin acids, etc., which also provide wash resistant fixation of colour pigments and at the same time give the material a full, not hardened handle.

Phthalates, phthalic acid ester Salts or esters of → Phthalic acid (exchange of carboxyl group hydrogen atoms by metals or radicals). Phthalic acid esters are used e.g. as plastification (softening) agent for paints, print thickeners (particularly based upon nitrate or acetate cellulose) in lacquer, bronze and pigment printing, and for coating, plastic finishing, etc. Compared to cellulose esters, phthalates act as a solvent and gelatinizing agent at the same time.

Phthaleins Derivatives of triphenylmethane-carboxylic acid (can also be understood as largely derived from xanthene, therefore → Xanthene dyes). Typical representatives are phenolphthalein, fluorescein, eosin, rhodamine.

Phthalic acid $C_6H_4(COOH)_2$, application: For the manufacture of → Phthalates, Phthaleins and modern surface active textile assistants (→ Sulphonated polycarboxyl acid esters and amides).

Phthalic acid ester → Phthalates, phathalic acid ester.

Phthalocyanine dyes possess extraordinarily clear, luminous colour shades with extremely good light fastness and usually excellent wear fastness. Constitution: → Metal-complex dyes.

I. Phthalocyanine metal complexes:

1. Soluble as direct dye type, made soluble by sulphonic groups. Individual, familiar, brilliant blue and green dyes have good light fastness and (with cationactive after-treatment) good wet, washing, sweat and ironing fastness; also good suitability for vulcanized items; for many purposes e.g. useful corrosiveness; however typically differentiated acid sensitivity. Application for natural and chemical fibres and for half-wool materials.
2. Primarily made soluble (vattable). a) Sulphur dye type, b) vat dye type in the form of “ansulphated” cobalt phtalocyanine with a clear blue shade, excellent light fastness and good washing fastness, but

only poor chlorine and peroxide bleaching fastness (not for bright bleaching items); easily vattable even with only a small amount of caustic soda liquor; particularly suitable as a dye for liquor dyeing of cellulose fibres with excellent dye penetration; c) cationic-active soluble type.

3. Insoluble copper phthalocyanine, sometimes strongly chlorinated, blue and green colour pigments with the clarity and brilliance of cationic dyes and the fastness of the best vat dyes for practically all fibre types, particularly for jet dyeing and pigment printing.

II. Metallizable phthalocyanine: A phthalocyanine, the solubility of which is brought about by acid groups, which subsequently form insoluble lacquers with chrome salts (phthalocyanine-chromium complex dyes). This lacquering occurs with exceptional speed and is controlled such that the reduction of the added chromates to trivalent chrome can occur at the moment the dye has penetrated into the fibre. Then the remaining bright blue pigment is fixed by steaming.

III. Metallizable phthalocyanine generated on the fibre: Synthetic generation of the dye/metal complex directly onto cellulose fibre by the pad dyeing process or direct printing; excellently reservable.

Phthalocyanine metal complexes → Phthalocyanine dyes.

Phycomycetes Aquatic fungi (→ Moulds).

Physical chemistry Science of mutual relationships between → Physics and chemistry and reaction research particularly of the fine structure of the atom (atomic theory, atomic energy), molecules, ions (colloid electrolytes), their behaviour in, and in relation to, other state forms and the regularity of chemical reactions, etc.

Physics (Lat./Gk.), science of conformity of regular and altered inorganic materials, energy and their transformation.

Physiological triangle → Wesel triangle.

Physiology (Gk.), study of the processes of life, in particular in humans, and their scientific relationships. →: Ergonomics; Clothing physiology.

PI,

I. Paper fibre (yarn), → Textile fibre symbols, according to the → EDP code.

II. Polyimides, → Textile fibre symbols, according to BISFA.

Piassava fibre → Palm fibres (Africa, Brazil) for mats, brushes, brooms, ropes, braiding, also stiff fabric. Light to dark coloured, containing silicic acid. Dyeing properties similar to coir.

Pick-and-pick bobbin changing (pic-à-pic), change of weft colour or weft thread after each weft insertion into the fabric.

Pickle (to) Treatment in special steel plants to limit corrosion due to chlorine dioxide during chlorite bleaching. This is achieved using concentrated solutions of H_2SO_4, HNO_3 and HCl.

Pick-up → Liquor pick-up as a percentage.

Pico- (Gk), standard unit for one trillionth = 10^{-12}, e.g. 1 pm = 10^{-12} m.

PID control (Proportional-Integral-Differential), generally valid temperature control principle that uses an additional measuring device to rule out variations in temperature control due to the delayed response of the control elements and guarantee an optimal constant temperature.

Piece-dyed goods Raw materials, which are dyed as a piece of fabric, in contrast to → Yarn dyeing or → Loose stock dyeing.

Piece dyeing machines (with fabric movement) The following general principle applies: the piece goods move, whilst the liquor remains stationary; for example → Winch beck, Jigger, Padder, Jet dyeing machines, Overflow dyeing machines. However, a clear demarcation of this type cannot be made. In jet dyeing machines, for example, both the material and the liquor are in motion.

Piece dyeing machines (with liquor movement) The following general principle applies: The liquor moves and the item to be dyed remains stationary; for example →: HT beam dyeing machines; Star frames. Only the discontinuous working mode is possible.

Piece dyeing plants Machinery, consisting of dye application equipment and associated fixing devices; sequence in semi-continuous or continuous processes (e.g. → Thermosol plants).

Piece glass (pick counter). A magnifying glass with horizontal and vertical measuring scales for determining the yarn count (woven fabrics) or stitch density (knitted fabrics).

Piece identification system If CIM (Computer Integrated Manufacturing) is to gain a foothold as a production control element in textile finishing, reliable piece identification systems are required. All such attempts have previously failed, because they were not universally applicable. Suitable piece recognition markings (e.g. using barcodes) must be resistant against

– mechanical effects (rope treatment such as milling, shearing, roughening, emerizing),
– against dyeing with disperse dyes,
– against shrinkage due to the effects of heat in order to remain readable.

Piece weight → Fabric weight.

Pie wool (pied wool), → Skin wool of hide pieces, obtained by bacterial decomposition.

Piezo- Relating to pressure, press. Piezo effect: electric charge caused by elastic deformation.

Piezo-electricity → Ultrasonics.

Piggyback process Term for a process used to prevent tangles in polyester fabrics in HT jet machines (caused by floating). A second piece is attached to the continuous rope.

Pigment The virtually insoluble, solid, finely dispersed colorant in binders, solvents or binder dispersants, which gives a coloured appearance when finely distributed. Application in the form of inorganic or organic pigment during delustring, in textile printing, in pigment dyeing, for paints, etc.

Plastics are dyed using soluble or insoluble, inorganic or organic dyes. Insoluble dyes are called pigments. Dyes and pigments are added to plastics in quantities of 0.001–5%. High demands are made in relation to heat resistance, dispersability, migration, light and weather fastness, physiological harmlessness, shades and price. Heat resistance is necessary due to the usually high processing temperatures. Light, weather and migration resistance and physiological harmlessness are tested by means of specific tests. The shade (shade, colour strength, colour purity) depends, in addition to the chemical constitution and the crystal modification, upon the particle size. Dyed plastics are transparent, if the pigment particles are smaller than half the wavelength of the light falling on the plastic. Pigments should have diameters between approx. 0.3–0.8 μm. Foils and threads up to a minimum thickness of 20 μm can be dyed using this type of pigment. For thinner foils or threads, so-called thread break occurs because the pigment particles are comparable in size to the foil thickness and the material breaks at the location of a pigment particle. Lighter shades can be obtained by grinding; however this also increases their swelling capacity. The coverage increases as the difference between the refractive indices of pigment and plastic increase.

Pigments can be inserted into the polymer by different methods. In soft polyvinylchloride they are usually mixed into the softener as a paste. In many cases a master batch (dye concentrate) is used or the pigment is mixed with a filler, to facilitate weighing. The surface of granulates are coated with pigment particles during mixing with pigments in granulate mixers due to the electrostatic charge; in this manner a total of up to 1% pigment can be inserted. Pigments used in lacquering and print pastes are often surrounded by so-called coating resins. So-called copolymers made of vinyl acetate and vinyl chloride, hydrated colophony or ethyl cellulose are used as coating resins.

Lumpiness of the pigments is determined by the inclusion of air; air is removed by the creation of a vacuum. Furthermore, pigments must be easily wettable. Improved wetting properties can, for example, be achieved by treatment with surface active agents. The totality of the pre-treatment processes for pigments is called conditioning.

The following inorganic pigments are most commonly used:

white: titanium dioxide (only rutile modification), ZnO, ZnS, lithopone ($ZnS + BaSO_4$).

yellow: CdS (acid sensitive), $Fe_2O_3 \cdot xH_2O$, $PbCrO_4$ (chrome yellow), benzidine yellow, flavanthrone yellow.

orange: pigments from the anthraquinone group.

red: CdSe, iron oxide red, molybdenum red and many organic substances.

bordeaux: CdSe, thioindigo, quinacridone.

violet: many organic pigments.

blue: ultramarine blue, cobalt blue, manganese blue ($Ba(MnO_4)/BaSO_4$), phthalocyanine blue.

green: chromium oxide, chlorinated copper phthalocyanine.

metal powder: aluminium.

pearly lustre pigments: leaf shaped lead carbonate.

(according to Elias).

Pigmentation processes for vat dyeing In a package dyeing machine, for example, these distribute the non-vatted dye first, in order to then make it soluble at the end of the exhaustion phase in the form of pigment adsorbed on the fibre surface. Normally the following procedure is followed for vat dyeing: Pre-vatting in the liquor (Fig. 1).

Benefits:

- preferred process for deep shades, including black;
- temperature stage variants (30–80°C) guarantee better levelling than other variants of the leuco procedure;
- result largely independent of the quality of the commercial form of the dye;
- suitable for all vat dyes.

Limitations:

- pre-vatting is labour intensive;
- preparation vessel is recommended;
- success depends upon levelling behaviour of the dye.

Vatting in long liquors is more widespread than the stock vat method, because handling is easier. This procedure can be used when the dye used has good levelling behaviour.

A time saving is achieved in the HT variant of the pigmenting process, as illustrated in Fig. 2.

Advantages:

- excellent levelling;
- virtually an “all-in” process.

Limitations:

- slightly limited dye selection;
- less suited for deep shades (rubbing fastness);
- special reducing agent necessary;
- reduction in degree of polymerisation possible;
- time consuming.

As a rule of thumb, the levelling capacity of a vat dye roughly doubles for each 10°C increase in the dyeing temperature. Due to the following advantages, the hot pigmenting process (Fig. 3) is widespread in practice:

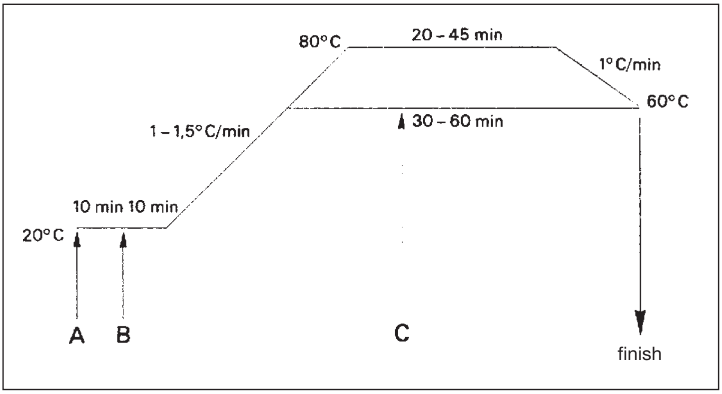


Fig. 1: Dyeing diagram for leuco processes (temperature level variants) with preliminary vatting. A = Albatex FFC (Ciba-Geigy), Irgasol CO (Ciba-Geigy) sequestering agent, dispersant additive, caustic soda, hydrogen sulphide (BASF), Albatex OR (Ciba-Geigy); B = stock vat; C = salt.

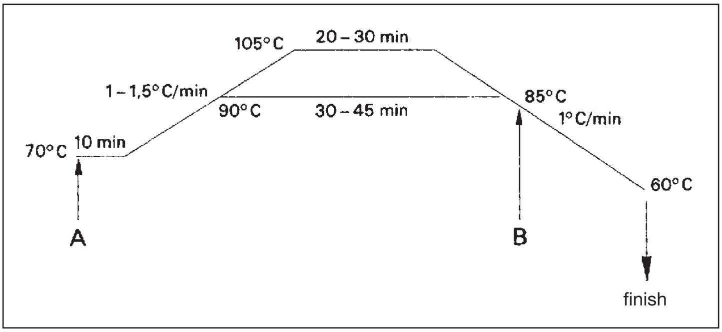


Fig. 2: Dyeing diagram for HT dyeing processes for pigmentation vat dyeing. A = Albatex FFC (Ciba-Geigy), Irgasol CO (Ciba-Geigy) sequestering agent, dispersant additive, dye, caustic soda, Rongal HT (BASF), Albatex OR (Ciba-Geigy); B = hydrogen sulphide (BASF).

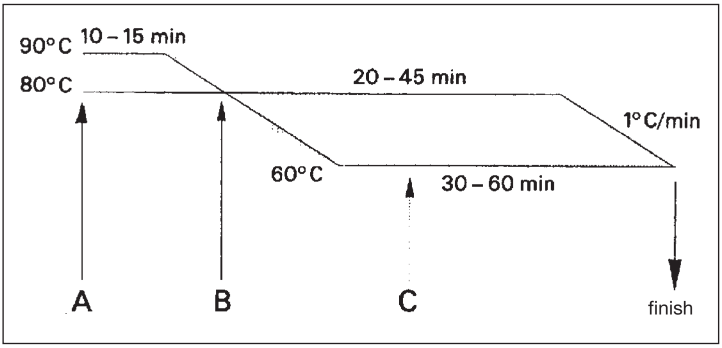


Fig. 3: Dyeing diagram for hot pigmentation processes. A = Albatex FFC (Ciba-Geigy), Irgasol CO (Ciba-Geigy) sequestering agent, dispersant additive, dye; B = caustic soda, hydrogen sulphide (BASF), Albatex OR (Ciba-Geigy); C = salt.

The greatest possible uniformity of pigment distribution on the material being dyed is striven for. A dispersing auxiliary is very useful. It is advisable to add caustic soda, reducing agent and levelling auxiliary together, because if caustic soda is added, agglomeration is only possible in the pigmenting phase.

Advantages:

- good penetration of the package at a high initial temperature in neutral medium;
- suitable for all shade depths (except black);
- problem free in difficult conditions, e.g. when using dyes belonging to different groups.

Limitations:

- not an “all in” procedure.

(according to Horn).

Pigment colorants Dyes with organic pigments, which are insoluble in water and only slightly soluble in organic solvents. Depending upon requirements, they can be applied as:

I. Metal free pigment dyes: Up to approx. 85% azo pigments (in particular red, yellow and orange shades). Further representatives of the carbonyl dyes are, for example, thioindigo derivatives, acrylamino anthraquinone, quinacridone, derivatives of naphthalene and perylene tetracarboxylic acid, indanthron and dioxazine.

II. Metal chelate complex pigment dye: Fastest blue and green pigments of insoluble phthalocyanine dye.

III. Colour lakes: The precipitation of water soluble dyes into slightly soluble salts. Earth alkalis, including bi and higher valent metal salts, are usually used as precipitating agents for anionic dyes, for cationic dyes hetero polyacids are used, amongst other things. Such colour lakes are manufactured from anthraquinone, azo, thiazine and triphenylmethane dyes.

Properties: Crystalline, particle size and dispersability represent critical preconditions for the application technology. They influence colour shade and colour intensity and are decisive for the resistance of usage options. Hardness and size of the pigment particles have a bearing upon the wear fastness of prints and are determined by the type of agglomerates precipitated during manufacture and drying. Excessively hard particles are difficult to reduce and disperse. Dispersability influences the stability of pigment distribution in the corresponding application media and can be improved by the addition of dispersants. The optimal particle size for pigments, depending upon application, is 0.05–0.5 μm.

Commercial form (so-called dispersal pigments, also formated pigments): Pastes, powder, platelets, flakes. Such preparations each contain additives suitable for the application. Pigment dyes for spin dyeing (spin pigments) must, as far as possible, guarantee a monodisperse pigment distribution in the spun substance, without the additive having a detrimental effect on the spinning process. Pigment dyes for printing and dyeing processes contain a binder that is necessary for anchoring to the substrate: Virtually all synthetic resins are soluble in water or solvents or are dispersible in water and also form a film that will bind sufficiently to the substrate. In pigment printing usually emulsion print pastes of W/O type (pigment dispersion in water) or O/W type (in organic solvent). Thickener and binder can be dissolved or dispersed in both the aqueous and the organic phase.

Pigment dyeing In the narrow sense it is an extension of the term → Pigment printing which is used to dye articles using pigments applied through the pad dyeing process. In terms of procedure it resembles the classic proofing process with pad-dye impregnating, drying and curing. The pigment dyeing process makes use of water-insoluble pigment dyes of either inorganic or organic nature which are fixed to the fibres with the aid of a fixing agent. Since no affinity between fibre and dyestuff is involved, dyeing can be carried out on all fibres and fibre blends. The following requirements for the fixing agent may be derived from the desired characteristics of the dyeing which results:

- bonds very effectively to pigment,
- a clear, colourless film,
- adheres well to the textile fibre,
- abrasion resistant, wash fast and can be dry-cleaned,
- minimal tackiness of film,
- very little or no hardening of the handle of the textile article,
- no yellowing, i.e. good light and aging resistance,
- resistant to mechanical and chemical agencies,
- compatible with other textile auxiliaries,
- smooth running characteristics,
- vessels, apparatus and machine parts can be cleaned easily and thoroughly.

These requirements can be met if the following conditions are applied:

- pigment dyeing without cross-linking agent, contains catalyst and anti-migration agent, fabrics have full handle.
- pigment dyeing with cross-linking agent, optimum fastness only in conjunction with cross-linking agent, fabrics have soft handle.
- pigment dyeing with and without cross-linking agent, fabrics have soft handle.
- pigment dyeing with and without cross-linking agent, particularly for dark shades with good fastness.

Even distribution of the dye pigment over the textile during dyeing is first and foremost a function of the machine technology. The pad rollers must apply pressure evenly. The dyebath must be agitated continuously to prevent settlement of the actual pigment. If possible air exposure should follow contact with the pad. Drying either in a hot flue or on stenter frames must proceed evenly and gently. Further, migration of the dye pigment must be avoided as far as is possible in the interests of even/level dyeing. It is penetration and migration which determine level dyeing (see Fig.). Penetration may be understood to mean the transport of pigment which begins with pad dyeing and must be concluded at least by the onset of drying. Penetration is favourably influenced by good preparation of fabrics and by a period of time (in air) between the pad dyeing

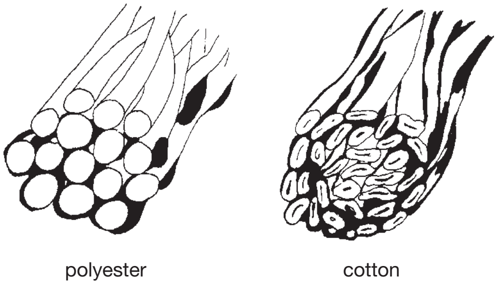


Fig.: Schematic representation of the distribution of fixed pigment on and within a thread made from polyester and from cotton; as a result of moderate penetration and/or of migration, the pigment is unevenly distributed (Bechter).

stage and the drying stage. In contrast to this, migration is a process which normally does not begin until drying takes place. Dyestuff migration may be minimized by the following means:

- reduced uptake of dye bath (greater squeeze pressure on the pad roller),
- adequate swelling time,
- gentle drying, i.e. reduction of fan speed and a maximum temperature of 120°C in the first two drying zones,
- anti-migration agent.

Ethylene/propylene block copolymer has proved effective as an anti-migration agent. At the onset of the drying phase the product physically absorbs the dye pigment and adheres it firmly to the surface of the fabric. At the same time it lends the textile both soft handle and good hydrophilic properties. Magnesium chloride or diammonium phosphate accentuate the anti-migration effect. The advantages of the pigment dyeing process are:

- Economy: one drying and curing stage instead of two production stages; large savings of water, chemicals and energy.
- Simplicity: pad dye impregnation, drying, curing; no post-treatment.
- Environmentally friendly: almost no pollution due to effluent or air except for formaldehyde given off by the fixing agent during curing.
- Fastness: wash fast in normal laundering and drycleaning, wear fast light colours and nowadays also dark colours; good to excellent light resistance.
- Universal application: all fabrics made from natural, synthetic and fibre blends can be dyed uniformly

(according to Haug).

Pigment dyeing process The simplest dyeing process which excludes affinity problems. The dye is padded, the material is dried and heat set. After-treatment is not necessary. Good fastness. Wash fastness depends upon the binder and not the dye. Suitable pretreatment necessary to create good absorbency, as are faultlessly functioning padder and drier (dye migration). Only light shades and possibly some medium shades are possible because the rubbing fastness is insufficient in darker shades. The pigment dyeing process is suitable for all natural and synthetic fibres and is used primarily for cheap qualities. If light pigment dyeings are combined with pigment printing, then the intermediately dried padding is printed and then dyeing and printing are fixed together.

Pigment dyeings/prints, test for The most reliable methods by microscopic testing of a fibre cross-section at 100–250 fold magnification. Evaluation by dye pigment distribution:

1. Evenly distributed over the total cross-section = spin dyeing.
2. Only surface layer with intercalation, attachment or depositing = pigment printing, pigment dyeing.

Pigmented wool bleaching i.e. bleaching of black hairs, that occur individually in wool fibre fleeces of white-yellow colour. The pigment dye of the pigmented wool is charged in a ferric salt mordant with iron ions, which bond to the carboxyl groups of the pigment melanin. After the excess iron has been rinsed out of the white wool, the whole fleece is treated in a peroxide bleach, which primarily relates to the pigmented hairs due to the presence of the iron catalyst.

Pigmenting process → Solvent technology in textile finishing.

Pigment printing Printing technique based upon a system of pigment and binder. Water insoluble white or coloured pigments with no fibre affinity are fixed to the textile material using synthetic resin binders. It differs from normal printing in that the dye is present in the form of insoluble bodies with no affinity to the substrate.

This type of printing gained importance with the development of suitable auxiliary substances (binders/thickeners/softeners), and is now the most important printing process in the world, representing 50% of all printing. Advantages of this system are:

- simplicity, good value for money (absence of all after-treatment processes),
- high light fastness (the diversity of pigments permits a strict selection),
- in theory applicable on all types of fibres.

Disadvantages:

- low fastness level (rubbing fastness, solvent fastness),
- negative influence on material handle if a suitable softener is not used.

The shortcomings listed are dependent upon the type of fibre and the fabric structure of the substrate to be printed.

The fields of application of pigment printing are to be found in the domestic textiles sector, in the fields of garden, camping and furniture material and in the outerwear sector. Pigments are insoluble or only very slightly soluble (solubility < 0.001 g/l), colorants, which as a further characteristic have no affinity to the fibre. They are fixed by means of a binder that creates a film, which surrounds the colour pigment and is responsible for fixing to the substrate. In addition to the textile sector (printing and dyeing of textiles), this class of dye is also used for the dyeing of paints, rubber and plastics and in paper printing. In the textile sector, pigment dyes should only be used in low and medium concentrations for reasons of cost, because at higher concentrations a poorer colour strength build up occurs due to the overlapping of pigments on the individual fibre.

Pigment dyes can be subdivided into inorganic and organic pigments. Fig. 1, which shows the different pigment groups with one or more typical representa-

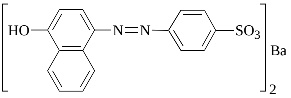
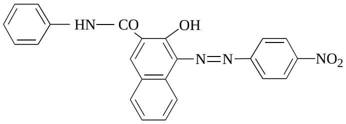
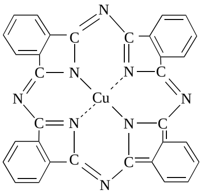
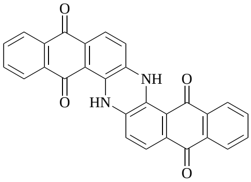
carbon black	
metal powder	bronze, gold, silver
metal oxides	Fe, Ti, Cr, Zn, Mn
inorganic salts	$PbCrO_4$, CdS, ultramarine, Berlin blue, $BaSO_4$
natural dyes	buckthorn yellow, catechu
colour lakes	
naphthol pigments	
metal complexes	 *Cu-phthalocyanine*
vat dyes	

Fig. 1: Representation of pigment dyes.

tive, should serve to illustrate the different types of soft pigment.

Previously, the pigments were generated on the fibre itself in material printing; this working method includes, for example, chromium green, iron oxide, Prussian blue and colour lakes of natural dyes. The growth of organic pigments increased the selection of dyes available. From a chemical point of view, organic pigments can be considered superior to all other dye classes. They differ from soluble representatives of a dye class due to the lack of solubilizing groups. Vat dyes, which in their soluble (reduced) form are also used in classical printing procedures, can be taken as an example.

Binder properties are primarily drawn upon to explain the fastness of pigment printing or dyeing, however the fastness of the pigments also plays a certain role. A great advantage of this dye class is its high light fastness, due to the fact that pigments are crystals, which consist of a large number of dye molecules. In addition to the binder film, the rubbing fastness is dependent upon the particle form of the pigment, because sharp edged crystals will more readily scratch the binder film under rubbing loads than rounded off shapes with fewer edges. Furthermore, the pigments must demonstrate solvent resistance and thermal resistance, i.e. they may not melt, sublimate or be destroyed at the application temperature. They must also be resistant to the assistants that are also used in the dyeing or printing recipe.

The particle size of the pigments influences the dye yield, the brilliance, the dye quality and some fastnesses. Excessively large pigment particles only achieve low dye yield and brilliance. The reason for this is in the lower total surface area of larger particles compared to smaller particles of the same mass. Likewise, binder coating is made more difficult, as for the pigment shape, which again results in a detrimental effect on rubbing and wet fastness. Large pigment particles can lead to an excessively skittery colour quality, and where there is an excessively small particle size there is the danger of the pigment diffusing through the network of the binder when solvent treatments are used, which leads to lower fastness. Furthermore, secondary agglomerates can form, i.e. two particles do not give rise to a uniform crystal of double the size, but an agglomerate of the two joined parts, that still exist as such. The formation of secondary agglomerates can be prevented by coating the primary particles with dispersants.

For the textile sector the particle size should be around 0.2–1 µm, an optimal size is achieved at 0.2–0.5 µm. The dye finish generally consists of a milling or kneading of the pigment with dispersant and water. Ethoxylation products are usually used as dispersants. This process brings about a reduction of the dye agglomerate, whereas the dye aggregate (particles bound by areas) is barely influenced. The formation and size of the aggregate can only be influenced within the manufacturing period. The dispersions obtained in this manner contain 25–45% pigments.

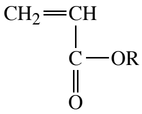
The binder serves as an adhesive between pigment particles and substrate. The properties of the binder determine the quality of the printed or dyed textile with regard to the quality of the handle and fastness properties. Due to the important role of the binder in the pigment process it is subject to a number of requirements:

– resistance against acids and lyes,
– wash resistance,
– swelling resistance,
– light fastness,
– resistant to ageing, weather and heat,
– dry and wet rubbing fastness,
– soft handle,
– physiological harmlessness,
– easy removal from machine components (e.g. rollers, screens, backcloths and rubber blankets,
– film formation.

The film formation properties represent the most important property of a binder. The film formed must be colourless, clear, of uniform thickness, neither too soft nor too hard, i.e. possessing elastic properties. Furthermore, it must coat and adhere to the pigment well and possess resistance to both mechanical and chemical loads. The listed requirements of the binder make it clear that the development of the pigment printing or pigment dyeing process followed the development of suitable binders.

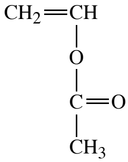
Modern binders are selected high molecular compounds, which are built up from single monomers by polymerisation, polycondensation or polyaddition. In textile printing, primarily weak dispersion binders are used, which are manufactured by emulsion polymerization. Common monomers are:

– different esters of acrylic acid (R = alkyl)



$CH_2{=}CH{-}C({=}O){-}OR$

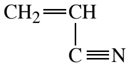
– vinylacetate



$CH_2{=}CH{-}O{-}C({=}O){-}CH_3$

– ethylene $CH_2{=}CH_2$

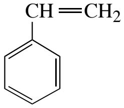
– acrylonitrile



$CH_2{=}CH{-}C{\equiv}N$

– butadiene $CH_2{=}CH{-}CH{=}CH_2$

– styrene



The homopolymers of the listed monomers cannot fulfil the diversity of required properties. For this reason, mixed polymers are used. These copolymers can be designed by targeted selection of the type and quantity of monomers according to the desired application. The glass transition temperature of the various homopolymers (see Tab.) represents a selection criterion. Because this has a direct relationship with the film hardness, predictions can be made regarding the handle quality. It is true from the Tab. that the film hardness increases with increasing glass transition temperature of the homopolymers. Thus certain monomers (those with high glass transition temperatures) do not come into consideration for the textile sector due to their excessive stiffening effect.

monomeres	glas temperature of polymer in °C
butadiene	–87
ethylene	–70 to –77
2-ethyl hexylacrylate	–85
n-butyl acrylate	–52 to –57
ethyl acrylate	–22 to –27
methyl acrylate	5 to 8
vinyl propionate	7 to 8
vinyl acetate	30 to 37
vinyl chloride	80
styrene	90 to 95
acrylnitrile (not fully crystalized)	100 to 106
acryl acid	166

Tab.: Glas temperatures of homopolymerisates.

Fig. 2 illustrates how a copolymer can be built up. If we conduct a polymerisation of two monomers of different hardness (butyl acrylate as the soft component and styrene as the hard component) then by varying the quantity ratios of the two individual components in relation to each other the softening range can be altered to suit the application. The softening range must be broad, because the temperatures, to which the pigment printed substrate is exposed, can be very varied (0–200°C). A quantity ratio of 60 parts by weight butyl acrylate to 40 parts by weight styrene yields a product that satisfies the main requirements. However, this copolymer also has disadvantages with regard to its resistance to higher temperatures and solvents. The latter can be achieved by the inclusion of a small proportion of a reactive compound, which brings about the cross-linking of the binder. If other monomer types are selected, the characteristics of this monomer give rise to corresponding relationships. So, if butadiene is used as the soft component a soft film is obtained with increasing butadiene content. This, however, has the disadvantage that the ageing resistance is greatly reduced due to the remaining covalent bond of the butadiene polymer.

In addition to variations due to monomer types and quantities, the degree of polymerization can be altered and thus influence exerted on the molecular weight and the chain length of the macromolecule generated. An important task of the binder is film creation. In order to make this possible the binder must be used in a suitable application form. It should be homogeneously distributed in the print paste and, if possible, uniformly separated. The aqueous solution and aqueous dispersion represent homogeneous distribution forms. The dispersion form is given preference due to the low viscosity, the high degree of water and wash fastness of the binder and the safeguarded procedure technique during manufacture.

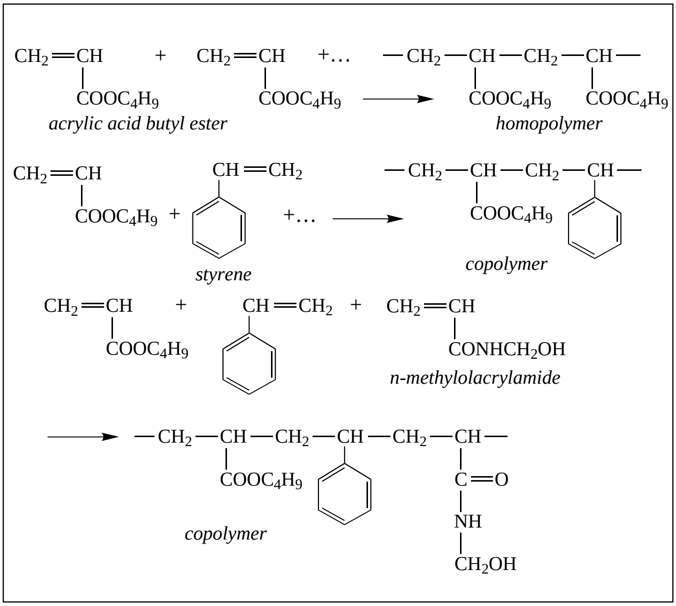


Fig. 2: Diagram representing a polymerization of butyl acrylate.

1. Self cross-linking: This type of cross-linking occurs if the chain molecules have reactive groupings such as N-methylol groups, which are capable of reacting with each other with the aid of a catalyst (acid or acid donor) at fixation temperature. Fig. 3 shows a schematic representation of this type of cross-linking, whereby N-methylolacrylamide has been selected as the reactive component. Both the condensation reactions described can occur.

2. Foreign cross-linking (cross-linking with additives): Multifunctional compounds in monomer or precondensed form, e.g. melamine resin or urea formaldehyde precondensate are added to the binder containing the functional groups. This type of cross-linking is necessary if the reactive group of the binder cannot react with itself (Fig. 4).

In addition to its influence on the viscoelastic properties, the cross-linking of the macromolecules also influences the swelling power of the binder film and thus the washing and solvent fastness (Fig. 5). By the formation of covalent bonds between the linear binder polymers, the rubber elasticity that exists to a small degree due to secondary bonds becomes more strongly marked. Rubber elasticity is the term used to describe the situation where exter-

Film formation takes place in two stages. First, water is extracted from the binder or print paste by vaporization and capillary action of the fibre and thus the stability of the emulsion removed. The disperse solids coagulate into a layer of thick spherical packings. In the second stage the coagulated particles coalesce under simultaneous deformation into a film surrounding the pigments. This has no elasticity and adheres only loosely to the textile, because the linear macromolecules can still move in relation to one another. It is only due to the cross-linking reaction that takes place during fixation that an elastic film is created.

We differentiate between two different types of cross-linking polymer binders:

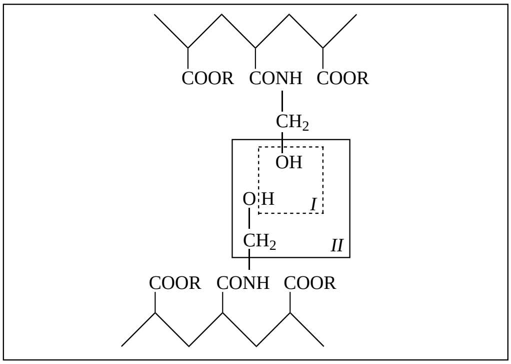


Fig. 3: Diagram representing spontaneous cross-linking.

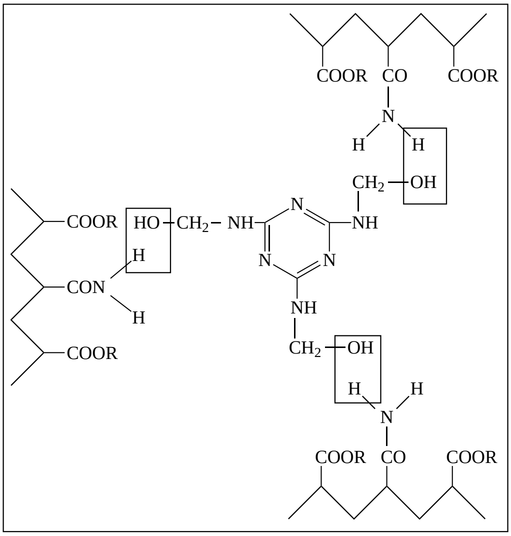


Fig. 4: Diagram of assisted cross-linking with acrylamide as the reactive component.

Pigment printing

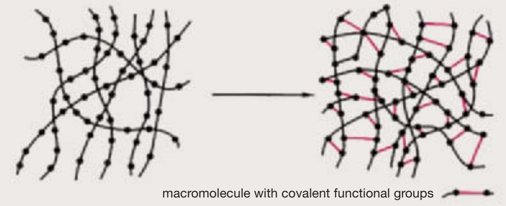


Fig. 5: Cross-linking of a binder film.

nally acting forces no longer impart lasting deformation; in the ideal case the deformed body can return to its initial position after the forces have been removed. As the degree of cross-linking increases, the swelling resistance improves, but the rubber elastic deformability falls; the film hardness is reduced. The objective of cross-linking is therefore to achieve the greatest possible swelling resistance with the lowest possible cross-linking.

The cross-linking takes place at the end of the whole process, because the binder for the pigment must remain accessible and able to be washed out of the substrate and devices for as long as possible.

The adhesion of the binder onto the dyed or printed textile determines the fastness to rubbing and washing of this substrate. We differentiate between three active components:

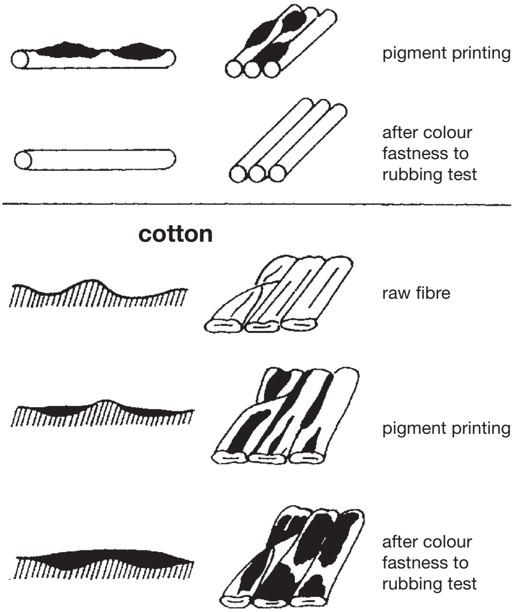


Fig. 6: Diagram representing the distribution of binder on polyester and cotton following shear loading (according to Bechter).

1. Physical bonding forces (adhesion forces) are dependent upon binder type and quantity of cross-linker. Fastness experiments have shown that for a given binder type the cross-linker concentration has no influence on the level of fastness of the substrate.
2. Chemical adhesion forces can only arise if both the binder polymer and the fibre material possess suitable (capable of reaction) functional groups. In the case of cellulose these bonding forces are so low that they can be disregarded.
3. Mechanical adhesion of the binder to the rough surface of the cotton fibre is the reason for the higher level of fastness of this type of fibre (Fig. 6).

A finished piece is expected to have a pleasant handle. Because a normal thickener, i.e. a water soluble high molecular bond, has a negative influence on the handle and wet fastness when inserted into the binder film, pigment printing was only able to achieve success after the development of emulsion thickeners. In these thickeners, benzine and water are used as the emulsion components, and they are known as oil in water or water in oil emulsions depending upon the distribution (Fig. 7).

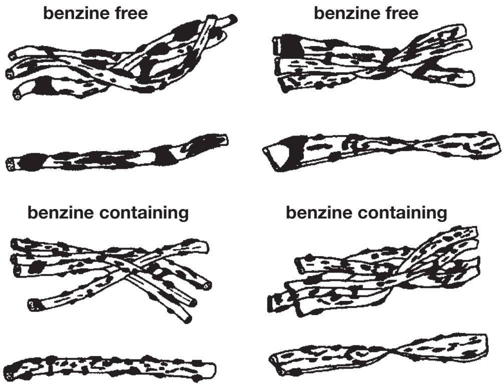


Fig. 7: Diagram contrasting binder deposition in the cases of benzine free and benzine containing pigment printing. Left: on polyester fibres; right: on cotton fibres.

A stock liquor (1000 g) contains the following approximate proportions:

150 g	water,
10 g	emulsifier,
50 g	low solids thickener (e.g. methylcellulose 7%),
30 g	ammonium sulphate 1 : 3 (as acid donor),
580 g	benzine (crystal oil),
180 g	resin binder.

The oil in water emulsion is formed from the water, emulsifier and benzine. The low solids thickener (methylcellulose) improves the printing properties of the print paste. The resin binder is the fixing medium, which is fixed by the acid donor (ammonium sulphate).

Naturally the benzine evaporates when the print dries, which is why the emulsion breaks down. The exhaust from the dryer must therefore be subjected to an expensive cleaning process using active carbon filters. Synthetic thickeners are better suited for pigment printing from an ecological point of view.

The following statement was taken as the starting point in the search for a thickening system with similar properties to the emulsion thickener: The product should be a high molecular, water soluble substance with high effectiveness, which is similar in structure to colloidal thickeners, but should show similar rheological behaviour to that of emulsions. Polymers were found in the homopolymers and copolymers of unsaturated acids such as acrylic acid (Fig. 8) and maleic acid (Fig. 9) that partially fulfilled the requirements.

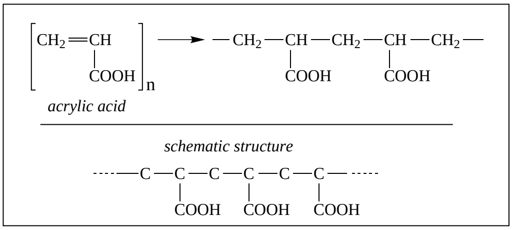


Fig. 8: Polymerization of acrylic acid.

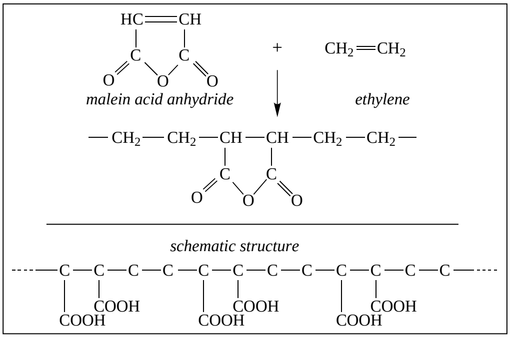


Fig. 9: Copolymerization of malein acid anhydride with ethylene.

The polymers are characterised by a multitude of carboxyl groups, which facilitate solubility in water. In aqueous solutions the macromolecules are present in the form of irregular balls. The viscosity of these solutions is in a functional relationship with the density of the balls, which is for its part dependent upon the molecular weight, the structure of the polymer chain, the solvation, the temperature and the degree of dissociation. If the acid groups are neutralised by the addition of alkali (e.g. ammonia) (if the acid groups go over from the non dissociated to the dissociated state), then a charge takes place along the chain, and the individual groups repel each other (Fig. 10). This causes an expansion of the molecule ball causing stretching.

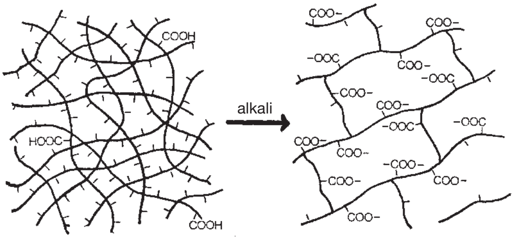


Fig. 10: Swelling of polymers caused by neutralization.

This increase in volume increases the viscosity, thus the effect of the thickener achieved. The viscosity increases until the balls have opened up to their maximum, which occurs before the neutralisation point. If further bases are now added, the dissociation is driven back (after a while quantitatively dissociated salts are formed), the balls shrink and the viscosity falls. This viscosity break down also occurs if ions are added in another form, e.g. as salts. For the printing company, this disadvantage of electrolyte sensitivity means that care must be taken that as little electrolyte is added to the print paste as possible. In the development stage described above, the thickener possessed good thickening properties but inadequate rheological properties. These could only be achieved by the addition of di or

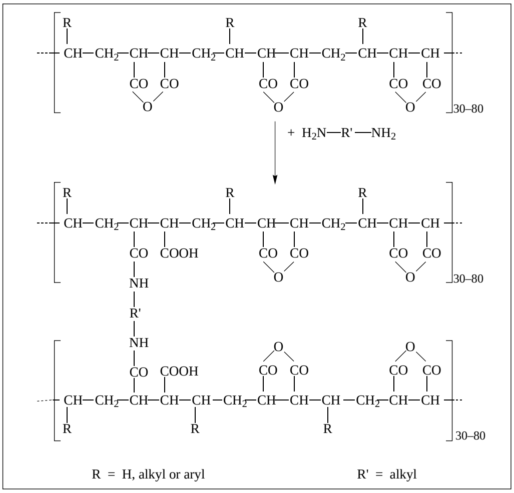


Fig. 11: Alternating copolymerisates of malein acid anhydride with olefines and subsequent cross-linking with polyamines.

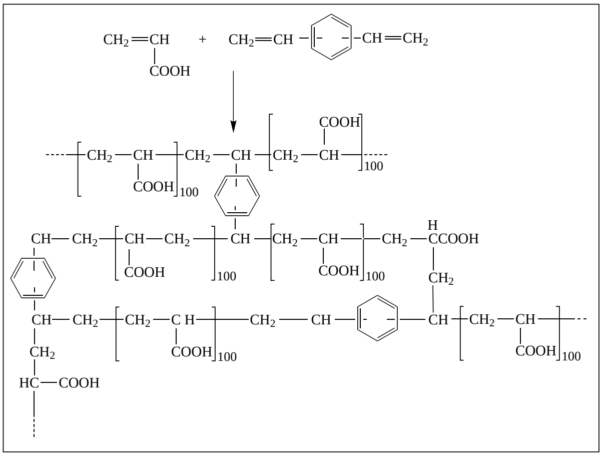


Fig. 12: Copolymerization of acrylic acid together with divinyl benzene.

trifunctional monomers into the polymer chain because they effect a cross-linking of macromolecules (as can be seen in Figs. 11 and 12).

By precise control of the polymerisation conditions it is possible to obtain polymers with a low particle size (1–10 µm) and targeted cross-linking. The cross-linked macromolecules are now no longer water soluble, but are still extremely swellable. The synthetic thickeners are low solids thickeners that can take on over 100 times their original volume in water. They are therefore particularly well suited for printing processes, in which a low solids content is desirable. Their rheological behaviour is characterised by a strongly falling structural viscosity with marked flow limits. This behaviour is caused by the deformability of the swelling bodies that occur in flow gaps. The polymer particles are aligned in the direction of flow and lose part of their solvate shell under the influence of shear forces, which leads to a rod-shaped deformation of the particles and can cause a loss of viscosity if the shear increases (Fig. 13). For pigment printing this viscosity behaviour facilitates the use of finer screen gauzes. Disadvantages of such thickeners are, in addition to the electrolyte sensitivity, the flushing sensitivity. This property can be improved by the addition of small amounts of colloidal thickeners or dilatant products such as polyglycolether derivatives. However, this results in a lower brilliance and colour depth of the prints.

Unlike pseudoplastic substances, these dilatant flowing substances show an increase in viscosity under shear stress (Fig. 14) (curve a). From a certain concentration the flowing resistance can become so high that the substances take on the consistency of a solid under certain circumstances. Depending upon the quantity of such products used in relation to the dispersion thickener (curve b) a viscosity curve is obtained with a correspondingly pushed out flow limit (curve c) and thus thickeners with altered printing properties.

The advantage of the pigment dyeing and printing process is that it can be used for many types of fibres

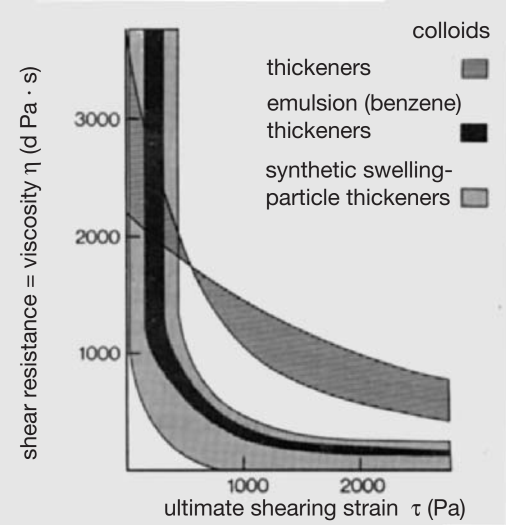


Fig. 13: Viscosity curves for different thickening systems (by Bayer).

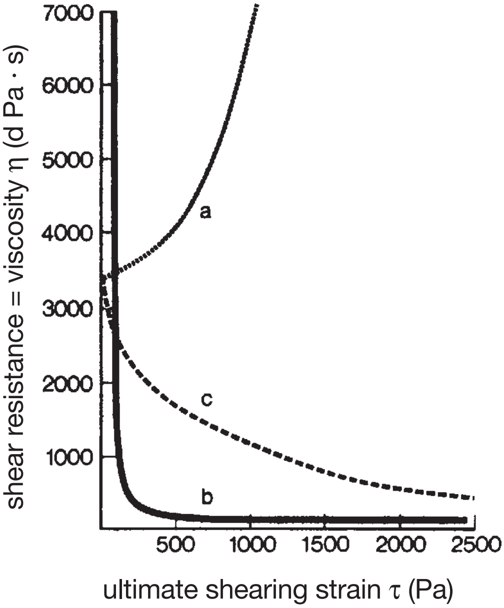


Fig. 14: Viscosity curves.

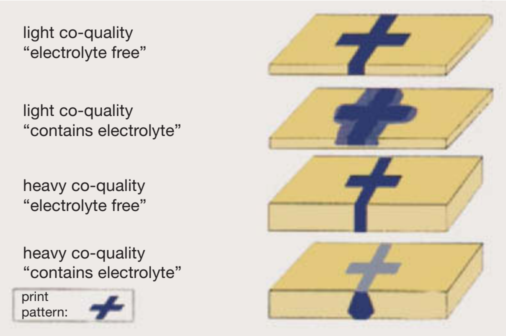


Fig. 15: Influence of the substrate on the outcome of pigment printing (by CHT).

and fibre mixes and is simple and economical to use, whilst at the same time yielding good fastness and general characteristics. A particular advantage of pigment printing is that it does not necessitate thickeners that need to be washed out after printing, as is the case with other printing processes. Originally emulsion thickeners with solvent naphtha were used for increasing the viscosity. Benzene free pigment printing is becoming increasingly common for ecological reasons.

In pigment printing every printer is familiar with the negative influence of excessive quantities of electrolyte on the material, but precise experimental regulations or even limit values for electrolyte concentration on the material are unheard of. The effects of material containing electrolyte on the printing quality in pigment printing are many. They extend from insufficient print stability, through colour shifts, to a worsening of the wear fastness of the textiles in question. It is common in practice for a pigment printer to have to print pretreated material from different finishers. Fig. 15 shows schematically the relationships in printing using pigment systems. If the printer has an ideally washed material available, then a good print stability and penetration would be achieved with both light and heavy material. However, if there is electrolyte on the material, the print on the light material quality will tend to bleed, because the print paste is not capable of distribution within the fabric. In heavy qualities, on the other hand, the print will penetrate too deeply, making the material appear significantly lighter (accordting to Becher, Wiggler, Burlesinger and Dorn).

Pigments for lustre and glitter prints The following pigments are used for special effects in pigment printing:

- metal pigments,
- pearly lustre pigments,
- glitter pigments.

The foil extraction process is also available for high lustre effects.

Procedures for the creation of laminar metal pigments use a highly pure copper cathode and a zinc electrolyte, because the pigments must be soft, ductile and extensible. The colour tones, the so-called natural colours, are determined by the zinc content, which can be 5–30%. The most important of the various alloys are:

- rich gold: Highest zinc content approx. 30%, colour yellowy green.
- rich pale gold: Medium zinc content approx. 20%, colour yellow.
- pale gold: Lowest zinc content approx. 10%, colour reddish.

The appropriate metal melt is poured onto horizontally rotating, water cooled disks and quickly solidifies to form palm sized disks of approx. 1 mm thickness. They are then reduced by cold working in ball mills in the dry (eddy mill) process or wet process (Hall process), with the addition of lubricants. During this process the surfaces of the freshly prepared metal pigments are covered with a lubricating film, thus preventing cold welding (secondary welding). Metal pigments of different sizes, shapes and properties are commercially available. Gold bronzes prompted textile printers to produce special lustre effects on textiles. They were put to use in ladies’ outerwear and decorative textiles. In addition to the so-called gold printing, silver printing using pure aluminium powder is also encountered. However, it has not achieved any great importance because it is associated with significant printing difficulties and fastness problems.

The fineness of pigments is of utmost importance for textile printers. Although the larger, predominantly laminar pigments provide the best lustre effect, they can block screen openings if the correct mesh number is not selected. Extremely fine, ball shaped pigments, on the other hand, allow problem-free printing; however the prints have a significantly reduced lustre effect. The size of the pigments for textile printing lies between 20–50 µm at a thickness of 0.3–0.5 µm.

Three main factors are of decisive importance for the quality of a gold bronze print:

- type of metal bronzes,
- selection of thickening system,
- selection of binder.

In the metal bronzes for textile printing we differentiate between single and coated types. Coating with a layer of silicium dioxide or a borate protects the metal against chemical influences and weathering. This also improves print paste stability and prevents premature “greening”. Gold prints using coating pigments have better perspiration and wash fastness (perborate-containing washing agents). No fine “void free” coating exists, and therefore it is not possible to provide complete and permanent protection against the above-mentioned influences.

The following thickening systems are available:

Pigments for lustre and glitter prints

Benzine emulsions, colloidal thickeners, dispersion thickeners. Print pastes based upon pure benzine emulsion have not proven themselves in practice, because they possess very poor running properties. Furthermore, the print pastes go green after a relatively short time; the keeping qualities of the print paste are very limited. Colloidal thickeners, on the other hand, have proven themselves, in particular polyvinyl alcohol and hydroxyethyl cellulose. In the first case, a high-solids thickener with high adhesiveness is available, which is particularly well suited for roller printing. Hydroxyethyl cellulose, on the other hand, (possibly in combination with polyvinyl alcohol) is better suited for flat and rotary screen printing because it is less detrimental to the handle of the prints, less than polyvinyl alcohol. Alginate thickeners are less favourable, because they do not react with the binders/cross-linking agents and thus achieve poorer fastness. When borate-containing bronze is used in conjunction with polyvinyl alcohol pastes a swelling of the print paste occurs in the alkaline range (above pH 7). This coagulation can be rectified by adjusting the bronze paste using diluted phosphoric acid at pH 7.

However, although bronze pastes used with synthetic thickeners provide prints of low hardness, the print pastes have a strong tendency to go green; their keeping quality is significantly poorer. The fastness level of the print also falls as pastes get older. This is due to the ammonium salt and the free ammonia in the print pastes because copper ions form, particularly under the effect of atmospheric oxygen (during the printing processes). These copper ions also damage dyeings using reactive dyes, because in the wet state (in washing during manufacture or domestic washing), depending upon the dwelling time, dye-metal complexes form that have a significantly altered colour shade. Only an intensive washing process using complexing agents may be capable of redissolving these complexes. Phosphate ions (diammonium phosphate) act against the greening of the pastes, because they precipitate the copper ions that are created. For these reasons, synthetic thickeners are not recommended for bronze print pastes.

Bronze pigments are fixed on the textile using both polyacrylate and polybutadiene binders. In specific cases, e.g. next to vat dyes in discharge printing, it may even be advantageous to use a polyurethane binder, because fixing is achieved by intensive drying of the prints above approx. 120°C.

Prints are often cold calendered on a calender at approx. 6 t pressure in order to improve the lustre, insofar as the printing material permits this. Printing with “silver bronze”, i.e. with aluminium powder, is not recommended because the print paste stability is not guaranteed. The pigments are coated with an hydroxide layer, accompanied by the formation of hydrogen, causing them to increase in size and block the print screens. The colour fastness to rubbing of such prints is poor, because the silver bronze has a strong tendency to “write” (determined by the softness of the metal).

Pearly lustre pigments (as suggested by their name) impart a pearly or mother-of-pearl type lustre. They are transparent, plate-like, thin, have smooth surfaces, high refractive indices and normally no intrinsic colour. Interference effects on and with suitable material are achieved by the precipitation of titanium oxide onto plate-like carriers, usually glitter. Printing with pearly lustre pigments is subject to the same condition as that described above for metal pigments: The diameter of the pigments is of significant importance for the lustre of the prints. The larger the plates, the greater the lustre effect, but the more problematic the printing process. The size of the pigments for printing is 10–50 µm. An opening of at least 3–4 times the plate size is necessary due to the so-called roof tile effect, whereby the pigments overlap like roof tiles, and can thus close screen openings. Because the pigments demonstrate indifferent chemical behaviour, print pastes with synthetic thickeners are the most favourable. It is important that the pearly lustre pigments are sufficiently well dispersed to be completely embedded in the binder system.

Glitter pigments impart a correspondingly high lustre due to their particle size. They are manufactured by the reduction of metallised foils made of polyester, polyepoxide or polyester/polyacrylate. They are gold, silver, mother-of-pearl in shade and can also be obtained in bright colours. Their high edge lengths (e.g. 0.2 × 0.2 × 0.01 mm) requires correspondingly large screen holes. In flat screen printing, gauzes with a maximum of 9 threads / cm should be used. In addition to possible clogging of the screens, there is also the danger of the print paste separating during printing. The specific light glitter forms a cream and floats on the surface of the print paste, but can be worked in again by intensive stirring. Therefore it is expedient to work from highly viscose, short print pastes, which hinder separation. The danger of flushing of prints during printing is particularly great with glitter, because these pigments remain on the surface of the textile due to the coarse nature of the pigments necessary for achieving the desired lustre effect. Multi-coloured prints using glitter pigments can only be achieved if there is an appropriate intermediate drying stage.

The foil stripping process for high-lustre effects takes place as follows: Metallically lustrous prints in gold or silver, but also bright and patterned (e.g. snake skin) can be created in melt-transfer. The textile is first printed with a suitable thermoplastic, colourless special adhesive. The drying temperature must not lie above the distortion temperature of the adhesive, so that the material does not stick together during plaiting down. Printed material and foil (with the matt foil side towards the printed material side) are combined on a transfer calender or a transfer press and, depending upon the type of adhesive, pressed together at 150–200°C under pressure. After the material has cooled the foil is removed. The points printed with binder appear as a pailletine effect. A closed, saturated binder film between textile and foil is necessary for good adhesion of the foil onto the textile. Such prints are effective, but unfortunately they are sensitive to alkali and ironing and furthermore often have insufficient washing fastness. In addition, the manufacture of such items is expensive, because the foil can only be used once (according to Wigger).

Pile,

I. Fine 2ply cellulose yarn, usually gas treated for weeds and mercerized.

II. Surface of velvet, plush and pile carpets in the sense of pile (III).

III. Right side material in carpets with marked three-dimensional character. According to DIN 6115: Material that forms the → Pile layer.

Pile brushing frame Used for the patterning of double ribbed fabric before → Moiring. The fabric ribs are scratched.

Pile carpets → Carpets with pile or → Pile layer (pile loops), in the form of knotted carpets, tufted carpets, or woven carpets; →: Axminster carpets; Bouclé carpets; Brussels carpets; Chenille, Plush carpet; Tapestry carpet; Tournay carpet; Velvet carpet.

Pile cutting machine Special form within the group of → Shearing machine. Whilst classical shearing machines always cut in several passes, new models make only a single shearing passage. Long pile items are cut to the desired pile height in a single stage. This makes it possible to economically reuse the cut off fibres.

Pile fabric Collective term for all plush, velvet, terry and carpet fabrics, whose decisive characteristic is vertical knops or loops, which are created by a certain pile warp. The loops may remain closed (frisé or bouclé) or are opened (coupé, e.g. velours). Cutting can take place directly on the power loom in single pile fabrics (Fig. 1) or on special cutting machines in the case of double fabrics (Fig. 2).

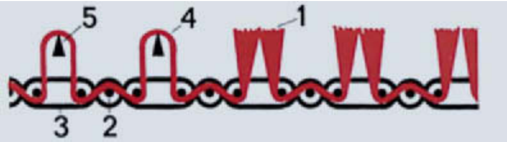


Fig. 1: Conventional process in which only a single woven fabric is produced.
1 = pile; 2 = weft; 3 = backing warp; 4 = pile warp; 5 = pile wire.

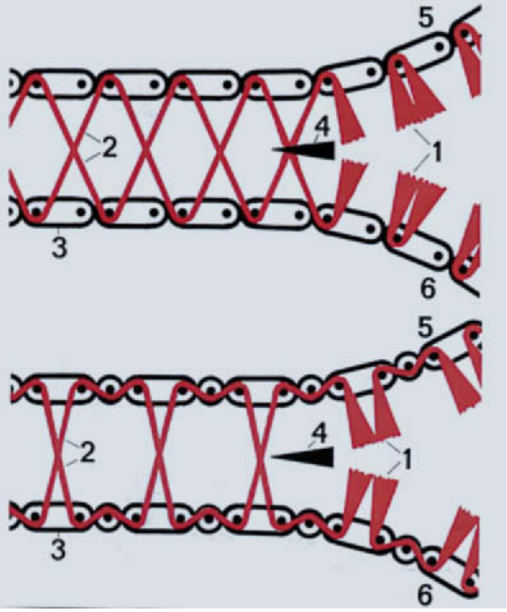


Fig. 2: More economical process for velour weaving; two woven fabrics are produced using a single pile warp.
1 = pile; 2 = pile warp; 3 = backing warp; 4 = band knife; 5 = upper weave; 6 = lower weave.

Pile firmness → Knops resistance.

Pile formation Undesired phenomenon in velour materials, particularly carpets. Pile fibres lie to one or other side in patches, giving rise to a blotchy appearance on the surface of the velour.

Pile goods Sheet goods, the third dimension of which in the form of thread or fibre ends (pile) is more strongly emphasized.

Pile height According to DIN 61151: Height of the pile layer above the carpet primary backing.

Pile-knitted fabrics Manufactured according to the type of → Plush cloth with pile surface, i.e. cut/shorn, pile quite short up to 14 cm long. Application for lining fabrics, outer cloth, imitation fur, blankets etc. Since the end of the 1950s particularly for imitation fur, for example, preferred base made of modacrylic fibres, also cotton, pile of polyamide fibres, or less commonly polyester and polyamide. The back is gummed, foam bonded, etc. if necessary. Sometimes such imitations are washable, but caution is advisable when dry cleaning, depending upon the material.

Pile layer Wear layer in carpet material (see Fig.) which contains an additional pile forming material above a special → Carpet primary backing.

Pile lifter Used in carpet shearing machines, for example, for aligning each pile row for shearing using a pile lifting roller fitted with special needles.

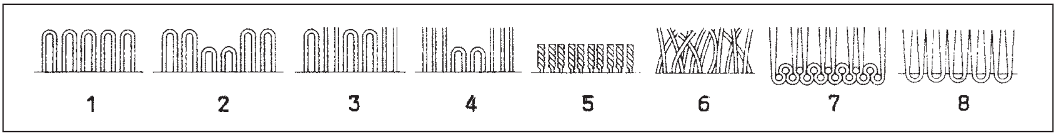


Fig.: Pile forms for carpets.
1 = level-loop pile; 2 = high-low pile; 3 = tip sheared pile (partially unsheared); 4 = cut-loop pile; 5 = Saxony; 6 = shag; 7 = woven tufting; 8 = tufting ware.

Pile-lifting machine Is used in the → Shearing of fabrics for the alignment of the pile or fibres to be sheared.

Pile loops,

I. In pile fabric systems that have closed or cut open yarn loops, typically for → Pile carpets.

II. Thread sections of the → Pile warp between the cutting/untying or bonding points. → Knops.

Pile opening With the aid of a pile opening machine (see Fig.) pile threads, which are usually made of twisted yarns, are gently opened in wool plush items, for example. The material is processed wet to minimize the material loss.

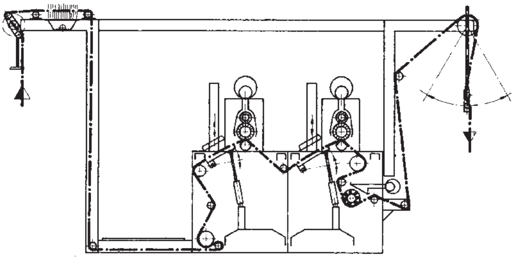


Fig.: Hergert PT II-D pile opening machine.

Pile patterning The surface of pile fabrics or pile knitted goods can be patterned using different methods:

- stencil brush (Fig. 1),
- whirling brush (Fig. 2),
- partitioned shearing tables, which are rotatable and driven (Fig. 3).

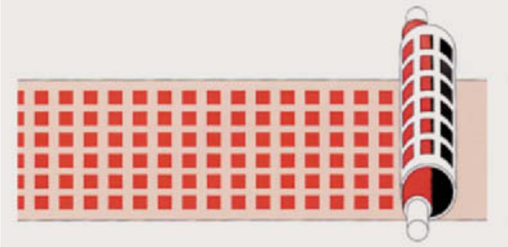


Fig. 1: Screen brushing.

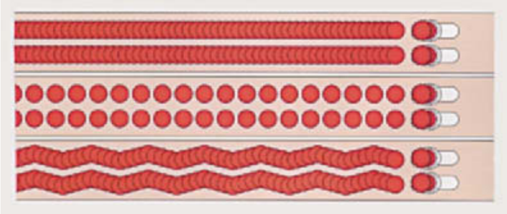


Fig. 2: Rotary brushing.

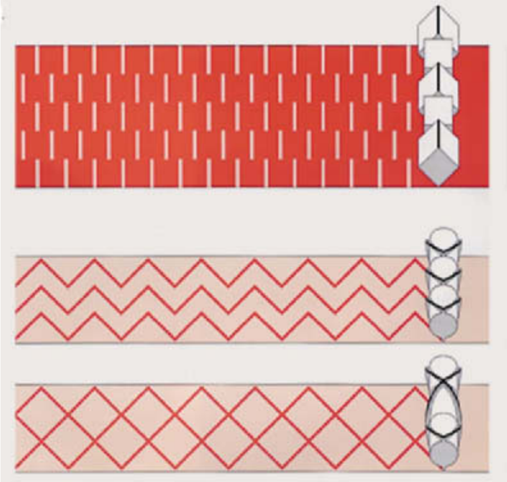


Fig. 3: Pattern cutting assembly with drive for geometric and floral designs.

Pile rotor → Glaze finishing machine (Fig. 1) for all pile and plush textiles with a working roller, the tem-

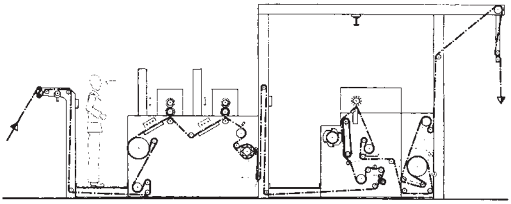


Fig. 1: Example of the final finishing of a acrylic velour by pile rotor treatment (right).

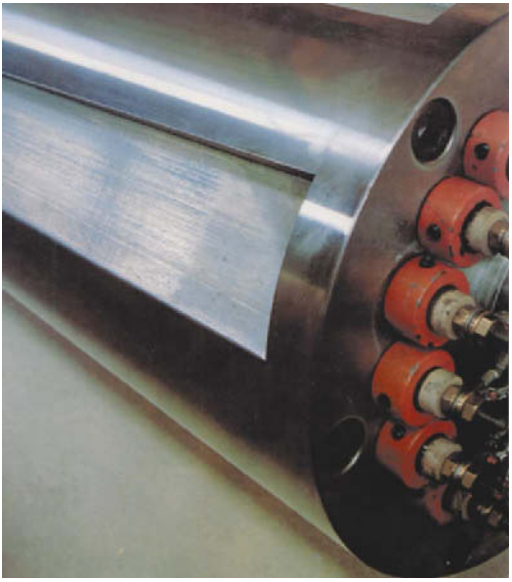


Fig. 2: Pile rotor with typical grooves and electric heating.

perature of which can be adjusted up to 500°C (Fig. 2). Roller rotation speed up to 1200 rpm. Material speed infinitely variable up to 15 m/min, working width up to 5000 mm. Lifts the pile of soft velours carpets and thus improves their lustre. Function see Fig. 3.

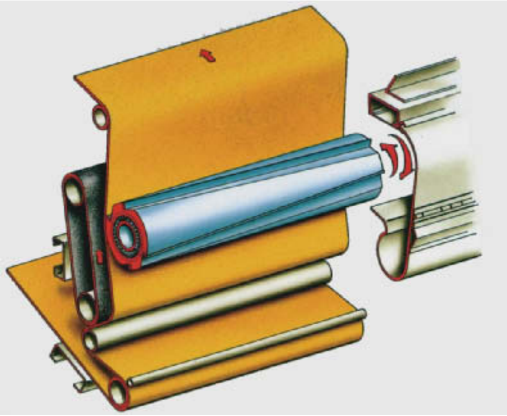


Fig. 3: Pile polishing unit (SMH).

Pile thermal treatment On thermally functioning → Raising machines for plush manufacture of synthetic fibres; can be used before and after dyeing. For final finishing of dyed material with shell damping, beaters and two infrared emitters and a cooling roller at the material exit, which prevents folding creases. When the material flow is interrupted the hot plate is pneumatically swung back from its work position, preventing the possibility of damage to the material.

Pile thread → Pile yarns.

Pile warp Warp ends for the creation of the → Pile layer and its bonding into the → Carpet primary backing.

Pile weight,

I. Weight in grams of the pile yarn processed per m^2 of carpet.

II. Weight in g/m^2 of the pile material protruding above the carpet base; determined by shearing (shaving) the pile.

Pile wires Thin metal rods used in weaving technology for pile fabrics. If the pile threads are to form drawn loops or pile loops, tension pile wires (with cutting blades on the end) are used.

Pile yarn → Pile.

Pile yarns Threads in → Velvet or → Plush, which form the characteristic pile. This occurs by threads being placed across thin metal rods (pile wires) during weaving, which are subsequently pulled out, creating loops over the base fabric, which can also be cut open. If the pile yarn is a warp thread this creates warp velvet; if it is a weft thread it creates weft velvet.

Pilgrim-step processing In order to increase the dwell time of material in a liquor, whilst keeping the material in motion with a short liquor ratio, a type of motion can be used that is reminiscent of the Echternacher spring procession: 3 forwards, 2 back.

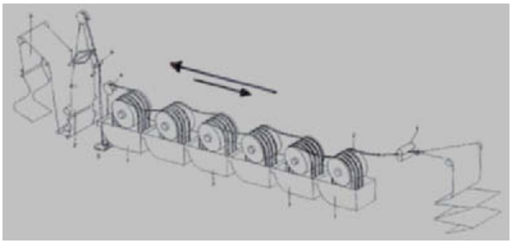


Fig.: The Rope-O-Matic principle.
1 = feed rollers; 2 = winch; 3 = washing vats; 4 = run-out winch; 5 = control panel; 6 = paired squeezing rollers; 7 = rope opener; 8 = plaiting down system.

The principle underlying the Stork Rope-O-Matic (see Fig.) is that at speeds of 30 m/min the bobbins carrying the fabric in rope form periodically change their direction of rotation, instead of having a continuously rotating movement. This pilgrim step movement of the bobbins vigourously moves the rope in the liquor, protectively, backwards and forwards, thus achieving a good washing effect. The forward speed is continuously variable. At speeds above 30 m/min the pilgrim step movement automatically switches off and reverts into continuous movement, which is adjustable up to 75 m/min (120 m/min in special cases).

Pillar stitch So-called single chain stitch seam, in which all stitches consist of one thread system and are easy to undo again, e.g. as decorative stitching and as piece goods sewing.

Pilling (pills, from the Lat. pila = hair balls), faulty, knop-like places that arise at points on clothing that are subject to particular wear due to the undesired rolling together of fibre ends on the surface of the fabric. It gives rise to a rough material surface (pilling effect) which is virtually impossible to dye uniformly. Most common on mixed fabrics and knitted goods made of wool with synthetics (polyamide, polyester or polyacrylonitrile fibres), also in pure synthetics.

Pilling is caused by rubbing and chafing. Textile surfaces made of staple fibres are affected. There are several factors responsible for this effect, for example, material, bonding, density, etc. Internationally, there are many different methods for evaluating the susceptibility of clothing materials to pilling, none of which are satisfactory for all applications: They are suitable for specific fabric or knitgood constructions or fibre types. In Great Britain, the British Standard (BS) is based upon the use of the ICI Pilling Box; in the USA, the ASTM is based upon the Atlas Random Tumble Pilling Tester (RTPT, Accelerotor), whereas in France the Balprest device is used when testing according to the ITF procedure.

The testing conditions to be applied for each individual testing procedure are carefully determined. The assessment and evaluation methods for the pilled sample surface are determined after comprehensive correlations with practical experiments and all test methods are in practical use.

The process of pill formation and development is rather complex and the speed of the creation of pills depends not only upon the fibre properties, the yarn structure and the construction of the pattern, but it is also determined by the surrounding conditions and the intensity of the loading. In the field of outerwear there are even significant differences, e.g. between pullovers for women's outerwear, men's outerwear or children's outerwear or between rompers for babies and jogging suits for adults. It is difficult to simulate such differences by a test method, although each of the standard test methods attempts to introduce certain differences in the severity of the stresses. In the case of the ICI Pilling Box and the Balprest Instrument these are achieved by varying the duration of the test; in the accelerotor the testing conditions are varied by exchanging the abrasive canvas or adding cotton linters. Consequently it is unavoidable that when testing a sample according to the same test procedure and using the same testing conditions, these test conditions are often totally unsuited to the intended field of use.

Low pilling polyester fibres exist, primarily in the form of fibres for wool spinning, the development of which is being particularly furthered in Europe. These fibres corresponded with the required soft, woolly handle and the demands of spinning and weaving. The pilling behaviour was also satisfactory in practice. The use of certain treatments within the finishing process, e.g. singeing, could be reduced for these fibres, which preserves and does not detract from a good handle. The development of the "rotor" and "Air-Jet" spinning techniques and the associated increases in the speed of carding, drawing and spinning itself was only possible after the development of a PES standard cotton type fibre. Due to their low mechanical resistance in comparison to standard fibres, low pilling fibres have forced spinners and weavers to reduce the speeds of cards, drawing and ring spinners and weaving machines and to avoid processing on rotor spinning machines altogether. For polyacrylonitrile fibres, the influence of the spinning type on the pilling behaviour has been proven (see Fig.).

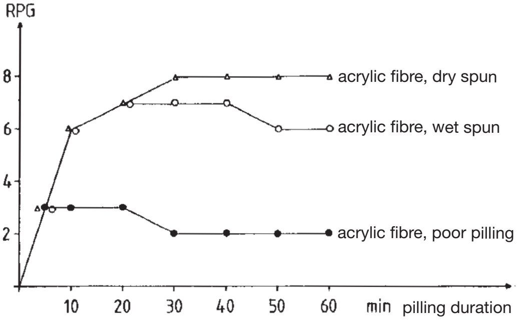


Fig.: Relationship between pill formation and the method of manufacture of the acrylic fibre; RPG (Reutlinger pill standard) = optical assessment grade.

The formation of pills may also be the result of inappropriate fabric construction. For example, pilling is promoted in mixed fabrics, particularly where there is a combination of a fibre of high abrasion resistance with a fibre of, at most, medium abrasion resistance. So, for example, there is some justification for thinking that softeners could promote this effect. Pill removal is dependent upon the material, and can be performed by shearing off or singeing but also by an → Antipilling finish.

Pilling behaviour, test methods Method: Fibre ends are extracted from the material by rubbing and balled by movement. Procedure and devices as for testing of → Abrasion resistance according to DIN 53 863, but with milder abrasive and lower stress.

Pilling effect, artificial Rarely used term meaning “pearl shaped” for the corresponding effects generated by → Friezing (pearl ratiné, perlé).

Pill in loop form → Pilling of texturized filament yarns in the form of twisted → Loop, which often also incorporates other fibre components. They appear mainly during processing as warp in loosely set elastic items, in which pill in loop is usually a result of increased surface wear perpendicular to the warp direction.

Pill test Method for testing the burning behaviour of carpets. A metheneamine pill is ignited upon the test piece and the combustion effects evaluated.

Pilot Dense, ribbed cotton fabric (a type of English leather or moleskin); usually dark coloured or black.

Pilot plant Semicommercial scale, in order to scale up experimental results from the laboratory scale, i.e. to reproduce them in the next largest scale.

Pin clips → Clips.

Pineapple cone → Biconical package, conical with spherical face. → Crosswound yarn package.

Pineapple fibre (pineapple leaf fibre) → Bromelia fibres.

Pineapple leaf fibre → Bromelia fibres.

Pine oil,

I. Product of destructive distillation (up to approx. 250°C) of resinous wood waste. Purified pine oil is extracted from raw pine oil, which produces a dark and unpleasant smelling oil, by the removal of acids, phenols, tar, etc.: Density 0.86, colourless to slightly yellowish, litmus neutral, with solvent properties and application similar to → Turpentine oils.

II. Wood turpentine, contains → Terpenes and considerable quantities of → Terpineol. Colourless to yellowish. Density 0.925–0.942. Soluble in most organic solvents. Application: Solvent, thinner, disinfectant, antifoaming agent, wetting agent, also for acetate delustring and as a swelling agent for polyvinylchloride dyeing.

Pink salt → Stannic chloride.

Pinning down In hand screen printing, fastening of the fabric onto the screen printing table, which is covered with felt and backcloth, or onto needle chains for linked fabric guidance.

Pin plates → Clips.

Pin wheel Derived from the → Palmer as a weft straightening device. The fabric runs on two inclined, non-driven (i.e. transported by the fabric) pinwheels (see Fig.). The wheels, which are each tilted forwards and outwards, create vectors in the warp direction, which accelerate the lagging weft side. When the pin wheels turn, their angle puts the weft threads under tension. This is therefore the setting device for positioning the two wheels in their angle in relation to one another. After a rotation angle of 180° between the in and out needling the weft thread position is once again at the right angle to the material warp.

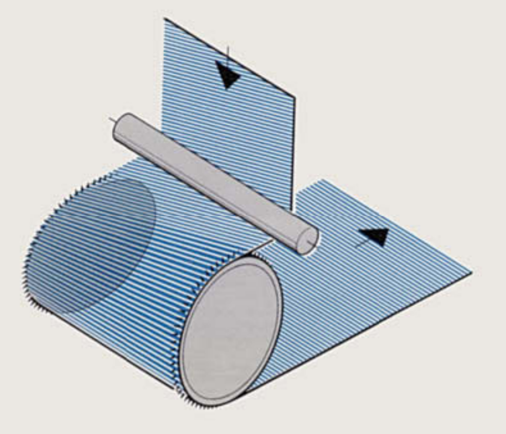


Fig.: Pin wheel device for aligning weft threads.

Pipette Narrow glass tube, with suction piece at the top, with a larger cylindrical area in the middle, pointed at the bottom; either with a calibrated ml filling mark (volumetric pipette) or graduated from top to bottom (scale pipette). Used for the removal of liquids during → Titration.

Pipework colour coding → Colour coding for pipework.

Piping Narrow border or strip of edging on seams, edges, collars and necklines.

Piping, cording Term for:

I. Yarn made of a large number of twisted individual threads.

II. Plaited threads, round cords.

III. Colored stripes or folds in clothes and uniforms.

Piqué (Fr: stepped), the characteristic stepped property is a result of the weave, sometimes also by an embossing treatment. Genuine piqué (fur piqué) consists of a fine plain weave top cloth and a coarse back cloth. The effect is created by filling and figuring wefts made of thick material and bound according to a pattern, which imprint onto the fine threaded surface to form the embossed pattern. In double piqué the material has two right sides. In press piqué, a non-genuine piqué, the figuring pattern is pressed into the smooth fabric by the embossing calender; often made durable by a special synthetic resin finish. These mechanically applied embossing effects are not always wash fast. Piqué matelassé, which has a relief-type jacquard pattern made up of 2 warp and 3 weft thread systems, is a piqué-like step fabric. A marked plastic effect is achieved by the internal filling weft. The plasticity can be increased still further by special finishing procedures due to a polyamide component in the material composition.

Pirn Short or long package, with or without cone, primarily for filling yarn.

Piston shaping unit Smoothly polished, perforated steaming and pressing piston, without a cover, for rapid special shaping of outer clothing. Different piston shapes, e.g. for upper section, shoulders and sleeves. Usually 2(–4) pistons per work table make up a so-called unit (set). Each piston has a steam supply, pedal operated, without or, more commonly, with suction. A pressing iron can also be connected to each piston (with a copper gauze filter insert to prevent water spots, or covered with sailcloth).

Piston steamer Piston steamer for the continuous dyeing of loose wool and polyamide flock. It consists of a long tube, which is steam heated by a double jacket and also has a connection for the direct entry of steam. Loose, impregnated fibres are inserted continuously into the steam pipes through a funnel, where pistons moving to and fro compress the fibres and propel them to the steamer outlet.

PIT → Phase inversion temperature.

Pita fibre → Mauritius hemp.

Pitch mark Several mm long indentation of approx. 1 mm diameter on the edge of the engraving of a printing roller for repeat setting.

Pitch pin Used for precise repeat setting of print rollers in the → Pitch mark.

Pitch pine Valuable American tropical wood type (pine), characterized by its special hardness and resistance cability. Used for bleaching and dyeing vats, which are also clad with porcelain or corrosion resistant metals.

Pitch tips Resin and pitch part of wool, characteristic of the sheep. Difficult to remove, they travel with the wool into the raw wool scouring, sometimes also to the milling stage, where they can be removed by appropriate fat-solubilising soap.

Pith straw → Straw.

Pitting corrosion (pitting), special case of → Corrosion, which appears in the form of point erosion and corrosion, in plates, equipment walls, etc. that are several millimetres thick, with undamaged areas between locally corroded points. Appearance after previous → Electrolytic corrosion mainly in solutions of halogens. Thus, special steels can also be rapidly locally corroded at points by solutions containing chloride ions (primarily at low pH and increased temperatures). Special steels containing molybdenum, on the other hand, are more resistant.

Pitting, selective corrosion,

I. In metals → Pitting corrosion.

II. In textiles: The → Alkali treatment of polyester with caustic soda liquor is not, as previously assumed, a weight reduction process in the sense of a transfer of the polymer mass in layers from the shell to the core. Rather, polymer degradation takes place in the form of point pitting corrosion (see Fig.).

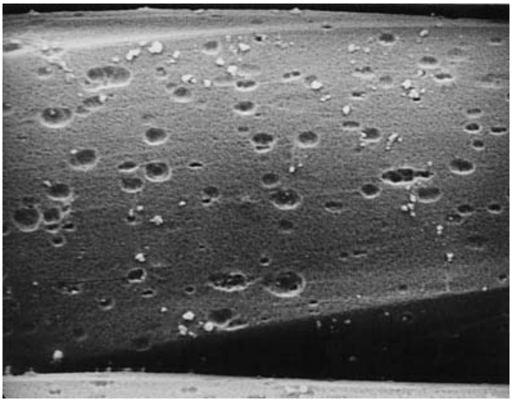
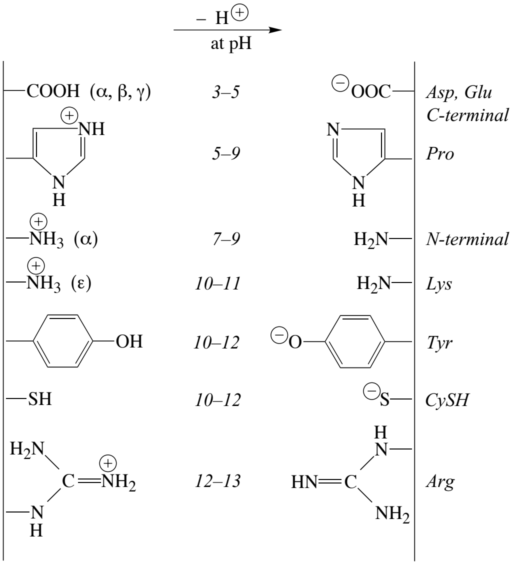


Fig.: Pitting on a polyester fibre exposed to alkali.

pK value Is the pH at which a compound splits off a proton by the addition of alkali or attaches a proton by the addition of acid. Plays a role in reactions of amino acid side chains of wool.



For example, if the pK_S value of peracetic acid lies at pH 8.2; at this pH there are the same concentrations of peracetic acids and peracetate anions.

PKN Polish standards association → Technical and professional organizations.

PKS bleach process (peroxide continuous fast process), the continuous immersion bleach process without a padder is suitable for the bleaching of all cotton, cotton mix and linen fabric as well as coloured fabric, particularly where relatively high demands are made of the material quality, such as good absorbency, absence of scale good handle, uniform degree of

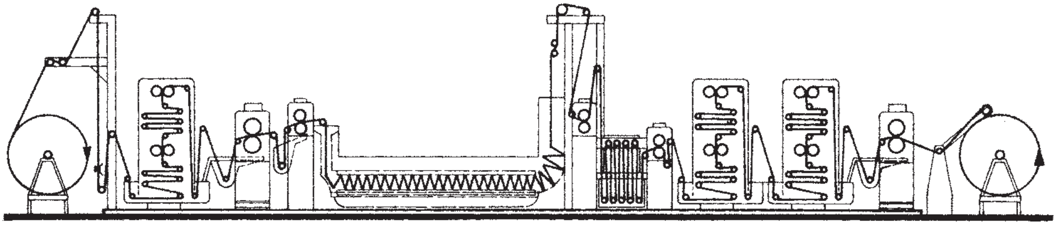


Fig. 1: PKS bleaching with immersion accumulator by Menzel.

bleaching, good material shrinkage, short bleaching time and low fibre damage. Bleaching takes place in strong, well stabilized peroxide liquor at 92–98°C with a dwell time of 8–20 min, chemical consumption approx. 20 ml/l hydrogen peroxide (35% by weight). The sectional drawing in Fig. 1 shows a continuous immersion open-width bleaching with tower washing units using the counter-current principle (economical water consumption 5–6 l/kg material).

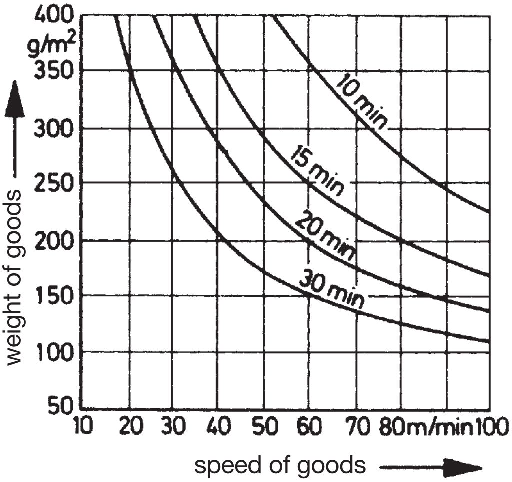


Fig. 2: Immersion time in the PKS bleaching immersion accumulator.

Fig. 2 shows material speed in relation to material weight and dwell time with an immersion accumulator (type 4000) with delivery lengths of 4 m.

PL → Polyester fibres, → Textile fibre symbols, in accordance with → EDP Code; → PES.

Place on the star frame, to Pinning piece material down onto the star frame of a star dyeing machine or star steamer.

Plaid Tartan fabrics; general patterning term for bright, checked fabric or cloth in wool, cotton, viscose, etc. The checked pattern is characteristic. Woollen plaids are woven from wool coloured carded yarns in a loose arrangement, usually milled and provided with a long nap. Application as travelling rugs and shawls.

Plain dyed fabric Single coloured, unpatterned.

Plain fabric Manufactured in plain weave, (usually) smooth material made of flax or cotton of different fineness, density and finish (the finest plain fabric = batiste).

Plain raschel fabric → Raschel-knitted fabrics, in which a guide bar forms the base and a further guide bar inserts a weft in accordance with the pattern, which achieves the side connection of the stitch wales (e.g. weft pattern).

Plain weave → Weave.

Plain weave cotton fabric Collective term for plain weave fabrics of different finenesses and thread densities made of single cotton yarn (nettle cloth, coarse cotton cambric), which are sometimes used raw, bleached, dyed or printed. The 3 basic qualities in increasing fineness of the fabric structure are a) → Cretonne; b) → Renforcé; c) → Calico.

Plaited goods wagon Means of internal transport for materials in stacked or rope form.

Plaiter Device for stacking material in folds.

Plaiting down Stacking of continuous fabric lengths (see Fig.) in a zigzag form. Takes up more space than batching.

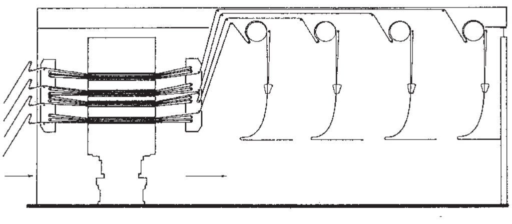


Fig.: Diagram of a Hattersley-Pickard intermittent operation boarding press (semi-continuous) and multiple plaiting down.

Planetary paddle mixer Mixing machine with two paddle mixers, which revolve around their axes and around each other.

Plangi (Malysian: bright, recessed spot), a resist technique that is still widespread in South East Asia and Africa (like the Japanese → Shibori technique) for the patterning of clothing materials. Before dyeing yarn package or binder resistance take place (→ Ikat), which appears as recessed pattern after dyeing. Stitch plangi is called → Tritik. In a wider sense the plangi technique is performed by folding, knotting or weaving, by screens, by resist application (sludge, paste, wax) and by negative resists using dye mordanting. Often several techniques are combined.

Planographic printing Mode of working in paper printing, whereby printing and non-printing positions on the printing block are adjacent in one plane and differ due to the application of a certain preparation which determines the acceptance or rejection of the print paste.

Plant comparison Comparison of the characteristics of different plants with the aim of selecting the most suitable plant for a given task. The following points are considered: a) Costs (plant and maintenance costs); b) Technology, operating safety, ease of combination; c) Performance parameters (cycle and operation characteristic figures); d) Delivery, guarantee and service.

Plasma Physics tells us that material is made up of atoms, which can themselves be subdivided into atomic nuclei and electrons. The decisive differences between the different states of matter is due to the compound make up of these particles. Plasma is the least organized collection of electrons and atomic nuclei, i.e. it is a mixture of these two components. The gaseous phase on the other hand, is characterized by the formation of atoms, the bonding of atomic nuclei and electrons. A further increase of order by the linking of atoms to form unordered, but dense bonds, allows the liquid phase to be created. The highest level of order is, however, in solid bodies such as crystals by the symmetrical organisation of atoms. The removal of the atomic bond between electrons and atomic nuclei, typical in plasmas, gives rise to the decisive difference between gases and plasmas. Whereas gases are electrically neutral, plasmas can conduct electric currents and can be manipulated by electromagnetic fields. Because this characteristic also occurs if the atomic bond is not completely ionized, and thus atoms have not given up all electrons, the term ionized gas and plasma are used synonymously.

Plasma is thus characterized by the following properties:

- contains an increased number of charge carriers (conductivity),
- quasineutrality (same number of positive and negative charges in a unit volume),
- increased energy and heat content,
- creation of equilibrium states (charge carrier formation and recombination is stationary),
- existence of speed and energy distribution functions (permit the characterization of the plasma by temperature).

Just as there are differences between individual solids or liquids, there are also different plasmas. An arc is fundamentally different from the discharge in a fluorescent tube. Primarily, the type of atoms and ions characterize the plasma. Further parameters that determine the properties of a plasma are energy content, pressure and expansion. Whereas in small plasmas, for example, those used in technical applications, the interaction of the plasma with its environment is of critical importance, this factor is of lesser importance for cosmic plasmas. Often it is just such boundary effects that are exploited for technical applications. So in arc welding, the interaction of plasma with a metal is exploited.

But the energy content is also an important factor for differentiating between plasmas, e.g. of the arc with a fluorescent tube. Whereas an arc possesses energy of a few kilowatts, the luminous discharge of a fluorescent tube only consumes a few watts. In addition to other parameters, pressure is critical in determining the properties of the plasma. Whereas arcs burn at atmospheric pressure (1000 mbar), the luminous discharge ignites in the region of 1 mbar.

Fig. 1 shows a classification of electrical discharges according to their current-voltage characteristic. After the application of a voltage to a gas line there is a region in which very low currents flow and this can be called the Townsend or non-self-maintained dark discharge. Adjoining this is a region called the corona discharge. It is characterized by a weak current discharge when a high voltage is applied (however an isolator hinders dielectric breakdown) in preferably bent elec-

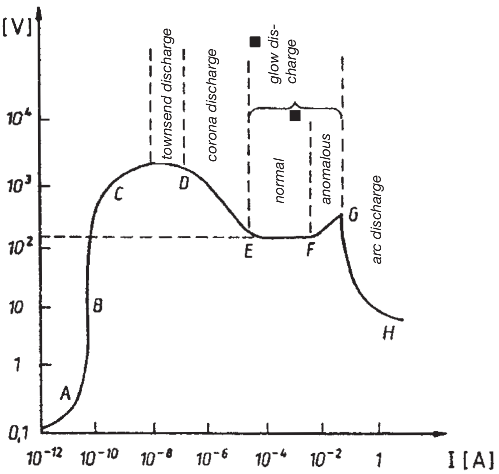


Fig. 1: The current-voltage characteristic of electrical gas discharges.

trodes accompanied by a weak glow. Luminous discharges occur at comparatively low pressures of approx. 10 mbar. In comparison to corona discharge, the luminous discharge can be performed at lower voltages and higher currents. Arc discharge represents the typical type of discharge at high pressures of 1 bar and above, in which very high currents occur.

Solid/liquid and liquid/gas phase transitions can be triggered by the addition of heat. At the same time we associate lightning, sparks and arcs with very high temperatures. The efforts to ignite a nuclear fusion plasma have also led to extraordinarily hot plasmas. Even though the temperature required for the self-sustaining ignition of a fusion plasma has not yet been attained, plasmas hotter than the sun have been attained. However, these high temperatures do not represent a necessary criterion for the existence of a plasma.

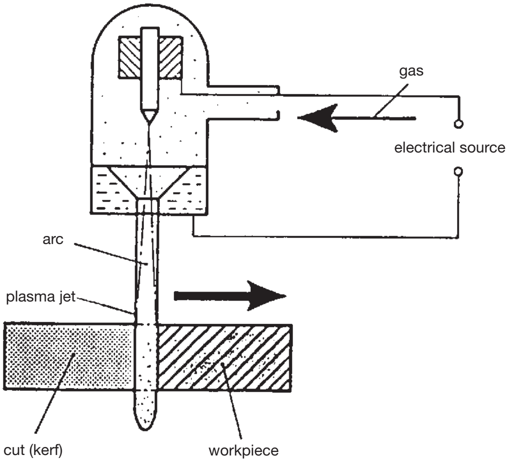


Fig. 2: Working principle of thermal separation with the aid of plasma.

In thermal cutting using plasma, the heat required at the work point is transferred to the workpiece by a gas in the plasma state (Fig. 2). Such plasma is an extremely hot gas with a temperature of 10 000–20 000°C, whereby all atoms split to create a mixture of ions and free electrons. The most common procedure for producing plasma is gas penetration through an electric field. This is achieved using a device commonly known as a “Plasma torch” and consists of a device that converts electrical energy into thermal energy and thus generates high-pressure plasma. When working according to the “not transferred” manner, the arc remains inside the torch. The high-temperature plasma jet is blown through the nozzle. Because the arc is formed inside, power consumption is limited by nozzle erosion. However, due to the precise construction of the internal torch geometry it is possible to maintain plasma jets with a small diameter and power densities of MW/cm^2. This torch type is suitable for cutting thin, non-conducting materials. The cutting process of the plasma jet consists of heat transfer from the jet to the cutting material by convection and the disposal of the material from the interface by mechanical means. The quality of cut performed by a plasma torch is influenced by a number of variables both inside and outside of the torch. New torch designs have reduced these to: arc power, gas pressure, nozzle diameter, distance (between nozzle and material), quality of the plasma gas. Cutting quality also depends on the cutting speed.

Torches are used for cutting textiles, from heavy polyamide belts to clothing materials. The latter field is of particular importance. Test cuts have been made on a number of clothing materials, such as smooth knitted wool, polyester, polyacrylonitrile, and cotton, with excellent results with regard to cutting quality and cutting speed. When cutting workpieces made of thermoplastic fibres the thermal procedure is superior to the conventional procedure when there is a small number of complicatedly shaped parts, for which even steel band cutters would not be economically viable. If there is a large number of different parts like this the need to keep stocks of tools is also dispensed with. However, the greatest advantage, particularly in the contactless thermal procedure, lies in the great flexibility in material and shape at low layer heights and in the possibility of integration into X-Y controlled plants with low tool mass at high path speeds. The development of cutting and separating techniques in textiles extends to complete plants including easily programmable controls and computers, in particular the guidance of crosswise and lengthways cutting and shape cutting are automated, giving rise to the need for light cutting heads.

In addition to this “hot” plasma, so-called “cold” plasma has increased in importance technologically. The word “cold” expresses the low energy content of these plasmas. Thermodynamically, temperature is defined by the movement energy of the particles. If we consider the kinetic energy of the two types of particle (electrons and ions), then we find that in low-pressure plasmas this energy is different for ions and electrons.

The electrical energy stored in the plasma is converted into the following energy forms:

– movement energy of the charged particles (electrons, ions),
– excitation energy of activated particles,
– electromagnetic radiation, which is emitted as visible UV and IR light and is a result of the recombination of the charged and activated particles.

The following elementary processes occur in plasma:

1. excitation: $A_2 + e^- \rightarrow A_2^{\bullet} + e^-$
2. dissociation: $A_2 + e^- \rightarrow 2\,A + e^-$
3. ionization: $A_2 + e^- \rightarrow A_2^{+} + 2\,e^-$

4. ionizing dissociation: $A_2 + e^- \rightarrow A + A^+ + 2e^-$
5. dissociation into radicals and ions: $AB + e^- \rightarrow A^\bullet + B^-$
6. electron capture: $A_2 + e^- \rightarrow A^- + A$
7. radical formation due to radiation.
8. formation of new molecules, atoms and radicals by neutralisation, recombination and structural reorganizations.

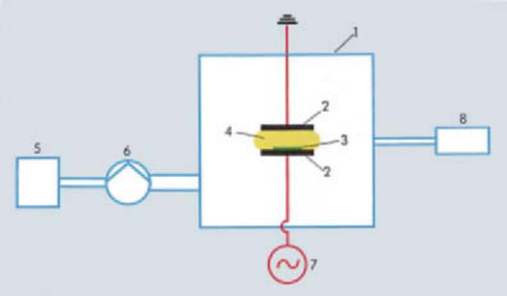


Fig. 3: Sketch diagram of a parallel plate reactor for plasma polymerization.
1 = vacuum chamber; 2 = electrodes; 3 = substrate;
4 = plasma; 5 = exhaust gas cleaner; 6 = vacuum pump;
7 = high frequency generator; 8 = gas supply (CH_4).

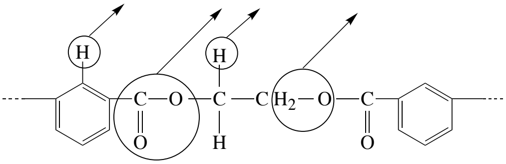
The high-frequency electromagnetic transmitter (Fig. 3), which is often used for the generation of a technical plasma, primarily give their energy up to the electrons, because these are significantly less inactive that the ions. This means that the electrons are "heated" and thus their average kinetic energy, i.e. their temperature, increases. Collisions between electrons and ions cause electrons to pass their energy on to the ions. Due to the great mass difference this energy transfer is only small. A number of collisions are necessary to achieve a balance between ion and electron temperatures. The number of collisions which a particle undergoes depends upon the pressure. At a high pressure the number of collisions is high, and there is a rapid equalization of the average energy of electrons and ions. In low density plasmas, on the other hand, this thermalisation between the particle types is not effective, and a system is created made up of hot electrons and cold ions.

In addition to thermal equalisation, collisions also play a role in the maintenance of the charge carriers. A mixture of electrons and ions will tend to form neutral atoms by the combination of the two particles. This process is known as recombination. This recombination leads to the two free charge carriers (electrons and ions) becoming a neutral atom, thus causing the plasma to lose some of its conductivity. Recombination is the process that converts an ionized gas into a "normal" gas. The stable burning of ignited plasma requires an equilibrium between the destruction and generation of charged particles. This source consists of the above-mentioned collisions between electrons and atoms or ions. If a hot electron hits an atom, it can knock out a captive electron (ionization). Whereas originally there was one free charge carrier, after the collision there are three. If equilibrium exists between recombination and ionization, then the plasma will burn in a stable manner.

However, the ionization of an atom is not the only process that can be triggered by an electron collision. In order for an electron to ionize an atom, it must transfer minimum energy to the atom during the impact, the ionization energy. If energy transfer due to the impact is less than the ionisation energy, then the struck atom is excited. The excited states are usually not stable, and such an atom returns to its original state, the basic state, radiating light as it does so. This is the cause of the illuminated appearance of plasmas.

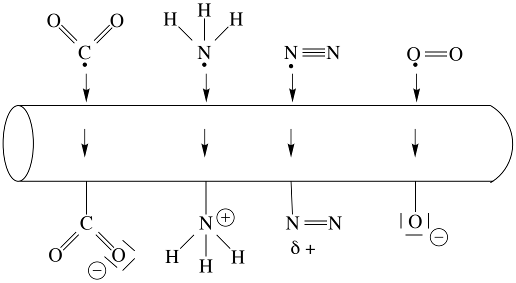
Plasma applications to fibres Low-pressure plasma can be used to chemically change the fibre surface in four areas:

I. Polymer etching: Oligomers are decomposed from the fibre surface in an inert gas plasma according to the following chemical mechanism (on polyester fibres).



In a longer treatment (1 min) and high power input (in watts) the etching is associated with a roughening of the fibre surface, increased refractive index and apparently darker colouring. Etching of wool fibre surfaces creates a sheen due to the partial removal of cuticle irregularities.

II. Functionalization: If, instead of a pure vacuum or inert gas atmosphere, "reactive" gases such as oxygen, air, nitrogen, carbon dioxide, ammonia are used, then the fibre surface is rendered hydrophilic and the immediate surface of the fibre is decrystallized.



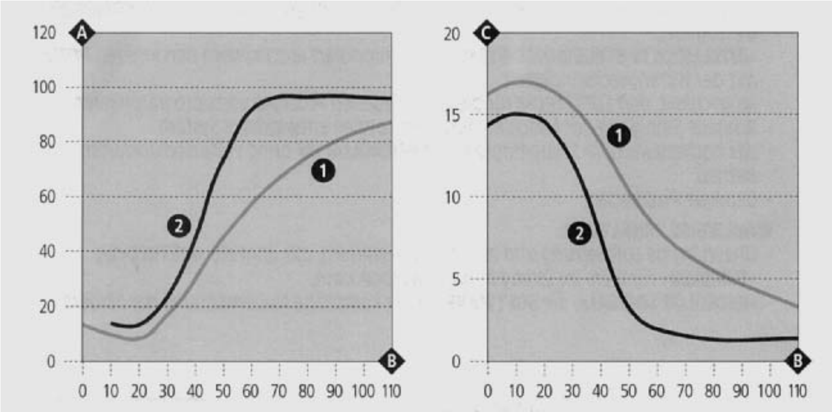


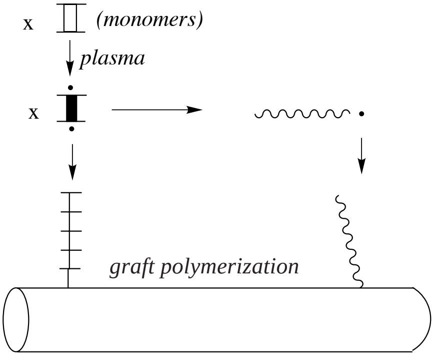
Fig.: Dye extraction by untreated and plasma treated wool when dyed with 3 % by weight of 1 : 2-metallic complex dye. A = dye extraction in %; B = treatment time in minutes; C = chromium content in mg/l; 1 = untreated; 2 = plasma treated (according to Höcker and Thomas).

This effect can be demonstrated, for example, on polyester filaments. Filaments that have not been plasma treated normally hold only 10 µl water as drops from a fine dosing spray (with the filament in the horizontal position), whereas in this test a plasma treated filament will hold 30 µl water in the form of drops, before they fall off. If, for example, aramide fibres are treated with ammonia plasma, then due to the improved polymer compatibility the fibre can subsequently be embedded in epoxy resin, without delamination. In Japan, Yunica fabrics are discontinuously evacuated in a batch process (150 m) for 15 min and plasma treated for 1–3 min in order to render the fabric hydrophilic.

Treatment of wool with oxygen plasma increases the oxidized sulphur species in the cuticula, whilst undoing the disulphide bridges. However, this modification is limited to a few monolayers. Nevertheless, the fibre affinity increases, particularly in reactive dyes, but also in 1 : 2 metal-complex dyes (see Fig.).

This means that for a given shade, less dye is required to dye a plasma wool than is the case for the non pre-treated material. Because the bath exhaustion at the end of the dyeing process is also partially dependent upon the quantity of dye used, this provides (in addition to economic benefits) a further possibility for reducing the pollutant loads in the waste water of wool dying. Furthermore, wool can be pressure pretreated without the use of chlorine. If the above-mentioned reactive gases are replaced by the gas CF_4, then a polyester film can by rendered hydrophobic by such a plasma treatment (increase in contact angle from 75° to 180°).

III. Plasma polymerization: If gaseous, radical polymerizable gases (with double bonds in monomers) are allowed to flow into an evacuated plasma generating device, which contains synthetic fibres, and a plasma luminous discharge is generated, then plasma polymerization can be observed on the fibre surface by grafting:



More conductive fibres can be generated in this manner, for example by the grafting of organometallic polymers. Fire resistant textiles are created by the use of monomers containing phosphorus. Surface fluoridation is performed by first removing surface oligomers by argon etching, followed by impregnation with fluorocarbon monomers and finally grafting with CF_4 plasma gas.

IV. Sputtering: Aluminium can be steamed onto fibres with plasma.

(→ Low-temperature plasma).

Plasma treatment Excited neutral atoms or ions can be purposefully used for the creation of thin films. To achieve this, plasma is not ignited by an inert gas, as for example in the “neon” tube, but with a reactive gas, such as methane. In a methane molecule one carbon atom and four hydrogen atoms come together to form a particle. If a plasma is ignited with such a gas, then like the atomic inert gas plasmas, molecule ions and excited molecules form. In addition, however, molecule fragments are also formed if an electron strikes a molecule and in doing so splits a hydrogen atom, for example. Such a plasma then consists, in addition to electrons, of a number of molecule ions, excited molecules and fragments, which are sometimes the reactive radicals. If these radicals possess a great affinity to each other, then larger molecules are formed in and on the edge of plasma. If such a plasma is in contact with a solid surface then a thin film of these molecules can develop on the substrate. If this film is made from an organic compound, such as the monomer ethylene, then we talk of plasma polymers. The main differences between these and conventional polymers is due to the high number of reactive particles in the plasma. Whereas a polymer such as polyethylene is made up of a regular arrangement of one type of molecule, a plasma polymer can be composed of a large number of different molecules and thus have a highly cross-linked and irregular structure. In principle, the entire plasma polymer layer, which can have a thickness of up to a few microns, can be viewed as a single macromolecule.

The process of film formation consists of radicals from the plasma being deposited onto the substrate surface. The film begins to grow due to the subsequent diffusion of reactive particles from the plasma to the surface. The actual film formation mechanism depends greatly upon the parameters, with which the plasma is operated. So, for example, under certain conditions the radicals join together to form larger clusters in the gas phase, which are only deposited onto the substrate after this gaseous growth phase. Under different conditions the molecules adsorb on the surface, and only there are they met by electrons, excited and react with the substrate.

At low pressure, the number of collisions between particles is relatively low; accordingly the electrons can be accelerated to a high energy level between two collisions. Because of this the molecules become greatly fragmented and converted into many small fragments, e.g. H_2 molecules and CH radicals. Such a discharge is known as “hard” discharge. If the ions generated in the plasma are additionally accelerated by an electric field on the substrate, then films are formed with a high mechanical hardness, which are known as diamond-like films. They differ from polymers due to their structure and low hydrogen content. In contrast, the molecules in low energy discharge (known as soft discharge) are only fragmented to a small degree. This is due to the lower average movement energy of the electrons and ions in such a discharge. The film created is similar in composition to the initial compound used, e.g. styrene.

In addition to pure hydrocarbons, other compounds can also be used as a process gas. One example is silicon organic compounds. By varying the plasma parameters, films can be created with properties ranging from polymer-like to quartz-like. For coating plastics there is the possibility of going from a polymer-like structure to a quartz-like structure within the applied plasma film by continuously changing the plasma parameters during the discharge (according to Söder).

Plasma treatment allows plastic surfaces to clean themselves of adhering foreign bodies due to decomposition. High vacuum rolling plants for foils or for CD disk polymer lines are used in the sputtering process, in order to vapour-deposit surfaces with metal. “Hot” plasmas under normal pressure are important for the metal coating of, for example, resolution cylinders in spinning.

In plasma spraying, the surface being coated is sprayed with droplets in the same way as colour spraying. In contrast to colour spraying, the film material in plasma spraying is not liquid, and must first be melted by a high-energy heat source and then sprayed onto the cold surface of the fabric or three-dimensional body. When the droplets hit the surface they are flattened and cool off instantaneously due to heat transfer to the base material (substrate). The particles solidify and shrink. The films adhere primarily due to mechanical adhesion and locally due to chemical bonding forces of different types. In order to achieve a strong film adhesion, the cleaned surfaces are roughened by sandblasting. This gives good adhesion, because the particles penetrate into the surface roughness and shrink onto the peaks.

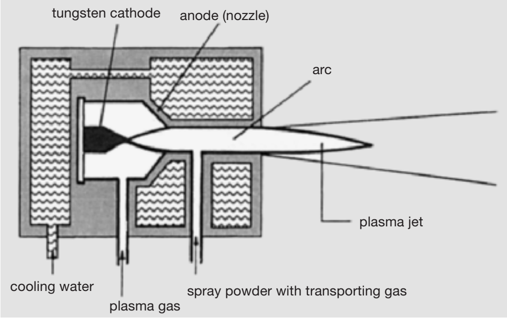


Fig. 1: Diagram of a plasma spray.

The heat source used in plasma spraying is an electric arc in a nozzle, which heats up a flow of gas (usually argon, nitrogen or helium) to very high temperatures (Fig. 1). Gas temperatures in excess of 20 000°C occur, which lead to the splitting of molecular gases and the partial ionization of atoms. As a result of the high temperatures a marked increase in the volume of the gas (plasma) takes place, which flows out of the nozzle at high speed. In plasma spraying plants the flow speed of the plasma jet reaches several times the speed of sound. The powdered film material is injected into this high-energy plasma jet with the aid of a carrier gas (Fig. 2). The particles themselves are melted and blasted onto the pretreated base material. The particle speed itself, how-

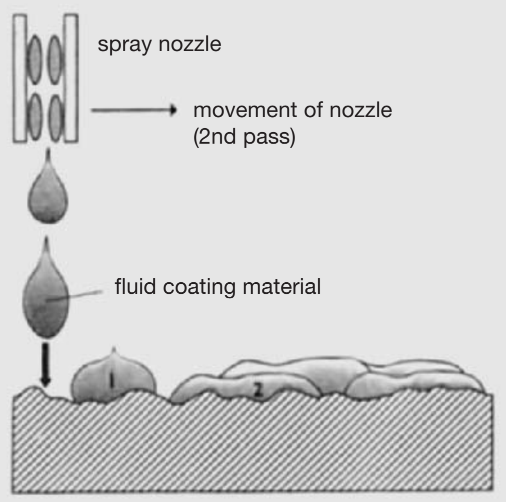


Fig. 2: Plasma spraying process.

ever, is below the speed of sound. Almost all materials which melt without decomposing and can be manufactured in a suitable grain size, can be processed into high quality coatings by plasma spraying. Normal plasma spray coatings are generally chromium oxide coatings or aluminium oxide coatings. However, tungsten carbide cobalt coatings and pure tungsten coatings can also be applied by plasma spraying (according to Schmolke).

Possible applications for low temperature plasma treatment in a vacuum in textile technology are currently envisaged in the following fields:

a) Antifelting finish of wool: The gas discharge “rounds off” the scales of the wool.
b) Improving the wetting properties and dyability of chemical fibres: In this process, hydrophobic chemical fibres are usually rendered hydrophilic.
c) Increasing the adhesion of composite textiles: There are interesting applications, for example in improving the adhesion of aramide or carbon fibres for composite materials.

The possible applications for the modification of fibre surfaces always compete with wet chemical procedures. Multi-layer printed circuit boards made of acrylate/polyimide have holes drilled while in continuous contact with copper plates. Previously, the only method of cleaning the hole walls in multi-layer circuits to remove grease from the drilled hole involved sulphuric or chromium acid, i.e. by wet chemical means. Over time, however, problems cropped up which could no longer be solved using this procedure and which made it necessary to look for other procedures. In 1983 the permanganate procedure was also introduced.

In addition to the wet chemical procedure a dry gas procedure, in the form of a low-pressure plasma technique, was developed. If rigid-flexible multi-layer plates based upon polyimide/acrylic adhesive were to be manufactured, the process of sulphuric acid or chromic acid cleaning, which was common at the time, encountered limitations. The acrylic adhesive, which easily smears as a result of drilling, could not be removed by wet-chemical means. Today, plasma desmearing and etch back plants are an integral part of the manufacturing process in multi-layer factories. All the problems of hole wall cleaning and etch back can be solved using this procedure. The hole wall cleaning process using oxygen-freon-plasma is fundamentally different from all wet-chemical procedures. This is a gas phase reaction, in which gases activated by high frequency react with the base material and oxidize it to CO_2 and H_2O. Because the reactions generally take place at above 100°C, the inclusion of any liquid is avoided. In contrast, a tempering occurs, which dries the printed boards. Because the plasma state can only be maintained whilst high-frequency is present, no “after-reaction” can take place, because at these temperatures the gases in normal (ba-

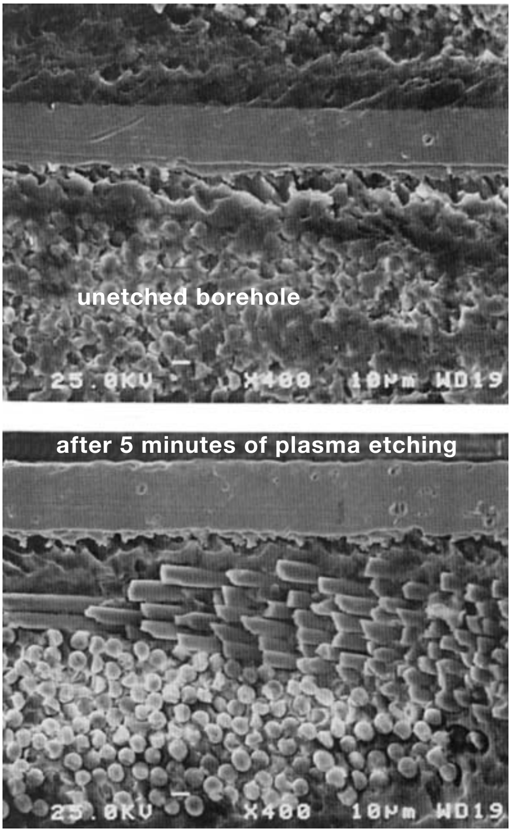


Fig. 3: Removal of borehole luting (top) on printed circuit boards (acrylate/polyimide bonding).

sic) state do not react. In the plasma procedure, oxygen/freon gases are continuously added and the reaction gases CO_2 and H_2O are continuously extracted.

The power of the plasma can be demonstrated by a few estimates. Approx. 1.6×10^{16} particles arise per second on the surface of a drilled hole with a typical diameter of 0.4 mm at a temperature of 400 K and a working pressure of 0.3 mbar. If we assume that the surface of the drilled hole is smooth, then these particles are opposed by approx. 1.8×10^{12} surface atoms. In reality the surface is of course roughened. But 1.6×10^{16} particles per second working on slightly more than 1.8×10^{12} atoms, illustrates the potential of plasma treatment. The particles themselves move at a thermal speed of above 400 m/s and have a typical dwell time of approx. 18 s. The smaller the holes to be cleaned, the more difficult is material exchange with viscose liquids; in hole diameters below 0.4 mm strong capillary forces are already noticeable. The viscosity of gases is at least a power of ten lower than that of liquids. Gases will penetrate the finest fissures and cracks (in the manufacture of semiconductors structures <0.5 μm can be etched). Small hole diameters are thus no obstacle to achieving uniform cleaning or etch back with gases (Fig. 3) (according to Tepla).

The advantages of plasma treatment also include the environmentally friendly nature of the process and the possibility of achieving effects, which rule out all analytical detection and are thus particularly “know-how intensive”. Plasma procedures are also non-contact and energy saving.

The problem of treating textile fabric lengths, which is dependent upon a costly procedure due to the necessary negative pressure, has not yet been satisfactorily solved. The increasing use of plasma procedures in the field of high-technology (semiconductor manufacture, magnetic tape manufacture, etc.) gives hope for new possibilities in textile applications (according to Kauter and Saiger).

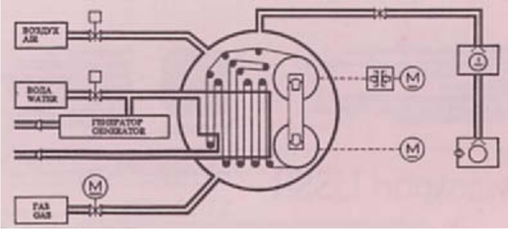


Fig. 4: Section of the Russian system for the non-continuous plasma treatment of fabric.

A first usable plasma treatment plant for textiles was presented at the ITMA in 1991 by Russian engineers (Figs. 4 and 5).

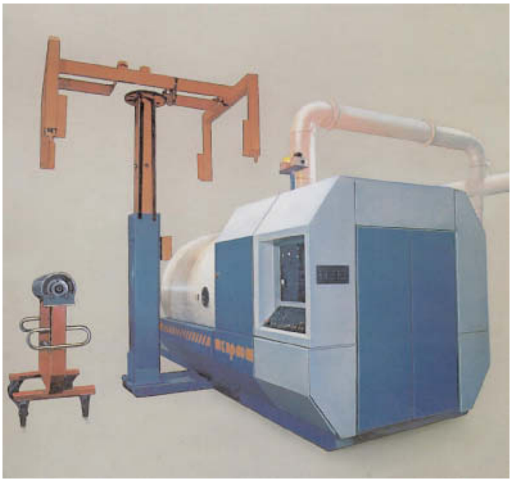


Fig. 5: External view of the Russian plasma treatment machine.

Plastic-coated textiles In its widest sense, this group also includes materials of various fibre composition with coatings, rubberizing and coating finishes. More specifically, it is used to describe products in which yarns, knitted goods from cellulose, natural or synthetic fibres are overall coated with synthetic polymers (during manufacture or as a subsequent permanent finish).

Plastic dye tube properties If single-use cross wound yarn package tubes (→ Dyeing tubes for yarn dyeing) are used in the pressing process, i.e. subject to axial deformation, their behaviour under pressure is influenced by three characteristics (see Fig.).

1. Intrinsic stiffness: The intrinsic stiffness of the tubes is such that they can be processed on all 6 inch spinning and winding components. Furthermore, it is also guaranteed that the tube can also be dyed in an unpressed state, with closed dyeing column and no spacer.
2. Pressability: When the yarn package is compressed by 1–30%, the tube deforms from the centre outwards; it is guaranteed that the two seams on the thread reserve and in the run-off head of the tube only deform at full pressure. The segmented deformation of the tube provides the option of completing the dyeing at 1–30%, depending upon the material and package thickness.
3. Distance trunnions: Because the behaviour described under 2 achieves a variable effect, the distance trunnions are also enlarged, in order to guarantee that the material always flows through. The largest distance trunnions are the ones on the two external seams (according to Giljam).

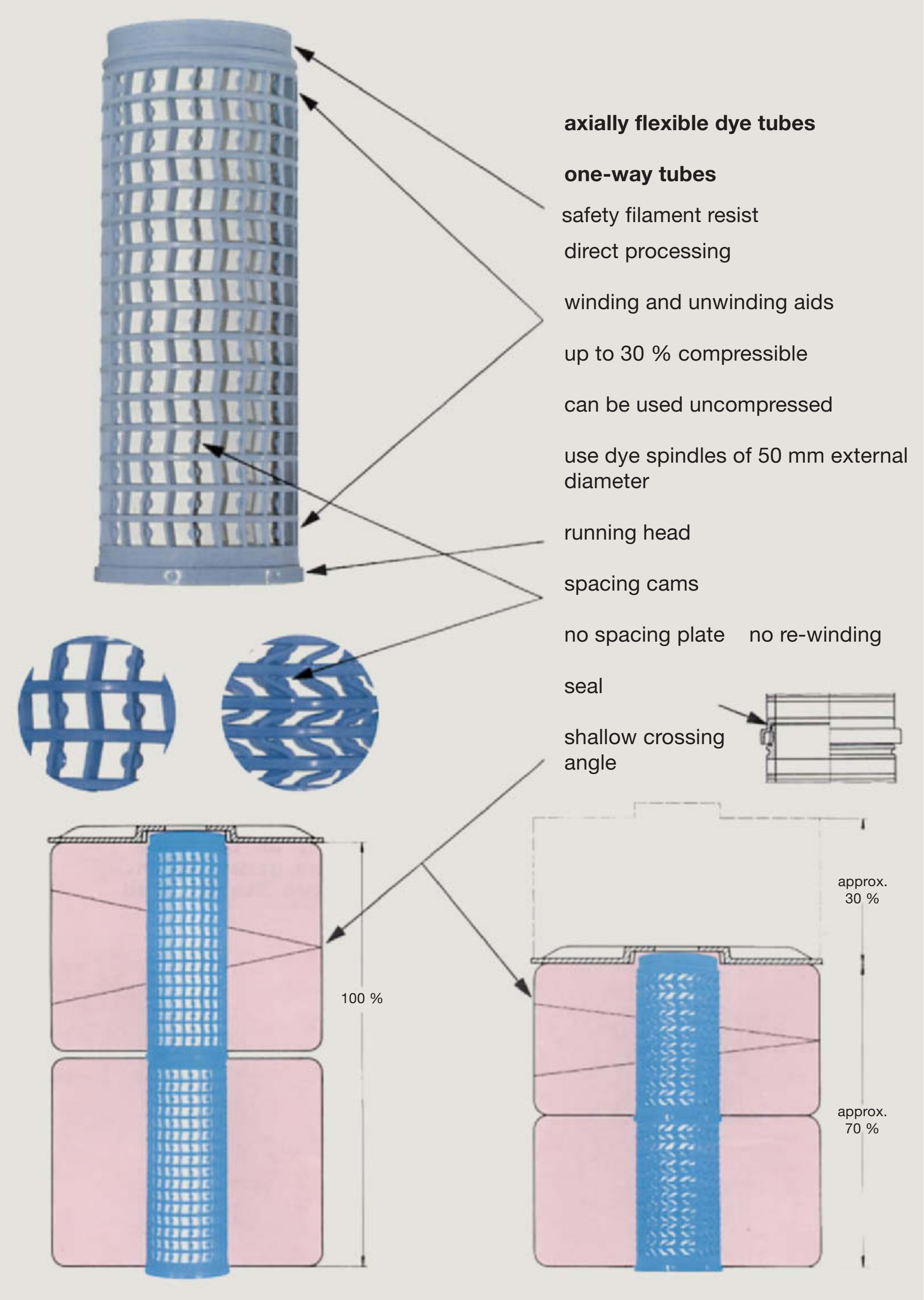


Fig.: Axially flexible dye tubes (Eisbär-Zimmermann).

Plastic foam (expanded plastics) → Expanded foam.

Plasticizers (softeners and gelatinizers), specific softeners used in the lacquer, rubber, synthetic resin and leather industries. They also play a role in textile lacquer, bronze and pigment printing, etc., because they have a favourable effect on the adhesiveness, suppleness and elasticity of such film-forming agents or printing thickeners, particularly those based upon nitrate and acetate cellulose. When added to a polymer, a plasticizer should improve the softness, suppleness, extensibility and workability of the former (effects include lowering the freezing point, modulus of elasticity, melting viscosity). For cellulose esters and resins plasticizers are practical, difficult to evaporate, organic solvents (phthalates, glycolethers, polyalcohols and synthesis alcohols) with boiling points between 250–350°C. Plasticizers differ significantly in their chemical structure from softeners used in actual textile finishing. They contain at least one polar group, whereby there is a dipolar bond with the basic molecules of high molecular film-forming agents. The latter differ from cellulose esters (nitrate, acetate cellulose).

1. Gelatinizing plasticizers (gelatinizing agents), which act like non-volatile solvents on nitrate cellulose, for example, to form a solid gel. Such films possess rubber-like elasticity; if too much is added or the temperature increases too much they may also become sticky.
2. Non-gelatinizing plasticizers, which are taken into the film compound without any solvent power and form more tough-limp films, which remain relatively hard even when a large amount is added.

Plasticizers in coating pastes The most frequently used coating paste is based upon the polymer, polyvinyl chloride. The polymers are sometimes obtained in the form of monomodal primary particles after synthesis, in which case the three-dimensional network structure gives rise to high ductility in coating preparations. The viscosity of bimodal pastes depends on the fact that small particles embed themselves between larger ones and act as ball bearings. When they exchange positions due to shear forces, the large particles need only overcome a low activation threshold to start flowing. Furthermore, in bimodal distribution, less space must be filled by plasticizers, if the coasting paste is used. The primary particles agglomerate on drying to form secondary particles. Plasticizers are used to convert these secondary particles in the pasty state into coating paste.

So-called hinge plasticizers (Fig. 1) have proved their value for the purpose of achieving a time limited plasticizing (swelling) of coating preparations. If greater quantities of plasticizers are used (over 20%), then the molecules act as a “hinge” between the dipole/dipole associates, making the molecule chains more mobile in relation to one another. This decreases the glass transition temperature (from around 70°C in plasticizer-free PVC to 0°C in PVC with 30% plasticizer), and a material which is more flexible and softer at room temperature is created.

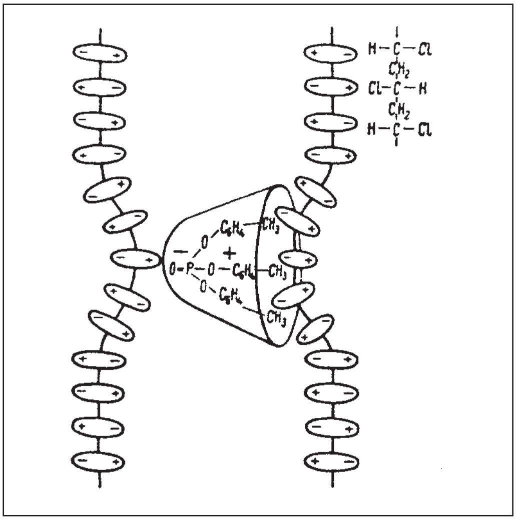


Fig. 1: Softening by means of an articulating plasticizer (coupling effect) – tricresyl phosphate molecule between two PVC chain molecules.

Permanent plasticizing is primarily achieved using phthalic acid ester by means of the shielding effect (Fig. 2). Phthalic acid esters make up around 90% of

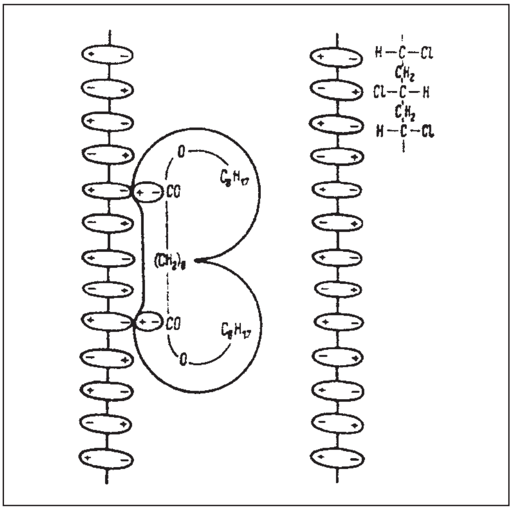


Fig. 2: Softening by means of a screening plasticizer (separation effect) – dioctyl sebacate molecule between two PVC chain molecules.

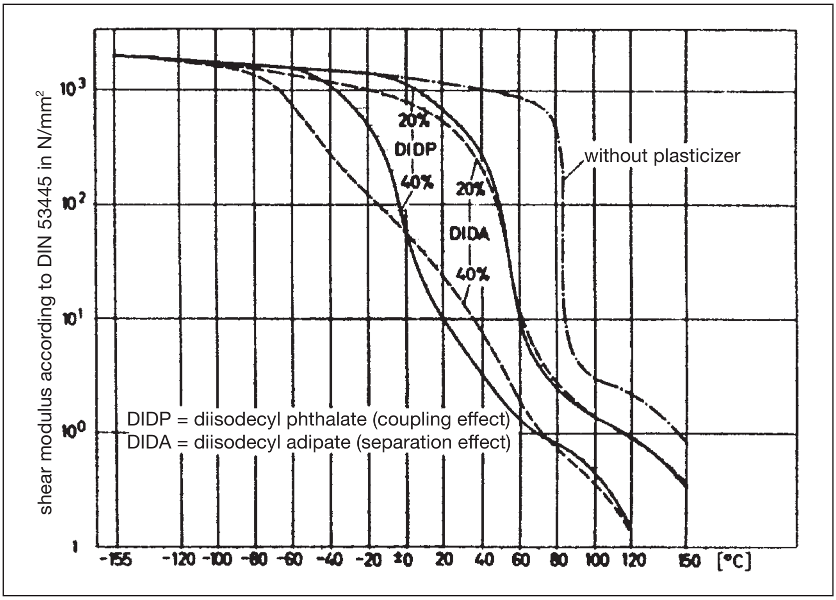


Fig. 3: Influence of various types of plasticizer on the shear modulus of suspension polyvinylchloride (S-PVC).

the market due to their economically favourable manufacturing capability combined with good technical properties. The low polarity of dioctylsebazate (DOS) is due to the low polarisability of the aliphatic CH_2 chain. They retain their nonpolar character and shield the dipole at the other end, so that the effect remains limited to one direction only.

The main difference between hinge and shielding plasticizers is that shielding plasticizers become brittle less quickly in the cold and soften less quickly in the heat, because the mobility of their molecules is less temperature dependent due to the double bond to the PVC molecule and the nonpolar groups. Fig. 3 shows the different effect of the two plasticizer types on the temperature dependency of the shear modulus, of suspension polyvinyl chloride (S-PVC). When an applied coating preparation is stirred, its viscosity may vary over time because the secondary cross-linking points are optimized between the softener molecules and polymer dipoles because the plasticizer molecules find the optimal dipolar interaction positions by diffusion.

The plasticizer thus has two tasks to perform: firstly it should give the finished coating the necessary degree of softness and secondly it should covert the PVC into a pasty state to facilitate processing. The change in viscosity over time can be explained in these highly viscose suspensions by the adsorption of the plasticizer by the primary particles and by its penetration into the particle. In this manner the more rheologically active plasticizers are removed from the suspension. The viscosity of a PVC plasticizer system depends largely upon the quantity of freely available plasticizer (Schollmeyer).

Plasticizing carriers The dying of polyester fibres using disperse dyes made it necessary to develop a whole range of carriers for the dying of polyester fibres. However, the chemical structure of such products did not always meet the requirements regarding toxicity and biodegradability. An alternative with regard to toxicity is represented by the o-phthalesters, whereby the application of some of them as components in textile assistants, i.e. carriers for the dying of polyesters, has been patented. There is a unified opinion about the mechanism of the accelerated action of carriers: They plastify the structure of the thermoplastic fibre and thus reduce the glass transition temperature. The dye diffusion through the polymer mass determines the speed, and the diffusion coefficient plays the role of a dyeing speed constant. The validity of the Williams-Landel-Ferry equation has been quantitatively demonstrated several times for a glass transition temperature (T_g) and dyeing temperature (T), whereby

$$\lg \frac{D_T}{D_{T_g}} = \frac{A\,(T - T_g)}{B + (T - T_g)}$$

This equation shows the degree of change of the dyeing speed under the influence of the plasticizer (the acceleration is greater, the greater the difference between the dyeing and glass transition temperature). On the other hand, the prognosis of the carrier effect of a substance requires a number of experimental data, not only in relation to the degree of change of the glass transition temperature, but also with regard to the interaction of the carrier with the fibre type in question, in order to bring about a plasticizing effect or a reduction of the glass transition temperature.

Plastic material lengths Collective term for synthetic foils, synthetic leather and other composite plastic and textile material lengths.

Plastics,

I. Very generally speaking, synthetically manufactured materials. More specifically, macromolecular organic compounds either thermosettable (→ Duroplastics) or thermal imaging (→ Thermoplastics) or elastic (→ Elastomers).

1. Regenerated natural substances, e.g. based upon cellulose (such as →: Cellulosic fibres, regenerated; Cellulose derivatives) or based upon casein-formaldehyde (such as → Casein plastics) or as vulcanized natural caoutchouc (such as rubber, hard rubber).
2. Synthetic plastics (→ Synthetic resins): Built up synthetically from low molecular basic substances, either a) → Polymerization products (such as polyvinyl products and butadiene), b) → Polycondensation products (such as aminoplasts, phenolic plastics, polyamides) or c) → Addition polymerization products (such as polyurethane, epoxy resin).

solvent \ plastic	polyethylene	polyamide	polyvinyl acetate	vinyl chloride acetate*	cellulose acetate	polyvinyl acetate	ethylene/vinyl acetate*
acetone	U	U	K	Q	K	H	U
alcohols	U	H	H	U	U	H	U
formic acid	U	H	K	U	H	K	U
cyclohexanone	H	H	H	H	H	K	H
dichloromethane	U	U	K	Q	Q	H	U
dimethyl formamide	U	H	K	H	K	K	H
ethyl acetate	U	U	K	U	K	H	U
hydrocarbons							
– aliphatic	U	U	U	U	U	U	U
– aromatic	H	U	H	U	U	H	H
tetrahydrofuran	Q	U	K	H	H	K	H

Tab. 2: Solubility of some plastics (= copolymers).*
U = insoluble; K = soluble cold; H = soluble hot; Q = swells.

Application: In addition to extremely large scale use for consumer goods and materials of all types in the form of injection moulded parts (high-grade synthetic resins, casting resins) and moulding compounds (with or without filler), for textile machine and equipment components (phenolic plastics, aminoplasts, polystyrene, polymethacrylic acid ester, polyvinyl chloride, polyvinylidene chloride, polyethylene, polyisobutylene), for synthetic fibres and foams and monofilaments and for a wide variety of purposes in textile finishing.

Tabs. 1 and 2 and the Fig. show typical properties of plastics. Plastics cover a wide elasticity range, and the same applies to ductility and impact strength. Reversi-

resistant to: \ plastic	plexiglass	polyamide	polycarbonate	high density polyethylene	low density polyethylene	polypropylene	polystyrene	polytetrafluoroethylene	polyvinyl chloride
acids:									
– weak	A	C	A	A	A	A	A	A	A
– strong	A	C	A	A	A	A	A/B	A	A
– oxidizing	B	C	B	C	C	C	B	A	A/B
– hydrofluoric acid	B	C	C	A	A	B	A/B	A	A/B
halogens (dry)	B	C	A	C	C	B/C	C	A	B
alkaline solutions:									
– weak	A	A	C	A	A	A	A	A	A
– strong	A	B	C	A	A	A	A	A	A
solvents:									
– alcohols	B	A	A/B	A	B	A	A	A	A
– esters, ketones	C	A	B/C	A	B	A/B	C	A	C
– ethers	B	A	C	B	C	B	C	A	C
– halogen alkanes	C	A	C	B/C	C	B/C	C	A	B/C
fuels and oils:									
– benzol	C	A	B	B	C	B/C	C	A	C
– benzene	A	A	A	A/B	B/C	A/B	B	A	A
– fuel mixture	C	A	A	A/B	C	B	C	A	B/C
– mineral oil	A	A	A	A/B	B	A	B	A	A
– fatty oils	A	A	A	A	B/C	A	A	A	A

Tab. 1: Chemical resistance of some plastics.
A = resistant; B = partially resistant; C = non-resistant.

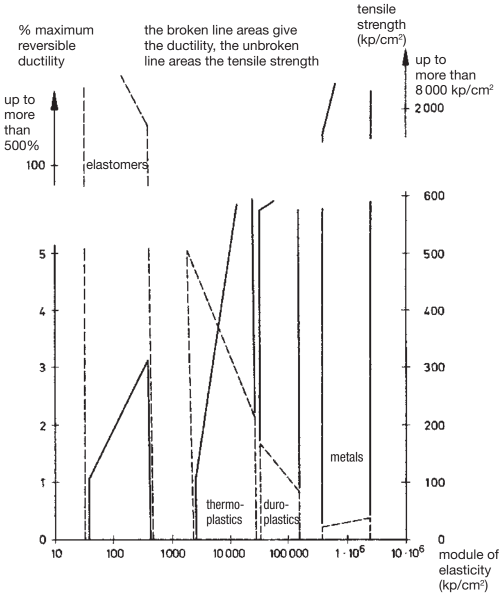


Fig.: Tensile strength, ductility and module of elasticity of plastics (1 kp/cm^2 = 9.81 · 10^4 N/m^2).

ble ductility and tensile strength oppose each other in homogeneous plastics. The ranges shown in the Fig. indicate the possible construction properties of homogeneous plastics. Many combinations of properties are possible within these ranges.

II. Term proposed according to DIN 7731 for plastic synthetic resin substances.

Plastic sheeting →: Foil; Simulated leather foil.

Plastic white scale →: Ciba-Geigy white standard; Whiteness scale.

Plastisol coating (paste coating), working method using → Plastisols, consisting of synthetic resin, softener, pigment, stabiliser, etc. in premixed form, which is spread upon the fabric or knitted goods, upon which the resin is hardened.

Plastisols Dispersions of plastic powder in → Plasticizers, which do not gelatinize the plastic powder when cold, e.g. vinyl resin dispersions plus softener or polyvinyl chloride paste made up of polyvinyl chloride plus softener.

Plastomers → Thermoplastics.

Plate cutting tool Application in pantograph engraving. Using an epidiascope a two to five-fold enlargement of the pattern is projected upon a whitened zinc plate, with subsidiary lines for repeating and pattern offset, and all contours traced by the draughtsman with a pencil. The plate cutting tool then engraves the contours of the pattern into the plate.

Plated steel Substitute material for solid metal sheets in equipment construction, for fittings, etc. Principle: Coated metal surface as the carrier of corrosion resistance. Manufactured by a sealed rolling process (in the absence of air). Non-ferrous metal coatings on steel sheets or special steels.

Plate felting machine For the manufacture of fabric felts, which are usually used as technical felts. In the plate felting machine the upper plate (50°C) describes a circular or elliptical path, whereas the lower plate (40°C) is fixed. The pressure is mechanically applied.

Plate heat exchanger Reclamation of heat energy by means of compression moulded plates, which are sealed at the edge. The two media involved in the heat exchange are alternately led through gaps. If there are large device dimensions and costly air channels, air inlet and exhaust air flows and external air and escaping air flows meet at the device separating walls (crossflow plate heat exchanger). The heat exchange takes place directly via the exchange surfaces (glass, metal, plastic). There is no exchange of moisture nor dirt transfer from the escaping air flow to the external air flow.

Free flow plate heat exchangers are particularly suitable for the heating or cooling of very dirty fluids containing fibre or solids and for energy reclamation from dyeing and washing liquors (see Fig.).

Plate spring in roller printing With plate springs a more elastic pressure can be applied to printing rollers than with → Roller printing. This conserves cloth, printing roller surface and fabric.

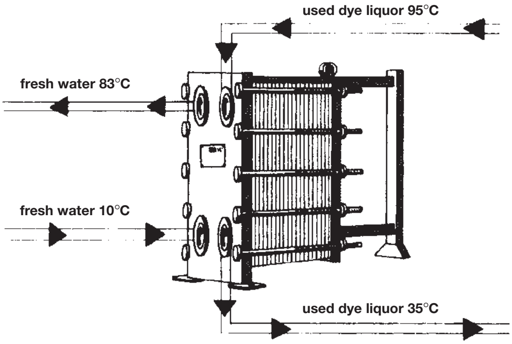


Fig.: Diagram showing heat exchange in a plate heat exchanger.

Platinum Abbreviation Pt; atomic weight 194.8; whitish grey, tough heavy metal; ductile, weldable; stable in air; density 21.4; melting point approx. 1764°C; soluble in chloronitrous acid (hydrochloric acid/nitric acid 3 : 1). Sensitive to sulphur alkalis and liquids containing chlorine. Marked tendency to form complex salts. Application: Laboratory devices (crucible, basin), electrodes, thermoelements, physical equipment; catalyst (oxidation accelerator), in x-ray technology, etc.

Pleated sheet structure (chain lattice), two-dimensional system consisting of chain molecules (keratin sheet structure in wool, lamella in cellulose, basic structure of silk fibroins), a skeleton-like primary valency bundle with side chains protruding from both sides. The three-dimensional system grows from layered, bundled, chain lattices in the form of →: Crystallites; Micelles.

Pleating Creation of very varied shapes and arrangements of folds on textiles using → Pleating machines. Permanent, wash-resistant pleating can be produced:

I. On cellulose fabrics and mixed fabrics with a high cellulose content: Padding with heat-hardenable synthetic resins, followed by pleating and hardening.

II. On wool: Padding or soaking with substances

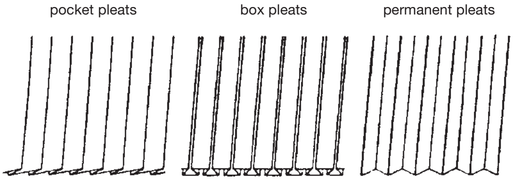


Fig. 1: Pleat forms.

suitable for wool fixing (thioglycolates) followed by pleating, steaming/ironing/pressing.

III. On synthetic fibres and mixed fabrics with a high synthetic fibre content: Pleating, thermofixing.

One differentiates between the following mechanically produced pleat types: knife pleats, squeezed pleats, box pleats and group, crystal, accordion, fancy, wave and harlequin pleats. Shaped pleats are parallel pleats such as sunray and special pleats (Fig. 1).

The term "pleat" comes from the French, and is used to describe material pressed into narrow folds. Pleating experienced an enormous boom due to the development of synthetic fibres. The fact that the thermoplastic properties of synthetic fibres make it possible to produce a permanent pleat using heat, has opened up fields to pleating, which were previously closed to it: Underwear, blouses, clothing, etc.; once formed, the pleats are permanent, moisture resistant and washable.

In principle, all fibres can be pleated, however, a permanent, i.e. water and wash resistant pleat, can only be generated in vegetable and animal fibres by the use of certain chemicals. A permanent pleat in woollen fabrics can be achieved by the use of the Siroset procedure. In this process the woollen material is evenly sprayed with thinned Siroset solution, until the weight has increased by up to around 40%, laid in the correct shape (preferably with intermediate layers of tulle) and then steamed. However this process has not become widespread, because unpleasant side-effects occurred due to the high degree of moisture. The pleat shapes had a significantly reduced lifespan, because the card became too wet. A further difficulty was presented by the condensate, possibly containing Siroset, which formed in the templates, causing spotting in the material. Due to the relatively high degree of moisture in the material, any relaxation shrinkage had a greater effect than is the case during steaming; this increases the tendency to bagginess in fabrics. Furthermore, the increased moistening of the material leads to possible decatizing losses, i.e. loss of sheen and handle. With the intermediate layer of tulle problems were encountered in the laying of the material on the template and due to imprints on the material, some of which could not be removed.

A material quality is said to be normally pleatable if pleating can take place without special precautions. Materials intended for pleating must have certain shrinking and dyeing fastness values, and these should be taken into account in the finishing.

In general, pleating permanence means that the pleats have a certain durability when worn, above all when sitting down, and after clothing care. Permanence also relates to the maintenance of the sharpness of the folds (including following a garment care treatment).

When pleating with pleating machines, steam cabinets and autoclaves and when pressing folds using special fixing presses, the first step is the crease formation. But at the same time attention must be paid to the smooth surface of the material between the fold lines. These material areas between the fold lines appear in the form of the visible fold width and underlay area (fold depth) and in the form of the outflow (smooth areas e.g. at the hips). We differentiate between economy and full folds. In economy the fold depth (underlay area) is less than the fold width (Fig. 2); in full folds the fold depth is the same as the fold width.

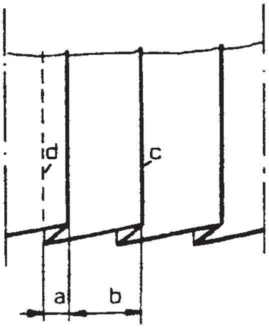


Fig. 2: Example of pleat folds.
a) pocket (fold depth); b) visible fold width; c) pleat fold; d) hidden pleat fold.

Although, in principle, there are only a few basic forms, there is an extraordinarily large number of possible pleat variants. We differentiate between (Fig. 3):

- sunray pleat based upon shaped template (circle or segment of circle),
- straight pleats with parallel folds based upon straight template,
- straight pleats with conical folds based upon straight template,
- special pleat (fancy pleat) with plastic patterns based upon straight or shaped template.

There are also the basic fold types:

- knife pleats (on one side),
- box pleats or squeezed (knife pleats lying to both sides),
- accordion pleats.

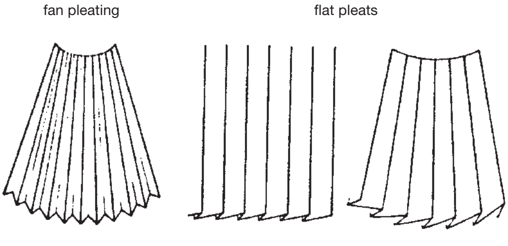


Fig. 3: Basic pleating forms.

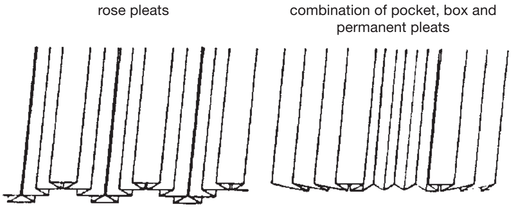


Fig. 4: Combination of pocket, box and permanent pleats.

These fold types can be used alone or in combination. A good example of combined arrangement of knife pleats and box pleats are the rose pleats. Fig. 4 shows a combination of knife, box and accordion pleats.

The fold depth (underlay area) and the outflow provide a wide range of possibilities for variation, as does the arrangement of pleats on top of each other and the fold height. Crystal, arch and gather pleats can be described as variants of accordion pleats, although they have no genuine fold. Sunray pleats and straight pleats with conical folds have special properties with regard to cutting and laying compared to straight pleats with parallel folds. Sunray pleats must always be cut in a circular shape.

We differentiate between hand pleating and machine pleating processes, which are not mutually exclusive, but complement each other. In hand pleating a so-called pleating template is used, in which the cut piece of material is placed by hand. The pleating templates are made of a special cardboard with a high number of folds and consists of two identical pieces of card in the shape of the desired pattern. These templates are for an upper and lower layer with the same pleat pattern.

Unlike the package for the steaming cabinet, the thin card laid in folds is placed in a steam forming press in a even condition. The steam is forced through the template and material under pressure and at the same time contact heat fed from the heated work surfaces of the press. The steam only needs to penetrate a single layer of card to act on the material; the inside of the folds are heated through more quickly due to the temperature at the top and bottom. With a treatment time of 1–2 min per pressing procedure this method requires only a fraction of the treatment time of approx. 20 min in the annealing cabinet. The programme for steam, action and cooling time is regulated via automatic switches and is fully automatic. Temperature and pressure are also adjustable, so that the pleating press can be set up according to the material quality.

Hand pleating is mainly significant for the manufacture of sunray pleats and conical pleats with a greater underlay area at the top, using special pleating templates. The disadvantage of hand pleating is that productivity is low and a great deal of working space and personnel are required.

Machine pleating has the advantage that high performance can be achieved with significantly less personnel. In principle, the folds are laid by rearranging the fabric over the entire width of the machine with the aid of a metal bar (knife). The fabric folds then run between a heated metal roller and a roller covered with felt (Fig. 5). The upper roller covered with felt presses the fold against the metal cylinder. It may be accompanied by an over and under paper or just an under paper. The paper thickness depends upon the material quality.

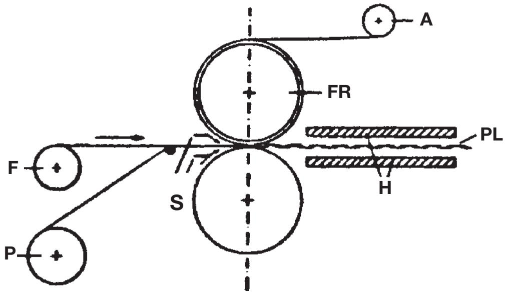


Fig. 5: Diagram of a pleating machine.
FR = felt roller; F = fabric reel; H = heating plates;
A = adhesive tape for edges; S = open shears; P = paper reel; PL = pleated fabric.

Pleating machines Used for → Pleating:

I. Knife, squeezing and group pleating machines for the generation of a wide range of different patterns (approx. 1 mm to several cm underlay area and fold width).

II. Crystal pleating machines for the generation of vertical folds (approx. 1–5 mm fold height).

III. Accordion pleating machines for upstanding folds (5–50 mm fold height). Such machines usually have straight, serrated or corrugated sets of blades for fold formation. The pleating is fixed on the material, which is usually accompanied by a special paper, passing through heated rollers, and subsequently travelling through a water cooling device to increase the fold permanence of synthetics. There may also be an electrically heated condensation heat table for the creation of permanent pleats on resin finished cellulose materials (cotton, viscose) as an add-on device. The material is not normally fully fixed, but pre-fixed (10–30°C below the optimal fixing temperature; with dry heat max. 140°C, with steam fixing max. 1.5 bar). The pleating temperature is always dependent upon the fibre type (thermofixation):

cellulose	150–200°C
fibre mixes	150–210°C
polyamide 6	180–194°C
polyamide 6.6	190–208°C
polyacrylonitrile	120–160°C
polyester	160–180°C

Care should be taken to ensure that there are no thermo-yellowing impurities (greases, softeners), and sublimation fast dyes are used. Material that has already been fixed can be provided with wash fast pleats if previously resin finished (cellulose).

Pleat resistance Of fabrics after complete moistening (like creasing). The remaining folds are determined in % = (fold height after the wetting : fold height before wetting) × 100.

Pleionomers (Gk.: Pleion = more; meros = smallest component/basic building block), homogeneous molecular homologous polymer with molecular weight above 1000, which unlike → Oligomers can no longer be sufficiently differentiated with regard to their physical properties to be separated into homologues. Pleionomers play a role in synthetic fibre-forming polymers.

Plexiglass Transparent, colourless plastic made of → Polymethacrylic acid ester (density 1.18; tensile strength 700–759 kg/cm^2; light permeability 90–99%) castable, polishable, cuttable, grindable, weldable, etc. Application as → Safety glass.

Plie Piece material laid in uniform widths; hanging in plie (e.g. when suspending silk goods), i.e. hung folded on the stick. The stick has three notches for suspension loops, onto which the piece ends can be attached.

Plissé Folded material, which can be achieved in different manners.

I. Woven plissé: Produced by an additional device on a power loom; 2 warp systems of different tension achieve drape. Folding can also be achieved by suitable bindings. In knitgoods folds are created by stitching.

II. Shrunk plissé is produced by the use of synthetic fibres with different shrinking properties.

III. Finishing plissé: The material is laid in folds, which are thermally fixed in so-called pleating machines.

Application for clothing materials, skirts, etc.

Plotter Peripheral device for electronic data processing plants. The plotter is a computer controlled output device for the graphic representation of curves, text, symbols, etc., it represents a further development of the XY writer used in measuring technology. We differentiate between flatbed plotters (moveable drawing pen, fixed drawing sheet) and drum plotters (drawing sheet on rotating drum, drawing pen only moves in the crosswise direction).

Ploughing up Damage to engraving and doctor blade during printing due to poorly distributed pigments in the print paste.

Plucker (opener, willow). Preparation machines in spinning. Classified as tearing, beating, striking, oil lubrication, mixing, carding plucker, etc. according to application.

Plucking out Term for pulling out dark hairs from white woollen materials. This manual work can be replaced by selective bleaching.

Plugging, repair of printing rollers Concerns the reworking of worn engravings, caused by frequent use of the printing rollers. Dabbing can be carried out on a grinder.

Plumbic acid → Lead.

Plung suction device Additional device in the debris trap in wide wool washing machines with which liquor is sucked in and released by means of a rubber suction cup. The purpose is to intensify the washing process and liquor exchange. Manuf.: Hemmer.

Plush,

I. Woven plush: high pile → Velvet.

II. Knitted plush: Plush-like appearance due to pile formation in tricot by a plush loop. → Plush cloth.

Plush carpet General term for carpets with cut open pile warp (thread pile); either shorter velour-like (velours carpet, → Tournay carpet) or longer pile (plush carpet). Named according to material and pattern: Hair yarn, linen, wool, knotted, striped plush carpet, etc. Manufactured in the form of → Wire carpets or as → Face-to-face carpets (face-to-face tournay carpet).

Plush cloth (plush fabric, knitted plush), 2–3 thread → Knitted fabrics usually made of ground thread and plush thread. The latter are formed into long loops and either closed, curled, frizzy (thermal underwear, jogging suits, lining material, etc.) or cut, shorn for velvet, pelt or fur like pile goods (lining material, outer material, fake fur, blankets). → Pile-knitted fabrics.

Plush trimming Trimming the pile loops of knitted plush fabrics by → Shearing.

Ply-yarn Thread made of two or more → Yarns twisted together. We talk of 2-ply, 3-ply, 4-ply yarn, etc. Soft ply-yarn made of numerous slightly twisted yarns is also called a wick.

Pm Element symbol for promethium (61).

PN Polska Norma, Polish standard.

pNa value Concentration of sodium ions. Can be measured using a sodium-sensitive measuring chain by potentiometric methods, in a similar way to measuring pH, e.g. concentrations of sodium chloride or sodium sulphate solutions.

Pneumatic (Gk), moved by air pressure (→ Compressors), e.g. → Pneumatic cylinder.

Pneumatic cylinder Pneumatics is the technical application of tools (cylinders, motors, valves) driven by air. Low pressure pneumatics include static switching elements, for example, membrane and piston valves, whilst air jet elements belong to the group of dynamic switching elements. Compacted air is called compressed air. It is the energy carrier of the pneumatic system. Compressed air exploits an important property of gases: Compressibility. Gases, unlike solids and liquids, are very compressible.

If the microprocessor in a control circuit sends an instruction for the elements in a process to carry out certain actions, then this often means the generation of movement or the performance of a service of one type or another (mechanical, electrical, thermal). The pneumatic cylinder is a tried and tested drive for the generation of linear movements. The pneumatic cylinder consists principally of a cylinder tube, a piston and connecting rod, a return spring, the compressed air connection and the exhaust connection (Fig. 1). If the cylinder chamber A admits compressed air, then a pressure acts upon the piston surface. If the force generated by the pressure (Force F = Pressure p × Piston area A) is greater than the opposing force of the spring, then the piston moves to the right with the connecting rod. This movement is called a forward stroke. The compressed air in the right-hand cylinder chamber B can escape via the exhaust connection. If the compressed air supply is interrupted the power of the spring is sufficient to allow the piston to move back to the left and allow the air to escape from the cylinder chamber A. This movement is called the return stroke. The term “single acting cylinder” refers to the fact that mechanical work can only be performed during the forward stroke. This work is greater, the greater the piston area and the air pressure in the cylinder chamber A. The stroke of this cylinder is around 100 mm.

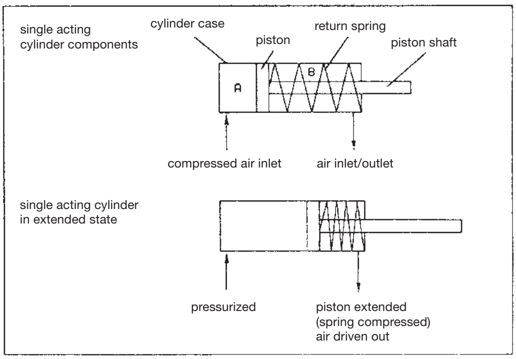


Fig. 1: The single acting pneumatic cylinder.

In addition to the piston cylinder another form of single acting cylinder is the membrane cylinder. In this, a stiff membrane is stretched between two halves of a cylinder. Compressed air impinges on the membrane and causes it to flex. The degree of flexing determines the cylinder stroke; the connecting rod is directly connected to the membrane. We differentiate between the single membrane cylinder and the roller membrane cylinder.

A 3/2 way valve has three connections and two switching positions (Fig. 2); the method by which it switches between one position and the other can vary. The example shows a valve, which is held in the rest position by a spring. In this position the compressed air is shut off from the valve. This is called a 3/2 way valve with blocked rest position. In situation 1 the valve is drawn in the rest position; there is a connection from the cylinder via the valve to the vent. The cylinder chamber A is ventilated and the piston retracted. The arrow F in situation 2 indicates the operation of the valve. There is only a connection from the valve compressed air connection to the cylinder, so that the cylinder chamber admits pressure and the piston extends.

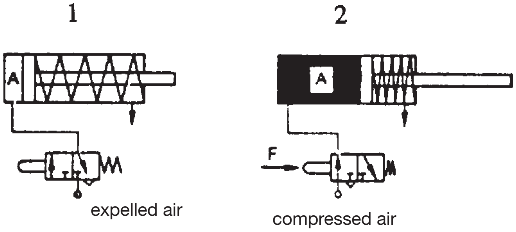


Fig. 2: Control of a single acting cylinder by means of a 3/2 way valve. F = auxiliary manual control moved into working position.

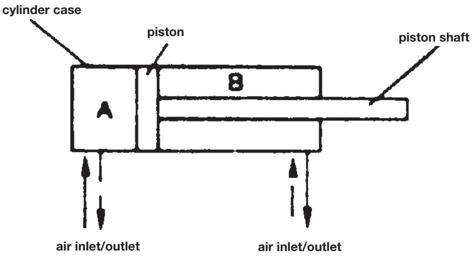


Fig. 3: The dual acting pneumatic cylinder.

The principal structure of the dual acting pneumatic cylinder is similar to that of the single acting cylinder (Fig. 3). However, there is no return spring, and each connection can be used either as an air inlet or an air outlet. If air enters the cylinder chamber A and is withdrawn from B then the forward stroke takes place. The return stroke takes place after air inlet to B and air outlet from A. This has the advantage that the cylinder

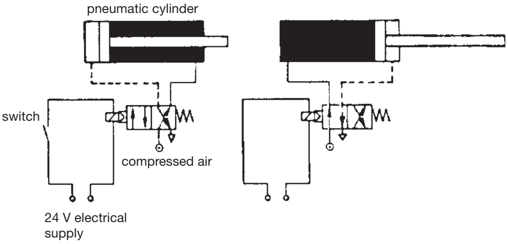


Fig. 4: Electro-pneumatic control.

can perform work in both directions of travel. If there is electro-pneumatic control an electric sensor triggers the movement of the pneumatic cylinder (Fig. 4).

Pneumatic guiders Expander and edge uncurling device. Works with 2 pneumatic blowers and photoelectric sensors; material is scanned and expanded using compressed air. Differs from mechanical guiders due to non-contact, low tension material guidance.

Pneumatic squeegee In this screen printing squeegee the squeegee rubber is held pneumatically and can be changed quickly and easily.

Pneumatic stretching frame Can stretch all screen sizes between 800 × 1100 and 1800 × 2850 mm (screen manufacture). The gauze is held, tensioned and, after pasting to the frame by hand, released by quick release clips. After the necessary tension has been achieved via a control panel, the gauze is lowered onto the frame without altering the tension and pasted onto it. Starting from the largest screens the device can be converted for smaller formats using extension tubes.

Po Element symbol for polonium (84).

POC (particulate organic carbon), describes the carbon content of suspended particles in biological waste water cleaning (→ TOC).

Pocket piping Pocket opening with → Piping.

Poil-grege (high twist grey pile yarn). Highly twisted → Grège threads with approx. 1000–2000 twists/m.

Point bonding Point welding of nonwovens. → Spot-bonded nonwovens.

Poise Outdated measure for dynamic → Viscosity. Replaced in the SI system by Pascal seconds (Pa · s): 1 P = 0.1 Pa · s.

Poison Substance which has a harmful (→: Corrosive poison; Toxicology) or lethal effect on living organisms even in small quantities, always a question of dose (→: Tolerance limits; Lethal index). Examples of inorganic poisons are ammonia, arsenic compounds, barium salts, lead compounds, bromium, chlorine gas, chromium compounds, etc. A further group relates to the poisons generated by the organism itself, known as metabolic poisons or toxins. Toxins are highly toxic, protein-based, natural substances with a specific effect. Most toxins are formed by bacteria: Endotoxins are constituents of them, exotoxins are discharged from them, e.g. the tetanus toxin. Most bacterial toxins act as antigens. The following classification of poisons was drawn up on the basis of the EC guidelines of 18.9.1979 (per kg body weight):

highly poisonous substances	≤ 5 mg,
very poisonous substances	5–25 mg,
poisonous substances	25–200 mg,
less poisonous substances	200–2000 mg.

for an LD-50 (→ LC-50 and LD-50 values) in a rat with oral intake. Skin irritation and inhalation criteria are determined in the same way. Furthermore, the EC guideline defines additional terms in relation to harmful substances: Irritating, environmentally hazardous, carcinogenic, teratogen, mutagenic.

Polar Terminal, working in opposite directions (→ Dipoles). For example, in textile auxiliary products the polar arrangement of the hydrophilic group in relation to the hydrophobic group. In the wetting process, water molecules are in a polar arrangement to the auxiliary at the boundary layer, if the latter aligns its hydrophilic (negatively charged) groups against the positively charged groups of the surrounding water.

Polar-apolar structure Relates to the presence of at least one → Polar group and a larger → Nonpolar group, which gives the molecule in question a hydrophilic and lipophilic character.

Polar bond → Ionic bond.

Polar group Functional group, the electron distribution of which gives the molecule a considerable → Dipole moment (→ Polar). It determines the affinity to markedly polar liquids (particularly to water) and the → Hydrophilic molecule character.

Polar interaction → Adhesion.

Polarity → Dipoles.

Polarization Eccentricity of centre of gravity of negative and positive electricity, whereby e.g. → Dipole molecules are created. If a molecule has a permanent dipole, then it is able by induction or influence to give a dipolar alignment to other nonpolar molecules, in which the centre of gravity of negative and positive charges coincide. This creates an “induced dipolar moment”, which brings about small additional intermolecular attraction forces, so-called induction forces (→ Secondary valency forces). This charge eccentricity is a displacement polarization, in which around 85% of electrons (electron polarisation) and around 15% of ions (ion polarization) are involved.

Polarized light Using a double slit crystal, “normal” light consisting of different amplitudes and different directions is split into two perpendicular radiation directions it is linear polarized (→ Birefringence). If one radiation direction is eliminated, pure linear polarized light is obtained, i.e. only light of one plane of polarization.

Polarography A special case of voltametry used for plotting current-voltage curves. Dripping mercury is often used as the collector due to its clean surface. The measuring currents can be easily smoothed electronically, or, by use of a highly damped recorder, ensure that only small pulsations caused by the growth of the drop remain. If a cell voltage and current change is recorded on the print out of an indicator recorder then a d.c. polarogram is obtained.

Polarography is rarely used for the detection of organic compounds. The substances in question must be easy to reduce. The detection limit is around 10^{-5} Mol/l. The main field of application is in the detection of metal ions. In special cases, such as differential pulse polarography (DPP), the detection limit lies in the picogram range.

Pole-change finishes “Pole-changing” is the term used to describe the change of contact potential (in the course of spinning processes), which a non-softened or prepared fibre shows compared with iron. The normal contact potential of the fibre compared with iron is negative in the unprepared fibre. After completed softening the contact potential has become positive: The polarity of the fibre has been changed. Often a reduction in the charge is sufficient.

Pole finding test paper Filter paper soaked in sodium chloride and phenolphthalein solution; used moist to determine the electrical negative pole (cathode = red colouring).

Polishing Mechanically increasing the lustre on yarns or fabric lengths (plush material, imitation fur, floor coverings, etc. on → Polishing machines; → Lustring.

Polishing bench for engraved printing rollers are used for grinding and polishing of damaged rollers: Device similar to a lathe, in which the printing roller spindle is mounted so that it can turn, and is rotated by engaging a clitch. The polishing bench also incorporates a water basin, in which the roller is submerged approximately 5–10 mm during the polishing process. Dabbing can also take place using the polishing bench.

Polishing machines,

I. One differentiates between polishing machines (II) according to their field of application:

1. For yarns (sewing machine yarns), in order to give them the most lustrous finish possible.
2. For fabrics, in order to give long-pile materials in particular a lustrous finish (Fig. 1).

II. Universal finishing machines for polishing (Fig. 2). Lengths of fabric are transported under tension on heated, rapidly rotating cylinders with beater bars, etc., also in combination with cutting cylinder (polishing-cutting machine) or other functions (e.g. face fibre finisher, pile rotor, super finish, etc.).

Polishing shearing machine → Polishing machines.

Pollution control in textile finishing Successful measures to date are as follows:

1. Reduction in water consumption:

– reduced water quantities due to short and ultra-short finishing baths (liquors),
– minimum application processes (e.g. spray, foam application),
– optimized rinsing processes,
– combination of procedure stages (e.g. dyeing and finishing),
– recovery and multiple use of water (→ Recycling).

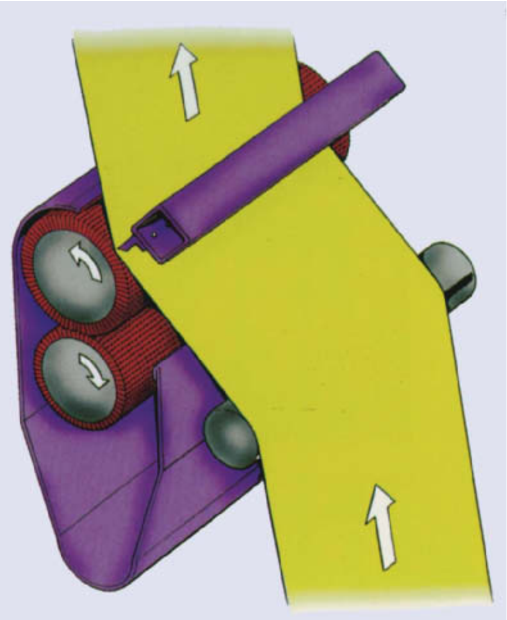


Fig. 1: Tigering unit.

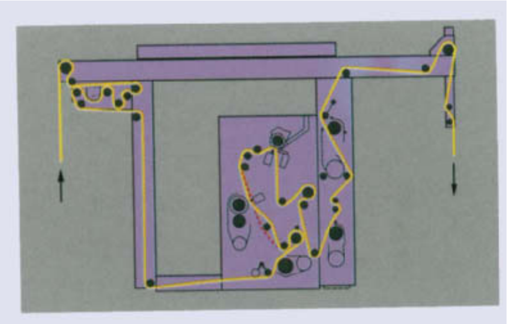


Fig. 2: Tigering machine OPTICUT GTS by Gematex.

2. Decolorization of waste water: dyes remain visible, even if there are just 3 parts dye in 10 million parts water. Reactive dyes with high washing fastness for fashionable materials, made of cellulose fibres in particular, are often noticeable for this reason. Although in these concentrations they are a long way from being able to cause damage, even this visual problem is undesirable. It can be combated by precipitation with specific flocculation and precipitation chemicals and adsorption by activated carbon or decolorizing with oxidizing or reducing agents. However, additional substances are introduced during decolorization, and polluted foam is generated during flocculation. There are still no satisfactory solutions to this problem. Therefore the search

goes on unabated for better methods. → Waste water treatment.

3. Avoidance of heavy metals: small quantities of heavy metals, e.g. chromium, copper, nickel or zinc, are contained in specific, usually, in particular, light and wash fast dyes, pigments or a few auxiliaries of textile finishing. The metal of the dye is largely combined in the form of a complex, i.e. a fixed component of the dye molecule. The proportion of free heavy metals, which may be contained as traces in some dyes, is being reduced further by improved manufacturing processes. In addition, heavy metal-containing compounds are increasingly being substituted in auxiliaries.

4. → APEO and → AOX: alkyphenolethoxylates (APEO) have excellent properties as washing and cleaning agents. However intermediate products can occur during their biological breakdown, which are harmful to fish above certain concentrations. The manufacturers of washing and wetting agents in Germany therefore switched to APEO free products. In other textile auxiliaries the use of APEO was stopped by 1992. AOXs, the adsorbable organically bound halogens, include above all highly volatile halogenated hydrocarbons and the chloraromates. As part of a voluntary agreement, German manufacturers are avoiding the use of LHKW in washing and cleaning agents. Chloraromates have been largely replaced in dyeing auxiliaries. Even during bleaching, attention is paid to low AOX values. Chlorine-containing bleaches are increasingly being replaced by peroxides.

5. Reduction of organic and inorganic pollution: the polluting of waste water and outfalls with organic substances is a central environmental problem. Private households are just as involved in this as agriculture or industry. A criterion for the pollution of water is the chemical oxygen demand of the introduced substances. Around 60–70% of the COD pollution, e.g. in dyeing waste water, stems from sizes and preparations. They were applied to threads and yarns in preceding work stages, in order to facilitate or ease further processing. Once their task of strengthening and smoothing threads and yarns is fulfilled, they must be removed again – and end up in the waste water. Traditionally, natural starch is used for sizing, which is very biodegradable. Due to the associated high oxygen demand, efforts are increasing to replace them with effective, and at the same time, regenerative synthetic sizing agents. However, procedural problems are associated with effective → Recycling, and intensive work is underway to overcome these problems. Chemicals based on phosphates, which can contribute to the overfertilization of waters, have already largely been replaced by other chemicals. In order to reduce the nitrogen pollution of waste water from textile finishing, attempts are underway to find a replacement for urea, which is necessary for some processes in the dyeing or printing of fabrics made of cellulose fibres.

6. Reduction of exhaust air emissions: Strict requirements are also imposed upon exhaust air quality of the textile finishing company (→ Exhaust air problems in textile finishing). These have the aim of preventing dust, smoke and harmful substances in the air and eliminating odour nuisance. Switching over to environtmentally friendly power is significant: natural gas already represents more than 60%. Dyeing at low temperatures, cold dwelling processes, etc. also contribute to low power consumption. The → TI-air, the technical regulations for maintaining clean air, sets high standards for production plants. By means of improved processes and environmentally friendly textile auxiliaries, it was possible to significantly reduce pollution. Progress in the technology of exhaust cleaning plants also brought about a significant improvement.

7. Safety in storage and transport: most chemicals used by textile finishers belong to water hazard class I (slightly hazardous to water). In all cases strict requirements are imposed on the labelling of substances, fire prevention and rinsing water recovery. Detailed safety data sheets provide the necessary information for transport, storage, handling and emergencies.

8. Avoiding waste, reclamation of materials: textile, paper, plastic and metal wastes are separated out to a large degree in companies within the textile finishing industry and recycling is carried out. Packaging is increasingly being limited to the degree necessary for transport and storage and designed in such a way that it can be refilled or the material recycled. Expensive techniques, such as automatic, computer controlled dosing, application with minimum quantities or computer controlled calculation of dye recipes, have led to a marked reduction in dye residual quantities. However, fibre, dye and chemical residues, which must be treated as special waste, have not been eliminated. Therefore the important task of finding safer disposal routes still remains. Ever stricter requirements force the textile finisher, like other industries, to take on more and more obligations, often of a voluntary nature.

Pollution control representative In order to ensure that companies have a comprehensive grasp of the current state of environmental protection and can recognize weak spots, regular environmental audits must be performed (similar to audits in the field of quality assurance). This information, in addition to the environmental protection guidelines and the organisational division of environmental protection, forms the basis for the creation of an environmental protection handbook. The obligations of a company to protect the environment are not limited to the generally known maintenance of emission limit values for pollutants and noise and the associated maintenance of existing plants. They cover:

- proper handling of hazardous substances,
- timely disposal of hazardous substances,

organization	task
Zentralstelle der Gesellschaft für Energie und Umweltschutz (central office of the society for energy and environmental protection)	– collecting, evaluating and communicating environmentally relevant regulations – advice – examination of projects – liaison with authorites/ministries – contribution to external expert groups
Werkstelle für Umweltschutz (office for environmental protection)	– introduction of new regulations – advising production units – inspecting operational facilities in respect of operation in accordance with regulations
Zentrales Umweltschutzlabor (central environmental protection laboratory)	– carrying out periodic emission checks – the handling of environmental protection problems – advice – drawing up specialist analyses – decisions on the classification of waste and refuse
Werkstellen für Giftverkehr (offices for the transportation of hazardous substances)	– advising production facilities on the handling and storage of hazardous substances – monitoring
Fire Brigade	– prevention and minimization of damage caused by accidental releases

Tab.: Organizational structure for assuring the carryng out of environmental responsibilities.

- planning of new plants in accordance with environmental requirements,
- accident prevention,
- handling special wastes according to regulations.

All environmental regulations and legislation must be noted, then read and understood, interpreted, applied to own conditions, introduced, implemented and monitored.

In large textile finishing companies the organizations listed in the Tab. ensure that all these requirements are fulfilled.

Smaller companies employ a pollution control representative, who should have the highest authority to issue directives, to assist the business management.

Pollution control responsibility Criticism of the supposed chemical and thus pollution loading of textile materials has aroused the general public. The textile industry has been burdened with a range of legislation by the authorities, which impose difficult tasks on textile manufacturers and finishers. This legislation includes:

- segregated flow treatment (disposal of waste water at the location of production, Textilabwasser-VwV [textile waste water administration regulations]),
- storage of water-hazardous substances (chemical and auxiliary storage in accordance with § 19 g Section 1 of the WHG [Wasserhaushaltsgesetz – Water Resources Law]),
- control of in-company waste water channels (self-checking of channel network),
- exhaust air treatment plants (for plants requiring a licence in accordance with BImSchG [Bundes-Immissionsschutzgesetz – Federal Immission Protection Law]),
- waste disposal (disposal of special wastes and residual substances subject to compulsory monitoring) and
- self-checking (Eigenkontrolleverordnung EKVO of Baden-Württemberg [self-checking act] with tightened requirements for indirect emissions).

The title of a draft act for pollution control responsibility act reads “Law Governing Responsibility for Environmental Pollution and changing the Water Resources Law and the Federal Immission Protection Law” (Gesetz über die Haftung für Umweltschäden und zur Änderung des Wasserhaushaltsgesetzes und des Bundes-Immissionsschutzgesetzes). An extension of the “polluter pays” principle is planned within this law, and thus extends the guilt-independent hazard responsibility from water protection to land and air.

The following new rules are planned as focal points:

- introduction of an absolute liability “for the protection of land and air” in addition to the existing absolute liability “ for the protection of water” in § 22 Water Resources Law (WHG). This absolute liability is like that in WHG, a liability that is independent of guilt.
- absolute liability for the operation of “environmentally hazardous plants” including normal operation and not just “accidents” as is the case in the WHG.
- lessening the burden of proof for the determination of causality of environmental effects not covered by the WHG.
- victims’ right to information from plant operators and licensing authorities, which the WHG does not provide.
- extension of the natural restriction, i.e. improvement of the options already in place in the BGB (Bürgerliches Gesetzbuch – Civil Code) for victims to “undo” damage to the natural condition of their property at the cost of the polluter.
- “compulsory insurance” for plants with “particularly high danger potential”.

The WHG covers not only the chemical industry, but also the “chemical producing and chemical using” textile industry, in particular, textile finishers. In the future it will cover all production plants, which represent a certain potential danger, thus not only the plants covered by the BImSchG. Where infringements of environmental legislation were already punishable according to the previously applicable environmental penalty law, the “new environmental penalty law” brings with it a marked tightening of liability and thus disciplinary action. The draft agreed on 14.2.1990 by the Federal Cabinet for a second law for combating environmental crime includes the following main new, proposed regulations:

- introduction of a statute against ground pollution (over and above § 326 STGB [Strafgesetzbuch – Criminal Code] – environmentally hazardous waste disposal);
- extension of the penal provision against air pollution (§ 325 STGB) by the introduction of an emission statute (§ 325 STGB was originally based upon imissions considerations);
- introduction of a general regulation concerning the irresponsible handling of hazardous substances (which also covers the particularly dangerous transport of hazardous goods);
- stronger safeguards to nature and water protection areas against harmful influences;
- penalties for the illegal export of hazardous waste;
- increased penalties, raising of financial penalties and introduction of custodial punishment;
- extension of the rules concerning voluntarily averting the effect of a wrongful act to encourage the timely averting of hazards;
- protection against contraventions in companies is improved; the penalty arrangements regarding the commercial contravention of supervisory duties (§ 130 OWeG) is made more practical, and the possibility of attaching financial penalties against legal persons (§ 30 OWeG) is made easier.

Particular importance is attributed to the law for the improvement of the previously patchy protection of soil against damaging influences. Furthermore, the law is intended to cover all infringements of regulations in the operation of plants causing air pollution and noise. The previous, gross, non obligatory infringement is replaced by “any culpable, negligent behaviour”. Furthermore, the gross, wilfull release of pollutants into the air is made a punishable offence, without the need to prove that damage has been done in the individual case. Furthermore, a general penal provision regarding the negligent handling of hazardous substances or materials and goods is introduced. Thus hazardous wastes termed as economic goods and so-called “illegal waste tourism” is also made a criminal offence.

The liability for breach of duty is extended to include all independent and responsibly acting supervisory persons in addition to the company owner or the company management (according to Hemmpel). → Legislation on environmental protection.

Pollution control sample archive Strategy of the German Federal Ministry for Environment, Nature Protection and Reactor Safety, under the scientific co-ordination of the German Federal Office for the Environment (UBA – Umweltbundesamt), Berlin, in the form of a systematically structured archive for the conservational storage of selected pollution control samples.

Main aims:

- retrospective identification of environmental chemicals; even those that were unknown at the time the sample was taken.
- retrospective repeat analysis of inorganic elements or organic compounds in samples that have already been analysed, which were stored under conservational conditions.
- checking the success of legislative environmental protection measures in the handling of chemicals that are viewed as being hazardous to man and the environment.

Authentic samples from various fields of the environment play an important role.

It was recognized at an early stage, that samples from biological collections do not permit reliable conclusions to be drawn regarding environmental pollution, because neither conservation nor storage methods are designed for retrospective investigations. This recognition gave rise to the demand for the creation of a collection, which can provide the environmental samples of today to future generations. Thus the evidence required to answer relevant questions will be available. Comparatory samples, which must be drawn upon for the determination of trends in the chemical pollution of the environment, can be optimally processed in accordance with the current state of technology. New findings regarding environmentally hazardous substances and improvements in analytical methods and the ability to draw upon authentic stored sample material facilitate the detection of long-term trends in the environment. Any need for action to implement preventative measures can be determined (according to Schwuger).

Pollution index (waste water), characteristic figure relating to waste water, derived from measured COD values (mg O_2/l), BOD values and water quantity in l/kg material; → Waste water evaluation.

Pollution index (effluent) Term from the waste water taxation act. According to this act a penalty is incurred for discharging waste water into an outfall, the level of which depends upon the hazard of the discharge. This hazard is expressed as a pollution index. It can be calculated on a flat rate basis for all textile finishers who do not discharge directly, possibly per m^3. The person liable to pay the levy must bear the cost of measuring the hazard themselves (→ Waste water evaluation). The following formula is proposed for the calculation of the pollution index from the analysis data (possibly regionally with other factors): for sewerage and pit water the following applies for determining the pollution number in the main pollution period:

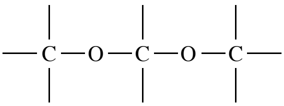
$$B = \frac{Q}{0,15}\left[0,04 + 0,25\,\frac{A - 0,3}{6,0 - 0,3} + 0,35\left(0,5\,\frac{BOD - 20}{250 - 20} + 0,5\,\frac{COD - 80}{500 - 80}\right)\right]$$

B = pollution number in resident values;
Q = discharged water quantity in m^3/day (without precipitation);
A = taxable substances in ml/l (without carbon component);
BOD = biochemical oxygen demand in mg/l of the taxed sample;
COD = chemical oxygen demand in mg/l of the taxed sample.

Polwarth wool Wool from New Zealand sheep. Cross-breed with smooth structure and shrinking property.

Poly- (Gk.), determinative element of compounds meaning “many, multiple representations”.

Polyacetals Formaldehyde and higher aldehyde homopolymer and copolymer. → Polyoxymethylenes.



$$-\overset{|}{\underset{|}{C}}-O-\overset{|}{\underset{|}{C}}-O-\overset{|}{\underset{|}{C}}-$$

Poly acids Anionic → Polyelectrolytes; can be described as high acid anhydrides, created from more than two acid molecules giving off water, e.g.:

$$3\,H_2SiO_3 \rightarrow H_2Si_3O_7 + (2\,H_2O)$$

From the same acid molecules iso-polyacids form from different hetero-poly acids. The following are well known (only in aqueous solutions or salt form):

I. Inorganic poly acids, for example → Polysilicic acids (salt type: water glass or sodium silicate Na_2SiO_3, $Na_2Si_2O_5$), → Polythionic acid, polyphosphoric acids (salt type: Polyphosphates).

II. Organic poly acids of type → Polyacrylic acid.

Polyacrylates,

I. →: Polyacrylic acid salts; Polyacrylic acid ester.

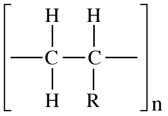
II. Polyacrylate products are for example used as finishing agents, coatings, binders for pigment printing, fibres, laminating agents, adhesives, sizes, thickeners, materials.

Polyacrylate size recycling The already high waste water loading in textile production (50–80% due to sizing agents) can be reduced by the co-application of polyacrylate sizes. Polyacrylate sizes in the filament field with low BOD_5 values have good biodegradability. The degree of polymerization appears to influence the degradation behaviour, so for example acrylic acid homopolymers with growing chain lengths are usually degraded slowly. High levels of short chain alkyl esters of acrylic acid are associated with satisfactory biodegrading of polyacrylate sizes. Such polymers can for example contain up to 20% by weight polymerized acrylonitrile, without biodegradability being noticeably inhibited. The earth alkali polyacrylate sizes promote low waste water loading due to their high reclamation rates, in addition to the fact that the residual polyacrylate size can be quantitatively precipitated out of the washing water by mineral acids.

Reclamation and reuse is the only option for the dramatic reduction of size costs for the sole use of high-value - but expensive, compared to starch products, synthetic sizing agents. One such option is a polyacrylate reclamation process called the Recupra process (BASF): In this the high swelling and dissolving speed of the polyacrylate sizes are exploited for selective swelling (by the application of sized raw fabric with minimal water content) and then the reusable reclaimed solution (4–8%) is separated from the fabric by high performance squeezing machines. The prerequisite for good weaving results and successful multiple recycling is sizing with pure polyacrylate, “dry” weaving environment, minimal use of auxiliaries (oil, wax). Due to its characteristic curve, size generation of thermostable earth alkali polyacrylates in particular offers a high reclamation rate and thus lower waste water loading. Therefore it is particularly important that raw thermofixable products (e.g. sodium/calcium salts, magnesium salts) can be manufactured as up to approx. 100% solid products and in this concentrated form facilitate higher reclamation rates. → Recycling.

Polyacrylate sizes possess great variation in molecular structure; numerous polyacrylate sizes are used in fibre yarns and filaments of almost all fibre types (→ Sizing agents). Modifications can be made by the copolymerisation of different types of monomers. Specific copolymers of acrylic acid with dominant homopolymer properties also facilitate the sizing of untwisted polyamide, even at high humidity. The degree of polymerisation and substituents determine important properties of polyacrylate sizes, such as film hardness, adhesive power, rubbing fastness, solubility and electrolyte compatibility. Polyacrylonitrile (and to a lesser degree polyacrylamide) increases the toughness and abrasion resistance of the size films. Esters promote elasticity and adhesiveness, particularly in filaments. In the ester, the length of the residual alcohol has a decisive influence upon the film hardness. The longer the carbon chain, the softer and stickier the polymer. Polymethacrylates yield harder films than the corresponding polyacrylates. Generally speaking, polyacrylate sizes of the same gross composition can differ greatly in their properties. The functional groups can be converted by chemical transformation. The carboxyl groups responsible for solubility and adhesiveness are capable, for example, of salt formation. Sodium salts are more soluble than ammonium salts, but more hygroscopic. At the same time, a higher proportion of carboxylate groups brings about marked adhesion to cellulose and polyester/cellulose mixed yarns and also improves washing off. Developmental differentiation of polyacrylate sizes according to the type of salt form:

I. Conventional polyacrylate sizes primarily in the form of sodium or ammonium poly salts:



$$\left[-\overset{\displaystyle H}{\underset{\displaystyle H}{C}}-\overset{\displaystyle H}{\underset{\displaystyle R}{C}}-\right]_n$$

R = $-COO^-NH_4^+(Na^+)$,
$-CN$, $-OH$, $-CONH_2$,
$-OOCCH_3$

Liquid products are becoming more and more prevalent (with the exception of powder products based upon polyacrylamide) so, for example, polyacrylate staple fibre sizes for cellulose and polyester cellulose in the form of usually aqueous ammonium salt solution (less tendency to stickiness than corresponding sodium derivatives), which are also far less hygroscopic, but have some drawbacks due to moisture sensitivity and thermoinstability. However, in mixtures with excess starch sizes, the hydrophilic nature of the polyacrylate sizes is positively influenced. These combinations (staple fibre sizes), which are almost exclusively prevalent for cost reasons, guarantee good weaving properties even at high humidity. On the other hand, the tendency of ammonium polyacrylate sizes to split ammonia under thermal stress leads to undefinable cross-linking in raw thermofixing and thus, sometimes to poor washing off properties, particularly in the presence of starch, whereby an alkali shock treatment sometimes helps to counter this effect. → Desizing with enzymes.

Polyacryate sizes of very different chemical composition in the form of “universal sizes” are an important class of size products for filament yarns in general. They produce good effects when used in water jet power looms, with a size film that is resistant to the influence of cold, neutral water. After weaving the polyacrylate sizes, present in acidic form, can be made water soluble again at an alkaline pH and washed out.

II. Earth alkali polyacrylate sizes: New generation moisture insensitive and thermostable sizes by partial or total substitution of ammonium or sodium in specific copolymers (acrylonotrile/acrylic acid) by earth alkalis (e.g. magnesium, sodium, calcium salts). Such Polyacrylate sizes can be completely washed off even after raw thermofixing because they are soluble in hot and cold water at high concentrations (up to approx. 25%). Furthermore, this substance class is electrolyte compatible, possesses high adhesiveness and offers high reclamation quotas, i.e. low waste water loading. In a mixture with starch sizes evening of viscosity variations (product safety), high thermal stability e.g. during machine down time or raw fixing, elimination or drastic reduction of starch degrading enzymes, particularly for native starch sizes, elimination of enzymatic desizing when suitable starch combinations are selected (“Sizes as a desizing agent”), accelerated desizing.

The functional principle is illustrated by the model of the structure of earth alkali salt bridge (see Fig.).

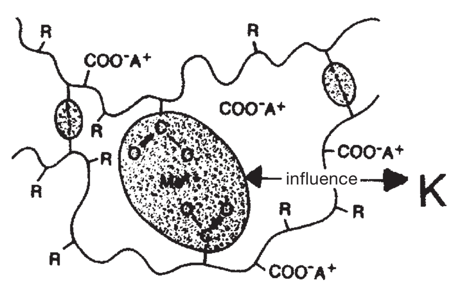
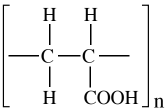


Fig.: Influence on the adhesion force K of two carboxylate groups on different polymers of polyacrylate size caused by the metal Me^{++} *(magnesium or calcium) acting as cross-linking agent between them.*

The polymer chain mobility is limited, the glass transition temperature of the polyacrylate is thus increased. Calcium is more active than magnesium. The reason for this is the lower water absorption of polymers containing calcium. With increasing earth alkali content the film hardness systematically increases, thus providing significantly better resistance against mechanical weaving stresses, as does thermostability. The ammonium ion acts as a monovalent cation in all products. After raw thermofixing, combinations including carboxymethylcellulose (CMC) can be easily and completely washed out after 50% neutralization with earth alkali. The functional principle also facilitates problem free, easily manageable, approx. 100% powder marks. In comparison to ammonium salts the earth alkali derivatives show significantly increased desizing speed when mixed with starches.

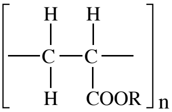
Polyacrylic acid Polymer of → Acrylic acid. Glass-like when solid; as solutions, emulsions and jellies; insoluble in water, soluble in alkali, gives sticky to hard films.



$$\left[-\overset{\displaystyle H}{\underset{\displaystyle H}{C}}-\overset{\displaystyle H}{\underset{\displaystyle COOH}{C}}-\right]_n$$

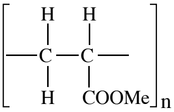
Application for sizes, finishes, adhesives, binders, etc. → Polyacrylic acid ester and → Polyacrylic acid salts are of greater importance.

Polyacrylic acid ester Polymer methyl, ethyl, propyl, butyl ester (mixtures) of → Acrylic acid.



$$\left[-\overset{\mathrm{H}}{\underset{\mathrm{H}}{\mathrm{C}}}-\overset{\mathrm{H}}{\underset{\mathrm{COOR}}{\mathrm{C}}}-\right]_n$$

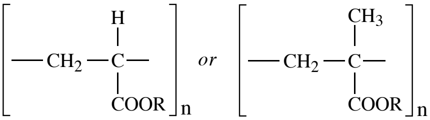
Polyacrylic acid salts Sodium and ammonium salts of → Polyacrylic acid.



$$\left[-\overset{\mathrm{H}}{\underset{\mathrm{H}}{\mathrm{C}}}-\overset{\mathrm{H}}{\underset{\mathrm{COOMe}}{\mathrm{C}}}-\right]_n$$

Water soluble, produce solid, elastic films with antistatic properties. Application: Sizing agents, finishing agents, thickeners for synthetic dispersions in coating finishes, coatings.

Polyacrylic compounds Polyacrylic acid and polymethacrylic acid, the salt esters and copolymers of which are used in a wide range of products in the form of acrylate polymers and polyacrylate for sizes and finishing agents. Polyacrylic acid base products and their salts are water soluble (e.g. for animal feeds and back finishes) and resistant to microorganisms. → Polyacrylic acid ester is water insoluble.

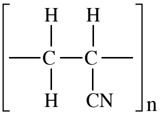


$$\left[-\mathrm{CH_2}-\overset{\mathrm{H}}{\underset{\mathrm{COOR}}{\mathrm{C}}}-\right]_n \quad \textit{or} \quad \left[-\mathrm{CH_2}-\overset{\mathrm{CH_3}}{\underset{\mathrm{COOR}}{\mathrm{C}}}-\right]_n$$

Aqueous dispersions of polyacrylic acid esters produce excellent water fast, transparent, light and water resistant films of high strength. Polyacrylates produce softer and stickier films the longer is the alcohol residue. Polymethacrylates are harder and less sticky than polyacrylates with the same alcohol residue. A linear alcohol residue leads to softer polymerisate, a branched alcohol residue gives a harder polymerisate. The solvent resistance falls with the length of the alcohol residue. Comonomers with acrylates or butadiene increase the solvent and oil resistance of the polymer. Polyacrylates are also suited for use in softeners (e.g. light rain coats), laminating, fibre/thread binding without the addition of a softener. Further application as weighting and stiffening finish, anti-slip finish, for fixing of calender effects (e.g. chintz, silk finish, embossing), increasing serviceability (abrasion resistance, breaking strength in bending, ladderproofing). In organic solvents (e.g. ketones, aromatic hydrocarbons, etc.) dissolved polyacrylic compounds are suitable for further water-fast special finishes (coatings, synthetic leather, hat stiffeners).

Polyacrylic ester →: Polyacrylic acid ester; Polymethacrylic acid ester.

Polyacrylonitrile (polyacrylic acid nitrile, polyvinyl cyanide), polymer of → Acrylonitrile.



$$\left[-\overset{\mathrm{H}}{\underset{\mathrm{H}}{\mathrm{C}}}-\overset{\mathrm{H}}{\underset{\mathrm{CN}}{\mathrm{C}}}-\right]_n$$

Used in emulsions or dispersions (particularly copolymers with butadiene, styrene, vinyl ether) primarily for wash fast finishes, for coating and laminating, as a material and for synthetic fibres (→: Polyacrylonitrile fibres; Modacrylic fibres). Acrylonitrile polymer emulsions with ammonium chloride as a catalyst can develop, when hardening, a toxic bi-chloromethylether (lung cancer hazard).

Polyacrylonitrile copolymer fibres → Modacrylic fibres.

Polyacrylonitrile fibres Group of synthetic polymeride fibres, the chain of which is made up of at least 85% → Acrylonitrile. The composition of the polyacrylonitrile fibres varies due to the polymer addition of affinity increasing foreign substances (monomers such as vinyl acetate, vinyl chloride, vinylidene chloride, vinyl pyridine, methacrylate, methacrylamide, etc.). “Pure” polyacrylonitrile fibres are subdivided into a) fibres consisting solely of polyacrylonitrile (non dyeable) and b) so-called modified polyacrylonitrile fibres(→ Modacrylic fibres) with up to 15% foreign substances (good dyeing properties), whereas if there is c) a high foreign substance content, we talk of polyacrylonitrile copolymer fibres. Polyacrylonitrile fibres are produced by dry or wet spinning and drawing (8–12 fold). Further processing from single titre 0.6 dtex upwards. The cross-section varies, usually dumbbell-like (dry spinning process) or kidney-shaped (wet spinning process).

Crystallite structure: The formation of crystalline areas in polyacrylonitrile fibres takes place due to the formation of laminar chain lattices by hydrogen bridges between the macromolecular chains (formation of → Lamella). Accessability and reactivity are of course reduced to the same degree as functional groups are attached due to intermolecular forces in the crystal lattice, which must be taken into account in the understanding of the dyeing process.

Properties (→ Synthetic fibres): Density low (< 1.13;

modified polyacrylonitrile fibres possibly higher: up to 1.37); full handle; absorbency below 0.5%; swelling value below 1%; highly resistant against microorganisms and insects including termites; physiologically harmless; excellent light and weather resistance; heat resistance relatively good (boiling fast, ironing fast up to 150°C), however shrinks at higher temperatures (approx. 4% with 100% hot air). Low hot-wet modulus gives rise to the danger of slight irreversible distortion or deformation particularly in knitted goods during hot-wet treatments above 60°C. Softening range 190–230°C (modified fibres possibly 150–160°C), becoming sticky at 300–320°C (does not melt, but decomposes). High breaking strength; lower abrasion resistance than polyamide and polyester. Crease reforming good (similar to polyester); breaking strength in bending high (similar to polyamide); elastic stretching and bulk elasticity good. Chemical resistance against acids, oxidants and solvents good; alkali sensitive. Washable and quick drying. Dye affinity varies (→ Dyeing of acrylic fibres). Can be electrostatically charged. Application: Sport and work clothing, swimming costumes, rainwear, imitation fur, clothing material, fleece, quilt fillings, curtains, decorative and furniture materials, tarpaulins, technical fabrics (acid protective clothing, filter cloths, leader and back grey cloths). Important as mixed fibre with wool, polyester, polyamide, viscose, copper and acetate fibres.

Polyacrylonitrile fibres in direct printing,

I. Cationic dyes: Brilliant and wet fast shades can be achieved with good light fastness. Print pastes contain the dye in dissolved or finely dispersed form. Powder dyes are dissolved by the addition of organic acids (acetic acid) and thiodiglycol and stirred into the thickener; then a non-volatile acid (e.g. tartaric acid) is added to the print paste, in order to maintain the acidic medium during fixation, because the dye is destroyed by alkalis. The addition of a carrier increases the colour depth, furthermore the fixation time can be reduced and the fixation temperature decreased. Cationic blue types based upon azo dyes are created by a reductive process; the reaction is accompanied by slight colour loss or shade change. The addition of an oxidant can help. When working with print pastes, in which the dye is present in finely dispersed form, they contain a slightly anionic dispersant in addition to the above-mentioned additives. It generates a finely dispersed, colloidal precipitation of the cationic dye in the print paste. This protects the dye in the paste against electrolytes and thus increases the stability of the paste. Furthermore, differences in the diffusion capacity of the individual products are equalised, which makes it possible to achieve more uniform and reproducible prints.

If the print paste contains a carrier, fixation takes place for 20–30 min in saturated steam, either discontinuously in the star steamer or continuously in the universal loop steamer. Print pastes with no carrier can only be discontinuously fixed with a low pressure of 0.3–0.5 bar. Then the material is thoroughly cold rinsed, soaped at 40–50°C or subjected to a reductive after-cleaning, rinsed again, dewatered and dried.

II. Disperse dyes are only used in certain cases, e.g. for large area patterns that are problematic from the point of view of evenness or for sharp contours. A further option exists if light beige or olive shades are required, which are difficult to achieve using cationic dyes due to reproducibility. The brilliance and wet-fastness of cationic dyes cannot be achieved with disperse dyes.

III. Dispersible 1 : 2 metal-complex dyes: subdued shades are achieved with good fastness.

The following dyes are used for mixed fabrics containing cellulose fibres:

a) Vat dyes are used according to the Rongalite-potash procedure.
b) Disperse/reactive dyes behave in a similar manner to when printing on polyester/cotton fabrics, however the selection of dyes is smaller; wet and light fastness is moderate.
c) Cationic/direct dyes: brilliant, shades are achieved with relatively good light and wet fastness.
d) Cationic/reactive dyes: brilliant shades with good light and wet fastness.

The following dyes are used for mixed fabric containing wool:

a) Disperse/acid dyes: brilliant shades with good light and wet fastness are achieved.
b) Selected metal-complex dyes: subdued shades with very good light and wet fastness.

Polyacrylonitrile fibre solubility Solvents for polyacrylonitrile fibres are sulphuric acid (96%) with a “Huggins constant” of kn = 0.32 and dimethyl formamide with kn = 0.24. The Huggins constant is found by measuring the viscosity of the solution.

Polyalcohols Alcohols with several OH groups, which includes glycols, glycerol $C_3H_5(OH)_3$ and sugar alcohol, but specifically high molecular alcohols such as polyglycol, polyglycerol, polyvinyl alcohol, cellulose (approx. 10 000 OH groups).

Polyamide blends, suitable dyes for,

I. Wool union/polyamide mixes are dyed with selected wool union dyes.

II. Wool/polyamide: selected acid, chrome (mordant), metal-complex dyes.

III. Cellulose/polyamide: selected direct dyes and mixtures with disperse dyes in single bath process. Disperse dyes including dyes that can be used for cellulose are applied in the two bath process.

IV. Acetate/polyamide: selected disperse dyes. Products are selected according to a) the tone-in-tone dyeing in self shades and b) the degree of soiling of the accompanying fibres in bicolour dyes.

Polyamide dyes Practical term for dyes for dyeing polyamide fibres. Selected dyes, specifically for dyeing polyamide, are disperse, acid and metal-complex dyes, which are usually classified into specific ranges. Developing, chrome and reactive dyes are also suitable. Pigment dyes can also be used for light shades.

Polyamide dyes, identification tests,

I. Agster: Staining reactions: Dissolve the dye from several fibre samples using certain solvents (→ Dye class identification on fibres), clean liquor and boil down. Put dye residue in hot water and neutralise with acetic acid or ammonia. Perform the dye test. Vat, vat leuco ester and naphthol dyes remain insoluble.

II. Bode: The dye is boiled sequentially with solvents for 6–8 min without intermediate rinsing.

III. Schumacher:

a) Boiling stripping with 5% formic acid. Disperse, water soluble disperse, cationic, chromium complex, chromium complex disperse and acid dyes are detected.

b) Boiling stripping with 5% ammonia. Chromium complex, acid, substantive and chrome dyes are detected.

c) Separation takes place at boiling point with 50 g/l zinc formaldehyde sulfoxylate conc. and 0.5 ml/l formic acid conc.

Vat dye = vatting usually in 10–20 s, colour shade re-oxidizable.

Leuco vat ester dye = vatting usually only after 2 min.

Naphthols = decolorizing in 1–2 min, the colour shade is not reoxidizable.

Pigment dyeing = no change, microscopic detection.

Polyamide fibre dyeing The neutral dyeing capacity defines the degree of bath exhaustion in percent at pH 6 and boiling temperature for a dye of double standard strength after a defined dyeing time. Dyes with low neutral dyeing capacity are strongly pH dependent and thus are only absorbed completely into the fibres in an acid bath. Dyes with high neutral dyeing capacity possess a high affinity to fibres and thus are completely absorbed by the fibres from a slightly alkaline or neutral bath.

The migration capacity is a measure for the migration of a dye from a dyed to an non dyed fibre in the dye bath. It is determined by boiling a 1/1 standard strength dyed fabric together with a non dyed sample at pH 6 in a colourless liquor for 60 min. A dye with a high migration capacity leaves the accompanying fabric colourless.

If the dyes are graphically represented in relation to the neutral dyeing and migration capacity, then the following positioning of the dye classes is found (see Fig.).

1. Reactive dyes show practically no migration at boiling temperature and have a medium to low neutral dyeing capacity.
2. Metal-complex dyes migrate slightly and possess a medium to high neutral dyeing capacity.

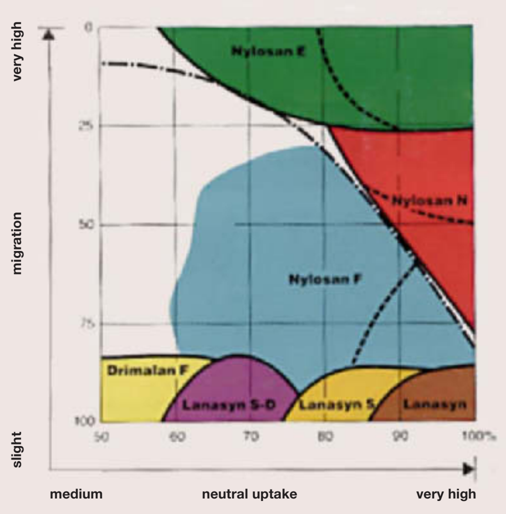


Fig.: The positioning of dyes for polyamide fibres according to their migration and neutral uptake (by Sandoz). (Drimalan F = reactive dyes; Lanasyn = metal-complex dyes; Nylosan = acid dyes.)

3. Acid dyes are spread over a wide range and their migration and neutral dyeing capacity vary greatly.

The representation conveys only a rough overview. In acid and metal-complex dyes a fine classification of dyes according to their dyeing behaviour and their fastness level has proved to be unreliable for experts. This classification permits a more precise selection of suitable products and their combinations, with the objective of increasing the operating safety and reproducibility of the dyes.

Acid dyes are, for example, divided into

- easily neutralized
- neutral dyeing types.

These two dye groups consist primarily of monosulphonated acid dyes. They can be combined well within their groups.

A further classification groups together wet-fast acid dye types. These dyes contain two sulphonic groups per molecule and are primarily used for self tints in double combination, specifically for brilliant shades. They also come into consideration as highlights for wet-fast metal-complex dyes.

The following groups of metal-complex dyes are of practical significance: 1 : 2 metal-complex dyes with

- “masked” sulphonic groups,
- one sulphonic group
- two sulphonic groups,

also some water insoluble, finely dispersed metal-complex dyes.

With the exception of metal-complex dyes with two sulphonic groups, metal-complex dyes can be combined well within the groups, because polyamide fibres have a good dye absorbency for such dyes. Under certain circumstances combinations of elements from neighbouring groups can also be used (according to Schwer).

Polyamide fibres Group of synthetic polycondensate fibres made of a chain of repeating functional amide groups (–NH–CO–). This group of synthetic fibres is important from a textile-technical and economic viewpoint. They are generally manufactured by spinning (see Fig.) from the melt (also as microfibres). The cross-section is round, profiled or smooth.

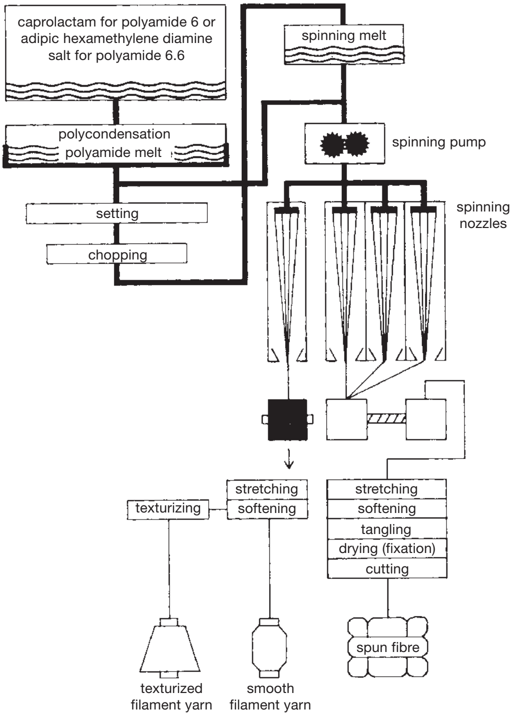


Fig.: The manufacturing process for polyamide fibres.

There are many options for polyamide production, depending upon the manufacturing process and the use of different basic materials. The figure next to the word “polyamide” (e.g. polyamide 6.6) gives the number of carbon atoms in the monomers which form the polyamide. The different number of CH_2 groups effects the properties of the finished fibre. Despite chemical similarity and sometimes a high level of similarity of the properties, there are differences. Physical constants of different polyamide fibre types are shown in the Tab.

Further properties: A certain acid sensitivity accompanied by good alkali resistance; soluble in phenols, conc. mineral acids and formic acids and glacial acetic acid at higher temperatures; sensitive to certain oxidizing agents, particularly peroxide; tendency to auto-oxidation, therefore not very light resistant (light sensitivity can be increased by the addition of light stabilisers during manufacture). The plasticity range, which is important for hot fixing, lies at 160–195°C for polyamide 6, for polyamide 6.6 this is 220–240°C. Polyamide fibres possess favourable strength characteristics (abrasion resistant), therefore used particularly where good wearing properties are required, e.g. carpets, but also widely for underwear, hosiery, outer clothing, fleece. Low swelling in aqueous media guarantees excellent dimensional stability when washed. Rot resistance and bacterial resistance (fishing equipment) are good. The low density and low absorbency mean that it is suitable for rainwear and swimwear.

Dyeing behaviour: → Dyeing of polyamide fibres. The dyeing behaviour of individual types of polyamide fibres, which is in itself very good, varies widely, and can be varied further by polymer additives in order to achieve differential dyeing polyamide fibre types.

Modification of polyamide fibre types:

1. Different (acid) dye take-up by changing the amino terminal group content. a) Low types: reduction of the amino terminal group content by coating with acrylic resin; b) Deep types: increasing the amino terminal group content by amidation of the carboxyl groups with basic groups.
2. Affinity to cationic dyes: blocking the amino terminal groups by a) addition of acid comonomers (e.g. metal salts); b) dispersing of sulphonated ethylene polymers (e.g. metal salts). Grafting of acrylamide (e.g. polymethacrylic acid).

Polyamide fibres in direct printing Acid and metal-complex dyes are most common. The print paste contains dye thickeners (e.g. locust bean flour derivatives, guar flour derivatives, crystal gum, starch ether), hygroscopic agents (e.g. thiourea, urea, thiodiethylene glycol), acid donors (e.g. ammonium tartrate, ammonium sulphate). Specifically in metal-complex dyes an acid donor can be dispensed with. Specific assistants are used to prevent a frosting in texturized polyamide. Alkylamine polyglycolether sulphate is used to eliminate unevenness, which occurs in particular on smooth fabrics with light shades. The addition of a swelling agent (e.g. phenol) sometimes darkens the colour shade considerably; application is problematic due to waste water pollution. Procedure: print, dry, steam with or without low pressure. Specifically in texturized polyamide there is a tendency to soil the white ground colour. This soiling is prevented by condensed phenolic bodies in the washing bath. The same substances are used as after-treatment agents for the improvement of the wet-fastnesses, as are tannin tartar emetic (potassium antimonyl tartrate).

PA types (*)	specific weight (g/cm³)	moisture uptake at 65 % relative humidity (%)	glass transition point (°C)	softening zone (°C)	melting point (°C)	specific heat (cal/g/°C)
polyamide 3	1.33	7.7			340	
polyamide 4	1.25	7.7			256	
polyamide 6	1.14	4.3	50	210	215	0.45
polyamide 7	1.10	3.0		220	225	
polyamide 8	1.09	2.9		180	200	
polyamide 9	1.09	2.5		190	210	
polyamide 11	1.04	1.2		175	190	
polyamide 12	1.01	0.9			180	
polyamide 6.6	1.14	3.8	45	236	255	0.40
polyamide 6.10	1.08	2.6			214	
alicyclic PA	1.04	2.5	135		275	
aromatic PA	1.38	4.5			decomposes at 370°	0.29

Tab.: The physical constants of various types of polyamide fibre.

Further dye application possibilities: The rarer disperse dyes are used in blotch printing in light to medium shades due to their good levelling capacity. With strong shades their wet-fastness is usually inadequate. Reactive disperse dyes are also hardly ever used. Reactive dyes (including wool reactive dyes) can, in principle, be fixed on polyamide, however only a certain dye proportion is chemically linked to the fibre; there is therefore inadequate reproducibility. The fixing degree is also highly dependent upon the fibre. Direct dyes are used if cheap items are to be printed without particular fastness requirements.

Polyamide fibres, solubility Polyamide fibres can be differentiated by their different solubility in ethylene glycol and propylene glycol at different temperatures (see Tab.).

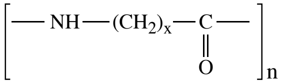
	ethylene glycol [˚C]	propylene glycol [˚C]
PA 6	135	129
PA 8	149	133
PA 11	insoluble	145
PA 6.6	153	153
PA 6.10	156,5	139,5
aromatic PA	insoluble	insoluble

Tab.: Differences in solubility of various polyamide fibres.

Polyamide gauze This has several advantages compared to metal gauze, such as greater elasticity, better dye paste penetration, alkali insensitivity, resistance to tearing. Disadvantages: Increase in elasticity when wet, the fabric must therefore be greatly stretched. Temperature variations also change the dimensional stability. → Screen making.

Polyamide imide → Aramidimide.

Polyamides Synthetic polycondensate, e.g. from diamine and dicarboxylic acids. The films are very scratch resistant, elastic, resistant to ageing, light, water (certain swelling property), alkali, oil and temperature (130–185°C and above), however poor acid resistance. Polyamides are also resistant to aliphatic hydrocarbons, esters and ketones.



$$\left[-NH-(CH_2)_x-\underset{\underset{O}{\|}}{C}- \right]_n$$

The functional groups are the acid amide groups –NHCO–. Polyamides (alcohol-aqueous solutions, emulsions, foils) are used as coatings, lacquer raw materials, materials for gears, etc. We differntiate between synthetic polyamides (polyamide fibres such as polyamide 6 and 6.6) and natural polyamide (wool, silk).

Synthetic polyamide fibres are named as follows according to the number of the carbon atom forming the monomer in question:

- polyamide 3, polyamide from β-lactam (β-alanine). Fibre raw material.
- polyamide 4, polyamide of γ-butyrolactam.

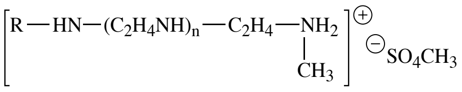
- polyamide 472, polyamide of diamino dicyclohexylmethane and decane dicarboxylic acid.
- polyamide 6, polyamide of ε-caprolactam. Important fibre raw material.
- polyamide 6.6, polyamide of 1.6-hexamethylene diamine and adipic acid. Important fibre raw material.
- polyamide 6.6/6, polyamide of → Adipic hexamethylene diamine salts and ε-caprolactam. Copolymer made up of polyamide 6 and 6.6.
- polyamide 6.9, of 1.6- hexamethylene diamine and nonadicarboxylic acid. Fibre raw material.
- polyamide 6.10, of 1.6-hexamethylene diamine and sebacic acid. The threads in moist state are stiffer than polyamide 6.6/6. Application specifically for wire and brushes.
- polyamide 6.12, polyamide of 1.6- diamino hexamethylene and dodecane carboxylic acid. Fibre raw material.
- polyamide 7 (polyheptanoic acid amide, polyoenanthic acid amide), of 7-amino-oenanthic acid (7-oenantholactam).
- polyamide 8, polyamide of 8-caprolactam.
- polyamide 9, of 9 amino-nonanoic acid.
- polyamide 9.1, polyamide of 1.9-nonamethenediamine and urea.
- polyamide 11 (polyundecanoic acid amide), polyamide of 11-amino undecanoic acid, which is extracted from castor oil. Fibre raw material.
- polyamide 12 (polylauryl lactam), polyamide of lauryl lactam (12-amino dodecanoic acid). In the form of homo and co-polyamides as fibre material, e.g. as monofilament and adhesive fibres.
- polyamide mP.I., aromatic polyamide of 1.3-phenylenediamine and isophthalic acid. → Aramide (fibres).

Polyamines, polyimines High molecular compounds with internal clustered imine groups NH, either uninterrupted with amino groups NH_2 (polyamines) or as follows with C_2H_4NH chains (polyimines):

alkyl polyimines: $R–NH(C_2H_4NH)_nH$

acryl polyimines: $R–COHN(C_2H_4NH)_nH$.

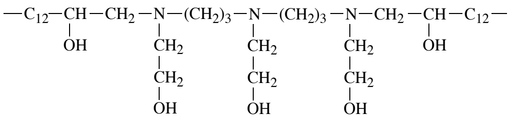
Due to the clustered NH bridges, products of this type have a cationic character. In particular, substituted polyimines with a high level of imine ethylation (C_2H_4NH), ethyleneimines, are markedly cationic. Familiar substituted polyimines, form e.g. cationic softeners such as: $R–CO(NHC_2H_4)_nNH_2$ or cationic fastness aftertreatment products for substantive dyes:



$$\left[R-HN-(C_2H_4NH)_n-C_2H_4-\underset{\substack{|\\ CH_3}}{NH_2}\right]^{\oplus}\ {}^{\ominus}SO_4CH_3$$

Polyamines are recommended to a greater or lesser degree as partly quarternisation scrooping active contents (fabric softeners) and also as flocculation agents in waste water cleaning. This group includes e.g. oxethylated bis(hydroxyalkyl)-dipropentriamine with three hydroxyethyl groups. With regard to softening power and manufacturing properties the product with two hydroxy-tetradecyl residues provides favourable conditions.

bis(-hydroxyalkyl)-dipropentriamine + 3 EO



$$-C_{12}-\underset{\substack{|\\ OH}}{CH}-CH_2-\underset{\substack{|\\ CH_2\\ |\\ CH_2\\ |\\ OH}}{N}-(CH_2)_3-\underset{\substack{|\\ CH_2\\ |\\ CH_2\\ |\\ OH}}{N}-(CH_2)_3-\underset{\substack{|\\ CH_2\\ |\\ CH_2\\ |\\ OH}}{N}-CH_2-\underset{\substack{|\\ OH}}{CH}-C_{12}-$$

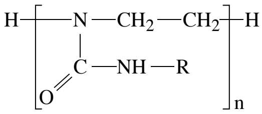
Polyamyloses Term related to soluble starches. → Amylose.

Polyaramide fibres → Aramide (fibres).

Polyaramides Aromatic long-chain polyamides, in which at least 85% of the amino groups are directly connected to two aromatic rings and whereby up to 60% of the amide groups can be substituted by aromatic imide groups. → Aramide (fibres).

Polyases Group of → Enzymes belonging to the hydrolases or carbohydrases, which split high molecular carbohydrates to some degree.

Polyaziridines have the formula



$$H\left[\underset{\substack{|\\ O=C-NH-R}}{N}-CH_2-CH_2\right]_n H$$

They can cross-link polyester polyurethane. They are applied, dried and fixed (cross-linked) as an aqueous dispersion of the two polymers e.g. by nip padding.

Polyazo dyes → Azo dyes.

Polybases Cationic → Polyelectrolytes.

Polybasic Term for acids with several active acid-hydrogen atoms, which can be ionized and replaced by metals, e.g. →: Dibasic; Tribasic, in contrast to monobasic.

Polybenzimidazole fibres (PBI fibres), were originally developed for space suits and parachutes. They have the same comfort properties as cotton, do not burn, do not give off toxic gases in a fire and possess similar processing properties to polyester.

Polyblends (polymer mixes, polymer blends), there are polyblends (Fig. 1) with:

- macroscopic phase boundaries in the form of composite materials;
- microscopic phase boundaries in the form of intermolecular mixtures (blends);

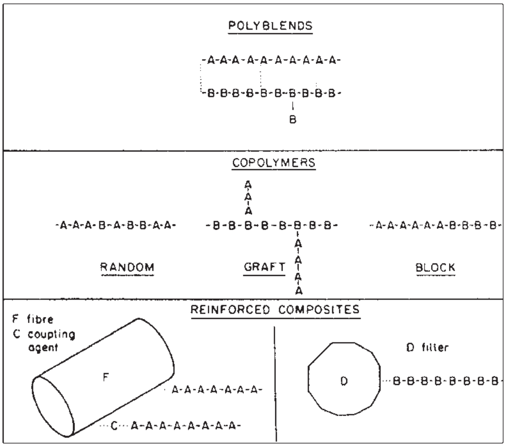


Fig. 1: Multiple component polymer systems (according to Platzer).

– quasi homogeneous intramolecular compounds in the form of graft copolymers and ionomers.

"Compounding" is the term used to describe the addition of a different hard-brittle polymer (e.g. styrene) to a tough-soft elastomer, so that a hard-tough thermoplastic is the result.

Cotton, wool and silk are examples of naturally mixed macromolecular systems in the form of biological composite materials. Synthetic polymers always represent mixtures, because the polymerization process leads to differing chain lengths, but a one hundred percent fractionation is not possible. Like the chain length distribution, the low molecular residues and other impurities remaining in the substance after the polymerization process can also lead to mixing effects. Mixtures also arise in the finishing of materials with softeners, stabilisers, dyes, etc. and during dissolving and swelling. Filled and reinforced materials and polyblends , if they are in inhibited equilibrium states, can be described by the thermodynamics of the mixtures. Block and graft copolymers with high sequence lengths, on the other hand, although they behave in a similar manner to mixtures, defy precise description by phenomenologic thermodynamics, because in this case mixing takes place on an intramolecular level. A differentiation can be made between homogeneous and heterogeneous mixtures. Homogeneous mixtures are characterized by a uniform, location-independent composition. Their properties are generally not additive, i.e. in addition to the contributions made by the individual components of the mixture to the properties of the system as a whole, the characteristic mix members also appear. It is possible to differentiate between different mixture types depending upon the type of these mix members. Heterogeneous mixtures consist of homogeneous subareas (phases) of different composition. Finally, the incompatibility of polymer mixtures in solution, which occurs in almost all polymers, should be mentioned. This is the phenomenon, whereby two polymers, when separately dissolved in the same solvent, form a homogeneous solution, but when these two solutions are combined a phase separation occurs. For example, if 10% solutions of polystyrene in benzene and polyvinyl acetate in benzene are mixed, then despite the use of the same solvent a phase separation occurs, which results first in a noticeable cloudiness and then leads to the formation of two separate phases. One phase contains more of polymer 1, the other more of polymer 2; however both phases always contain a certain proportion of the other polymer. This limited compatibility of polymer mixtures can be explained in terms of thermodynamics and depends upon various factors, such as the structure of the macromolecules, the molecular weight, the mix ratio of the two polymers, the overall polymer concentration and the temperature. Often small structural differences are sufficient to bring about an incompatibility of macromolecules. Sometimes compatible blends are desirable, in other cases incompatible blends are required. For example, natural rubber and poly(styrene-co-butadiene) give compatible elastomer blends; poly(styrene) with poly(2.6-dimethyl-phenylene-oxide) leads to a compatible thermoplastic blend. Impact resistant blends made of thermoplastics and elastomers, on the other hand, are incompatible; for example polystyrene is incompatible with poly-α-methylstyrene and polymethylacrylate is incompatible with polyethylacrylate. Copolymers from the same monomers often become incompatible even where there are only slight deviations in composition.

Marked morphologies may occur in polymer mixes depending upon external circumstances. For example, a polyacrylic ester-polystyrene-polyacrylonitrile product (ASA), which contains acrylic ester as an impact resist-

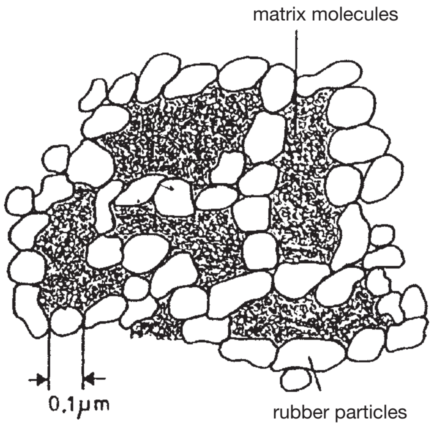
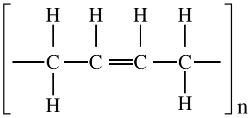


Fig. 2: The morphology within an ASA product (acrylic ester/ styrene-acrylonitrile copolymer) as a polyblend.

ant component in a styrene/acrylonitrile copolymer, has the structure illustrated in Fig. 2. The mobility of the matrix molecules within the cell is reduced, as long as the particles hold together. Under high stresses, however, the cell structure falls apart and thus the mobility of the matrix molecules increase, allowing flow processes.

Polybutadiene Polymer → Butadiene in the form of a substitute rubber material for rubberizing, coating, laminating, etc.

Polybutadiene fibre Synthetic polymeride monofilament made of butadiene, manufactured using the wet spinning (stretch) process. Water absorption 0.02%; dyeable only in spinning solution.



$$\left[\;-\underset{\mathrm{H}}{\overset{\mathrm{H}}{\mathrm{C}}}-\overset{\mathrm{H}}{\mathrm{C}}=\overset{\mathrm{H}}{\mathrm{C}}-\underset{\mathrm{H}}{\overset{\mathrm{H}}{\mathrm{C}}}-\;\right]_n$$

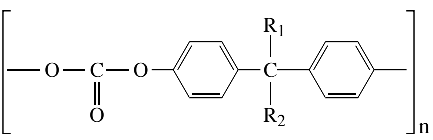
Polybuteneterephthalate (PBTP) → Polytetramethylene terephthalate fibre.

Polycaproamide fibres Rare term for → Polyamide fibres of type polyamide 6 or polyamide 6.6.

Polycaproamides Group of polyamide fibres of type polyamide 6 (base → Caprolactam).

Polycarbonate fibres Synthetic polycondensation fibres (polyester group) (formula principle → Polycarbonates). Manufactured from diphenylpropane and carbonic acid esters (easily accessible due to phenol and acetone). Properties: Density 1.2; water absorbency 0.6%; elongation at break 80–100%; highly heat resistant; high melting point; insoluble in benzine, diluted acids and lyes; soluble in acetone, ethyl acetate, benzene, dichloromethane, carbon tetrachloride.

Polycarbonates Thermoplastic, synthetic polycondensates in the form of polyester e.g. carbonic acid with divalent phenols.



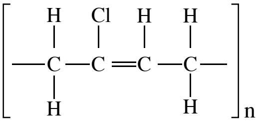
R_1, R_2 = e.g. $-CH_3$

Can be described as a “mirror image” of so-called polyester, also with similar properties: Colourless, transparent; resistant to water, weak alkalis, mineral acids, oils, hydrocarbons. Polycarbonate plastic is also light, rigid, hard, unbreakable, shock-resistant, (can be nailed, and can itself be used in the form of nails); has good electrical properties, is heat resistant up to approx. 137°C; odourless, physiologically harmless. Application: foils, fibres; materials for street lights, fluorescent tube mountings, bottles, transport containers.

Polycarboxylic acids → Carboxylic acids with several COOH groups, e.g. succinic, fumaric, maleic, malonic, oxalic, phthalic, tartaric, citric acid.

Polychlorinated biphenyls (PCB). Is a carcinogenic substance unsuitable for textile finishing.

Polychlorobutadiene Synthetic polymeride, in solutions and emulsions, for coatings and container linings.



$$\left[\;-\underset{\mathrm{H}}{\overset{\mathrm{H}}{\mathrm{C}}}-\overset{\mathrm{Cl}}{\mathrm{C}}=\overset{\mathrm{H}}{\mathrm{C}}-\underset{\mathrm{H}}{\overset{\mathrm{H}}{\mathrm{C}}}-\;\right]_n$$

Polychloroprene → Polychlorobutadiene.

Polychromatic Multi-coloured, bright. Opposite of → Monochromatic.

Polychromatic and monochromatic measuring arrangement In → Spectrophotometer. Optical path length for:

I. Polychromatic measuring arrangement: light source, monochromator, receiver.

II. Monochromatic measuring arrangement: light source, monochromator, sample, receiver.

Fluorescent samples can only be measured using polychromatic measuring arrangement. For non-fluorescent samples the measuring arrangement is unimportant. The results from correct and the incorrect measuring arrangements are shown in the curves in Fig.

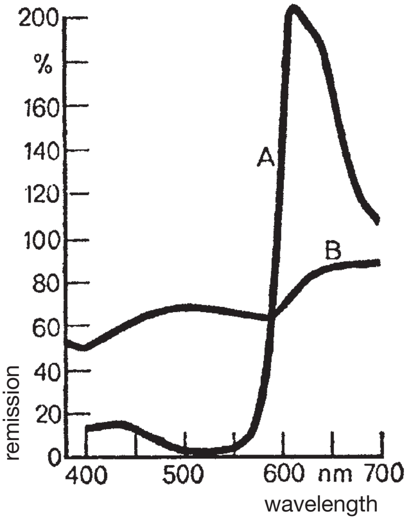


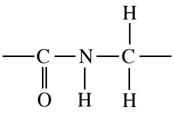
Fig.: Remission curves for a fluorescing red dye obtained using the right (A) and the wrong (B) measuring arrangement.

Polychromatic dyeing For fabrics and carpets. In principle this consists of aiming separate jets and dye solutions at continuously running lengths of material, before and whilst the material passes through squeeze rollers. The application device consists of a number of colour jets and is attached to two or more rods. The length of the rods is the same as the width of the application machine. The nozzles direct the jets of dye liquor at an inclined plate and from there onto the length of material (Dye Weave) or directly onto one of the two squeezing rollers (Flow Form). The nozzle rods can be moved backwards and forwards and in this manner form patterns and colour mixtures (→ Space dyeing).

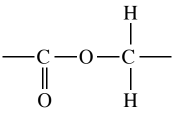
Polychromatic printing Multi-coloured printing with a printing roller. → Orbis printing.

Polycondensation → Condensation polimerisation.

Polycondensation fibres Currently the most important main group of → Synthetic fibres (natural fibres also belong to the group of polycondensation fibres), which are created by → Condensation polymerisation, i.e. by a condensation reaction between the different molecules (intermolecular condensation), whereby smaller molecules, such as water or alcohol, form due to splitting or as a secondary product. Unlike → Polymerization fibres, the main chain contains carbon and foreign atoms (usually nitrogen, sulphur, oxygen) or linking polar groups (–COONH–, COO–, etc.).



$$-\underset{\underset{O}{\|}}{C}-\underset{\underset{H}{|}}{N}-\overset{\overset{H}{|}}{\underset{\underset{H}{|}}{C}}-$$



$$-\underset{\underset{O}{\|}}{C}-O-\overset{\overset{H}{|}}{\underset{\underset{H}{|}}{C}}-$$

Polycondensation products (polycondensate, polycondensation resin, polycondensation plastic), products of → Condensation polymerisation, in the form of plastics or synthetic resins, such as →: Alkyd resins; Epoxy resins; Urea-formaldehyde compounds; Ketone resins; Melamine-formaldehyde compound; Phenolic plastics; Polyamides; Polycarbonates, Polycondensation fibres; Polysulphides.

Polycondensation resins → Polycondensation products with a synthetic resin character.

Polycotton Abbrev. for mixed fabric made of polyester and cotton.

The mix ratio varies depending upon area of origin. Typical values = 70 polyester : 30 cotton or 65 : 35 or 50 : 50. Pretreatment as pure cotton plus heat setting.

Polycyclic vat dyes Group of → Vat dyes with valuable properties. The molecules of many vat dyes can be enlarged by condensation reactions, without having a detrimental effect on the properties of the dye. Polyindigo, polythioindigo and polyindanthrene are produced in this manner and used to dye polyamide fibres. Polycyclic vat dyes can be dissolved in alkali and sodium dithionite, but are only slightly soluble, some are not soluble at all. Their poor adsorption by the fibre gives rise to a significantly higher wet fastness. Critical from an economic point of view is the freedom from sublimation in heat as a result of the increased size of the molecule, which no longer vaporizes. A further advantage is the protection of the fibre itself against thermal degradation. Whereas undyed polyamide 6.6 no longer has any solidity after 5 h at 200°C and indigo dyed polyamide 6.6 has only 8% of its initial solidity after 48 h, polyamide dyed with polyindigo retains 20% of its solidity. Polycyclic vat dyes therefore represent additional, valuable, heat resistant stabilisers against thermal degradation of fibres.

Polydialkylsiloxane (alkyl silicone) → Silicones.

Polydimethylsiloxane There are three generations of silicon emulsions:

1st generation: polydimethylsiloxane with terminal OH groups.

2nd generation: polydimethylsiloxane with amino groups in the side chains.

3rd generation: micro-emulsions.

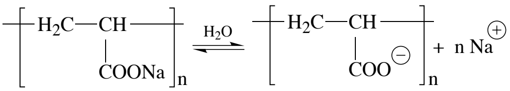
The 1st generation, which had been developed as early as 1972, relates to poydimethylsiloxane with terminally cross-linkable OH groups. The 2nd generation differs from the 1st due to the amino groups in the side chains. These are also called unitary elastomer systems. The 3rd and most modern generation is represented by the silicon micro-emulsions. Chemically these are amino functional polydimethylsiloxanes. Because these products have no terminal OH groups, they cannot be cross-linked like the above-mentioned emulsions. Despite this fact, there are advantages with regard to handle, effect level, mechanical and thermal stability and permanence due to the particle size and degree of distribution. → Silicones in finishing.

Polyelectrolytes High molecular → Electrolytes, natural (e.g. protein polysaccharide) or synthetic (e.g. krilium) macromolecules with incorporated ionic groups; their charge can be positive (cationic polyeletrolytes = polybases), negative (anionic → Poly acids, e.g. polyacrylic acid) or neutral (poly salts, e.g. salts of polyacrylic acid as polyacrylate sizes). Polyelectrolytes can be strong or weak electrolytes. Aqueous polyelectrolyte solutions conduct electric current, have higher osmotic pressure and higher viscosity than the same amount of non-ionic macromolecules. Polyelectrolytes are components e.g. of some boiler scale prevention agents, synthetic resin ion exchanger, sizes, thickeners, etc.

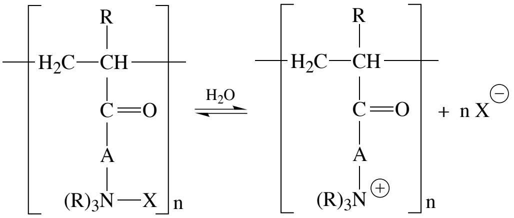
Monomer sodium acrylate dissociates in water into the polymerizable anion acrylate and the (cationic) counterion sodium.

$$H_2C{=}CH-COONa \xrightleftharpoons{H_2O} H_2C{=}CH-COO^{\ominus} + Na^{\oplus}$$

The polymerization of sodium acrylate leads to sodium polyacrylate. This dissociates into the polyanion polyacrylate in water, which is balanced by many sodium ions as counterions.



In the same way a cationic polyelectrolyte can be produced from a cationic polymerizable electrolyte, which dissociates into polycations and anions in an aqueous solution.



If the solution of an anionic polyelectrolyte is mixed with the solution of a cationic polyelectrolyte, then the polymer ions interlace in such a way that precipitation is the result. In copolymers, not all chain members must have an electrolytic character. It is perfectly possible for ionic monomers to be polymerized together with nonionic monomers. The greater the proportion of non-ionic monomers selected, the weaker is the ionic nature of the copolymer. Then, there are, for example, weak or strong cationic polyelectrolytes.

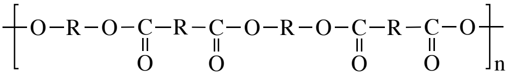
Polyenes Polymerized → Dienes.

Polyepoxides Polymer epoxy resin, → Epoxy resins.

Polyester,

I. Synthetic polycondensate made of e.g. multivalent alcohols and dicarboxylic acid, to higher and high molecular (ester) compounds such as phthalate resins (of glycerol and terephthalic acid). Polyester containing a hydroxyl group (e.g. glycol-adipic acid polyester) with 2–10% OH content are soft resins, oils or waxes, which organically soluble, can be additively cross-linked with di-isocyanates to form elastic-soft coatings (→ Polyurethanes).

II. Generic term for polyester fibres, according to an American proposal those of at least 85% by weight of an ester of a diol and terephthalic acid.



$$\left[-O-R-O-\underset{\displaystyle O}{\overset{}{\underset{\|}{C}}}-R-\underset{\displaystyle O}{\underset{\|}{C}}-O-R-O-\underset{\displaystyle O}{\underset{\|}{C}}-R-\underset{\displaystyle O}{\underset{\|}{C}}-O-\right]_n$$

Polyester amides Polyaddition product of type $-OOC-NH-R_1-NH-COOR_2-$; → Polyurethanes.

Polyester amines as demulsifiers The chemistry of demulsifiers is complex and has many variants. The base products are ethylene oxide/propylene oxide (EO/PO) block polymers with molecular weights of several thousand. These modules can be further cross-linked to increase the molecular weight and then have an improved effectiveness spectrum. Polyester amines (see Fig.) are frequently used to improve the quality of separated water. They have a slightly cationic character and are condensation products of one oxyethylated fatty amine, one dicarboxylic acid and one ethylene oxide/propylene oxide block polymer (Hoechst).

Polyester/cellulosic blends Sequence of pretreatment work stages: singeing, desizing, washing, scouring/bleaching, drying, fixing, mercerizing, drying. A continuous treatment process guarantees uniform treatment with the required chemicals, thus

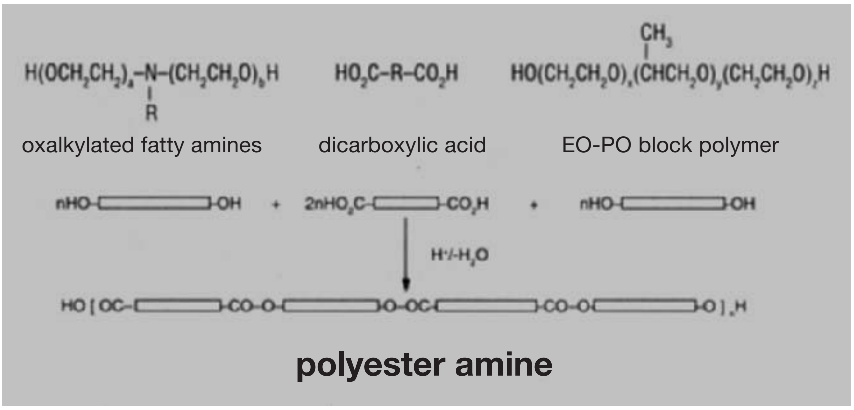


Fig.: The synthesis of polyester amine.

achieving good pretreatment effects with a high degree of reproducibility. Uneven dyeing will result if different swelling states exist between the centre and edges of the material. More intense local singeing of fabrics made of polyester/cellulosic mixed yarns can lead to thermal damage of the polyester fibre or the whole fibre composite and subsequently give rise to colour shade or nuance differences.

The ease with which sizing agents used in the manufacture of fabric can be removed varies. Removeability of sizing agents during pretreatment:

Easy to remove	**Difficult to remove**
I. sizes:	
polyacrylates	native starches of maize, rice and potatos
modified maize and potato starch	tapioca starch
CMC	glue containing sizes
polyvinyl alcohol*	
II. size auxiliaries:	
emulsified tallow	paraffin
PEO wax	non-emulsified tallow
PPO wax	silicon defoamer

* on condition that the pretreatment does not begin with an alkali stage

The use of water soluble sizes is becoming ever more prevalent, particularly in mixed fabrics made of polyester/cellulosic fibres. However, almost all of these products are not directly soluble in water, but only after swelling. Therefore, care must be taken that there is sufficient liquor take-up; furthermore the swelling process takes some time.

The fully continuous process with singeing, washing out of the water soluble sizes, scouring and bleaching requires the use of a device after the singeing stage, which allows the material soaked in wetting agent to dwell for several minutes before it is rinsed out. Such a device consists of two impregnation points with an air passage between them. The fact that particular importance is attributed to a good wetting agent with regard to the liquor take-up, is largely due to the material speed of up to 150 m/min when using a singeing machine. Surfactants with a good wetting power and a high emulsifying and dispersing capacity are preferred. Enzymatic desizing has the disadvantage that it cannot be combined with other processes. Therefore, oxidative desizing is preferred, which can be carried out in combination with the alkali stage and is therefore more economical.

Low tension pretreatment has become increasingly important for items previously assumed to be able to stand up to lengthways tension of any type during pretreatment without damage, or for which this was even considered necessary. The material quality and handle is influenced by completely tension-free scouring such that the final quality of material dyed according to a continuous thermosol pad steam process barely deviates from material dyed using an exhaustion process, e.g. by a jet.

Hot bleaching with hydrogen peroxide is the dominant continuous bleaching process. Catalytic damage hardly ever occurs as a result of bleaching processes such as NET processes or the PKS process. It is not necessary to bleach for coloured material. For light and, above all, brilliant colour shades, the cotton fibres are bleached with hydrogen peroxide. Chlorite bleach plays no role in continuous bleaching processes because it is less suitable for continuous pad-steam processes. Hypochlorite bleach is hardly ever used as a preliminary stage for a subsequent peroxide bleach due to environmental legislation (AOX). The demand for continuous pre-treatment is primarily a question of the quality of the material and the uniformity of the effects (according to von der Eltz).

Polyester cotton mixes are attributed great importance, because textiles manufactured from them possess good wearing properties and high wear resistance. Natural and synthetic fibres complement each other excellently. The mix ratio is usually polyester/cotton 67/33 or 50/50. The most important items are shirt and raincoat material. Tone-in-tone pastel shades can be achieved both in the exhaustion and the padding procedures using selected dispersion dyes alone. Finished dye mixes (mixed dyes) are in the ratio 67/33 and guarantee uniform shade dyeing of both fibres.

Polyester confirmation test Reaction to prove the presence of polyester. 0.5 g of hydrated oxide of iron (rouge) is moistened with a little methanol and then dissolved in 50 ml of m-cresol (hydroxytoluene). Short lengths of fibre are cut using blunt scissors and immersed in the reagent for five minutes at room temperature. The fibres are then thoroughly rinsed with methanol then briefly rinsed with acetone and finally washed with alcohol. The ends of any polyester fibres will appear coloured strongly red. The previously used phenol and oil red test reaction is no longer to be recommended because of the solubility of some forms of polyester in phenol.

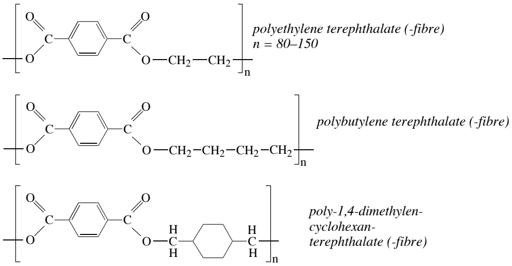
Polyester dyes Simplified practical term for dyes for → Dyeing of polyester fibres.

Polyester dyes, identification tests (according to Agster),

1. identification plan: procedure identical to that for → Acrylic dyeings, Identification of dye class.
2. dyeing reaction: procedure as for → Acrylic dyeings, identification of dye class. Azo and vat dyes remain insoluble (blank vat).

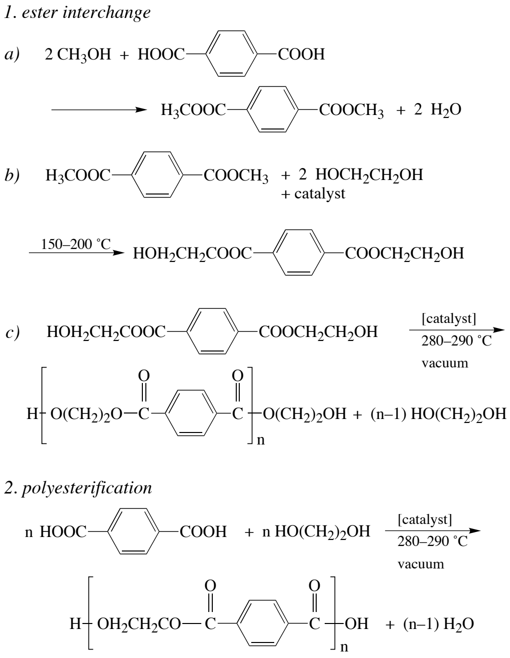
Polyester elastomers (polyester rubber), → Elastomers based upon polyester, which require no crosslinking. Some properties: unusual resistance against impact/bending cracks, good fabric adhesion; resistance against diluted acids good, against concentrated acids poor; against solvents excellent/good; against oxidation (ozone) excellent; against sunlight good; against ignition moderate to good.

Polyester fibres Group of synthetic polycondensate fibres made of terephthalic acid and ethylene glycol. The following polyester fibres, listed in order of decreasing importance, have proven their value in technical applications:



In the manufacture a differentiation is made between polycondensation, i.e. the synthesis of the polymer, and the melt-spinning process. The discontinuous process of “ester interchange” is used to produce special fibres in small quantities, whereas larger quantities (e.g. tyre cord) are produced in a continuous process combining synthesis and melt-spinning according to the process of “polyesterification”.

Whereas in the ester interchange process, the polyester fibre is produced in three stages:



- dimethylester production,
- ester interchange in the VK pipe (simplified continuous) with granule production (Fig. 1),
- melt-spin process,

in the polyesterification process polyester fibres are produced by the spinning process in a single step (Fig. 2).

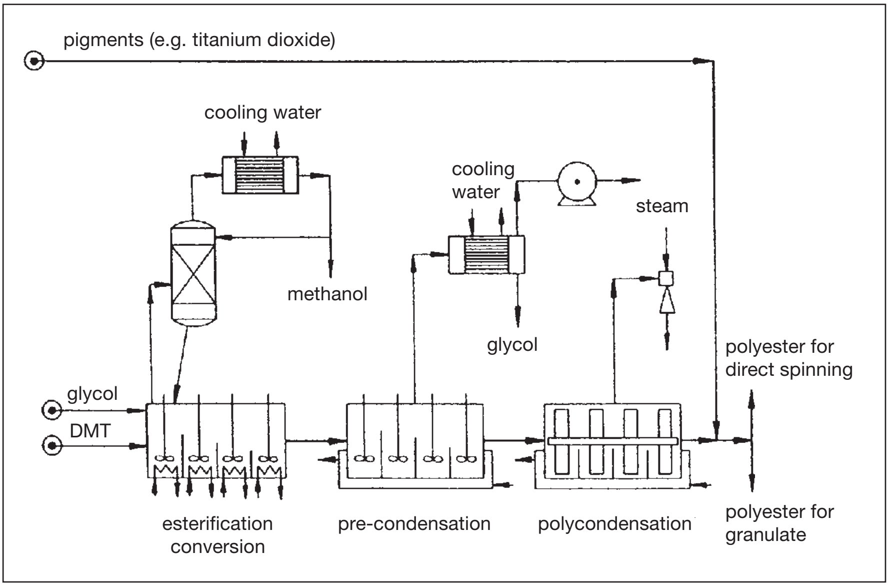


Fig. 1: The continuous production of polyester from dimethyl terephthalate (DMT) (according to Pelousek).

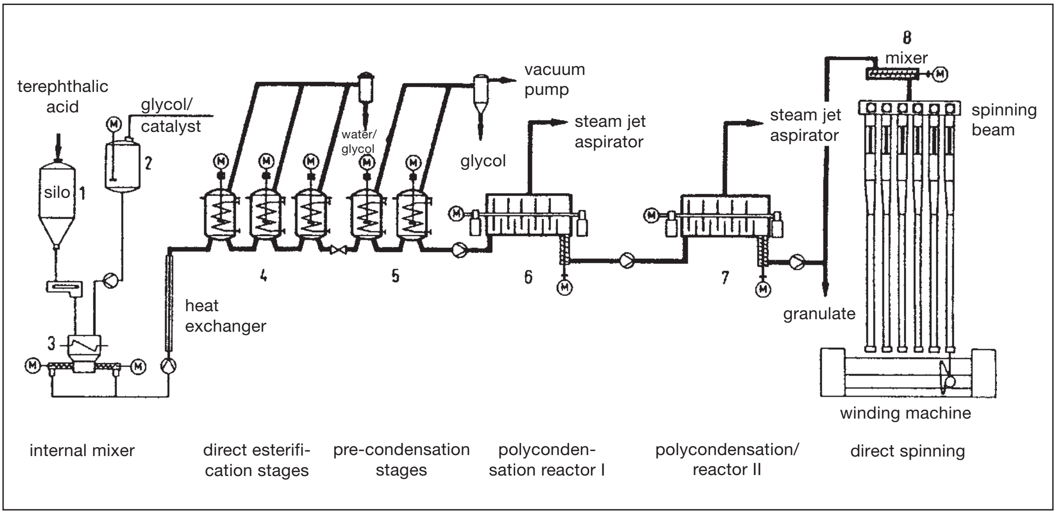


Fig. 2: Process diagram of a continuous polymerization facility with direct spinning for the manufacture of polyester cord, the starting point being terephthalic acid (according to Pelousek).

Depending upon the property profile one differentiates

a) in relation to the spinning speed (Figs. 3 + 4):

- 1000–2000 m/min LOY (low oriented yarn),
- 2000– 4000 m/min POY (pre-oriented yarn), amorphous, pre-elongation necessary;
- 4000–6000 m/min HOY (highly oriented yarn), part-crystalline, pre-oriented in a preferred direction;
- 6000–8000 m/min FOY (fully oriented yarn), fully elongated.

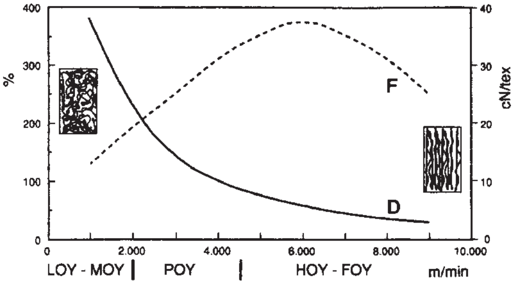


Fig. 3: Drawing speed (m/min) during the melt-spinning process together with the consequent expansion D (in %) and firmness F (in cN/tex).

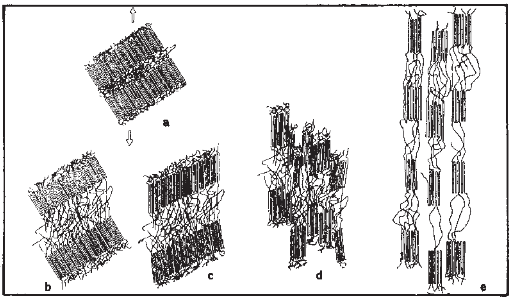


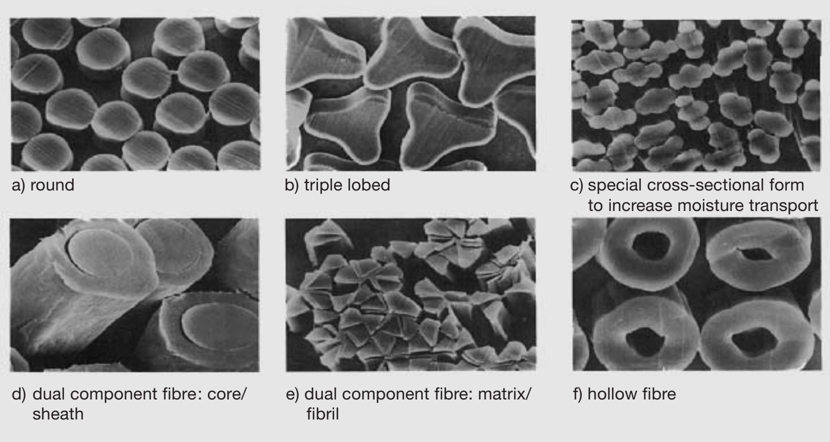
Fig. 4: Different degrees of drawing (a–e).

b) in relation to diverse influences:

- high-strength filaments with high degree of drawing for tyre cord and other technical textiles;
- low pill type due to reduction of the average degree of polymerization and thus low breaking strength in bending (pills break off);
- high-shrinkage fibres which shrink when boiled to achieve high-bulk during finishing;
- types that can be dyed without a carrier due to the inclusion of block polyethylene in the ester interchange process, thus reduced glass transition temperature;
- types that can be cationically dyed due to copolycondensation of terephthalic acid, isophthalic acid, sulphonicisophthalic acid, ethylene glycol or 1.4–methylcyclohexane.

c) in relation to the spinning profile (Fig. 5):

- microfibres between 1.0 dtex and 0.3 dtex;
- profile fibres such as triangular or pentagonal star in order to alter the lustre and handle; round, trilobal;
- bicomponent fibres (side-by-side type, S/S) with three dimensional ripples;



a) round

b) triple lobed

c) special cross-sectional form to increase moisture transport

d) dual component fibre: core/sheath

e) dual component fibre: matrix/fibril

f) hollow fibre

Fig. 5: Cross-sectional forms of polyester (according to Wulhorst, Tetzlaff and Dahmen).

- biconstituent fibres (bicomponent fibres of the matrix / fibril type, M/F) of polyamide with polyester as fibrils;
- hollow fibres.

d) According to the dyeing status:

- spin dyed (Fig. 6);
- white-delustred;
- flock, yarn, piece dyed;
- thermosol dyed.

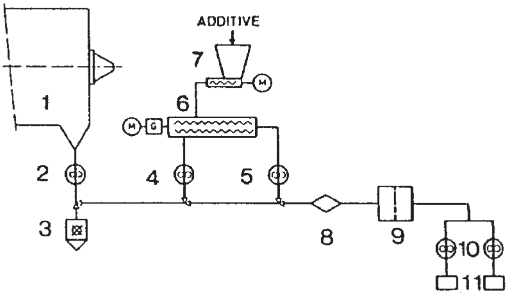


Fig. 6: Flow diagram of a facility for melt modification. 1 = final reactor; 2 = application pump; 3 = granulator; 4 = delivery pump; 5 = return pump; 6 = twin shaft extruder; 7 = additive dosing device; 8 = static mixer; 9 = melt filter; 10 = spinning pump; 11 = spinning heads.

e) according to the make-up type (Fig. 7);

- tow;
- staple fibres (broken or cut);
- smooth filament;
- Air entangled yarn (filament);
- texturized filament yarn.

Spinning process: after the first roll batching devices for higher speeds became available at the beginning of the 1970s the era of “high-speed spinning” had begun. This was not only an important step towards the improvement of product characteristics. Due to the change to product characteristics as a result of the higher speeds, there was a significant simplification of the process. The products became less sensitive towards external influences and new, more economical after-processing and further processing stages could be developed. Due to the feed speeds, which had increased to 2500–3500 m/min, and

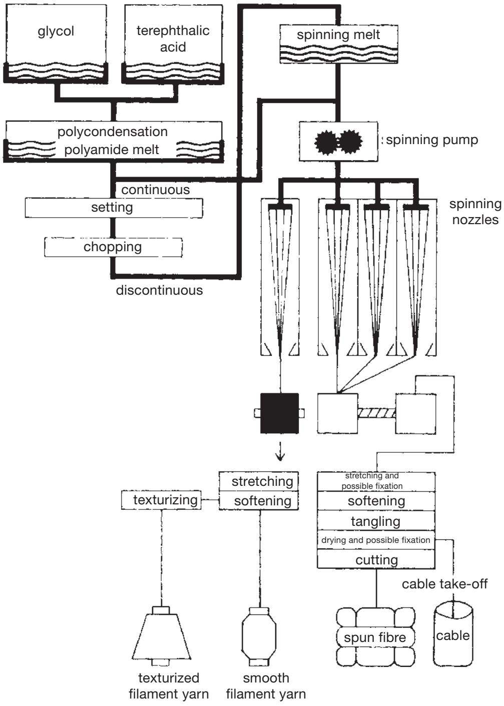


Fig. 7: The entire process of polyester fibre manufacture.

the resulting increased thread tensions the chain molecules were more aligned in the fibre longitudinal axis. The resulting yarn is therefore significantly more pre-oriented and is therefore called a pre-oriented yarn (POY). As Fig. 3 shows, this is associated with increased strength and lower elongation at tear.

However, the actual revolution triggered by these innovative yarn types lay in their stable and reproducible product characteristics. The yarns have excellent storage and despatch properties, which resulted in a previously unheard of flexibility in time and space. This high product stability is due to the presence of very small crystalline areas, which prevent the reorientation of the molecular structure at room temperature. However if the temperature is increased above the glass transition point T_g, then there is an increased reorientation of the amorphous (non-crystalline) oriented molecules towards their original disoriented position. This is associated with a shortening of the yarn, so-called “shrinkage”. The shrinkage value increases with increasing amorphous orientation. If the spinning speed is further increased, tension induced crystallisation occurs, i.e. amorphous areas are converted into energetically stable crystalline zones. This blocking increases the molecular reorientation of the amorphous phase, even at temperatures above T_g, and results in a drastic reduction of the shrinkage value. For the manufacture of smooth yarns, draw twisting is used as a subsequent process. Furthermore, the good and reliable product characteristics of the POY facilitated the development of the stretch warping process, in which a large bunch of POY reference yarn is stretched and at the same time, batched to warp beams for weaving. However, the development of POY is of greatest significance for the stretch texturizing process, which is used in the majority of POY production. As a result of the special molecular properties of POY, the temperature at which the heat induced crystallisation occurs is approx. 30°C lower than for LOY. This facilitates the single stage stretch texturizing process, in which the drawing and fixing of the applied yarn twist takes place on a heating element, without (as is the case for LOY) sticking to the hot plate. If we disregard the so-called highly oriented yarns (HOY), which must still be subsequently stretched or used where the higher yarn twist is acceptable, the next development stage is the FOY produced in a single stage process. The products created in this manner are exclusively flat yarns, which can be subjected to the air-jet texturizing process. There are different options for single stage manufacture from fully drawn yarn (FDY similar to FOY). They all have in common the fact that the drawing process is integrated and takes place between nozzle and batch rolling device (according to Zengel).

The dyeing properties depend upon the morphological structure of the fibre (Fig. 8), which is primarily influenced by the thermal and mechanical history of the fibre prior to the dyeing process. The dye absorbency increases with increasing thermofixing temperature, before increasing at above approx. 190°C.

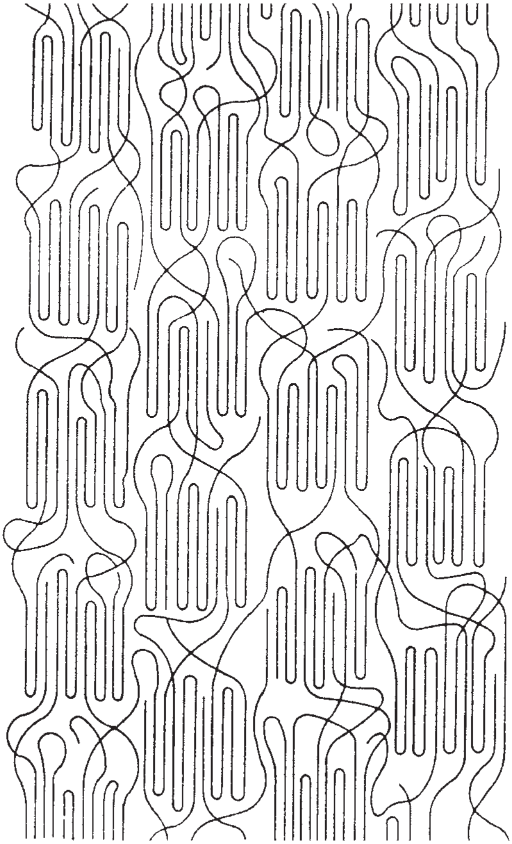


Fig. 8: Three-phase model of the structural make-up of polyester fibres, being composed of crystallized zones with chain folding and alternately adjacent amorphous zones together with interfibrillar voids.

Dyeing takes place

- using the exhaust dyeing process with a “carrier” [more correctly called a “plasticizing carrier” because the carrier (e.g. phthalate) predominates and the glass transition temperature falls, which improves the accessibility to disperse dyes after adsorption on the fibre surface];
- using the exhaust HT process at 130°C in accordance with the free volume model;
- using the thermosol process, in which at 200°C increased amorphous areas of sometimes, gaseous, sublimated dyes, are easily accessible, and show joint co-crystallization upon cooling.

Properties: Relatively flame resistant; resistant to micro-organisms and insects; physiologically inert; good

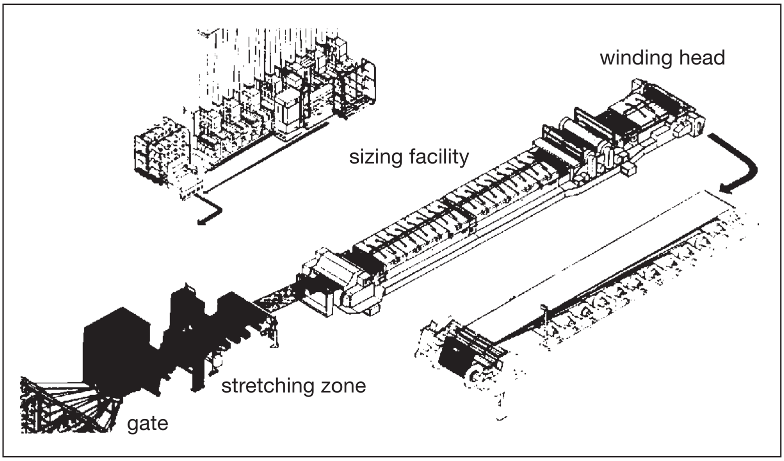


Fig. 9: Stretching and sizing facility for polyester fibres (Barmag-Tsudakoma system).

weather and light resistance (better than polyamide 6.6, lower than polyacrylonitrile); thermoplastic; softens at 230–250°C, melts at 256–292°C; elongated fibres shrink in boiling water (more than in air at 100°C) and hot air, therefore polyester textiles require thermofixation prior to heat treatments and to guarantee dimensional stability and freedom from creases (usually < 220°C; temperature increases cause temporary reduction in strength (at 180°C approx. 50% relative strength). The electrostatic chargeability can be managed by specific finishes (preparation, inclusion, fibre mixes). Breaking strength can be varied in broad bounds depending upon manufacturing conditions. Abrasion resistance good. Crease resistance excellent. Deformation resistant. The tendency towards pilling can be managed by certain polyester types and processing conditions. Chemical resistance: particularly excellent against cold acids, oxidizing agents and solvent. Easily washable, quick-drying. Low moisture absorbency. Some alkali sensitivity. Low dye affinity (→ Dyeing of polyester fibres).

Subsequent treatment processes such as drawing or sizing are sometimes linked; e.g. drawing in spinning or stretch-sizing (Fig. 9). In addition to the stretch sizing, size stretching and stretch sectional warping are also practised. In the former, drawing is done directly on the sizing machine, i.e. without a previous stretching zone. In stretch sectional warping, warp beams are manufactured in full thread density, which are used immediately prior to the weaving and knitting machines.

Application: men's and women's clothing material, non-wovens, blouses, sports shirts, knitted clothing, underwear, ties, raincoat material, swimming costumes, work clothing, sewing thread, net curtains, curtains, awnings; technical applications: gauze, filter material, drive belts, ropes, insulation material, tyre cord, etc. Great importance in fibre mixes (with wool, cotton, viscose spun fibres).

Polyester fibres in dyeing The use of dyes (→ Dyeing of polyester fibres) that form stable dispersions under dyeing conditions and neither agglomerate nor recrystallize is an important prerequisite for uniform jet, yarn or beam dyeing. However, even if this condition is met, uniform exhaust dyeing cannot be guaranteed. If the glass transition temperature is exceeded during the heating up phase, the substrate of the adjacent fluid layer begins to extract the dissolved dye. If the dye were to be supplied instantaneously by diffusion or by the dissolving of dispersed particles, then the concentration of dissolved dye would be the same at each point of the substrate surface and would be equal to the solubility of the dye. The sorption speed would be the same everywhere, and the result would be a completely uniform dyeing. This limit sorption speed is determined only by the diffusion process within the substrate. However, because the dye is supplied at a

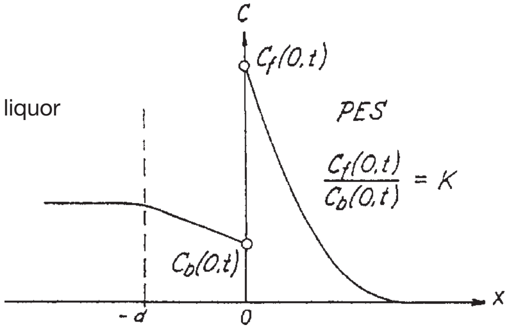


Fig.: Concentration profile at the boudary layer between liquor and substrate.

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limited speed, dissolved dye is depleted at the boundary layer (see Fig.). This depletion results firstly in a reduction of the sorption speed and at the same time an increase in the flow of dissolved dye to the boundary layer. The concentration C_b (0,t) of dissolved dye at the phase boundary liquor/substrate (x = 0) is always such that sorption speed and supply are equal. If the depletion at the boundary layer is low, because sufficient liquor exchange ensures a supply of disperse dye from the liquor, uniform dyeing can be expected. The supply of dissolved dye in this case is less dependent upon local flow conditions. If, on the other hand, depletion is high, then the supply is strongly dependent upon the thickness of the hydrodynamic boundary layer (according to Gerber and Griesser).

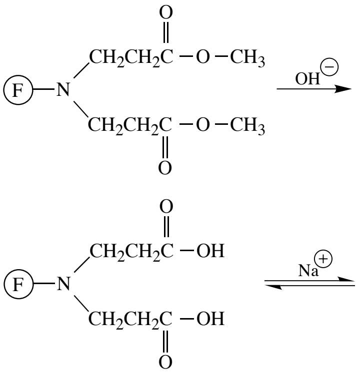
Polyester fibres in printing Disperse dyes are used for direct printing procedures. They can be classified on the basis of their fixing properties:

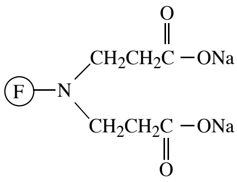
- fixation type and time,
- hot air 15–30 s,
- saturated steam 45–60 min,
- high pressure saturated steam 20–30 min,
- superheated steam 2–9 min.

When fixing in superheated steam, hot air or contact heat on hot cylinders fixation accelerators, e.g. based upon alkyl phenols, can be useful.

In order to be able to produce polyester prints with extremely fine lines, a naturally occurring inorganic polymer (bentonite) was mixed with conventional thickening agents to form a system with rheological behaviour suitable for fine prints. In etch printing, the light polyester fabric dyed using the exhaust dyeing process is printed during steaming with hydrolyzing auxiliaries (and possibly in coloured discharge printing with an alkali resistant disperse dye). If steaming takes place at 180°C for 7 min, the following reactions take place in the disperse dye due to its alkali sensitivity, while the alkali resistant printed disperse dye diffuses into the fibre.

alkali discharge:





In principle, when performing continuous background dyeing for etch printing, it is advisable to perform thermosol fixation only after printing, because then the disperse dye to be etched is still present, adsorbed on the fibre surface, and can be etched more easily than when it has migrated into the fibre and been fixed, i.e. is inaccessible to the etching paste.

Polyester fibres of modified dyeability The aim is to achieve easy dyeability without a carrier using the measures listed in the Tab.: polyester fibre modification.

There are deep dye polyester types, some of which can be dyed using cationic and disperse dyes. These polyester fibres can be satisfactorily dyed in a boiling bath with no carrier, and the dye take-up is greater than in normal polyester fibres. Although the dye take-up is roughly the same in all modified polyester fibres, penetration differs from fibre to fibre. So one fibre type may have a penetration of only 70% after a dwell time of 2 h in a boiling bath (or 15 min steaming), whilst other fibres are fully penetrated after 1 h boiling (or 10 min steaming) at normal pressure. Such differences are reflected in the thermofixation fastness. The dye migrates slightly from the fibre. The superior penetration in modified fibres in comparison to normal polyester results in higher dye yield and better rubbing fastness (therefore: reductive cleaning only with the deepest dyes). The lack of light fastness does not appear to be a problem with modified polyester.

All polyester fibre modifications are dyeable with disperse dyes. Reduced soiling rests in principle on the spinning in of (or subsequent finishing with) water soluble products, which promote the removal of dirt during washing; such substances may also influence the electrostatic behaviour of polyester. Polyester fibre modifications are also clearly less susceptible to pilling.

Polyester gauze The low moisture absorption, which results in good deformation resistance is particularly beneficial for → Screen making. Polyester gauze also possesses good light resistance and low elongation with good elasticity. Polyester gauze has to a large degree supplanted → Polyamide gauze, although dye paste penetration and abrasion resistance are somewhat lower.

Polyester hydrolysis In the finishing of materials made of polyester fibres, with the aim of improving the wear and hygiene properties of the end product, the surface hydrolysis of the fibres (“deweighting”) with a

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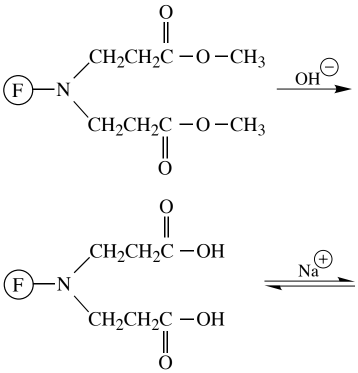

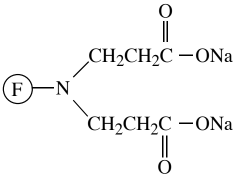

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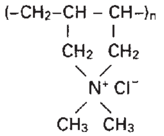
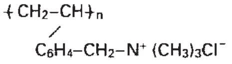
Polyester hydrolysis

target	modification	particulars
stronger dye take-up, so-called deep types	manufacture of copolymers by the addition of e.g. – dicarboxylic acids such as adipic acid, azelaic acid, sebacic acid, isophthalic acid – hydrocarboxylic acids – diolene	– lowering of glass transition temperature and melting point – evenness of dyeing
carrier-free dyeing with dispersion dyes	inclusion of – dicarboxylic acids – hydrocarboxylic acids – diolene manufacture of block polymers on the basis of polyethylene oxide	– lowering of glass transition temperature and melting point – risk of decomposition during manufacture – fixation not possible above 180°C – somewhat inferior high temperature and washing performance – caution with choice of dye (light fastness) – even dyeing – influence on mechanical and technological characteristics
	polyester on the basis of polytetramethylene terephthalate	– reduced melting point: 220-225°C – density 1.32
affinity with cationic dyes	– inclusion of acidic reacting groups in the molecular chain, e.g. isophthalic acid – addition of polymers with acidic reacting groups in the polymer melt	– influence on mechanical and technological characteristics
affinity with acidic dyes	inclusion of basic reacting groups, e.g. tertiary amines	– problems with fibre extraction – yellowing due to tertiary amines

Tab.: Polyester fibre modification.

mass loss of up to 10–25% is particularly important. Such a treatment improves the surface aspect and handle, yielding a similar effect to that of natural silk. The topochemical reaction of the hydrolysis of ester groups on the surface of polyethylene terephthalate fibres in a sodium hydroxide solution can be accelerated by additives that cause the fibres to swell or by amines and quaternary ammonium compounds (see Tab.). The addition of alkyl dimethyl benzyl ammonium chlorides, stearyl trimethyl ammonium chlorides and similar compounds, accelerates the saponification process and allows the alkali concentration in the solution to be reduced. Quaternary ammonia compounds are effective in the saponification of polyester fibres in solutions with a minimal NaOH content at temperatures higher than 100°C. Cationic polymers are of particular importance here. Fibre mass losses of 20–25% at 130°C in the presence of polydimethylaminoethylmethylacrylate derivatives are achieved in 30–45 min; in contrast, 6 h is needed without a catalyst.

In the case of heterogeneous hydrolysis of polyester fibres, the catalytic effect of the cationic polymers can only be seen at the phase boundary. Therefore the nature of the forces that hold the catalyst to the fibre surface, and its interaction with the reaction products, takes on particular importance in hydrolysis. This mainly relates to interactions of polycations with anions and polyanions. The catalytic activity of quaternary

compound	structural equation
1 tetraethyl ammonium bromide	$(C_2H_5)_4\,N^+\,Br^-$
2 triethylbenzyl ammonium chloride	$(C_2H_5)_3\,C_6H_5\,CH_2N^+\,Cl^-$
3 methyldiethyl aminomethyl polyglycol ester benzene sulphonate	$R-C_6H_4-O(CH_2-CH_2-O)_{10}-$ $-CH_2N^+(C_2H_5)_2CH_3C_6H_5SO_3^-$
4 polydimethyl diallyl ammonium chloride	 $(-CH_2-CH-CH-)_n$ $CH_2\quad CH_2$ $N^+\,Cl^-$ $CH_3\quad CH_3$
5 poly-4-vinylbenzyl trimethyl ammonium chloride	 $(-CH_2-CH-)_n$ $C_6H_4-CH_2-N^+(CH_3)_3Cl^-$

Tab.: Catalysts for the hydrolysis reaction involving polyester fibres.
(1 + 2 were used in solid form, 3–5 in aqueous solution.)

polymer ammonium compounds is greater than that of their low molecular counterparts. The catalytic effectiveness of the polymer catalysts depends upon their ability to enter into a hydrophobic interaction with the polyester fibre. In the NaOH solution there is a partial conversion of the quaternary ammonia salt groups of a polymer into base groups, followed by the adsorption of the polymer catalyst on the fibre surface and the hydrolysis reaction of the polyester ester groups with a subsequent transfer of the terephthalic acid anions, together with the polymer catalyst, from the fibre surface into the solution. Individually, the reactions are represented in the following systematic-parallel stages:

The formation of the quaternary ammonia base groups in the cationic polymer (1), its absorption at the fibre surface (2), splitting the ester bond into macromolecules of polyethylene terephthalate (3). There is the possibility of a reaction (3) of the complex cationic polymer / DNaPS, which decomposes in the next stage (4) under the effect of the NaOH solution. The polymer catalyst absorbed at the fibre surface is quantitatively regenerated (according to Jemaitaitiene).

$$1\quad (\mathrm{Poli\ Q^{+}})_{n}\,\mathrm{Cl}^{-}_{n} + m\,\mathrm{NaOH} \rightarrow (\mathrm{Poli\ Q^{+}})_{n}\,\mathrm{Cl}^{-}_{n-m}\,\mathrm{OH}^{-}_{m} + m\,\mathrm{NaCl}$$

$$2\quad (\mathrm{Poli\ Q^{+}})_{n}\,\mathrm{Cl}^{-}_{n-m}\,\mathrm{OH}^{-}_{m} + \mathrm{PES} \rightarrow \mathrm{PES}\,(\mathrm{Poli\ Q^{+}})_{n}\,\mathrm{Cl}^{-}_{n-m}\,\mathrm{OH}^{-}_{m}$$

$$\begin{aligned}3\quad & \mathrm{PES}\,(\mathrm{Poli\ Q^{+}})_{n}\,\mathrm{Cl}^{-}_{n-m}\,\mathrm{OH}^{-}_{m} + \mathrm{HO}\{\mathrm{OC{-}C_6H_4{-}COO{-}(CH_2)_2{-}O}\}_{m}\mathrm{H}\\ & \qquad\qquad \downarrow \mathrm{NaOH}\\ & \mathrm{PES}\,(\mathrm{Poli\ Q^{+}})_{n}\,\mathrm{Cl}^{-}_{n-m}\,(\mathrm{OOC{-}C_6H_4{-}COO^{-}})_{m} + m\,\mathrm{HO\,(CH_2)_2\,OH} + m\,\mathrm{H_2O}\end{aligned}$$

$$\begin{aligned}4\quad & \mathrm{PES}\,(\mathrm{Poli\ Q^{+}})_{n}\,\mathrm{Cl}^{-}_{n-m}\,(\mathrm{OOC{-}C_6H_4{-}COO^{-}})_{m} + m\,\mathrm{NaOH} \rightarrow\\ & \text{—}\,\mathrm{PES}\,(\mathrm{Poli\ Q^{+}})_{n}\,\mathrm{Cl}^{-}_{n-m}\,\mathrm{OH}^{-}_{m} + m\,\mathrm{NaOOH{-}C_6H_4{-}COONa} + m\,\mathrm{H_2O}\end{aligned}$$

Polyester-polyamide biconstituent fibres represent a two-phase system, composed of a polyester matrix containing evenly distributed polyamide fibrils. Acid and metal-complex dyes only dye the polyamide component. As the dyeing effect is only superficial it can be influenced by treating the biconstituent fibres in such a way as to bring about an increase in the polyamide content in the surface layers of the fibres and the formation of micropores, thus promoting the diffusion of the dye solution.

The main purpose of modifying the polyester fibres is to improve their dyeing properties. One process that is of interest is the joint spinning of polyester with polyamides, which have good dye affinity. When spinning melt dispersions of polyester with polycaproamide with a polycaproamide content of above 20%, the absorbency of the fibres for disperse dyes is greatly increased. Only at above 40% polycaproamide is dyeing with acid and metal-complex dyes possible. The spinning of melt dispersions could in principle be realised in the following two ways:

1. In the production of polyester-polyamide biconstituent fibres, polyamides must be selected that have a higher affinity to acid dyes than the traditional polyamide 6 and polyamide 6.6. This reduces the necessary quantity of polyamide, and the objective can be achieved with a mix ratio of the two polymer components that guarantees normal spinning and drawing.
2. Polyester-polyamide biconstituent fibres must be sought on the basis of polyethylene terephthalate and traditional polyamide 6 or polyamide 6.6, in ratios that guarantee the normal procedure of the technological processes of spinning and drawing and in which the subsequent effect upon the morphology of the fibres and the phase distribution bring about the desired dyeability by acid dyes (according to Georgiev et al).

Polyester resins High molecular cross-linking products made of unsaturated → Polyester and unsaturated polymerizable compounds (e.g. styrene). Of interest for lacquers, coatings and materials, because many polyester resins are available as more or less viscose fluids (so-called casting resins), which only harden after the addition of a catalyst (peroxy compounds) and accelerator, e.g. with excellent strength, proven on fibre glass materials as a binder.

Polyester rubber → Polyester elastomers.

Polyester sizes For example, type of a dispersion of isophthalic acid/diethylene glycolate with 5-Sulphonicisophthalic acid units formed by condensation.

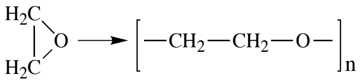
Water solubility of polyester sizes is achieved by the continuous side incorporation of salt functions (primarily sulphonate groups) via diol or dicarboxylic acid components of polycondensate. Polyester sizes have proven particularly suitable for polyester warp yarns. Due to their chemical similarity they posses an extremely strong adherence to polyester fibres. Due to sulfonicisophthalic acid formed by condensation, polyester sizes disperse in water but are not soluble. They are sensitive to strong electrolytes and high concentrations of weak electrolytes. There are possible variations in the polymer arrangement due to the use of other aromatic or aliphatic dicarboxylic acids and longer chain polyethylene glycol as building blocks. Sometimes polyester sizes are also used in the form of → Polyurethanes. Polyester sizes posses some important disadvantages compared to → Polyacrylate sizes:

- sometimes poor storage stability in disperse products (recrystallization, precipitation, hydrolytic splitting);
- impossibility of sizing polyester filaments on conventional sizing machines;
- narrow optimal effective range (“blocking”);
- electrolyte and alkali incompatibility (problematic desizing);
- poor biodegradability.

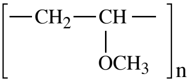
Stain washing off properties: the greatest problems are caused by polyester size stains, because they cannot be removed using normal washing recipes and conditions.

Even dwelling processes with increased lye quantities are not always successful. The most effective method is solvent treatment using dichloromethane. Other common chlorinated hydrocarbons are not suitable. In the absence of a cleaning plant using dichloromethane, polyester size stains can be removed by alkali treatment. This is performed at low temperatures and low caustic soda concentrations to avoid high polyester weight reduction.

Polyethers By the polymerization of ethylene oxide we obtain the simplest type of aliphatic polyethers, polyethylene oxides (→: Polyglycol ethers; Polyethylene glycol),



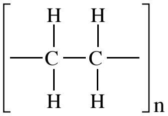
which also includes, for example, polyvinyl ethers.



$$\left[-CH_2-\underset{OCH_3}{CH}-\right]_n$$

Aromatic polyethers usually contain built-in benzene cores. Linear aliphatic and aromatic polyether with a melting point of approx. 130–150°C possess the ability to form synthetic fibres.

Polyethylene Polymer → Ethene.



$$\left[-\overset{H}{\underset{H}{C}}-\overset{H}{\underset{H}{C}}-\right]_n$$

Either in the form of high pressure polyethylene (softening point approx. 115°C) or low pressure polyethylene (Z-polyethylene after the inventor Ziegler), manufactured at low pressure and a temperature up to 70°C, with a higher softening point up to approx. 145°C, resistance to boiling, high resistance to tearing and abrasion. Applied films are translucent, flexible, with a waxy handle, non-yellowing due to light or heat, extremely resistant to chemicals and solvents, moderately resistant to oils, greases, aliphatic hydrocarbons, insoluble at room temperature in all solvents. Polyethylene is attacked by free halogens and dissolved by chlorinated hydrocarbon at above 70°C. The lightest plastic: Density 0.92–0.94. Commercial forms: pearls, powder, foils, monofilaments, fibres. Solutions are not normally manufacturable. Used in the form of a dispersion in organic solvents or water. Application particularly as material (pipes), packaging foil, container linings, chemical resistant containers, for acid protection fabrics, for coating ("hot sealing" or bonding of nonwovens, collar lining materials, etc.) and laminating (also laminated as a hot foil using rollers). → Polyethylene fibres.

Polyethylene fibres Synthetic polymerizate fibres of the group → Polyolefin fibres made of polyethylene, either in the form of branched high-pressure polyethylene fibres (used for special applications) or the more important low-pressure modified polyethylene fibres. Most common in the form of stretched coarse monofilaments (0.1–0.5 mm). The cross-section is normally round with a smooth delimitation (see Tab.).

	high pressure polyethylene (branched) [modified]	low pressure polyethylene (linear)
reaction type (according to Koch)	soluble in boiling carbon tetrachloride	soluble in hot decalin (■)
specific gravity	0.92 – 0.94 {0.94}	0.95 – 0.96
shrinkage	40°C onset 90°C approx. 40 % (less if tempered!)	loss of stretch effect for stretched polyethylene at 90°C
	may be stabilised up to approx. 60°C at 75°C approx. 5 % shrinkage	
folding	avoid during finishing (otherwise folds may well be fixed!)	
softens at	90 – 104°C {120°C}	105 – 120°C
melts at	105 – 120°C {130°C}	125 – 135°C
moisture absorption normal	practically 0	practically 0
tear resistance dry/wet	0.9 – 2.1 p/dtex {3.0}	5.0 – 7.2 p/dtex
elongation at break (necking) dry/wet	20 – 60 % {20}	14 – 40 %

(■ = this specific solubility allows the viscosity of the solution to be determined).

Tab.: Comparison of the characteristics of high pressure and low pressure polyethylene fibres (p/dtex = cN/dtex).

Further properties of the linear fibres in particular are waxy smooth and soft handle, high elasticity, excellent electrical insulating properties, resistance to mildew, bacteria and insects. Polyethylene fibres are completely waterproof and burn slowly. They have chemical resistance to acids and alkalis. They are insoluble in solvents at room temperature, but have a tendency to dissolve at higher temperatures. Difficult to dye, usually in spin dyeing. Application primarily for technical purposes such as electrical insulation, filter cloths, protective clothing, reference materials, awnings, car cover materials, cables, ropes, nonwovens, etc.

Polyethylene glycol (PEG) → Polyethylene glycols.

Polyethylene glycol esters → Polyglycol ethers.

Polyethylene glycols (polyethylene glycol, polyethylene oxides), type $HO–C_2H_4–O–(C_2H_4O)_n–C_2H_4–OH$. Polymers of (ethylene) glycol with molecular weight of up to 10 000, whereby its external state ranges from fluid (200–500) via vaseline-like (500–900) to similar to soft and hard wax (over 1000). As a result of the heaped oxethyl groups all members, even the highest, which are like hard wax, are completely water soluble. They represent colourless and odourless products; soluble in water, alcohol, ketones, esters, aromatic hydrocarbons; insoluble in benzine; hygroscopic to some degree, neutral, usually resistant to hardness agents, acids, alkalis, salts and boiling. Polyethylene glycols are superficially similar to oil substances, have a flash point far above 210°C, have a marked lubricating property and are therefore used as a popular machine lubricant that can be washed out, preparations for synthetic fibres, additives to sizes, finishing agents, printing additives, etc. From a chemical point of view, polyethylene glycols are polyalcohols due to the presence of two reactive OH groups. Of these, one terminal OH group can be substituted by etherification, esterification or other conversions. Because the majority of these compounds have properties more like ether than alcohol, one talks of “substituted → Polyglycol ethers”.

I. Liquid and semi-solid polyethylene glycols are excellent dye solvents, high quality glycerol substitutes in sizes, finishes, prints.

II. Solid polyethylene glycols (synthetic waxes): the hard wax character, setting point, density and viscosity increase with the molecular weight, whereas the hygroscopicity decreases fully. Particularly useful as high-quality components for lubricants, starch sizes (increase starch solubility, decrease viscosity, promote penetration, smoothness, adhesion, can be washed out without residue) and finishes (improve lustre).

Polyethylene oxides →: Polyethylene glycols; Polyglycol ether emulsifiers.

Polyethylene terephthalate (PET, PETP) → Polyester fibres.

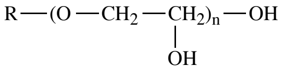
Polyethylene waxes Synthetic waxes, based upon polyethylene. They are either produced at high pressure and increased temperature in the presence of radical formers (high-pressure polyethylene waxes) or according to the Ziegler low pressure process with organometallic catalysts (low-pressure polyethylene waxes). Polyethylene waxes or polyethylene hard paraffin (correct term) can be further processed into oxidants or partially saponified products. Using suitable emulsifiers, these can be dispersed in water or “emulsified”.

Polyfluoroethylene fibres Type $(CF_2–CF_2)_x$, $(CF_2–CHF)_x$ or $(CF_2–CFCl)_x$; synthetic polymerizate filaments and fibres based upon tetra and trifluorethylene. Manufactured from fluorinated ethylene (starting base chloroform and hydrofluoric acid) by polymerization, spinning by jets under high pressure.

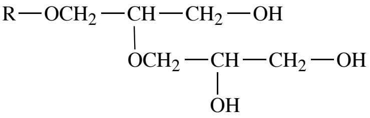
Polyformaldehyde fibre Synthetic fibres based upon thermostabilized → Polyoxymethylenes, in the form of homopolymers or copolymers of formaldehyde or meta-formaldehyde with polyacetal structure. As melt fibres with round cross-section, 200–500% extendible, density 1.38–1.42; slightly hygroscopic (0.2% at 65% relative humidity), thermo resistant from –60 to +130°C; high mechanical properties (1200–1400 N/mm^2 at 8–10% elongation); chemically relatively resistant; can be dyed using the normal processes.

Polyfunctional Multiple actions, e.g. a chemical compound with several → Functional groups, or a multi-purpose machine.

Polyglycerol Similar to diglycol or triglycol, for example, etherification product of several glycerol molecules in linear structure or in the form of complex polymers, e.g.:



$$R-(O-CH_2-\underset{\underset{OH}{|}}{CH_2})_n-OH$$



$$R-OCH_2-\underset{\underset{OCH_2-\underset{\underset{OH}{|}}{CH}-CH_2-OH}{|}}{CH}-CH_2-OH$$

Also mixed glycol-glycerol ethers, which become more similar to higher → Polyethylene glycols with increasing oxyethylation. Like → Glycerol, proposed for dyeing and printing purposes.

Polyglycol ether emulsifiers Non-ionogenic emulsifiers, based upon polyethylene glycol, are water soluble (at least up to the cloud point).

In pigment printing, selected non-ionogenic emulsifiers based upon ethylene oxide addition compounds are used on selected alkylphenols. These products, which were specially developed for pigment printing, have the advantage of better print fastness compared to anionic emulsifiers. Furthermore, they are effective in an acid and alkaline environment and have a lower foaming effect. As detergents, they have the task of reducing the interfacial tension between water and disperse phase in disperse systems. In pigment print pastes, they guarantee the maintenance of dispersion stability of the pigment, binder, softener and if necessary also heavy benzines.

The solubility of emulsifiers is determined by the length of the polyether glycol chains. Hydrophilicity increases with the ethylene oxide content, therefore highly ethoxylated products are only soluble in water and polar solvents. Whereas in the water free state the polyether glycol chain has a zig-zag structure, in aqueous solution a “meander” form is created. The creation of this meander form, in which the hydrophilic oxygen atom is pushed outwards (while the hydrophobic methylene group is protected in the interior), is the real cause of the water solubility of a polyethylene glycol chain. Polymethylene glycol, on the other hand, which should be even more hydrophobic due to its high oxygen/methylene ratio, is insoluble in water, because no corresponding structural conversion is possible. The favourable position of the “meander” oxygen atoms in the polyethylene glycol chain facilitates first the association of water molecules. Initially a primary hydrate layer forms, onto which further water molecules are deposited (secondary hydrate shell), giving rise to water solubility. The technical application properties of an emulsifier are classified according to its HLB value (hydrophile-lipophile balance), a ratio between 0 and 20. The HLB value for pigment print emulsifiers lies in the range between 13.8 and 15.5.

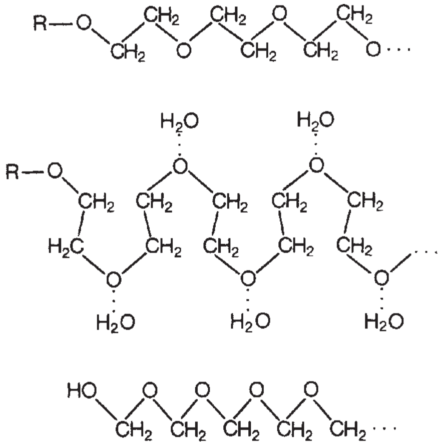
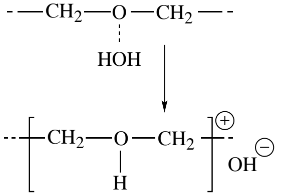


Fig.: The structures of polyethylene chains in both water-free state and in aqueous solution compared with a polymethylene glycol chain.

When using non-ionogenic surfactants based upon polyglycol ether emulsifiers, care should be taken that the washing temperature is always below the cloud point (e.g. 60–70°C). At higher temperatures the hydrogen bridges between the ether-oxygen of the chain and the water molecules are broken (see Fig.), the surfactant precipitates causing clouding, but goes back into solution as the temperature falls.

Polyglycol ethers Polyoxyether (polyoxyester) of type $R–O(C_2H_4O)_nH[R–COO(C_2H_4O)_n–H]$ (n = degree of ethoxylation). Addition products of ethylene oxide (ethylene oxide addition products) to fatty alcohols, fatty acids, amines, alkyl phenols, alkyl naphthols, etc. Polyglycol ethers form the group of non-ionogenic surfactants. A cationic character is also possible, because the water molecules, in aqueous solution with the residual valency of its O atoms, attach to the residual valencies of the ether oxygen atoms. This additive compound then stabilizes to form co-ordination compounds:



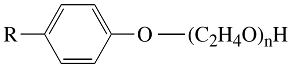
Polyglycol ethers are textile auxiliaries and due to their chemical resistance are often used as wetting, dispersing, levelling, stripping and, above all, washing agents, as well as emulsifiers and scrooping agents.

Polyglycol ether groups:

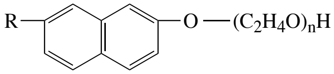
I. Alkyl polyglycol ethers are addition products of ethylene oxide to fatty alcohols. Depending upon the degree of ethoxylation they provide emulsifiers, washing agents or levelling agents.

$$R—CH_2—O—(C_2H_4O)_nH$$

II. Alkylphenol polyglycol ethers arise due to the addition of ethylene oxide to alkylphenols (preferably nonylphenolpolyglycol ether). Water solubility increases with increasing ethoxylation. The majority of these products are used as washing and wetting agents.



III. Alkylnaphthol-polyglycol ethers are addition products of ethylene oxide on alkyl naphthols. Are suitable for use as washing agents.



IV. Acyl-polyglycol ethers arise due to the addition of ethylene oxide on fatty acids. They form high-quality emulsifiers and softeners (for scrooping handle).

$$R—CO—O—(C_2H_4O)_nH$$

V. Ethoxylated alkanol amides are suitable for use as emulsifiers, washing agents and softeners.

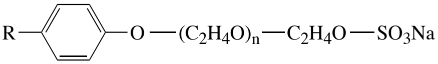
$$R—CO—NH—(C_2H_4O)_nH$$

VI. Ethoxylated fatty amines are proven levelling agents.

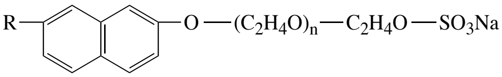
$$R—NH—(C_2H_4O)_nH$$

In acid solution these compounds have a slightly cationic reaction.

Polyglycol ether sulphates Sulphated → Polyglycol ether emulsifiers of an anionic nature, with increased solubility and foaming power, specific washing agent, which is derived either from alkyphenols:



or from alkylnaphthols:



Polyhedron Object with many surfaces; body limited by polygons (e.g. foam).

Polyhedron foams are represented by compounds of polyhedron shaped bubbles, which have lost their independence. The bubble compound of a polyhedron foam can only be formed of lamella bubbles and not of single bubbles. The polyhedron foam can be viewed as dewatered ball foam (→ Foam structures). It is metastable.

Metastable foams are characterized by the fact that the interlamellar fluid between the foam lamellae does not continue to flow until the foam is destroyed, but stops at some point. A metastable state occurs, which depends upon the stability of the lamellae, or upon the stability of the surfactant boundary layer films. The resistance of these films is influenced by a number of factors: firstly by the surface viscosity, i.e. the viscosity of the boundary film to the interlamellar fluid; secondly by the sufficiently high concentration of surfactants to form a closed film.

If two bubbles approach each other until contact is made, then a marked deformation is possible before the bubbles join. When the bubbles join together at the point of contact, part of the two outer films disappears, but the inner films remain. Both bubbles are surrounded by a common outer film and are subject to the same capillary tension. The same applies to the formation of bubble compounds. In polyhedron foam formation with spatial extension, polyhedron shaped forms (see Fig.) are created with a marked channel system. Due to the polyhedron type arrangement, triangular channels form at the polyhedron corners, where polyhedron edges are arranged in the form of tetrahedrons. At the edges of the polyhedrons, where three bubbles join together, crack-shaped channels are formed, which are smaller than the triangular channels. Both channel systems are connected together and play an important role in dewatering: The foam falls apart from the top down and the interlamellar fluid flows away through the channel system of the foam below, without destroying the foam. The foam below is thus irrigated with interlamellar fluid, which assists stabilization.

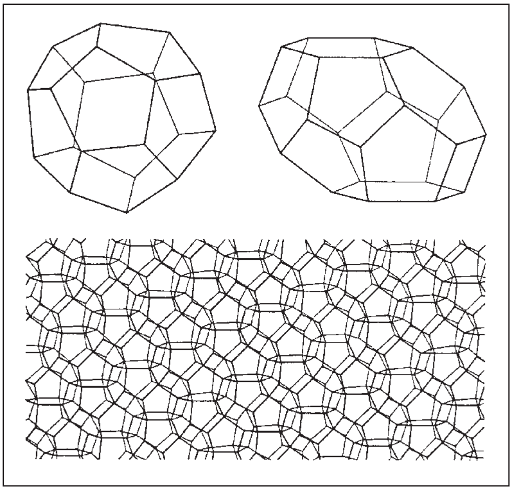


Fig.: Polyhedral shaped gas bubbles in a foam. Top left: pentagonal dodecahedron; top right: beta tetrakaidecahedron.

In the mathematical model of a polyhedron foam, identical polyhedrons, the surfaces of which meet at an angle of 120°, must be joined together if possible in such a way that the space is filled. Of the regular polyhedrons (those in which all surfaces are made up of the same regular polygon) this can be best achieved with the pentagonal dodecahedron. However, hollow cavities still exist. Furthermore, the lamellae of a genuine foam do not just form pentagons. A more realistic approximation is provided by an irregular polyhedron, the beta-tetrahedron. Although none of the models that currently exist, properly reflect all geometric properties of a genuine foam, the relationships between fluid content, bubble size, film thickness and foam geometries can at least be approximately calculated on the basis of such models.

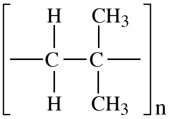
Polyhexamethylene sulphone fibres → Polymethylene sulphone fibres.

Polyhydroxyl fibres Fibres, which have hydroxyl groups as prosthetic groups, above all cellulose and cellulose regenerate fibres, also appropriately modified synthetic fibres.

Polyimides → Aromatic polyimide fibres

Polyimines → Polyamines, polyimines.

Polyisobutene (polyisobutylene). Synthetic polymer (obtained from isobutene or from isobutanol by water splitting) (also as copolymer with styrene, butadiene, etc.).

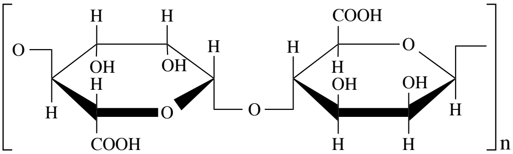


Depending upon the degree of polymerization viscous-oily, semi liquid-viscous, tough-sticky, extensible-elastic like soft rubber, flexible. Cannot be vulcanized, not cross-linkable (not dimensionally stable under load, therefore of no interest as fibre raw material), density 0.93; thermoplastic above 100°C; resistant against many acids, alkalis, alcohols, esters, ketones; soluble in benzine, benzene, chlorinated hydrocarbon; processing in solution and dispersion. Application: particularly for adhesives, coatings (raincoats, car cover material, carpet back coating), foils and container linings (for temperatures up to 85°C), etc.

Polyisocyanates Addition polymerization products of → Isocyanates or (preferably because more reactive) aromatic → Diisocyanates. Application: as adhesive, cross-linking component for coatings, lacquers, strong compounds, etc.

Polyisoprene → Natural rubber.

Polymannuronic fibre Alginate fibre type, so-called because → Alginic acid represents a polymer d-mannuronic acid (with pyranose structure):



Polymer dispersions are used for the bonding of technical textiles, for coating and in finishing. As a pigment binder and flock glue they must (as in finishing) give the finished textile material a good handle after application. The field of application is strongly oriented towards the physical properties of the film on the fibre. Therefore, polymer dispersions can be classified according to the hardness of the film formed (Tab. 1).

The following factors are critical

- minimum film formation temperature
- glass transition temperature.

The interaction of these factors, in relation to the profile of requirements for the textile material to be finished, determines the combination of the monomers used for emulsion polymerization (Tab. 2).

Vinyl acetate-ethylene dispersions are used for the stabilization of non-woven items, whereby ethylene is the copolymerized softener in the copolymer.

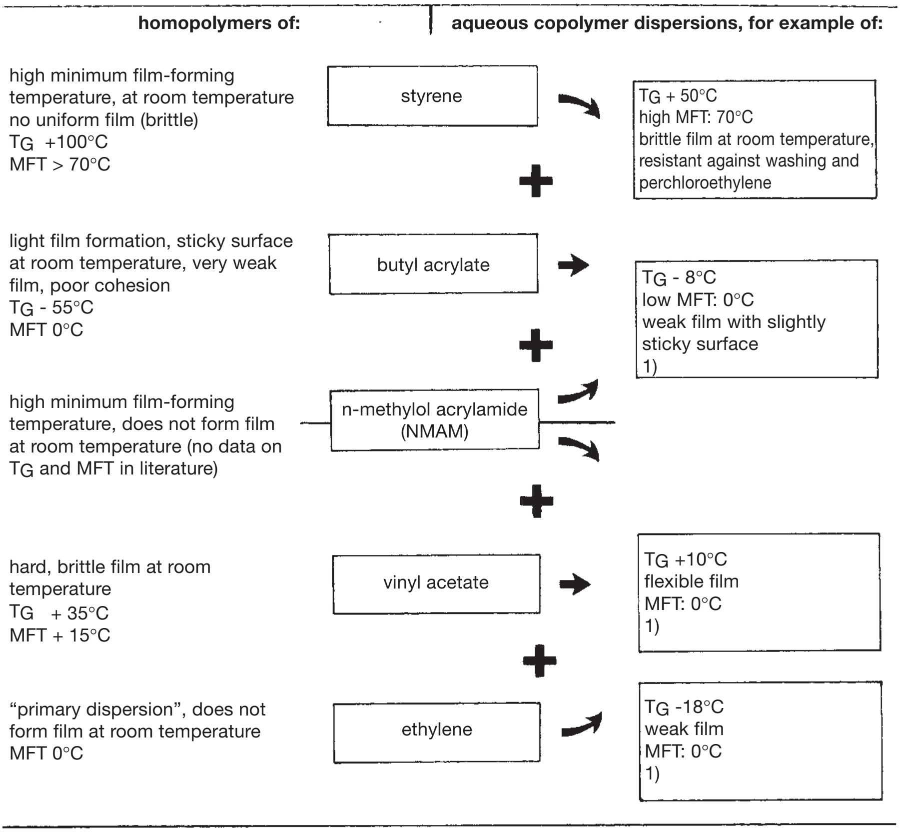
Some examples of application of aqueous dispersions should illustrate the importance of the polymer dispersion building block in the creation of a technical textile:

- *Polyester-spun-bond lining for roofing material:* hard, thermostable film former, styrene-containing copolymer
- *Textile glass fabric for roofing materials:* hard film former based upon vinyl acetate or styrene
- *Webbing:* soft film former based upon vinyl acetate-ethylene or acrylate-styrene
- *Car carpets for subsequent polyethylene powder coating and shaping:* medium-hard to soft film former based upon vinyl acetate-ethylene
- *Bonding:* depending on hardness, vinyl acetate-homopolymers, vinyl acetate-copolymers with ethylene or acrylic esters
- *Bonding emulsions:* vinylacetate-ethylene or acrylate-copolymers with low glass transition temperature
- *Technical flock items:* soft film former based upon acrylic ester, additive of melamine resin
- *Textile glass wallpaper:* viscoplastic film former based upon vinyl acetate-ethylene-vinyl chloride
- *Textile glass-construction fence:* medium-hard film former based upon vinyl acetate-ethylene or styrene-acrylate
- *Milk filter:* soft film former based upon vinyl acetate ethylene or acrylic ester
- *Hard coatings of technical fabrics:* styrene-acrylic ester copolymers
- *Nonwoven waddings:* hard film former, also medium-hard, no surface stickiness, based upon acrylic-methacrylic ester and vinyl acetate-acrylic ester or vinyl acetate-ethylene
- *Nonwovens for cleaning purposes:* soft film formers based upon vinyl acetate-ethylene or acrylic ester
- *Needle punched felt, mouldable for cars:* hard film formers based upon styrene-acrylic ester
- *Technical knitted fabrics:* soft film formers based upon vinyl acetate-ethylene
- *Back coating of technical knitted plush:* soft film former based upon vinyl acetate-ethylene, vinyl acetate acrylic ester, acrylic ester-styrene, acrylic ester
- *Filters:* soft film formers with surface stickiness based upon vinyl acetate-ethylene, acrylic ester
- *Sails:* combination of hard acrylate binder with melamine resin.

The use of polymer dispersions in finishing also orientates itself towards the glass transition temperature resulting from the copolymerization of vinyl acetate and vinyl acrylate (+ 33°C to – 40°C) (Tab. 3).

hard film-forming agents glass transition temperature zone > + 25°C	less hard, soft film-forming agents glass transition temperature zone -10 to +25°C	soft to very soft film-forming agents glass transition temperature -10 to -30°C	very soft, strongly adhesive film-forming agents glass transition temperature < -30°C
strong starch, interlinings nonwoven wadding fastening filter felts needle punched felt fastening tufting under-coat woven carpet backing starch glazed textiles light screening laminates edge fastening formable textiles	starch for inlet material, lining material, matress drill finishing of glazed textiles woven carpet backing starch textile coating roller blind coating milk filter	nonwovens starching of warp-knitted fabric coating of warp-knitted plush adhesive films pigment binder flock adhesive	bonding adhesive

Tab. 1: Division of polymer dispersion films.



homopolymers of:

aqueous copolymer dispersions, for example of:

high minimum film-forming temperature, at room temperature no uniform film (brittle)
TG +100°C
MFT > 70°C

styrene

TG + 50°C
high MFT: 70°C
brittle film at room temperature, resistant against washing and perchloroethylene

light film formation, sticky surface at room temperature, very weak film, poor cohesion
TG - 55°C
MFT 0°C

butyl acrylate

TG - 8°C
low MFT: 0°C
weak film with slightly sticky surface
1)

high minimum film-forming temperature, does not form film at room temperature (no data on TG and MFT in literature)

n-methylol acrylamide (NMAM)

hard, brittle film at room temperature
TG + 35°C
MFT + 15°C

vinyl acetate

TG +10°C
flexible film
MFT: 0°C
1)

“primary dispersion”, does not form film at room temperature
MFT 0°C

ethylene

TG -18°C
weak film
MFT: 0°C
1)

Tab. 2: Dispersions of in each case three monomers. T_G =glass transition temperature; MFT = minimum film-forming temperature (according to Fischer).

glass transition temperature T_G (°C)	vinyl acetat	acrylate	self cross-linking	film textile handle	application
+ 33	only	–	–	very hard	finishing: collar inliners stiffening
+ 40	only	–	+	very hard	nonwoven wadding binder
+ 32	very many	very little	+	very hard	nonwoven wadding binder
+ 22	many	little	+	hard	“soft” binder for nonwoven wadding, finishing
0	half and	half	+	soft	nonwovens, fishnets
– 3	half and	half	+	soft	coatings, e.g.carpet backs, nonwovens
– 5	half and	half	+	soft	print binder
approx. – 20	little	many	+	very soft	print binder
– 15	little	many	+	soft	finishing, softener
– 40	–	only	+	very soft	additive with high quality finishing agents, particularly soft handle finishes, component in pigment binder

Tab. 3: Polymers from vinyl acetate and acrylic ester.

In the resin finishing of cotton fabrics, dispersions are used not only to improve handle, but primarily because of their positive effect on strength; of course they must not have a detrimental effect on the crease angle.

Fig. 1 shows how dispersions and crosslinkers complement each other on a cotton fabric. The crease angle dry (lower curve) and wet (upper curve) are plotted as ordinates as the sum of warp and weft, the application quantities of crosslinkers and dispersion are plotted in g/l on the abscissae.

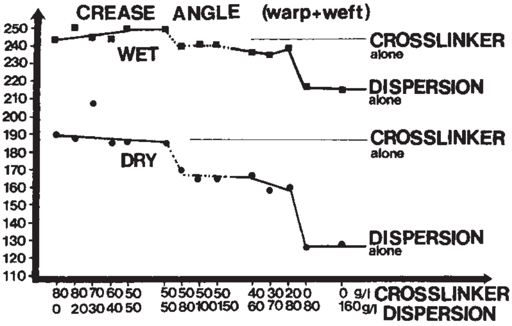


Fig. 1: Crosslinker and polymer dispersion very weak; crease angle dry and wet.

The recipes are:
80–0 g/l crosslinker (etherified, low formaldehyde),
16–20 g/l catalyst (heavy metal free),
0–160 g/l dispersion.

The curves begin on the left with the values for finishing with crosslinker and catalyst only, without dispersion (80 parts crosslinker). At the second point, 20 parts polymer dispersion have been added to the 80 parts crosslinker. The crease angle barely changes. In this recipe the dispersion acts as an additive and improves the resistance to tearing and abrasion. Thereafter, instead of the ratio 80 parts crosslinker/20 parts dispersion, the quantity of crosslinker was reduced in increments of ten and the quantity of dispersion similarly increased, thus less cross-linker and more dispersion was used. Up to a 50/50 ratio of cross-linker/dispersion, the crease angle remains the same. If more than 50 parts dispersion are added to the 50 parts (80, 100, 150 parts), then a lower crease angle is obtained. This is represented by the central part of the curve, which is dotted. Because the dispersion only increases the crease angle slightly (visible in the two points at the right on the curve), if there is a further reduction of the quantity of crosslinker to 40, 30, 20 parts with 60, 70, 80 parts dispersion, the crease angle also falls (according to Fischer).

Dispersions of polymers are produced by the emulsion copolymerization of the corresponding monomers (Fig. 2). If water insoluble monomers are mixed with an aqueous solution containing an emulsifier (whereby the ratio of aqueous phase to monomer phase is 2 : 1 to 1 : 1) we get an emulsion with a milky appearance. If a water soluble initiator is now added to this emulsion, then a lively polymerization begins in the absence of oxygen at 40–70°C. The milky character remains during polymerization, and after the reaction has run its course a polymer dispersion similar to natural rubber is obtained. The particle size is 0.05–0.15 µm. The advantages of this type of polymerization are, on the one hand, the ease with which the reaction heat is dissipated and, on the other hand, the low viscosity of the formed lattice (even at high concentrations up to 60%) in comparison to corresponding solutions. Mainly anionic (e.g. alkali salts of fatty acids, sodium salts of sulphonic acids with 10–16 carbon atoms) and non-ionogenic emulsifiers are used. Primarily hydrogen peroxide, potassium peroxodisulphate, combinations of water insoluble hydroperoxides and water soluble reducing agents, for example cumene hydroperoxide amine, come into consideration as initiators.

The reaction begins in the aqueous phase and initially takes place in the emulsifier micelles and later in the latex particles that have been created. The emulsifiers form micelles in aqueous solutions from a certain concentration, which are imagined as being arranged in parallel or radially, whereby the hydrophilic parts form the outer boundary. Monomers can be stored between the lamellae of the micelle (where the hydrophobic re-

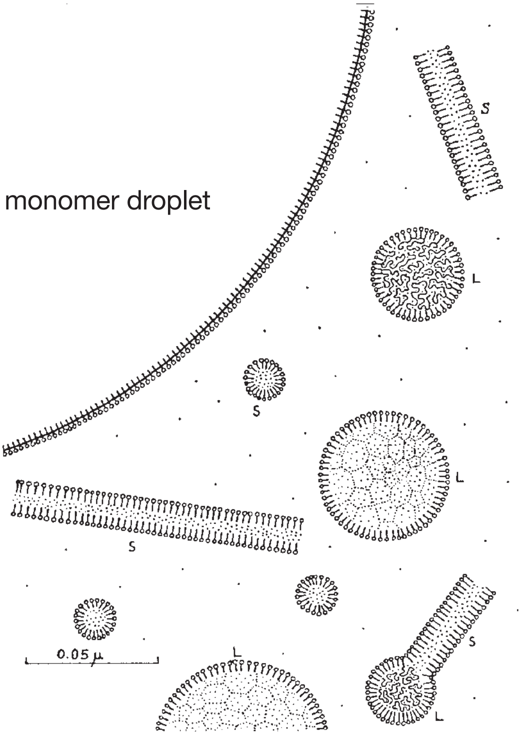


Fig. 2: Diagram representing relative sizes of emulsion polymers.
S = soap micelle; L = latex particle; ⚲ = monomer molecule in the aqueous phase; special symbol required = surfactant molecule.

mains collide). It is assumed that due to the high monomer concentration in the emulsifier micelle, the beginning of the chain starts by the absorption of a radical formed in the aqueous phase within the micelle. Although the chain can also start outside the micelle, it is assumed that the nucleii formed in this manner in the presence of emulsifiers are also absorbed by micelle.

The polymer finds the monomers required for the growth in the emulsifier micelle. If the monomer concentration is reduced in this due to polymerization, then the monomers are supplied from monomer drops via the aqueous phase. The saturation value of the monomer concentration in the water phase remains constant as long as monomer drops are still present. Due to the growing polymer chain, the emulsifier micelles are expanded and destroyed, so that a polymer particle surrounded by the individual molecules of the micelle is created. The surrounding of the polymer particle prevents coagulation with other polymer particles or with the monomer drops, which are also surrounded by emulsifier molecules.

The further chain growth now takes place in these polymer particles. Growth within the emulsifier micelle or of a polymer particle surrounded by an emulsifier layer is interrupted by the absorption of a second initiator radical. So in the course of polymerization the system shifts: Emulsified monomer particles become emulsified latex particles via the aqueous phase. The polymer dispersion formed in this manner consists of a large number of macromolecules (depending upon the latex particle size and molecular weight of the polymers between 50 and 500). It is used as a binder immediately without prior coagulation.

Polymer doping In 1977 a phenomenon was discovered, which led to an almost turbulent development of polymers, which possessed an intrinsic conductivity, i.e. without the addition of electrical conductors. It was found that polyacetylene manufactured according to the so-called Shirakawa process acquires a high electrical conductivity if it is brought into close contact with an oxidizing agent (in this case iodine) (see Fig.). This process is now called doping, in an analogy to semiconductor physics. Conductivity rose by a billionfold compared to undoped polyacetylene.

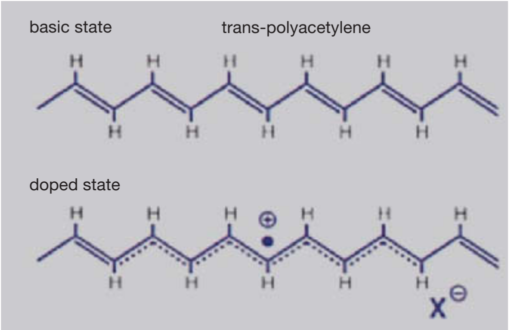


Fig.: The functional principle of intrinsically electrically conducting polymers.

Subsequently a number of polymers were discovered, in which intrinsic conductivity could be produced by doping. This was achieved not only with polyacetylene, which has a relatively simple structure, but also in polymers with a ring structure or in heterocyclical polymers. All polymers that can be brought into a conductive state, have an alternating sequence of chemical single and double bonds. In the basic state they are fixed in time and space so that electrical charge carriers cannot initially move along the polymer chain. Only in the doped state, e.g. by oxidation, are parts of these double bonds dissolved. They are now no longer localised and charge carriers possess a certain degree of mobility along the chain structure. So the polymer takes on new electronic states, which are termed solitones, polarones and bi-polarones. In the case of polyacetylene, specific electrical conductivities of up to 400 000 S/cm can be achieved. These are, at least as much as for copper and thus such a plastic can be termed a “synthetic metal”. The other “intrinsic” (from within) electrically conductive polymers (for example polyparaphenylene, polyaniline, polypyrrol, polythiophene) have values of a few hundred S/cm. They thus fall within the range of semi-conductor materials (e.g. doped silicon).

The almost revolutionary discovery of the intrinsic conductivity of certain plastics originally led to expectations of the turbulent development of this class of substances in industrial applications. There are various reasons for the fact that this has not been the case. The main reason is that it has become apparent that the stability of the electrically conductive state is usually very low. So, in the case of polyacetylene, conductivity falls by several powers of ten within a few weeks. A further significant disadvantage is that the above-mentioned polymers are insoluble and unmeltable in their conductive, doped form, which means industrial processing is impractical (Hoechst).

Polymer fibre specific gravities If polymers are spun into fibres the main difference between them is their density. The most important natural fibres can be classified in an appropriate tabular listing (see Fig.).

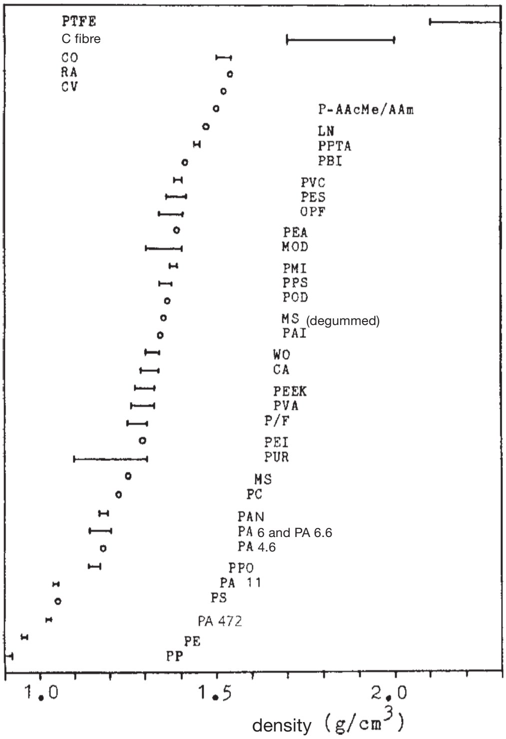


Fig.: Densities of natural fibres and synthetic fibres (for codes see: DIN 60001).

Polymer homologues → Macromolecules made up of the same basic building blocks (→ Monomer), but with a different → Degree of polymerization.

Polymer hydrophily relates only to properties of the polymer/water boundary layer and characterizes the structure forming influence of the polymer on the H_2O layer near the boundary layer. It is not possible to predict the → Hydrophilic property of polymers. However, rough estimates of the H_2O content can be made, based upon the H_2O binding capacity of the functional group of the monomers. Instead of a real measured number, however, variables such as sorption, swelling value, wetting angle, water permeability, mobility of the adsorbed H_2O, and H bridge bonding coefficient correlate with the hydrophily of the system.

Polymer implants Fibres are modified by chemical and physical processes (plasma treatment), in order to increase their mechanical or chemical (hydrolysis) stability or to develop a biologically active polymer surface. In the latter case, the aim is to produce a biocompatible or haemo- compatible material, which has a recognition sequence (pentapeptide of the fibro-nectine) for vascular inner skin cells (see Fig.). By the exchange of the carrier polymer, the polymer surface finished in this manner can be used for various medical implant purposes.

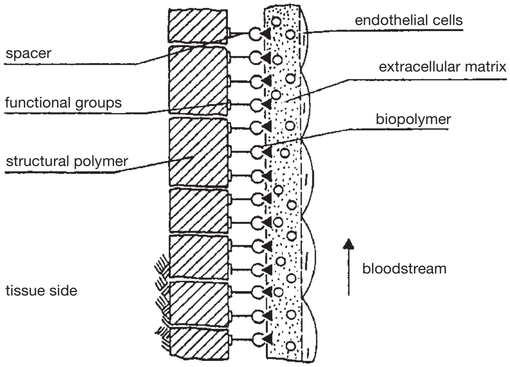
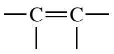


Fig.: Structure of a modified polymer surface for colonization by endothelial cells (according to Höcker).

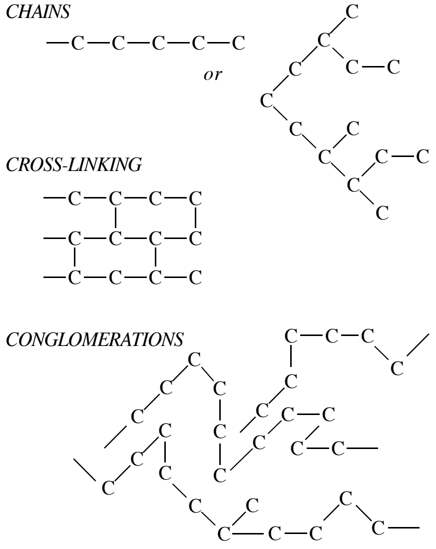
Polymerization Chemical linking of the same (isopolymerization) or different (copolymerization) monomers to polymers without the splitting of secondary products. One of the most important chemical addition reactions in nature and synthetic chemistry. All unsaturated compounds with double or multiple bonds are polymerizable.



$$-\underset{|}{C}=\underset{|}{C}- \qquad -C\equiv C- \qquad =C=C=$$

$$=C=NH \qquad -C\equiv N$$

They possess the ability to join together to form large molecules (growth of molecules) and to combine many thousands of individual molecules (→ Macromolecules). This occurs by the saturation of free valencies, by the shifting of unstable ring systems or by hydrogen migration. This creates either unbranched or branched chains, cross-linking or conglomerations:

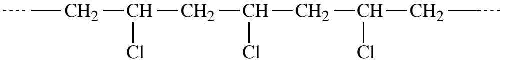


Either long extended (so-called chain or thread molecules) or round macromolecules (so-called ball molecules) form.

According to the chemistry of polymerization, e.g. polyvinyl and polyacrylic products are synthesized from acetylene (HC = CH), these may be polyvinyl alcohol ($(H_2C = CHOH)_x$), polyvinyl chloride, polyvinyl ester, etc.; similarly also polyacrylic acid, its esters and other derived compounds. A polymerization product therefore has the same percentage composition as the starting substance, but a fraction of its molecular weight. In general, a progressive change takes place to the chemical-physical properties of the starting substance as the → Degree of polymerization increases: Increase in density, increase in the melting and boiling points, increase in viscosity, loss of solubility and increase of the coherency (solidity).

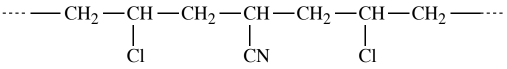
Classification:

I. Iso-polymerization: Built up from a single, chemically unified substance (rubber, polyphosphate, polyacrylic acid ester, polyvinyl chloride, etc.); e.g. polyvinyl chloride:



$$\cdots-CH_2-\underset{\substack{|\\ Cl}}{CH}-CH_2-\underset{\substack{|\\ Cl}}{CH}-CH_2-\underset{\substack{|\\ Cl}}{CH}-CH_2-\cdots$$

II. → Copolymerization: Built up from several (usually two), chemically different basic molecules. The latter may have the same polymerizability, which usually creates chain molecules with often innovative or modified properties (e.g. better dyeability, high water absorbency, lower thermoplasticity, etc.); → Copolymer fibres, e.g. polyvinyl chloride acrylonitrile copolymer:



$$\cdots-CH_2-\underset{\substack{|\\ Cl}}{CH}-CH_2-\underset{\substack{|\\ CN}}{CH}-CH_2-\underset{\substack{|\\ Cl}}{CH}-CH_2-\cdots$$

When the individual components have different polymerizability we talk of hetero-polymerization, which occurs, for example, in copolymers of polyvinyl or polystyrene and maleic acid. → Polymerization reaction for fibre-forming macromolecules.

Polymerization cross-linker Reactive compounds, which are capable of polymer formation and cellulose cross-linking, e.g. N-methylolacrylamide, N-methylolmethacrylamide, N-methylolpolyethylene urea. They yield a favourable ratio of resistance to tearing and abrasion in → Resin finishing.

Polymerization fibres Extensive main group of synthetic fibres, the macromolecule of which contains the same or different continuous long carbon chains, formed by → Polymerization, which is unique to all polymerization fibres (unlike → Polycondensation fibres), and which differ from each other due to side chains containing other foreign atoms (chlorine, fluorine, cyanogen, etc.) or groups ($-CH_3$, $-OH$, $-CONH_2$). This group includes e.g. polyacrylonitrile fibres, polybutadiene fibres, polyolefin fibres, polystyrene fibres, polytetrafluorethylene fibres, polyvinyl alcohol fibres, polyvinylacetate fibres, polyvinylchloride fibres, polyvinyl fluoride fibres, polyvinylidene cyanide fibres, polyvinyl copolymerization fibres.

Polymerization products (polymerizate, polymerized synthetic resins, polymerization plastics), products of → Polymerization, either in the form of → Plastics or → Synthetic resins, e.g. →: Polyacrylic acid; Polyacrylic acid ester; polyacrylates; Polyacrylonitrile; Polybutadiene; Polychlorobutadiene; Polyethylene; Polyisobutene; Polymerization fibres; Polymethacrylic acid ester; Polystyrene; Polytetrafluorethylene; polyvinyl alcohol; Polyvinyl ethers; Polyvinyl acetals; Polyvinyl chloride; Polyvinyliden chloride; Polyvinylpyrrolidone.

Polymerization reaction for fibre-forming macromolecules “Polymerization reaction” is the name given to all syntheses, which lead from low molecular (monomer) to high molecular (polymer) compounds. Polymerization reactions only occur if the appropriate chemical, thermodynamic and mechanistic conditions are fulfilled.

1. From a chemical point of view, polymerization reactions are only possible if the monomers are at

least bifunctional. However, functionality is not a constant for a compound being considered, but rather depends upon the reaction partner.

2. From a thermodynamic point of view, the free enthalpy ΔG_p of the polymerization reaction must be negative. In polymerization reactions, monomers M are either attached to or incorporated into a growing chain M_n^*, e.g.

$$M_n^* + M \rightleftharpoons M_{n+1}^*$$

or already formed chains $M_n + M_p$ (possibly with different building blocks M) are linked together.

$$M_n + M_p \rightleftharpoons M_j + M_k$$

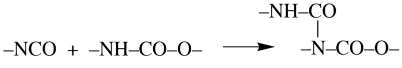
both reaction types are basically reversible.

3. Mechanistically two conditions must be fulfilled. First the molecules to be linked must be easy enough to activate. Furthermore, the speed of the linking reaction must be much higher than the sum of the speeds of all reactions which block the functional positions.

Chain molecules are formed when the functionality of the monomers is equal to 2. An isocyanate group –NCO is, for example, monofunctional compared to a hydroxyl group if both groups are present in roughly the same molar ratios. To form polyurethanes with the urethane group –NH–CO–O– therefore, di-isocyanate must react with diols:

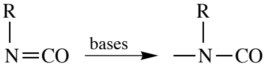
$$n\ \mathrm{OCN{-}R{-}NCO} + n\ \mathrm{HO{-}R_1{-}OH} \longrightarrow (\mathrm{-CO{-}NH{-}R{-}NH{-}CO{-}O{-}R_1{-}O-})_n$$

However, the urethane groups can convert to allophanates with excess isocyanate groups:



$$\mathrm{-NCO} + \mathrm{-NH{-}CO{-}O-} \longrightarrow \mathrm{-\overset{\overset{\displaystyle -NH{-}CO}{|}}{N}{-}CO{-}O-}$$

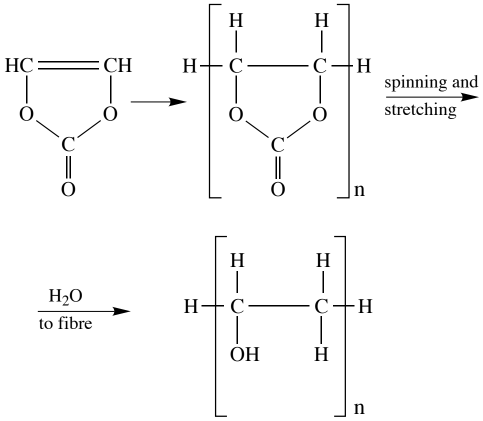
For the formation of allophanates, two isocyanate groups react with one hydroxyl group. The isocyanate group is always bifunctional in relation to the polymerization initiators



$$\overset{\overset{\displaystyle R}{|}}{N}{=}CO \xrightarrow{\text{bases}} -\overset{\overset{\displaystyle R}{|}}{N}-CO$$

Functionality is thus not an absolute property of a group, but should always be considered as relative to the reaction partner.

If we want to manufacture fibres from macromolecular substances, the fibre forming polymers must have a linear structure. The appropriate spinning process takes place from the solution or the melt; it is not possible with cross-linked molecules because this would make the orientation of the macromolecules more difficult. The chain length of the molecules, the type of covalent bond between the monomers of a chain and the possible interaction forces between the polymer molecules (dipolar forces, hydrogen bridges, crystal lattice forces) determine the fibre formation. Although polyvinyl alcohol, for example, is soluble, stretched polyvinyl alcohol fibres are insoluble in water.



PVA-fibre

The molecule type, molecular weight and molecule arrangement are determined by the chemical molecule type and the manufacturing process. All these variables determine the solid state, which is characterized by the “secondary bonds” and “crystallite formation”. The term “properties” used in this context refers to the mechanical and thermal properties, swelling and solution properties, density, stiffness and hardness and the dyeing properties.

By the → Polymerization of vinyl compounds, linear macromolecules are manufactured by the mechanism of radical, ionic or coordinative complex chain reactions. There are also secondary reactions in the chain reactions. Polypropylene is only slightly polymerized in the radical manner, so Ziegler-Natta catalysts are used. Due to lack of interaction between the chains, particularly in polypropylenes, high molecular weights are necessary for fibre formation.

Ring opening polymerization of cyclical polymers produce linear macromolecules, which are able to form fibres, if we use:

a) cyclic ether (3.3 bischloromethyloxethane),
b) cyclic ester (β-lactone and lactide),
c) cyclic amide (lactane, e.g. ε-aminocaprolactam).

By → Condensation polymerization as a chain reaction or as a stage reaction, thread forming macromolecules with a linear structure can be manufactured in the form of

a) polyester made of dicarboxylic acid and diols (e.g. of terephthalic acid dimethyl ester and ethylene glycol by re-esterification),
b) polyester made of hydroxycarboxylic acids,
c) polyamide made of dicarboxylic acids and bisprimary amines.

→ Addition polymerization is used in combination with condensation polymerization for prepolymers for the manufacture of linear macromolecules for elastic fibres based upon polyurethane (according to Elias).

Polymerized linseed oil Thickened or pre-oxidized, manufactured by heating in the absence of air or at reduced pressure with water vapour treatment. Yarns sized using polymerized linseed oil have a lower strength loss compared to untreated → Linseed oil. → Oil size.

Polmerized synthetic resins → Polymerization products with → Synthetic resin.

Polymer-like reaction The systematic alteration of functional groups of polymers is called chemical modification. If all basic building blocks react in the same way in a chemical reaction on a macromolecular material, without chain splitting or noticeable secondary reactions occurring, then the molecular weight will change, but not the degree of polymerization, i.e. the average number of linked basic building blocks, depending upon the macromolecule. Such conversions, which occur along the chain without the chain breaking, in which the macromolecule is retained during the chemical modification, are called polymer-like conversions. The chemical conversion at the macromolecule is often associated with a certain degree of chain degradation, particularly if there are ester, amide or acetal bonds, for example, between the monomers rather than a continuous carbon chain, because these bonds are easily split by the H^+ or OH^- ions that are necessary for many conversions (Fig. 1).

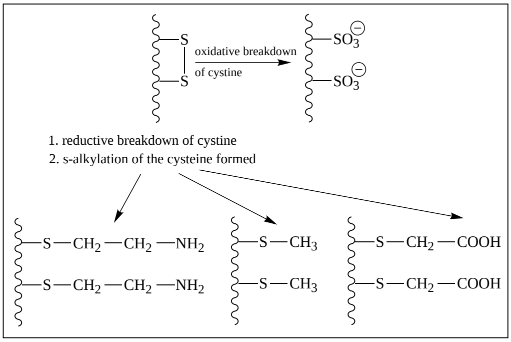


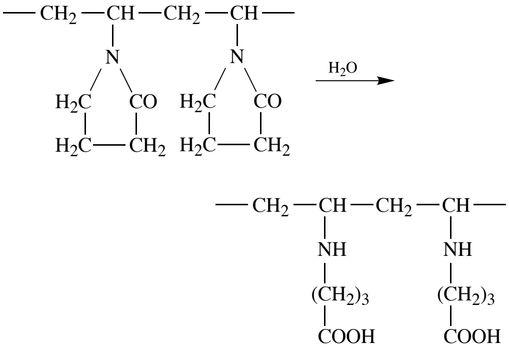
Fig. 1: Diagrammatic representation of chemical modifications of the cystine bridges in the scale protein of wool fibre, being a typical polymer-like reaction within a heterogenous system.

The degree of polymerization can be increased by the subsequent graft copolymerization or cocondensation and by cross-linking, by the conversion of two different reaction points in a chain with a reagent that is at least bifunctional. On an industrial production scale the cross-linking of natural and synthetic rubber is performed by the addition of a few percent sulphur to hard or soft rubber by "vulcanization".

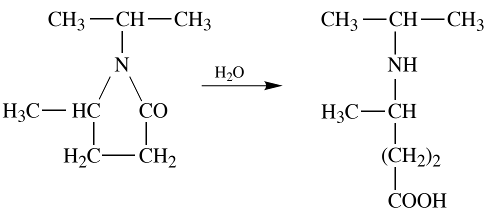
If macromolecules are converted using bifunctional reagents, then the cross-linking reaction may be not only intramolecular, but also intermolecular. In the latter case the reaction products become insoluble and usually unmeltable. Various cellulose reactions are amongst the important chemical conversions of macromolecular materials. The three hydroxyl groups per basic building block can be partially or fully esterified or etherified. One differentiates, for example, between cellulose triacetate, cellulose $2^1/_2$ acetate and others, depending upon the number of acetylized hydroxyl groups, for example, per basic building block. A further technically important conversion of cellulose is the transition into dithiocarboxylic acid ester (xanthate). Aqueous solutions of sodium salts are known as "viscose"; they are spun into threads and when precipitated in acids, accompanied by the regeneration of cellulose, supply the viscose fibres.

The group of polymer-like conversions also includes those that only affect the terminal groups, whilst retaining the chain structure (chain-like conversion). Examples include the reactions of terminal hydroxyl groups of polyesters with phthalic acid anhydride, terminal carboxyl groups with diazomethane or reactive dyes of polyamide fibres.

In polymer-like conversions, the reactivity of the functional groups is independent of the molecular weight of the polymer. So, for example, the alkaline hydrolysis (breaking of the ring) of polyvinylpyrrolidone

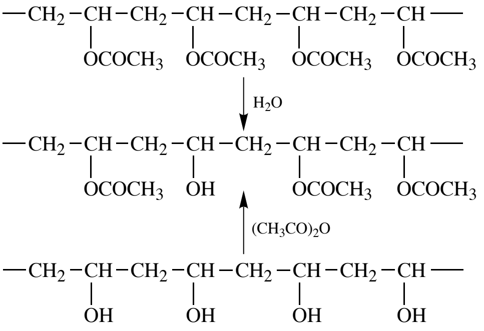


and N-isopropyl-γ-valerolactam



take place at virtually the same reaction speed and with the same activation energy.

If the chemical conversion of a polymer takes place in different directions, or if, when the conversion takes place in a uniform direction, no complete conversion is achieved, then the high molecular compounds obtained represent copolymers of the initial and final products or the initial, final and intermediate products. For example, a copolymer of vinyl acetate and vinyl alcohol is always the result of the incomplete saponification of polyvinyl acetate. A copolymer also forms as a result of the partial acetylization of polyvinyl alcohol:



$$-CH_2-\underset{OCOCH_3}{CH}-CH_2-\underset{OCOCH_3}{CH}-CH_2-\underset{OCOCH_3}{CH}-CH_2-\underset{OCOCH_3}{CH}-$$

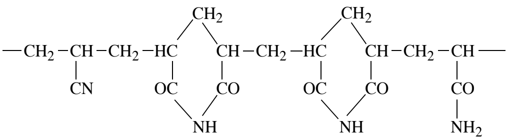
$$\downarrow H_2O$$

$$-CH_2-\underset{OCOCH_3}{CH}-CH_2-\underset{OH}{CH}-CH_2-\underset{OCOCH_3}{CH}-CH_2-\underset{OCOCH_3}{CH}-$$

$$\uparrow (CH_3CO)_2O$$

$$-CH_2-\underset{OH}{CH}-CH_2-\underset{OH}{CH}-CH_2-\underset{OH}{CH}-CH_2-\underset{OH}{CH}-$$

The product of the acid hydrolysis of polyacrylonitrile is a complicated copolymer of acrylamide and cyclical α-methylglutarimide:



The speed of the chemical conversion of high molecular compounds and the uniformity of the product obtained largely depends upon the physical state of the polymers, because the majority of high polymers are only soluble in a limited number of solvents and in most cases the reactions take place in a heterogeneous medium. Most polymers are non-uniform. Crystalline polymers are two-phase; they contain crystalline and amorphous areas. The molecules of individual sections of single phase, amorphous polymers can have different degrees of arrangement and different packing densities. The diffusion speeds of the reacting substances, and therefore the bonding speed of corresponding polymer derivatives, are different in the crystalline and amorphous areas and in the areas with more or less arrangement. It is therefore necessary for a uniform reaction sequence that the polymers dissolve and swell in the reaction medium.

In solid polymers the degree of conversion that can be achieved under given conditions is often limited by the complete accessibility of the polymers to the chemical reaction. Because even arrangement and accessibility are themselves often changed by the reaction sequence (swelling processes), neither the regularities of the homogeneous nor the heterogeneous chemical equilibrium can be unambiguously applied, and the kinetics of such conversions are often very complicated due to the interaction of chemical conversion and diffusion or swelling processes. When the conversion of polyacrylic acid derivatives with fatty chemical partners (alcohols, amines) takes place as a polymer-like reaction, products with different consistencies are yielded (Fig. 2).

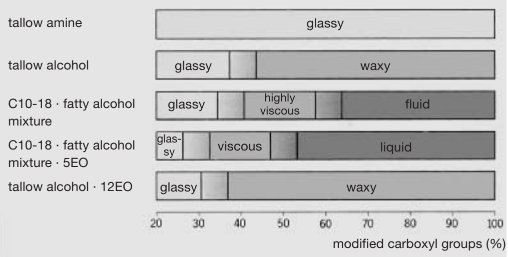


Fig. 2: The modification of polyacrylic acids with various alcohols.

The hydrophilicity or hydrophobicity of the fatty chemically modified polymers can also be adjusted within broad limits by the above-mentioned variables. The range extends from hydrophobic polymers with a high content of (non-ethoxylated) fatty side chains to products that are water soluble or self-dispersing in water. The latter are obtained by reaction with ethoxylated fatty products and/or only partial conversion of the carboxyl groups of the polymer. Further variations exist because in addition to fatty chemical residues, additional side groups can be introduced into the polymers. E.g. polymers with tertiary amino groups in the side chain become accessible due to the reaction of polyacrylic acid with a mixture of fatty alcohol and amino alcohol.

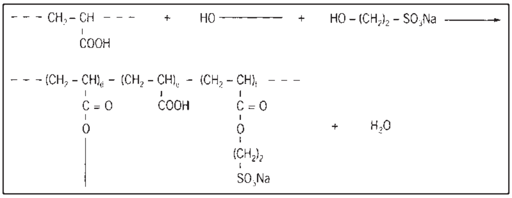


Fig. 3: Additional sulphonation when using sodium hydroxyethane sulphonate during the modification of polyacrylic acid with a fatty alcohol.

For applications, in which for example the dispersions of fat chemically modified polymers require good acid and salt resistance, the additional inclusion of sulphonate groups with the aid of hydroxyethanesulphonic acid is advisable (Fig. 3).

Polymer mixtures → Polyblends, suitable dyes for.

Polymer physics of fibres is concerned with the relationship between the structure and properties of fibre forming macromolecules. Attempts are made by modelling to theorize about what happens in the individual stages of fibre manufacture regarding the arrangement of the macromolecules in the fibre. If it is imagined that molecules take on a ball-shape in the melt prior to the spinning nozzle, then they are partially aligned within the spinning nozzle due to the high shear force, i.e. the chain molecules take on a preferred orientation (Fig. 1). If the fluid threads leave the nozzle at normal pressure, the orientation process is largely reversed due to thread expansion. Due to the influence of gravity and shear forces and due to further forces acting upon the thread discharge a contraction of the thread occurs, causing a new preferential orientation of the chain molecules. Depending upon the polymers in question a partial crystallization of the macromolecule or just a preferential orientation takes place. It is therefore known that polyamide fibres crystallize (Fig. 2) even in spun fibres, whereas polyethylene terephthalate fibres remain strongly amorphous with a preferential alignment.

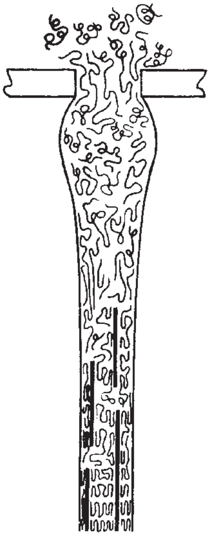


Fig. 1: Change to molecular conformation during spinning (model according to Katayama et al.).

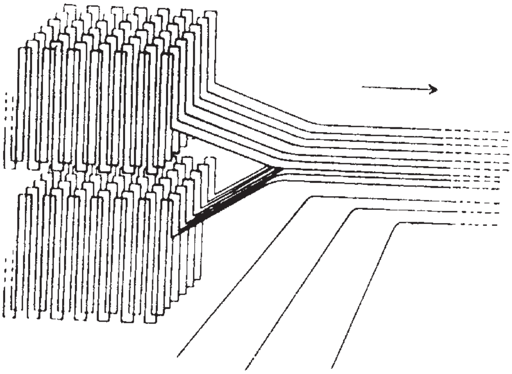


Fig. 2: Molecular model of drawing (according to Kobayashi).

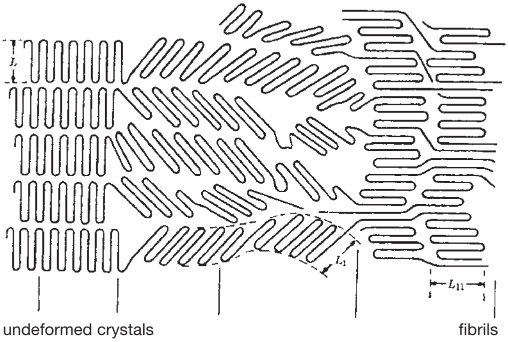


Fig. 3: Molecualr model of drawing (according to Peterlin).

The orientation processes during drawing (Fig. 3) occur both in the crystalline areas and in the non-crystalline intermediate layers. The following equation

$$f_m = \alpha\, f_c + (1-\alpha)\, f_{am}$$

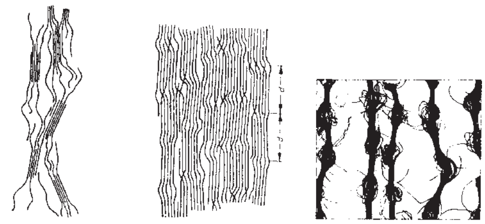
where

$f = (3\cos\Theta - 1)/2$,

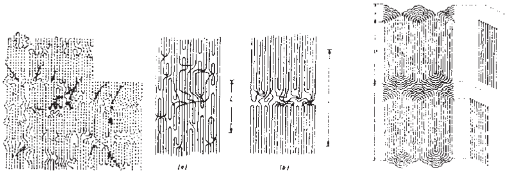
α = degree of crystallization.

shows the link between average molecular orientation f_m, orientation of the crystalline areas f_c and orientation of the molecules in the non-crystalline areas f_{am}.

All models of the fine structure of drawn, part-crystalline high polymers have in common the fact that they differentiate between phases (Fig. 4) of greater arrangement (crystalline areas) and lesser arrangement (amorphous areas).



strands and micelles model Hess-Kiessig model Statton model



Bonart-Hosemann model Fischer model (a = untempered; b = tempered) Pechhold model (meander)

Fig. 4: Two phase model of partially crystalline drawn polymers.

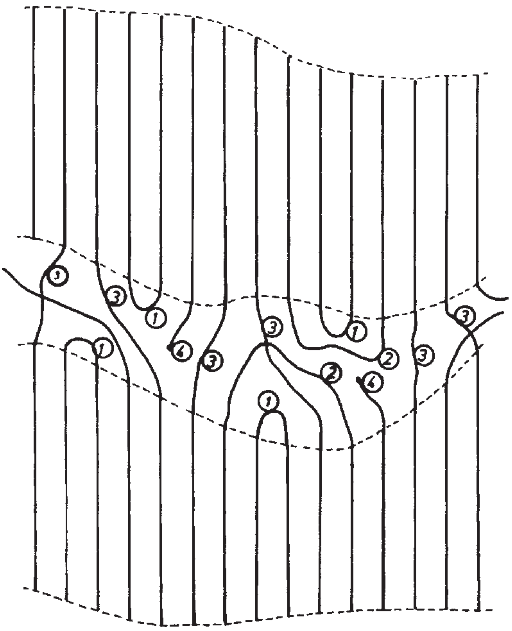


Fig. 5: The arrangement of molecules within the non-crystalline intermediate zone of drawn and partially crystallized high polymers.
1 = acute fold; 2 = loop; 3 = chain sequence under tension; 4 = chain end.

Model considerations have shown that the condition of the non-crystalline areas plays a decisive role in the physical behaviour of the drawn high polymers. The following molecular information is in the non-crystalline intermediate layers (Fig. 5):

- sharp chain folds (1),
- long chain loops (2),
- crystallite binding chain segments, which can be more or less distorted (3),
- chain ends (4).

In addition, there may also be crystalline bridges between the individual crystallites. Furthermore, chain segments, which bind together individual adjacent fibrils, should also be taken into account (Fig. 6).

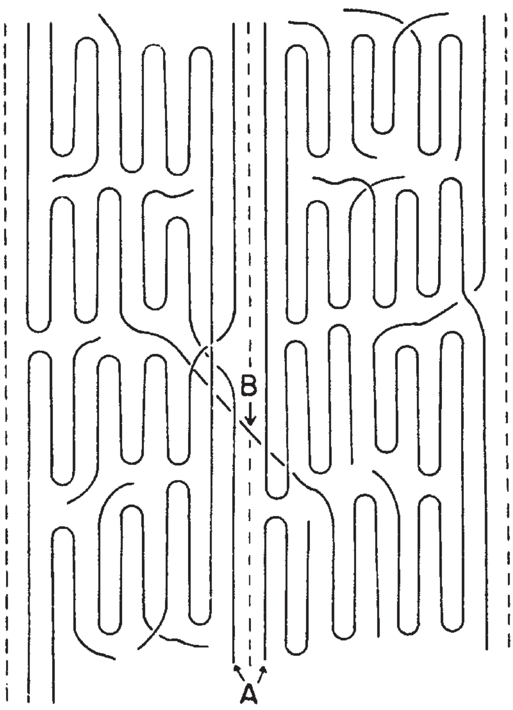


Fig. 6: Fibril model with interfibrillar linking molecules (according to Peterlin).
A = boundary of a fibril; B = interfibrillar zone.

The strength and elasticity modulus of a fibre is influenced by (Fig. 7):

- the number of chain segments binding the crystallite,
- the length distribution of the intercrystalline segments,
- the orientation due to drawing.

The degree of crystallisation has a lesser influence on strength, extension and modulus of elasticity than the

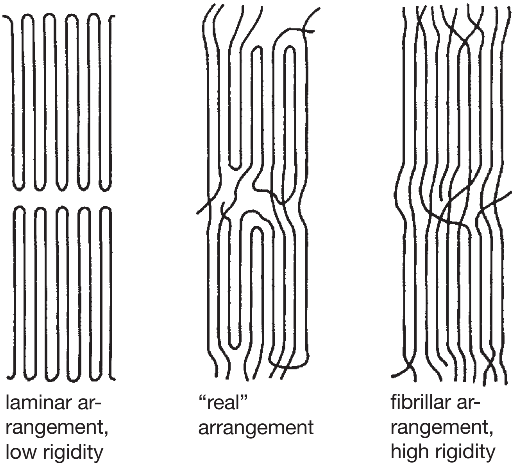


Fig. 7: Laminate and fibril arrangements.

layout of the crystallite. For example, in the crystalline areas of polyamide 6 there is the formation of so-called lattice planes, i.e. molecule planes, in which all the hydrogen bridges are arranged (Fig. 8).

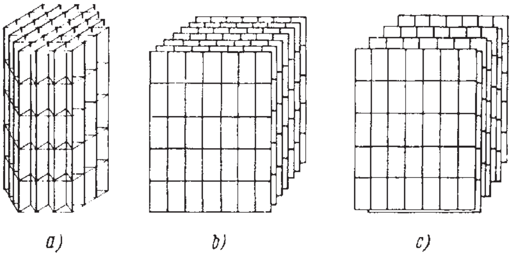


Fig. 8: Polyamide 6 crystal structures with lattice planes (according to Reichle and Prietzschk).
a) = hexagonal form; b) monocline β-form; c) monocline α-form.

There are no hydrogen bridges, or only a reduced number, between these lattice planes so that the lattice planes can slide over each other like sheets of paper when a voltage is applied. The sliding of molecules or molecular compounds is co-decisive for the level of the breaking strength and breaking elongation. The arrangement of crystalline and non-crystalline areas (Fig. 9) plays a decisive role in determining the stress/strain behaviour of oriented high polymers.

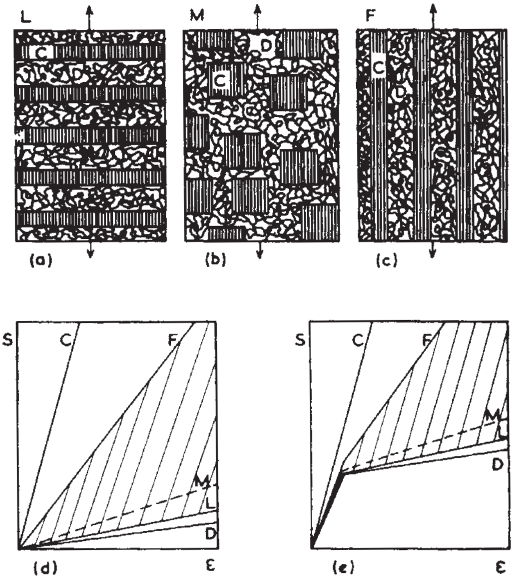


Fig. 9: The tension/extension behaviour of various superlattice structural arrangements (according to Hearle).
a = laminar system (L); b = micellar system (M);
c = fibrillar system (F); d = force/extension profiles without yield point; e = force/extension profiles with yield point.

If we consider extension in the direction of the molecular axis, then in the lamellar arrangement, the amorphous area, i.e. the area with the lower modulus of elasticity, is loaded first; in the event of higher elongation the crystalline area is loaded. The opposite is true for the fibrillar arrangement: When there is a slight elongation the crystalline area, which normally has the higher modulus of elasticity, is loaded. Only after a partial destruction of the crystallite, are the molecules in the amorphous areas involved in the extension process to a significant degree. The micellar arrangement, which corresponds best with the relationships in practice, represents an arrangement that lies somewhere between the fibrillar and lamellar structures. The stress/strain diagrams depend upon the arrangement in question (according to Hinrichsen).

Polymer recycling through depolymerization

Whilst the energetic recycling of polymers (burning) in many cases represents a suitable method, albeit one which has limited public acceptability, the pyrolitic and hydrogenating recycling of plastics generally leads to a multitude of low molecular products, which can only be converted back into suitable monomers by cracking. In contrast, “thermodynamic recycling” represents a method that, in the ideal case, provides polymerization-free monomers. In the presence of suitable catalysts, the thermodynamic equilibrium is shifted from the polymers to the monomer(s), which can be separated by distillation and then once again added to the polymerization. This process can be used on all polymers that can be degraded to polymerizable 5 or 6 link heterocycles. This includes polytetrahydrofuran, polycarbonates of polysiloxane, and many others. The particular advantage of the method is that mixtures of the above polymers can undergo this process just as block copolymers (according to Höcker).

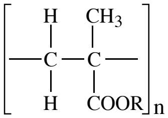
Polymers (high polymers), → Macromolecules created by → Polymerization, → Condensation polymerization or → Addition polymerization (natural, artificial or synthetic). The cellulose chain molecule of cotton forms a typical natural polymer (→ Degree of polymerization) made up of approx. 2000 cross-linked glucose residues.

Polymers are organic chemical compounds, which have different molecular weights together with the same qualitative and quantitative composition, e.g.:

glucose (residue):	$C_6H_{10}O_5$
hydrocellulose:	approx. $(C_6H_{10}O_5)_{100–300}$
cotton:	$(C_6H_{10}O_5)_{2600}$

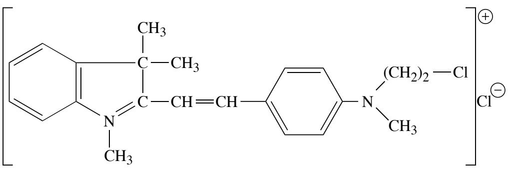
Polymethacrylates Identical to → Polymethacrylic acid ester.

Polymethacrylic acid ester (polymethacrylate), similar to → Polyacrylic acid ester, but significantly harder (butyl, ethyl, methyl ester with softening points of +18°C, +50°C, +100°C), sometimes very brittle. In the form of solutions and emulsions.



$$\left[-\overset{\displaystyle H}{\underset{\displaystyle H}{C}} - \overset{\displaystyle CH_3}{\underset{\displaystyle COOR}{C}} - \right]_n$$

Polymethine dyes (cyanine dyes), contain several linked methine groups (–CH =), which form a system of conjugated double bonds, e.g. a chain with trivalent and quadrivalent nitrogen at the "ends". Such symmetrically structured polymethine dyes are extraordinarily non-lightfast. Polymethine dyes of this type are used as sensitisors in the manufacture of panchromatic films. In contrast, certain asymmetric polymethine dyes have medium to good light fastness, a fact exploited by acetate printing with specific dyes and polyacrylonitrile dyeing.



Polymethylene chains Methylene groups arranged in a chain-like sequence [$–CH_2–CH_2–CH_2–$] in high molecular compounds (e.g. in textile accessory materials).

Polymethylene sulphone fibres (polyhexamethylene sulphone fibres), $[–(CH_2)_6–SO_2–]_x$ synthetic polycondensation fibre type. Manufactured e.g. from polythioether by oxidation with peroxide, spinning as a fused mass and cold drawing. Cross-sectional shape is round. Properties: density 1.2; normal moisture 2.2%; breaking strength 27.5–37.3 cN/tex, 95% moist; elongation at break 10–18%; soluble in most inorganic and organic solvents; dyeable with disperse dyes.

Polymolecular Property of → Macromolecules; their construction from different molecular sizes due to e.g. non-uniformity, i.e. varying length of the → Chain molecules. The results include varying → Degree of polymerization, strength differences in fibres, etc.

Poly-(m-)phenylene isophthalamide Flame retardant fibre material, which has the same mechanical properties as polyamide except for greatly increased temperature resistance.

Polynosic Derived from the French "polymère non synthéthique" (non-synthetic polymer). Since 1961 the trade name, protected by trademark law, has been "Association Internationale Polynosic" - members for → Polynosic fibres. The scope of protection is controversial, because countries with a fibre declaration of "polynosic" do not recognize it as a generic term.

Polynosic fibres Modified viscose fibres, subgroup of the cotton-like → Modal fibres. Differ from → High wet modulus fibres due to their good alkali resistance (mercerizability). They possess a characteristic uniform structure of fine fibrils in a rather homogeneous arrangement distributed over the entire round cross-section. Therefore, they have good penetration and reactivity at low swelling (approx. 60%) compared to finishing resins. They have good dimensional stability due to the high wet modulus. Cross-section round; DP 450–600. Application: 100% polynosic fibres for domestic textiles, coating base fabrics; in mixtures with cotton (40–50%); with wool for outer clothing; with polyacrylonitrile for clothes, skirts, sport and winter clothing and for nonwovens. As filament yarn for dimensionally stable high pressure hoses.

Polyolefin fibres (olefin), polymerization fibres of min. 85% ethylene, propylene or other olefins (→: Polyethylene fibres; Polypropylene fibres). Manufactured by polymerization as the polyethylene type, either under high pressure, branched structure (plays hardly any role as a fibrous material) or under low pressure with linear structure (for fibre manufacture), further as polypropylene type (as monofilament and multifilament) with isotactic structure of the side groups ($–CH_3$, $–CH_2–CH_3$, etc.). When drawn, such polyolefin fibres achieve significant strengths along with an increased melting range (see Tab.).

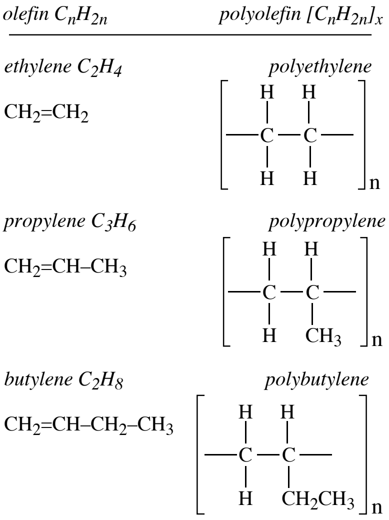
Polyolefin fibres are sometimes relatively coarse, but are also spun in fine titres in pure form or with cotton, wool and synthetics. Properties: bacteria and insect resistant, density < 1, water absorbency virtually 0, thermostabilizable (which makes them up to 170°C resistant without decomposition or yellowing), electric

	density [g/cm³]	melting zone [°C]	rigidity [cN/dtex]
polyethylene			
branched (HP)	0.92–0.94	105–120	1–3
linear (LP)	0.95–0.96	125–135	3.5–7
polypropylene			
isotactic	0.90–0.92	160–175	2.5–6

Tab.: Characteristics of polyolefins.

insulator, slow burning (fine polyolefin fibres melt first; increased flame resistant polyolefin fibres by spin-melt coatings). Chemical resistance good, insoluble in all concentrated alkalis and acids (exception conc. hot nitric acid and oxidizing agent at higher temperature). Aromatic solvents (benzene, toluene, etc.) and chlorinated hydrocarbons have a swelling effect at room temperature, and a solvent effect at higher temperatures (70°C). Mineral and vegetable oils are easily absorbed and have a swelling effect, increasingly so at higher temperatures. Subsequent dyeing difficult (only modified fibres) (mainly spin-dyeing).

Polyolefins (poly-α-olefins), polymer of α-olefin. Polyolefin designation, although there are no longer any double bonds (thus → Paraffins); Examples:



Polyols Multivalent → Alcohols, i.e. containing several OH groups, such as diols (e.g. glycols), tertiary alcohols (e.g. glycerol), etc.

Polyoses High molecular → Carbohydrates, made of hexose molecules, e.g. (from glucose) starch and cellulose.

Polyoxy compounds →: Oxyethylation; Polyethylene glycols; Polyglycol ethers (and polyglycol esters), etc.

Polyoxyether Type of → Polyglycol ethers.

Polyoxyethylation → Oxyethylation.

Polyoxyethylene thioether Surfactant of polyoxyethylated thioether type.

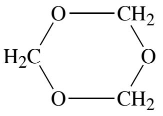
Polyoxymethylenes $(CH_2O)_x$, manufactured from gaseous → Formaldehyde, is easily polymerized to a low solubility mixture of different polyoxymethylenes in the presence of H or OH ions (water), usually in the form of a crystalline white substance, which can be depolymerized again and brought into solution by acids or alkalis. The reaction of formaldehyde in its hydrate form as methylene glycol $HO{-}CH_2{-}OH$ whilst giving off water (polycondensation) to dimethylene glycol, which is ethylated with a further mol of methylene glycol to give trimethylene glycol and high molecular polyoxymethylene:

$$HO{-}CH_2{-}O\boxed{H\ +\ HO}CH_2{-}O\boxed{H}+\ldots$$

$$\longrightarrow\ {-}O{-}CH_2{-}O{-}CH_2{-}O{-}\ +\ H_2O$$

This process is similar to the production of → Polyethylene oxides and → Polyglycol ethers. The different polyoxymethylenes are characterized by molecular size, degree of polymerization (determines physical constants such as melting point, solubility, etc.) and terminal molecule groups (determine the chemical behaviour). Examples:

1. paraformaldehyde: mixture of different polyoxymethylene-dihydrates, DP 3–100, approx. 95% formaldehyde content, develops gaseous formaldehyde from 100°C (space disinfection).
2. α-polyoxymethylene: $HO{-}CH_2{-}O{-}(CH_2{-}O)_x{-}CH_2{-}OH$, a polyoxymethylene-dihydrate with DP = 2 to above 100, reductive action, is split by sodium sulphite.
3. γ-polyoxymethylene: $H_3C{-}O{-}CH_2{-}O{-}(CH_2{-}O)_x{-}CH_2{-}O{-}CH_3$, a polyoxymethylene-dimethylether, DP = 2 to above 100, no longer has reductive action, no splitting by sodium sulphite.
4. trioxane (meta-formaldehyde): trimere cyclic form $(CH_2O)_3$

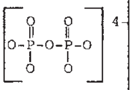
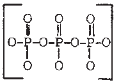
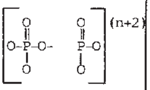


very soluble in water and organic solvents (unlike paraformaldehyde), very stable; for example as stabiliser for trichloroethylene.
5. tetroxane: tetramere cyclic form $(CH_2O)_4$.

Polypeptide High molecular linked → Peptide.

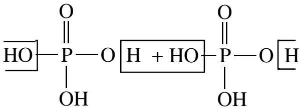
Polyphenylene sulphide $(–C_6H_4–S–)_n$, thermoplastic polycondensate, highly temperature resistant up to 160°C (as coatings up to 350°C), resistant against many solvents, self-extinguishing properties. Application: shaped parts, coatings for glass and metals, electrical insulator, special fibres.

Polyphosphates Phosphates with varying degrees of condensation and a chain-shaped molecular structure. Diphosphate (= pyrophosphate = two chain), triphosphate (= tripolyphosphate = three chain), tetraphosphate (= tetrapolyphosphate = four-chain), etc. up to high molecular polyphosphates = Graham's salt $(25\,Na_3PO_4)$. When dissolved in water, polyphosphates show the typical behaviour of complex formers. They dissociate max. at 30%. In water softening (i.e. bonding e.g. of calcium ions) initially non-dissociated sodium atoms (or H atoms in polyphosphoric acids) are continuously exchanged. The solubility of the complex salts decrease with increasing calcium content. If there are excess calcium ions, dissociated sodium ions are also replaced by calcium and water insoluble calcium polyphosphates. It follows from this that polyphosphates must always be dosed in a certain stoichiometric excess, in order to obtain soluble calcium (or other metal) complexes. Application: for masking water hardness and heavy metal ions, in washing, bleaching, dyeing, printing, resin finishing, as a component of domestic and industrial washing agents.

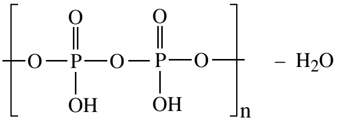
name	di-(pyro)phosphates e.g. sodium pyrophosphate	triphosphates e.g. sodium triphosphate	polyphosphates e.g. Graham salt
chemical formula	$\overset{I}{Me}_4(P_2O_7)$	$\overset{I}{Me}_5(P_3O_{10})$	$\overset{I}{Me}_{n+2}(P_nO_{3n+1})$
structural formula			
properties			
decalcifying power	moderate	medium increases →	very good
dispersion capability	good	good	moderate
detergency	good	good decreases →	moderate
antiredeposition capability	good	good	moderate
stabilization of emulsions	moderate	moderate increases →	good
stabilization of hydrogen peroxide	good	unfavourable	moderate
buffering capability		decreases →	

Tab.: Overview of the most important polyphosphates together with their properties.

We talk of polyphosphates when there are substances with more than one PO unit, which are arranged sequentially in a chain-like formation (see Tab.). They are formed due to condensation of orthophosphates according to the following diagram:

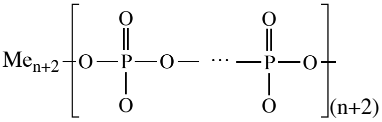


o-phosphoric acid (H_3PO_4)

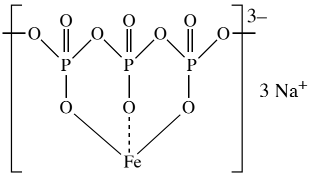


polyphosphoric acid ($H_{n+2}P_nO_{3n+1}$)

Therefore the following general structural formula applies for polyphosphates:



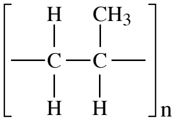
The stabilizing effect of polyphosphates on the H_2O_2 bleach liquor is often attributed to its capability of complex forming and its buffering ability. Furthermore, the polyphosphates are able to mask catalysts by binding them into a chelate complex:



The properties of the polyphosphate often vary with the chain length. Pyrophosphate is the shortest with two $NaPO_3$ units and Graham's salt is the longest chain-shaped polyphosphate with an average of 25 $NaPO_3$ units.

Their disadvantage is their hygroscopicity, which gives rise to the danger of agglomeration, making dosing difficult. A further disadvantage is their poor biodegradability. If polyphosphates find their way into waste water, they can lead to the eutropification of bodies of water. When used in textile finishing, therefore, quantities must be checked. Furthermore, when used in H_2O_2 bleach the bleaching conditions must be thoroughly checked, to see whether the danger of hydrolysis exists for the polyphosphates under certain circumstances (high temperatures, strongly alkaline range).

Polypropylene (PP). Synthetic polymer (→ Polyolefins), which has been manufactured since 1957, with an isotactic structure (low-pressure polymer of propylene and stereospecific catalysts).



$$\left[-\overset{\displaystyle H}{\underset{\displaystyle H}{C}}-\overset{\displaystyle CH_3}{\underset{\displaystyle H}{C}}- \right]_n$$

It is significantly softer and more flexible than low-pressure polyethylene. Particularly suited for the manufacture of foils and fibres and also for hot water pipes (tolerated up to 130°C).

Polypropylene bicomponent fibres Fibres of matrix/fibril type, which are fundamentally different to the earlier polypropylene standard fibres used in the carpet industry. The greatest difference is in their dyeability. In addition to spin-dyed polypropylene fibres these fibres can also be dyed during textile production at atmospheric pressure and boiling temperature using disperse dyes without a carrier. The fibres are available as semi-matt, lustrous or highly lustrous. Furthermore, there is the option of piece or padder dyeing for tufted goods. They can also be processed for pile yarns using semi-worsted yarn or carded yarn spinning processes. The surface structure which has been developed for the fibre imitates that of wool, which contributes to the natural handle of this fibre.

Polypropylene fibres (PP). Isotactic → Polyolefin fibres made of → Polypropylene, manufactured according to the melt-spin process and drawn. Production began in 1959. They are important as monofilaments and multifilaments. Properties: breaking strength 2.5–6 cN/dtex, 100% moist; elongation at tear 15–30%, 100% moist; softening range (unloaded) 149–160°C, melting range 163–170°C. Application: polypropylene fibres are becoming increasingly important in the textile industry in the form of filaments and fibres. Due to the improvement of their water absorbency and dyeability, the original fields of application (technical textiles, geotextiles, carpet primary backing fabrics, nonwovens) has been expanded, and now, for example, furnishing and decorative materials or swimming costumes and knitgoods are manufactured from texturized polypropylene. Microfine fibres are processed into insulating lining fabrics.

Polypropylene fibres, dyeing With the increasing use of propylene fibres in the fashion industry the question of subsequent dyeing has come further to the forefront. It is a well-known fact that polypropylene fibres are difficult to dye; large items are therefore spin-dyed. This has the disadvantage that rapid adaptation to ever-changing, diverse fashionable shades is not possible. Numerous attempts have been made to improve dyeability. Dye penetration can be increased by the use of dyeing auxiliaries, such as non-polar swelling agent for the fibres, however the washing fastness and solvent fastness are inadequate. The dyeing behaviour of the fibre can also be influenced by chemical modification. This is mainly performed by grafting reactions, with mainly acrylic acid, acrylic ester, vinyl acetate, vinyl pyridine and vinyl pyrrolidone being grafted. Partial oxidation of the methyl groups, conversions with chlorine, bromide and fluoride, with chlorosulphuric acid and hypochlorite give rise to the possibility of dyeing with cationic dyes, however these dyeings have a low light-fastness. The spinning in of dye affinity additives, in particular of nickel compounds, has been thoroughly investigated. Polypropylene fibres can also be spun-dyed with pigments.

The dyeing of spun polypropylene fibres however is associated with significant difficulties. Up until now no satisfactory process has been found for dyeing polypropylene fibres after the completion of fibre manufacture. The poor dyeability of a fibre can have many fundamental reasons. A prerequisite for dye uptake is the spatial accessibility of the fibre to dye molecules. Dyeing processes only take place in the amorphous areas of the fibre. Crystallite is not accessible to dye molecules. Fibres with a high degree of crystallization are therefore difficult to dye, as is the case with the aramides, for example. The degree of crystallization of polypropylene fibres is about 60%, which means that there should be enough amorphous areas for dye uptake. But even the amorphous areas have a limited degree of accessibility to the dye. Only if the chain segments in these areas are mobile is there a free volume, which facilitates dye uptake. This means that in the amorphous areas dye uptake is only possible at above the glass transition point T_g. If the glass transition point is high, as is the case in polyester fibres, for example, then only when using auxiliaries which lower the T_g is dye uptake possible at normal dyeing temperatures of 100°C. In polypropylene fibres the glass transition point should not present any dyeing difficulties, because it is very low, being only 35°C. Even if the steric relationships are favourable for dye uptake, it is still possible for no dye to be drawn into the fibre. Only if interactive forces are generated between fibre molecule and dye molecule, and if there is an affinity of the dye to the fibre, can dye take-up by the substrate occur according to the exhaust dyeing method. Fibres with ionic or polar groups are generally able to create such interaction forces. However, polypropylene does not possess polar or ionic groups, so that only van-der-Waals forces come into consideration for the generation of intermolecular forces, which at 4.2 kJ/Mol are very weak.

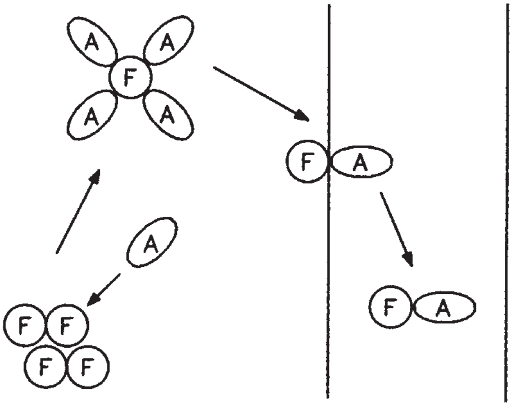


Fig. 1: The dyeing process during emulsion dyeing with affinity meditors (A) and dyestuff (F), represented diagrammatically (according to Herlinger).

Auxiliaries are substances, which can form interaction forces to the dye, but at the same time show an affinity to polypropylene. Such substances can be called affinity providers. Their possible working method is shown in Fig. 1. The auxiliary substances form interaction forces both to the dye molecules and the fibre molecules and in this manner ensure an affinity bridge between fibre and dye.

The affinity of a dye to polypropylene can be assessed using a lipophile parameter, which is easily accessible due to the “reversed” chromatography of the dye. Fat and oil soluble dyes, which have a few long or several short alkyl groups are best suited for dyeing polypropylene. Monoazo dyes have an inadequate degree of fastness, even though an improvement can be achieved by increasing the methyl group number in the dye. Significantly better results can be achieved with biazo dyes. The transition from unsubstituted parent substance Solvent Red 23 to Solvent Red 27 substituted with four methyl groups brings about an extremely large increase in the dye take-up. The washing fastness of this dye is at 60°C at mark 5. The overall fastness level is satisfactory.

1.4-bis-alkylaminoanthraquinone with different substituents of increasing chain length at C_{18} and the unsubstituted 1.4 diaminoanthraquinone and Disperse Red 60 are used as anthraquinone dyes. The dyeing properties range from very poor to very good with the transition from unsubstituted 1.4 diaminoanthraquinone to 1.4 bis-octadecylaminoanthraquinone. The quality of the dyes can be improved further by the addition of 10 g/l toluene to the colour baths. The mechanical-technological properties of the fibre are not impaired by the toluene treatment. The inclusion of longer alkyl residues or several shorter alkyl groups in dyes represents a possibility of manufacturing polypropylene affinity dyes with a built in affinity provider, giving satisfactory fastness.

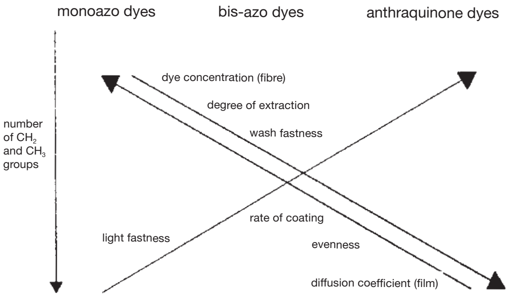
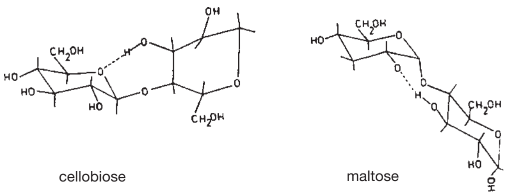


Fig. 2: The influence of dye constitution on the dyeing properties of polypropylene fibres (values increase in direction of arrows) (according to Herlinger).

Phenomena dependent upon diffusion, such as levelling capacity and exhaustion speed, become poorer with increasing alkyl chain length and number, whereby monoazo dyes are better than biazo dyes, and these appear to be better than anthraquinone dyes. The washing fastness depends upon the ease with which a dye can be diffused out of the fabric. For this reason they improve in reverse order. Exhaustion degree and dye concentrations on the fibre improve with increasing alkyl chain length and number. For the investigated dyes the best suited monoazo dyes were poorer than the biazo dyes and these were poorer than the high affinity anthraquinone dyes. The exhaustion degree and dye concentrations on the fibre can be increased further by the inclusion of even longer chains in monoazo and biazo dyes. The light fastness behaves differently. So the anthraquinone dyes are more light fast than biazo dyes and these are clearly more light fast than monoazo dyes. Increasing the number of alkyl chains has a negative influence upon the light fastness (Fig. 2). (according to Herlinger).

Polypropylene glycol Synthesis product, colourless, non-volatile, does not corrode metals, highly to slightly soluble in water, cold resistant. Application: for lubricants, solvents, non-ionogenic cleaning products, synthetic resins, softeners, etc.

Polysaccharides The most important polysaccharides for textile finishers are the related substances of cellulose and starch. As polyols they have the ability to strongly interact with water and form hydrogen bridges. Whilst cellulose, being a structural polysaccharide, forms hydrogen bridge bonds intramolecularly but above all intermolecularly and as native fibre (cellulose I), crystallizes even without water, water represents an integral component of starch. Completely dry starches show an amorphous x-ray diffraction diagram. This shows that even at the dimers: β-cellobiose crystallizes without water, β-maltose only as monohydrate.



cellobiose

maltose

Fig.: The conformation of cellobiose and maltose.

We can see from the basic pattern of the dimers that the equatorial-equatorial β(1.4) glycosidic bond imitates the extended zigzag chain of cellulose, which determines the parallel arrangement of the chain, intermolecular hydrogen bridges and low solubility; the axial-equatorial α(1.4)-glycosidic bond promotes a helical or more ball-shaped structure of the amylose, and thus comparably better solubility (according to Pfannmüller).

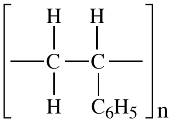
Poly salts → Polyelectrolytes.

Poly-Set-Process Two-stage → Permanent-press process: Stage I cross-linking in the presence of weak catalysts such as zircon acetate. Stage II after manufacture using strong catalysts such as zinc nitrate.

Polysilicic acids Higher → Silicon oxo acid e.g. of the type $(H_2SIO_3)_n$, the most well-known salt of which is water glass or → Sodium silicate.

Polysiloxanes → Silicones.

Polystyrene (PS, polyvinyl benzene), polymer → Styrene.

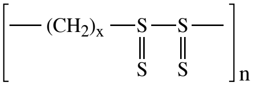


$$\left[-\overset{\overset{H}{|}}{\underset{\underset{H}{|}}{C}}-\overset{\overset{H}{|}}{\underset{\underset{C_6H_5}{|}}{C}}- \right]_n$$

Industrial form: grains, powder, organic solutions, emulsions. Applied films are colourless, transparent, non-yellowing (due to light or heat), hard, brittle. Resistant to water, alkalis, acids; not to hydrocarbons, chlorinated hydrocarbons. Application: lacquers, foils, materials, finishes and acetate sizes (particularly acrylic, butadiene, vinyl copolymers), → Polystyrene fibres.

Polystyrene fibres Synthetic polymer monofilaments. → Polystyrene spun from the melt, then drawn. Coarse, colourless monofilaments (synthetic horse hair), hard, brittle. Properties: burnable; density 1.04–1.06; softening point 70–80°C, depolymerization from approx. 190°C; normal moisture take-up 0% (in water 0.3–0.5%); no water swelling; strength dry/wet 6–7 cN/tex; elongation dry/wet 20–40%; resistant to acids and alkalis; soluble (varies according to degree of polymerization) in benzene, benzine, ether, esters, ketones, chlorinated hydrocarbons. Application: only for technical purposes, e.g. due to good solubility in a range of solvents as support fibres, which are later dissolved. Also as bristles or monofilaments for brushes.

Polysulphides Usually contain 2–5 sulphur atoms. Occur in the form of inorganic alkali polysulphides and compounds with the alkyl polysulphide group of the type

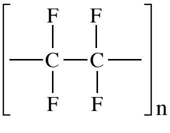


$$\left[-(CH_2)_x-\underset{\underset{S}{\|}}{S}-\underset{\underset{S}{\|}}{S}- \right]_n$$

Used for stabilizing sulphur alkaline dyeing liquors against atmospheric oxygen in the jigger, in the winch beck or in the jet.

Polysulphonated dyes → Acid dyes.

Polytetrafluoroethylene (PTFE, fluorocarbon plastics), synthetic plastic polymer of tetrafluoroethylene (manufactured under extreme conditions from chloroform, antimony fluoride and hydrofluoric acid).



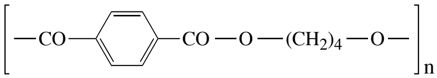
$$\left[-\overset{\overset{F}{|}}{\underset{\underset{F}{|}}{C}}-\overset{\overset{F}{|}}{\underset{\underset{F}{|}}{C}}- \right]_n$$

Translucent, beige-brown, soft-waxy. Until now uniquely inert. Resistant against all chemicals and solvents. Application: material (insulation material, seals, linings, chemical containers), technical fibres (→ Polytetrafluoroethylene fibres).

Polytetrafluoroethylene fibres Synthetic polymer fibres made of polytetrafluoroethylene chains. They possess extraordinary chemical and physical stability. Produced by the melt-spin process, extremely fine threads can be spun and cold drawn. Appearance: beige-brown (bleaching with boiling aqua regia, without damage), soft slippery, cross-section round. Properties: density 2.3; normal moisture absorbency 0.02%

(unwettable); virtually non-flammable (glows in flame); softening point approx. 327°C; at 225°C, 15% fall in tear resistance; at 310°C no strength; difficult fabric fixing, at 315°C, it takes 1 min to extract the decomposition gases (toxic); melting range from approx. 400°C (simultaneous decomposition); strength dry/wet 16–27 cN/tex; elongation dry/wet 13–15%; dermatalogically harmless; resistant to mildew, bacteria, insects, weather resistant; almost totally resistant to acids, alkalis, organic solvents; difficult to dye (disperse dyes; spin dyeing). Application: for technical purposes (filter cloth, packing material, protective clothing, dye bags, screen printing gauze, etc.), also for non-wovens.

Polytetramethylene terephthalate fibre Polyester modification, which can be dyed without a carrier, e.g. for domestic textiles. Density 1.31; melting point up to 224°C; glass transition temperature 40°C.

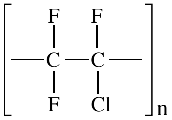


Polythioethers Synthetic polymers with → Thioethers (alkylpolysulphide), e.g. of type $[-CH_2CH_2S-]_x$. They form the basis for synthetic rubber-like products and as synthetic fibre formers (→ Polymethylene sulphone fibres).

Polythionic acid Higher → Sulphur oxyacids of the type $H_2S_{3(-6)}O_6$ which only occurs in salt form or aqueous solution. In alkaline solution decomposition to thiosulphate and sulphite.

Polythioureas → Polyureas.

Polytrifluorochloroethylene (polytrifluoromonochloroethylene), synthetic plastic polymer of trifluorochloroethylene (of hexachloroethane and hydrofluoric acid). Similar to → Polytetrafluoroethylene, but easier to process.



$$\left[-\underset{F}{\overset{F}{C}}-\underset{Cl}{\overset{F}{C}}-\right]_n$$

Density 2.1–2.2; colourless; translucent, hard and strong (not brittle); softening point approx. 230°C; unburnable; resistant up to above 100°C against almost all acids, lyes and solvents (highly-halogenated hydrocarbons and some aromatic compounds have a swelling effect). Commercial form: flakes, rods, tubes, 60% organic solvent dispersions pure or mixed. Application: packing, membranes, pipes, equipment parts, containers, etc.

Polyurea fibres Further development within the group → Polyurethane fibres made of spun → Polyureas. The properties of the polyurea fibres largely correspond with those of polyurethanes, having the following advantages compared to the latter: Low density of 1.07 and significantly higher melting point of 237°C.

Polyureas Organic conversion products of di-isocyanates and diamines, e.g.:

$$2\,H_2N-(CH_2)_6-NH_2 + OCN-(CH_2)_n-NCO \quad \textit{(Monomer)}$$

$$H_2N-(CH_2)_6-\underbrace{NH-CO-NH-}_{\textit{urea residue}}(CH_2)_n-\underbrace{NH-CO-NH-}_{\textit{urea residue}}(CH_2)_n-NH-$$

$$\underbrace{\left[-HN-(CH_2)_n-NH-CO-NH-(CH_2)_6-\right]_m}_{\textit{polyurea}}$$

While useable foils and threads can be manufactured according to this principle, threads produced in a similar manner from polythiourea have no useful properties due to their marked thermoplasticity, thus the latter are attributed no technical importance. Application: adhesives, cements; animalization; hydrophobing; fibre material (→ Polyurea fibres); moulded plastics; synthetic leather, etc.

Polyurethane carpet backing → Backcoating of carpets with polyurethanes is fundamentally different to other coating methods, because the rubber-like polyurethane polymer is formed on the back of the carpet by the spontaneous reaction of a hydroxyl group of (polyester or polyethylene) with (toluylene or diphenylmethane) di-isocyanate to form → Polyurethanes according to the diagram:

$$R-NCO + R-OH \longrightarrow R-NH-CO-O-R \ \text{(+ heat)}$$

Application now takes place either by air/gas impact (Dow process) or with a blowing agent, or the reaction described above is supplemented by the reaction of di-isocyanate and water to urea groups, whereby carbon dioxide serves as the gas component for foaming:

$$\begin{tikzcd}
R-NCO + H_2O \arrow[r] & R-NH-COOH \arrow[d] \\
 & R-NH_2 + CO_2 \arrow[d] \\
 & R-NH-CO-NH-R \ \text{(+ heat)}
\end{tikzcd}$$

Classification as follows depending upon the foam application:

I. transfer process.

II. spray coating: direct, single stage chemical foaming (ICI process).

III. knife-coating process: Mechanical foaming; reaction to the formation of polymer after a delay, coating substance is applied directly to the back of the carpet with a doctor blade (process according to BP Union-Carbide); in the Dow process foam generation is by the mechanical impact of air/gases.

The advantages of the polyurethane carpet backing compared to natural latex foaming are many: Smooth cut edges, high elasticity and better recovery power, high temperature and ageing resistance, high wheelchair and knops resistance, good sound-absorbency, good wet fastness and dimensional stability, as is also shown by the table comparing physical properties (polyurethane foam and non-gelled latex foam). The flame resistance is judged to be better than that of polyacrylo-butadiene and styrene-butadiene coating. The formation of hydrocyanic acid during burning should not represent a danger.

	polyurethane	latex
backing weight		
pre-coating	-	~ 800 g/cm^2
foam	~ 1250 g/m^2	~ 600-1000 g/m^2
foam density	~ 350 g/l	~ 200-350 g/l
foam thickness	~ 2.5-3.0 mm	~ 2.5-3.0 mm
tensile strength	> 5 kp/cm^2	< 4 kp/cm^2
expansion	140-180 %	150-250 %
repetition capability	> 95 %	~ 85 %
parting force	> 600 g/cm	200-400 g/cm
elasticity	~ 40 %	~ 40 %
crush resistance		
at 25 %	~ 0.7 kp/cm^2	0.1-0.2 kp/cm^2
at 40 %	~ 1.2 kp/cm^2	0.2-0.5 kp/cm^2
at 65 %	~ 4.2 kp/cm^2	1.0-1.8 kp/cm^2
hysteresis	< 35 %	40-50 %
pile fastening strength (loop on tape fabric)	~ 5 kg	~ 4 kg

Tab.: Comparison of the properties of polyurethane and latex (1 kp/cm^2 = 9.81 N/cm$^{2)}$.

Polyurethane coating Coating with solvent-free systems, e.g. laminating with foils or coating with aqueous dispersions or foams (see Fig.). An important criterion of polyurethane coating is its resistance to ageing. Under the influence of UV rays discoloration and decomposition of the coating takes place. The addition of light stabilisers greatly delays light damage.

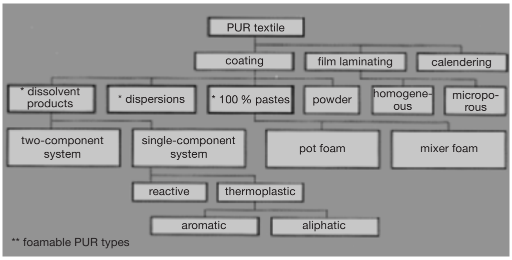


Fig.: The possible applications of polyurethane to textiles. The foamable types of polyurethane are bordered with heavier lines. PUR = polyurethane.

Polyurethane elastomer fibres According to DIN DIN 60 001, elastomer fibres made of high polymers, which consist primarily of segmented → Polyurethanes. The elastomer behaviour owes its elastic stretchability to amorphous soft segments (60–80% by weight), and to crystalline hard segments (40–20% by weight) for chain coherency (elastane fibres). Polyurethane elastomer fibres have rubber-like high elasticity. Compared to → Rubber fibres, finer, lighter, more stretchable, more tear resistant, retain elastic strength longer, are smoother, good dyeing properties, resistant to sweat, chemicals, oils, oxidation resistant, light resistant, resistant against “rubber poisons” and chlorinated hydrocarbons. Further properties: handle sticky-fishy, approximately white in colour, density 1–1.2, tear resistance dry/wet 5–8 cN/tex, elongation at break 500–700%, moisture absorbency 0.3–1%, melting point approx. 230–250°C, softening point 170–180°C (also higher), sometimes more heat sensitive, relatively good resistance against cold diluted acids and alkalis (at higher temperature, tendency to discolour and decompose; H_2SO_4, pH 2, boiling/90 min good compatibility), sensitive to chlorine bleaches and exhaust gas. Dyeable even in pastel shades using most dyes, specifically acid, metal-complex, disperse dyes. Soluble in boiling dimethylformamide and boiling cyclohexanon. Application: usually spun into → Core-spun yarns for foundation garments, hosiery, sports clothing, stretch fabrics of various types.

Elastane polyurethane fibres are manufactured in a two-stage process (Figs. 1–2). First the prepolymer is

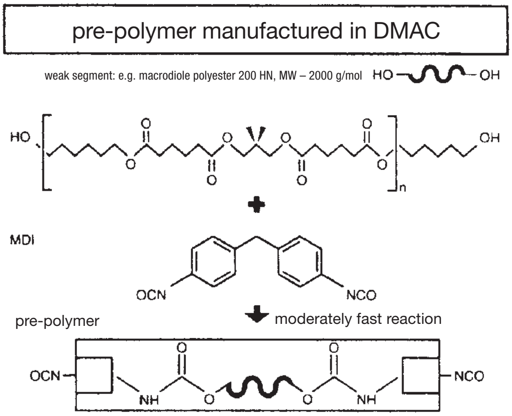


Fig. 1: The manufacture of an elastomer spinning solution; 1st stage.

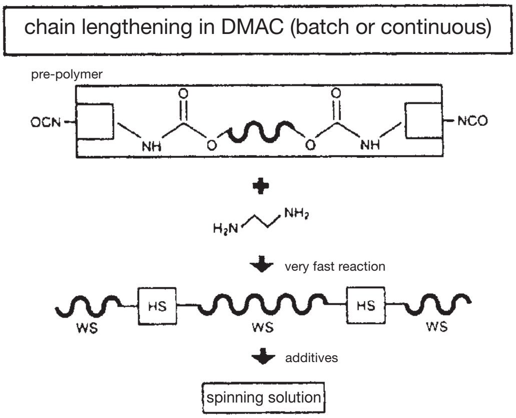


Fig. 2: Chain lengthening.
WS = weak segment; HS = hard segment.

produced. The moderately fast reaction occurs both in solution and solvent-free in selected conditions. The NCO terminated prepolymers are now “chain-extended” in a separate stage, i.e. they are built up by addition polymerization with diamines to form polyurethane ureas or with short chain diols, e.g. butandiol 1.4 to form high molecular polyurethane. Whereas the diol extension, as a reaction, can also be carried out in the melt (in principle thermoplastic polyurethane is also manufactured), diamin addition to polyurethane urea must be carried out as an extremely rapid reaction in a suitable solvent (usually dimethylacetamide). This synthesis step is particularly important for the quality of the elastane yarn and requires (carried out as batch or continuous process) a clean fine-tuning, in particular regarding the chain controller that is also used for the limitation of the molecular mass. After the addition of the necessary or desired additives, which must fulfil a specific task either in processing or in the finished part, we now have the finished spinning solution. This can in principle now be spun into elastane filament yarns in the wet or dry spinning process.

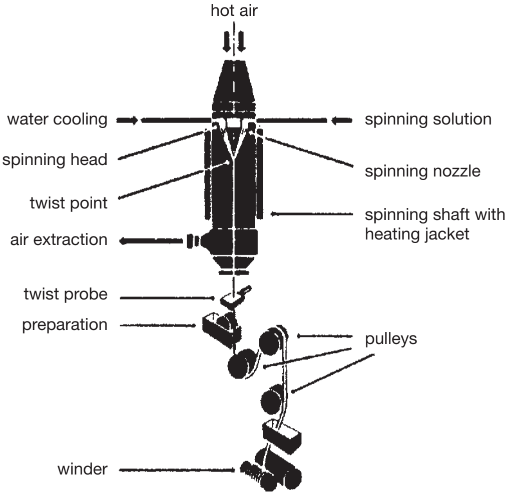


Fig. 3: Dry spinning process.

World-wide, the dry spinning process shown in Fig. 3 has largely gained acceptance. In the dry spinning process the heated, highly viscose spinning solution is fed to the heated spinning shaft and pressed through multi-hole nozzles, whereby the solvent is quickly vaporized by hot spinning air. The spinning conditions (in particular the discharge velocity, spinning temperature and twist) have, depending upon the type of elastane and the concentration of the spinning solutions, a significant influence, above all, on the mechanical properties of the filament yarn. The finished filaments are bundled to form a yarn in the spinning shaft, depending upon the desired titre, and stuck together to form a quasi-monofilament thread by a twisting device, prepared and wound onto packages.

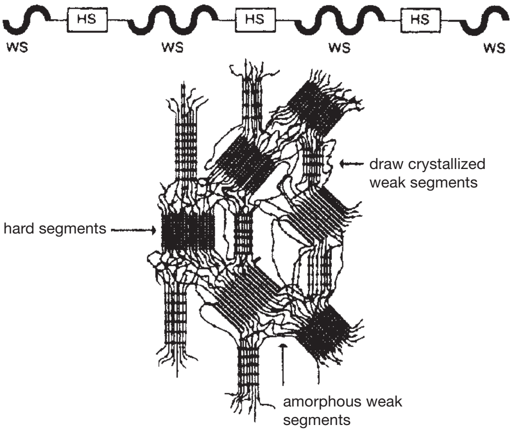


Fig. 4: Model of domains in segmented polyurethane (according to Bonart and Rinke).

We can see from Fig. 4 that the substances manufactured according to the di-isocyanate addition polymerization process are block copolymers, in which long, soft, mobile segments alternate with relatively short, hard segments in a continuous sequence. In finished threads, the soft segments form a cohesive, fluid matrix, in which the crystalline hard segments, which are associated with hard domains, are incorporated and thus physically cross-link the entire system. The principal structure of the elastanes follows the classical theory of rubber elasticity. Long chain molecules with freely mobile segments, with only weak interaction between them (as in a liquid), are cross-linked at defined points to form a three-dimensional network. Whereas rubber is known to be a chemically cross-linked polydiene, in which, in addition to the -diene component, the cross-linking density is determined primarily by wear properties. In elastane cross-linking takes place via crystallized hard segments in the hard segment domains. The shorter hard segments, in a regular, crystalline arrangement, cross-link the soft segment matrix, which in the extended state can be part crystalline, like rubber. Unlike rubber, the cross-linking points have spatial expansion and thus have the effect of a filling material. This is important for the strength of the elastane. In contrast to the chemical cross-linking in rubber, the physical cross-linking has a certain mobility. Thus thermal deformation is possible, and tension peaks can be smoothed out to a certain degree. The matrix of soft segments is present in the form of a melt at normal temperature, whereas the hard segments are glass hard or part-crystalline. Fig. 5 summarizes possible soft segments and shows their principle suitability for elastanes as building blocks.

type (molecular weight 1000-3000)		principle suitability
● polyeser made from		
– butane diole		−
– hexane diole	plus adipic acid	±
– butane diole/hexane diole		+
– hexane diole/NPG		++
– E-caprolacton		±
– butane diole/E-caprolacton/adipic acid		+
● polyether		
– EO, PO, EO/PO		−
– poly-tetrahydrofurfuryl		++

Fig. 5: Polymer dioles as weak segments.

Of the almost indefinitely large selection of polymers only those whose glass transition temperature lies below room temperature are suitable, in particular copolyester made of hexandiol and neopentylglycol with adipic acid. Polyethers based on ethylene oxide and/or propylene oxide are less suitable due to inadequate constancy of functionality and their susceptibility to hydrolysis in elastanes. Polytetrahydrofuranes have established themselves as the dominant soft segments world-wide. Below the congealing temperature of the soft segments, i.e. below the glass transition temperature or, in crystallizing soft segments, below the melting temperature, the rubber-elastic elongation disappears, leaving the elastane threads hard and brittle (according to Haug, Spilgies and Meyer).

Polyurethane fibres Synthetic fibres with the repeating urethane group –NH–COO–. They are spun as fibres, threads, monofilaments and bristles, predominantly as solution in a precipitation bath or according to the dry spinning process. Of the many manufacturing possibilities, addition polymers of di-isocyanate and glycols (formula → Polyurethanes) are of particular interest, which, spun directly from the melt and cold drawn (approx. 400%) are harder and stiffer than, e.g. polyamide 6.6. Cross-section round. Physiologically faultless. Properties: density 1.19–1.32 (oriented), moisture content 1–1.5%, strength 28–37 cN/tex (approx. 90% moisture) and elongation dry/wet 18–24%, softening point 170°C, melting point 183–184°C, slow decomposition above 220°C, chemical resistance, good against acids (conc. mineral acids dissolve, not conc. HCl), relatively good against alkalis, similar to polyamide against organic solvents (soluble in phenols, cresols), dyeable with disperse, selected acid (< pH 2), direct, vat dyes; increased affinity after steaming at 2–2.5 bar; polyurethane fibre fabrics are easy to stabilise by shrinkage process in hot water at 90°C. Application: synthetic horse hair, bristles, brushes, sieve fabric.

Polyurethane fine coating Mainly polyurethane, in the form of solutions or aqueous dispersions, is used for coatings. Polyurethane solutions are divided into two groups, which can each be further subdivided (see Fig.).

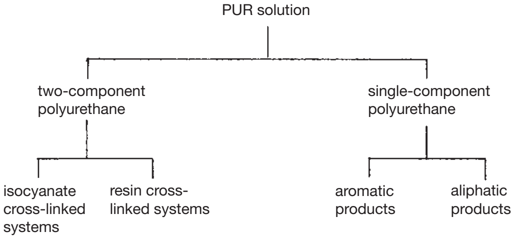


Fig.: Subdivision of fine coatings using polyurethane (PUR).

Two-component polyurethanes are systems of a solution of high molecular reactive polyester in a suitable solvent (ester, ketone), which has not yet been cross-linked, and a cross-linker, which is initially separated, and generally a reaction accelerator. It should be noted that the reactivity of the mixture means it has a limited useful life. After the volatilizing of the solvent, the formation of urethane or a final cross-linking of the polyurethane takes place in the drying channel. Because these films consist of cross-linked macromolecules, an increased level of fastness is achieved. Polyurethanes are resistant against solvents, but are no longer thermoplastic.

In the isocyanate cross-linkable systems (usually trifunctional isocyanate), the cross-linking, which occurs at a relatively low temperature, takes place at room temperature over a period of four to six days. The resin cross-linkable systems require a higher temperature, which guarantees a complete cross-linking in the vapour phase. Single component polyurethanes are fully reacted linear polyurethanes, which require no additional cross-linking. According to their molecular structure they are thermoplastic and are characterized by their resistance to benzine, mineral oils, greases and tetrachoroethylene. Depending upon the selected isocyanate, the cheaper aromatic single component polyurethanes are obtained, which are only soluble in strong polar solvents, or the aliphatic products, which are soluble in weaker polar solvents and have excellent light fastness.

Dispersions can be created by the inclusion of hydrophilic groups in the polyurethane molecule or the use of external emulsifiers, whereby, however, the self-dispersability of the molecule generates a stable product. The use of dispersions is generally environmentally friendly if only water is vaporized, so less safety precautions are necessary. The extraordinarily high fastness created result from strong physical bonds between the macromolecules. Most polyurethane dispersions are aliphatic and therefore possess high light fastness. A further advantage is the high solids content at low viscosity, the thermoplastic behaviour and the relatively good miscibility with other plastics. The dispersants, emulsifiers, and thickener remaining in the plastic film can have a detrimental effect upon water susceptibility. The high energy consumption and frost sensitivity of most products, which result in limited stability during storage, should also be mentioned. Undesired high swelling or redispersing during film formation can be avoided by careful structuring of the product.

Polyurethane preparation plants Plants are used in → Polyurethane carpet backing for storage, conveying, dosing, mixing and intermediate storage of the individual components of the mixture and the finished compound. The so-called chemical stations are completely piped up and programme controlled. In the spread coating process the plant consists of silos and tanks for calcium carbonate, aluminium hydroxide as an infill material, (because of its flame retardent property), polyol, isocyanate and additive for dosing in the weighing and mixing containers in accordance with the recipe.

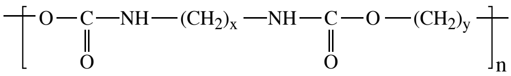
I. For procedures according to BP Union Carbide, compound (calcium carbonate, polyol, additive) and isocyanate are circulated by pump to separate process plant and containers, from there fed to the foam mixer and transported to the application. Weighing, mixing and mechanical equipment (which is water cooled). Polyol, isocyanate and compound are stored in dry air.

II. For processes according to Dow Chemical, the compound is stored in intermediate containers; isocyanate, polyol and compound containers have a protective gas atmosphere. Compound and isocyanate are pumped into separate machine pre-containers and the controlled pumping station conveys them, along with the catalyst, to the foam mixer and then to the application.

III. For procedures according to ICI (spray coating): chemical station of calcium carbonate silos and tanks for polyol, isocyanate, for surface reagents and catalyst. Program controlled chemical feed and dosing to the mixing head. In parallel to the chemical pipes there is a cleaning pipe for solvent to the spraying heads, where the spray application takes place.

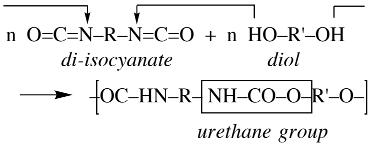
Polyurethane rubber (urethane rubber), synthetic rubber based upon → Polyurethane elastomer fibres.

Polyurethanes (polyester amides), addition polymerization products of high polymer → Urethanes:



$$\left[-O-\underset{\underset{O}{\|}}{C}-NH-(CH_2)_x-NH-\underset{\underset{O}{\|}}{C}-O-(CH_2)_y- \right]_n$$

The fundamental principles of polyurethane chemistry, which have been used to produce polyurethane (PUR) since 1940, were developed by O. Bayer and his colleagues in Leverkusen in 1937. Polyurethane is created by addition polymerization, i.e. the linking of different types of monomers, of multivalent isocyanates with multivalent alcohols. The H atom of the alcohol group migrates to the N atom of the isocyanate, at the same time splitting the N = C covalent bond. This principle is illustrated based upon the example of the addition polymerization of di-isocyanate and a diol to form a linear polyurethane.



$$n\ \underset{\textit{di-isocyanate}}{O{=}C{=}N{-}R{-}N{=}C{=}O} + n\ \underset{\textit{diol}}{HO{-}R'{-}OH} \longrightarrow \left[OC{-}HN{-}R{-}\underset{\textit{urethane group}}{\boxed{NH{-}CO{-}O}}{-}R'{-}O{-} \right]$$

However, medium to high molecular polyester or polyethylene with terminal OH groups are generally used rather than low molecular diols. Polyurethanes are actually polyester or polyethylene with an intermediate polyurethane group.

Polyols are the reactants of the second main component of polyurethane, and isocyanates, and this reactant is attached to any type of “active” hydrogen. Linear high molecular addition polymers are created with numerous polar urethane groupings. These thermoplastic polyurethanes are only soluble in strongly polar solvents. The use of multivalent starting materials permits the generation of three-dimensionally cross-linked addition polymers, which allows polyurethane to be manufactured in the form of thermoplastics, elastomers and duroplastics as required. The combination of different diol and isocyanate components, their quantity ratios and synthesis methods permit many variations in the properties of the material. The application spectrum is further extended by the individual customization of additives to suit the intended application. Important additives are: accelerators, reaction inhibitors, cross-linkers and/or chain extenders, surface active additives, foam stabilisers (ageing protection agent). The broad application spectrum shows that there is no uniform set of properties, therefore polyurethanes are subdivided into product classes.

The chemical structure and molecular size of polyol significantly influences the properties of the polyurethanes manufactured from them. The polyol is responsible for

- resistance to cold or heat,
- hydrolysis stability,
- swelling behaviour in solvents.

Polyester and polyethylene polyols fulfil the demand for technically and commercially useable materials. The molecular weight of polyols lies between 400 and 6000. Polyester for the manufacture of polyurethane achieves a molecular weight of 2000 and contains a typical ester grouping,

e.g. polyester alcohol (n = 2–20):

$$HO–R–[O–CO–R–CO–O–R]_n–OH$$

Polyethylene polyols have a molecular weight of 300–8000 and include the typical ethylene grouping, e.g. polyethylene alcohol (n = 5–80):

$$HO–[CH_2–CH_2–O]_n–CH_2OH$$

Because of this subdivision, two polyurethane groups are created with characteristic properties, which are listed in the Tab.

	polyesterurethane	polyetherurethane
mechanical properties	+ e.g. wear resistance, good firmness, high degree of softness without stretching	- high degree of elasticity, good low temperature flexibility
resistance to hydrolysis and to weathering	-	+ however, sensitive in comparison with polyesterurethane to light and to oxygen
colour stability	–	+
resistance to solvents	+	– e.g. shows strong swelling in solvents
resistance to oil	+	-

Tab.: Comparison of polyesterurethane with polyetherurethane.

Isocyanates are low molecular substances, which are produced in pure form. This occurs for example by the conversion between amines and phosgene:

$$COCl_2 + H_2N(CH_2)_6NH_2 + Cl_2CO \rightarrow OCN(CH_2)_6NCO + 4\ HCl$$

These highly reactive compounds require careful handling, because they also react with the cellular protein of human tissue. The isocyanates determine the hardness, strength, thermoplasticity and light fastness. The selection of isocyanates to be used permits a further subdivision into a) aromatic and b) aliphatic polyurethanes. The aliphatic polyurethanes are characterized particularly by their light fastness, but also by their higher price.

The physical structure in the macromolecular composition makes a significant contribution to the differentiation of the mechanical properties. The construction has a segmentation, in which the diverse urethane segmented groups, as hard segments, alternate with the relatively long-chained polyester or polyethylene chains, the soft segments, which have the cubic, elastic structures (see Fig.).

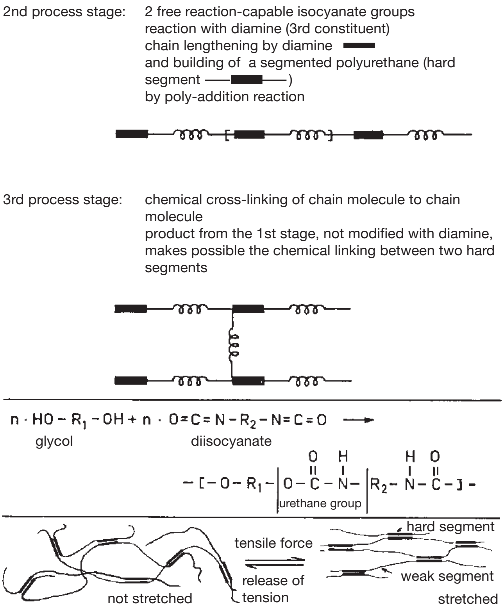


Fig.: The segmentation of polyurethane molecules.

Hydrogen bridges form in the hard segments, which are broken by mechanical loading and can then be immediately reformed. Thus any forces occurring are uniformly distributed and lead to excellent values of elongation at break, resistance to tear propagation, breaking strength and permanent deformation. The proportion of hard or soft segments is determined by the combination of starting products. Polyurethanes with a linear structure represent the normal commercial thermoplastic polyurethane fibres, whilst three dimensionally cross-linked polyurethanes are used for finishing purposes and are prepared directly onto the material from organic solvents.

Properties (adjustable within certain bounds): excellent adhesive properties (even on smooth synthetic fibres and glass fabrics); hard to elastically soft (even without the addition of a softener): high abrasion resistance and bending strength, resistant to ageing (but yellows in light); cold and heat stability between approx. – 60 to +170°C; highly water resistant (even at higher temperatures); resistant to chemical cleaning and oil/grease; good adhesion; good pigment binding (own weight on pigments, bronzes, etc.). Application: finishes, coatings, adhesives for laminates and flocking, adhesives, lacquer, material, foam plastic, fibre material.

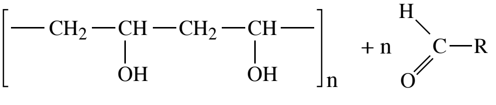
Aqueous polyurethanes for ionic coagulation: for the creation of fibrous porous surface effects by the aqueous ionic dispersion of a polyurethane with covalently bonded, solubilizing ionized groups, whereby the polyurethane coagulates in the length of material. Such dispersions consist of fully reacted polyurethanes, which have no free N=C=O groups, but have ionic groups in covalent bonds with the polymer. These groups have the advantage of making the product self-dispersing, i.e. the dispersion consists only of the polymer (up to 30–40%) and water; this is in contrast to other aqueous polyurethane dispersions, which require further solvents or dispersants. The stable dispersion can be immediately destabilized by the removal of the ionic group or its conversion into non-ionic forms; sudden coagulation occurs: textile impregnation with the aqueous dispersion followed by coagulation due to the effect of 2% acetic acid, then washing out and drying. The process is performed on normal textile finishing machines (no polyurethane migration during drying; no air pollution, no problems with machine soiling/cleaning). In contrast to comparable closed film coating obtained by the dry process a poromeric, water vapour permeable structure is obtained.

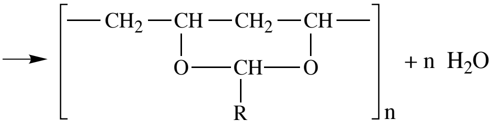
Polyvalent Active in many different ways, with several functions.

Polyvinyl Generic term according to DIN 60 001 for fibres made of high polymers, created by straight chain polymerization of vinyl compounds.

Polyvinyl acetal fibres Fibres of → Polyvinyl acetals; → Vinylal fibres.

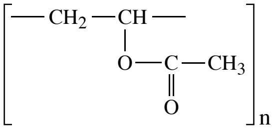
Polyvinyl acetals are created by the conversion of → Polyvinyl alcohol, polyvinylacetate or copolymers of other vinyl esters with aldehydes according to the following principle:





Due to the possibility of partial acetylation, polyvinyl acetals can be produced with a defined content of acetate, ester and hydroxyl groups, whereby variation products with different solubility and differentiated properties can be produced. In general, thermoplastics prove to be brittle to tough-elastic with high softening point and excellent breaking and tensile strengths. Application: for difficult adhesions (metal to metal, etc.), synthetic leather production, rubber substitute, raincoats, lacquer raw material, coatings (with softener), laminating, etc.

Polyvinyl acetate Thermoplastic synthetic polymer of vinyl acetate (produced from acetylene and acetic acid). Also as copolymer.

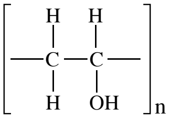


Chunks, pearls, powder, organic solvents, for textile purposes usually aqueous dispersions; solutions and dispersions of different viscosity (thick flowing dispersions; dilute slowly whilst stirring, otherwise clumps will form). The dispersions are frost sensitive. The applied films are clear, colourless, stiff, non-slip, elastic, somewhat hard (high polymers), and softer. As softener: phthalic acid ester (if too much: stickiness). Softening point 30–100 °C (depending upon degree of polymerization); insoluble in water (but swellable), soluble in ketones, esters, chlorinated hydrocarbons. Application: particularly for finishes (weighting stiffening effects, hat stiffeners, ladderproof finishes, cheap coatings (synthetic leather, nitrate cellulose line end), laminating, pigment print pastes (production shortly before processing due to rapid hardening), lacquer raw material, adhesive, seam free floor covering.

Polyvinyl acetate fibres Vinyl acetate is represented in copolymers with polyvinyl chloride and polyacrylonitrile fibres as a modification component. Polyvinylacetate fibres can be dissolved.

Polyvinyl acetate sizes → Polyvinyl acetate, as waterproof sizes for polyester chains for use on water jet weaving machines. Properties: good water solubility and adhesiveness. Variable properties with regard to degree of polymerization and saponification, whereby the solubility decreases with increasing hydrolysis. Fully saponified polyvinyl alcohol swells only in cold water, only goes into solution above 75°C. Polyvinylacetate dispersions containing carboxyl can be brought into solution by neutralization with ammonia.

Polyvinyl alcohol (PVA, PVOH). Synthetic polymer, produced by the saponification of → Polyvinyl acetate.



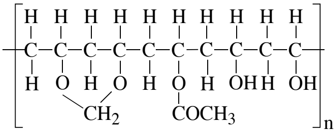
$$\left[\begin{array}{ccccc} & H & & H & \\ & | & & | & \\ - & C & - & C & - \\ & | & & | & \\ & H & & OH & \end{array}\right]_n$$

White, amorphous substance, granular, powder, solutions (jellies), emulsions. Slightly soluble in water (quick dissolving powder: Wetting with methanol, elutriation in water whilst stirring). The solutions are to some degree viscous, depending upon the degree of polymerization (addition of methanol, boric acid, sodium tetraborate, etc. also increases viscosity until gelling and precipitation). Polyvinylalcohol emulsions can be non-ionogenic, anionic or cationic. The applied (water soluble) films are clear, solid and stretchable (both increasing with increasing degree of polymerization). Glycerol, ethylene glycol, and polyethylene glycols act as softeners. The water solubility of polyvinylalcohol dispersions, etc. is significantly decreased by heat treatment above 120°C. Application: particularly for sizes (also polyvinyl alcohol copolymers), finishes (dry-cleaning resistant), printing thickeners, as emulsion protective colloid and stabilizer), for screen printing screens (sizing agent) adhesive, washing additive, foils; → Polyvinyl alcohol fibres.

Polyvinyl alcohol, dye ranges Selected individual dyes of different dye groups:

- direct dyes and
- 1 : 2 metal-complex dyes for light to medium subdued shades;
- vat and vat leuco ester dyes for light and wash fast dyes;
- disperse and
- acid dyes are only used in exceptional cases.

Polyvinyl alcohol fibres



Synthetic polymer fibres of min. 85% vinyl alcohol. Usually produced by wet spinning from → Polyvinyl alcohol (always with certain proportion of non-saponified polyvinylacetate) and subsequent hardening, usually with formaldehyde. Polyvinyl alcohol fibres are similar to cellulose fibres due to their OH group structure, whereby variations are usually gradual (polyvinyl alcohol fibres have less OH groups). Special polyvinyl alcohol fibres also contain e.g. acetyl sulphide (this makes them more heat stable), chloroacetaldehyde (water and chemical resistant), higher aliphatic aldehydes (more elastic), chloracetaldehyde and amines (more elastic, water resistant and good acid dye affinity). The cross-sectional is bean-shaped.

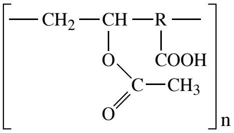
Properties: density 1.26–1.30; normal moisture absorbency 4.5–5.5%; softening temperature wet 110°C, dry 220–210°C (iron with care, similar to polyamide 6 and acetate fibres); melting point 210–238°C; swelling water absorbency at 20°C approx. 30%; shrinkage in boiling water 2–3% (fixing at 90–98°C); greater shrinkage above 110°C (steam); strength 22–36 cN/tex (65–85% moisture); elongation 16–30% (20–40% moisture) abrasion resistance dry and bending strength very high, but low crease resistance (crease-resist finishing normally impossible). According to Japanese experience significantly higher abrasion resistance and durability in fabrics than wool, 3–5 times longer lifetime than cotton hosiery, longer than wool hosiery; tearing strength of ropes 30–50% higher than that of manila hemp ropes. Electrostatic charge low; resistant to fungi, bacteria, insects; good boiling stability, but not particularly resistant to hot water (at 100°C relative fastness 70%); good resistance against acids (better than polyamide 6.6), good resistance against alkalis, salts and organic solvents (at above 60°C swelling and dissolving in formic acid, phenol, cresol).

Dyeability: normally only light and medium shades can be produced (deep shades and black are difficult); selected disperse dyes (colour depth similar to acetate fibres) are suitable, possibly acid and direct dyes (+ magnesium chloride also deep shades) and light fast and wash fast metal-complex dyes, vat and leuco vat dyes. Significance: relatively low, great efforts particularly in Japan (one of the cheapest synthetic fibres, cheaper than Japanese polyamide 6.6, more expensive than cotton), also attempts in England, USA and Germany (surgical sewing threads). Application: for industrial purposes (filter screens), sail cloth, fishing nets. Mixtures for underwear, socks, work clothing, cheap outer clothing, lining material, covers, curtains, carpets. Unhardened polyvinyl alcohol fibres (= water soluble) as substitute for alginate fibres for burn out lace (embroidery background), (soluble) washing bag cords, etc.

Polyvinyl alcohol sizes → Sizing selection criteria.

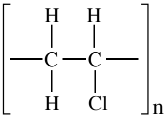
Polyvinyl benzene → Polystyrene.

Polyvinyl carboxylic acid Thermoplastic synthetic polymer in powder and solution for sizes and finishes.



Polyvinyl chloride

Polyvinyl chloride (PVC). Thermoplastic synthetic polymer of vinylchloride, produced e.g. by attaching hydrogen chloride to acetylene.



$$\left[-\overset{\displaystyle H}{\underset{\displaystyle H}{C}}-\overset{\displaystyle H}{\underset{\displaystyle Cl}{C}}- \right]_n$$

Polyvinyl chloride, which is an important coating polymer, is produced as follows: caustic soda liquor and chlorine are produced from sodium chloride (NaCl) in chlor-alkali electrolysis by the consumption of energy. Sales of these two different chemicals vary greatly depending upon the current market situation. Since 1936, excess quantities of chlorine have been combined with ethylene from natural gas, or petroleum, or acetylene from coal, to form the intermediate product, gaseous vinyl chloride (VC). Because of the ability of the VC molecule to bind itself into long, chain-shaped macromolecules in a polymerization reaction, the powder polyvinyl chloride (PVC) is created. By means of various technical conversion processes the polyvinyl chloride base material is manufactured by the plastics industry, which is a part of the chemical industry. The subsequent mixing is performed either by the polyvinyl chloride manufacturer or the polyvinyl chloride processor. The semi-finished and finished products are then produced by the plastic processing industry. The addition of specific, different additives greatly alters the properties of the polyvinyl chloride. These additives influence the durability and resistance to a number of different stresses in specific fields of application and the lifetime of the polyvinyl chloride plastic product. Of the 7.8 million tonnes of plastic produced in the Federal Republic of Germany in 1986, approx. 1.3 million t were polyvinyl chloride. Polyvinyl chloride, which makes up approx. 15% of total plastic production is subsequently processed into soft polyvinyl chloride (32%) and hard polyvinyl chloride (68%) (Fig. 1). The polyvinyl chloride products produced from this break down as follows: Over 55% in the construction sector, 2% in the electrical sector, 4% in the vehicle manufacturing sector, 16% in packaging and 23% in other fields such as medicine, agriculture, environmental protection and the grocery industry.

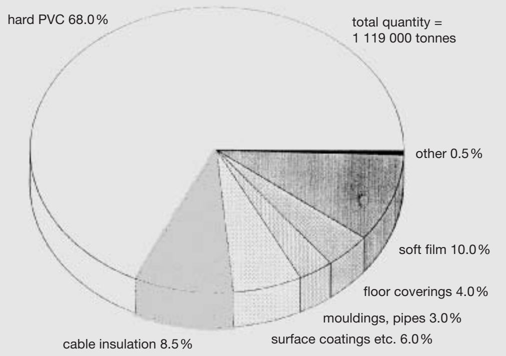


Fig. 1: Uses of polyvilnyl chloride (PVC) in the FRG.

The basic materials of polyvinyl chloride are hydrogen (H), carbon (C) and chlorine (Cl). The chlorine content of 57% in polyvinyl chloride decreases in polyvinyl chloride products due to additives such as stabilizers and possibly pigments, extenders and softeners. In hard polyvinyl chloride products it is between 52–57% and in soft polyvinyl chloride products it is, on average, 40%. The stabilizers used (critical for processability, lifetime and ageing resistance of the polyvinyl chloride products) are calcium, zinc, magnesium, barium and cadmium soaps; tin acetyl compounds, basic lead compounds, calcium zinc, epoxidized soya bean oil, pentaerythritol ester and sorbitol. Cadmium soap, which is now only used as a stabilizer in long life hard polyvinyl chloride products such as window frames and roller shutters (Fig. 2), must be classified as a particularly critical product. Cadmium is a very problematic heavy metal in water, both in the air and in the ground. Because the polyvinyl chloride industry is aware of these environmental problems associated with cadmium, attempts are underway to largely replace cadmium with stabilizers consisting of organic metal compounds of tin, lead, calcium/zinc and barium/zinc.

The pigments used such as titanium oxide (white), carbon black (black), cobalt (blue), iron oxide (yellow/

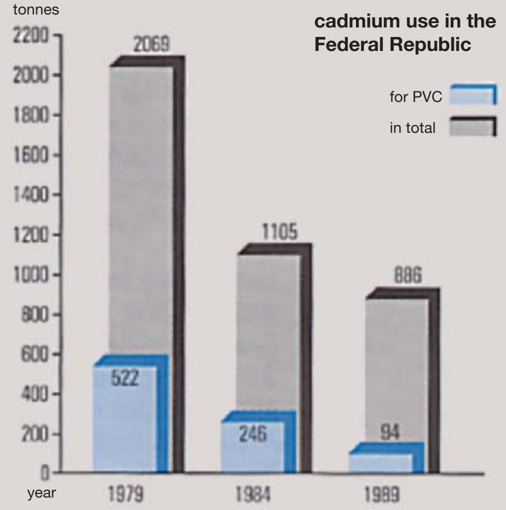


Fig. 2: Use of cadmium, a stabilizer for polyvinyl chloride, in the FRG.

black/brown/red) and other organic products do not give rise to problems in the treatment and disposal of used polyvinyl chloride. The lubricants added in the form of soaps and waxes such as metal soaps, montan and paraffin wax, waxy polyethylene types, fatty alcohols and esters, silicon and glycerol esters are not problematic. Softeners increase flexibility at different temperatures and consist, amongst other things, of phthalate types, phosphate types, epoxidized fatty acid esters, alkyl sulphonate acid ester, adipic acid ester, azelaic acid ester and sebacic acid ester, trimellitic acid ester. Di-(2-ethylhexyl)phthalate DEHP (previous term DOP), used as a softener e.g. for floors or cable sheathing, is only harmful to health in extremely high concentrations. The possibility of a carconogenic effect on organisms can be ruled out within the range of normal concentrations in plastic. The softeners used in the production and use of polyvinyl chloride are naturally degradable by photochemical and microbial means. They therefore do not represent a burden on the environment (Fig. 3).

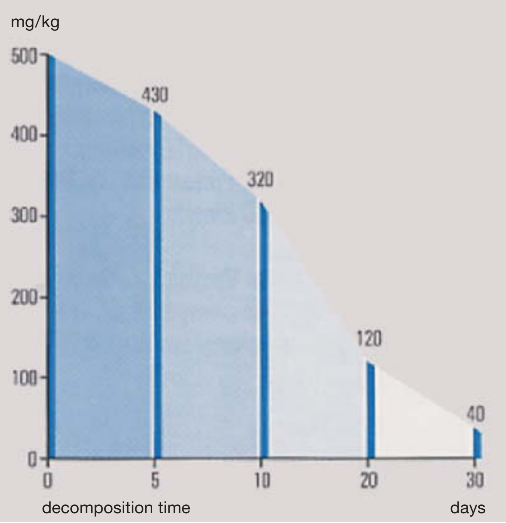


Fig. 3: The residual soil concentration of DEHP, a softener for polyvinyl chloride.

Flame retardants reduce ignitability, flame formation and burning. These are mainly aluminium-magnesium oxide hydrate, phosphoric acid derivatives and antimony trioxide. Antimony is classified as a class III heavy metal according to TI-air, highly volatile at high temperatures, but it can be non critically condensed in filter dust. Extenders improve the physical usage properties of polyvinyl chloride. The addition of extenders is mostly limited to soft polyvinyl chloride products, whereby extenders such as chalk, mica, talcum, limestone, marble, gypsum, quartz powder, kaolin and magnesium oxide do not lead to disposal hazards.

Commercial forms: white powder, aqueous dispersions, emulsions ("polyvinyl chloride pastes"), fillable and dyeable dispersions in plasticizer (without solvent). The normal commercial types of polyvinyl chloride may or may not contain sodium carbonate (heat stabilized against HCl splitting). Polyvinyl chloride is soluble in cyclohexanon, tetrahydrofuran. As plasticizer: e.g. dibutylphthalate (for coating pastes approx. 30–50% plasticizer; pastes with high K value + 20–30% plasticizer + 5–10% organic solvent such as benzine, for better coatability). The polyvinyl chloride films are translucent, rubber-like or leathery hard, softening above approx. 70°C, non-flammable, resistant. Film forming, e.g. after coating, by brief heating to 160–180°C. If embossing is desired this must take place after heat treatment whilst the polyvinyl chloride layer is still hot. Pure polyvinyl chloride is not stable, i.e. particularly under the intensive effects of heat and sunlight it tends towards hydrochloric acid splitting, which can have an autocatalytic accelerating effect, forming polyenes (metal corrosion, discoloration from yellow to black, brittleness).

It has been known since the 1970s that monomer vinyl chloride is toxic and has a carcinogenic effect. The question was soon posed, whether polyvinyl chloride depolymerizes to form vinyl chloride when welded, thus posing a hazard in the workplace. Thermal decomposition was therefore thoroughly investigated. Even at temperatures of 100–120°C polyvinyl chloride shows clear decomposition effects. If it is heated in air, at between 250–300°C it splits the majority of the chlorine in the form of hydrochloric acid. In addition, carbon dioxide, carbon monoxide and benzene are emitted as further main components.

Welding takes place within the temperature range of 180–230°C. No depolymerization occurs at this degree of thermal loading, however any residual monomers from production may be converted into the gaseous phase. Whereas prior to 1974 raw polyvinyl chloride contained residual monomer proportions of 1000–10 000 µg/g, now usually less than 10 µg/g is detected. In animal experiments pyrolysis gases of polyvinyl chloride containing a plasticizer have proved to be more toxic than products without a plasticizer.

As part of preventative health measures, toxicologically relevant substances, which can occur during the welding of polyvinyl chloride coated fabrics, have been detected within the breathing range of those carrying out the welding. In addition to vinyl chloride, hydrogen chloride and benzene, the associated plasticizer diethylhexylphthalate was also detected analytically. The measured pollutant concentrations were below the relevant TLV values for both hot air welding and heated wedge pressure welding. In heated wedge pressure welding, however, due to the pyrolysis of polyvinyl chloride residues on the hot metal wedge, at a temperature of approx. 400°C, significantly increased pollutant concentrations occurred. Although these were outside the direct breathing area, in unfavourable air conditions the TLV values could be temporarily exceeded. Therefore, heated wedge pressure welding plants should be ventilated in the pyrolysis area.

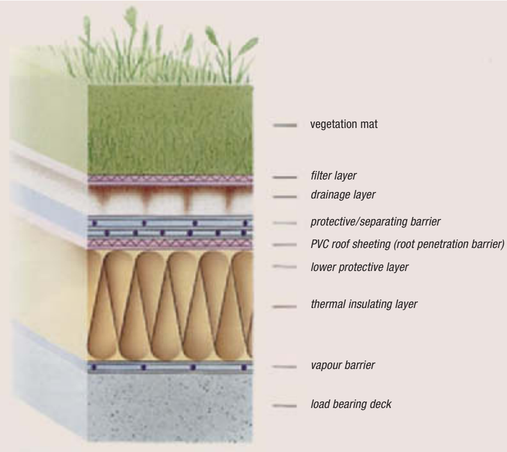


Fig. 4: The construction of a grassed roof sealed using polyvinyl chloride sheeting.

Polyvinyl chloride is one of the most versatile raw materials for the coating of textile and other carriers. Its most outstanding property is the pasteability of types manufactured according to the emulsion polymerization process. With the aid of plasticizers, e.g. dioctylphthalate, the polyvinyl chloride grain is converted into an easily spreadable plastisol, which can be gelled into an elastic film after application. Technical polyester fabrics coated with plastisols are used widely in the form of awning materials for various fields of application. Noteworthy examples are lorry tarpaulins and materials for air-inflated structures and also use in geotextiles (Fig. 4).

The breakthrough in the fashionable, leather-look field, owes its existence to both the foamability of polyvinyl chloride and the diverse thermoplastic shaping options, which are due to the wide softening range. The result is synthetic leather, which consists of a compact, e.g. leather-like formed covering film, a volume-providing, chemically inserted foaming layer and a textile carrier.

PVC can also be applied to textile bases in organic solvents, in the form of aqueous dispersions and in particular as thermoplastic masses. The properties of the so-called dry blend can be varied in widely by compounding. However, the group of polyvinyl chloride coated textiles still includes fields, upon which requirements with regard to physiological behaviour must be imposed. In general, this applies to cushion, shoe and clothing materials. Although there has been no shortage of attempts to make these coatings "breathable", it must be said that the sitting and wearing comfort of coated products is unsatisfactory. The same also applies to the various rubber types (according to Brocks, also Schefer et al.).

Polyvinyl chloride copolymer fibres Vinyl chloride copolymers, group of modified polyvinyl chloride types in the form of multipolymer fibres. Application: technical fabrics, protective clothing; also heat-pressure welded with other fibres, however usually mixed due to low strength and high expansion (cotton, wool, viscose staple).

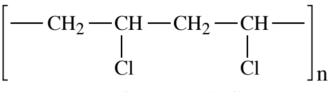
Polyvinyl chloride dyeings, identification tests,

I. Similarly to → Acrylic dyeings, identification of dye class, for the detection of disperse dyes the fibre sample is boiled with the following solvents one after the other: water (= no colouring or only a trace); alcohol (clear colouring); glacial acetic acid (strong colouring); concentrated ammonia (no colouring or trace); benzene test.

II. Disperse dyes under consideration are detected as follows: boil sample in test tube for 4–5 min with 5–8 ml of the following in succession: 1. Water; the solution is not coloured; 2. Denatured alcohol; the solution is slightly coloured. Or place the sample in a mixture of alcohol and acetic acid ester 1 : 1 for approx. 10 min at room temperature. Disperse dyes go completely or mainly into solution. The latter is now vaporized, absorbed in water and used to dye acetate fibres experimentally at 70–75°C with the addition of soap. If colouring takes place then disperse dyes are present.

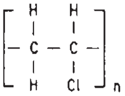
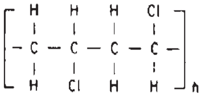
Polyvinyl chloride fibre modification In addition to → Polyvinyl chloride copolymer fibres the varied tacticity in the polyvinylchloride macromolecule structure has found practical application, which has an effect on important fibre constants, as shown in the Tab.

Polyvinyl chloride fibres Group of synthetic polymer fibres (the first commercially available synthetic fibres) made of at least 85% → Polyvinyl chloride (if lesser proportion: → Polyvinyl chloride copolymer fibres), which can also be post-chlorinated, whereby two polyvinyl chloride fibre types can be differentiated:

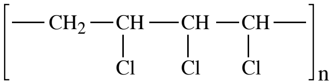


$$\left[-CH_2-\underset{\displaystyle Cl}{\underset{|}{CH}}-CH_2-\underset{\displaystyle Cl}{\underset{|}{CH}}- \right]_n$$

PVC (55–57 % Cl)

	normal PVC	syndiotactic PVC
structural diagram	 $\left[-\overset{\overset{H}{\vert}}{\underset{\underset{H}{\vert}}{C}}-\overset{\overset{H}{\vert}}{\underset{\underset{Cl}{\vert}}{C}}- \right]_n$	 $\left[-\overset{\overset{H}{\vert}}{\underset{\underset{H}{\vert}}{C}}-\overset{\overset{H}{\vert}}{\underset{\underset{Cl}{\vert}}{C}}-\overset{\overset{H}{\vert}}{\underset{\underset{H}{\vert}}{C}}-\overset{\overset{Cl}{\vert}}{\underset{\underset{H}{\vert}}{C}}- \right]_n$
glass transition point °C	70	100
softening temperature °C	65 - 70	125 - 130
decomposition temperature °C	160 - 200	160 - 200
strength cN/tex	2,0 - 3,0	2,5 - 3,5
expansion dry %	10 - 25	30 - 60
		poor solubility

Tab.: Differences between atactic (normal) and syndiotactic PVC fibres.



$$\left[-CH_2-\underset{\underset{Cl}{\vert}}{CH}-\underset{\underset{Cl}{\vert}}{CH}-\underset{\underset{Cl}{\vert}}{CH}- \right]_n$$

PVC+ (60–64 % Cl)

Manufacture according to dry or wet spinning process (drawn 3–8-fold). Properties (basic physical and chemical properties → Synthetic fibres), to the extent that they are approximately comparable: external fibre shape similar to cotton (preferably milky-cloudy, not delustred); difficult to burn, difficult to ignite; normal moisture content virtually zero, therefore does not absorb sweat; water immune (no swelling); same mechanical properties dry and wet; easy to wash, quick drying and highly crease resistant; heat retention capacity good; excellent electrical insulator; electrostatic charge has a specific anti-rheumatic effect; good light and weather resistance (exceeds that of polyester). Excellent resistance to micro-organisms and pests; physiologically harmless; heat sensitive, i.e. heat resistant < 60°C (not ironing fast); high shrinkage > 70 °C. Within certain limits thermofixable up to 100°C (hot water 30 min or dry steam 3–10 s, e.g. stenters). Chemical resistance: excellent against alkalis and oxidizing agents, excellent against acids, variable against organic solvents. Trichloroethylene brings about high shrinking, swelling and hardening. Dye affinity is normally not particularly good (→ Dyeing of polyvinylchloride fibres). The addition of a swelling agent is advisable. Application: mainly for technical purposes such as work clothing, filter cloths, screen fabrics, brushes and awning cloth, blankets, decorative material, cushion covers, quilt fillings; (in fibre mixes) for non-wovens, rheumatism underwear, underwear, knitgoods, pullovers, swimming costumes, filling material for cold weather clothing, shrunk for imitation suede (sports clothing, gloves), etc.

Polyvinyl chloride fibres in printing Polyvinyl chloride can be printed using cationic dyes precipitated with anionic auxiliaries. The high plasticity of the fibres, e.g. during fixing, and the often moderate light fastness should be borne in mind.

Polyvinyl chloride recycling For years, production residues from polyvinyl chloride have been collected and re-used. This type of recycling contributes towards optimizing production and reducing costs. From a technical point of view, the re-use of waste is no longer a problem, because polyvinyl chloride can be recycled with other plastics and also on its own. Therefore numerous projects have come into being, particularly in the field of construction, for returning used polyvinyl chloride products. New floors are made from old. The first European recycling plant for polyvinyl chloride floor coverings in Grossefehn in East Friesland commenced production as early as 1990. This plant produces a high-value powder from old floor coverings, which is used by floor covering manufacturers in the production of new floors. The recycled material can also be used in other fields of application. At the same time a pilot project, initially in three areas in Lower Saxony, North Rhine Westfalia and Rhineland-Palatinate, was initiated to collect used floor coverings. The working group Polyvinyl Chloride Floor Covering Recycling (AgPR – Arbeitsgemeinschaft Polyvinylchlorid-Bodenbelag Recycling), a union of 20 polyvinyl chloride raw material and floor covering manufacturers from Germany and other European countries, initiated and financed this large project (Fig. 1). In large consumers, such as public institutions or industrial companies, the person laying floor covering collects

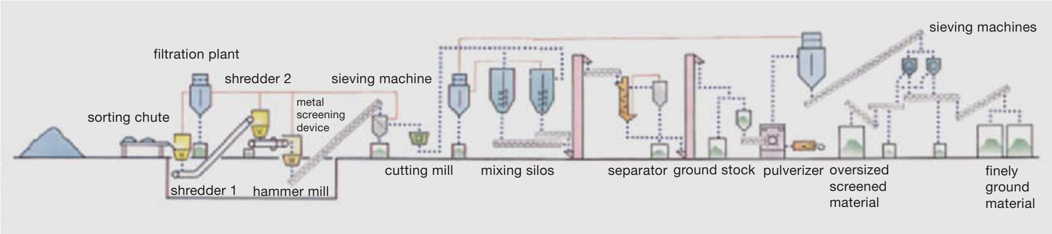


Fig. 1: The Großefehn facility for recycling PVC floor covering material. On delivery the disposed flooring is sorted and coarsely shredded before passing to the actual recycling process. The end result of the process is a finely ground PVC powder which can be used again in the manufacture of PVC floor coverings.

the old floor covering and delivers it to Grossefehn for processing. There are containers in large shops and DIY supermarkets for the free depositing of old material. The AgPR believes that in the medium-term it will be possible to collect approx. 30 000 t old floor coverings annually. This represents around one third of total production. The plant in Grossefehn is commercially viable, if only approx. 6000 t old material is delivered annually. Six to eight plants would be necessary for the reprocessing of all old floor coverings in Germany in the long term.

As there is only a small market for the material reprocessing of the proportion of polyvinyl chloride and polyvinyl chloride mix products contained in domestic waste and because polyvinyl chloride is a high-value fuel, the waste heat utilization of this product currently seems justified. If modern exhaust gas cleaning processes are used in accordance with the anticipated exhaust gas cleaning conditions there is no need to fear critical environmental pollution from the constituents of polyvinyl chloride, either in the form of chlorine or heavy metal emissions or in increased dioxin and furane emissions. Even now, reusable residual substances such as sodium chloride, calcium chloride and hydrochloric acid can be generated from the chlorine of the polyvinyl chloride, and these products are taken back by the chemical industry. Thermal utilization of the medium and long-life polyvinyl chloride products, possibly containing cadmium, which do not belong in domestic waste, should be ruled out due to the necessary purity of the wastes and the possible feed back into the material cycle. The use of pyrolysis, hydrolysis or hydration as thermal processes for these polyvinyl chloride products does not count as thermal waste reprocessing, but as a thermal “decomposition” process for the reprocessing of the polyvinyl chloride constituents. When waste is burnt, organic pollutants in waste gas are the only pollutants, which are partially recreated after thermal decomposition of the charging material. All other pollutants, heavy metals, salts, etc. come

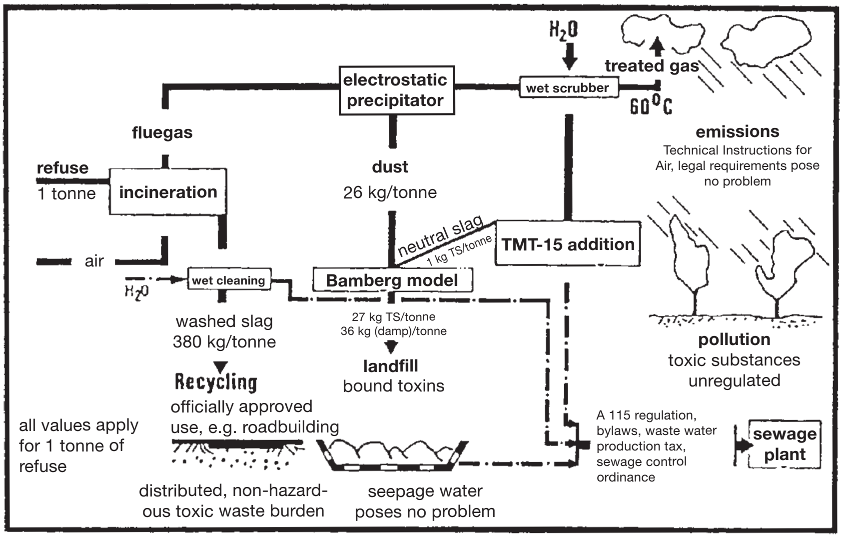


Fig. 2: Waste incineration process technology.

from the waste charging product itself. Many investigations have provided evidence showing that organic pollutants are released in almost all thermal processes. At temperatures > 800 °C if cold draught is avoided in the combustion area the creation of organic pollutants can generally be avoided. Prerequisites for the formation of dioxins and furanes are favourable temperatures of 300–400°C, the presence of chlorides, carbons, fly ash, oxygen and metal constituents with a catalytic action, and a sufficiently long reaction time. The chloride present in domestic waste, even without polyvinyl chloride, is in itself sufficient for the formation of dioxin. The above-mentioned conditions are normally in place during the flue gas cooling phase from the boiler until the first stage of gas cleaning. The creation of dioxins and furanes can be reduced, e.g. by improved cleaning of the boiler tubes, by constructional improvements in the boilers and by low flue gas temperatures after the boiler or before dust collection.

The use of inhibitors in the raw gas at a temperature of approx. 400°C or the use of activated carbon for adsorptive retention of emissions and organic pollutants, or an oxidation stage by ceramic catalysts may prove to be a trend for the extensive reduction of polychlorinated and polybrominated hydrocarbons, including dioxins and furanes. Using these methods it should be possible to maintain the extremely low emission limit required by the new 17th BImSchG (Bundes-Immissionsschutzgesetz – German Federal Immission Protection Law) for dioxin/furane of 0.1 ng TE/m^3. In waste combustion it is known that dioxins are not created with optimal combustion management and if possible complete burning at high temperatures is important in the combustion zone (Fig. 2).

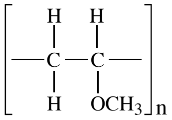
Polyvinyl cyanide → Polyacrylonitrile.

Polyvinyl derivatives Plastics or synthetic resins as polymerization products of vinyl derivatives, which have in common the vinyl group $CH_2=CH–$ (polyvinyl group: $–CH_2CH–$).

Important vinyl derivatives:

$CH_2=CH–CH=CH_2$	divinyl (butadiene)
$CH_2=CH–C\equiv CH$	vinyl acetylene
$CH_2=CH_2$	ethylene
$CH_2=CH–HCO$	acrolein
$CH_2=CH–Cl$	vinyl chloride
$CH_2=CH–F$	vinyl fluoride
$CH_2=CH–OH$	vinyl alcohol (unstable)
$CH_2=CH–OCOCH_3$	vinyl acetate
$CH_2=CH–OCH_3$	vinyl methyl ether
$CH_2=C(CH_3)_2$	isobutylene
$CH_2=CH–C_6H_5$	styrene (vinyl benzene)
$CH_2=CH–CN$	acrylonitrile (vinyl cyanide)
$CH_2=CHCOOH$	acrylic acid
$CH_2=CH–COOCH_3$	methacrylic acid ester
$CH_2=C–CH_3COOH$	methacrylic acid
$CH_2=C–CH_3COOCH_3$	methacrylic acid methyl ester
$CH_2=CCl_2$	vinylidene chloride
$CH_2=C(CN)_2$	vinylidene cyanide

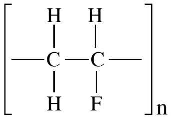
Polyvinyl ethers Synthetic polymer of → Vinyl ether. Particularly polyvinyl methyl ether.



$$\left[-\overset{\displaystyle H}{\underset{\displaystyle H}{\overset{|}{\underset{|}{C}}}}-\overset{\displaystyle H}{\underset{\displaystyle OCH_3}{\overset{|}{\underset{|}{C}}}}- \right]_n$$

Soluble in water and organic solvents. Resistant to saponification. Reversible coagulation point at 30°C in aqueous solution. Generates full soft handle. Application: sizing agent, finishing agent, printing thickeners (organically soluble); adhesive; lacquer raw material; softener for nitrate cellulose.

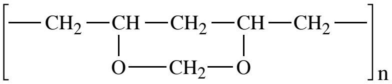
Polyvinyl fluoride Polymerized vinyl fluoride, produced from acetylene and hydrogen fluoride (polymerization at 810 bar).



$$\left[-\overset{\displaystyle H}{\underset{\displaystyle H}{\overset{|}{\underset{|}{C}}}}-\overset{\displaystyle H}{\underset{\displaystyle F}{\overset{|}{\underset{|}{C}}}}- \right]_n$$

Polyvinyl fluoride fibres are produced in the melt-spin process and drawn (100%). Properties: melting point 175–200°C; softening point 130°C; temperature resistance and shrinkage are superior to those of polyvinyl chloride fibres, as is their resistance to light and chemicals; insoluble in xylene; very difficult to dye (thus spin-dyeing). Dyed polyvinyl fluoride is used as a heat resistant fibre glass application.

Polyvinyl formal Conversion product of → Polyvinyl alcohol and formaldehyde (→ Polyvinyl acetals).

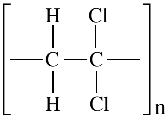


$$\left[\begin{array}{ccccc} -CH_2- & CH & -CH_2- & CH & -CH_2- \\ & | & & | & \\ & O & -CH_2- & O & \end{array}\right]_n$$

Softening point approx. 190°C; specifically soluble in chlorinated hydrocarbons (such as dichloromethane, chloroform), ketones, aromatic hydrocarbons (toluene, xylene), aromatic alcohols (such as benzylalcohol) and such mixtures. Application: lacquer raw material (plus softener, chlorinated aromatics), compatible only with nitrate cellulose and phenoplasts. Polyvinyl formal fibres of this type have not yet gained any importance in the textile field, in contrast to → Polyvinyl alcohol fibres, which are subsequently formalized under other conditions (only approx. 35–40% of the OH groups; thus not pure polyvinyl formal) and are thus completely insoluble and also resistant against most organic solvents.

Polyvinyl formal fibres → Polyvinyl alcohol fibres that are subsequently hardened with formaldehyde (degree of formalization approx. 35–45% of the OH groups) are also termed polyvinyl formal fibres.

Polyvinylidene chloride Synthetic polymer; of asymmetric dichloroethylene, produced by, e.g. chlorinated vinyl chloride and HCl splitting.



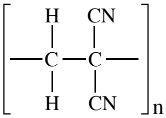
$$\left[-\overset{\mathrm{H}}{\underset{\mathrm{H}}{\mathrm{C}}}-\overset{\mathrm{Cl}}{\underset{\mathrm{Cl}}{\mathrm{C}}}-\right]_n$$

Application: emulsion for lacquer, adhesive, for coating; (acrylonitrile copolymer:) acid resistant pipe and container lining, also tank linings for benzine and petroleum products → Polyvinylidene chloride fibres.

Polyvinylidene chloride fibres Synthetic polymer fibres of min. 80% vinylidene chloride. When spun and drawn, such polyvinylidene chloride fibres mainly form horsehair-like monofilaments (for wear-resistant cushion and grille cloths, filter cloths, sieve fabrics, conveyor belts, ropes, bristles, decorative materials) and also for continuous filament yarn and smooth and curly fibres (for nonwovens, technical felts, upholstery and grille cloth, blankets, carpets, etc.). Cross-section round or oval. Properties (largely similar to polyvinyl chloride fibres, superior, e.g. against solvents, more recent polyvinylidene chloride fibres also in thermal behaviour): Density 1.65–1.75; normal moisture 0–0.1%; strength dry/wet 13–21 cN/tex; elongation, dry/wet 20–30%; difficult to burn, dirt repellent, resistant against mildew and bacteria, good resistance against cold acids (except H_2SO_4 conc.), alkalis (except concentrated) and most organic solvents including acetone (if they contain oxygen, e.g. dioxane, there is a swelling or softening effect); heat resistance differs depending upon origin: shrinks even at 60–75°C (softens at 90–135°C), sometimes boiling resistant, softens at 115–140°C, shrinking range starts at 145–155°C and melting point 150–175°C. Chlorine resistance poor; dyeable (usually jet dyeing) with disperse dyes. Detection → Morpholine test.

Polyvinylidene cyanide → Polyvinylidene dinitrile.

Polyvinylidene dinitrile (polyvinylidene cyanide, ethylidene dicyanide, 1.1 dicyanoethene), synthetic polymer of vinylidene cyanide. Used as copolymer (vinylidene cyanide/vinyl acetate 1 : 1) for the production of → Polyvinylidene dinitrile fibres.



$$\left[-\overset{\mathrm{H}}{\underset{\mathrm{H}}{\mathrm{C}}}-\overset{\mathrm{CN}}{\underset{\mathrm{CN}}{\mathrm{C}}}-\right]_n$$

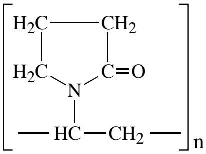
Polyvinylidene dinitrile fibres (dinitrile fibres), copolymer fibres of type → Polyvinylidene dinitrile, 50–230% drawn, cashmere-like character. Properties: cross-section kidney shaped, density 1.18; normal moisture take-up 2–3%; softening point 171–176°C; melting point 175°C; breaking strength 20–40 cN/tex (wet 15 cN/tex); elongation at break dry/wet 30–35%; burnable similar to cotton; good weather resistance; good resistance against mildew, rotting, insects; low shrinkage even after repeated boiling wash (max. 1%); very good continuous heat resistance (e.g. 195 days at 149°C: 100% breaking strength); insoluble in diluted acids; soluble in dioxan, dimethylformamide; sensitive against strong alkaline baths, dry temperature above 160°C, wet temperature above 120°C. Bleach with acid hypochlorite or sodium chlorite. Dyeing: particularly disperse dyes and naphthols, dark shades with carrier (methylsalicylate); polyvinylidene dinitrile fibres are more difficult to dye than polyacrylonitrile fibres, despite loosened "packing density" due to copolymerization. Application: pure or mixed (wool, cotton), particularly for knitgoods, high quality pile fabrics (e.g. imitation fur coat materials, downy soft, elegant fall, no pilling), for nonwovens, etc.

Polyvinylidene group ($–CH_2–CR_2–$); for R = Cl → Polyvinylidene chloride; for R = CN → Polyvinylidene dinitrile.

Polyvinyl methyl ether → Polyvinyl ethers.

Polyvinyl products → Polyvinyl derivatives.

Polyvinylpyrrolidone (PVP). Synthetic polymer of type



Polyvinylpyrrolidones can be produced in any desired chain length by polymerization, are soluble in water and many organic solvents; possess a certain structural similarity to protein substances, and this gives rise to very varied applications. Low viscosity polyvinylpyrrolidones form a high-quality blood replacement fluid with unlimited lasting qualities, whereas more viscose polyvinylpyrrolidone has adhesive properties (colloids), which are suitable for use as thickeners and finishing agents in aqueous solutions or emulsions. Particularly interesting property: even relatively low quantities of polyvinylpyrrolidones bind many dyes in solution and make removal impossible.

Polyzymes → Amylases, belonging to the class of bacterial enzymes, however not so heat resistant; effectiveness from 40°C; high liquefaction power, low saccharification power for starches. Bred from cultures of aspergillus orzyae on wheat germ.

POM → Polyoxymethylenes.

POM derivatives As POM dimethylether, less as diacetate, application in resin finishing as a cross-linker (formaldehyde donor) for dry cross-linking processes with, e.g. magnesium chloride as catalyst; usually together with reactive resins, particularly DMEU with buffering → Methoxymethylmelamines; wash and wear finishes with particularly good wet crease resistance.

Pond No longer permissible unit of force. SI unit is → Newton. Conversion: 1 p = 9.80665 mN; 1 kp = 9.80665 N.

Pongee Thin Chinese silk taffeta (warp: grège; weft: grège or schappe) for lining and clothing materials.

Poplin Plain weave fabric with very tightly set warp (1.5–3 times more than the weft) made of cotton, viscose, wool or silk, often in mixtures. Particular characteristic is a marked cross ribbed quality, which arises due to the somewhat loosely set weft. Ply-poplin: warp ply, weft single yarn. Full poplin: warp and weft ply; the material quality is somewhat more lustrous on the right side. Imitation poplin: ratio of warp and weft 1 : 1, ribbing is achieved by an appropriately thick weft. Only fine yarn numbers of certain, particularly fine cotton are used in the manufacture of good cotton poplin. The material is dyed and printed. It is also sanforized and impregnated for different applications. Application: men's shirts, pyjamas, ladies' dresses and blouses, rain and dust coats, camping equipment, etc.

Population equivalence (PE). Measure of the amount of organic pollutants (→ Waste water pollutant load), which is transported with waste water. A population equivalence corresponds with the pollutant load which an inhabitant produces per day on average, namely 60 g BOD_5 per day. Calculation from → BOD_5 of the waste water A (mg/1) and discharge Q (m^3/day) according to:

$$\mathbf{PE} = \frac{A \cdot Q}{60}$$

Populations Whole, collective, the quantity underlying the → Statistical analysis of all units or events. Finite populations only incorporate a certain, finite number of units. In an infinitely large population the number of units is indeterminate (e.g. quantity of all possible measurements under similar conditions).

Porcelain printing In hand printing with zinc plate screens small white, plastic dot patterns applied to dark coloured, usually black, silk.

Porcupine creel Carrier for a cross-wound package dyer in which packages are mounted individually on spindles which radiate horizontally from a hollow cylinder; no longer commonly used for cotton.

Pore size of fibres Of primary interest from the point of view of finishing technology are the intermicellar gaps (crystallite) of the → Pore volume of textiles. The so-called pore width of cellulose fibres is approximately 0.6 nm in dry state (with a few larger gaps and hollows of around 5–13 nm diameter and approx. 100 nm length), in aqueous swollen state 4–6 nm. These areas are initially only reached by water molecules and only after widening by swelling by dissolved substances. In swollen cellulose acetate we can only expect pore widths of 5–6 nm. The ratio of pore widths in dry and swollen wool is around 0.6 : 4 nm. The significantly more compact synthetic fibres with their low water take-up or water swellability only achieve pore sizes up to around 0.8–1 nm even in aqueous wetted state, which in combination with the lack of hydrophilic groups explains some dyeing difficulties, so that preswelling with suitable substances (carrier) should be given increased practical importance for the widening of the inner pore volume. Generally it is of dubious value to compare the pore sizes of water swollen fibres with the dimensions of dye molecules, because the intermicellar areas actually have poorly defined shapes, no clear demarcations and probably varying sizes. Furthermore, thermal energies (diffusion speed) and other fibre specific factors also play a decisive role.

Adsorption methods (nitrogen adsorption, mercury porosimetry) or x-ray small angle dispersion (crystallinity changes) are possible investigative techniques that lend themselves to the quantitative description of pores for solids and textile materials. The transferability of the results achieved with a dry fibre sample to behaviour in aqueous systems is dubious, particularly for cellulose, because the water present in the cellulose fibre, bound in different structural states, plays a significant role in determining the accessibility of the gaps in the swollen fibres. However, almost all textile pretreatment and finishing takes place in aqueous treatment liquors, in which one must logically assume a water swollen state. For this reason, the method of determining the pore structure using so-called "feeler molecules" of different sizes can be used, in which the penetration depth into the cellulosic substrate can be determined on the basis of the dilution of an aqueous solution of precisely known content. Large molecules cannot, or can only partially, penetrate small pores, i.e. they are "excluded" from the uniform distribution in the pore system. This approach takes its name from this effect, namely size-exclusion (SE) method (Fig. 1). These measurements permit a characterization of the water filled pore proportion, which is accessible to the molecules of a size typical of dyeing and finishing chemicals. However, a number of multiple measurements must be taken in order to plot a so-called size-

Pore size of fibres

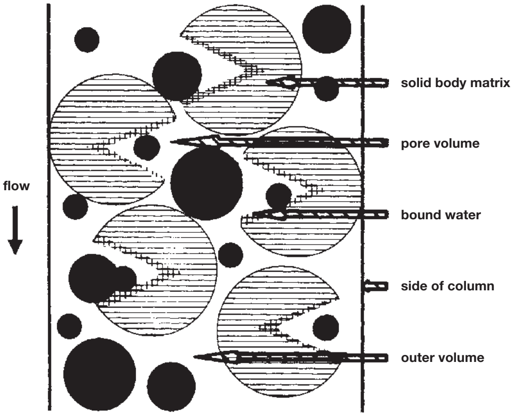


Fig. 1: The principle of exclusion chromatography in cellulose material. The matrix of cellulose solid bodies (dry weight m) possesses both bound water (not accessible) and water-filled (accessible) pores (volume V_p). Large molecules become distributed within the "outer volume" V_o, while medium and small sized molecules have available appropriately sized pores as their distribution volume.

exclusion curve for the molecular size range that is of interest; furthermore the investigation conditions (temperature, sample concentration) should be precisely checked, because otherwise significant disruptive possibilities can strongly scatter the measured data. As an alternative, the size-exclusion chromatography technique (SEC or gel permeation chromatography GPC) first used for milled cotton can be used for measurements on mercerized cellulose.

In all size exclusion chromatography methods, a chromatographic column made of glass or special steel is filled ("packed") with the textile material (the so-called "stationary phase") in a defined manner and swollen with water. The hollows thus created, or expanded, are more easily accessible to small molecules than large ones, so that different dwell times (chromatographic retention times) occur in the columns depending upon their size. Under the condition that no interactions occur between the molecules and the gel-like swollen textile material (usually cotton), the available internal volume can be calculated from the measured retention time. Therefore, an image of the gap distribution can be obtained by the use of differently sized molecules. Evaluation takes place using the so-called elution volume V_{el} (ml), which is calculated from the retention time t_R (min) of the sample molecules and the constant throughflow of elution agent (water) u (ml/min):

$$V_{el} = t_R \cdot u$$

This value is plotted on a diagram against the logarithm (base 10) of the molecular weight (log MW) of the compound in question, because the molecular weight can span several powers of ten. In the ideal case an S-shaped curve is obtained (Fig. 2), the path of which can be explained as follows: for substances with a high molecular weight, the elution volume is virtually independent of the size of the molecules, because they only move in the "external water" in the direction of flow and cannot penetrate into the pore system. As the size falls, V_{el} begins to increase, because from a certain molecular size the pores become accessible and thus the volume that is available for distribution amongst the molecules is increased. In small molecules, size differences are again meaningless for the elution volumes, because they penetrate fully into the hollows. Based upon the intersection point and axis projections drawn in Fig. 2 the "distribution or separation range" and the accessible total pore volume V_p and the "external volume" (size-exclusion volume V_o) can be read off from the curve. The elution data for individual columns soon differ from one another due to different values for the external volume V_o and the dry mass of the column packing m, determined by the column geometry and the packing process, so the curves must be "normalized". A tried and tested method is moving to the left of the value V_o and division by m, from which a "relative elution volume" is obtained:

$$V_{rel} = (V_{el} - V_o) \cdot m^{-1} \text{ (ml/g)}$$

This value represents the available inner volume per unit mass of the textile substrate for a molecule.

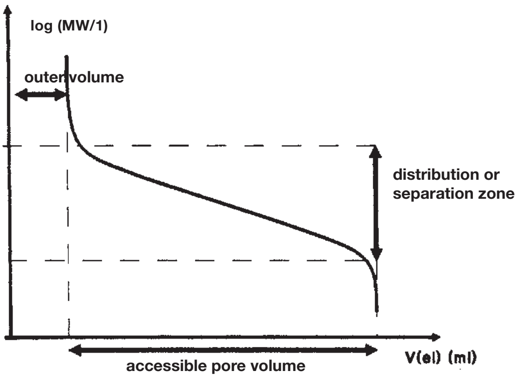


Fig. 2: Evaluating data from exclusion chromatography: determination of the "outer volume" V_o, the total accessible pore volume V_p, and the distribution or separation zone.

In the selection of the "feeler molecule", the approximately spherical molecules of dextran-fractions (polysaccharide) and the oligosaccharides and monosaccharides are usually used; or also the long chained poly(ethyleneglycol) molecules, which have the same molecular weight as dextranes and because of their long form can penetrate less far into the pore system. These two types of molecules can be viewed as limiting examples for a particularly marked form; most dyeing and finishing chemicals, because of their shape, lie between these two extremes (according to Bobleter).

Pore volume of textiles Porosity is made up of three elements:

1. porosity within the fibres, so-called intrafibrillary porosity.
2. porosity between the individual fibres, so-called interfibrillary porosity.
3. the gaps between the yarn threads, so-called yarn porosity.

The part of this total porosity that is accessible to fluids is called effective porosity and is composed primarily of 2 and 3. The current fabric porosity (also → Air permeability) is subject to great differences. The pore volume of textile fabrics is calculated as follows:

$$\frac{\text{density} - \text{volumetric weight}}{\text{density}} \cdot 100\ \%$$

Pores Small holes, fine openings; → Porosity.

Porosimetry The properties of fibres are determined to a large degree by the topographic condition of their surface. However, meso and micropores (< 50 nm) can be generated by redox or acid treatments, which can have a strong influence upon swelling behaviour and dyeing properties. Meso and microporosity bring about a significantly increased specific fibre surface. Macropores, on the other hand, are only transport routes, and make a much lower contribution to the specific surface. The porosity of the fibre can be determined either by gas sorption or mercury penetration measurements. Using a fully automatic gas sorption device for the volumetric determination of complete adsorption and desorption isotherms and with the aid of the microstructure data station, problem-oriented evaluation is possible in accordance with the Brunauer-Emmet-Teller method and according to Dubinin. Information is obtained about the specific surface, the pore diameter and the pore volume, which provides data about manufacturing process or topographic modification as a result of finishing processes. The mercury porosimeter is computer controlled equipment for determining the porosity in the range of 0–4000 bar according to the mercury penetration method. Pores with radii between 2 nm and 600 μm are detected. The method can be used to make predictions about the size of the specific surface and the specific pore volume, density, porosity and distribution of pore radii and particle sizes.

Porosity We need to make a differentiation here between fabric porosity, thread porosity and fibre porosity. If we describe a fabric as a porous plate and assume that threads and fibres are massive, then the proportion of empty space in the fabric is characterised by the fabric porosity ε_g (Fig. 1). This porosity plays an important role in the hydrodynamics of a liquid soaking into the fabric and in the transport of substances by conveyance in a film of liquid.

Fig. 1: Fabric porosity: the fabric is a porous plate, while the threads are solid.

If, however, the threads are assumed to be porous and the fibres are assumed to be massive, then we are dealing with so-called thread porosity ε_f, to determine the proportion of empty space in the threads (Fig. 2).

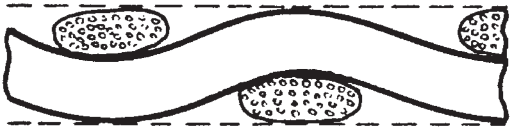


Fig 2: Thread porosity: the threads are porous, while their fibres are solid.

The overall material porosity ε_o is found by the definition formula:

$$1 - \varepsilon_o = \frac{\rho'}{\rho_s\, d}$$

ρ' = material mass per unit area
ρ_s = true material density
d = material thickness

and is made up of the two porosities ε_g and ε_f according to the material balance:

$$1 - \varepsilon_o = (1 - \varepsilon_g) \cdot (1 - \varepsilon_f)$$

The theories of dyeing kinetics are concerned with the nature of dye diffusion in polymer solids. They are primarily based upon two important, fundamentally different model assumptions of dye diffusion in fibres, namely the pore diffusion model and the free volume or segment movement model (Fig. 3). The pore mode represents the fibre as a solid with a network of interlinked channels or pores, which are filled with the dye-

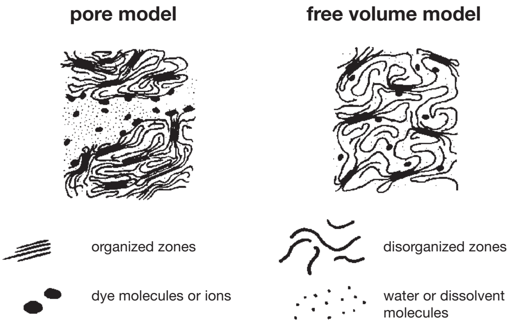


Fig. 3: The diffusion of dye within fibres: compare the pore model with the free volume model (according to Meyer, Rohner and Zollinger).

ing liquid, normally water. The dissolved dye diffuses through these pores, at the same time being adsorbed into the pore wall. The porosity P, i.e. the pore proportion of the entire volume of the fibre and the adsorption equilibrium are the main factors in making quantitative predictions regarding the diffusion speed.

The free volume model, on the other hand, describes the dyeing process as the diffusion of dye through disordered ("amorphous") parts of the polymer matrix. The diffusion speed is thus determined by the segment mobility of the polymer chains.

The most important evidence supporting this theory is the observation that the temperature dependency of the dyeing speed of a fibre type lies above a certain temperature. This means that the resistance of the fibre's solid structure against the penetration of the dye is much less above this temperature. This is called the glass transition temperature (T_g) of the fibre in question, more precisely as the glass transition temperature under dyeing conditions or the dyeing transition temperature (T_D), because the classical glass transition temperature is a value measured in the dry state. Both values T_g and T_D correspond with the temperatures at which (from a microscopic point of view) the non-ordered part of the polymer goes over from a glass-like to a visco-elastic state or (on a molecular basis) at which the disordered segments of the macromolecules become mobile in relation to one another, i.e. to a certain degree become "micro-fluids".

Whether pore or free volume diffusion dominates depends upon the physical structure of the fibres and the reaction conditions. At low temperatures, for example on highly porous polyacrylonitrile fibres, pore diffusion can be detected. Above the dyeing transition temperature the pore diffusion will be an equilibrium of the subsequent diffusion in the solid body according to the free volume model (according to Wassing and Zollinger et al).

Porous coatings A meltable polymer (polyamide/

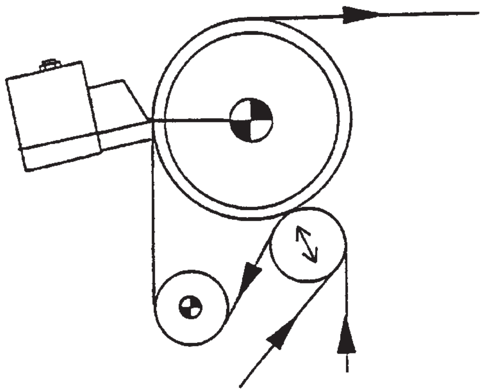


Fig. 1: The application of a porous coating against the coating roller in order to achieve good penetration (Nordson).

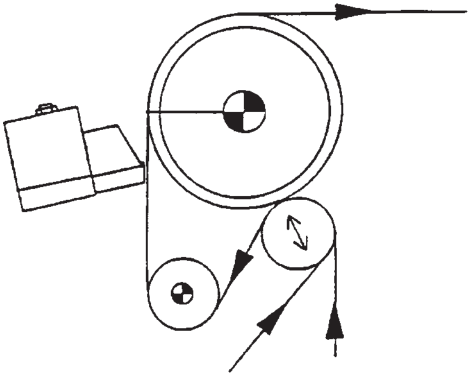


Fig. 2: The application of a porous coating onto the free fabric for the purpose of surface coating (Nordson).

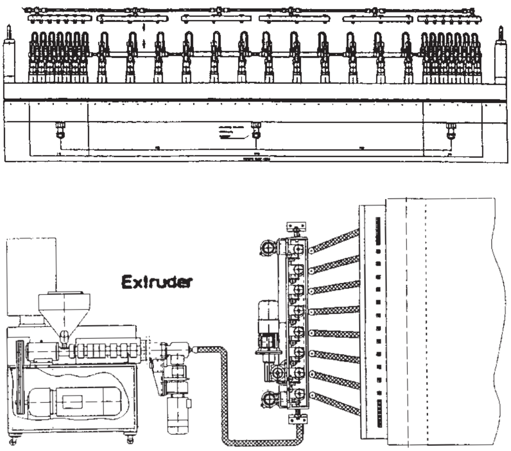


Fig. 3: A typical porous coating facility with extruder and application nozzles (Nordson).

polyethylene or polyurethane) is pressed from extruders mounted on a bar across the width of the material, and applied directly to the material. This gives rise to deep penetration if the extrusion takes place on material running around a roller, whereas extrusion on a free running material gives rise to a surface coating only (Figs. 1–3).

Portal steamer Continuous steamer for single or two-phase printing, combined underfloor/elevated machine type with oil heated steamer cover. Spiral-shaped roller arrangement in narrow arch or channel shape, without deflecting bar. Guaranteed freedom from drips, air and folds. For pile and stretch fabrics; material guidance usually from inside to outside; water stabilization gates for slow cooling off of polyacrylonitrile pile, also warm air gates. All rollers are driven. The spiral-shaped material flow has proved particularly beneficial when used on a continuous production line, e.g. for printing after-treatment or pile fabric dyeing, thus in continuous dyeing. Material content single track 45–170 m, multitrack correspondingly greater content.

Positioning of screen register crosses The automatic repeating of round screens in rotation printing requires a fixed optic for each screen and a fixed point on the screen (register cross). The register cross on the screen can then be detected (e.g. by means of a laser beam). The position of the carrier peg for the screen can also be located in the screen hole of the printing group, which also occurs optically by means of suitable sensors. This relies on there being an end ring glueing device. By means of a simple optical sensor the position of the register cross in relation to the end ring and thus also in relation to the point of application of the carrier peg on the screen opening of the printing machine can be set precisely and reproducibly (see Fig.). Precise cutting of the screen stocking and the control of thermal problems when glueing are further requirements, so that less corrections are necessary in the repeating of the screen in the printing machine.

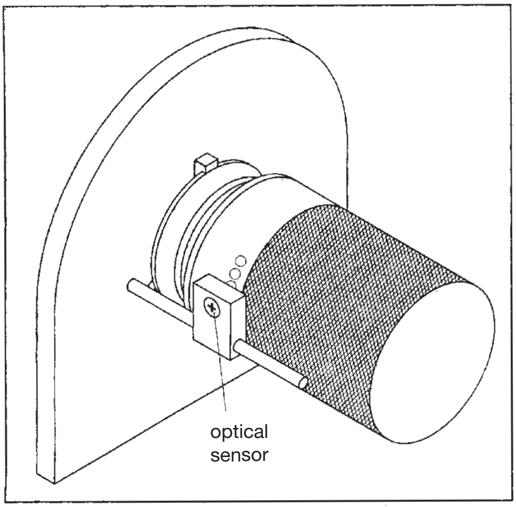


Fig.: An end ring glueing machine with an optical sensor for positioning the screen register cross.

Positive process for screen making The pattern is copied onto the gauze by placing a positive between lamp and photochemical layer and then illuminating. The positive can be produced either photographically or by placing a light-impermeable colour layer over a transparent foil. Whatever the method used, the pattern parts must be impermeable to light. The positive process differs according to working method or type of photosensitive layer:

I. Intensifier process: the illuminated and hardened gelatine layer applied to the gauze should be protected against chemical and mechanical influences during the printing process by a lacquer coating. Initially the gelatine layer (may also be polyvinyl alcohol, etc.) is applied, illuminated through the positive, and hardened thoroughly. This layer is reinforced by coating the inside of the screen uniformly with a film of lacquer. Before the lacquer is dry after coating, the still wet lacquer is rubbed out of the drawing sections on the back with a soft cloth. The gelatine layer, which is not soluble, ensures that the applied lacquer can only be rubbed out of the open areas, which are free of gelatine. Finally, the remaining lacquer film is removed by solvent without leaving a residue. Even greater durability of the screens is achieved if the gelatine layer is also reinforced on the back in the manner described. Another possibility is removal of the lacquer coating from the pattern points by direct suction.

II. Pre-lacquering process: in this method, the gauze is uniformly coated with screen lacquer before the screen is painted with the light sensitive coating. After drying, the light-sensitive coating is uniformly applied to the underside of the screen. It is then illuminated and developed in the normal manner. The lacquer coating on the points covered by the drawing, and thus not illuminated, can now be removed using solvent from the side of the gelatine coating and wiped away. After completion, the gelatine layer can be dissolved thus obtaining a screen printing screen with an extremely durable covering layer.

III. Photolacquer process: this process involves photo lacquers, which have good durability after illumination and washing without additional reinforcement. Particular importance is attributed to this process in the manufacture of screens with half-tone drawings, because the highest possible requirements apply for the drawing fineness to be achieved.

Postboarding Process (Am.) postforming in hosiery fixing, → Boarding.

Post-Cure → Permanent-press process.

Post-curing Variously called delayed and deferred curing: → Permanent-press process.

Post-dyed-bonded-Fabrics American term for laminated fabric or knitgoods, which are dyed after lamination. The binder (polyacrylic or polyurethane base) must endure the entire dyeing process.

Post-mercerization The abrasion resistance of linen cloth with an anti-crease finish can be significantly improved by mercerization after the hardening of the synthetic resin.

Post print washing → After-print-washing.

Potash alum → Aluminium potassium sulphate.

Potassium (K), atomic weight 39.15. Silver-white metal, melting point 62.5°C, cuts easily, lighter than water (specific gravity approximately 0.86). Further properties → Alkali metals. The positive potassium ion forms colourless salts with colourless acid anions, usually with good water solubility, with the exception of potassium bitartrate (cream of tartar).

Potassium bitartrate (cream of tartar, potassium tartaric acid, double potassium tartaric acid), $C_4H_5O_6K$, molecular weight 188. Slightly soluble in cold water, better in hot water. Application: No longer used.

Potassium carbonate (carbonate of potassium, potash), $K_2CO_3 \cdot 2\,H_2O$. Molecular weight 174. White (anhydrous) granular powder or crystalline mass, both hygroscopic, deliquescent, water soluble, solution strongly alkaline. Application: Milder alkali than sodium carbonate, particularly for wool treatment, in printing, as soap component, etc.

Potassium chlorate (chlorate of potassium), $KClO_3$, molecular weight 122.5. Transparent, monoclinic plates, water soluble. Application: As oxidizing agent, particularly for textile printing and aniline black dyeing.

Potassium chloroplatinate → Potassium hexachloroplatinate.

Potassium chromate (potassium chromic acid, potassium mono chromate), K_2CrO_4, molecular weight 194.5. Rhombic prisms, made of potassium dichromate and potassium hydroxide or carbonate, water soluble. Application → Potassium dichromate.

Potassium dichloroisocyanurate → Chloroisocyanuric acids.

Potassium dichromate (bi-chromate of potash, red bi-chromate of potash; double bi-chromate of potassium, potassium bichromate), $K_2Cr_2O_7$, molecular weight 294.5; density 2.7. Large crystals, anhydrous and dry, stable in air, orange-red, toxic, water soluble, solution weakly acidic, possesses oxidation property. Application: aftertreatment of chrome development dyes to improve fastness; dye mordant for wool; component of metachrome mordant; oxidizing agent for the development of fast dyeing and printing; vigorous decolorizer for wool. The applicable discharge limits should be observed.

Potassium ferricyanide → Potassium hexacyanoferrat III.

Potassium ferrocyanide → Potassium hexacyanoferrat II.

Potassium fluorozirconate → Potassium hexafluorozirconate.

Potassium hexachloroplatinate (potassium chloroplatinate). K_2PtCl_6, molecular weight 486.16; density 3.5. Small yellow crystals. Decomposition at 250°C. Soluble in water 1:100, concentrated hydrochloric acid; insoluble in alcohol, ethers. Application: determining the Hazen colour number, etc.

Potassium hexacyanoferrat II (yellow prussiate of potash, yellow potassium prussiate), $K_4[Fe(CN)_6] \cdot 3\,H_2O$. Light yellow crystals, stable in air, water soluble, insoluble in alcohol and ether. Application: Iron indicator.

Potassium hexacyanoferrat III (red prussiate of potash, red potassium prussiate), $K_3[Fe(CN)_6] \cdot H_2O$. Red crystals; break down in sunlight, gradually decomposing to potassium hexacyanoferrat(II) (yellow prussiate of potash) due to the separation of iron(III) hydroxide; strong oxidizing agent. Application: discharge printing, in analytic chemistry as an iron indicator.

Potassium hexafluorozirconate (potassium fluorozirconate). K_2ZrF_6. White crystals, soluble in hot water. Application: IWS flame retardant finish for wool.

Potassium hydroxide (caustic potash, potash lye), KOH. Molecular weight 56, density 2.04. White, highly caustic crystal mass (K_2O) or pieces, fragments, plates, powder; highly hygroscopic (eagerly attracts water and carbon dioxide, therefore store in sealed container); readily deliquescent, readily water soluble when warmed, also in alcohol; or viscous lye, strongly alkaline, strongest dissociated base. Application: similar to → Sodium hydroxide, soap component, etc.

Potassium iodide starch paper Filter paper, which is soaked in boiled starch paste and 3–5 g/l potassium iodide before drying. Application:

I. Detection of traces of free chlorine (in bleaches, etc.) = wetted material is dark blue.

II. Detection of acid traces on cellulose goods = dark blue colouring.

III. Testing of diazotization baths (detection of free nitrous acids), if no blue colouring occurs then there is no nitrite or acids. Principle: released iodide determines the formation of blue iodide starch.

Potassium percarbonate $K_2C_2O_6$, molecular weight 198.3. Bleaching agent and component of oxidative washing agents.

Potassium permanganate (permanganate of potash), $KMnO_4$, molecular weight 158; density 2.7. Dark violet crystals with metallic lustre, stable in air, water soluble; solution dark violet (store in brown bottles), strong oxidizing agent in a) acidic, b) alkaline and c) neutral solutions. In case a) release of 5, in case b) and

c) of 3 oxidation equivalents and manganese dioxide deposits, soluble with disulphite, sodium dithionite, oxalic acid, sulphurous acids or hydrogen peroxide, perborate and acetic acid aftertreatment. Application: Bleaching agent (for wool, silk, cellulose fibres); bleaching spotting agent; antidote for hydrogen cyanide poisoning (drink approximately 0.5 g potassium permanganate in a glass of water), etc.

Potassium persulphate (potassium sulphate peroxide), $K_2S_2O_8$, molecular weight 270. White, crystalline salt, 98–99%; contains 5.7–5.9% active oxygen, water soluble. Bleaching and oxidizing agent for greases, oils, silk, wool, dyes; starch degradent (desizing); for mordanting, browning, cleaning.

Potassium phosphates More readily soluble than → Sodium phosphate and less volatile in water vapour, therefore much more active. It is possible to differentiate between:

1. Primary potassium phosphate = mono potassium phosphates (sour potassium phosphate, potassium di-hydrogen phosphate), KH_2PO_4; density 2.338, molecular weight 136. White salt, somewhat hygroscopic, readily soluble. Reaction weakly acid, 1% solution pH 4.53. Application: water treatment for boiler feed water (steam purity). Detergent builder.
2. Secondary potassium phosphate = dipotassium phosphate (dipotassium hydrogen phosphate). K_2HPO_4; density 2.34, molecular weight 174.18. White salt, decomposes in air. Very readily soluble. Application: Occasionally for corrective final softening of boiler feed water after cation exchange, specifically for high pressure boilers (low steam solids as with disodium phosphate).
3. Tertiary potassium phosphate = tripotassium orthophosphate, K_3PO_4, density 2.56. White, granular powder, deliquescent in air; readily soluble. Application: Cation exchange.

Potassium polymetaphosphate Metal-complex phosphates, → Metaphosphates of potassium. Metal-complex parent substance (KPO_3) is pure, highly condensed potassium polyphosphate (previously erroneously known as potassium metaphosphate or “Kurrol Salt”). With a condensation level between approx. 1000 and sometimes well above 1 000 000, this compound represents the final member in the series of → Polyphosphates. The high and extremely high viscosity types have a fibre structure similar to asbestos or cotton wad. Sodium chloride, sodium sulphate, but preferably sodium pyrophosphate or sodium hexametaphosphate (Graham’s salt) are used as an organotropic compound. By selecting a suitable organotropic compound it is possible to firstly influence the pH of the aqueous solution created, and also to a certain degree the viscosity. The ratio of potassium polyphosphate : organotropic compound is usually 1 : 2–4. The application quantity of potassium polyphosphate varies; sometimes the effects can be achieved with just 0.1%, sometimes the final concentration is increased to 2–3%. In so-called “low viscosity” types, aqueous solutions have viscosities of 1–2 mPa · s. One talks of “high viscosity” types if values of around 6 mPa · s are obtained. Viscosities decrease over time, but are clearly detectable weeks later. The reduction in viscosity is accelerated by increasing the temperature, particularly above 50°C, disappearing completely when boiled, without decomposition of the potassium polyphosphate occurring due to normal hydrolysis.

Some metal-complexes that can be made soluble possess an intrinsic cleaning, washing and soil suspending capability, and facilitate particularly gentle washing, milling, etc. and their handle becomes fuller, softer and has improved elasticity and brighter colours. Water hardening salts, iron and manganese salts are kept in solution or, if insoluble (lime soap), redissolved. Metal-complex solutions themselves do not foam, but increase the foaming power of wash-active substances considerably, as well as the washing effect.

Potassium polyphosphate → Potassium polymetaphosphate.

Potassium tetroxalate (sal acetosella, “sorrel salt”, aceto oxy aceto of potash), KOOC–COOH + HOOC–COOH + 2 H_2O. Molecular weight 254. White crystals or fine crystal powder, toxic, water soluble, insoluble in alcohol, solution acidic. Soluble double salts are formed with iron. Application: substitute for potassium bitartrate (tartar) in dyeing; lightening of straw hats, etc., spotting agent for rust and ink spots.

Potassium thiocyanate (potassium rhodanide), KCNS, molecular weight 97; density 1.9. Colourless crystals, transparent, deliquescent, hygroscopic, water soluble (in cold solution), also soluble in alcohol. Application: for increasing the dye affinity of wool, analytic (iron indicator = blood red dye).

Potato starch Powder, pure white; Handle crunchy, floury, cool; usually pure; water content 19–21%. Properties: insoluble in water. If heated from slurry at 46.25°C swelling takes place, at 58.75°C gelatinization begins, at 62.5°C gelatization ends. Paste: jelly-like, slimy, sticky, slightly grey translucent, not very stable, has the lowest stiffening and adhesive power of all starches. Gradual liquefaction if continuously boiled. Boiling with oxidation product (e.g. sodium perborate) leads to (water)soluble starch; degradation by enzymes. Acids lead to dextrose. Alkalis (depending upon concentration) increase the viscosity at normal temperature (great adhesive power), boiling gives rise to very tough, creamy solution (without particular adhesive power). Similar also tannin, salts, paraffin, oils, etc. Finishing handle: mild, soft, supple, full. Application → Starch.

Potential difference The transmission of energy and matter generally occurs due to potential differences, e.g. current “flows” in a conductor due to a voltage difference. For the movement of liquids or gases in a closed system a potential "pressure difference" is necessary. Heat "flows" in solid bodies due to the presence of a temperature difference. So, in general, the following applies for stationary states: heat and matter transport are proportional to the applied potential difference. In → Thermodynamics it has become normal to denote the proportionality factor for heat transmission or transition as α and that for the transmission of gases as β.

Potential hydrogen-ion concentration affects the current → pH. → Normal solutions.

Potentials →: Standard electrode potential; Thermodynamics.

Potentiometer Electrical device for → pH measurement with hydrogen, quinhydrone, antimony or glass electrodes. The prevailing pH is read directly off a scale.

Potentiometric measurements For determining the ion concentration by measuring the potential E of measuring networks, which each consist of a measuring electrode (indicator electrode, such as, e.g. glass, antimony, silver/silver chloride electrodes, etc.) and a reference electrode. E is the difference between the two individual potentials ε_m and the reference electrode ε_b:

$$E = \varepsilon_m - \varepsilon_b$$

The potential of all reference electrodes is independent of the composition of the solution. The value of ε_m, on the other hand, depends upon the concentration c_i of a certain ion (→ Nernst's distribution law):

$$\varepsilon_m = \varepsilon_0 + 58.2 \cdot \log c_i \cdot f_i \text{ (mV)}$$

For diluted solutions the activity coefficient $f_i = 1$. If the concentration changes by a factor of 10, then the potential changes by 58.2 mV. A particular measuring electrode must be selected for each type of ion (for pH e.g. the glass electrode; → pH measurement).

Potentiometric recorder Recording device, in the form of a point or line recorder, which functions according to the potentiometer method or using an automatically adjusted bridge circuit.

Potting → Wet decatizing.

Potting fastness Resistance to the effect of boiling water (wet decatizing). Guideline applies for wool and possibly in mixture with other fibres. Roll test piece around a glass rod, treat for 1 h in boiling distilled water with backflow. Dry in air at ≤ 60°C. Evaluation: change of shade, bleeding of white adjacent fabric (wool or cotton) with grey scale.

Pour point, setting point Lowest temperature, at which an oil becomes stiff and ceases to "flow". Plays an important role, for example, in mineral oil lubricants, lubricating oils, heating oils, etc.

Powder coating plant Used for sprinkling thermoplastic powder on two or more surfaces in order to stiffen or stick them together.

The powder can be sprinkled in dot form or superficially (see Fig.).

Powder dispersal sinter process is particularly suitable for heavy materials, for example, shoulder pads. Thermoplastic powder is sprinkled superficially on the cold length of material and then melted and sintered (Fig. 1). In order to distribute the powder uniformly over the entire area, in contrast to point coating, powder is scattered from special needle rollers from an

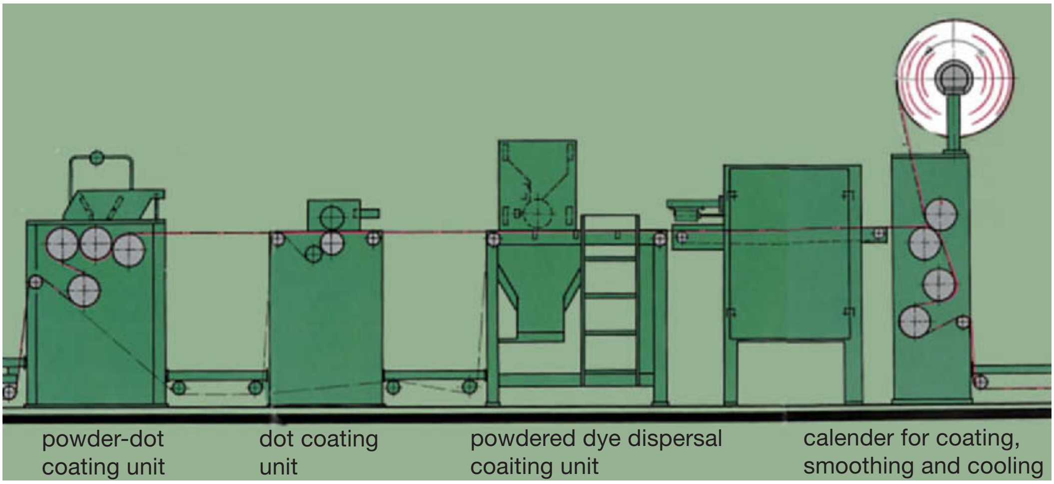


Fig.: A coating facility (Santex) allowing the choice between powdered-dot coating, dot coating or powdered dye dispersal coating, with dry and gel channels and with a calender for coating and smoothing.

oscillating hopper and brushes (Fig. 2), which distribute it on the material.

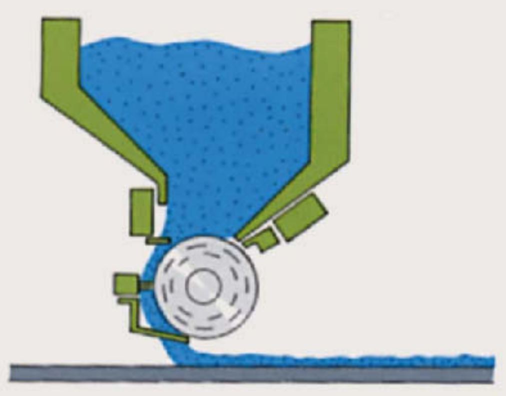


Fig. 1: Powder dispersal sinter process.

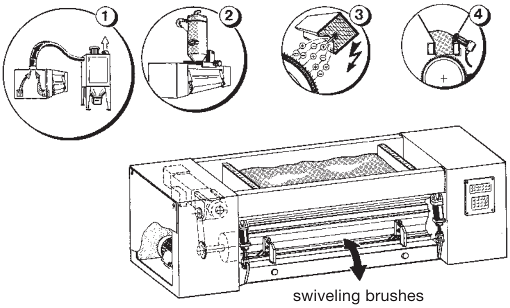


Fig. 2: The Villars powder dispersal unit with traversing dispersal funnel (2), special needle roller (4) whose electrostatic charge is compensated (3), and suction removal of excess powder (1).

Powder dissolving station For the use of dyes, chemicals, etc. Powder dyes require costly dissolving stations, which consist of stainless steel dissolving and storage containers. A smaller dissolving tank of 250–1000 l capacity with a connected storage tank is usually adequate for dissolving. The dissolving tank should be fitted with a stirrer and be heated directly by steam. The dissolved dye is further diluted by continuous stirring with cold water, before it is discharged into the storage tank via a fine-meshed sieve. The minimum capacity is determined by the production quantity, depth of colour and the solubility of the dye used. The storage tank should also be fitted with a stirrer to prevent undesired settling out or creaming. The dissolving of powder brands to form a parent solution is very energy-intensive especially for dyes with limited solubility. Considerable quantities of water and heating steam are necessary. Care must also be taken that the cold solubility is not exceeded. This applies even for short term storage. Un-dissolved or precipitated dye particles may re-dissolve into the substance (although quite often they do not). They then not only block the dosing system by blocking pipes and valves, but also represent a financial loss. Furthermore, it makes it difficult to precisely calculate the quantity needed for the parent solution in advance: residual amounts may no longer be discharged into waste water, missing quantities must be reclaimed under time pressure.

Powder-dot coating For light outer clothing materials to fine ladies' blouses, the powder dot coating process is used for coating the front fixing material. The indentations of a heated engraved roller are filled with thermoplastic powder which is then slightly agglomerated (Fig. 1). The material is heated to above the melting point of the coating powder on a heated roller. The hot fabric is pressed against the powder filled hollows, the powder melts and adheres to the fabric in the form of droplets. In the subsequent sintering zone the droplets are melted to form hemispherical pearls, which sit cleanly upon the surface of the fabric (Fig. 2). In contrast to the → Powder dispersal sinter process, patterns are generated.

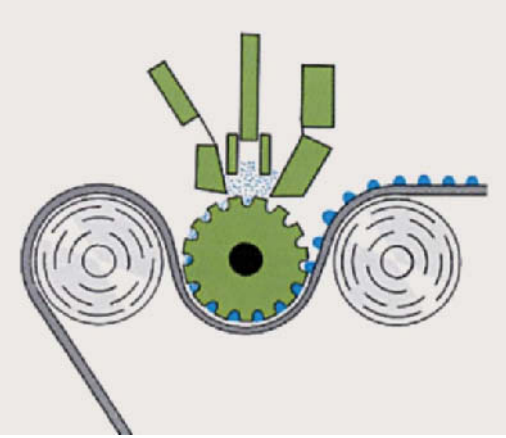


Fig. 1: The powder-dot process (Caratsch).

For the dot-like adhesion of material layers by powdered thermoplastics of different composition, e.g. for air permeable front fixing. Thermoplastic powders (such as high and low pressure polyethylene, polyvinyl chloride, polyolefins, vinyl acetate, polyamide and compounds of different types), which (partially) add desired characteristics of different basic components are used. Development is moving towards the creation of boiling, washing and dry cleaning resistant powder

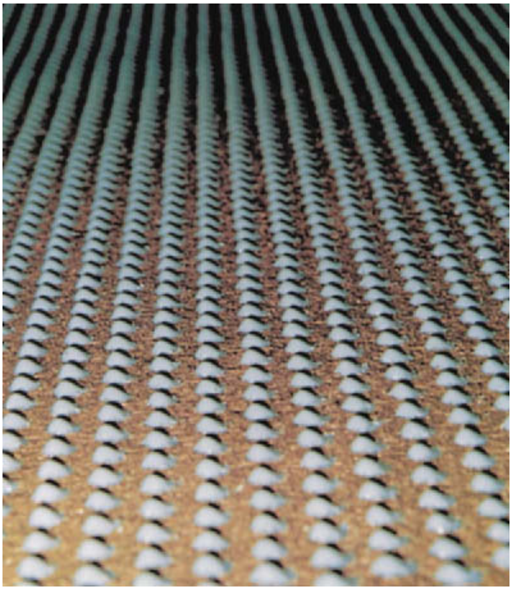


Fig. 2: Powder-dot application (according to Knobel).

qualities combined with optimal adhesion during the thermo process.

Powdered dye dispersal process Dyes or chemicals are sprinkled on the material in powder form, shaken up (shaker process) and, depending upon the nature of the material (dry, wet, dyed, undyed, not desized, etc.), provide dye, flow or resist effects. In accordance with another process, powdered dyes are sprinkled on the material together with water and crystallised salts. In the subsequent contact heat treatment the crystallised water is evaporated from the salts, dissolves the dye, and this is absorbed into the fibre and immediately fixed.

Powder point process → Powder-dot coating.

Powder-scatter coloration technique A technique for the production of coloristic effects which involves the application of dyes, together with salts containing water of crystallization, to textile materials by means of a powder-scatter machine (→ Powder dye dispersal process). After application, the fabric is passed over hot metal rollers in order to fix the dye/s. A notable feature of this coloration process is the fact that the water required to bind the dye to the fibre is provided by water of crystallization only.

Power As physical variable: → Work done per unit time, SI unit is Watt (W) = J/s.

POX Pergable (can be blown out) organic halogen; in addition to AOX (adsorbable) and POX we also differentiate EOX (extractable) as values for chlorinated hydrocarbons, which cause problems for the environment.

POY (Pre-oriented yarn) → Polyester fibres.

PP → Polypropylene fibres, → Textile fibre symbols, in accordance with DIN 60 001 T4/08.91.

ppb (parts per billion), billionths = 10^{-9}.

ppm (parts per million), millionth = 10^{-6}.

PR → Protein fibres, → Textile fibre symbols, according to the → EDP key system.

P.R. (Pressley-Ratio) → Pressley-Index.

Pr Element symbol for praseodymium (59).

Prato wool Italian cloth export from Prato, previously made primarily of → Reclaimed wool, which after the Second World War achieved world-wide importance due to its low price (around 50% of production for export was for the Orient, West Germany, England, etc.).

PRAVDA Product Recycling Altfahrzeug Verwertung Deutsche Automobilindustrie (Product recycling of used vehicles in the German automotive industry); interest group made up of seven German car manufacturers for the development of strategies for car reclamation and the extraction of valuable materials for recycling. Support of development work for similar types of plastics and fibres for trim.

Prayer mats Small, easily transportable oriental carpets for praying outside the mosque, on journeys, etc. The prayer niche is a rectangular, tapered internal panel.

Precipitation,

I. Formation of a solid deposit in a solution due to the addition of another solution.

II. Insoluble sediment. Arises as a reaction product of two dissolved substances in one another (also gas in liquid). Often becomes soluble again.

Precipitation and flocculation Related terms used in waste water cleaning. The waste water is partially cleaned by the coupling of precipitation and flocculation processes. The use of biological processes is ruled out for the cleaning of industrial waste water, or they can only be used as a third stage treatment. In this case, precipitation and flocculation methods are often used as the preliminary cleaning process. Basically, it is worth including a precipitation/flocculation stage if heavy metals, difficult to degrade → COD, mineral oils and precipitates or colloids need to be separated out in large quantities. Phosphates, which encourage eutrophication, and foul-smelling hydrogen sulphide can also be eliminated by precipitation and flocculation. It is also a commonly used method for decolorizing waste water. In the procedural technique used for waste water cleaning it is difficult to separate the two basic operations. Because of the complexity of waste water, it contains impurities with very different properties, which must be separated out using different reaction mechanisms. In addition, both processes interact and support each other. Chemicals used to promote precipitation and flocculation are metal salts or alkaline earth metal compounds, which form hydroxide floc or difficult to dissolve compounds in the waste water. The commonly used metal salts are chlorides and sulphates of iron and aluminium (aluminium sulphate $Al_2(SO_4)_3$, Iron(II) sulphate $FeSO_4$; Iron(III)chloride $FeCl_3$ or Iron-III-chloride sulphate $FeClSO_4$). One commonly used metal salt is iron(II)-sulphate, which is preferred due to its low price, plus it has proved to be a much more effective decolorizer than for example the more expensive iron(III) sulphate. Calcium, which is frequently used, deserves a mention as a representative of the alkaline earth metal compounds. Metals salts have been known to be used in combination with calcium.

The basic operation of precipitation allows various dissolved substances in waste water to be converted into non-soluble form. This makes it possible to precipitate hydrogen sulphide (H_2S) using iron (II) sulphate (odour prevention). The hydrogen sulphide reacts with iron sulphate according to the following reaction diagram to form water-insoluble, black and odour inactive iron sulphide FeS:

$$FeSO_4 + H_2S \longrightarrow FeS + H_2SO_4$$

In textile waste water, we can expect to find hydrogen sulphide if cellulosic substrates are dyed using sulphur dyes, using sodium disulphide as a reducing agent. Heavy metals are eliminated by precipitation with calcium hydroxide $Ca(OH)_2$, whereby the metals are precipitated as metal hydroxides according to the following reaction equation:

$$ZnSO_4 + Ca(OH)_2 \longrightarrow Zn(OH)_2 + CaSO_4$$

In order to precipitate a sufficient quantity of the metal ions as hydroxides, the pH must lie within the range of the solubility minimum of the metal hydroxide in question, because outside this range the metal ions cannot be precipitated in a sufficient quantity, or will dissolve again. In the textile finishing industry heavy metal traces may enter waste water due to stripping agents, dyes and catalysts. After inorganic carbon, phosphorus is one of the most important elements for the growth of algae and can be viewed primarily as a cause of eutrophication in bodies of water. To avoid excessive eutrophication, which may result in the “biological collapse” of a body of water, phosphates (ortho phosphates, pyrophosphates, tripolyphosphates, etc.) should be removed from the waste water. The easiest way of removing o-phosphates (PO_4^{3-}) from the waste water is by chemical precipitation in the form of poorly soluble iron, aluminium or calcium salts.

a) Aluminium phosphate precipitation:

$$Al_2(SO_4)_3 \cdot 18\,H_2O + 2\,PO_4^{3-} \longrightarrow 2\,AlPO_4 + 3\,SO_4^{2-} + 18\,H_2O$$

b) Iron-phosphate precipitation:

$$FeCl_3 \cdot 6\,H_2O + PO_4^{3-} \longrightarrow FePO_4 + 3\,Cl^- + 6\,H_2O$$

c) Lime-phosphate precipitation:
The individual stages of the process of lime phosphate precipitation are not yet fully understood. The phosphate ion is precipitated in the form of hydroxyl apatite, which may have different compositions, by adding lime and at the same time increasing the pH. Calcium hydrogen phosphate $CaHPO_4 \cdot 2\,H_2O$ is probably formed first, which then is converted over time into the more stable apatite $Ca_5(PO_4)_3(OH)$. The chemical reactions can be described in more detail as the following approximation:

$$2\,Ca(OH)_2 \longrightarrow 2\,Ca^{2+} + 4\,OH^-$$

$$2\,Ca^{+} + HPO_4^{2-} + 4\,OH^- \longrightarrow Ca_2HPO_4(OH)_2 + 2\,OH^-$$

$$4\,Ca_2HPO_4(OH)_2 + 2\,Ca^{2+} + 2\,HPO_4^{2-} \longrightarrow Ca_{10}(PO_4)_6(OH)_2 + 6\,H_2O$$

In the event that solid particles are not able to sediment sufficiently well, the separation of the precipitation must take place by flocculation using flocculation colloids (→ Flocculation).

Precipitation chromatography → Chromatography.

Precision regulator Used for the adjustment and automatic control, e.g. of set temperature values (temperature controller), relative air humidity (air conditioning units), etc. In principle contains a so-called impulse device, a bimetallic strip, a highly sensitive fluid temperature controller or pressurised fluid or compressed air (pressure regulator), an electrical resistance thermometer or hair hygrometer. The generated impulse is transferred (possibly electrically) to control device (membrane lever, valves, etc.).

Precision-wound packages Always a regular winding at all diameters (see Fig.). The rewinding tube is positively driven and has an adjustable, constant ratio to the movement of the thread guide at all times. The thread distance can also be selected. The number of windings per winding stroke remains constant from the starting diameter to the full batch diameter. The most advantageous winding can be adapted at will to the yarn material and field of application. (→ Crosswound yarn package).

Pre-coating of screen In order to facilitate possible painting of screens by hand, the screen is pre-coated e.g. with an auxiliary layer of gelatine or sodium alginate.

Pre-Cure → Permanent-press process.

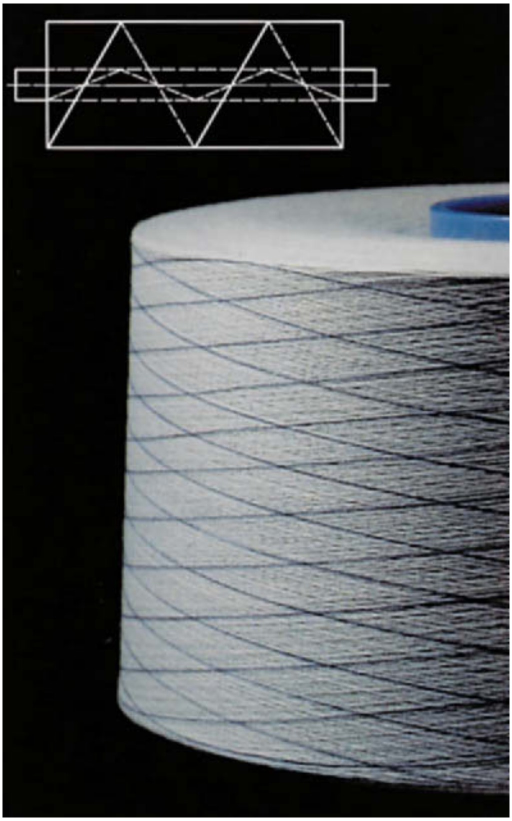


Fig.: A crosswound yarn package with precision winding (Schweitzer).

Precutting in mill engraving After the drawing has been transferred onto the molette, the predrawn lines are precut with a suitable graving tool.

Pre-dip Pretreatment of yarn or fabric with an auxiliary that promotes the adhesion of the subsequent impregnation.

Predrier Should prevent migration in the main dryer due to the mild nature of drying.

In fibreglass wallpaper impregnation with high product application (liquor application by impregnation in the horizontal two-bowl padder run “split”, in the order of magnitude of 150–200%) should achieve contactless drying in the IR duct with residual moisture of around 25–30%, before it is “pressed” on a subsequent cylinder drier.

Predriers can be:

- air supported jet driers,
- predrier with support sieve,
- hotflue with trough injector (Fig. 1),
- mostly, however, infrared driers with gas or electric operation (Fig. 2).

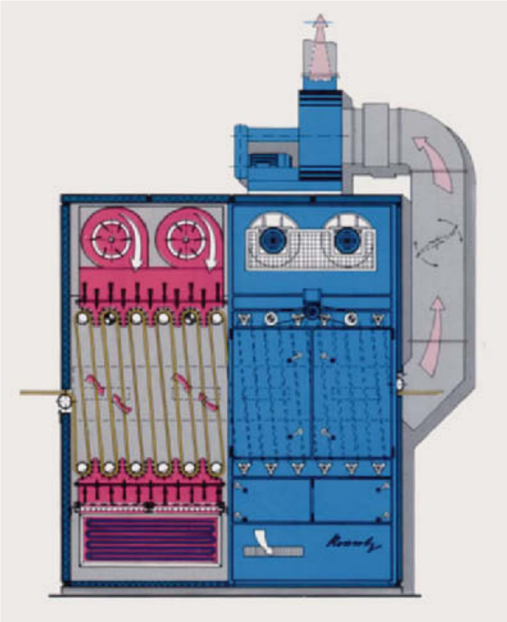


Fig. 1: Hotflue predrier with trough nozzles (Krantz).

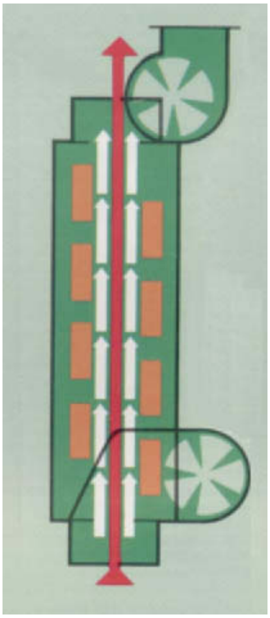


Fig. 2: IR predrier (Monforts).

Pre-drying → Water extraction.

Prefelting machine Prefelting of folded fur hats by means of rotating rollers or rollers with strong rope wound around them (ropemill).

Preference (Lat.: praeferre = prefer), preference, priority; e.g. in → Whiteness formulae as white preference (“white taste” of the observer), blue green preference, shade preference.

Preferential orientation of silicones on hydrophilic fibre surface to their water repellent finishing (see Fig.). The hydrophilic part of the silicon polymers align themselves to the fibre surface, whereas the hydrophobic parts point outwards.

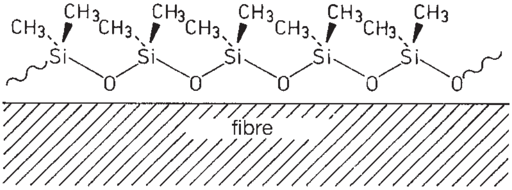


Fig.: Preferential orientation of silicones on hydrophilic fibre surface.

Prefix (Latin: praefixum = prefixed). In chemical compounds prefixes are a term or syllable placed before the root word for the differentiation of the word stem in question. Examples: Beta, cis, cyclo, di, meta, methyl, mono, para, poly, tri, etc. Opposite → Suffix.

Pre-keratin Preliminary stage of → Keratin formation in the hair root. The lower part, the hair papilla, contains soft protein liquid, which contains water and has almost circular cell nuclei, so-called ball or ring proteins. Then follows the so-called protein zone, in which the stretching process takes place. In the pre-keratin zone the partially hardened hair begins to grow from the previously closely enclosed, diffused hair root, fully cross-linking via disulphide bridges in the keratin zone. It now grows past the junctions of the follicular glands and emerges visibly through the outer skin.

Pre-lacquering → Positive process for screen making.

Preliminary finishing Pretreatment of textiles in wet finishing. → Wet processing.

Premetallized dyes → Metal-complex dyes.

Pre-milling Practical term for → Milling. It is used in the finishing of woollen fabrics to describe a slight felting of the fabric surface. Milling machines have a suitable setting (see Fig.).

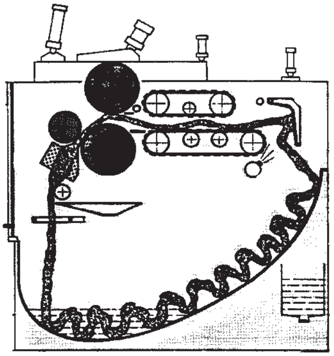


Fig.: Pre-milling.

Pre-mordanting → Chroming.

Preparation (formulation). Mixtures and solutions made of two or more substances.

Preparation vessel In textile finishing machines the treatment liquor is often prepared in a separate container (see Fig.), which is then supplied to the machine by a pump.

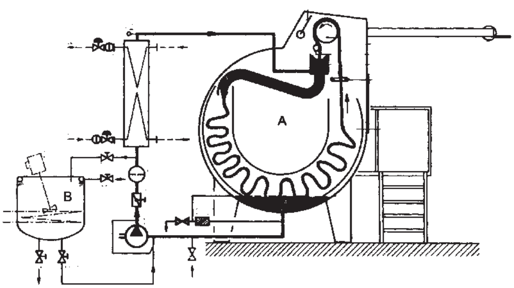


Fig.: Subtilo (Scholl AG).
B = separate preparation vessel; A = dyeing machine.

Preparing Pretreatment operation:
1. In dyeing with naphthols.
2. For turkey red dyeing.

Preparing salt → Sodium stannate.

Prepigmentation Unvatted vat dyes are padded onto fabric as a dispersion and deposit themselves onto the fibres as pigments during drying. Subsequent padding of chemicals (reducing agents and alkali) vats the dye to a solution, which diffuses into the fibre in the subsequent steaming process (see Fig.).

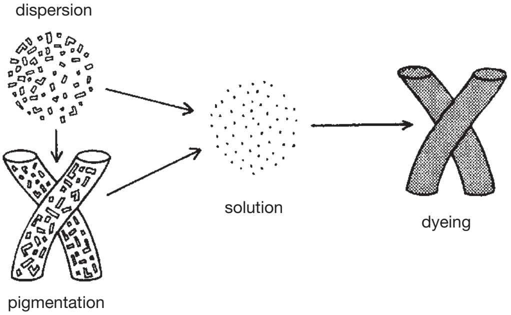


Fig.: Prepigmentation: the process of dyeing with either a dispersion dye or a vat dye.

Prepreg A fibrous mat impregnated with a heat hardening matrix material, which can be further proc-

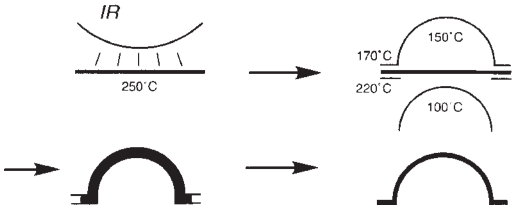


Fig. 1: The processing of a prepreg in a deep drawing process.

essed by heat pressing. Prepregs are not free-flowing, and therefore cannot change shape independently (Fig. 1). Prepregs consist of thermoplastic fibres (PA 6.6) or non-meltable fibres (in the field of prepreg forming), such as glass fibres, carbon fibres or para-aramide fibres; this selection is based upon the profile of requirements of the fibre-reinforced plastic component to be produced, above all on the requirement for drapability of the prepreg. By their use, a high fibre volume proportion of above 50% can be achieved. The use of this material promises to considerably reduce the cycle time compared to duroplastic materials. The shaping processes that come into consideration are similar to the deep drawing process common in sheet processing. Processing for laminate manufacture using a cold forming press is also possible (Fig. 2), above all with PA 12 as the matrix polymer.

One differentiates between stiff and bendable prepregs. The fibres should be embedded into the matrix as homogeneously as possible so that a high fibre/matrix adhesion is achieved, without the inclusion of air bubbles. The strength of the prepreg naturally increases with an increasing fibre proportion. The limits are determined, on the one hand by the geometry of the fibres, i.e. by their maximum achievable packing density, and on the other hand by the adhesive power of the matrix. A certain layer thickness of matrix material is necessary, which depends upon the thickness of the matrix polymer. The corresponding values are thus defined depending upon the material. Based purely upon arithmetic considerations, on the assumption of a round fibre cross-section and a max. packing density, the fibre volume proportion in a circular prepreg cross-section with seven threads is 78% (Fig. 3); in a rectangular cross-section, with e.g. eight threads, this proportion is 76% (Fig. 4). In this calculation, however, one assumes that the circular fibres rest upon the surface.

The stiffness of prepregs is determined by the fibre volume proportion, the number of threads used, the total diameter of the prepreg and the fibre and matrix type. Elastic matrix materials in combination with non-rigid fibre hanks, give a prepreg that can be processed as a normal textile fibre. If the fibre volume proportion is high or if stiff thread materials are used or a matrix material with a high Shore hardness is used, the prepreg has a high stiffness and is comparable to a monofilament with regard to processability. Such prepregs can be used for example for pultrusion.

The following processes as well as starting materials can be used in the manufacture of thermoplastic fibre composite materials:

- thermoplastic foils in combination with pure textile areas;
- solvent coated fibre hanks;
- hybrid yarns, consisting of reinforcing fibres and thermoplastic matrix fibres;
- powder coated fibres;
- melt impregnated prepregs.

For environmental reasons, the processing of solvents in the impregnation of fibre hanks should be viewed particularly critically, because toxic solvents are necessary for most thermoplastics. Furthermore, often only amorphous thermoplastics can be processed in this manner. In hybrid yarns both fibre components lie parallel to the fibre hank, whereby a certain mixing of the fibre components arises through air turbulence. However, fibre mixing can also be achieved by spinning or winding processes, although these processes do not achieve a homogeneous mixing of the fibres. In powder coated fibres the matrix material is mainly only applied

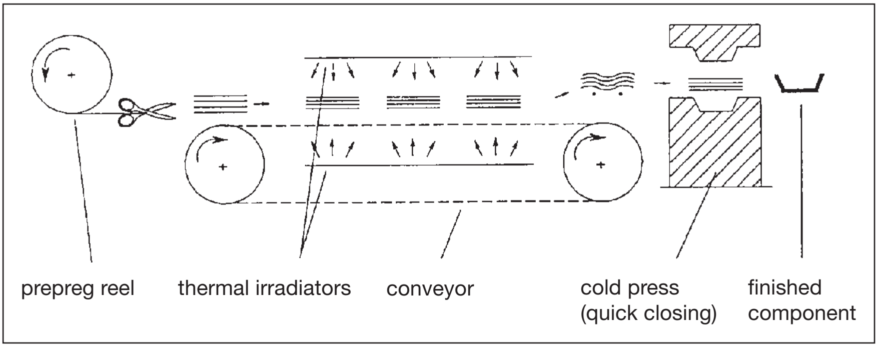
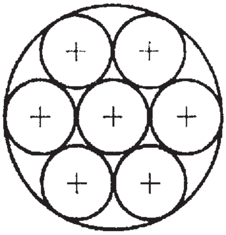


Fig. 2: The manufacture of components using VESTOPREG and a cold forming press (Hüls).

fibre volume ratio
theory (maximum packing density, obtained by calculation)
round cross-section:

7 threads: diameter d, radius r
Prepreg: diameter D = 3 d; radius R = 3 r



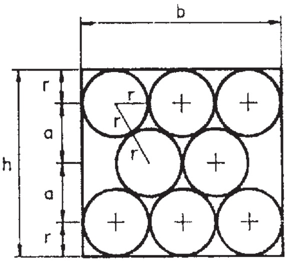
$$\text{fibre volume ratio } V_F = \frac{\text{area threads}}{\text{area prepreg}}$$

$$V_F = \frac{7\pi r^2}{\pi R^2}$$

$$= \frac{7\pi r^2}{9\pi r^2} = 0{,}78 \dashrightarrow 78\ \%$$

Fig. 3: The fibre volume ratio of a round cross-section (Planck).

rectangular cross-section:
8 threads: diameter d, radius r
prepreg area: $F_P = b \times h$
whereby $b = 3D = 6r$
$h = 2r + 2a$
$a^2 = 4r^2 - r^2 = 3r^2$
$a = r\sqrt{3}$
$h = 2r + 2r\sqrt{3} = 2r(1 + \sqrt{3})$
$= 5{,}46\ r$
$F_P = 6r \times 5.46\ r = 32.8\ r^2$



$$V_F = \frac{F_F}{F_P} = \frac{8\pi r^2}{32.8\ r^2} = 0.76 \dashrightarrow 76\ \%$$

in practice: limitation: adequate matrix/thread adhesion
--> adequate matrix thickness

empirical limit for adequate matrix / fibre adhesion: max. approx. 65 %

Fig. 4: The fibre volume ratio of a rectangular cross-section (Planck).

to the exterior surface of the reinforcing fibre hanks. When the textile is pressed in the component mould under pressure and heat, the thermoplastic component melts and in the ideal case penetrates into the reinforcing fibres. The reinforcing fibres are however compacted by the applied pressure. This brings the individual filaments together, so that, based upon the filter effect, only a low penetration of the matrix into the reinforcing hank is possible. This can only be improved slightly by the use of a vacuum (according to Planck).

Pre-printed resist →: Half-tone resists; Resist printing.

Prescouring agent (prewashing agent). System washing agent for prewashing in the two bath process. Should wet, swell, increase dirt viscosity and dissolve dirt. Prewashing agents contain less wash-active substances compared to the subsequently used → Fabric clean washing agent, more or less alkali and no bleaching additive.

Preservative Used to protect textiles and finishing substances (sizes, printing thickeners) against decomposition due to micro-organisms. Common preservatives in textile finishing are fungicides and bacterial poisons, often typical → Disinfectants, which should be used with care. In the preservation of textiles one differentiates between active and passive finishes. Active procedures are based upon the use of preservatives. Passive protection against the rotting of textiles is achieved by acetylization and the application of e.g. melamine formaldehyde condensates. Requirements of preservatives: safe action, fibre preserving, not aggressive to the materials of the treatment vessels, skin compatibility, low toxicity, easy application (in water) and washing fastness for the final finishing of textiles. In addition to formaldehyde, the following preservatives can be used for finishes and rot-proof finishing of textiles: salicylic acid, organic copper salts (copper soaps, copper-naphthenate, etc.). Chlorinated phenol (pentachlorophenol, lauryl pentachlorophenol, dihydroxydichlorodiphenylmethane), salicylanilide and bromine derivatives of salicylanilide, organic tin compounds (bis tributyl tin oxide), organic mercury compounds (phenylmercuric acetate) and also quaternary ammonium compounds. From an ecological point of view all the preservatives mentioned are problematic.

Presetter Used for the presetting of unsewn hosiery blanks, for fixing hosiery or socks made of polyamide (→ Hosiery setting) and for the relaxing of tufted carpets (→ Carpet pre-steamer). Working method for hosiery in saturated steam process with or without vacuum plant.

Pre-setting → Heat setting at temperatures that lie below the softening range of synthetic fibres, so that they are protected against creasing and folding in subsequent finishing operations, specifically wet processes.

Pre-shrink Steam or hot water pre-treatment for textured yarn for the development of texture.

Preshrunk Quality term for material that has been relaxed to the degree that under the effect of a normal ironing the length and width of the sample decrease by no more than ± 1% (→: Shrinkage; Sanforize). Such a material may still have a press lustre, for example, (final treatment on the flat press) which is not itself fast to hot pressing or spotting.

Pressboard Special cardboard, which is used as glazed millboard in → Flat press and is placed between the layers of material.

Pressboard press → Flat press.

Pressing Finishing character work. Relief printing treatment for the refinement of appearance and handle, particularly on wool, silk, viscose fabrics, etc. that are sensitive to roller printing. Usually performed prior to decatizing and before cutting and also immediately before completion. The → Flat press, one of the oldest devices in the cloth industry, is usually used for wool and wool mix fabrics, which are folded edge to edge with intermediate layers of polished pressboard inserted; electrically heated boards are inserted between each pack, and every 3–5 cm this is replaced by an electrically heated pressboard. The entire pack, consisting of different pieces, one on top of the other, is enclosed at the top and bottom by two thick sheets of cardboard (fire-resistant cover) and is usually left overnight in a hydraulic press at a pressure of 100–600 bar. The most common procedure is re-cutting with the break points of the first pressing in the middle of the pack, and then pressing again. Achieving the particular pressing effect by a flat press is labour intensive, and thus costly, so the flat press is rarely used.

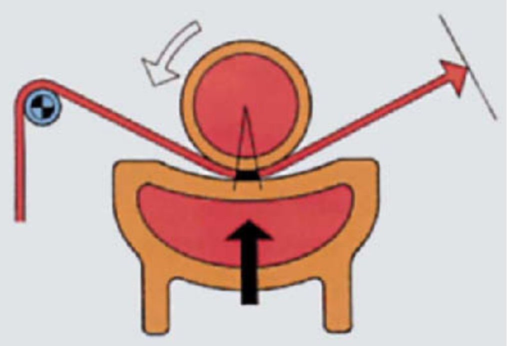


Fig. 1: Diagram of a rotary cloth press.

The rotary cloth press or cylinder press works quicker, is cheaper to run and guarantees fold-free material. However, the effect is not always as good and as permanent and, furthermore, slight loss of width and longitudinal stretch can occur. The machine (Fig. 1) consists of a rotating, heated cylinder, the underside of which travels on a semicircular, also heated, finely polished adjustable basin. Numerous rotary cloth presses have brush rollers and a steaming device at the material entry point. The material passes between cylinder and basin, this is necessary in order to exclude unwanted sheen, with an endless felt backcloth between the material and basin or cylinder. In the felt press, which, in principle, corresponds with the rotary cloth press, there is felt either around the cylinder or in the basin to prevent any sheen effect. The felt press is therefore used

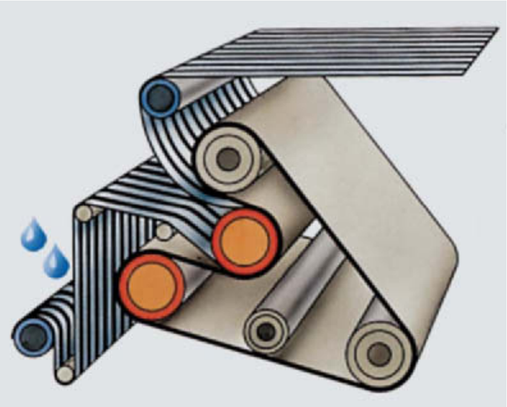


Fig. 2: Diagram of a contipress machine by Menscher.

for matt finishes and in finished pressing. The danger of width losses and longitudinal stretching associated with the rotary cloth press is almost ruled out in the felt press, which means it is also suitable for shrinkproof material and material that is ready for making-up.

In the conventional rotary cloth press, the friction between the stationary basin and the rotating pressure roller stretches the material by up to 6%. The contipress process guarantees stretch-free pressing because there is no relative movement during pressing (Fig. 2). In the contipress (Menschner) all rollers run synchronously. The material is thus not pulled through the machine. A special pressure band presses the material against an effect roller with controllable surface pressure (Fig. 3). Both elements are heated independently of each other. Moistened material is thereby placed under extreme surface pressure at a comparatively high temperature, with a marked sweating and fixing process being produced with pressure. Moisture, temperature and surface pressure (decisive factors for the fixing process) are available simultaneously. The pressure effect is achieved more intensively over an incomparably longer route. This has opened up new fields of application, not only for wool, but also for wool mix fabrics, cotton and cotton mix fabrics.

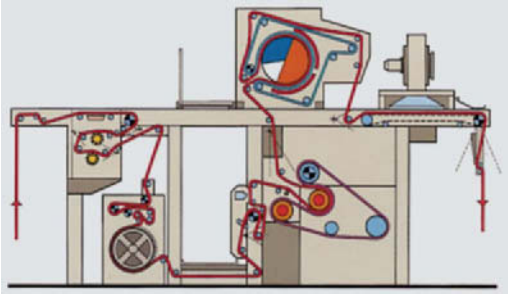


Fig. 3: Contipress machine by Menscher with pin-wheel take-up and with chilling unit at the run-out.

Pressing marks The accidental occurrence of “stripy”, curved or wavy folds or pleats as a result of unskilled ironing.

Pressley-Index (P.I.). Pressley ratio (P.R.), Pressley strength weight ratio. Describes the fibre bundle tensile strength (fibre strength) of cotton fibres. A parallelized fibre bundle is held in the Pressley tester by means of two clamps, the tensile force is achieved by a weight. The P.I. is calculated from the measured tensile force and the weight of the fibre bundle.

Press packing dye tubes →: Dyeing tubes for yarn dyeing; Plastic dye tube properties.

Pressure Mechanical tension. The derived SI unit is the Pascal (unit symbol: Pa).

$$1\ \text{Pa} = 1\ \frac{\text{N}}{\text{m}^2} = 10^{-4}\ \frac{\text{N}}{\text{cm}^2};\ 1\ \frac{\text{N}}{\text{cm}^2} = 10\ \text{kPa}$$

Special name for the tenth part of the mega pascal (MPa) is the Bar (unit symbol: bar):
1 bar = 0.1 Mpa = 100 kPa = 10^2 kPa = 10^5 Pa
1 bar = 1000 mbar
The previously used Torr, at., and kp/cm^2 units are no longer permitted:
1 mbar = 0.750 062 Torr

$$1\ \text{bar} = 1{,}019\ 716\ 21\ \frac{\text{kp}}{\text{cm}^2} = 1{,}019\ 716\ 21\ \text{at}$$

Pressure adhesion With hot melt foils for laminating fabric surfaces (see Fig.: pressure adhesion systems (Guttacoll)). Continuous roller pressure (calender) with IR preheating of the foil. Roller cloth pressure for gentler pressure. Discontinuous working method for small parts. Thermoform laminating, with the shaping pressure generated by vacuum, the shaping body is perforated and evacuated during the shaping process (heating from above).

Pressure boiler Autoclaves for the preparation of starch, rubber or tragacanth thickeners. The boiling time is reduced with temperatures above 100°C; thickeners are highly homogeneous.

Pressure difference in beam dyeing The most common way of checking the differential pressure or making a target-actual comparison during dyeing is as follows: Starting from no-load operation, i.e. with the bypass open or the butterfly valve almost closed and with the liquor temperature as high as possible, the beam dyer begins, during the next 2–5 minutes, to continuously close the bypass or open the butterfly valve. The differential pressure in which this results is then used for an actual comparison with a beam dyed batch of the same type which has already been dyed, which tells the dyer whether he can continue the dyeing process (if the target-actual difference is < 15%) or should interrupt the process, because at a higher differential pressure (> 15%) there is a high probability that another yarn package is present, that there are higher axial liquor losses, because the covering width is not correct or the covering collar has slipped, that the beam dyeing yarn package was wound on another machine or with different tension, etc. The foreman then uses his experience to decide whether to continue dyeing at this target differential, despite the high risk of false dyeing, whether to use additional dyeing auxiliaries or lower heating-up rate, or to interrupt dyeing and rectify the causes by rewinding, etc. It is therefore advisable to make an actual target comparison of differential pres-

Pressure difference in beam dyeing

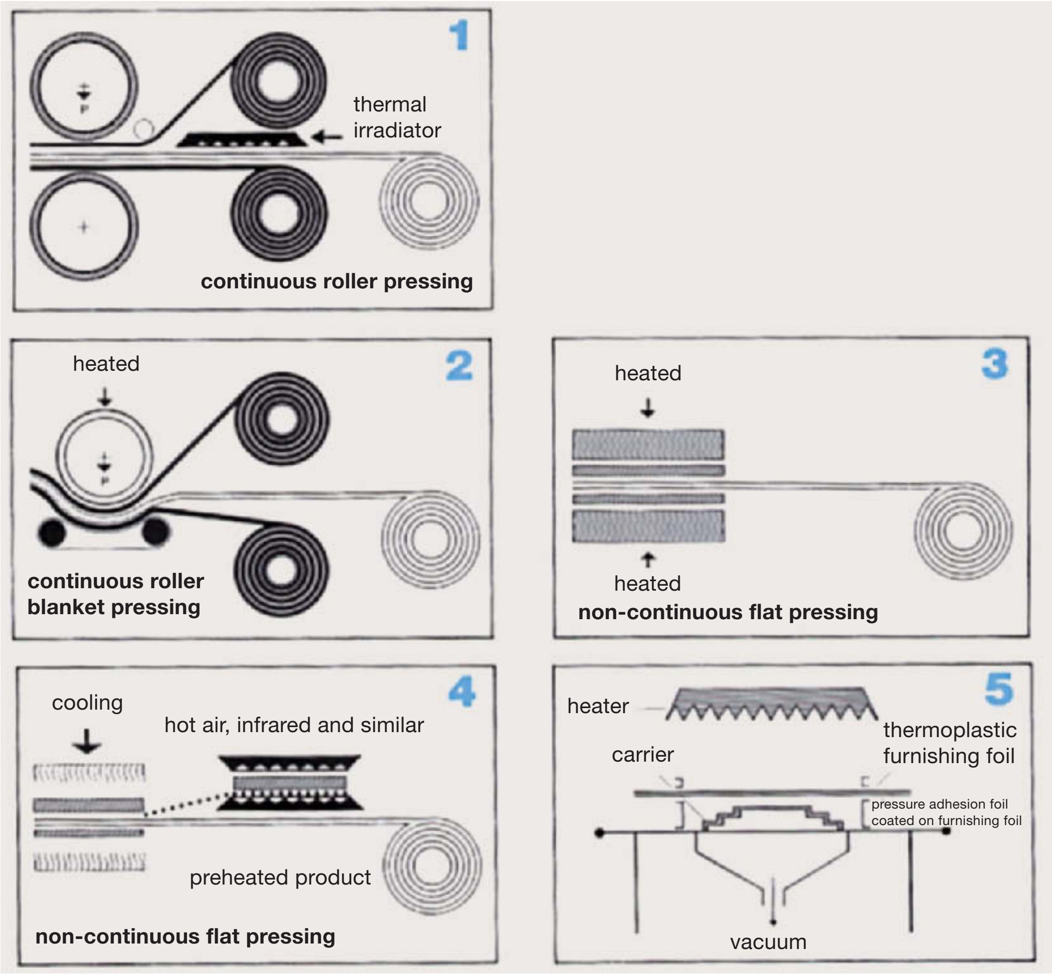


Fig.: Pressure adhesion systems (Guttacoll).

sure in critical batches before adding the dye, because dyeing time and the costs of false dyeing are saved.

The axial liquor content increases as the yarn package width falls, i.e. given the same beam package weight, the proportional axial liquor loss is greater for narrower yarn packages. This results in greater levelling or dyeing risks with narrower yarn packages (and the lower risk of oversized beam dyed yarn packages). Therefore it is advisable to reduce the yarn package height h_L of narrow yarn packages roughly in proportion to the yarn package width $\sqrt{b_T}$. For example, if a yarn package width of $b_T = 1.50$ m is dyed with a yarn package height of $h_L = 0.30$m then a narrow yarn package of the same item where $b_T = 1.00$ m should be dyed with a yarn package height of $h_L = \sqrt{1.00/1.50} \cdot 0.030 = 0.25$ m (Fig. 1).

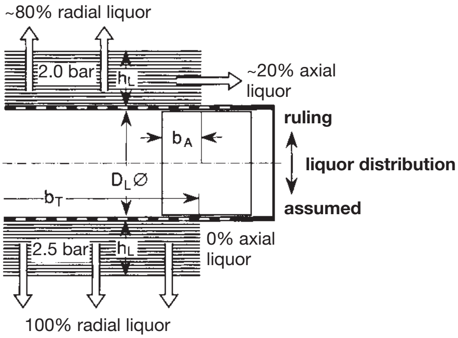


Fig. 1: Schematic example of radial and axial liquor distribution in a flooded beam dyed yarn package and covering cuff arrangement (Kretschmer).

Frictional forces as a function of viscosity are responsible for the pressure loss between inside and outside. Darcy's law applies here:

$$D_f = -\frac{k \cdot F}{\eta} \cdot \left(\frac{\Delta p}{\Delta x} + \rho \cdot g\right)$$

D_f = flow per unit time,
F = area,
η = dynamic viscosity,
Δp = pressure reduction,
Δx = distance over which pressure falls,
ρ = density of the liquid,
g = acceleration due to gravity,
k = constant, which depends only upon the properties of the porous material.

The constant k is described in the theory of permeability as a function of porosity ε and specific surface F_0:

$$k = c \cdot \frac{\varepsilon^3}{F_0(1-\varepsilon)^2}$$

$$\varepsilon = \frac{\text{solid matter volume}}{\text{total volume}}, \qquad F_0 = \frac{\text{solid matter surface}}{\text{solid matter volume}}$$

c = constant

The equation illustrates the strong influence of packing density upon the relationship of flow per unit time D_f/pressure reduction Δp.

At each flow speed a Reynolds number can be allocated according to the relationship:

$$Re = \frac{w \cdot d}{\nu}$$

w = flow velocity,
d = average pore diameter,
ν = kinematic viscosity.

If this falls below a so-called critical Reynolds number then inertial forces act in addition to frictional forces, which leads to the formation of a vortex. This value fluctuates from $Re_{crit.} = 0.1$ through $Re_{crit.} = 1$ to $Re_{crit.} = 75$. It is therefore not possible to quote a critical Reynolds number for all porous materials, above which Darcy's law, i.e. the linear relationship between flow quantity or velocity and pressure reduction, no longer applies. Furthermore, it is difficult to calculate the Reynolds number for flows in textile yarn packages because the average pore diameter (d) cannot be determined with sufficient accuracy. The reason for this difficulty is that the proportion of flow through the yarn filaments, compared to the proportion of flow through free volume, i.e. around the yarn, is dependent upon the packing density. For the practical case of a cotton cross-wound yarn package with a packing density of 0.23 g/cm^3, it has been calculated that only 6% of the total flow goes through the yarn. This percentage increases with higher packing densities. It should also be borne in mind that the flow rate in the yarn package is inversely proportional to the radius. Therefore, there may be areas within the yarn package, where the flow is laminar and Darcy's law applies, and areas where there is turbulence.

Above this critical flow rate the pressure reduction Δp over the flow distance Δx depends upon a quadratic component D_f^2 in addition to the linear proportion of the flow over time D_f. Where a and b are constants:

$$\frac{\Delta p}{\Delta x} = a \cdot D_f + b \cdot D_f^2$$

Pairs of hollow measuring needles are arranged in the yarn package to detect the pressure difference, and are connected to pressure differential detectors outside the dyeing equipment by heat resistant tubes and pipes fitted with a pressure tight seal into a flange (Fig. 2). In these differential pressure detectors an extended wire element is part of a Wheatstone bridge. Pressure changes are transmitted via a membrane on the extended wire element and effect a change in resistance and thus a shift of the bridge equilibrium. Bridge supply, output signal rectification and amplification are performed by a carrier frequency measuring amplifier. The output voltages are proportional to the differential pressures and are drawn by a multilinear recorder. Total pressure in the dyeing equipment and the liquor temperature can also be registered on this recorder (according to Kretschmer and Glander).

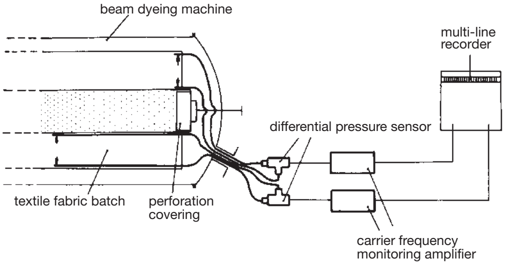


Fig. 2: Construction principle of a differential pressure measuring unit on a beam dyeing machine (Glander).

Pressure drier In this drier the system is completely closed and pressurised, up to 8 bar. The moisture is extracted from the circulating air via a cooler, heated up and fed back into the boiler; the water is removed by a separator. → Yarn dryer, air stream.

Pressure kier Wrought iron autoclaves for the kier boiling of loose stock, yarn, wound packages and piece material.

Pressure regulator Device based on the principle of fine control with a pressure sensor (impulse unit) and remote transmission (by compressed air, liquid or electric current), whereby the pressure in pipes (air, water, steam, gas) is automatically controlled by control equipment (motor-driven, reducing and shut-off valve). Application: For steam boiler operation; hydraulic and pneumatically operated components; as throttling controller, volume controller, circulation regulator, etc.

Pressure screws for printing rollers Steel spindles onto which the printing roller cylinder is screwed.

Pressure steamer Continuous steamer for steaming at temperatures above 100°C for developing pad dyeings and prints or HT bleaches. Discontinuous for combed tops (vigoureux) printing, loose material and piece goods. → HT pressure steamer.

Pressure steamer for hosiery For all types of forming processes for the preforming (preboarding) of undyed polyamide hosiery or socks, for forming dyed hosiery that has not yet been preformed (postboarding, recommended prior steaming of the unsewn hosiery blanks) and for subsequent forming (finish boarding).

Pressure steaming process Fixing, for example, of disperse dyes in the pressure steamer at 130°C with saturated steam. Application on polyester combed tops and spun tow. → Thermosol dyeing processes.

Pressure vessels All vessels or pipe layouts in which, when in use, there is a positive operating pressure greater than 0.1 bar or a negative operating pressure of under 0.2 bar. The directive regarding “Pressure vessels, pressurised gas vessels and filling plants” has been in existence since 1.7.1980 as the so-called Pressure Vessels Regulation ZH 1/400, available free of charge from the responsible textiles and clothing professional and technical associations. In the operation of HT dyeing machines it should be noted that material handling takes place under hydrostatic pressure at liquor temperatures well above boiling point. Due to these high liquor temperatures, even after the pressure inside the boiler or equipment has been reduced to atmospheric pressure (by opening the pressure valves and cocks, which are sometimes mechanically operated) so-called heat pockets may arise with temperatures above 100°C, which may once again bring the hot liquor to the boil. Due to sudden re-evaporation and the increase in pressure, the loosened, but not yet raised lid can be flung off and the contents explosively ejected, exposing the operating personnel to extreme danger. It is important to observe the following operating rules:

1. The boiler or device lid must never be opened immediately after the pressure has been released from the container.
2. Do not open the cover lock until you are certain that the temperature of the charge and the liquor has fallen to 80°C. It is then advisable, either to discharge the liquor prior to opening the vessel, or to pump it back into the preparation vessel (when charging with warp beams or crosswound yarn packages, etc.), or to rinse the vessel with cold water or cold liquor for a long period before opening (charging with loose material, flock, ropes, etc.).
3. The pressure pipes and valves should be checked on a regular basis for blockages due to clumps of fibres, etc.

Pressure Vessels Regulation HT equipment and vessels, in which gas can be formed (e.g. during bleaching with peroxide) are subject to this regulation. According to paragraph 3.1.2 of the “Technical Regulations Concerning Pressure Vessels TRB 403”, safety devices to prevent excess pressure must be designed such that when the permissible operating pressure has been exceeded by 10% the maximum mass flow can be discharged. According to section 3.1.3 of TRB 403, rupture disks should be used instead of safety valves, which cannot discharge the mass flows that occur, for example, due to the sudden formation of gas or steam. A further contribution can be made to increasing safety by designing pressure vessels for a higher maximum operating pressure.

Pretreatment All processes for the improvement of wetting capacity and absorption, dye take-up capacity, purity of the textile material, to increase the degree of whiteness and for better material development, i.e. for relaxing and structure development. At the same time tension (Figs. 1 and 2) and material non-uniformity (Fig. 3) arising from prior weaving and knitting processes should be removed.

In general, this finishing stage should take place in an intensive, but low tension process, in order to prevent relaxation and fabric compacting. Different processes and machines are required for the generation of the above-mentioned effects, depending upon material and requirements.

The raw material contains natural impurities such as grease, pigments or mineral substances and artificial or accidentally applied substances, e.g. sizes, mineral oil specks, caused during weaving, etc. All these impurities must be removed because they impair subsequent finishing. Precise analysis methods facilitate the detection of the different criteria of the pretreatment effects. Special machines, processes and products are necessary for removing the impurities without significant fibre damage.

Correct pretreatment is therefore dependent upon:

– the substrate (natural or synthetic fibres),

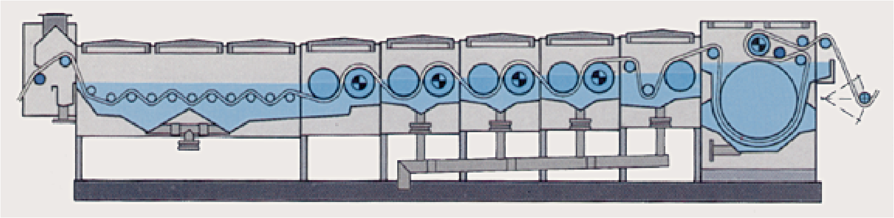


Fig. 1: "Flipper" (Küsters) for relaxation washing.

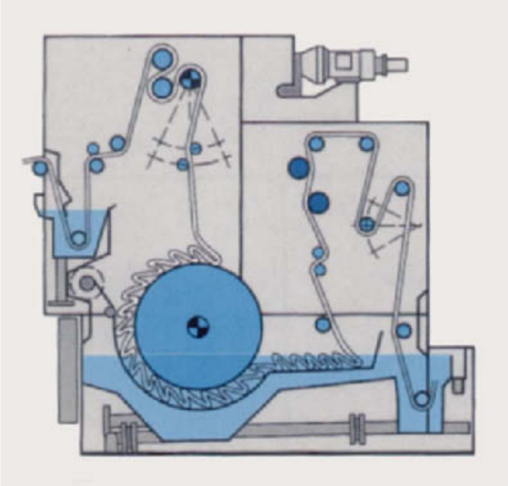


Fig. 2: Open-width rotary washing machine for low-tension washing (Küsters).

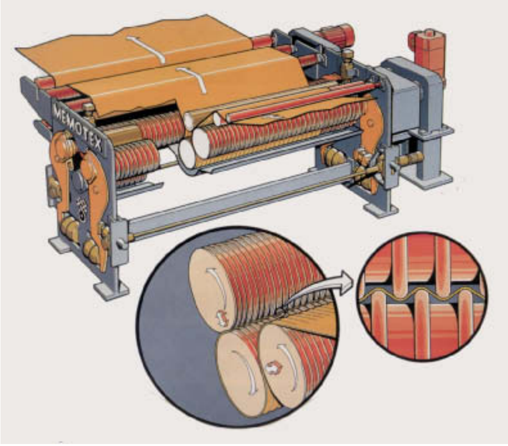


Fig. 3: Memotex woven fabric stretching machine for levelling out material irregularities (Küsters).

- making up form (fabric, knitted material, etc.),
- the procedure (desizing, scouring, alkali treatment, bleaching),
- the machines (continuous, discontinuous, semi-continuous),
- the chemicals (enzymes, wetting, washing, complexing, stabilizing, reducing, oxidizing, anti-foaming agents, etc.).

Numerous machines are available for pretreatment. The main continuous processes use pad-steam, J-box, U-box and immersion devices. The material flow speed is an important factor. Below 50 m/min counts as low speed and above 100 m/min high speed.

There are also discontinuous pretreatment devices, namely the winch beck, the jigger, the jet or autoclaves. The liquor ratio plays an important role. The individual process stages follow each other, whereby each step requires its own setting-up time.

In the semi-continuous process approx. 2000–5000 m of material are impregnated and treated for a dwelling time of 12–24 h at room temperature (pad batch) or 1–3 h using saturated steam feed (pad roll) (Fig. 4).

The following units are always needed in all pretreatment combination processes:

- impregnation unit (wetting trough, sieve drum, roller vat),
- dwelling section for time processes (under/over liquor, in steam environment).
- intensive washing units for the removal of impurities and chemicals,
- drying unit.

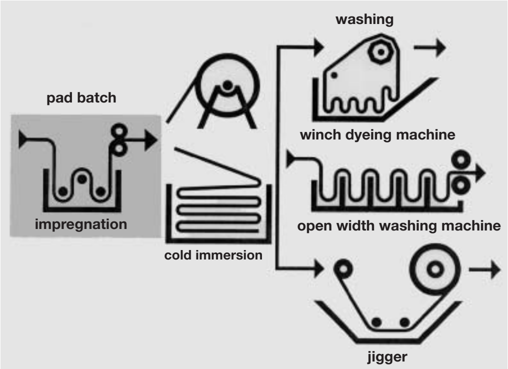


Fig. 4: A typical pad-batch situation in the pretreatment of cotton fabric.

Pretreatment for printing

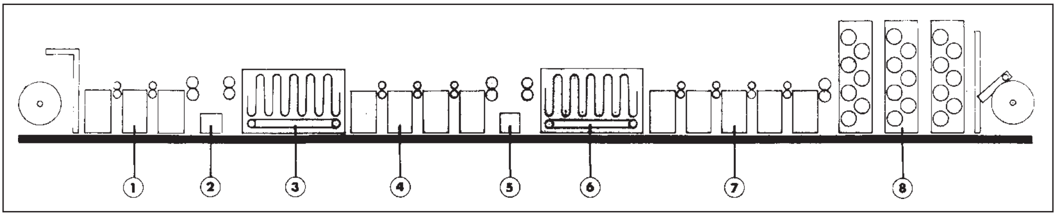


Fig. 5: A three-stage conventional pretreatment facility for desizing, scouring and bleaching cotton fabrics. 1 = washing out the degraded starch; 2 = impregnation with sodium hydroxide ready for the scouring stage; 3 = scouring stage steamer; 4 = roller vats for washing out the degraded products from the preceding stage; 5 = impregnation with hydrogen peroxide; 6 = peroxide steamer; 7 = washing following the bleaching stage; 8 = cylinder driers.

The following are amongst the pretreatment processes (Fig. 5):
- scouring,
- bleaching,
- desizing.

The Tab. illustrates the energy and water consumption in cotton pretreatment.

facility/plant components	final quantities consumed	
	water l/kg goods	steam without heat recovery kg/kg goods
conventional pretreatment		
1. pre-washing following desizing	4	0.6
2. impregnation with sodium hydroxide	1	–
3. immersion in combinination steamer box for scouring	–	0.5
4. washing following scouring	4	0.6
5. impregnation with hydrogen peroxide	1	–
6. immersion in combination steamer box for bleaching	–	0.5
7. washing following bleaching	6	0.9
8. cylinder drier	–	0.9
in total	16	4.0

Tab.: The requirements for energy and water consumption in cotton pretreatment (Kleinewefers KTM).

Pretreatment for printing The greatest proportion of these items are those made of 100% cotton. Specific requirements are imposed with regard to absorbency (wettability), dimensional stability and uniform whiteness with the greatest fibre protection. The quality of the print is dependent upon the absorbency of the material. The absorbency must be high if the print is to be visible on the reverse of the material. The dye consumption is thus correspondingly higher. If the print only needs to be faultless on the right side, then a deep effect is not necessary. Pretreatment therefore needs to be directed towards the demands of the printer. The classic process is 4-stage: desizing, mercerizing, alkali treatment and peroxide bleaching. Depending upon the quality of the fabric and the demands on the finished material, open-width treatment or treatment in rope form are possible for stages 1, 3 and 4. The trend is towards continuous treatment in open-width form.

Pretreatment jigger For desizing, bleaching, scouring and rinsing, also for impregnation during pad-roll bleaching.

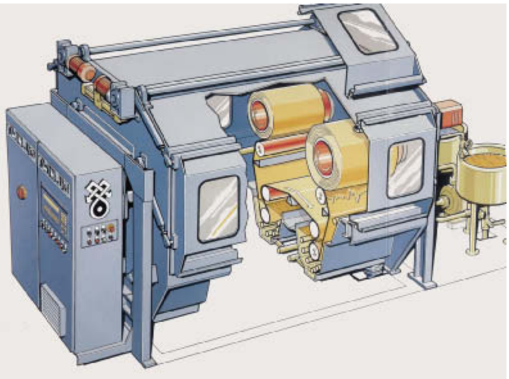


Fig.: Twin-Jig (Küsters) for dyeing and for batch-type pretreatment.

The pretreatment jigger counter-current water feed, (see Fig.) from the front to the rear basin is available for washing processes. An adjustable height spreading pipe between the basins improves liquor separation. Pressure rollers, which are pressed against the batching roller with adjustable pressure, ensure additional liquor exchange. Material feed problems, which occur with certain items due to liquor wrapping, are avoided with pressure rollers.

Pretreatment of cotton The raw cotton and the fabric produced from it contain non-cellulosic attendant substances and impurities. The impurities, such as seed shells, pectin, wax, etc. can have a detrimental effect upon the cotton finishing, because they are generally present in varying quantities and in a non-uniform distribution. The task of pretreatment is to use physical, chemical and biological processes, to largely and uniformly free the cotton from attendant substances in order to achieve a high and consistent dye take-up capacity and as high and uniform level of absorbency as possible. Furthermore, the cotton must be shell free and have a high DP value. The degree of whiteness is not always the most important quality feature, because the material is only lightened sufficiently to guarantee the colour shade and the brilliance of the dye or print. The quality of a dye or print depends upon the correct performance of the pretreatment (Fig. 1).

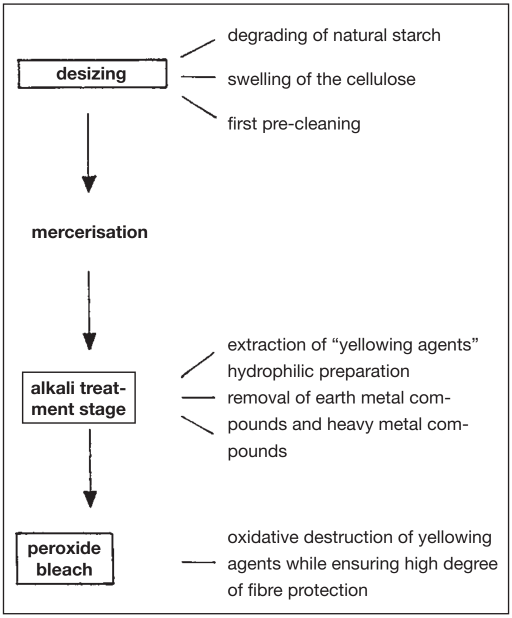


Fig. 1: The pretreatment of 100% cotton fabric for dyeing and printing.

The task of pretreatment is to remove substances from the raw material, which are brought into the cotton in the form of natural and process-related attendant substances by means of processes like singeing, desizing, alkali scouring, acid treatment and bleaching, with the associated passage of water (Tab. 1).

The attempt to reduce the aims of cotton pretreatment to a common denominator could be formulated as follows; preparation of a textile material, which as far as possible satisfies the demands of the subsequent finishing stages in dyeing, printing, and/or finishing.

naturally occuring	*arising through processing*
hemicellulose, pectins	size
proteins	fats
seed husks	oils
remnants of fruit capsules	waxes
pigmenting substances	metal filings
immature cotton	
salts	

Tab. 1: Contaminants in cotton.

Procedures and recipes, once worked out, should be reproducible without major modifications and loss of time at a low cost. Not only the interests of the dyeing and printing company must be taken into account, but also the mechanical and chemical final finishing: requirements, including those relating to crease resistance and dimensional stability, are becoming ever more demanding.

Pretreatment can make a critical contribution towards achieving the technological values, because important chemical properties are attained and mechanical damage such as the formation of folds, crease marks and uncontrolled stretching of the material are prevented (Tab. 2).

chemical technological	mechanical technology
rapid re-wetting high degree of absorption low ash content free of size level of whiteness shell-blemish free high dye take-up capability	evenness of styling effects (edge-centre-edge longitudinally and as a cross-section of the fibre and thread structure) dimensional stability freedom from folds and creases

Tab. 2: Requirements applying to the pretreatment processing of cotton piece goods.

In addition to these criteria, which can usually be clearly defined and the value of which can alter the application purpose of the material, managers are also interested in processes with:
- good safety,
- good reproducibility for different cotton provenances,
- applicability for all types of sizes,
- applicability on as many and varied items as possible,
- favourable cost/performance ratio.

Many faults can occur during pretreatment (Tab. 3).

Pretreatment can be performed as rope or in open-width form, in bound or free material feed (Fig. 2).

Pretreatment of cotton

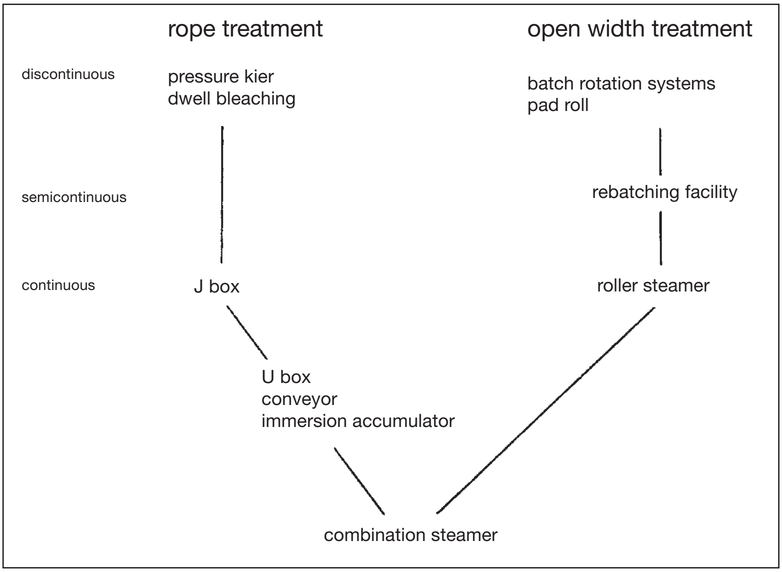


Fig. 2: The development of pretreatment facilities.

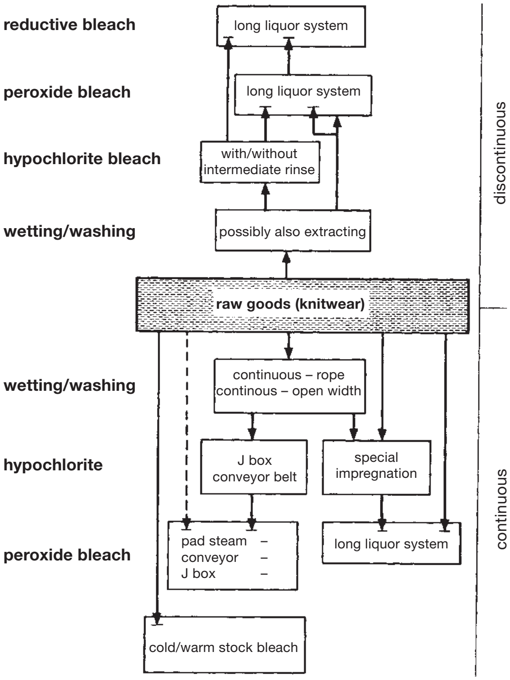
impurities	colouristic effects
coloured soils	lower degree of whiteness (mostly red-cast)
seed husks, leaf and stem residues, neps	restless fabric appearance
residual matter: – insecticides – growth regulating agents – defoliants	staining, resisting
metal traces	rust spots, bleaching damage, holes
foreign fibres, fibre fly	resisting, coloured ends
size and spin finish residues	unlevelness, resisting
lubricating oil and graphite residues	light/dark spots
soiling, e.g. dust	unlevelness, resisting

Tab. 3: Possible fault causes in pretreatment.

Fabrics (e.g. woven and knitted material) are pretreated (Figs. 3 and 4).

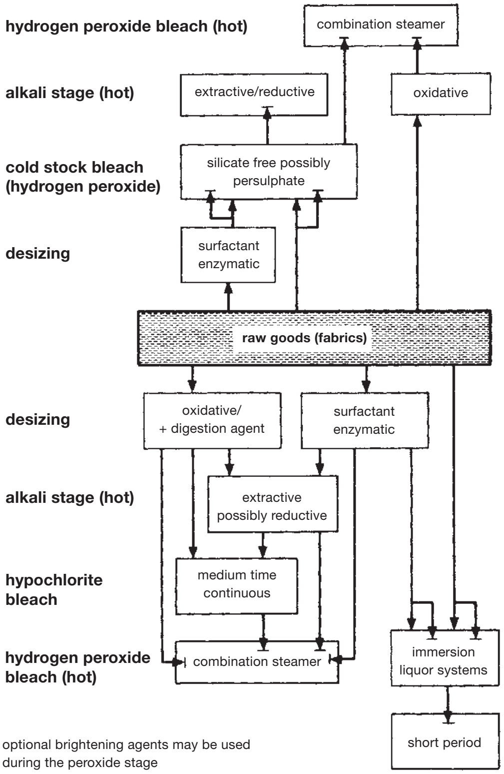
Pretreatment is carried out continuously or discontinuously depending upon the item and batch size (Tab. 4). Fig. 5 shows the classic operation sequence in pretreatment on a continuous line for cotton or mixed fabric. The mercerization (alkali treatment) may be dispensed with.

For environmental reasons, only bleaching with peroxide is recommended, because hypochlorite produces high AOX values in waste water. If only a single stage peroxide bleach is desired, it is recommended that normal moisture application (Fig. 6 and Tab. 5) wet-in-wet is dispensed with in favour of high moisture application (Fig. 7).



optional brightening agents may be added either during the peroxide bleach or during the reductive bleach stage

Fig. 3: The process cycles for cotton knitwear.



optional brightening agents may be used during the peroxide stage

Fig. 4: The process cycles for cotton fabrics.

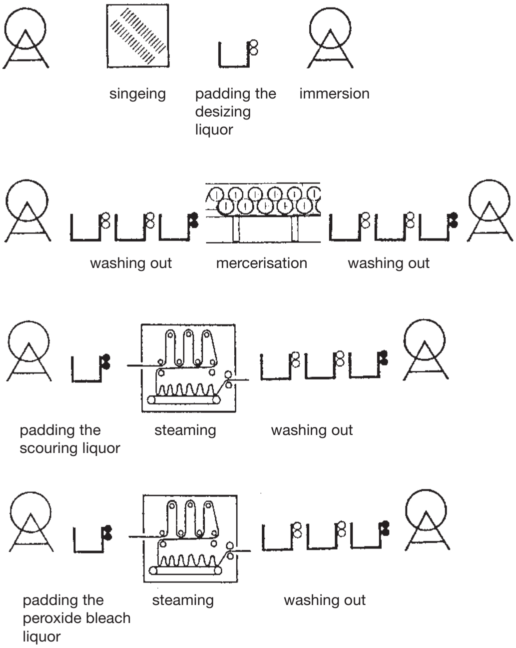


Fig. 5: Diagram representing the choice of processing cycle for each different type of article during pretreatment.

rope type	open width treatment
discontinuous	*discontiuous/semicontinuous*
winch dyeing machine jet, overflow package dyeing system (with automatic loading system)	jigger (programmable large volume pretreatment jigger) beam apparatus recirculation systems (e.g. Rotowa) cold stock immerson systems (pad batch) hot stock immerson systems (pad roll) – moveable batch waggon – stationary chambers – bleaching tunnel
continuous	*continuous*
J box with and without sump system: Becco Du Pont Steinzeug Kleinewefers KTM rope accumulator (Menzel) continous winch dyeing machines continous jet liquor immersion dwelling for rope form	continuous pad roll (Bentel rebatching chamber) dwelling system without incorporated movement of goods – tier conveyor 40–60 min – U box 8–24 min – roller bath facility 8–24 min – L box 30–45 min dwelling system with incorporated movement of goods (combination steamer) principally with integrated movement 1–2 min movement, 6–10 min dwelling principally with dwelling 20–30 seconds movement, 9–24 min dwelling atmospheric short period pretreatment steamer 1–3 min high temperature (pressurized) systems – only tied movement of goods 1 minute (HTP steamer) – tied or loose movement of goods 1–3 min (Vaporlock) immersion bleach – long loop – conveyor dwellers (15–40 min) – (Steepmaster system approx. 16 min) – (Star-Trans system approx. 45 min)

Tab. 4: Characterization of pretreatment facilities.

Pretreatment of cotton

	desizing	alkali treatment	scouring	bleaching
process 1	–	–	–	pad batch (room temperature)
process 2	–	CRC process	–	if needed
process 3	–	–	with persulphate	if needed
process 4	–	–	pad steam following bleaching	pad batch (room temperature)
process 5	–	–	pad steam with persulphate	pad steam or U box
process 6	–	CRC process	–	pad batch or pad steam
process 7	pad batch enzymatic	–	–	pad batch cold
process 8	pad batch enzymatic	–	–	pad steam
process 9	enzyme shock	–	–	pad steam
process 10	pad batch enzymatic	mercerisation	pad steam	pad steam
process 11	pad batch enzymatic	mercerisation	pad steam	pad steam

Tab. 5: Various normal humidity coating systems in classic cotton pretreatment (CRC by Sandoz).

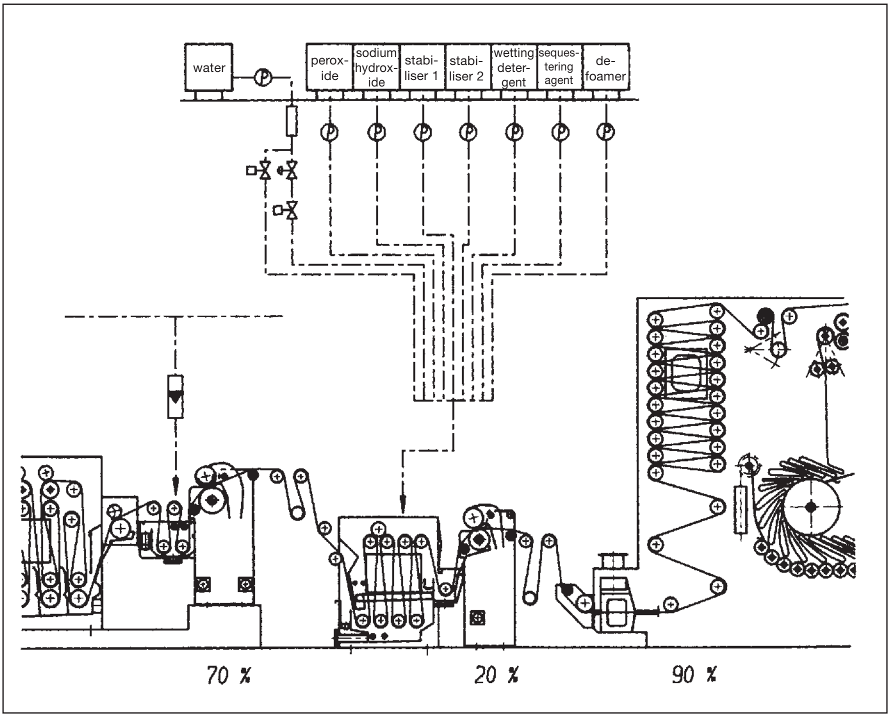


Fig. 6: Wet-in-wet liquor application including the impregnation stage.

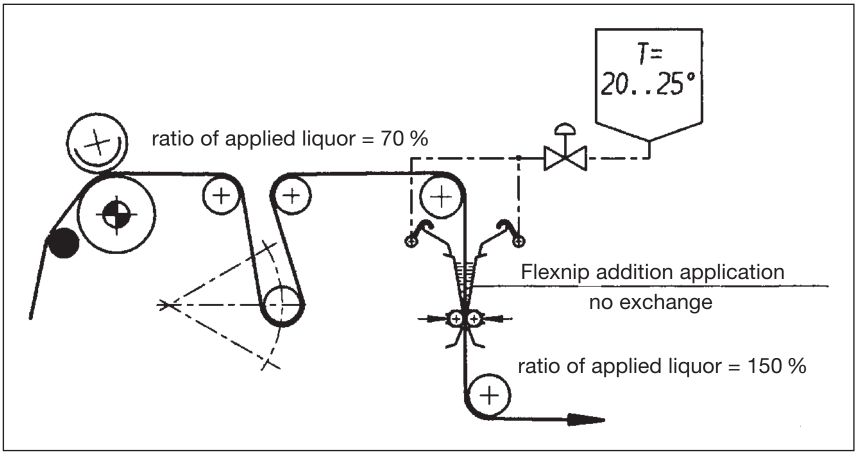


Fig. 7: Liquor addition application (Küsters Flexnip).

Higher degrees of whiteness are achieved using the pad-steam process with a longer liquor ratio. Using flexnip high moisture application, the material to be bleached is put into the steamer for peroxide bleaching with 150% liquor application (Figs. 7 and 11).

In order to make the pretreatment as reproducible as possible, it is recommended that the necessary chemicals are dosed according to consumption (Fig. 8).

High moisture application can also be achieved by the wet-in-wet process with two horizontal padders (1st horizontal two-bowl padder, 2nd padder “split”); this is achieved in the Optimax (Fig. 10). Maximum liquor application is desirable in textile pretreatment. New procedures facilitate, e.g. the combining of the scouring and bleaching processes into a single pretreatment stage following desizing. In the Optimax process total residual liquor values of approx. 150% of the dry weight of the material are measured in cotton twill material (Fig. 10). A section of the continuous pretreatment plant is shown in Fig. 9. After the washing out of the desized material on a tower open-width washing machine, the pretreatment liquor is applied in the subsequent application device. Because this is an addition application process, there is no dilution of the liquor. The continuous titration of the liquor can therefore be dispensed with. Then the material passes to a combination steamer of approx. 100 m with bound material feed and double stacking.

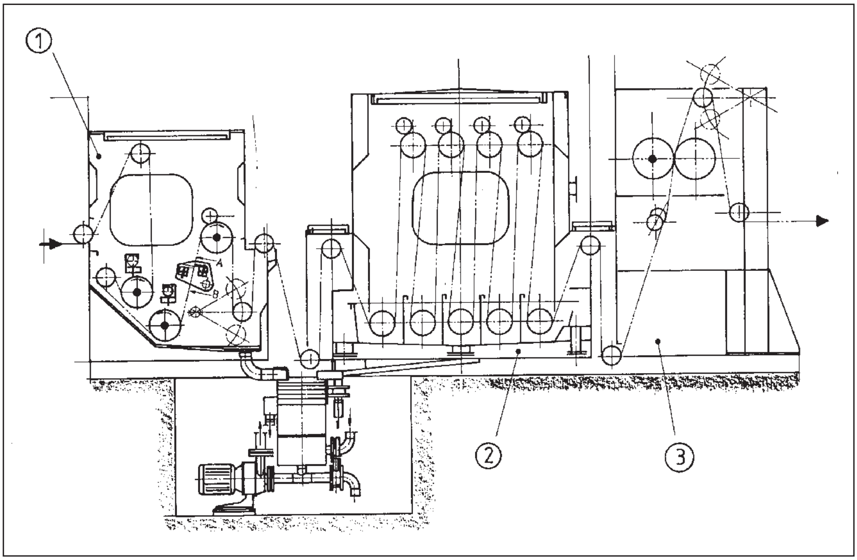


Fig. 8: Babcock Super-Sat laboratory machine for the Lower Rhine College of Technology. 1 = Super-Sat impregnating section with Polykomat dosing and recycling sump; 2 = Convitex: combined steam roller vat; 3 = squeeze traction unit.

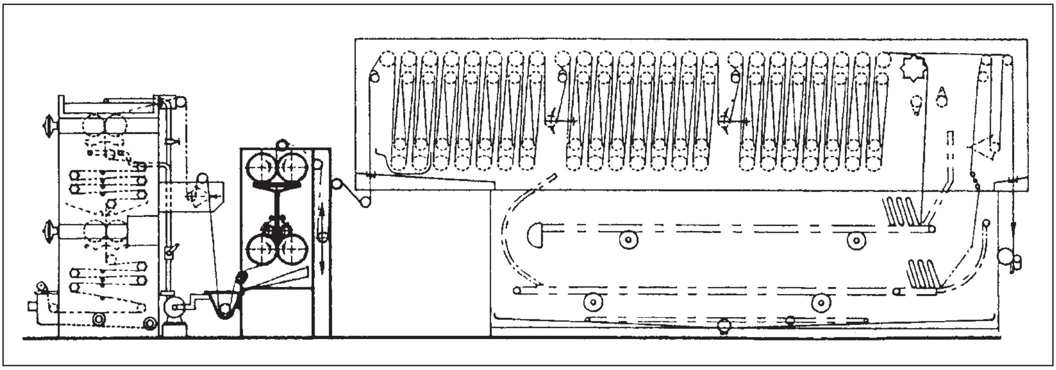


Fig. 9: Pretreatment line with Optimax applicator (Menzel).

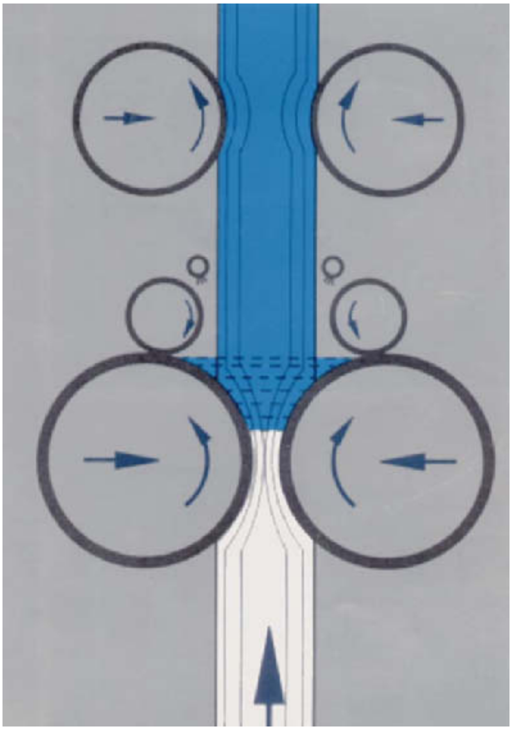


Fig. 10: Optimax high wet liquor application (Menzel).

If we compare single stage bleaching with the integrated scouring stage of the Flexnip system (Fig. 11) with the Raco-Yet process (Fig. 12), then we notice that after the hot impregnation in the Raco-Yet, shorter steaming times without free material feed (thus without dwell chambers) are possible (after the washing out of the water soluble size in a prewash) (according to Fornelli and Günther, Hager, Herlinger et al., Reineke, Rösch and Schlicht).

Pretreatment of knitgoods → Knitgoods, pretreatment.

Pretreatment of man-made fibres For the removal of preparations, softeners, sizes (see Fig.: Result of polyester fibre product pretreatment), the active surfactants are non-ionogenic products in an acid, neutral or alkaline medium depending upon the degree of soiling. In alkaline preparations synergetic mixtures of non-ionogenic/anionic components have proven themselves. There still appears to be no optimal recipe against oligomers in polyamide and polyester, with the exception of solvent-containing washing baths (e.g. tetrachloroethylene emulsions), also recommended for polyurethane fibres. In the case of polyamides, anionic surfactants can block basic groups (impairing subsequent dyeing with acid dyes). Polyacrylonitrile tends to yellow in alkaline liquors (i.e. wash acid or neutral). Polyester undergoes surface hydrolysing due to highly alkaline washing, whereas acetate fibres may not be

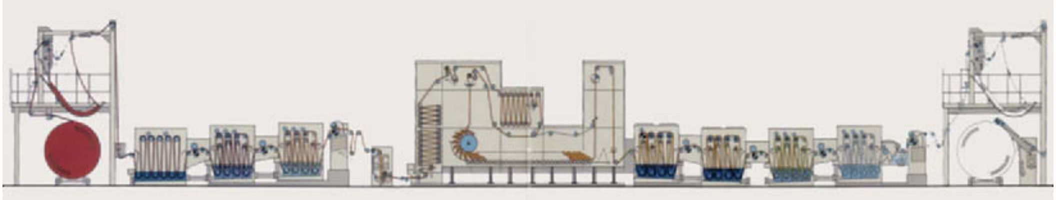


Fig. 11: Küsters cotton pretreatment with Flexnip addition application and with combi-steamer for longer steaming.

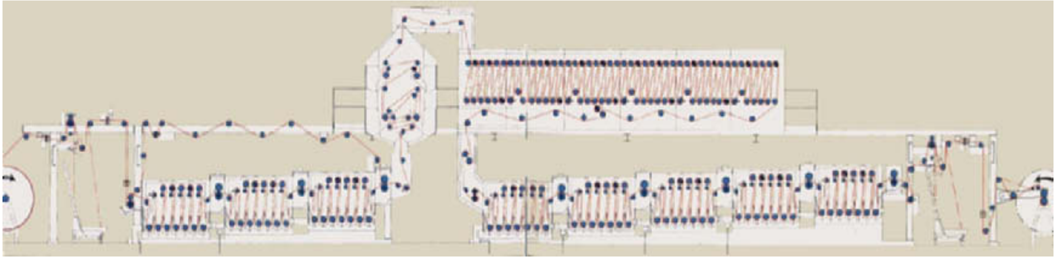


Fig. 12: Raco-Yet confined passage aerosol liquor application with short period steamer (Kleinewefers KTM).

treated at greater alkalinity than pH 9 (otherwise there is a danger of acetyl groups splitting). In regenerated cellulose with heavy metal ions catalytic hazards are possible during subsequent bleaching, thus the addition of complexing agents is advisable.

Primary cellulose acetate fibre → Triacetate fibres.

Primary colours

I. represent the three sensory powers ot the visual organ: yellow, blue, red; all other colours can be obtained from these by mixing. Mixing two primary colours yields the → Complementary colour of the third, e.g. yellow + blue = green = complementary colour of red.

II. The visual organ can achieve eight extreme sensory options. In a mixing system (→ Colour mixtures) for opaque colorants all eight colours are needed: cyan, black, green, violet blue, magenta red, white, orange red and yellow.

Primary energy carrier → Energy carriers.

Primary salts Acid salts of multivalent acids, in which only one hydrogen atom is replaced by metal; e.g. primary acid sodium phosphate NaH_2PO_4 derived from phosphoric acid H_3PO_4. →: Secondary salts; Tertiary salts.

Primer (bonding agent), if incompatible polymers (e.g. textile base fibre material and coating polymer) are nevertheless to form a composite material, a primer must be applied between the polymers. These bonding agents, in the form of block copolymers usually with two types of blocks distributed in the copolymer, are compatible both with the base material and the coating material. So the primer can be applied to the base material first, followed by the coating components (see Fig.: A coating facility for adhesive tape).

Principal valency In organic compounds each valency (→: Valency; Chemical bonds; Atomic bond) which, in contrast to the → Secondary valency forces, does not tend to dissociate and corresponds with the tetravalency of carbon.

Principal valency chains → Chain link number and chain molecules.

Print adhesives → Table adhesives.

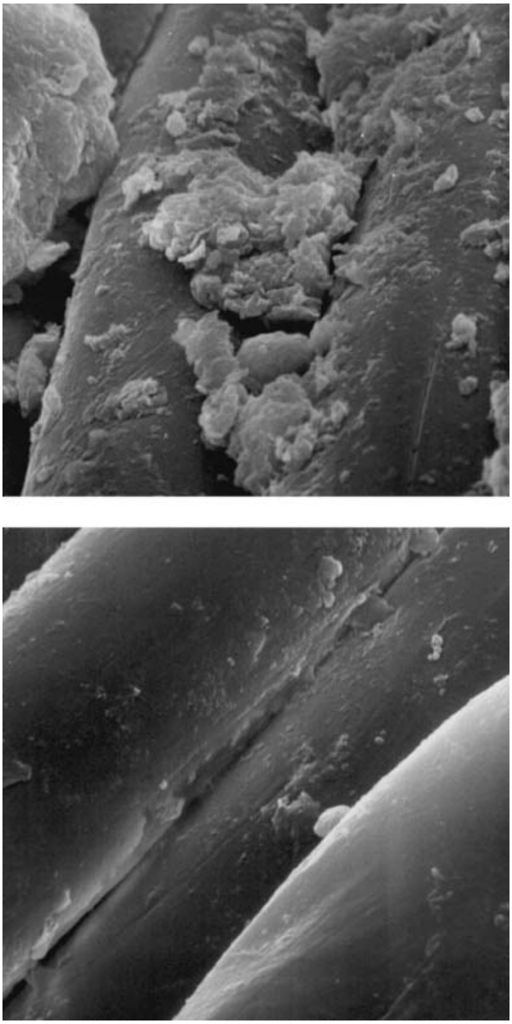


Fig.: Result of polyester fibre product pretreatment. Top: spin finishes and other fibre coatings; bottom: cleaned fibre surface.

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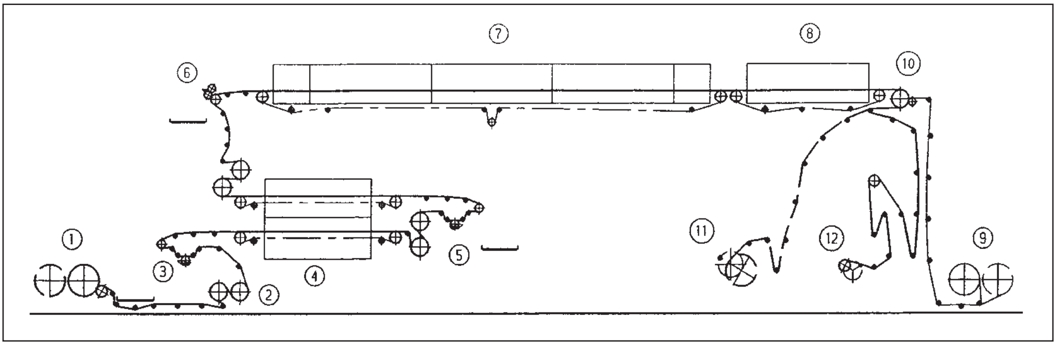

Fig.: A coating facility for adhesive tape (conceived by Olbrich) with primer application (3) and film application (5) as intermediate substrate and adhesive coating.
4 = drier; 7 = inert gas drier; 8 = cooling zone; 9 = winding the finished adhesive tape; 12 = PVC film winding.

Print bonding Procedure for the strengthening of nonwovens by the application of print pastes containing a binder and cross-linking by thermal treatment (→ Overall bonding). Print bonded fabrics are → Nonwovens, the fibre structure of which is bonded in patterns of dots. Better handle compared to full bonding. Disadvantage: lower strength.

Print coverage In textile printing the ratio of dye applied/printing area.

Print definition The so-called staying power of a print paste, i.e. the upper limit of possible thickener concentration for printing purposes (→ Flow properties of thickeners and print pastes) at which the print paste covers the fabric uniformly (not to be confused with full print penetration). At an even higher concentration, the print would already “grin”. On the other hand, the lowest limit of printability of a thickening agent is the point at which the print paste bleeds hopelessly making acceptable prints impossible. Comparative measurements of print definition (the actual extent of any tendency for the print paste to “run”) in extremely fine design contours can be carried out on the fabric to be printed or on standardised filter paper, with an appropriately engraved roller in roller printing, and with a ring, spiral or wedge stencil in screen printing.

Print-Dye process 2-stage process consisting of printing/drying and dyeing/rinsing for floor coverings. There are various processes, either mechanical displace or chemical change processes. Using the rotation printing machine, chemicals or resist agents are applied to the material in a colourless print paste. In the mechanical displace technique the fibre is coated with chemicals, so that no or only a small amount of dye take-up is possible at these points. In the chemical change technique, the paste application with resist agents brings about a change of the affinity of the polyamide fibre to the dye. Different effects, e.g. half and full tone resists, but also bright resists with a contrast effect, can be achieved. The colour change can be influenced by different concentrations of chemicals or resist agents in the print paste. After the printing process the paste application is fixed on the material in the dryer. The pre-treated material is now dyed in a dye vat, usually with a dark dye. At the points where no chemicals have been applied, the colour of the liquor in the vat appears, whereas at points where chemical has been applied, a lighter shade is generated in the upper area of the carpet pile and the base of the pile is dyed by the dyeing liquor.

Printed damask effects → Pigment printing.

Printed suede Silk screen printed suede fabric produced as piece goods for high quality womenswear and menswear.

Print flushing arises due to excessively deep engraving, inadequate absorbency of the printed material and excessive pressure by the printing roller on the material, either on one side or on both sides. Print flushings show up on the material as blurred, lacerated contours, which usually run opposite to the printing direction. Prints can be flushed by subsequent printing rollers if previous printing rollers have applied too much print paste to the material. The problem is rectified by altering the engraving depth, adding wetting agents, reducing the roller pressure or altering the viscosity of the print pastes.

Print impression method This was developed for examining the surface of engraved calender rollers and rotary screens for screen printing, and are based upon the creation of an imprint in polystyrene by means of a silicon rubber negative. The print impression method, originally developed for use with the scanning electron microscope, is now used with the stereomicroscope.

Printing Printing is local dyeing in zones according to patterns. Thickeners ensure that these zones defined by the engraved pattern are adhered to. The type and size of the artistic design determine the printing process and method of dye paste application. Various

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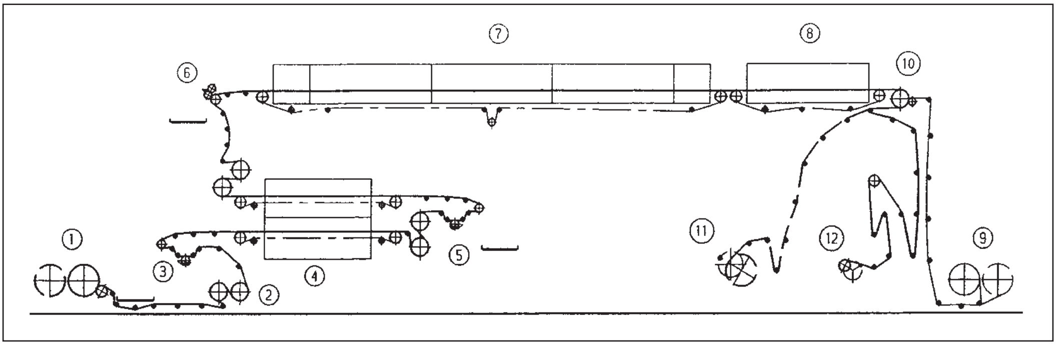

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Printing Printing is local dyeing in zones according to patterns. Thickeners ensure that these zones defined by the engraved pattern are adhered to. The type and size of the artistic design determine the printing process and method of dye paste application. Various printing types (→: Direct printing; Discharge printing, Resist printing) and techniques (→: Roller printing; Flat screen printing; Rotary screen printing; Transfer printing) are available to the colourist for the realisation of a print idea. Each printing technique is performed according to a specific printing process, which is usually based upon a uniform sequence of operations (printing, drying, steaming, washing).

Textile materials in a wide variety of finishing stages, for example combed tops (tops printing or vigoureux printing), yarn, (yarn printing and warp printing), and hosiery goods (material or textile printing) and fleece, come into consideration as substrates for printing. The mechanism of dye take-up by the fibres in textile printing is largely identical to the procedures for dyeing in the dyeing bath. As is the case for dyeing, the dye is bound to the fibre by

- adsorption or adhesive van der Waals forces,
- formation of hydrogen bridges by dipolar forces,
- formation of salts (ionogenic bonds due to electrostatic attraction forces), e.g. between anionic dyes and ammonium or positively charged amino groups of the fibre or cationic dyes and acid groups of the fibre,
- metal-complex formation or dative bonds between dye, metal and fibre,
- homopolar or covalent bonding involving reactive hydrogen atoms of the substrate (of hydroxyl groups for cellulose or amino or imino groups for protein fibres) and reactive groups of the (reactive) dyes.

Often, however, several of these bond types work together. This gives rise to the possibility that by strengthening the auxiliary valence forces (metal complexes) that give rise to the adsorption bond or by enlarging the molecule by diazotation and coupling, the fastness properties will be improved just as much as by the conversion of a water soluble or temporarily soluble dye into a slightly soluble or non-soluble form, e.g. by splitting or conversion of the groups conveying solubility (vat leuco ester dyes, vat dyes). On the other hand, dyes from water soluble, more or less substantive components, can be synthesized into insoluble products (insoluble azo, oxidation, phthalogen dyes) on or in the fibre, for example by coupling or condensation. Reactive dyes can also be chemically bonded to the fibre. Pigment printing occupies a special position, with the insoluble pigment dye being affixed to the substrate by inclusion, i.e. incorporation into a synthetic resin film.

The most marked difference between the relationships during dyeing and printing is that dyes and chemicals are present in relatively low concentrations in the dye bath, whereas in printing they are usually combined in higher concentrations in a print paste (Fig. 1), which also contains a thickening colloid. The concentration increases still further when the print paste dries on the fibre after printing. The subsequent treatment to transfer the dye from the print paste into the fibre and for fixing is usually achieved by steaming rather than in a bath and is subject to totally different concentration relationships than is the case during dyeing.

There are three significant factors regarding the absorption of liquids by textiles: the capillarity of the substrate, and the absorbency and the wettability of the individual fibres. In order to achieve sharply delimited

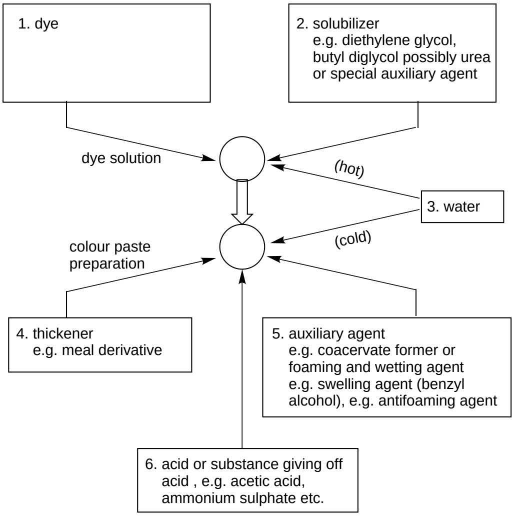


Fig. 1: Diagram of printing paste preparation for direct printing.

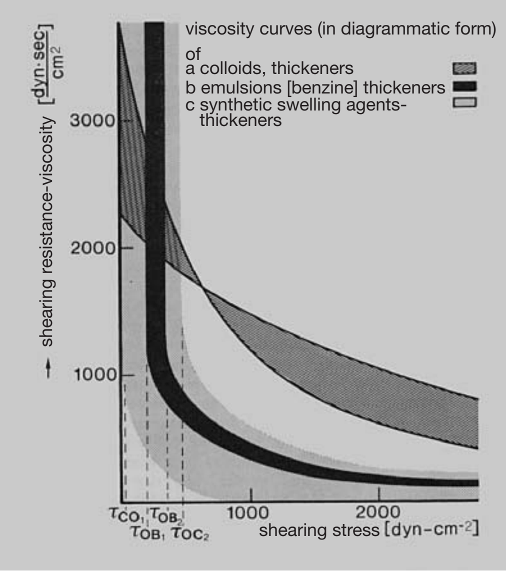


Fig. 2: Viscosity curves (in diagrammatic form, source Rasche).

print effects the capillarity of the substrate must be compensated by thickening the dye solution. Starch products, mucilages, flours, etc., which possess a high swelling capacity, are used as thickeners. The thickeners produced by adding water to these products are colloidal solutions (sols) or gels, whose main characteristic is a relatively high viscosity and a considerable, but not unlimited, water absorbency. If the environmental laws in force in the country in question still permit this, pasty emulsion thickeners of both oil-in-water and water-in-oil types with hydrocarbons (heavy gasoline, petroleum) are used as the oil phase. The dyes or chemicals are generally stirred into the thickeners in the form of aqueous solutions or dispersions.

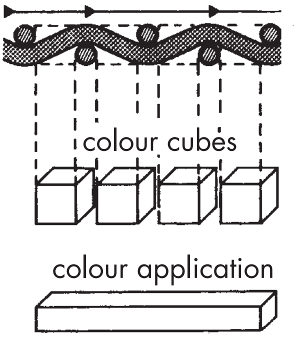


Fig. 3: Schematic representation of the printing process.

The characteristic feature of the print pastes used with thickeners is their structural viscosity (Fig. 2). If a highly viscous print paste is applied to the print screen, the tenacious print paste will not run through the screen holes provided until it is doctored. However, as soon as the doctor blade applies a shear stress to the print paste due to its pulling action the viscosity falls sharply. The thin solution flows spontaneously through the screen holes provided and comes into contact with the fabric (Fig. 3). The capillary forces of the textile now come into effect, and the solution is sucked out. However, a large proportion of the thickener remains on the surface of the fibre, because once the doctor blade has passed, the viscosity of the print paste spontaneously increases once again due to the reduction in shear stress. This prevents the print from running.

There is normally a drying process after the application of the print paste. Most of the water in the print paste evaporates during this stage; the paste dries to form a film, which adheres only to the surface of the fibre. Depending upon the type and composition of the thickener such films differ in their structure and their swelling capacity and water absorbency. In addition to these factors, the delivery of dye to the fibre when moisture is subsequently applied also depends upon the type of bond between dye and thickener and the penetration depth of the print paste into the textile material during the print process. This is the reason for differences in the quality of the colour depth and in the colour yield when different thickeners are used.

The dye and effective substances are usually transferred into the fibre by steaming, i.e. by a short or long period of residence in a steam atmosphere, and transfer can also be promoted by appropriate measures, such as the addition of wetting agents, dispersal agents, swelling agents or solvents to the print paste. During steaming both fibres and, in particular, the thickener absorb water from the steam and swell. The dye particles and chemicals are dissolved once again and diffuse. The diffusion of dyes and chemicals from the print paste

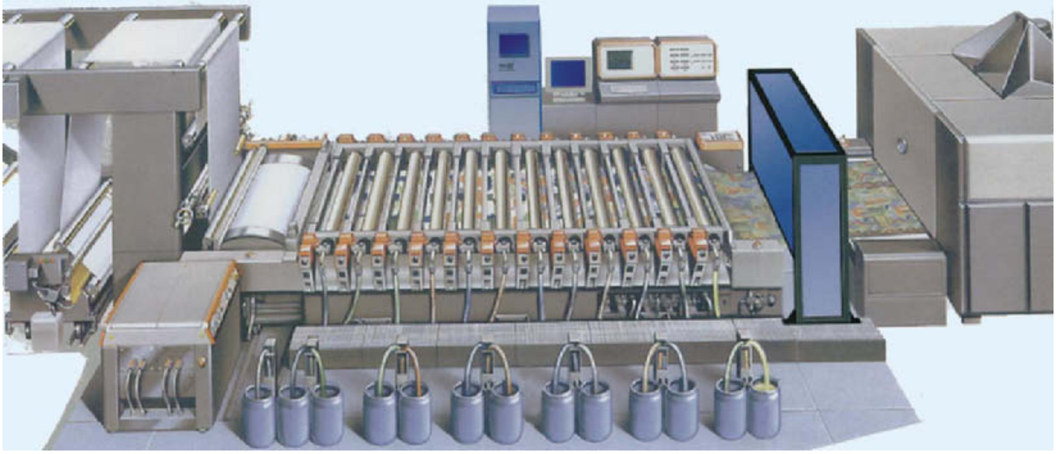


Fig. 4: Printed Fabric Monitoring as in-line defect inspection system (according to EVS).

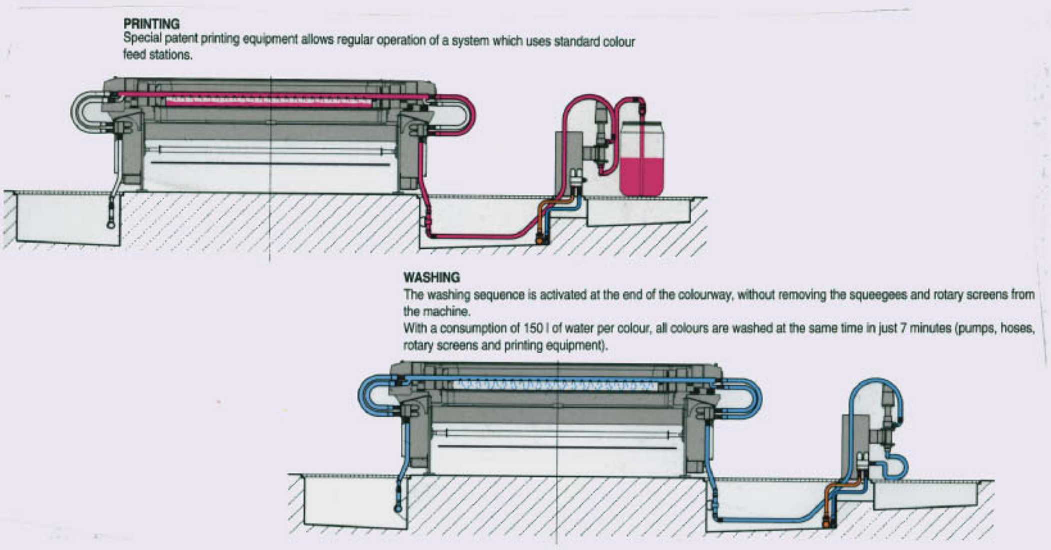


Fig. 5: Colourway or pattern change in printing.

into the fibres however occurs more slowly than the capillary absorption of liquids.

Printed Fabric Monitoring as in-line defect inspection system (Fig. 4) enables on-line detection of repetitive printing defects, thus improving the first quality yield. The system's proprietary processing technology enables it to process and analyse the extensive amount of data acquired by the sensors positioned over the moving printed fabric. Printed fabric faults are displayed in real-time on a video monitor enabling locating the fault and performing the required corrective action.

Every printing sequence (useful cycle) is always preceded and followed by colourway change or pattern change operations (squeegees and rotary screens washing, pumps washing) (down time). The Washing On-line system revolutionises the working cycle/down time ratio to the advantage of the former and this advantage is all the more evident the higher the number of colours and the shorter the run per colourway (Fig. 5). The data which support this revolution in productivity are simple:

– max. washing time:	7 min
– restart time:	5 min
– total water consumption:	150 l/colour
– equipment handling (rotary screens, squeegees):	none

Being able to rely on such figures and in every production cycle and every working environment means:
- the output is unaffected by short runs
- no seconds due to frequent start-ups
- no breakage due to rotary screens handling
- no handling (one person less)
- 2 to 4 times lower water consumption.

Printing area That part of the gauze of a screen printing screen that is permeable to print paste.

Printing auxiliaries These include: discharging agents, discharge printing assistants, mordants, printing oils, print thickeners, colorant binders, dye solubilizing and dispersing agents, after-treatment agents (to increase fastness), reducing agents.

Printing blanket Endless rubber coated fabric, which in roller printing is pulled over the lapping on the main cylinder.

Printing blanket seam join Using specific seam

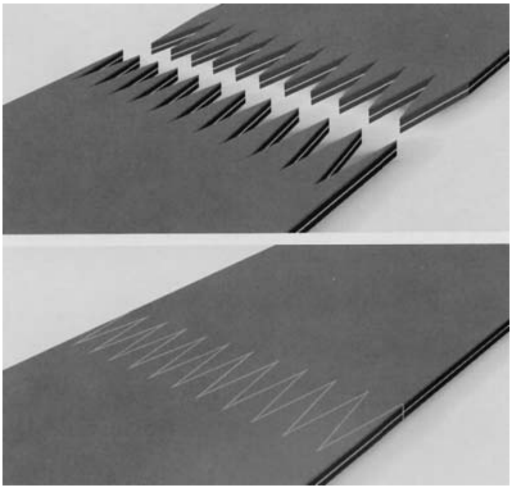


Fig.: Habasit printing blanket.

join systems high-performance pressure blankets can be directly seam joined in the printing plant. This dispenses with the need for dismantling and assembly work, and machine down time is correspondingly short. The actual seam join (hot pressing) is simple: The prepared ends of the printing blanket, which are stamped in a zigzag shape, are laid in the hot press device according to instructions, precisely fitted together and fixed. The heat compensation plate is put into place and the hot press device closed. After approx. 45 min the printing blanket is seam joined and ready for immediate use (see Fig.).

Printing carriage A movable carriage in which the printing screens are mounted one at a time. The carriage is supported on wheels running along rails at either side of the printing table. The printing screen is raised or lowered by lever action, and the squeegee (used to force print paste through the screen) is driven across the screen by a motor attached to the carriage. Printing carriages of this type represent a partial mechanization of the hand screen printing process.

Printing colour → Print pastes.

Printing cylinder A large cylinder (→ Central cylinder), which is not driven directly, but by the back cloth that runs around it and the printing rollers. In order to obtain an elastic underlay, it is wrapped in lapping. This is a cotton/wool fabric, which may be either gummed or ungummed. The lapping must be fitted with care. The start and end of the lapping must be at an angle and must mate up in such a way that there is no thickening at any point, which would later cause marking during printing. The printing roller is pressed against the printing cylinder. This is either done mechanically by springs and weights or pneumatically by compressed air. The printing roller may not be pressed on rigidly, but must be flexibly mounted, so that it can deflect when it encounters fabric seams (see Fig.). This elasticity is achieved in the lower roller using weights and in the upper roller by springs.

Printing gauze → Screen mesh, screen gauze.

Printing group Part of the printing machine where the actual printing process takes place.

Printing machines Tools are needed to transfer the print paste onto the pretreated material in the form of a pattern:

1. the model for letterpress or stamping printing (e.g. manual printing).
2. the engraved pressure roller for gravure printing (e.g. roller printing).
3. for screen printing, flat screens in the case of flat film screen printing or rotary screens in the case of rotary screen printing.

All these tools are the patterning elements for the printing technique in question. The mechanical pressure needed to liquefy the thickener and transfer it from the patterning instrument to the material is provided by doctor blade systems in modern machine printing. Because the output of printing machines is limited due to the required set-up times the material, possibly from several printing plants, is stored or collected after drying and is then fixed by a high performance steamer. The after-print washing takes place on a separate plant, which may even be a pre-treatment department. Procedural peculiarities include transfer printing and flock printing.

In flat screen printing the screens consist of wooden, metal or plastic frames and are covered with a sieve-like fabric (gauze) made of silk, phosphor bronze, polyamide or other synthetic fibres. The areas on this cover where the print paste should not pass through during printing are covered by a layer of lacquer. The print paste is spread through the open areas on the screen by a doctor blade; the doctor blade is usually made of rubber or plastic of differing degrees of hardness and the blade edge has a different polished section, allowing printing sharpness and penetration to be varied. Rod squeegees are also used. In screen printing on screen printing tables, approx. 40–60 m long and covered with felt, several layers of cotton fabric or a wax or rubber blanket, the material to be printed is pinned or glued down. The number of dye pastes can be as high as required for screen printing on tables; however it is limited by the length of the printing table and the printing costs, which increase with the number of

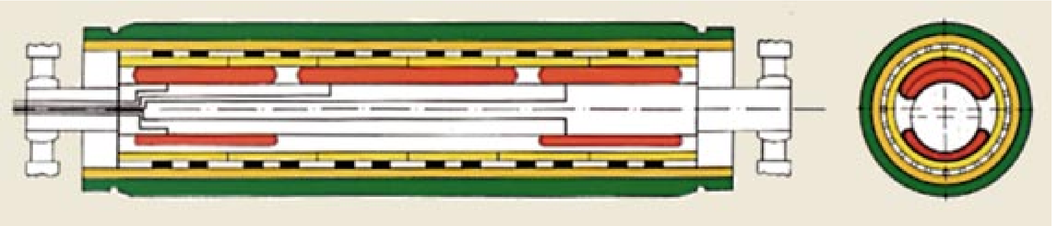


Fig.: Longitudinal and cross-section of a Bicoflex contact roller by Kleinewefers KTM as used in the gravure printing process as a printing cylinder to compress floor and wall coverings for the printing of coloured designs. The printing cylinder serves to ensure an even contact pressure against the gravure printing roller despite the large working width.

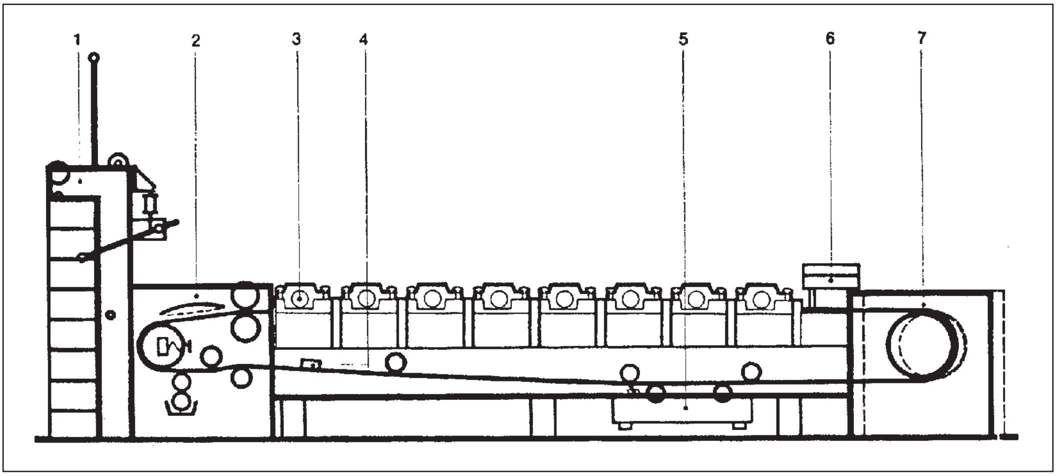


Fig.: Sectional drawing of woven fabric rotary screen printing machine (Buser).
1 = fabric entry stand; 2 = entry section with adhesive units, printing blanket guiding and drive motor for screen running only; 3 = printing head with print paste feed, screen mounting, squeegee system and individual operating station; 4 = interior squeegee; 5 = printing blanket washing machine; 6 = central operating station for printing machine and drier; 7 = exit section with printing blanket drive, screen synchronization, printing blanket tensioning unit and hydraulic station.

colours in the pattern. High-performance fully automated screen printing machines are characterised by repeat precision and high printing speed. In screen printing machines that use stationary flat printing screens, the material to be printed is mounted on endless conveyor belts made of rubber and repeatedly passed over the printing table, rhythmically moving and stopping. The screens can be lifted and lowered. Whilst the material is stationary, printing takes place using special doctor blades. This is therefore a semi-continuous printing process.

Rotary screen printing machines (see Fig.) work continuously using cylindrical screens and from the point of view of productivity are even more efficient than the fully automatic flat screen printing machines. The cylindrical screens consist of seamless, thin walled nickel foils; in perforated foils the print pattern is generated according to the same principles as in flat screen printing screens, in non-perforated foils the half-tone photoengraving process is used. Furthermore, patterned rotary screens can be produced by a photomechanical galvanoplastic method. The printing colours are inside the printing cylinder, as is the doctor blade (rubber doctor blade with special profile or magnet-roll doctor blade). These machines also have an endless rubber printing blanket, a glueing and material feed device and a connected drying device (→: Surface printing machines; Roller printing; Flat screen printing).

Printing path The length of fabric which occupies the printing zone of a printing machine during the printing operation.

Printing pressure In textile finishing this means the pressure at which the printing roller is pressed onto the central printing cylinder or various individual printing cylinders. Depending upon the design of the printing machine it is set by screw rods, disk springs, hydraulically, air-hydraulically or electromagnetically.

Printing pressure in roller printing Roller printing machines operate using oil or air-hydraulic pressure, which provides more protection to lappings, pressure blanket and material than is the case with screw spindles or plate springs. Furthermore, the applied pressure can be regulated from a control panel (can be read from manometers) and more quickly set for repeats.

Printing quality assurance The need to ensure uniformly high print quality on continuous lengths of material plays a decisive role in finishing. Colour deviations and printing errors of all types, for example, doctor blade, circulation and fabric faults, can be shown up by visualisation of the print pattern, thereby creating the conditions for precisely repeating printing, even in vat discharge printing. By monitoring the print pattern the production of quality material can be promoted and defects avoided. So, for example, a special video camera can be illuminated by a stroboscope synchronized with the machine. The amplified video signal permits the print surface to be represented on the monitor as a precise still. A zoom/macro function makes detailed monitoring possible. Such a system is also capable of saving picture sections (storage of a maximum of 90 camera positions and zoom positions and archiving in an order memory for repeat orders). Furthermore, reference pictures (masters) for example can be stored using picture technology. Using windows of selectable size and position the current picture can be compared with the stored pictures.

Printing result – parameters The decisive factors that influence the kinetics of the total process from the application of print paste to drying and fixing the dye depend both upon the type and composition of the substrate to be printed and the rheological properties of the dye thickener and the technical-procedural conditions. The mutual influence of these different printing result parameters on the quantity of print paste transferred or on the printing result in roller printing, is illustrated schematically in the Fig.

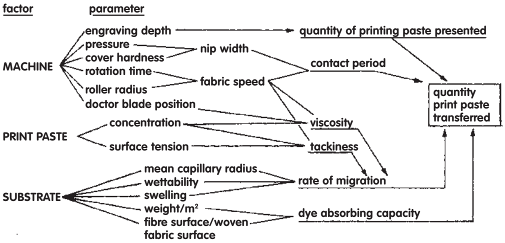


Fig.: Reciprocal effect of different parameters on the printing result in roller printing.

Printing rollers With regard to the type of colour paste application a differentiation is made between printing with deep engraved rollers, roller printing and relief printing, in which the rollers have the pattern embossed upon them.

Printing rollers, fitting on mandrels Pulling the print roller onto steel cores (spindles) with the aid of a roller forcing machine (mandrel jack, mandrel pedestal).

Printing rotation In roller printing the sequence of rollers that transfer the print paste to the material to be printed is known as the “1st, 2nd, etc. printing rotation”.

Printing screen locking units Printing tables are fitted with a U-shaped rail at the front, upon which repeat stops are mounted. The locking units fastened onto the screens fall into the repeat stops when the screen is lowered and thus hold the screen securely in the repeat.

Printing screens → Screens for screen printing.

Printing screen surface condition → Printing rollers resp. printing screens – determination of surface quality.

Printing speed and fabric quality In roller printing the quantity of print paste transferred falls as the printing speed increases, in a manner dependent upon the rheological properties of the print paste. At the same time, uniformity is improved. In rotary screen printing (regardless of the fineness of the screen gauze and diameter of magnetic-roll doctor blades) the amount of print paste transferred falls even more with increasing print speed (at 10 m/min, 30% > 40 m/min). At the same time print penetration is reduced and uniformity and contour sharpness are improved.

Printing styles Fundamental technical possibilities for printing fabrics→: Direct printing; Discharge printing; Resist printing; Blotch printing.

Printing table Support for the fabric to be printed in block screen printing and flat screen printing.

Printing table heating Electric heating below the printing blanket facilitates an increase in production of up to 300% in screen printing because of the accelerated drying of the printed repeat.

Printing thickeners Finished product of → Thickeners for printing (→ Print pastes). Every composition is dependent upon fibre material, fabric type, print pattern, dye group, printing process, etc.

Printing unit,

I. Print paste chassis with transfer and printing roller in the roller printing machine.

II. Dye factory (dyestuff manufacturer).

Printing without screens (digital printing) Trends today are sampling, agile manufacturing, quick response, improved quality (fastness properties), versatility, user-friendliness, flexibility, short printing runs, cost effectiveness, all of which are facilitated by digital printing. They are the driving forces to the modification of the printing devices. Today ink-jet technology for textiles is mainly being offered and used in the hitherto expensive and time-consuming procedure of design sampling. The aim is to create sample prints of 10–12 metres in length which have the feel and look of traditional prints without the costs of making traditional screens. In this way a final “go/no-go” decision can be made within a relatively short time and at a minimal expense. Only in very few cases is this technology being used for production scale printing.

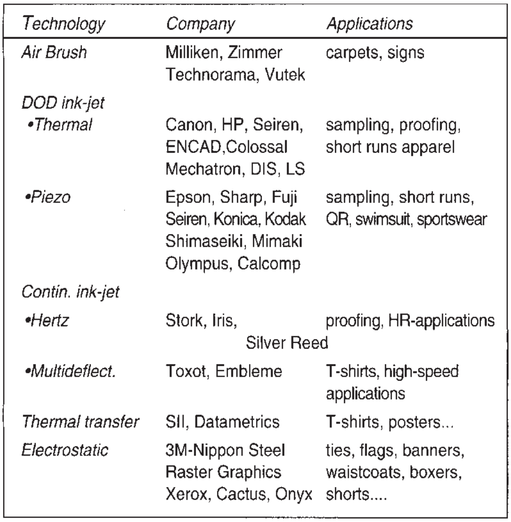
Only a few Japanese and American companies (Seiren and Apparel Technologies) are particularly active and are, perhaps, able to demonstrate the viability of full production digital printing. The jet-printing technology has yet to make a leap into the mainstream. The relative slow development of this technology and hesitation to introduce these technologies in the textile industry are due to specific technological limitations (hardware, print head or nozzle, ink classes) which must be overcome for the commercial exploitation of these new technologies. However, even in its current limited state-of-art, this new technology provides for many new business opportunities and cost savings, most notably in sampling, strike-offs and mass customisation. This resulted over the past two or three years in an increasing interest in the application of digital printing technologies to textile substrates. This interest has been fuelled by the rapid advances that have been made in digital printing technologies in home and office computer printing systems. Recent conferences and publications suggest that a much broader range of companies and suppliers are now willing to undertake the work required to solve the technological problems in fabric printing. Also the entrance of new players and "hijackers" on the printing market has put an external pressure on the traditional printing machine makers. Such competitors (Canon, Encad, Iris, etc.) have the know-how concerning the ink-jet systems for paper.

Digital printing means flexibility and a quicker response to market demands. Before any design is finally accepted and the "green light" given, there are many stages it must go through. To begin with colour and scale are not immediately relevant. Only if the design has potential, will it be scaled and put into repeat and then some idea of colouring developed. Re-sizing, repeat setting and separating into defined colour elements can be done manually or by scanning and working on a CAD-CAM system. Colouration ideas can be created on a monitor screen, but fabric samples are then required in several colourways to allow a final choice to be made. At this stage, time and money have to be invested in sampling screens and strike-offs. This alone can influence go/no-go decisions. The time and money investment before a design appears on fabric is one reason why, for example, automotive printing has been slow to develop in Europe. Much of the design and colouration can be done digitally and of course colour printing on paper can also help in the decision-making process. However, this is not the complete picture. Numerous recent advances in ink-jet technology mean that it is now possible to print on textile substrates with good resolution and colour reproducibility using inks based on textile dyes that fix to the fabric itself.

Major interest and research has centered on translation of ink-jet printing technologies from paper applications to fabric. Several important differencs in textile printing and paper printing will impact the applicability of ink-jet engines.

– The volume of ink required to print a square metre of fabric is significantly higher than that required for paper. Estimates suggest that typical fabric printing will require at least 30 ml of ink per square metre at current colorant loadings. This difference has important implications in speed, drop size, drop frequency and nozzle life for ink-jet printing of fabrics.
– Issues of image quality are also vastly different in the two types of printing. Image quality is a function of both the resolution (dots per inch or dpi) and the number of levels of colour (grey levels) that can be achieved at a given point in the image. In ink-jet paper printing, improvement in image quality has been generally in the direction of increased resolution with some ink-jet printers now delivering 1440 dpi. Colour has been produced by mixing four primaries: cyan, magenta, yellow and black (process colour). Textiles have traditionally been printed at much lower resolution (rotary screen mesh of 125 to 150) but with individually formulated colours (spot colour) which in essence gives an extremely large number of grey levels. As a result, the colour gamut required for textile printing is greater than the gamut traditionally obtained in printing on paper.
– The number of picks and ends in fabrics will impose a structure on the image that will limit the resolution that can be achieved without regard to the printer's capability. It has been estimated that with spot colour a resolution of 200 dpi will give very good image quality in printed fabrics, but process colour may require in excess of 360 dpi.
– In addition to these considerations, demands for fastness properties are quite different in both systems. In textile printing high fastness levels, particularly the abrasion, rubbing, light, wash and dry cleaning fastness are mostly required.

These differences in paper and fabric as substrates for ink-jet printing and different approaches taken to achieve image quality have important implications in the design of print machines for textile printing.



Technology	*Company*	*Applications*
Air Brush	Milliken, Zimmer Technorama, Vutek	carpets, signs
DOD ink-jet		
•Thermal	Canon, HP, Seiren, ENCAD,Colossal Mechatron, DIS, LS	sampling, proofing, short runs apparel
•Piezo	Epson, Sharp, Fuji Seiren, Konica, Kodak Shimaseiki, Mimaki Olympus, Calcomp	sampling, short runs, QR, swimsuit, sportswear
Contin. ink-jet		
•Hertz	Stork, Iris, Silver Reed	proofing, HR-applications
•Multideflect.	Toxot, Embleme	T-shirts, high-speed applications
Thermal transfer	SII, Datametrics	T-shirts, posters...
Electrostatic	3M-Nippon Steel Raster Graphics Xerox, Cactus, Onyx	ties, flags, banners, waistcoats, boxers, shorts....

Tab. 1: Overview of digital printing systems.

Commercial ink-jet engines – current systems: The different no-screen printing systems are summarised in Tab. 1. The earliest and most widely used system for commercial printing of textiles is probably the Millitron jet printer for carpets and upholstery fabrics. This machine operates on the continuous ink-jet principle with drop selection achieved by opening air valves to deflect the drops to the substrate. This machine operates with large drop sizes (to achieve the large volumes of dye required for heavy weight fabrics) and therefore is limited in resolution to about 20 dpi. It is an eight colours machine and uses spot colour rather than process colour. Colorants are predominantly acid and to a lesser extent disperse dyes with poststeaming and washing required. This machine has been successful because it can print at commercially acceptable speeds (up to 20 square metres per minute) with quality that exceeds standard carpet printing methods. Several other manufacturers such as Zimmer (Chromajet, now also available with a continuous moving textile substrate), Vutek, Technorama, Signtech, Big Image have produced similar machines for carpet printing.

The two most popular technologies being offered for modern digital printing on roll goods are direct and indirect digital printing techniques (Fig. 1): ink-jet and the indirect electrostatic sublimation transfer printing. The big difference between direct ink-jet printing and sublimation electrostatic printing is that electrostatic printing will only work on paper and the dye must then be transferred to the fabric by the sublimation process (indirect process). Ink-jet systems print on ink-jet paper with water-based systems or directly on the fabric and can therefore print other dyes such as reactive dyes, acid dyes or pigments. No sublimation dyes are required. In the direct digital techniques the pre- and postprocessing of fabrics are similar to traditional printing for the equivalent chemistries. Advantage of the transfer principle is that the transfer process does not require pre- or posttreatment.

- **Transfer printing (paper to textile)**
  - electronic printing
  - ink-jet printing (CIJ & DOD)
- **Direct printing (textile)**
  - ink-jet printing (CIJ & DOD)

Fig. 1: Digital printing for direct and indirect printing.

In the indirect printing different techniques can be used for printing the transfer paper: electrostatic printing and ink-jet systems (DOD, CIJ). Compared to conventional transfer printing these digital techniques have several advantages (Fig. 2) and are a cost-effective alternative to traditional processes, particularly where quick turn-around and complex designs are required. For short runs of flags and banners lead times of over a month would be typical with traditional offset or silk screening techniques. This can be reduced to a few days using the new technique, because it is not necessary to produce intermediate separation plates. This is a digital system, so photographs and files can be readily accepted, and any design change can be made quickly, on screen, prior to printing.

- Reduction of sampling costs
- Short production runs
- Simple technique and easy to use with a minimum of maintenance (support)
- Low investments and productions costs
- Flexibility
- Consistent and reproduceable printings
- Easy transfer of sampling results to production stage

Fig. 2: Transfer printing – digital printing compared to conventional transfer techniques.

Dye sublimation printing, often referred to as electrostatic or heat transfer printing, offers new opportunities for textile printers (p.e. Xerox 8054 DS) with the ability to transfer electronic images onto polyester fabrics. The dye is first printed onto paper using a digital electrostatic printing device then transferred onto the fabric using heat and pressure (a heat press). While dye sublimation printing has been used for many years and is not new technology, the big change is that the sublimable dye is now printed on the paper by the electrostatic process and not by an analogue offset printing process, avoiding the need to preprint a lot of paper and inventory, and facilitating the ability to print on demand. This technique demands dielectric paper (paper coated with dielectric components) and solvent-based toner systems (Fig. 3). Of course transfer techniques are restricted to thermoplastic material, especially polyester. The new process “Pictorico” developed by ASAHI Glass could extend this technique to other substrates. This technology treats fibres with a very thin PES coating so that a sublimation process without posttreatment becomes possible on these fibres.

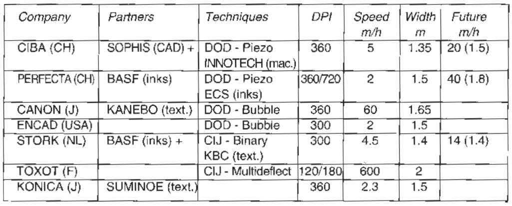
Analogue printing uses a “master”. For textiles this is usually an imaged rotary or flat-bed screen. The image to be printed is separated into patterns of consistent colour, and screens are made, one for each different colour to be printed. A screen may be prepared by digit-

Ink	**Ink-jet**	
Electrostat	**DOD-systems (bubble-jet, piezo)**	**Continuous-flow systems**
• *Dielectric paper*	• *Ink-jet paper*	• *Ink-jet paper*
• *Solvent-based* toner systems	• *Water-based* ink systems	• *Water-based* ink systems
• *Generation of* charge image toning	• *Drop on demand*	• *Continuous* ink-jet, selection from ink-jet
• *Up to 1,37m* printing width	• *Up to 1,6m* printing width	• *Up to 1,6m* printing width
• *Up to 100* m^2/h	• *1 to 100* m^2/h	• *Up to 1,3* m^2/h

Fig. 3: Indirect systems for transfer printing.

al techniques but it ultimately becomes an analogue “master” from which prints are made. Generally, printing is performed by pushing paste-like inks through the open pores of the screen onto and into the fabric being printed. Each screen is placed sequentially onto the textile being printed and different colours are applied separately. The result is a design generally made up of a relatively small number of “spot” colours, which together make up the printed design.

Direct ink-jet techniques, that have been developed for paper and industrial printing, are a non-contact technology able to print on virtually any textile surface, regardless of its porosity, using nozzles to spray microdrops of coloured ink directly onto the fabric at a particular point. It is a direct printing technology, providing in a single step a method for directly printing variable information onto product materials, independently of repeat length. With these techniques no physical “master” is produced. Each image element in the final printed textile is an individual spot of ink applied by a digital ink-jet printing process. Ink-jet print heads pass over the fabric and deposit one or more droplets of each colour of ink required in a pattern designated by the computer driving the print heads. The “virtual master” resides in the computer memory. Generally “process” colours, for example cyan, magenta, yellow and black inks, are used to produce the colours required by the design. In a few implementations 6 to 8 colours are used. With screen printing the inks may be dried between colours, with ink-jet all colours are printed simultaneously, wet on wet. Essentially all jet-print systems put colour on the substrate in the same way: tiny drops of colorant are sprayed onto the substrate. However, the method of drop generation and their route to the fabric can vary. A simple classification is that of drop on demand (DOD) and continuous jet (CIJ). In both of these technologies, high numbers of nozzles are used for each colour: nozzles are between 10 and 100 micrometres diameter, thus ensuring a resolution of up to 720 drops per inch (dpi). Between a thousand and a million ink droplets are processed per second. Both systems generally operate with constant basic “process” colours (4 or even more, up to 8) which are mixed on the substrate. The depth of the shade is controlled by the number of dots applied and pale shades are created by more base fabric being visible at any given point in the design. Using the same primary colours all the time means that no colour kitchen is needed. Both of these types of engines have advantages and disadvantages for textile printing and both have served as the basis for the devolopment of prototype printers for textile applications. Different commercial ink-jet systems are summarised in Fig. 4.



Company	*Partners*	*Techniques*	*DPI*	*Speed m/h*	*Width m*	*Future m/h*
CIBA (CH)	SOPHIS (CAD) +	DOD - Piezo INNOTECH (mac.)	360	5	1.35	20 (1.5)
PERFECTA (CH)	BASF (inks)	DOD - Piezo ECS (inks)	360/720	2	1.5	40 (1.8)
CANON (J)	KANEBO (text.)	DOD - Bubble	360	60	1.65	
ENCAD (USA)		DOD - Bubble	300	2	1.5	
STORK (NL)	BASF (inks) +	CIJ - Binary KBC (text.)	300	4.5	1.4	14 (1.4)
TOXOT (F)		CIJ - Multideflect	120/180	600	2	
KONICA (J)	SUMINOE (text.)		360	2.3	1.5	

Fig. 4: Digital printing systems.

DOD ink-jet engines deliver a drop of ink only when required for printing: it produces “drops on demand”, i.e. only when and where needed in the design. Although there are several technologies to generate a drop of ink on command from the control computer, the two of the most widely used are bubble-jet and piezo technology. A third less important is the valve-jet DOD system and uses solenoid valves to control the flow of ink to an air stream that carries the drops to the substrate. Resolution is limited to 25 dpi, and is only usable for special textile printing applications: to print banners, draperies, carpets and wall hangings.

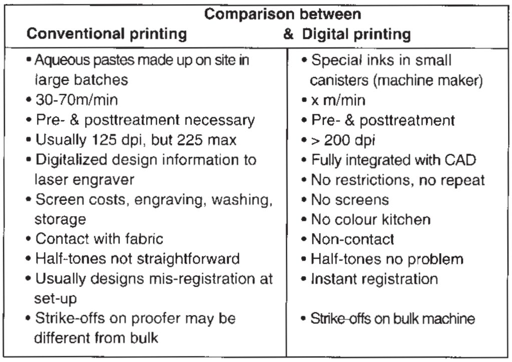
The largest number of DOD printers in current use rely on a thermal pulse to generate the ink drop: bubble-jet or thermal ink-jet system. In these engines, the computer signal heats a resistor to a high temperature (> 360°C) which creates a vapour bubble in a volatile component in the ink, the vapour bubble expands and exits the nozzle followed by a contraction of the bubble causing a drop of ink to be ejected on the textile substrate. The vapour bubble must then cool and collapse allowing the ink chamber to refill from a reservoir. Cycle time is limited to approx. 10 000 drops per second and the volume per drop of ink is typically 150 to 200 picolitres. Thus, a single thermal ink-jet can deliver approx. 0.1 ml of ink per minute. The major problem with the thermal ink-jet is the high nozzle failure rate. The high temperatures required for rapid drop ejection cause decomposition of ink components on the resistor which leads to poor heat transfer and/or nozzle clogging. Resistor failure resulting from rapid thermal cycling is also a major problem (head life of 50 to 500 ml of ink). The major advantage of the thermal ink-jet technology is the low cost of nozzle fabrication. Thus, thermal ink-jets offer low-cost print heads but suffer from unreliability and slow speed. The main suppliers are Canon, Encad, Colossal, Mechatron, Kamatsu, HP and Direct Imaging Systems (see Tab. 1). These companies have developed machines for proofing and very small production runs based on the thermal ink-jet technology. All of these systems reflect the inherent limitations of the thermal ink-jet technology.

Another important DOD ink-jet printing engine is the piezo-electric system. This type of printer uses electrostatic forces for the formation and spraying of the microdrops. The computer imposes an electrical potential across a piezo-electric material which causes a contraction in the direction of the electric field and an expansion in the perpendicular direction. The expansion causes a drop of ink to be ejected. The piezo on removal of the potential returns to its normal dimensions and the ink chamber is filled from an ink reservoir by capillary action. The cycle time of the piezo-based printers is limited by the ink replenishment rate and can be somewhat higher (14 000 cycles per second) than the thermal ink-jet but drop volumes are usually somewhat smaller (150 picolitres). The small drop size allows the piezo-based printers to produce very high resolution prints (1440 dpi is commercially available). These printers also have the advantage of much greater print head life than the thermal-based systems (100 times). Piezo-printing engines are now in use in a number of printers for textile substrates. A number of companies (Kodak, Idanit, Olympus, Konica, Shimaseiki and Mimaki, Fuji, Epson, Sharp (see Tab. 1 and Fig. 4) are producing and/or developing wide format piezo printers that could be modified to print on textiles. Further improvements in piezo-head technology could make this approach attractive for ink-jet printing on fabrics.

In continuous ink-jet systems droplets of ink are calculated and selectively printed. The ink is electrically conductive and as the ink passes between the charging plates, current flows in the ink column. As drops form they will have a net charge opposite to the charge on the plates. Continuous ink-jets produce a continuous stream of drops. Drop selection in most high resolution CIJ devices is achieved by inducing a charge on the drops and using an electrostatic field to select and deflect the desired drops for the image to the substrate and collecting the unwanted drops for recycle. Most CIJ devices for high resolution printing use mechanical stimulation to generate a uniform continuous stream of drops. This is usually achieved by subjecting the ink stream to acoustic waves generated by a piezo-electric operating at up to 1 000 000 cycles per second. The stimulated CIJ typically operates at high speed drops in the range of 50 to 100 thousand drops per second and with drop volumes that can be considerably larger than most DOD ink-jet devices so that the volume of ink delivered per unit time is an order of magnitude higher than with DOD printers. This can be a significant factor in printing on textile substrates that require high ink volumes.

The simplest system is the binary CIJ. In this approach drops are either charged or uncharged by the charging plates. The uncharged drops will be unaffected by the deflection plates which carry a charge opposite that of the charging plates. The undeflected drops then strike the substrate to form the image. Drops carrying a charge are deflected to a catcher or gutter by deflection plates for recycle. Main suppliers are Stork, Iris and Silver Reed.

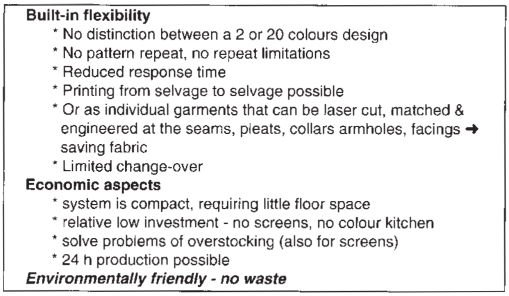
The multideflection CIJ has also been used for textile printing. This approach differs from the binary CIJ in the fact that the dye drops are given a variable charge that gives different deflections as the drops pass through the deflection plates. This allows multiple positions on the substrate (up to 30) to be printed from a single jet. This technology has been employed by Imaje in printers for industrial marking and served as the basis for T-shirt printers developed by Embleme.



Comparison between Conventional printing	& Digital printing
• Aqueous pastes made up on site in large batches	• Special inks in small canisters (machine maker)
• 30-70m/min	• x m/min
• Pre- & posttreatment necessary	• Pre- & posttreatment
• Usually 125 dpi, but 225 max	• > 200 dpi
• Digitalized design information to laser engraver	• Fully integrated with CAD • No restrictions, no repeat
• Screen costs, engraving, washing, storage	• No screens • No colour kitchen
• Contact with fabric	• Non-contact
• Half-tones not straightforward	• Half-tones no problem
• Usually designs mis-registration at set-up	• Instant registration
• Strike-offs on proofer may be different from bulk	• Strike-offs on bulk machine

Fig. 5: Comparison between analogous and digital printing.

The comparison between conventional and digital printing is outlined in Fig. 5. Digital printing offers many potential advantages, which are summarised in Figs. 2 and 6. The new systems can easily be characterised as creative, clean and competitive. The systems have a built-in flexibility. The principal attraction of jet printing is a means of transferring a design direct from CAD to textile. This means very quick customer response for both strike-off and bulk prints. Indeed, conventional printing suffers from the high proportion of unproductive time during make ready and design changes, a burden which jet printing does not share. The system does not distinguish between a 2 or a 20 colours design; nor does it care whether it prints one design or 10 on a given 100 metres of fabric. To add to this flexibility, there is no repeat and little change-over. Response times are very short, since there is no adjustment of equipment between runs. Engraving and sampling stages are eliminated entirely. Response time can



Built-in flexibility

- No distinction between a 2 or 20 colours design
- No pattern repeat, no repeat limitations
- Reduced response time
- Printing from selvage to selvage possible
- Or as individual garments that can be laser cut, matched & engineered at the seams, pleats, collars armholes, facings ➜ saving fabric
- Limited change-over

Economic aspects

- system is compact, requiring little floor space
- relative low investment - no screens, no colour kitchen
- solve problems of overstocking (also for screens)
- 24 h production possible

Environmentally friendly - no waste

Fig. 6: Digital printing – potential advantages.

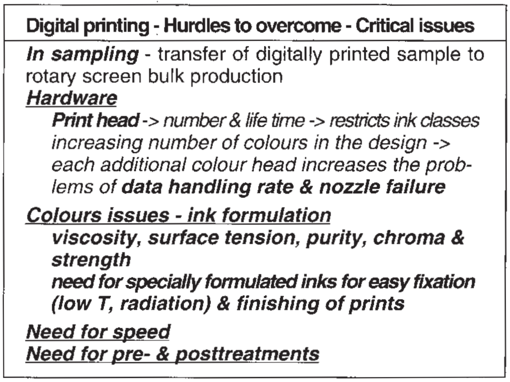
also be cut drastically. The system is compact, requiring very little floor space. The system also allows the textile printer to solve problems of overstocking simply by performing just-in-time printing on demand.

There is a close correlation between sample printing and bulk printing; knowledge of the component inks allows easier recipe formulation for ultimate bulk production. Any design can be scanned in and adapted by the software as required, and the equipment does not have to be cleaned between runs. In both ink-jet (DOD, CIJ) printing, printing is done on prepared (white) cloth which can dramatically reduce the investment required in piece goods as well as delay style decisions and minimise no-front commitments. It also creates some exciting opportunities to develop products that the market has never seen before. Whereas conventional textile printing requires a pattern repeat and printing of the fabric from selvedge to selvedge, printing of the fabric digitally has no repeat limitations other than the length of the fabric, and can be printed either from selvedge to selvedge or as individual garment parts that can be laser cut. This makes it possible to produce garments with highly engineered designs that not only can be matched at the seams, but can also be engineered around darts, pleats, armholes, collars and facings. It also saves fabric, as parts need to be laid only by the grain of the fabric, not the pattern repeat as well.

The system also features strong environmental benefits, since the inks are highly fast and no thickener, frequently no urea, are needed. Especially in DOD systems, there is no waste, since all the colour goes directly onto the fabric. There is also no recipe formulation involved. The engraving and sampling stages are eliminated and response time can be dramatically cut. Digital printing means also relative investment; no print kitchen and storage accomodation for screens are needed. Moreover, a special advantage is the cost effectiveness of short runs, which allows customised and personalised production at an acceptable price. In the current state of development, ink-jet printing provides far lower print speed than conventional by several orders of magnitude. It fits well today for sample, customisation and very short run markets. Increased speed will be needed before it can effectively address the main stream markets. Also the transfer of digital printed samples and rotary screen bulk production gives problems.

Reliability of ink-jet systems today has improved over that of only a few years ago, demonstrating how rapidly improvements can be made. To achieve the higher speeds required, work on effective reliability will be required. As the number of print heads and nozzles and their drop firing frequencies have increased, the demands on liability increase as well. Reliable printing is fundamentally a function of three parts of the system:

– the print head and its maintenance system
– the ink quality and its ability to avoid clogging of the nozzles
– redundancy in nozzles allowing non-performing nozzles to be replaced by functioning ones and/or randomisation of defects to render them invisible.



Digital printing - Hurdles to overcome - Critical issues

In sampling - transfer of digitally printed sample to rotary screen bulk production

Hardware

Print head *-> number & life time -> restricts ink classes increasing number of colours in the design -> each additional colour head increases the problems of* ***data handling rate & nozzle failure***

Colours issues - ink formulation

viscosity, surface tension, purity, chroma & strength

need for specially formulated inks for easy fixation (low T, radiation) & finishing of prints

Need for speed

Need for pre- & posttreatments

Fig. 7: Digital printing: technological limitations and problems.

The slow development of digital printing is due to specific limitations of the head or nozzle, which can also restrict ink classes (Fig. 7). Pigment and disperse inks cannot be used in continuous ink-jet systems in printers with a resolution of over 200 drops per inch (dpi). Dye-based inks are practically the only ones offered for drop-on-demand bubble-jet systems. The increasing number of colours in the design of systems for ink-jet printing of textiles is also problematic. Each additional colour head increases the problems of data handling rate and nozzle failure. It also significantly reduces the fraction of the printer that is not actively printing at any given moment, thus significantly reducing machine efficiency. Trade-offs in speed of printing, grey levels and number of colour heads will require significant additional thought to give machines the best combination of speed, image quality and cost.

Ink formulations for application by ink-jet heads to fabrics is probably the most difficult problem that must be solved for further penetration of this printing technology in the textile industry. All existing colorant systems have deficiencies that will limit their applicability to the wide range of fabrics that must be printed. The colorants must have very high strength and high chroma to achieve a broad colour gamut with a minimum number and amount of deposited colorant. Colorants need high built-up properties, if possible using the same chromophores as the traditional printing dyes. This means that there is a close correlation between sample and bulk printing. Knowledge of the component inks allows easier recipe formulation for ultimate bulk production. Fastness properties acceptable on printed fabrics should be achieved with no postprocessing. These requirements necessitate the development of textile colorant systems especially designed for ink-jet printing. This means also that there are several constraints on the physical properties of the inks that can be delivered by an ink-jet print head. Viscosities of ink-jet fluids must be quite low compared to rotary screen printing pastes. The viscosities of fluids for several typical types of ink-jet heads is shown in Tab. 2. High surface tension of the ink formulation and the need to use very high purity components (to prevent nozzle clogging in most ink-jet heads) are further limitations. Electrostatic deflection systems also require that the ink is electrically conducting which is difficult to achieve in organic solvent based systems.

	Viscosity (cPs)	Drop volume (pl)	Frequency KHz
Continuous	1-10	400	100
Thermal (aqueous)	1-3	200	10
Piezo	5-30	100	20
Valve jet	100	large	

Tab. 2: Typical operating parameters for ink-jet engines.

Colorants used for ink-jet printing on paper have typically been selected based on high water solubility and high chroma and with little regard for substantivity or wet fastness. Acid and direct dyes have been frequently used for printing on paper. These dye classes would not normally be used for printing on cellulosic fibre fabrics. Thus, most of the formulations used for ink-jet printing on paper are not acceptable for textile printing. In developing formulations for textile printing, most companies have gone to high purity reactive dyes or resin pigment systems. Both of these approaches have difficulties. Reactive dye systems require a pretreatment of the fabric and poststeaming and washing. The postprocessing, especially, presents a significant problem in the anticipated ways in which ink-jet printing will be used initially in the textile industry. Due to viscosity limitations of ink-jets, resin pigment systems require that a polymerisable resin is applied to the fabric and that the resin is UV or thermally cured on the fabric. Developing low viscosity resin systems with the required fastness and hand properties on the fabric has been quite challenging. Pigment resin systems have a number of attractive properties for fabric printing and will undoubtably be one of the systems delivered by ink-jet heads. Significant work remains in the development of resin systems that have the required viscosity for ink-jet printing and the hand, wet fastness and crock fastness requirements on the fabric.

The "process colours" approach produces the final colour on the textile by mixing and blending the primary colours on the textile drop by drop sequentially over a small area rather than being premixed in an ink kitchen prior to printing. In most cases the colour increments represented by single drops are too large to give the correct mixed colour. For that reason a larger area of fabric is chosen and the ink drops are applied over that area to give "average colour" which best matches the correct colour. This "dithering" and the effects of printing sequentially cause non-uniformities in the colour on the fabric in many instances, which may be objectionable. With screen printing as many as 10–12 primaries, mixed in any proportion, give the precise colour desired. Since they are premixed they do not suffer from variations due to order of printing the primaries. This gives screen printing the advantages of a closer match in colour, less variation in colour in solid areas and a "cleaner", brighter colour with less grey component to the mixture. Process colour involves substractive colour. Each primary must be transparent so that light passing one colour ink will not absorb or scatter the light from another colour ink beneath it. Pigments must be chosen which are inherently transparent and they must reduce particle size to less than half the wavelength of light. Larger particles will scatter light and cause "greying", making it appear dull and dirty looking. This is a much smaller particle size than is usually found in commercial spot colour inks used in screen printing. This attribute is also important when one wants to print variable information on coloured materials, like logos for example. Process colour inks will not hide the underlying colour since they are transparent.

The ink-jet technology and electrophotography have many potentials for textile applications, but textile-specific electrographic toners and ink-jet inks must be developed in order to gain acceptance of these technologies in the textile industry. The primary thrust of the research was in developing materials (toners/inks) for printing textiles. For indirect ink-jet techniques (drop on demand) BASF has recently introduced the "Baxifan inks". They are characterised by a well defined particle size and a minimum content of mineral products in order to avoid clogging of the nozzles. Some properties are summarised in Tab. 3.

Ciba has formulated special reactive inks (use of small canisters) for cellulose fibres (Cibacron MI),

	Viscosity mm²/s	**Surface tension mN/m**
Baxifan yellow TX4631	2,84	55,8
Baxifan red TX4347	3,17	54,8
Baxifan blue TX4633	3,56	57,6
Baxifan turquoise TX4634	3,22	55,9
Baxifan black TX4613	3,29	55,0

Tab. 3: Baxifan inks for transfer printing.

disperse inks for apparel and automotive applications (Terasil Di), disperse inks for special polyester applications (Terasil TI) and acid inks for silks (Lanaprint AI). Further developments will include specially formulated inks for the easy fixation and finishing of prints on all fibres. Ciba has long experience of textile printing and has developed economical preparation recipes for the ink-jet textile printing.

Pretreatment is still necessary e.g. to avoid bleeding of the print. In general, the fabrics are impregnated with alkali alginate in the case of reactive printing on cellulosic substrates and with alginate alone in disperse printing on PES. This could be performed with a minimum add-on device on the machine. Posttreatment consists of a conventional fixation (steaming) and washing process. In the case of pigments one can use radiation curing (UV and Electron Beam) or thermal processes (according to M. Van Parys).

Printing zone → Printing group.

Print oils Usually preparations containing mineral oil, used for making print pastes tacky and supple.

Printover Overpatterning of an undesired primary colour (red, yellow, blue) by suitable shading with dyes not listed in the recipe (orange, green, violet).

Print paste application Achieved in rotary screen printing by the interaction of the screen, which rotates around its own longitudinal axis, the doctor blade, the print paste and the continuously moving substrate. The print paste flows from the distribution pipe or channel on the inside of the screen. The doctor blade and screen together form a wedge-shaped open space. The rotary movement of the screen forces the flowing print paste into this space. In general one talks of the formation of a colour thread or print paste wedge. The print paste wedge has two main characteristics: There is a circulating flow and a build up of hydrodynamic pressure (back-up pressure). The circulating flow is caused by the print paste sticking to the screen and doctor blade. On the one hand the screen movement leads to a reduction in the viscosity of the normally structurally viscous print paste, and on the other hand more print paste is pushed into the open space than can flow through the holes in the screen. This causes back-up pressure, which allows the print paste to flow through the screen holes. The flow resistance of the screen and the penetration resistance of the substrate act against the back-up pressure (Fig. 1).

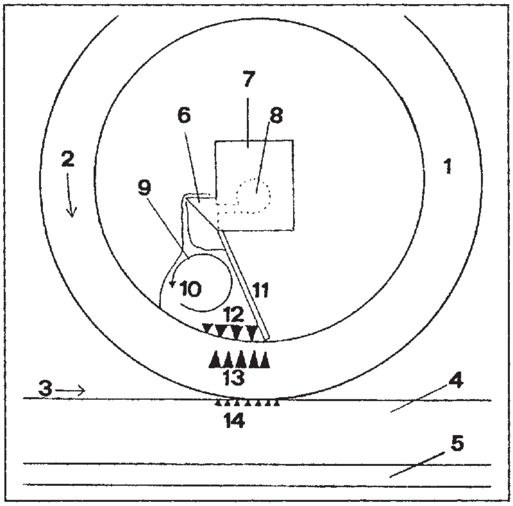


Fig. 1: Sketch of the principle of print paste application in rotary screen printing.
1 = screen; 2 = screen direction of rotation; 3 = substrate direction of movement; 4 = substrate; 5 = printing blanket; 6 = distribution duct; 7 = squeegee; 8 = feed pipe; 9 = print paste wedge; 10 = circulation flow; 11 = doctor blade; 12 = dynamic pressure; 13 = flow resistance; 14 = penetration resistance.

The basic prerequisite for print paste flow in screen printing generally is the generation of a back-up pressure. For print paste application to take place on and in the textile substrate the back-up pressure must overcome the resistances from the screen and substrate. This pressure, flow resistance and penetration resistance determine the print paste quantity that can flow out of the screen holes (available print paste). The absorbency of the

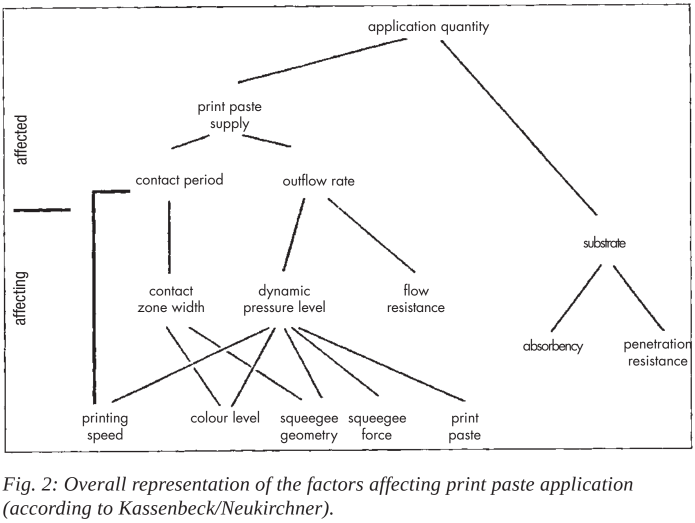


Fig. 2: Overall representation of the factors affecting print paste application (according to Kassenbeck/Neukirchner).

"substrate capillary system" determines the print paste quantity taken from the available quantity (application quantity).

The findings of Kassenbeck/Neukirchner yield the influence variables shown in Fig. 2. The contact time between print paste/screen/substrate and the flow velocity (flow velocity of the print paste as it leaves the screen holes) determine the print paste quantity which is available to the substrate (available print paste). The substrate characteristics determine how much of this available print paste is absorbed (application quantity). The contact time is determined by the length of the print paste wedge and the print speed. The length of the print paste wedge can be found from the quantity of print paste pumped into the screen (print paste level) and the doctor blade geometry (Figs. 3–7). The flow velocity is found from the level of back-up pressure and the flow resistance of the screen. The back-up pressure itself results from the doctor blade geometry, the doctor blade force, the printing speed and the flow behaviour of the print paste. The flow resistance is determined by the proportion of the screen that is open.

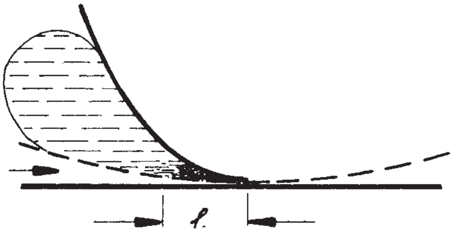


Fig. 3: Flat doctor blade installation with a relatively long nip l.

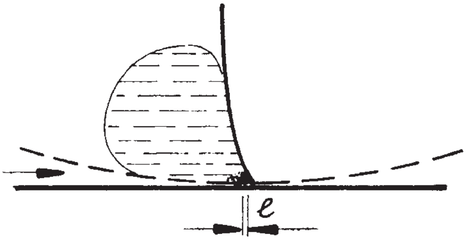


Fig. 4: Steep doctor blade installation with a short effective nip l.

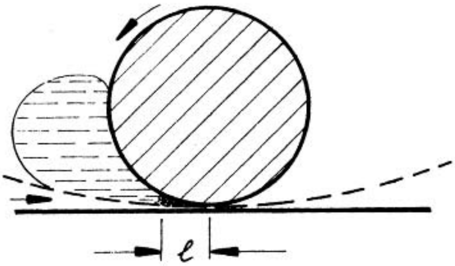


Fig. 5: Size of nip l with a large diameter doctor roll.

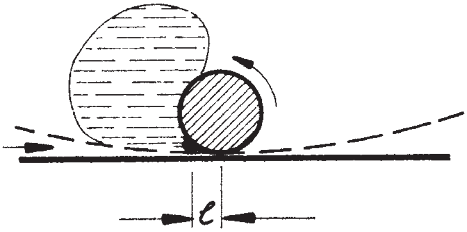


Fig. 6: Size of nip l with a 10 mm diameter doctor roll.

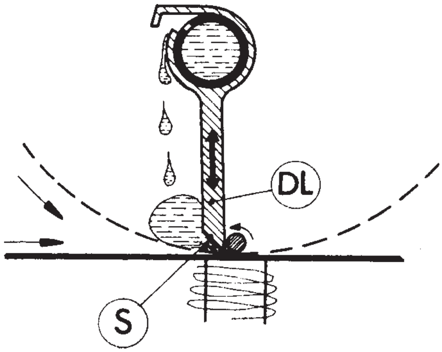


Fig. 7: Combined squeegee with a doctor blade as a sealing strip (DL), with a small roll and print paste retaining space (S).

variable	constant
Squeegee geometry Squeegee force Printing speed Colour level Print paste	screen substrate printing blanket

Tab.: Factors affecting print paste application in screen printing.

The influencing variables can be divided into variables and constants (see Tab). The constants cannot be altered, at least not without incurring significant time and financial costs. Variables, which can be altered during the process are costs which vary depending upon the doctor blade, are selected on the basis of these constants, to achieve the desired printing result (according to Hilden and Ferber).

Print paste application in screen printing,

I. Flat screens: discontinuous, repeating colour application (Fig. 1), the doctor blade moves on the screen. Knife coating may be repeated several times. Great variation of gauze finenesses, therefore print paste throughput is slightly variable.

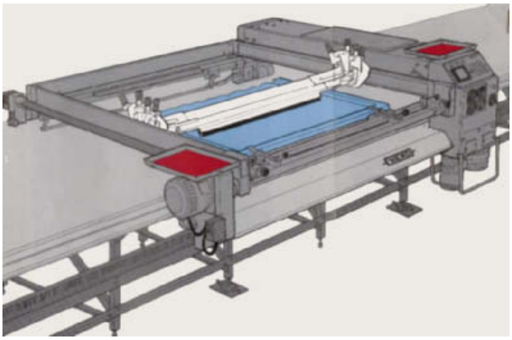


Fig. 1: VIERO print paste application carriage for table printing.

II. Round or rotating screens: continuous print paste application (Fig. 2), screen moves continuously, doctor blade fixed in position. Single knife coating, only small selection of relatively coarsely structured and easily deformed screens. Kinks may occur. Print paste throughput slightly variable.

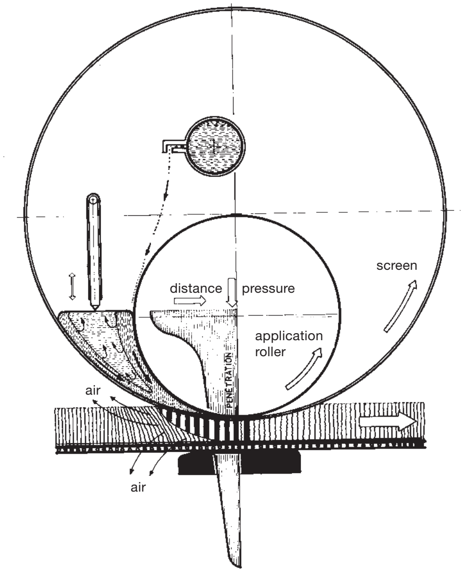


Fig. 2: Situation of a doctor roller in a rotary screen printing screen.

Print paste leftovers Remnants of unused print pastes.

Print paste pump system for printing machines According to the 38th appendix to the German Framework Administration Regulation of Waste Waters to the Water Resources Law (38. Anhang zur Rahmen-Abwasser-Verwaltungsvorschrift zum Wasserhaushaltsgesetz), residual print pastes are no longer allowed in waste water for indirect discharge, but must be collected, reused or disposed of as waste requiring special monitoring (TI-waste). If one bears in mind the fact that 1 kg print paste costs approx. DM 2.50, then for an average printing company the loss of residual paste, which was previously rinsed into the drains after each design or colour change, could easily amount to a sum of DM 1 million/year. Ecological reuse (e.g. by mixing to form black) therefore also represents a financial gain. In order to reclaim the residual paste left in pipes as dead volume after each printing process a switchable print paste delivery pump is required.

The starting position for the example (see Fig.) is a completed print paste application: At every piece of printing equipment used the print paste is pumped back from the doctor blade and the print paste hose. First the dye pipes and pumps are rinsed. Then pre-washing takes place – both processes use service water. Fresh water is only used for the final washing process.

1. Rinsing with service water: the print paste suction hose 2 and the dye paste feed hose 5 are put into the cleaning positions 8. With the slide 9 set to service water, the pump is switched on. In this manner, initially very dirty water runs into the rinsing water channel 11, through the open drain valve 12 and into the external waste water reservoir via the dirty water channel 13.
2. Prewashing: after the drain valve 12 has been closed the rinsing water, which is no longer as dirty, flows from channel 11 back into the service water channel 10. The pipes are thus prewashed with circulating service water.
3. Washing clean: by resetting the slide 9 the water supply is switched over to fresh water. The pumped water continues to flow via rinsing water channel 11 into the service water channel (it is guaranteed that this will overflow into the external pipe). When the washing cycle is finished, the rinsing water channel 11 is automatically emptied via drain valve 12 and the change-over slide 9 is set to service water again. The system is now back in the starting position.

The example shows the saving of fresh water (and the same quantity of waste water) with the Buser Oeko-System, for print paste pumps and pipes alone.

1. Assumptions: Buser Rotamac 4, 10 colours; capacity of pumps 26 l/min/ rinsing process 0.5 min; prewashing 1.5 min; washing clean 1.0 min (total washing time 3.0 min).

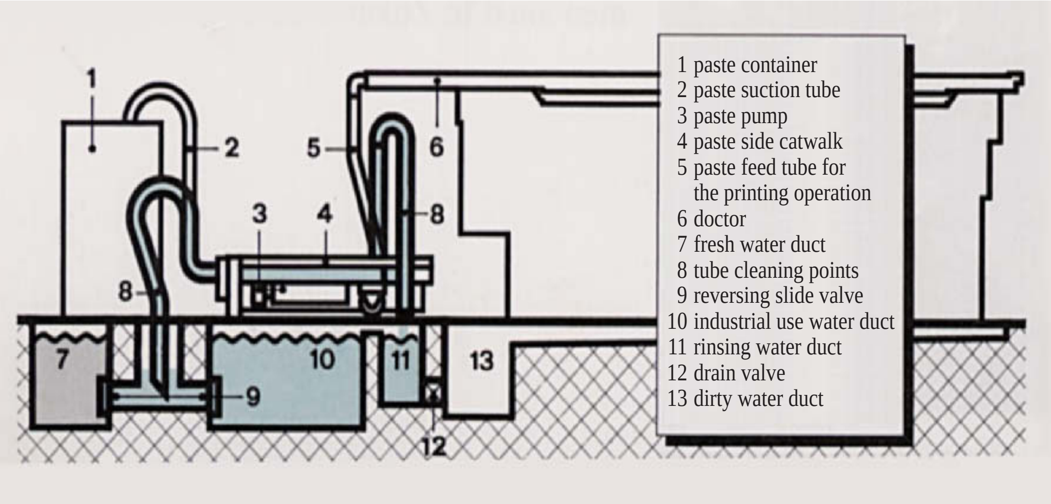


Fig.: Print paste conveyor system (according to Buser).

2 . Rinsing: 10 · 26 · 0.5 = 130 l service water.
3. Prewashing: 10 · 26 · 1.5 = 390 l service water (for filling the rinsing water channel: 100 l and circulation: 290 l).
4. Clean washing: 10 · 26 · 1.0 = 260 l fresh water. Without Oeko-System: 10 · 26 · 3.0 = 780 l fresh water.

Therefore approx. 500 l fresh water can be saved for each dye or design change.

Print pastes → Printing thickeners with or without dyes and chemicals, which are used in the printing of textiles.

Print paste sieving machine (sieving machine), is used for the →: Straining of print pastes; Printing thickeners and chemical finishing products. The method of operation can vary greatly; e.g. brush principle (with 1, 2 or 4 sieving points), pulsation principle, vacuum principle for sucking through the gauze at high sieving speed (vacuum filtering or screening machine), in which blocked screen sections cannot be ruled out however, and the colour grinding mill principle for particularly fine milling. For the purpose of screen printing, when print paste containers with replaceable silk cloth screens are used, the gauze one number finer than the screen gauze is always selected.

Print paste straining centrifuge The print pastes run into the centrifuge via a funnel. The inner screen mesh basket rotates and sieves the print pastes. In centrifuging, special inserts are used to separate the impurities from the print pastes by centrifugal force.

Print paste throughput of screen gauzes Decreases with increasing number of threads and decreasing thread cross-section. Further reduction of the print paste throughput is brought about by calendering the screen gauze (reducing the screen holes and thus reducing the proportion of free screen area).

Print paste wedge In screen printing, wedge-shaped area formed by the angle between blade/rod squeegee and flat/rotary screen. The print paste wedge is a determining factor for print paste application. If the blade squeegee is set at a shallow angle then a long, narrow wedge forms (print paste application is correspondingly lower); alternatively in rod squeegees of different diameters. The wedge is shorter in blade squeegees set at a steep angle. The wedge pressure created is decisive.

Print rollers resp. printing screens – determination of surface quality A non-destructive test method has been developed for microscopic examination of the surface quality of engraved printing rollers after etching and polishing operations. The method is likewise able to provide information on the motif dimensions and mesh openings of printing screens and allows measurements to be made.

Prints on dyed grounds Special type of direct printing on pre-dyed material, which does not involve the local destruction of the pre-dyed ground, as is the case in discharge printing. So, for example, light coloured material (pastel shades) are often printed like white material, whereby the print colours undergo a slight change in shade due to pre-dyeing, but are not spoilt. Very dark print colours on dyed grounds can be used on medium pre-dyed shades, e.g. dark brown on beige or light green, navy blue on pink, black on all light and medium shades.

Print steamers After the application of the dye paste and the drying of the printed textile the material passes through the print steamer to transfer the dye

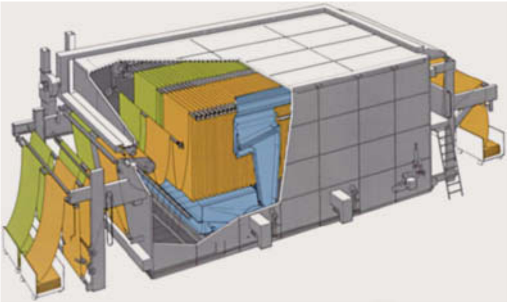


Fig.: Festoon-type print steamer for continuous operation (Stork).

from the thickener into the fibre. To achieve this the dried material is collected and passed onto a separate process, e.g. a high performance universal loop steamer with 2 adjacent tracks (see Fig.). If possible the moisture content of the steamer should be constant.

Prism If a beam of parallel, white light meets a triangular glass prism, it is broken up into its component parts and can be divided precisely into different colour lines (see Fig.).

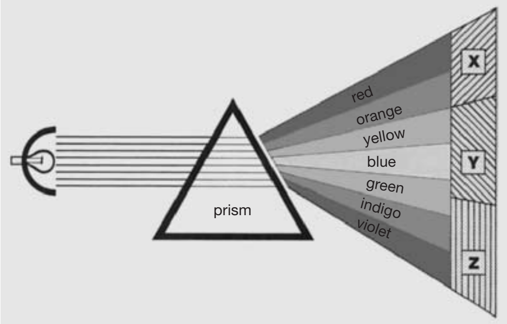


Fig.: The passage of light through a glass prism.

Probability Statistical frequency of comparable events in → Populations. The ambiguous term “probable” expresses the fact that there “appear” to be more arguments in favour of the prediction. The verification value is equal to zero in the individual case. We talk of mathematical probability because statistical probability evaluates the laws of large numbers (→ Stochastic).

Procambium In the structure of bast fibre stems (→ Flax stem structure), the parts still being created during growth (→ Phloem), which is also where the first bast fibre cells are formed (→ Cambium).

Process automation → Automation.

Process balance Once the discovery had been made that it is not a simple matter to set up eco balances for products for the entire process flow through all stages, a differentiated approach was tried. Attempts were made to create company, process and product balances with regard to current environmental compatibility of each (see Fig.: Systematics of preparing an ecological account in textile processing). The basic goals of an → Ecobalance apply. Ecobalance is as broad a comparison as possible between the environmental effects of two or more different products, product groups, systems, processes or modes of behaviour. It serves to expose weaknesses, improve the environmental properties of the product, aid decision making, procurement and purchasing, promote environmentally friendly products and processes, aid the comparison of alternative modes of behaviour and the justification of recommended actions. Depending on the underlying problem, there are further issues involved in this comparison, e.g. an assessment of the environmental protection efficiency of financial resources. A thorough investigation of the materials/preparations present, used and created at each process stage is necessary. The occurrence of environmental chemicals should be verified. It is the term used to describe substances that enter the environment, can exist there in large quantities and endanger the life of the ecosystem. These can be of natural or synthetic origin. A further, not uncommon classification of environmental chemicals, is made with regard to their origin, their field of use or effects. Last, but not least, a differentiation is made between natural and foreign substances. In this context it is important to note that predictions cannot be made regarding the hazardous nature of the substance based upon the classification. We should of course also consider harmful substances that can be differentiated according to the following criteria:

1. Harmful substances in terms of eco-toxicology are substances, which give rise to changes in the systems in question, which clearly exceed the normal variation range of population levels.
2. Harmful substances in the sense of emissions/immissions from the point of view of air pollution are substances that can occur locally, regionally or globally in higher concentrations and lead to acute direct or indirect damage to the biosphere.

All investigations of a process for a process balance should cover the following criteria:

1. Substance related criteria: this relates primarily to the propagation of substances in the environment, absorption/accumulation, degradation (biotic/abiotic), toxicological/ecotoxicological behaviour of substances.
2. Media related criteria: factors that should be noted here are the air-hygienic behaviour (observation of the TI-air, TLV values), local water pollution, the aquatoxic effect, global water pollution, soil pollution.

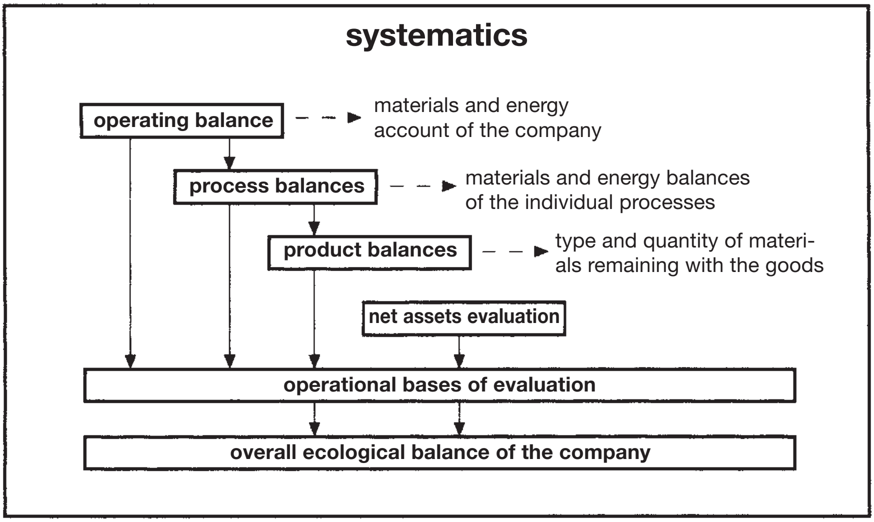


Fig.: Systematics of preparing an ecological account in textile processing.

3. Effect related criteria: important factors in this field are: mutagenicity, teratogenicity, carcinogenicity, absorption and retention, influence on ecosystems.
4. Evaluation principles: at the end of the chain are the evaluation of exposure, effects, and danger and risk effects.

Process control Instrument for the programmed control of largely automatic manufacturing stages. Such control systems often incorporate measuring and control devices; their target values are predetermined by the control system; they continuously regulate individual parameters in the process control sequence.

In contrast, the collection, registration and calculation of process data belongs to the field of data processing, not process control. The main difference lies in the cost of the necessary computer. Process control is an active aid to production and performs many activities previously performed by operating personnel (Fig. 1). Data processing, on the other hand, processes consumption rates, speeds, temperatures, etc. in a separate stage after the process, or in parallel to it, namely EDP (Fig. 2).

Process control engineering Electronic programming of any finishing process with regard to time, temperature, speed, pressure, addition or discharge of treatment liquors, dyes, chemicals, etc. that were previ-

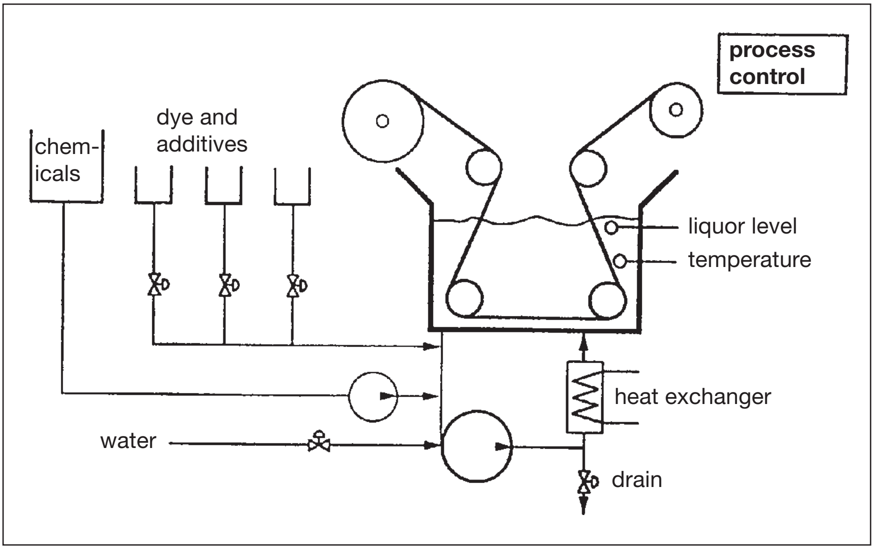
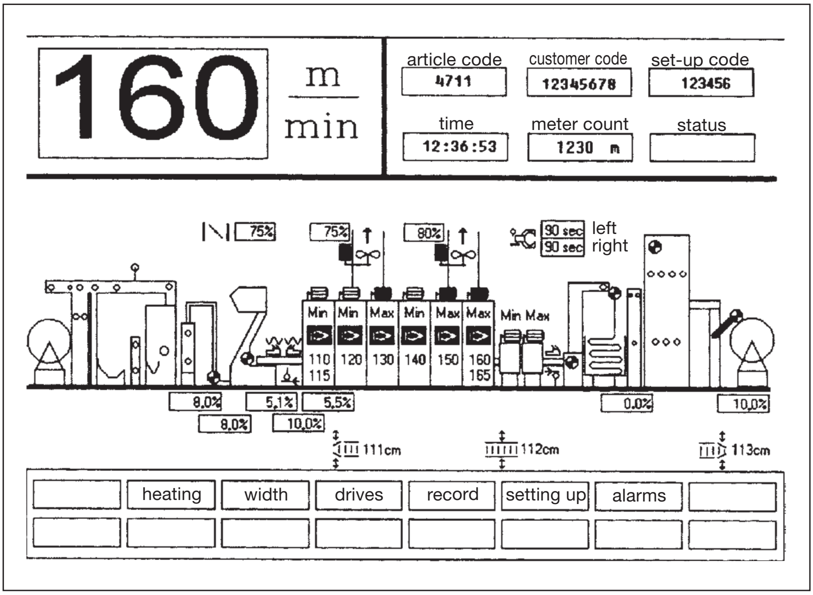


Fig. 1: Process control as exemplified by a jigger with peripheral equipment.



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time: 12:36:53

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Fig. 2: Diagram representing the processing of stenter frame data as displayed on a PC monitor.

ously manually controlled processes. → Automation in textile finishing helps to achieve economical and reliable production. On the basis of continuous monitoring of momentary quality measurements by the process computer, individual sub-systems should be produced automatically within a permissible tolerance range.

Processes were previously managed on the basis of modelling. If a plant is to achieve target values on the basis of a control algorithm, then it is necessary to develop a process model of the greatest possible accuracy. We can differentiate between theoretical and empirical process models. The theoretical models are based upon physical and chemical state equations. The advantages of theoretical models lie in the possibility of simulation and the calculation of non-measurable variables, the disadvantages are the high computing power needed, the high cost of development, the limited nature of predictions because simplified assumptions must be made and the difficulty of determining parameters of secondary conditions.

In the empirical model, the input and output behaviour of the system as a “black box” is statistically analysed. The advantages of this approach are the high level of precision and the low computing costs. The disadvantages are the narrow working range, the lack of extrapolation possibilities and therefore the impossibility of reacting to errors. Operating a system by heuristic methods requires a sufficiently good level of empirical knowledge. Based upon this knowledge, a process operator is able to specify target values for the process (Fig. 1). This type of process control operates in many plants. The plant manager has an overview of the process and is in a position to correctly interpret many secondary conditions. The disadvantages of this way of working are the different levels of qualification of different plant managers, who also have to concentrate on many other tasks.

In an → Expert system, the knowledge of the process operator is implemented on a computer, so that the computer monitors the process on behalf of the plant manager, using the knowledge base of the plant manager to input target values to the process. Even processes that cannot be modelled can be operated automatically and thus more consistently, more precisely and more economically.

The process operator therefore has to make a decision for every possible process situation. It is clear that a simplification must be made to enable one to deal with measured values in this world of infinite variation.

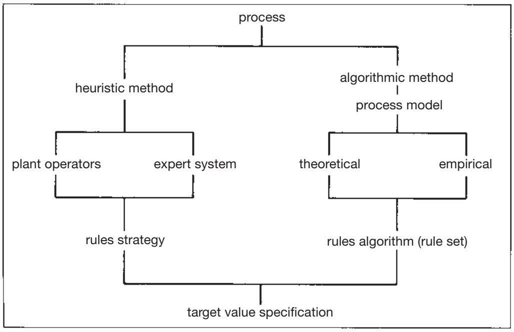


Fig. 1: Methods of specifying the target value.

Human thought is to a large degree characterised by the fact that it rests upon the use of concepts. Thus entities which can be differentiated are categorized and classified taking into account certain aspects and disregarding others. One can then react to membership of a group rather than the individual entity. The first stage of development is thus the grouping of the measured values into classes and thus concepts. This occurs on four language levels, from top to bottom:

- learning level,
- action level,
- monitoring level,
- object level.

The lowest level (object level) only contains information about the measured values of the process. The 2nd level (monitoring level) contains the compressed information about the object level. The primary observations of the process controller are structured in the form of concepts at this level. The first task is to uncover the relationship between process data and concepts. The definition of a trend is: a trend is indexed if the last two values (current and 2 h ago) change in the same direction as the third last (4 h ago) or the difference between the last and the third last value is at least 2% and the second last is equal to one of the two others. The information from the object level is thus compressed into the sentence “there is an upwards trend”.

The second important concept is the distance from a target value. Attributes such as “too high, much too high, normal, too low” are used. These attributes are described by the allocation of limits. The two concepts “trend” and “distance” have proved to be fundamental in this context. The rules in the 3rd level (the action level) are formed from these concepts: “If process situation, then action instruction”.

A further point is evaluating success. Human process control is largely characterized by the capacity to learn. There is often a lack of evaluation of the results of an action. This can occur on a fourth language level (learning level). To make an expert system capable of learning, it must evaluate past actions (reflection). This is achieved by introducing a new type of rules (“meta rules”) which use the results of the proposed target value to optimize the rules of the action level. The situation is as follows: if the old process situation and the completion of an action and the new process situation are “not equal to” the expected process situation, then the action must be changed.

Each action performed should achieve a goal. Each action is associated with an expected process situation. If this situation is not achieved, then the action instruction must be changed. In this manner, the rules of the action level can be increasingly modified to suit the current situation.

In order to implement the cognitive model described above on a computer, a shell is necessary that precisely describes these structures. An expert system consists of different modules linked together in a tree-like manner. Each module contains different states. A state consists of a number of actions, conditions and examples. The knowledge is input in a purely declarative form. The disadvantages of such a procedure lie in the generation of incomplete, redundant or contradictory rules. These disadvantages are eliminated in an expert system: An “If ... then ... else” structure is derived from the above declarative representation. A code generator now creates certain codes from this system.

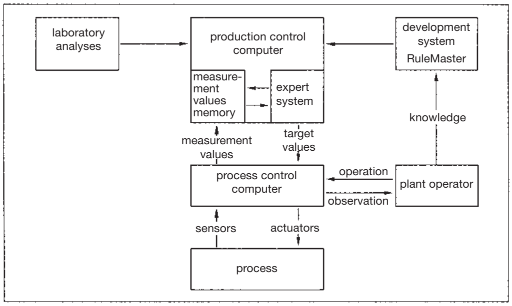


Fig. 2: Representation of an expert system in the stratification model of automation.

This code can be modified so that it runs on-line on a process computer. Fig. 2 shows the structure within the level model of automation. At the lower level, the so-called process control level, the process is controlled via the process control computer. The plant manager can monitor and control the process based upon flow diagrams. This level includes storage of measured values and the expert system. Furthermore, an operation laboratory computer is connected to the production control computer. This computer supplies the current laboratory analysis values from the system. The expert system analyses and interprets the process and analysis values and provides target values to the lower-level process control computer, which controls these target values using conventional algorithms (according to Soltysiak).

Process coupling The environmental problems associated with textile finishing have given a new significance to the need for process coupling. Where excess heat occurs in a process, attempts are made to control the quantity using → Process control engineering so that the correct amount of energy is consumed by a connected, heat consuming finishing process. Recycling requires a coupling of different processes via EDP (see Fig.), if all useful materials are to be optimally used.

Process data highway for the textile industry In textile companies an increasing number of production machines are connected to data systems. The machine

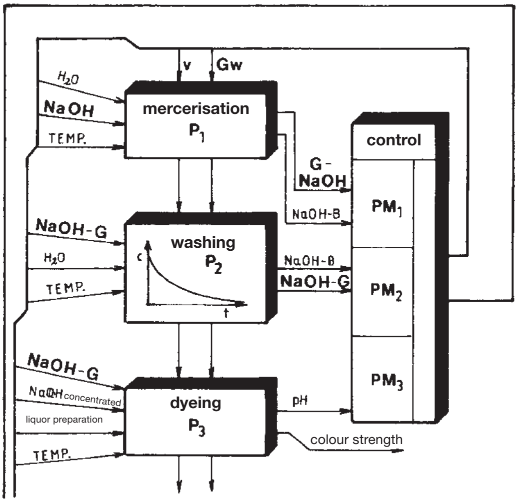


Fig.: Process coupling (NaOH-G = grams of NaOH/kg of cotton; NaOH-B = grams of NaOH/litre of liquor).

manufacturer's systems are designed to work with his own machines or machine groups and can only accept and process the data from these machines. There is a lack of compatibility. However, textile companies have many machines from different manufacturers installed in their company. This, therefore, leads to a collection of very varied data systems, which although they can capture and process the data from "their own" machines, they cannot understand the systems of the neighbouring machine. CIM (Computer Integrated Manufacturing) therefore represents an automation concept for textile companies, which provides a data connection between all sectors involved in production, from planning to quality assurance. Operational, quality control, process, and planning data, etc. must be taken into account. However, in order to achieve goals of this type, free data exchange throughout the whole company is necessary, i.e. between all machines and devices from all manufacturers. The different systems can only be connected at a significant cost or only to a limited degree in the event of manufacturer's data being unavailable. The costs incurred relate not only to the additional computer and programmes, it is often also necessary to modify buildings (cable ducts, space for computer). These expenditures are repeated each time changes are made to a company's machinery, i.e. each time a non-compatible data system is integrated. Such additional costs could become largely superfluous with the use of standardised data interfaces and bus systems for the textile industry. The guideline VDI 3665 for weaving and finishing (→ VDI) will be widely used for the current generation of machinery. For future generations of machines, however, an interface with bus capability without additional modifications is called for. Interfaces with bus capability permit the direct connection of several machines and devices to a common transmission cable. The huge amount of work involved in specifying a unified interface for the textile industry has led to a step-by-step process and to reliance on existing standards or standards under development.

The term field bus is used to describe a serial bus system, which possesses the technical and functional features necessary for the networking of individual machines and electronic devices for the capture of quality and production data to the process control level. The field bus covers the lower and middle performance range. The following goals should be achieved by the definition of a unified interface or bus system:

- free communication between the devices and machines from different manufacturers,
- low connection costs for individual machines and devices,
- forward looking and performance capability for the textile sector,
- based upon international standards,
- high transmission rates, to cope with future data quantities,
- high efficiency of transmission due to short messages,
- control of priorities for alarm handling,
- simple, economical cabling.

The Profibus has emerged as an option for further development from these and other criteria. The Profibus proposal also takes into account the efforts taking place on an international level to achieve free communication. As the basis, the ISO has published a reference model for the free, manufacturer-independent communication system, the OSI model (Open System International). The communication details are divided into 7

user

Anwendung **Application**		**layer 7**
Darstellung **Presentation**	**empty**	**layer 6**
Kommunikationssteuerung **Session**	**empty**	**layer 5**
Transport **Transport**	**empty**	**layer 4**
Vermittlung **Network**	**empty**	**layer 3**
Übermittlung **Data link**		**layer 2**
Bit-Übertragung **Physical**		**layer 1**

data link

Fig.: The 7 layers of communication.

layers, with each layer having its own specific functions to fulfil (see Fig.).

A higher layer therefore does not need to be concerned about the tasks of the lower levels. The transition from level to level is precisely specified and described. The specifications for the individual levels thus describe how these should behave in relation to the outside world. This means for example, that if the physical transmission medium (e.g. from twisted wires to coaxial cable) is changed, only the control of the physical medium (level 1) must be modified, if the transition from level 1 and 2 is identically specified for all solutions. For the application of the Profibus standard in certain applications, e.g. in the textile industry, additional specifications must be made. The selection of so-called basic standards and the specification of the variable interface parameters give rise to the communication profile of the field bus for the textile industry.

Process data logging Covers all data within the processing sequence (see Fig.): physical data (rotation speed, temperatures, material non-uniformity), data regarding operating states (running, stationary, operating faults), data about quantity/quality of the processed material, personnel data, machine data (→ Data logging). Data falling under individual sectors can be utilized for various purposes: for process control at the lower stage, e.g. to change machine settings (either manually “off-line” in the laboratory or “on-line” by process computers), for the recognition of machine defects, errors or false settings in process stages that precede the monitored stage; for process control at a higher level (for planning based upon data concerning throughput times, product quantities produced and product qualities) and for long term process optimization.

Process field bus The developments of the 1980s have clearly shown that there is a need for a computer controlled data exchange between production and management in the textiles sector. The activities summed up by the term CIM (→ Computer applications in textile dyeing and printing) include, amongst others, the capture of all data generated at the production machines and automatic process control. The networking of the machines and the superior systems in the production sector takes place using a bus system. The tasks and usage options of bus systems in the textile industry are:

- transmission of information (e.g. production, machine and quality data, target and actual values, fault and operation messages, sensor and actuator signals);
- networking of machines and plants (e.g. spinning preparation, spinning, rinsing, knitting, weaving and finishing machines and plants);
- connection of devices (e.g. control system computer, PC; data capture- BDE/MDE terminals; operating/observer operating fields, process control systems, control/regulation automated systems; production sector sensors and actuators).

In the past, such networks have been based upon the

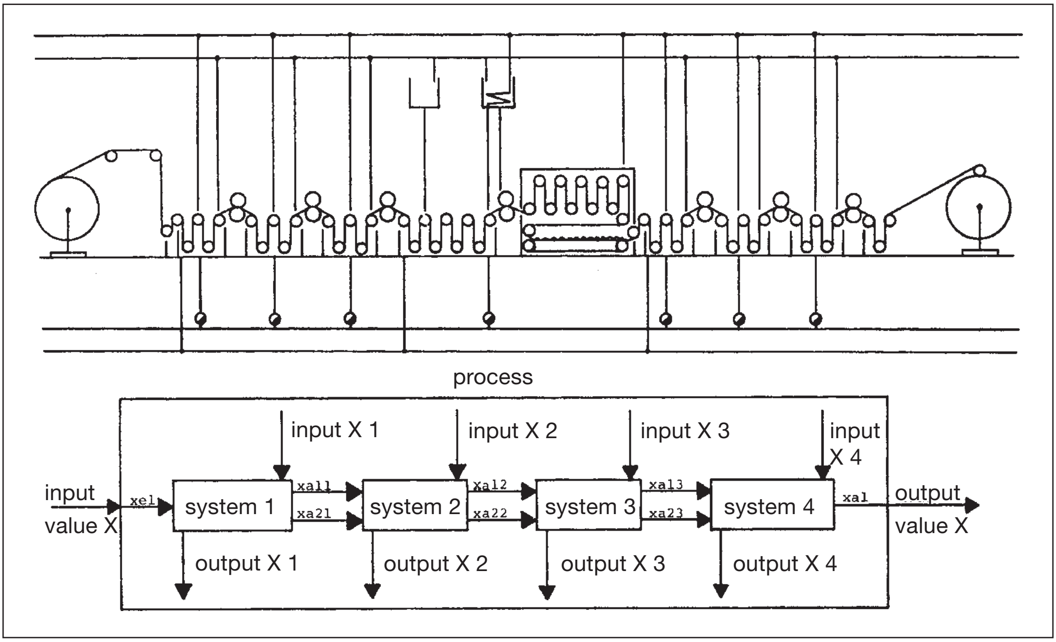


Fig.: Process data logging: diagram of a textile finishing process comprising several individual systems.

varied bus systems that were available on the market. In addition to the options offered by system houses, textile machine manufactures have incorporated their own solutions into their sales range. However, because a varied collection of machines from different manufacturers will be installed in a real textile company, this can also lead to a collection of very different bus systems. Although these can capture and process the data from their own machines, they cannot understand the systems of neighbouring machines. In the simplest case, even the cables and plug connectors necessary for data transfer are not compatible, so that different cables must be laid for each system. The case may also occur in which, although the data exchange can take place via uniform cables, the sending and receiving of data takes place in a different manner. This leads to problems in the entire network. The hardware and software can only be modified at considerable cost and huge expenditure in terms of time. The use of manufacturer specific systems in particular, for which the necessary documentation is not available, can lead to severe limitations.

The process field bus (Profibus) is recommended by the “Data interfaces to textile machines” committee. It aims to facilitate the linking of machines and systems from different manufacturers in the simplest manner possible. The basic principle behind the Profibus concept is based upon the following demands:

- communication functions of simple field devices (sensors) and also more complex units (automated systems) must be realised;
- the transmission technology used must be simple and good value for money;
- the application interface should possess a functionality that is based upon existing, international standards;
- high reliability of transmission with short reaction time.

(according to Bergmann).

Processing material directive (ArbStoffV – Arbeitsstoffverordnung). German directive regarding dangerous materials of 11 February 1982, which controls the trading and handling of dangerous materials and health monitoring of employees who work with dangerous substances; was replaced by the Directive for use of dangerous substances (→ Legislation on environmental protection) from 1 October 1986.

Processing sequence In the context of a work analysis this consists of individual processes: → Operating time, Production resources, Handling time factor. The processing sequence is also divided into a sequence of individual processes (examples Figs. 1–3).

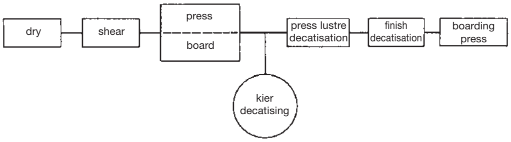


Fig. 1: Processing sequence (operational sequence) of the classic dry finishing of woven wool fabrics.

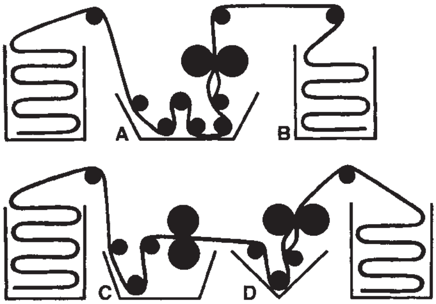


Fig. 2: Processing sequence diagram of the Vicontin-I process (Sandoz).
A = knitted fabric dyeing; B = cold dwell; C = rinsing; D = fixating with Indosol E 50.

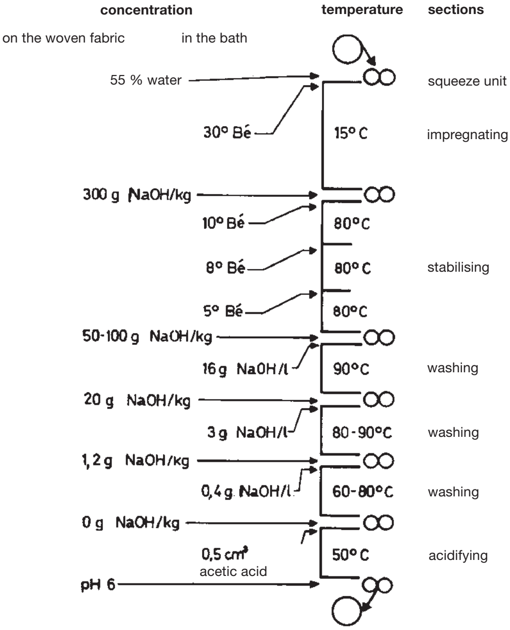


Fig. 3: Processing sequence of the classic mercerising process: diagram with detailed data on wet finishing.

Processing sequence in textile finishing Sequence of the individual working steps; these are often determined by the experience of the finisher. If the aims of the finishing process are specified in a logical manner based upon the profile of requirements for the finished material the processing sequence can be determined by factual arguments. Using the example of a polyamide warp-knitted fabric, which is to be used uni-white as a women’s outerwear item, the selection of

Processing sequence in textile finishing

discontinuous

processing sequence

A

winch:
bleaching*
optical brightening
softening
↓
rope opening
↓
stretching
↓
heat fixing

B

heat fixing
↓
winch:
bleaching*
optical brightening
softening
↓
rope opening
↓
stretching

or simplified

A

optical brightening
as rope
↓
heat fixing

B

heat fixing
↓
optical brightening
as rope

whereby the order of the subordinate operations of bleaching, optically brightening and softening can be changed

* if necessary on account of whiteness!

foulardtherm process

C

open width
bleaching*
↓
stretching
↓
padding:
with optical brightener
↓
drying,
heat fixing
↓
foulard (padder)
softening
↓
stretching

the sequence of processes cannot realistically be reversed for technical reasons, namely that the brightener can only be fixed once it has been applied!

Tab. 1: Various processing sequences as alternatives for the finishing of a product.

	A	B	C
dyeing (white)	+	○	+
design of goods (geometrical structure)	○	–	+
distribution of threads	+	–	○
glaze**	+	+	+
surface structure	+	○ *	○ *
stiffness (stiff = -)	+	○	○

evaluation:
\+ positive
○ acceptable
– negative
} with respect to subjectively assessed evenness (or harmony)

* transverse and longitudinal effect (knit structure)
** not in the sense of “stronger glaze is good!”

Tab. 2: Criteria used in selecting the processing sequence as laid out in Tab. 1.

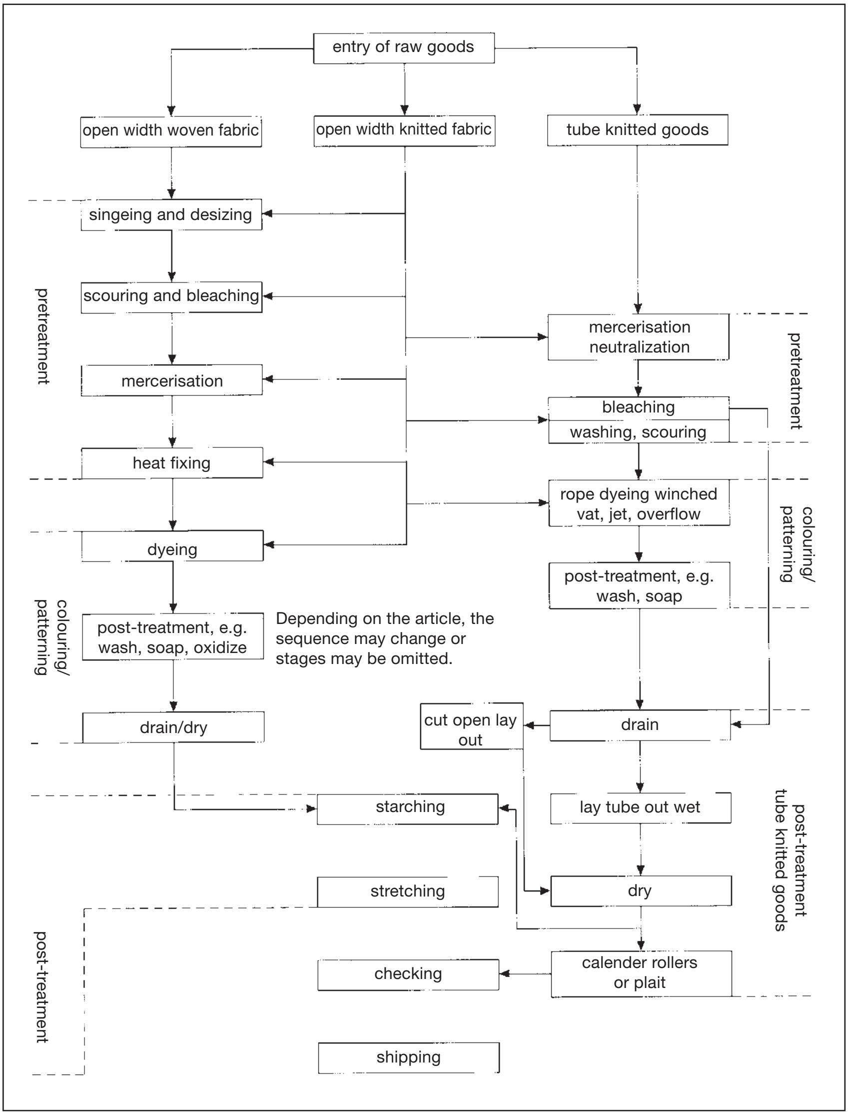


Fig. 1: Example of the processing sequence for piece goods in dyeing.

processing sequence (without pre-cleaning) can be represented as follows (Tab. 1).

Processing sequences A, B, C can be analysed with regard to their target properties. The subjective value of the equality factors is selected, whereby it is a prerequisite that the desired degree of whiteness is always achieved.

We can see from Tab. 2 that if a uniform equality is a specified objective, processing sequence A is the preferred alternative and processing sequence B should be rejected. Processing sequence C is a viable alternative for certain batch sizes (yardage).

However, the processing sequence not only breaks down the individual subsectors of textile finishing; rather from an integral point of view the entire system is structured in accordance with the areas of:

– pretreatment,
– colouring,
– post-treatment.

The processing sequence is significantly influenced by the type of colouring (dyeing or printing). Furthermore, the processing state of the material also determines the processing sequence, for example one critical factor is whether a knitted fabric is cut open or processed in tubular form. Fig. 1 and Fig. 2 show processing sequences for the finishing of fabrics in dyeing and printing.

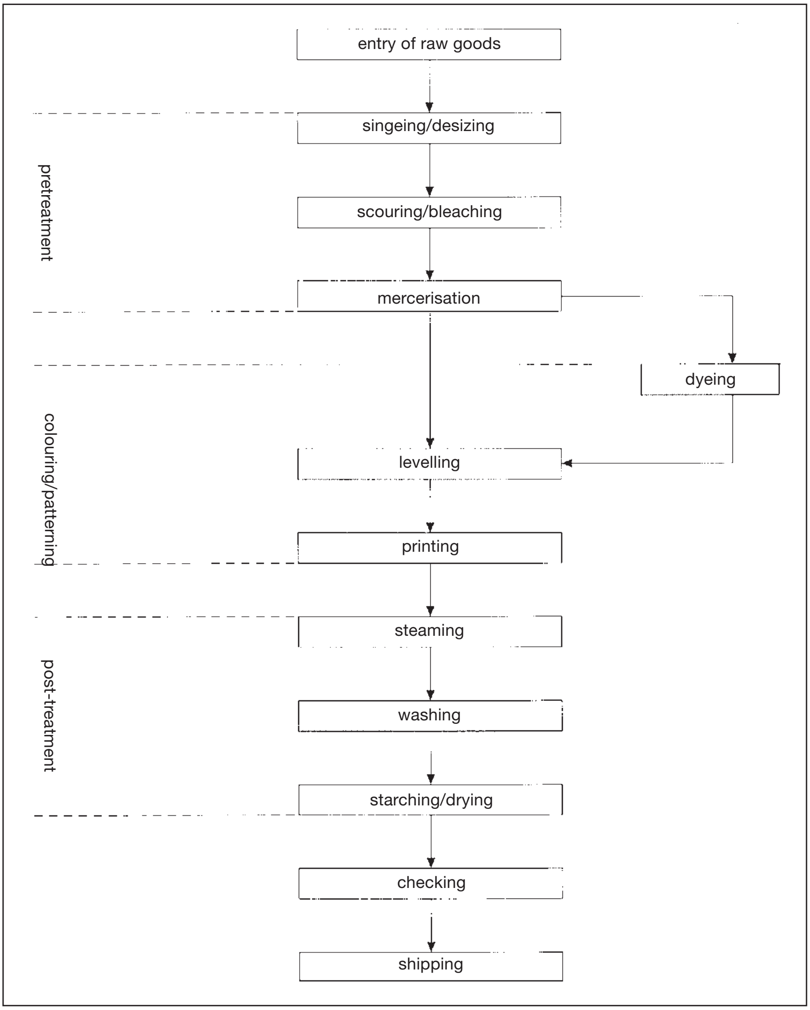


Fig. 2: Example of the processing sequence for piece goods in printing.

Processing time,
I. Part of the → Handling time factor or basic time for all direct processing operations on the material.

II. Operating time, usable life, gel time, → Working life; term for the period of time from applying a synthetic resin to when it is still just possible to process it, i.e. shortly before the onset of gelling. Important for condensation resins, because their viscosity falls sharply when the processing time is exceeded, whereupon they gel and then become unusable.

Process-integrated waste water treatment The increasing level of awareness regarding disposal technology has led to the recognition of various difficulties in an overall treatment of textile waste water. The considerations relate on the one hand to the enormous use of chemicals, associated with non-specific removal of pollution from the waste water, and on the other hand to the sludge load, the disposal of which is creating increasing difficulties. A decisive change to the situation can only be achieved by a process-integrated waste water treatment; only in this manner can the necessary biocompatibility be achieved, which is necessary for an unproblematic microbial disposal of the waste water. In principle biological treatment can be used for the waste water of all companies processing vegetable or animal substances. Examples include not only the food and sugar industry, but also the textile industry if the levels of inhibiting or toxic substances added during production are sufficiently low.

The great problem associated with aerobic decomposition is the use of oxygen, as power consumption is very high. So it is understandable that aerobic decomposition is only used in waste water with low to medium pollution levels (COD < 2000 mg O_2/l). The still fairly

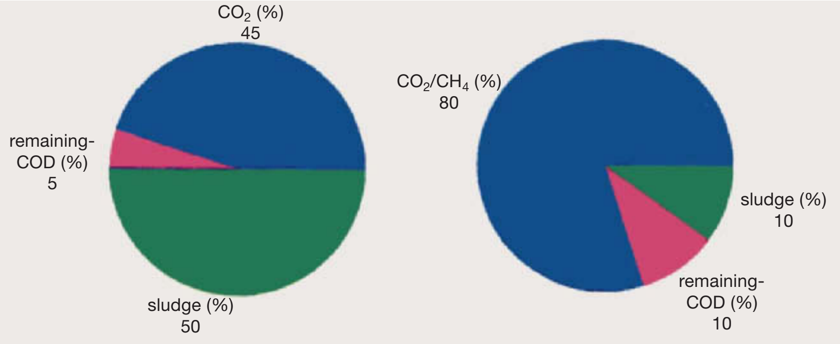


Fig.: The carbon balance for the aerobic (left) and the anaerobic (right) break-down of typical waste water from the sugar industry.

common practice of diluting highly polluted partial flows is an outdated technique and is no longer practical for cost reasons. The great advantage of anaerobic decomposition lies in the fact that high levels of waste water pollution (10 000–20 000 COD units) can be biologically treated using the stored chemical energy. In aerobic decomposition, by contrast, the chemical energy stored in the pollutants must be destroyed at even higher power consumption (addition of oxygen) (see Fig.). A particularly important advantage of anaerobic decomposition is the significantly lower sludge quantity in comparison to aerobic decomposition.

If we consider the pollution in the individual partial flows of textile production, then we find that the sizing and pre-treatment waste water is polluted with a high level of polysaccharide and that in fact the basic preconditions for anaerobic processing exist here. Exactly the same applies for many printing companies. The balance of substances in the partial flows and their mixtures facilitate decomposition results to be interpreted individually for each partial flow. The partial flows of textile waste water can be anaerobically pre-clarified with good results. In desizing and pre-treatment partial flows in particular, 80% decomposition can be expected as a result of optimization activities. This outcome means that a finishing company can expect a reduction of on average 50–60% of the total COD. Waste water from a printing company requires a different approach; for example, anaerobic decomposition is not possible if semi-emulsion thickeners are present, although pure alginate thickeners can be 90% decomposed. It appears that anaerobic disposal technology cannot be used with partial flows from dyeing, which means that one still needs to turn to conventional flocculation and precipitation techniques (according to Marte and Keller).

Process measuring and control plant Process measuring plant with measured value detection, measuring sensors, measuring transformer, measured value display and possibly measured value recording. Control plants control the process automatically or manually. Regulation plants perform automatic regulation of the process. Signalling, display of boundary states with acoustic or optical alarm signal. There are pneumatic, electric, electronic and hydraulic process measuring and control plants.

Process water In the past water was considered to be a consumable commodity that was available in top quality and unlimited quantities. Due to the ecological awareness that has now developed, great importance has been attributed to the sensible use and consumption of water. Water is still the most important auxiliary agent used in dyeing, which means that its properties have a great influence on the dyeing result. When speaking of fresh process water (service water) we differentiate between

- ground water (from wells and springs),
- surface water (from streams, rivers, lakes and ponds).

These two types of water can be used in the form of raw and treated water. In addition to fresh water and mains water, so-called

- recycled water

is also used. This term is used to describe water that has been cleaned after use and fed back into the production process without any intermediate stage as service water. Often one water type does not fulfil all the requirements, and then so-called

- mixed water

is created by mixing the different variants. The ideal service water for dyeing and bleaching would be distilled water, to which a little bitter salt (magnesium sulphate) has been added for the stabilisation of hydrogen peroxide bleaching baths. This type of water is, however, much too expensive and therefore is not used in dyeing. Condensate, under certain circumstances, is almost distilled water. It is a type of recycled water, because it has already performed work in the form of steam. If free of metals (iron ions from condensation vessels, pipes, etc.), it is an almost ideal process water. It contains no aggressive carbonic acids, no → Water hardening salts, no suspended matter or algae and it reacts almost neutrally. Of course, this condensate is too expensive for use as process water and is thus returned into the steam circuit. Cooling water could also be used as process water, depending upon the original water type:

a) Raw water, not used for dyeing. It cools and is discharged. The prerequisite is that enough raw water is available. Since the issue of communal directives stating that all water from a company must flow through the waste water treatment plants (waste water costs), this type of cooling is no longer relevant. Special arrangements allowing such cooling water to be fed into the main outfall are almost unheard of.

b) Untreated cooling water that can be used for dyeing.

c) Treated cooling water that is suitable for dyeing.

Ground water (spring and well water) is excellently suited for dyeing, if it is almost neutral (pH 6–7.5), has a low degree of hardness (5–7°d), contains no harmful, aggressive carbonic acids or metals and is free of suspended matter. However, such process water is a natural product and therefore varies in its composition, e.g. in its degree of hardness. → Water requirements for dyeing and finishing; Water as finishing medium.

Product (Lat.: productum), yield, result. From the point of view of value analysis also services.

Product application generally takes place in the form of solutions or dispersions/suspensions. Product application can be controlled indirectly by the measurement and control of the quantity of solvent or dispersant (generally water) with a few exceptions (e.g. due to high dye substantivity or differing dye take-up capacities of the fibre). A range of parameters should be consistently upheld:

- product concentration in the liquor,
- initial moisture of the fabric,
- fabric construction,
- dye take-up capacity by pretreatment (e.g. by mercerizing cotton, causticizing viscose, thermofixing polyester).

On the other hand, some variables influence liquor take-up such as:

- cross-linking capacity of the material,
- material speed,
- tension of the material run upon entry,
- padder-roller temperature,
- dwelling time in the liquor (without taking into account the dye substantivity effect or the “reversed tailing” effect).

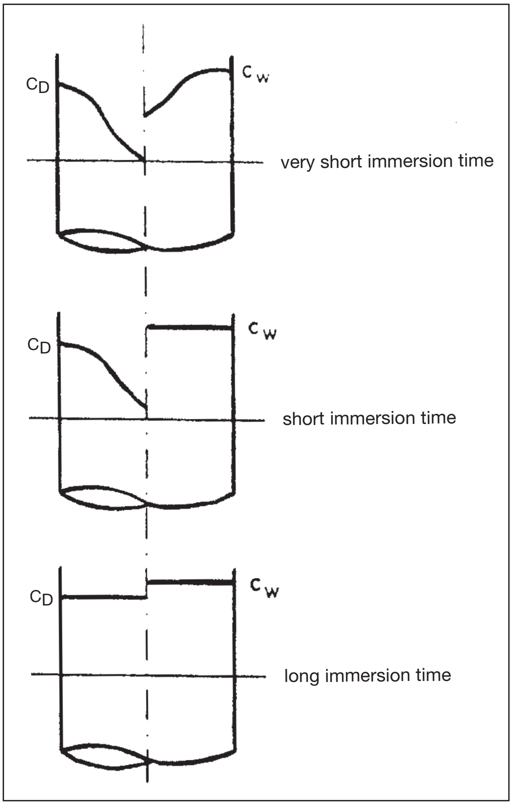


Fig. 1: Diagram representing the concentration profiles of both water (C_W) and dye (C_D) within a fibre during dyeing (according to Rüttiger).

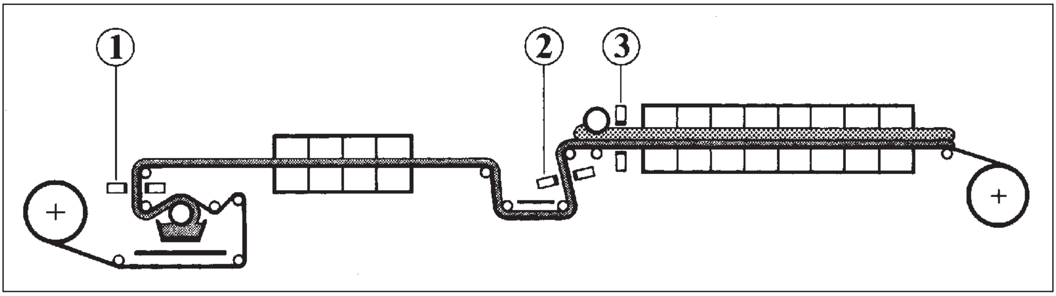


Fig. 2: The measurement and control of the application process as exemplified by tufted backing coating.
1 = high humidity measurement following nip padding; 2 = residual moisture measurement following intermediate drying; 3 = humidity measurement following foam application.

They can be compensated by the measurement and control of the dye take-up.

According to Rüttiger the exchange factor in the padder chassis depends primarily upon the submersion time, as is illustrated by the different diffusion coefficients of water and dye based upon the concentration profile in fibres (Fig. 1).

process	RL in %
nip padding technology MA process (Triatex)	<45 20 – 40
dip rollers engraved application rollers	from 40 up to 100, depending on type of roller
foam application direct, unpressurized foam application using blade or pad United Merchants and Manufac Dinting Engineering bubble colouration process Hoechst AG	
direct application of compressed foam Gaston County; FFT process Stork; RSF process Mitter; pile fabric 70 %, carpet	 10 – 25 20 – 30 40
indirect foam application Küsters, Janus Monforts, Vacu-Foam	 10 – 40 10 – 45
spray application jet-extrusion of liquor into an electrostatic field	30
rotor process Weko	<20

Tab.: Product application processes which involve a minimum application of product.
RL = liquor up-take.

In addition to the classic product application with the padder, high moisture product application (more than 100% liquor application) is significant in pretreatment (Flexnip, Super Sat, Optimax, Raco-Yet, etc.) and low wet pick-up (Tab.) is significant in resin finishing and continuous dyeing. Nip padding and foam application are also used in coating (Fig. 2). In special cases spotting is also used (Fig. 3).

Fig. 3: Liquor pouring as a method of product application (curved blade/West Point).

Product application must be checked for quality assurance. The example in Fig. 2 shows a tufted back coating plant in which

- measuring station 1 monitors and automatically controls the base coat,
- measuring station 2 monitors and automatically controls the intermediate moisture,
- measuring station 3 monitors and automatically controls the foam application.

The aim of measuring and controlling the continuous product application on textile material lengths is

a) to avoid lack of uniformity,
b) to improve the reproducibility of the material quality,
c) to quickly achieve matching of laboratory and production results,
d) to avoid excessive application.

Many product application machines can in principle be classified into mechanical processes, gas kinetic processes, capillary processes and low wet pick-up processes.

By the use of a size application measuring device it is possible to automatically regulate the squeezing pressure by continuous measurement of the actual size application (Fig. 4). A uniform degree of sizing can thus be achieved assuming there is a constant size concentration and temperature (viscosity).

The advantages for the weaver are:

- savings in size,
- uniform degree of sizing,
- higher weaving efficiency rate,
- recording of size application.

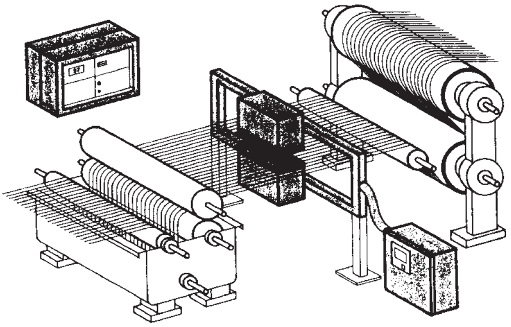


Fig. 4: Measurement of product application on sized warp yarns using a Pleva microwave high humidity instrument.

The advantages for the finisher are:

- savings in chemicals during desizing,
- lower waste water pollution,
- greater uniformity in pretreatment.

Product development is carried out by the textile designer (known as the designer in the cloth industry). After a creative phase, product development moves into the realisation phase; the pattern collection is developed (see Fig.). If the manufacturer has placed orders for blocks prior to the season and in the case of coloured material made colour classifications during the season, then the task of product development includes monitoring the production process, so that suitable conclusions can be drawn regarding the correct material construction. This also includes an attempt to monitor the behaviour of the item in use and its disposal routes.

Production Manufacture, generation of products from raw materials or semi-finished goods, e.g. by textile finishing. In a broader sense, factors of production as commercial service provision: purchasing, transport, stocks, manufacture, administration, checking; without financing and sales.

Production control,

I. The logging of process data and its processing and provision to the sender for decision making and influencing the process as part of manufacturing control. The automation devices used for production control consist of a central processing unit and a certain number of decentralized recording devices for manual entry or semiautomatic or automatic recording of data directly at work places, whereby the central processing unit incorporates at least a minicomputer.

II. → Quality control.

Production costs in textile finishing According to production cost classification in a static textile finishing company (in-house finishing), personnel costs are a significant cost factor in the production sector at 35%, min. 29%, max. 48%, depending greatly upon the type of finished item. 60% of the personnel costs or 21% of the total productions costs are spent upon internal material transport (textile material, finishing product). Requirements for reducing production costs: lowering the personnel costs for internal goods transport by shorter transport routes, lower frequency of transport and lower personnel related transport. → Production flow.

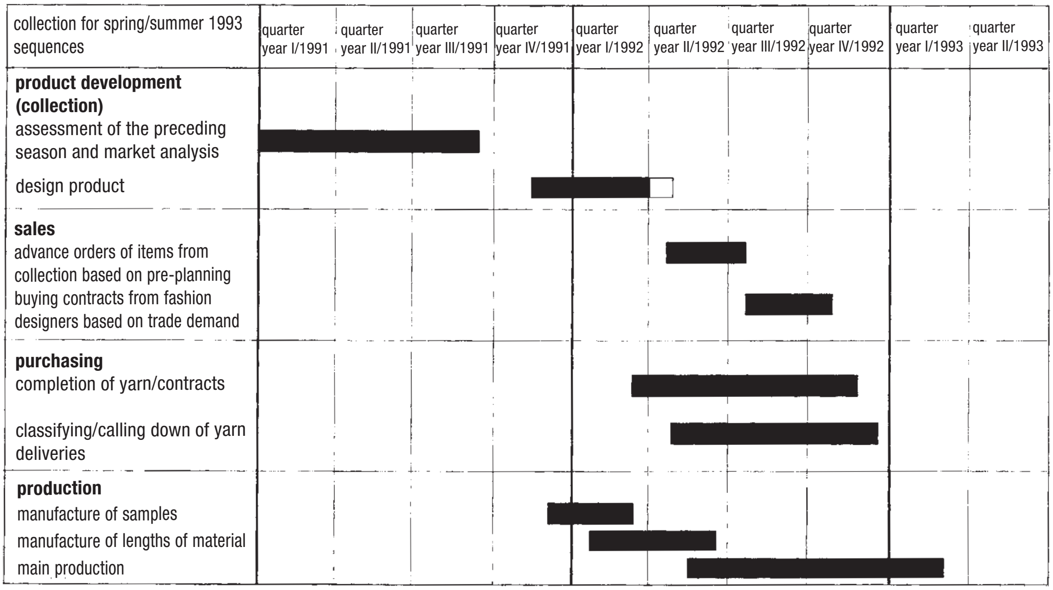


Fig.: The process of developing a collection by a fashion weaver.

Production data logging The logging of all determining variables and components necessary for production and follow-up calculations. The most important part of this is machine state logging, i.e. the logging of all data regarding the current state of the machine, e.g. rotation speed, infeed, etc. Information about the use of labour and data regarding material and planned process stages and procedures are also part of the manufacturing process.

Production flow A textile product, for example in the clothing sector, runs through the production sequence from raw material to sale in around 66 weeks (see Fig.). Of this, the proportion of storage and waiting time (approx. 80%) is significantly greater than the actual process time (approx. 20%).

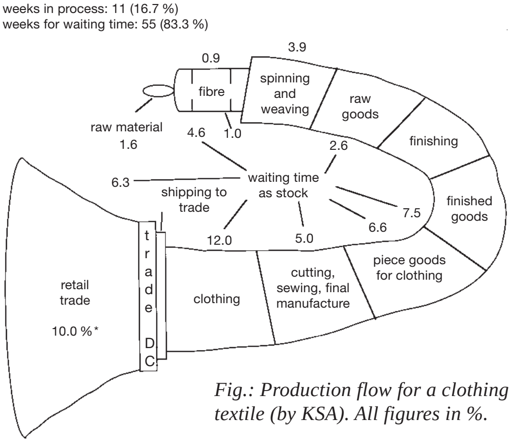


Fig.: Production flow for a clothing textile (by KSA). All figures in %.

Textile finishing is a transport intensive production process, in which 7 kg of textiles are impregnated per man and hour in static finishing operation, which at an average of eight treatment stations in the production flow represents a transport volume of approx. 53 kg material. Therefore, the personnel expenditure (→ Production costs in textile finishing) for transport is high at approx. 20% of the entire production costs. The cost-oriented production flow leads to targets for personnel expenditure, throughput time, production capacity and production quality. These lead to measures of an organisational, procedural, construction and production related nature, each of different importance. This is dependent upon the commercial structure and item range of the textile finishing. The aim of each measure and the goal of rationalizing the production flow should be to increase the profitability of the company. This is the predominant issue of a meaningful cost calculation.

Production planning After the priority, material group and colour number of a batch has been specified in accordance with the order, production planning prepares the reservation of equipment. Whereas in work planning, the weighed raw materials are made available and possibly put onto material carriers or converted into making up form, which are preconditions for the dyeing process, production planning is more concerned with the intellectual preparation for production. This phase is naturally fully integrated into the flow diagram, e.g. in dyeing (see Fig.). by means of EDP networking.

The reservation of equipment is continuously displayed to the operator on the screen, where it can however still be modified. Batches can be subsequently deleted, others added or batches swapped. Once all modifications have been made, a list can be printed out showing the sorted distribution of the batches on the dyeing equipment. It is up to the person in charge of the dyeing process whether to stick to the production plan in the proposed sequence. Any changes to the sequence are not checked by the system. Because, for example, adding an urgent order would lead to a new purchase order sequence, which would be more time-consuming than making a manual change, it is necessary to rely on the capabilities of employees. Because of the large number of boundary criteria (packages per machine, customers wishes, etc.), a computer generated reservation list is not produced for the equipment. The “purchase order” function can only be accessed from a viewing device, because operating the function from two devices would lead to undesired influences.

The preparation of raw materials, dosing of liquid dyes and weighing of powder dyes and auxiliaries belongs within the scope of production planning. The provision of materials is not computer-supported. The calculation of dye quantities and their dosing or weighing is, however, largely supported and controlled by the computer. The person in charge of the dyeing process inputs the material weight for the batch to be dyed; the resulting dye quantity is displayed. The computer calculates the quantities independently from the material quantity and the recipe. In addition to current values, past values for the same recipe are also displayed, as well as any after-dyeing that proved necessary in the past. With this additional information the operator can decide whether to correct the dye quantity or to add additional dyes, in order to avoid costly re-dyeing and to complete the dyeing process using less time and energy, thus more cheaply.

Only when the person in charge of the dyeing process has submitted a personal receipt, may the dyes be dosed from the hoppers. Liquid dyes are pumped into containers by dosing pumps. The warehouse worker initiates this process via the input keyboard of his monitor. The computer independently monitors the prescribed quantities based upon the recipe. Powder dyes and auxiliaries are weighed in the hopper itself. For this purpose there are weighing machines with different

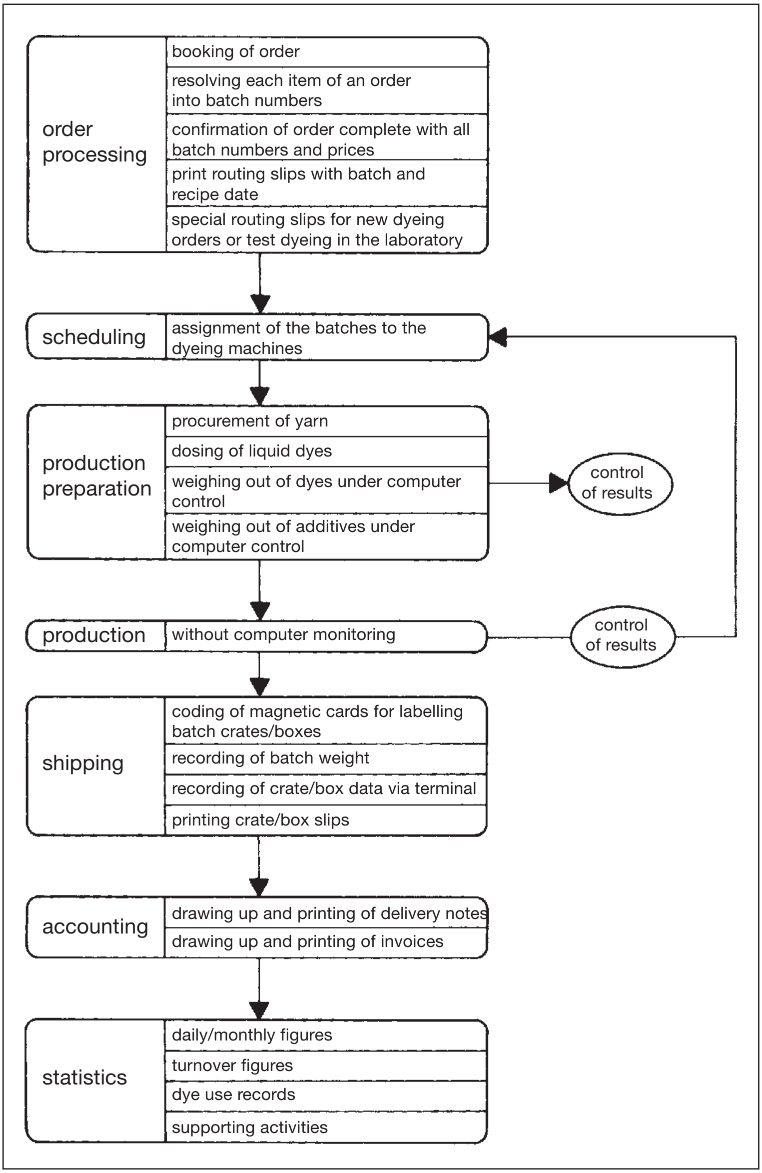


Fig.: Flow diagram for a dyeing company.

weighing ranges. The warehouse worker can see the product to be weighed on his monitor. The computer only accepts this process if weighing is precise and within a tolerance range. After the input of a completion message the computer checks the weighing process; if it has been done with sufficient accuracy the data for the next substance to be weighed is displayed upon the screen until the entire recipe has been processed. A check of the accuracy of the product does not take place.

Production quality control → Quality control in manufacturing.

Production resources Machines, equipment and devices necessary for commercial operation.

Production speed If we review technical developments in the second half of the 20th century, we see that there has been a qualitative and quantitative change: productivity viewed on the basis of production speed has increased significantly (see Fig.). On the other hand, a comparison between the different finishing stages is only possible logarithmically: The difference between weaving at max. 1 m/min and jet dyeing at around 400 m/min or continuous finishing at around 150 m/min is too great.

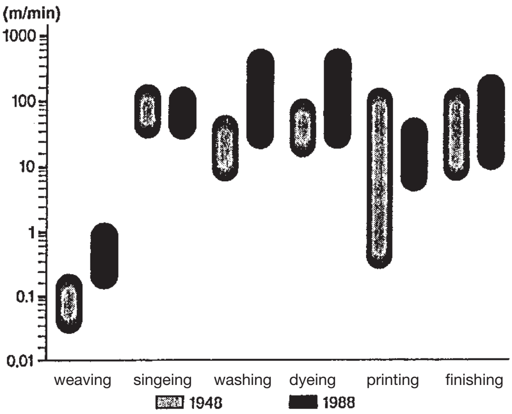


Fig.: The production speed of different operations in textile finishing (Kothe).

Production time table Textile products are produced according to a preplanned timetable in the pipeline of manufacturing to sale. The creation phase and implementation phase must be matched to the trade season. With a precisely determined process including the necessary consultation phase, production and delivery follow the plan as closely as possible (Figs. 1–3).

Productive time Component of → Operating time.

Product liability law In mid May 1985 new regulations came into force in the form of the “EC guideline for the harmonization of legal and administrative regulations for member states regarding liability for faulty products”. In August 1988 this law was incorporated into German national law. This new law tightens up product liability. The manufacturer is made liable for damage caused by faults in his product, even if it is not

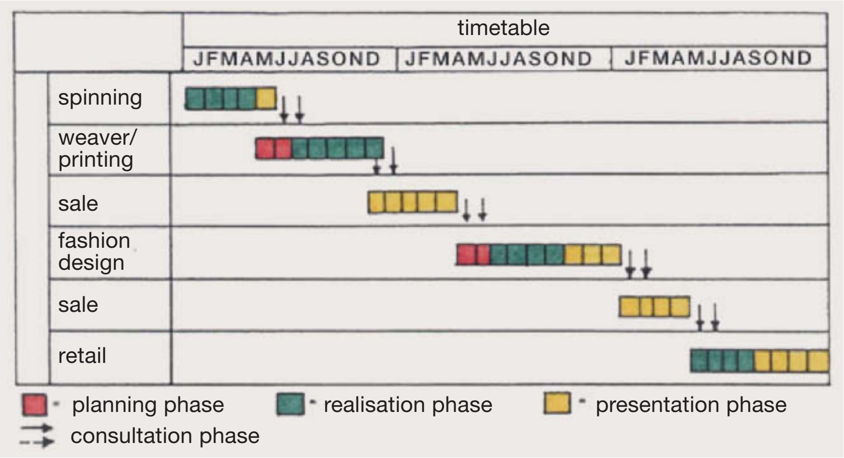


Fig. 1: Time table for the production stages between spinning and retail.

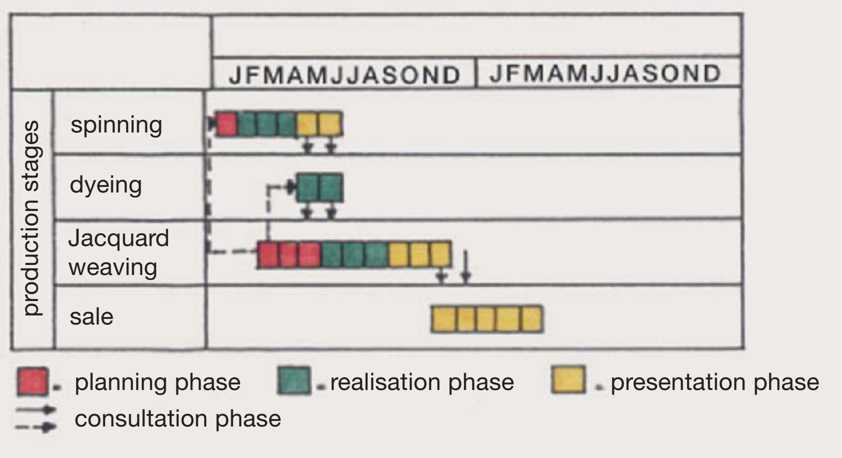


Fig. 2: Time table for the production stages between spinning and Jacquard weaving.

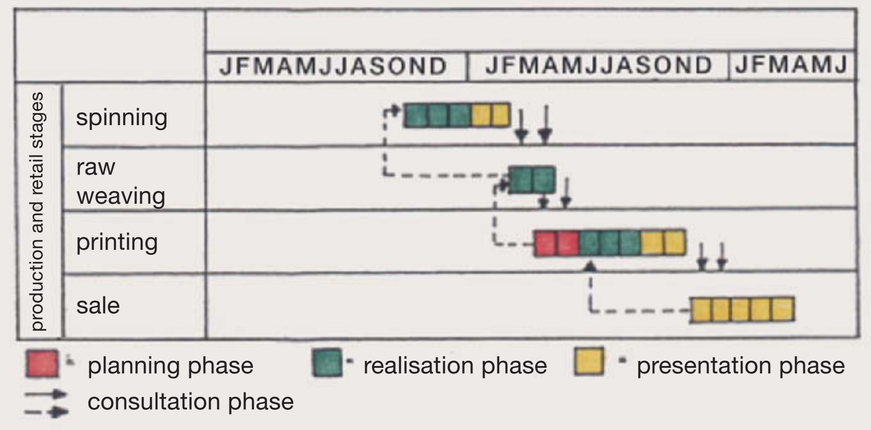


Fig. 3: Time table for the production stages between spinning and printing.

his own fault. The same applies to statements in technical information and advertising, which do not correctly reflect product characteristics. It is therefore necessary to carefully check all quality statements made by the company or its employees against the associated risk from a liability point of view. But it is also necessary to rethink production. Over and above the general duty of care, a quality assurance system with direct responsibility must be stipulated, similar to the GMP (good manufacturing practice) used in the development and manufacture of pharmaceutical goods. Quality assurance handbooks must be provided to customers upon request.

Product liability controls the rights a user has to claim against the manufacturer if damage occurs during the use of his products. It exists independent of consumer protection guarantee rights according to BGB (Bürgerliches Gesetzbuch – German Civil Code) and HBG (Handelsgesetzbuch – German Commercial Code) in the event of a notice of defect and thus does not require a binding contract (e.g. purchasing contract) for a liability claim (in contrast to warranty for defects). The German product liability law (Produkthaftungsgesetz – Prod. Haft G) thus represents an additional basis for a claim, which extends the liability obligations of a producer (called producer's liability). In the event of damage due to “faulty products”, German law distinguishes between three types of fault:

1. Design faults: despite observation of legal and technical standards the product is unreliable or dangerous in its design.
2. Fabrication faults: due to faulty production the product is unreliable or dangerous.
3. Instruction faults: use is unreliable or dangerous due to faulty instructions.

The liability arising, in accordance with § 823 BGB is a liability for intentional and negligent acts. However, culpability, and thus liability, only exists if the damage was caused by intentional or negligent action.

The main contentious difference between the absolute product liability law and the culpability related § 823 BGB lies in the following (the asterisks used have the following meaning: * = increase in liability; ** = no change to liability; *** = significant extension of liability):

– Intention or negligence are no longer a precondition for liability (culpability, burden of proof, etc. are without meaning, in contrast to earlier uses of legal language absconder is included*).
– The term “fault” used in accordance with regulations (expected safety due to design, product and instruction) is precisely defined (improper use excludes liability**).
– Both the manufacturer of the end product and the producer of raw materials and semi-finished goods are liable, as are “quasi-manufacturers”, i.e. importers and purchasers, who pass themselves off as manufacturers by putting their name on goods (extended meaning of the word manufacturer, even for import from countries of origin outside the European Community***).
– There is no liability where the fault only arose after the product was put onto the market, the faulty product corresponds with binding sovereign standards or there is no recognisable source of the fault according to the current level of knowledge and technology (development risk). The burden of proof for defence options lies with the manufacturer (***).
– Liability to pay damages covers all personal damage in the commercial and private sector, but damage to property only in the field of private use (enormously high maximum liability amounts apply for one or the same products with the same fault*).
– A claim for liability (liability to pay damages) expires 3 years after awareness of the damage, the fault and the liability, and expires 10 years after the

faulty product is put into service (if no summary judgement or lawsuit are pending*).

In the event of personal injury the product liability law also extends to the private sector (validity extends to all people suffering physical injury due to a product***); in relation to damage to property, on the other hand, it is a pure consumer protection law* with, not insignificant, own risk of the person suffering the damage (own risk). As before, liability for damage to property in the commercial sector can only be enforced according to the principles of liability for intentional and negligent acts (§ 459 BGB). Product liability law does not cover damages for pain and suffering. This must be enforced according to the conventional principles of liability for intentional and negligent acts (§ 823 BGB) (see Tab).

The development risk must be reduced as far as possible. In addition, the possible risks occurring during use must be thought out and tested in advance. In general, there will still be no liability for development risks in the future. "Faults" that are not yet recognized as such, but which would have been recognizable and avoidable according to current knowledge and technology, are not "development risks", and therefore liability exists for such faults.

If all these points must be considered for "normal" textile products, they become all the more important, e.g. in flame retardant textiles. These are associated with an increased risk of damage if they turn out not to be "flame retardant" in the event of a fire. Particular problems are encountered in the manufacture of flame retardant textiles, which did not previously exist in the manufacture of textiles for clothing and domestic textiles, or were of lesser importance. Burning behaviour cannot be tested directly on fibres and yarn. There are two reasons for this: firstly, all fibres and yarns are treated with preparations or assistants either during manufacture or with further processing. These usually burn well and thus give rise to false predictions regarding the burning behaviour of the fibre substance or the textile. Secondly, there are no burning tests for fibres or yarns. They must always be formed into a flat surface to be tested. Even a test often used in polymer development, such as the LOI (Limiting Oxygen Index), requires a surface for testing. In many cases where textiles are processed together with other burnable materials, e.g. in furnishing materials, even more expensive tests must be performed to obtain practical predictions regarding burning behaviour.

Flame retardant fibres contain, e.g. 0.6% phosphorus, which is sufficient to ensure flame retardance for

(BGB § 459 ff and following, also HGB § 377)	(Prod. Haft G of 15. 12. 1989)	(BGB § 823 ff, UHG and 2nd statute to counter environmental crime/in preparation)
warranty liability* – of the supplier – of the end manufacturer and/or – of a member of the retail chain	**product liability****	**environmental liability*****
faulty product	*damage or loss resulting from faulty goods*	*damage caused to the environment by a product*
(damage to the product)	(damages caused by a faulty product to other materials, goods, interests or persons; applies to – parties to a contract – their employees – users of the product and any persons not involved in the contractual arrangement)	(damages arising during manufacture, transport or use)
end user transportation trade etc.	end user	transportation trade etc also the end user under certain circumstances.

Tab.: The responsibilities of the producer with respect to liabilities.
**Adequate cover is posible through commercial liability insurance. **Adequate cover can be arranged through supplementation of commercial liability insurance. ***Adequate cover cannot, or can only in part, be arranged; legal protection for staff is also necessary.*
BGB = Bürgerliches Gesetzbuch (Civil Code); HBG = Handelsgesetzbuch (Commercial Code); Prod. Haft G = Produkthaftungsgesetz (product liability law); ff = and following §§.

the manufactured textiles according to DIN 4102, B1. For the user this means: he must bear in mind for each finish or dye that, ultimately, only the flammability of the entire system counts. The fibre manufacturer bears co-responsibility due to possible quality marks, which is why the fibre producer largely convinces the user about the responsible handling of his pre-product with the appropriate test certificate (according to Hemmpel, Zimmermann).

Product life span Product life spans in the textile sector are often short (see Fig.). Thus in many cases introduction, growth, maturity and death often overlap. Whereas, not so long ago there were two seasons in a cycle of six months, these phases have now been compressed into two to three months. To some degree, seasons no longer exist at all and have been replaced by a permanent pattern. The logical consequence of this is smaller, sometimes completely non-economic production batches, but of course, also greater stocks being held, if a company wants to work economically and, above all, deliver to the customer according to schedule. This also means that there will be some outdated products which are difficult to sell and can only be sold at a loss. It has been found that products and product groups develop differently. Individual products that immediately become winners have a high market growth and can be sold at a relatively low investment cost. Others are difficult to accommodate from the start and can sometimes only be placed on the market at high financial cost. Some products from the current range will remain on the market for a long time, produce profit, but do not have any particular growth rate. Only by a further expensive investment in marketing could a further increase in sales be brought about for such items. Finally, we should consider those products, which show a strong decrease in growth and returns. The latter are a burden to the company and sooner or later must be removed from the market, because they can only be sold at a loss.

Professional and technical organizations → Technical and professional organizations.

Professional organizations → Technical and professional organizations.

Profiled fibres This group, which includes hollow profiled fibres, consists of modified cross-section synthetic fibres, produced by spinning the melt from profiled jet orifices usually with a slit-shaped or pointed profile: Star-shaped, trilobal to multilobal, i.e. 3, 5, 6, 10 cornered/pointed, etc. (other cross-sectional variations, such as normal hollow fibre types, the straw type, flat shapes, large letter shapes, etc. are only associated in the broader sense). The development of “true” profile fibres opens up many possibilities due to the production of cross-section structures specifically designed for synthetic fibres (→ Polyester fibres, Fig. 5). Properties are for example: enlarged fibre surface, more subdued lustre, better thread endings, greater coverage and fullness (lower transparency), improved anti-slip properties, lower pilling tendency, greater stiffness; in hosiery lower thread pulling sensitivity, reduced tendency to run, increased serviceability and more comfortable wear, etc.

Profiled hollow fibres Hollow fibres based upon polyamide and polyester with additional cross-section profiling. Additional advantages compared to round cross-sections and also compact profile figures: further increased voluminosity (up to approx. 40%), greater stiffness, improved heat retention capacity (up to approx. 20%), reduced transparency of knitgoods (up to 50%), double the durability for hosiery. Recommend-

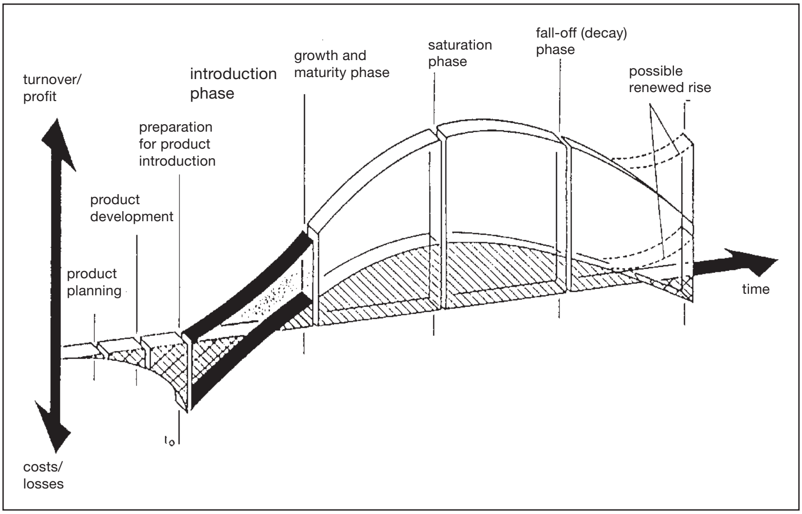


Fig.: Product life span (t_o = development costs).

ed: polyamide profile hollow fibres processed pure for the knitgoods sector, as mixed components for fashionable outer clothing, for hard wearing and work clothing. Polyester profile hollow fibres specifically for the carded yarn sector. Mixed yarns of other fibres with profiled hollow fibres possess a considerably greater cross-section, which makes it possible to save over 20% material for the same covering power and fullness.

Profiles The weighting of requirements as represented for profiles (→ Quality standards). This weighting is allocated as marks, for example, in concentric circles and the characteristics specified as requirements, in certain sectors (see Fig.).

Profitability level → Break even point.

Prograde mercerizing process Process patented by Coats under German Patent Number 1 136 417 for the mercerizing of sewing yarn on running threads (150–200 m/min). The yarn runs through liquid ammonia at –33°C for max. 10 s and the ammonia then removed by heat and steam, whilst the yarn is drawn. Ammonia consumption approx. 20–50% of material weight. The structural change of the cotton is similar to → Mercerizing with caustic soda liquor. A marked increase in breaking strength and dye take-up is achieved. The lustre, on the other hand, remains the same.

Program automation Equipment and mechanical procedure sequences are automatically controlled and

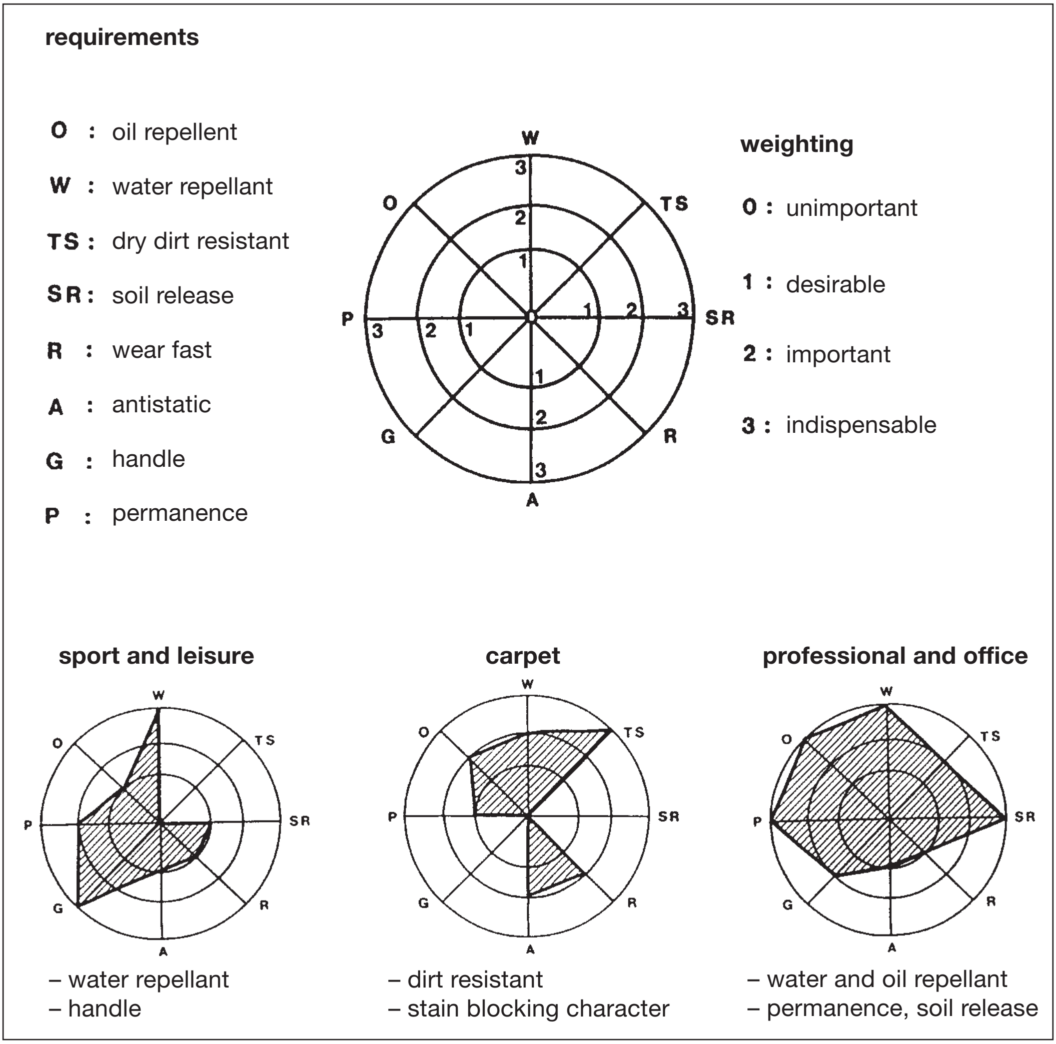


Fig.: Definitions and examples (below) of profiles.

regulated using program cards, rollers, etc. by means of → Control equipment. → Automatic control systems.

Program control → Control technology in dyeing.

Program matrix Matrix for the allocation of n input variables to m output variables. It is used in program control systems (→ Control technology in dyeing) and works according to the principle of crossbar distributor. There is usually a diode matrix, whereby the diodes are placed at the intersection points. The switching sequence can be altered by changing the diode layout.

Program regulator Precision regulators, which for example independently set desired temperature or humidity values in a certain sequence and at a desired level and maintain them for a certain time (→: Automatic control systems; Control equipment). For example, program regulators control the following sequence of processes: Filling a container, setting the steam, increasing the temperature curve according to specification, maintaining the dwelling time and turning off the steam after the completion of the program. In order that that no re-boiling occurs, the regulator also controls the emptying of the container, giving an optical or acoustic signal at the same time.

Progressive (Lat.: progressus = progress), increasing, continuing in stages; e.g. progressive feed of textiles, sequential wet/dry cycles, or progressing onwards from wash to wash, i.e. increasing shrinkage each time (in wool also as felting shrinkage).

Progressive jigger Machine designed according to the principle of the → Immersion jigger for the scouring of cotton and cotton/synthetic fibre mixed fabrics. Three batching rollers are arranged in line in an open tub. Material runs from roller 1 to roller 2 and from there to roller 3, while new material runs onto roller 1, etc.

Projectile weaving machines Weft insertion takes place from one side by means of so-called projectiles, i.e. non-positively moved bodies with a clamping device to accept the start of the weft thread (Fig. 1). The projectiles are accelerated by torsion bars, driven through the row and then driven back underneath the material (Fig. 2); generally several of these weft insertion bodies are in the row at the same time. Due to the high speeds, special oils are necessary, which guarantee fault free running of the projectiles, but any soiling of the material must be able to be washed out.

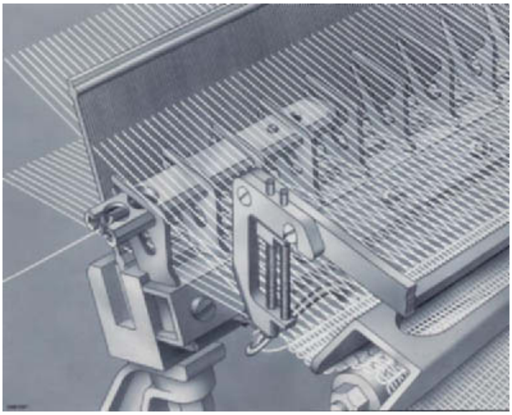


Fig. 1: Introducing the weft in a projectile weaving machine (Sulzer).

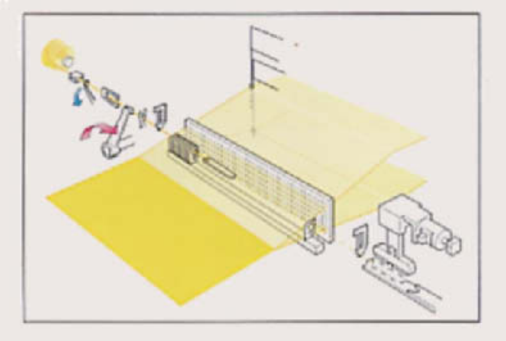
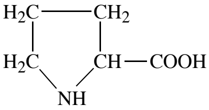


Fig. 2: The principle of the projectile weaving machine (Sulzer).

Proline An → Amino acids (monoimino-monocarboxylic acid), also pyrrolidine carboxylic acid,



contents in wool (6.75%) and silk (1.5%)

Proof sample Representative sample for the final quality of the goods.

Propane C_3H_8 → Saturated hydrocarbons.

Propane gas → Liquefied gas.

Propanetriol → Glycerol.

Propanol (propyl alcohol), C_3H_7OH; → Alcohols.

Propeller mixer Rapid mixer for mixing print pastes. The stirring body is shaped like a ship's propeller (this is why it is called a propeller mixer). During the stirring process the stirred material is drawn from above and propelled downwards.

Propene (propylene), C_3H_6; → Olefins.

Propenoic acid → Acrylic acid.

Propionic acid C_2H_5COOH. Present as organic fermentation product and in sweat.

Proportion (Lat: pro-portio = analogy), ratio; e.g. combining weights (→ Equivalent weight) of elements in relation to each other (law of so-called constant proportions).

Propoxy group $CH_3–CH_2–CH_2–O–$ (monovalent).

Propoxylation Addition of propylene oxide to compounds with active hydrogen for the production of surfactants.

Propyl C_3H_7 → Alkyls.

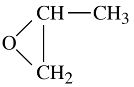
Propyl alcohol (propanol), C_3H_7OH or CH_3–CH_2–CH_2–OH; → Alcohols.

Propyl glycol Density 0.910–4; flash point 51 °C; relative evaporation rate 68. Miscible with water. Solvent for printing thickeners and lacquer.

Propylene → Propene.

Propylene glycol (1.2 dihydroxy propane), CH_3–CHOH–CH_2OH. Boiling point 102.5°C. Possesses similar properties to → Ethylene glycol. Good dye solubilizer and indicator, greater surface activity than in ethylene glycol, corrosion prevention capability, suitable as moisture holder and softener for foils. Also recommended for polyamide differentiation.

Propylene oxide



Condensation point 34.5°C, easily burnable liquid. Soluble in water, alcohol, ether. Application: as solvent for cellulose acetate, cellulose nitrate, vinyl resins, natural resins. Textile assistant primary product: oxyalkylising material (less important than ethylene oxide).

Propylene urea resins → Propylene ureas.

Propylene ureas Hexahydropyrimidone-2 and derivatives, in the form of dimethylol compounds an important reactive resin (propylene urea resins), e.g. DMPU; dimethylol-4-methoxy-5.5-dimethyl-propylene urea;-5-hydroxypropylene urea.

Prosthetic group → Co-enzymes.

PROT → Protein fibres, abbreviation according to → BISFA.

Protalbinic acid → Lysalbinic acid/protalbinic acid.

Protanopic So-called “red weakness”; → Anomalous colour vision.

Proteases → Enzymes from the main group of hydrolases, which hydrolytically split the peptide bond of protein bodies (→ Proteins and → Proteids) (so-called protein digestion) according to the diagram:

$$H_2N{-}R{-}CO{-}NH{-}R_1{-}COOH \xrightarrow{H_2O}$$
$$H_2N{-}R{-}COOH + H_2N{-}R_1{-}COOH$$

Proteases are also known as proteolytic or tryptic enzymes. We differentiate between the two subgroups depending upon whether only (poly) peptides are decomposed or higher proteins as well:

I. → Peptidases.

II. → Proteinases.

Proteases are contained in pancreas diastase, but are also generated by bacteria and mildew and play a significant part in the removal of protein, blood stains, etc. → Proteolysis.

Protease solubility of wool A certain proportion of keratin fibres can be dissolved by specifically acting proteases. The parts that are only weakly cross-linked by sulphur bridges are attacked by the protease, e.g. the endocuticula can be dissolved from the wool. The entire protease soluble proportion, 10–20% of the intact wool fibre, is made up, in addition to the proteins in the endocuticula, of proteins of the intramacrofibrillary complex, cell nucleus residue and cell membrane complex. The protease solubility has been proposed as a gravimetric determination method for the components in wool that are not resistant to enzymes, which are called non-keratins. Because protease only attacks areas which are only slightly cross-linked by cystine bridges, if the sulphur rich components are damaged we can expect to see an increase in the protease solubility compared to the undamaged fibre. So protease solubility lends itself to use as a method of quantitatively detecting the weathering depth for different fibre areas.

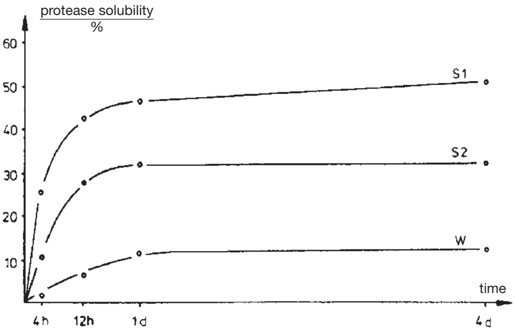


Fig.: The protease solubility with time of cut fibres of New Zealand wool (for explanation see text) (according to Höcker et al).

The Fig. shows the treatment of fibre sections from New Zealand wool with an enzyme/substrate ratio of 2 : 100 in relation to the incubation times of 4 h, 12 h, 1 day and 4 days. It is noteworthy that the high solubility of the 1st tip section (S1), which has been 25% dissolved after only 4 h and has achieved a maximum solubility of 51% after 4 days. The marked increase of the protease soluble proportion is not only promoted by the reduction in cystine content brought about by weathering, but the destruction of the outer cuticle layers allow the enzyme to diffuse in faster and dissolve out non-keratins and cystine damaged components. New Zealand wool shows more extensive damage along the fibre, because the path of the curve of the 2nd tip section (S2) shows a significantly faster reduction due to protease. At 16% after 4 days a protease solubility of the roots (W) was found, which corresponds with undamaged wool. As a result the protease solubility characterizes the different weathering along the fibre and is thus an indirect quantitative indicator for the skittery dyeing tendency (according to Klee).

Protective (Latin), preservative; for example in synthetic detergents relates to the electrical mechanism of the dispersing protective effect of the anti-redeposition agent components, usually carboxymethyl cellulose; the latter has an electrically negative reaction after adsorption by the cellulose fibres, like dissolved dirt surrounded by washactive molecules. The mutually repellent “protective” effect thus prevents the reattachment of dirt.

Protective clothing Clothing which provides protection against the effects of defined hazards, i.e. against harmful external effects. Its form and material are precisely specified to perform a particular protective function and it protects against specific effects. The type of protective clothing that meets the maximum possible number of protective requirements is the protective suit worn by an astronaut (see Fig.). The main protective functions of this type of protective clothing are as follows:

- protection against the vacuum of space, which without the suit would cause human blood to “boil”;
- protection against temperature differences, which range from –120°C to + 160°C on the moon;
- protection against micrometeorites and particles, which collide at high speeds;
- protection against the effects of fire due to accidental ignition of fuel;
- protection against ultraviolet radiation, which occurs to a degree that is unheard of on Earth.

Furthermore, the astronaut must be able to move, and heat and body moisture generated must be removed. He must also be able to breathe, i.e. in addition to a supply of oxygen being provided, the exhaled air must be removed. Initially, the oxygen supplied is passed from the helmet via the visor at a temperature of approx. 5°C and at a pressure of approx. 0.25 bar and then travels downwards along the body. At the same time, a liquid flowing through plastic pipes provides temperature balance. The suit incorporates two outlet valves, to the left and right of the body, to remove moisture and exhalation products. The oxygen supply and other technical devices that are part of the survival unit are located in a rucksack-like pack on the back.

Layers of material, like those used in the space suit for the “Apollo” project (from outer to inner):

- fabric made of polytetrafluoroethylene fibres: protection against impact and friction, as well as fire protection.
- fabric made of betaglass fibres, coated with polytetrafluoroethylene: fire protection; completely unburnable in an atmosphere containing oxygen.
- aluminized polyimide film, coated with a tulle made of betaglass fibres: reflective insulation, the glass tulle serves as a spacing and filling material.
- aluminized polyester film: reflective insulation.
- spunlaid fleece made of polyester fibres: filling material to provide a space between layers.
- polyamide fabric coated with chlorinated rubber: impermeable lining fabric.
- polyamide fabric: lining fabric/intermediate layer.
- polyamide fabric, coated with chlorinated rubber: sealing material, to retain the pressurized oxygen in the suit.
- light fabric made of temperature resistant aramide fibre: “comfort” lining.

Suit with additional cooling system:

- fabric made of elastane fibres: presses the pipe system onto the body.
- plastic pipes: flow of cooling liquid,
- light, porous polyamide fabric: creates space from the body.

Protective technology also uses textiles for other protective clothing. For example, fabrics to protect against heat and flames are covered with an aluminium film,

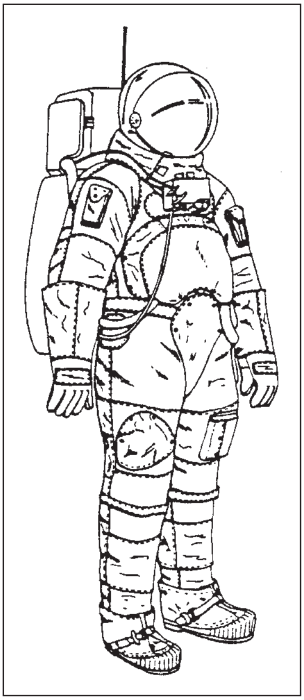


Fig.: Protective clothing of an astronaut.

this is achieved by laminating woollen or nonwoven fabric with a polyester foil containing aluminium particles. Other fibres such as glass filaments or aramide fibres can also be used as a carrier material if protection against metal spray is the primary requirement (blast furnace protection vests). DIN 66 083 applies. Fabrics can also be used to protect against cutting, for example to prevent saw injuries. Three dimensional textile construction incorporating air pockets is important to provide insulation against the cold in work clothing for polar regions. Chemical protection fabric (according to DIN 32 763) against toxic, corrosive or irritating substances must provide particular resistance against acids, lyes and solvents. Pure virgin wool is particularly suited for use in protective clothing due to the properties of the fibre (elastic, durable, water repellent, heat insulating) and can be optimized by flame retardant finishing. Such protective clothing made of virgin wool protects against a) heat stresses; b) hazards due to flames and flying sparks; c) hazards due to liquid metal spray; d) acids. There is functional protective clothing such as overalls, coats, protective gloves, but also knitted shirts, underwear, pullovers, hosiery, hats, which are made to meet the specific protective requirements of the different workplaces.

Protective colloids Lyophilic → Colloid, which delays the aggregation of the particles of a hydrophobic dispersion within certain concentration ranges. This tendency permits the protective colloid to attach itself to emulsified or suspended particles (precipitated lime soap, dirt, dye, delustring pigments, paraffin, etc.), envelop them and, because they have the same (negative) charge, to mobilize mutually repellent forces, which act against coagulation and keep them in a finely dispersed suspension. Natural colloids such as gelatine, glue, albumin, starch, etc. are very much classic protective colloids. Sulphite cellulose waste lye, oil sulphonate and fatty acid and protein condensation products and non-ionogenic polyether alcohols are synthetic protective colloids. Evaluation → Ruby number. Application as → Fibre protective agents.

Protective paint coatings Used in workshops, containers, machines, pipes, etc. to protect against corrosion or chemical decomposition (by water, acids, lyes, solvents, steam).

Protective paper is inserted in the transfer calender during transfer printing on the reverse of the textile material to be printed, in order to catch the dye that sublimates through the textile material.

Proteids So-called homogeneous → Proteins, which contain further components in addition to amino acids, e.g. paracasein also contains phosphoric acid (thus a so-called phospho-proteid).

Protein (conjugated proteins). Building blocks of all cells and organisms in animals and plants. Substances of high molecular composition (amphoteric) with characteristic nitrogen content in contrast to celluloses. Made up, on average, of 5% carbon, approx. 25% oxygen, approx. 16% nitrogen, approx. 7% hydrogen, 1–4% sulphur (not contained in silk). One differentiates between:

I. Simple proteins (→ Proteins) made of actual albumen (Protamines) or structural proteins (scleroproteins →: Fibroin; Keratin; Collagen).

II. Composite proteins (→ Proteids).

Proteins are typical colloids. They are relatively sensitive to physical and chemical influences (coagulation or congealing when heated, as a result of opposing electrical charge, due to alcohol, ammonium and metal salts, acids, tannin, etc.) The are "soluble" in alkalis (forming albuminate) and acetic acids or are decomposed with alkalis, acids, enzymes to form → Amino acids. Proteins, protein decomposition products, protein and fatty acid condensation products, etc. are very important in the entire field of textile finishing. Protein detection →: Adamkiewics reaction; Biuret reaction; Millon's reagent.

Proteinases Protein decomposing enzyme belonging to the group of → Proteases, which act specifically upon higher → Proteins, e.g. papain, pepsin, trypsin (tryptase).

Protein chemistry The fact that proteins are the basic substances of organic life is demonstrated for the textile finisher in the handling of animal hair wool. The wool finisher must get to grips with disulphide bridge chemistry, and dyeing wool is the fundamental application of protein chemical properties of wool. Protein chemistry also underlies the handling of other protein substances. So the food chemist uses thiol catalysed disulphide exchange as a differentiation criteria in the differentiation of casein and whey protein (there is a different EC subsidy arrangement for the latter than for casein).

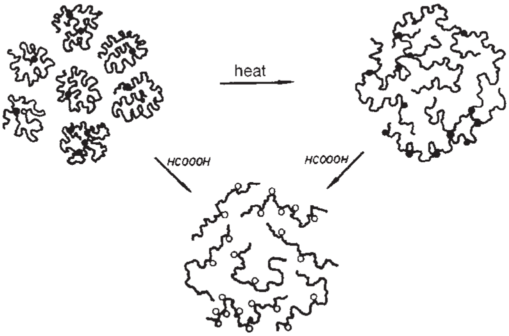


Fig. 1: The covalent cross-linking of proteins due to thiol-catalysed disulphide exchange and thiol oxidation during heating; oxidation with performic acid leads to the production of soluble monomers (according to Klostermeyer).

If such proteins are denatured during heating, e.g. milk protein bodies cross-link due to thiol disulphide exchange, they are then no longer soluble, which means that the solubility criteria for the differentiation of casein and whey protein no longer apply for heated milk (Fig. 1). However, if the heated mixture is subjected to a protective performic acid oxidation (cystine yields cysteic acid), the immunologic specificity can also be detected in oxidized casein, making a differentiation possible.

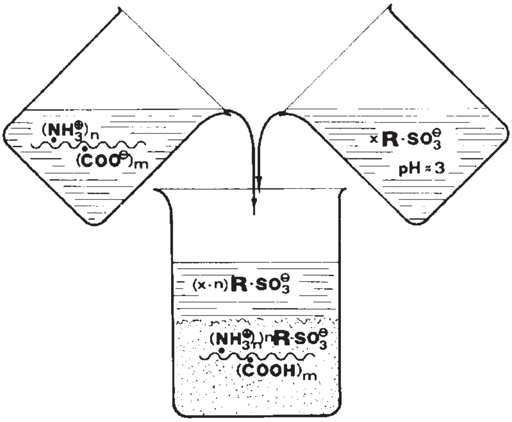


Fig. 2: The principle of rapidly determining the presence of dissolved proteins using acidic wool dye (according to Klostermeyer).

When dyeing dissolved milk proteins with amido black, an acid wool dye, the protein dye complex is precipitated, and the excess amount of dye in the filtrate that has not been used is measured (the quantity used is known in advance) (Fig. 2).

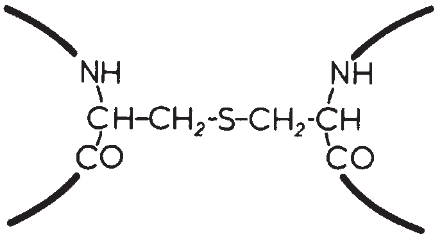


Fig. 3: The cross-linking of protein chains by lanthionine.

The occurrence of lanthionine in stored eggs (even in heated eggs) can be used analytically for quality testing (Fig. 3).

The examples document the close relationship between wool finishing and food chemistry; but studies on insulin also indicate many parallels between wool chemistry and the protein chemistry of insulin (according to Klostermeyer, and Brandenburg) (Fig. 4).

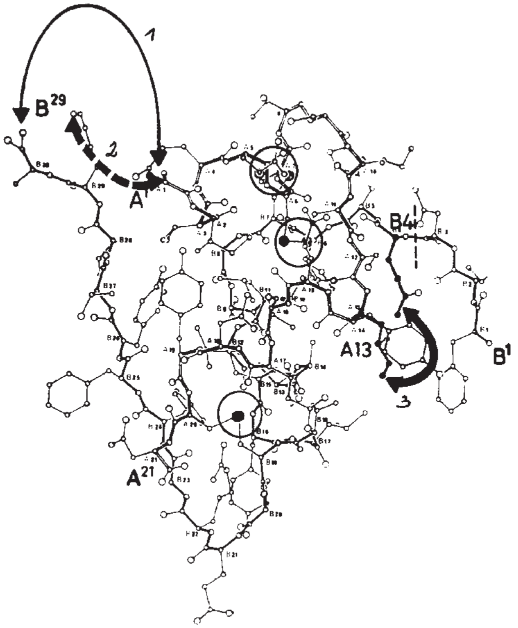


Fig. 4: The projection formula of insulin perpendicular to the three-number axis (according to T. Blundell, G. Dodson, D. Hodgkin and D. Mercola).
The disulphide bridges are marked with circles; 1 indicates the connecting peptide between the N terminus of the A chain and the C terminus of the B chain of proinsulin;
2 = dicarboxilic acid bridges in the insulins bridged between A1 glycine and B29 lysine; 3 = the location of bridges between the e-amino groups of the lysine residues included in the insulin derivative at positions A13 and B4.

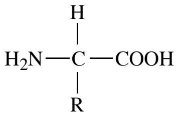
Protein cleavage products (protein degradation products) → Protein-fatty-acid condensation products.

Protein degradation or cleavage products → Protein-fatty-acid condensation products.

Protein-fatty-acid condensation products,

I. Protein decomposition products: When casein, albumin and glue, for example, are acid or alkali boiled, the protein molecule decomposes (in a similar manner to wool under alkaline conditions). Higher molecular amino acids extracted in this manner are converted and are used as so-called protein decomposition or protein cleavage products in the manufacture of high-value assistants.

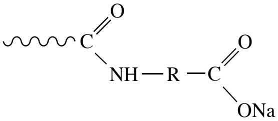
Amino acid type as the end product of the decomposition:



$$H_2N-\overset{\displaystyle H}{\underset{\displaystyle R}{C}}-COOH$$

Application: Excellent wool protection and levelling agent with high emulsifying and detergent power, specifically for wool dyeing, in stripping, etc.

II. Protein-fatty-acid condensate:



After the development of the first → Fatty acid condensation products the obvious next step was to condense high molecular amino acids with, for example, oleic acid. This created a new, larger molecule from the protein residue and fatty acid, which has excellent wetting, levelling and fibre protecting properties. Foaming and stable in hard water. Application: Typical fibre protective agent for wool used for washing (dirt emulsifier), milling, scouring, kier boiling, desizing, stabilizing of peroxide bleaches, as a fibre protective wetting agent in chlorine bleaching (in particular for delustring), handle improving substantive leveller, vat (also wool) and single bath mixed fibre dyeing, as a soaping after-treatment, etc.

Protein fibres →: Man-made protein fibres; Natural protein fibres.

Protein hydrolysates → Lysalbinic acid/protalbinic acids.

Proteins (Gk: protos = the first, original), general so-called single → Proteins, built only of amino acids. Molecular weights between 12 000 and 6 million. Although belonging to the “single” proteins, wool keratin and silk fibroin also belong to the group of proteins.

Protein sizes Usually based upon the decomposed protein substances; are often superior to starch sizes, but are losing ground to synthetic sizes.

Protein solvents → Proteases.

Protein substances → Protein.

Proteolysis Hydrolytic splitting of → Proteins by proteases. Enzymes capable of refining the physiochemical properties of the wool belong to the class of proteases. The reaction can be represented in simplified form as follows:

$$R_1-CONH-R_2 \xrightarrow[\text{proteases}]{H_2O} R_1-COOH + R_2-NH_2$$

There are two main groups of proteases (see Tab.):

- peptidases, which act specifically upon peptides and their derivatives, but leave proteins untouched. One differentiates between amino peptidases, dipeptidases, carboxy peptidases and prolinases, depending upon the substrate upon which they tend to act.
- proteinases, which split large molecular proteins into polypeptic chains or individual polypeptides. They act like endopeptidases, i.e. they split the –CONH groups not only at the chain ends, but also within the molecules. (Exopeptidases only attack the chain ends.)

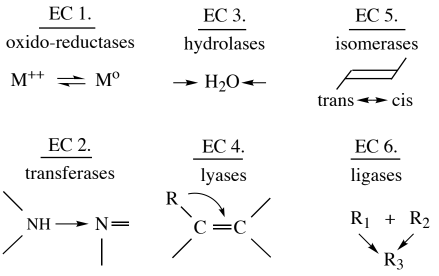
type	protease
pancreatic	trypsin, chymotripsin
vegetable	papaïn, ficin, bromelaïn
Bacillus type	subtilis, lichenformis, alcalophilus, cereus, natto, vulgatus, mycoïde
Aspergillus type	flavus oryzae, niger, saitoï usamii
Mucor and Rhizopus type	M. pusillus, M. mietrei

Tab.: The various proteases.

In order to name the large number of known enzymes (over 2000) and in view of the almost unlimited number of enzyme/substrate reaction pairs, the International Union for Biochemistry established in 1955 (or more precisely its Enzyme Commission) has developed a standardized nomenclature and classification system. This systems specifies the following for each enzyme:

- the reaction that can be catalyzed with it,
- a system name in accordance with official nomenclature,
- a register number (EC …), a four digit number, which provides information about the class (which in total covers 6 positions), the sub and sub-sub class and an ordinal number.

According to this system, proteases capable of proteolysis are allocated to the sub group EC.3, because they have a hydrolysing effect:



As is the case for all acid/base catalysts, the pH is of decisive importance here. The optimal pH range varies depending upon the enzyme type. There are different types:

- The enzyme EC.3.4.21.1, a serin proteinase, hydrolyzes amidic or ester compounds in the vicinity of aromatic amino acids. The optimal pH is 8.4.

- The enzyme EC.3.4.21.4, also a serin proteinase, acts upon amino and carboxyl groups of polypeptides in an alkaline environment, namely in the broad pH range between pH 8 and 11.
- The proteinase EC.3.4.4.10 has as its active centre the thiol group (–SH) of cysteins; it acts, at an optimum pH of 5–7, as esterase and amidase.

In the case of the proteases that act upon wool we can speak of a heterogeneous catalysis, because the (liquid) catalyst and the substrate (wool, solid) do not represent the same phase. At the beginning of the reaction the enzyme is adsorbed at the surface of the wool and migrates through the inside of the fibre. The reaction medium also plays an important role. The presence of unsuitable surfactants can interfere with the proteolysis, because the enzyme remains blocked in the surfactant micelles.

The natural colour of the wool ranges from white via cream, yellowy, brown to brownish-black. The function of the bleach (oxidative, reductive or combined) is to remove the natural colour pigments in order to achieve the correct shade. We can assume that the natural pigments of the fibre are stored at the fibre surface in the cuticle. During reductive bleaching the effect of the proteases on wool, or on its lightness and hydrophilicity, is tracked. A synergy effect occurs regarding the degree of whiteness, if hydrogen peroxide and protease are combined in a single bath. The selectively active enzyme hydrolyzes the lipo-protein fibre surface layer that contains the colour pigments. By dissolving away the hydrophobic substances in the lipoprotein surface, the peroxide is better able to bleach the lower part of the fibre (according to Fornelli).

Protolytic According to Brønsted → Acids and → Bases are grouped together as protolytes (from proton and electrolyte) and their acid/base function described as protolytic, in order to explain the acid and base character even of non-aqueous solutions. According to this, acids are substances which emit → Protons; bases are substances that accept a proton.

Reaction equation:

$$\text{acid} \rightleftharpoons \text{base + proton}$$

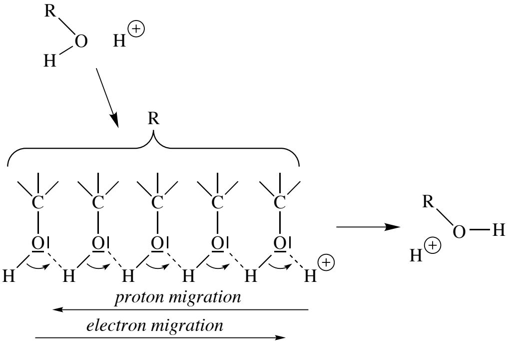
Proteolytic enzymes → Proteases, suitable → Desizing agent.

Protonation Due to their small ionic radius and their charge, hydrogen ions are mobile if they are attracted to an opposing charge or by free electron pairs. This property of acids is due to the electrolytic dissociation of substances, and thus to the fact that substances in aqueous solution decompose into electrically charged ions. Ions migrate in the electric field and always transport the same gram-equivalent quantity of electricity, namely 96 494 Coulombs. The conductivity of electrolytes is characterized by their strong temperature dependence, the ion charge number and the migration speed or mobility of the ions.

Ion	Λ^{o}_{+} $\Omega^{-1}m^{2}val^{-1}$	B^{o}_{+} $m^{2}s^{-1}V^{-1}$	Ion	Λ^{o}_{+} $\Omega^{-1}m^{2}val^{-1}$	B^{o}_{+} $m^{2}s^{-1}V^{-1}$
H^{+}	$34.982 \cdot 10^{-3}$	$36.3 \cdot 10^{-8}$	OH^{-}	$19.80 \cdot 10^{-3}$	$20.5 \cdot 10^{-8}$
Li^{+}	3.869	4.01	Cl^{-}	7.623	7.91
Na^{+}	5.011	5.19	I^{-}	7.68	7.95
K^{+}	7.352	7.61	CH_3COO^{-}	4.09	4.23
Ag^{+}	6.192	6.41	SO_4^{2+}	7.98	8.27
NH_4^{+}	7.34	7.60			
Ca^{2+}	5.950	6.16			
La^{3+}	6.96	7.21			

Tab.: The ion conductivity and ion mobility of some cations and anions at 25 °C.

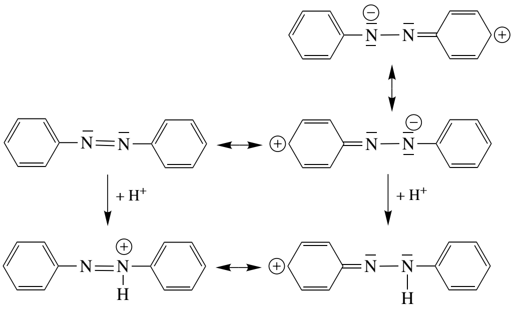
The Tab. illustrates ion mobilities of cations and anions. The most striking thing is the extremely high values for hydrogen protons and hydroxyl ions. Because both ion types are hydratized in the same way as all others, one needs to look for a reason for the high values. This reason lies in the particular movement mechanism. It can be traced back to Grotthus (1805) and is only possible for the medium of water; it is based upon a rapid proton migration, which is, however, effectively an electron migration.



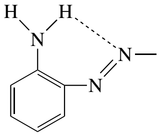
This movement cannot take place in other solvents, because ion mobilities of H^{+}- and OH^{-} ions do not differ significantly from those of the other ions.

Acids are characterized by the fact that they act as proton donors. If they are concentrated and strong enough they can attach to the nucleophilic points. These points are primarily characterized by free electron pairs and polar covalent bonds. A coordinative bonding of the hydrogen cation takes place. Azo groups, carbonyl groups, hydroxyl groups and amino groups plus the substituted hydroxyl and amino groups are carriers of free electron pairs in the dye molecule. A further characteristic of the points capable of protonation is the occurrence of mesomeric boundary states, which include an alternating polarization of the molecule. Protonation changes the resonance, and a charge transfer takes place. This is associated with a colour transition.

Due to the mesomeric boundary states of the azo group and of the free electron pairs on azo nitrogen in mineral acid, a proton attaches itself to the azo nitrogen atom. The dye molecule is thus given a positive polarity. The reaction is illustrated by looking at the example of azo benzene:

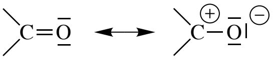


Just as a proton can be attached to a nitrogen atom of the azo group, it can also be attached to the amino group or to the substituted amino group by acid. The ammonium group $–NH_3^+$ is formed from the amino group $–NH_2$, which also generates a positive polarity in the dye molecule. When small quantities of acid are added in the presence of azo and amino groups, proton attachment occurs in relation to the basicity of the groups and the position of the amino group. In ortho amino groups a ring closure takes place via a hydrogen bridge bond to an azo nitrogen atom. This prevents the possibility of an ionic form being created.



In contrast, non-ortho amino groups are easily protonated. The addition of hydrogen ions is made more difficult by acetylization or alkylization, which reduce the basicity. Because protonation also takes place at the point of greatest basicity, the hydrogen proton in this case is added to the azo nitrogen. In a strongly acidic medium, one proton attaches itself to the azo nitrogen and one to the amino group.

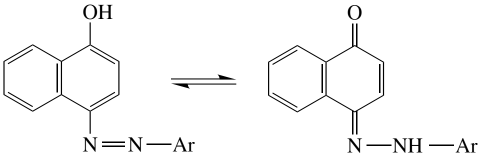
Carbonyl groups occur in polar limiting structures.



I *II*

In the bonding to an aryl group, electrons are also attached to the aromatic system (I) and, due to the strong electron negativity of the oxygen, electrons are attracted and the bond polarized (II). In the acidic medium an addition takes place to the oxygen atoms with greater electron density, as represented by limiting structure II.

The protonation of the hydroxyl group always takes place in connection with a hydrogen ion addition to an azo nitrogen atom. This can be illustrated using the example of a hydroxyazo compound. It is present in two tautomeric forms, the azo form and the hydrazone form.



azo form *hydrazone form*

In an acid medium a hydrogen proton is added to the carbonyl group of the hydrazone form. The change of the hydroxyazo compound however actually consists of the protonation of an azo nitrogen atom. Tautomerism also exists in the hydroxyazo bodies. It is not offset by the hydrogen bridges.

Proton bridges A typical example is → Hydrogen bonds.

Proton donor →: Donor; Protonation.

Proton number → Atomic number.

Protons → Atomic theory.

Protoplasm Primordial cell, the primary building block of physiological cells in the animal and plant kingdom. The latter consists of a cell nucleus (fine threaded lignin structure, chromatin as colour substance and nuclear sap), nuclear sap, cell walls (cytoplasms) and vacuoles (Fig. 1). In the primary wall of cotton this cell structure is the basis for a structure made up by the interweaving of glycoproteins, pectines, hemicellulose and cellulose (Fig. 2). Protoplast formation by enzyme mixture is the precondition for the enzymatic breakdown of the cell wall (Fig. 1).

Protoplasts are thus cell wall free cell residues, which loosen easily, i.e. can be dissolved out of the cotton fibre by water. Protoplast formation, i.e. the removal of the cell wall, takes place in two stages. First, the cells are dissolved out of the cell union. This is

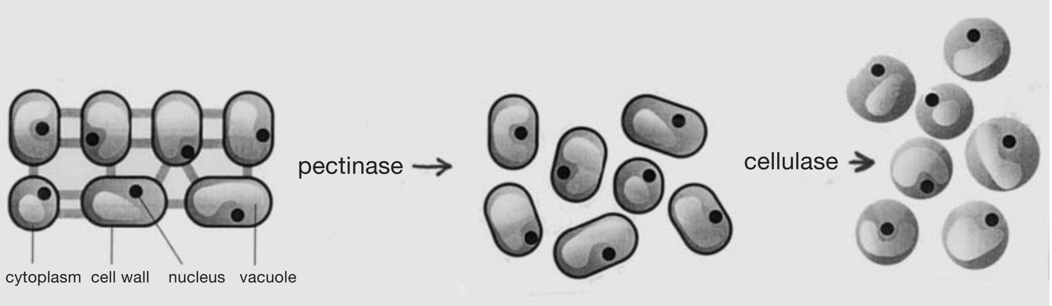


Fig. 1: Diagram showing the formation of protoplasts.

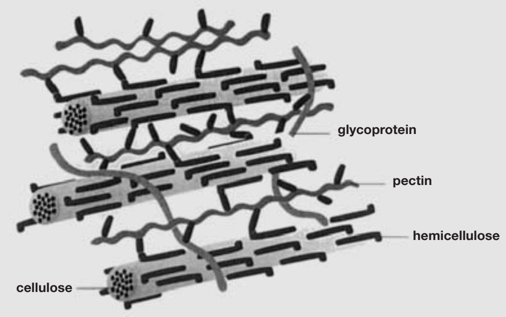


Fig. 2: Diagram showing the main constituents of the primary cell wall.

achieved using pectinase. This decomposes the polysaccharide chains of the middle lamella, which consists of pectines. Then the actual cell wall is digested by cellulose. The main components of the enzyme mixture made up of basidiomycetes are pectinase and cellulase. Xylanase, amylase, laminarinase and protease are also present as secondary activities.

Protoplasts can be generated and cultivated in this manner in isotonic solutions. Due to the composition of the enzyme mixture, protoplast formation can be performed in a single step. The conditions for protoplast formation vary significantly depending upon the origin and age of the vegetable cell material and must therefore be optimized from case to case (according to Merck).

Provenance (Lat.), origin, for example geographic origin as classification criterion for fibres of natural origin.

In cotton in particular there is a relationship between properties and provenance. As a relatively complex natural product made up of five different layers, cotton is subject to very different climatic and ecologically determined influences, so that quality differences based upon the area of cultivation are noticeable in the chemical and mechanical properties prior to resin finishing.

Prud'homme black → Aniline black.

Prussian blue → Berlin blue.

Prussian blue reaction, Turnbull's blue reaction Coloristic detection of hydrocellulose and oxycellulose. Two solutions are used, which should be manufactured cold and then stored in the dark.

Prussiate black → Aniline black.

Prussiate discharges → Oxidation discharges, e.g. for para red on indigo background. However, it only has an historical importance.

PS,

I. Pakistan standard.

II. Horse power. → Watt.

III. → Polystyrene.

PSA Philippine Standards Association, Manila; standards association for the Philippines; → Technical and professional organizations.

Pseudo- (Gk.), not genuine, imitation, apparent. Pseudo-hair: A "fake hair", for example the beard of a whale with its elastic-fixed intermeshed, scaly radial structure, which is similar to hair, but differs in its structure and purpose (filtering out plankton as food).

Pseudoplastic flow properties → Rheology.

PSI Pakistani standards association; → Technical and professional organizations.

PST → Polystyrene fibres, → Textile fibre symbols, according to DIN 60 001 until 1988.

Psychophysics links the two disciplines of psychology and sciences. The term psychophysics has been in scientific use since around the middle of the 19th century. Since then, leading scientists from different fields have contributed to the development of psychophysics, above all physicists, members of the medical profession and psychologists. Because the impetus for development came from different disciplines, the activities and findings of psychophysical research have been interpreted in different ways. Psychophysics has in the past been classed either as physics, medicine or psychology. However, psychophysics should no longer be viewed as part of one of the above-mentioned established disciplines, but as an independent science in its own right, which has a central, multidisciplinary, interdisciplinary role in relation to the sciences.

Psychophysical research concerns itself with the psychophysical relationship, i.e. the relationship between the spiritual and the material world. Accordingly, the term psychophysics can be understood as an amalgamation of the two Greek words “psyche” and “physis”. Today, the importance of psychophysics lies in its interdisciplinary, multidisciplinary approach to thinking, working and problem solving, which provides a basis for taking apart and solving even fundamental and multi-faceted problems. A typical example of creating relationships between subjective sensations and objective evaluations of a phenomenon in the human environment is the treatment of hair by the hairdresser to achieve a hairstyle with “body”.

The psychophysical property of hair normally described as “body”, is usually evaluated using subjective methods, which are themselves based upon visual or tactile sensations on the part of the hairdresser. A quantitative laboratory method is required if we are to make an objective evaluation that can validate and substantiate statements regarding treatments and products which claim to increase the body in hair. Numerous attempts have been made, taking into account both the visual and tactile aspects of “body”.

“Body” is a reflection of the resistance of a hair mass to external deformation and the ease with which it recovers from this deformation. We can measure the compression energy between two defined packing densities from a vertically hanging hair in a plane perpendicular to the axis of the hair. The capacity of the hair to recover from the compression is determined in a second compression cycle. The loss of compression energy in the first cycle depends upon the processes that occur during compression. In this manner the compression resistance and the degree to which the strand can recover from this deformation is determined.

In a hair mass, the fibre stiffness (modulus of bending) and the fibre/fibre adhesion or friction in relation to the resistance against external deformation due to lateral compression act in the same direction. However they oppose each other during the recovery phase, i.e. the fibre stiffness aids the recovery process, acting against fibre/fibre frictional resistance. Changes in the compression behaviour of a hair mass following different treatments can be characterized by the combination of changes in the compression energy in the 1st and 2nd cycle with a relative energy loss factor.

A method has been developed for determining the fibre/fibre adhesion, in which the force necessary to withdraw a single hair from a hair mass of defined packing density is measured. These measurements, in combination with compression parameters, are then used to quantify hair body. Furthermore, attempts have been made to correlate these measurements with subjective evaluations of hair body. The Kawabatas method of multiple regression was used, in a similar manner to its use for the interpretation of handle values for textile fabrics. With the aid of this method a significant model was developed, and the coefficient of the multiple determination was confirmed, which accounts for over 60% of the variation in body in the model (according to Röder, and Weigmann).

Psychrometer, wet and dry bulb thermometer Instrument for → Moisture content measurement made up of two thermometers (mercury or electrical resistance), of which one is kept continuously moist, the other continuously dry. The dryer the air passing the two thermometers (minimum speed 1.5 m/s), the greater the “psychometric difference” between the two thermometers. The values for absolute and relative air humidity can be read off from a table. The “aspiration psychrometer” is an internationally recognized standard instrument. The Siemens moisture measurement instrument, with direct display or remote transmission, is based upon the same measuring principle and is used for the measurement and control of absolute or relative moisture. Psychrometers based upon the principle of electrical resistance can be connected to control units (for air conditioning systems, etc.). Indicating psychrometers based upon mercury or bimetal designs are suitable for determining the relative air humidity, particularly in industrial companies, even for higher temperatures up to 200°C, and when fitted with an electrical contact device they can be used for moisture and temperature control.

Pt Element symbol for Platinum (78).

p/tex Pond pro tex, obsolete unit of force in relation to fineness. SI unit is cN/tex, (centinewton).

PTFE → Polytetrafluoroethylene fibres, → Textile fibre symbols, according to DIN 60 001 T4/08.91.

P-type conductor causes current flow in a → Photoelement made of selenium due to positive (= p) charge carriers.

PU,

I. → Polyurethane, → Textile fibre symbols, according to the → EDP key system; → PUR.

II. Abbreviation for → Liquor pick-up, quoted in %, related to the weight of the dry or wet textile entering the machine.

Pu Element symbol for plutonium (94).

PUA → Polyurea fibres, → Textile fibre symbols, according to DIN 60 001 until 1988.

Public relations (PR). In the broader sense this concerns efforts to win public trust on the part of a company, a branch of industry, etc. In the narrower sense it relates to all measures to achieve and maintain this trust.

Puckering In the sense of shrivelled, curled, folded, crumpled, in hems, seams, edges, etc., for example due to poor ironing.

PUE → Polyurethane elastomer fibres (elastane), → Textile fibre symbols, according to DIN 60 001 until 1988; from 1991 → EL.

Pulled wool → Skin wool.

Pullman mode → Drum washing machine with D-type drum division = Pullman washing machine. Removal of the washing is made easier by the surface which is inclined forwards slightly (sliding emptying).

Pulp bleaching Usually occurs in the form of combination bleaching: Hypochlorite – H_2O_2 – reduction – sodium chlorite (preferably chlorine free for environmental reasons).

Pump characteristics Pumps are used to overcome head differences, distances and also system pressures when moving liquids. A pump is always set up so that the main movement is on the pressure side of the pump. The head difference is the difference between the liquid level on the suction side and the liquid level on the pressure side of the pump (suction head + pressure head = geodetic total lift).

The liquids either flow to the pump from a higher vessel (Fig. 2) or the pump sucks them from a certain depth (Fig. 1), e.g. from a well. In the latter case, however, the liquid is not actually sucked up at all, but rather the self priming pump merely evacuates the air from the suction pipe, or the normal suction pump brings a flow into motion, and the atmospheric pressure, which acts upon the surface of the liquid, presses the liquid in the pipe up to the level of the pump. Then the pump pushes the liquid further into the pressure pipe. Because the air pressure is greater in the valley than on a mountain, a pump in the valley can “suck” from a greater depth than a pump on a mountain.

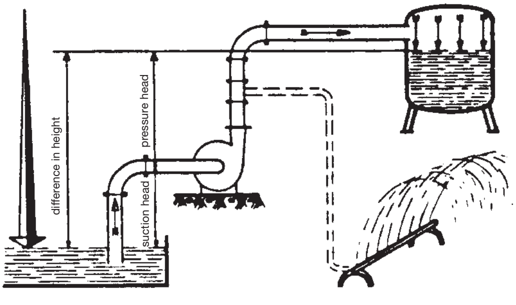


Fig. 1: Pressure pumping.

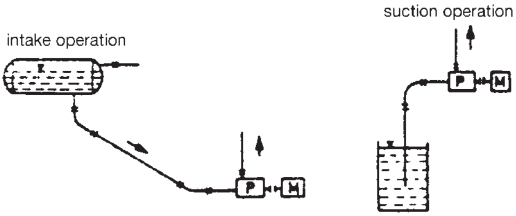


Fig. 2: The intake operation and the suction operation of pumps.

The flow rate Q is the useful liquid volume per unit time conveyed by the pump through its pressure connections:

$$Q = \frac{V}{t} \ [m^3/s]$$

The lift H of the pump is the increase of energy content in 1 kp (= 9.81 N) of conveyed liquid between inlet and outlet in mkp/kp, which corresponds to a head in m of the liquid head of conveyed liquid. A centrifugal pump thus conveys (at the same rotation speed) any liquid to the same lift, measured in m of the liquid head. The manometric pressure head H_{man} measured by a manometer is however dependent upon the volumetric weight of the liquid in question ($H_{man} = H \cdot \gamma$) .

In the most usual centrifugal pumps in textile finishing the lift is defined as follows:

$$H \equiv \frac{\xi}{g} \ (u_a w_a' - u_i w_i')$$

$$w_a' = u_a - v_a' = u_a - c_a \operatorname{tg} \alpha_v$$

$$w_i' = u_i - v_i' = u_i - c_i \operatorname{tg} \beta_w$$

$$H = \frac{\xi}{g} \ [u_a (u_a - c_a \operatorname{tg} \alpha_v) - u_i (u_i c_i \operatorname{tg} \beta_w)]$$

c_a and c_i are the radial components of the absolute liquid velocities w_a and w_i at the outer (a) or inner edge (i). The particle velocity w at the blade of the impeller results from the sliding velocity v caused by the centrifugal force and the tangential velocity u. g is gravity (9.81 m/s^2).

The lift H of the pump is made up of the difference between the heights of the outlet and inlet cross-sections of the pump

$$\frac{P_d - P_s}{\gamma}$$

P_d = pressure in the outlet cross-section of the pump in bar,
P_s = pressure in the entry cross-section of the pump in bar,
γ = volumetric weight of the liquor,

and the difference between the manometric lifts of the liquid between the outlet and inlet cross-sections of the pump

$$Z_d - Z_s$$

Z_d = loss of manometric lift at the pressure pipe in m,
Z_s = loss of manometric lift at the suction pipe in m,

and the difference in dynamic pressure of the liquid between outlet and inlet cross-section of the pump

$$\frac{C_d^2 - C_s^2}{2\,g}$$

C_d = flow rate in outlet cross section in m/s,
C_s = flow rate in the inlet cross-section in m/s.

Therefore:

$$H = (Z_d - Z_s) + \frac{P_d - P_s}{\gamma} + \frac{C_d^2 - C_s^2}{2\,g} \quad \{\text{m of liquid head}\}.$$

The head H of the system is the head to be achieved by the pump, in order to maintain the flow rate Q in the system. The positive pressure head tells us the minimum amount by which the total pressure head in the centre of the inlet cross-section of the pump must lie above the vapour pressure level of the conveyed liquid in order to guarantee a faultless functioning of the pump. If the positive pressure head of the system is less than that of the pump then the pressure will fall below the vapour pressure locally within the pump and part of the conveyed liquid will vaporise. The bubbles of vapour thus created reduce the performance of the pump, and furthermore the condensation of the vapour bubbles in areas of high pressure can also lead to the mechanical destruction of the internal components of the pump due to the sudden collapse of the vapour bubbles. This phenomenon is called cavitation. In order to prevent cavitation it is therefore particularly important to determine the maximum possible geodetic suction head or the minimum necessary feed height for the pump. As the temperature of the liquid increases (with increasing vapour pressure) the possible geodetic suction head falls and finally a geodetic feed head becomes necessary.

If a pump is used to move liquor at a given rotational speed, a defined quantity of liquor is conveyed per unit time; thus there is a typical relationship between flow rate Q (l/min) and manometric pressure H (m water head) for the pump, which is termed the pump characteristic. The flow rate is obtained at the cost of a certain power consumption (kW). The flow rate is reduced by resistance in the system. Resistance can be caused by: small pipe cross section, high viscosity of the liquor at low liquor temperature, or difficulties in flowing through dense material.

Due to the requirement that the same amount of liquor must flow through the wound package regardless of the size of equipment in the wound package dyehouse, different requirements are made regarding the shape of the characteristic curve for the liquor pump. Therefore, it is not possible to use the same type of pump for a whole range of equipment by merely increasing the impeller size. Fig. 3 shows a set of characteristic curves for the different centrifugal pumps used with increasing

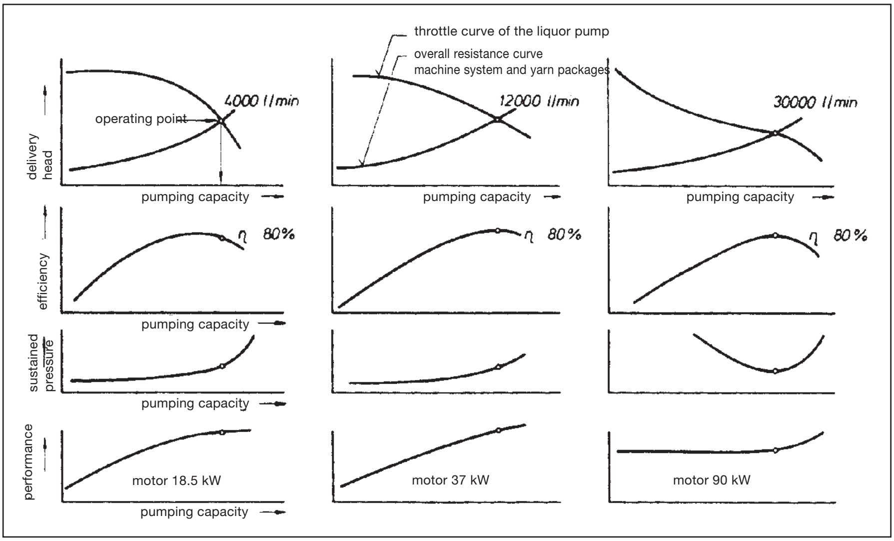


Fig. 3: The characteristic curves against batch weight of liquor pumps.

equipment size. The operating point, which is the intersection of the throttle curve with the total resistance line, lies within the optimum efficiency range of the pump. The total resistance line is found by adding all individual resistances in relation to the flow rate of the pump. The throttle curve of the pump shows the relationship between the flow rate and the lift of the pump and is termed the QH curve. If the flow rate at the operating point is higher than the desired flow rate through the textile, for example because of sensitive yarns, reduced dosage, or due to a treatment stage requiring a reduced flow, the flow rate must be adjusted. Depending upon the shape of the characteristic curve for the pump in question, this adjustment can take place by means of direct reduction of the flow rate, via a bypass, i.e. a return flow from the pressure side to the suction side of the pump, or by changing the throttle curve. Whereas the first two types of regulation are generally applicable depending upon the pump size, changing the throttle curve by means of a reduction in rotational speed is the optimal solution from the point of view of power consumption, because no throttle device or bypass is present. The desired flow rate through the textile thus still lies at the intersection between the total resistance line and the throttle curve for the adjusted speed. The extent to which the cost of a speed regulated motor drive for the centrifugal pump is justified depends on the field of application of the equipment.

The manometric differential pressure display can be read throughout the beam dyeing process and is a characteristic criterion for dye specific substance exchange processes. It is therefore recommended that the differential pressure display is used for checking and controlling or regulating the beam dyeing process. Fig. 4 shows the pump characteristic curve and the textile/batch characteristic curve, plotted on axes of the differential pressure Δp_L [bar] against the volumetric flow rate of the liquor Q_M [m^3/s]. It is clear that at a manometrically displayed differential pressure of $\Delta p_L = 2.0$ bar, 87% of the liquor flows through the package radially, i.e. producing a dyeing effect, whereas 13% flows away axially, i.e. from the front of the beam dyeing package.

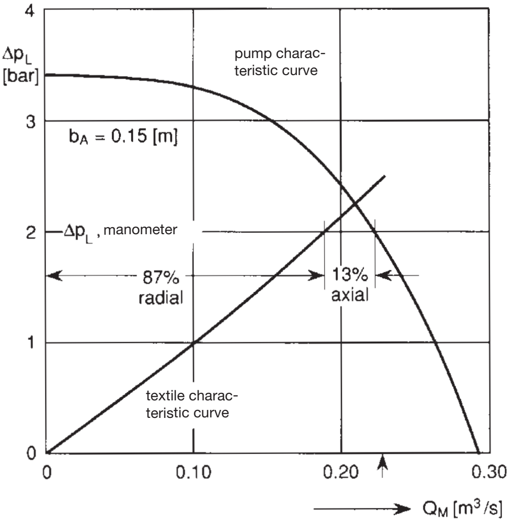


Fig. 4: Family of characteristics for the through-flow of a beam dyeing batch.
b_A = covering width of the cuffs.

Pump curve (equipment diagram, pump characteristic, QH curve), usually supplied by the equipment manufacturer in the form of a diagram. The liquor flow rate (for example) in l/min and/or kg/min or the liquor speed in m/s in relation to beam or dyeing tube diameter is plotted on the x-axis, whilst the feed pressure or differential pressure in mm WG or kg/cm^2 or bar is plotted on the y-axis (see Fig.). Using the pump curve it

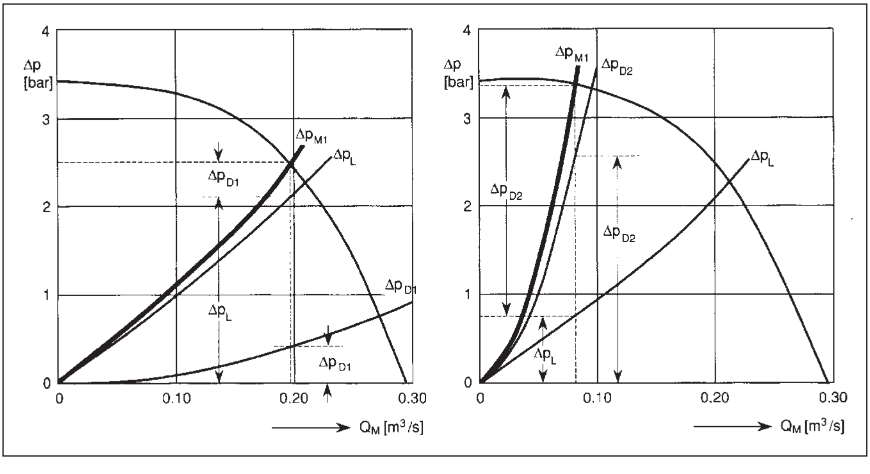


Fig.: Displacement of the operating point on a pump curve due to throttle valve control which produces too low a liquor throughput, whereby $\Delta p_M = \Delta p_L + \Delta p_D$. The picture at left shows a slight throttle valve effect, that at right shows a large throttle valve effect, both for the same differential pressure Δp_L across the beam dyeing fabric batch.

is possible to obtain a satisfactory approximation of the liquor speed in relation to differential pressure. → Pump resistance in dyeing machines.

Pump pressure process Japanese process, which is used particularly for Summer goods and requires a precise knowledge of the effects that can be achieved using individual dye groups (usually naphthol, sulphur, vat dye) and great artistic skill. A resist made of tough rice clay thickener is applied to 1 yard of material on a printing table with the aid of a screen (always 1 yard in length, clamped tightly in a frame fastened by means of folding hinges). Then (in accordance with the method of to and fro plaiting) the length of material is placed on the layer that has already been printed with the resist, the screen is folded back down, more thickener applied, etc., whereby the piece is resist-dyed by the thickener on both sides. So, in the end a pack of up to 48 stacked layers of material with the same number of thickener layers is created. This pack is now placed upon an iron grid (30 × 90 cm), which is above a basin, and the prepared dye liquor is poured over the pack. The dye naturally only penetrates areas of the material that have not been coated with the resist, and therefore these are the only areas that are dyed. Then the excess liquor is squeezed off, or the sides of the pack are covered with rubber strips and the liquor is pumped downwards by a suction device. The piece is again plaited and rinsed to remove the residual thickener. Single colour items with white patterning can be produced using this method, as can continuous multi-coloured patterns such as transitions from light to dark. Many variations can be achieved by the selection of different naphthols and different developers together with vat and sulphur dyes.

Pump resistance in dyeing machines In a dyeing machine the flow of the liquor from the pump is hampered by several sources of frictional resistance. In the normal pump diagram (Q on x-axis, H on y-axis) the pump resistance is found as the resultant of these interference factors, and to achieve optimal working conditions the → Pump curve should be adjusted to suit this (Fig.).

Pumps,

I. Are used for extremely varied transfer purposes. One differentiates between different pump types, e.g.:

1. Compressed air pumps: → Compressors.

2. Wing pump: at the left and right of the housing there are two flap-type suction and piston valves, with dual and quadruple action; suction and pressure. Application for water transfer purposes (suction head 7–8 m) in manual operation (capsule pump see under 8).

3. Piston pump: With suction pipe, suction valve, submerged piston, pressure valve, pressure pipe. Single and dual action. Suction head up to 7 m.

a) Pressure head up to 60 m or several hundred metres in special design triplex pumps.

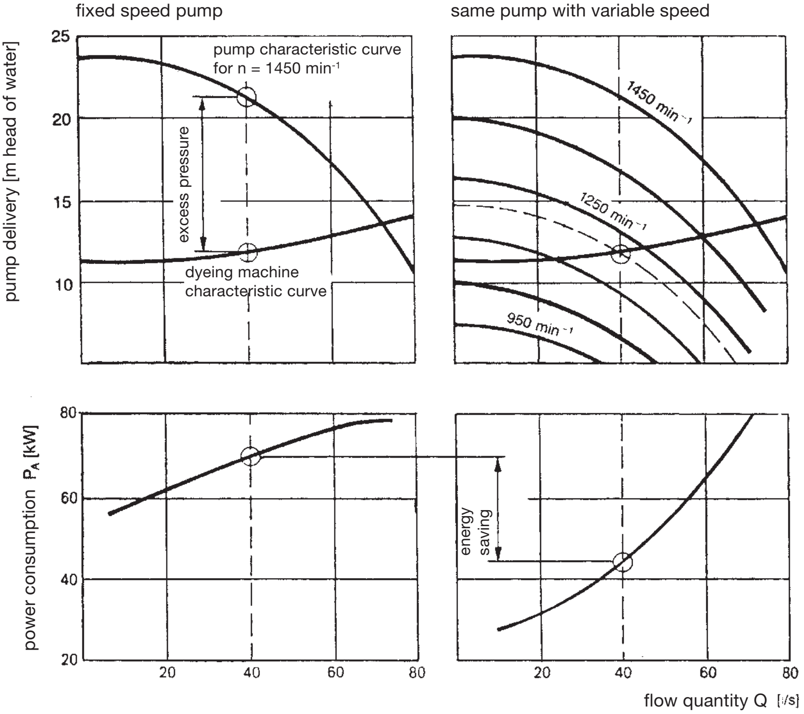


Fig.: Excess pressure between dyeing machine characteristic curve and pump characteristic curve and adaptation of pump characteristic curve by speed reduction to 1200 rpm, so that the power consumption of 71 kW falls to 43 kW (Thies).

b) As boiler feed pumps and pressure pumps. Generally more efficient than 4, but higher system costs and higher space requirement. Pressure can be as high as desired (also as hydraulic high pressure or press pump), is not (like 4) dependent upon the quantity pumped. Often preferred for small and medium output at high pressure heads, particularly with steam operation. Application , manual or power operation for water, acids, lyes (acid resistant grey cast iron or silicon cast iron, hard lead, bronze, vitrified clay). As steam pump in single or dual cylinder type; with so-called power pistons, single, double, triple, correspondingly known as simplex, duplex, triplex pumps; e.g. duplex pumps work smoothly without receiver.

4. Centrifugal pumps: With suction line, impeller (in annular or spiral housing) and pressure line. Usually not self priming like 3, therefore must first be filled with liquid and there is a foot valve on the end of the suction pipe. If put into service without the fluid, seals will seize. Preferred for continuous operation, higher flow rates and, depending upon this, greater lifts (up to 50 m). Efficiency 60–75%. Application usually with electrical drive for water, polluted waste water (also sludge), as a circulation pump for hot water, for acids and lyes (silicon cast iron, bronze, hard rubber, aluminium, vitrified clay, synthetic resin/asbestos; the latter is not suitable for caustic alkalis), similarly also for organic solvents. As high pressure pumps, single and multi-stage, with power drive for almost unlimited lifts, for boiler feed, for deep wells (running shaft in rising pipe, up to 30 m depth), for water supply, self-priming with back flow valve. With coupled direct drive (electric motor or steam turbine) for greater lifts, as vacuum circulation boiler feed pumps, etc. As extreme pressure pump up to 400 bar and 350°C water temperature. Multi-stage.

5. Membrane or diaphragm pump: With reciprocating membrane (instead of piston) made of, e.g. acid resistant rubber. Design varies, with or without pistons, without acid plug, with safety device, etc. Material vitrified clay, rubberized iron, silicon cast iron, hard lead, etc. With suction or suction and pressure, for manual or powered operation; lift up to 15 m; Application for water and aggressive fluids, also with dye components.

6. (water and steam) jet pump: Without moving parts, valve-free, suction (also as vacuum pump), pressure or dual action. Application for water up to 60°C, for acids, corrosive and sludgy liquids.

7. Deep well pumps: In the form of a centrifugal pump(IV) for 10–40 m lift or in the form of an underwater motor pump for up to 200 m (flow rates from 2–1000 m^3 /h).

8. Vacuum pumps: According to the piston principle, single or dual action, single stage up to 99% vacuum, with non-return valve and pressure compensation. Centrifugal principle single stage up to 95% vacuum. Generation of vacuum or pressure with a seal between impellor and pump cylinder achieved by the so-called sealing liquid (such as water, acid, lye or heavy vaporizing oil = oleo-pneumatic pump). Accordingly, optimal throughput of air up to 40 m^3/min. Usually belt drive or coupled with electric motor. Extraordinarily high suction of 36 m^3/s (with pressure of 1.33–0.0133 bar) , diffusion pumps, whereby the necessary high vacuum is obtainable in a relatively short time. According to other principles: for example (capsule pump) with an eccentrically rotating cylinder in a cylindrical casing with a gas-tight sealing. No moving parts also according to principle 6. With suction water jet, for even lower pressure with mercury vapour beam. Application for suction and conveyance of air (also for pneumatic conveying and control systems), gases and liquids.

II. Combed top or pressed conversion with a weight of 6–50 kg. Replace normal → Yarn package, whose weight only goes up to 5 kg. Pumps are pre-treated and dyed on circulation equipment using the pack system.

Pumps in textile finishing The following pump types are used in textile finishing:

I. Metering pumps of different designs:

– gear pump,
– rotary positive displacement pump,
– peristaltic pump,
– membrane pump,
– plunger pump.

II. Centrifugal pumps of different designs:

– radial pump (centrifugal pump),
– screw pump,
– propeller pump,
– axial-flow pump.

I. Metering pumps function as follows:

a) The gear pump is a positive-displacement pump (Fig. 1). The liquid is drawn into the gaps between the teeth, propelled along the housing walls, and forced out of the gaps into a compression area by the intermeshing of the teeth. This pump is used in the synthetic fibre industry for the conveyance of the substance to be spun to the spinning jets.

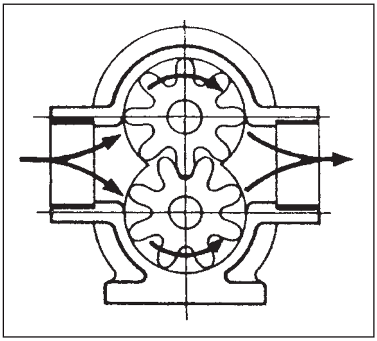


Fig. 1: A gear-type pump.

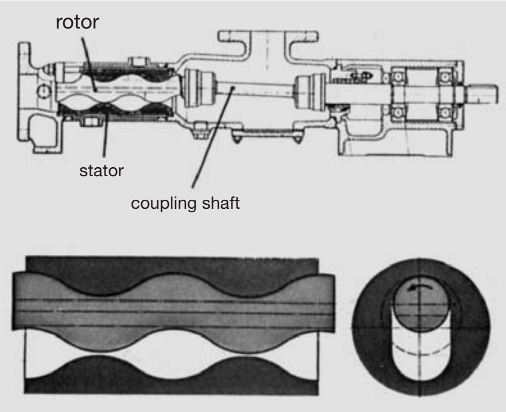


Fig. 2: A rotating positive displacement pump: principle as diagram.

b) A mixing device designed specifically for use in the CPB process, but is also used in foam generators, called the Netzsch-Mohne industrial pump, has as its main component a rotor made of chromium nickel steel and a stator made of special plastic (Fig. 2). The internal shape of the stator represents a double start round thread with large lead and thread depth. The rotor, in the form of a single-start screw with half the lead of the stator, rotates within the stator around its principal axis and thus around the axis of the stator cross-section. As the rotor turns, the transfer spaces thus formed between the internal shape of the stator and the rotor continually move axially from the suction to the pressure side. Stator and rotor can if necessary be easily exchanged on site. The disadvantage of this design principle lies in the low dry running capacity of the stator-rotor system. Even a short period of dry running of a few minutes leads to the destruction of the stator. In the recommended design, two ring sensors are fitted on the suction side in three sensitive areas, which immediately send a message to an electronic control device if there is an interruption to the supply of liquid.

c) Metering pumps are also in use in the form of a single plunger pump with fluid ferrule (Fig. 3).

d) A diaphragm is the heart of the metering pump (Fig. 4). The maximum deflection of the diaphragm through the piston is 3 mm.

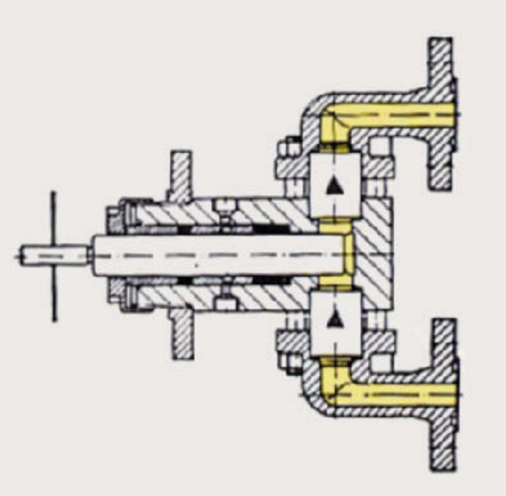


Fig. 3: Diagram of a plunger pump.

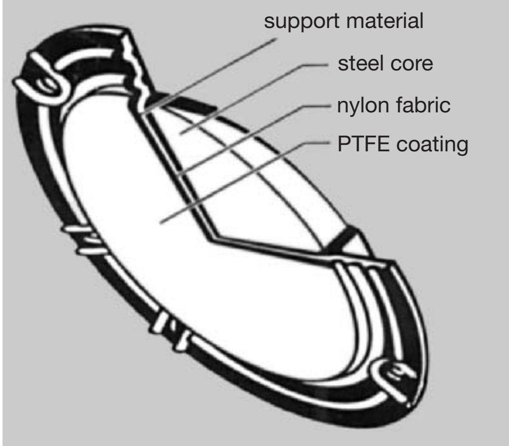


Fig. 4: The Developan metering membrane in the "Pro-Minent Varion" metering pump.
PTFE = polytetrafluoroethylene.

In specific CPB combination pumps there is a single diaphragm pump with two pump bodies made of polypropylene (Fig. 5). The membranes, which are each moved by a connecting rod, are characterized by high resistance to the specific chemical solutions used and thus a long life is guaranteed. The primary advantage of the diaphragm pump is that the drive, which runs in an oil bath and requires no additional lubrication, is completely sealed off from the conveyed medium by the diaphragm. The pump is thus maintenance free.

In other diaphragm pumps (Fig. 6) the plunger displaces a hydraulic fluid, which itself deflects a diaphragm that is in direct contact with the medium, thus bringing about the dosing process. In the multi-layer diaphragm pump head, two diaphragms are arranged behind one another. If a diaphragm breaks, the dosing medium or hydraulic oil penetrates from the pumping area behind the diaphragm into the area between the diaphragms and brings about a pressure increase. This is converted into an optical, electrical, or pneumatic alarm signal to indicate that the diaphragm has broken.

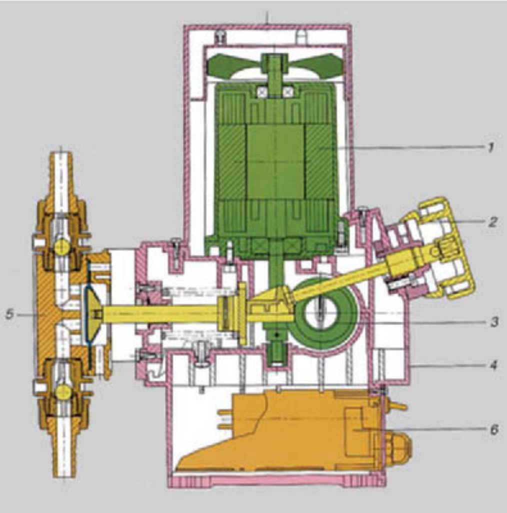


Fig. 5: A combination pump as a single membrane system with two pump bodies (Seybert and Rahier). 1 = motor; 2 = stroke adjustment; 3 = gear; 4 = housing; 5 = delivery unit; 6 = control insert.

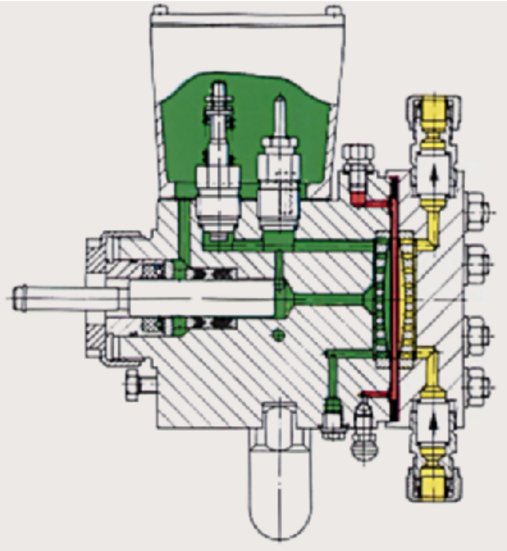


Fig. 6: A membrane pump by Bran & Lübbe.

Multi-layer diaphragm pump heads are used for environmentally problematic media.

The valves in a metering pump are always a potential source of problems. Although all devices are fitted with suction heads or filter systems, the risk that thread bundles or other foreign bodies can penetrate into the pump body cannot totally be eliminated. These can block valves, which under certain circumstances can lead to false dyeing. CPB combination pumps possess double valves as a special feature both on the suction and pressure side. This guarantees that these pumps will continue to function even if a valve does not close. The valves are spring loaded on the pressure side. This is normally sufficient for the suction operation. When working in liquor or where there is a large head between pump and padder chassis there should always be a pressure sustaining valve on the pressure side.

There are three designs available depending upon the desired field of application:

- with alternating current geared motor for on/off operation via level control. This is the cheapest design.
- with alternating current variable speed gear motor. The flow rate is mechanically regulated via a hand wheel on the pump. The control range is limited to 20–100%, i.e. it cannot be set at flow rates lower than 4 l/min.
- with variable direct current motor. The most expensive, but also most highly recommended design. A thyristor speed controller that can be connected separately controls the flow rate precisely and sensitively from 0.5–20 l/min. Even if a level control is connected, the flow rate can be optimally matched to the liquor requirement.

II. Liquor feed pumps for large quantities function as follows: in a centrifugal pump the fluid to be conveyed is transferred to a rotating paddle or impeller wheel. The kinetic energy of the liquid is converted into pressure.

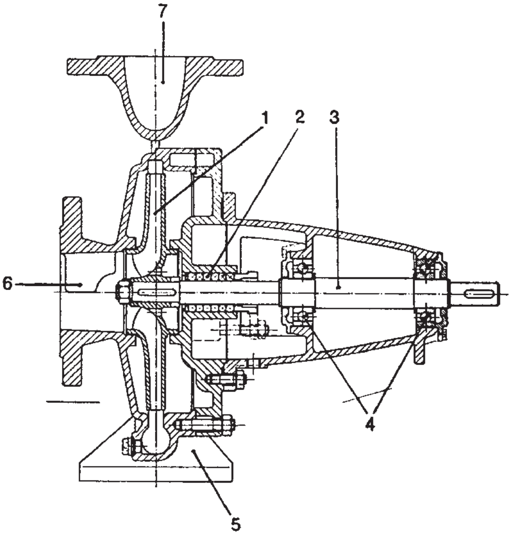


Fig. 7: A centrifugal pump.
1 = rotor; 2 = shaft seal; 3 = pump shaft; 4 = pump shaft bearings; 5 = housing base; 6 = suction side (intake side); 7 = pressure side (output side).

a) A centrifugal pump is a frequently used type of rotary pump, whilst the propeller pump is only used in modern textile finishing machines in individual cases. The centrifugal pump (radial pump) is suited for conveying large quantities of liquor over short distances. The centrifugal pump consists of the housing, impeller, an axial liquor supply and a side liquor discharge connection (Fig. 7). The liquid enters at the eye of the impeller. The rotating impeller sets the liquor to be conveyed in rotation. The centrifugal force that this creates accelerates the liquor to the discharging connections.

Centrifugal pumps have proved their value in most textile finishing machines due to their typical pump characteristic. The blades of impellers can have different shapes (Fig. 8). Self-priming centrifugal pumps are those that can independently evacuate a suction pipe and can therefore normally be mounted at up to 8 m above the liquid level. They are usually only filled with a priming liquid when starting and then can always prime themselves, because some priming liquid always remains in the pump when it is switched off again. Self-priming side channel pumps can convey air, and compress it.

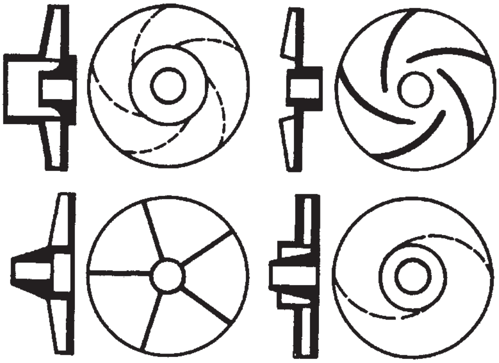
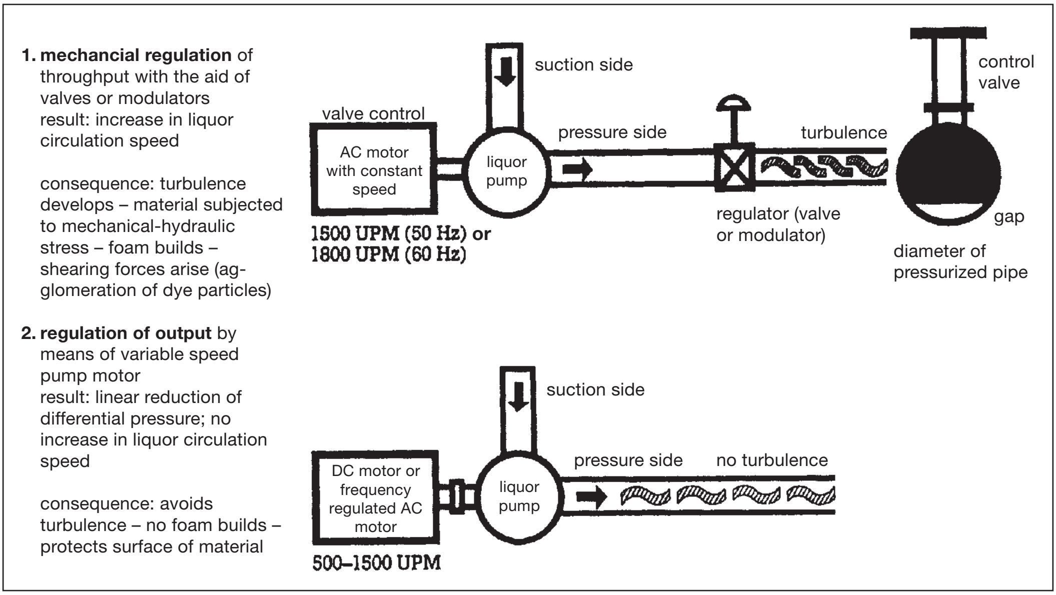


Fig. 8: Different forms of rotor blade to match different pumping media.

In contrast to self-priming pumps, when normal priming pumps are used the suction pipe outside the pump housing must be completely full of liquid. If the supply of liquid in the suction line is interrupted or air or gas bubbles form this type of pump will not draw in liquid. There must be a flow valve that closes properly at the end of the suction line, and the pipe itself must also be completely sealed. If air enters the pump will not work.

It is often necessary to adapt the supply data of a pump to changed operating conditions, i.e. to alter the head and flow rate. The simplest method of altering supply data is throttle control. The pump is initially designed for the max. flow rate and the associated head. A lower flow rate is achieved by throttling the pump, i.e. generating an additional head loss. Thus the operating point of the pump changes to the desired flow rate, whilst at the same time the head increases to a greater value than that required by the system.

Liquor pumps for piece and yarn dying equipment are normally connected to constant speed alternating



1. **mechancial regulation** of throughput with the aid of valves or modulators
   result: increase in liquor circulation speed

   consequence: turbulence develops – material subjected to mechanical-hydraulic stress – foam builds – shearing forces arise (agglomeration of dye particles)

2. **regulation of output** by means of variable speed pump motor
   result: linear reduction of differential pressure; no increase in liquor circulation speed

   consequence: avoids turbulence – no foam builds – protects surface of material

Fig. 9: Liquor control by means of the regulation of pump motor speed.

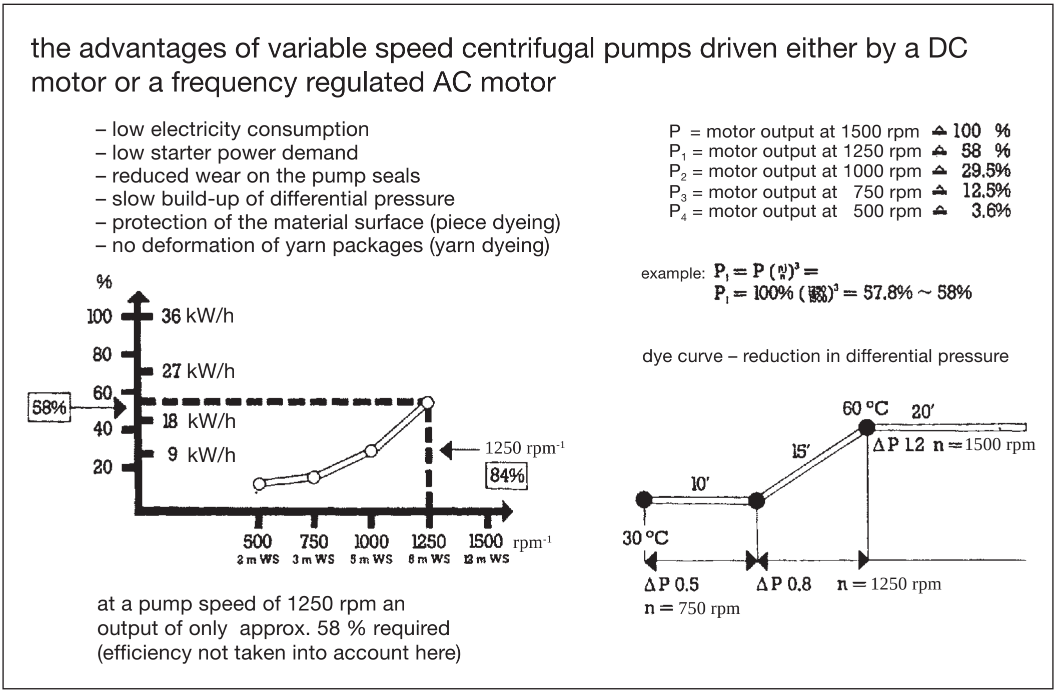


Fig. 10: Electricity consumption of an electric motor in relation to its speed or pump output.

current motors. They run continuously at the maximum speed, which, depending on the frequency lies at 1500 rpm (50 Hz) or 1800 rpm (60 Hz). In order to control the flow or the differential pressure the liquor stream must be mechanically reduced with the aid of valves or flow controllers. This increases the liquor velocity, which leads to turbulence in the pipe system. The result: the mechanical and hydraulic forces created contribute to generating roughening effects on the material surface in rope dyeing or to deformation of the wound package and yarn damage in yarn dyeing. Because of the high liquor velocities at the maximum motor speed, shear forces can also occur in the system, which can lead to agglomeration with some dye classes.

More beneficial is the precise control and programming of the flow rate (Fig. 9) or differential pressure. It is not limited to a slow reduction, but is adapted continuously to the kinetic parameters during the finishing process.

The liquor flow is regulated by controlling the speed of the pump motor. This is achieved either by thyristor control in direct current motors or by frequency converters in alternating current motors. The flow rate can thus be adjusted to suit the textile to be dyed, according to the pump characteristic. Despite higher investment costs for variable speed motors it is possible to dye more economically. The reduction of the speed of the pump means that the power consumption by the drive motor is lower (Fig. 10). The significantly re-

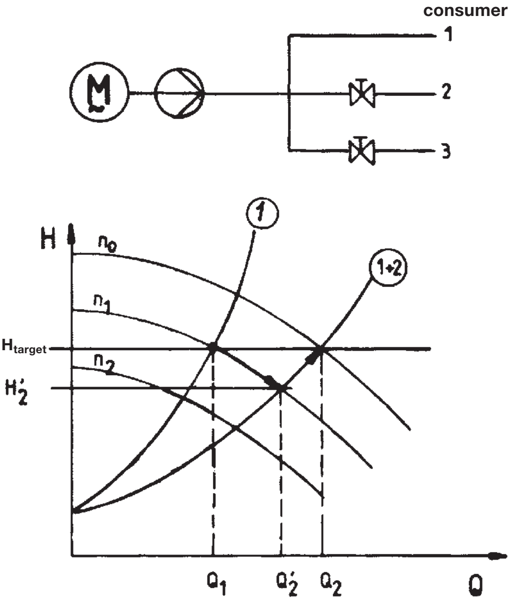


Fig. 11: Pump control lines for "H constant" (pressure).

duced power consumption brings about an energy saving, which justifies the additional cost for variable speed drive motors. An amortisation period of 4–8 months can be expected.

The speed of the pump can be controlled by two methods:

1. In the “H constant” control characteristic a target pressure is preset at the pressure regulator (Fig. 11). The actual pressure that currently exists in the plant is compared with the set point pressure and an adjustment signal sent to the frequency converter, whereupon the speed of the pump is altered such that it constantly runs at the desired pressure. Example: a pump supplies Consumer 1 at flow rate Q_1 and head $H_1 = H_{target}$. If Consumer 2 is also connected, the system works using the plant characteristic 1 + 2, whereby the pressure falls to H_2. When the pump is turned up to the new speed n_0, the pressure climbs back to the desired target pressure H_{target}, thus setting the flow rate at Q_2 (Fig. 12).

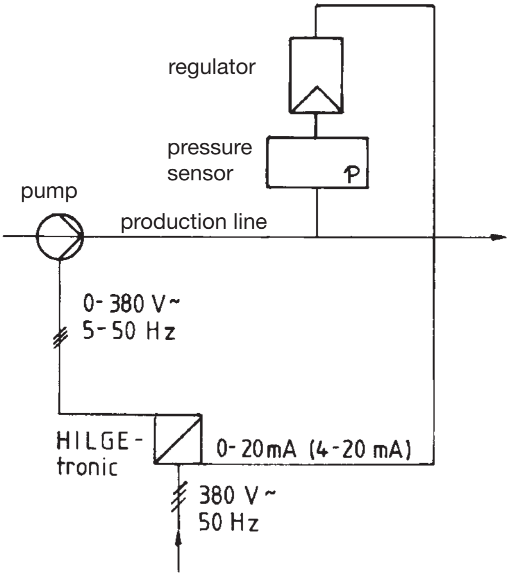


Fig. 12: Diagram showing pump control using a frequency transformer related to target pressure (Hilge).

2. In the “Q constant” control characteristic, a flow controller sets the desired flow rate (Fig. 13). The target value for the system is measured e.g. by an inductive flow rate sensor. The regulator compares Q_{target} with Q_{actual} and sets a constant flow rate at the pump by means of the frequency converter. Example: A pump provides a consumer with a flow rate $Q_1 = Q_{target}$. If the flow resistance in the system changes during the running time, the system characteristic 1 changes to system characteristic 2. In order to change the reduced flow rate Q_2 to the target value Q_{target}, the speed is increased from n_1 to n_0 (Fig. 14).

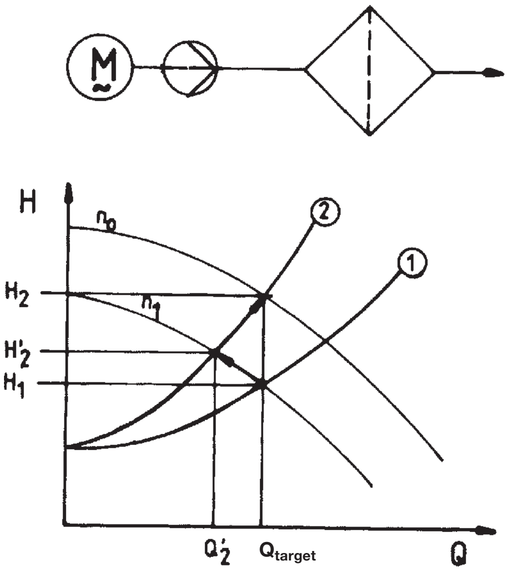


Fig. 13: Pump control line for “Q constant” (quantity).

b) Axial pumps: axial pumps gained importance when very high textile densities were introduced, which the liquor has to flow through on compressed crosswound yarn packages (specific volume 400–600 l/kg). Liquor feed and extraction takes place axially in such pumps. Unlike the centrifugal pump, the motor load increases as the resistance of the treated material increases. In the axial pump each stator has a rotor.

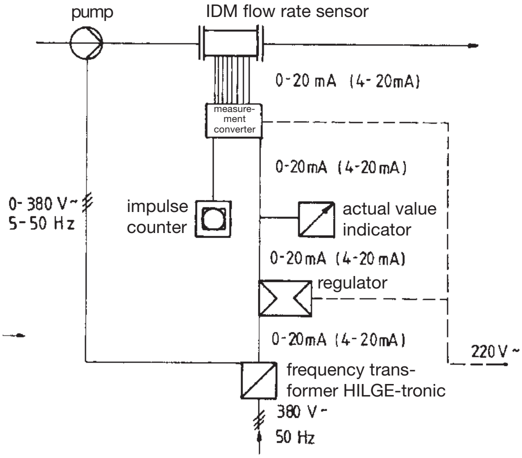


Fig. 14: Diagram showing pump control using a frequency transformer related to target delivery rate (Hilge).

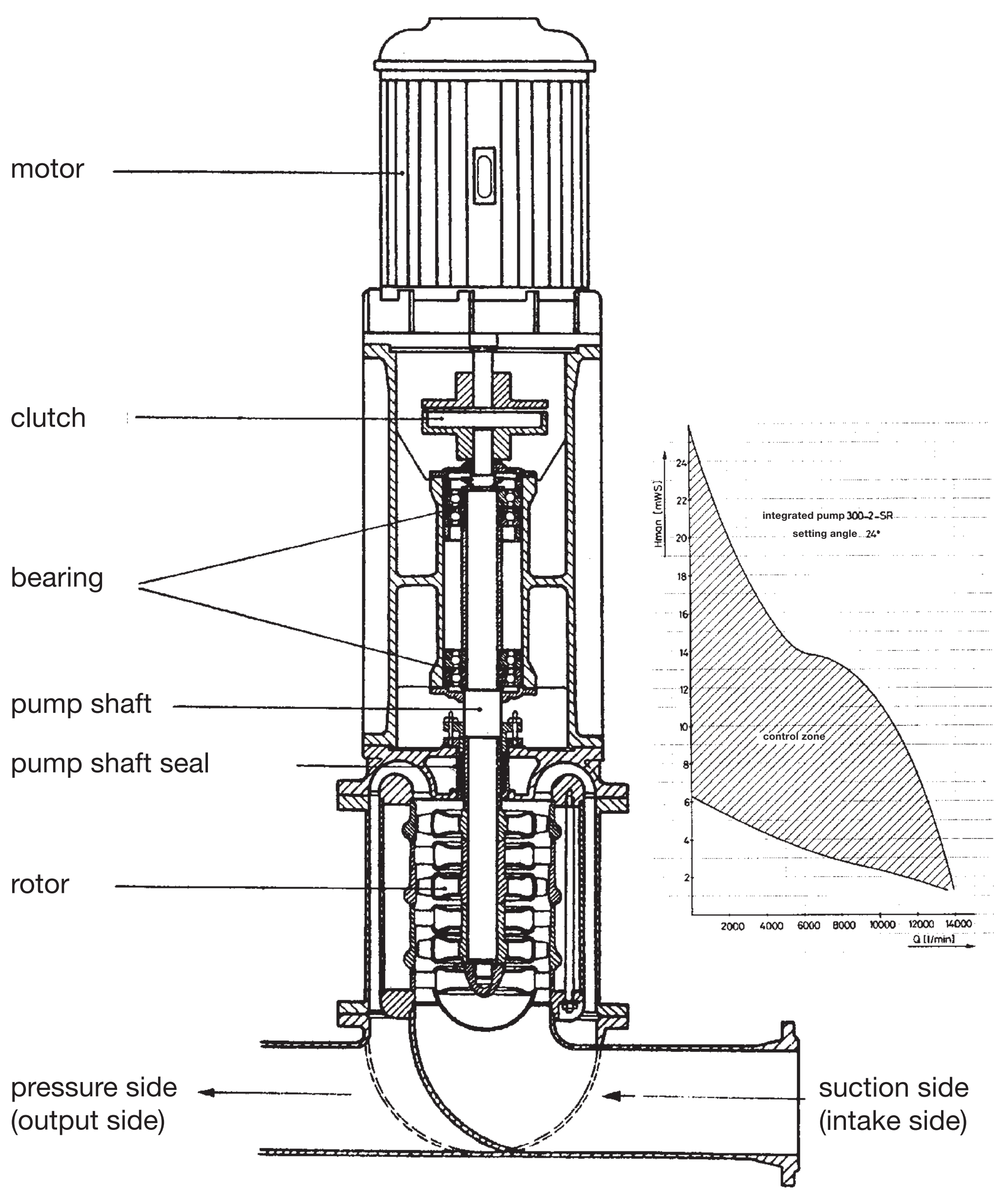


Fig. 15: A Krantz axial pump (control zone is shown below the pump characteristic line on the right).

Multi-stage axial pumps have several rotor-stator pairs in a row (Fig. 15). The pump characteristic can be altered by changing the speed of the drive motor. In the Turbo-rapid pump by Obermaier depicted in Fig. 16 the impeller is continuously adjusted by altering the position of the rotor blades.

A comparison of the common pump types (Fig. 17) shows: The pump characteristic becomes steeper as we go from propeller pumps via centrifugal pumps to multi-stage axial pumps (according to Kretschmar, Ungermann, Hedjans, Berdelle).

Pump speed control In order to increase the relia-

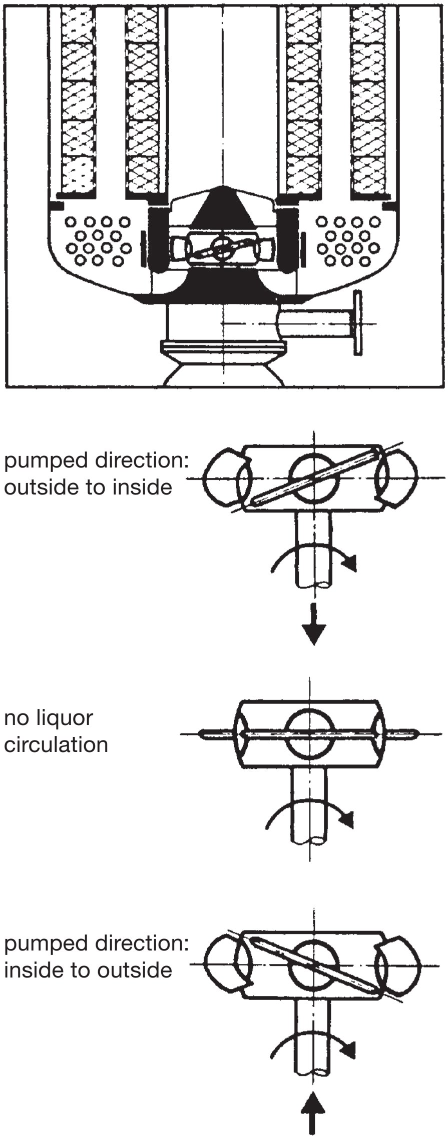


Fig. 16: The mechanism of the Turbo-rapid pump by Obermaier, showing the change in liquor circulation direction by adjustment of the rotor without stopping the pump.

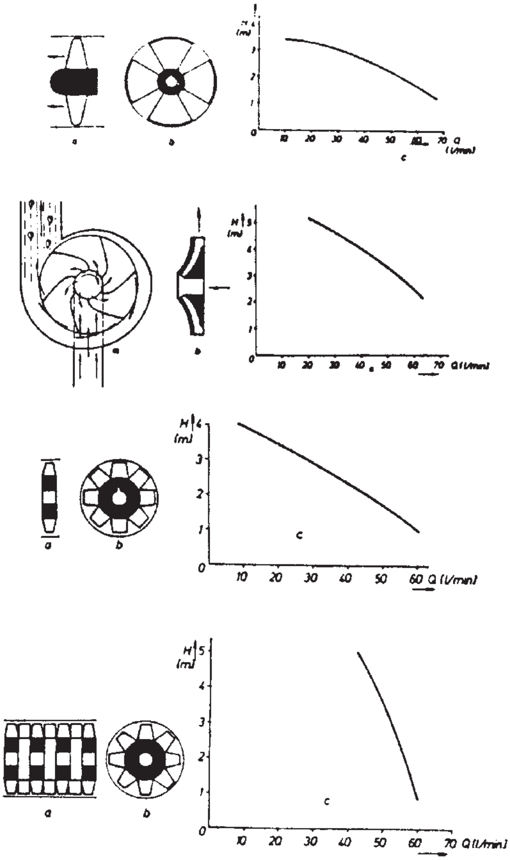


Fig. 17: Comparison between the gradients of the pump characteristic lines of a propeller pump (top), a centrifugal pump (centre) and an axial pump (below) of either the single stage (e) or multiple stage (m) variety.

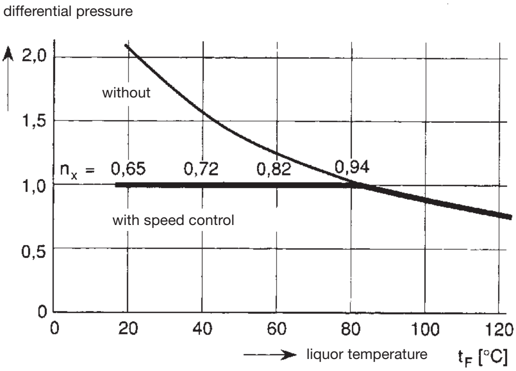


Fig: Plot of the differential flow pressure ΔpL [bar] relative to liquor temperature t_F [°C] (Kretschmer).

bility of dyeing with the beam dyeing system it is advisable to permanently regulate the pump speed from the start using the differential pressure programmed with the dyeing guide value F_F. It is clear from the Fig., that in this case the differential pressure can be reduced to around half. This significantly reduces the risk of dyeing problems, and this is achieved without influencing the time-temperature management or the heating up rate.

Permanent regulation is also recommended for yarn dyeing. In addition it is recommended that the differential pressure dependent pre-programmed regulation of the pump speed is also maintained for pretreatment, rinsing and aftercleaning. This reduces the colour specific spool delivery faults and increases dyeing reliability, without limiting process and temperature control.

Pump stripes Stripes on printed textiles in the direction of the weft, which can occur on rotary screen printing machines during the automatic pumping of printing colour paste into the distributor pipe of the rotary screen, if subsequently pumped print paste is of a different consistency to that in the doctor blade device or it has undergone a different change by the doctor blade process.

PUR → Polyurethanes, → Textile fibre symbols, according to DIN 60 001 until 1988.

Pure linen Fabric, in which the warp and weft must consist of 100% pure → Linen (usually in plain weave) and only in this case may be marked with the “Pure Linen” quality symbol of a hand raised in oath.

Pure new wool (South African), term for items made of pure → Virgin wool.

Pure soap content Proportion of pure, water free → Soap. Should be as high as possible for washing purposes (92–96%).

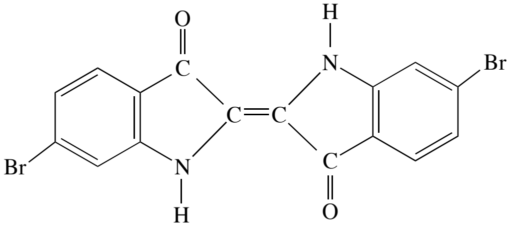
Pure spectral colour Optimal colour, which yields the lightest colour for a given → Type of colour and the most saturated colour for a given → Shade of colour. The colour valency associated with the shade is characterized by maximum brightness. According to Ostwald, every colour corresponds with the sum of pure spectral colour (P) (pure colour), ideal white (W) and ideal black (B) according to the equation P + W + B = 100. The so-called clear bright series is created from pure spectral colour + white and the so-called clear dark series is created from pure spectral colour + black (→ Chromaticity diagram).

Pure wool (South African). Fine → Animal hair fibres (mohair, alpaca, llama hair, cashmere).

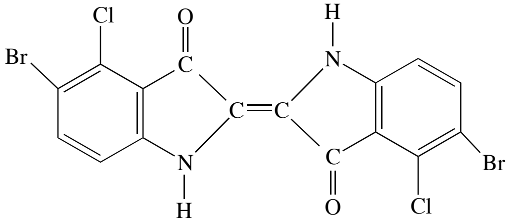
Purple Reddish violet → Natural dyes (vat dye) made of the gland secretion of dead murex snails (Mediterranean and West Indian coasts. 8000 snails provide just 1 g dye). Active component: Dibromoindigo.

Antique purple is not a brilliant red, but a somewhat red cast violet. This was shown by a colorimetrically measured dyeing of pure antique purple (6.6’-dibromoindigo) in comparison to a dyeing used for cardinals’ robes. This change of colour term is based on cultural and technological historical reasons and on the basis of biochemical findings about the creation of 6.6’-dibromoindigo and indigo from murex snails.

Irritations regarding the colour of purple arise above all due to the complicated biochemical and photochemical synthesis (see Fig.). Depending upon the snails, their glands contains various colourless pre-products of the dye, which only appear in the light as coloured compounds (different red, violet or bluish black).



antique purple



synthetic purple

In the Murex trunculus type these are the potassium salts of the sulphuric acid ester of 6-bromindoxyl and 2-methylsulphonyl-6-bromindoxyl (R = SO_2CH_3). In addition, however, murex trunculus also contains the comparable compounds without the bromine component, i.e. the forerunner of indigo. The female of this type of snail primarily forms the bromated, the male however almost exclusively the non-bromated product.

Purpurin (1,2,4-trihydroxyanthraquinone), madder purple. Naturally occuring together with alizarin in the → Madder (previous madder dyeing); provides reddish violet chrome lacquer.

Putrefaction, decay → Rot.

PVA → Polyvinyl alcohol fibres, → Textile fibre symbols, according to DIN 60 001 until 1988, from 1991 → PVAL.

PVA+ → Polyvinyl acetate fibres, → Textile fibre symbols, according to DIN 60 001 until 1988.

PVAL → Polyvinyl alcohol fibres, → Textile fibre symbols, according to DIN 60 001 T4/08.91.

PVC → Polyvinyl chloride fibres, → Textile fibre symbols, according to DIN 60 001 until 1988.

PVC+ Post-chlorinated → Polyvinyl chloride fibres, → Textile fibre symbols, according to DIN 60 001 until 1988.

PV dyes Selected pigments for the mass dyeing of plastics, particularly softened polyvinyl chloride.

PVM → Polyvinyl chloride copolymer fibres, → Textile fibre symbols, according to DIN 60 001 until 1988.

PVP → Polyvinylpyrrolidone.

PX → Trivinyl, symbol according to ISO.

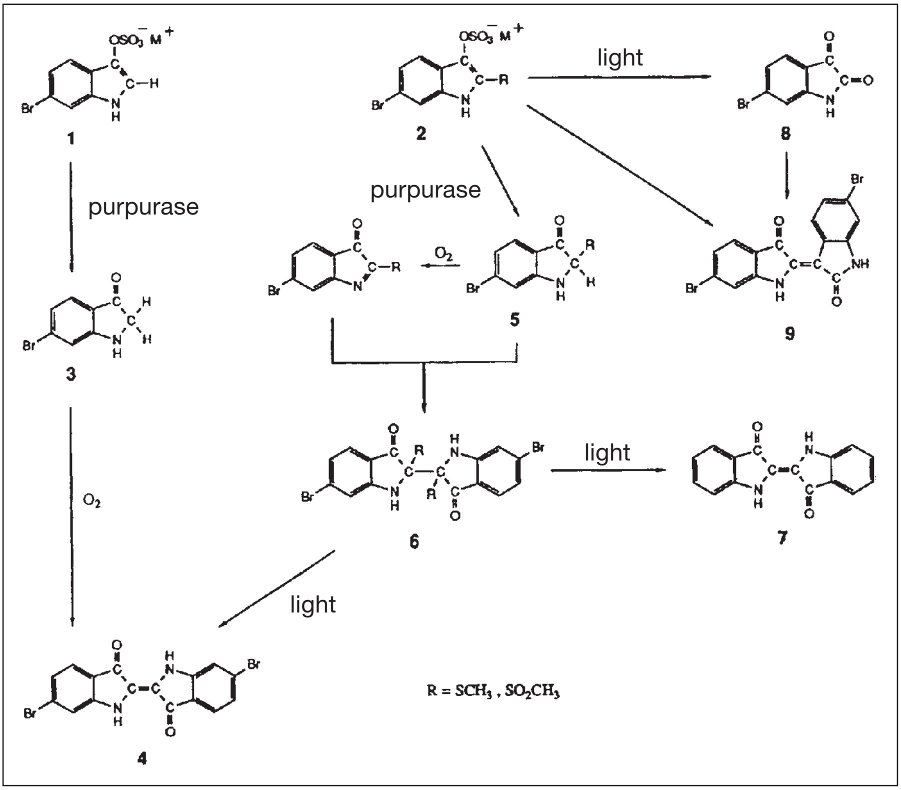


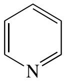
Fig.: Possible routes to the synthesis of purple.

Pyranometer (also incorrectly called → Pyrheliometer), device for the measurement of sunshine in the form of heat generated in Langley units (gcal/cm^2). Often used in meteorology. Not suitable for use as a substitute for → Blue scale in light fastness testing.

Pyrethroids Synthetic functional analogy to pyrethrumates (= composites, similar to marguerites). The latter have for centuries been amongst the strongest vegetable → Insecticides ("insect powder" or spray against house pests and moths, carpet beetles, etc.) and plant pests. Pyrethrum is highly toxic to lower animals (stomach, contact, muscle, nerve insecticide), however it is not photostable and is relatively expensive, which is why numerous synthetic pyrethroids have been created. Since 1973, these also include photostable pyrethroids as potential preventative agents against moths, fur and carpet beetles. Good moth protection effect, however it has poor activity against carpet beetle larvae. → Antimicrobial finishes.

Pyrheliometer Light sensitive measuring cell for illumination equipment, a thermoelement photometer consisting of two concentric rings with a black or white surface (hot solder points of a gold-palladium and platinum-rhodium thermoelement battery, attached to the black underside of the ring). The temperature difference measured between the two rings is almost proportional to the quantity of light falling upon the sensor. Thermo-currents generated by irradiation in light fastness tests are measured with a voltage meter, recorded and totalled by a counter.

Pyridine C_5H_5N:



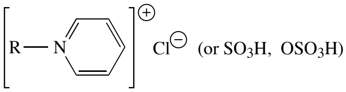
Molecular weight 69.09; density 0.977; boiling point 115°C. Colourless liquid (so-called heterocyclic base) with characteristic odour, slightly alkaline, miscible with water or alcohol; resistance against water hardness agents, acids, alkalis. Solvent and dispersant for substantive and acid dyes in particular (aids full penetration dyeing, levelling and generation of lively shades). Application: pasting up, dissolving, dispersing, full penetration dyeing of named dye classes (particularly for circulating liquor, clothing, felt, hat dyeing); for slight stripping of dyes (in hot liquor), etc. Can cause potency problems in the event of overdose by inhalation.

Pyridine test (dye detection), test with

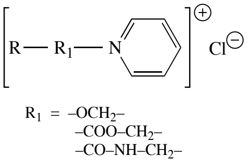
1. pure pyridine,
2. pour over diluted pyridine (30–50%) and boil for 1–2 min.

a) substantive dye (also after-treated): solution 1 not coloured, solution 2 strongly coloured.
b) cationic dye, naphthols: both solutions strongly coloured.
c) sulphur, vat dyes: both solutions not coloured or only slightly coloured.
d) reactive dyes: solution 1 not coloured or only slightly coloured (turquoise or blue types may be coloured), solution 2 not coloured or only slightly coloured.

Pyridinium compounds Quaternary pyridine complexes, which are derived from co-ordinative pentavalent pyridine nitrogen and yield a series of important cationic textile auxiliaries such as the alkyl pyridinium salt of the type:



For increasing the fastness of direct dyes, as a leveller and stripping agent for vat dyes, special emulsifiers, softening agent, etc. Waterproofing agents of the following type have achieved significant importance:



Products of this type are not thermostable; if the material is heated then the pyridinium compound would be split at the CH_2N bond and the hydrophobic, cationic part applied in such a manner as to be wash and dry cleaning fast.

Pyrimidine Heterocyclic six-membered ring compound, structurally similar to → Pyridine, however with two nitrogen atoms in 1.3 position. (→ Tetrahydropyrimidone resins).

Pyrithion Abbreviation for 2 pyridinthiol oxide C_6H_5NOS, in tautomeric equilibrium with 1-hydroxy-2-pyridinthion. Some commercially available metal salts have a fungicidal and bactericidal effect. Even better results are achieved by zinc complexes of this compound from aqueous polyethylene imine solution according to conventional pad/dry/condensation processes. If the solutions also contain urea, then the hydroxypyridinthion is bound to carbon monoxide. Materials treated in this manner prevent the growth of Staphylococcus aureus even after 50 washes; the fungicidal properties are however not so wash resistant.

Pyro- As a prefix in the designation of inorganic compounds created from water-containing ortho compounds by heating and the emission of water. Example: Pyrophosphoric acid $H_4P_2O_7$ (from $P_2O_5 + 2\,H_2O$) by the emission of 1 molecule of water from two molecules of ortho acid. Salts → Pyrophosphates.

Pyro acids/salts → Acid anhydrides.

Pyrocellulose Cellulose modification that has been damaged due to excessive heating. Always contains aldehyde and carboxyl groups. → Fibre damage (cellulosic fibres), tests for.

Pyrolignite of iron (iron liquor, iron mordant, black liquor), produced by dissolving iron waste in pyroligneous acid or double decomposition of iron (II) sulphate and pyrolignite of lime. Dark brown solution of 12–15°Bé = 50–55% iron. Application: Mordant for black dyeing of wool, silk and cotton using logwood.

Pyrolignite of lime (potassium acetate), brown lumps, produced by dissolving 5 parts lime in 25 parts water (→ Slaked lime) and 25 parts acetic acid 6°Bé, adjust to 5°Bé. Application: Cheap production of aluminium and chromium acetate for mordants (alizarin red), as additional mordant.

Pyrolysis Decomposition of substances by heat, for example dry distillation. In pyrolysis larger, heavier molecules are split into simpler, smaller molecules. Pyrolysis also takes place in fibre combustion processes (for example → Laevoglucosan) as irreversible chemical decomposition, caused by increasing the temperature without oxidation. → Burning behaviour of textiles.

The processes underlying the combustion have a physical-chemical nature. The combustion process is divided into five stages:

1. heating of the substrate,
2. decomposition (pyrolysis),
3. ignition,
4. combustion,
5. fire propagation.

The heating of the substrate is largely determined by

- specific heat,
- heat conductivity,
- heat of fusion,
- heat of vaporization.

The actual pyrolysis precedes the chain decomposition. At higher temperatures a slow pyrolysis starts, whereby a weight loss occurs, accompanied by the formation of low molecular, volatile and for the most part combustible compounds. As yet there is still no danger of fire. Only when a combustible gas mixture forms with air is there a danger of fire at the critical pyrolysis temperature.

External and self ignition bring about a change from the metastable state to the state of spreading fire (Fig. 1). In exothermic combustion the released energy con-

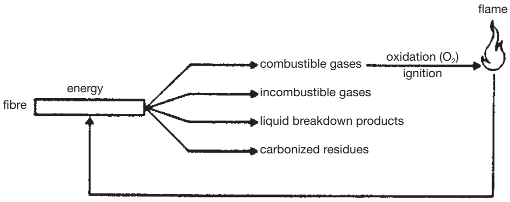


Fig. 1: Substrate combustion.

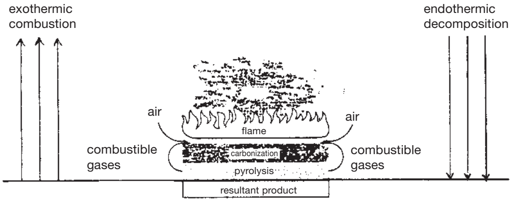


Fig. 2: Steady state.

tributes to an increase in temperature, whereas in endothermic decomposition absorbed energy, i.e. the transfer of heat to the inside of the substrate, is drawn from the heating process. Pyrolysis, for its part, feeds the flame with matter (combustible gases), and the flames feed the pyrolysis with energy. The actual burning process represents an equilibrium which is called the “steady state” (Fig. 2).

The thermal decomposition of plastic waste at high temperatures in the absence of oxygen is also known as pyrolysis. The plastic does not burn, but decomposes into petrochemical raw materials. All pyrolysis products can be used, so no waste gases are generated. The process is therefore particularly environmentally friendly. Fig. 3 shows the fluidized bed process.

Pyrometer Measuring instrument for high temperatures:

I. Thermoelectric pyrometer: The weak electric currents at the thermocouple junctions of two wires (thermoelements) are analyzed to measure the temperatures acting upon the junctions. Application: up to approx. 600°C in steam, hot water pipes, dry plants, waste gas

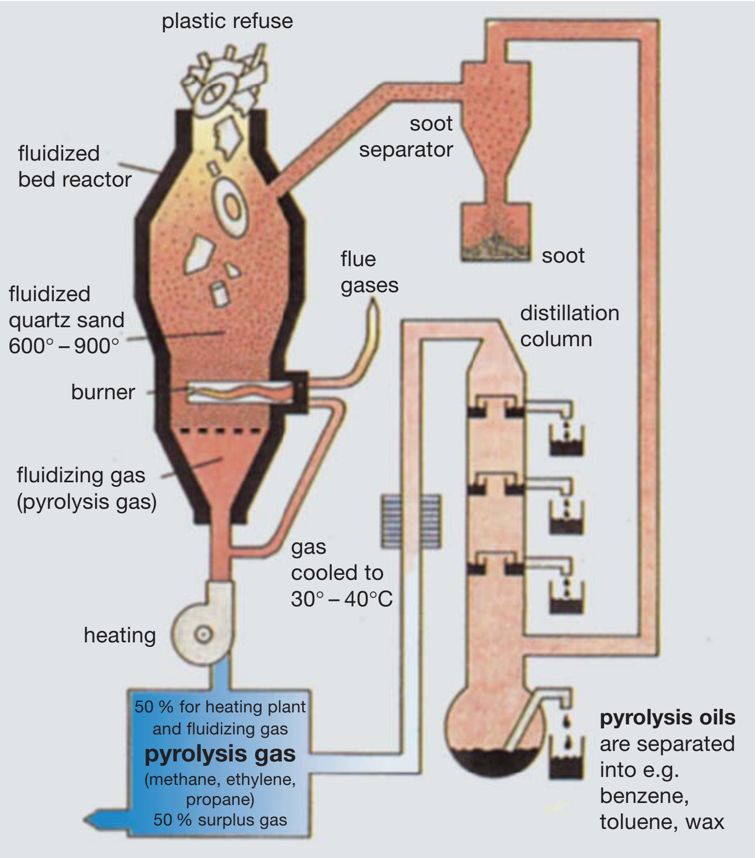


Fig. 3: Fluidized bed pyrolysis for the breakdown of plastic refuse into hydrocarbons.

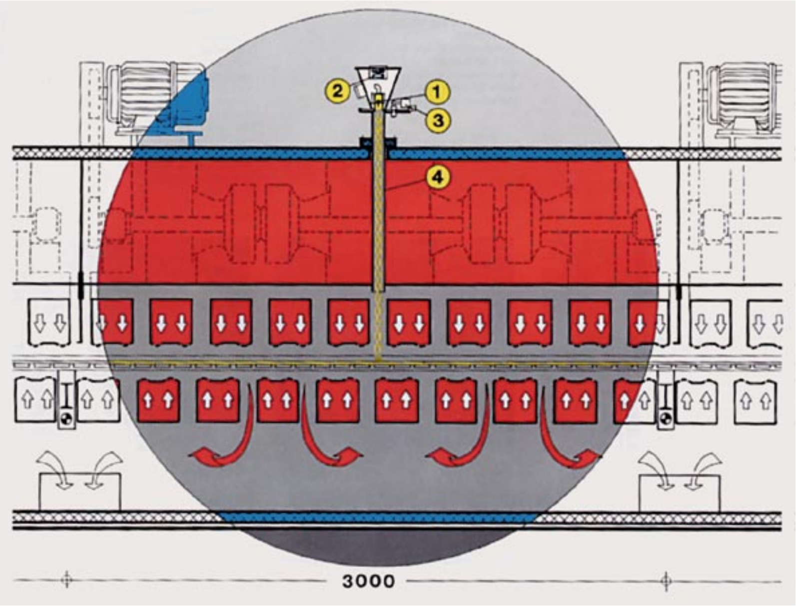


Fig. 1: Sensing head above flat stenter frames.
1 = radiation pyrometer;
2 = cooling ventilator;
3 = overheating safety device: if the cooling fan shuts down the sensing head swings to one side;
4 = pipe carrying measured radiation.

ducts, autoclaves, etc.; also available with remote and recording devices.

II. Optical pyrometer: measures the heat radiation by comparison with a filament lamp, the brightness of which can be regulated, whereby the lamp current produced is transferred to a current measuring device calibrated in °C.

III. Air pyrometer (vapour pressure, gas thermometer): Principle of expansion of enclosed air or gas; primarily for scientific work.

Normal thermometers are not suitable for the measurement of the material temperature of a moving length of material because they are influenced by the temperature of the surrounding air and by the frictional heat generated by the necessary contact with the material. However, the heat radiation from the material (Fig. 1) supplies a variable that is proportional to the temperature, which can be detected in a contact free manner independentl of distance (Fig. 2). Bodies and surfaces of all types emit a radiation depending upon their current temperatures, the energy of which extends from visible light well into the infrared region. The intensity of this radiation varies and depends upon the nature of the material. Textiles, regardless of fibre type, structure and colour, all have similar behaviour, which approximates that of the so-called “black body”.

The temperature dependent measuring signal is created in an optoelectronic receiver (radiation pyrometer), which collects the emitted energy and coverts it into an electric current. Because the distance of the radiation pyrometer from the measured surface is not a factor in the measurement, the pyrometer can be used

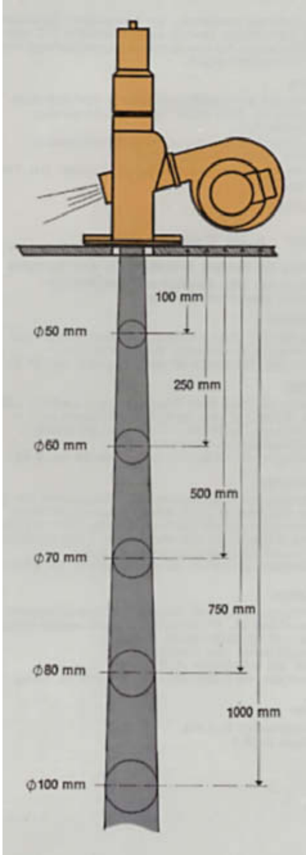


Fig. 2: The measured substrate (the fabric) may be at any distance from the pyrometer.

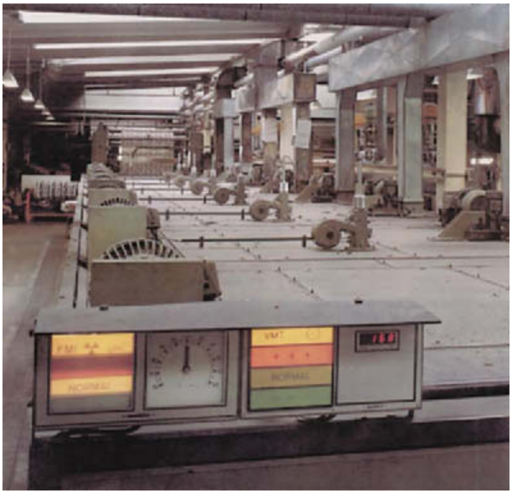


Fig. 3: Dwelling plant with 6 pyrometers on the ceiling of a horizontal stenter frame.

for example on the cover of a fixing machine, in which an opening has been cut for heat radiation to pass through (Fig. 3). The radiation is concentrated onto the converter by a mirror. The aperture of the mirror must be such that the pyrometer only receives heat radiation from the material and not from other objects in the radiation cone. An air curtain protects the detector from the hot air from the machine and ensures that the measuring equipment is largely maintenance free (Fig. 4). Colour, fibre type and structure of the textile have no notable influence upon measuring accuracy.

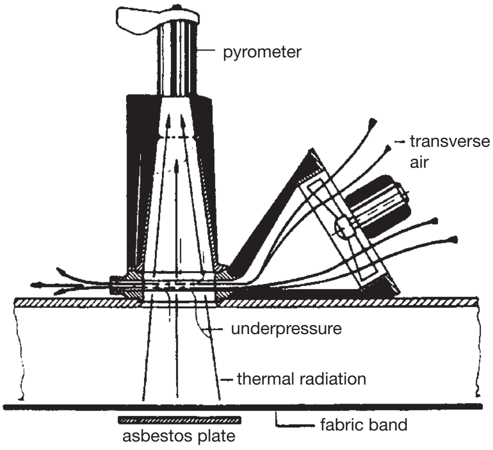


Fig. 4: Temperature measuring point on the roof of a drier, comprising a radiation pyrometer on the cooling tower with a transverse air barrier. The transversely flowing air prevents hot gases etc. penetrating as far as the radiation pyrometer.

The physical principle underlying temperature measurement by the radiation pyrometer is that every body emits heat radiation (Fig. 5) according to the formula

$$S = S_0 \cdot \varepsilon_r \cdot T^4$$

S = radiation power over all wavelengths, per unit time and area,
S_0 = constant,
ε_r = relative radiating capacity,
T = absolute temperature.

From this we can see that the radiation power is primarily influenced by temperature, because it is raised to the power of 4. According to its temperature the black body emits radiation energy, which depends upon the wavelength. Planck's radiation law sums up this relationship in the formula

$$E = \frac{c_1 \cdot \lambda^{-5}}{e^{c_2/\lambda T} - 1}$$

A total radiation pyrometer detects the radiation energy within a certain wavelength range, which corresponds with the area under the curve in question for a certain temperature. Different colours have no influence even in practice, because the energy contribution from the visible range is negligible (Fig. 5).

On a material surface passing through a stenter the cooling limit temperature of 50–60°C is maintained as long as water is still vaporizing from the surface

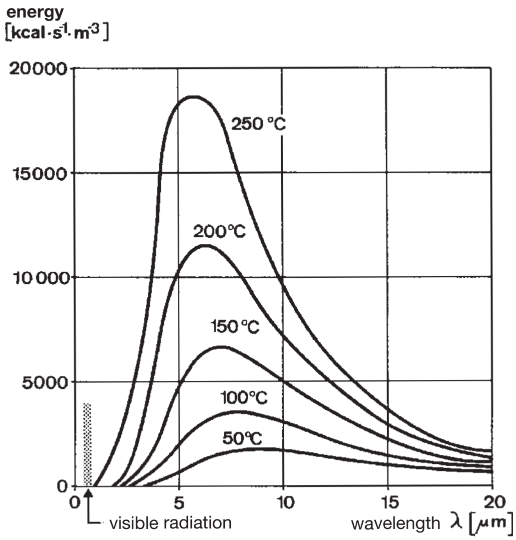


Fig. 5: Black body radiation energy as a function of wavelength at various temperatures.

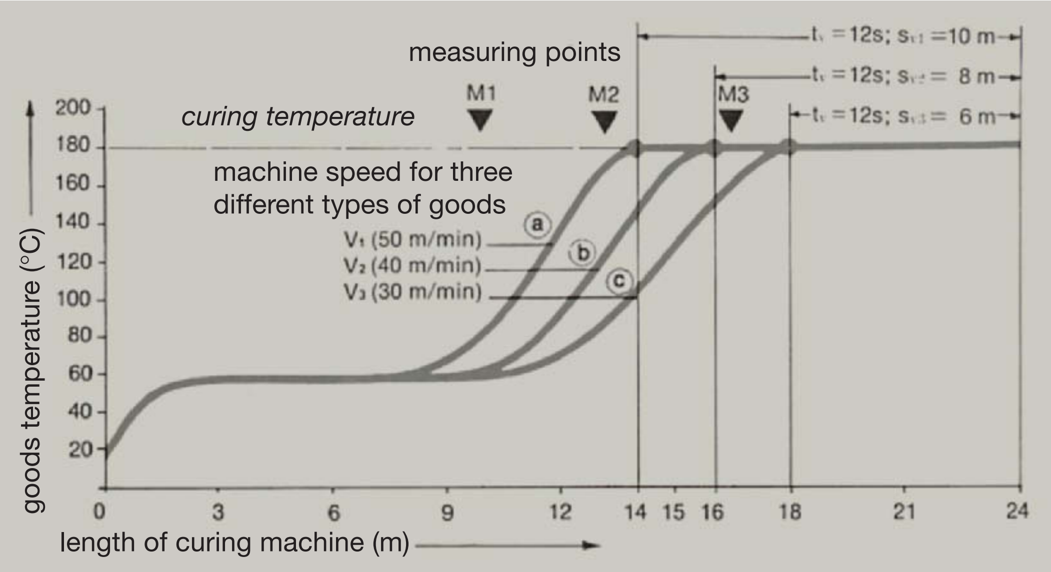


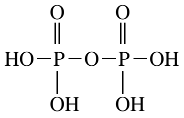
Fig. 6: The heating up curve for goods during the curing or condensing of initially wet goods.
a = goods light and quick drying, high machine speed; b = goods moderately heavy, medium machine speed; c = goods relatively heavy and slow drying, low machine speed; t_v *= specified dwelling time;* s_{v1-3} *= dwelling zones.*

(Fig. 6). Only when there is no longer any residual moisture left does this cooling effect by evaporation cease and the surface temperature begins to rise. Within this range the temperature corresponds with a very definite material moisture content. This means that it is possible to maintain a defined material moisture level by maintaining a preset material temperature. This works not only on thin textiles, but also on voluminous carpets and even back coatings, front coatings and foam. The advantage is that measurement with pyrometers (M_1, M_2 and M_3 in Fig. 6) is non-contact and barely influenced by the material.

A dwell time apparatus requires the measured values from at least three radiation pyrometers, which continuously monitor the material temperature in the range of the heating zone. A microprocessor continuously calculates the heating curve for the material from these temperature values. It interpolates between the measured values and extends them into a continuous curve. By altering the machine speed the regulator alters the position and gradient of this curve (in Fig. 6) such that for each material the currently set dwell time is given under the preset conditions. The process speed is thus varied and is held as high as the properties of the material permit. The dwell time, however, remains constant.

The process is independent of the type of the material. It can be used both for fixing and condensation processes, and also for other time-dependent heat treatment processes, for example in drying, gelling, vulcanization of latex foams. The number of radiation pyrometers required depends upon the length of the machine and on the heterogeneity of the product. More temperature measuring points are needed for long plants and products that differ in width and weight than for short machines and largely uniform materials. At least three pyrometers are needed; up to eight measuring points can be connected.

Pyrophosphates (diphosphates), salts of the tetrabasic pyrophosphoric acids $H_4P_2O_7$ (→ Phosphoric acids).



$$\mathrm{HO-\overset{\overset{\displaystyle O}{\|}}{\underset{\underset{\displaystyle OH}{|}}{P}}-O-\overset{\overset{\displaystyle O}{\|}}{\underset{\underset{\displaystyle OH}{|}}{P}}-OH}$$

We differentiate between:

I. “Neutral” pyrophosphates: type $Me_4P_2O_7$, only alkali salts soluble, with marked alkaline reaction: sodium phosphate.

II. “Acid” pyrophosphates: type $Me_2H_2P_2O_7$, soluble with acid reaction: disodium phosphate.

III. “Tertiary” pyrophosphates: type $Me_3HP_2O_7$.

Properties: pyrophosphates belong to the group of rare phosphates, and they possess the most marked metal corrosive behaviour of this group, particularly together with wash-active substances. Reactive behaviour like → Complex phosphates.

Pyrrole → Heterocyclic compounds.

Pyrrolidinecarboxylic acid → Proline.

Pyrrolidone → Polyvinylpyrrolidone.

Q

Q In the formula for nocuousness, the → Waste water quantity expressed as the amount of waste water in cubic metres per day.

QS-process Squeezing/suction technique in accordance with the principle of → Capillary dehydration developed by Pfersee. This is one of the low wet pick-up techniques; liquor reduction in the goods through capillary liquor exchange. Material which has been conventionally padded and squeezed in the first padder nip to the usual liquor absorption is brought together with the same, but dry, fabric, and pressed against it in the 2nd nip. This results in removal of the excess liquor (adhering liquor), leading to a reduction in the liquor uptake by a further 15–40%. Liquor treatment squeezing / suction methods on cotton approx. 40%. Advantages: → Low wet pick-up. Principally used in resin finishing.

Quadrant scales Yarn scales, for determining the weight of a certain reel length, by which the yarn count is determined.

Quality The definition of quality given in the standard DIN 55 350, part 11, which is derived from the English definition, as follows: Quality is the sum total of all characteristics and features of a product or an activity, which relate to their suitability for fulfilling set requirements.

The structure of the concept of quality shown in the figure can also clarify the concept of quality for the textile industry. The quality circle (according to Masing) is a model for intermeshing all measures and results which affect quality in the phases of the development and utilisation of a product or activity. Two of the terms named in the quality circle have long been differentiated in the English-speaking world, namely:

- quality of design
- quality of conformity.

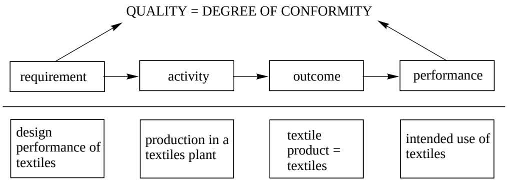


Fig.: The quality concept.

The latter is also known as quality of performance or quality of manufacture. When a textile item is sold, its technical (objective) and fashion (subjective) data play roles which are inseparable for one another. The fashion data are topicality, image-enhancing functions and wearability; whilst the technical data are defined by – amongst other things – strength, stability, fastness and processability. The task of each and every industrial production is to develop products which conform to a set quality standard (profile of requirements) in testing. The attempt to come to a clear definition of the term quality shows that quality is something mutable, dynamic. In contrast to the expert who is in a position to grade quality objectively to some extent, via measurable concepts, the consumer largely has to rely on the subjective assessment of the quality which he is purchasing. For the consumer, quality is not a physical parameter whose value can be measured, since it is a totality of many features and characteristics. Attractive products draw attention among textile consumers if the design is right, if one feels good in the product because of good physiological characteristics of the clothing, if the instinctive human desire for natural items is satisfied through the use of natural fibres, and the product is marketed in the right way. Specialities which arise through high expenditure on finishing in particular, appear to conform to these requirements for attractive products. For the textiles expert, these concern features whose values are recorded quantitatively and are compared with the quality standard. In terms of political economics, these economy-related quality criteria are supplemented by an increasingly important ecological quality criterion. According to conventional views of quality, the serviceable life of an article is at the fore. By contrast, a quality requirement in which fashion aspects have priority is less concerned with durability (high strength, fastnesses) of an article. Textile finishers often have to follow economic parameters; as manufacturers with an awareness of marketing, they will include the quality requirement in their economic considerations, and weigh up the attractiveness of the product. But the law increasingly compels them to take account of ecological quality criteria.

Quality assurance This is an essential measure for controlling production, to keep complaints about products within limits, to detect faults and eliminate them. In the textile industry, however, thorough quality assurance comes into conflict with ever shorter batch lengths and project times, and with ever smaller profits from finishing. In order to be able to produce economically in terms of time and costs, in the last few years, many firms have invested in the field of quality assurance, under the motto “quality is profitable”.

Quality is the condition of an item in respect of its suitability for fulfilling requirements which have been established and prescribed. For the prevention of faults, a number of points must be noted:

1. Quality planning in the design department, with performance checking.
2. Selection and appraisal of materials and suppliers.
3. Test planning, laying down responsibility for the Quality Control department and analysis of faults.
4. Quality training and promotion.
5. Incoming goods checking and supplier monitoring, to check qualification and performance of delivery.
6. Working out offers which are utilisation-related and process-technology oriented.
7. Establishing responsibility for checking documentation.
8. Final testing, packing and despatch, with test criteria.
9. Detection and elimination of product defects, customer service, and tracking of a product.
10. Environmental protection measures and product liability, for the purpose of risk reduction.

Manufacturing testing is subject to standards and technical rules for tests based on qualitative features. Here, rules are stated, to which one can refer between or during the individual operations and situations.

Manufacturing testing can be applied for the testing of:

- end products,
- parts and materials,
- work procedures,
- working materials and tools,
- warehouse stocks,
- repair capability,
- monitoring devices and measuring equipment.

Testing is the process of measuring, investigating or trying out an object, or otherwise checking it for conformity to requirements. During testing, the object is classed as either good or defective. Classification of defects requires grading according to the severity of their consequences.

Critical defects are defects of which one can assume or it is known that they will probably hinder the object in question in fulfilling its function. If an object is graded as important in terms of safety engineering or function, then 100% testing for critical defects is carried out. Minor defects are defects which will probably not significantly reduce usability for the intended purpose, or else they are a deviation from the applicable rule, which only slightly affects the use or operation of the object.

Deviations in quality which are established only at the final check can only be corrected at great expense. The final check must therefore primarily document for the client and for one’s own in-house quality planning, that all quality requirements are fulfilled with a high degree of certainty. If there is repeated failure to conform to minimum requirements, then quality assurance in production must be improved, rather than increasing expenditure on testing in the final check.

Most textile tests require considerable amounts of staff, material and time. They must be planned very carefully, taking into account the possible error risks. With production planning and production control systems, the frequency of testing can be specifically arranged according to these criteria:

- risks of process engineering
- production frequency and quantity
- customer requirements
- error rates in previous production.

The available testing capacity is deployed with considerably greater efficiency than with simple procedures which subject each batch to very extensive testing programmes, practically regardless of the construction and quality requirements of the article. Two testing programmes – short test and long test – are distinguished. The short test is always carried out for every batch, and is used to decide on release of the batch after finishing. For this, only the most important risk factors are tested. The long test covers all essential technological quality features of an article. It is used in the following cases:

- in the first production batches of new articles
- after process conversions
- after a certain production quantity, to check the overall quality standard.

The test specifications for a certain article may be, for example:

1. A short test, with the test criteria of finished width, tear strength, slipping tendency, and washing shrinkage per batch.
2. A long test, with the additional test criteria of thread count, mass per unit area, dry crease angle, smoothness profile, fastness to chafing, and colour fastnesses for every 10th batch, but at least once every quarter.

The test data are processed by computer. The testing programmes for all articles are thus stored together with the respective applicable target values and tolerance limits. After the test values have been recorded, the following evaluations can be undertaken: print-out of all test values outside the tolerance, for fast information for the departmental management, takes place in freak value records. The control card is the print-out of a selection of test values, represented in control card form. Statistical comparison of selected test data for specific clarification of questions such as “Change in the technological values following a process modification” or “Comparison of two production runs with differing provenance of raw materials” takes place regularly. The final colour of each batch is assessed visually and by colorimetry. With the so-called “sewing sample”, the colour evenness is visually checked over length and breadth. Where the client specifies the maximum permitted colour ranges, this test can also be carried out colorimetrically. Larger consignments are additionally sorted according to colour groups. This sorting generally takes place visually, since colorimetric sorting using measuring equipment is still relatively time-consuming and unwieldy.

Responsibility for the quality of the products and by-products is borne by the management of the textile finishing company. The management lays down the targets towards which quality assurance in all areas of the organisation is to be directed. This plan is called the quality policy. It determines, in concrete terms, the structure of the quality assurance system and the implementation of quality assurance. Quality assurance is the sum total of the activities of quality planning, quality control and quality testing. The aim of a quality assurance system must be “process under control”. The aim is to ensure that the product- and quality-related influencing variables are recognised and established in time. A monitoring system ensures that the individual stages remain standard. For this, standards which relate to the profile of requirements must be produced, and kept up to date with the latest developments. The reporting system includes the evaluation of the interim production yarn/raw fabric and, on a monthly basis, the evaluation of the manufactured production. Furthermore, customer complaints, returns, after-treatments etc. likewise form an important constituent, as information, for controlling production (Fig. 1).

A distinction is made between input, i.e. raw goods, performance of work, and output, i.e. the product. Included under product are the reports concerning quality outcome, analyses and any changes which result from this for manufacture. For the spinner, input includes the fibres which are necessary for a corresponding yarn; for the weaver, it includes the raw fabric standards, which also apply for the buying in of raw fabric. The finisher will subject the raw textile goods which have been supplied (knits, fabrics, yarn, flock), but also dyes and auxiliaries, to an incoming goods check. The article profile must be determined in writing, and this includes not just strength and error rate, but also statements about sizing, right down to selvedge construction. The information contains all work instructions. The aim of quality assurance is a “fault-free culture”, development in accordance with the quality requirements of the client; it can only be achieved with a corresponding attitude on the part of the producer. Condition, serviceability, reliability features and a usage-oriented level of requirements determine the required quality elements. The quality policy of a firm defines performance and application policies within the framework of quality assurance, through reliability planning, test planning, quality engineering, test procedure plans, supplier appraisal, materials testing and goods testing, and incorporates them into a quality assurance verification system. The DIN and ISO standards mentioned in this quality assurance manual are used on a case by case basis. They form the subject of the order, when they are mentioned (e.g. acceptance class) in the order confirmation.

Quality assurance is divided into:

- quality management
- quality planning
- quality control
- quality testing.

Within a firm, integrated quality assurance forms part of the duties of each employee (Fig. 2). It starts with the

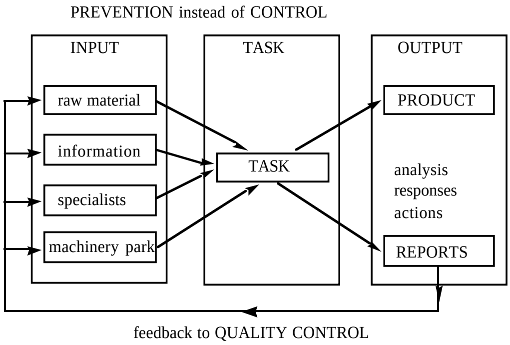


Fig. 1: Part of a control loop at Marks & Spencer aimed at avoiding defects.

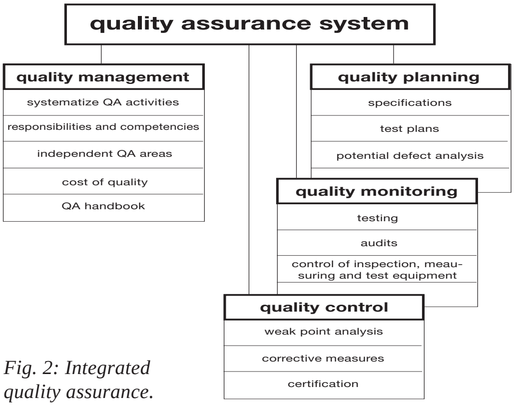


Fig. 2: Integrated quality assurance.

invention of new products and extends through their development, the purchasing of starting products, incoming goods checking and warehousing of raw materials, production, in-process monitoring, quality testing at the end of fabrication, the selection of suitable packaging, correct labelling and secure storage, orderly storage of reference samples, down to despatch and processing by the customer. Clear traceability of the individual batches, heeding facts relevant to quality assurance (such as customer and product specifications, standards, target values, packaging, warehousing regulations etc.) when drawing up contracts with subcontractors and customers, or the handling of products which do not conform to the quality, are an important part of quality assurance. It likewise includes periodic execution of in-house quality assurance audits. Quality assurance is a seamless system, running through all activities within a firm, which is also closely linked with its surroundings: with the market, product liability and standards, as well as with official stipulations and legislation. Quality assurance must, in accordance with this central topic, form part of the content of management board meetings, and the management board must fully identify with the chosen quality assurance system and its consequences.

The situation with quality testing is considerably simpler. It is necessary that both production and quality testing are integrated when drawing up specifications, target values, test schedules and test procedures; however, once they have been established by mutual agreement, performance of the duties resulting from them represents a routine which must be strictly adhered to. In order to preserve constancy of quality, changes to the test specifications, must consequently be avoided so that comparability with earlier results is not lost. However, if the quality of the available starting products should require process improvements, or should new measuring technologies, changed requirements in the market, a different type of profile of requirements for the product, or stricter, extended statutory regulations, amongst other things, call for corrections, then the possibility of a change in quality must be planned, and realised if possible. By agreement with the production and marketing departments, the quality testing department then sets up a new test standard, and the internal and external offices as well as the customers must be informed. Fundamentally, all test results and measurement results are subject to a certain error probability in comparison with the true value. For this reason, besides the reliability and reproducibility of test methods, particular attention must also be paid to keeping and checking test standards. This in turn is a quality-assuring measure for quality testing. It is recognised that those offices responsible for quality assurance and quality testing should report directly to the management board. In this way, they are independent of departments and functions, as well as from production. A logical conclusion from this is to embed the quality testing function in quality assurance. Final checks are insufficient for achieving far-reaching elimination of defective production, even if they are supported by statistics. To achieve this aim, more or less comprehensive quality assurance systems or quality assurance monitoring circles are absolutely essential. Fig. 3 shows an example of quality assurance in a larger company.

Quality assurance for a single finishing stage is shown in Fig. 4. Equipment and procedure for process monitoring should detect quality-reducing influences during the process, and eliminate their cause. Process monitoring systems work continuously. An example is temperature regulation or liquor application regulation. Production checks should detect errors which occur, so

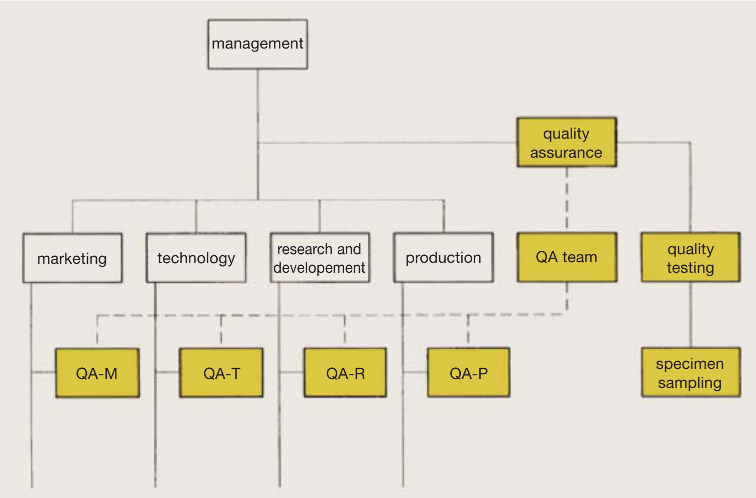
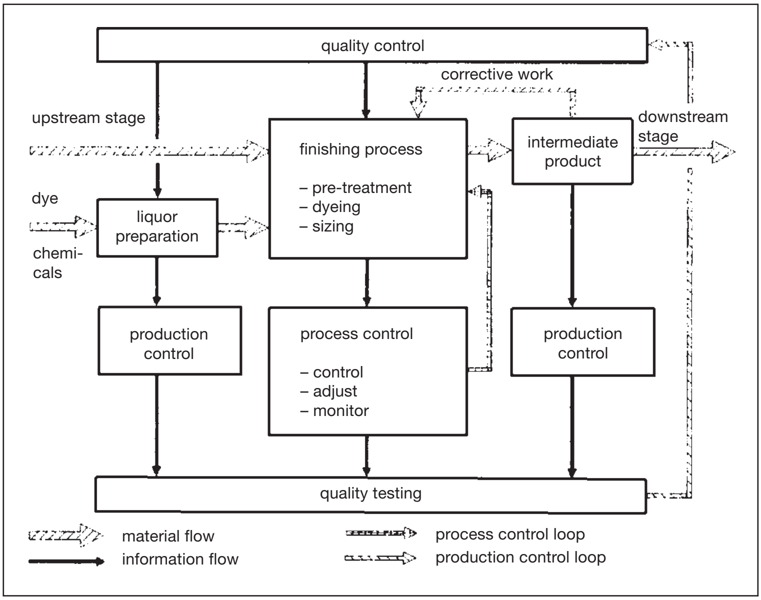


Fig. 3: Example of matrix organization for quality assurance in a large company.

Fig. 4: Quality assurance system for a single textile finishing stage.



that these can be corrected by re-working the preceding stage or by special measures in the subsequent stage. Recurrent faults must be systematically eliminated by adjusting the process engineering. Production checks are carried out either on the entire production or on statistically secured random samples. Examples are checking the colour outcome after dyeing, or monitoring de-sizing after pre-treatment. Two important control loops of quality assurance are thus recognised in production. The inner control loop is formed by the finishing process and process monitoring system, whilst the outer control loop is formed by the finishing process, quality testing (production monitoring on the intermediate product) and quality control. Corrective measures via the outer control loop are always considerably more expensive that those in the inner, shorter, control loop.

Besides the overall reasons for a quality assurance system, ecological aspects, which naturally, in turn, have an economic background, speak for quality: warranty liability, product liability and environmental liability. Only company-specific quality assurance measures provide a guarantee that the profile of requirements agrees with the performance in textile production, and that suitability for the purpose can be guaranteed. Only through consistent quality assurance measures can one guard against even concealed defects, in order to prevent later complaints and recourse claims. In itself, product liability does not bring any new risks with it, but with regard to consequential damage due to faults in both domestic and foreign trade, a risk assessment is indispensable.

The product information system of DTB (Dialog Textil-Bekleidung) can provide important assistance in guarding against complaints and consequential damage due to faults. The aim of this product information is to secure the usage purpose, wearing characteristics and quality image with the aid of technical characteristic data, and thus at the same time to ensure that suitability for the intended purpose is in fact given. Six groups of data relating to construction features, finishing features, processing features, care labelling, colour fastnesses and mechanical-physical characteristics provide information about the quality features of goods, and what the goods are capable of (and what they are not).

Ecological risks can no longer be ignored by textile firms. Textile finishers in particular handle chemical substances; they store them, and carry out chemical processes. Waste water and exhaust air have claimed the undivided attention of the legislators. Careful and responsible handling of textile finishing chemistry within the framework of quality planning and quality control systems are unavoidable as technical elements of the quality assurance system. Short term but also medium term measures are necessary in order to be able to stand up to any future environmental liability and the environmental protection laws. Risk assessment, planning and control of the textile quality which is produced are of particular importance from the point of view of environmental legislation.

In view of the liability obligation of a producer within the framework of quality assurance, the question naturally arises as to how far the liability remains insurable. The new liability regulations contained in the German environmental liability law of 10.12.1990 caused the liability insurers (HUK-Verband), together with the BDI and the DVS (German insurance protection association), to re-work the previous system of liability insurance through the introduction of the environmental liability policy ’92. With the new environmental liability policy, environmental cover of the company liability insurance, water pollution liability insurance and the environmental policy ’78 are combined to form a uniform insurance concept. The general terms for liability insurance (AHB) were adapted to this new policy; thus an exclusion of compensation for environmental damage by the company liability insurance was inserted in the AHB. On the other hand, the extended product liability insurance continues to be covered within the framework of company liability insurance. Environmental damage due to products thus remains insured in the company or extended product liability insurance (exception: installation recourse). (Source: Korte, also Hohl, and Hemmpel).

Quality circle The quality circle is a model for the intermeshing of contributions which the various functions make to the quality of a product or service (Fig. 1). Quality arises as a result of activities or processes in the planning, realisation and utilisation phases.

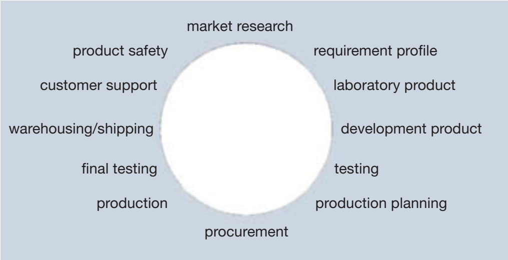


Fig. 1: The quality circle.

Fig. 2 attempts to illustrate the action area of product-monitoring and quality control in interaction, for the purpose of quality assurance for textile finishing. Quality control represents a checking of results, both at the start of the finishing chain and at the end of it. Product monitoring, on the other hand, has an immediate production-controlling function, in that it assesses the effect of individual finishing stages, and thus intervenes directly in the finishing procedure. Quality assurance represents a force for order in relation to article optimisation, process optimisation, and improvement of the economic result of a finishing process. This is possible only if quality assurance has direct access to the production and non-manufacturing departments such as plant engineering, laboratory, development and purchasing, so that questions relating to process engineering, substrates, chemicals, auxiliaries and dyes, concerning assurance and optimisation aimed at economy in articles and their production, can be solved quickly.

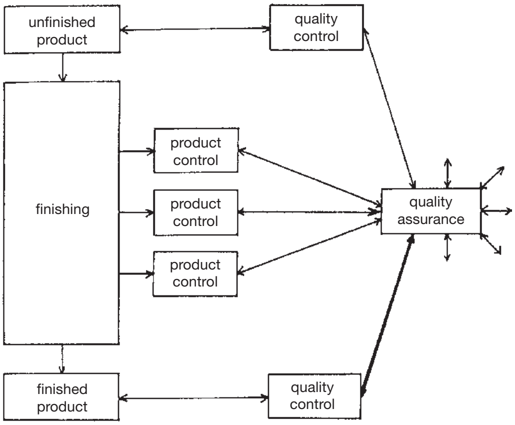


Fig. 2: Quality assurance as a function of product and quality control (Windel).

Quality circles Quality circles (QC) are working parties of approx. 10 people led by a chairman, which have grown to become a full-blown movement in Japan. In the USA and Europe too, they have been a permanent fixture for several years.

When setting up a quality system, the company management must be clear from the outset about how they can do justice to the demand for “continuous improvement” of quality management at all hierarchical levels. This requirement means that in the organisation in question, problems are continuously investigated, and where possible are solved by those employees who are most affected by the effects. When such a participatory concept is introduced, consideration must above all be given to the question of how the priorities are to be set, between those projects regarded as important by “the top” (the management) and the workplace-related problems which interest those “at the bottom” (those employees who carry out the work). In principle, intradisciplinary problems can be handed over for solving to individuals, hierarchical groups or groups composed of volunteers. The hierarchical group can be a problem-solving group which – if it consists of two people – is called a “dyad”. In the case of volunteer groups, this could be a modified quality circle, insofar as it accepts problems proposed from outside. Interdisciplinary problems are usually handed over to a project team or committee. In the normal case, the latter differs from a project team in that it has the restricted task of just submitting proposals for solutions. Project teams, on the other hand, should, wherever possible, also be entrusted with implementing the solution, or at least with monitoring the problem-solving process.

From the point of view of those responsible, the formation of groups of volunteers has, above all, the purpose of giving those employees mainly entrusted with hands-on work the opportunity to assume their own responsibility by being able to work through problems which they have themselves identified. This support for self-help and for reinforced self-confidence leads to increased motivation among individuals at work, and also has a considerable positive effect on the working climate in the quality circles. Both are requirements for the fulfilment of set performance targets and for constant improvement in productivity. From the company point of view, therefore, the issue is that the staff can effectively and continuously utilise their intellectual potential to constantly improve the work procedures and to deal with their tasks and problems.

Quality control (fabrication, manufacturing, production control). Quality values are recorded quantitatively and compared with a set quality standard (profile of requirements), or are merely assessed subjectively. A feature is therefore the characteristic which enables the units which form a whole to be distinguished, namely either quantitatively (quantitative feature, size) or qualitatively (qualitative feature). For each feature, one has to know the required and the observed values. Systematic testing and monitoring of → Quality before manufacture (incoming goods checking), during manufacture (quality control system) and afterwards (final testing, acceptance testing) are carried out. Statistical methods (→ Statistical quality control). are frequently used, or opto electronic testing plants.

Quality control for textile chemicals and dyes Textile chemicals and dyes are almost never chemically homogenous (reaction mixtures) and polyvalent. The quality of the product is defined by the requirements of the market. In the case of textile dyes, these can be for example coloristic tolerances (Fig. 1) as well as problem-free application, freedom from specks after application, low dust (in the case of powder dyes), dispersion stability in HT dyeing, stability in transit and storage, suitable viscosity, ecological and toxicological harmlessness, pad liquor stability, solubility (e.g. in the case of ionic and reactive dyes), fastnesses and redispersibility. To this list one could also add other desirable characteristics such as combinability and migration behaviour.

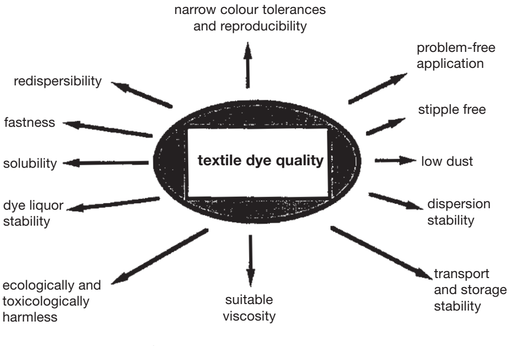


Fig. 1: Factors influencing dye quality.

adhesion dosible	**weaving**
wettability and washability extraction power bleach liquor stabilising power	**pre-treatment**
support of dyeing and printing processes	**dyeing and printing**
reactiveness tolerability influence on handle	**final finishing**

Fig. 2: Quality criteria for textile additives in various finishing stages.

A corresponding listing can, of course, also be made for the different auxiliaries for pre-treatment, dyeing or printing, after-treatment or resin-finishing (Fig. 2).

Products with these characteristics are developed to a high level with tight tolerances, depending on the range, formulations and strengths of the individual firms in the dyestuffs and auxiliaries industry, in partnership co-operation with the textile finishers, and are put on the market. This market supply is supported by the service and advice provided by the manufacturers. Taking an example from the area of “handling of dyes”, divergent – sometimes even contradictory – demands can be made of the quality of a product. In accordance with the various methods of application, the demands made of handling are wide-ranging, e.g.

- easy dissolution in the dyeing vessel,
- setting of stock liquors and pad liquors,
- stirring into printing pastes,
- weighing out the smallest amounts for tinting,
- processing with metering pumps.

In all these manipulations, the dye should not form dust, should not form lumps when introduced into water, should dissolve quickly and without leaving residues or be well miscible, should not be deposited or solidify anywhere. The manufacturer must also make sure that the dye’s characteristics do not change until processing, even under transportation and storage conditions which are sometimes extreme. For even when a dye preparation has left the works in which it was produced, it is exposed to hazards. Liquid preparations above all are, in extreme storage conditions, at risk of crystallising out, precipitation of components, and coarsening; also of changes in viscosity and thixotropy, which can lead to sediments. But granulate or powder brands too can change in the course of time by absorbing small amounts of moisture from the air, or by influences on the dust behaviour. Even the dispersibility of solid dispersion dyes can worsen when stored under unfavourable conditions, due to grain coarsening. Simple handling and safe processability are therefore determined to a high degree by the commercial form in which the dye is supplied (Fig. 3). Individual manufacturers use the most varied designations for commercial forms. They can be grouped according to external aspects.

Powder brands are generally supplied as largely low-dust. Dusting is frequently prevented by the addition of an emulsifiable oil. The de-dusting agent however has the peculiarity of migrating into the individual dye particles during storage, and thus over the course of time it can lose its de-dusting effect, depending on the character of the dye. Another way of achieving low-dust products is granulation. The glassy pellets produced during drying by spraying in hot air furnaces do not dust after manufacture. However, particularly during transportation, depending on the hardness and shape of the grain, dye can be rubbed off, which then becomes unpleasantly apparent as dust. For the manufacturer, granulation brings the additional difficulty that with drying through spraying of the dye solution, the standardisation must be concluded. A granulate cannot, by its nature, be tinted. Also, dusting fines have to be dissolved and returned to the manufacturing process of the dye. The advantage of powder brands of higher concentrations lies in their more favourable transportation weight and easier handling, when large amounts are to be processed. Less storage space is needed, and fewer drums accrue as waste. On the other hand, weighing errors and inaccuracies in the formulation have a far greater effect than with dyes with weaker settings. Many powder preparations have the common feature that they are hygroscopic and can take up moisture from the air in the room when drums are not hermetically sealed. Sometimes the dye solids bring hygroscopic characteristics with them ; often, however, there are also salts or surfactants which are used as setting agents or dispersing agents, and which attract moisture from the air. A low amount of moisture absorbed from the air is sometimes still undetectable in the outer aspect of the dye powder, but through weight increase it can become unpleasantly apparent in a notionally low dye strength. Pastes traditionally have a firm place in textile printing. Ease of working into the printing paste is the main advantage. Difficulties are to be expected with granulates, particularly coarse-grained ones, which do not distribute themselves evenly in the printing paste without prior dissolution. Liquid brands are however welcomed by continuous dyers, who have to set a large amount of dye in a concentrated pad liquor. Liquid brands can largely be handled without dust problems, and in this respect are also to be preferred for reasons of work hygiene. In the quality control of his dyes, the dye manufacturer must therefore, because of the overall complexity of the application, check the characteristics shown in Fig. 4.

The quality records play an important role in quality assurance. The description of the test procedure represents the basis of quality testing. For this reason, descriptions of the methods according to which textile dyes are tested are obtainable from all dye manufacturers. The recording of test results must be accorded par-

	powder	powder concentrate	granules	microgranules	paste	liquid solution	”liquid” dispersion
storable, ageing resistance	●	●	●	●			
no segregation, separation or sedimentation	●	●	●	●			
no dust			◐	◐	●	●	●
shipping costs		●					
sprinkles			●	●			
not hygroscopic			◐	◐	●	●	●
not agglutinating			◐	◐	●	●	●
precise weighing	●		●	●			
solubility, distribution			◐	◐	●	●	●
pump dosed						●	◐
processes large quantities		●				●	●

Fig. 3: Commercially available forms of textile dyes.

colour strength, shade	transmission remission visual analytical	exhaustion process, continuous process, printing
parameters from physical-chemical penalty tests	solubility insolubility finish	different conditions according to dye, e.g. filter test, praxitest, HST, aspect
	pH viscosity density conductivity	liquid dyes
	heavy metals content dust production	powder and granular dyes

Fig. 4: Important assessment parameters for the quality control of textile dyes.

ticular attention, since they will be required for the evaluation of samples in subsequent re-testing, for example in the case of complaints, and for statistical methods. Test parameters relevant to evaluation include e.g. the result of transmission measurement or reflectance measurement (i.e. colour strength, brilliance and shade) in various methods or data concerning solubility, viscosity, density, finish etc., which result from additional physical-chemical tests. In this way, several hundred thousand pieces of data are collected per year, with the number of original data (i.e. those resulting directly from the measurement process) and the raw data (after analogue-digital conversion) not being recorded. Dealing with this amount of data efficiently is only possible these days with the aid of data processing. An efficient option for this is provided by laboratory data collection systems or laboratory information and management systems (LIMS).

LIMS are systems for computer-aided

- sample administration,
- method administration,
- order production,
- protocol production,
- administration of reference samples.

Saving data in databases enables

- recording of the raw data from the analytical equipment,
- monitoring of calibration,
- research,
- long-term statistical evaluation,
- monitoring of costs.

With this system, complete sample administration is possible, from receipt of samples to protocol production and the administration of reference samples to the calibration of systems (Fig. 5). The storage of data, which sensibly also includes the raw data of the connected analytical equipment, ensures adherence of the calibration, enables research and long-term statistical evaluation, and – if applicable – monitoring of costs.

Important requirements of DIN ISO 9003, namely test equipment monitoring, checking the state of testing, quality records and the possibility of carrying out statistical methods, can thus be dealt with. They therefore satisfy not only the customer demands for quality assurance, but also in-house necessities. LIMS can only be employed efficiently if practically all analysis results of the various investigation points are included.

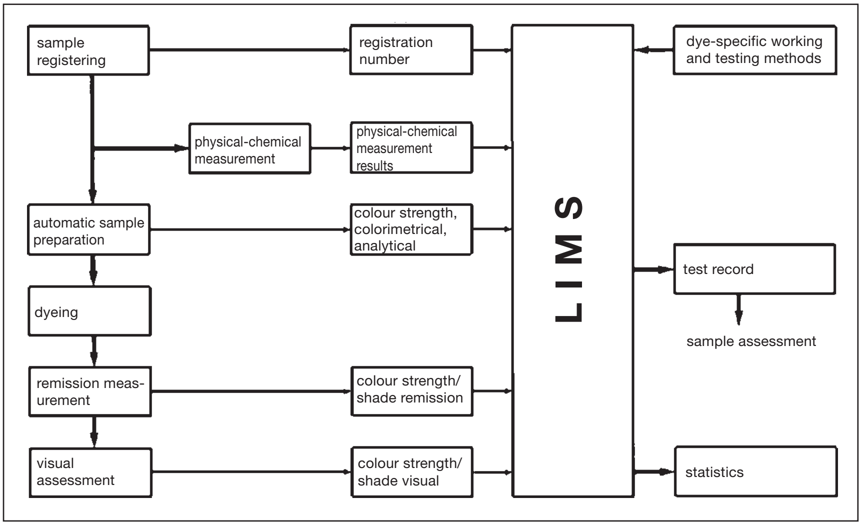


Fig. 5: Inclusion of LIMS in the quality control of textile dyes.

The possible integration of a LIMS into the organisational procedure of the quality control laboratory for textile dyes is shown in Fig. 5.

The LIMS is a central component for monitoring the work sequence. First of all, in the introductory phase the work methods and test methods for each dye must be precisely defined. The general work sequence of a sample, from registration through sample preparation and coloristic processing, right down to visual assessment, including the necessary physical measurements which include also qualitative and quantitative chromatographic methods of analysis, is emphasised. The values obtained for monitoring and evaluation parameters are transferred to the LIMS either automatically in-line, or via diskette transfer. The values of certain physical-chemical measurements, such as e.g. those of solubility determination and of visual assessment, have to be entered manually. As soon as the work list defined at the outset has been fully equipped with results, comprehensive sample evaluation can be carried out on the basis of the test protocol. The result of quality testing can then – possibly via in-company networks – be made available to all those sections which depend on them, e.g. in Production, Operations Planning and Despatch.

The heart of the plant is the automatic sample preparation, which due to the large number of data which accrue, is linked directly with the LIMS. Automatic sample preparation is to be regarded as an important step in the test sequence. Particular attention must be paid to it with regard to increasing the accuracy which can be achieved. Particularly in dyes which can be dyed with good reproduction, such as e.g. dispersion dyes, the reproducibility of sample preparation represents a decisive input into the overall reproducibility, and must therefore not be neglected. In order to determine the reproducibility of an automatic sample preparation system or laboratory dosing system, it is not sufficient to determine the metered amounts or concentrations of a dye by means of spectrophotometric determination. Balance-controlled testing of the reproducibility of a dosing system is absolutely necessary. This yields better reproducibility of automatic dosing systems in comparison with the average manual method. Through their higher level of reproducibility, dosing systems then also have their legitimacy for dye classes which can be dyed with less good reproducibility.

Besides this general increase in accuracy, by using automatic sample preparation systems, one is also freed of other human-related faults which come about through error. Thus with the introduction of laboratory dosing systems, there is an influence both on random, statistically controllable faults as well as on the systematic faults which are not statistically controllable. Laboratory robots which can take over the entire procedure of sample preparation are available for use as sample preparation systems in various versions. Sample registration takes place on the monitor by means of a barcode reader pen. It can also be carried out automatically from the sample vessel, with a laser scanner. Weighing in of solid or liquid dyes is carried out automatically by the robot. The addition of water in the case of balance-controlled solution and thinning is carried out with a hose pump, and in the final phase through jets controlled by stepped motors, to achieve the required accuracy. For transmission measurement, an aliquot amount is taken automatically, the weighed-in amount is determined precisely, thinned accordingly, and this solution is measured.

On the basis of the measurement results, dosing of the dye solution into the dyeing tubes takes place. The dosing of dye solution and auxiliaries into the dyeing tubes is monitored by means of a balance. At this point, the weighed substrate can be assigned if necessary.

Colorimetric determination of colour strength, i.e. transmission measurement, represents a partial stage within automatic sample preparation. The transmission measurement is therefore of particular interest in quality control, since it enables fast, orienting determination of colour strength and, within limits, the shade too, with good reproducibility. In the case of dye classes which take up more or less completely from the bath to the fibre, and in which standard and sample behave identically, it leads to good results. Specifically in the case of reactive dyes, transmission measurement has recently achieved increased status through its use in combination with chromatographic methods of analysis. This modern type of colour strength determination, based on purely analytical methods, should in the future appear alongside traditional colour strength determination by means of coloristic methods. In reactive dyes, the problem is well known that during synthesis, it is inevitable that a certain proportion of non-reactive hydrolysed dye arises, which contributes to the overall chromophore content in the transmission measurement. If one is able to determine quantitatively this non-fibre-reactive constituent, or better, to determine the overall reactive proportion of a sample, then this can be placed in relation to the transmission measurement, and the coloristic colour strength can be determined analytically. The possibility of quantitative analysis of dye samples is provided by quantitative thin-layer chromatography and HPLC.

The reproducibility of dye strength determination is determined by the quality of the separation of the individual components present in the sample. The method has to be optimised for each dye, in relation to the stationary phases and mobile solvent mixtures used. If the involvement of the dye components in question in the dyeing process is known, and if good chromatographical separation of the constituents is achieved, then a smaller standard deviation of the colour strength determination compared to the coloristic method is to be anticipated, i.e. the dye strength can then be determined with greater accuracy. This requires extensive preliminary analytical work for each dye. The standard deviation of the photometric-chromatographic determination of the colour strength is – due to the problems already mentioned – not generally smaller than that of coloristic colour strength determination. Since in the coloristic determination method too, dye-dependent fluctuations in the standard deviation can be detected, to achieve optimum reproducibility one must select the most suitable method in each case. It can therefore be said with some certainty that the quality control of textile dyes will in future not move exclusively towards purely analytical methods. Dyeing methods will retain their legitimacy, particularly because shade determination can be carried out by analytical methods only with great difficulty. As is known, dye-active secondary components of the order of <0.1% can cause a discernable shade displacement of the dyeing, through which the tolerance range of the shade can be exceeded. In this concentration range, the reproducibility of the chromatographic methods is not yet sufficient to make an accurate prediction. (Source: Varwig, as well as Leube, and Kunze).

Quality control in the textile finishing industry This is necessary in order to guarantee quality within the field of textile finishing. Quality can be guaranteed, because the textile expert has learned to take account of unevennesses, e.g. in the case of different consignments of raw materials, through the use of finishing technology, in that evaluation criteria are used to characterise the raw goods and the finished goods. Quality assurance starts with the selection of quality characteristics, and establishing required and reliable values for them. For example: measurable (quantitative) features, e.g. mass per unit area; countable (qualitative) features, e.g. defects in the goods; (subjective) classifiable features, e.g. handle; mixed forms (if a colour is evaluated in a colour measuring device, this is a quantitative feature, but if it is appraised visually with a limiting sample, then this is a qualitative feature). The corresponding test methods are laid down in DIN standards.

Quality control system (quality regulation). The control of manufacturing processes to achieve the required → Quality.

Quality costs An essentially incorrect expression used to denote costs which arise in the course of efforts to secure the → Quality of satisfactory services, and as a consequence of quality standards which have not been maintained. Quality costs thus relate to services which have been or are yet to be rendered. Quality cost groups according to the DGQ (German Society for Quality) include: error prevention costs, testing and evaluation costs, error costs.

Quality criteria in pretreatment The pretreatment of cotton fabrics influences the quality of the fabric, above all in the case of boiling off and bleaching. The success of bleaching is measured by determining the degree of whiteness (by colorimetry). To determine the quality, the absorbency is tested after boiling off. For this purpose, one can also determine the residual fat content by means of Soxhlet extraction (see table). True absorbency should be achieved. Complete removal of the fatty substances is not recommended, since this results in an unpleasantly brittle and rough handle. In some cases it is necessary to determine the residual content of mineral substances (residual ash content). If damage from alkaline treatment is suspected (e.g. the formation of oxycellulose), then the decrease in the degree of polymerisation or the tear strength must also be checked. In many cases, boiling off is sufficient as a preparation for coloration (e.g. for dark dyes or covered, full print surfaces); bleaching is not necessary.

goods	unfinished	desized	scoured
absorption	0	0	60 mm
whiteness	52,0	52,2	58,2 (Elrepho 46)
fat content	1,02%	0,80%	0,19%
size content	6,75%	0,55%	0,33%
ash content	1,26%	1,01%	0,22%
iron content	62 ppm	53 ppm	11 ppm
degree of polymerization	3020	2940	2810

Tab.: Measurement of quality factors.

The consequences of pre-treatments which have been improperly carried out are often problematic. First and foremost are the formation of creases and marks. Individual patches which have dried on during the boiling off stage, or residues of sizing agents, also leave visible traces after dyeing. Partial or irregular removal of the fats or mineral substances leaves traces in the form of uneven or weak dyeing, changes of shade from selvedge to centre, or poor penetration of printing. In the case of boiling off under unfavourable conditions, the risk of the formation of oxycellulose increases. In the case of polyester / cotton fibre blends, the delamination effect on the polyester must definitely be taken into account.

Quality number for fibres,

I. Conventional reference value for (tensile) strength, titre strength in cN/dtex (previously g/den; p/dtex). Conversion to (substance) tenacity: quality number multiplied by 9; conversion into substance strength: quality number multiplied by 9 multiplied by density.

II. In the quality number, 5 characteristic, mechanical, technological properties of different fibre types are assigned to a so-called ideal fibre = 100 reference basis. From this, the characteristics for each fibre type its are expressed as percentages, and their mean value represents the quality number. With the rankings which are thus calculated, polyamide fibres for example are assessed at 82.7, polyester fibres at 75.8, cotton at 53.2, polyacrylonitrile fibres at 50.6, and PVC fibres likewise at 50.6, etc. This classification according to this evaluation principle does not take account of the actual material quality and important characteristic properties.

Quality protection This covers the establishment of quality features which are decisive for serviceability, and the organisation for monitoring these features, with the aim of achieving assured reproducibility. → Quality symbols.

Quality-related abbreviations,

TQM = Total Quality Management
CAQ = Computer Aided Quality Assurance
QA = Quality Assurance
PSG = Problem-Solving Groups
FMEA = Failure Mode and Effects Analysis
SQC = Statistical Quality Control
SPC = Statistical Production Control
LIMS = Laboratory Information and Management System

Quality sample Representative sample for the final quality of the goods.

Quality standards → Requirement profiles.

Quality symbols These are logos or symbols, or both, which are used as a guarantee mark to label goods or services which fulfil certain characteristics generally regarded as important for the quality of particular goods or services, and which are measured on objective scales, and the bearers of which are quality associations which set up publicly accessible quality conditions, and monitor their fulfilment, or which are based on statutory measures. The quality conditions result from the principles for quality symbols issued by the RAL (RAL = German Committee on Conditions of Supply and Quality Assessment), which have been set up by the leading organisations of the Germany economy together with the Federal Ministry of Finance, in accordance with the prevailing view. Examples: charmeuse quality symbol, creaseproof, rapid iron, Scala d'oro, Schwurhand, Super Cotton, attested.

Quality testing Determination of the degree to which goods meet the requirements made of them. → Quality assurance must be guaranteed.

Quantitative dye determination on textiles,

I. Extraction method: With the aid of a solvent or an azeotropic mixture, the dye is loosened from the fibre by means of extraction. The concentration is determined via a photometric assessment of the extract, by comparison with known extinction coefficients. In this method, there is the risk of dye changes through the long reaction time at high temperatures. Also, there is only a limited number of solvents and azeotropic mixtures available. This method is uneconomic for small substance samples.

II. Solvent method: Dissolution of the fibres and the dye in a suitable solvent (e.g. polyamide in 85% formic acid and in m-cresol, or cellulose in 80% sulphuric acid). This method is quick, but not universal. There is the risk of clouding through dulling agents, discoloration through substrate decompositions, and lack of solubility of the substrate after cooling.

III. Residual liquor method: This is based on determining the dye which has not been taken up. This method is somewhat cumbersome, since dye which is removed during rinsing also has to be taken into account.

IV. Repeated boiling out in solvents or solvent mixtures. The fibre material is heated up repeatedly together with fresh solvent. This method is very versatile and saves dye, and there is a greater choice of solvents, since the fibres can be allowed to swell or even lose their shape.

V. Specific detection methods for some characteristic elements, such as, e.g. the colorimetric determination of copper, nickel, iron, cobalt, etc.

VI. → X-ray fluorescence.

Quantity of heat →: Joule; Radiant energy.

Quarter,

I. English measure for carpet width: 1 quarter = 9 inches = approx. 23 cm.

II. German carpet measure, now obsolete, equivalent to $^1/_4$ cubit, or approx. 17 cm.

Quartz In the case of glass, an isotropic mixture of silicates. However, there are also uniform, glass-like compounds such as quartz glass (silica glass), an amorphous silicon oxide. For this glassy state, it is characteristic that - in contrast to crystals - it does not have the space lattice consisting of strictly regulated repeating elements, but that the connection of its particles is irregular. This is also clear from an X-ray diagram, which is similar to that of amorphous substances.

The characteristic feature of such a compound consists of the fact that it is composed of the spatial network of SiO_4 tetrahedrons, in that each Si^{4+} ion is surrounded tetrahedrally by four O^{2-} ions. These tetrahedrons connect with one another in such a way that two tetrahedrons have only one oxygen ion in common. Such a network is present in quartz, but also in other modifications of silicon oxide, where however the arrangement is strictly regular. In glass, the tetrahedrons form irregular rings which consist of groups of different numbers and which are not periodic, but which have sufficient space in their clearances for alkali ions and alkaline-earth ions (see Fig.).

Since this network is irregular (amorphous), its physical attributes do not depend on its direction, since through statistical compensation each individual direction will have the same value. The glass is thus isotropic, and does not have double refraction. A further feature of this amorphous body is that glass does not have

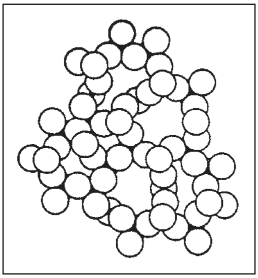


Fig.: Tetrahedral-like spatial reticular structure of quartz.

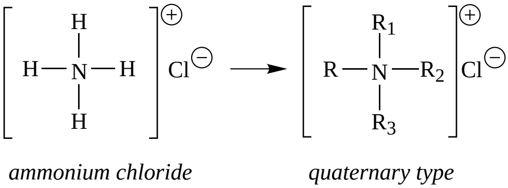
a fixed melting point. Rather, during heating its characteristics change gradually, with weakening strength.

Quartz fibre (quartz wool) Quartz fibres represent a special form of → Glass fibres. Quartz is a fusion product of silicon oxide, which does not show any crystal arrangement when cooled slowly (lattice silicate). The way in which these are obtained corresponds to that for glass fibres. Quartz fibres are stable up to a temperature of 1200–1300°C, and the melting point lies at around 1700°C. Resistance to acids is very good, and resistance to alkaline solutions is good. The remaining characteristics are similar to those for glass fibres. Used mainly for insulation purposes, filtration, and sensitive measuring instruments. Due to their high level of brittleness, quartz fibres are not used for textile purposes.

Quartz lamp (quartz mercury lamp). → Ultraviolet lamp.

Quaternary (from the Latin quattuor = ‘four’). Quadruple substitution, e.g. by alkyl groups, such as with the most important → Quaternary ammonium compounds and phosphonium compounds, where the alkyl complex occurs as a cation.

Quaternary ammonium compounds Bases and salts which are derived from the ammonium group (NH_4), in which all four H atoms are replaced by → Alkyls, as shown in the following example diagram:



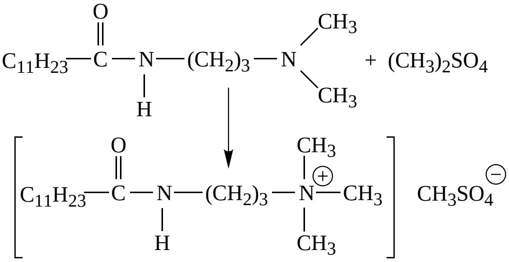


Fig.: Quaternary ammonium salts (lower alkylamine/-amide).

The free ammonium bases are, similarly to caustic soda, strong bases and are water-soluble even with higher-molecular alkyl residues. Their salts form neutral aqueous solutions, practically do not hydrolyse, behave like soaps (so-called invert soaps), but are decidedly cation-active. Products of this type thus lead to a range of well-known textile auxiliaries as cation-active softeners, for increasing the wet-fastness of direct dyeings, for levelling out cationic dyeings, and for stripping. Also of interest are discharge salts and bactericides.

Characteristics:

- well soluble in water,
- high adsorption tendency on surfaces,
- anti-microbial action,
- high derivation ability for electrostatic charges.

For this reason, quaternary ammonium compounds are used as:

substance	symbol	R code	S code	water endangerment category	special characteristics	remarks
stearylamine X1OEO	Xn	22-38-41	26-28/W 37/39	2	contains etholylated amine	–
stearin acid-dimethylaminopropylamide stearin acid-dimethylentriamide stearin acid-aminoethylethanolamide	Xi	36/38	24/25	1	none	–
cocodimethylbenzylammoniumchloride	C	22-34	24/25 36/37	3	contains quaternary ammonium compounds	hazardous substance
distearyldimethylammoniumchloride	Xi	10-36/38	26-28/W 38/39	2	–	hazardous substance
methyl-di(talgamidoethyl)-ethanolethylammoniumethylsulfate	Xi	10-36/38	26/28/W 37/39	2	–	hazardous substance for sea and air transport (except as formulation)

Tab. 1: Products ordered according to the Dangerous Substances Ordinance – softener raw materials.

substance	fish toxicity LC_{50}	daphnia toxicity EC_{50}	algal toxicity EC_{50}	oral toxicity LD_{50}	breakdown OECD	WEC
DS DM AC	1–6	0,1–1,0	1,4	5000/20000	94 %	2
imidazolinium salts	1,5–40	1,8–100	3,2 16,6	3300/10000	90 %	2
alkylbenzyl DMAC	3	5,7 bacteria		600		3
alkylamin-ethoxylate	0,7 1,0–2,5 5–10	1,3 3–10 10–30			80 %	2
	a	b	c			

evaluation number

$$WEN = \frac{ENa + ENb + ENc}{3}$$

WEN		WEC
0–1,9	=	0
2–3,9	=	1
4–5,9	=	2
6	=	3

grading LC/EC_{50}	
1 mg/l	very toxic
1–10 mg/l	toxic
10–100 mg/l	moderately toxic
100–1000 mg/l	slightly toxic
1000 mg/l	barely toxic

Tab. 2: Determination of the water endangerment category of quaternary ammonium compounds, alkylamine-EO.

- soft handle agents,
- retarders in polyacrylonitrile dyeing,
- discharge agent additive in vat dyeing,
- colourfastness improvers,
- anti-static agents,
- bactericides, fungicides, algicides,
- flocculants in waste water treatment.

Certain amines (see Fig.) are toxic, however, and are therefore to some extent classified in lower water endangerment classes (Tab. 1).

The particular toxicity in relation to aquatic life forms (Tab. 2) is based on a blocking of gill breathing through interface activity in combination with a marked tendency towards adsorption. In relation to mammals, some species develop a subcutaneous toxicity similar to that of the arrow poison curare used by South American Indians (Tab. 3). Once they have entered the bloodstream, a competitive effect occurs at the polysynaptic acetylcholine receptors, which leads to neuromuscular blocks e.g. of the respiratory musculature, and thus to death with full consciousness. Examples of this are the recently developed silicon polyquats, which with increasing quat modification to improve softness, bath exhaustion rates, water solubility, electrolyte stability etc. suddenly become highly toxic when certain neuronal distances are fulfilled, in the manner of the lock-and-key principle.

beef-tallow:	no value found
stearin acid:	10000 mg/kg
stearyl alcohol:	2000 mg/kg
stearylamine:	2000 mg/kg
oleylamine:	200 – 2000 mg/kg

Tab. 3: Oral toxicities.

If one follows the evaluation diagram for substance classification into water endangerment classes in accordance with section 19 of the German water resources law (KBwS), quaternary ammonium compounds should be assigned to classes 2 and 3. If the legislator acts in accordance with the principles of consistent environmental protection, as has already happened with non-ionic and anionic surfactants, then a global classification of all quaternary ammonium compounds under class 3, may be expected although on the basis of the evaluation diagram only individual representatives would be placed here. In accordance with the catalogue of requirements for “storage”, this circumstance may result in considerable investment costs, associated with a prohibitive explosion in costs.

Quaternization of monochlorotriazine reactive dyes Normally, monochlorotriazine reactive (MCT) dyes react with cellulose only under alkaline conditions. However, if one adds tertiary amines to a neutral printing paste, the reaction can proceed during steaming even below pH 7 (Fig. 1).

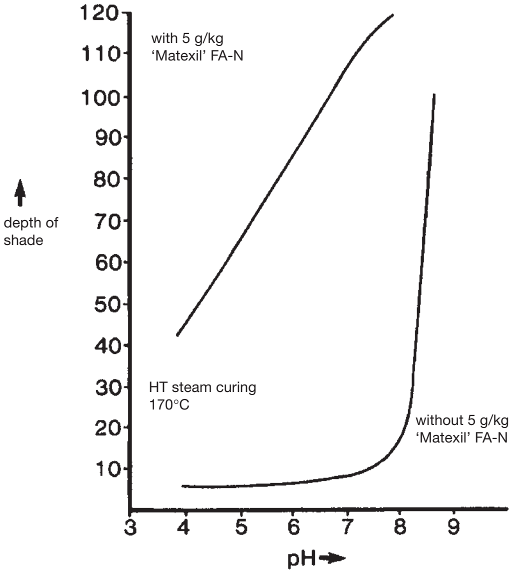
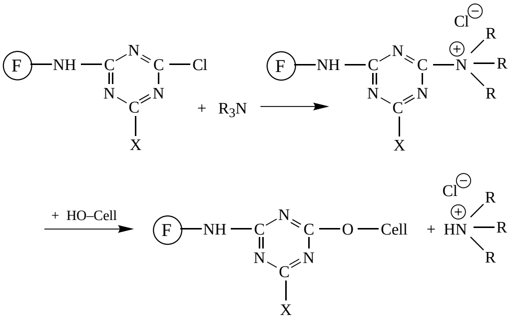


Fig. 1: Dye yield in relation to pH for the reactive dye component of Procilene-Red-N-4G-mixed dye (ICI) in liquid form on mercerized cotton (Matextil FA-N is a class 3 quaternary catalyst).

Here, one can establish a basic reaction in the four classes of differently active amines (Fig. 2).



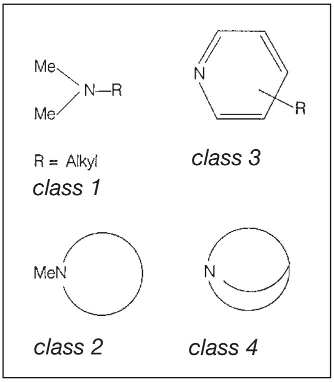


Fig. 2: Classification of typical quaternary compounds. Class 1: e.g. simple aliphatic amine; Class 2: e.g. N-methylpyrrolidin; Class 3: e.g. alkylpyridin; Class 4: bridged structures such as that of 1,4-diazabicyclo-(2,2,2)-octane (DABCO).

Quats → Quaternary ammonium compounds.

Quick-action drain valve enables a plant to be drained even at temperatures of 135°C, without the contents of the apparatus having to be cooled to at least 80 °C, as is usually the case. Drainage is thus accelerated. In the case of polyester, the oligomers are largely removed at the same time. Waste water can be used to cool the liquor which has been drained off, which saves on costs. The HT quick-action drain valve (Fig.) can be retrofitted onto plants of all types, and in some cases 2–3 machines can even be drained one after another by means of one device.

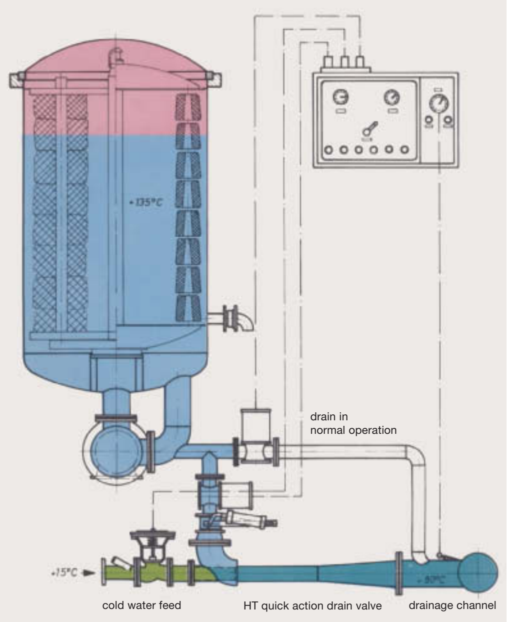


Fig.: HT quick action drain valve by Jasper.

Quick-action stop valve Actuating drive with high regulating speed. Used for example on otherwise hand-operated valves, in order to effect fast closure of the valves.

Quick copper detection in effluent or water 50 ml of the water to be tested is added to 2 ml of a light coloured oleic acid. After the mixture has been thoroughly shaken, the creaming oil layer reveals a weak to strong green discoloration in the presence of copper (copper oleate). The presence of more than 1.2 mg/l of iron upsets this colour reaction of course.

Quick dyeing Rapid dyeing process for synthetic fibre material. The reduction in time is enabled by rapid heating of the dyeing liquor and by a rapid cooling phase. It is predominantly polyamide fibres which are dyed by this method.

Quick lime (calcium oxide). White to grey in colour, formed through heating and roasting of calcium carbonate (chalk, limestone, marble) $CaCO_3$. Very fire-resistant, melts only at 3000°C. Used for furnace lining, etc.

Quick response (QR). Sales-oriented flexibility of textile production works, aimed at responding quickly to the market. In contrast to "just in time" solutions, QR does not aim at minimising warehouse stocks, but attempts to keep the production aligned as optimally as possible to the customer's requirements, in both technical terms and by integration into holistic business management procedures. In practice, this results from the acknowledged necessity of flexible production, which derives from a profile of requirements:

– more variants,
– higher quality,
– more economical offers,
– rapid delivery;

in other words, requirements which, according to classical business management wisdom, make the manufacture of large batches almost impossible.

Key points of the quick response strategy in the textile and clothing sector are new forms of inter-company co-operation in a vertical direction (possibly also horizontally), in order to be able to serve the markets faster and in a more targeted manner. The aim is thus a concretisation of strategic alliances, taking account of the "textile pipeline". It is to be expected that further reserves of synergy can be opened up through vertical and interdisciplinary co-operation.

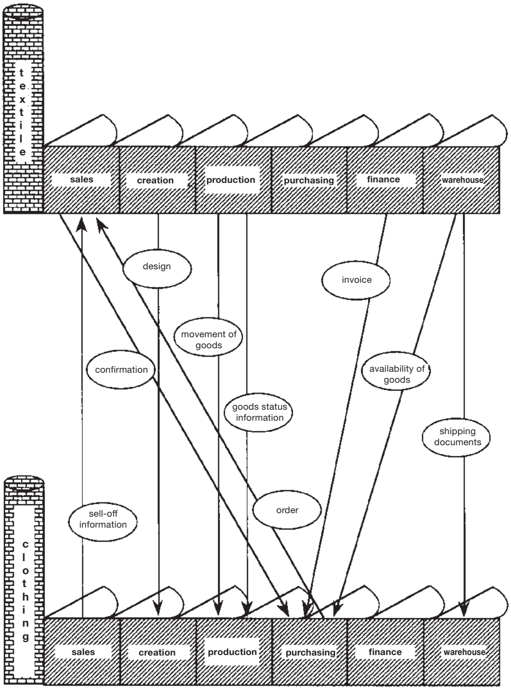


Fig.: Only the complex networking of the textile and clothing industry by means of EDP makes "quick response" possible.

Quick response is to be regarded as a marketing strategy which combines technical and economic areas with one another via a thorough information system. However, this information connection must also be seen as extending across production stages and across companies (see Fig.). This requirement includes dealing with two problem areas: a) On the one hand, the problems of technical data exchange between firms (data formats, synchronisation etc.) must be solved. An initial standardisation is emerging in the form of the EDI format (Electronic Data Interchange), for which initial sector-specific adjustments are in progress. The data format EDIFACT (Electronic Data Interchange For Administration, Commerce and Transport), developed for the textile industry, is relatively unknown at present, and has only limited circulation. It is expected that EDIFACT will become the standard in the future. b) On the other hand, it must be acknowledged that the free exchange of data can also bring with it business management problems. The possibility of being able to have free access to suppliers' data demands responsible handling of this information by all those involved. Without an understanding of the co-operation as a "risk partnership", this concept barely stands any chance of realisation, since smaller enterprises will hardly take the risk of "master-slave co-operations". Whether this risk can be applied to smaller firms without a market-controlling position remains controversial for the time being. Current observations suggest that QR initiatives are particularly to be found in larger enterprises with important market positions (e.g. Benetton, Schiesser, Bogner).

In-house logistics optimisation is an important prerequisite for the functioning of QR. There are initiatives for computer-aided warehouse administration as well as chaotic warehouses; the use of barcodes is aimed at. In the area of production planning and control, there are at present no standard solutions available on the market. Individual company solutions require a high expenditure on implementation. An essential part of a production planning and control system is the order processing, order tracking and the organisation of queues, on the basis of disposition which takes account of need. Simulation is available as an instrument for this; the first simulation solutions can already run on PCs. The aim is "knowledge-based production planning", which cannot be realised without the use of databases. Also, production planning can only develop its full effect if it is realised in connection with quality planning.

Quillaya bark → Panama soap.

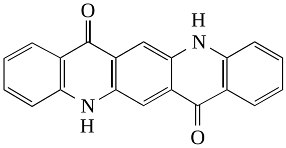
Quilt fabric → Piqué.

Quilt in, to Transfer of the printing dye paste from the chassis to the → Blocks for printing (hand printing).

Quilt lining Lining material from quilted non-woven fleece (padding), wadding or foam material on lining material, duchesse, serge, etc.

Quilt wadding Goods of the → Maliwatt fabrics; for wadding, lining purposes, layer base for tensioning purposes, insulating material, etc.; 200–425 g/m.

Quinacridone Sub-group of the → Carbonyl dyes, as a dicarbonyl compound:



Since 1957, they have played a large role as pigment dyes, in various crystal modifications. The excellent solvent fastness as a consequence of their low solubility is, in turn, attributable to the strong dipoles of the acridone rings and the intermolecular hydrogen bonds between the associated, planar molecules.

R

R (formula residue), used in chemical formulas as abbreviation for "residue" e.g. residual fatty acid with a simple or branched (hydrocarbon) chain.

ºR Degrees → Rankine.

RA → Ramie → Textile fibre symbols, according to DIN 60 001 T4/08.91.

Ra,

I. → Ramie, → Textile fibre symbols, according to DIN 60 001 until 1988; → RA.

II. Element symbol for radium (88).

Rabbit hair →: Hare and rabbit fibres; Angora.

Racemates (racemic compounds). Lat. acidum racemicum (grape acid), where this phenomenon was first investigated. They occur in chemical reactions in which optically active compounds are involved, by releasing and re-linking bonds. So-called racemates or racemic mixtures are produced from sterically unique compounds (dextrorotatory or laevo-rotary) as mixtures of both types. → Optical Activity.

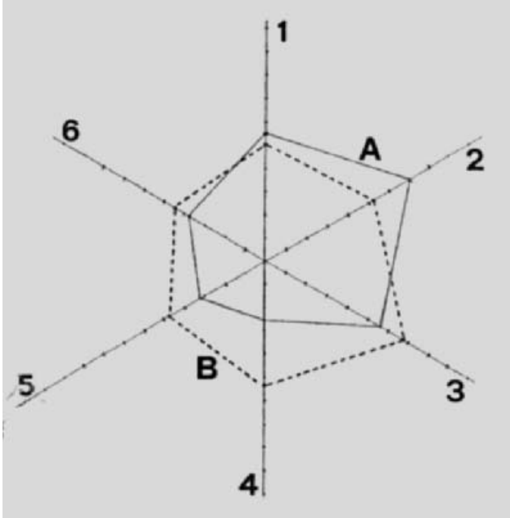


Fig. 1: Rader diagram showing the assessment of handle (as by Kawabata) of a material made from super-microfibres, both in the raw state (A) and following treatment with alkali. 1 = stiffness (koshi); 2 = poor fall (hari); 3 = body and softness (fukurami); springy elasticity (shari); 5 = silkiness (kishimi).

Rader diagrams Used for depicting handle, determined on 6 axes using the → Kawabata system, for example. Fig. 1 shows a Rader diagram comparing the handle of a rough and of a finished fabric. Although there is a reduction in the stiffness value (hari/koshi), there is an increase in flexibility, handle (shinayakasa), volume and softness (fukurami) and elasticity (shari).

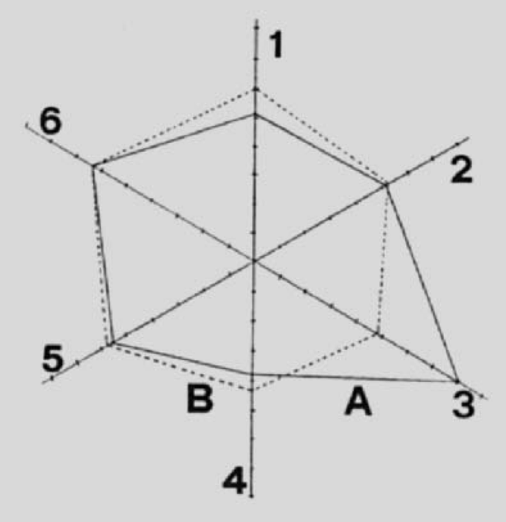


Fig. 2: Rader diagram of a super-microfibre fabric (A) and a silk fabric (B).
1–5 see Fig. 1; 6 = elasticity (shinayasaka).

Fig. 2 shows a Rader diagram comparing the handle of a super-microfibre fabric to that of a silk fabric. It is assumed that the elasticity of the super-microfibre fabric is less than that of the silk fabric; however, the fullness and softness are much better, whereas both the stiffness and flexibility with a soft handle are almost the same.

Radial Radiating from the centre (of a circle) to the periphery; e.g. the horizontal radial section of the → Flax stem structure.

Radial dyeing machine Packing system dyeing machine with circulating liquor. Either (older version) as round dyeing machine made from cast iron for dyeing hank yarn or made from stainless, acid-resistant steel with liquor recirculation (see Fig.). Usually heated indirectly by steam. The material block is lifted after dyeing on the material carrying plate and is spun in a conventional centrifuge, the upper rim of which can be removed. This kind of special centrifuge is no longer in use, since a normal centrifuge can be used after a batch has been dyed in the radial dyeing machine. This includes other batches such as piece goods, hanks, bobbins. Radial dyeing machines are also used for dyeing wool, cotton, viscose, polyamide, acetate, polyacryl nitrile, hair and rags.

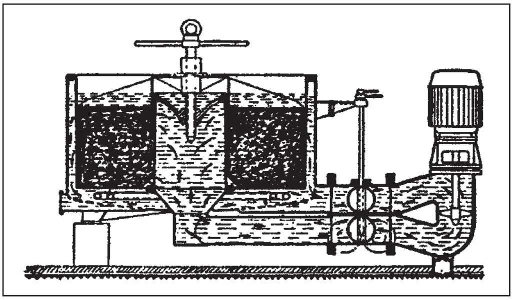


Fig.: A radial dyeing machine (Krantz) for loose fibres.

Radiant energy, quantity of heat In the → SI System of Units the radiant energy watt (W) or joules per second (J/s) and multiples; as a unit of quantity of heat the watt second (Ws) or joule (J) and multiples (i.e. also kilowatt seconds).
W = 1 J/s = 0.86 kcal/h
1 Ws = 1 J = 0.239 cal = $0.239 \cdot 10^{-3}$ kcal
1 kWh = 3.6 MJ = 860 kcal

Radiant intensity per unit area → Brilliancy.

Radiant-Panel-Test (heat radiation shield) combustion reaction at an elevated temperature is measured by subjecting a horizontal sample to heat and burning it. The minimum heat flux at which the carpet starts to burn is assessed.

Radiation One differentiates between wave radiation (e.g. electromagnetic radiation) and particle radiation (e.g. radioactive radiation); →: Light wavelengths; Radiation, comparison of different types. For textile applications, e.g. in drying or measuring and control technology, different types of radiation are utilized, e.g. →: Infrared; Microwaves; Radioactive emission; Ultraviolet radiation.

Radiation, comparison of different types Energy rich or ionizing → Radiation (see Tab.) from a few kiloelectron volts keV to a few megaelectron volts MeV is of interest for radiation chemical applications (electronvolt definition: 1 eV is the energy which an electron possesses, if the potential energy of 1 Volt passes through it).

radiation type character	type of radiation	energy	wavelength
electo-magnetic radiation	infra-red	0.01-1.6 eV	780-1000 nm
	visible light	1.6-3.3 eV	380-780 nm
	ultra-violet	3.3-6.2 eV	200-380 nm
	vacuum ultra-violet	6.2-310 eV	4-200 nm
	X-radiation	keV-MeV	< 100 nm
	γ radiation	keV-MeV	< 100 nm
corpuscular radiation	α radiation	1-10 MeV	—
	β radiation (electron radiation)	keV-3 Mev	—
	accelerated electrons	0.25;15 Mev	—
	neutrons (^{1}n)	1 to a few MeV	—

Tab.: Comparison of radiation types.

Radiation heat losses from dye liquors and dyeing machines Radiation and evaporation at open liquor surfaces:

equation for the calculation of heat loss:

$$Q_2\ [\text{Joule}] = q_2 \frac{[\text{Joule}]}{[\text{m}^2] \cdot [\text{h}]} \cdot F_2\ [\text{m}^2] \cdot T_H\ [\text{h}]$$

Q_2 = radiation and evaporation losses [joules],
F_2 = radiating open liquor surface [m^2],
T_H = temperature retention time [h] (in this equation minutes are also used instead of hours and divided by 60),
q_2 = temperature dependent radiation coefficient for open liquor surfaces [joules/m^2/h].

The following temperature dependent values apply for the radiation coefficient q_2 [kJ/m^{2}h]:

20°C	440
30°C	2055
40°C	4735
50°C	8590
60°C	13 575
70°C	21 200
80°C	31 720
90°C	43 030

These figures are valid for air temperatures above the liquor surface of 25°C and air speeds < 1 m/s.

Some findings from this: at air temperatures higher than 25°C, which almost always prevail in the layers of air above the liquor surface, e.g. in preparation and overflow vessels, due to heat radiation, the air humidity absorption power is correspondingly higher, which equates to higher evaporation losses. The same also applies if a stronger air flow carries away the moisture saturated air in the overflow vessel. These influence variables have been disregarded here. However, comparing the radiation values of q_1 with q_2 for uninsulated vessel surfaces, then one finds that open liquor surfaces that are not absolutely necessary must be eliminated for reasons of energy economy.

Radiation at uninsulated autoclaves:
equation for the calculation of heat loss:

$$Q_1\,[\text{Joule}] = q_1\,\frac{[\text{Joule}]}{[m^2]\cdot[h]}\cdot F_1\,[m^2]\cdot T_H\,[h]$$

Q_1 = radiation losses [joules],
F_1 = radiating surface of the equipment [m^2]
T_H = temperature retention time [h],
q_1 = temperature dependent radiation coefficient for uninsulated equipment surfaces [joules/m^2h].

The following temperature dependent values apply for q_1, the radiation coefficient of uninsulated equipment surfaces [kJ/m^2 h]:

30°C	80
40°C	755
50°C	1215
60°C	1680
70°C	2265
80°C	2850
90°C	3480
100°C	4110
110°C	4775
120°C	5450
130°C	6285

These figures only apply with static environmental air. If the temperature varies over time, e.g. heating up, cooling down, then the temperature dependent radiation coefficient q_1 also changes. In this case, the heat loss is calculated based upon average temperature for heating up (from 40°C to 130°C, thus by 90°C), working with the corresponding q_1 value. Alternatively, the heating up curve may be divided into several vertical temperature increments and a corresponding number of horizontal retention times, whereby it is possible to detect the heat loss during the heating up phase in as many individual calculation operations as desired (iteration). The smaller the "step height" of the "temperature stairway", the more calculation operations have to be performed. The number of calculation operations determines the precision of the result.

Radiation intensity of a light source corresponds to its power. It is significant for the illumination times in copying processes (contact printing process) for pattern transfer on rotary screen printing screens, however it does not influence the copying definition. Because the radiation intensity should be distributed as uniformly as possible during the illumination of a round screen cylinder, which is most true for parallelized light that falls at a radiation angle of 90°, screens are used to aid uniform distribution (e.g. honeycomb screens).

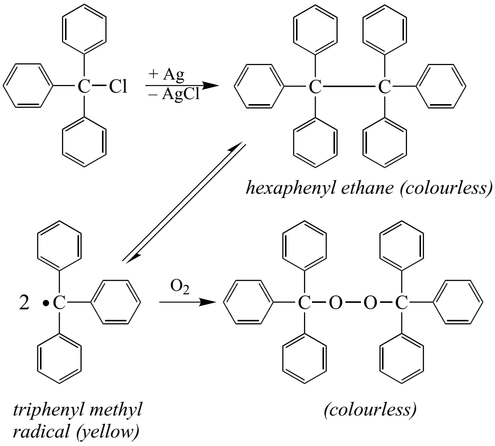
Radiation meters Electrical devices for the direct detection of radiation, e.g. radioactive emission, ultraviolet radiation, X-rays, etc. Usually so-called counter tubes, in which the locally scanned radiation impulse (due to the ionization of the contents of the counter tube, a discharge impulse occurs, which triggers a voltage impulse at a working resistance) is measured via an amplifier by the deflection of the pointer of a normal current measurement instrument, or by means of a counter if there are low particle numbers. One common radiation sensor is the so-called Geiger-Müller counter, with which the intensity distribution along a length of material, length of thread, etc. can be measured.

Radiation pyrometer Instrument for non-contact measurement of temperature of bodies, e.g. of textiles during heat treatment.

Radiation singeing Indirect → Singeing, without contact between material and flames. The effect is achieved by re-radiation from bricks heated to high temperatures.

Radicals (Lat: radix = root) groups of atoms with free valency that cannot exist under normal conditions (unbound electrons). For example, if triphenyl methyl chloride is treated with finely-distributed silver in benzene in a vacuum, a yellowy solution is produced. If this solution is treated in air, the yellow colour disappears.

Radicals contain unpaired, free electrons that cannot be localised in the molecular structure because more than one valency structure (and therefore mesometric stabilisation) guarantees the existence of the radical. The free valency (the unpaired electron) is stabilised by the exchanging of many atoms (resonance) in the molecule.



Radioactive density determination

The greater the number of possible mesomer forming limits, the greater the delocalisation of the free electron, thus reducing the total energy level of the radical and making it more stable (long-lasting). In the triphenyl methyl radical the unpaired, free electron can occur in ten different positions, namely in methyl carbon and in all other o and p positions in the three phenyl nucleii. The resulting resonant energy of the radical is about half as great as the binding energy of the C–C bond in hexyaphenyl ethane. The stability of the two triphenyl methyl radicals is so great that the equalisation reaction is displaced to the side of the dissociated substance. The colour of the triphenyl methyl radical results from the mesomer structures' capability of absorbing light energy.

In magnetic measurements radicals proved to be paramagnetic, because the spin of the lone electron is not compensated for. Organic compounds are normally diamagnetic.

Radioactive density determination If emissions from radioactive isotopes penetrate material, its intensity is weakened in accordance with the mass of the irradiated layer (Fig. 1). The surface weight, thickness or density of the measured material can therefore be determined from the change in energy received from a radiation source of known intensity. The measurement is continuous and non destructive and has no effect on the properties of the tested material. The accuracy of surface weight measurement using isotope radiation and the measurement resolution are so good that changes of < 1 g can be determined in a material with a weight of 150 g/m^2, for example.

The radiation source is in a stable, radiation-proof housing whose efflux window is only opened when the device is switched on. If the power fails or is turned off, a steel disk covers the window automatically in order to protect the operators. Surface weight measuring systems also comply with the relevant radiation safety regulations. Special models can be provided (Fig. 2) for various measuring tasks such as monitoring and controlling the surface weight per square metre of effective material, measuring the thickness of coatings and other application techniques.

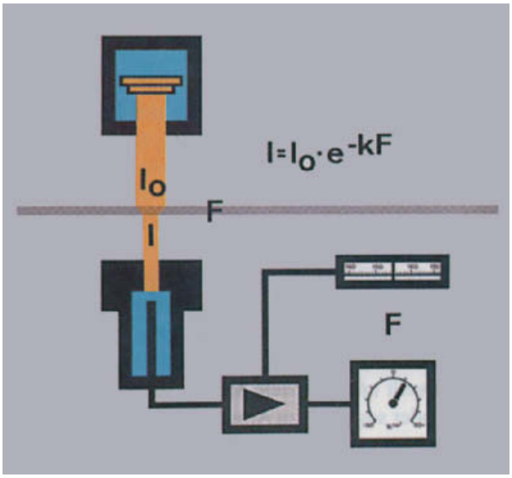


Fig. 1: The principle of determining the density of planar structures with the aid of radioactive emissions (Mahlo).

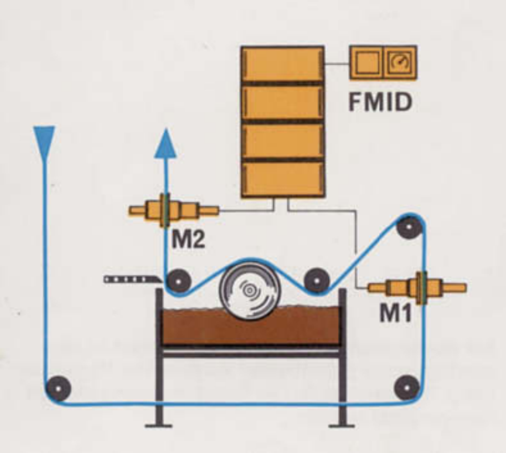


Fig. 2: Control (FMID) of product coating using a kiss roller by means of radioactive density determination (Mahlo) before (M1) and after (M2) coating.

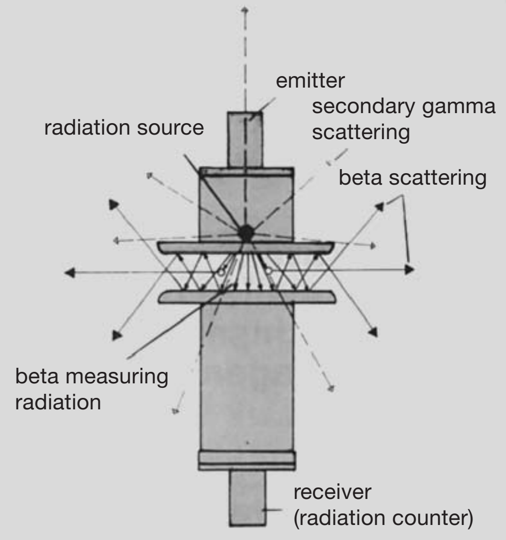


Fig. 3: The pattern of emissions from a Gravimat (Mahlo) for radioactive density determination when the radiation emission window is open.

During normal operation (device switched on, radiation efflux window open) most of the radiation originates from the transmitter, passes through the material into the receiver and is absorbed by both. Only a small proportion of the β-radiation crosses the measuring gap after several reflections. This rogue radiation only travels a short distance before it is absorbed by the air (Fig. 3). The effective quantity (dosage) of radiation around the measuring device with the radiation efflux window open and closed can be read off from so-called iso-dosage diagrams (Fig. 4). The curves in the diagram are calculated by combining values for the same dosage. The control range limit is also entered.

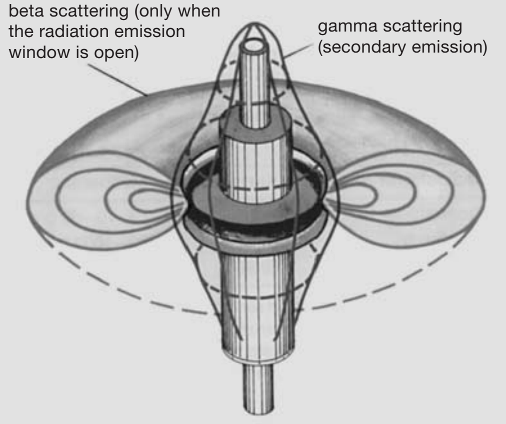


Fig. 4: The distribution of radiation emission surrounding the measuring device (Gravimat by Mahlo).

Since radiation is only emitted at the level of the material, hands and lower arms may be exposed to radiation during normal use at the stenter outlets (Fig. 5), on coating and laminating machines (e.g. when pulling in the material). The limits for partial exposure therefore apply when defining the monitoring area.

The currently applicable radiation safety legislation specifies radiation dosage limits for various groups of people, adherence to which ensures, with a high degree of probability, that radiation damage will not occur. In the eyes of the law, operators of machines and systems that are equipped with radiometric monitoring devices are not considered to be exposed to radiation at work, even if they occasionally come into contact with radiation. This group of people may only be subjected to a maximum dosage of 0.5 rem per annum if the entire body is exposed, and 6 rem per annum if only the hands, lower arms, feet and lower legs are affected. Starting from these limits, the radiation safety legislation defines a so-called monitoring area around a radioactive source. A dosage that is higher than the permitted body dosage may be received in this area; for this reason people are only allowed to be present in this area for a limited period. The maximum period is calculated from the radiation dosage at the location (local dosage) and the permitted limit. There are no access time restrictions outside the area.

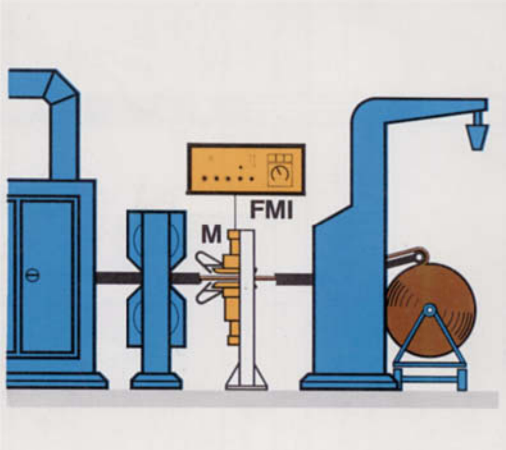


Fig. 5: Installation showing a Mahlo radioactivity based density determination device at the exit from a drier.

As with anything else to do with radioactivity, radioactive density determination is subject to strict monitoring by the relevant supervisory body, which only issues short-term usage authorisations that have to be renewed at certain intervals.

Radioactive emission Energy emitted by so-called nuclear reactions from naturally radioactive elements (radium) or artificially produced radioactive → Isotopes of different elements. Consists of the following three types of radiation (neutrons, protons, etc. also occur in artificial radioactivity):

I. Alpha radiation (α radiation) emitted at considerable speed (initially approx. 17 000 km/s) by positively charged helium nuclei; considerable amount of ionisation, therefore only short range (approx. 3–8 cm), energy approx. 5 million eV.

II. Beta rays (β rays) are negatively charged electrons; they are extremely fast (initial speed 100 000 km/s. to almost the speed of light), penetrate much thicker layers than alpha beams (medium range), energy approx. 1 (– 3) million eV.

III. Gamma rays (γ rays) are extremely energy-rich light quantums (photons) with extremely short wavelengths (10^{-12} m), identical to x-rays from an x-ray tube operated at high voltage; they have little ionising effect (approx. 100 times less than beta rays, therefore long range and intensive penetration capability (including metal, water, etc.); much stronger than alpha and beta rays, gamma rays have an essentially destructive effect on fibres.

Radioactive isotopes Isotopes that are used industrially for measuring textile coating thicknesses or other volumes and for measuring residual moisture. The density of the surface structure is always measured. → Radioactive density determination.

Radioactively-contaminated clothing, cleaning of According to a Japanese study on clothing contaminated with $^{60}CoC_{12}$, polyphosphates, minerals from inorganic polyacids and surface-active substances were investigated as possible “decontamination agents”. It was proven that chelate formers with higher stability constants are the best decontaminating agents. The decontaminating effect of the chelate formers depends on the pH of the solution.

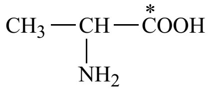
Radioactive tracers →: Isotope; Radioactive tracing.

Radioactive tracing One of the goals of biochemical research is to explain the reaction mechanisms of the chemical process that occur in human, animal or organisms. Basically, everything that is absorbed by or built up in the organism is broken down after a time and excreted. Metabolism takes place between absorption and excretion. Among other things, the organism’s dynamic state is characterised by the fact that no molecule stays in the same environment for a long period of time and many types of molecule are broken down into groups of atoms or even individual atoms and used by the organism to form other molecules. In order to trace the progress of the metabolic processes (e.g. sewage treatment) the use of radioactive molecules is usually unavoidable. Since the biochemical properties of the substance are not altered in any way by suitable marking, the molecules entering the organism can be differentiated from identical molecules that are already in the organism. Because of the radiation that they contain, marked substances can be identified at any time in any location without interfering with the progress of the metabolic process that is being investigated.

Using the tracer method it is possible to trace the route of a molecule type through the organism and determine any changes to which it may have been subjected. Kinetic investigations of the reactions in which the molecule is involved can also take place. As well as these possible applications, radioactive isotopes can also be used as indicators in various biochemical analysis methods in order to improve the accuracy thereof.

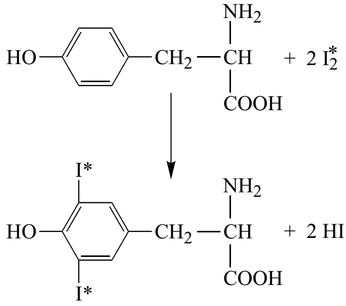
A distinction can be made between four basic marking methods using radionuclides:

1. Uniform marking (these kinds of marked compounds are identified with “U” in the literature). C-14 activity, for example, is statistically evenly distributed to all C atoms.
2. General marking (identified with “G”). This means that when using tritium marking, for example, all identical atoms are marked but the activity is not necessarily evenly statistically distributed.
3. Specific marking (marked by specifying the position, e.g. Alanine-1-C-14). In this case not all identical atoms in a compound are marked, e.g.



$$CH_3-\underset{\displaystyle NH_2}{CH}-\overset{*}{C}OOH$$

4. External marking. A radionuclide that is external to the molecule has been introduced, e.g.



These types of markings or combinations thereof can also be found in double marking. Double marking means that isotopes of different elements have been introduced in the same molecule, e.g.

2–^{14}C–5-di–^{3}H mevalonic acid or

$H_2{}^{15}N–{}^{14}CH_2–COOH$.

Radio-frequency drying → High-frequency drying.

Radiometric control systems Testing procedure using isotopes such as → Radioactive density determination.

Radiometric emission dust monitoring Portable device for the continuous measurement and registration of mass concentration of dust in exhaust gases, e.g. from chimneys. The surface weight increase of a filter through which air or exhaust gas is flowing is determined by absorbing β rays. The following can be measured: dust quantity in kg, dust flow in kg/h, dust concentration in mg/Nm^3.

Raffia bast (raffia fibres), leaf bast (fibres) from the rapia palm (South Africa, Madagascar, South America). Flat, brown/yellow bast strands (for gardener bast and as braided bast for arts and crafts), easily divided lengthways to form solid fibre elements (for string and coarse yarns).

RAG RUG → Allgaeu carpet.

Rags Term for the remains of worn, more or less worn-out items of clothing from households. Usually end up in approx. 200 kg balls for further processing, which consist of grades (Class I = Shoddy, II = Tibet wool, III = Mungo, IV = Alpaca or Extract) and is used for manufacture of → Reclaimed wool, also → Reclaimed cotton.

Rain-Grown-Cotton Cotton cultivated under natural climatic conditions (→ Irrigated cotton).

Rain resistance → Water spotting fastness.

Raised finish (brushed finish, napped finish) → Brushed fabric.

Raised resist print Printing of pigment white and/or pigment dyes. Subsequent drying is followed by friction texturizing, condensing and raising. Produces a raised pile in non-printed areas, whereas printed areas are not raised.

Raising This finishing work is used to create a different feel and a velvety material surface on fabrics and knitwear by loosening a large number of individual fibres from the fabric and subsequent raising (velour raising) and napping (nap raising) in order to create a dense raised surface. This also produces more fullness and softer handle. A distinction is made between card roller raising (see Fig.) and table raising. Table raising machines are used to open knitwear, whereas card roller machines are used for raising threads (flat fabric or knitted fabric) or for raising felt (for milled woollen fabric) (→ Raising machines).

Depending on the kind of material, raising is carried out on right and/or reverse side of woollen materials, before milling in order to produce an extremely dense hair cover (for foulé), after milling for raising, the milling felt and also raising the face weft (for floconné) in cheap semi-woollen materials also without milling, before and/or after de-tanning (Melton character) in cotton materials, in order to give a woollen appearance and handle.

Raising is carried out on the raising machine, using either natural teasels or metal cards. Natural teasels are the heads of the teasel thistle (→ Raising machines). They have small hooks that are flexible and resistant and are suitable for achieving fine raising effects. The teasels are either placed in rods in rows (rod teasel raising machine) or put on small, rotating spindles (roller teasel raising machine) and arranged in an appropriate position on the raising cylinder, over which the material runs until the desired result has been achieved. Rod teasels produce a combed raising surface in the nap, and roller teasels produce more of an uncombed upright raising surface. In the first case the material is raised when damp and in the latter case is carried out when dry (for blankets, flannels, paletot materials). Coarse raising effects are achieved using metal cards. Cards are small wire hooks that are pulled over small rollers as a covering (→ Raising elements). Approximately 12–36 rapidly rotating card rollers are distributed around the large raising cylinder. The roller (card) raising machine has alternating nap and counter-nap rollers, i.e. with teeth that move with and against the direction of movement of the cylinder and the material. In universal card raising machines the cylinder moves in the direction of movement of the material and the card rollers run in the opposite direction, whereby counter-nap rollers also run between the latter. Raising machines have fine material tension, material web, raising roller speed, nap and counter-nap torque conversion (felting raising) control. The procedure can be simplified by arranging several successive machines, possibly with shearing machines at the end (raising shearing line). Raising machines allow the desired raising effect to be accurately set. Patterned high/low effects can be achieved by means of a combination of printing and raising. The low-lying areas are protected from the effect of the raising rollers by printing on a resisting agent and can also be dyed. A coloured or colourless artificial resin pre-condensate can be printed onto the raised material, calendered, condensed and then the nap brushed up again. The printed areas are now visible and embedded into the material.

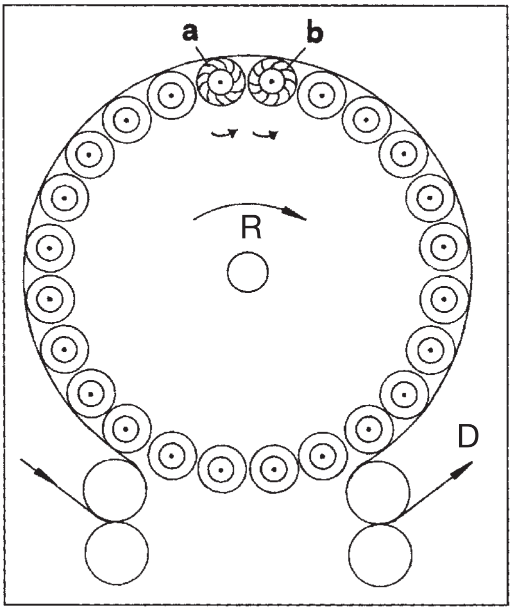


Fig.: The method of working of a raising machine fitted with carding rollers.
R = reel drum; D = direction of goods; a = counterpile roller; b = pile roller.

Raising apparatus Small → Roller card raising machine before the rod teasel machine (wet brushing machine) central cylinder for pile lifting.

Raising effect Correct material tension is a decisive factor for a good raising result. If the tension is too high, the raising card cannot easily grip the weft thread, and if it is too loose the material may become tangled or even wrap around the raising rollers. The material must therefore always run at the best possible tension for the item that is being manufactured. On a PLC-controlled raising machine the material tension is automatically kept constant depending on the torque.

In a normal case, approximately equal amounts of nap and counter-nap energy are used on the nap/counter-nap raising machine. More nap energy is used to achieve certain material effects such as napped velour and less energy for a short, covered material surface. For nap velour, blankets and articles with voluminous raising, the raising machine is fitted with an additional lifting device above the cylinder. This equipment splits the cylinder into two zones; the raising capacity is increased and more volume is produced on the surface of the material. In this case too, the material tension is automatically kept constant depending on the torque.

If the raised surface of the material that has been raised using nap/counter-nap is to be made even denser, a semi-felting process is frequently carried out using a nap/counter-nap raising machine. In this case the nap energy is under zero and low-grip counter-napping is carried out. If the surface of a material has to be extremely compact, the full felting raising procedure is used. In this case the cylinder rotates against the direction of movement of the material, and all the raising rollers operate in the nap direction. It is important that the elements are symmetrical, i.e. both banks of rollers are at the same angle.

Different raising elements are used for certain materials. As well as the shape of the wire (round, oval, sectoral or biconvex wire) the embedding and straightness of the wires, the number of naps, the row and the density of the braiding must be taken into consideration for further characterisation. The wire shape and straightness are important criteria for raising card wires, and the grinding of the tip of the card wire is also extremely important. During the processing of woven materials, equalised, side-ground and polished raising elements that have been ground outside the tambour raising machine must be used. In knitwear where raising and velouring take place using a raising card wire tip, the raising card wire tips (controlled by a preselected PLC program) are ground in the raising machine.

An important parameter during raising is also raising energy. This generally refers to the set nap and counter-nap roller speeds. Because of the complicated kinematics of a wire raising machine, these speeds cannot be directly measured. Most machines have dimensionless scales for setting the raising energy, which make it possible to reproduce the settings that have already been used.

Raising energy is the rotation energy E_{rot} of a raising roller:

$$E_{rot} = {}^{1}/_{2} \cdot l \cdot w^2$$

l = moment of inertia of the roller,
w = angular velocity of roller.

If w is expressed as the rotating speed, the following applies to E_{rot}

$$E_{rot} = 2\,\pi^2 \cdot l \cdot n^2$$

For a certain roller, E_{rot} is proportional to the square of its rotating speed.

$$E_{rot} = \text{const.} \cdot n^2$$

No raising energy is transferred at the “zero point” of the respective machine, since the hooks embedded in the covering roll off the material without carrying out any raising work. The energy figure EZ is used as a measure of the raising work carried out on the material by the covering:

$$EZ = \frac{n^2 - n_0^2}{1000}$$

n = roller speed at any setting (rpm),
n_0 = zero point speed (rpm).

The energy figures are > 0 for counter-nap rollers and < 0 for nap rollers. The speeds of the individual sets of raising rollers can only be measured using expensive measuring equipment. In most cases, the sets of rollers are driven using toothed wheel transmission and a slip-free belt drive. Since the energy figure that is only significant for the examined machine for a defined roller drive transmission, the speed of an easily accessible toothed wheel outside the tambour can also be used. Additional speed sensors with an appropriate display must be installed for the nap and counter-nap rollers at this measuring point. Another benefit of these measuring points is that they can also be used for monitoring and adjusting the zero point of the machine (according to Hübner and Kux).

Raising effect dependence on grey fabric The physical characteristics of the fibre are extremely important during raising, since the stress on the fibres to be pulled out is mainly mechanical. The fibre resists being released from the composite yarn to a certain extent. This means that the fibre must not be broken but merely pulled out at one end. The other end must be well engaged in the spun yarn. In order to achieve this the fibre must be extremely strong. The loosening of the individual components also depends on the shape and surface of the fibres. For example, the friction coefficient of wool (flaky surface structure) is greater than that of smooth synthetic fibre. Regardless of the material that is used, loss of strength in the weft direction can be expected when raising fabrics since it is essentially the weft fibre that is raised. The rigid bonding is disturbed by raising. The weft yarn that produces the raising pile must be carefully selected. The choice of weft yarn depends on staple length, fineness, twist and yarn number.

1. Staple length: in order to make weft yarn raising easier, a material that has as short a staple as possible must be used. The many fibre ends can be pulled to the surface of the fabric after relatively few raising passages, where they form a dense raised fleece. However, using short-stapled material rapidly reduces the tearing strength of the fabric in the weft direction because the fibres have not internal cohesion. An unstable pile is also created. More passages are required if long-staple material is used, but this produces better tearing strength and a balanced, stable raising surface. Raising loss is also minimised.

2. Fibre fineness: the fineness of the fibres must be tailored to the respective grey material. Coarser, long-staple fibres are the most suitable for carpet and blanket manufacture. Finer material is better for clothing, since it has to form a short, dense pile surface. The fineness and length of the fibres play an important part with regard to the density and length of the pile.

3. Yarn twisting: the harder a yarn is twisted, the further the raising wire has to engage into the bond. This characteristic can be used to positive effect if a light, short surface pile is all that is required. Attempting to obtain a voluminous surface may cause loss of fabric tearing strength and raising. The number of raising passages also increases, which is undesirable from an economic point of view. With regard to the effect of the yarn number on raising fallout, it can be said that the coarser the weft yarn, the better the grip of the small raising hooks, thus making the raising process easier. For warp yarn a finer yarn number must be selected, since the warp thread should be covered as little as possible.

4. Fabric binding: the raising effect mainly depends on the binding of the material. A correctly selected binding plays an important part in retaining fabric tearing resistance in the warp direction. Bindings with long weft floats make raising easier, but there is a risk of irregular pile formation. Cloth binding, which is frequently used in raising, is extremely suitable because its floats are not too long and the fact that the number of intersection points is adequate. Since every thread crossing counteracts the loosening of the fibres, cloth binding does not produce a tight pile. Cloth binding is therefore used in cases where short, wash-fast raising fleeces are required. Tight surfaces are achieved using weft satin. More raising density is achieved, which is given a velvet-like character by shearing. A large number of other binding types are used in raising (Köper, Atlas, etc.). The choice always depends on the article's requirement profile.

In raising a distinction is made according to the type of material to be processed (cotton, wool, synthetics) and according to the type of raising.

- raising of threads,
- raising of felt.

When raising threads a pile cover is formed by pulling out fibres from the threads or by lifting or tearing the thread, which is bound into the surface as floating or raised loops. The raising of felt, on the other hand, is only used in wool raising, i.e. the wool is given a short, dense fibre pile cover in the milling process. Wool felts during milling, because of its flaky surface structure. In this case raising does not have the task of pulling fibres out of the bonding but loosening the felted surface pile. A distinction is also made between different raising procedures:

- raising with/against the nap,
- nap raising,
- felting.

Raising effect tester Used to measure the raising effect (pile height) so that this effect can be reproduced under the same conditions.

Raising elements A distinction is made between nap and counter-nap rollers as far as raising rollers is concerned. An alternating series of these rollers lies against the raising drum. Basically, the two types of roller differ in that the card teeth are bent in different directions in relation to the direction of rotation. On the basis of the direction of movement of the material, the direction of rotation of the cylinder and the nap and counter-nap rollers, it can be seen that the bent card runs against the material in the counter-nap, whereby the nap roller merely strokes the material.

The raising cards have to grip into the fabric, and the nap and counter-nap rollers have to be separated in order to do this. The raising effect can be increased by:

- reducing the speed of the nap rollers,
- increasing the speed of the counter-nap rollers,
- reducing the tension of the material so that the material to be raised has contact with the raising rollers over a larger area (Fig. 1).

The following principles apply:

a) The lower the speed of the nap rollers, keeping the rotating speed of the raising drum constant, the longer and more powerful the effect of the counter-nap effect on the fabric.
b) The greater the speed of the counter-nap rollers, the greater the raising effect.

The raising machine can also be set up such that the nap and counter-nap rollers just roll against the material. This is called the zero effect, i.e. there is no raising effect in this setting (Figs. 2 and 3). The effect of a raising machine can therefore be varied from no raising effect in the zero setting up to an intensive nap and counter-nap roller effect until actual damage is caused to the material, whereby the fabric tearing strength in the weft

Raising elements

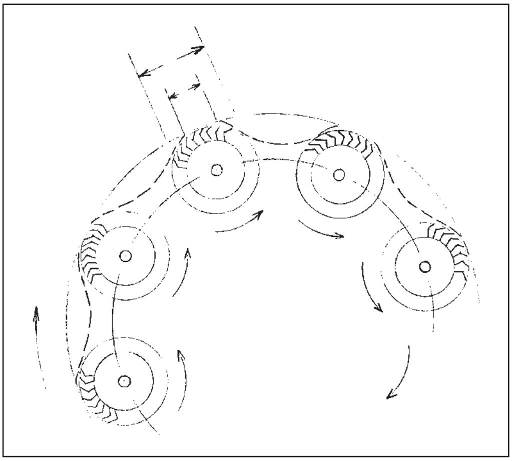


Fig. 1: Nap and counter-nap rollers and the influence of the tension of the fabric.

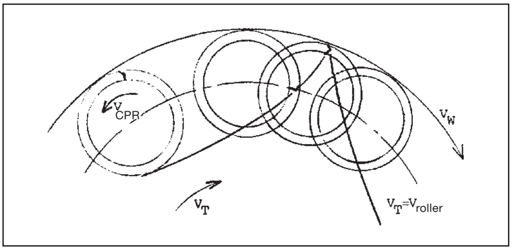


Fig. 2: Curve showing the motion of a raising roller (here a counter-nap roller) where $v_T = v_{roller}$ (zero effect).

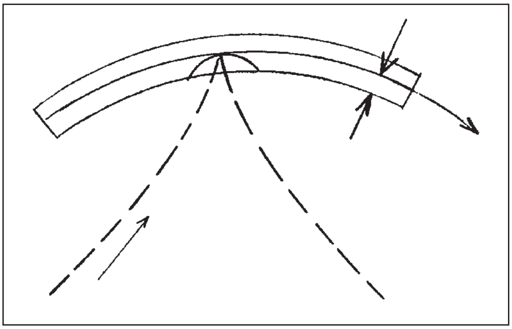


Fig. 3: Curve showing the motion of a carding hook against the fabric at the zero effect point.

direction falls below an acceptable level. Because the raising rollers and the cylinder move in opposite direction, hypo-cycloidic movement curves occur, i.e. a curve that forms at a peripheral point on a circle if this circle rolls off the inner side of another fixed circle. The shape of the curve is determined by the cylinder speed to roller speed ratio. The material speed and tension (depth of raising hook engagement in fabric) also play a part in determining the movement curve of a raising hook in the fabric. When the material speed changes, the movement of the card hooks in the fabric is no longer identical with the hypo-cycloids of the free-running raising roller. In order to guarantee that the nap rollers have a raising effect, the circumferential speed must be reduced (Fig. 4). In the operating position, the card hook approaches the material web in a slightly bent line (Fig. 5). When the card touches the material web it has time to scrape along the surface of the fabric over a short distance. It is then removed from the material web. On the counter-nap roller the roller speed is increased in order to achieve the raising effect (Fig. 6).

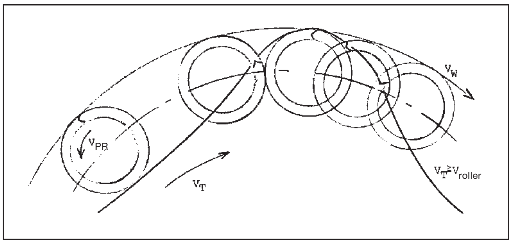


Fig. 4: Curve showing the motion of a carding bristle on the nap roller at the working position ($v_T \geq v_{roller}$).

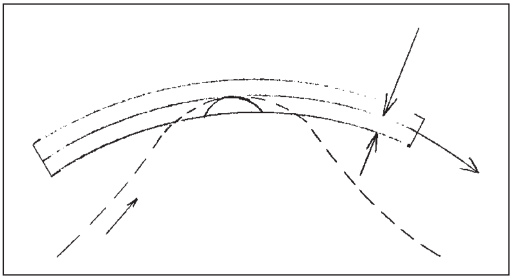


Fig. 5: Curve showing the motion of a pile roller hook against the fabric.

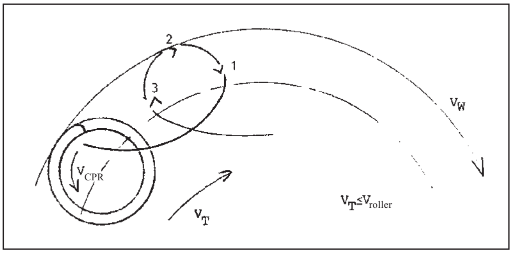


Fig. 6: Curve showing the motion of a carding bristle on the counter-nap roller at the working position ($v_T \leq v_{roller}$).

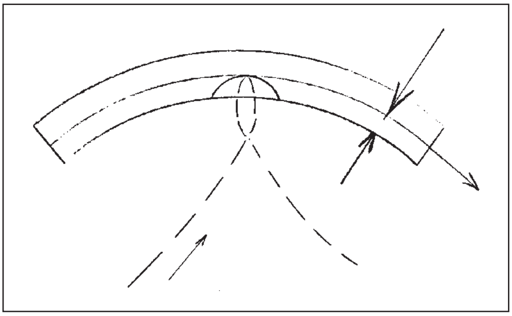


Fig. 7: Curve showing the motion of a counter-nap hook against the fabric.

The tip of the card, which is aligned against the material direction of travel and at an angle to the cylinder movement, runs along a loop-like route when it approaches the fabric (Fig. 7). After a brief, rounded engagement into the surface of the fabric, the card tip is removed from the material extremely rapidly. The greater the speed, the larger the loop. This causes the raising card to engage in the fabric for a longer period. In summarising it can be said that the material (v_W), cylinder (V_T) and raising roller speeds (v_{roller}) influence the raising effect. If one considers the movement of the raising cards, the regularity of the actual raising speed and the operating speed of the raising rollers V_{OCPR} and V_{OPR} can be calculated. The formula for calculating the operating speed of the nap and counter-nap rollers is:

$$V_{OPR} = V_T - V_{PR} - V_W$$
$$V_{OCPR} = V_{CPR} - V_T + V_W$$

V_{OPR}; V_{OCPR} = operating speed of nap and counter-nap rollers
V_{PR}; V_{CPR} = circumferential speed of nap and counter-nap rollers
V_T = cylinder speed
V_W = material speed

A distinction between raising cards is made according to the type of wire and the carrier material. As far as wire is concerned, a distinction is made between round wire, biconvex wire, sector wire, ovoid wire and flat wire in different sizes. Card wires are made from high quality cast steel with carefully controlled alloys. Carbon (0.57–0.62%), manganese (0.5–0.6%), silicon, phosphor and sulphur are used as alloying materials. These additions produce a wire that meets all elastic, hardness, durability and processing (polishing) requirements. Depending on the use, rubber or felt covered plates are used as the carrier. The selection depends on the type of raising material and the required raising effect, i.e. the card elements must meet the following requirements for the article concerned:

- adequate strength,
- the required elasticity,
- the required card tooth angle effect.

The carrier materials consist of various layers of textile fabric that are bonded together. As far as rubber plates are concerned, the layers of material are covered with a mineralised and vulcanised rubber plate. The thickness of the rubber plate depends on the use (usage area). As far as felt covering plates are concerned, the layers of material are bonded with felt. The choice of carrier material depends to a great extent on the required elasticity of the raising card.

The needles that are used are subject to the following requirements:

- adequate strength,
- required elasticity,
- high degree of wear resistance,
- same angle and tip height.

Selecting the correct type of steel can meet the first three requirements. The first two items are also influenced by wire thickness and cross section. Wear resistance can be improved by hardening the element tips. Galvanised elements are available for wet and damp raising. Particular attention must be paid to the last item, since it is responsible for raising failure and performance. A distinction is therefore made between two types of trimming elements:

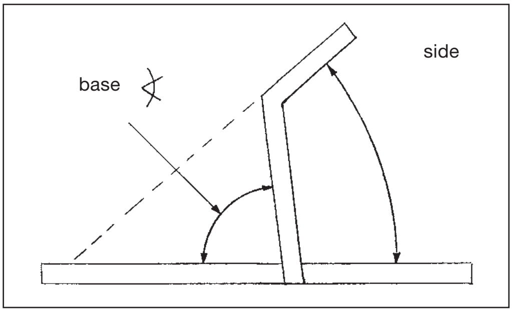


Fig. 8: Normal trimming elements.

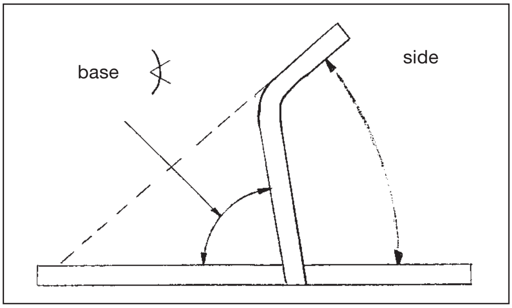


Fig. 9: Round knee trimming elements.

Raising elements

a) normal elements (Fig. 8),
b) round knee elements (Fig. 9).

The basic angle setting is intended to give the trimming elements more elasticity. If the basic angle is reduced (wire bent backwards) the raising card has more elasticity. Normal versions have basic angle settings of 75–85°. If a less elastic version is required, a curved needle (round knee elements) is chosen rather than a needle with a sharp bend (normal elements).

The raising elements get their appearance (angle, wire length, rows of carding teeth) during the manufacture of the raising card belts in setting machines. The wire is cut to the required length and bent into a "U" shape; this creates two element needles. Holes are punched into the carrier material into which the bent wire is subsequently inserted. When the wire is inserted the card is given its final shape, angle position (basic and leg angle) and arrangement of rows of carding teeth (Figs. 10, 11). The row of teeth describes the arrangement of the element needles in the carrier material.

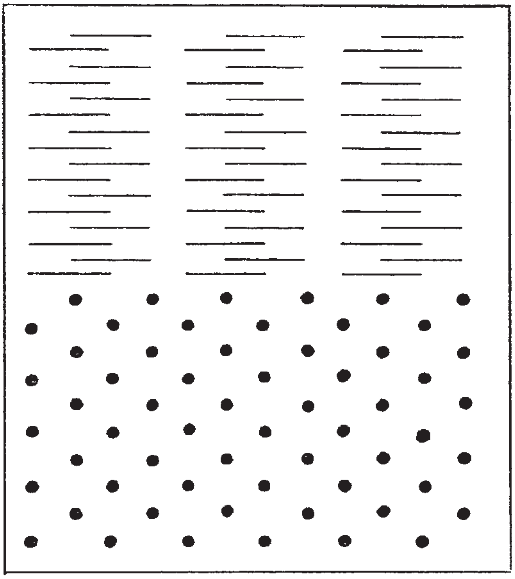


Fig. 10: Rows of carding teeth for raising: two column pattern, 12 rows of teeth.

The occupied element belt is not yet capable of raising, since there are not yet any tips on the legs of the element needles. The wire ends (legs) are ground on large drums by the card belt manufacturer. During grinding a distinction is made between equalising (also known as level or surface grinding), side grinding and polishing.

During equalising an even tip height is first produced. This is not always guaranteed when the element belt is manufactured, since erroneous wire lengths may be produced. The back is given its shape by the grinding disc pressure and the grinding time. A distinction is made between: grinding, thin grinding and flat grinding (Figs. 12–14).

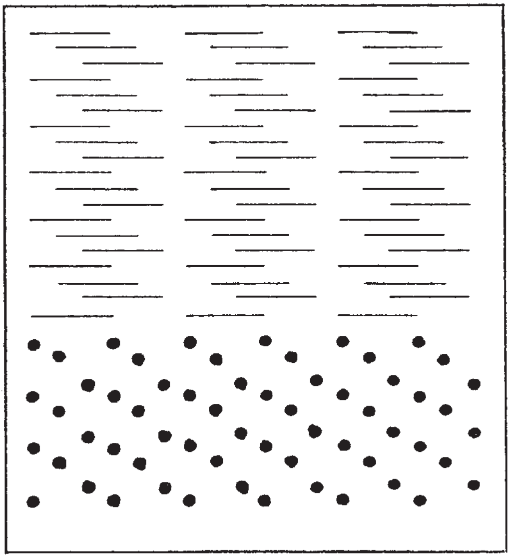
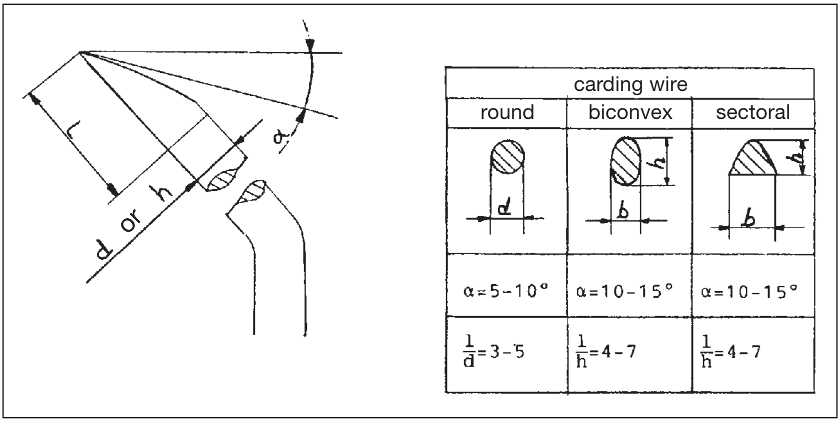


Fig. 11: Rows of carding teeth for raising: three column pattern, 18 rows of teeth.

The tips and card edges are formed during side grinding. For some time, raising experts were not certain whether side grinding was required. In the meantime it has been established that side grinding makes raising more economical and does not affect quality. This is why card manufacturers always supply side-ground raising elements. Here too a distinction is made between grinding, thin grinding and flat grinding. The advantage of side grinding is that the element needle can penetrate the fabric more easily. The needle stays sharp for longer. The disadvantage is that a burr is created on the underside of the leg. The fibres to be loosened can catch on the sharp edge and plucks and holes can appear in the fabric. In practice, new elements are initially used for pre-raising only. In order to prevent this problem the card elements are polished. The card elements wear during long periods of use, i.e. they become blunt, the card tips slowly back in the direction of the wire shape. The wearing process is accelerated by harder materials and weft yarns with a stronger twist. The continual wear of the card tips reduces the performance of the raising machine. This results in multiple passes being required. On the other hand, open bindings and softer weft yarns increase the service life of the raising card and reduce the need for grinding.

Worn raising elements are ground in, thus produc-



carding wire		
round	biconvex	sectoral
d	b h	b h
α=5-10°	α=10-15°	α=10-15°
$\frac{l}{d}=3-5$	$\frac{l}{h}=4-7$	$\frac{l}{h}=4-7$

Fig. 12: Grinding forms for levelling: grinding.

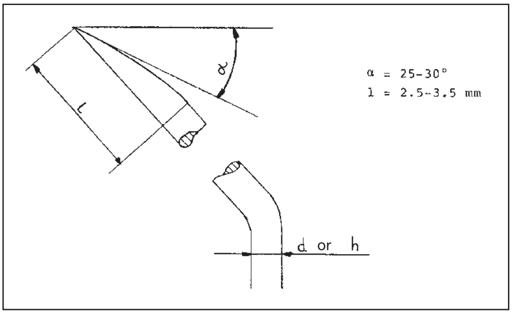


Fig. 13: Grinding forms for levelling: thin grinding.

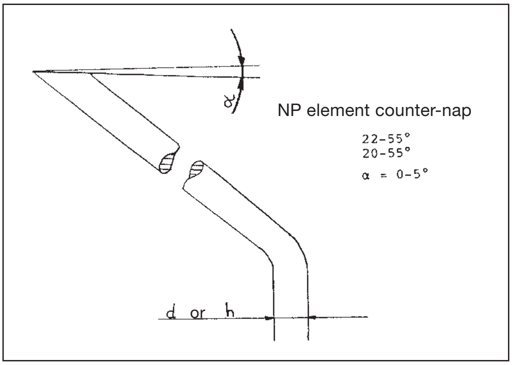


Fig. 14: Grinding forms for levelling: flat grinding.

ing a good raising effect. There are two ways of grinding raising rollers:

1. Grinding the removed raising card roller on a grinding stand (Fig. 15).
2. Grinding the card elements in the raising machine (Fig. 16).

Both grinding methods work according to the principle of equalising, side grinding and polishing. The raising card elements that have already been used must first be cleaned. Flocks, threads, dust, etc. obstruct the grinding process. This leads to different grinding results that are subsequently noticeable on the article to be raised

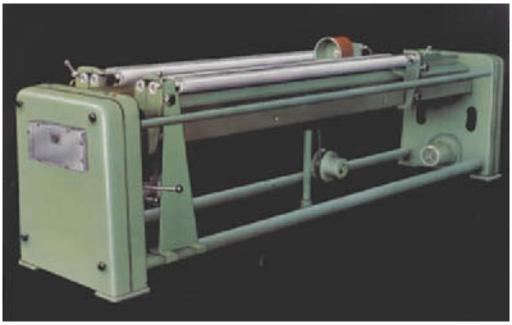


Fig. 15: A card grinding machine AH 5 (grinding stand) by Franz Müller.

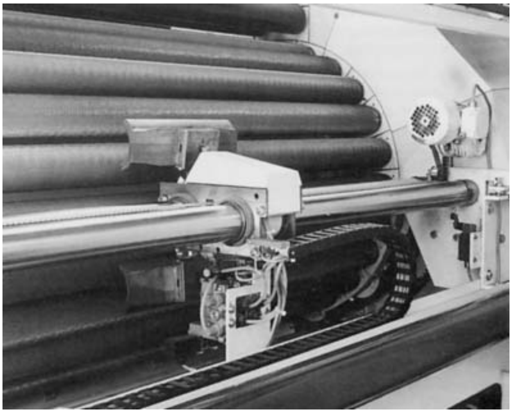


Fig. 16: An automatic raising element sharpening device from the Sucker-Müller company.

(e.g. unequal nap). The grinding procedure for raising cards on the grinding stand is as follows. If there are uneven areas on the raising cards, they must be evened out. Two rollers are placed in the machine such that a grinding spindle with an equalising head (grinding stone unit in grinding stand) and the raising rollers rotate in the same direction. The tips of the cards must point backwards. The raising rollers must then be positioned so that they lightly touch the equalising head. The grinding procedure continues until the needles are of equal height again.

In order to perform side grinding the equalising head is removed and replaced with a grinding head consisting of grinding discs. The grinding discs must engage approx. 1–1.5 mm between the card tips. When enough side grinding has been done the grinding head is removed. Then de-burring (polishing) is done. In this case the raising rollers are allowed to run into each other, whereby a certain quantity of oil and fine grinding paste must be added, since polishing would otherwise not be possible. When in-machine grinding is carried out, equalising, side grinding and polishing is carried out using so-called grinding blocks. These blocks have different grain sizes. A special grooved grinding stone is used for side grinding, unlike other grinding stones. These grooves rub past the side edges of the card.

The card belts are pulled onto bare, smooth metal tubes, each winding in turn coated with adhesive in a spiral. For safety reasons the ends are held down by screws. Tightening must be done with the same tension so that the belt winding is flexible and the surface evenness of the raising card therefore guaranteed. The strength of the tightening is partly responsible for the flexibility of the cards. Flexibility is decisive for quality and evenness. If the tightening is too strong, the card loses the required flexibility, i.e. it does not give way when it engages into the material, resulting in multiple passages and inadequate nap formation. The tightening force is controlled by suspending tightening weights in a belt loop. These weights vary between 5 and 20 kg. The reason for the large difference is that hard and heavy materials have to be raised and tightened harder (less flexibility, more weights). For looser and softer material more flexibility is required, and fewer weights are used for tightening. Too weak tightening an element (without weights) causes running, i.e. the element starts to wander and runs off the roller. The result is that the material tears and the element is destroyed; it gets caught up in the other raising rollers and the element needles break off. The screw-shaped tightening of the elements positions the wire leg at a certain angle to the direction of travel. If all the raising rollers were bent in the same direction, the material web would wander off to the side. For this reason alternate right-hand and left-hand rollers are installed. If possible, the change should take place within the two groups, which thus guarantees that more nap and counter-nap effect can be achieved. Since the width of the elements is rarely the same as the material width, the material is allowed to run on the one side and then the other in an attempt to produce even raising element wear.

Raising energy Classic raising machines of the card roller type vary the raising energy using the following facilities:

1. Ratio of nap rollers (non-raising, but regulating) to counter-nap rollers (raising). Fig. 1 shows six options:

A: All raising rollers against the nap.
B: Roller ratio 1 : 1; one roller with and one against the nap.
C: Roller ratio 1 : 2; one roller with and two against the nap.
D: Roller ratio 1 : 3; one roller with and three against the nap.
E: Roller ratio 1 : 4; one roller with and four against the nap.
F: Roller ratio 1 : 5; one roller with and five against the nap.

Depending on how many rollers the raising machine concerned contains, configurations B to F produce the roller number ratio shown in the Tab.

In the multisystem cylinder raising machine shown in Fig. 2 the number of nap and counter-nap rollers in the operating position and the relative positions thereof can be individually varied. On this 24-roller machine there are twelve triangular locating devices in each side section of the roller, in which a total of 36 raising rollers are arranged. Two of the three raising rollers in each of these locating devices lie against the edge of the cyl-

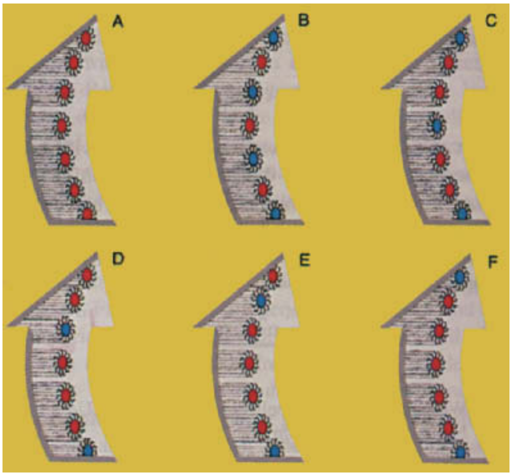


Fig. 1: The ratio of counter-nap rollers (red) and nap rollers (blue) on the reel drum determine the level of raising energy applied.

	24	28	30	32	36
1×1	12-12	14-14	15-15	16-16	18-18
1×2	8-16	—	10-20	—	12-24
1×3	6-18	7-21	—	8-24	9-27
1×4	—	—	6-24	—	—
1×5	4-20	—	5-25	—	6-30

Tab.: Ratio of rollers according to the roller arrangements B–F.

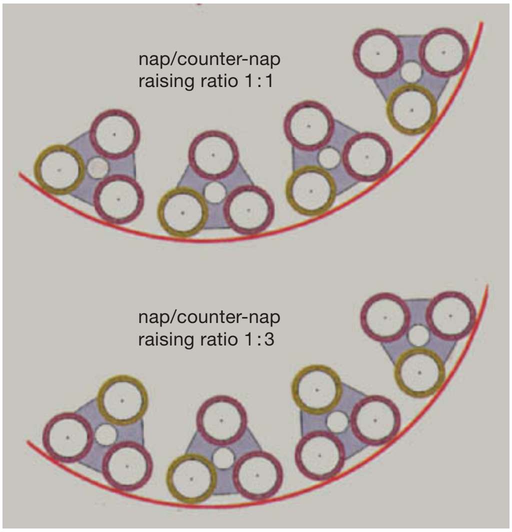


Fig. 2: Different ratios of nap roller raising energy (yellow) to counter-nap roller raising energy (red) provided by the multisystem on the Model 6728 raising machine by Aue Textile Machine Manufacturers.

inder and perform raising work on the surface of the textile that passes over them, whereas the third magazined raising roller facing the inside of the cylinder runs at a set speed with the cylinder rotation. The swivelling and arresting of the triangle of raising rollers by 120° in the locating devices is carried out by the central control system during slow cylinder running, depending on the angle of rotation of the cylinder by pneumatically operated mechanisms, in accordance with the desired raising method. The patented raising roller arrangement therefore provides the option of using different raising procedures within a raising process on a textile surface that is being raised.

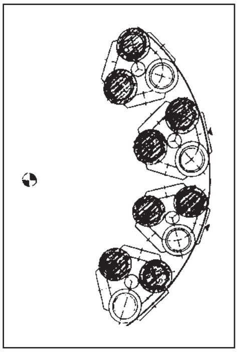


Fig. 3: Raising roller ratio 1 : 1 (12 nap and 12 counter-nap rollers).

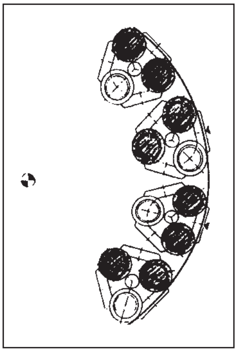


Fig. 4: Raising roller ratio 1 : 3 (6 nap and 18 counter-nap rollers).

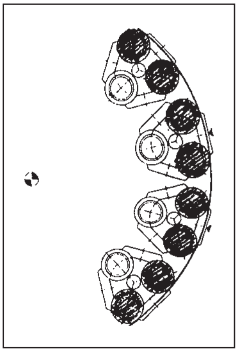


Fig. 5: Raising roller ratio 0 : 24 (24 counter-nap rollers).

Figs. 3–5 show three methods, in which the shaded circles represent counter-nap rollers and the non-shaded circles represent nap rollers. The raising roller arrangement shown in Fig. 3 depicts a 1 : 1 nap to counter-nap roller ratio as the starting point. Fig. 4 shows how a raising roller ratio of 1 : 3 is achieved by swivelling alternate locating devices by 120°. Rotating the mounting device, that has been arrested since the starting point, places all counter-nap rollers in the operating position, as shown in Fig. 5.

2. The raising energy can be varied by altering the circumferential speed of the nap and counter-nap rollers because both can be driven separately. If the counter-nap rollers and nap rollers alternate on the cylinder, a V-belt on the one side drives the nap rollers, whilst the V-belt for the counter-nap rollers runs on the other side

Raising energy

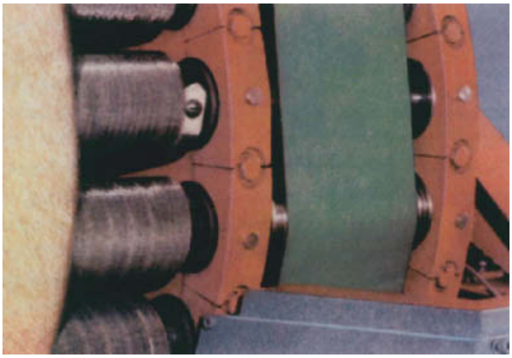


Fig. 6: Flat belt driving counter-nap rollers.

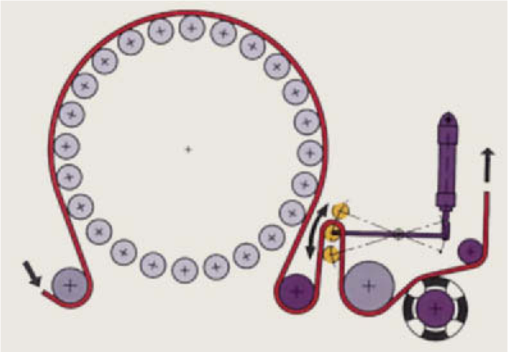


Fig. 8: An automatic fabric tensioner fitted to a raising machine from Aue Textile Machine Manufacturers.

(Fig. 6). These two V-belts run at different speeds, independently of the cylinder and material speeds.

3. Nap and counter-nap rollers can rotate either in the direction of travel of the material or against the direction of travel and therefore influence the raising energy. In Fig. 7 the energy of the rollers running with the nap is shown as "P" and the energy of the rollers running against the nap as "CP". The raising energy that is used when the raising roller (or group of raising rollers) rotates in the same direction as the fabric is shown in red, whereas the energy that is used when the cylinder rotates in the opposite direction to the material is shown in blue. "C" indicates the zero energy point (or zero point), which is used in all cases.

4. The raising effect on electronic raising machines can be influenced by the material tension: the lower the material tension on the raising rollers, the greater the amount of raising energy that can be transferred. The material tension can be measured using dancer rollers (Fig. 8).

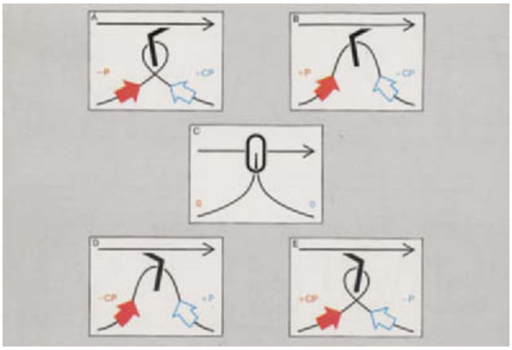


Fig. 7: Diagrams showing raising energy.
P = the energy of the rollers turning with the nap; CP = the energy of the rollers turning against the nap with "CP".

Compared to other methods, raising on electronic raising machines requires a certain rethinking process. In this case the expansion effect produced by raising is exploited and evaluated by a microprocessor control system. The slack that is produced in the rear cylinder area is distributed along the entire cylinder by reducing the raising energy. More material is wound round the counter-nap rollers, which improves the raising effect. The AGT raising effect (Menschner) has the task of creating an optimum raising effect at the minimum material tension around the entire circumference of the cylinder at all raising rollers (Fig. 9). Furthermore, an attempt is made to find a balance between nap and counter-nap rollers so that evenly distributed winding on all raising rollers is achieved in the entire cylinder area. From this knowledge it becomes clear that the optimum raising effect cannot be achieved using the measures that were previously state of the art, namely by maintaining a constant material tension between the cylinder area entrance and exit. It now becomes difficult or even impossible for the raising machine operator to react to all these parameter settings in order to achieve the above-mentioned ideal situation. Consistently making the correct judgement to attain the best possible settings is made even more difficult if raising materials with different expansion characteristics are used. The operator cannot be expected to judge whether and how much the ratio between the circumferential speeds of the material tensioning rollers (VII/VI) and/or above all the ratio between the nap and counter-nap energy (VGS/GS) must be adjusted, since the optimum point can only be found by chance, even if the operator had a great deal of experience and knowledge. In the AGT raising procedure, raising effects are reproducible by the microprocessor control system.

The desired raising parameters can be retrieved from memory using an item number, for example. The diagrams shown in Fig. 9 are intended to indicate a sim-

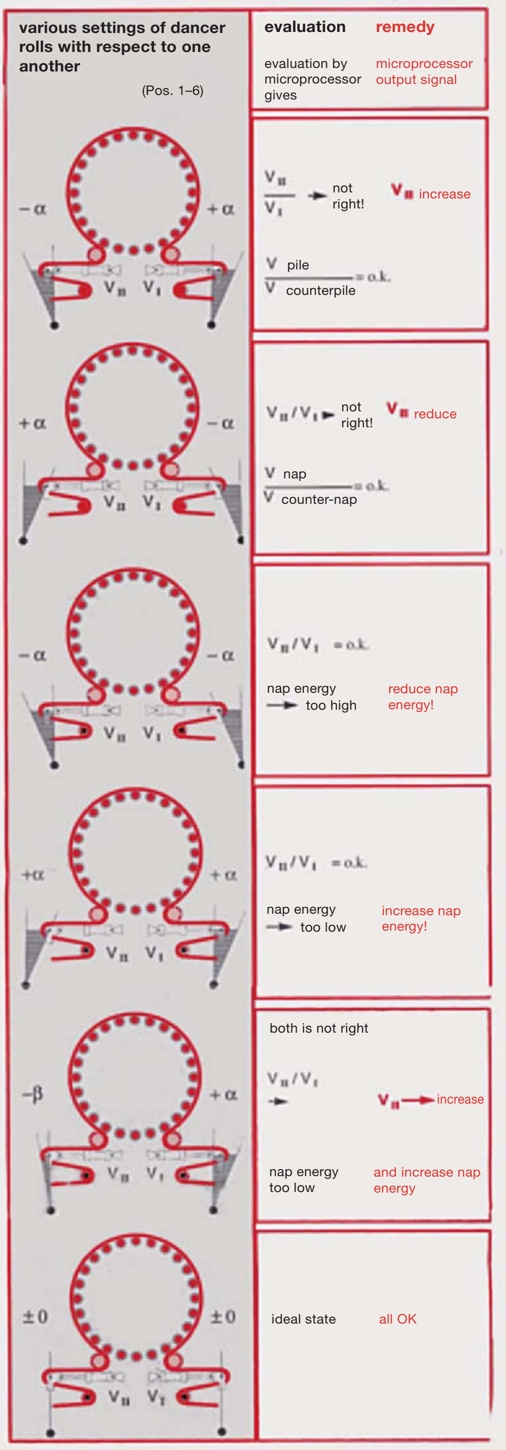


Fig. 9: Settings of dancer rolls with respect to one another (Sistig).

plified form of the possible dancer roller positions and the commands which the microprocessor issues to the nap energy and/or material speed VII, adjusting mechanisms after evaluating this input data. The AGT does not have central drive systems. All the rollers have their own electronically controlled servo drives, i.e. the material pull-in roller, the counter-nap rollers, the nap rollers, the material pull-off roller and the cylinder itself. Two dancer rollers are controlled as sensors, one between the material pull-in roller and the cylinder and the other between the cylinder and the material pull-off roller. Depending on the position and trend of the dancer roller settings, the nap roller energy and the material speed are controlled by the material pull-in roller so that the specified counter-nap roller energy is increased or decreased depending on the amount of winding. This is how the AGT machine independently controls the raising energy depending on the quality of the material.

Raising machines are categorised into teasel and card raising machines. There are also table raising machines for pile fabrics. The former have natural teasel as raising or carding elements, which are either fixed or attached to rods (rod raising machine) or rotate around their longitudinal axis (roller card raising machine). Both types are used in wool finishing – rod raising machines are used for nap raising and roller card raising machines for velour raising. Natural teasels are only used in the manufacture of extremely fine brushed fabrics; they can also be replaced by metal roller teasels.

Unlike fabrics and knitted fabrics made from other fibres, woollen and semi-woollen fabrics are raised in a slightly damp condition. In a rod raising machine only the warp is raised, and in the roller card raising machine both the weft and the warp are raised.

Card raising machines are used to raise fabrics made from wool, cotton, chemical fibres and mixtures thereof. Bent steel wire hooks that are embedded in belts,

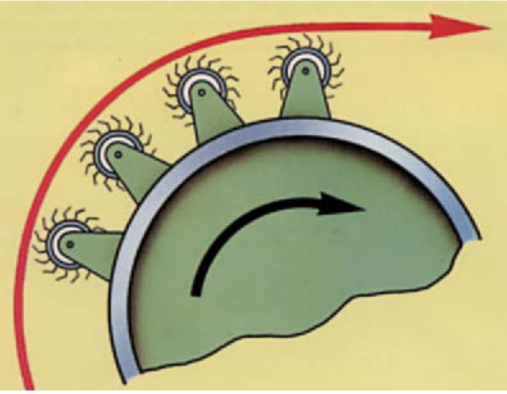


Fig. 1: Normal nap/counter-nap process: the reel drum rotates with the direction of travel of the fabric (Sucker-Müller).

thus forming the carding element in card raising machines. The belts are pulled onto metal rollers in a spiral, thus forming the card rollers. There are special raising elements for the various types of fabric. Card raising machines are categorised into universal (nap/counter-nap) raising machines (Figs. 1–2) and felt raising machines (Figs. 3–4).

A typical universal card raising machine consists of a cylinder, around which 24 or 36 card rollers are distributed (Fig. 5). The rollers rotate clockwise, whereby the circumferential speed is greater than the material speed.

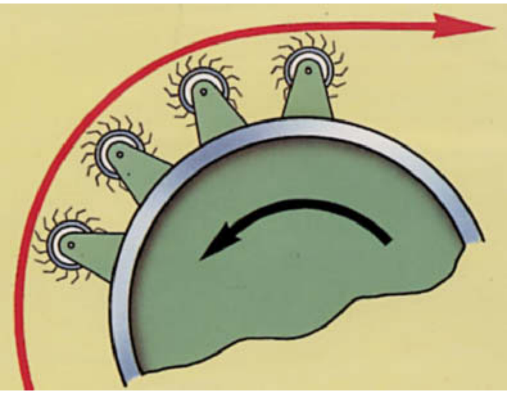


Fig. 2: Contra nap/counter-nap process: the reel drum rotates against the direction of travel of the fabric (Sucker-Müller).

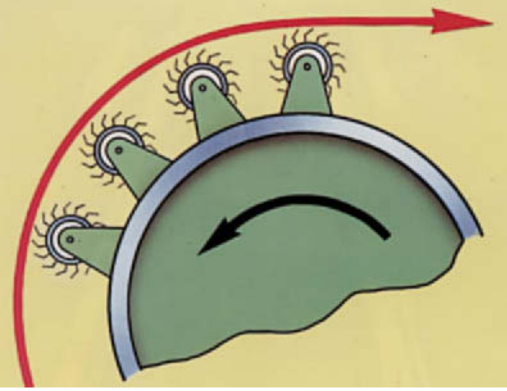


Fig. 3: The normal full felting process (Sucker-Müller).

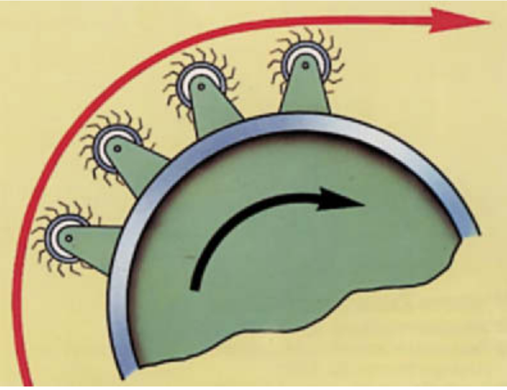


Fig. 4: The contra full felting process (Sucker-Müller).

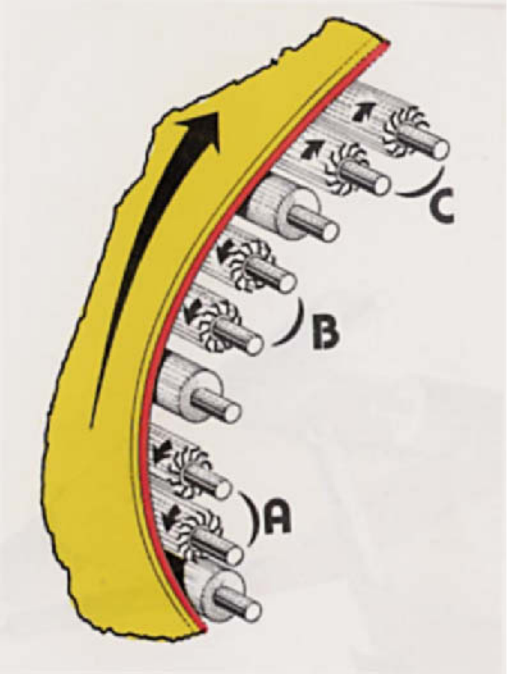


Fig. 5: The Lamperti combination of nap rollers (A), counter-nap rollers (B) and rollers with felting effect (C).

The card rollers rotate in the opposite direction, engage into the material and pull out the fibre ends. In order to achieve a more even raising effect each counter-nap roller is followed by a nap roller, whose wire hooks are not bent in the direction of movement of the material but in the direction of movement of the cylinder. These hooks are there to loosen and disentangle the fluffed-up fibres that have been pulled out by the counter-nap rollers. The raising effect depends on the rotating speed of the nap and counter-nap rollers and the tension of the material. No raising effect is present if the nap and counter-nap rollers have the same circumferential speed as the fabric, i.e. they just roll off it (zero point). The rotating speed of the nap and counter-nap rollers is independently controlled (continuously adjustable). Normally the counter-nap rollers run at a faster circumferential speed than the nap rollers. Pulling rollers transport the material to be raised over the raising cylinder. The material speed is also adjustable. Raising machines operate at up to 60 m/min. The speed of the card rollers and the material can be adjusted in a reproducible way using a microprocessor. This makes raising considerably easier. Furthermore, machines also exist which make it possible to automatically set the same raising intensity at different material speeds. In spite of this, considerable experience is still required for this finishing process.

In order to provide continuous operation for the required number of passages, pieces of smaller items are continuously sewn together and a material collector used at the end of the machine. If both sides of the material are to be raised, an in-line turning device is also used (Fig. 6). For larger production runs several raising machines are combined to form a continuous raising line (Fig. 7). Raising is often continuously combined with subsequent shearing.

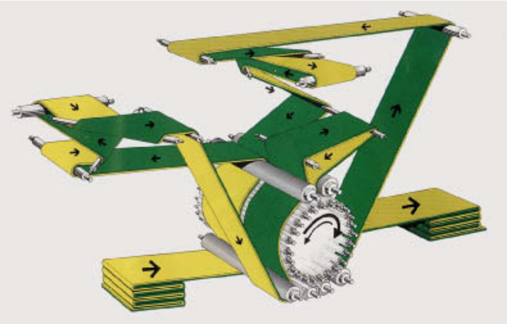


Fig. 6: A Lamperti raising machine with turning devices for tube knitted goods.

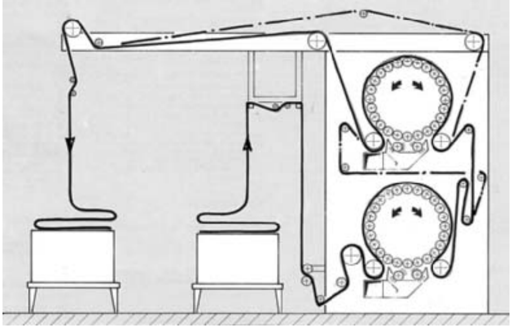


Fig. 8: A duplex raising machine by Lafer.

The moisture content and tension of the running fabric web have a considerable influence on the raising effect. If knit tubing is to be raised, a special wide holder is required that extends over all the raising rollers. The creases remain unraised. Raising both sides in one operation without turning can be achieved on a dual-cylinder raising machine (Fig. 8–9). The cylinder is replaced by a table in table raising machine used to manufacture high-nap materials such as plush. Higher efficiency is reached by cleaning brushes inside the drum (Fig. 10).

Working on the Sistig (AGT 1) raising machine requires a certain re-thinking process. Normally the material tension is an important factor for the raiser in controlling the raising effect. If the material tension is increased, one would assume that the counter-nap rollers would work harder. If the material tension is reduced, as must be the case when raising sensitive knitwear for car upholstery, the amount of material wrapped around the counter-nap roller increases. The raising effect on the Sistig raising machine is controlled by control loops by correctly setting the raising intensity of the nap roller and controlling the material infeed tension. In order to do this, the machine is equipped with two main elements:

1. The rollers are no longer driven by a central drive, but each roller (material infeed roller, counter-nap rollers, nap rollers, material pull-off rollers and cylinder) has its own electronically controlled drive.

2. Two dancer rollers are used as sensors, one between the material infeed roller and the cylinder and another between the cylinder and the material pull-off roller, and are controlled by the material tension. De-

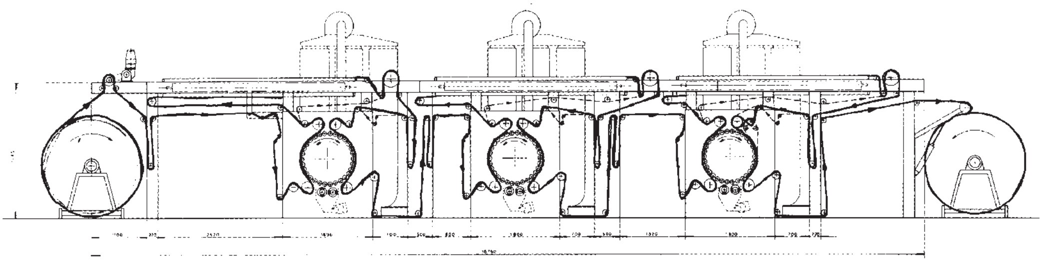


Fig. 7: Raising machine line (Lamperti).

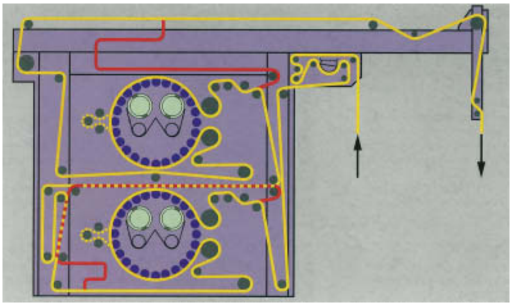


Fig. 9: Double drum wrapping machine (Gematex).

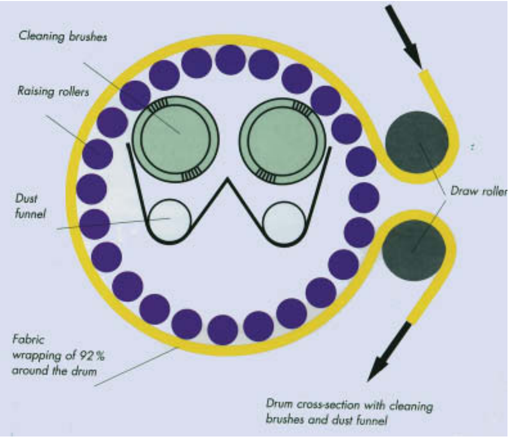


Fig. 10: Higher efficiency by cleaning brushes inside the drum of a raising machine (Gematex).

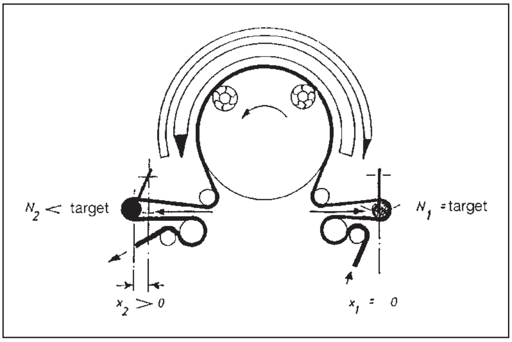


Fig. 11: On the Sistig AGT 1 raising machine absolute stability is sought by using separate drives for the reel drum, the counter-nap rollers and the nap rollers together with sensor dancer rollers N_1 and N_2 for goods take-up (x_1) and output (x_2).

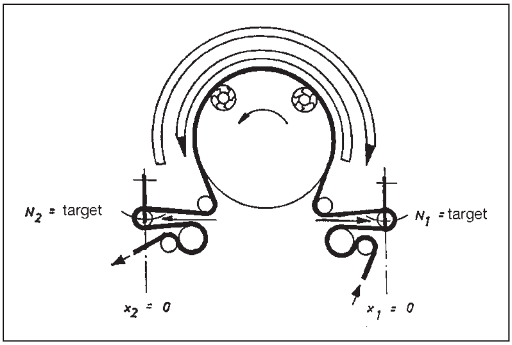


Fig. 12: If there is too little tension-sensitive product in the machine and the raising energy is too low, the product output rate is reduced and thus the raising energy increased.

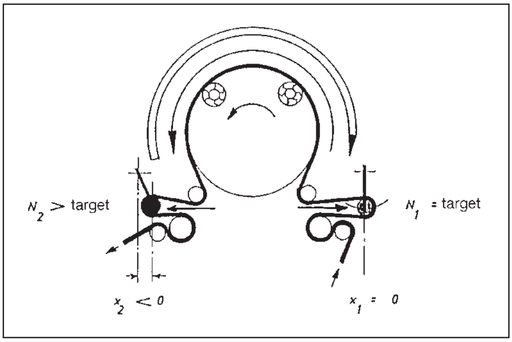


Fig. 13: If there is too much tension-sensitive product in the machine and the raising energy is too high, the product output rate is accelerated and thus the raising energy decreased.

pending on the position and tendency of the dancer rollers (Figs. 11–13) the nap roller energy and the speed of the material movement are controlled by the material infeed roller, so that the specified counter-nap roller energy is used more or less depending on the amount of looping.

In this way the Sistig machine controls the raising intensity independently depending on the material quality. Of course, like all raising machines the degree of wear of the raising rollers in these systems must be occasionally checked by a raising expert in order to carry out subsequent sharpening by grinding off if necessary.

The automation of the Sistig machine is so good for high quality, tension-sensitive raising materials, that two different processes can be considered:

a) Longer-term retention of all machine settings with regard to certain processed items in order to draw conclusions about the state of the cards from the number of passages that are required and therefore set the point in time when the cards need to be sharpened.

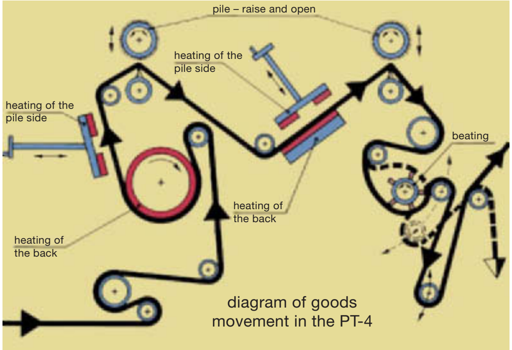


Fig. 14: The POL-Therma PT-4 bench raising machine (Sucker-Müller).

b) “Jigger”-type raising of velour material, whereby the Sistig machine can raise forwards and backwards from batch roll to batch roll, without switching the material from back to front. This method is made possible by the machine’s individual drive facilities.

A distinction must be made between card roller raising machines and table raising machines. Fig. 14 shows a table raising machine for cotton warp velvet for pile opening before dyeing and for preparing the pile after dyeing. When processing articles made from synthetic fibres, the back of the material is formed thermoplastically by steam heating, and the nap side using IR radiation.

Raising machines for yarns provide voluminous appearance before insertion into the fabric, particularly in the case of weft yarns.

Raising needle felt cloth According to DIN 61 205, raised fabric whose raised surface is reinforced by needles.

Raising teasels Natural teasels on thistle heads that are used for → Raising. The thistle heads can be inserted into rods (rod teasels) or attached to rotating rollers (roller teasels) that themselves rotate on a cylinder.

RAL Ger.: (Reichs-)Ausschuß für Lieferbedingungen und Gütesicherung (e.V.) beim Deutschen Normen-Ausschuß (DNA – German Standards Committee).

Ramie (China grass, nettle), → Bast fibre, formed in the stems of nettles. Method of obtaining fibre: manually or automatically (Ramie decorticator) from freshly-cut stems and by cottonizing. The Ramie stem structure is comparable to that of the → Flax stem structure. Raw fibre: pure white, fine, silky gloss. Individual fibres: 50–260 mm long, ∅ 20–100 µm. Microscopic: tape-like, conspicuously wide and uneven, irregular longitudinal stripes, also cracks in longitudinal and lateral directions, often has wall displacement, possible twisting. Tearing resistance: dry 40–60 cN/tex, 10–20% more when wet. Breaking elongation 2–3%. Chemical: (raw fibre) 66% cellulose, 10% water, 10.5% water solubles, 0.5% fats and waxes, 13% pectin/lignine/hemicellulose, 1.2–5% ash. Chemical properties similar to flax (particularly with regard to sensitivity to alkalis and bleach), has similarities to cotton when dyeing. Usage: for lingerie, tablecloths, fishing nets (rot-resistant), carpets, etc.

Ramina Braiding made from Ramie for hats, bags, arts and crafts, etc.

Random crease photographer → Photographic standards for fabric creasing.

Random sample/chemical According to DIN 50 001 is only for orientation purposes and in itself is not to be evaluated as an average sample, because it is usually only based upon two or three values. → Chemicals, sampling of.

Random sampling/textile If an appropriate number of individual values (random sample size) are taken, this should provide a reliable estimated value for the dispersion of individual values, which can be drawn upon in the evaluation of variations in characteristic values (e.g. tolerances). Precondition: defined sampling with representative probability, correspondingly unified confidence interval and confidence factor. → Technical textile sampling.

Random Tumble Pilling Tester Device for testing → Pilling behaviour, consisting of six round containers lined with cork or plastic. Three samples of a type of material whose edges have been bonded with glue are placed in each round container, together with 25 mg of cotton lint. The samples are tumbled around for 1 hour by a paddle rotating in the round container (1200 rpm). The cotton lint is used to make the pilling effect visible. Visual evaluation. Graded from 1 (extremely strong pilling) to 5 (no pilling).

Random webs → Nonwovens without preferred fibre orientation.

Random winding →: Package winding systems; Yarn packages, preparation.

Range (statistical) Statistical difference between the greatest and smallest values of n (random sample range): $Rn = x_{max} - x_{min}$.

Rankine scale (°R). Degrees Rankine is a normal unit of temperature in England and the USA: start of the scale (like → Kelvin) at absolute zero is 0°R, freezing point 491.67°R, vapour point 671.67°R. Fundamental difference between freezing point/vapour point is 180°R, which is equivalent to 180°F; 1°R is therefore equal to 1°F:

1 Rankine unit = 1 Fahrenheit unit
= $^5/_9$ Celsius unit
= $^5/_9$ Kelvin unit.

Ranking test General test method for evaluating characteristics that are difficult to record objectively, such as handle of textiles, visual evaluation of optically brightened samples, smells, etc. For example, it can be said with defined statistical certainty whether there is a difference in the effect of two products made from different raw materials. Principle: pair-wise comparison of two test samples in a series by at least three checkers. The "better" sample is given a mark of 1, and the "worse" sample is given a mark of 0 (in cases of doubt, both samples are given a mark of 0.5). The overall rating totals for the individual test samples can be combined into a ranking and mathematically/statistically processed. This method is better than simply ranking test subjects, according to increasing or decreasing characteristics, by making a continuous decision between three test subjects.

Rapid ager Most common continuous steamer especially for brief steaming (1–10 min) and high outputs in roller printing for vat and developing dyes, also for discharge printing. There is a row of driven guide rollers above and below. The fabric runs in a zigzag arrangement, alternately downwards and upwards, each facing the rollers with the reverse and printed side of the fabric, therefore cannot be used as a screen printing steamer. The oven roof is double-walled and steam heated (protection against spotting), with an exhaust duct or fan. Oven base has perforated steam pipes and condensate collector, the level of which can be regulated externally. This provides the option of generating saturated steam (steam supply from the condensate) and acid steaming (addition of volatile organic acids, or alternatively by spray nozzles). Steam temperature usually 101–103°C. The material is preheated and the air is evacuated (particularly necessary for vat printing) in a heated pre-chamber.

Rapid bleach processes All processes, in which the material to be bleached is exposed to the bleaching bath for less than 10 min.

Rapid cleaning of padders The automatic rapid cleaning of padders makes it is possible to economically dye even small dyeing batches on a continuous dyeing plant or in accordance with the pad batch process. The squeezing and guide rollers are automatically cleaned according to a pre-selected program when the batches are changed. The padding trough is automatically emptied, cleaned and filled with new liquor. The cleaning time is less than 8 min (see Fig.).

Rapid cross-linking → Shock-cure process.

Rapid desizing Continuous → Desizing by a large quantity of desizing agent (usually bacterial amylases) and subsequent steaming, whereby the starch is decomposed at an accelerated rate.

Rapid drier In the rapid drier (see Fig.), in contrast to the → Pressure boiler, heated fresh air is blown through crosswound yarn packages and discharged as moist exhaust air and is not reused.

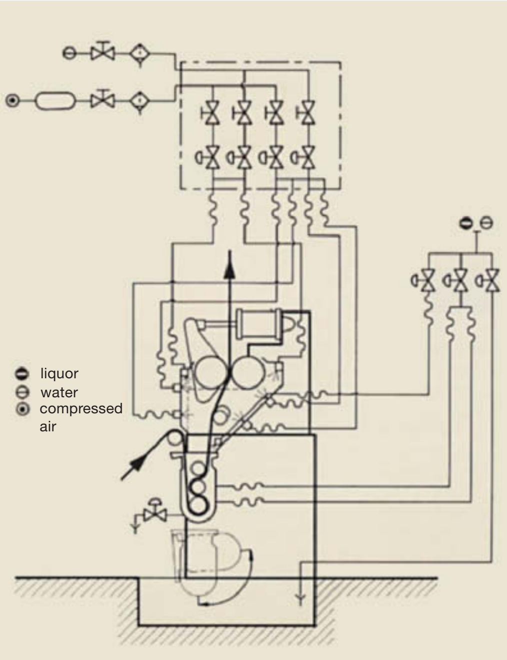


Fig.: Rapid cleaning system in dye padder (Monforts).

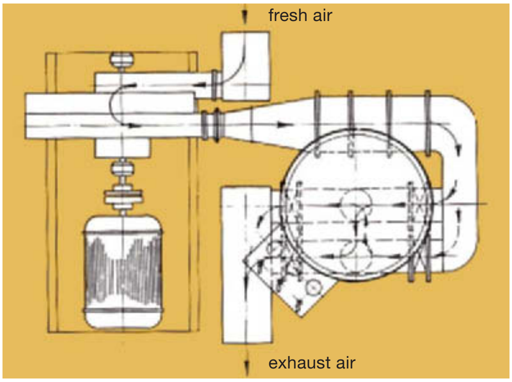


Fig.: Rapid drier (Krantz).

Rapid dyeing machines serve to increase production (prerequisite: low set-up time, sufficient material feed) and as multi-purpose rapid dyeing machines. They differ from conventional dyeing machines because of the use of high performance pumps (increase in liquor throughput to approx. 150 l/min/kg), heaters (heating-up rate of approx. 15°C/min), heat exchangers, shock dyeing devices, short liquors up to 1 : 5 and less (e.g. due to dividers), change of liquor direction, etc. (see Fig.). On the other hand there is an increase in

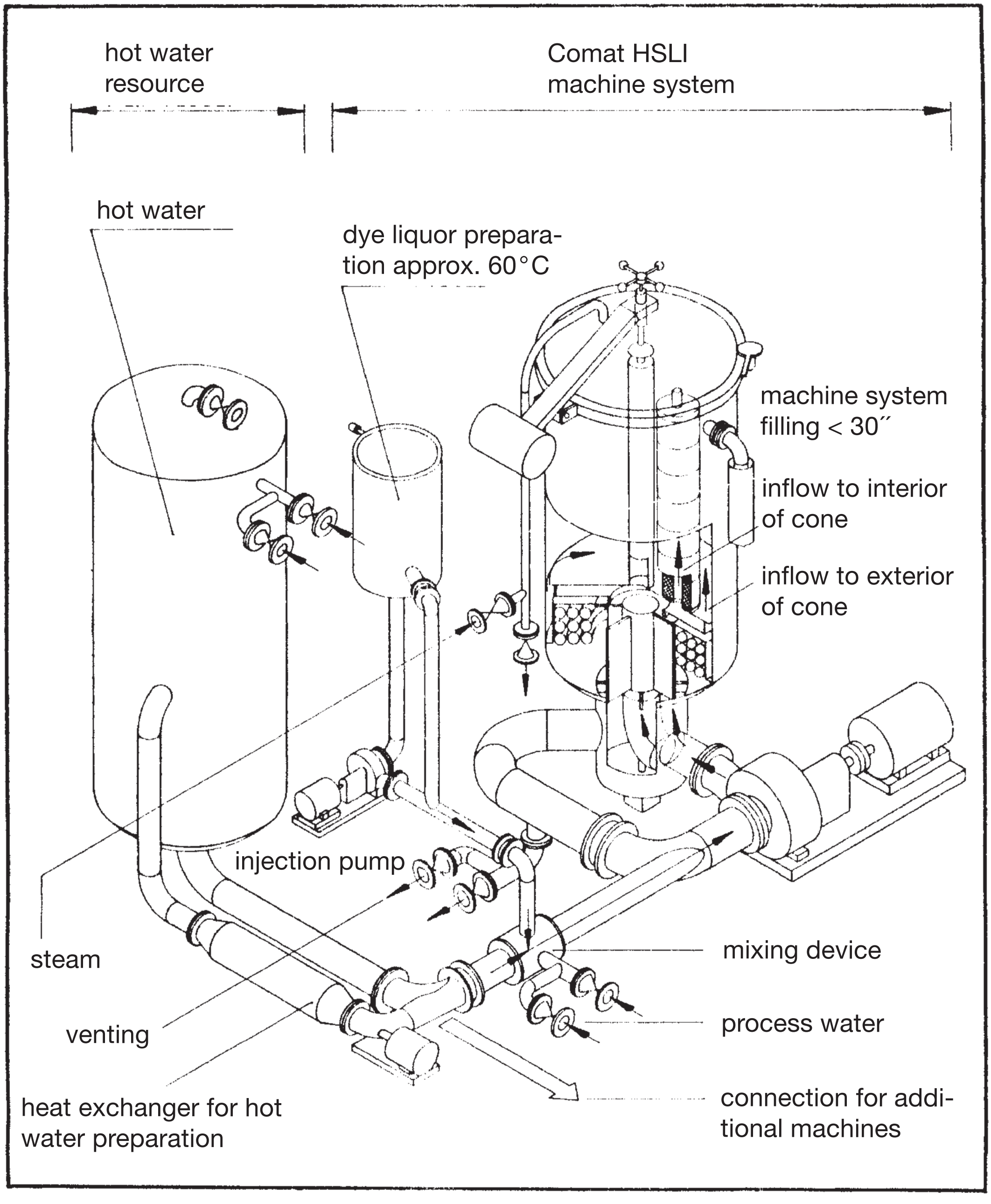


Fig.: The Then-Comat HSLI, a typical example of a rapid dyeing machine.

the energy used for heating (HT = although the temperature is slightly higher, time is reduced) and pumps for higher liquor throughput (compensated by shorter pump running time).

Rapid dyeing of loose wool CSIRO continuous process (derived from the cold dwelling process for wool): high concentration of urea is padded together with the dye, then steamed for 5–10 min, washed and dried.

Rapid dyeing processes Term for shortened dyeing processes. Thanks to reduced treatment times, rapid dyeing processes make it possible to notably reduce

Rapid dyeing processes

property		requires
group	G	exhaustion zone, combination zone
diffusion	D	time at maximum temperature
levelling	L	heating rate
migration	M	additional time at maximum temperature (if required)
compensation number	Az	cover of fibre differences

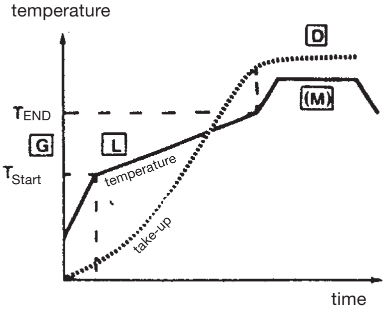


Fig.: Dye properties and application requirements for the purpose of rapid dyeing (by Bayer).

finishing costs. However, it is only possible if operating reliability and reproducibility are retained.

In controlled exhaust dyeing processes, the heating-up time can be reduced if heating takes place faster outside the critical exhaust range of the dye (see Fig.). The location of the exhaust range is dye-specific and moves to higher temperatures as the quantity increases. It is common to divide disperse dyes into groups according to the location of their exhaust range. The exhaust range can usually be calculated sufficiently accurately from the group and quantity. In combination dyeing the relative location of the exhaust range of the individual dyes should be taken into account. Tone-in-tone exhaustion should be viewed as a significant criterion for uniform dyeing. Normally, tone-in-tone exhaustion only occurs with disperse dyes in certain application quantities (shades). However, virtually tone-in-tone exhaustion is possible with some dyes over a wide range of shades: Dyes with higher solubility, those that have a mutual influence over each other or can be levelled by auxiliaries, i.e. mixtures of components of close shades with displaced exhaustion ranges. Almost tone-in-tone exhaustion is beneficial for levelness, because shade differences are avoided. It is not so important in disperse dyes as it is for ionic dyes, because disperse dyes do not block each other; it is therefore often only of secondary importance for their levelling capacity.

The V numbering system of the Yorkshire Company is worth mentioning in this connection. With the aid of this system so-called V factors, which ensure a uniform shade structure in combination dyeing, are calculated for dyes. The V factors are determined for the dye in question as follows:

1. A dyeing is performed under precisely defined conditions.
2. An exhaust curve is determined for the dye by taking adsorption measurements of the liquor at certain temperature and time intervals.
3. Based upon this information, the time is determined at which half the final colour separation was achieved ($t^1/2$). This value is converted to a parameter V, which represents a negative function $t^1/2$.

It is easy to reach the following conclusion from this: The greater the V factor, the faster the exhaustion rate. These measurements are repeated at many concentrations of each dye. In this manner the V factors are determined for all desired dyes of different shades and the results represented in graphical form. Due to the rapid increase in the V factors for shades < 1%, the V factors are represented logarithmically in relation to concentration. Specific curves are found for each dye. At a dye concentration < 0.05%, the precision of the measurement falls due to the definition of the V factor, because this has a limited maximum value of 7 at 0 % dye concentration and, therefore, all graphics relate to this value. Combinability, and therefore, a tone-in-tone colour structure, is expected if all individual dyes in a recipe have similar V factors. A difference of 0.5 is tolerable. The V factors are not applicable on dyes which are themselves a mixture.

A further option for guaranteeing the combinability of disperse dyes, and thus the levelness of dyeings, is the concentration error diagram. Concentration differences in the dye are the main cause of non-uniformity at various points on the textile. Concentration differences are caused by:

- differences in liquor circulation,
- temperature differences,
- differences in penetration,
- different auxiliary influences.

However, when measuring non-uniformities it is difficult to associate differences in visual impression with specific differences in dye concentration on the textile material. Directly applicable quantitative guidelines can be obtained from a concentration error diagram. The colour differences of off-shade dyeing, which are dyed using defined concentration differences in comparison with a basic recipe, are plotted on this diagram. This diagram can then be used to find the magnitude of the expected colour differences with a defined deviation in the dye concentration from the initial recipe consisting of several dyes. It is easy to deduce from the total colour difference which components of a combination will give rise to concentration errors and may be particularly visible due to differences in the speed of exhaustion and which shades are particularly sensitive to errors with regard to non-uniformity.

In order to create a concentration diagram (according to Leube and Rüttiger), defined concentration errors are predetermined (starting from a certain recipe). Fibre samples are dyed in liquors, which contain the dyes measured with concentration errors; the colour difference from the standard recipe is then determined by colorimetry based upon the spectral reflection of the finished dyeing. The following can be derived by considering the concentration error diagram:

- The diagram forms a bridge between colorimetrically measurable concentration differences and coloristic evaluation practice.
- The same concentration error, which can be expressed in dye percentages, will have a different effect due to the variable sensitivity of the human eye and due to shade dependency of the colour differences.
- The measured colour differences do not allow conclusions to be drawn regarding the observed non-uniformity.
- In the optimization of the recipe, particular attention is paid to the dye for which the concentration error caused the greatest colour difference in the error diagram.

With the introduction of the Ku_{20} factors, characteristic quantities became available in polyester HT dyeing works for disperse dyes, which allow predictions of practical value to be made for short period techniques.

$$\mathrm{Ku}\,[\%] = \frac{c_{max} - c_{min}}{c_{min}} \cdot 100$$

c_{max} = max. dye concentration on the fibre,
c_{min} = min. dye concentration on the fibre.

The non-uniformity of a standard depth dyeing can be calculated using this formula. Dyes with Ku_{20} values of 2–5 are particularly well suited for an efficient dyeing process with a high heating-up rate and have been collected together to form a range.

The Hoechst Rapidcolor process is an isothermal dyeing process which takes place at the fixation temperature of the dye. This type of procedure is made possible by a previous steaming phase and a rapid filling of the dyeing kettle in the HT range. The dyeing process can be subdivided into the following process steps:

1. preheating of the textile and dyeing kettle,
2. filling process,
3. dyeing and aftertreatment.

The cooling of the incoming dyeing liquor should be avoided as a precondition for the immediate start of dyeing at the fixation temperature of the dye. If complete impregnation and uniform dye distribution is to be achieved, no trapped air should be present in the wound package. Therefore, the textile is steamed at the beginning of the treatment process, whereby the position of the steaming process in the sequence of flow is such that that volumetric expansion and density differences in the two media cause the air to escape from the textile and is vented from the machine. Condensation of the steam in the material being dyed and at the machine components gives rise to a very rapid heating up of the entire system.

In practice, the steam is allowed to flow into the dyeing kettle containing the dyeing batch at a pressure of approx. 4 bar. As the steaming time increases the steam pressure increases within the dyeing kettle and is limited to 1.5 bar. At the beginning of the process the HT discharge is opened briefly, until the air initially present in the system has been removed. Then the actual heating-up process takes place in an atmosphere of saturated steam. Temperature measurements within polyester wound packages with inserted thermoelements have shown that there is a uniform temperature distribution in the different yarn layers across the diameter of the wound package, which remains constant and the temperature reached depends upon the saturation state of the steam (i.e. in this case 127°C). This creates good preconditions when the dyeing kettle is subsequently filled with dyeing liquor.

The water quantity necessary for the dyeing is heated to 140°C in a water heater. A cushion of steam is maintained above the liquor level in the water heater. The steam cushion is maintained at slightly above the saturation pressure. Dyeing auxiliaries can be added to the hot water receiver. When the connection line to the dyeing machine is opened the hot water at 140°C flows into a mixing device due to differential pressure. The disperse dye batch, prepared in an open preparation vessel and heated to 160°C, is simultaneously dosed into the incoming stream of hot water via a mixing device with the aid of an injection pump (this procedure excludes the possibility of thermal stress in the dye dispersion prepared in the preparation vessel). The finished dyeing liquor with all additives enters the dyeing kettle, and liquor feed takes place to both the inside and outside of the wound package due to the suitable positioning of the liquor return unit. The purpose of this type of filling process is to achieve a uniform liquor supply and to avoid hydraulic pressure differences during the filling phase. Since there is no air in the system during this process, no foaming takes place; therefore there are no irregularities in the flow through the wound package due to foaming. The sequence of the filling process is as follows: after running through the feed line behind the mixing section the dyeing liquor at approx. 135°C enters the steam atmosphere at 127°C, which corresponds to a saturated steam pressure of 1.5 bar. The saturation pressure of the dyeing liquor at 135°C corresponds with 2.2 bar. As the level of the liquor within the dyeing kettle increases, the steam volume above the liquor falls, with a corresponding increase in steam pressure. When the saturation pressure of the liquor is reached, the steam pressure cushion begins to condense. The steam condenses continuously, because the pressure difference due to the superimposed pressure in the water heater is maintained until the final level in the dyeing kettle has been reached. Then compressed air pressure is applied and liquor circulation starts at 60 l/kg/min. A mixing temperature of 129–130°C is soon set after the beginning of liquor circulation.

Rapid fill Rapid transfer of dye liquors into a dyeing machine.

Rapid fixation dyeing units Small continuous plant for universal application or as washing/rinsing machine for pre-treatment (desizing, bleaching). The steamer can be flooded and used as a washing plant. Counter current principle; extremely low water consumption. Modular structure.

Rapid mixers, rapid stirrers are high speed mixers. They differ due to the size and shape of the stirrer assembly (mixing heads), upon which the fine distribution depends: stationary, portable or transportable. In textile finishing above all for the application of printing thickeners and dye solutions.

Rapid steam generator Boiler with up to 1000 kg/h performance (→ Steam boiler).

Rapier loom Weft insertion takes place by means of so-called rapiers, i.e. positively moved rods (Fig. 1) or belts (Fig. 2), with rapier heads attached to the tip, which convey one weft thread through the weaving line for each weft. The rapiers can be fitted on one side (in this case they cross the entire weaving line) or on both sides (the thread is transferred from one rapier to the other in the middle of the line). Furthermore, we differentiate between tip and loop insertion or transfer.

The principle of a rapier weaving machine can be explained as follows based upon the example of a Dornier rigid rapier with tip insertion and controlled central transfer: The rapier movement is derived from complementary double cam centres, which have curve paths that optimize the rapier movement and thus minimize the strain on the weft yarn. Both rigid rapiers work without lead teeth in the weaving line. Before entry into the line the left-hand rapier grasps the yarn presented by the passing needle with an open clamp. After the clamp has closed a clipper cuts the weft thread on the fabric side. The weft thread is transferred from the left-hand to right-hand rapier in the centre of the machine. Two independently adjustable opener levers, each of which is driven by cams and roller levers, serve for the positive control of the weft transfer. The opener lever dips under the weaving line before the laminar

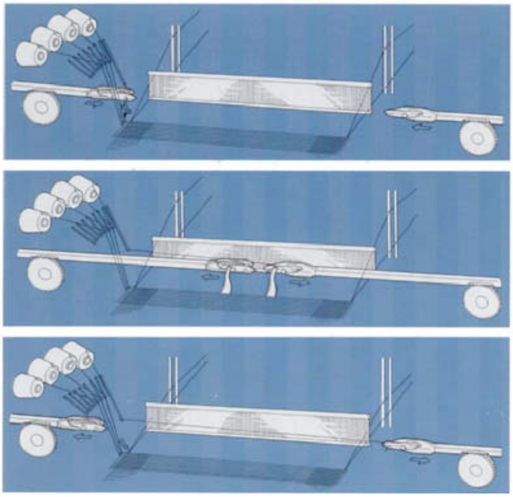


Fig. 1: Rigid rapier principle (Dornier) in a gripper loom.

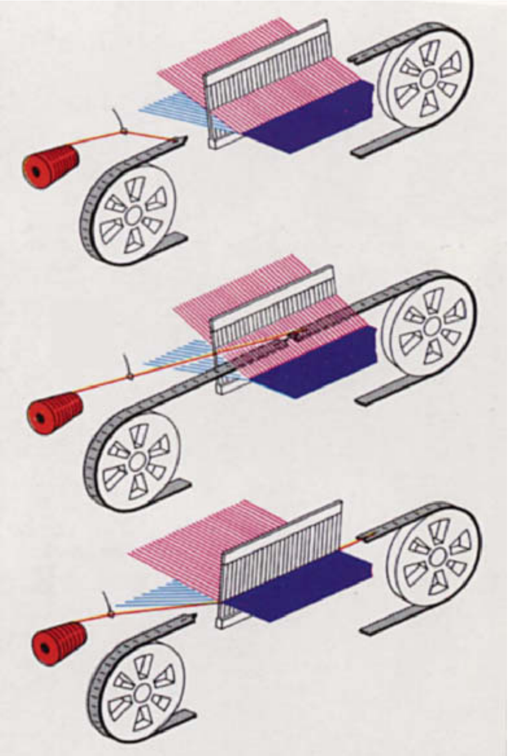


Fig. 2: Flexible rapier principle (Nuovo Pignone) in a gripper loom.

stroke, so that no fabric striping occurs. After the low tension thread transfer the taker rapier takes the weft to the right-hand edge of the fabric. During the insertion phase the weaving line remains open. The weft thread is only released from the controlled rapier clamp when it is held by the claw strip.

Rare earth metals Metals belonging to the rare earth group, e.g. cerium (Ce), lanthanum (La). They are described as rare earths due to chemical relationship with aluminium, “alumina”.

Raschel batt-on-base carpet Textile floor covering. Instead of pile yarns a fibre nonwoven is used in combination with auxiliary yarn using the raschel technique to form a bouclé carpet, which is then shorn to produce → Velvet pile carpets.

Raschel carpet (knit-woven carpet), a velour carpet manufactured on a raschel machine, where the ground weave is woven at the same time. The pile threads, which are loose in the base material to start with, are fixed in place using reverse-sided coating (latex, artificial resin). Similar appearance to tufted carpets. Usage: e.g. stair carpet material.

Raschel-knitted fabrics → Warp-knitted fabrics made on the raschel machine (from the French: Rachel) for curtains (raschel curtains), lace, carpets, tulle, fashion materials (outerwear, underwear), etc.

Raschel tulle Net-like knitted fabric that is manufactured with two retracted guide rails in accordance with a pattern. Each warp thread has a weft thread assigned to it. The effect of the honeycomb-like openings is not shown to its best advantage until finishing has taken place.

Ratchet effect Relates to wool scales and the fact that they hook onto each other as in the so-called directional friction effect (DFE) assumed to play a major role in → Felting.

Rate of dyeing Rate at which the dyeing bath is exhausted. A suitable measure is the inverse of the → Time of half-dyeing or the time after which 70% of the dye has been absorbed.

Rate of evaporation Increases with increasing temperature, because the average molecular speed increases at the same time, and therefore so does the percentage of molecules with above average speed, which can escape from the surface.

Rate of fixation,

I. In reactive dyes the fixation speed is characterized by the period of time in which a stable bond is formed between the dye and fibre molecule. It is dependent upon the reactivity of the reactive group in the dye molecule, alkalinity of the fixation medium and temperature.

II. In disperse dyes the fixation speed depends upon the diffusion speed of the dye in the synthetic fibre, which is determined by the dye concentration and temperature and pressure relationships during fixation.

Ratiné (French: crimped), carded yarn-like double cloth with small knots, knops or twisted ringlets; also in the form of compressed waves (= Welliné), manufactured as woven or knitted fabrics. Usage: for winter coat materials.

Ratiné finish Woollen fabric character with wave-like appearance on the surface.

Rationalization Meaningful organisation of working processes with the aim of optimising the cost/result ratio. For example, this includes conversion to continuous operation, increasing the speed of the material, use of the → Combination process, utilisation of the heat in sewage and exhaust air, use of water-saving washing machines, avoiding intermediate drying, i.e. use of wet-in-wet process, etc.

Ravensberg process → Bleaching of linen.

Raw cotton composition 83.71% cellulose, 6.74% water and impurities 0.61% grease, wax (→ Cotton wax), 5.79% hemicellulose, pectins, 1.50% proteins, 1.65% ash. According to Bowman: 91.35–90.80% cellulose, 0.40–0.42% wax-oil-grease, 0.53–0.68% protoplasm, 0.22–0.25% mineral components, 7.50–7.85% water.

Raw cotton dust Contains a considerable proportion of dust (fragments of cotton, cellulose, stalk, leaves, seeds, seed leaves, bolls, mineral components, etc.). Dust is created throughout the processing of the raw cotton, from the opening of the bales by the preprocessing machines to the carding machine, and this enters the lungs and can cause an illness, so-called → Byssinosis, in workers. Therefore the total amount of dust (fibrous and non-fibrous components) in the air of the processing areas should not exceed the TLV value (maximum workplace concentration).

Raw hide Untanned leather, from which the outer and inner skin connective tissue has been removed by lime soaking. Quickly decays in damp air, becomes stiff like horn in dry air and swells in boiling water to form glue. Tanning is vital to counter these effects.

Raw linen → Unbleached linen.

Raw silk Non-degummed → Silk (grège silk), still glued with silk gum and non-twisted individual threads.

Raw wool (greasy wool), is shorn → Wool, which still contains dirt. It contains 20–50% pure fibres, 6–17% wool fat, 10–30% wool grease, 20–40% impurities and (air dried) up to 18% water.

Raw wool scouring Preliminary washing process for the removal of wool fat, wool grease, dirt pigments (Fig. 1), etc., e.g. on the leviathan with soap and sodium carbonate. Soap can be replaced by lime resistant synthetic products, which facilitate clear rinsing, particularly in the final baths, or gentle acid scouring or scouring with solvents. Additives of ammonia or grease solvent washing agents are used for wool containing pitch tips. The wet process can be made significantly

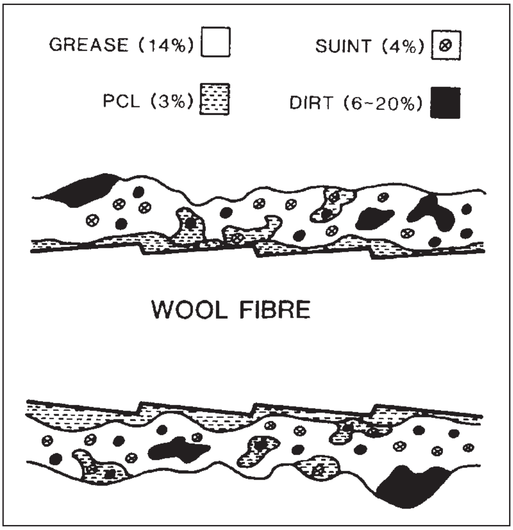


Fig. 1: Diagram as suggested by CSIRO (C. A. Anderson, B. O. Batenp, I. R. Christol, I. I. Wanner) to describe the soiling of raw wool.

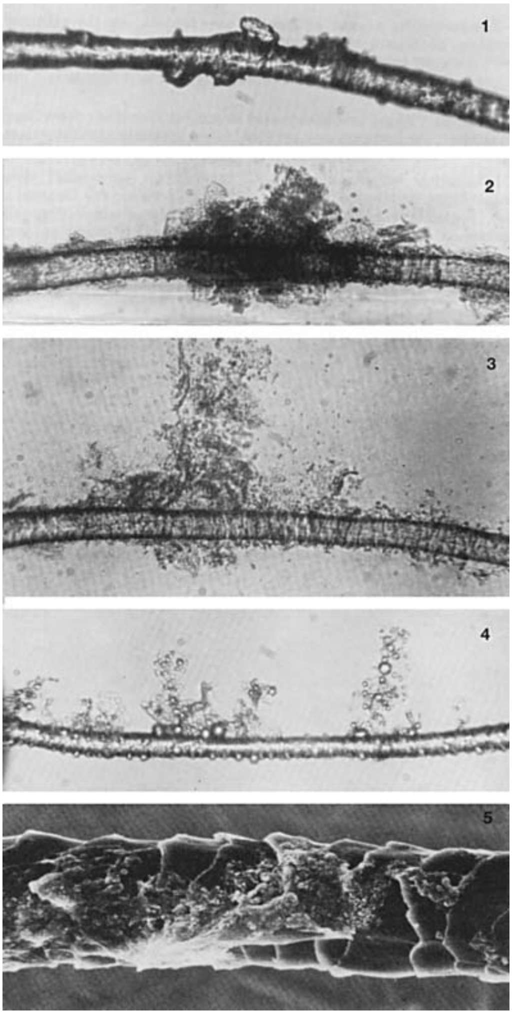


Fig. 2: The progress during the scouring of a wool fibre of 21 μm thickness (according to CSIRO).
1 = greasy wool; 2 = initial swelling of the inpurities; 3 = removal; 4 = advanced scouring stage; 5 = protein contamination of a scoured fibre.

easier if the maximum possible amount of vegetable impurities and sand is removed beforehand by a mechanical treatment (Morolan process). DIN 60415 describes the different work processes in wool scouring and combing works.

Raw wool is washed in aqueous liquor. Solvent scouring is of lesser importance. The pH of the aqueous extract from wool varies between 5.5 and 9.5. Attention should be paid to this in the composition of the washing baths.

Warm water is used for the 1st bath (approx. 40–45°C), the primary aim of which is to remove the wool grease (Fig. 2). The potassium carbonate contained in the wool grease influences the wash activity of the baths. Washing baths, the temperature of which lie a little above 38°C, the melting point of the wool fat, follow the soaking phase. In most companies, washing is managed in such a way that soap and sodium carbonate are used in the first degreasing trough, but a lime resistant washing auxiliary is used in the second. This measure makes the subsequent rinsing process easier. In some companies the wool is treated with a sodium hydrogen sulphite solution before the last rinsing section. No clear conclusions can be drawn about the harmful influence of sodium carbonate in wool scouring. If the temperature of the washing baths does not rise significantly above 38°C, little fibre damage can be expected. The greatest degree of fibre protection should be achieved at the isoelectrical point of the wool, i.e. at approx. pH 4.6. Various acid resistance, non-ionogenic washing agents are used for this purpose. However, wool washed in this manner will exhibit worse behaviour in the combing and spinning works than wool washed at pH 9.5. Acid scouring is not important in practice.

Previously, washing took place continuously on the so-called leviathans; these are component groups consisting of several washing and rinsing vats interspersed by squeezing units (Fig. 3). The mechanically loosened wool flock was moved forwards in the vats by conveyor forks. In a system by Fleissner suction drums, of which there are 5–6 one after the other, replace the conveyor forks to achieve gentler transport of the wool (Fig. 4). The Charpentier and Chaikin systems use con-

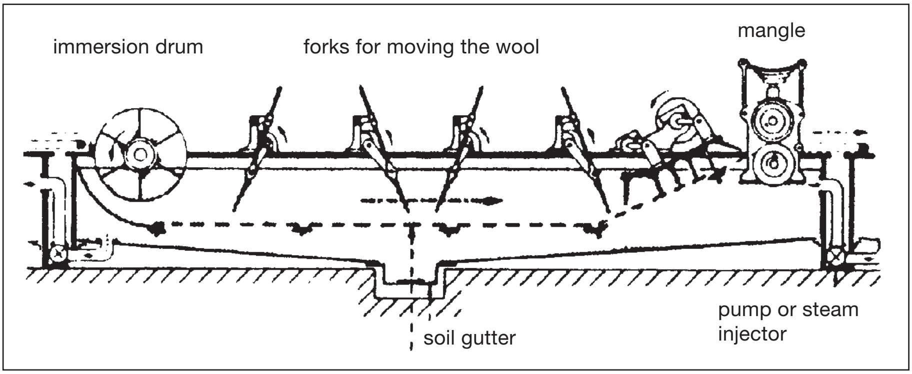


Fig. 3: Part of a leviathan used for scouring raw wool.

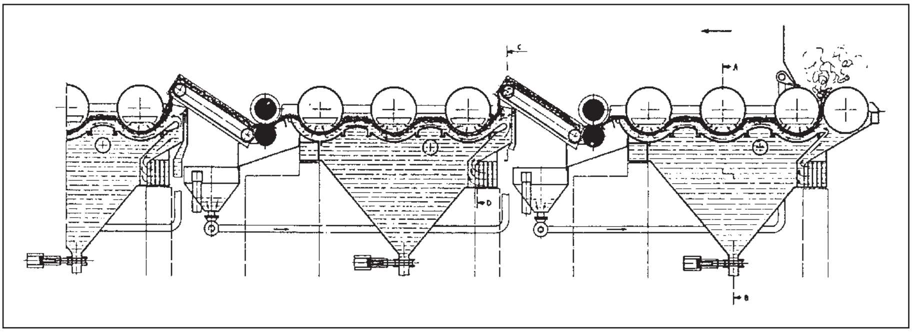


Fig. 4: Diagram of a three-tup wool scouring machine with suction drums to transport the wool (Fleissner).

veyor belts, as do Australian “flat bed” washing machines, which do not use jets or squeezing rollers; these processes are called “hydrodynamic wool washing” processes. Drums, connected by steel pipes are used in the CSIRO “jet scouring” processes.

The wool fat (lanolin) is reclaimed from the baths used in raw wool scouring. In the past it was assumed that raw wool auxiliary substances consisted only of wool fat, dried sheep sweat salts (wool grease) and mineral impurities. Investigations by CSIRO proved that a further, previously unknown, impurity was present, a protein substance that plays an important role in raw wool scouring and also in general washing processes. Amino acid analyses of this protein component proved that it most probably consisted of flakes of skin and possibly also the inner root sheath of the sheep skin follicle. Although such flakes of skin do not form a continuous layer around the entire fibre (Fig. 1), there is still contact with the fibre at various points, and it is into these flakes and fibres that wool fat, grease and other impurities embed themselves. It is also possible that the flakes overlap at various points on the fibre and thus form a barrier, which is difficult to overcome during washing.

This model of the structure of wool impurities has, with the aid of microscopic investigations into raw wool fibres in the washing liquor, led to new considerations with regard to the functional mechanism underlying the removal of impurities by washing in hot water. The mechanism consists of the penetration of water and the added surfactant into the impurity, which rapidly makes the fat and protein substance swell, the formation of balls of grease and the removal of the easily removed grease, dirt and protein components, which do not adhere to the fibre surface, together with the grease and dirt particles contained within them.

Experiments by CSIRO have shown that the highly soluble impurities can be removed in the first two hot washing sections of a conventional washing line. The difficult to remove pollutants on the other hand remain on the fibre. They cannot be removed in the subsequent rinsing sections either and have a detrimental effect on the properties of the washed wool, particularly on the ash content.

CSIRO proposes a solution to this problem by the concept of a two-phase washing process (Fig. 5), in which the two categories of impurity are removed in two separate sections of the washing line. Ideally, in the first section the washing liquor should contain an active surfactant and a washing agent booster, which dissolve the easy to wash out dirt particles from the wool. In the second washing phase, the wool should be exposed for

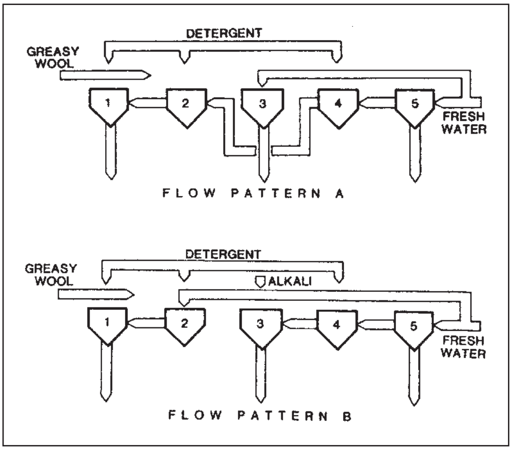


Fig. 5: Two among several possible configurations of the two-phase washing process. Significant features are the addition of surfactants in the 1, 2, and 4 scouring stages and the separation of stages 2 and 3.

as long as possible to a special liquor consisting of surfactants, washing agent boosters and enzymes, with which the difficult to remove dirt particles are removed from the raw material.

Raw wool scouring machine Further development of the → Suction-drum washing machines (suction-drum leviathan). The main component is the discharge drum. The propeller pump starts the washing liquor circulating, takes liquor from the discharge drum (Fig. 1) and conveys it back to the bath. Liquor thus flows through the washed material on the drum and the material floats freely between the drums. Several individual components can be connected in raw wool scouring lines (Fig. 2), which are computer controlled.

Rayon (reyon), designation for viscose filaments (fibres) that is no longer permitted. Also generally used for regenerated cellulose fibres in older literature (pre-1953).

Rayon staple fibre No longer permissible term for viscose staple fibres.

Rb Symbol for the element rubidium (37).

R-clauses (risk phrases). Risk instructions according to the working-substance regulations in accordance with EC Directives, i.e, identification of particular risks associated with dangerous working materials. In each case, the substance in question is provided with a number or number combination, for example, R9 = risk of explosion if mixed with flammable substances.

Re Symbol for the element rhenium (75).

Reactant-fixable dyeings Crosslinking agents

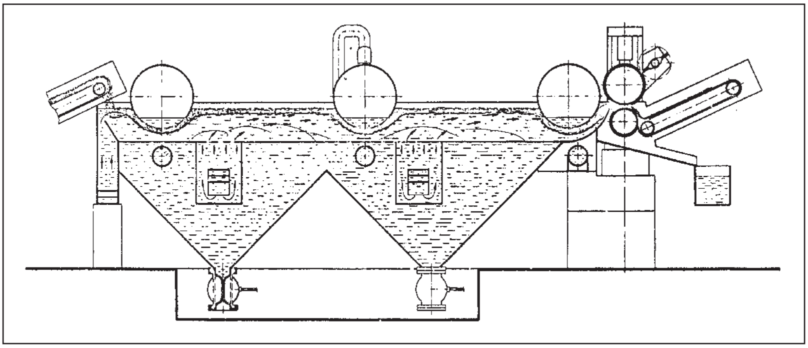


Fig. 1: The liquor circulation in a sieve-drum raw wool scouring machine (Fleissner).

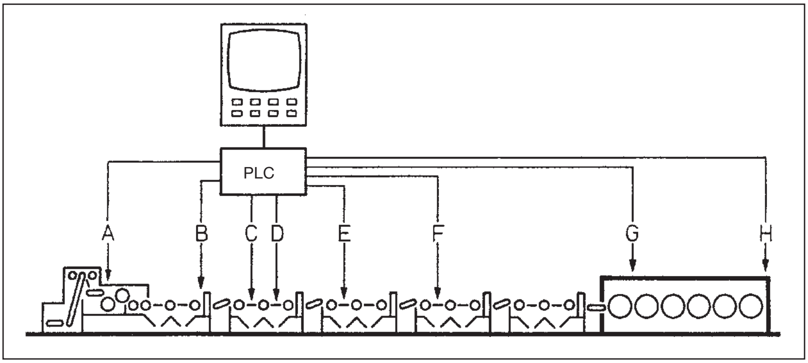


Fig. 2: A Fleissner raw wool scouring line system. A = steady feed of material; B = transportation drive and circulation pump revolutions; C = temperature (all baths); D = chemicals and fresh water dosing; E = reverse flow control (all baths); F = clarification (all baths); G = extraction air humidity and quantity; H = final humidity and drier temperature.

are used to bond direct and reactive dyes to cellulose in order to improve their wash fastness.

step A: the cellulose fibres are dyed with reactant-fixable dyes in a similar way to direct dyes.
step B: the reactant fixer is used to fix the dyeing.

During the fixing process, the dye is linked to the cellulose fibre via a special bond (Fig. 1). At the same time, the cellulose fibres are crosslinked via their active OH groups. Apart from the above-average wet strengths, easy-care properties are imparted to the product such as reduced crease acceptance, improved dimensional stability, reduced fibre swelling and, therefore, increased drying speed after washing.

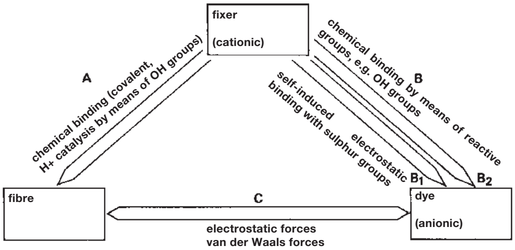


Fig. 1: The hypothetical mechanism of a dyeing system using reactant-fixable dyes.

During the fixing process, it must be ensured that the following reactions take place simultaneously (Fig. 2).

1. Crosslinking of the cellulose fibre, in association with a reduction in the swelling properties in both neutral and alkaline aqueous liquors.
2. Blocking of the free sulphonic acid groups ($–SO_3$) of the dye which has been applied.
3. Reaction of the dye with the active groups of the fixing agent.

The cellulose fibres are crosslinked by polycondensation of the fixing agent with the active OH groups on the cellulose. These are genuine covalent bonds. The water solubility of the complex is reduced by blocking the dye's water-affinity groups, such as sulphonic acid groups. The blocking process is an electrokinetic reaction triggered by the formation of salt from the anionic dye with the cationic side of the fixing agent. The changes which occur while the dye reacts with the fixing agent are not completely explained. A chemical reaction must also be involved, i.e, bonds must be formed which give the whole dye/fibre/fixing agent structure new properties.

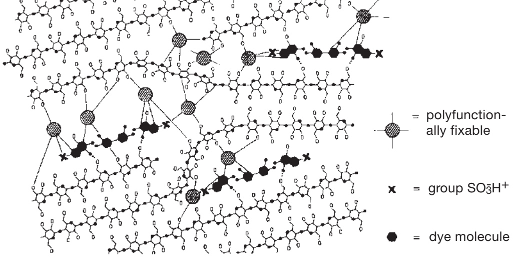


Fig. 2: The hypothetical fixing mechanism during dyeing with reactant-fixable dyes.

Reactions 1 and 3 must be catalysed by proton donors; Reaction 2 does not require a catalyst but takes place most efficiently in acid media. Evidence for the reactions mentioned can be obtained on the one hand by comparing the fastnesses achieved with state-of-the-art techniques (the new fastness specifications cannot be met even by the cationic post-treatment of direct dyeings) and on the other, by checking the individual reactions.

The crosslinking of cellulose fibres can be seen from the reduced fibre swelling in water or, for example, in 10% caustic soda. Conclusions can also be drawn from the stability of the bond achieved after repeated washings. The blocking of the water affinity groups of the dye can be confirmed by means of precipitation reactions between the reactant fixer and an aqueous solution of the dye or by analyses using chromatography. The new bonds formed between the fibre by the reactant fixer can be established by means of the DIF test (boiling in a dimethylformamide/water mixture), as is the case for reactive dyeings. It has been shown that only dyes with certain properties and groups in the molecule are suitable for reactant fixing.

Complete fixing is best achieved in the padder process with a 30 s condensation period (180°C) for dried goods. 80–130 g/l reactant fixer is used depending on the application, depth of colour, effects desired and substrate. All chemicals required for the finished goods, such as softeners, auxiliary aids, elastomers, hydrophobic or oleophobic agents and products to improve sewability, etc. are added to the dyebath at the same time as the fixing agent.

Reaction chamber Chamber, usually mobile, for heat and moisture treatment (hot air and steam heating) of piece ware batch rolls after padding with bleaching agents or dyes on a pad-roll machine.

Reaction, chemical Chemical conversion which takes place between two or more mutually interactive substances (atoms, atomic groups or molecules). The substances produced by the reaction are called reaction products.

Reaction product Substance produced by a → Reaction.

Reaction, rate of The rate of a reaction is equal to the change in concentration of chemical reactants divided by the time it takes for them to react and depends on factors such as the distribution of the reactants, their concentration and the temperature of the reaction. Because the rate of reaction, r, generally changes during a reaction, it is defined as the differential flux in concentration of a substance involved in the reaction divided by the stoichiometric number v_i (the reaction volume is regarded as a constant).

$$r = \frac{1}{v_i} \frac{dC_i}{dt}$$

where the stoichiometric number vi is negative for the reactants on the left and positive for the reactants on the right. The reaction rate of a generalised reaction

$$v_A A + V_B B + v_C C + ... \rightarrow v_L L + v_M M + v_N N + ...$$

is

$$r = -\frac{1}{v_A}\frac{dC_A}{dt} = -\frac{1}{v_B}\frac{dC_B}{dt} = -\frac{1}{v_C}\frac{dC_C}{dt} = \cdots$$

$$= \frac{1}{v_L}\frac{dC_L}{dt} = \frac{1}{v_M}\frac{dC_M}{dt} = \frac{1}{v_N}\frac{dC_N}{dt} = \cdots$$

If the external conditions (P, V and T) are constant, the rate of reaction usually depends on the concentration of one, several or all of the reactants taking part. The equation which describes this relationship is called a rate equation. For many reactions, it has been found empirically that the dependence of the reaction rate on the concentrations can be described by functions of the form

$$r = \frac{1}{v_i}\frac{dC_i}{dt} = k \cdot C_A^a \cdot C_B^b \cdot C_C^c \cdots$$

if it is assumed that the reaction goes from left to right only. The parameter k is the rate constant, the exponents a, b and c are partial orders and the sum of exponents (a + b + c ...) the order of reaction. The partial orders may be whole numbers or fractions; in general, they are not identical to the stoichiometric numbers. Thus, it can be seen that the overall reaction need not be identical to the reaction mechanism. → Reactivity in textile finishing processes.

Reactive and vat dyes on the fibre These behave differently on the fibre according to the following tests:

I. Solvent (→ Reactive dyes on the fibre, test for): Reactive dye = no or little bleeding; vat dye = significant bleeding.

II. Blank vat: azo-based reactive dye (usually red or yellow) = decolorizing or discoloration. The colour does not return to its original shade (unlike vat dyes).

III. Zinc chloride/nitric acid test (for phthalocyanide derivatives only, i.e, blue and green proprietary brands): reactive dyes react positively and vat dyes react negatively.

Reactive dyeing Reactive dyes form covalent bonds with the free neucleophilic groups of fibres. In the case of silk fibroins, the dye mainly reacts with the tyrosine residues which are located at the end of the crystalline zones. These present the dye with a hydroxyl group as the active counterpart. Here, there is a certain degree of similarity to the fibre chemistry of cotton. Other amino acids such as threonine and serine also present the dye with hydroxyl groups. As well as forming bonds with the hydroxyl groups, bonding also takes place via the amino and imino groups of the fibroin, lysine in particular. In spite of this, the N terminal amino acids and the amino acid histidine have other amino or imino groups available for bonding. Similar groups play a part in the case of reactive dyes for wool, but these are mainly amino groups. Cellulosic fibres also have OH groups.

There are two types of reactive dyes and these can be distinguished from each other by their reaction mechanism: those that react by addition and those that react by substitution.

1. Addition reaction of reactive dyes. On the one hand, these dyes react with the fibre via a nucleophilic addition reaction such as, for example, the vinylsulphone compounds. A prerequisite for reaction with the fibre is the formation or presence of unsaturated vinyl sulphones. These are produced from sulphonatoethylsulphone with the addition of an alkali. The active vinylsulphone can now react both with hydroxyl groups, such as those of cotton, and with amino groups, such as those of the fibroin of silk. Reaction with hydroxyl groups produces an ether linkage (R–O–R) without generating any side products. The reaction with the vinylsulphone group follows the following route:

$$\textcircled{F}\!-\!SO_2\!-\!CH_2\!-\!CH_2\!-\!O\!-\!SO_3Na + NaOH$$

sulphatoethylsulphone

$$\longrightarrow \textcircled{F}\!-\!SO_2\!-\!CH\!=\!CH_2 + Na_2SO_4 + H_2O$$

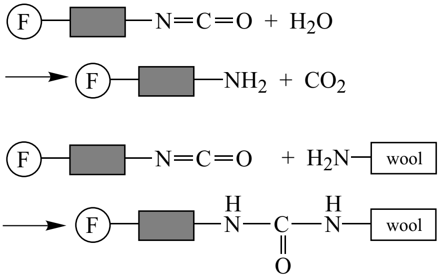
reactive vinylsulphone

$$\textcircled{F}\!-\!SO_2\!-\!CH\!=\!CH_2 + H_2N\!-\!\text{silk}$$

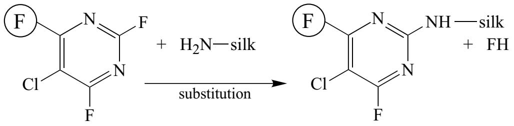
$$\xrightarrow{\text{addition}} \textcircled{F}\!-\!SO_2\!-\!CH_2\!-\!CH_2\!-\!NH\!-\!\text{silk}$$

An isocyanote active group can also react according to the addition mechanism (see structure).

2. Substitution reaction of reactive dyes. Nucleophilic substitution is another reaction route. In this case, the reactants are halogen-substituted, nitrogen-containing heterocyclic groups, the nucleous of which usually consists of a triazine or pyrimidine ring. These

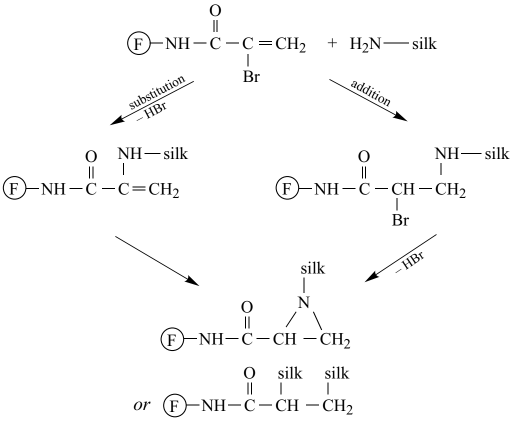


active groups are already available to react because the halogen atoms (chlorine and fluorine) are immediately replaced by an active basic group on the fibre:

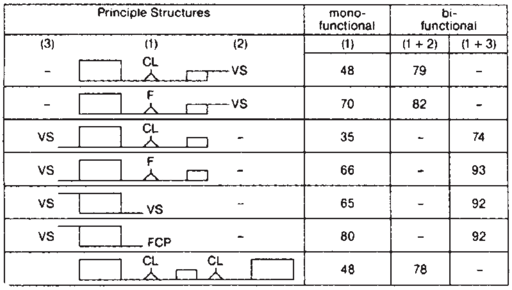


The reactivity of this dye is determined by the active halogen atoms. Due to its reactivity, the fluorine atom in position 2 reacts first. The reactivity of the fluorine atom in position 4 is only high enough to take part in a second reaction with nucleophilic groups.

3. Combined substitution and addition reaction of reactive dyes. Dyes which react both according to a nucleophilic substitution and a nucleophilic addition at a double bond represent a special case. The active group is an α-bromoacrylamide. The end product of both reactions is the same aziridine three-member ring but theoretically, crosslinking of the substrate is also conceivable.



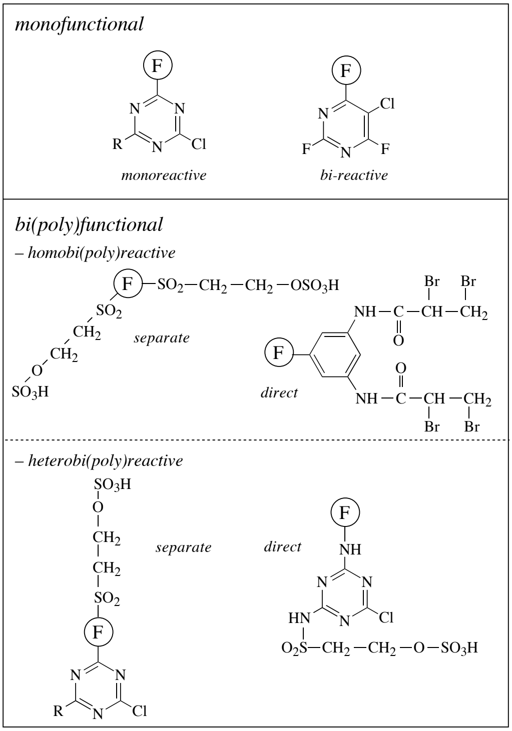
Another characteristic feature of reactive dyes is the number of active groups. In considering a monoreactive dye (dye A) with a selectivity of 60% (degree of fixing approx. 60%) and a dye with two reactive groups per molecule (dye B) each showing a selectivity of 60%, then the degree of fixing achieved by dye B in practice is 85% against the barely 60% achieved by the monoreactive dye, dye A (Tab. 1).



Principle Structures			mono-functional	bi-functional	
(3)	(1)	(2)	(1)	(1 + 2)	(1 + 3)
-	CL	VS	48	79	-
-	F	VS	70	82	-
VS	CL	-	35	-	74
VS	F	-	66	-	93
VS	VS	-	65	-	92
VS	FCP	-	80	-	92
	CL CL		48	78	-

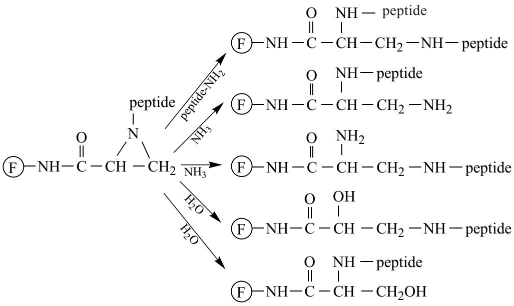
Tab. 1: Differences in the fixing yield depending on the functionality and the structure of the reactive dye.

Bi-reactive dyes are capable of producing the following reaction products:



In regard to the active site on the fibre, → Bi-functional reactive dyes are capable of anchoring at two sites on a single polymer chain or linking two chains together (crosslinking). No differences can be found between the two cases based on the fixing ratios or stabilities of the dye/fibre bond. In general, however, crosslinking leads to a significant change in the solubility of the polymer. Where the amount of fixed → Dual-anchor dye has exceeded a certain boundary limit, correspondingly reduced solubility has been established in the case of, for example, silk in 49% aqueous lithium thiocyanate. The two solubility curves shown in Fig. 1 represent a series of mono- or bi-functional dyes.

In order to achieve the high wet strengths required by the International Wool Secretariate, it is necessary to post-treat the reactive-dyed wool with alkali to wash out any non-covalent bonded fixed dye after dyeing at dye concentrations greater than 1% of the fibre weight. During this process, the pH increases from around 4.5 to 8.5 by addition of ammonia which leads to a sudden increase in the number of deprotonised amino functions of the lysine or ornithine groups by a factor of 10^3 to 10^4. This and the additional ammonia present and higher concentration of hydroxide ions make it possible for additional reactions to take place on the azidine system which lead to crosslinking of the fibre or hydrolysis of the azidine ring to give the following products:



The wash-fastness of a reactive dyeing does not only depend on the degree of fixing or the efficiency of the washing out of hydrolysed or reactive dye, which is still intact. The stability of the dye/fibre bond also affects the wash fastness according to the pH (Fig. 2).

Since the invention of vat leuco ester dyes, the emergence of reactive dyes in 1957 has been the most important event in the area of cotton dyeing and printing. For the first time, ICI and CIBA chemists were able to manufacture dyes which formed a genuine chemical bond with cellulose. A number of reactive dyes were characterised by a high purity of shade. In this, they were similar to cationic dyes but differed by their far superior fastnesses on cellulose. The fact that these dyes had a greater affinity to the hydroxyl groups of cellulose than to those of water was so surprising that the chemical reaction between the cellulose and the dye was doubted by some experts for a long time.

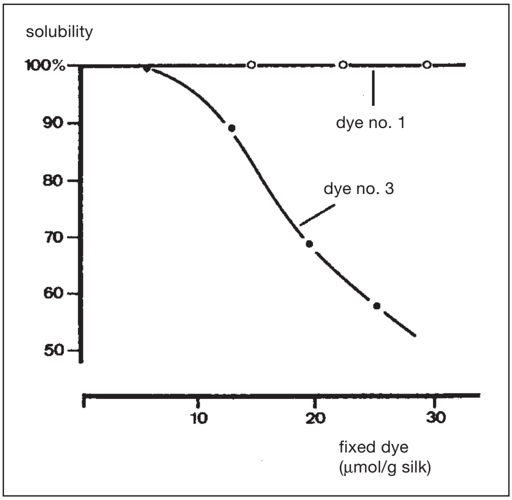


Fig. 1: The solubility of dyed silk in 49 % lithium thiocyanate in relation to the quantity of chemically fixed reactive dye. Dye no. 1 = monofunctional; dye no. 3 = dual-anchor dye.

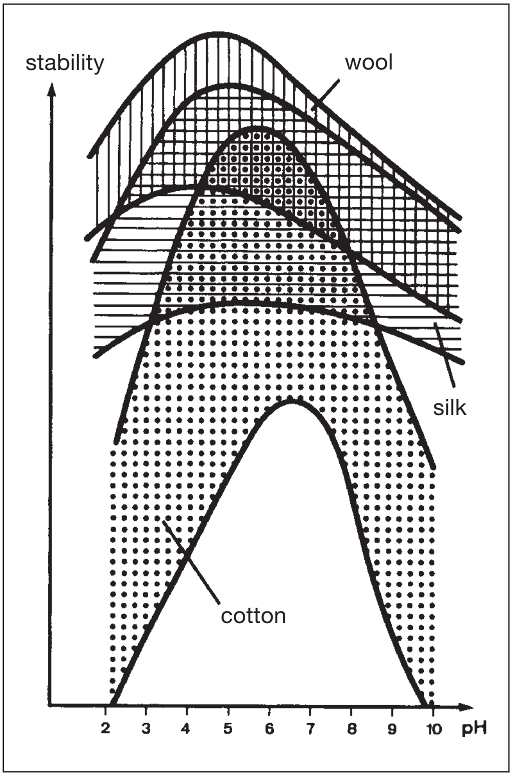


Fig. 2: Crude comparison of the binding stability of reactive dyes on silk, wool and cotton. Stability = reciprocal of the quantity of dye separated out in the stability test (according to Zollinger et al.).

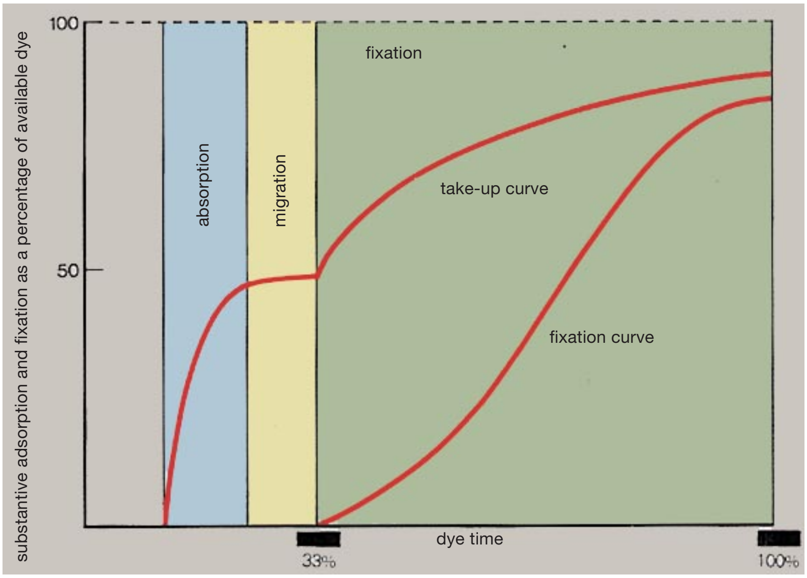


Fig. 3: The three phases in the dyeing of celloluse fibres with reactive dyes (sodium carbonate added at 33% of way through dyeing time) (by Bayer).

All reactive dyes have one feature in common: a colour-producing group or chromophore, usually an azo or anthraquinone derivative, and a reactive group. The application properties depend on both the chromophore and the reactive group, the reactivity of which is effected by, among other things, the reaction time. Thus for example, dichloropyrimidine dyes react significantly faster than monochlorotriazine dyes. The shade and substantivity both depend on the colour-producing group. The last mentioned determines, among other things, the ease or difficulty with which non-bonded dye is washed out after dyeing is finished. The substantivity of a reactive dye increases with the formation of reactive groups (for example, when alkali is added) and this alters the shape of exhaust curve (Fig. 3).

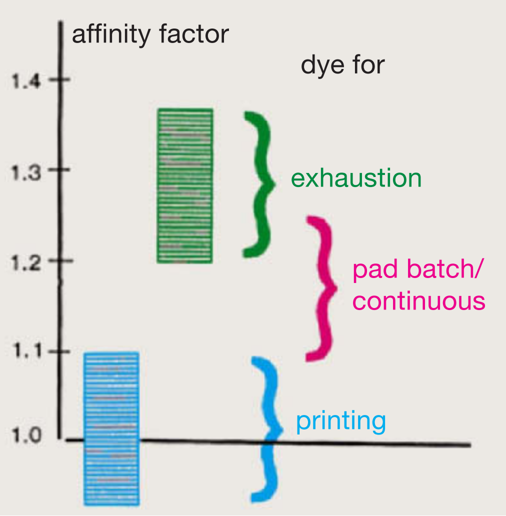


Fig. 4: The use of different affine reactive dyes in different colouring processes.

Optimised chromophores and custom-made reactive groups give the dyes a low to average affinity which considerably reduces the risk of tailing (difference in shade and colour intensity between the beginning and the end of the batch), dichroism and migration. Fig. 4 shows the affinity factors of reactive dyes intended for continuous dyeing (which characterise the affinity and therefore the tailing and combination ability), compared with dyes for the exhaustion process (which normally have a higher affinity) and dyes for printing (which must be of lower affinity). The reactivity of the commercial product varies according to the reactive group of the reactive dye used (Figs. 5–6).

Before the reactive dye which is being used in the exhaustion process (Fig. 3) attains its reactivity, it may migrate. The dye does not begin to react with the fibre until the reactive group has been activated (fixing curve in Fig. 3) and when the dye bonds to fibre it is no longer able to migrate (becomes immobilised).

The reactivity can be controlled via the temperature and pH. Both factors affect the fixing of reactive dyes because they influence the reaction between the reactive group with the fibre as they do with water. The reaction between the hydroxyl groups of the cellulose and the dye takes place via substitution or addition depending on the class of dye. The reaction proceeds in an alkali media. One exception to this is Procion T dye

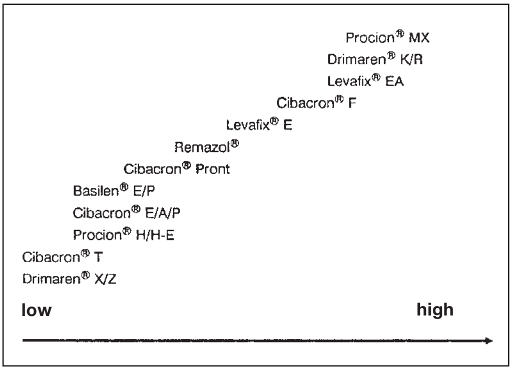


Fig. 5: The reactivity of various trade products.

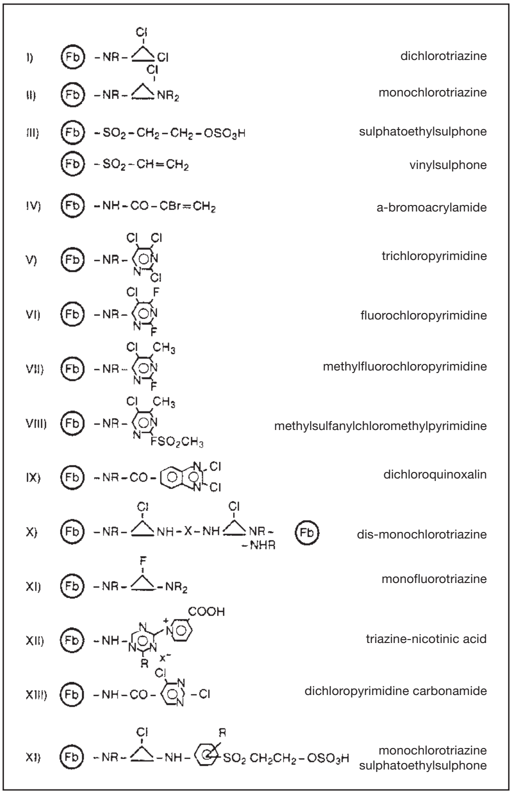


Fig. 6: Important reactive systems.

(ICI) which fixes both in neutral and in weakly acid media. This dye is never 100% fixed and requires greater quantities of alkali and/or higher temperatures to complete the bonding, depending on its reactivity (Fig. 7). The alkali used is either caustic soda, sodium carbonate, tri-sodium phosphate or waterglass, either alone or mixed together depending on the process.

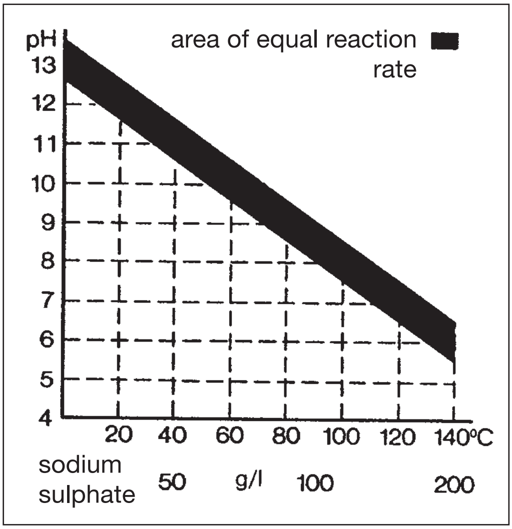


Fig. 7: The relationship between pH and temperature during the fixation of Levafix dye (Bayer) in exhaustion dyeing.

The degree of saturation on the cellulose is small for reactive dyes: less than $^1/_{100}$ of the available hydroxyl groups may be occupied. For this reason, the chemical properties of reactive-dyed cotton are no different to those of the undyed cotton. Small differences can, at most, be traced to the relatively high alkaline conditions required for fixing.

For this reason, reactive-dyed cotton fabrics can be treated with reactant resins and crosslinking agents, as are fabrics dyed by other methods. The stability of the bond between the fibre and the dye depends on the reactive group which also governs whether the resistance of the bond to acid or alkaline hydrolysis is high or low. The ester linkage, for example of mono or dichlolorotriaxine dyes, is stronger in the alkali range than it is in the acid range. With the ether linkage of vinylsulphonate dyes, the situation is reversed. Thus, the initially perfect wet fastness of a dyeing or print may be impaired if the goods are stored in acid atmospheres. The bond can also be broken at high temperatures (thermocracking). If a reactive dyeing is exposed to direct sunlight while wet, under certain circumstance, in a few cases the dyes may rapidly bleach (wet light-fastness). The chemical reaction between the cellulose and the dye does not proceed quantitatively (Fig. 8). Some of the dye is hydrolysed in the dye bath. Dye which has not been used or has hydrolysed must be washed out when dyeing is finished. Not until then does the dyeing achieve its wash-fast and non-bleed properties. The washing and soaping process is therefore very important.

	fixation method	name of process		significance	
exhaustion	wet treatment	exhaustion process	winch dyeing machine	●	=
			dyeing machine	◐	+
			jigger	◍	–
padding	wet treatment	pad jig		◍	–
		caustic shock		○	+
	dwelling	pad batch		●	+
		pad roll		○	–
	steaming	pad steam		●	+
		single bath steam		◍	=
		wet steam		○	+
	dry heat	thermofixation process: 2 stage		◐	+
		pad dry process: single stage		◐	+
printing	1 phase	steam process		●	+
		thermofixation process		◐	–
		high temperature steam		◍	=
	2 phase	caustic shock		◐	–
		short steam		◐	=
		cold dwelling process		◍	=

present significance:
● major
◐ moderate
◍ minor
○ almost none

future tendency:
+ increasing
= remaining constant
- decreasing

Tab. 2: Processes for the application of reactive dyes to cellulose fibres.

Tab. 2 shows the methods of application used for reactive dyes on cellulose fibres. From this, the advantages of reactive dyes can be seen in regard to the range of shade and variety of application methods. This class of dyes has made possible completely new applications in piece dyeing, such as the cold-pad-batch process. The suitability of a reactive dye for a certain process is not only determined by the reactive group but also by the diffusibility and substantivity of the dye in question. These properties depend on the chromophore which accounts for there being dyes with different properties in every range of reactive dyes. Thus, some are suitable for both exhaustion and padder methods and others which are appropriate for just one or the other. The specific suitabilities are indicated by the class number of colour shade. Reactive dyes with different reactive groups should not be used in combination. Methylol compounds are special groups which are fixed in acid media. They can only be used in thermofixing processes.

The medium and high substantive dyes are the most suitable for the exhaustion process (Fig. 9). Despite this, they require fairly high salt concentrations in comparison to substantive dyeings. The dyeing and fixing temperatures vary between 30° and 40°C depending on the dye group. The alkalis used for fixing are sodium carbonate, sodium hydrogen carbonate, tri-sodium phosphate or caustic soda. With some classes of dye, dyeing and fixing are carried out at the same time (all-in), with others, the process is initiated by adding alkali after the period of dyeing is over. In a few cases, separating the exhaustion and fixing periods has its particular advantages, as in the case of dyeing-machine dyeing, when yarn packages which are difficult to penetrate have to be dyed, especially those of regenerated fibres. Fibre swelling is at its lowest at high temperatures where the rate of diffusion is at a maximum. In the case of the shortest and simplest but not always usable method, the dye, salt and alkali are added at the beginning, dyeing is started cold and the

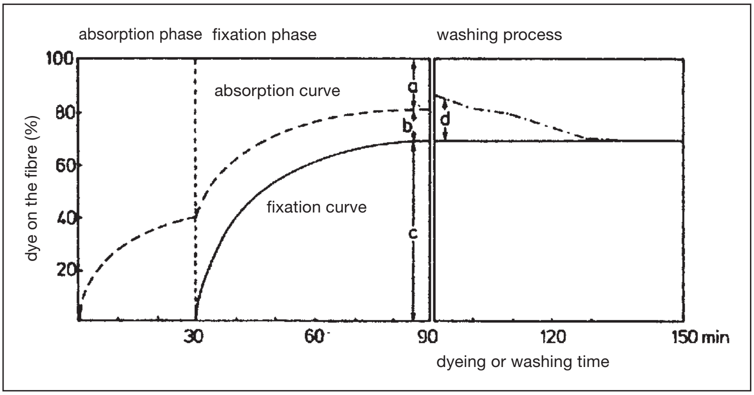


Fig. 8: Diagram showing the processes in their entirety during an exhaustion process reactive dyeing.
a = dye in dye bath; b = hydrolysed dye on the fibre; c = fixed dye; d = dye to be washed out.

Reactive dyeing

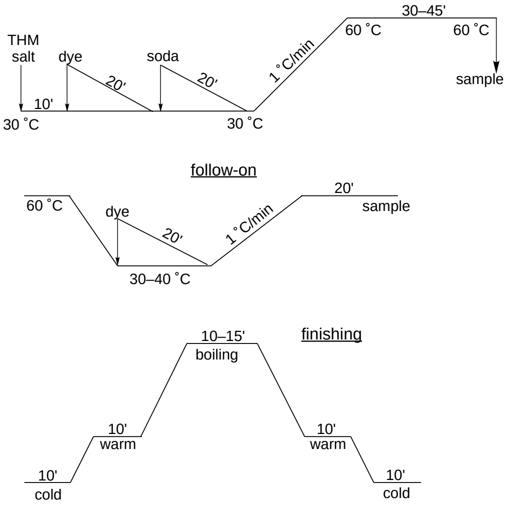


Fig. 9: The "all-in" process for dyeing cotton with reactive dye in a modern jet dyeing machine (by Bayer).

temperature raised later for fixing. In order to promote the actual reaction between the reactive dye and the fibre and suppress the competitive hydrolysis reaction, the reactive form should come into contact with water for the shortest possible time.

When analysing the reaction rates of hydrolysis and fibre reaction (Fig. 10) it appears that the slope for the fibre reaction is flatter than it is for the hydrolysis, which leads to the conclusion that the activation energy is less for hydrolysis. The distance between the slopes increases with increasing standard depths. This means that the portion of dye which becomes unviable for fixing in the case of processes where energy is added, i.e, hot-fixing processes, must be greater than that for processes carried out at room temperature.

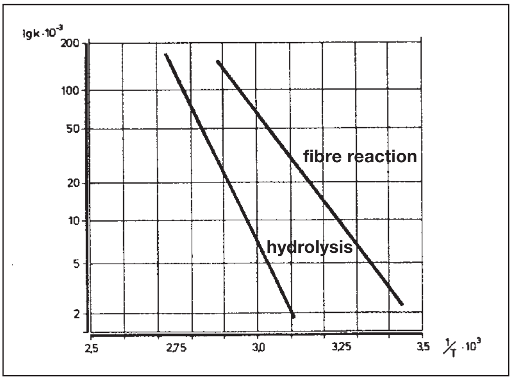


Fig. 10: The temperature dependence of the reaction rate constants for vinylsulphone dyes (Remazol, Hoechst).

Dyes which develop their reactive form under alkaline conditions only (vinylsulphonate type), can be optimised in this respect by temperature and alkali addition (Adcon/Then dosing system ADC 100). For the following reaction route:

$$\text{Ⓕ}-SO_2-CH_2-CH_2-O-SO_3H$$

ester form
low substantivity
no reactivity

$$\downarrow \text{+ alkali}$$

$$\text{Ⓕ}-SO_2-CH{=}CH_2$$

vinyl form
high substantivity
high reactivity

it is advisable to use automated, progressive alkali addition at constant temperature in order to avoid the rapid increase in fixing during the start phase which would otherwise give rise to the risk of uneven dyeings. Because the individual dyes in a range always have their own individual diverse dyeing behaviours, the fixing curve of a selected dye mixture can be controlled individually so that the alkali dosing curve is correspondingly flat or steep (Fig.11).

Thorough rinsing with hot water is important for good wet fastnesses. Cold water is sufficient only for the removal of salts. Reactive dyes which are suitable

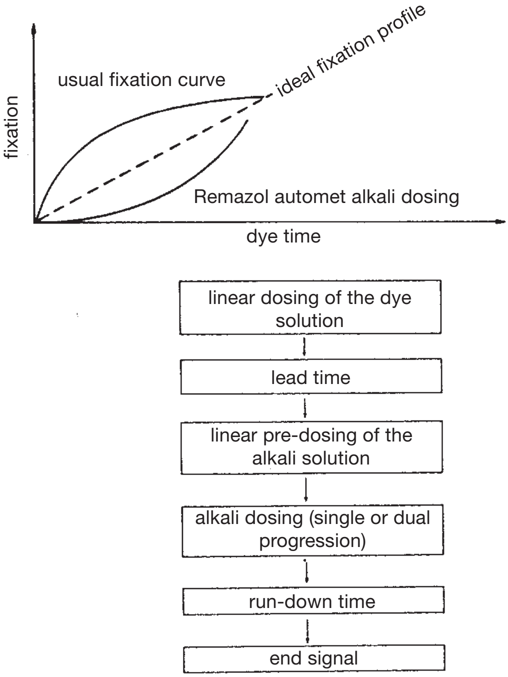


Fig. 11: Remazol automet, ADC 200; programming the entire dyeing process.

for the exhaustion process must have a certain degree of substantivity. As this depends on the chromophore rather than the reactive group, the hydrolysed dye also is correspondingly substantive and therefore more difficult to wash out than products with lower substantivity which are used in the padder process. Temperature, time and the number of bath changes have an effect on the thoroughness of rinsing. Post treatment using a cationic agent is frequently recommended for preventing subsequent deteriorisation in wet fastnesses caused by thermo-cracking, etc. This also fixes a small amount of the portion of hydrolysed dye remaining on the fibre after rinsing.

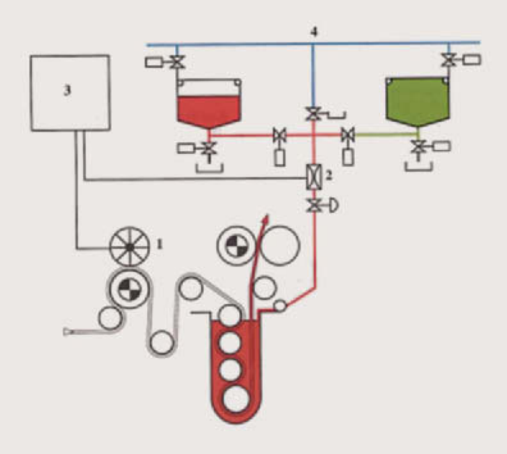


Fig. 12: The principle layout of dye liquor usage analysis for a pad dyeing machine: only an extremely small amount of active dye liquor is to be found in the padding trough. The dye solution (red) is activated with alkali (green) immediately before flowing to the trough.
1 = metre length counter; 2 = throughput metering;
3 = processor; 4 = water connection for automatic flushing (Küsters process technology).

Padder processes: the impregnation methods with their variations are numerous. Either the dye is padded together with the alkali or the dye is padded alone and then the alkali is padded afterwards. In the case of very reactive dyes, the first method has the disadvantage that the batches hydrolyse in the padder too quickly which means that mixing equipment has to be used for dosing (Fig. 12). The equipment requires precise monitoring and careful maintenance. All methods have their advantages and disadvantages. It must be left to the dyer to discover the methods most suitable for his works and quality of goods. The dye yield can be quite different depending on the method used, so this point must also be checked.

The cold-pad-batch method is of interest from the point of view of economics. The following relationship exists between bath stability and dwell time: with a low bath stability, only a short fixing time is possible but if the bath stability is high, a longer fixing time can be used. In order to achieve level dyeings with a short fixing time, the goods must first have an even absorbancy, i.e, the pre-cleaning must be particularly good. For large batches and long dwell times, the batches must not be allowed to remain in acidic atmospheres as this will give rise to light edges due to neutralisation. In order to achieve the optimum dyeing, the fixing time must not be too long or too short for the particular temperature in question. The dwell times range from 2 h (in the case of dichlorotriazine dyes) and 48 h (in the case of trichloropyrimidine dyes). The method is particularly suitable for dyeing knitware. Circular knitted goods in particular can be padded in the raw state, providing they are not contaminated. A wetting agent and retention aid must be added to the liquor. The dyeings are more level the longer the liquor remains on the goods (110–130%).

The padded goods can either be stored in box trucks or batch rotated. The washing, neutralising and soaping processes can be carried out on a single batch. These devices are equipped with a centrifugal pump for circulating the liquor. A two-step cold-dwell method with intermediate drying has been suggested to avoid the uncertainties in the bath stability. Padding is carried out during the first step with dye and during the second step with a waterglass solution. However, the drying which takes place between the two steps increases costs and can give rise to undesirable migration effects. In most cases, when using multi-component dosing equipment for dyes and alkali in the single-bath process, stability problems do not arise.

In principle, the dwell process can also be used for hank yarn and cross-wound yarn packages according to the dip/extract method using little in the way of substantive products. In the thermo-fixing process the dye yield is very good – even dead cotton is covered. Now and again, difficulties arise when there is insufficient ventilation in the condensation box. The urea vapour (hydrotropic agent) then solidifies in the box. Dicyandiamide, which does not vaporise so much, has limited use as a substitute due to its corrosive effect. Before heat treatment, the goods should already have a moisture content of 10–15%. The yield is greater in the presence of water. The conditions for fixing are 2–6 minutes at 140–160°C. Before the wash out, the dried goods must be protected from direct sunlight as certain reactive dyes are sensitive to light in the presence of alkali. Dyeing carried out in accordance with the thermofix method may have somewhat lower light and chlorine fastnesses than those carried out according to other application methods. For all processes using drying between stages, a migration-free operating dryer must be used.

The single-bath vapour method is of interest only when a large evaporator is available and background dyeing and print can be fixed together. In the case of fabrics which show high liquor-retention behaviour (cord and terry cloth, etc.) the method can also be carried out on pad-steam plants. The steaming may be by saturated steam or superheated steam. ICI and Artos have worked out a high-temperature wet steam method for high-reactive dyes. In the wet-heat-dwell method developed by Hoechst, fixing is carried out in an air/steam mixture with controlled moisture and drying temperatures in a steamer designed by Brückner with a steaming duration of 1 minute. In the pad-steam process, a loss in yield may occur under certain circumstances in the case of reduction-sensitive dyes. An addition of an oxidising agent is suggested to prevent this from happening. With all hot-fix methods, the specified temperatures and times must not be exceeded otherwise the fibre/dye linkage may break (deterioration of wet strength due to thermo-cracking).

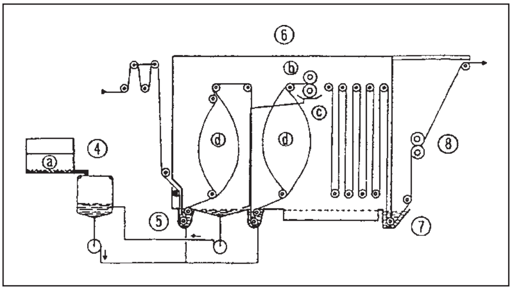


Fig. 13: The VH-Tric-O-Steam dye process for knitted goods (Henriksen).
4 = salt reservoir tank with solid salt feed from a; 5 = salt bath impregnation of the knitted goods tube containing dye as it comes from the padder; b = squeezing; c = recycling; d = inflation of tube; 6 = steamer; 7 = steamer surge tank; 8 = squeezing.

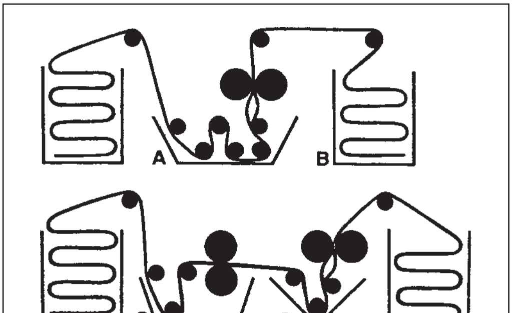


Fig. 14: Sequence diagram for the continuous Vicontin I process for tubular tricot (Sandoz).
A = dyeing process (soft rollers, ballooning); B = cold dwelling (16 hours); C = rinse (cold water, hard rollers); D = fixation with Indosol E-50 (soft rollers, ballooning).

When developing the VH-Tric-O-Steam method, Henriksen started by reducing the salt loading of the effluent while dyeing with reactive dyes. In the plant padder, a dosing system is used to apply 1.2 l/kg water, 20 g/l sodium carbonate and the dye (Fig. 13). The steamer is circulated with 75 l liquor which is maintained at a salt concentration of 250 g/l. In this case, the temperature of the liquor is 80°C while saturated steam at 103°C is used. The plant consumes 25 kg salt per hour for 300 kg tubular knitgoods per hour, and 23 l/kg rinse water for the washing out which follows.

Reactant-fixable dyes can be applied in the same way as direct dyes. The nucleus of these dyes contains groups which react with polyvalent fixers so that in addition to crosslinking the fibre, the dye bonds to the cellulose fibre, while the solubilising SO_3 groups on the dye are blocked at the same time. This fixing method produces high wet fastnesses and easy-care properties which make further resin finishing superfluous. Accordingly, there are two steps (Fig. 14):

step 1: dyeing with direct dye;
step 2: fixing.

Reactive dyeing, process control by metering

Three objectives are pursued when → Metering dye in the reactive dyeing process:

1. automation of the dyeing process,
2. matching of the addition functions to the distribution and mixing capacity of the machine,
3. control of the kinetics of the reaction mechanism.

Carrying out this three-point programme while using a simple linear addition controller when dyeing with reactive dyes is achieved by dosing by alkali. The course of the reactive-dyeing process is determined by the dye concentration, salt concentration, temperature and pH. In order to transfer the dyeing of specified laboratory formulations to an industrial finishing process in a manner which is reproducible, level and economic, the sequence of conditions which occur in the dyebath must be established exactly. As reactive dyeing processes are not defined according to the principle of dyebath exhaustion but by the fixing yield in % of the dye supplied, any change in the kinetic conditions of the reaction in the dyebath will result in a change in the final fixing yield. Because three dyes with non-identical substantivities and reactivities are generally used during the usual tri-chromic dyeing processes, the dyebath is subject to a continuous change in composition and reaction conditions throughout the dyeing process. The momentary reaction rates of each individual component is dependent on the pH at any one time. For this reason, reproducibility of results on an industrial scale can only be achieved by reproducing all of the steps in the process. This can only be realised by using a programmed sequence of process functions.

At the same time, the main problem in process control is the addition functions for dyes and chemicals. The supply and distribution of energy in the dyeing machines is regulated by heat exchangers. The addition of dyes and chemicals, on the other hand, has been carried out manually both from the time in the dyeing process and as a time function with insufficient adjustment to the mixing properties of the machine. Thus, the most important functions in the reactive dyeing process depend on the room for manoeuvre for each machine operator in making his decisions. Because reactive fixing is irreversible, differences in the kinetic behaviour of the reaction cannot be evened out later by long periods at high temperatures. Thus, the manual control of reactive dyeing processes demands a high degree of reliable operation and, therefore, a high proportion of cost in terms of labour.

For this reason, a change to controlling the reactive dyeing process exclusively by temperature as an all-in process took place early on. However, this mode of operation cannot be applied generally and has some disadvantages:

- When the goods are running badly and transfer and mixing is insufficient, the dye, salt and alkali are added at high temperatures.
- The amount of chemical used is high because more salt is required for fixing at high temperatures.
- The control route is only suitable for temperatures ≥ 40°C.
- The quality of the goods is impaired.

In order to dye at constant temperature, i.e, under constant running and transfer conditions, the addition of dye and alkali must be adjusted to the transfer, mixing and distributions characteristics, i.e, to the goods turnover and liquor circulation. Programmed addition of dye and alkali produces new process conditions in the exhaustion method. Programmable dyeing units are characterised by control valves, metering valves or metering pumps in moving or static goods depending on the dyeing principle.

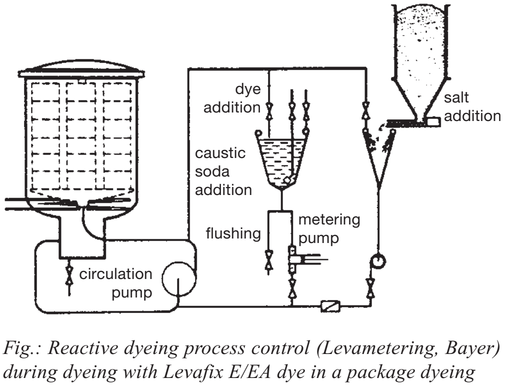


Fig.: Reactive dyeing process control (Levametering, Bayer) during dyeing with Levafix E/EA dye in a package dyeing machine.

When dyeing with or without liquor circulation or with or without static pressure, dosing is carried out directly using a distribution tube, via the addition vessel or in the main circulation stream on the suction side of the pump (see Fig.).

From looking at the metering processes which are required (Tab. 1), the automatic addition of solid salt must be achieved with a relatively high outlay in costs under the conditions which exist in most factories. There are basically two possible ways of adding the salt:

- before adding the dye,
- after adding the dye.

process types			process
I	II	III	
dye	salt	alkali	controlled pH
dye	alkali	salt	controlled salt
alkali	dye	salt	controlled salt
alkali	salt	dye	controlled temperature
salt	dye	alkali	controlled pH
salt	alkali	dye	controlled temperature

Tab. 1: The systematics of reactive dyeing; process sequences.

If the salt is added before the dye, it does not need to be metered. Automation can then easily be achieved by using brine. If the salt is introduced first, the dye must be metered in order to guarantee level absorption on at least 10 circulations of the goods.

If the salt is added afterwards, it is added manually as a solid or automatically by a solids metering unit. In the manual case, these additions are frequently progressive, for example, $^{1}/_{10}$, $^{2}/_{10}$, $^{7}/_{10}$. Mechanically automated salt dosing does not need to be progressive and can lead to real operating problems if the maximum delivery rate is over loaded in the steep part of the dosing curve. In this case, simple holding periods in combination with linear delivery are considerably more robust and more reliable. When dosing is complete, 40–70% of the total amount of dye is evenly distributed on the goods in the case of reactive dyes.

The second step, so-called fixing, is essentially easier to carry out. While the addition of dye is a function of time and represents a simple distribution function (because it takes place under conditions in which there is no reaction), the dye/fibre reaction starts with the addition of alkali. The addition of alkali determines the increase in pH in the bath and the final pH required for the fixing yield and fixing time (Tab. 2). The final pH at

colour depth	liqour ratio	salt g/l	NaOH g/kg	final pH 45 ˚C
1 %	1 : 5–1 : 15	5–30	10	11.0
3 %	1 : 5–1 : 15	40–50	11	11.1
5 %	1 : 5–1 : 15	60	13.5	11.2
> 5 %	1 : 5–1 : 15	70	15	11.4

Tab. 2: Reactive dyeing process control (Levametering, Bayer): Alkali metering in relation to colour depth and quantity of salt (temperature: 45 °C; water hardness: 0.5 g/l sodium hydrogen carbonate).

45–50°C is between 11.0 and 11.5, depending on the dye, and is correspondingly lower at higher temperatures. The amount of alkali required to adjust the final pH is determined empirically, and for normal industrial process water, must be adjusted by elementary measurements.

Programs are characterised as 1-, 2- or 3-step dosing programs according to whether it is 1, 2 or 3 additions which are made. The longer the dosing continues, the greater the certainty that the machine is applying the solution evenly on the fibre. For a dyeing time of 120–135 min, the dosing time is in the region of 60 min.

In comparison to the dilution and distribution capacities of the dyeing machine, the shape of the dosing curve is of secondary importance. During the development of metering technology, the time-dependent delivery characteristics were considered to be particularly important, in addition to selecting a suitable controllable pump. This has led to the drawing up of a whole family of curves for progressive and digressive metering programmes (source: Bayer).

Reactive (dye) printing Direct printing with reactive dyes. After suitable pretreatment, fabric or knitwear goes through the same sequence of operations for reactive printing as for any other printing processes (Fig.). However, when the reactive dye is used on a suitable fibre, such as wool, silk, cotton, viscose or polyamide, chemical bonding of the dye to the fibre during the fixing (steaming) process is assured. The after-print washing process increases the fastness of the reactive print because the dye which is not fixed is washed out. Reactive printing is then followed by a finishing process appropriate for the substrate.

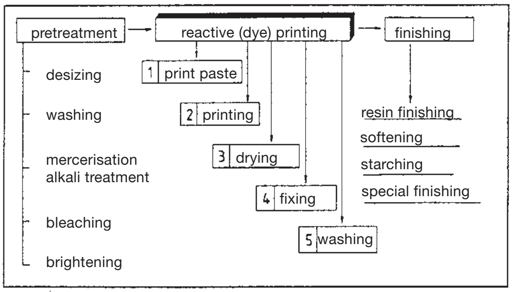


Fig.: The sequence of operations in reactive (dye) printing (by Hoechst).

Reactive dyes, compatibility The characteristics of a reactive dye for exhaustion dyeing are usually divided into its substantivity in the electrolyte phase and the exhaustion and fixing values after the addition of alkali. Fixing involves the formation of the covalent bond between the dye and the fibre. These characteristics significantly depend on the structure of the dye molecule and the reactive system. Thus, a homobifunctional monochlorotriazine dye (bifunctional reactive dye with identical reactive groups) is characterised by an average to high substantivity, a relatively low reactivity and a high fixing value. These provide an excellent profile of properties for exhaustion dyeing. Production which is to run properly at the first attempt requires even dyeing and the right degree of colour tone reproducibility. The “natural” property of bi-monochlorotriazine dyes of even dyeing can be attributed to their low reactivity which gives rise to a high level of migration. Apart from this, because the substantivity of the dye is high, there is a high proportion of dye which is available for diffusion into and out of the cellulose fibre during the neutral migration phase.

Using a linear addition of alkali to fix the dye on the fibre requires almost linear fixing behaviour during this phase. This can cause simultaneous secondary exhaustion and reduce fixing to a minimum, thereby reducing the danger of non-level dyeing. The compatibility of dyes with similar characteristics in combination produces exhaustion, migration and fixing properties which are similar to a single dye and maintains a similar dye angle throughout the whole process, thus ensuring that dyeing is even in the exhaustion process as well.

In the case of combinations of dyes for binary and ternary colour tones, the degree of compatibility of the individual characteristics and the interactions between the dyes must be taken into account. Dyes with molecules designed with the compatibility of characteristics in mind can at least be classified and are random variables during production. The behaviour of individual dyes in combination can be tested using on-line, through-cell light transmittance measurements.

Reactive dyes, Fibre-reactive dyes Dyes for dyeing and printing which have been commercially available since 1956 and which bond with substances via reactive groups (such as OH and NH_2). Reactive dyes are among the most important groups of dyes used for cellulose fibres because they give fast results and, to some extent, brilliant shades.

A reactive-dye molecule consists of a chromophore and a reactive group. The chromophore is the compo-

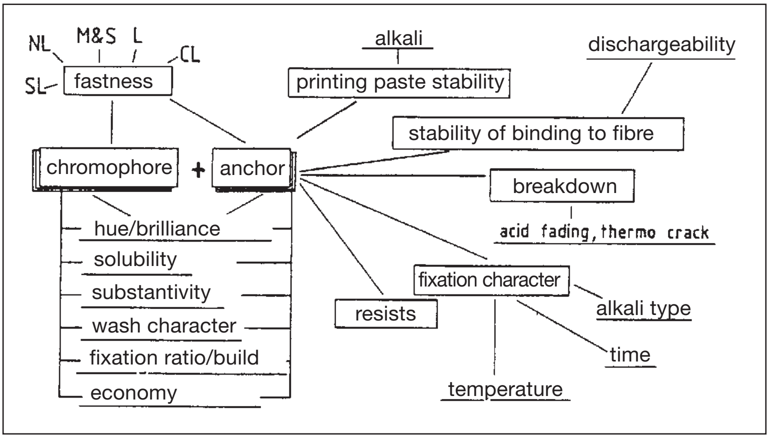


Fig.: Factors influencing the use of reactive dyes in printing (by Hoechst).

nent responsible for the colour, most of the performance characteristics of the dye (such as substantivity, wash-out properties and rate of diffusion, etc.) and most of its fastness properties (Fig.). The reactive group is responsible for bonding the dye to the fibre. It is therefore also responsible for the high wet fastnesses of reactive-dye dyeings or prints. The type of reactive group determines the reaction rate, saponification rate (reaction with water) and stability of the dye/fibre bond to acids or alkalis. Within a certain range of reactive dyes, however, differences are found between the dyes. Apart from their reactivity, reactive dyes can be classified into three main groups:

I. Cellulose reactive dyes.

II. Reactive dyes for wool, silk and polyamide.

III. Dispersion reactive dyes for polyamide.

The reactive dyes in Group I form covalent bonds with the fibre substrate in the presence of alkali (either ester or ether linkages depending on the nature of the reactive group) but not all of the available dye is fixed. Some of the dye reacts with water during the dyeing or printing process. In order to achieve the optimum wet fastness, dye which is not bonded (dye which is hydrolysed and cannot be fixed) must be carefully washed out. The dye/cellulose fibre bond can be hydrolysed in both acid and alkali media – the stability depending on the reactive group in the dye molecule. Hydrolysis results in a reduced wet fastness. → Reactive dyeing.

Reactive dyes in direct printing A universal class of dyes both in relation to substrate, cellulose fibres, wool, silk and with regard to processes.

I. Steam method: method most commonly used. Printing paste: dyes, urea, thickener, mild oxidising agent and alkali (sodium hydrogen carbonate or sodium carbonate).

II. Thermofixing method: as for Method I. but with more urea.

III. HT steam method: printing paste as for Method I. Fixing in flash agar (without padding liquor) or in the HT universal loop steamer at 140–160°C.

IV. Short-steaming method: printing paste as for Method I. Fixing by brief periods of steaming at 102–103°C. Method reserved for fast-reacting reactive dyes.

V. Print-dry method: printing paste as for Method II. Energetic drying at 140–160°C is sufficient for fixing. Only suitable for fast-reacting dyes on cotton.

VI. Print-lay method: printing method as for Method II. Leaving exposed to the air for several hours is sufficient for fixing (depending on the reactivity of reactive dye). Only suitable for fast-reacting dyes on cotton.

VII. Prepreparation method: printing paste contains no alkali and is applied to the goods before printing. Energetic drying at 120–130°C is sufficient for fixing. Only suitable for fast-reacting dyes.

VIII. Two-phase printing method: thickened dye (possibly with urea) printed on to substrate, dried, padded with alkaline solution containing electrolyte, steamed in flashagar for 20–60 seconds at 120–140°C without intermediate drying, then washing out. Variant: spraying the solution on instead of padding.

IX. Caustic shock method: printing paste as for Method VIII. Print, dry, treat in roller vat with boiling alkaline liquor containing electrolyte for 20–40 seconds and wash out.

X. Cold-pad batch method: printing paste as for Method VIII. Print, dry, pad with cold, strongly alkaline liquor containing electrolyte, roll up or fold. Fixing is achieved by storing at room temperature and then washing out.

XI. Steam-wet-fixing method: as for Method IX. However, short period of steaming before treatment in the roller vat. Preferred method for viscose.

XII. Print on naphthol-treated goods: reactive dye alone, with or in a mixture with diazo salts. Sodium hydrogen carbonate as alkali. Steam or caustic-shock method.

Reactive dyes in direct printing – fixation by hanging → Fixation of reactive dyes in direct printing by hanging.

Reactive dyes in discharge printing Used as coloration for white discharging, neutral or strongly alkaline discharging paste depending on the dischargability of the reactive dye. Used for vat dye coloured discharge pastes according to the usual sulphoxylate potassium carbonate method. → Discharge printing.

Reactive dyes in resist printing,

I. As a colorant: printing acid-splitting substances (such as ammonium chloride) which neutralise the alkali contained in the dye liquor and therefore act as a resist against the reactive dye fixing to the printed fabric (white resist). For vat dye colour reserving; method according to the usual sulphoxylate potassium carbonate process. Principle: print resist, dry rapidly, nip-pad in the padder with reactive dyes (printed side faced down), dry, steam for 5–8 minutes and wash.

II. As colour resists: a) with aniline black with increased amounts of alkali (e.g. sodium carbonate) as a resisting agent (possibly with additional zinc carbonate); pre-print or over-print resist. b) with naphthol with resist agents such as potassium sulphite, sodium hydrogen sulphite; preferred overprint resists. Formulation of pad baths according to the ammonium thiocyanate method.

III. As resin resists: white and colour resists (with reactive dyes) using pad dyeing method with reactive dyes. While reacting with the dye, the synthetic resin pre-condensate also reacts with the cellulose. This prevents the reactive dye from the padding liquor from fixing on the printed areas. Principle: printing paste containing reactive dye (or white pigment), synthetic resin pre-condensate, acid donor and emulsion thickener, dry, thermofix (at 180–200°C), nip-pad with padding solution consisting of reactive dye, urea and alkali, dry, thermofix and wash.

IV. Half-tone resists: pre-print of thickener and glucose or mat white. Overprint reactive dye is brightened.

Reactive dyes on the fibre, test for,

I. Boil for 2 minutes in 5% NaOH together with a cotton piece (mercerized). Zero to significant desorption of dye from the dyeing.

II. Solvent: dyeing for 3–4 minutes in each of the following solutions one after the other (with a cold rinse between each bath): glacial acetic acid and ethanol mixture (1 : 1), 1% ammonia solution, dimethylformamide and water mixture (1 : 1) and dimethylformamide. Staining of solution in the case of reactive dyes: slight or non existent.

III. Boil dyeing together with wool piece, with 1 ml concentrated sulphuric acid and 1g/l sodium sulphate calc. Wool coloration by ester-forming dyes (monochlorotriazine, dichlorotriazine and trichloropymidine dyes, etc.). No coloration by ether- and oxyethylsulphone-ester forming dyes.

IV. Boil for 2 minutes in a solution of 20 g sodium formaldehyde sulphoxylate, 50 g ethylene glycol and 150 ml water.

V. Heat slowly to boiling point in 10 g sodium dithionite and 10 g/l caustic soda.

VI. Observe colour change in cold solution of 100 g tin (II) chloride, 100 ml conc. hydrochloric acid and 50 ml water then slowly heat to boiling point and continue to observe colour change.

Reaction in the case of IV, V and VI: decoloration or colour change. With the addition of peroxodisulphate, either no change or no further colour change (return to original colour only occurs in rare cases).

VII. Tin (II) chloride/nitric acid tests: positive for phthalocyanine derivatives (blue and green marks).

Using these methods, practically all groups of reactive dyes and their individual brands can be identified. Black brands are tested and identified in a similar way based on their decoloration or change in colour after treatment with concentrated nitric acid, concentrated sulphuric acid, concentrated hydrochloric acid and tin (II) chloride/hydrochloric acid solution.

Reactive groups for dyes The chromophore component of a reactive dye produces the colour shade and determines its substantivity. The reactive group determines the type of bond between the dye and the fibre and, therefore, some of the dye's performance characteristics. In addition to the fastnesses, dye/fibre bond and performance characteristics, the reactive groups also determine the fixing value when dyeing with a reactive dye. Basically there are two types of reactive group:

1. The reactive groups which exchange basic nucleofuges for a dissociated hydroxyl group. Among these are the heterocyclic aromatics such as triazine, pyrimidine and benzopyrazine derivatives.
2. The reactive group which can add a functional group and a proton to the fibre. This group is represented by the vinylsulphones.

The trichlorocyanidine derivatives are the ones most used for the reactive component. The trichlorocyanidine ring has a deficiency in π electrons caused by the electronegativity of the nitrogen atom and, therefore, has a reactive halogen which can undergo nucleophilic substitution with an OH group on cellulose or an NH_2 group on wool or silk. The reactivity of the chlorine atom on the cyanuric ring decreases in stages, which explains the lower reactivity of a monochlorotriazine dye in comparison to a dichlorotriazine dye. For steric reasons, the nucleophilic substitution which takes place between the ring system and cellulose favours the formation of an ester linkage with the primary alcohol group (at position 6 on the glucose unit). In addition to the triazine derivatives, there are still other heterocyclic reactive components based on pyrimidine and benzopyrazine compounds. Of the last mentioned, only the difluorochloropyrimidine components have been introduced commercially. A significant advantage of the ester-forming reactive dyes is the stability of the bond to acids.

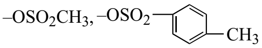
Among the reactive groups which form ether links between the dye and the fibre, it is almost only the vinylsulphone links which are of importance. The generalised formula for this group is as follows

$$\textcircled{F}-X-CH_2-CH_2-Y$$

X = $–O, –SO_2, –CO, –NH, –SO_2NH,$

$–NHSO_2, –CONH, –CH_2–S$

Y = $–Cl, –Br, –OSO_3H, –OPO_3H_2,$



In the case of vinylsulphone dyes, the sulphone group functions as the link member X. Aliphatic reactive groups preferably undergo substitution in two parts on cellulose as this is the most reactive. The reactivity of the dye is largely determined by the reactive group (Fig. 1).

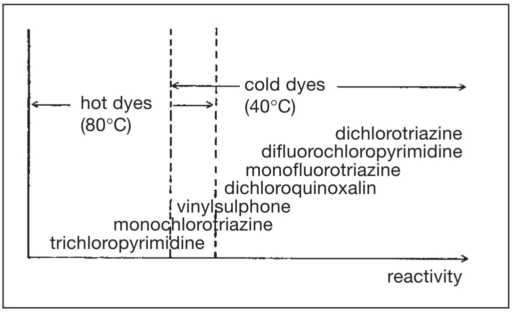
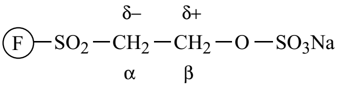


Fig. 1: The reactivity of the different reactive groups.

In organic compounds, a sulphone group causes the aliphatic residue to which it is bound to polarise so that the carbon atom in the α position to the sulphone group becomes electronegative and the β position becomes electropositive in character.



$$\textcircled{F}-SO_2-\underset{\alpha}{\overset{\delta-}{CH_2}}-\underset{\beta}{\overset{\delta+}{CH_2}}-O-SO_3Na$$

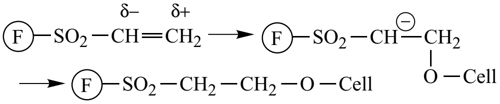
In the β-sulphatoethylsuphone the electron attraction of the SO_2 group makes this group easy to remove. In alkali media, this leads to the formation of unsaturated vinylsuphones:

$$\textcircled{F}-SO_2-CH_2-CH_2-O-SO_3Na + NaOH$$
$$\longrightarrow \textcircled{F}-SO_2-CH=CH_2 + Na_2SO_4 + H_2O$$

In alkali media, the reaction starts immediately and is necessary for the reaction of the dye with the fibre. The fact that cellulose is also activated in alkali media is an advantage:

$$\text{Cell}-OH + {}^{\ominus}OH \longrightarrow \text{Cell}-O^{\ominus} + H_2O$$

The cellulose attaches itself at the polarised vinylsulphone double bond. The nucleophilic cellulose anion, which is present in the alkali medium, attacks the positive polarised carbon atom and is added in the second step.



$$\textcircled{F}-SO_2-\overset{\delta-}{CH}=\overset{\delta+}{CH_2} \longrightarrow \textcircled{F}-SO_2-\overset{\ominus}{CH}-\underset{\displaystyle |\atop O-\text{Cell}}{CH_2}$$
$$\longrightarrow \textcircled{F}-SO_2-CH_2-CH_2-O-\text{Cell}$$

Two requirements must be fulfilled for this to come about:

a) an activated double bond

b) a labile proton.

In addition to the desired bond formation with the fibre, hydrolysis of the double bond in particular takes place as a competitive reaction:

$$\textcircled{F}-SO_2-CH=CH_2 + H_2O$$
$$\longrightarrow \textcircled{F}-SO_2-CH_2-CH_2-OH$$

The resulting oxyethylsulphone dye does not play any part in the dyeing process. The activated double bond of the vinylsulphone group is still viable for side reactions, such as those with amines and alcohols, which may also be present in the dye liquor. In comparison to the hydrolysis reaction already mentioned, the remaining competitive reactions only play a subordinate role.

Vickerstaff attempted to explain why the reaction between cellulose and the reactive group is dominant: the internal pH of the cotton is one pH unit lower than that of the dyebath, so the reaction rate of the dye ↔ fibre reaction is higher than that of the dye with the water. On the other hand, Hildebrand explained the strong preference for alcohol hydrolysis in comparison to water hydrolysis as being due to the higher nucleophilicity of the cellulose anions.

The ether-type β-ethylsulphone/fibre bond shows a greater resonance in comparison to acids, whereas the stability of the ether bond to alkalis under certain conditions is insufficient. This instability of the bond in regard to alkalis is a significant disadvantage for ester-forming reactive dyes. The cleavage of this bond in two parts by the sulphone group substituted ether proceeds

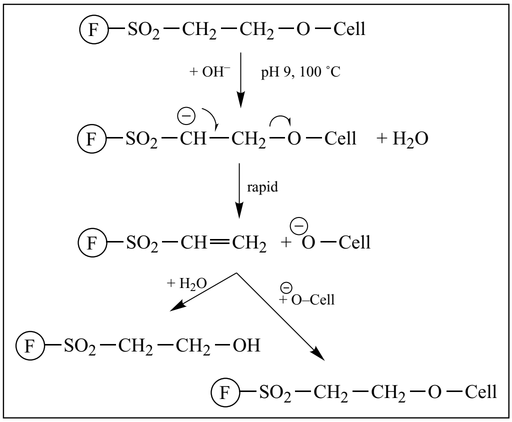


Fig. 2: The hydrolysis of a vinylsulphone dyeing.

via the vinylsulphone as the second step – the release of the proton from the carbon atom next to the SO_2 group being the rate-determining step (Fig. 2).

Undyed cotton may be soiled in a side reaction by the vinylsulphone which has been released. However, the low resistance to alkalis no longer represents a problem in today's applications as the sodium carbonate in household washing has been superseded by milder but more effective products which make boiling superfluous. Moreover, most vinylsulphone dyes are stable up at temperatures of 75°C.

In the acid pH range, the stability of the ether linkage is greater than the glucosodic cellulose bond. Thus, the cellulose will decompose before the ether linkage is broken. For this reason, it was possible to demonstrate the covalent nature of the dye/fibre bond by breaking down dyed cellulose to the glucose unit. The ether bond is so stable that it remains intact even in acidic, industrial atmospheric environments and at high temperatures. This group of dyes is therefore of particular interest in the case of polyester/cotton mixtures which are over-dyed with dispersion dyes at acidic pH.

In the presence of certain reducing agents, the azo groups on azo dyes are reduced to amines and the ability of the dye to form a bond is lost. This means that the dye can be stripped in the case of possible defective dyeings. With discharge printing, which is becoming increasingly important, the dyed goods are treated with alkaline reductive printing paste. This can break the azo bond and the alkali attacks the ether linkage at the same time (→ Dye cleavage products).

Unlike the ester-type bonding dyes, in the case of vinylsulphone reactive dyes, no decomposition products remain on the fibre during reduction when carried out in alkali media. In the case of → Bifunctional reactive dyes, the crosslinking is destroyed due to the effect of reducing agents. The properties created by cross-linking are lost at the same time. It is plausible that bifunctional reactive dyes have a greater opportunity to form covalent bonds than monofunctional reactive dyes, because the loss of one reactive group through hydrolysis does not prevent the dye from performing its actual function as a dye. Bifunctional reactive dyes are characterised by their outstanding fastnesses and the considerable comparative ease with which the shades they produce can be reproduced. Due to the higher degree of fixing, their washing out properties are significantly improved.

The degree of fixing of monofunctional dyes on the fibre is around 70% while that for bifunctional dyes can be as high as 98%. Within the range of products offered by dye producers, bifunctional or even polyfunctional alternatives are appearing more and more in addition to the monofunctional reactive dyes. Reactive dyes with at least two reactive components are assigned to new groups of dyes.

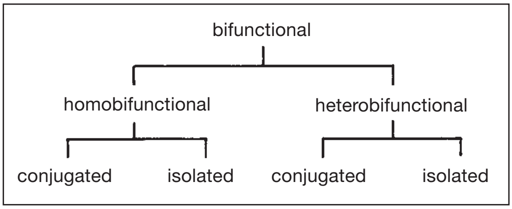


Fig. 3: The fixation possibilites of bifunctional reactive dyes.

Bifunctional reactive dyes are classified into two groups: the homobifunctional and the heterobifunctional dyes. These are subdivided again into conjugate-bonded and lone-bonded reactive dyes (Fig. 3).

The following bifunctional reactive dyes can be distinguished (R1, R2, are either identical (homobifunctional) or different reactive groups (heterobifunctional)):

Type 1: chromophore–R_1–R_2.
Type 2: R_2–chromophore–R_1.
Type 3: chromophore–R_1–R_2–chromophore.

Both aromatic heterocycles and vinylsulphones are used as reactive groups. The following combinations are known:

MCT/MCT	monochlorotriazine /monochlorotriazine
MCT/VS	monochlorotriazine /vinylsulphone
VS/VS	vinylsulphone /vinylsulphone
FT/VS	fluorotriazine /vinylsulphone
FCP/VS	fluorochloropyrimidine /vinylsulphone

In the case of bifunctional dyes, it is understandable that the number of reaction possibilities is significantly greater than it is for monofunctional dyes. In the case of simple reactive dyes, only two reaction products are really possible: the hydrosylate and the cellulose deriv-

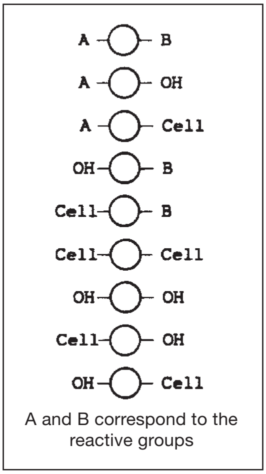
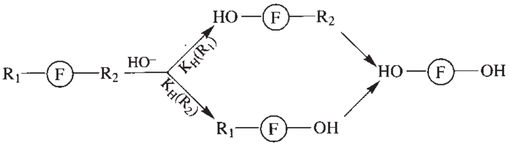


Fig. 4: The reaction possibilites of bifunctional reactive dyes.

ative. Bifunctional dyes, on the other hand, can statistically produce eight compounds (Fig. 4).

The partial hydrolysis of the bifunctional dyes with water leads to two different secondary products. Total hydrolysis produces a uniform dye which can no longer react with the cellulose (Fig. 5).



K_H = speed constant of hydrolysis

Fig. 5: The hydrolysis of bifunctional reactive dyes.

The speed of all hydrolyses is equal to the sum of the individual reaction rates. For the heterobifunctional dyes, this is the sum of two different rates but for the homobifunctional dyes it is the sum of two identical rates. This indicates that bifunctional dyes could undergo a further undesirable reaction. In this case, several reactive dye molecules link together intermolecularly to form oligomers. Before a reactive dye forms a covalent bond with cellulose, it is absorbed on to the fibre by van-der-Waal forces. For steric reasons, it is possible for the second group of a bifunctional reactive dye to react with water rather than the OH group on the cellulose. Under these circumstances, crosslinking cannot take place although the dye is fixed on the fibre. The dyeing process in the case of heterobifunctional reactive dyes must be oriented to the specific properties of the reactive components. Thus, the vinylsuphone group of the MCT/VS combination has to react first before the slower monochlorotriazine group. The sequence for homobifunctional dyes is essentially of no consequence.

Bifunctional reactive dyes are a useful development from an ecological point of view, because the high degree of fixing means that the proportion of dye lost via the effluent can be minimised. This also means that the costly treatment of effluent contaminated with dye can, in some cases, be drastically reduced. For this reason, the increasing pressure from stricter environmental requirements will lead to the increased use of dyes with high fixing properties. In general, from an ecological point of view, attention must be directed towards the contribution of halogen-containing reactive dyes to the AOX value in effluent.

Using vinylsuphones in multi-anchor dyes is a good way to improve the stability of the dye to acids in particular. This reaction group differs from aromatic heterocycles by the way it reacts and, for this reason, can significantly increase the number of possible applications when combined with other dye reaction groups. The VS/VS group double-anchor dye is used especially in the marine/black range. This class of dyes is characterised by the benefit of its almost CPB fixing. The ease with which these dyes are synthesized and their efficient use makes the marine/black range of colour tones more accessibly economic than any other.

Reactive resin (reactive crosslinker, reactant). Resin finishing agents which, under certain crosslinking conditions, preferably react with cellulose and to a lesser extent with itself (unlike → Self-crosslinking resins) such as certain methylol compounds (e.g, → Dimethylolethyleneurea) or epoxides, chlorohydrins and divinylsulphones. For example:

$$-\mathrm{N}-\mathrm{CH_2OH} + \mathrm{OH}-\mathrm{Cell} \xrightarrow{H^+} -\mathrm{N}-\mathrm{CH_2}-\mathrm{O}-\mathrm{Cell} + \mathrm{H_2O}$$

$$-\mathrm{O}-\mathrm{CH_2OH} + \mathrm{OH}-\mathrm{Cell} \xrightarrow{H^+} -\mathrm{O}-\mathrm{CH_2}-\mathrm{O}-\mathrm{Cell} + \mathrm{H_2O}$$

Reactive sensitivity →: Detection limit; Limit concentration.

Reactive-under-reactive resists The properties of reactive dyes, which contain vinylsulphone groups, of reacting with sulphur dioxide and, because this reaction proceeds very quickly, of losing their ability to react with cellulose, are exploited. Reactive-under-reactive resists are achieved by combining reactive dyes, which are insensitive to sulphur dioxide, with compounds which release sulphur dioxide or sulphurous acids on slow heating, and printing this combination on sulphur-dioxide sensitive reactive grounds (Fig. 1).

For example, it is possible to pre-print using monochlorotriazine dyes and reactive resists under alkaline conditions (sodium carbonate) and produce the wet-on-wet overprint using vinylsulphone dyes. This is the simplest and most economic method of patterning. Wet-on-wet printing is of particular interest from the point of view of cost because there are no other machine costs involved, as this is a single print-run proc-

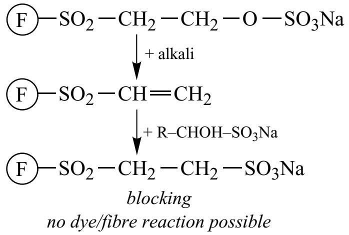


Fig. 1: The blocking of a vinylsulphone dye for the purpose of resist printing.

ess. Another advantage is the flexibility and speed of design. The wet-on-wet print is done so that the different resists can be pre-printed and then the grounds printed afterwards (Fig. 2).

Printing on dried ground padding is carried out so that the vinylsulphone dye is continually dyed as the ground (not dried above 100°C) and then overprinted with monochlorotriazine dye and reactive resist. Patterning using this method fully imitates classical vat-discharge prints. However, the following advantages of this reactive-resist printing method should be pointed out:

- simple handling (formation of halos in the case of high overdoses of resist),
- long shelf-life of pad baths which can still be used after several weeks storage,
- because the optimum pH is reached automatically, the padded goods can be stored for several weeks before they are printed,
- simple monitoring between drying and printing because boiling washout of the padding immediately provides information about resist capacity. It is therefore no longer necessary to dye test pieces, and good reserve capacity is ensured.

(according to Opitz).

Reactivity in textile-finishing processes A reaction in a homogenous system is described by the reactivity of the reaction components and in particular, by the restructuring of molecules through the dissolution and reformation of chemical bonds. The reaction mechanism describes the hypothetical behaviour of all atoms in the reaction. The reaction is force driven. In order to describe a reaction as precisely as possible, it is necessary to calculate the energy relationships of the educts and products. An energy balance, such as this, can be represented by an energy profile in which the abscissa describes the reaction co-ordinates which show the progress of the reaction quantitatively. The ordinate describes the (Gibbs) free energy G (sometimes identified as E) and indicates the thermodynamic stability of the educt or the product as the total energy content (vibration (wave) energy, heat content, kinetic energy and light energy, etc.). If G cannot be quantified in absolute terms then at least ΔG, the difference between free energy at the beginning and at the end of the reaction, can. This can be obtained either via the maximum possible yield of reaction products under the given reaction conditions or by a definition of the equilibrium constant K of the reaction as follows:

$$\Delta G = -RT \ln K$$

R = gas constant
T = temperature in Kelvin

According to the law of mass action, the equilibrium constant is dependent on the concentrations of the educts introduced and the concentrations of the products produced:

$$K = \frac{[P_1] \cdot [P_2]}{[E_1] \cdot [E_2]}$$

The equilibrium constant is temperature dependent. From the above, a negative value for ΔG indicates a

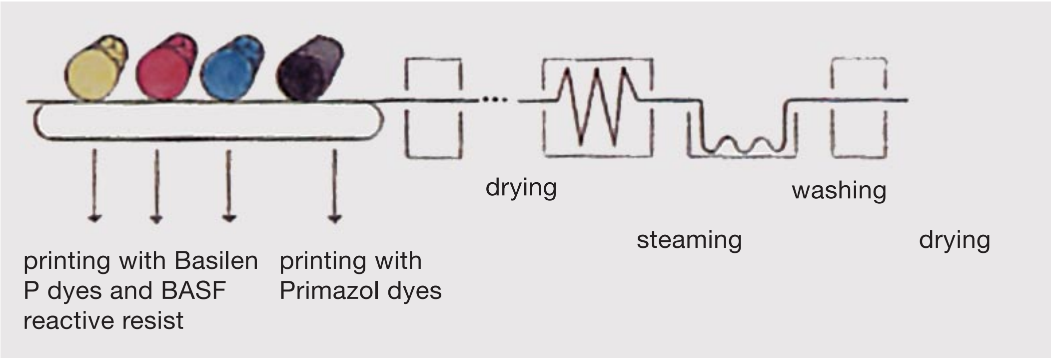


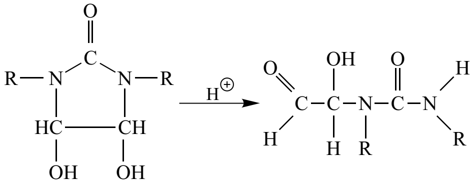
Fig. 2: The possible processes for resist printings (wet-on-wet with a ground).

large product yield and a positive value indicates a small product yield.

ΔG, the free energy differs from ΔH, the heat energy or enthalpy for the reaction, but they are related to each other by the Gibbs-Helmholtz equation as follows:

$$\Delta G = \Delta H - T\Delta S$$

If the heat content of the educt is greater than that of the product, then the reaction is exothermic, and if the heat content of the product is greater than that of the educt, then the reaction is endothermic. S denotes the entropy of a system and ΔS is a measure of the difference in the degrees of order between the educt and the product. If ΔS is large, then the product is in a less ordered state than the starting materials. When a crosslinking agent is used in finishing cotton, for example, the acid catalyst may open the ring substance as a side reaction and the entropy increases, i.e, ΔS is large:



With a high negative value for ΔG the reaction equilibrium is almost completely moved to the right in favour of the products. However, strictly speaking it is assumed that even in this case a fraction of the product is taken up in the reverse reaction as every reaction is chemically reversible.

$$A + B \rightleftharpoons C + D$$

Because there are several possible reaction routes for each reaction, they show different reactions for the same educts, products and therefore, the same K.

The reaction route appears in the energy profile as the "energy barrier" or activation energy ΔG*. This is the energy required to bring the educts (and in the case of the reverse reaction, the products) and the atoms taking part in the reaction into a state suitable for the breaking and reformation of the chemical bonds. This does not represent any possible intermediate products. Normally, the overall reaction is made up of several steps each with their intermediate products because a single-step reaction would require far too high an activation energy for completion and would take far too long to yield the final products. As the reaction splits up into several stages, the activation energies for each stage are significantly lower which makes it possible for the overall reaction to take place via the individual intermediate products (in finite time). However, as the rate-determining step, the reaction component with the highest activation energy is crucial in defining the rate for the overall reaction. Generally, the rate is determined by the step which takes the longest, together with all the previous steps. In this connection, by taking part in the reaction, catalysts reduce the activation energy to such a degree that the reaction proceeds spontaneously (i.e, by forming a new transition state of low energy as the transition state for the non-catalysed reaction). Thus, hydrogen peroxide is relatively stable providing no iron ions are present to act as a catalyst for its explosive decomposition. Catalysts have a considerable effect on the speed of the reaction without changing the equilibrium position because, after taking part in the new transition, they are released as the products are formed and are able to intervene again in the reaction of educts.

The position of the equilibrium for a reaction can be influenced in the form of an increase in the yield by:

- removing from the homogeneous system of the reaction in solution one of the reaction products in the form of a gas or precipitate or
- adding one of the reaction educts to excess.

The equilibrium constant K is not altered by this but is altered by changing the reaction medium, for example, the solvent. In order to increase the rate of a simple reaction without using catalysts, it is possible to affect the rate constant k as the proportionality factor for the relationship of all concentrations taking part in the reaction:

$$k = \frac{k'T}{h} \cdot e^{-\frac{\Delta G^*}{RT}} \qquad ; \frac{k'T}{h} = A$$

k' = Boltzmann's constant
h = Planck's action constant

The rate of a reaction is defined as the change in concentration per unit of time. The rate with which a reaction proceeds in a single direction via its transition state depends on the concentrations of all the educts taking part.

$$[A] \rightarrow [Z]$$

For example, Z is formed as quickly as A is consumed. The decrease in [A] therefore equals the increase in [Z]:

$$-\frac{\Delta[A]}{\Delta t} = +\frac{\Delta[Z]}{\Delta t}$$

Because all reactions are reversible, the rate at which the concentration of a substance taking part in the reaction changes is always equal to the difference between the rate of formation and the rate of decomposition of this substance:

$$A \underset{v_{-1}}{\overset{v_1}{\rightleftharpoons}} Z$$

$$v_Z = \frac{d[Z]}{dT} = v_1 - v_{-1} = k_1[A] - k_{-1}[Z]$$

The following applies to the equilibrium state

$$\frac{k_1}{k_{-1}} = K = \frac{[Z]}{[A]}$$

By increasing the temperature of the reaction and therefore the energy content of the educts by activating a large proportion of the reaction components, the activation energy of the new increased initial energy level of the transition state will be lower and therefore the rate of reaction will be faster as ΔG^*, as defined by the equation:

$$k = A \cdot e^{-\frac{\Delta G^*}{RT}}$$

becomes smaller. Thus, the reaction rate can be increased by

- catalysts,
- increased temperature,
- increased concentration of reaction components.

The following pre-conditions apply to the reactivity of textile fibres which are to react with a liquor of dissolved educts in a heterogeneous system:

1. $\Delta G \leq 0$. Both the absolute energy content and changes in ΔG for the fibre modification are difficult to determine, which means that calculation of the equilibrium constant is also difficult. Therefore, exactly which reaction steps control the process is difficult to assess from the point of view of the kinetics and thermodynamics of the reaction.
2. In a heterogeneous system, the transport of educts out of the solution to the functional groups on the fibre substrate immediately precedes the actual chemical reaction so that the reaction-controlled process may actually become a diffusion-controlled process.

The heterogeneous system is further complicated by the fibre matrix where the transport is affected by laminar and turbulent flow. The reaction is characterised by the rate constant k whereas the transport phenomena are described by the diffusion coefficient D. The two parameters can be compared via the relaxation processes of both processes. In each case, this represents the time, within which, both processes subside to $^1/e$ (to be distinguished from the half life). For a simple first-order reaction, the relaxation (or decay) time is $^1/k$ and for the associated diffusion it is

$$\frac{L^2}{D}$$

where L is the average distance covered by a dissolved compound before meeting a co-reactant in the fibre matrix.

Semi-quantitative statements on the limiting relationship can be made as to whether

- a textile finishing process is influenced by the reaction and not the diffusion processes, i.e, is reaction controlled:

  $$\frac{D}{k \cdot L^2} > 1$$

  In this case, the breaking and making of bonds (according to the definition of the reaction) is the rate limiting phase.
- a textile finishing operation is controlled by diffusion processes but the actual chemical reaction is considerably faster once the educts have arrived at the functional groups:

  $$\frac{D}{k \cdot L^2} \leq 1$$

  In this case, the diffusion process is the rate limiting phase.

For solutions, small molecular compounds apply where the diffusion coefficients $D_{real} = 10^{-6}$ [cm^2/s]. However, those in porous substances become still smaller than the apparent diffusion coefficients because the free diffusion is superimposed by adsorption/desorption processes which slow it down ($D_{sch} \approx 10^{-7}$ [cm^2/s]. A typical rate constant for textile finishing reactions is $k = 10^{-3}$ [s^{-1}] (corresponding to a relaxation time of around 16 minutes).

As individual fibres represent a porous substrate with radii smaller than 10^{-2} cm, processes are reaction-controlled on individual fibres and the diffusion effects are not significant. In the fibre matrix, however, this situation can change crucially.

If the radius of the individual fibres increases above 10^{-2} cm, then the fibre will be populated from the outside inwards in shells. If the reaction is interrupted, the reaction will be found to have taken place in the mantle zone while the core of the fibre remains unmodified. This reaction can be accelerated by increasing the porosity of the fibre above the normal values (0.1–0.4).

An increase in the porosity of 100% will increase the apparent diffusion coefficient by a factor of 2.

Increasing the temperature does not have a significant effect on the diffusion process because of its low activation energy. Diffusion into the fibre matrix and into the porous structure of the fibre is accelerated considerably if the absorption processes can be suppressed. This can be achieved by

- raising the temperature,
- blocking the absorption sites, using compounds which do not actually take part in the chemical reaction, making it possible to prevent ring dyeing by the addition of levelling agents when dyeing cotton.

The amount of absorbed substance can be calculated when this substance is to react with the starting concentration C_0:

$$C_{absorbed} = S \frac{C_0K}{1 + C_0K + C_BK_B}$$

S = total concentration of absorption sites,
C_B = bath concentration of blocking agents (e.g, levelling agents),
K_B = absorption equilibrium constant of the blocking substance,
C_0 = bath concentration at the start of the reaction.

(according to Rys).

Reactor drum steamer Type of steamer with a large, teflon-coated, steam-heated steel drum (standard reactor drum steamers are 2.50 m diameter) over which the approx. 100% squeezed off fabric, which is to be treated, is run. The fabric is fully covered with a continuous overlapping rubber belt which seals it from the outside and provides a steam environment directly on the fibre, where it accelerates all the reactions taking place. An impregnating roller vat, padder and continuous washing machine can be added. Thus for example, it is possible to de-size broad widths of cotton fabric as a continual process (contact time 4–6 s at 130–135°C, fabric speed 75–112 m/min). The reactor drum steamer can also be used for steam fixing prints (two-phase print method) and for pad-dyeing with vat, substantive or reactive dyes or for condensing aminoplasts in a steam atmosphere (Manuf.: Monforts).

Re-adhesion Supplementary to → Strike through, in particular, the undesirable sticking together of two wrong sides of lining material which lie against each other, as in the case of external sandwich-fixing. It is the effect of steam from a steam iron or a steam ironing press or edge press within the temperature range of 100–130°C, for example, when ironing the lapel on a finished or semi-finished garment. This is particularly diadvantageous in the case of lapels when the wrong sides of lining materials are more or less stuck together and should be separated after ironing. Even if the coating is reduced, a small amount of re-adhesion is not entirely avoidable. Adhesives such as these have so far been based on polyamide copolymers. It will require a different adhesive system, such as a so-called non-polar based double-spot adhesive, to avoid lapel re-adhesion completely.

Ready for making-up A terms used for goods which combines the terms “pre-shrunk” and “decatized”. Ready for making-up goods are those which can easily be manufactured, ready for wear.

Ready-made curtains → Net-curtain fabrics in fitted sizes, 1–2 m wide and 2.5–4 m long.

Realgar → Orpiment.

Real net product Production costs, less payment in advance (purchased material and services).

Real-Wax → Batik printing; indigo styles in African print.

Rebatching steamer Steamers for wide treatment with two batchers which unroll and roll goods at the same time. Longer dwell times are made possible with a continuous run of goods. Rebatching steamers are designed for batches of 600 and 1100 kg dry goods and reaction times up to 2 hours. Used for desizing, drying off and bleaching cotton and cotton blends.

Recalcination Recovery of lime, for example, in the → Kaloz process (effluent treatment). The precipitation aid, lime (milk of lime), is recycled from precipitated sludge: the organic component is burnt and calcium oxide recovered while the carbonic acid produced is used for neutralizing the effluent.

Recipe scales The electronic scales prints out a record of the net weight together with the date, formulation no. and dye no. Weighing systems such as these are a valuable aid in monitoring formulations. They are available with ranges from 10 mg to 60 kg and include a dialogue weighing system for connection to a calorimetric unit and computer.

Recirculating tumble drier A combination of tumble drier and heat pump (single stage) (see Fig.).

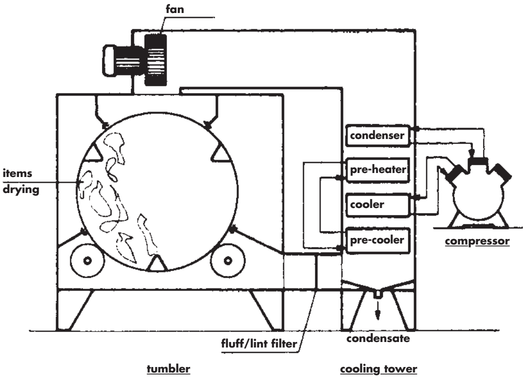


Fig.: Schematic of a recirculating tumble drier.

In contrast to a conventional tumble drier, saturated extracted air (still carrying a significant amount of energy) is not vented externally but instead ducted into an attached “cooling tower” where it passes over a “pre-cooler” and “cooler” and its temperature is reduced in stages to approximately +5°C. By lowering the temperature below the dew point, the major portion of the water vapour carried by the air is caused to condense out, resulting in a relative humidity of the air downstream of the cooler of only approximately 12–13%. This drier air is then warmed in stages by the “pre-heater” and “condenser” to 70–75°C and returned to the tumbler. The cooling of the air is achieved by means of a closed water circuit in the “pre-cooler” (pre-cooler/pre-heater) and by a refrigerant in the “cooler”. The refrigerant is drawn through the cooler by the compressor, expands within the heat exchanger piping of the “cooler” and in the process extracts energy from the air passing over the piping. The first stage in re-heating the dried air is achieved by the “pre-heater” by means of transfer from the water circulation it shares with the “pre-cooler”. Final heating is done by the condenser, whereby compressed refrigerant warms air passing over the condenser to a maximum of 75°C. Compared to a conventional tumble drier requiring about 6300 kJ/l of condensate, the energy consumption of a recirculating tumble drier, which requires only about 1700 kJ/l, is approximately 26%. These figures justify a slightly longer drying time (approximately 15%). The low drying temperature of the operation is of advantage for, in particular, natural fibres (wool, cotton) through improving handle, reducing yellowing and so on.

Reclaimed cotton (effilochées), cotton reclaimed from cotton rags.

Reclaimed fibre bonding with phenolic resins New textile off-cuts, textile ready-to-wear hosiery goods and washed rags are used as hard die-moulded components for special applications in car manufacture. The textiles are identified chemically according to quality and visually sorted in an elaborate process. In the reclamation process, the textiles are mechanically reduced to fibres. At 15–35 mm, the resulting reclaimed fibre is relatively long stapled. At this point in the technical process, it is possible to include additives or extra materials which either affect the manufacturing process or even impart special properties to the finished product. These may be fusers, scrooping agents, fungistats or water repellents.

The low melting point of the phenolic binder facilitates preliminary adhesive bonding of the raw nonwoven, which is necessary for handling the material. The grain size and the grain-size distribution of the resin powder in particular are important both for even distribution within the nonwoven fibre and the statistical frequency of bonding where the individual neighbouring fibres meet one another at a tangent. Additives can even be mixed with the resin which make it easier to work, or mixed with other additives, such as dust bonding agents or substances which affect the finished product, such as inorganic fillers; fire retardants (borates) and fungistats, etc. can be added.

The recovered fibre and phenolic resin powder are mixed in different proportions depending on the special requirements of the finished product. The usual proportions lie between 80 : 20 and 60 : 40 wt.%. The mixing itself is carried out by mechanical means (extreme homogeneity being necessary) separately or while the nonwoven is being formed. Formation of the nonwoven is achieved using either a mechanical or aerodynamic process or possibly a combination of the two. Carding machines (combing, etc.) and aerodynamic random-web machines are used for this purpose. In each case, the following are necessary for the formation of nonwoven:

- quality of the recovered goods in regard to type, degree of break-down of the original material, length, previous history and additives;
- performance in regard to degree of break-down of original material (uniformity) and rate in kg/hour;
- quality of the prefabricated component in terms of the uniformity of the physical properties.

The nonwoven is formed directly after the preliminary curing of the phenolic resin. During this time, the resin should on the one hand be partially adhesive bonded (in order to facilitate handling of the nonwoven) while on the other, retaining its latent capacity for chemical reaction during the final pressing process. Once the nonwoven has been consolidated in hot air, it is cut into panels and can be stored in this form for two months providing the temperature is less than 25°C. The pre-consolidated, plan-shaped, nonwoven panels are moulded under mechanical high pressure in heated moulding presses in which the resin (Duroplast), which is incorporated into the panel, is melted and finally cured.

Components without any defects are considered for a subsequent finishing process (Fig.). This involves coating them with polyvinyl film, stitch-bonded pile fabrics or tufting (previously provided by stamping) or something similar. Direct coating is carried out with pigmentation systems using pastes, Either from an aqueous phase or from a solution consisting of organic solvents. Either immersion or electrostatic spraying is used or a method along the lines of a curtain coater. During the laminating process, the fabrics are moulded to shape and fixed to the hard-pressed moulded component which is to serve as a base using adhesive. Mechanical shaping and vacuum techniques are in common use. Latent crosslinking adhesives, reactive adhesives and solvent-based adhesives are used for the fixing. They are sprayed on, coated using curtain coaters or printed on one or both sides of the substrate.

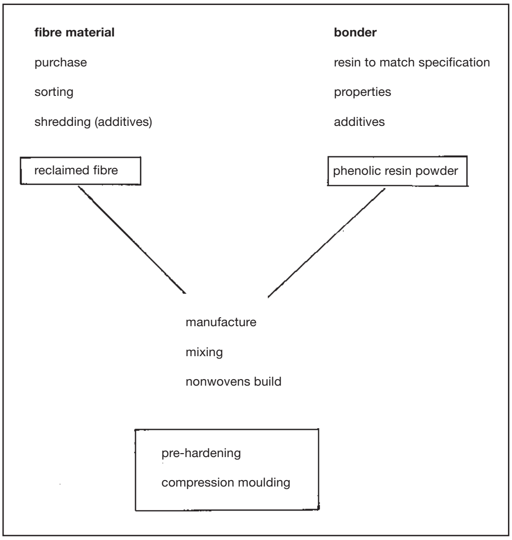


Fig.: The production sequence for the manufacture of hard compression moulded parts.

After complete curing, phenolic resins (phenolplasts) behave as typical Duroplasts. They are manufactured via acid or alkaline condensation of phenol, cresol, hydroxyxylene, other alkyl phenols or polyhydric phenols with aldehydes (preferably formaldehyde). The various different morphological states which the phenolic resin passes through on its way to complete curing are of particular importance in the process used for manufacturing hard-pressed moulded components. In practice, the transition between these states is smooth. These are as follows:

– A-stage: initial state, resinol (one-stage) or novolak (two-stage), liquid or fusible and soluble.
– B-stage: intermediate state, resitol, non-fusible but still mouldable when heated, swellable with low mechanical strength.
– C-stage: final state, resite, non-fusible, insoluble, high mechanical strength and high chemical resistance.

(according to Eisele).

Reclaimed wool Produced from various types of wool products, waste fibres from the spinning mill, weaving mill, knitting mill and hosiery mill as well as (→ Rags) domestic waste fabrics, waste new fabric from the weaving mill or tailoring shop, etc. Types of woollen spinning yarn recovered by mechanical processing (carbonizing and dyeing, etc.) are classified as follows: Grade I = shoddy; Grade II = Tibet; Grade III = Mungo; Grade IV = alpaca and extract and golfers.

Recontamination Contamination of fabric after disinfectant washing or disinfectant cleaning processes or an breakdown of these processes. Recontamination can be judged according to two types:

a) unavoidable recontamination by rinse water and ambient air, depending on the amount of adherent water and exchange volume, or lime sediments;
b) avoidable recontamination by machine operators and animals (insects).

Recovered wool (reused wool). Recovered wool is similar to → Skin wool but is produced from tanned pelt wastes and wool rags. The quality and extent of damage of recovered wool varies widely (inferior to fleece wool) and is dependent on the amount of wear-and-tear and degree of tanning. The material is therefore generally unsorted. The following disintegration processes are used to recover the wool:

I. Acid disintegration (treatment at the boil, cheap, quick, increased damage).

II. Enzyme disintegration (treatment requires several weeks, causes no further damage).

III. Vacuum steaming disintegration (virtually no damage).

Recovery and reuse in textile processing The → Recycling of operating materials and raw materials is becoming increasingly important in the textile industry. Examples of this are:

1. Water economy in a textile finishing works which may include the reuse of treated effluent (→ Waste water treatment).

2. Dyeing in a standing bath uses well exhausted dye liquors for the next dyeing of the same class.

3. After dyeing or printing a textile, chemical finishing is frequently carried out in order to impart special performance characteristics to the material. Multi-component systems are generally used for this purpose, i.e, a finishing liquor contains a plethera of different substances. For this reason, residual liquors cannot be used again in most cases. Appendix 38 of the German Framework Administration Regulation for Waste Waters (Rahmen-Abwasser-Verwaltungsvorschrift) is particularly relevant to the use of residues in textile finishing. The possible reuse of finishing liquors is therefore of great interest.

4. The reuse of textile effluents as operating materials may also be appropriate, for example:

– in collar linings (blended textile),
– in dusters (not products made from filament yarns),
– in moulded components in the car industry (identical grades or similar grades of textile are better for reuse than blended textile),
– in sound insulated walls (blended textiles),
– in park benches (identical grades of synthetic materials),
– in heat-insulation materials in residential buildings (blended textiles; fire protection)
– as a raw material in a textile fibre recycling process (identical grades of synthetic materials, undyed;

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cotton waste in viscose production and cellulose processing).

Recovery capacity of fibres All fibres under tension (→ Tensile elasticity) experience tensile recovery which, at least, to some extent, can be reversed (except in the case of an invevitable albeit normally very small degree of irreversible elongation). This is the so-called elastic recovery or secondary effect, the quantitative comparison of which between different fibres is significantly dependent on the conditions under which the extension and relaxation takes place. The recovery capacity of fibres is related to the magnitude of the force applied, its duration and the time available for recovery. → Relaxation.

Rectification Special type of solvent distillation used for solvent recovery where high levels of purity are achieved by multi-stage evaporation.

Recuperative energy recovery → Heat recovery.

Recuperator (Lat.: recuperatio = recovery), preheater, heat accumulator, → Heat exchanger.

Recupra process Used for the recovery of polyacrylate finishes. BASF/Benninger process (→ Recycling) facilitates recovery of 60–80% of the coated finish. The goods to be desized no longer pass through the desizing bath. Application is by small counter-rotations in three stages and squeezed out and concentrated in a heavy press. The remaining desizing can be combined with the next finishing stage.

Re-Cure (recuring permanent press process). It is a variant of the pre-cure process (→ Permanent press process). Fully cured synthetic resin coatings (aminoplasts) are partially hydrolysed by subjecting them to particular cycles of steam ironing ("re-crosslinking" the cotton component) and curing them in the new shape simultaneously. This produces wash-resistant creases and fitted shapes and can be used to bond, for example, the polyester component by thermo-plasticization. Principle: ready-to-wear manufacture, pre-cure-finished goods, then steam on special ironing presses, dry by extraction and subject to conditions for post-condensation at 180°C for about 20 seconds.

Recycling Recovery of used raw materials for re-use in a similar or different form. In order to make a contribution to overcoming the problems of waste production, recycling concepts are being sought in the textile industry in addition to the strategy for the avoidance of waste. In the clothing industry, apart from the efforts to build up collections using biodegradable textiles, attempts are being made to control the logistical route for packaging films and clothes hangers in such a way that it will be possible to re-use them. Increasing numbers of driving licences means that there is an increasing number of old cars. The environmentally friendly disposal of this scrap has become more important with the increasing proportion of plastics. The reprocessing of worn-out vehicles and their components is also a requirement for preserving global reserves of raw materials. Reprocessing means the recovery of raw materials and reintroducing them into production. The term "recycling" describes this figuratively in the sense of a circulation of materials. The following distinctions are made between the different forms of recycling (for example, of vehicles):

1. Direct recycling: the raw materials are recovered from vehicle components and used in the manufacture of new vehicle components. The most familiar example of this is the recovery of steel from vehicle scrap or recycling of PVC-based composites (Fig. 1).
2. Indirect recycling: old vehicle components are recovered, processed and used for other industrial purposes not in the car industry.
3. Inverse recycling: while 1 and 2 represents the recycling of vehicle waste which is re-processed for manufacturing purposes, it is also possible to use particular recycling components for vehicles, the recycled raw-material of which has come from other manufactured goods. In this case, the circulation of materials is in reverse (inverse).

I. Recycling fibres: recycling includes both in-house routes as well as used textiles. If these are composed of natural fibres, there are no problems – wool is used to produce shoddy and silk is used to produce schappe or bourette. Even in the case of cotton, recycling should be possible in the OE spinning process. Fibre dust from spinning mills can be used in nonwoven products. Thermoplastic synthetic fibres can be turned into granules.

In a few areas in the textile industry, waste materials have always been reprocessed (for example, shoddy). When waste materials (or secondary raw materials) are re-introduced into textile production, the type of material used must be matched with the article being made. A whole industry emerged a long time ago for mastering the distribution between the volume of secondary raw material and material requirements and, if the preparation of raw materials is included, even an international, secondary raw-material textile industry. The terminology used for the materials was introduced internationally and is understood worldwide.

Collections of old clothes are sorted into those which are in good condition and distributed for social purposes until they are worn out and those which cannot be used any longer. These are disintegrated by an opening machine and used again for textile purposes (shoddy). The reprocessing of textiles by tearing has been carried out on an industrial scale for more than 100 years. So-called reclaimed fibre has also been processed with plastic as a binder for twenty years. Another development has now opened up possibilities for numerous applications for this combination of materials, particularly in the car industry.

An example of this is phenolic-resin bonded non-

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cotton waste in viscose production and cellulose processing).

Recovery capacity of fibres All fibres under tension (→ Tensile elasticity) experience tensile recovery which, at least, to some extent, can be reversed (except in the case of an invevitable albeit normally very small degree of irreversible elongation). This is the so-called elastic recovery or secondary effect, the quantitative comparison of which between different fibres is significantly dependent on the conditions under which the extension and relaxation takes place. The recovery capacity of fibres is related to the magnitude of the force applied, its duration and the time available for recovery. → Relaxation.

Rectification Special type of solvent distillation used for solvent recovery where high levels of purity are achieved by multi-stage evaporation.

Recuperative energy recovery → Heat recovery.

Recuperator (Lat.: recuperatio = recovery), preheater, heat accumulator, → Heat exchanger.

Recupra process Used for the recovery of polyacrylate finishes. BASF/Benninger process (→ Recycling) facilitates recovery of 60–80% of the coated finish. The goods to be desized no longer pass through the desizing bath. Application is by small counter-rotations in three stages and squeezed out and concentrated in a heavy press. The remaining desizing can be combined with the next finishing stage.

Re-Cure (recuring permanent press process). It is a variant of the pre-cure process (→ Permanent press process). Fully cured synthetic resin coatings (aminoplasts) are partially hydrolysed by subjecting them to particular cycles of steam ironing ("re-crosslinking" the cotton component) and curing them in the new shape simultaneously. This produces wash-resistant creases and fitted shapes and can be used to bond, for example, the polyester component by thermo-plasticization. Principle: ready-to-wear manufacture, pre-cure-finished goods, then steam on special ironing presses, dry by extraction and subject to conditions for post-condensation at 180°C for about 20 seconds.

Recycling Recovery of used raw materials for re-use in a similar or different form. In order to make a contribution to overcoming the problems of waste production, recycling concepts are being sought in the textile industry in addition to the strategy for the avoidance of waste. In the clothing industry, apart from the efforts to build up collections using biodegradable textiles, attempts are being made to control the logistical route for packaging films and clothes hangers in such a way that it will be possible to re-use them. Increasing numbers of driving licences means that there is an increasing number of old cars. The environmentally friendly disposal of this scrap has become more important with the increasing proportion of plastics. The reprocessing of worn-out vehicles and their components is also a requirement for preserving global reserves of raw materials. Reprocessing means the recovery of raw materials and reintroducing them into production. The term "recycling" describes this figuratively in the sense of a circulation of materials. The following distinctions are made between the different forms of recycling (for example, of vehicles):

1. Direct recycling: the raw materials are recovered from vehicle components and used in the manufacture of new vehicle components. The most familiar example of this is the recovery of steel from vehicle scrap or recycling of PVC-based composites (Fig. 1).
2. Indirect recycling: old vehicle components are recovered, processed and used for other industrial purposes not in the car industry.
3. Inverse recycling: while 1 and 2 represents the recycling of vehicle waste which is re-processed for manufacturing purposes, it is also possible to use particular recycling components for vehicles, the recycled raw-material of which has come from other manufactured goods. In this case, the circulation of materials is in reverse (inverse).

I. Recycling fibres: recycling includes both in-house routes as well as used textiles. If these are composed of natural fibres, there are no problems – wool is used to produce shoddy and silk is used to produce schappe or bourette. Even in the case of cotton, recycling should be possible in the OE spinning process. Fibre dust from spinning mills can be used in nonwoven products. Thermoplastic synthetic fibres can be turned into granules.

In a few areas in the textile industry, waste materials have always been reprocessed (for example, shoddy). When waste materials (or secondary raw materials) are re-introduced into textile production, the type of material used must be matched with the article being made. A whole industry emerged a long time ago for mastering the distribution between the volume of secondary raw material and material requirements and, if the preparation of raw materials is included, even an international, secondary raw-material textile industry. The terminology used for the materials was introduced internationally and is understood worldwide.

Collections of old clothes are sorted into those which are in good condition and distributed for social purposes until they are worn out and those which cannot be used any longer. These are disintegrated by an opening machine and used again for textile purposes (shoddy). The reprocessing of textiles by tearing has been carried out on an industrial scale for more than 100 years. So-called reclaimed fibre has also been processed with plastic as a binder for twenty years. Another development has now opened up possibilities for numerous applications for this combination of materials, particularly in the car industry.

An example of this is phenolic-resin bonded non-

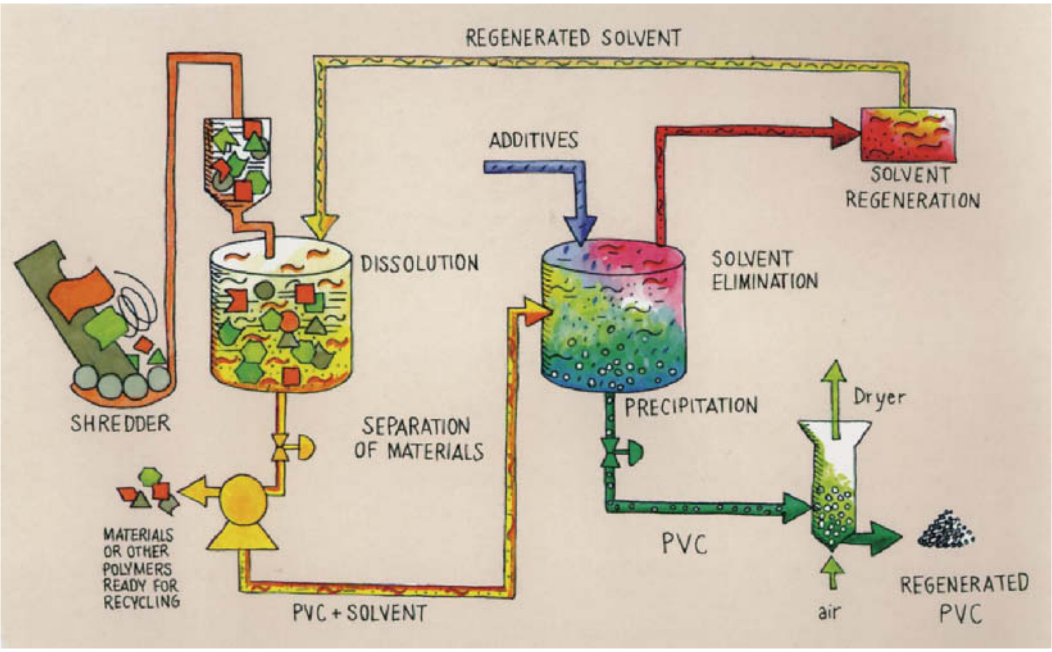


Fig. 1: Recycling of PVC-based composites (Vinylop process by Solway).

wovens made from reclaimed fibre which are in use at densities of 50–100 kg/m^3 and weights of 500–1200 g/m^2. In the form of flat stampings, self-adhesive combined with thick solids, they are used to absorb airborne sound or vibration. They are always applied to the lower surface. Preformed components of similar composition (with or without textile covering) have been used for 10 years. Sometimes covered and sometimes visible, they serve equally well for sound absorption and, if necessary, in the form of self-supporting elements. With densities ranging from 100–250 kg/m^3, their handle is therefore more-or-less soft, elastic on compression, or firm. The following is a list of applications in car production:

- engine bonnet insulation,
- end wall insulation,
- panel insulation,
- leg space (up to the bulkhead),
- tunnel covering,
- wall, dividing the boot from the passenger area,
- floor of the boot and roof deadening.

Spacing fabrics with decorative side are knitted fabrics used for cowlings or other places in the vehicle and are given a padding effect during manufacture. Additional layers of polyurethane foam, separate backing fabric or nonwoven, and the entire prefabrication process becomes superfluous. Thus, this is economic in the case of items specially developed for special applications. For articles such as these, the huge diversity of possible patterns with yarn-coloured material on the decorative side appear to be a promising route for the future. After successfully concluded trials, materials such as these were used for the inner-lining of cabrio-hoods from 1992. For the purpose of sound and heat insulation, the hood is put together in three layers: the external layer, which is a three-layered hood material, then a thicker coarse fibre felt and finally an inner lining. However, spacing fabrics will be found in a broad range of uses as

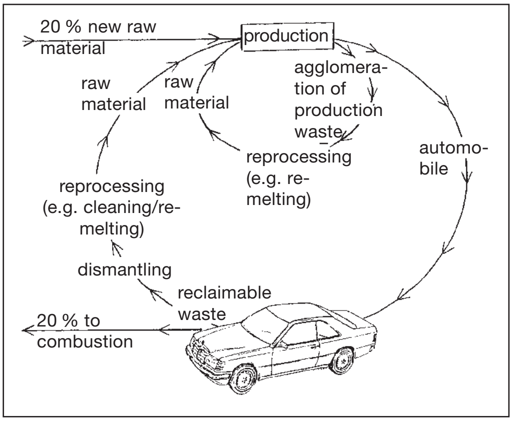


Fig. 2: The cycle for the recycling of production waste and used materials from automobile interior fittings.

a covering fabric and will first be seen on pillars, door linings, seat-back covers including the pockets, seat-base coverings as well as the inner lining of the roof as the main areas. It will not be used for hat racks or possibly instrument panels and seat covers until the testing and optimization phases are over. It is of particular interest because of its decorative finish and outstanding permeability to air (an improvement on seat air conditioning in comparison to polyurethane-foam pre-fabricated parts). These types of covering components for the internal furnishings can be pure grade and yet manufactured as a laminated product. The two resulting recycling processes – production waste and used material – are shown in Fig. 2. Theoretically, this means waste-free production and utilisation of resources introduced just once. In practice, it would be good if 80% is recycled and 20% is new material with 20% burnt to produce so-called recycling energy. This would correspond to a total of 6 1/2 cycles in the recycling process (five cycles in used-material recycling and one cycle (corresponding to 5 x 20% waste) in the production waste circulation, and one half use for combustion).

II. Recycling effluent constituents: in the textile industry, apart from heat recovery and the use of secondary growth raw materials (vegetable and animal fibres, natural thickeners, etc.) it is also possible to recycle water and textile auxiliary aids such as sizes. Recycling process water in its entirety is a comprehensive solution for conserving water resources and taking account of the water resources law, which also restricts substances in effluent which is discharged indirectly. In the meantime, apart from mechanical-biological clarification, a series of methods has become available for reprocessing, in which case, combinations of oxidation, adsorption and precipitation phases have proved to be successful.

Total recycling of process water is possible, for example, by distilling the effluent or reintroducing condensation. When recycling process water which has been purified, the residual organic content can be neglected. On the other hand, the effect of salts on process control and the specified finishing objective is regarded as definitive. These salts are essentially the non-precipitating or partially precipitating alkali and alkaline earth (Group I & II metal) salts of chlorides, carbonates and sulphates. Although so-called salt accumulation during treatment does not have to be performed by the purification process itself, this has been unavoidable when trying to introduce re-circulation. A demineralization step would basically resolve this problem but this would involve a considerable increase in cost.

Envi-col-ex method (Fig. 3): The heavily loaded effluents (liquors and baths, etc.) are fed into special buffer and holding ponds and extracted by level control and then fed to processes where they are treated fully automatically. The process consists of flocculation/adsorption treatment which preferably removes dyes, hydrocarbons and particulates. The resulting slurry-free water can either be discharged into the drains directly or returned to the plant as recycled water via a fine neutralization step and adsorption treatment process. Rinsing waters which are not heavily loaded flow via a heat-recovery plant into separate buffer and holding ponds from which they are extracted via level control and returned to the plant via a continuous neutralization and adsorption unit. The activated carbon adsorption step in the percolation process selectively removes the organic lipoid constituents (hydrocarbons and dyes) so that these waters can be re-used for rinsing purposes. If the waters are not required for re-use, they can be discharged into the drains in compliance with the law without the need for an adsorption treatment step. With the special decoloration flocculation method used in the Envi-col-ex process, both the genuinely dissolved dyes (such as the reactive or vat dyes, etc.) and the dispersion and pigment dyes as well as hydrocarbons can be extensively removed at minimum cost. Harmful substances are removed using methods which are based on adsorption and precipitation and, depending on the composition of the effluent, these reduce the chemical oxygen demand (COD) or total organic carbon (TOC) by a considerable amount.

III. Recycling liquor residues: an important aspect in print shops and the dyeing of textiles in continuous

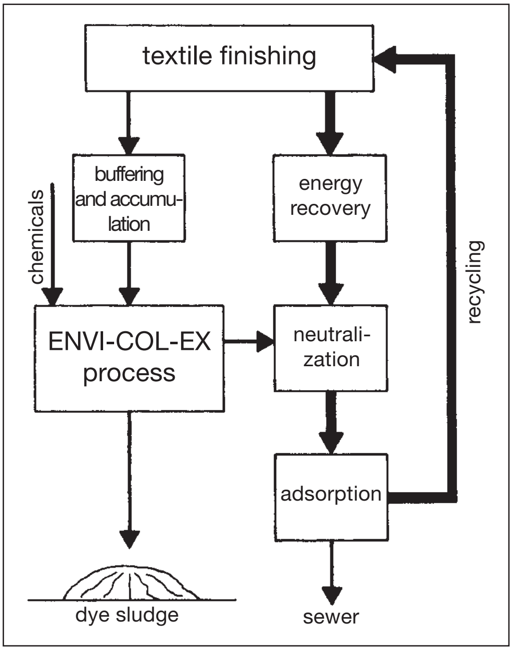


Fig. 3: Waste water processing scheme for the textile finishing business (Enviro-Chemie AG).

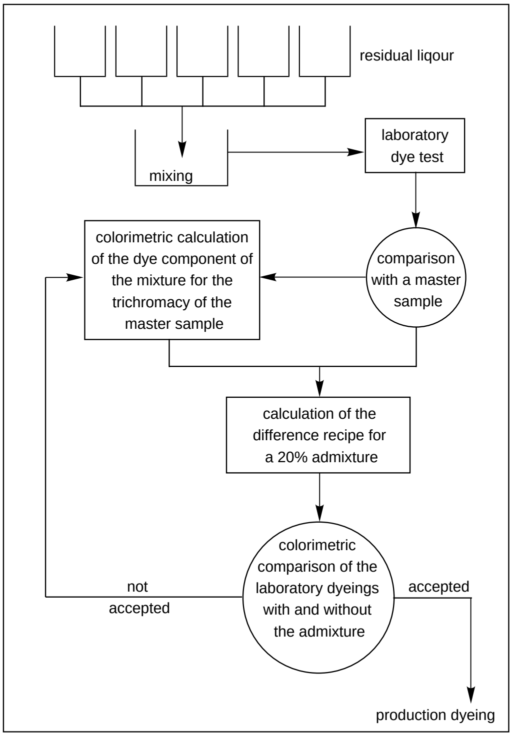


Fig. 4: The recycling of residual liquor in pad jig and pad steam dyeing by including a maximum 20% contribution of residual liquor to the mix in preparation for the following batch (according to Marzinkowski).

plants is the re-use of residual print pastes (print-paste residues) or residual liquors. In the case of pad-jig dyeing of viscose linings for example, up to 10% of the liquor results in residual liquor (Fig. 4). It consists of residues from the padder trough (in spite of the economy trough) and a "safety pool" as the liquor pick-up may vary due to fluctuations in the composition of the material. The discharge of this residual liquor not only means high loading for the effluent but a loss in terms of unused dye. However, as the residual liquor from the padder trough contains an unknown concentration of dissolved size, its re-use so far has been very rare and is usually confined to black dyeing. However, it is possible, using colorimetry and interdisposed laboratory dyeings, to re-use any mixtures of residual liquors. The mixture is first used for laboratory dyeing. This is then compared with the pattern of the next larger production batch which should be as close as possible to the colour tone and shade of the mixed dyeing. A recipe is calculated colorimetrically for the dyes in this pattern so that dyeing can be carried out using the mixture. Using this recipe, the amount of dye can be calculated while taking a maximum of 20% of the mixture into account in the new batch of liquor. This is dyed again and compared colorimetrically with a dyeing without making allowances for the mixture. This procedure is necessary because the concentration of dye at the end of the padding process is different from that at the beginning of the treatment. There are limitations in the method in the case of brilliant and pure colour tones. This must be taken into account before mixing. As well as this, several collection and mixing tanks must be available. The fact that not more than 20% mixing liquor can be worked into the next batch also has to be taken into account, otherwise sizing components and spin finishes contained in the mixing liquor will have a detrimental effect on the result. This method of recycling liquor residues is also more labour intensive.

Multi-use of dye liquors is only possible to a limited extent. When dyeing in standing baths, which is only possible for similar sequential dyeings, the chemical consumption during the first dyeing is increased by corresponding subsequent additions of reducing agents. However, as it is not possible to remove the secondary products of the reducing agents, the chemicals continue to concentrate in the liquor. Using dyeing liquors for different colour tones and complete recycling is currently not possible.

IV. Recycling sizes: In Germany, sizes are recycled according to two methods:

a) In the "wash-out method" a recycled product with increased liquor concentration which can be used for sizing is produced by modifying the conventional washing process. However, the recycled product contains only a part of the total amount of sizing agent to be dissolved during the pre-treatment. The term used therefore is "partial recycling".

The principle of the Recupra method relies on the fact that the size is not washed out but swollen up and squeezed out by heavy squeezing units (Fig. 5). Standing liquors are never used. The running cloth is beaten only to swell the size with water or diluted size solution and after a short dwell time, the swollen size solids are squeezed out. The plant is constructed in three stages so that the fresh water added at the third stage acts as a counter current, concentrates at each stage and is then recovered from the first squeezing unit in the form of a high-concentration sizing liquor. The first stage functions as a swelling zone. The reduced level makes it possible to operate with a small amount of standing liquor and shortens the warm-up time for concentrating the bath. The simple textile feed increases access to the rollers for the required cleaning operations. Subdividing the liquor in the first swelling zone is not necessary, as a washing process is not expected during the swelling phase. After the first stage, the squeezing unit removes about 40% of the swollen size. In the second stage, washing takes place according to the counter-current principle and then the swollen size is squeezed again.

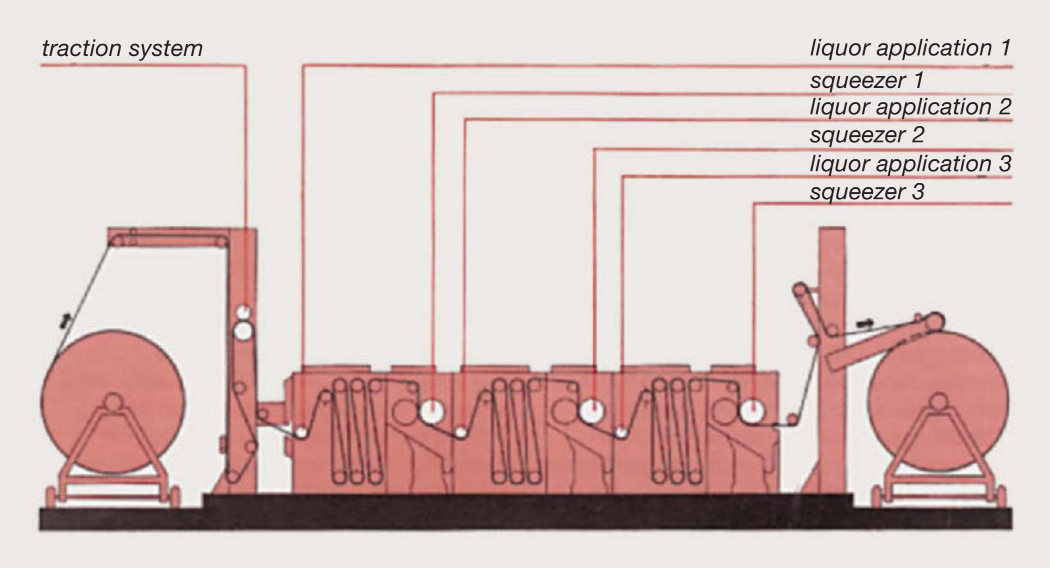


Fig. 5: The path of goods through the Recupa facility for the recovery of size, System BASF.

b) When recycling using ultrafiltration, a recyclable concentrate is produced from the de-sizing liquor by the selective removal of water at the ultrafiltration membranes (Fig. 6). This concentrate contains all of the sizing substances released from the fabric. Thus, in this case, the term "full recycling" can be used.

Ultrafiltration is a method of separating the solvent (water) and dissolved substances (size). The separation take place on a semi-porous membrane, the pores of which are so small that they retain the macromolecules of the size, while allowing the smaller water molecules to pass through. In order to separate the two types of molecule, the de-sizing liquor must stream through the membrane under pressure. Fig. 6 shows a schematic example of this process in a tubular membrane. The "concentrate" remains inside the tube while the "permeate" passes through the walls to the outside.

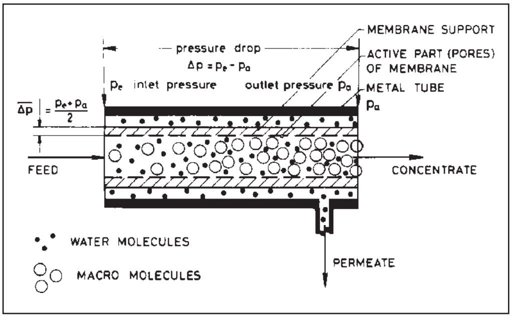


Fig. 6: The principle of ultrafiltration for the recycling of process water. Feed = an approx. 5% solution; concentrate = an approx. 15% solution.

Full recycling of the size makes sense for the following reasons:

1. The ultrafiltration membrane technology is proven and has been successfully used in different industrial sectors for many years, both in the production and in the recycling of valuable materials.
2. From an ecological point of view, this technology is preferred above all others because the effluent (and ultimately the surface waters) are completely freed from size loadings, unlike partial recycling where approximately 50% of the size on the fabric continues to find its way into the effluent. With full recycling, the two circuits, concentrate and permeate, are closed; 100% of the concentrate is returned to the sizing plant and 100% of the permeate is returned to the washing machine.
3. Under certain pre-conditions, the ultrafiltration plant makes it possible to save a considerable amount of the costs relating to the sizing agent. It is significantly more economic than washing out and, of course, cheaper than the conventional method where sizing agent, water and thermal energy are consumed during disposal.

In the USA, water-soluble size is recycled by evaporating the de-sizing liquors until the sizing concentration has been achieved.

However, recovery and recycling size is only possible in the case of sizing agents which can be dissolved from the fabric without any loss in viscosity and which do not alter their viscosity during repeated boiling and stirring during reprocessing. A prerequisite for the swelling and complete dissolution of the sizing agent is a sufficiently long dwell time for the goods in the washer unit. The recycled product recovered from the de-sizing plant must be more or less concentrated depending on the amount of sizing liquor the sizing plant is able to process. At the same time, a high concentration of recycled product means a low rate of recovery. The maximum possible concentration of size [g/l] in the wash liquor is given by:

$$C_0 = \frac{x}{FV}$$

Here, x represents the size loading on the goods in g/kg and FV the liquor ratio, i.e. litres of wash water per kg goods. Another formula shows the increase in concentration of recycled material [g/l] in relation to the wash-water addition I [l/min], amount of liquor in the washing machine V [l] and time [min.].

$$C_t = C_0 \cdot \left(1 - e^{-\frac{l \cdot t}{V}}\right)$$

From this it can be seen that, for example, a large volume of material in the washing machine greatly increases the time required to reach 95% of the maximum concentration C_0. An increased amount of added water shortens the time but reduces C_0 and C_t. A few examples with figures can be used to illustrate this point.

Assume that goods at 240 g/running meter are to be de-sized at the rate of 100 m/min. The goods would have a loading of 7%. The goods throughput per minute = 0.24 x 100 = 24 kg/min. The liquor ratio FV = 1.5, i.e. the amount of water added I = 24 x 1.5 = 36 l/min. The liquor ratio in the wash compartment is 10 00 l.

$$\mathbf{C_0} = \frac{\mathbf{70}}{\mathbf{1.5}} = 46.7 \text{ g/l max. possible concentration.}$$

Steady state in the plant has been reached when 95% of the maximum possible concentration has been achieved.

$$t = -\frac{V}{l} \cdot \ln\left(1 - \frac{C_t}{C_0}\right) = 83.2 \text{ min.}$$

During this time, 8320 m goods have passed through the system.

Recycling tumbler Special tumbler with solution recovery device (condensation principle) for drying in the so-called → Cold unit of dry-cleaning cabinets. The time required for drying, ventilation and recovery is between approx. 12–20 minutes for a 90–98% solvent recovery.

Redeposition Redeposition of material, for example, already dissolved particles of dirt on textile goods (→ Soil suspended property).

Redevelopment of former industrial sites When textile finishing plants move site, the old site may be encumbered with problems arising from finishing-products residues left behind in open waters or soils.

The clearing up of old deposits which are actually classified as inherited burdens, according to risk assessment, represent a great challenge to municipalities as well as trade and industry, both locally and nationally. These sites have to be cleaned up so that they no longer pose any risk to the environment. This discipline, which has only recently been introduced, must pursue numerous starting points together. Apart from the structural development, among others, thermal, extraction, biological and hydraulic methods of treatment must be considered as well. These methods of soil renovation are applied according to the conditions found (Fig.):

- on site after excavating the contaminated soil,
- after dispatch at the central treatment plants as well as
- on site in its original position without excavation.

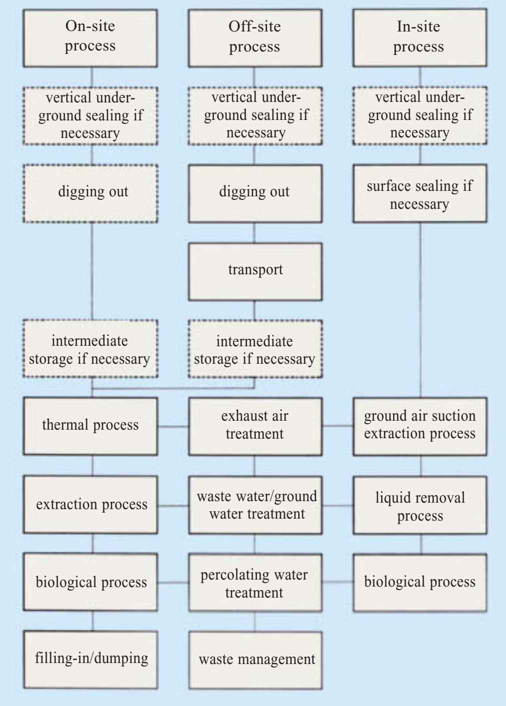


Fig.: Redevelopment of former industrial site process.

Red-green test Another term for the → Goldthwaite test.

Red mordant (red liquor) → Aluminium acetate.

Red oils → Turkey red oils.

Redox meter An electrical instrument with a direct readout which is used for → Redox potential measurement.

Redox potential (expressed as r_H). “Redox” is an abbreviation of the term reduction-oxidation. The redox potential scale is used for classifying reduction and oxidation processes in solution, the electrical voltage (potential) in question being measured in volts or millivolts against a reference electrode (→ Standard electrode potential). A scale is produced which is based upon the r_H according to the energy and rate of reduction as well as the, often very strong, dependence on the pH of the solution. Because the number of electrons which can be donated by a reducing agent is decisive for the reaction strength of a solution, the r_H expresses the activity of the electrons taking part in the reduction as a negative logarithm. Thus, at 1 bar pressure, the activity of the reducing electron for hydrogen has been set at 1, which corresponds to log 10^{-0}, so $r_H = 0$ for the hydrogen electrode. For oxygen, the activity is about 10^{-42} (oxygen electrode). The potentials of most other reducing and oxidizing agents lie between these two values. In general, stronger reducing agents (lower r_H values) will reduce weaker ones (higher r_H values), or to put it another way, a substance with a higher redox potential will appear as an oxidising agent to a substance with a lower r_H. No pronounced oxidizing or reduction properties can be expected within the redox potential range $r_H = 17–25$ (the so-called neutral range). Consequently, a particular redox system may be reducing or oxidizing depending on the reaction conditions. In most cases, it can be assumed that solutions with $r_H = 17$ more or less reduce whereas those with $r_H = 25$ clearly oxidize (see Tab.).

Redox potential measurement The → Redox potential is monitored as follows:

I. Using colorimetric-type redox indicators where the change in colour is characteristic for the reaction. The reduction state of vat dyes is monitored according to this principle using indanthren yellow paper (does not respond in the range below $r_H = 4$ which is important for many vat dyes). Dissolved redox indicators are not stable, i.e. they are sensitive to light and oxygen.

II. The potentiometric measurement of r_H is best carried out using a measurement instrument which has a glass electrode. In this case, the reduction potential (E) is the value in millivolts in relation to the hydrogen electrode potential which equals zero. r_H measurement instruments are relatively sensitive devices which are either portable or permanent and are available with or without a recorder and controller. Application of r_H measurement: apart from redox titrations, there are numerous applications in dyeing which involves reduction processes (such as vat, sulphur and vat leuco ester dyes) and oxidation processes (such as diazotization, aniline black dyes and colour-lake formation), in dye stripping and printing (such as vat dyes and reductive discharges), for maintaining favourable conditions during reduction and oxidation bleaching, and recording reductive capacities during boiling and kier boiling (oxycellulose r_H 14–20), etc. Continuous monitoring of the state of reduction in vat dyeing has proved itself in particular. This is mainly of interest in continuous processes.

Redox reactions Important redox reactions in textile finishing, such as the reaction of sodium dithionite with oxidizing agents, are often written using a single arrow in the equation pointing from left to right (Fig.).

Effectively however, redox reactions only exist as a redox equilibrium. Even when the starting product and

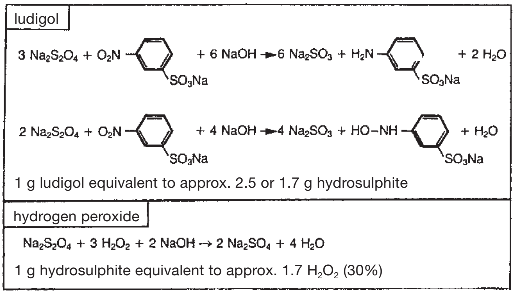


Fig.: The reaction of sodium dithionite (hydrosulphite) with an oxidizing agent (by BASF).

reduction zone		neutral zone	oxidation zone	
← 0–8.5 → strong	← 8.5–17 → weak	← 17–25 → indifferent	← 25–34 → weak	← 35–42 → strong
sodium dithionite	sodium hydrogen sulphite sodium thiosulphate	water hydrochloric acid sodium hydroxide	iodine solution	potassium dichromate potassium permanganate bleach liquor, ozone

Tab.: The redox potential r_H of various chemicals.

the end product are known from the frequently problematic determination of the stoichiometric coefficients, a redox reaction cannot readily be clearly described. A redox reaction is made up of two so-called half-reactions. One half-reaction is the oxidation reaction where the substance (reductant) looses electrons. The other reaction is the reduction reaction where the substance (oxidant) accepts electrons. Both reactions must be coupled together to form the complete redox reaction as electrons cannot exist in solution in isolation. This procedure is explained using the oxidation of Fe^{2+} ions with permanganate as an example. The individual steps in the reaction are as follows:

1. Equations for the reactants and products:

$$\begin{array}{lcll} \mathrm{Fe^{2+}} & \rightleftharpoons & \mathrm{Fe^{3+}} & \text{(oxidation half-reaction)} \\ \mathrm{MnO_4^-} & \rightleftharpoons & \mathrm{MnO_2} & \text{(reduction half-reaction)} \end{array}$$

2. Balancing the number of oxygen atoms taking into account the water:

$$\begin{array}{rcl} \mathrm{Fe^{2+}} & \rightleftharpoons & \mathrm{Fe^{3+}} \\ \mathrm{MnO_4^-} & \rightleftharpoons & \mathrm{MnO_2 + 2\,H_2O} \end{array}$$

3. Balancing the hydrogen atoms with H^+:

$$\begin{array}{rcl} \mathrm{Fe^{2+}} & \rightleftharpoons & \mathrm{Fe^{3+}} \\ \mathrm{4\,H^+ + MnO_4^-} & \rightleftharpoons & \mathrm{MnO_2 + 2\,H_2O} \end{array}$$

4. Charge balance with free electrons:

$$\begin{array}{rcl} \mathrm{Fe^{2+}} & \rightleftharpoons & \mathrm{Fe^{3+} + e^-} \\ \mathrm{3\,e^- + 4\,H^+ + MnO_4^-} & \rightleftharpoons & \mathrm{MnO_2 + 2\,H_2O} \end{array}$$

5. The first half of the reaction is multiplied by the coefficient 3 and then the two half-reactions are added together:

$$\begin{array}{rcl} \mathrm{3\;(Fe^{2+}} & \rightleftharpoons & \mathrm{Fe^{3+} + e^-)} \\ \mathrm{3\,e^- + 4\,H^+ + MnO_4^-} & \rightleftharpoons & \mathrm{MnO_2 + 2\,H_2O} \\ \hline \mathrm{4\,H^+ + 3\,Fe^{2+} + MnO_4^-} & \rightleftharpoons & \mathrm{3\,Fe^{3+} + MnO_2 + 2\,H_2O} \end{array}$$

6. However, this reaction takes place in alkaline solution and so another equation for the dissociation of water is also taken into account:

$$\begin{array}{rcl} \mathrm{4\,H^+ + 3\,Fe^{2+} + MnO_4^-} & \rightleftharpoons & \mathrm{3\,Fe^{3+} + MnO_2 + 2\,H_2O} \\ \mathrm{4\,H_2O} & \rightleftharpoons & \mathrm{4\,H^+ + 4\,OH^-} \\ \hline \mathrm{2\,H_2O + 3\,Fe^{2+} + MnO_4^-} & \rightleftharpoons & \mathrm{3\,Fe^{3+} + MnO_2 + 4\,OH^-} \end{array}$$

7. Finally, in alkaline conditions, $Fe(OH)_3$ precipitates out. The final step is therefore:

$$\begin{array}{rcl} \mathrm{2\,H_2O + 3\,Fe^{2+} + MnO_4^-} & \rightleftharpoons & \mathrm{3\,Fe^{3+} + MnO_2 + 4\,OH^-} \\ \mathrm{(Fe^{3+} + 3\,OH^-} & \rightleftharpoons & \mathrm{Fe(OH)_3)} \\ \hline \mathrm{2\,H_2O + 3\,Fe^{2+} + MnO_4^- + 5\,OH^-} & \rightleftharpoons & \mathrm{Fe(OH)_3 + MnO_2} \end{array}$$

In this case, Fe^{2+} is oxidized (it losses electrons) while the permanganate ion is reduced (it receives electrons). The Fe^{2+} ion is the reductant and the MnO_4^- ion the oxidant.

Redox reactions with inorganic starting products are generally clear and relatively easy to formulate. If the oxidant and reductant are either inorganic or organic, which is frequently the case in aqueous chemistry, or organic and inorganic, then the relationships may be complex. The oxidation of Fe^{2+} with dichromate, which is often cited, should be examined as an example of redox equilibrium. In detail, it is as follows:

$$\begin{array}{rcl} \mathrm{6\,e^- + 14\,H^+ + Cr_2O_7^{2-}} & \rightleftharpoons & \mathrm{2\,Cr^{3+} + 7\,H_2O} \\ \mathrm{6\,(Fe^{2+}} & \rightleftharpoons & \mathrm{Fe^{3+} + e^-)} \\ \hline \mathrm{14\,H^+ + Cr_2O_7^{2-} + 6\,Fe^{2+}} & \rightleftharpoons & \mathrm{2\,Cr^{3+} + 6\,Fe^{3+} + 7\,H_2O} \end{array}$$

Hexavalent chromium (VI) in the dichromate ion is reduced to trivalent chromium (III); while, the divalent iron (II) ion is oxidized to the trivalent iron (III) ion. During this change, the orange colour of the dichromate ion turns into the green colour of the trivalent chromium ion. The equilibrium constant for the reaction, $K = 10^{57.2}$ is large, i.e. the equilibrium lies completely on the right-hand side of the equation. The thermodynamic expression

$$G^0 = -RT \ln K$$

shows that the standard free energy of this reaction is strongly negative and the direction of the reaction is clearly established as being towards the right (according to Peschel and Belouschek).

Redox systems as polymerization initiators Numerous radicals produced during redox reactions trigger polymerization reactions. Organic and inorganic per-compounds are mainly considered for use as oxidizing agents and low-valency-state multivalent metal ions or non-metal compounds which are easily oxidized (such as a few of the sulphur compounds) are used as reducing agents. Apart from these, redox systems also exist which consist of a per-compound, metal ions (such as Fe^{2+}) and another reducing agent (such as hydrogen sulphite). The hydrogen sulphite reduces the Fe(III) ion, which has been produced during the redox reaction between the per-compound and the Fe(II) compound, back to its divalent state. Thus, in most cases, only small amounts of iron ions are required for the reaction.

The radicals which trigger the polymerization are produced, for example in a redox system, from per-compounds and an iron(II) salt by the transfer of electrons from the divalent iron to the per-compound, the peroxide bond being split while the radical is formed:

$$\mathrm{R{-}O{-}O{-}R} + \mathrm{Fe^{2+}} \longrightarrow \mathrm{R{-}O^{-}} + \mathrm{Fe^{3+}} + \mathrm{R{-}O^{\bullet}}$$
$$\mathrm{R{-}O^{\bullet}} + \mathrm{CH_2{=}CH{-}X} \longrightarrow \mathrm{R{-}O{-}CH_2{-}CH^{\bullet}{-}X}$$

Suitable oxidizing agents for triggering a radical polymerization would be, for example, hydrogen peroxide, peroxide sulphates and diacyl peroxides, and suitable reducing agents would be Ag^+, Fe^{2+}, Ti^{3+}, hydrogen sulphite, sulphite, thiosulphate, mercaptans, sulphinic acids, amines (such as N,N-dimethylanilin), endiols (sugars), benzoin/Fe^{2+} or hydrogen sulphite/Fe^{2+}.

Red prussiate of potash → Potassium hexacyanoferrate (III).

Reducing agents Either have the effect of adding hydrogen or removing oxygen. In practical terms they are important, for example, a) in → Reductive bleach-

reducing agent	advantages	disadvantages
sodium dithionite $Na_2S_2O_4$ »Hydro«	– adequate reduction potential for vat, sulphur and indigo dyes – good liquor stability of the attached liquor	– waste water contamination (hinders the biological breakdown of the waste water and leads to a strong oxygen depletion) – expensive – over-reduction at higher dyeing temperatures as well as alteration in hue – expensive storage (safety)
sulphinic acid derivatives	– adequate reduction potential – particularly suitable for high temperature dyeing – good stability in air	– potential strongly dependent on temperature
hydroxyacetone CH_3COCH_2OH	– biodegradable – easily metered (liquid) – relatively stable	– does not achieve its full reduction potential (particularly suitable for indigo and sulphur dyes) – intrusive odour – expensive manufacture (price)
sodium sulphide sodium hydrogen sulphide Na_2S, NaHS	– favourably priced	– intrusive odour due to hydrogen sulphide – toxic – poor reduction potential (particularly suitable for sulphur dyes) – large quantitites required
glucose	– no environmental effect – favourably priced – non-toxic	– poor reduction potential (particularly suitable for sulphur dyes) – only at dyeing temperatures of approx. 90°C

Tab.: Overview of the most commonly used reducing agents.

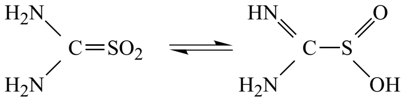
ing (sodium sulphite, pyrosulphite, sodium dithionite, sulphur, sulphurous acid and oxalic acid); b) in fast dyeing for converting vat and sulphur dyes into water-soluble leuco forms suitable for dyeing (dithionites, sulphoxylates, sodium sulphide); c) in dye stripping. The water-soluble analogues (leuco compounds) are formed from the corresponding dyes which are more or less water soluble; d) in printing, either added to the printing pastes in the form of stabilized sodium dithionite preparations of sulphoxylates (→ Reductive discharges) or for post-development of prints with non-reduced vat dyes using dithionites.

The most important reducing agents in regard to their applicability are shown in the Table. Different problems with products currently in use must also be taken into account. The agent used must not only reduce the dye in question but also remove oxygen from the air already present in the dyebath as well as that dissolving in the dyebath during the dyeing process. The reduction potential, between – 500 mV and – 1000 mV depending on the dye, required by silver/silver chloride must be maintained during the whole period of treatment. This means that altogether, a relatively high excess of reducing agent is needed.

In order to convert the reduced dye back into its insoluble oxidized form, the dyebath is to a great extent removed or drained. After removing the liquor, the dye is oxidized by flushing through with fresh water containing oxygen or by using liquors containing oxidizing agents. Because the liquor which has to be replaced contains excess reducing agent, effluent originating from vat and sulphur dyeing has a very high level of oxygen consumption.

Commonly used reducing agents are as follows:

1. Sodium dithionite, which is used as a standard agent for the colour yield and quality of dyeing, especially micro evenness, in vat dyeing.
2. Hydroxymethanesulphinic acid has proved itself as a reducing agent in printing. It is a sodium dithionite derivative with significantly reduced redox potential. The advantage of this compound over 1. is that its use results in only half the sulphur loading in the effluent.
3. Glucose has been known for a long time as a reducing agent. However, its low reactivity requires high addition rates, high alkali concentrations and prolonged steaming times. The COD loading in the effluent is relatively high.
4. Acetol is a reducing agent which has now gained favour in certain areas. It has the advantage of being free from sulphur but the disadvantage of having a strong unpleasant smell.
5. Formamidinesulphinic acid or aminoiminomethanesulphinic acid has been known in textile finishing since the early fifties. However, it has not been able to overtake 1. on account of its high price. One advantage is that it has half the sulphur loading of 1. The tautometry of formamidinesulphinic acid is important for the single-bath process:



In the product and in neutral solution, formamidinesulphinic acid exists alone and this does not have a reducing effect. Sulphinic acid only forms under alkali conditions.

Reducing valves (pressure reducers), are used, for example, for safely extracting compressed gases from high-pressure steel gas bottles (up to 150 bar) by reducing the operating pressure to the order of 0.5 bar (cylinder heads).

Operation (Figs. 1–3): when the adjustment spring (1) is eased off, the return springs (4 and 11) hold the main valve (2) and the control valve (3) closed.

Steam reaches the control valve chamber via the hole (A) and the dirt filter (5) (Fig. 1). When the low pressure is adjusted using the adjustment screw (6), then the adjustment spring (1) is compressed and the membrane (7) bulges downwards, presses on the control ram (8) and the control valve (3) opens. Steam flows into the chamber (Fig. 2) above the piston (9) and forces it downwards. The piston ram opens the main valve so that steam can flow to the low-pressure side. Before reaching the main valve, the steam flows

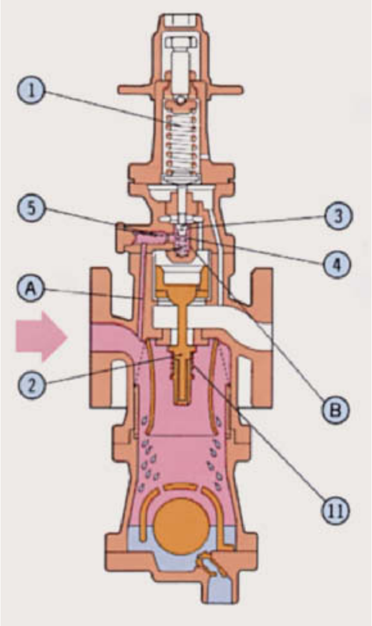


Fig. 1: The working mechanism of a reducing valve when at rest.

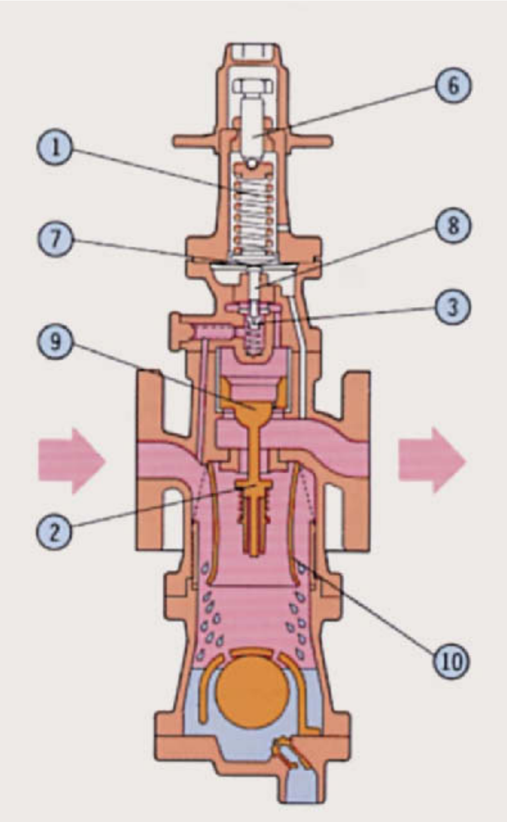


Fig. 2: A reducing valve under the influx of steam.

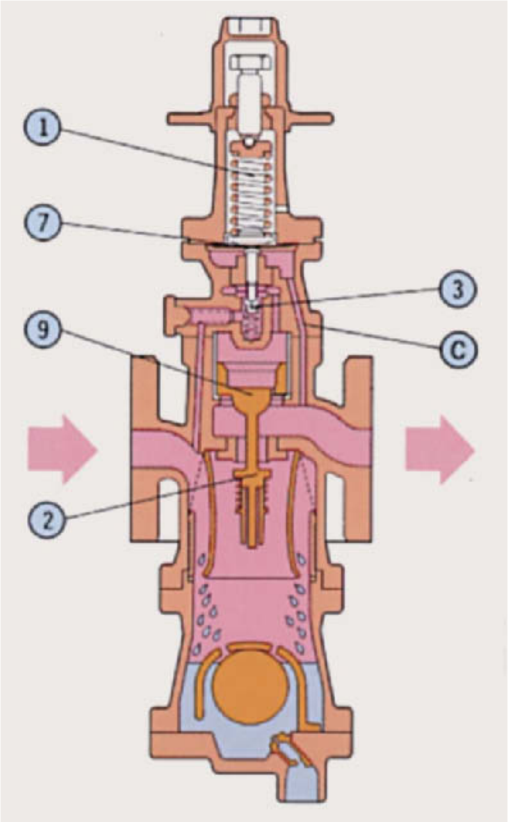


Fig. 3: The means by which reduced pressure is created in a reducing valve.

through the drier (10). The drier control device causes the stream to rotate, the condensate is discharged and immediately fed away from the condensate drain. On the low-pressure side (Fig. 3), the steam flows through the hole (C) and under the membrane (7) to which it transfers the low pressure. The position of the control valve (3) is determined by the balance between pressure acting on the membrane from underneath and the counter-pressure exerted by the spring. The position of the control valve (3) determines the pressure above the piston (9) and the position of the main valve (2), so dry saturated steam is produced at a constant low pressure.

Reduction The bonding of hydrogen or receiving electronegative charge or release of oxygen or electropositive charge in chemical compounds. Typical example: lead oxide + hydrogen = lead + water ($PbO + H_2 \rightarrow Pb + H_2O$). Opposite → Oxidation.

Reduction potential The main reducing agent used for reduction processes is sodium dithionite ($Na_2S_2O_4$), which has a reduction potential of –1000 mV (against the Ag/AgCl/3M KCl- reference electrode) in alkali media. Sulphinic acid derivatives are used for reductions at higher temperatures (such as steam processes or HT processes) (reduction potential at 50°C approx. –1000 mV). At temperatures below 80°C, the reaction rate of sulphinic acid derivatives is relatively small but compounds such as these can be activated by adding heavy-metal compounds (such as nickel cyano complexes and cobalt complexes, etc.). Other reducing agents are thiourea (–1100 mV), acetol (–810 mV) and sodium borohydride (–1100mV).

As the reduction potential of indigo dye (approx. –600 mV) lies within the required range between vat dyes (approx. –950 mV) and sulphur dyes (approx. –500 mV to –600 mV), among other organic substances with low reduction potentials, acetol/sodium hydroxide can be used as a reducing agent as well as sodium dithionite. Sodium sulphide (Na_2S) and sodium hydrogen sulphide (NaHS) (approx. –500 mV) can be used with sulphur dyes. Glucose/sodium hydroxide mixtures, among other organic reducing agents, can be used because of the low reduction strength required.

Reductions in printing Paler colour tones obtained by cutting back a full tone (→ Reduction thickener).

Reduction thickener (blend), addition of a thickener with reduced chemical activity for a printing paste (stock colour or full colour) to obtain lighter printing inks, for example, 1 : 9 = 1 part printing paste + 9 parts thickener (1/9).

Reductive bleaching Bleaching with → Reducing agents, predominantly for animal fibres. With other fibres, possibly used in a second bleach bath in combination with oxidising bleaches (→ Bleaching).

Reductive bleaching agents → Bleaching chemicals and products.

Reductive bleaching of wool The aim of bleaching wool is to destroy the yellow chromophor by oxidation or reduction. This is carried out as a separate process or jointly with other wool processing steps (for example, during dyeing or washing). Bleaching improves the brilliance of the colours, particularly in the case of pastel shades. Often, bleaching counteracts yellowing of the wool which develops during processing. Bleaching agents differ depending on whether they are oxidative or reductive. So-called full bleaching is a combination of the two processes.

In addition to sulphite, sodium dithionite, sodium hydroxymethanesulphinate and formamidinosulphinic acid are usually used for reductive bleaching.

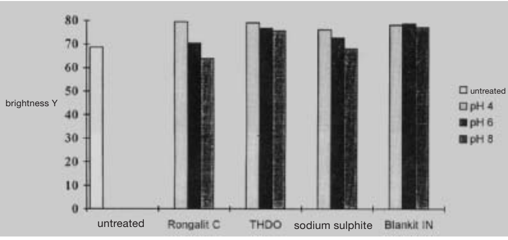


Fig. 1: The standard colour value Y of bleached wool in relation to the reducing agent and the pH of the bleaching liquor (according to Höcker et al.).
Blankit IN (BASF) = stabilized Rougalit C (BASF) = sodium dithionite; sodium hydroxymethane sulphinate.

The effects of bleaching a woollen fabric with different reducing agents at different pH are compared in Fig. 1.

Stabilized sodium dithionite and formamidinosulphinic acid also give good results in a weakly alkaline pH range. Sodium sulphite and sodium hydroxymethanesulphinate are not suitable for bleaching in weakly alkaline liquors. Indeed, fabric “bleached” using these reducing agents is darkened.

The effects which impair the quality on wool fibres can be established both by chemical methods, such as cystine determination or solubility in alkalis, and mechanical measurements.

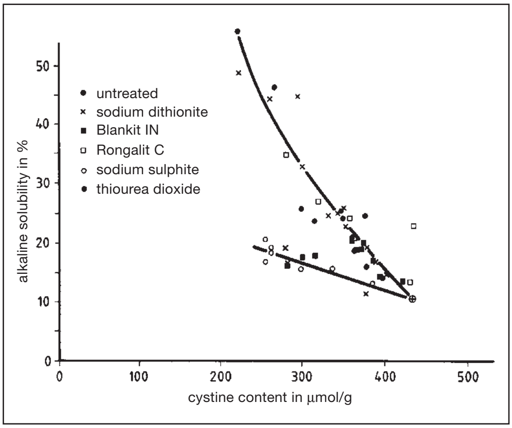


Fig. 2: The relationship between alkaline solubility and the cystine content of reductively bleached wool (according to Höcker et al.).

In the case of reductive treated wool (Fig. 2), there is a linear relationship between the cystine content and alkali solubility. The curve steepens at higher degrees of reduction. For all bleached samples containing Bunte salt, the solubility in alkali is less for the same cystine content. Bunte salt is produced in addition to thiol as a result of the reductive cleavage of wool cystine with sulphite:

$$\text{R–S–S–R} + \text{HSO}_3^{2-} \rightleftharpoons \text{R–S–SO}_3^{-} + \text{R–SH}$$

(according to Kwasny, Deutz and Höcker).

Reductive discharges Discharges (→ Discharge printing) based on a reduction effect where the dyes in question, a) are split up into colourless soluble compounds, i.e. fully destroyed and have to be removed by subsequent washing (for example, direct, acid and mordant dyes or naphthols) or, b) because of their solubility, particularly in alkaline solution, are more or less removed before the fibre is re-oxidised, i.e. are not destroyed (for example, indigoids and anthraquinoid dyes, such as indigo and vat dyes as well as cationic dyes as derivatives of triphenylmethane).

Redyeing Dye packages may have to be dyed a second time because of faults or stock packages may have to be redyed as they cannot be sold due to their particular shade. In both cases, → Stripping of dyeings is usually necessary first.

Reel →: Yarn package; Winch.

Reeled silk Silk winched from the cocoons of the silk worm as → Grège derived from almost continuous elemental fibres.

REF Fibres (REF = Roll Embossed Fibre), made from → Tape yarns by embossing the yarns with longitudinally-grooved profile rollers followed by width stretching, where the areas on the fabric that have been thinned by the embossing process tear open, forming multi-filaments (elemental filaments with a high degree of uniformity and high strength).

REFA Darmstadt. Function and objective: to continue the work of the German "Reichsausschuss für Arbeitsstudien [National Committee for Work Studies]" founded in 1924. The abbreviation of this committee has been adopted by the current institution carrying out this work. Conditions and methods of efficient structuring and payment compensation for human labour based on efficiency is researched, developed and disseminated among all branches of the business sector and management on a new and extended basis. Other functions include the publication of reference books and journals for work studies (REFA Nachrichten [REFA News] and Fortschrittliche Betriebsführung [Advanced Factory Management]) and the organization of courses, meetings, presentation and consultation evenings. The association functions on a non-profit making basis. → Technical and professional organizations.

Reference number That is to say, "industrial data collated using a reference number". Absolute reference numbers within a company are independent parameters such as the number of hours of production or turnover of a financial period. Relative reference numbers give information about the relationship between certain data such as turnover per hour of production or real net output per employee. The source data are either the company's internal sources (tax accounts, purely commercial accounting, fully extended accounting) or figures external to the company (such as available statistics, reference comparisons and external analyses). Basically, it makes sense to decide on the reference number within the company which helps the company's own management to improve quality and lower production costs. Reference numbers are only useful if they are critically discussed, if they are seen in the larger context (graphical presentations ease the interpretation of the relationships) and if they are used as target parameters in planning. Reference numbers which relate to the process are useful for quality and production control and require suitable measurement equipment.

Reference sample An order sample for the → Colour matching of dyed/printed samples.

Reference temperature A fixed point on a scale of temperatures, for example, the melting point of ice ± 0°C and the boiling point of water + 100°C at ntp (→ Temperature).

Reflectance → Reflection of rays in the form of reflected coloured light. The reflectance properties express how incident light has been modified by the refection, i.e. (except in the case of fluorescent dyes) depending on the type of body, the incident light is weakened by different amounts in different parts of the spectrum. The degree of reflectance is the reflection parameter, as the quotient of intensities of the reflected ray and incident ray or, as the sensation of brightness (→ Colour measurement) the ratio of the → Lightness or radiant intensity per unit area of a coloured surface (body colour) to a surface seen as matt white under identical conditions of illumination. All results from reflectance measurements are quoted in relation to → Standard white = 100%. An exemplary presentation of reflected colour tone is obtained by plotting the reflection value (degree of reflectance) against the wavelength. This procedure produces the so-called dye curves (transmission or reflectance curves) which are fundamentally characteristic for any particular dye.

A pair of colours are only identical to all observers under all conditions of illumination if their reflectance curves are in agreement. This is only possible by using identical dyes at the same concentration on the same substrate. Dye curves for dyehouses are important for dye tests. The addition of curves yields additive mixtures and curve multiplication leads to subtractive mixtures.

Reflectance curve The point associations (from a spectral photometer or automatic recording) of the per-

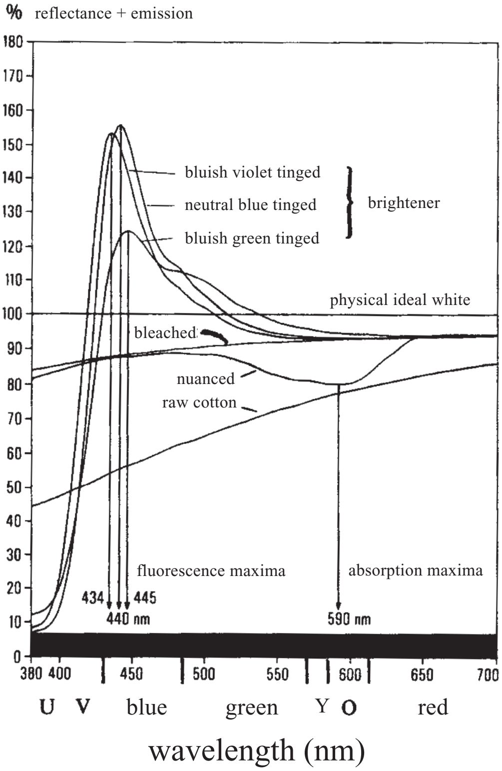


Fig.: The reflectance curves of variously pretreated cotton fabrics.
U = ultraviolet; V = violet; Y = yellow; O = orange

centage → Reflectance plotted against the wavelength in a coordinate system produces the reflectance curve. In the visible range (400–700 nm), these characterise the ratio of reflected light to incident light, thereby yielding calorimetric information on the physical parameters of each dye or dyeing. In the case of fluorescing dyes, the emitted light adds to the reflected light, i.e. light energy is absorbed by optical brighteners in the UV range in order to be emitted in the visible range as bluish violet light. The colour tone of brighteners can be roughly assessed by the position of the fluorescence maximum, as shown by the characteristic reflectance curves for different brighteners in Fig.

The rather dull brightner is noticeable with its flat longwave decent on the fluorescent curve.

Reflection Component of incident light meeting a surface which is neither subject to → Absorption nor → Transmission (→ Reflectance). In the case of reflection, the incident energy is only briefly absorbed by the individual atoms in order to be reflected again as potential energy. The angle between the reflected ray and the surface is the same as that of the incident ray. On bent surfaces, reflection takes place at a tangent to where the incident ray meets the surface. The visibility of illuminated non-self-illuminating bodies and their colours relies on selective absorption and reflection in the visible spectrum. Diffuse reflection is the splitting up of parallel incident ray bundles into different directions and this determines the colour of the object. In fact, most surfaces are not ideally smooth, so in practical terms reflection is almost always diffuse. Contrary to this, mirrored reflection gives the sense of glaze which, for example, implies that a matt pattern of the same colour as a shiny pattern is always experienced as being darker and vice versa. As well as reflection in the visible spectral range of wavelengths there is also reflection in the non-visible ultraviolet and infrared ranges.

Reform weave A weave which results in warp-reinforced fabric with main warp.

Refraction → Refraction of light.

Refraction of light (refraction), guiding or changing the direction of light as it passes through the boundary between different media such as light/water. While doing so, the long wavelength light (red) is not so strongly refracted as the short-wave light (violet/blue). The standard scale used for measuring refraction is called the refractive index (refractive exponent): quotient of the sine of the angle of incidence and the sine of the angle of refraction:

$$\frac{\sin \alpha}{\sin \beta} = \text{const.} = n$$

In most cases, refractometric determinations are carried out using light of a single wavelength or monochromatic light. The yellow D line of sodium is predominantly used, from which is derived the symbol nD for the refractive index. The refractive index of air (in comparison to vacuum) is practically equal to nD 1; as, for example, the refractive index of solutions varies with concentration, this parameter can be used to determine the concentration. The refractive index is also utilised in fibre microscopy in the so-called immersion system where immersion fluids are used with a refractive index matched to that of the test fibre.

Refractive index (refraction exponent) → Refraction of light.

Refractometer Instrument for measuring the → Refraction of light.

Refractory (Lat: refractarius = contrary), insensitive, unimpressionable: refers, for example, to non-biodegradable refractory carbon compounds in effluent.

Refractory metals High purity, heat-resistant metals (alloys) which in super fine capillary form have a high surface-area-to-volume ratio (e.g. niobium capillary filaments of the smallest diameter, until now 0.6 μm). Used for metal filaments.

Refractory residues These are (persistent) residues which remain in water after biological treatment by water treatment plants or natural processes. They are not decomposed by bacterial enzyme systems and, under certain circumstances, may concentrate in certain places. As they concentrate over time, they may become locally toxic if they exceed the toxic threshold value. Below this threshold value, they appear to be harmless. The Zahn Wellens Test (up to 400 mg/l DOC) is the test which is most suitable for assessing the biodegradability of highly concentrated → Segregated streams with the aim of determining the relationship between the input in segregated streams and their residual refractory loading. The German Chemicals Act does not recognise biodegradablility as a risk factor although it must be regarded as the main test criterion for substances. The German Water Resources Law (WHG, Wasserhaushaltsgesetz) mentions "dangerous substances according to § 7a WHG". In general, substances under this description are, or can be understood to be "poisonous, long-lived, carcinogenic, embryotoxic or genome modifying". The most comprehensive interpretation of § 7a WHG would be that only one of the effects mentioned would have to apply for it to be regarded as "dangerous according to § 7a WHG", in which case, the inability of a substance to biodegrade would suffice. The basis of the draft statute for the fifth amendment of the WHG also allows this view. However, the current national and local interpretation is that one of the "biologically harmful effects" mentioned must be included in the property "refractory". In any case, according to the § 7a WHG, the substances of so-called List I and II of EC Directive 76/464/EEC are counted as dangerous. The lists contain heavy metals, organochlorine compounds, pesticides and aromatic compounds. However, there is a “transition area” which ranges from the substances in Lists I and II to harmless substances. According to the WHG draft statute mentioned above, harmless substances are “substances which are biologically harmless or can rapidly be converted into substances which are biologically harmless”. According to this statement, refractory substances which have a biologically harmful effect are counted as dangerous substances. However, the last mentioned has so far not been precisely defined (according to Schönberger).

Refrigerants Volatile liquids (flourochlorohydrocarbons) or vapours which, because of their thermal properties, are suitable for use in refrigeration plants.

Regain → Moisture regain.

Regenerated cellulose “Recovered cellulose” which, unlike native cellulose (cotton) has a lower degree of polymerisation (and correspondingly different characteristic properties). Identical to → Cellulosic fibres, regenerated (viscose, acetate and cupro fibres).

Regenerated fibres → Cellulosic fibres, regenerated; → Man-made protein fibres.

Regenerated protein fibres → Man-made protein fibres.

Regenerated protein fibres distinguishing reactions → Man-made protein fibres, distinguishing tests.

Regenerator Heat exchanger with reverse flow, one way being heated by the exothermic cloth flow, and the other being cooled by the heat-absorbing cloth flow.

Registered design Creations based on three-dimensional shapes or colours, which are intended to create a positive aesthetic influence. Patent law or registered design law can be applicable simultaneously if, apart from the construction which is protected by the patent, the object is designed in such a way that its external appearance creates an aesthetic impression, and it fulfils the requirements of registered design law.

Registered trade mark → Trademark.

Register in printing,

I. Re-drawing of a pattern drawing to the correct repeat size (→ Repeat for printing, design drawing).

II. Correct alignment of pattern to fabric in screen printing or roller printing. The printing machinery is adjusted to take into account lengthways, crosswise and diagonal repeat.

Register in screen printing,

I. Matching (congruency) or likeness of the print pattern between the original pattern (slide) and the pattern printed on the fabric, also between the print at the beginning and end of a piece.

II. Position consistency of the print pattern = unchanging position of print pattern. The screen is the main factor that determines congruency, although not the only one; position consistency is also strongly influenced by the accuracy of the printing machinery. Size differences in film material are caused by temperature and humidity. If there is an increase in temperature or humidity the slide increases in size, which is mainly caused by expansion of the photo-emulsion, slowed down by greater stability of the polyester carrier; blank polyester film is used as a base mounting and exhibits almost completely stable behaviour.

Register marks In roller printing, the pattern being reproduced is broken up into a large number of dots using a reproduction camera with a traverse or shading screen, so that the dots are graded in size according to the shades.

Registration accuracy Factors upon which registration accuracy in screen printing is dependent:

I. Dimensional stability of the slide.

II. Dimensional stability of template (dependent on template frame, frame material, type and tension of template gauze, template manufacture, atmospheric conditions in preparation and printing rooms, treatment and maintenance of templates).

III. Printing process: print stretching, dependent on strain properties of fabric, type, position, hardness, length and speed of squeegee, viscosity of print paste, surface condition of print fabric.

Registration requirements for hazardous substances Since January 1982, the Hazardous Substances Protection Law (Gesetz zum Schutz vor gefährlichen Stoffen – Chemikaliengesetz, ChemG, Chemical Law) has been applicable in the Federal Republic of Germany. Any new materials that are to be used in consumer articles are subject to this law, which incorporates a catalogue of test procedures for assessing the risk involved with the materials. The scope of these tests is incrementally linked with the production quantity of that material, annually or cumulatively, and the results of the initial orientation tests.

The German Federal Health Office (Bundesgesundheitsamt) has not published any specific recommendations for consumer articles concerning tests to establish that either man-made fibres, or articles/substances containing or having been treated with these, cause no detrimental effect to health. However, such recommendations have been published for plastics that come into contact with food, for instance. To clarify that there is no detrimental effect to health for the consumer, the tests used are orientated to a direct textile effect, e.g. abrasion, pressure, hydration, temperature blocking, etc., and the after-effects thereof. Local and systemic effects that are of toxicological relevance must also be addressed by means of extractable samples. In other words it would be of particular interest to establish the qualitative and quantitative composition of a global extract of the final product. This type of migration test is carried out, for example, during the analysis of plastics that come into contact with food, where the substance or product undergoing testing is brought into contact with various food simulants (distilled water).

Certain finishing plants have also been required to register since 1st January 1992. Registration includes description of location and facilities, as well as waste water, residual substance and exhaust air quotas, etc.

Regression analysis Test of structure-effect relationships, recording as many parameters as possible, such as solubility and distribution coefficients, influence of substituents, etc.

Regular-Dyeing Polyamide → Differential dyeing polyamide fibres.

Regulators for peroxide bleaching Peroxide decomposition can be influenced by the use of appropriate bleaching agents, known as regulators. Regulators mean substances or substance compounds that are able to preserve the perhydroxy anions (HO_2^-) responsible for the bleaching effect for as long as possible, and largely suppress decomposition. The essential point of this is to prevent uncontrolled peroxide decomposition during the bleaching process, by means of regulators acting on the reaction sequence. A regulator has to fulfil a large number of requirements, the main ones being the following:

- predominant stabilization of perhydroxy anions,
- anti-catalytic effect by means of complex formation,
- to maintain alkaline earth metal ions in a sufficient quantity in homogeneous distribution by means of dispersion,
- stability in bleaching conditions (oxidation, pH and temperature),
- biological degradability,
- economic efficiency.

The way many regulators function is not understood in fine detail. Some stabilizers can be categorized as catalyst poisons, others as protective colloids and possibly buffer substances. As well as this, the way they function depends significantly on the physical and chemical substances. Stabilization is essentially dependent on two factors:

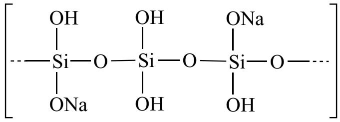
- the alternating attraction forces which are active between the activated HO_2 ion and the alkaline earth metal ion,
- the extent to which the heavy metal ion is masked by the stabilizer, or the formation of hydrogen peroxide radicals is prevented.

Regulators can be categorized as inorganic and organic substances.

1. Inorganic:
    - silicates (water glass) in association with alkaline earth metal ions,
    - phosphoric acid, alkali phosphates, polyphosphates and pyrophosphates,
    - stannates,
    - borates.
2. Organic:
    - products based on complexing agents, e.g. polyaminocarboxylic acids, polyoxycarboxylic acids and phosphonic acids,
    - products based on dispersion agents, e.g. fatty acid condensation products, fatty alcohol sulphates, ethoxylates, organic sulphonic and phosphonic acids.
3. Combinations of inorganic and organic compounds.

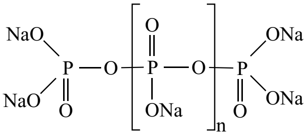
The following text will describe in more detail the properties and the effects of this class of substances, inasmuch as they are known and relevant to alkaline peroxide bleaching.

I. Silicates: The waterglass frequently used in peroxide immersion bleaching is a water-soluble sodium silicate with a ratio of: $Na_2O : SiO_2 = 1 : 3.3 \equiv Na_2SiO_3 \cdot 2\,H_2O$.



The advantages of waterglass are its low cost and high performance, and the fact that hardly any stabilizing agents are as good as waterglass in combination with alkaline earth ions, at least not in pad-steam processes. As an inorganic compound it is resistant to oxidization and heat. It has the additional advantage of buffering significant quantities of alkali, in other words an alkali reserve is generated without altering the pH and thereby the activation of the bleaching bath. However, it does exhibit certain disadvantages, and for this reason alternative substances are being sought as a replacement. The main disadvantage is the tendency to dehydrate at high temperatures. When this happens, the polysilicic acid chains stick together to form silicates that are not easily soluble. As a consequence of this, deposits are left on fabric and machinery parts. This has a detrimental effect on the handle and absorbency of textiles. Furthermore, dye resistance and stains can arise during the subsequent dyeing process. Silicate deposits in the bleaching equipment, particularly on the rollers, can cause raising, creases both lengthways and crosswise, and under certain circumstances even tearing of the fabric.

II. Polyphosphates: These are produced as a result of the condensation of orthophosphates. The following example illustrates the condensed polyphosphate group (inorganic):

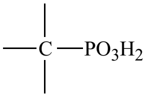


The properties of these substances usually change depending on the length of the chain. The advantages of this group include detergent and soil-suspending properties, solubility properties, and complexing characteristics for calcium, magnesium and polyvalent heavy metal ions. However there are several disadvantages. At temperatures above 80°C and in a strongly alkaline medium above pH 11, polyphosphates exhibit low stability. Particular problems include sensitivity to hydrolysis in hot, strongly alkaline bleach baths, and the lack of selectivity for heavy metal ions in the presence of alkaline earth ions. Furthermore, there are ecological considerations with respect to water eutrophication.

III. Aminopolycarboxylic acids: The best-known compounds in this group include the following: nitrilotriacetic acid (NTA), ethylene diaminetetraacetic acid (EDTA), diethylenetriaminepentaacetic acid (DTPA), and hydroxyethylene diaminetriacetic acid (HEDTA). The aminopolycarboxylic acids form water-soluble complexes in combination with alkaline earth and heavy metal ions. These compounds have an increased stability at high temperatures, as well as high selectivity for heavy metal ions. However, at high temperatures (> 90°C) and in strongly alkaline solutions they only have limited resistance against oxidation. This has a negative effect on their complexing properties. The alkali salts of type Na_4-EDTA aminocarboxylic acids exert a fibre-protective action if oxygen is present, peroxide or atmospheric oxygen. They do not have protective colloids or dispersing action. Furthermore they only function in stoichiometric numbers, in relation to the heavy metal ions.

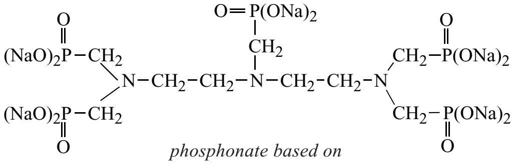
IV. Polyhydroxycarboxylic acids: These compounds include citric acid, oxalic acid and gluconic acid. The advantages of these are exceptional sequestering properties; in other words they are able to maintain a solution of metal ions even in the presence of precipitation agents where acid/lye concentrations are very limited. They also exhibit high selectivity for individual metal ions. The main disadvantage is that the effect of this type of compound is strongly dependent on the pH, and for this reason only limited use is possible.

V. Phosphonic acids: The salts of phosphonic acids are known as phosphonates, and are derived from the following group of phosphonic acids:

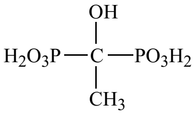


$$-\overset{|}{\underset{|}{C}}-PO_3H_2$$

There are many different phosphonic acids, and an exemplary selection of the important ones is featured here:

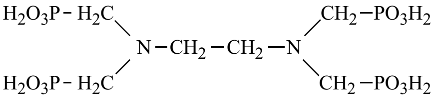


phosphonate based on diethylene-triamine-penta-methylene-phosphonic acid (DETPMP)



$$H_2O_3P-\overset{\overset{OH}{|}}{\underset{\underset{CH_3}{|}}{C}}-PO_3H_2$$

hydroxy-ethylene-diphosphonic acid (HEDP) without nitrogen



ethylene-diamine-tetra-methylene-phosphonic acid (EDTMP)

Contrary to many other complexing agents, phosphonic acids have a high level of thermal stability. They are stable whether the liquor is strongly alkaline or oxidizing, and they act selectively on heavy metal ions. With regard to detergent and dispersing efficiency, they exhibit average to good builder properties. They also act in the same way as sequestering agents, which are able to prevent or at least delay precipitation or crystallization. In addition to this, phosphonic acids exhibit a "threshold effect"; in other words they are effective even in sub-stoichiometric concentrations. Of the phosphonate group (aminophosphonates, hydroxyphosphonates and carboxyphosphonates), the ones considered to be the best are the aminophosphonates with nitrogen substituents and at least two phosphonate groups. Compounds based on phosphonic acid have a wide range of applications; among other reasons, this is due to the broad pH spectrum in which they can be used, and because of their hydrolysis stability. In addition to their application as stabilizers and complexing agents, they can also be used as softeners, exchangers and corrosion agents. However, although these compounds are very effective, which is influenced by the bleaching conditions, they are not comparable pricewise with waterglass. Where bio-degradability is concerned, there have so far only been problems in a few cases. From a toxicological and dermatological point of view no problems have yet occurred.

Re-impregnation process → Water-impermeable test. Today solvent impregnation is more widely used.

Reinforcement strips on printing screens Made of gauze, fabric or adhesive tape as a reinforcement to protect against tearing or splitting at the delicate points where the gauze meets the frame.

REK Russian fastness commission → Technical and professional organizations.

Relative humidity (RH) → Air humidity.

Relaxation (Lat.: relaxatio = easing), time-related reduction of fabric tension whilst maintaining a constant length. During textile production, the textile is subject to tension resulting from mechanical processes, which is partially reduced during storage, for instance. Some finishing processes aim to achieve total relaxation, → Relaxation shrinkage. Insufficient → Dimensional stability is a consequence of insufficient relaxation.

The problem of dimensional stability in knitted cotton fabrics became particularly apparent as tumble-dryers have become increasingly popular, as they can trigger latent shrinkage potential in textiles. The behaviour of certain knitted fabrics that exhibit significant dimensional changes after washing and tumble-drying is firstly due to the technology, and secondly because of the finishing techniques (→ Dimensional change). The Fig. shows a schematic flow chart depicting the behaviour of cotton rib knit during the manufacturing process. It shows firstly that identical knitted fabrics aim towards one final dimensional status (relaxation theory), and secondly that deviating shrinkage potential occurs at the end of varying process curves. After each stage of the process there are more or less effective opportunities to correct shrinkage potential, but also to make it worse (broken line).

Relaxation shrinkage Refers to the fact that if woollen cloth, for instance, is moistened, then any tension originating from processing (spinning, weaving, finishing) will return to a state of equilibrium, in other words without any external work. The principle factors that determine relaxation shrinkage are humidity, temperature and time.

Fig. 1 shows classic shrinkage behaviour in a two-phase pretreatment plant. The fabric being treated was single jersey quality (120 g/m^2), which is very sensitive to stretching. The theoretical curve represents the stretch resulting from stress-strain behaviour, as well as the shrinkage properties of the fabric. The curve represents a linear connection between individual measurements recorded at the plant under production conditions. A comparison between the two shows a relatively high level of coincidence between the two behaviour curves at the measured points.

However, the most important conclusion drawn

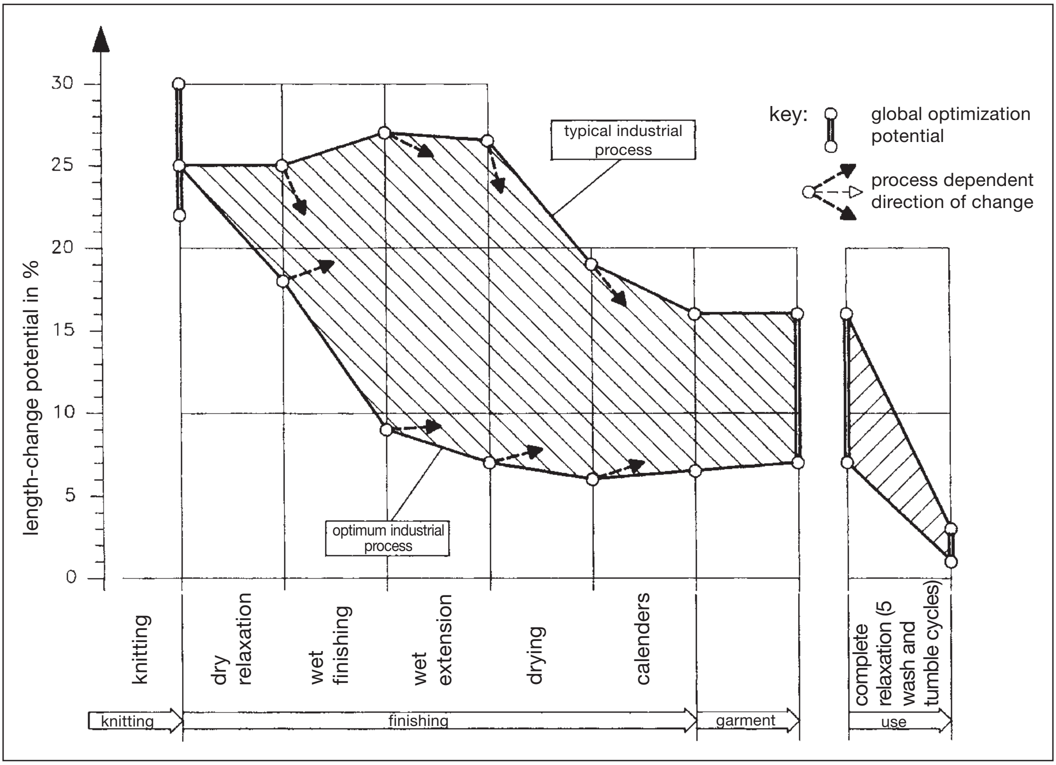


Fig.: The longitudinal behaviour of cotton rib knit in the course of both manufacture and use.

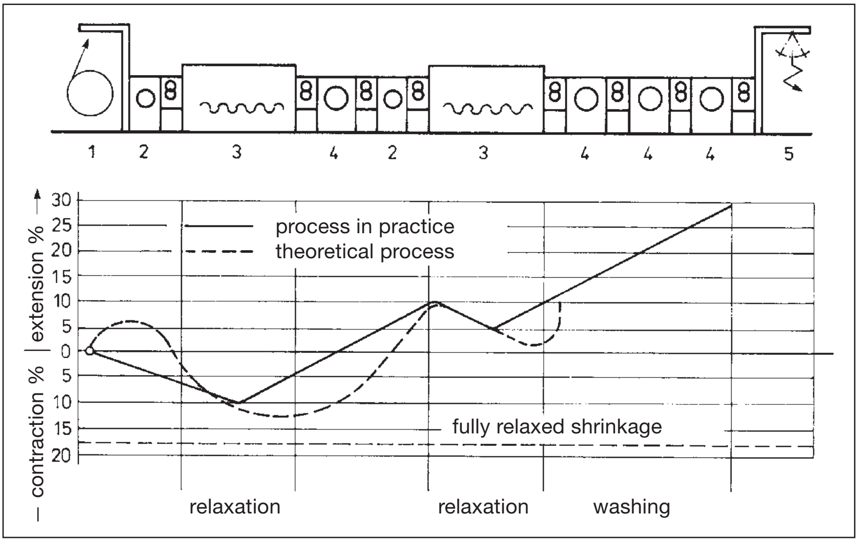


Fig. 1: The shrinkage process.
1 = entry;
2 = impregnation section;
3 = dwell section;
4 = wash section;
5 = exit.

from this is that the fabric shrinkage in the relaxation sections, which is caused by the fabric guide forces, is more than compensated for in the subsequent processes.

A relaxation section is situated at the beginning of a plant for the purpose of shock-shrinking fabric and knits. The dry fabric is guided via a traction device with adjustable overfeed onto the first ribbed drum with ∅ 620 mm (Fig. 2). At the same time, the run of cloth is coated with hot liquor from the spray and pumping equipment (30 m^3/h), and then immersed in liquor to relax further. This procedure must be carried out with a fixed fabric guiding system to avoid marking.

The hydroshrinkage determines the subsequent quality of the textiles. There are integrated swing rollers to compensate for dimensional changes in the fabric run itself, and these compensating rollers are also responsible for controlling the precise speed of cloth feed in and out (Fig. 3.).

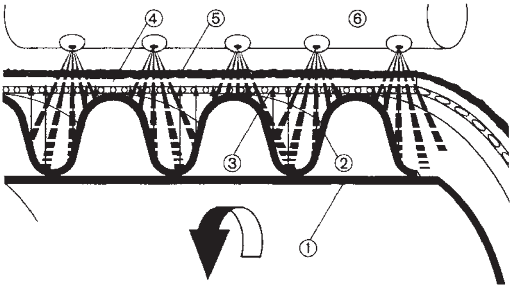


Fig. 2: The active washing principle using a ribbed drum (Kleinewefers KTM).
1 = closed body of drum; 2 = rib profile; 3 = wetting bath; 4 = goods; 5 = outer liquor film; 6 = spray tube.

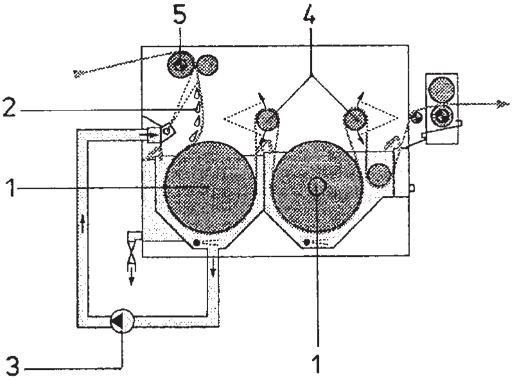


Fig. 3: Relaxation section.
1 = ribbed drum; 2 = spraying device; 3 = circulation pump; 4 = compensation rollers; 5 = feed roller.

Relaxation time In order to compare the kinetics of different processes, for example to test reactions occurring in a finishing process for possible diffusion control, the relaxation time τ (the time after which all processes being compared have decayed to $^1/_e$) is defined instead of the half-life period. In the Fig. this method is used to compare the reaction speed of cotton crosslinking with formaldehyde, at different degrees of swelling and with different catalytic effects of the hydrochloric acid used in acetic acid / water mixtures, with the diffusion speed of formaldehyde in cellulose with no reaction. During the relaxation period it becomes apparent that crosslinking is a controlled reaction when over 25% water is present in the system, but below 25% water in the system means that fibre swell-

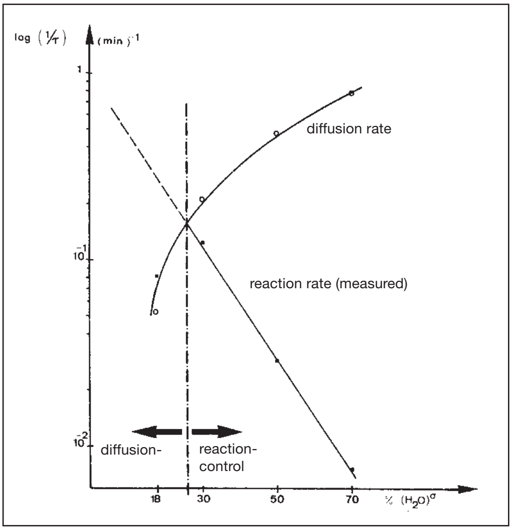


Fig.: Application of the relaxation time τ for diffusion and reaction in order to compare the two processes in a system of cellulose/formaldehyde/hydrochloric acid in water/acetic acid mixtures as dissolvent (swelling agent for cellulose) (according to Zollinger et al.).

ing is so negligible that formaldehyde diffusion in the pores is the factor affecting speed (diffusion control).

Relay Automatic switching device (→ Control equipment):

I. An electrical relay transfers electrical impulses in one circuit to another or (electromagnetic relay) makes contact with a second circuit. a) Control relay or relay controller: controls resistance (e.g. electronically in line with comparative resistance set point). Also as signal relay for automatic control of a variety of different applications (pressure, flow, humidity, concentration, quantity, temperature, vacuum, etc.). b) Cut-out relay: Safety switch for low or high-current electrical circuits to protect against overload, short circuits, etc.

II. Pneumatic relay: Controlled by compressed air.

III. Mercury relay: e.g. Contact-pointer thermometer with a mercury vertical relay.

IV. Thermal relay: Contact control by bimetallic strips carrying current.

Release In wool wet finishing: before dry finishing, a final complete wet finish cycle, carried out almost exclusively for high quality wool cloths in order to improve quality. Covalent bonds imposed to set the cloth in a particular form (e.g. width) are removed by water to enable this form to be modified.

Release emulsions These are responsible for preventing "sticking" or adhesion of material in certain work sequences, e.g. when garments are ironed, mangled, etc. so that they do not adhere to heated metal surfaces, the mangle cloth, press cover, etc. This type of release emulsion can consist of high-molecule polyoxy compounds, for example.

Release paper Carrier paper for coating compounds or foam for → Transfer coating.

Relief engraving machine → Engraving.

Relief printed effects (three-dimensional printing). This does not refer to roller printing with relief rollers, which is widely known, but to the combination of chintz printing or → Emboss printing with particles of crêpe prepared in caustic soda on cotton fabrics. With this technique, there is a local shrinkage effect on parts of the fabric that have not been treated with synthetic resin, and any areas that were protected by the synthetic resin appear raised. Essential requirements: no pre-mercerized fabrics; appropriate fabric adjustment; suitable choice of print design (spots, dots or circles generally stand out in relief and long, stripe-type motifs produce concave and convex relief patterns); acute pre-tension before printing; gloss-preserving thickener must be used (locust bean flour or polyvinyl alcohol; starch and methyl cellulose are not suitable).

Relustring Restoration of gloss finish. Aftertreatment, particularly for modacrylic fibres, partly combined with the drying process.

Remaflam drier Drier specially designed for the → Remaflam process, situated directly above the dye padder to save space, environmentally friendly drying duct. Fabric temperature always < 100°C; heat required for drying is generated by methanol combustion (see Fig.) – Manuf.: Brückner.

Remaflam dyeing plant Continuous dyeing and drying plant for piece goods. Impregnation padder with 36% methanol and required additives, contact-free in short IR heating duct until methanol reaches flash point, ignition in combustion chamber causing water to evaporate, combustion temperature 750°C, fabric temperature 45–70°C (never as high as 100°C if no dye setting), air cooled. – Manuf.: Brückner.

Remaflam process Drying process developed by Hoechst and Brückner, in which methanol is used as an energy carrier (→ Methanol/Water flashpoint). Process for padding and drying textiles, in which textiles are soaked in a flammable liquid (e.g. methanol). At the next stage, combustion of the liquid takes place, causing the water to evaporate. Remaflam drying has an initial speed of 10 m/min; after approx. 5 min the speed is 70% of the ultimate speed (which is reached after approx. 20–30 min). The average drying speed is therefore dependent on the length of the cloth run. As a result of extended tests (polyester/cotton, 320 g/m) it has been established that the optimum speed had been reached after approx. 30 min. The volume of air extracted by the fan reaches equilibrium after approx. 45 min; the residual moisture of the fabric shows constant values from the start of the test. The combustion chamber reaches the selected temperature, based on experi-

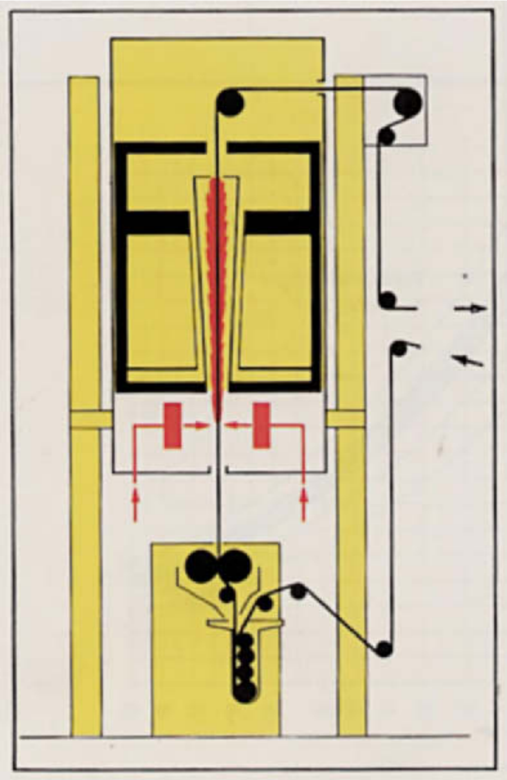


Fig.: A Remaflam drier from Brückner (red = methanol combustion).

ence, after only a few min; however the post-combustion takes 30 min to reach optimal conditions. Driers based on the Remaflam process are not only economical in operation for high volumes; short fabric runs can also be processed very economically using this equipment.

Remaflam-Thermocontact process Combination of the → Remaflam drier with a thermocontact plant. The exhaust gases generated in the Remaflam plant as a result of incomplete methanol combustion are used to heat the cylinder in the thermocontact plant. This means that they are burnt for a second time, thereby achieving optimum utilization of energy as well as incorporating the Remaflam plant in the continuous thermosol process.

Advantages:

- a short fabric heat-up time by means of thermal contact transfer reduces the overall time taken;
- heat transfer by convection from surrounding hot air on the contact cylinder both externally and internally ensures that the cylinder heats up absolutely evenly;
- small cylinder spacing ensure that the fabric rapidly changes sides on contact with cylinder surfaces, increasing dyeing evenness;
- undesirable fabric shine caused by contact occurs much less frequently, if using contact cylinders with a large diameter, than with smaller-diameter rollers;
- relaxed cylinder operation ensures that fabric runs without stretching or creasing with no lengthways tension;
- the equipment is of a compact design with a relatively low fabric content, and therefore saves energy and space.

Manuf.: Brückner.

Remobilization Aminocarboxylic acids that bond cadmium or mercury in sediments or sludge release these heavy metals successively. If a purification sludge is deposited in which heavy metals are temporarily immobilized by means of adsorption, they can be remobilized by extraction through seepage water, and thus accidentally be transferred to the ground water.

Remobilization potential R Ecological parameter for phosphate substitutes. Definition of the maximum quantity of heavy metals to be remobilized from sediments under defined conditions. For ecological requirements the following applies:

$$\mathbf{R < \frac{300}{100 - B}}$$

R = remobilization potential,
B = biodegradability.

The standard remobilization value can be defined as follows

$$\mathbf{R_{St} = \frac{\mu Mol\ metal}{\mu Mol\ complexing\ agents} + 100\ R_{St}}$$

= relative conversion in % for concentrations of 100 μ Mol/1 complexing agents.

Remobilization potential R of nitrilotriacetic acid ≈ 100, of citric acid = 96–138, of polyhydroxyacrylic acid = 7.5, of maleic acid ethylenecopolymer = 1.

Render fast to hot pressing → Decatizing.

Rendering hydrophilic Interfaces can be classified according to their wettability as follows:

a) hydrophilic interfaces, that form a wetting angle with water of $\theta < 90°$, in other words the immersion energy with water is positive;
b) hydrophobic interfaces, that form a wetting angle with water of $\theta > 90°$, in other words the immersion energy with water is negative.

Paraffin is the most hydrophobic, with $\theta = 105°$ and an immersion energy of –0.027 N/m. Glass, quartz and aluminium oxide are hydrophilic, in other words the wetting angle is so minute as to be insignificant, the

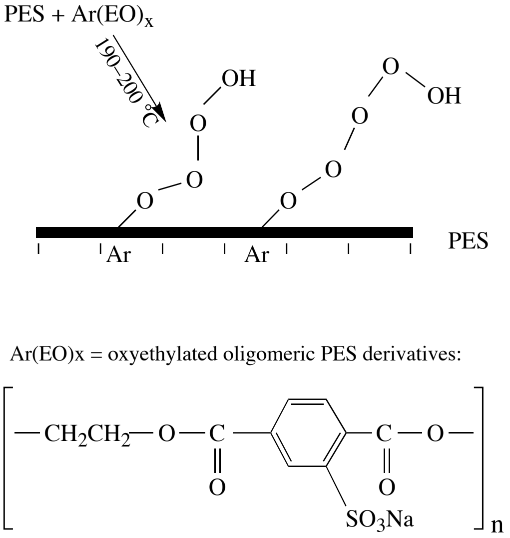


Fig. 1: Making polyester (PES) hydrophilic by co-crystallization.

immersion energy is 0.077 N/m. Hydrophobic fibres can be rendered hydrophilic so that they become wettable in water, which is recommended for garments made of synthetic fibre as it improves washability and ensures greater wearing comfort. Polyester fibres can be treated with alkali. For all synthetic fibres, treatment with hydrophilic polymers is known as soil-release finish. An interesting mechanism for permanent fixing of hydrophilic polymers to hydrophobic fibre surfaces is the principle of co-crystallization of the copolymers with the fibre surface, which has been softened at fixing temperature (Fig. 1).

There is also the theory that soil-release polymers are deliberately washed out gradually from the fibre surface; during this desorption process they take the soil particles with them more easily into the wash liquor.

1. Improvement of water absorption capability: hydrophilization can be achieved using several different techniques, e.g. by incorporating hydrophilic groups (such as the “Antron” polyamide fibre made by DuPont), by means of appropriate yarn structure in spinning, or bonds in the weaving. During the finishing process it is possible to graft hydrophilic groups onto the fibre, or to coat it with a hydrophilic film. The “Refresca” process (Surface Activation Corp.) belongs to the first category; polyacrylic acid is grafted onto polyester using cold electric beams in a vacuum. To create a hydrophilic film on the fibre, anionic, cationic and non-ionogenic products can be used. A further advantage of hydrophilization is the reduction of soilability and electrostatic charge.
2. Soil-release finish: When an oil-soiled fibre is washed, it can be seen under a microscope that the water-based washing liquor forces the oil out of the fabric surface, and subsequently the surface energy is saturated by the water molecules. This process is known as a roll-up or re-wetting mechanism (Fig. 2).

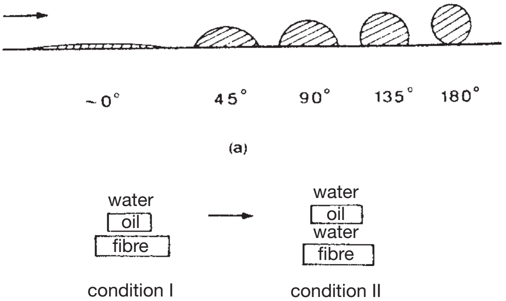


Fig. 2: Displacement of oil soiling by the washing liquor during re-wetting.

The oil, which initially coats the surface in the form of a thin layer, is joined together to form droplets by the wash liquor, and finally removed by the current. Re-wetting can be explained using thermodynamics. To simplify, the energy forces in situation I and II, can be regarded as the total sum of all interfacial energy forces.

$$E_I = \gamma_{water/oil} + \gamma_{oil/fibre}$$
$$E_{II} = 2\,\gamma_{water/oil} + \gamma_{water/fibre}$$

Performing the subtraction E_{II} - E_I results in the energy equilibrium value for the oil desorption and subsequent water adsorption.

$$\Delta E = E_{II} - E_I = \gamma_{water/oil} + \gamma_{water/fibre} - \gamma_{oil/fibre}$$

If energy is released during this process (ΔE negative), then the conversion will occur spontaneously. To fulfil the condition ΔE negative in the above equation, $\gamma_{oil/fibre}$ must be a high value and $\gamma_{water/fibre}$ must be low. This can be achieved by rendering the fibre surface hydrophilic with polar groups. The interfacial energy $\gamma_{water/oil}$ is dependent on the type of surfactants and concentrations used. Normally the value $\gamma_{water/oil}$ is small in comparison with the other interfacial energy values. Where acidic acrylates are present, the primary carriers of hydrophilic characteristics are carboxylic groups. Their bonds to the fibre or to large chains of molecules can be of a physical nature (van der Waals forces). There are basically three categories of compound that are used for soil-release finishing:

a) Copolymers derived from acrylic acid (or methacrylic acid) and from comonomers such as alkylacrylates (or alkylmethacrylates): There are various different methods of producing this type of product synthetically. In every method, acidic acrylates are generated, which exhibit an optimum carboxylic group content for soil-release effectiveness. Systematic tests have shown that products with the same molecular weight and the same ratio of carboxylic and ester groups, but with different methods of manufacturing the polymers, lead to varying soil-release properties. Bonding of this type of product is adsorptive; however there are also acidic acrylates containing reactive groups, causing a chemical bond with the substrate.

b) Oxyethylation products that are polymer-based (specifically for synthetic fibres) or based on alkylphenol derivatives (specifically for cellulose fibres): An interesting mechanism for bonding polymers physically to a thermoplastic substrate has been suggested for these products. When a polyester fibre, for instance, is heated above the glass temperature, the polymer diffuses into the less ordered components of the fibre. If the polyester fibre is subsequently cooled, the level of arrangement of the polyester increases slightly. Since the internal friction during the cooling process increases exponentially as the temperature drops, a separation can no longer be assumed, making the diffusion of the soil-release polymers during the washing process more difficult.

c) Modified fluorocarbon polymers (e.g. poly-[N-methyl-perfluoro-octanyl-sulphonamido-ethylene-acrylate]): this type of block polymer with hydrophilic and hydrophobic blocks guarantees dual action in air, i.e. during use, an oil-repellent effect is achieved, suspended in water because the chemical groups of polymers dedicated to each medium are re-arranged, so that the hydrophilic groups allow soil release.

Initially the textile substrate is coated with soil release agents in emulsion form (usually in association with cellulose-based resin finishing chemicals). It would be possible to apply soil-release finishes in solution form. In contrast to low-molecular chemicals, a macromolecule has some freedom and is therefore capable, even in a state of adsorption, of a considerable degree of mobility, and within the adsorption layer it is even capable of deformation and creasing. In addition to this, it is possible for a macromolecule to form a multiple physical bond with the surface of the substrate because of the number of atoms in the polymer. The macromolecule of the soil-release agent with this arrangement is able to adsorb soil particles preferentially, depending on their chemical composition, so that they do not accumulate in non-accessible areas of the substrate. The solvent used influences the mobility of polymer segments, degree of convolution, and the space they occupy. If the competitive adsorption of the solvent at the substrate surface is strong, the adsorbed layer of the polymer will remain small. If possible the solvent should not swell the substrate excessively, so that the soil-release polymer is retained on the fibre surface. The influence of the solvent used for finishing can be tested for wash permanence using the desorption curves of an acrylic acid -n- butylacrylate copolymer applied on polyester/cotton mix fabrics with different solvents. Alcohol and ether-base solvents seem to be unsuitable, because only a few polymers are adsorbed from the substrate. Strongly polarized solvents such as water, pyridine, glacial acetic acid and dimethylformamide cause initial high quantities of the polymer on the substrate, so that any partial desorption that occurs is insignificant.

The polymer adsorption at the substrate surface is also influenced by the molecular weight of the polymers. Low-molecule polymers tend to be irreversibly adsorbed because of their rapid surface diffusion, thereby preventing polymers of a higher molecular weight forcing their way in at a later point. However an increase in the quantity of substance adsorbed with higher molecular weight was observed. Evaluations of the polymer additives and the carboxylic group content on treated polyester/cotton mix fabrics showed that copolymers with a molecular weight of between 50 000 and 100 000 are the slowest to desorb, and that their desorption equilibrium (after approx. 10 washes) was much higher than copolymers with a higher or lower molecular weight. The adsorption strength is based on the type of adsorbed polymer molecules, for which convolution and solvency are influential factors. In extreme cases convolution and bristles are visible; however most observations indicate macromolecule adsorption in the form of loops or severely deformed convolutions. In polymers, the conditions for complete miscibility are particularly unfavourable. This is known as commonly occurring polymer incompatibility. Polymer separation is more likely to occur the larger the molecular weight. Even minimal differences in the chemical composition of polymers can cause incompatibility. It is therefore evident that a soil-release copolymer, for instance, one based on acidic acrylates, and a polyester fibre, cannot be mixed. For this reason, highly intensive contact of the two polymers to ensure a permanent finish is difficult. However, the polymer systems described here retain their oil-in-oil emulsion character even after removal of the solvent. This type of polymer mixture consists of the two polymers being blended together and a block or graft copolymer, which is responsible for stabilizing the “frozen” emulsion. As one would imagine, the application of emulsion-based soil-release agents due to the presence of this type of emulsifier is permanent, and has advantages in comparison with solvent-based applications. If the correct type of emulsifier is used, an oil-in-oil emulsion of the soil-release polymer in the fibre polymer is created.

Renforcé Also known as dense plain weave cotton fabric; medium-fine cotton quality, finer than cretonne. Available as raw material, bleached, dyed and printed. → Plain weave cotton fabric.

Renovation dyeing → Job dyeing.

Rental linen Textiles and → Industrial workwear hired from rental laundry firms (such as hospital linen, hotel linen, etc.). Examples of hirers are hospitals, institutions, caterers, commerce, industry and civil service.

Re-oiling agent for dry cleaned leather Oils and fat liquors necessary for leather after treatment in drycleaning to restore the soft handle and shape stability of the leather.

Repeat Generally: Unit of pattern or pattern repeat, e.g. weave repeat (woven fabric) and pattern repeat on printed textile runs.

Repeat for printing, design drawing Before screens can be made, all design drawings must be redrawn to the correct → Repeat size. The entire surface of a screen can be filled with a single repeat, or several evenly distributed repeats can be fitted onto the screen. The definition of the repeat limits must be dependent on this; in the case of open and geometric patterns they are usually in straight lines. Separation of essential parts of the pattern must be avoided at all costs, to ensure that the pattern does not tear during printing if screens are set badly to the repeat limits. In such cases, the designer plots a selection of repeat lines that are the same on the facing sides, to guarantee that the repeats will match up. Guidelines on the drawing and screen simplify the transfer process.

Repeat length setting systems in screen printing After each print impression, the → Screen must be offset by a certain amount (screen repeat). In order to define precisely where the screen must be placed, various repeat systems can be used. With only a few exceptions, these consist of → Repeat rails with repeat stops, and a repeat stop on the screen.

Repeat rails in screen table printing Located on the long side of the printing table. The repeat stops, which are adjustable, are fixed to it, so that the screen position can be set to accommodate varying repeat sizes. → Printing screen locking units.

Repeat size Extent of → Repeat in the direction of warp (repeat height) and in the direction of weft (repeat width).

Repeat stops,

I. (guide pins) Tool used in screen printing, to ensure that the print screens are offset precisely and to accommodate the repeat.

II. → Printing screen locking units.

Repeat wheel Cogs on → Embossing calender to adhere to positive and negative on embossing rollers and elastic rollers.

Repellent (repellate), substances with specific repellent, but non-damaging, properties, such as → Insect repellent finishes.

Replacement cost standard market price → Service life of textile plant and equipment.

Reproducibility Capacity to repeat the properties defined in the specification, such as colour shade. The evenness of dyeing is assessed on the padder (see Fig.).

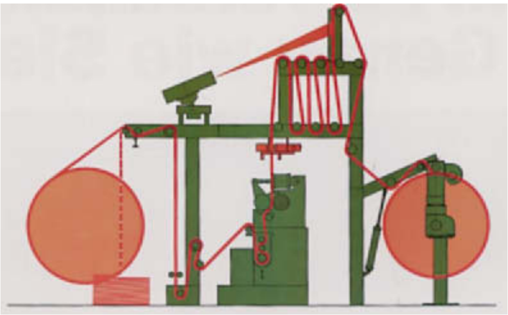


Fig.: Wet colorimetry on the Monforts Matex-Colour-Foulard.

The system used for monitoring and correction is → Colorimetry. Measurements are carried out from a safe distance, independent of external influences such as steam, temperature, light reflection, or fluttering of the fabric. Colorimetry can detect differences in fabric properties, as well as in the pretreatment immediately after the fabric has been squeezed off and is still moist. If required, a high-humidity measuring instrument with one or three measuring heads can be used as a supplementary tool for early error detection. In the next stage, the software, which has been appropriately configured and is directly interactive, is responsible for rapid adjustment to the required standard and ensures an ongoing even distribution of colour. As well as correct point precision of colour correction, it is also possible to perform edge/middle/edge corrections to the colour liquor application. This results in rapid control from batch to batch. For knitted fabrics, guidance is monitored up to the point of rolling. Residual liquor is minimized by the use of a small trough and measurement of liquor utilization.

Reproduction camera For the manufacture of → Photographic colour separations, print patterns are photographed on film using a reproduction camera, so that the repeat size can be corrected by enlargement or reduction.

Requirement profiles Designing clothing is a creative process which must nevertheless take into account how certain ideas can be realised. Thus, for example, under certain circumstances, the highest demands can be made of textiles which are specifically to be used in certain areas. Influences such as clothing

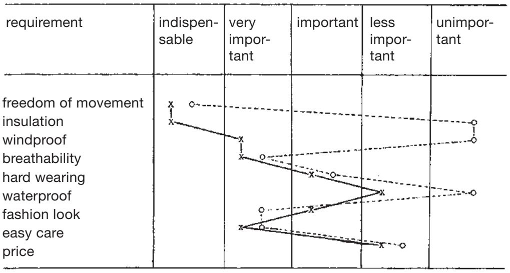


Fig. 1: Possible requirement profile for sportswear.

physiology, movement sequences, climatic conditions, the textile fabrics envisaged, must all go into the model design. This means engineering design of the overall clothing system, for example. Specifically in the case of functional sports clothing, it has been shown that pragmatic considerations must take precedence over fashion. In order to do justice to this principle, it is necessary to produce a profile of requirements for the clothing which is to be designed, containing all the features which need to be taken into account (Fig. 1).

The profile of requirements for the made-up piece yields the choice of material, i.e. the choice of the textile fabric as well as the ingredients. The wealth of textile fabrics on offer, e.g. for sports clothing, also brings the risk of confusion. It is therefore sensible to produce a profile of requirements for their choice too (Fig. 2).

For home textiles which are used directly as textile fabrics, e.g. curtain fabrics (Fig. 3), the textile finisher also must produce a profile of requirements for retail for these textiles.

For hygiene articles in the contract sector in particular, e.g. hospital linen, the profile of requirements (Fig. 4) is decisive for the correct choice of textile finishing processes.

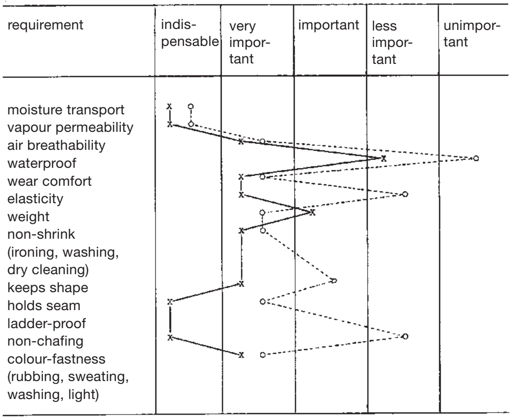


Fig. 2: Possible requirement profile for fabric for sportswear.

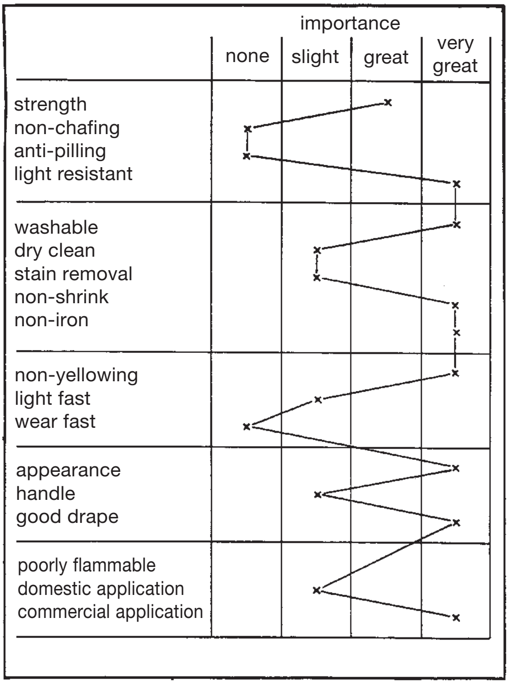


Fig. 3: Possible requirement profile for a curtain.

The disposal aspect must also be taken into account in a profile of requirements.

Research Intellectual activity of individuals or groups, with the aim of making new discoveries using methodical, systematic and verifiable techniques. Experts redefine this to the effect that research encompasses all work where it is initially unclear how it could be applied in practice and for proof purposes, and where the methods used to reach the objective are unknown (fundamental research).

Specialist journals record the dialogue between research and industry. Research encompasses new areas of science and technology, and by exchanging ideas with industry, as well as by means of important scientific and technological achievements and marketing of discoveries and inventions, research establishes the prerequisites for these to be used viably in industry (Fig. 1). Imparting knowledge, for instance via scientific/technical publications, means there is a broad information and application base. The transfer of technology as a specific, organized process for passing on experience, research results or achievements, sets the parameters for economic use of these principles. The solution of scientific/technical problems and the development of new technologies are essential for the preservation of competition in industry. The high proportion of quality technical goods from Germany can only be maintained if research and industry aim towards the

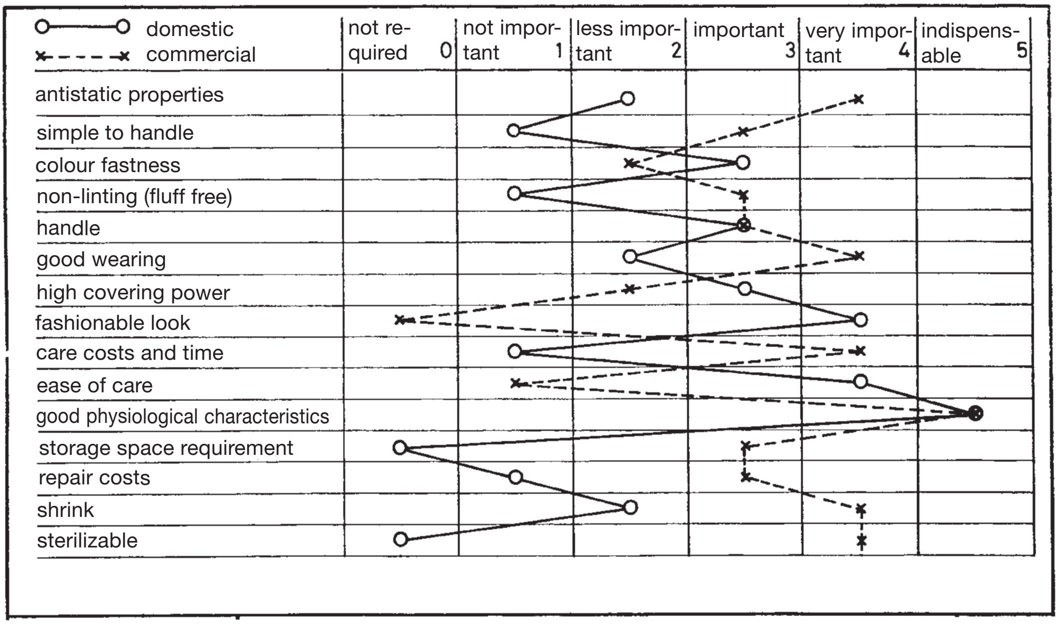


Fig. 4: Possible requirement profile for domestic and commercial bed linen.

shared objective of systematically reaping the full benefits of innovation potential and consistent utilization of "the 4th most important production factor, knowledge". This is apparent in the increasing level of co-operation between research and industry in many future-orientated technologies, where there is intensive implementation and marketing of research results, as well as joint development of solutions. In this complex technical/scientific environment, technology transfer as an organized, process facilitating co-operation between industry and research is gaining in importance.

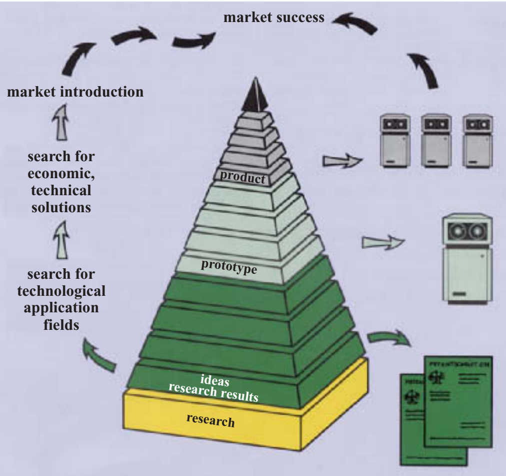


Fig. 1: From the idea to market sucess: research and development (R & D).

Research plays an important key function in the implementation of scientific discoveries into industrial practice. It provides significant contributions towards closing the gap after the scientific result and before industrial production. Research is a supplier of industrial standards, and as such it provides contributions towards further specialist development as well as scientific/technical results to enable standardization and reproducibility, for example. Research itself is a complex co-operative system, with a hierarchical structure from the level of international co-operation down to the efforts of individuals and institutions. The discoveries resulting from the research of complex systems can be applied to the research system itself (so-called self-reflection). The method of controlling research by "decree", which is sometimes recommended, is obviously a linear approach, which reflects a classic technomorphic philosophy. Nothing can be built up with this approach, only destroyed; research success, as is the case with any complex system, cannot be simply "made to order", research is open by nature. However, with this omen it is a great challenge to address present and future problems, and scientists worldwide, particularly in areas of specialist research such as textile chemistry, have to meet this challenge.

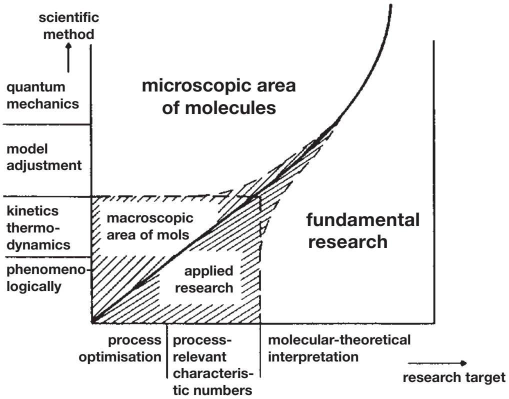


Fig. 2: Fundamental research and application technology overlap in a varied form.

A typical approach to research in the field of textile finishing is empirical recording of the significant, fundamental, mechanical phenomena for which an appropriate interpretation is required (Fig. 2). By its very nature, when this optimization method is applied, the search for a coherent interpretation that is as comprehensive as possible, into which the fundamental phenomena not only fit easily, but which can also provide a basis for prediction, remains unresolved. Another possible way of carrying out research into textile chemistry is to couple the fundamental phenomena of a textile finishing process with scientific facts derived from structural research as a comparison with the standard model. However, using this method of interpreting phenomena theoretically has relatively rarely proved to be a success. It can be assumed that the reason for being unsuccessful is the fact that there is not enough exchange of ideas between experts and structural researchers. Experts unmistakably let their aversion to so-called fundamental research be known. Although for instance there are some very sophisticated, substantiated structural theories on the morphological structure of cellulose, experts have doubts about using these models as a possible way of interpreting fundamental, mechanical processes theoretically. On the other hand, structural researchers lack some of the practical experience necessary for them to be able to test the models they have developed themselves for viability in practical application. The finisher tends to regard the final result of treatment to be of the most significant. However, in fact, a systematic investigation of the processes during the course of treatment would provide an insight into how application conditions, chemical reactions and textile-related, mechanical properties operate together to influence the final product. As an example, an attempt was made to classify the fundamental phenomena observed during the application of formaldehyde to cotton using a structural model of the cotton, a situation that arises frequently in the field of structural research. The main emphasis was on establishing the chemical structure of the crosslinked cotton. In this way, the morphological quality can be linked with the textile-related, mechanical properties of the final product of the reaction. A further way of describing a phenomenon using theoretical prediction is based on statistical, thermodynamic considerations, and results in a description that is independent of every model and therefore precisely correct from a mathematical point of view.

The difference between fundamental research and applied research is purely arbitrary and therefore artificial. Assuming that many of the major technical innovations have their roots in fundamental science, the following must be realized: An idea that originates in physics or chemistry can be applied in more and more different forms over a period of time, until it eventually comes to fruition in its final form in a product or process. However it is impossible to define boundaries between fundamental research/development/applied research, because there is no point at which it can be said that “the idea is no longer scientific, but technical”. Chemistry-based textile research must not be approached on a statistical basis. In fact it is rather the case that carrying out the working methods discussed shows that flexible cut-off points between each stage of the suggested scale are possible, in fact in some cases necessary. However if this continuous spectrum is accepted, it is important to be aware that the outcome hinges on how the task is approached. If somebody uses empirical methods, his work is often regarded as applied in nature. If another person bases his work on theory, it can easily be categorized as fundamental research. However it is the objective of the work that is the important factor.

Due to the current legal situation and the urgent significance of the subject, one major aspect of research is environmental protection and the problems associated with it. Since short-term solutions are necessary for textile finishing in particular, the existence of fundamental and application-orientated research is clearly justified. In 1991, Gesamttextil published research objectives for environmental protection in the textile industry, which are as follows:

I. Objectives: the target for environmental research is to develop process techniques that are both environmentally friendly and suitable for industrial application in all areas of the textile industry. Any substances or combinations of substances that cause damage to the environment or constitute a health hazard should be replaced or eliminated, natural resources should be used as sparingly as possible whilst fulfilling the quality standard of German textile products. Environmental research in the textile industry should enable known process techniques that are already implemented in other industries to be converted for the requirements of the textile industry. In the current globally interwoven climate, international co-operation should be further intensified.

1. Avoidance:
   a) forgoing certain substances and processes,
   b) reducing input of substances and energy by means of exact process control,
   c) using process techniques with minimalized substance quantity and energy consumption.
2. Recycling: Reclaiming substances and energy by means of
   a) controlled process operation,
   b) making optimum utilization of appropriate recycling procedures,
   c) integrated utilization of internal and external resources.
3. Minimization: reduce utilization of substances and energy in existing processes as far as possible by optimizing recipe formulae, machinery and processes.

Avoidance, recycling and minimization must be the primary research interests. The primary reason for this is because assessing and optimizing internal process techniques as well as stringent process control and monitoring mean that significant reductions in the discharge of environmentally damaging substances and in energy consumption can be achieved. Secondly, it is because in the long term industrial activity should not be based on the concept of "end of the pipe" philosophy, i.e. using more and more extensive purification plants situated peripherally in the company.

II. Emphases, e.g. in the category water, waste water:

1. General topics:
   a) recording and logging of individual processes according to type and quantity of environmental pollution, as well as the amount of water required and discharges into polluted waste waters;
   b) purification and decolorizing of textile waste water, with the objective of lowering BOD and COD, as well as dye and solid substance content;
   c) development of processes with integrated purification stages (filtration, ion exchange, energy reclamation, chemical treatment);
   d) development of computer-controlled process operation with the objective of minimizing waste water (integrated analysis);
   e) utilization of emitted heat for distillate concentration of liquor desizing;
   f) utilization and expansion (technical) of existing waste water treatment plants for chemical-physical purification of waste water from processes (circulation);
   g) possible utilization of surface water, rain water (cisterns);
   h) possible utilization of internal overlapping water circuits.
2. Specific themes:
   a) reduction of liquor quantity in textile finishing processes;
   b) increase in dye extraction quantities in dyeing processes by improving machinery and mechanical aspects of process operation, as well as improving chemical and chemical/physical aspects of the process;
   c) analysis of the physical bleaching processes (UV light).

Research institutes → Technical and professional organizations.

Reservoir fabric e.g. Made from polyester, functions as re-dyeable dye carrier (typewriter ribbon principle) in the → Transfer dyeing unit.

Residual additives Overall amount of residual surfactants, sizing agents and scrooping agents on fabric of print-ready quality. The quantity of residual surfactants is a significant factor affecting textile properties during the printing process. If the quantity of residual surfactant preparations in general use increases, the rate of increase of use at a monomolecular adsorption level measured using the capillary rise method remains continuous, with a maximum rate of 0.5–1.0%. There is a linear, degressive link between the absorbency of a fabric treated with anionic and non-ionogenic surfactants by padding and air-drying, and the sharpness of outline and print penetration. For this reason the printing treatment should be adapted according to the required result.

The application of a skim-coat to a polyester fabric (with negative zeta potential) using surface-active compounds is categorized by a layered structure, as shown in the Fig. This illustrates how, after the monomolecular adsorption layer is formed, increasing the level of surfactants as a result of interaction between the principle hydrophobic surfactant molecule groups (with possible influence from cations), successive adsorption sub-layers are formed, so that water-repellent finishing can continue because the residual hydrophobic groups have an affinity to the solution. If the problems arising during build-up of multi-layers are taken into account, then the hydrophobic characteristics of the polyester and the hydrophilic surfactant characteristics determine the surface properties when there are small amounts of residual additives. However, if there are large quantities of residual additives, both the hydrophobic and hydrophilic properties of the surfactants will be the decisive factor (according to Schollmeyer).

Residual chemicals control in running webs Any untreated cloth contains extraneous substances because of the type of fibre, yarn scrooping and warp yarn finishing. These organic and inorganic extraneous substances can cause problems in the various different

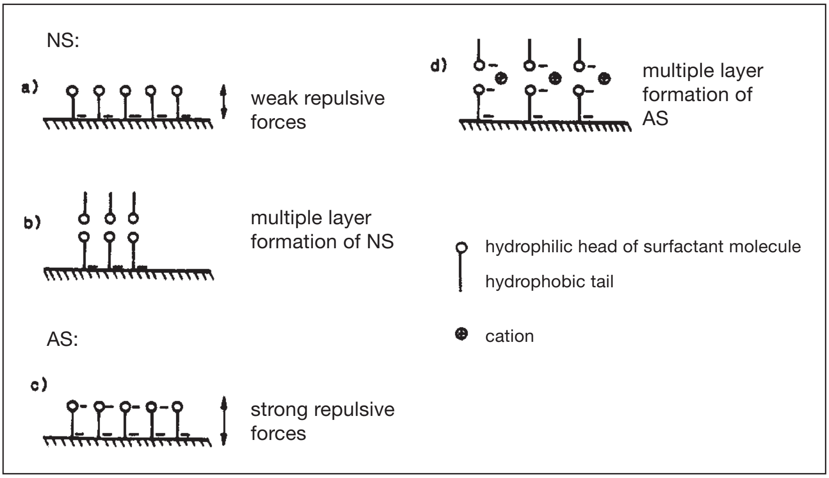


Fig.: Diagram showing the adsorption of surfactant residual additives on polyester fibres in an aqueous solution (according to Berth and Schwuger). NS = non-ionogenic surfactant; AS = anionic surfactant.

stages of fabric finishing (pretreatment, dyeing, print finishing, etc.) if they are not removed sufficiently. The same applies to chemicals used in finishing for an additive or subtractive effect, which can cause problems as residual chemicals, or even become very destructive.

Example:

- Residual alkali can cause problems in subsequent dyeing, printing, and particularly final finishing (catalytic toxins, etc.).
- Residual alkali can lead to yellowing and other negative effects to the fabric during the drying process and other types of heat treatment.
- Residual acid can damage cellulose during the drying process, and during finishing can result in unwanted intensification of catalysts.
- All extraneous substances can influence effect and fabric strength.

The consequences for the finishing trade are high costs for necessary after treatment (i.e. corrections and repairs), exceeding delivery deadlines and reduction in profit as a result of lower quality and rejects. Residual chemical control systems use special sensors so that they can detect and record the condition of the fabric run continuously (see Fig.). The measurement values are obtained by blowing steam onto the fabric run while it is being processed. The steam is subsequently sucked back up, and the condensed material is then collected in a container where it is analysed with special sensors:

- residual alkali and acid by means of pH electrodes;
- degree of electrolyte buffer effect (more or less) by means of conductivity;
- all types of ions by means of ion-selective sensors;
- measurement of organic load by means of oxidation;
- colour and turbidity status by measuring extractions at 350–900 nm.

The recorded measurement values are displayed digitally on a screen or on an analogue display if preferred, so that information is available constantly.

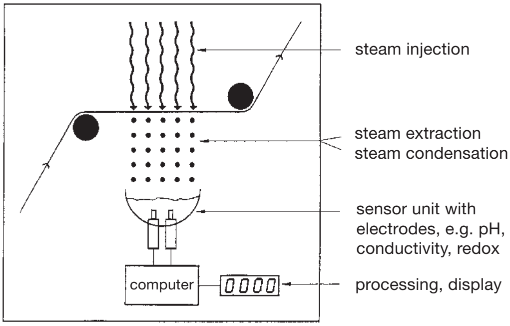


Fig.: A residual chemical control system (the Mahlo Chemocon CMC-9).

Residual grease content Content of wool grease (% of the washed wool weight) after → Raw wool scouring. Dependent on the organic solvent being used. Can also be defined as extract soluble in dichloromethane.

Residual liquor method → Dyes on textiles, quantitative determination.

Residual liquor minimization In practice, when applying dye or finish in the padder, frequently too much liquor is used, so that a large quantity of liquor is wasted at the end of the batch. This increases production costs and pollutes the environment unnecessarily.

As a first organization measure, it is a good idea to summarize batches (Fig. 1). Tightening up on the variety of products and recipe formulae is often an essential step in textile finishing optimization, with the objective of mimimizing residual liquor. However, the ideal or-

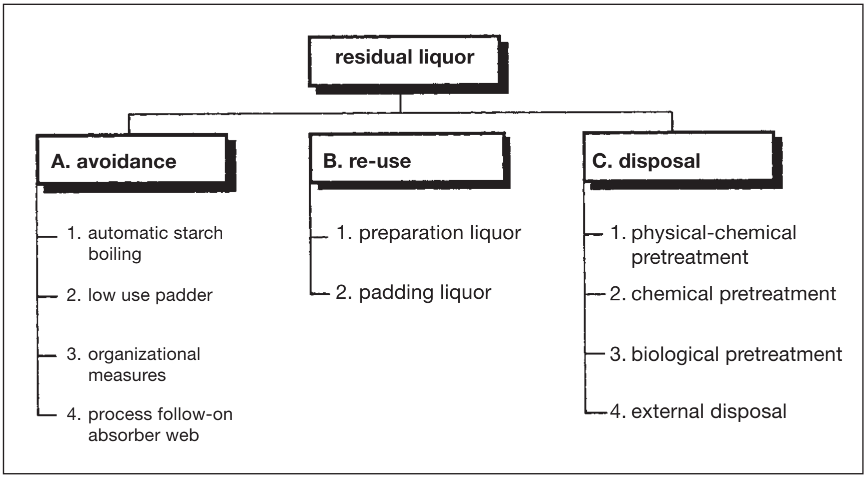


Fig. 1: Overview of proposed solutions to the problem of residual liquor in the textile finishing industry.

ganizational improvements can often not be implemented because of timescales and deadline pressures, unusual customer requirements (particularly in commission finishing) and the typically short lives of fashion textiles. The drastic limitations of recipe formulae and the use of less products, but ones that are optimized from a technical and ecological point of view, is a sound basis for a production process that is close to ideal from an automation and organizational point of view, and generates very few residual substances. A production process that is organizationally optimized not only has a positive effect on the environment, but also saves wages, since interim cleaning of the finishing machinery is no longer necessary, and the logistics of the fabric for finishing are not as complex. As a result of the reduction in textile agents, the number of containers also drops correspondingly. The required finishing chemicals, being implemented on a larger scale, can be delivered by tanker, which is of better value and more convenient from the point of view of packaging. The future of modern, effective and high quality use of liquor is based on the automated finishing kitchen. Some of the necessary experience for this technique can be drawn from printing and dyeing, where this process technique has already become established, and transferred to textile finishing.

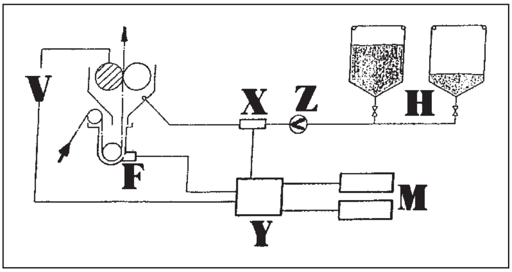


Fig. 2: Control of residual liquor in the dye trough. F = pressure sensor; H = liquor feed tanks; M = display and printer; V = metre counter; X = through flow meter; Y = PLC; Z = pump.

From a technical point of view, residual liquor from the padding process can be minimized as follows:

The amount of liquor required can be reduced to about 10–20 l using new types of construction, whilst retaining the same finish quality. In the case of older plants, the same effect can be achieved by installing dividers. For technical reasons related to the process, there are geometric limits to colour box construction, meaning that further residual liquor reduction aiming at zero is not allowed. In addition to this, rinse water is produced during the process of padder cleaning, which is also highly concentrated and therefore needs to be treated. A reduction in the volume of rinse water can be achieved by using high-pressure purification equipment. If the predicted liquor requirements are wrong, disposing of an excess of finishing liquor can be avoided by last-minute adjustment to the liquor consumption forecast (Fig. 2)

On-line measurement of liquor utilization with specific liquor level monitoring facilitates a reduction of residual liquor (Fig. 3). These measurements provide a constant record of liquor used per metre of fabric, actual consumption in litres, and the remaining fabric meterage. The trend display on the monitor shows at the start of the process whether enough liquor is being used, both as a graphic representation and as a unit of volume (litres). If the trend display indicates that the amount of liquor is insufficient for the current batch, the precise volume of additional liquor required can be dispensed without interrupting production.

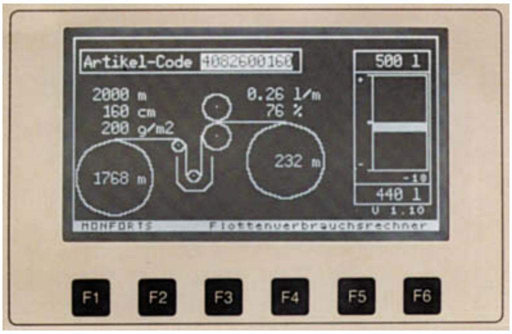


Fig. 3: An on-line liquor use prediction system from Monforts.

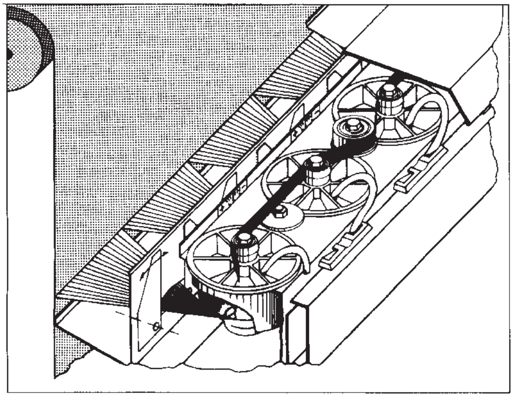


Fig. 4: Diagram of the Weko rotor dampener.
a = rotors; b = spray chambers; c = material web; d = rotor carrier; e = shutters.

The most reliable way of cleaning the padder is the end-cloth method. A highly absorbent run of fabric is put through immediately after the fabric that is being finished, to remove the residual liquor from the padder. During the subsequent drying passage, approx. 90% of the liquor is removed, primarily in the form of water, via the ventilation system. Obviously organic impurities will be released from the water as well as vapour, but if ecologically optimized methods are used, the level of organic impurities will fall well within the stringent limits of the technical instructions to prevent air pollution (TI-Air). The concentrated impurities on the end-cloth can be disposed of as water-free waste.

There are other liquor application techniques apart from padding, which generate less residual liquor. If spray application is used (Fig. 4), the liquor in the dispensers can be monitored so that they can be topped up if necessary towards the end of a batch, meaning that there is hardly any residual liquor left at the end.

Residual moisture content Moisture content of fabric after the drying process. In practice the residual moisture levels are generally between 20 and 40%, depending on fabric composition. Pre-driers should be designed so that fabric moisture after drying is maintained at the same level so that, among other reasons, dye migration at the fibre surface is kept constant throughout the dyeing process.

The residual moisture can be measured by means of → Microwave moisture measurement, for instance; equipment suitable for this can be affixed behind the pre-drier (Fig. 1). Another possibility is isotopic radiation measurement.

If the values measured by the residual moisture device are implemented, and a controller is installed, the performance in the IR duct can be controlled, or in other words the moisture requirements can be kept at a

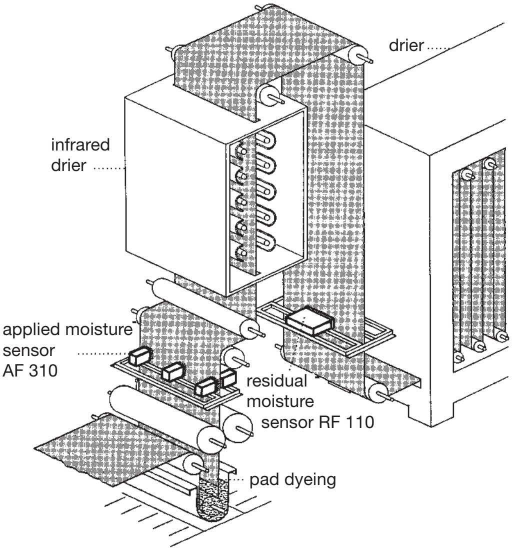


Fig. 1: The determination of residual moisture content downstream of an IR drying shaft by means of microwave absorption using the Pleva AF 310.

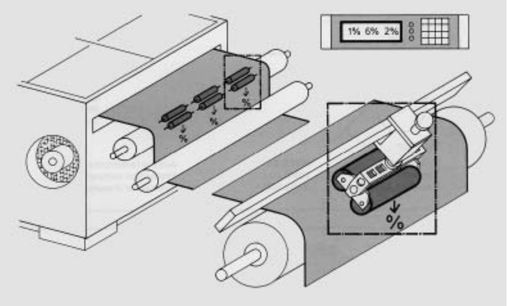


Fig. 2: Residual moisture measuring unit PR 1.3 (Pleva).

constant level. It is not recommended to control the power of the IR radiator by switching off individual radiator lines, it is better to control the voltage of the predrier. New equipment based on conductivity measurement have been introduced which are more reliable than before (Fig. 2), because electrostatic side effects are avoided.

Residual print pastes (print paste returns). Unused print paste left on the print machinery or printing table because a greater quantity than necessary for the meterage was applied for safety reasons. In areas where there is little awareness of environmental issues, the residual print pastes are usually mixed with solvent and released into the sewerage system as a disposal method, or alternatively the residual print pastes can be mixed together to form a black print paste (→ Recycling). This is usually the case in pigment printing. In the 38th Waste Water Management Standard in Germany (Abwasserverwaltungsvorschrift), it is stated that residual print pastes must no longer be disposed of with waste water, instead they should be treated as hazardous waste. Hazardous waste can be disposed of either by taking it to disposal sites, or incinerating it. Both methods of disposal can involve high costs and considerable amounts of additives, and for this reason both the chemical industry and textile printers are trying hard to develop ways of minimizing residual print paste, and in an ideal situation to avoid it completely. To achieve this, the following options must be considered:

a) avoidance and minimization of quantities of residual print paste;
b) reduction in the cost of residual print paste disposal.

The following considerations could be addressed to achieve avoidance and minimization of residual print pastes:

– trichromatic printing could be used if there is a problem with residual print pastes;
– more precise calculation of level of coverage;
– colour measurement to help cope with residual print paste problems;
– use of the most modern colour kitchens and automatic dye dispensing stations;
– printing the design on a short fabric meterage, and subsequently calculating the precise quantity of print paste required for the entire print consignment.

In the context of residual print paste, the shelf life of print pastes should be mentioned, as it is significantly dependent on the thickener. The shelf life of the thickener is in turn closely linked with the problem of conservation. This can lead to problems if, for instance, different thickeners are used, because, if the residual print pastes are mixed in order to use them up, it will result in the mixing of thickeners from different suppliers that have been conserved in different ways. If this happens, it could possibly lead to polymer incompatibility between thickeners.

Residual shrinkage Dimensional changes to the surface of a textile after the first wash. → Shrinkage.

Residual substances Any energetic conversion process involves an unavoidable increase in entropy, which is irreversible and cannot be converted back into useable energy. If this fact is applied to the circulation of chemical substances, it is obvious that even with the implementation of ingenious methods of recycling, energy conversion in any production process will involve an increase in entropy, and in parallel with this valuable substances are irreversibly converted to residual substances.

Residual substances are defined according to § 5 Sec. 1 No. 3 of the Bundes-Imissionsschutzgesetz (BImSchG – German Federal Immission Protection Law) which regulates pollution, as substances that are generated during the processing of other substances, but which are not required. This includes solid substances, liquid substances, industrial waste water, etc. However, waste gases have not yet been classified as residual substances. The BImSchG Law encompasses more than just pollution control. It includes hazards, disadvantages and nuisances that are not caused by pollution. The third principle defines avoidance of residual substances as a legal obligation, which like the other principles must be observed during construction and operation of any plants requiring approval.

This is supposed to ensure that production of residual substances is avoided, even if they can be re-used where they are produced, or elsewhere. Recycling strategies are permitted to reduce the quantity of waste which arises (recycling must comply with regulations and not present a hazard). However if avoidance and recycling are not possible or reasonable, waste may be disposed of in line with regulations. This means that the legal obligation can be treated with a degree of flexibility.

In this context, the BImSchG is relevant to other legal standards, such as waste legislation and water economy legislation (→ Legislation on environmental protection). In particular, Appendix 38 of the General Management Standard Guidelines on minimum requirements for the introduction of waste water into ground water (Anhang 38 AbwVwV zu der Allgemeinen Rahmen-Verwaltungsvorschrift über Mindestanforderungen an das Einleiten von Abwasser in Gewässer) stipulates extremely comprehensive technical requirements that affect the textiles industry, which is indirectly responsible for waste water introduction. According to this legislation, the residual contents of treatment baths after the finishing process must be disposed of as waste if recycling is not a possibility. In addition to this, waste legislation states that the avoidance principle takes precedence over reduction or recycling/disposal. Appendix 38 of the German Administration Regulation of Waste Waters (38th AbwVwV – Abwasser-Verwaltungsvorschrift) will include a radical amendment – the stipulation of more stringent threshold limit values for waste water, not only for textile finishing as a whole, but also the definition of threshold values, and if these are exceeded it will indicate an underlying tendency towards a requirement for treatment. The reason behind these standards is that almost all process techniques have a higher standard of cleaning action the higher the concentration of the waste water to be treated. If the concentrates are allowed to be thinned by the rest of the waste water, the communal purification plant, which also has to cope with more stringent parameters as well as a constantly increasing volume of waste water, will not be suitably equipped to eliminate the hazardous substances to a satisfactory level. In addition to this, a conventional purification plant is generally not equipped to deal with industrial waste water. Its purpose is to purify the broad spectrum of waste water from different sources in compliance with the law and drainage requirements, over a period of only a few hours.

Residual substance handling should be based on an integral concept of technical optimization of the relevant textile finishing processes. The implementation strategy for all optimizing action should be planned in the sequence which is generally applicable in environmental protection: firstly avoidance or minimization, then recycling, and disposal only of residual substance components that can be reduced no further. This hierarchy should be borne in mind when planning strategies, because the first two suggested optimization points can be implemented relatively quickly, and also relatively inexpensively. Any type of disposal process will always incur costs for setting up the necessary infrastructure, running costs, and under certain circumstances, extra personnel costs.

The term “avoidance” should be understood in such a way that raw materials, agents, processes, techniques and machinery that generate no residual substances, or only small quantities, are implemented. Incorporation of residual substances in products manufactured at a plant is also regarded as avoiding action. If the textile finishing plant incorporates its own biological purification plant into its disposal strategy, it should be borne in mind that residual substances can still remain in waste water that has been purified in this way. These so-called refractory residues consist of residual substances that cannot be broken down by the biological microorganisms in the purification plant (Marzinkowski).

Residual valency →: Secondary valency forces; Van-der-Waals forces.

Resin Term for the physical quality of compounds with very different composition, usually vitreous-amorphous in form, insoluble in water, have a specific solubility in organic solvents, fusible, have thermoplastic properties and notable film formation properties from organic solvents.

I. Natural resin is an amorphous waste product of plants, particularly coniferous woods such as →: Colophon; Dammar resin; Copals; Mastic; Succinates, Tall oil, or of animal origin e.g. → Shellac. Plant resins are complex compounds consisting predominantly of resin acids that can be crystallized and non-volatile, with a volatile proportion; so for instance pine resin can, in principle, be termed an incomplete solution of native resin acids in turpentine oil. The composition of commercial resin formed as a product of the distillation residue (e.g. colophony with possibly in excess of 90% abietic acid) is not precisely identical to non-processed plant resin of the same origin. For this reason, pine resin stains, from oxidation and polymerization changes, are particularly difficult to remove. Application: restricted to exceptional cases for technical reasons specific to textile finishing (for oil sizes, silk ribbon finish). Inappropriate or excessive addition of resin can cause unwanted stickiness. → Resin soaps (in combination) are more important.

II. → Synthetic resins (for textile finishing).

Resin acids The major component of natural → Resin, particularly those derived from coniferous wood. There they occur in the form of native resin acids or so-called turpentine acids (primary and sapinic acids) which, after volatile components have been distilled off (→ Turpentine oils), remain in the residue (→ Colophony) in the form of colophonic acids. Those that have the empirical formula $C_{20}H_{30}O_2$ are for the most part isomeric hydroaromatic monocarboxylic acids of the type abietic acid, which has many derivatives that are useful in the textile industry.

Resin alcohols (abietinols), products of the → Abietic acid type (as di- or tetrahydro-) abietyl alcohols, which bear a certain resemblance to fatty alcohols. Sulphation leads to the formation of alkyl sulphates, which are similar to fatty alcohol sulphates. Resin alcohols are also condensed with ethylene oxide, polycarboxylic acids (crosslinking and emulsion agents), etc.

Resin antifelting finish → Antifelting finish of wool on the basis of synthetic resins. → Hercosett process.

Resinates →: Resin ester; Resin soaps.

Resin dyeing process → Dyeing and finishing combination processes.

Resin ester (resinates), esterified → Resin acids, in the form of ester alone or in combination (in a large number of modifications). Used frequently for resin varnishes, sometimes for slip-resistant finishes, for instance in the form of modified →: Phenolic resins; Modified resins; Maleic resin, either on their own or in the form of a glycerine compound as glycerine resinates, or just as resin ester in the form of methyl or ethyl resinate for plasticizers, etc.

Resin exchangers Synthetic → Organoliths.

Resin finished German → Quality symbols issued by the → GüTV for garment and outerwear fabric made of viscose, as well as cotton cloth, with guaranteed minimum requirements.

Resin finishes, analysis of Qualitative and quantitative analytic definition of resin finishing agents on fibre. Test reactions are usually not carried out on the fabric directly, but in the hydrolysate or distillate after boiling treatment with hydrochloric acid, e.g. formaldehyde, hydrolysates of resin finishing products in chemical, chromatographic, electrophoretic or spectroscopic analysis (see Fig.). In the context of quantitative analysis, the parts that can be stripped with hydrochloric acid (resin additives), and the nitrogen and formaldehyde parts, are significant.

I. Synthetic resin test according to Schliefer and Valk: In this test, separation is by means of thin layer chromatography. Method:

1. Detaching the resin from the fabric by means of acidic hydrolysis: treatment for a period of 60 min in a boiling water bath with 0.1 n hydrochloric or sulphuric acid. For amino-formaldehyde products, carbonyl compounds and acetals.
2. Alkaline hydrolysis: 1 hour in a boiling water bath with 0.1 n NaOH. For crosslinking agents containing sulphur in combination with amino-formaldehyde products, carbonyl compounds and acetals. Sulphurous products are stable during acidic hydrolysis.
3. Acidic total hydrolysis: Hydrolysis-resistant finishes on cellulose (very stable bonding with fibre, crosslinked polymers, etc.) can be defined after total hydrolysis of the fibre. Method: total hydrolysis or acetylization of fibre material with conc. sulphuric acid, then subject material to a chromatographic or IR-spectroscopic analysis. Suitable for testing: stable crosslinking, e.g. epichlorohydrin, graft copolymers (acrylic and vinyl compounds), crosslinked polymerisates or polycondensation products (polyvinyl alcohols, polyacrylates, polyvinyl chloride, etc.).

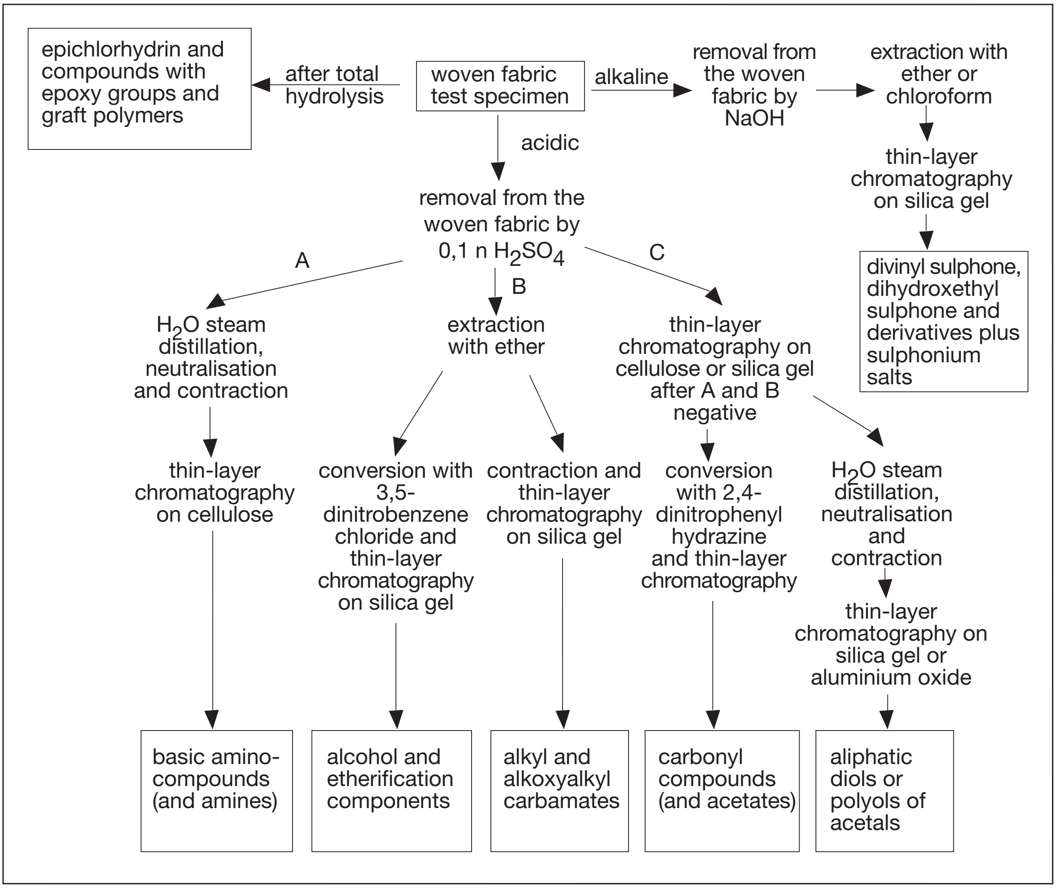


Fig.: Chart of the analysis process for the chromatographic detection of resin finish products on textiles (according to Schliefer).

II. Test for aldehyde and aminoplasts: Initial sampling: mechanical/technological tests (wet and dry creasing angle, swelling value, water retention properties, breaking strength, etc.), cloth construction, solubility in copper oxide ammoniac (cuoxam), chlorine retention analysis, test for formaldehyde (or carbonyl) compound (carbazol/sulphuric acid reaction), nitrogen test, urea test, etc. Procedure of analysis: distil a fabric sample for 10–30 min in gently simmering 0.1 n hydrochloric acid.

Testing the acid extract:

1. nitrite reaction indicates urea, thiourea, dicyandiamide and glyoxalurine.
2. hypochlorite reaction in an alkaline medium: Generation of gas = urea and thiourea (with possible sulphur separation). Yellow to brown colouring after standing for a period, no gas generation = melamine and acetoguanamine.
3. picric acid (basified with sodium acetate): clouding or precipitation = melamine.
4. copper (II) sulphate (at 80°C): blue-green clouding on cooling = thiourea (copper compound).
5. silver nitrate with ammoniacalized acid extract: black-brown clouding or precipitation (silver sulphide) = thiourea.
6. → Ninhydrin reaction = triazone, primary amines, imidazolidone and triazone.
7. → Ehrlich's Reaction = urea, amines, imidazolidone and triazone.
8. methylene blue-sodium hydroxide reaction = reduced sugar.
9. methylene blue-potassium cyanide reaction = glyoxal and glyoxalmonourine.
10. paper chromatic test.

Test of the distillate:

1. carbazol/sulphuric acid reaction = aldehyde.
2. Fuchsin-sulphuric acid (Schiff's reagent) reaction = aldehyde.
3. chromotropic acid reaction = formaldehyde.
4. paper chromatic test.

Resin finishing General finishing that gives each fibre additional properties depending on requirements (soil-release, moth repellent, antifelting, creasing resistance). Finishing that has a significant practical value, and causes permanent improvement in wear resistance (wash and dry-cleaning resistant), particularly shrinkage stability and crease recovery, of textiles made out of cellulose or cellulose compounds, by means of intercalation and/or modification of the cellulose (→ Resin finishing processes) with certain finishing products (→ Resin finishing agents). Also known as: → Permanent press process, Wash and wear finishing, Anti-crease finish, Non-shrink finish, Swelling resistant finish, Easy-care finishes, No iron, Non-iron, durable press, minimum-iron, and rapid-iron finishes. Originally only considered for regenerated cellulose fibres, has only in the past 30 years become important for other cellulose types, such as cotton and linen, as well as synthetic fibre mixes. As a result of resin finishing, there is a more or less significant reduction in abrasion resistance, breaking strength and resistance to tear propagation, particularly in textiles made from native cellulose. However acceptable limits can be maintained, for instance by means of the type and quantity of resin finishing agents, the process technique, and the addition of so-called additives. In order to increase the fastness and effectiveness of a finish, a chemical conversion can be performed with the finishing chemicals themselves, or with the fibre. This type of finish can be comprehensively termed resin finishing, even though in practice this expression is used for anti-crease finishing of cotton, which also comes in this category. The products and process techniques used in resin finishing in the broadest sense of the word, are of course, orientated to the specification of the article.

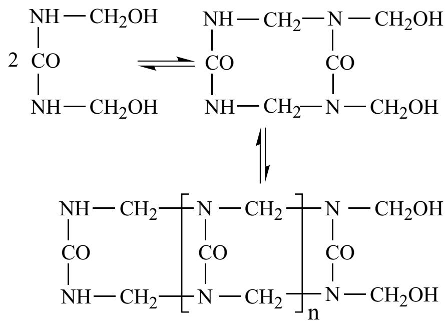
The behaviour of components, which are primarily cellulosic, in chemical reactions can be explained from knowledge of the structure and properties of cotton. It is assumed that the conversion of cellulose fibres is a case of reactions in a heterogeneous system. These can progress to a greater or lesser degree, depending on accessibility of the different cellulose areas. The reactivity and accessibility of the hydroxyl groups in the glucose rings play an essential role, particularly the primary hydroxyl group on the C_6 atom, and the secondary groups on the C_2 and C_3 atoms. These groups exhibit different levels of reactivity, and it is assumed that substitutions occur particularly on the C_6 atom, further on the C_2 atom, but also on the C_3 atom. Three different situations are possible in the reaction:

1. Formation of a covalent bond between a monofunctional or polyfunctional reagent and a cellulose chain.
2. Formation of at least two covalent bonds between a polyfunctional reagent and a cellulose chain (intrachenary bridge).
3. Formation of at least two covalent bonds between a polyfunctional reagent and two cellulose chains (intrachenary bridges).

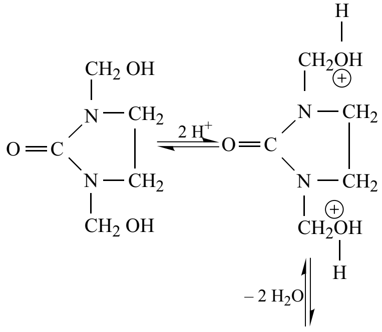
The last type of reaction is called crosslinking. All of these reactions that lead to covalent bonds have the effect of improving crease properties, but crosslinking does so the most distinctively. However, if this type of bond is used, polymer intercalation and the formation of adjacent monofunctional and bifunctional bonds commonly occur.

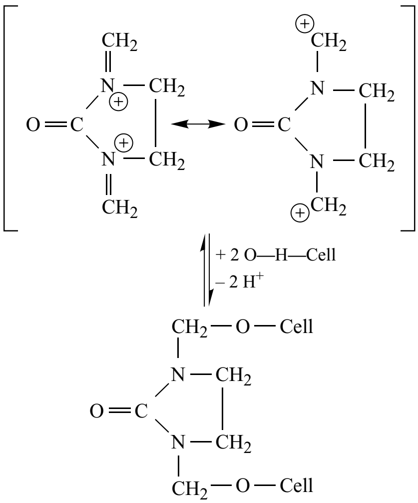
A large proportion of the properties of cotton are dependent on its high swelling capacity, which is caused by the tendency of hydroxyl groups to retain water. A reduction in swelling capacity can be achieved if a part of the hydroxyl groups is blocked by chemical reactions. This is possible in resin finishing. N-methylol compounds that are created by converting formaldehyde with compounds containing NH or NH_2 groups are used almost exclusively as resin finishing agents. They are mostly derivatives of urea and melamine (self-crosslinkers), as well as cyclical urea derivatives (reactive crosslinkers). This type of cellulose modification is based on two different procedures:

1. Polycondensation of a low-molecule chemical whilst depositing a high-molecule synthetic resin; only a few bonds are formed between the polycondensate and the cellulose (self-crosslinker). Example:



   The mesomeric-stabilized carbenium-imonium ions (carbenium = $CO(NH)_2$; imonium = NH), 2 mol dimethylolurea reacts to methylolmethyleneurea, for instance, if further condensed to polymethyleneurea; if this reacts with further methylolureas, a high-molecule, three-dimensional synthetic resin, polymethylolmethyleneurea, is created. This resin formed in the fibre contains methylene bridges (>N–CH_2–N<) as well as methylene ether bridges (>N–CH_2–O–CH_2–N<), and high temperatures and a low pH are favourable conditions for the first type. The synthetic resin is mostly bonded to the fibre by hydrogen bridges; it is also possible that a small quantity of covalent bonds will be present.
2. Crosslinking of the cellulose hydroxyl groups with reactive groups of the crosslinker, whilst forming stable atom bonds between different cellulose molecules (reactive crosslinker). Example:





As the reactive resins have no hydrogen atom on nitrogen, for further reactions like self-crosslinkers, they do not form resin, but tend to become bound to the hydroxyl groups of the cellulose as monomers. It is also possible that linear self-crosslinking of some monomers will occur. However most of the products being used will react bifunctionally by forming transverse bridges (crosslinking). This reaction mechanism of these compounds in the methylol groups with the hydroxyl groups of the cellulose is known as ureidomethylization. The crosslinking of the cellulose limits the possibility of chain molecule displacement, which means that crease recovery and dimensional stability improve correspondingly with the level of crosslinking. However, at the same time the elasticity of the fibre is reduced, which results in brittleness and therefore a reduction in abrasion resistance, breaking strength and resistance to tear propagation. These depletions in strength are particularly common in native cellulose fibres. Regenerated cellulose exhibits different properties because it has a different morphological structure. Water retention in these fibres is significantly higher and can be reduced considerably by the finish, causing the relative wet strength, which is low in comparison with cotton, to increase (if there is water permeation, less hydrogen bridges can be split, because the hydroxyl groups are blocked by the crosslinker). Resin finishing of modal fibres encompasses two fibre types, HWM fibres (= high-wet-modulus) and polynosic fibres. The former are similar to viscose, and like viscose they are usually finished with self-crosslinkers. Characteristic features are greater strength and less shrinkage. The latter behave in a similar way to cotton, and are usually finished with reactive crosslinkers.

The type of crosslinker chosen is primarily dependent on the fabric specification, the type of process and the construction of the substrate. In addition to having good finishing effects such as crease recovery together with low strength reduction, and low residual shrinkage as well as good handle quality, a crosslinker should not exert a negative influence on the textile quality. So, for instance, the colour shade should not be altered, and the colour fastness should not deteriorate. At the same time the crosslinker should exhibit a good level of resistance to chlorine and fluorescent brightening agents. N-methylol compounds largely fulfil these requirements. As many different products are available, crosslinkers are classified according to their chemical constitution in the context of process techniques. The processes that are mainly used in practice are dry crosslinking, moist crosslinking and wet crosslinking. However it is only the first process type that has established commercial significance. The crosslinkers used in this method are the following:

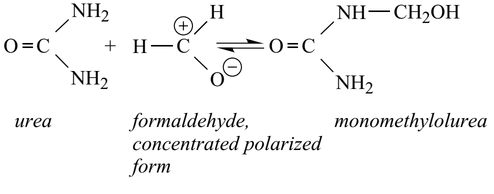
1. In dry crosslinking:
   dimethylol or dimethoxymethyl compounds of
   - urea,
   - melamines,
   - carbamates,
   - cyclic ureas with 5 or 6 ring atoms,
   additionally
   - carboxylic acid amides,
   - alkane dicarboxylic acid amides,
   - alkane diol diurethanes.
2. In moist crosslinking:
   - methylolized cyclic ureas with 5 or 6 ring atoms.
3. In wet crosslinking:
   - methylolized cyclic ureas,
   additionally
   - epichlorohydrin,
   - sulpho-betaines (intramolecular salts).

In order to convert these compounds to an active form, the presence of protons is necessary, as is the case with the ureidomethylization reaction. These are mostly provided by acid donor catalysts.

Resin finishing agents Finishing products with varying chemical composition, used in various different process techniques for → Resin finishing (→ Resin finishing processes), to improve wash and wear properties, shrinkage stability and crease recovery in textiles, for permanent pleat and calender finishes (embossing-chintz-grooved effects), in hydrophobic and oleophobic finishes, for permanent fixing of finishing agents such as polyvinyl alcohol, starch and starch derivatives. Resin finishing agents are usually water-soluble, low-molecular, polyfunctional products that, in the presence of → Catalysts for resin finishing, which work in an acidic or alkaline environment, are converted to either water-soluble, high-molecular compounds that are resistant to washing and dry-cleaning (→ Self crosslinking resins), and/or crosslink with the cellulose fibres (→ Reactive resin). The most significant compounds are acidic crosslinking → N-Methylol compounds, and also →: Aldehydes; POM derivatives; O-Methylol compounds and compounds containing →: Chlorohydrins; Acrylamide group and epon, and sulphurous compounds.

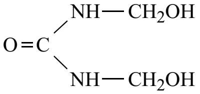
As a result of much debate about formaldehyde, more and more textiles are available that are not resin-finished. Terms such as “bio-finish” and “green cotton” reflect this tendency. This debate has ultimately motivated textile finishers to consider whether they should reject resin finishing as an option. Approximately 180 000 t of crosslinkers are manufactured worldwide, which for the most part are used in resin finishing. The fact that this is such a large amount shows that there is obviously a demand for it. The success of resin finishing was and is possible, although the formaldehyde debate began in the seventies, and this type of treatment also has disadvantages, such as loss of strength, colour shade shift, whiteness influencing and reduction in hydrophilic properties, etc. Resin finishing has become widespread because resin-finished as opposed to untreated textiles, have a range of advantages after washing, dimensional and shape stability being the top priority.

I. Self-crosslinkers: The primary reaction is with themselves, forming high-molecular condensates, and only secondarily do they react with the hydroxyl groups of the cellulose. This type of product is generally used for crease-resistant finishing of textiles, for which a high level of dry creasing angle recovery and elasticity is required, and which are not usually washed at temperatures in excess of 60°C. The self-crosslinker group includes urea formaldehyde curing products that are available non-etherized, or partially or completely etherized with methanol. To manufacture urea formaldehyde pre-condensates, 1–2 mol formaldehyde is allowed to react with 1 mol urea in a neutral or mildly alkaline bath. Where the ratio is 1 : 1, the resulting product is monomethylolurea, from 1 : 2 dimethylolurea.



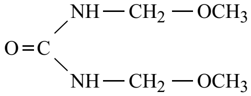
This exothermic, reversible reaction represents the addition of formaldehyde to the free pair of electrons of the amino group (NH_2) of the urea. If the temperature is increased, the equilibrium is shifted to the left. The self-crosslinkers that are usually used in resin finishing are structured on the following basic formulae:

a) dimethylolurea (DMU):



Characteristics: extremely reactive, however it reacts scarcely at all with the cellulose hydroxyl groups, but mainly with itself as a self-crosslinker, resulting in three-dimensional, high-molecular condensates. This type of product is principally used for regenerated cellulose finishing. The finishing liquor, which contains catalysts, can only be kept for a limited period because of its high level of reactivity.

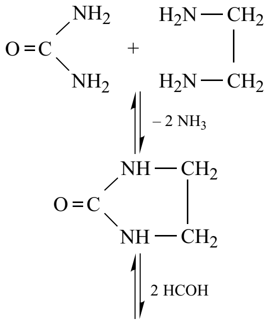
b) dimethoxymethylurea:

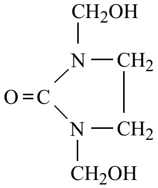


This type is manufactured by etherizing dimethylolurea with methanol. Characteristics: More stable than DMU, both in storage and in the finishing liquor. In comparison to DMU-finished textiles, the fabric has a softer handle.

II. Reactive crosslinkers: reaction is primarily water release with the hydroxyl groups of the cellulose. Under normal condensation conditions they exhibit no self-condensation, because there are no amino groups present, as is the case with self-crosslinkers. The reactivity of individual types varies, generally they are inert in reactions. The fabric handle is not usually altered significantly by reactive crosslinkers, elasticity is less pronounced than with self-crosslinkers. This type of product has distinguishing features such as anti-crease effects that are resistant to boiling washing, chlorine resistance and hydrolysis stability. The best known are cyclic ethylenes and propyleneureas, e.g.

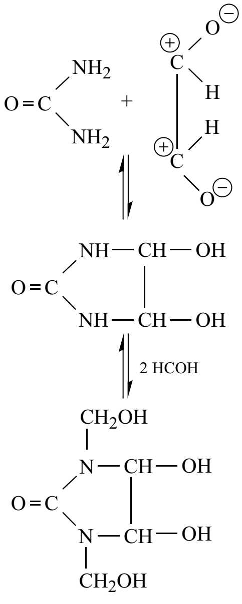
a) Dimethylolethyleneurea (DMEU): The most simple compound in this series; manufactured from urea, ethylenediamine and formaldehyde at a reaction temperature of 250°C.





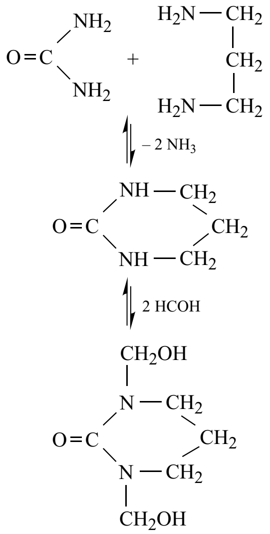
Characteristics: high avidity compared with cellulose, crosslinking occurs even at low temperatures (approx. 100–129°C). The possible fields of application are limited substantially because of its poor chlorine resistance, significant reduction in breaking strength, and deterioration in light fastness of substantive and reactive dyes.

b) dimethyloldihydroxyethyleneurea (DMDHEU): This compound is the most commonly used; made from urea and glyoxal; the reaction is in two phases, i.e. after conversion of the first aldehyde group, ring closure of the second aldehyde group occurs.



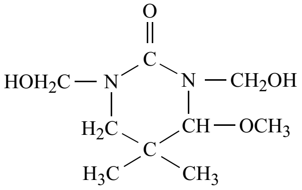
Characteristics: offers great technical advantages in application, such as no worsening in light fastness of substantive and reactive dyes, good wash and wear effects, good resistance to hydrolysis, etc. Slightly less reactive than DMEU, so a higher energy level is required for the reaction (catalyst, condensation temperature). Has the basis of a permanent finish.

c) dimethylolpropyleneurea (DMPU): made from urea, propylenediamine and formaldehyde.



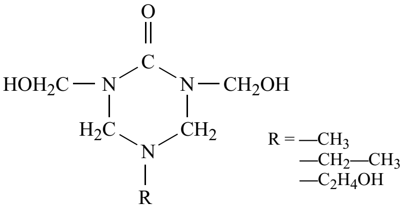
Characteristics: has similar properties to a) and b). Outstanding resistance to chlorine is achieved as a result of the six-ring system, making it suitable for high-quality white fabrics. The crease recovery behaviour is not quite as good as DMDHEU; the light fastness of substantive and reactive dyes is negatively influenced.

d) dimethylol-4-methoxy-5.5-dimethyl-propyleneurea:



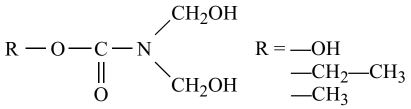
Characteristics: this propyleneurea, which has undergone multiple substitution, combines the advantages of DMPU and DMDHEU. It is very resistant to chlorine and hydrolysis, produces insignificant deterioration in light fastness of substantive and reactive dyes. Very inert, so a strong catalyst is required (thereby possibly forfeiting breaking strength).

e) dimethylol-hexahydrotriazinone (DMT):



Characteristics: sometimes split into initial components during the crosslinking reaction, releasing amine, which can cause a fishy odour on the fabric. Washability is good, chlorine resistance is satisfactory, good crease recovery properties.

f) dimethylolcarbamate (DMC):



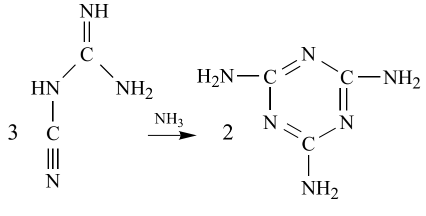
Characteristics: chlorine and hydrolysis-resistant finishes are manufactured in strongly acidic conditions (which are required due to extreme inertness). Excellent crease recovery properties. Reduction in strength with pure cellulose, but very high, therefore usually used for polyester/cotton mixes.

g) others: further acyclic reactants exist, such as dimethylol compounds of aliphatic dicarboxylic acid diamides, however these are not significant.

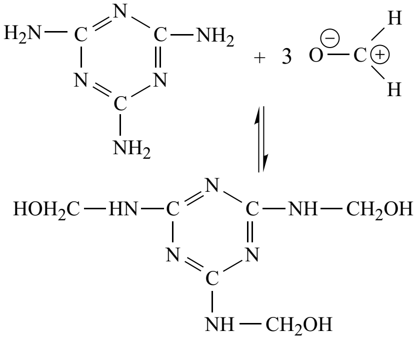
III. Self-crosslinkers/Reactive crosslinkers: these types of crosslinker with mixed reactivity contain self-crosslinking groups as well as reactive crosslinking groups. The most commonly used are methylol melamines. These are so-called pre-condensates. Depending on the level of methylolization, there are different categories from trimethyl to hexamethyl melamines. The higher the degree of methylolization, the less pronounced the self-condensation, and the more priority can be given to cellulose crosslinking.

Solutions of urea or melamine-formaldehyde precondensates only have limited stability even at low temperatures, particularly if catalysts are present. After a certain period, which is influenced by temperature, concentration and type of catalyst, high-molecule compounds begin to form in the finishing liquor. These compounds cannot permeate the fibre, and they form a deposit on it. Stability can be increased by using etherized melamine formaldehyde resins. Etherization is carried out in an acidic medium at low temperatures (50°C). The alcohol most frequently used for this is methanol.

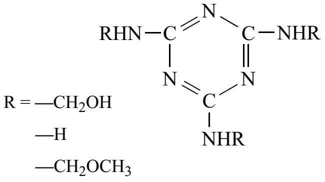
Melamine (2,4,6-triamine-1,3,5-triazine) is manufactured by heating dicyandiamide to 200–300°C under pressure in the presence of ammoniac. The reaction mechanism is not yet fully understood.



With formaldehyde, the melamine amino groups react to methylolmelamines. With 3 mol formaldehyde and 1 mol melamine in a weakly alkaline medium, the resulting product is trimethylol melamine.



All 6 hydrogen atoms in the amino groups can be replaced by methylol groups. However the only product to have any technical significance in application is trimethylol melamine:



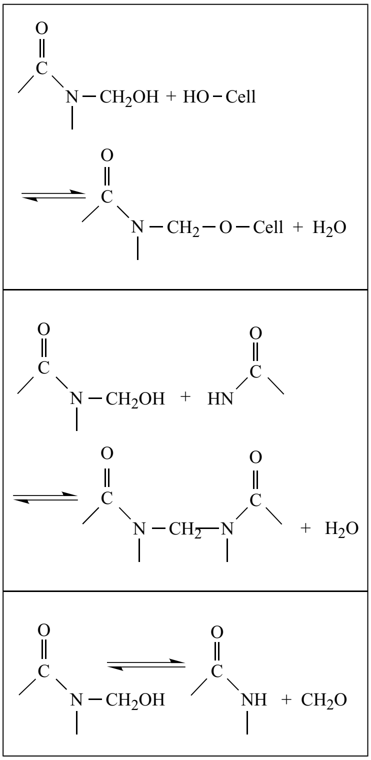


Fig.: Reactions of N-methylol compounds depending on degree of crosslinker and store conditions.

Characteristics: etherization with methanol results in relatively stable liquid products. The finishing effects achieved are similar to those of dimethylurea products, however they are significantly more washable, hydrolysis-resistant and chlorine-fast. The resulting fabric handle is much harder and fuller, making it suitable for stiffened finishes. At the same time, melamine resins are used as additives.

IV. Low-formaldehyde crosslinking: if cellulose molecules are crosslinked with N-methylol compounds, self-condensation and formaldehyde release occur as a secondary reaction depending on the type of crosslinker (see Fig.).

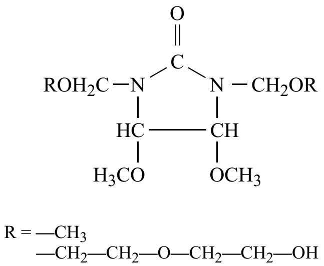
The content of free formaldehyde in the product and in the finishing liquor is dependent on chemical constitution, concentration and temperature. The formaldehyde release from the finishing agent or the finished fabric depends on the hydrolysis stability of the carbon-nitrogen bonds. If these bonds split, formaldehyde is immediately released. Additionally if there is a residual content of non-crosslinked N-methylol groups in large quantities, it results in formaldehyde release, which occurs particularly if the finished fabric is stored in a moist, warm place. Care should be taken that free formaldehyde is adsorptively bonded to the dry cellulose fabric. Since water or vapour has a stronger tendency to bond, if moisture is present, a formaldehyde/water exchange will occur. There are technical methods that can be applied during the process to reduce formaldehyde content, and a wide selection of products is available to achieve this:

a) Technical methods during process:

- aftertreatment washing of finished textiles,
- addition of formaldehyde acceptors to the finishing liquor,
- aftertreatment of fabric by spraying on a urea solution.

Aftertreatment washing does not just remove the free formaldehyde, it also removes some of the N-methylol groups that are not crosslinked with the cellulose. However many garments cannot be subsequently washed because of the fabric quality (altered handle, reduction in fullness and stiffness) and also mainly for cost reasons. One method that has been used for a long time is the addition of substances to bind the formaldehyde, such as urea and ethylene urea, to the finishing liquor. Taking this action achieves a reduction in formaldehyde release during the finishing process and in storage. There is a further option of spraying the finished fabric immediately after curing with a 10% urea solution (approx. 10% spray application); further drying is not necessary afterwards.

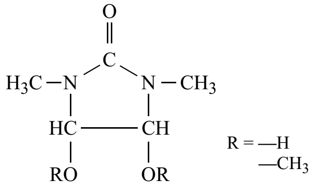
b) Product variants: this covers crosslinkers that exhibit a high level of hydrolysis stability of the methylol groups, and also as little free formaldehyde as possible in crosslinking solutions. This type of product includes partially-etherized dimethyloldihydroxyethyleneurea and modifications of this type.



partially-etherized DMDHEU

The partial-etherization of the hydroxyl groups has the effect of limiting avidity, which can be largely compensated by the addition of free acids or sodium fluoroborate (for instance) to the catalytic reaction with magnesium chloride. Although low-formaldehyde products certainly offer ecological advantages, a successful finish is even more dependent on the pH of the fabric than it is in "normal" resin finishing. Adding acetic or citric acid to the liquor resolves the problem only up to a point, because the neutralization products, such as sodium acetate, have a buffering effect on the catalyst, so that crosslinking may possibly be worse and therefore cause higher levels of formaldehyde on the substrate.

V. Formaldehyde-free products for resin finishing typically have the following composition:

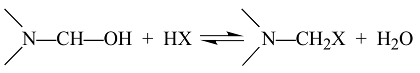


Resin finishing catalysts Inorganic or organic compounds to speed up reactions in → Resin finishing. Selection of catalyst particularly dependent on type and reactivity of → Resin finishing agent and crosslinking compounds. The most commonly used are ammonium salts such as ammonium chloride or ammonium nitrate; metallic salts such as zinc nitrate and magnesium chloride; inorganic and organic acids such as specific mixes for wet crosslinking and shock-cure processes (→ Shock catalyst). However alkaline catalysts such as caustic soda liquor and sodium carbonate are not significant. In addition to good dimensional stability and minimal creasing tendency, the requirement for a low proportion of potentially releasable formaldehyde is also an important factor in the resin finishing of cellulose textiles. Crosslinkers that are stable in hydrolysis are inert crosslinkers, and they require active resin finishing catalysts if they are to be used in single-phase drying/curing processes. Resin finishing requirements:

- low creasing tendency or good crease recovery,
- dimensional stability during processing and after treatment,
- low quantities of free and potentially releasable formaldehyde, as well as being odour-free,
- no chlorine retention,
- no change to the colour shade or grade of whiteness, either directly after curing or after storage,
- minimal strength reduction.

All these desired effects cannot be realistically achieved just by using conventional resin finishing catalysts based on magnesium and zinc salts, with short curing periods and at temperatures of 160–180°C, depending on the type of crosslinker. However, a method that has proved successful is the activation of magnesium chloride ($MgCl_2$) with citric or glycolic acid, as well as sodium borofluoride ($NaBF_4$). If the magnesium chloride is activated in this way, condensation is possible within approx. 20 s at 150–180°C. The reliability of this method is extremely limited, as in practice colour changes are possible (after condensation/storage) at condensation temperatures that are still very high. For this reason, the ideal catalyst systems are those that permit shock drying condensation because of higher activity levels.

Resin finishing is based on the condensation of N-methylol compounds of ureas, carbamates, melamines, etc., which is accelerated by catalysts (α-ureidoalkylization), where the reactions either take place on a polycondensation of the crosslinker itself (self-crosslinking), or on cellulose crosslinking by means of a non-polycondensing crosslinker (reactive crosslinker). In principle these condensation reactions can be catalysed either by acids or bases, because the condensation reaction mechanism for methylols is largely analogous with the α-aminoalkylization reaction (Mannich reaction). For this reason the direction of the reaction and the conversion are dependent on the basicity difference between the attacking reagents HX and the emerging OH group:



Crosslinking with acid catalysts has proved to be of practical use, since crosslinking that has been catalyzed on an alkaline basis under comparable curing conditions results in a finish that is not wash-resistant, because of the low level of crosslinking. Of the acidic catalysts, mineral acids and strong organic acids are not economically viable as an option for dry crosslinking, firstly because they decompose cellulose under normal curing conditions, and secondly because a further subsequent washing process is required, which is economically inefficient. Latent acidic catalysts only become active in curing conditions; this applies to ammonium salts as well as magnesium and zinc salts, which are preferable. However ammonium salts have the disadvantage of causing secondary reactions that shift the pH of the finishing liquor to lower values after standing for only 1 h, which in the case of methylolurea, for example, results in the formation of insoluble methyleneurea. As well as this, ammonium salts react with the crosslinker, depending on type, in the proofing liquor, and the formaldehyde present in the textile is converted to methylamine, causing the unpleasant fishy odour typical of this type of finish.

The varying levels of activity of metallic salts are determined by the cation as well as the anion. The effectiveness of the cations is correlated with the level of acidity ($Al^{3+} > Zn^{2+} > Mg^{2+}$), which makes the free acid available to the anions with the dissociation constants ($BF_4^- > NO_3^- > Cl^-$). For magnesium and zinc salts, catalysis occurs by means of a metallic ion/methylol component complex. Crosslinking that has been catalysed with magnesium salt is more stable during washing than zinc salt catalysed crosslinking. The reason for this behaviour is related to the varying reaction properties of these two salts with cellulose. Magnesium salts only react with the primary hydroxyl groups, however zinc salts (particularly zinc nitrate) also react with the secondary groups (oxidative release in the presence of alkali). Since in the latter case a lower level of crosslinking in comparison with magnesium chloride is found to occur, it is assumed to be the result of intramolecular crosslinking of the hydroxyl groups on the C_2 and C_3 atoms of the cellulose, causing formaldehyde release. If the magnesium chloride is activated with aluminium chloride, the fabric will have a lower level of free formaldehyde.

In order to carry out crosslinking under curing conditions which put as little strain as possible on the fibre and/or with as short a condensation period as possible, catalyst combinations consisting of magnesium chloride and other metallic salts or organic acids have become more widespread in use. The higher catalytic activity resulting from this additive is based on an effect resulting from the combination of Lewis acid (magnesium chloride) and Brønstedt acid (organic acid). If the additive is sodium borofluoride ($NaBF_4$) it is based on a solely synergetic effect, since $NaBF_4$ on its own does not cause crosslinking. Borotrifluoride (BF_3) is considered to be the effective catalytic agent, which is generated during the drying and curing processes.

drying:

$$NaBF_4 + 3\,H_2O \rightleftharpoons B(OH)_3 + 3\,HF + NaF$$

curing:

$$B(OH)_3 + 3\,HF \rightleftharpoons BF_3 + 3\,H_2O$$

As well as the strong nature of Lewis acid, which is essential for catalysis, the easy bonding of BF_3 to aldehyde is clearly responsible for the low level of free formaldehyde. The high catalytic activity of zinc borofluoride ($Zn[BF_4]_2$) and magnesium borofluoride ($Mg[BF_4]_2$) is a positive factor, but on the other hand this activity results in pH lowering of the finishing liquor. This in turn causes decomposition of the hydrolysis-stable crosslinkers, as well as a significant loss of strength in the cotton. Zinc salts cannot be activated in such a clear-cut way using additives, because unlike magnesium salts, this metallic salt hydrolyses under curing conditions, and the resulting hydrogen ions already provide the same effect as Lewis acid/Brønstedt acid. It is not yet fully understood how the combination of magnesium chloride and hydroxy/cyanic/aminoacetic acids works. If citric acid is used for activation, a magnesium/ citric acid complex is formed, if glycolic acid is used for activation, a co-reaction with the crosslinker and formation of terminal carboxyl groups can be detected in the finished fabric.

Despite good finishing results, the use of trichloroacetic acid as an additive is out of the question, because chloroform is produced during condensation, which creates a new set of problems. Activation with phosphoric acid or its ammonium salts requires a subsequent wash, and is therefore uneconomical. In practice, the best method of activation is magnesium chloride with glycolic and citric acid, with single phase drying/ curing processes, where condensation conditions are approx. 150°C/3 min. The important factor to consider when selecting from a spectrum of possible additives, such as maleic acid, glycolic acid, hydrochloric acid, phosphoric acid, etc., is that the pH of the fabric after curing (from 120°C/3 min) should be approximately 6. This is because some of the acids are volatile during condensation, and some of the released basic crosslinker components are neutralized (according to Heidemann).

Resin finishing of cellulosic knitgoods Good dimensional stability and good sewability are the crucial factors in resin finishing. N-methylol compounds of ethylene and hydroxyethylene urea (60–90 g/l, 45%) and melamine formaldehyde compounds, usually partially etherized and often as additives with a buffer function, are often used as resin finishing agents for improving shrinkage stability. Reactive catalyst systems (→ Shock catalyst) are preferable. It is difficult to use additives based on polyethylene dispersions, fatty acid condensation products and dimethylolpolysiloxanes - whether on their own or in combination with another substance - to improve sewability or to influence the fabric handle. Finishing procedure: impregnation, with sufficient overfeed and low-tension across the guide rail width. Drying and curing at 150–160°C in one process on the stenter (→ Shock-cure process). Mercerization of knitgoods during pretreatment has positive effects on dimensional stability and strength.

Resin finishing processes Process techniques in → Resin finishing. Application of → Resin finishing agents under specified crosslinking conditions. Largely responsible for defining intended finishing effects. Major processes: → Dry cross-linking, moist crosslinking, wet crosslinking. Used alone, they represent multiphase crosslinking processes. When selecting crosslinkers and catalysts for a process, there is a range of combination possibilities from a technical point of view. In industrial production there are two basic condensation types – high temperature condensation and cold dwell condensation. In general, condensation in resin finishing is a chemical reaction between crosslinkers and cellulose, usually causing water release.

$$\text{Cell–OH} + \text{HO–CH}_2\text{–N}< \longrightarrow \text{Cell–O–CH}_2\text{–N}< + \text{H}_2\text{O}$$

The objective from a chemical point of view is to allow the crosslinking reaction to progress with as high a yield as possible, whilst restricting the damage caused to the cellulose chains by the crosslinking catalyst.

I. High temperature condensation: dwell treatment of the textile at a temperature range of approx. 130°C to a max. 200°C, between 20 s and 6 min on “curing machines”. Normally these consist of a heat-up zone with a high level of heat transfer, a dwell zone, in which the target temperature of the textile is kept constant without much interaction with the medium, and a cooling device (e.g. cooling drum). Usually curing is carried out on a stenter with programmed process control. Dry crosslinking is the most common crosslinking type for reasons of economy. In this process, the standard procedure is impregnation, drying, curing. The characteristic feature of this technique is that the material is crosslinked while it is dry, i.e. in a de-swollen state. Latent acid catalysts, such as metallic and ammonium salts, are used as accelerators for the reaction. The pH must be between 5 and 6. The different crosslinking processes differ in that there are extra operations between the phases, or sometimes two phases are amalgamated into one (such as drying and curing).

a) The following variants of classic finishing can be defined (Fig. 1):

– normal classic finishing,
– wet-on-wet finishing,
– mechanical finishing,
– classic finishing with after-washing and scrooping.

Of these variants, the one portrayed here is normal classic finish. The diagram shows how the dry textile (humidity only) is fed into a padder, and a defined amount of crosslinking liquor is applied to the fabric. The drying process takes place in the stenter to ensure that the shape is fixed (overfeed ensures end width and start in warp direction). After drying there is a cooling process – in particular for quality articles (cooling fan, cooling drum), and the fabric is batched, or if it is not fold-sensitive, it can be plaited down. Finally the curing process takes place, with strict adherence to process conditions. Cooling is the last finishing process. The fabric is then given a basic after-wash to improve handle, and can then be scrooped.

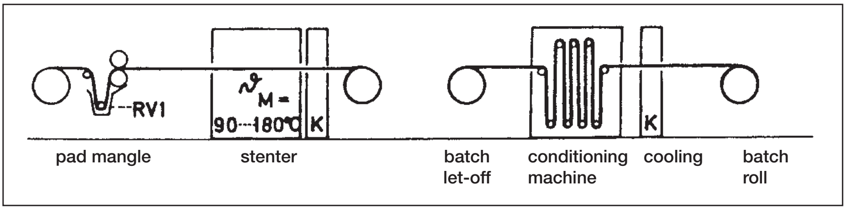


Fig. 1: Production diagram: classic finishing. RV1 = cross-linking agent; K = cooling.

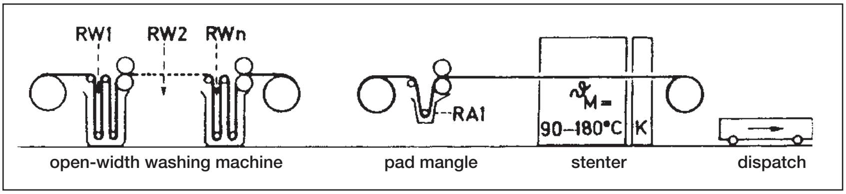


Fig. 2: Production diagram: after-washing and after-softening. K = cooling; RW = open-width washing unit; RA1 = after-softener.

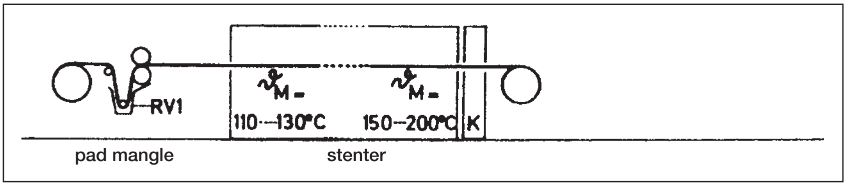


Fig. 3: Production diagram: shock-dry curing process. RV1 = cross-linking agent; K = cooling.

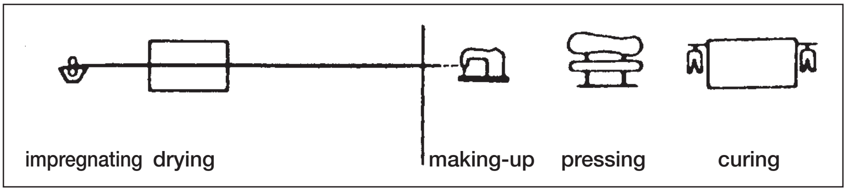


Fig. 4: Post-curing process.

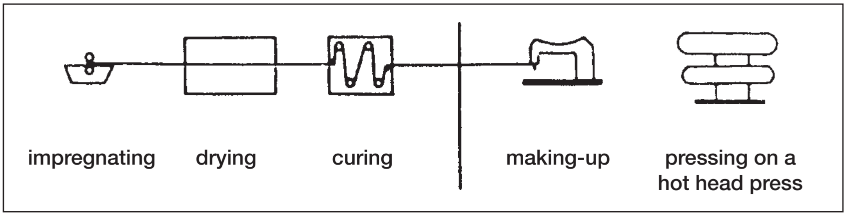


Fig. 5: Pre-curing process.

After-washing (Fig. 2) is mainly done on open-width washing machines. This treatment gives the fabric a much better handle. The subsequent wet-in-wet scrooping process can improve the handle even further.

Classic finishing usually aims to achieve the best dry and wet creasing angles, and a good level of dimensional stability.

b) Shock-dry curing process: The amalgamation of drying and curing into one phase is characteristic for this process (Fig. 3). The throughput time for the combined process of drying and curing is dependent on the type of crosslinker, fibre type and fabric settings. The effects achieved are similar to classic finishing if the same catalysts are used. If stronger catalysts are used, the curing period of this process can be shortened even further. Specific complex catalysts are used in this context. The aim of this is rapid curing. If the speed and temperature of condensation increase, it can lead to fluctuations in the stenter temperature, uneven absorption of the liquor and machine interruptions cause major catalytic damage to the fabric. If coloured goods are being treated using the shock-curing process, it is highly likely that there will be colour shade shifts due to the high temperature, and yellowing is a strong possibility in the case of white fabrics for the same reason. For that reason, this type of process is not particularly common.

c) Durable press process: Until now this type of process has had little commercial significance, however it is interesting because of unusual techniques. In conventional synthetic resin finishing, the textile fabric is cured in widths with the crosslinker. When the fabric is later re-shaped by the clothier, it has a tendency to return to its original shape (“flat memory”). If this phenomenon is applied to a garment, it means that a deliberate crease will only remain in place for a short time. The durable press process is based on the following principle: The textile finisher pads and dries the fabric. It is important that the crosslinker being used can tolerate storage, because the curing process is not complete until the clothier has pressed the fully-fashioned garment in a specially designed method of pressing using high temperature ironing presses (temperature up to 200°C). This process can be divided into three principle groups:

- post-curing process,
- pre-curing and thermoplasticizing process,
- 2-phase process (BASF P2 process).

For the post-curing process (Fig. 4), the fabric is impregnated with crosslinker plus catalyst, and dried. The resulting fashioned garment is pressed at a low temperature (120°C) and cured in special curing ovens.

The pre-curing and thermoplasticizing process (Fig. 5) is used for mixed fibres (cellulose with synthetic fibre). The finisher impregnates, dries and cures the fabric, and after fashioning, the synthetic fibre content is thermoplasticized on high temperature presses.

In the 2-phase process, the fabric is impregnated with finishing liquor containing two chemicals (crosslinkers) with very different curing properties. After the fabric has been impregnated and dried, the first finishing phase is curing at a temperature of up to 130°C, during which one of the two products condenses. The fabric retains dimensional stability. The second phase is the condensation of the second product on the press after the garment has been fashioned.

II. Cold dwell curing: a long-term reaction that is normally carried out at room temperature on the batch roll. As opposed to most high-temperature curing processes, the cold dwell process is carried out discontinuously, meaning that it takes much more time. The advantage is that condensation reactions take place at low temperatures, meaning that the fabric is subjected to less stressful treatment.

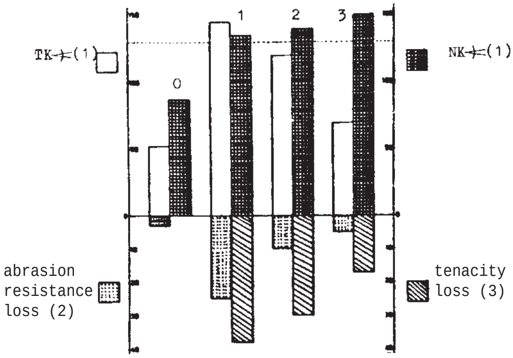


Fig. 6: Relation of crease recovery to loss of strength of different resin finishing processes.
0 = untreated cotton; 1 = classic dry finishing; 2 = moist cross-linking; 3 = wet cross-linking (acid).
(1) = mean warp and weft; (2) accelerotor 3000 rpm; (3) = weft.

If dry crosslinking is used, a high dry and wet creasing angle is achieved, which is associated with relatively high loss of strength (Fig. 6). In contrast with this, moist crosslinking results in less loss of strength, but a similar creasing angle value. Wet crosslinking provides very little strength reduction and a good wet crease recovery. The high strength loss in dry curing result from the fact that the fibre is kept at a temperature in excess of 140°C for long periods, which means that an unnatural state of dryness must be maintained for the reaction to take place. The fabric undergoes structural and dimensional changes. In a normal climate, crosslinking prevents the fibre from returning to its original shape, due to the inner tension produced which affects the strength. The low levels of strength reduction that occur after moist and wet crosslinking can be attributed to the even distribution of the crosslinking bridges across the fibre cross-section. Bunching of the crosslinker in certain places results in a negative influence on the strength according to this theory.

a) Moist crosslinking: variant of the process, in which reactions occur on partially swollen fibres with a specific level of residual moisture, the temperature is below 50°C and room temperature is the ideal. The dwell or reaction time is correspondingly longer (over 10 hours, frequently 16–24 h). In moist crosslinking, fabric moisture, reaction temperature and liquor pH are closely related to each other. If the temperature is lowered, a longer reaction time and a stronger catalyst is required. If moisture levels increase, acid concentration in the liquor must also increase. Working pH levels should be between 1 and 2. The essential phases of the moist crosslinking process are impregnation, drying (to residual moisture levels), dwelling and washing. The technical problems associated with the process are mainly in the following areas:

– recipe formulation,
– drying phase,
– residual moisture retention.

The problems associated with recipe formulation are selecting the crosslinker and the catalyst. The crosslinker must be hydrolysis-resistant because of the low pH level. 5 and 6 link N-methylol compounds (reactive resins) are used almost exclusively for this. So-called “caustic catalysts” are used; these are usually a mix of metallic salts with medium-strength organic or inorganic acids. It is also important to maintain a constant drying temperature (100 – max. 120°C) because of the low pH level. Higher temperatures result in extreme or unacceptable reduction in breaking strength and abrasion resistance, even if the residual moisture level remains constant. If catalytic salts or compounds are used in the drying process, the problem is avoiding troublesome early reactions. In addition to this, residual moisture has a significant effect on the final quality of the fabric. The dry creasing angle increases in proportion to the decrease in residual moisture, and in this instance the reduction in breaking strength and abrasion resistance. The “safe area” can only be defined approximately because of differences in the equipment used for measurement and control, and because of the large quantity of articles. The level of moisture that is the closest to ideal must be defined individually for each plant, depending on the circumstances. If residual moisture is to be maintained at an exact constant level, devices for measuring and controlling moisture must be installed on the drying machines.

b) Wet crosslinking: as is the case with moist crosslinking, the crosslinking reaction takes places during the dwell period, i.e. in a swollen state (long-term reaction). Usually a very high wet creasing angle, a moderate dry creasing angle and low strength loss are targeted in wet crosslinking. If cellulose that has been swollen in water is crosslinked, the more permeable areas between the fibrils (amorphous) are opened up to such a degree that the intervals between neighbouring micro-fibrils of the crosslinker molecules can no longer be bridged. For this reason, crosslinking occurs mainly within the denser area (crystalline) of the elementary fibrils, in other words it is an intramicellar reaction. The wet crosslinked fibres can undergo interim drying and then re-swell when water penetrates into the amorphous areas where hardly any crosslinking has taken place.

Resin-free finishing High-grade (resin) finishing process, which leads to cellulose crosslinking, in other words, self-crosslinking of the finishing agent is eliminated. In practice, resin-free finishing is almost impossible. Resin-free finishing includes → Formaldehyde finishes.

Resin migration Migration of pre-condensates and catalysts within the yarn and between thread systems during the drying process in resin finishing. The main effect of this is worsening of abrasion resistance in crosslinked cotton fabrics.

Resinous cement Melt 1 part colophony and 1 part beeswax in an iron bowl. After cementing, residue is removed using spirit or carbon tetrachloride. Application: Cement for bonding metal/wood.

Resin resist printing → Wax resists.

Resin soaps (resin acid metals, resinates, colophony soaps), manufacture by boiling → Colophony with caustic soda liquor. If pre-made commercial soaps are bought, they must be guaranteed free of resin, or the resin content must be declared (x% fatty acid, x% resin acid). Although resin soaps foam well and have good cleaning properties, they only represent moderate soaping qualities (extreme hydrolysis), which can be significantly improved if they are used in combination with fatty acid soaps. Resin soaps are used as a basis for anti-slip and anti-snagging treatments, and are sometimes incorporated with ordinary hydrophobic agents. Manganese and cobalt resin soaps, etc. can still be used as drying agents.

Resin-soluble dyes →: Synthetic resins; Oil- and-fat soluble dyes.

Resin stains Fresh: sticky; older: sensitive to fingernail pressure; becoming darker in colour on ironing. Removal: a) initial softening with turpentine oil, then benzene or (warmed) tetrachloroethylene (perchloroethylene); b) benzene/carbon tetrachloride 1 : 1–5; c) acetone, particularly with benzene 1 : 1; d) carbon disulphide, followed by benzine or benzene; e) sulphurized ether, poss. with chloroform. Must be repeated several times.

Resin sulphonation products Direct sulphonation of resins (e.g. colophony) results in products of a sticky nature that are suitable for sizing and anti-slip finishes. Under intensive conditions, lime-resistant resin sulphonation products with wetting agent characteristics are produced. Sulphonate compounds of abietic acid and castor oil have good wetting and foaming properties. The sulphonate of abietine, combined with terpineol or pine oil, also has excellent wetting properties. Decarboxylised resins generate non-oxidized oils suitable for use as scrooping agents, etc. Finally hydroabietinols are sulphated, forming similar products to fatty alcohol sulphates for wetting, sizing, crease elimination, etc. However they have not achieved the significance of other surfactants.

Resin varnishes → Lacquers.

Resistance thermometer (resistance pyrometer, → Thermometer). Resistance thermometers are the most suitable instruments for measuring temperature precisely (see Fig.). These thermometers use a conductor (e.g. platinum coil with 100 Ÿ at 0°C) to measure the temperature dependency based on ohmic resistance. The stability over a period of time, measured over a year, is better than ± 0.5°C. Since the measuring insert with an internal conductor and resistor is contained within a protective tube, and the mass of the protective tube is usually far too great, the response time is usually correspondingly high. For this reason, resistance thermometers of this type are unsuitable for an environment where measurement and control needs to be rapid.

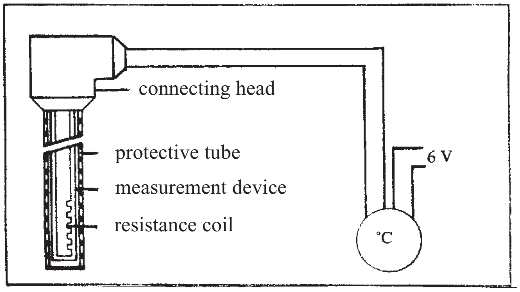


Fig.: A resistance thermometer.

Resistance to creasing Scale for measuring the resistance of textiles to → Creasing. → Crease resistance.

Resistance to deformation If an external force acts on a textile, it will be stretched or compressed; the usual measure for resistance to deformation is the modulus of elasticity (→ Tensile elasticity).

Resistance to tear propagation Required strength when → Tensile force is applied to the bearing width for sudden tear propagation of a fabric section from an initial cut. There are various different methods of testing this.

Resistance value, flexing fatigue limit (flexional resistance). Fibres, yarns and fabrics are tested whilst subject to initial tensile stress, under a certain bending or flexion angle (generally ±180°) by bending in alternate directions until breakage point. The result is what is known as the flexing fatigue value or flexional resistance value, for which Böhringer gives the following rounded figures:

flax	880
jute	1050
acetate filament	300
viscose filament	2500–7000
viscose spun fibre	800–1400
cuprammonium rayon	20 000
cotton	65 000
silk	75 000
sheep's wool	156 000
polyamide 6.6	45 000
polyamide 6	500 000

It should be noted that small differences in grip pressure and grip quality can give rise to widely varying values. In principle the level of the flexing fatigue value depends to a great extent on the type of raw material and yarn, the fabric structure and also from any finish effects. Lower values indicate high brittleness and low chafe resistance (especially at fabric edges and folds). Equipment for testing the flexing fatigue limit is therefore not only used for the evaluation of the wear resistance of textiles, i.e. the practical wear resistance and durability, but also to test the effectiveness of finishes of all kinds.

Resist effects by reversible fibre modification Bi-colour cellulose fibre formation arises as a result of printing of crosslinking agents, initiating crosslinking by means of heating, fabric dyeing with cellulose dyes, where crosslinked areas will resist the dye. Subsequent hydrolysis of crosslinking agents with acids, and finally re-dyeing of the entire fabric.

Resist fibre stripping Stripping of fibre areas where a resist effect is required when dyeing mixed fibres.

Resist printing (resists, reserve print). There are two different types, pre-printed and over-printed resists, depending on whether the resist print paste was applied before or after preparation of the fabric with dye solution. In both cases, the dyeing of printed areas is prevented. The most suitable context for application is in conjunction with non-dischargeable dyes. The following categories can be distinguished:

I. Mechanical resists (paste resists): wax reserves (resin, wax, etc.) block dye access to the printed areas mechanically.

II. Chemical resists: break down the chemicals required for dye-fixing on printed areas.

III. Chemical-mechanical resists: combination of I and II. As well as breaking down the dye-fixing chemicals, insoluble salts are usually formed as well as an extra layer of protection.

All resist processes can be divided up into white and colour resists. With white resists, only resist agents are used, for colour suitable dyes or dye combinations are added to the resist agent (colour illumination). In addition to selecting a good dye combination, the pH should be monitored very carefully. Adhering to the appropriate parameters for ground and resist is imperative to ensure that a high standard of reproducible resist effects is achieved. Dispersion dyes can be used under certain circumstances as well as anionic dyes for colour illumination in the resist printing of polyamide carpets. Since no resist is necessary for dispersion dyes, their fixative action is not negatively affected either by the resist agents used or by the pH. Further variants are possible if cationic dyes are used, which in turn are capable of dyeing resist agents with fibre affinity. However, the light fastness is usually insufficient.

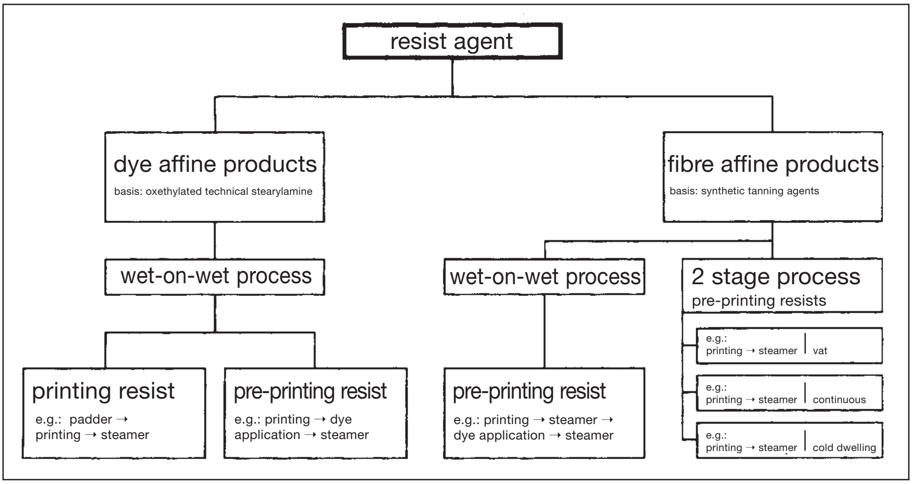


Fig.: Resist agents and resist processes as shown by the example of polyamide carpet resist printing (Bayer).

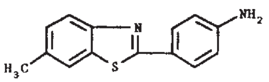
The resist agents can be split into two chemical categories (see Fig.), i.e. during the process there should be a differentiation between the use of resist agents with dye affinity that alter dye uptake and the compatibility of dyes in combination with each other, and resist agents with fibre affinity that are used for instance to block the amino groups in polyamide fibres (Wirtz).

Resist techniques in transfer printing → Transfer printing resist effects.

Resolution Optical: interval between two points of the object (specimen), so that they can still be distinguished as separate entities under the microscope, for instance. Calculated by dividing the wavelength of light used for illumination (in the visible spectrum resolution limit approx. 0.4 µm) by the selected numerical aperture (formula for centrally-positioned illumination, almost double the resolution for angled light).

Resonance spectroscopy → NMR Spectroscopy.

Resonance structure Dye molecules are chemically structured so that a large number of π electrons in conjugated double bond systems can be excited by light energy. So there are a number of limited mesomeric forms, which are captured by the π electrons in a very short period due to oscillation (→ Mesomeric resonance). The most stable form of energy is thereby the limited mesomeric structure formula with the lowest energy level. The benzolthiazol group causes resonance in each molecule and the transmission of one resonance form into another in turn results in the colour of the compound. With a larger number of resonance forms, the transmission of one resonance form into another requires less energy. This leads to a colour enhancement, as was observed in the transmission from mono- to di- and tri-dehydrotoluidin.



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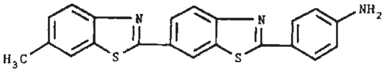

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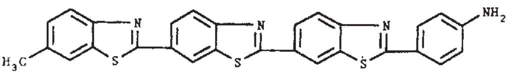

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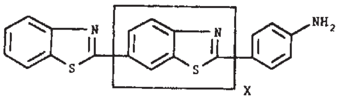
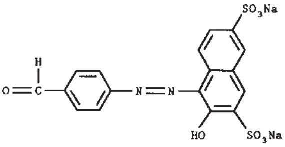


IV

If the formation of a colour can be due to the resonance within a molecule, dyeing on the other hand, is likewise due to resonance, namely between molecules, e.g. between dye and cellulose. An intermolecular resonance system is therefore formed, which determines the affinity of the dye to the fibre. With intermolecular resonances, the space in which they can be active is increased to two molecules. An increase in the possible resonances and a reduction in the energy demand when transmitting from one resonance into the other therefore results. This follows a deepening of the shade as is the case with benzaldehyde-p-azonaphthol-disulphonate (V), whose red dyeing on cellulose fibre turns into violet when lightly heated using water.



V

(according to Riesz).

Resorbable yarns Medical sewing thread should normally be removed from the body by extraction. Work is in hand to develop sewing threads, which are resorbed after healing especially for stitches on internal organs. These may, for example, be collagen sewing threads, which are not rejected as similar protein by the body or polyvinyl alcohol threads, which are gradually dissolved and eliminated as a water-soluble polymer.

Resorcinol (metadioxy benzene), $C_6H_4(OH)_2$; molecular weight 110; density 1.283; colourless crystals, slightly sweet tasting, water-soluble; also soluble in alcohol, ether, glycerol; melting point 110/111°C. Gives violet dyeing with iron chloride solution. Use: solvent (phenol considered) for cationic, united chrome dyes and tannic paints; for the fixation of cationic dyes on acetate; saponification of acetate; antiseptic (finishing effectiveness practically the same as phenol).

Resorption (to absorb). Drawing in and/or soaking up, e.g. of dirt particles distributed in the liquor by laundry articles. The washing agents should counteract this effect through their soil suspending property.

Respiratory poison (odour poison). Poison, damaging to the respiratory organs, such as ethylene oxide (tear gas), chlorine gas, phosgene and carbon disulphide. Respiratory poison health hazards: → TLV values. Respiratory poison for textile parasites: → Mothproofing.

Response factor In environmental analysis, certain analysis methods reproduce true content with a certain error. Above all, in exhaust gas analysis, a one-hour test with silica gel or activated carbon in the bypass of an exhaust air outlet should, for example, be

Response factor

substance	proportion of carbon	response factor r_S	correction factor K
methanol	0.38	0.77	5.5
ethanol	0.52	0.90	3.4
i-propanol	0.60	0.70	3.8
propane diole	0.47	0.80	4.3
formaldehyde	0.40	0.30	13.4
decane	0.85	0.95	2.0

Tab.: The response factor and correction factor for FID (far infrared) measurements.

carried out by gas chromatography/mass spectroscopy (GCMS). The exhaust air contents so adsorbed must be extracted in the laboratory (off-line) using a solvent (e.g. carbon disulphide) before the resulting solution is injected into the gas chromatographs. The answer (response) to this complex isolating operation is a material loss in the individual steps; above all only a percentage of the harmful pollutants are desorbed depending on the chemical structure of the adsorbed molecules. The Fig. shows such vapour space material analyses, which are discharged from polyurethane fabrics at 180°C.

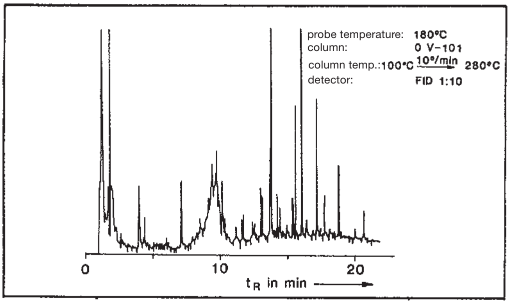


Fig.: Head-space-analysis of the drying of polyurethane raw goods and their heat fixation at 180°C.

The test was carried out in a commercial apparature by head/space gas chromatography. It reveals that a multitude of individual components is emitted into the surrounding air at high thermofixation treatment temperatures. These can be identified and quantified in a full analysis with the aid of comparative materials. In identification, the combination of gas chromatographs with a mass spectrometer and/or an IR spectrograph could considerably alleviate the analytical task; but even then the qualitative and quantitative analysis of the contents of exhaust gases still remains an extensive job, as the evaporable substances of other fabrics or of fabrics with other dyes may have a completely different composition. Due to this costly separation, identification and quantification, it is customary to determine so-called summation parameters such as methane or propane equivalents. In this connection the organic contents are not separated, but directly detected using an FID and the common signal compared with a corresponding methane or propane concentration.

The FID signal is proportional to the carbon concentration of the reference substance, e.g. propane c_{CP}, and the substance to be determined c_{CS}, if the measuring test only contains one substance:

$$r_P \cdot c_{CP} = r_S \cdot c_{CS}$$

The respective response factors r_P and r_S are firstly unknown. The response factor of the reference substance is arbitrarily assumed to be r = 1. The carbon concentration of the substance to be determined is consequently

$$c_{CS} = \frac{c_{CP}}{r_S}$$

The conversion into the mass concentration of the substance to be determined c_{MS} results in

$$c_{MS} = \frac{(MG)_S}{r_S \cdot n_{CS}(AG)_C} \cdot c_{CP}$$

$(MG)_S$ = molar weight of the substance to be determined,
n_{CS} = number of C atoms in the substance to be determined,
$(AG)_C$ = atomic weight of carbon.

This is calibrated to the volumetric concentration of the reference substance propane c_{VP}, so results in

$$c_{MS} = \frac{(MG)_S\, n_{CP}}{r_S \cdot n_{CS} \cdot \text{molar volume}} \cdot c_{VP}$$

and with the carbon proportion of the substance to be determined

$$(\mathbf{C\ proportion})_S = \frac{n_{CS} \cdot (AG)_C}{(MG)_S}$$

This is how the connection between mass concentration of the substance to be determined and the volume concentration of the calibration gas propane is obtained

$$c_{MS}\ [mg/m_N^3] = \frac{1.6}{r_s\ (\text{C-proportion})_s} \cdot c_{VP}\ [ppm]$$

$$= K \cdot c_{VP}\ [ppm]$$

Some response factors determined using propane as a reference substance are compiled in the Table. The correction factors given result from the factor 1.6, divided by the respective response factors and C proportions of the substance to be determined. These correction factors can be very different depending on the substance. In particular the low responsiveness (factor 13.4) of the FID to formaldehyde is emphasised. That is why formaldehyde is not directly determined in the exhaust gas. On the assumption that the exhaust gases from fixation processes in textile finishing, for example, contain principally long-chained aliphatic compounds with low concentrations of functional groups, the correction factor 2 can be used approximately for the conversion of the directly determined propane equivalent in the mass concentrations of organic substances.

Retarder Auxiliaries, which decelerate the uptake of cationic dyes, e.g. in polyacrylonitrile dyeing, and thereby have a levelling effect. These are colourless cationic substances, which enter the fibre with the dye in competition for binding sites, or systems of anionic and non-ionic auxiliaries, which have a dye affinity.

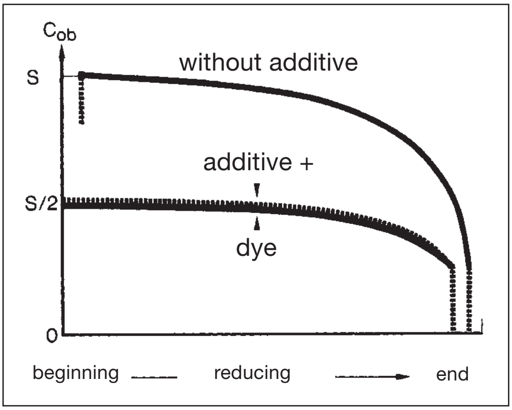


Fig.: Change in the concentration of dye C_{ob} on the fibre surface during the dyeing of polyacrylnitrile fibre (a) without and (b) with a retarder, having the same dyeing properties and in the same quantity (according to Bayer).

Retarders influence the adsorption characteristic (see Fig.). With the correct choice of retarder and quantity used, the impoverishment of the liquor only has a small effect on the fibre surface. Added to this is the fact that temperature differences have less effect, as the retarder also influences the diffusion in the fibre, which encourages migration. Uptake control devices and retarders complement each other. The retarder quantity can be reduced if higher affinity products are used, which uptake before the dyes. This is rarely exploited, as it involves the risk that the dyes uptake too quickly in the 2nd half of the uptake phase. Control devices and/or the use of these drafted temperature programs can avoid this risk. Retarder quantity and uptake time can be optimised this way.

Retarding Slowing down, decelerating, braking; e.g. the dye uptake speed, which occurs in all dyes involved in the sense of levelling, but which is also capable of having a selective effect on certain dyes and would at least severely disrupt the levelling of such dye combinations.

Retarding agent (retention agent), is used to prevent staining of a fibre type when dyeing textile blends. Retarding agents mostly have properties of mordants, which effect the textile fibre to be retarded before or during dyeing and consequently cause a change in the dye affinity (→ Mordanting). This in practice has the effect that in blended fabrics the retarded portion appears white or a different colour, if already dyed before retarding. So-called sulphurised phenols (thiophenols), sulphurised oils (for retarding polyamide), phenol condensates and inorganic salts (as well as e.g. ammonium thiocyanate and the like), are chiefly considered as retarding agents.

Retention Retentivity of fibres, e.g. →: Chlorine retention; Water retention.

Reticulation process is used to remove spurious glittering of the surface of foam coatings, which is caused by the network structure.

Retouching,

I. Removal of blank, yellowed, colourless fabric areas or those altered in colour, caused by intensive → Stain removal on non-colourfast parts or by concentrated chemicals, by possible careless stain removal or by the effect of perspiration (armpit areas), etc. Implementation:

a) using retouching pencils (coloured → Wax crayons and/or pastel crayon) especially for smaller areas on rougher materials;
b) using concentrated dye solution (benzine or alcohol soluble dye) soaked soft small woollen pieces of cloth or
c) by means of compressed air spray gun, which repre-

sents a considerable enhancement to stain removal and requires a lot of knowledge and practice because it should be "invisible", although its colour fastness is usually only low.

Final steaming of retouched areas encourages better durability.

II. Processing or levelling of defective textile fabrics or garment panels. Improving visible defects by artistic means.

Retouching inks Distinctions are made between liquid, paste and powdery retouching inks. Liquid retouching inks usually contain alcohol or oil soluble dyes. Retouching print pastes, for example, represent substances pulped with oleic acid, which are used directly or possibly diluted with benzine. Retouching ink powder (→ Spotting agent) are chiefly so-called coloured → Talcum varieties, mostly dust-free, for dusting and rubbing in, for refreshing dry-cleaned gloves, etc.

Retouching of rollers in roller printing Manual work to restore damaged printing rollers.

Retouching pencils For retouching, repairing afterdyeing and/or darkening of light materials or of dyeing faults, even in ready-made fabrics. Pressure-fast and fast to hot pressing pastel chalks/wax crayons are chiefly used as retouching pencils in large ranges of colour or with pencils filled with retouching ink. Permanent retouching pencils should be suitably sharpened in the form of a flat spatula before retouching. Finally a little re-levelling by hand or small pieces of cloth in order to achieve better colour transmission.

Retroactive (Lat.: retro = backwards), retrospective.

Retrogradation Degeneration. Common term for, e.g. retrograded starch. Usually starch liquors, after a short time, become cloudy again at low temperature and insoluble starch flocks fall out. This retrogradation of amylose molecules (through strong secondary valency forces) can cause just as unfavourable shifting of the sizing effect as possibly later aggravated desizing after a longer dwelling period. However, only liquors (pastes) made from natural starch and not those made from alcoholic precipitated starch, which are frequently for sale as soluble and/or partially decomposed starch products, can retrograde.

Retting (maturing stage). Biological degradation (rotting process due to bacteria and/or pectinase and fungi) for the exposure of → Bast fibres by decomposition of the vegetable glue and/or locking of the cellulose cells and exposure of the fibre bundles. Varieties: dew, water, hot water retting. Duration (days or weeks) dependent on variety and type of bast fibre, temperature, etc. → Flax processing.

Returns Batches rejected by the customer due to deviations from the quality standard, with the condition of remedying the faults.

Reusable dye tubes Dye tubes made from plastic can be used several times (reusable) for the dyeing of yarn reels (particularly in full range plants). However → Disposable dye tubes are subject to the recycling process (melting and repressing).

Potential problems from reusable dye tubes:

- staining with disperse dyes,
- costly storage space,
- deformations with shrinking fibres,
- in-house logistics.

Reutlinger matte Network made from thin textile fibres for the separation of oil from waste water.

Reutlinger pillstandard (RPG). For the visual assessment of pill formation (→ Pilling behaviour, test methods). Contains 8 stages: RPG 1 = stippled, bobbly fibrous; RPG 8 = maximum pilled. During the test operation, the degree of pill of the sample is visually assessed at certain intervals using the RPG and the value found, input into a diagram depending on the pill duration in the tester. The pilling tendency of the processed fibres can be developed from the pilling curves obtained in this way.

Reverse coloration method (RCM). The colour is applied onto the pre-padded, wet carpet material from the back side using dye liquor. It is also possible to carry out the dye liquor application repeatedly using different liquors.

Reversed-tailing-effect Designation for end unevenness in padder dyeings, is caused by the fact that the fabric takes up more dye than corresponds to the absorbed liquid volume; dye concentrate increases in the colour box so that the end of the batch is darker than at the beginning.

Reverse Dyeing Process for polyester/cellulose Discontinuous dyeing process for bright to medium shades of colour in machines, winch becks and jet equipment. In contrast to the customary dyeing methods of polyester/cellulose materials, in the reverse dyeing process the cellulose fibres are dyed first and then the polyester fibres. This process can only be used in cases in which a reductive after cleaning treatment is not applicable. The reverse dyeing process saves energy and time. In addition, it can be processed using simple machinery.

Reverse osmosis (hyperfiltration). Membrane separation process (→ Permeation), which is used for filtrating waste water. The process is becoming ever more widespread, as the level of development of membranes permits correspondingly large cleaning rates (tubular membrane modules for example, promise greater throughputs).

The reverse osmosis results from a pressure (of 40, 60, 80 bar) exerted by the concentrated solution on the semi-permeable membrane (polyamide 6.6-/acetate sheets). The solvent (water) migrates from the concentrated solution through the membrane and is described as a permeate. The dissolved substances remain as a

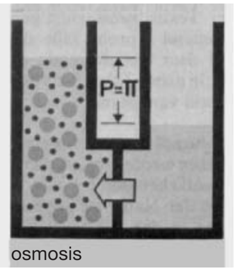


Fig. 1: The principle of the process of osmosis.

concentrate. This process is called “osmosis”. After some time, this process reaches a state of equilibrium, at which a hydrostatic pressure is adjusted by the volume shift, which is described as the “osmotic” pressure (Fig. 1). If a pressure is exerted on the concentrated solution after the state of equilibrium has been achieved, which is higher than the osmotic pressure ($p > \pi$), the process of osmosis can be reversed (Fig. 2). Then solvent from the higher concentrated solution migrates into the diluted solution. The membrane retains the dissolved materials, which accumulate into a “concentrate” in the residual solution. The “permeate” (and/or “filtrate”) penetrates the membrane. This process is suitable for the separation of ions or small organic molecules; adjacent macromolecules are likewise retained.

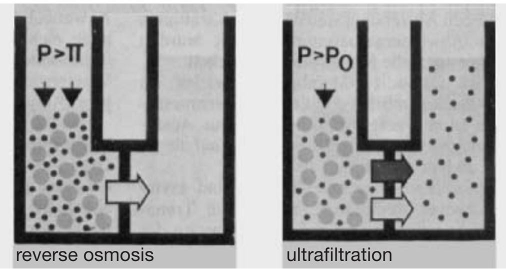


Fig. 2: Diagram showing the processes of reverse osmosis and of ultrafiltration.

The separation process is carried out by → Ultrafiltration similarly as in reverse osmosis. The difference lies in the separation of dissolved particles of different sizes. Totally dissolved macromolecular substances and emulsions are included; ions and smaller molecules pass through the membrane. The osmotic pressures of solutions of high molecular materials are much smaller than those of solutions of low molecular substances of equal weight concentrations. That is why the osmotic pressure in ultrafiltration is negligibly lower and the operating pressures are considerably lower than in reverse osmosis.

The membrane is the most important element in the application of this process technique. Besides its chemical resistance to substances occurring in the textile waste water it should also be mechanically robust and not susceptible to breakdowns as well as have a permeate output as high as possible.

This process is used for the separation of macromolecular substances, such as polyvinyl alcohol, of the solvent (water), of ions and low molecular substances. Chemical changes do not take place in the course of the process.

Reverse roller coating Coating method, in which the coating preparation is not directly applied onto the substrate, but firstly on rollers. In the reverse roller coating in Fig. 1, a doctor blade cleans the roller, which comes into direct contact with the fabric, while a third roller in the Reverse Roll Coater operates without being cleaned (Fig. 2).

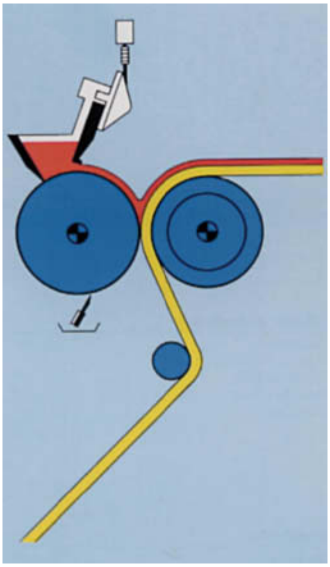


Fig. 1: Reverse coating (Kleinewefers KTM: Universal Coater).

Reverse winder is used for the turning of rounded or piece goods sewn in the tube.

Reversible Reversible; opposite to → Irreversible (not reversible). Designation for state of equilibrium in chemical reactions with corresponding properties; e.g. a precipitate formation, which under certain conditions (e.g. temperature) results in re-dissolution and the converse; also in colour formations. Example: base exchange water-softening processes, in which the working method of the zeolite (filter) has a typically reversible character.

Reversible carpet Jacquard patterned, thick → Flat carpets made from two or more interwoven warp and weft systems. The design on the top appears col-

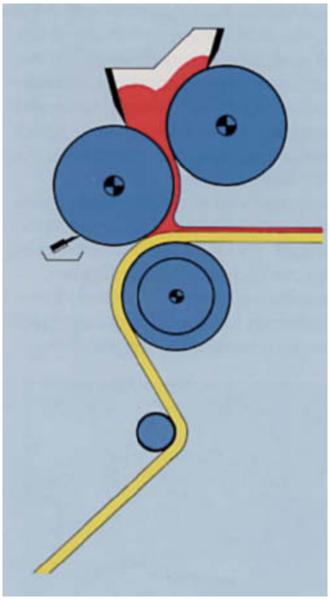


Fig. 2: Reverse roll coating (Kleinewefers KTM: Reverse Roll Coater).

ourwise to be a negative of the bottom (Kidderminster carpet, treeply or double-faced carpet).

Reversible fabrics Garment and coat materials, which can be used on both sides and are distinguished by weave (e.g. on the right, twill weave, on the left, satin weave; also double binding of materials such as in coat materials with woven lining), lustre or colour. Reversible crêpe e.g. →: Crêpe reversible; Crêpe satin.

Reversible methylene blue method For the determination of the → Methylene blue number. The methylene blue absorbed on the fibre is removed from the fibre using diluted hydrochloric acid and determined by colorimetric measurements.

Reversing action Intermittent change in direction of rotation of machines, in contrast to → Rolling.

Reversing drum A drum, for example, in multi-stage stenters and drying machines for the controlling and reversing of piece goods.

Reversing, stenter Stenter with non-contact, air-supported reversing of the material web (see Fig.). Entry and exit of the material length at the same end of the machine. Operating area corresponds to that of the → Single-layer stenter.

Rewetting Important part of the washing process, which runs in the opposite direction from previous → Wetting, because a fibre, for example initially "wetted" by oil, is wetted by the aqueous detergent solution at the end of the washing process, after removal of the adhesion forces of the oil smuts (ball formation). This phenomenon is described as rewetting.

Rewinding machine For the rewinding of dyeing muffs on reels for sale, with an outlet velocity of 200 to approx. 500 m/min, electric shutdown devices for thread breakage and when reel diameter is reached.

R_f (retardation factor). The distance between substance starting point and migrated substance stain (stain centre) in paper and thin layer chromatography, divided by distance between starting line and front of flowing material.

The dissolved substance examined is characterised by R_f value and colour of the substance stains migrated on the adsorbent. R_f is regarded as a substance-specific constant Ï with a strong deviation tendency (usually restricted reproducibility demand) depending on operating conditions; it is especially not ideal to depend on the subjectively established stain centre, but more oval or diffuse stains. It is therefore better to talk of an R_f range and consider this only as a reference point for the suitability of the fluid agent, i.e. whether the chromatographic compound is not too close at the start or migrates along in the front of the flowing material. Working with comparative substances or at least with test mixtures is recommended in order to eliminate the most likely errors. Only completely dissolved substances are clearly suitable for the formation of stains, as undissolved particles dissolve again in the flowing material and encourage an irritating "tail formation".

RF-Drying → High frequency drying.

RF value (degree of wash whiteness) → Whiteness, degree of.

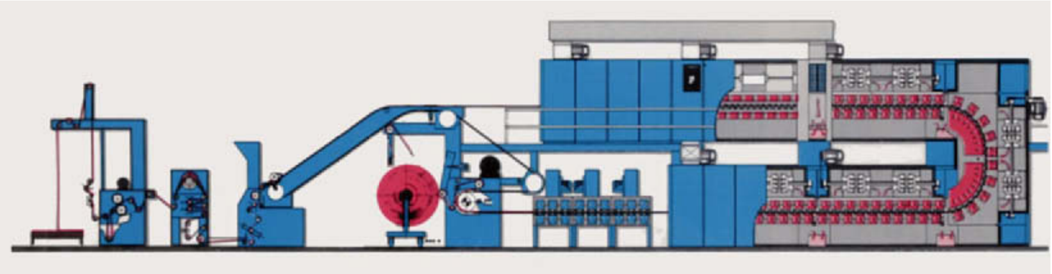


Fig.: The Krantz K 10 D reversing stenter.

RGB colour measurement system This so-called “international trichromatic RGB system” is based on the law that any four types of radiation can have a known relative light composition, but an unknown light intensity from any two are independent from three types of radiation in the corresponding mixture. The following radiation components were selected for filters in this system:

R = red = 700.0 nm
G = green = 546.1 nm
B = blue = 435.8 nm.

Rh Element symbol for rhodium (45).

r_h → Redox potential.

Rheological behaviour of solutions Newton’s law of viscosity is the starting point:

$$\text{dynamic viscosity} \quad \eta = \frac{\tau}{D}$$

I. Newtonian fluids obey Newton’s law of viscosity. The viscosity is a constant at constant temperature. The flow curve is straight. The angle ϑ is a measure of the viscosity.

II. Non-Newtonian fluids (high polymer solutions especially in higher concentration) do not obey Newton’s law (only very few exceptions). The viscosity η is not a constant; it depends on the shear gradient D and possibly on the stress period t. Model:

1. η depends on D, i.e.
   a) η grows with increasing D = dilatant behaviour.
   b) η decreases with increasing D = structural viscosity (pseudoplastic) behaviour.
2. η depends on D; a flow limit τ_0 exists (minimum stress), below which the substance behaves like a solid = plastic behaviour, often connected with structural viscosity.
3. η depends on D and t (time) (often connected with a flow limit τ_0), i.e.
   a) η grows with t = rheopexic behaviour.
   b) η decreases with increasing t = thixotropic behaviour.
4. Viscoelastic behaviour, if besides ultimate shearing strain (characterises viscous behaviour and permanent deformation) compressive and tensile stresses (characteristic of flexibly reversible deformation) also have an effect on the solution.

→ Rheology in printing and coating.

Rheology (Gk.: rheo = to flow), describes how a body is deformed by externally loaded forces. In the case of print pastes and coatings, for example, it concerns fluids, which are subject to ultimate shearing strains. The paste is made to flow by an applied shear force, i.e. the polymer molecules move past each other. The resistance to this forced irreversible volumetric change is called → Viscosity. This is substantially influenced by the molecular weight and density of the particles. →: Rheopexy; Thixotropy; Viscoelasticity.

Rheology in printing and coating Laws of rheology play a crucial role both in printing and in coating as the basis for these textile finishing processes. The flow behaviour of the print pastes influences the print quality. In many cases empirical methods for the assessment of print paste consistency no longer fulfil the requirements in accordance with production safety and reproducibility. It is possible to record the parameters of a print paste which determine quality, viscosity and flow characteristics of printing thickeners and print pastes metrologically using rotary viscometers.

The coating process may be regarded as a complex process. The rheological characteristics of the print paste should be regarded as factors which determine quality if the adjustable and influential sizes on the machine such as printing speed, squeegee setting, squeegee pressure and level in front of the doctor blade are kept constant. So the following factors are significant for the metering of the applied quantity by means of an air blade system:

– viscosity of the paste,
– rheological behaviour of the paste,
– tensile stress of the fabric,
– development of the coating knife bevel,
– inclination of the coating knife,
– speed at which the fabric is moved under the coating knife.

Coating pastes generally represent complex rheological bodies: They do not obey Newton’s law over a large measuring range, but show dependencies on the demand period and the shear gradient. The apparent viscosity and a likewise shear dependent elasticity are declared as the characterisation of the pastes. The thickness of the coating depends on the following sizes in the direct application method:

– distance between doctor blade and base material,
– type of base material to be coated,
– type and shape of doctor blade (roller doctor blade, air blade, etc.),
– viscosity of the paste,
– outlet speed of the base material.

As is obvious from these parameters, the rheological properties of the coating pastes are of particular importance: rheological processes, interfacial processes and drying processes are basic functions, in which the rheological processes should be observed under the machine conditions.

The flow of coating and print pastes corresponds to the model of the flow between two parallel sheets, in which one of the sheets is reduced to the size of the cutting width of a doctor blade and the other sheet corresponds to the substrate. Substrate or doctor blade can be moved alternately. A laminar flow is produced in the fluid between the sheets. The main values of the vis-

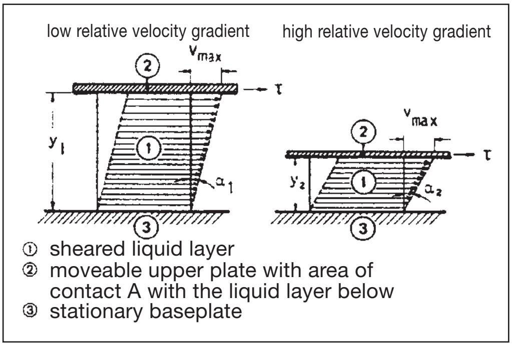


Fig. 1: Flow within the space between two parallel flat plates moving in opposite directions.

cosimetry, the shear stress τ and the shear gradient D can be defined via the sheet model (Fig. 1).

The basic law of viscosimetry is:

$$\eta = \frac{\tau}{D}$$

The shear stress τ is the ratio of the force F relative the surface A of the liquid contained beneath. An effective shear stress allows the liquid to flow according to its internal resistance. In this laminar flow (i.e., infinitely thin fluid layers move in parallel to each other) a shear rate D develops at right angles to the gap y. These correlations show that not only are the effective forces important in fluids, but also how quickly they are applied. One therefore talks of the dynamic viscosity η. The unit of dynamic viscosity η is the pascal second Pa s (1 Pa s = 1 N s/m^2).

The flow properties of a fluid can also be represented as a flow curve (rheogram) or via mathematical conversion of the measured results in a viscosity curve (viscosity characteristic curve). Fig. 2 shows the simplest case of a flow curve and the corresponding viscosity curve.

The viscosity of print pastes or coating agents, i.e. the physical behaviour of the fluid while it is in shear, may depend on four parameters:

- physical/chemical quality of the substance,
- temperature,
- shear gradient,
- time.

These parameters result in the fact that the viscosity is not a constant, but varies. Various viscosities therefore, appear in a paste at rest or during brushing. Liquids may have distinct rheological differences. Only Newtonian fluids show a viscosity behaviour as in Fig. 2. These are, for example, water and sugar solutions. The rheology of pastes or solutions of macromolecular substances differs significantly. The viscosity flow is not linear, but depends on the shear rate (Fig. 3). Such “non-Newtonian” liquids are more common by far.

1. Materials, which degrade their viscosity due to increasing shear rates, are called structurally viscous or pseudoplastic. A lot of technical and commercial substances such as emulsions, suspensions or dispersions belong to this group. The particles or molecules adapt themselves and may slide more easily over each other, i.e. the viscosity is reduced during shear.

2. Dilatant substances, which increase their viscosity with increasing shear rate, show contrary behaviour. Dilatancy is found in highly viscous suspensions, e.g. polyvinyl chloride plastisols; it is, however, relatively rare. It complicates the production processes in coating, as the flow resistance may be so high that the fabric webs to be coated may tear or even break machine parts.

3. The flow curve of plastic substances does not start at the zero point, but runs on the ordinate in order to be dissolved at the yield point. Plastic substances have a solid character at rest. As internal forces are greater than external acting shear forces, no flow at first takes place. Only when the flow limit is exceeded, i.e. with a certain applied force, can the volume elements

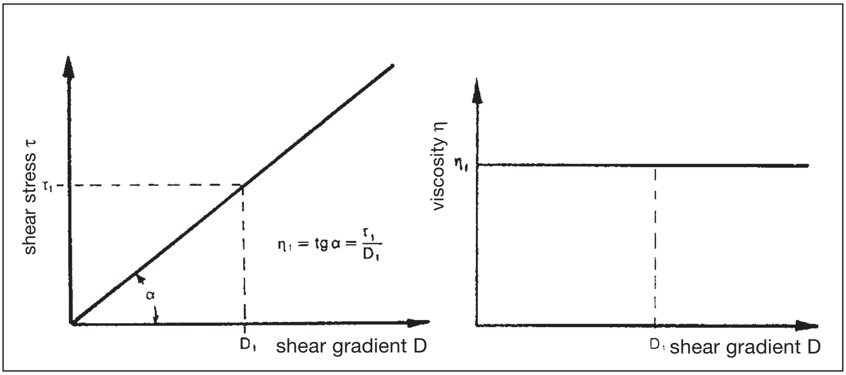


Fig. 2: The flow curve of a Newtonian fluid together with its corresponding viscosity curve.

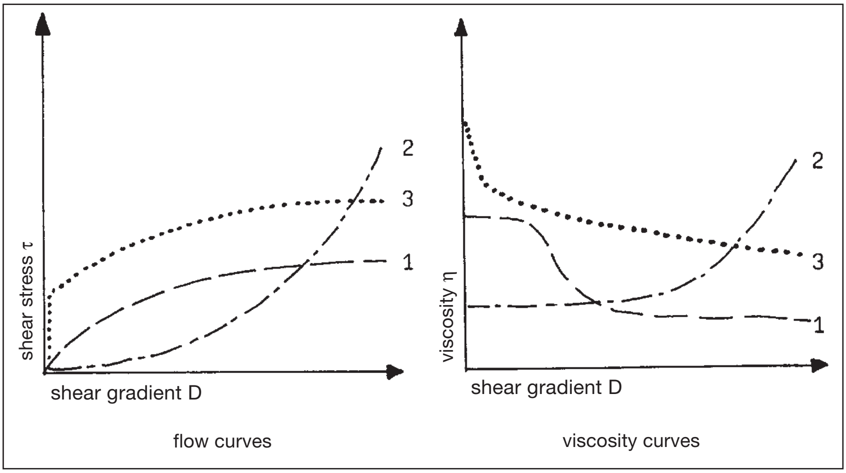


Fig. 3: Different types of common fluid behaviour. 1 = liquid with structural viscosity; 2 = dilatant fluid; 3 = plastic fluid.

change place. Plasticity is found in dispersions with large internal bonding forces. For example fats are typical representatives.

4. Over and above this, there are also substances with a flow behaviour, which strongly depends on the treatment period, e.g. shearing or regeneration time. These fluids usually also have a flow limit. Thixotropic or rheopexic liquids require a regeneration time in order to develop their typical viscosity, i.e. their internal forces, against a load (Fig. 4). Many dispersions show one of the degradation and/or structure dependent shearing times of bonding forces between the molecules or particles in the form of thixotropy. True rheopexy, i.e. increase in flow resistance with the shearing duration, is found extremely rarely. Rheopexy is often broken down by mistake, e.g. by setting or gelling. These processes, however, show no coincident hysteresis curves in a multiple program run as is the case in rheopexic and thixotropic liquids.

It is clear that the viscosity of print pastes or coating agents represents an essential parameter for the resultant textile finish. The viscosity has a significant effect on the coating strength and is considered in the choice

– of size of the doctor blade gap,
– of the shape of the doctor blade and
– the working speed.

In print systems, correlations can be combined between macromolecular structures in the colloids, their rheological phenotype and the print result, as shown in the Tab.

Two tasks fall to the softeners in coating pastes. They should give the necessary degree of softness to the finished coating and transfer the polyvinyl chloride into a paste state for workability. These kinds of paste produce highly viscous suspensions. Plastisol polyvinyl chloride powders are thereby mixed into liquid softeners. The viscosity of a paste for a given polyvinyl chloride softener system depends on the quantity of the freely available softener for the movement of the polyvinyl chloride particles in suspension. As this firstly divides the existing agglomerates into primary particles, a large specific surface area develops in the system.

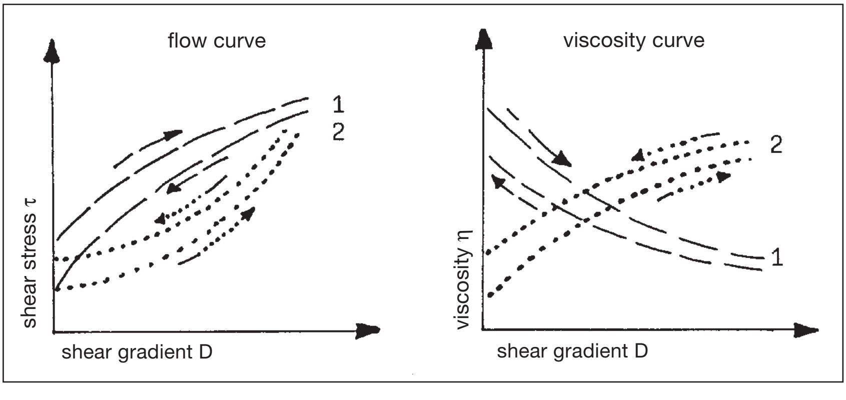
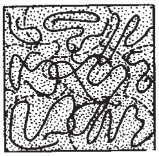


Fig. 4: Thixotropic (1) and rheopexic (2) flow characteristics.

Rheology modifiers/thickeners

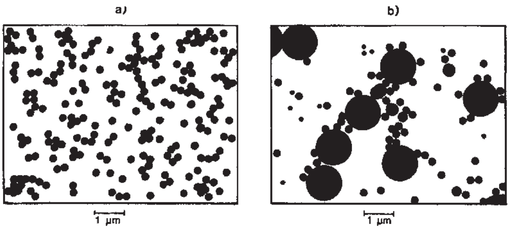
structure of the network solution	recognition features	rheological characterization	printing outcome	remedies
	polymer concentration $<c_{critical}$ free liquor	viscosity: low shear susceptibility: slight elasticity: none	colour density: high contours: poor ground: bleeding of free liquor into the fabric capillaries	increase the concentration of thickener consequences: viscosity increases, shear susceptibility increases, elasticity increases
	polymer concentration $>c_{critical}$ no free liquor few solid bodies small gel tangles	viscosity: medium shear susceptibility: n>0.5 elasticity: weak	colour density: high contours: good	optimum high dry material content
	polymer concentration $>c_{critical}$ no free liquor many solid bodies large gel tangles	viscosity: medium shear susceptibility: pronounced elasticity: strong	colour density: low contours: poor ground: inadequate colour density	increase doctor blade diameter, increase concentration of thickener since water may be removed from the network solution consequences: high to very high viscosity, shear susceptibility increases further, elasticity increases further

░ bound dissolvent ▨ free dissolvent ∞ chain material ⬚ volume of tangles

Tab.: Thickeners without a liquid limit: flour derivatives, alginates, cellulose derivatives, vegetable gums, hydroxycelluloses (according to DITF).

Because of this, rheologically more effective softener is extracted from the system due to the adsorption on the primary particles. As this process is executed, an increase in viscosity, controlled by diffusion, ensues with storage time.

Fig. 5 shows electron microscopic images of primary particles of medium high viscous plastisol with monomodal particle distribution (< 1 µm) and low viscous with bimodal distribution (particles ≥ 1 µm). In monomodal types, the structure of a three dimensional network, which results in high viscosity, is conceivable. In bimodal distribution, in general, low viscous pastes, their viscosity behaviour can be understood in such a way that small particles are bedded between large ones and so cause a ball bearing effect (Fig. 6). The large particles only have a lower activation threshold S to overcome in their change of position. In addition, it is conceivable that less space needs to be filled with softener in a bimodal distribution (according to Schulz and Herlinger as well as Knittel and Schollmeyer).



enlargement 20 000 x

enlargement 20 000 x

Fig. 5: Electron microscopic images of primary particles in polyvinylchloride paste types; enlargement 20,000 x. a) monomodal; b) bimodal.

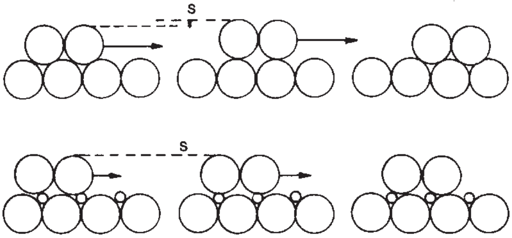
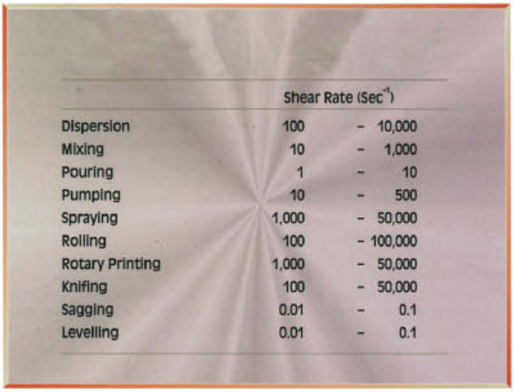


Fig. 6: Conceptual model of polyvinylchloride types of differing viscosity with monomodal or bimodal particle distribution. S = energy threshold for change of place.

Rheology modifiers/thickeners Although viscosity is often treated as a constant, only a few materials such as water and some mineral oils possess a constant "Newtonian" viscosity. In most fluids, viscosity varies with shear stress or shear rate. To completely describe the rheology of a formulation, it is necessary to know how the formulation handles, pours, pumps, coats, penetrates and spreads. Therefore, the correct choice of a thickener or rheology modifier is an impor-

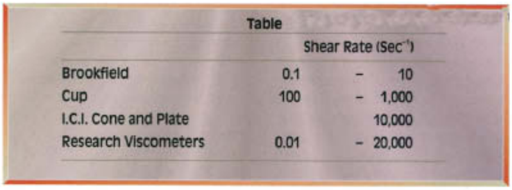


	Shear Rate (Sec^{-1})
Dispersion	100 - 10,000
Mixing	10 - 1,000
Pouring	1 - 10
Pumping	10 - 500
Spraying	1,000 - 50,000
Rolling	100 - 100,000
Rotary Printing	1,000 - 50,000
Knifing	100 - 50,000
Sagging	0.01 - 0.1
Levelling	0.01 - 0.1

Tab. 1: Typical ranges of shear rates for manufacturing and coating equipment.

tant one. The difficulty in making this choice is that the different processes involve different rates of shear. Generally, latex viscosities decrease with increasing rate of shear (pseudoplastic) and decrease with constant rate of mixing (thixotropic). However, every rheology modifier affects the overall viscosity profile differently. A useful principle for optimising performance of the latex is to test at the shear rates experienced during the course of processing and application. These operations occur over a wide range of shear rate which are shown in Tab.1.

Usually only research laboratories have equipment to measure all these flow situations. Typical plant viscometers, such as Brookfield or Cup (Ford, Zahn etc.) measure viscosity at low shear rates as shown in Tab. 2. This is adequate for pumping, pouring and possibly mixing, but it does not measure the flow characteristics of the coating in higher shear regimes where the system is less Newtonian. A simple tool recommended as a useful indicator to the coating chemist as well as for plant quality control is an I.C.I. Cone and Plate viscometer. When readings are coupled with those from a Brookfield viscometer, the rheological behaviour is seen over a much wider operating range. In these technical notes Brookfield readings are used to describe the handling characteristics of the product or formulation before application – the higher the number, the more viscous the product. Readings from the I.C.I. Cone and Plate viscometer are used to depict high shear behaviour such as those encountered during an application such as roller coating.



Table

	Shear Rate (Sec^{-1})
Brookfield	0.1 - 10
Cup	100 - 1,000
I.C.I. Cone and Plate	10,000
Research Viscometers	0.01 - 20,000

Tab. 2: Typical plant viscometers.

The wide variety of Rohm and Haas Acrysol thickeners and rheology modifiers that are available allow the formulator to choose the thickener that is ideal for his specific needs. Cellulosic materials like hydroxyethyl cellulose (HEC) do not offer the same wide range of products. The Acrysol thickeners provide improved rheological properties, handling chracteristics and resistance to microbial attack. In addition, the thickeners and rheology modifiers can be blended to get an optimal rheology for any application.

Alkali soluble or swellable emulsions: These Acrysol thickeners are acrylic polymers containing acid carboxyl functional groups that are designed either to dissolve or to swell when neutralised with a base. Compared to natural water-soluble thickeners, the Acrysol ASE family of polymers are considerably higher in molecular weight. Because they are produced by emulsion polymerisation, these polymers are present as dispersed particles (not in solution). They are therefore supplied and can be handled at low viscosity, and the shipment of viscous low solids solutions is avoided. These emulsions are much easier to use than conventional cellulosic and polyvinyl alcohol solutions. At the point of use, the Acrysol products are neutralised to produce clear, viscous solutions (Acrysol ASE-95) or clear, highly swollen dispersions (Acrysol ASE-60). These products can be incorporated directly into formulations to be thickened without any necessity for slow preliminary preparation of a separate thickener solution. This in-situ thickening is a marked advantage over procedures usually used with natural thickeners (e.g. alginates) or with semi-synthetic polymers (e.g. methyl cellulose, carboxy methyl cellulose). However, it is highly desirable to predilute the Acrysol emulsion with at least an equal amount of water and to keep the pH as low as possible until the Acrysol thickener has been thoroughly stirred in. Adjustment of the pH to swell or dissolve the thickener then brings the formulation to the desired viscosity smoothly and rapidly.

Associative thickeners (AT's) are water soluble/dispersible polymers containing hydrophobic groups which are capable of forming intermolecular associations and absorbing onto the surface of dispersed particle, thus providing thickening power much greater than unmodified polymers of similar molecular weight. Because AT's are capable of non-specific hydrophobic association similar to surfactants, they are sometimes referred to as polymeric surfactants. Just as surfactants are capable of absorbing onto both the latex binder and pigment particles in a formulation, the AT's can absorb onto these dispersed particles, both enhancing thickening efficiency and, in a properly formulated coating, assuring a stable, uniform dispersion. Emulsions thickened with these products are characteristically free from flocculation, and possess more nearly Newtonian rheology than comparable emulsions thickened with conventional water soluble polymers such as cellulosics. In practice, these features provide benefits of improved flow and firm build and improved film formation. The Acrysol associative thickeners can be broken down into two groups: the nonionic ethylene-oxide based urethane block copolymers and the anionic hydrophobically modified alkali-soluble acrylic copolymers. With these two classes, a growing number of products provide performance/cost benefits suited to a wide range of formulation types. The former provide the highest level of performance in terms of both rheology and film properties, but generally are more difficult to handle than the alkali-soluble associative thickeners. Films of emulsions thickened with the nonionic AT's have improved water and alkali resistance. The anionic AT's are supplied as low viscosity acidic latexes which can be added directly to the formulation and neutralised for in-situ thickening.

Effects on thickening efficiency: Since the hydrophobic association and absorption exhibited by these thickeners is non-specific, it is greatly influenced by the presence of surfactants and water miscible organic solvents. The hydrophobes of surfactants may compete for absorption sites on particle surfaces and can hinder or enhance associations between thickener hydrophobes, depending on the surfactant HLB (Hydrophile-Lipophile Balance). Nonionic AT's rely heavily on association to build low shear viscosity and are therefore very responsible to formulation modifications that have the effect of decreasing association between thickener molecules or with dispersed particles. Therefore, since the nonionic thickener is low in molecular weight, low shear viscosity can decrease rapidly as thickener is desorbed from the latex surface. Viscosity at high shear rates, where associations have less of a role, is essentially unaffected.

The choice of latex binder can have a major effect on interaction with the associative thickeners. This is not unexpected, since latexes vary in surface hydrophobicity due to their composition and the surfactants and stabilisers used in their preparation, and can vary in the surface available for associaton due to the wide particle range in which latexes are supplied. Type and particle size of pigments and extenders are not usually important, since these tend to be more hydrophilic. Choice of dispersing agent and the level used often have important effects, both by bringing the pigments into the interaction and by associating directly with the rheology modifier. Water-miscible solvents can modify the association by changing the solubility parameters of the aqueous continuous phase, relative to the dispersed phase of the coating.

Methods of thickening and formulating: It is helpful to understand the function of all three Acrysol ASE products as thickeners to consider their neutralisation analogous to a weak acid-base tritation. See Fig. 1 for Acrysol ASE-60 and Fig. 2 for Acrysol TT-615. Ammonia is the base employed in nearly all applications because it is fugitive and therefore does not harm the water resistance of the formulation after application and drying. A volatile base is also necessary when curing the conventional, acid-catalysed, self-crosslinking, acrylic chemistry. Thickening always occurs rapidly to the Acrysol ASE products. The time required is essentially the same as that necessary to obtain intimate mixture with the base solution. Often the Acrysol ASE acrylic thickeners can be added directly to a system without pre-neutralisation. This eliminates the handling of a highly viscous solution entirely. In these cases, the Acrysol emulsions should be pre-diluted with an equal weight of water being added to the sytem. The diluted emulsion should be dispersed quickly and uniformly to avoid localised concentration of acid polymer. This will prevent any undesirable "pH shocking" of the system which results in grit formation. Solubilisation and thickening will take place in-situ if the system contains enough free alkalinity. If it does not, alkali can be added to induce thickening. Thickener solutions are shear thinning and therefore easy to mix. When any of the Acrysol ASE products are added to formulations that are pre-neutralised or partially neutralised, good agitation is always necessary to ensure complete mix-

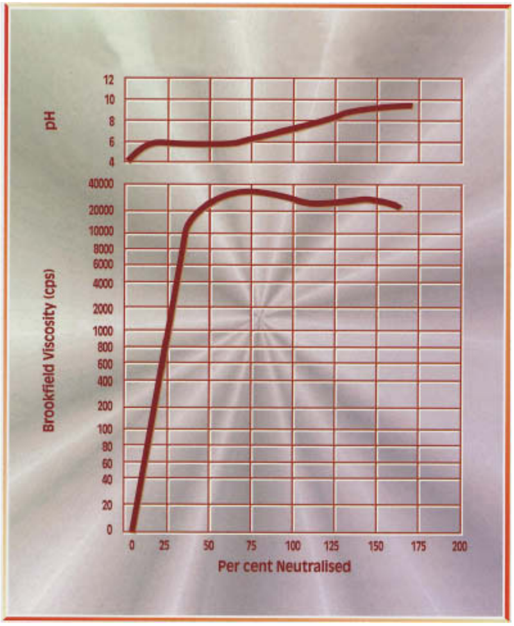


Fig. 1: Viscosity and pH change upon neutralisation of Acrysol ASE-60 with NH_4 OH at 5% polymer solids.

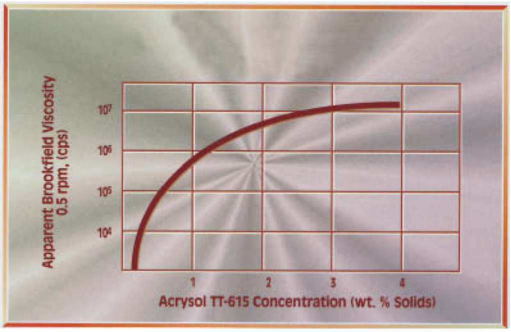


Fig. 2: Viscosity vs concentration for neutralised Acrysol TT-615.

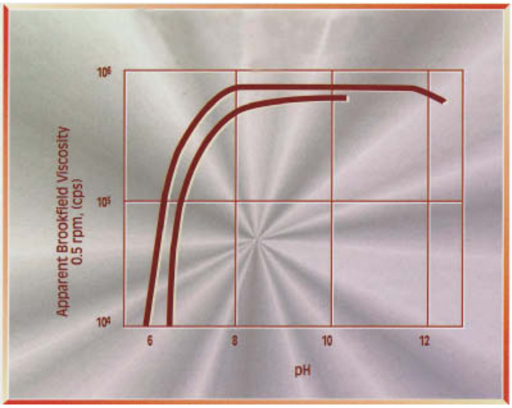
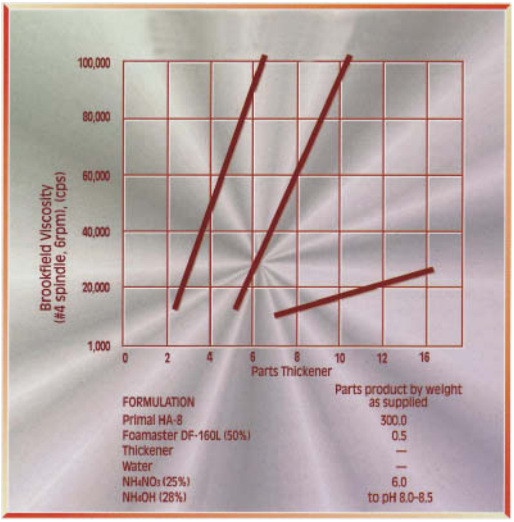


Fig. 3: Viscosity vs pH neutralised Acrysol TT-615 at 1% solids.

ing. However, a vortex should be avoided to prevent unwanted air entrapment. Once neutralised and put in soluble form, the emulsion thickeners cannot be reverted to emulsion form, as a reduction in pH will precipitate the polymer. The Acrysol ASE emulsions are completely neutralised at approx. pH 8.0. The polymer on which the formulation is based will affect the thickening efficiency of the Acrysol products.

Acrysol TT-615 is an alkali-swellable acrylic polymer emulsion. Viscosity is developed by neutralisation to a pH of 7 to 10. Its thickening efficiency is unmatched by any other polyacrylate thickener especially in formulations having a high electrolyte content. It is particularly suited for low solids formulations used in textile printing or highly filled and "difficult" formulations in addition to standard backcoating, flocking and laminating applications. The thickening efficiency is even greater when electrolytic catalysts, such as ammonium nitrate, are not used. Acrysol TT-615 thickener can be added to formulations on the acid side and the compound mix then thickened by the addition of base. The product contains functional groups that are designed to dissolve or swell when neutralised with a base. It should be pre-diluted with at least an equal weight of water before being added to the mix. The diluted emulsion should be dispersed quickly and uniformly to avoid localised concentration of acid polymer. Any base appropriate to the formulation can be used: ammonia, sodium, hydroxide, sodium carbonate, triethanol amine, etc. Alternatively, Acrysol TT-615 can be pre-neutralised; addition of base and alcohols yield a viscous syrup for use where the formulation is already at high pH. The effect of thickener concentration and pH on the viscosity of aqueous solutions of Acrysol TT-615 thickener is shown in Figs. 2 and 3. Fig. 4 compares the performance of Acrysol TT-615 with Acrysol ASE-60 and ASE-95 in a typical textile backcoating formulation.



FORMULATION	Parts product by weight as supplied
Primal HA-8	300.0
Foamaster DF-160L (50%)	0.5
Thickener	—
Water	—
NH_4NO_3 (25%)	6.0
NH_4OH (28%)	to pH 8.0-8.5

Fig. 4: Comparison of thickeners in a typical backcoating formulation.

Acrysol RM-825 is an efficient nonionic associative thickener. Because it is supplied at a low solids, it has a lower viscosity and is easier to handle. Its thickening efficiency is not sensitive to changes in pH. It is supplied as a pumpable liquid and should not require dilution. However, if dilution is desired, it should be done with a blend of 25 butyl Carbitol/75 water (the same solvent composition as in the thickener.) Diluting with butyl Carbitol alone offers no reduction in viscosity over the solvent blend and can cause flocculation of the thickener. On dilution with water, the viscosity of the solution will decrease to a minimum and then increase rapidly.

Rheometer Device for measuring rheological properties, consisting of two coaxially arranged movable cylinders.

Rheopexy (flow bonding), rheological property, which in the disperse system under isothermal, reversible and temporary conditions, results in an increase of the apparent → Viscosity under the influence of mechanical shearing strain (dilatancy). The → Thixotropy contrasting behaviour that solidifies a sol or a suspension during movement, e.g. through rhythmic beating or scutching, into a solid mass (e.g. gel), becomes liquid again immediately after the movement stops.

Rib fabrics Collective name for all materials, which have a ribbed appearance. The ribs may be in a longitudinal or transverse direction (longitudinal or transverse rib), in which the latter predominates; even diagonally in exceptional cases (inclined rib). For the transverse rib, in addition to the rib weave (→ Weave) the cloth weave is also considered, whereby the warp should have considerably more dense threads and the weft should be very coarse. Made from worsted and/or carded yarns, in which generally higher valency yarns are used for the outre thread system. Chiefly used for women's outerwear.

Ribbed spreader rollers On hank contacts for expanding work. Are provided with externally raised spiral ribs running from the centre to left and to right (Fig. 1), which stretch the fabric web through the gripping angle as the two ribbed spreader rollers of the same type rotate (Fig. 2).

Fig. 1: A ribbed spreader roller.

Fabric web correction is carried out using two swivel/slide rollers, driven by a d.c. motor. Scanning of the fabric web or edge is done by optoelectronic sensors. The controller transmits the signal to the actuator drive. The actuator speed is proportional to the deviation from the desired value in the corresponding sensors. Tracking using wide-angled light barriers is not applicable for different fabric widths.

Ribbon → Narrow fabric.

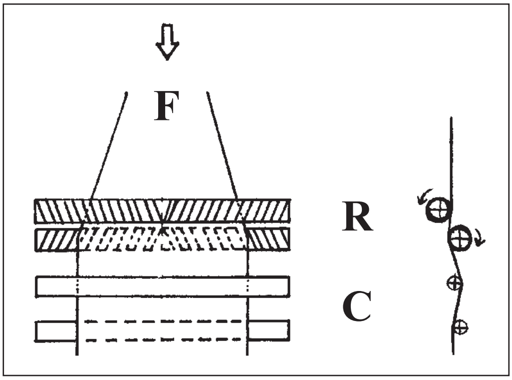


Fig. 2: Fabric feed when using two ribbed spreader rollers. F = fabric; R = ribbed spreader rollers; C = control rollers.

Ribbon cutter Textile or other stiff fabrics may be cut into ribbons using circular knives (see Fig.), electrically heated wires or by laser beams and/or ultrasound.

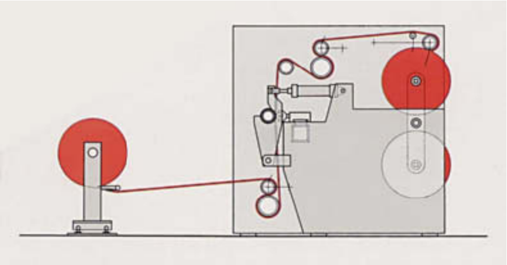


Fig.: Ribbon cutter (Menschner).

Rib-knit fabrics → Knitted fabrics which appear to have only plain stitches on both sides, although plain and reverse stitches alternate and in each wale there are only either plain or reverse stitches. They are described as double-face due to the fact that the look is the same on both sides. Two-way stretch and more elastic than (single face) plain knit goods. Use: for sweaters, jackets, knitted tops, sleeves, trouser leg cuffs, underwear.

Rice starch Crystal, lump, powder form. Pure white, similar to wheat starch; break and surface area are smooth; not yellowish. Handle smooth and supple. Water content 12–14%. Rarely adulterated. Heated bloating: swelling at 53.7°C, start of gelatinisation at 58.75°C and ends at 61.2°C. Paste: similar to wheat starch, hygroscopic; greatest adhesive strength of all the starch pastes. Finishing handle hard and robust. Used as starch.

Rigid foam → Foam.

Ring accumulator A dwell device (see Fig.) for

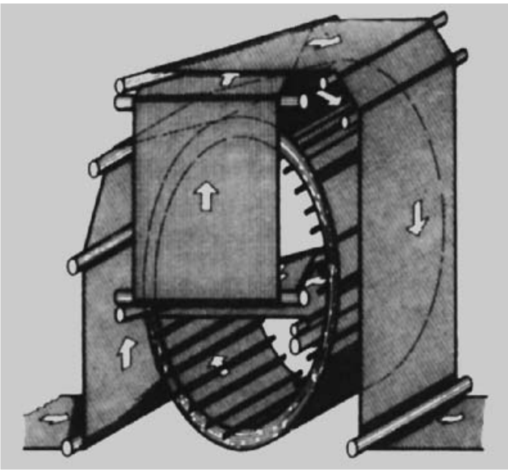


Fig.: A continuous reaction ring accumulator (Babcock-Artos).

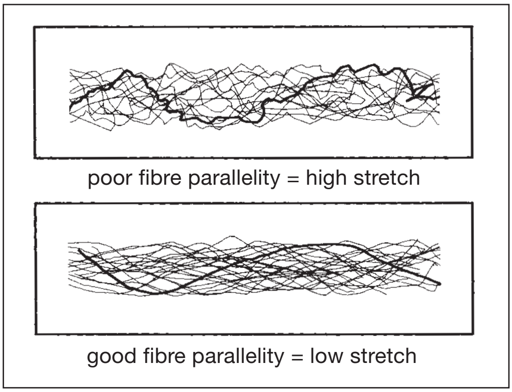


Fig. 1: Consequences of the different parallel layouts of the fibres in yarn and yarn twist.

advantages	disadvantages
– low yarn irregularity – reduced thin and thick points depending on the spinning machine – more favourable winding tension (less barriness in the weft) – higher extension coefficient – better abrasion resistance – better running	– yarn structure – harder, stiffer threads – dull appearance – strength

Tab. 1: The differences of rotor-spun yarn (compared with ring-spun yarn) from the point of view of finishing.

processes which require a set time for continuous implementation. The floor space for a corresponding steamer is considerably larger for the same output.

Ring dyeing Dyeing, in which the fibre cross-section is not completely dyed through. The dye is like a sheath on the outer periphery of the individual fibre; the fibre core is not stained or only stained to a slight degree. Depending on process, fibre type and dye, ring dyeing is a common occurrence, particularly for densely packed, crystalline fibre materials, for large molecular dyes and for short-time dyeing processes. In extreme cases, ring dyeing results in visually higher yields, in poor colour fastness to rubbing and in use in whitish worn areas (cut-pile carpets).

Ring main Main starting from the central supply system and leading back again with individual tappings at the point of consumption. Facilitates simultaneous supply of several machines or devices widely separate from each other.

Ring-spun/rotor-spun yarns, behaviour in finishing If the structures of two different yarns shown in Fig. 1 are considered, the correlation between yarn twist and fibre parallelism becomes clear. It is plausible that a yarn with a less parallel structure would have a higher elongation than a yarn with a higher fibre parallelism, as the fibres which are not lying parallel are firstly tightened and almost uncurled before higher tensile forces can be taken up. Such a confusing situation may however not be the aim of an optimised yarn design. A considerable increase in the parallel position of the fibres in the rotor ring has meanwhile been achieved through improving the spinning process in rotor spinning and influencing the spinning elements. This led both to a reduction in the elongation at break and to an increase in yarn strength. An important step towards having fewer fibres in the yarn cross-section was thereby made at the same time and to a reduction in the twist coefficient.

Another yarn structure (Tab. 1) is inevitably produced from the principle of different yarn production of rotor and ring-spun yarn. A lower reflection of light occurs in the rotor-spun yarn and items manufactured from this seem darker and more matt as a result (Tab. 2). In order to obtain more gloss, brighter shiny fibres may therefore be used by preference in the case of man-made fibres. Higher reflection values should only conditionally be obtained in cellulosic fibres using chemical processes so that you should fall back upon mechanical finishes and/or upon particular pre-treatment processes. The strengths of rotor-spun yarns are less than in ring-spun yarns, which has an effect on the finished article. The harder, stiffer thread, which is produced by the OE-spinning technique, eventually causes the main problem for rotor items, namely the tough and hard handle.

Rotor-spun yarns have fewer anti-slip problems due

Ring-spun/rotor-spun yarns, behaviour in finishing

rotor-spun fabric	characteristics	ring-spun fabric
rougher	handle	smoother
lower	tear resistance	higher
lower	Elmendorf tear strength	higher
approximately the same	abrasion resistance	approximately the same
less	reflectivity	better
higher	liquor take-up	less
usually a little better	seam strength	usually a little worse
usually a little better	pilling	usually a little worse
a little higher	swelling number	a little lower
worse	emerizing and roughening	better
greater	volume	smaller
approximately the same	wash-and-wear effect	approximately the same
approximately the same	crumpling	approximately the same

Tab. 2: Finishing characteristics of fabrics woven from either ring-spun or rotor-sprun yarns.

to the stronger mechanical adhesion tendency. Poorer dry crease angles, but better wet crease angles are obtained with fabrics made from rotor-spun yarn (independent of the cellulose crosslinker type) than with ring-spun yarn. Ring-spun yarns have a more favourable reaction in the washing shrinkage test, which is possibly related to the lower source value. Water repellent effects are achieved on both yarn types in a similar order of magnitude.

There are problems with the handle of rotor-spun yarn items; such high softener additives are required, that tear resistance and seam strength suffer. The explanation for the poorer handle in rotor items can be found in the fact that on the one hand the processed rotor-spun yarn has a greater rigidity and lower flexibility. On the other hand, a rougher surface results because of the confused position of the fibres compared with the greater parallelism in the ring-spun yarn. In special cases where normal softener systems do not have any success, the use of microemulsions may be of help, as an optimum degree of distribution is achieved as a result of the smaller particle size and the desired "inner softness" occurs as a result.

The fabric handle consists of at least three individual characteristics as does the fabric optics:

– softness (flexural strength),
– surface roughness,
– knitted volume and/or fabric thickness.

The knitted volume is in turn determined by the thickness and compressibility of the knitting. Rotor-spun yarn knits are slightly thinner than ring-spun yarn knits with the same density factor (Fig. 2). This becomes particularly noticeable in the fabric handle. The yarn volume represented by the yarn hairiness can be established as the cause of the lower thickness. Despite worldwide efforts, no one has yet succeeded in recording by measurement techniques the differences, never-

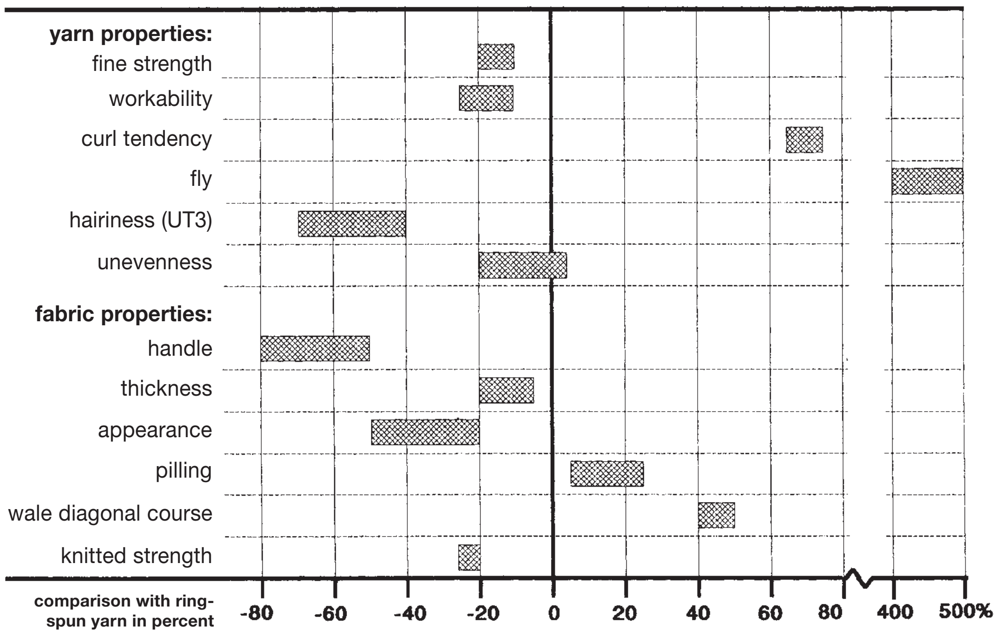


Fig. 2: The characteristics of rotor-spun yarn articles compared with ring-spun yarn articles, given in %.

	ring-spun yarn fabric	rotor-spun yarn fabric
reflectivity	better	lesser
liquor take-up	lower	greater
mercerisation effect	a little better	a little worse
appearance when wet	equal	tippy
soiling	a little less	a little stronger
evenness of weave	less regular	tighter
roughening/emerizing effect	good	worse
pilling process	worse	better

Tab. 3: Differing characteristics of ring-spun yarn and rotor-spun yarn articles.

theless small, in flexural strength and surface roughness between ring-spun yarn and rotor-spun yarn items of the same yarn counts, sensed well by experienced and also by inexperienced test persons. The yarn parameters predominantly responsible for the fabric handle are hairiness (yarn volume) and twist (rotation coefficient).

There are cases where it is no longer possible to improve the handle with normal padder finishing. Even an extremely high amount of softeners brings no improvement in these cases. It is necessary to take measures to crush the fabric even before finishing. Mechanical processes (calendering, emerizing, crushing, microstretching processes [Raduner], etc.) are used for example and/or additional chemical finishing processes (caustic treatment, pre-scrooping agents, etc.). Microemulsions are chiefly used in the so-called pre-scrooping agents in order to obtain an optimum distribution. Drying then takes place and the actual finish recipe formulation is applied on the padder. The usual drying, condensing and final finish of the material follows. So considerable additional quantities of products used and/or process changes and thereby a rise in the cost of finishing are partly necessary for fabrics and knitgoods manufactured from ring-spun yarn. In many cases, however, as mentioned, no other possibility is available with regard to improving the handle and an increase in costs must therefore be accepted.

For a long time, rotor-spun yarns have been used chiefly for coarse to medium fine qualities, even finer yarns (up to approx. 14 tex) are manufactured cost-efficiently today and are, for example, used in the shirt, blouse and dress goods sector. This means a rethink for the finisher (Tab. 3), who has been used to expect rotor-spun yarns only in coarser fabrics and was not so strongly confronted with the problem of handle and strength. A hard, brittle handle and a too great loss of strength are chiefly the criteria on rotor-spun items, which are to be optimised in the finishing. In addition, a better gloss is often demanded whereby this is however of secondary importance. So the finisher must know whether the fabric to be finished is manufactured from ring-spun or rotor-spun yarn, as different treatment methods are necessary (in accordance with Tetzlaff as well as according to Schönung and Bay and according to Bühler and Haid and according to Brockmanns and Landwehrkamp).

Ring-spun/rotor-spun yarns, properties of The replacement of the relatively heavy spinning wings of the wing-spinning machine from Arkwright with a trailing circular slide was the birth of the ring-spinning machine. The crucial invention goes back to the Americans Thorp and Jenks from 1828 and 1830 (Fig. 1). Only towards the end of the 19th century did industrial installation take place as a continuously operating, universal spinning machine. The ring spinning process has in principle hardly changed today and still represents the dominant spinning process. The almost complete replacement of knot technology by splicing and the possible link of spinning and rinsing machines produced an increase in the efficiency of the spinning process besides an improvement in quality in the spun product.

In ring spinning, the relative strengths are as shown in Fig. 2 and the processes in the spinning delta as in Fig. 3.

In a 4 mm long spinning delta, 75% of all the fibres are merged between clamping line and yarn end in the conventional ring spinning process; 25% of the fibres "swim". If the spinning delta becomes larger at higher spinning rates, the percentage of "swimming" fibres increases, which worsens spinning stability. The traveller speed increases from 34-38 m/s (conventionally) by approx. 20% during heavy duty spinning. Considerably

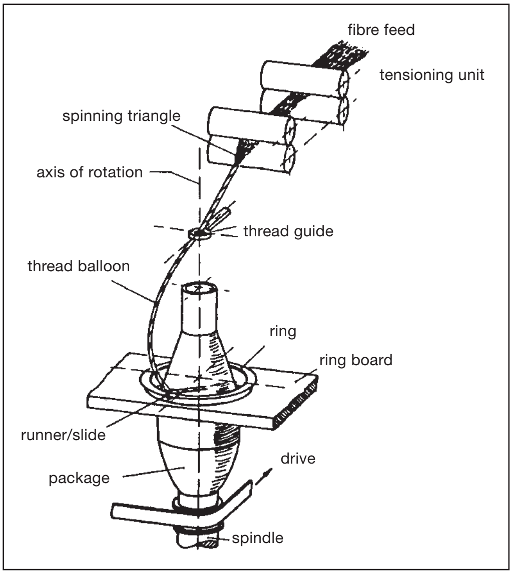


Fig. 1: The ring spinning principle.

Ring-spun/rotor-spun yarns, properties of

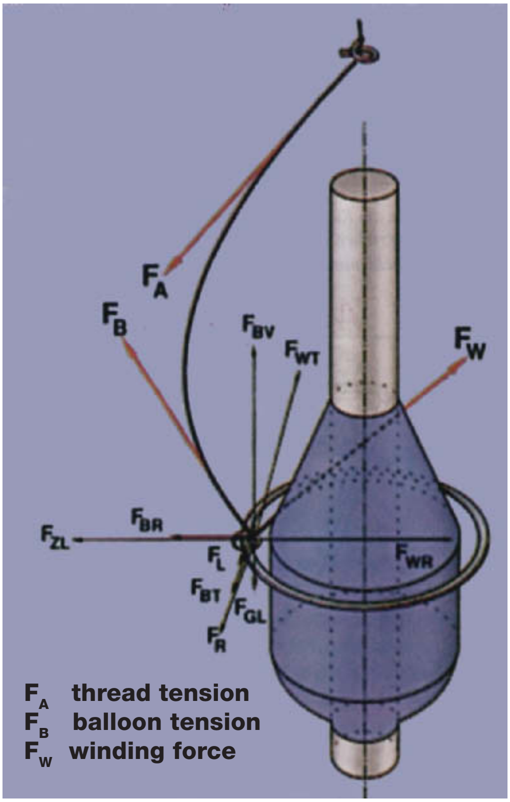


Fig. 2: Forces in the ring spinning process.

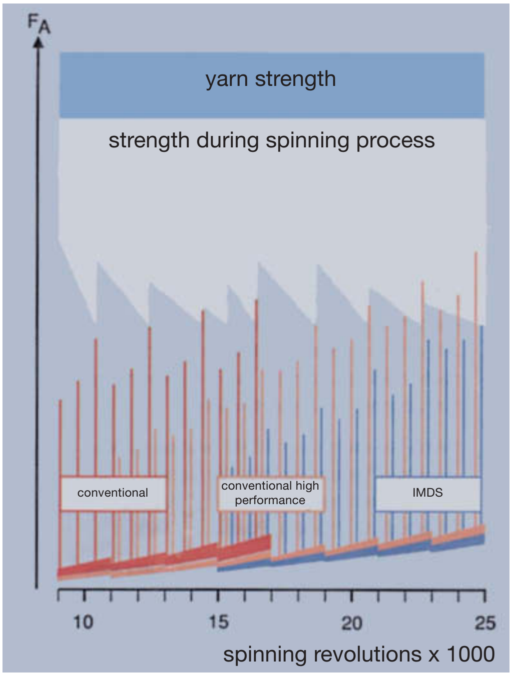


Fig. 4: Thread tension during ring spinning.

higher spindle speeds (up to 20 000 rpm) are achieved using individual spindle drive (IMDS), in which the thread tensile force F_A acting into the spinning delta is

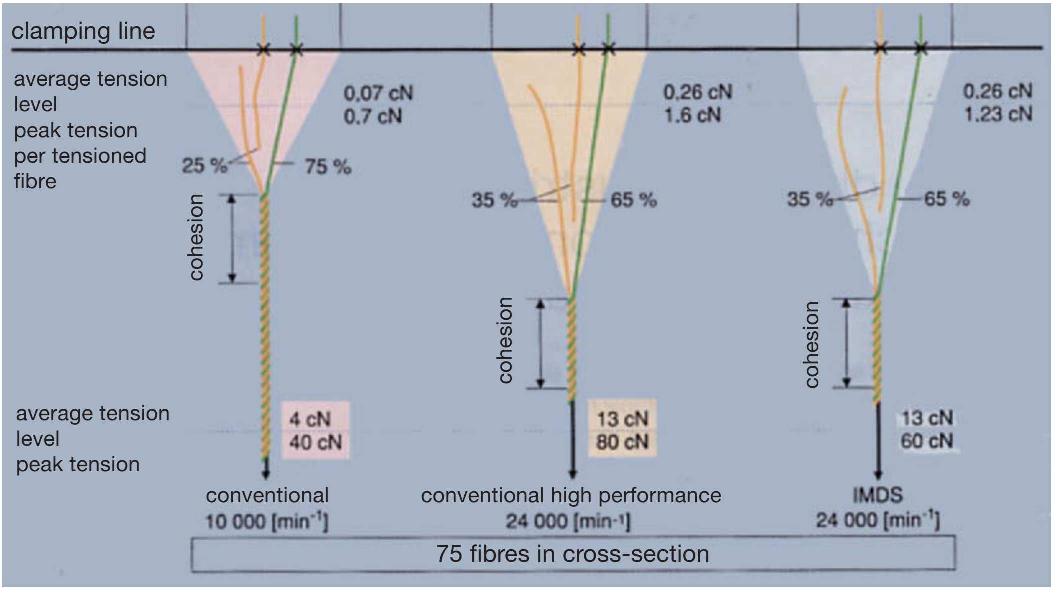


Fig. 3: The formation of yarn during ring spinning (spinning triangle).

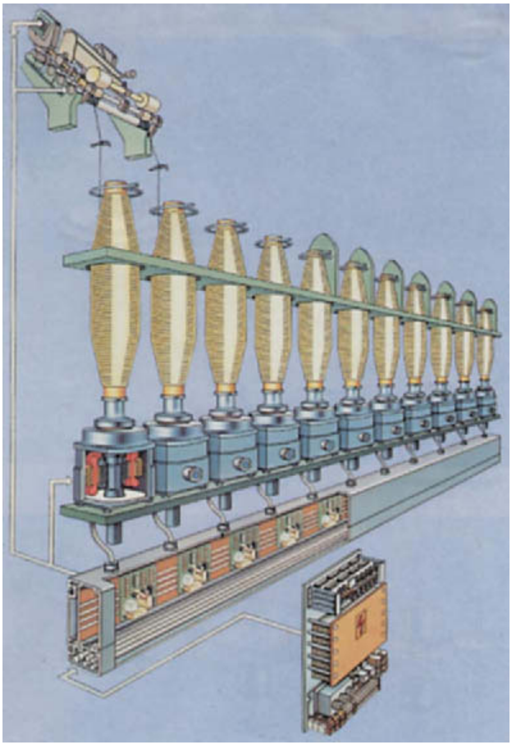


Fig. 5: The IMDS individual motor drive system on a ring spinning machine.

equal in heavy duty types (band drive in groups or individually; individual motor drive IMDS) (Figs. 3–5).

The demand of the ring spinning process for a combination yarn twist and yarn winding restricts the speed of the spindle and therefore the production speed as a result of the thread loads. The maximum possible rotor speed and the necessary power required furthermore restrict the format of the yarn carrier. The obligatory interruption of the spinning process, after filling the yarn carrier, and the desire for an increase in production speeds had already led to completely new thoughts on yarn formation and yarn bonding at the start of the 19th century.

The manufacture of a spun yarn with ring-like twist structure is thereby additionally possible in accordance with the classical principle by means of distortion of a fibre lattice and twist issue with the rotating yarn carrier on which isolated fibres on the free end of a thread are twisted (Fig. 6). This type of spinning is described as open-end spinning due to the necessary temporary loss of contact of individual fibres underneath each other. The big advantages of this process compared with ring spinning lie in:

- the considerable reduction in the rotary mass required for giving twist,

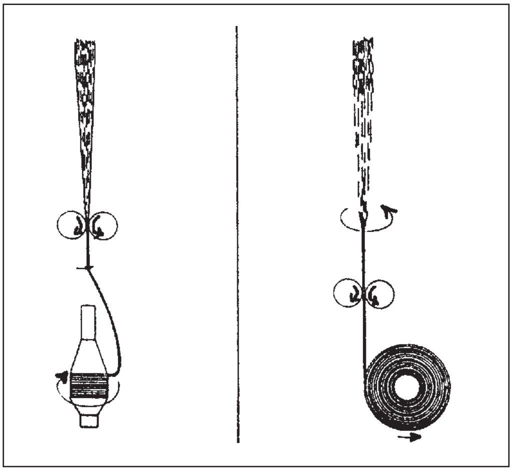


Fig. 6: Uninterrupted spinning (left) and spinning with an "open" yarn end (right).

- the independence from the reference format
- the independence from the format of the winding media.

In contrast to the ring-spinning process, the distortion mechanism and given twist are switched between the flow of material in the → OE-spinning process (Fig. 7). The yarn twist is hereby produced by rotating the bent yarn end around the yarn and/or rotor axis. The rotor groove picks up the yarn end and the distance of the rotor axis to the rotor groove represents the moment arm to produce a torque.

The counter-torque created in the finished yarn causes a twist in the piece of yarn within the rotor during each rotor revolution. The yarn rotation causes the

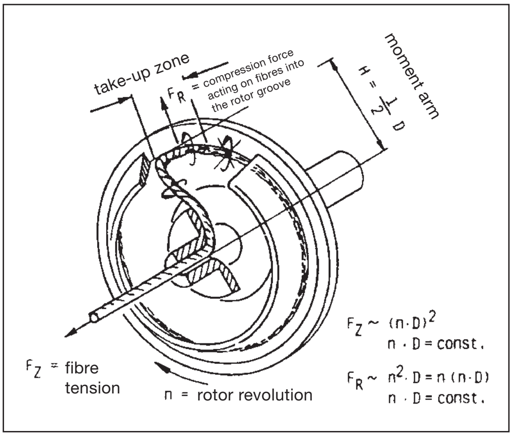


Fig. 7: The take-up zone and the relationship of forces during OE rotor spinning.

fibres built up in the rotor groove to interlink. The twist of the yarn is reproduced in the rotor rotational direction until the torque acting on the yarn is in equilibrium with the frictional force between yarn and rotor grooved wall. This zone is described as the merging zone and represents an important dimension as regards spinning technology. The longer the merging zone the more safely the spinning process runs in general. The advantage of higher spinning stability at longer merging zone length may however be faced with disadvantages as regards yarn technology.

An enhancement in performance of rotor spinning machines can be achieved to a certain degree via the reduction of the rotor diameter (Fig. 8).

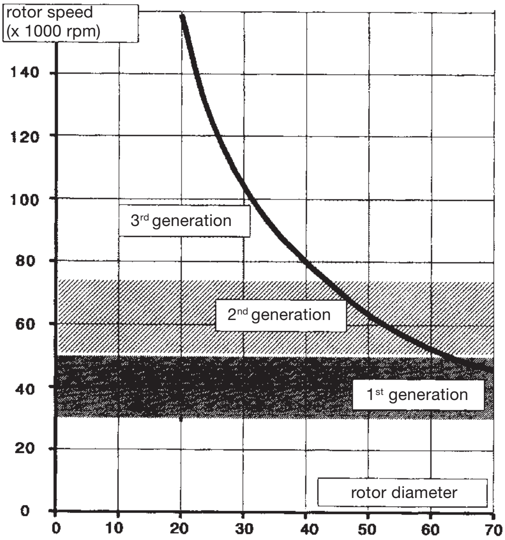


Fig. 8: Increasing the rotor revolution rate by reducing rotor diameter.

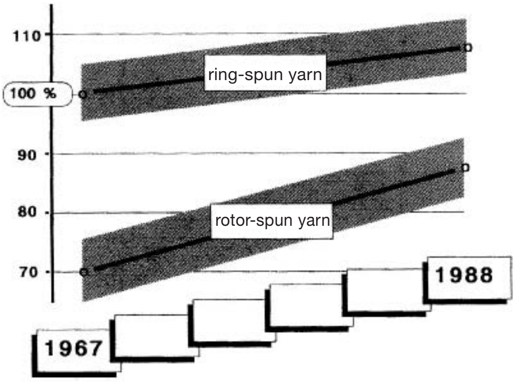


Fig. 9: Advancement in yarn tear resistance from 1967–1988 (Schubert and Salzer).

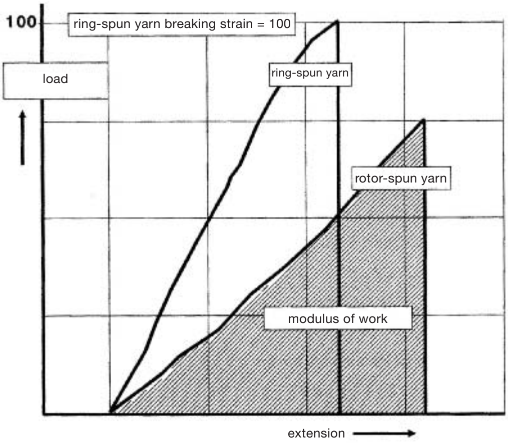


Fig. 10: Diagram showing the breaking strain, extension and workability of ring-spun and rotor-spun yarns.

In principle the tear strength of a ring-spun yarn is higher than that of a rotor-spun yarn (Fig. 9); however an improvement in tear strength by 20% could be achieved by enhancement of the ring-spun yarn strength by 10% as a result of machine construction improvements on ring-spinning machines at the same time through optimisation of the rotor spinning machines. The properties of ring-spun yarn and rotor-spun yarn prove to be considerably different in the force/extension curve (Fig. 10) as well.

Ring-spun yarn Yarn from the ring spinning frame.

Rinse liquors, economization Lowering the water consumption in machine dyeing through process controlled reduction of the amount of rinse liquors. Reduction in rub fastness, etc., is feared, for example, which is why rinsing is carried out for a longer time in case of doubt. A controlled delimitation of the amount of rinse liquors is offered to lower water consumption, as according to experience, the machine is filled 3–6 times for rinsing. If the rinsing process is regarded as a measure to be derived from laws of liquor dilution, it has the advantage that order of priority and effectiveness of water-saving measures during rinsing can be assessed more certainly and carried out in a more targeted way. Control of the rinsing is regarded as a favourable alternative, over remaining liquor concentration through inductive liquor conductance measuring systems, which are relatively insensitive to addition and coating influences and it also has a sufficiently broad effective range (→ Rinse water control systems). Convenient installation on the rinse liquor exit. Installation in the liquor circulation of the machine is recommended, principally in the supply to the circulating pump, as such current measurements also make the

Next Page

process run more transparent; possibly practical with connection of a recording device (for process comparisons, item conversions and similar).

Rinse water control systems offer checked, controlled injection of fresh water required in accordance with the principle "in each rinsing phase of determinable electrolyte content" or using continuous colour measurement in accordance with the transmission principle.

Rinsing Thinning, washing out, rinsing away of substances attached to the surface or inside fibres with water or solvent.

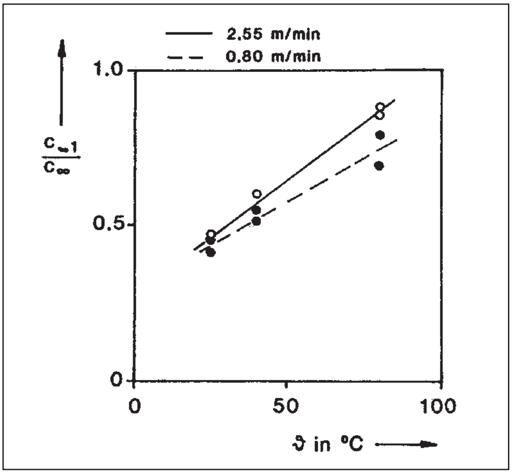


Fig. 1: Accessibility. A reactive dye hydrolysate on cotton (according to Heidemann and Schollmeyer).

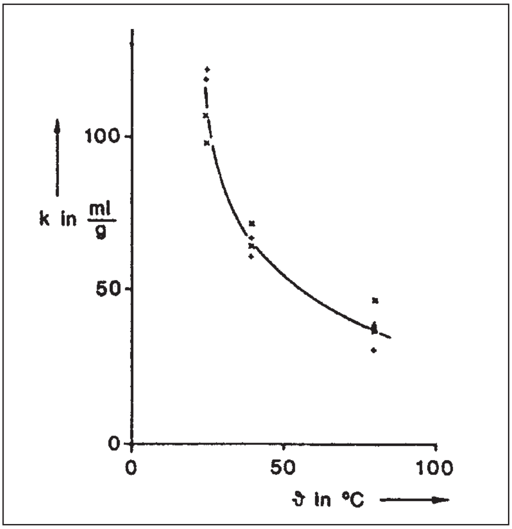


Fig. 2: Coefficient of distribution. A reactive dye hydrolysate on cotton (according to Heidemann and Schollmeyer).

In practice distinctions are made between the following:

- batch rinsing (15l/kg water consumption) and rinsing in the overflow (20l/kg water consumption),
- the counter current principle of rinsing in each individual wash compartment in continuous operation.

Apart from the time and the amount of water and besides the flow mechanisms in dyeing, temperature has an influence on the rinsing effect. The rinsing of a reactive dyeing (washing off of the hydrolysed dye), for example, comprises the influence of the temperature on

- the mass transfer coefficient, which is only slightly greater at a higher temperature because the diffusion coefficient of reactive dye hydrolysates does not increase so much with the temperature;
- the accessibility of cotton, which considerably increases with the temperature (Fig. 1);
- the distribution coefficient, which is reduced with increasing temperature (Fig. 2).

A slow and quick process is evident (Fig. 3).

$$c_1 = c_{\infty 1}\,[1 - \exp(-\beta_1\, t)]$$
$$c_2 = c_{\infty 2}\,[1 - \exp(-\beta_2\, t)]$$

$$c = c_1 - c_2 = c_{\infty 1}\,[1 - \exp(-\beta_1\, t)] + c_{\infty 2}\,[1 - \exp(-\beta_2\, t)]$$

$$\frac{c}{c_\infty} = \frac{c_{\infty 1}}{c}\,[1 - \exp(-\beta_1\, t)] + (1 - \frac{c_{\infty 1}}{c_\infty})\,[1 - \exp(-\beta_2\, t)]$$

$\beta_1 >> \beta_2$, then the following applies for a large value of t

$$\ln(1 - \frac{c}{c_\infty}) = \ln(1 - \frac{c_{\infty 1}}{c_\infty}) - \beta_2\, t$$

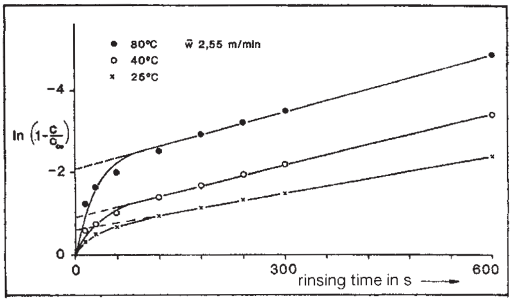


Fig. 3: Rinsing, reactive dyeing on cotton in a stationary bath (according to Heidemann and Schollmeyer).

When the first partial process has run, calculations can be made from the equation and the measured values for c for the times t using a compensating calculation c_∞, $c_{\infty 1}$ and β_2. β_1 can also be calculated from a measuring point with a small t.

process run more transparent; possibly practical with connection of a recording device (for process comparisons, item conversions and similar).

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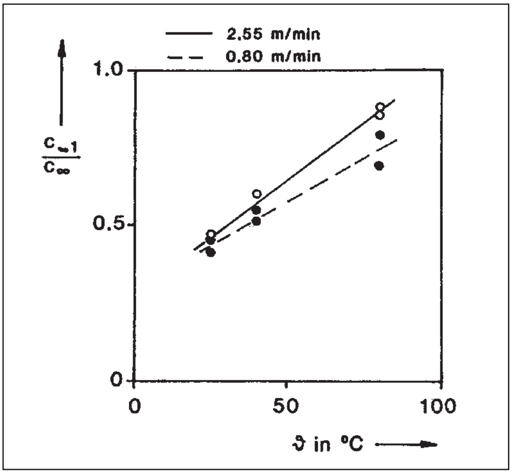

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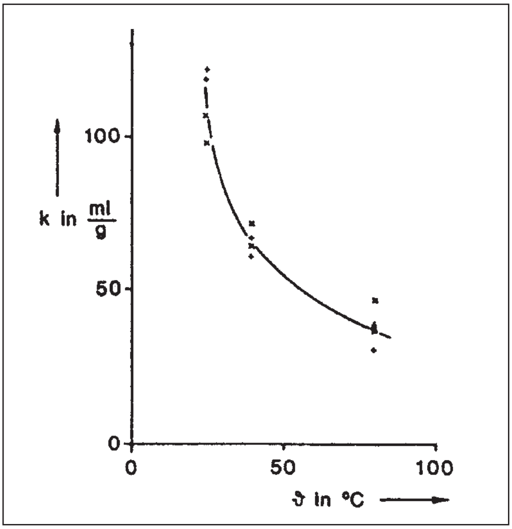

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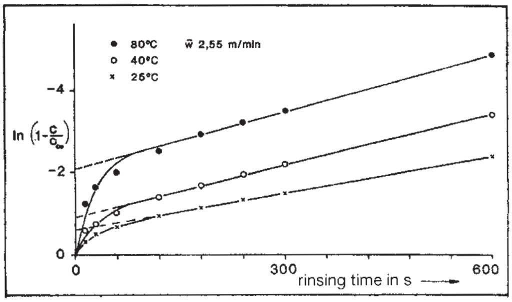
$$\frac{c}{c_\infty} = \frac{c_{\infty 1}}{c}\,[1 - \exp(-\beta_1 t)] + \left(1 - \frac{c_{\infty 1}}{c_\infty}\right)[1 - \exp(-\beta_2 t)]$$

$\beta_1 >> \beta_2$, then the following applies for a large value of t

$$\ln\left(1 - \frac{c}{c_\infty}\right) = \ln\left(1 - \frac{c_{\infty 1}}{c_\infty}\right) - \beta_2 t$$



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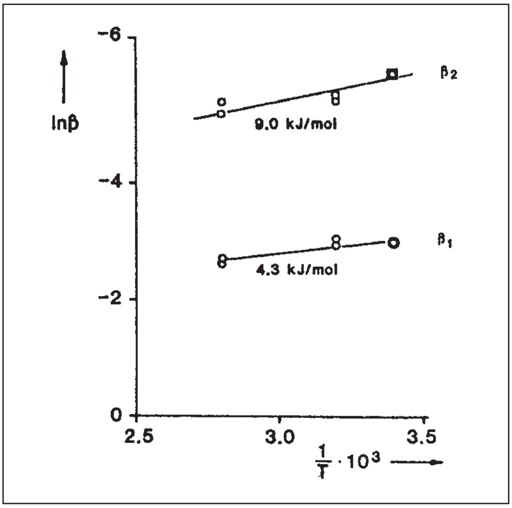


Fig. 4: The activation energy of desorption. A reactive dye hydrolysate on cotton (according to Heidemann and Schollmeyer).

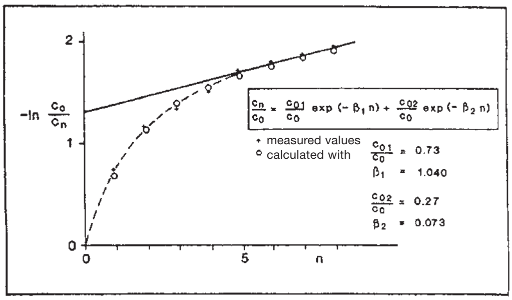


Fig. 5: Open width washing following reactive dyeing. Operational trial: 60 m/min of 165 g/m² cotton fabric (according to Heidemann and Schollmeyer).

An Arrhenius equation of the mass transfer coefficients (Fig. 4) produces very little activation energies for dye desorption, in which the lower accessibility of the ranges of the 2nd process also requires a higher activation energy. The distribution coefficient can be calculated from the equilibrium values calculated for the liquor and the quantity of dye hydrolysates padded on the fabric, which shows a distinct temperature dependency (Fig. 3). In summarising, it can be established that the rinsing of a reactive dyeing on cotton can be described using two desorption processes of pseudo 1st order running in parallel. The model can be converted freely in practice as the results described in Fig. 5 show, which were obtained on an open-width washing unit with eight compartments. The concentrations calculated in the individual wash compartments agree well with the measured values (Heidemann and Schollmeyer).

Rinsing contact Correct condition for optimum rinsing effect/time is the most rapid thinning possible of the substance sticking to the fabric surface. Can be achieved through intensive fabric movement, intensive air mixing, counter current or series rinsing in cascades. → Rinse water control systems.

Rinsing water is used for washing out (rinsing out) in accordance with the washing process. Important in all textile finishing processes in order to completely remove remains of textile auxiliary.

Rising roll batcher,

I. Batching device for open-width fabrics, operating at constant surface speed, with indirect drive. The batching roller lies on two driven rollers located horizontally adjacent to each other its axis is fitted laterally into vertical gliding rails. The roller rises in the rails as the diameter of the batching roller increases. The rising roll batcher is only suitable for smooth piece goods, as the whole weight of the yarn package constantly presses onto the fabric.

II. → Roll batcher in which the yarn package lies on one or two rollers, of which at least one is driven at constant speed. The winding spindle rises in a guideway as yarn package diameter increases. (→ Batching drives).

Rkm Tearing kilometre; → Breaking length.

Rn Element symbol for radon (86).

Roasted starch → Dextrines.

Roberto rolls Squeeze rollers, with a pressed steel core with porous natural/man-made fibre. 20–50% improvement in the squeezing effect compared with soft rubber roll. Action: firstly saturated with liquor, then squeezing as other squeeze rollers, at the same time the highly elastic, porous covering is compressed,

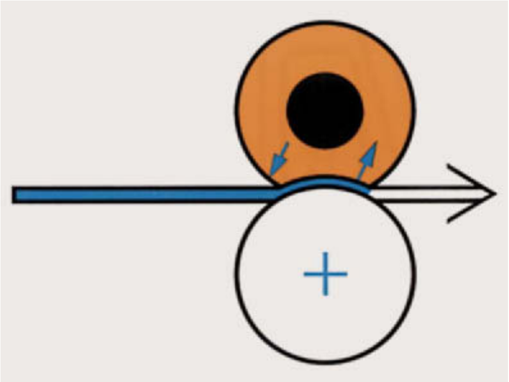


Fig.: The principle of the Roberto roll. The solid rubber roller (below) presses the fabric, from which water is to be removed, against the Roberto roll (above) which has an outer layer of deformable hygroscopic material and which removes additional water due to the capillary forces within this material.

and a portion of the moisture contained in the covering is pressed out in front of the nip (see Fig.). After the nip, the covering is opened again and thereby additional drawing out of moisture from the fabric takes place using capillary action. – Manuf.: Roberto.

Robotic systems Increasing → Automation is making a considerable contribution to the human welfare in the working world. Two things should be understood by this: on the one hand the human structure and on the other hand the organisational structure of work. The first case concerns the protection of staff from dangerous and burdensome work, the other the combat of monotony, as, for example, employees are freed from monotonous and extremely compartmentalised work by the use of robots. On the other hand the use of robots also results in rationalisation and thereby in the loss of jobs. In general, attempts should be made to get away from a course of action based on the division of labour and to increase the scope of decision-making and action for employees through the creation of more quality jobs per employee and through increased complete processing in the sense of “job enlargement” and “job enrichment”. With the aid of modern techniques such as flexible manufacturing systems and autonomous production islands, it is possible to meet these demands to a large extent.

One definition of the robot reads as follows: “programmable, multifunctional manipulator with the purpose of moving material, parts and tools”, or “a special device for the execution of a multitude of jobs by means of programmable movements”. The fundamental concepts from both these definitions are:

- programmable,
- multifunctional,
- manipulator.

Programming always means conditioning a device or a procedure to a particular, but replaceable purpose; so one aim lies in flexibility; but it also concerns the permissive detection and processing of information. Information is produced in a robot internally on the one hand, for example, about its present state of motion, about its mechanical loading, etc. On the other hand, information is produced from a perception of the environment, whether tactile, visual or acoustic components, which are to be detected. A comparison with the human nervous system including the sense organs and the central nervous system suggests itself. Information processing organs, which were summarised until now in machine technology in the term “logic controls”, are required to realise, control and master sequences of motions and forces.

Precursors are numerical or computer-controlled machine tools, i.e. automatons. There is therefore a fluid transition between automatons and robots, and it is largely a matter of opinion to which category products are regarded as belonging. An automaton is all the more a robot the more flexible and in particular the greater its capability for adaptation with regard to environmental

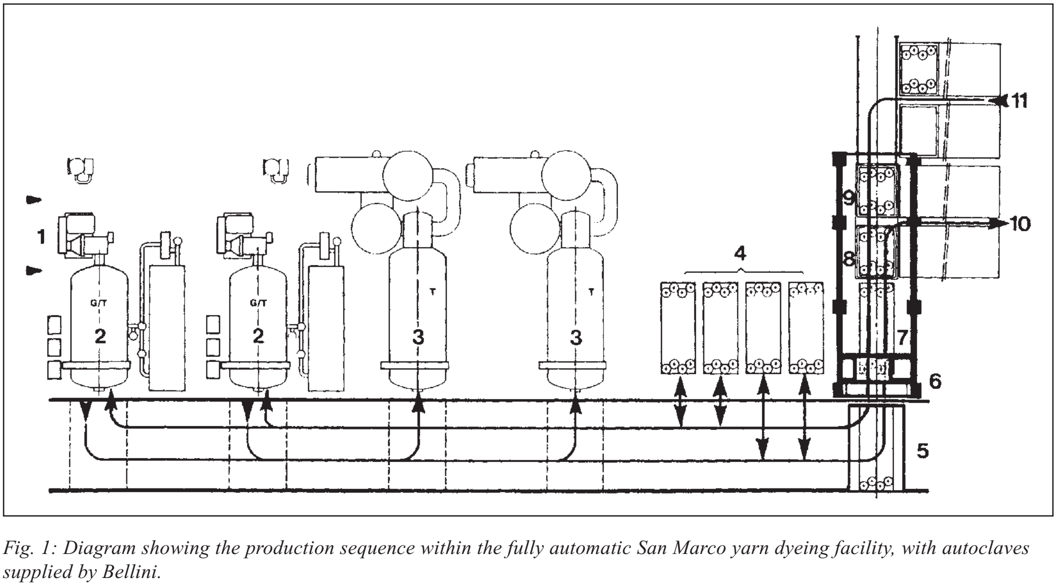


Fig. 1: Diagram showing the production sequence within the fully automatic San Marco yarn dyeing facility, with autoclaves supplied by Bellini.
1 = delivery from the colour kitchen; 2 = HT dyeing machines; 3 = rapid pressure driers; 4 = material parking positions; 5 = rail-mounted trolley; 6 = loading robot; 7 = material carrier; 8 = material carrier with dyed yarn packages; 9 = material carrier with raw yarn packages; 10 = to automated warehouse for dyed yarn; 11 = from automated warehouse for raw yarn packages.

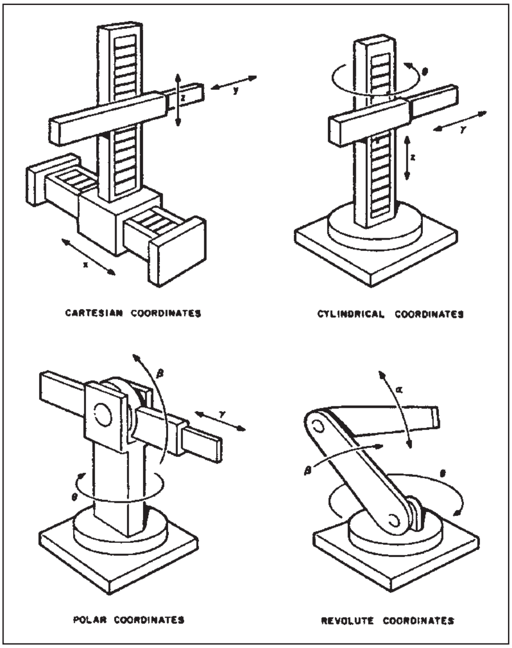


Fig. 2: "Playback" robots. Three degrees of freedom of movement are required in order to be able to reach any point within a defined radius. The most commonly used kinetic configurations are shown here. The "human" model is almost no longer recognisable.

information. In accordance with the Japanese Industrial Robots Association (JIRA), industrial robots should be divided into four classes:

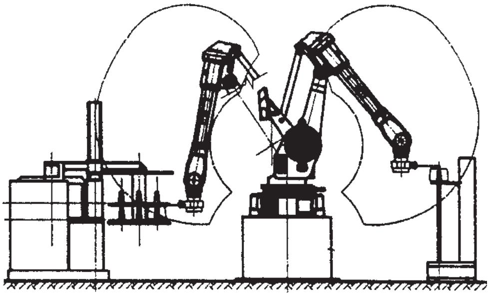


Fig. 3: A single-armed robot in different operating positions (left: filling material carriers; right: picking up a yarn package).

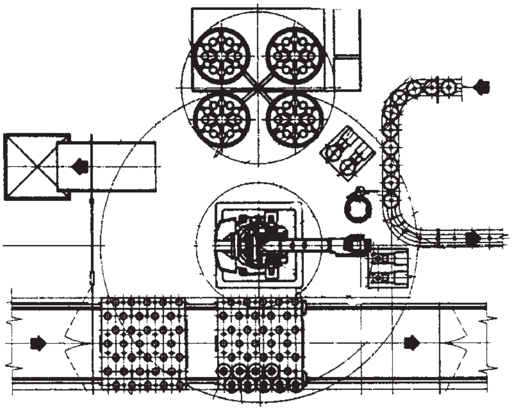


Fig. 4: The working radius of an all-round operating robot (ABB-Robotica) used for loading and unloading crosswound yarn packages.

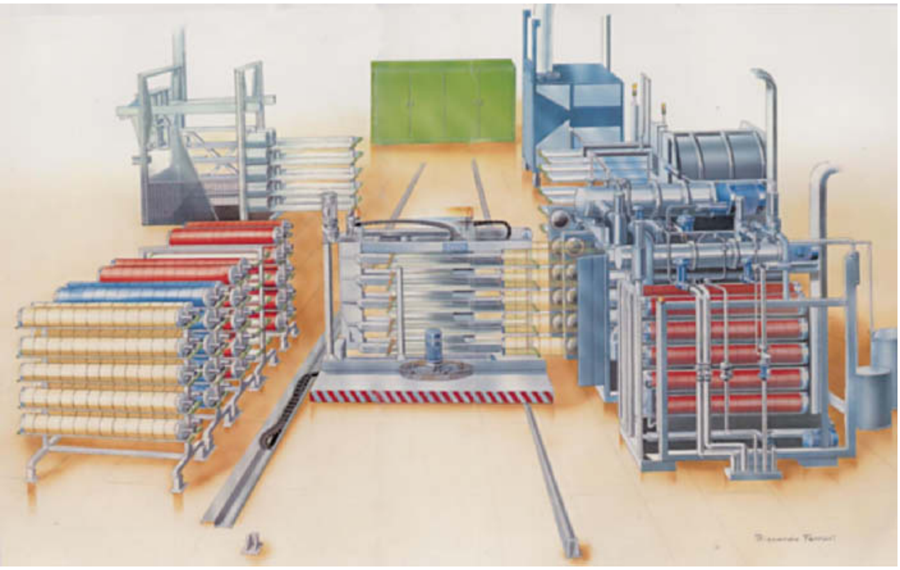


Fig. 5: A robot working in yarn dyeing (OBEM).

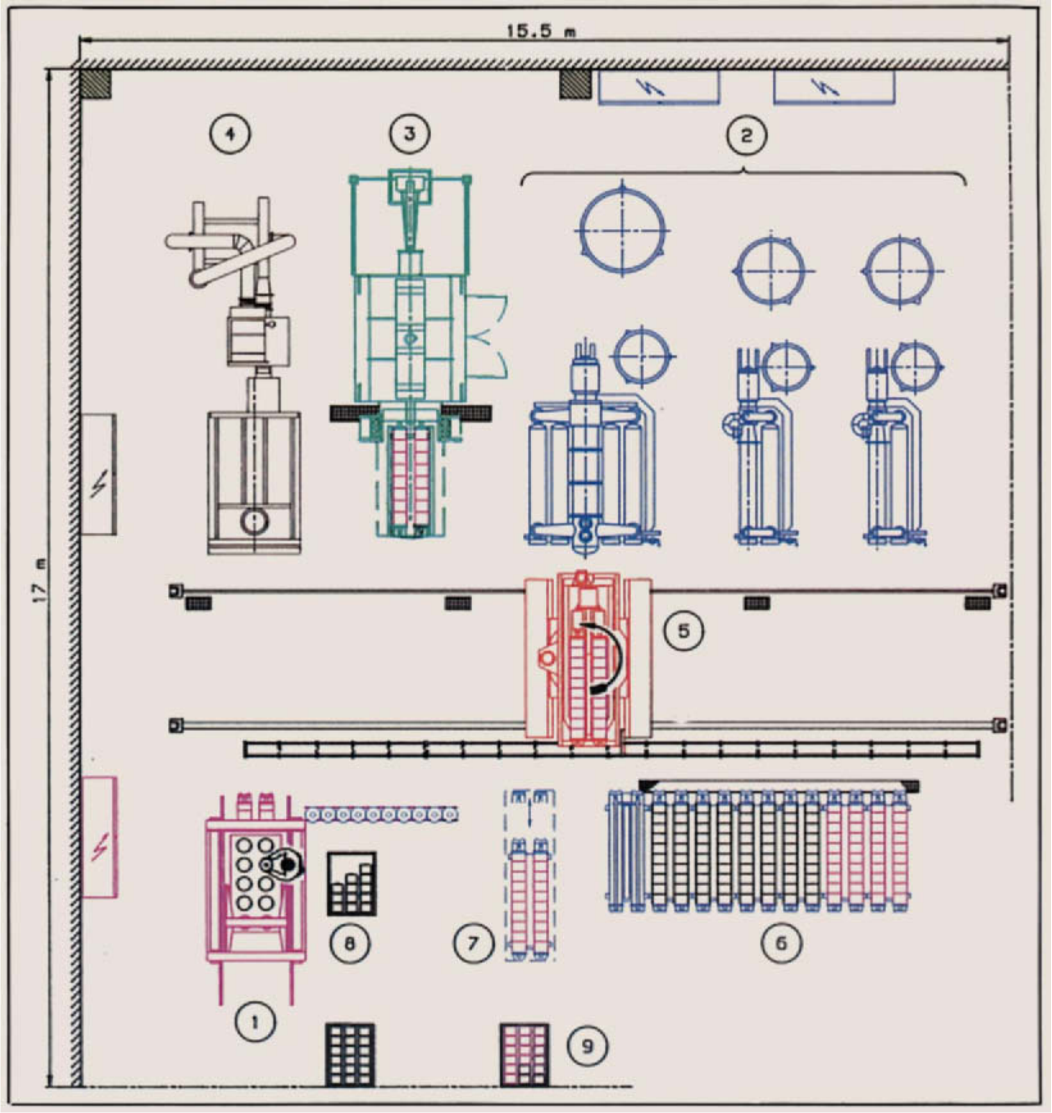


Fig. 6: The sequence of operations in yarn dyeing, automated by the use of robots (according to OBEM).

1. manual manipulators for fixed or specified sequences.
2. playback systems, which repeat fixed instructions.
3. NC robots, which execute operations on the basis of loaded programs.
4. intelligent robots with autonomous detection and environmental information.

Class 1 devices (Fig. 1) would no longer be assigned to robots (the high numbers of robots installed in Japan can be put down to the fact that these simple manipulators are also included). The class 3 robots come really close to conventional numerically controlled machine tools.

Classes 2 and 4 have typical, original and autonomous robotic characteristics at their disposal: in robotics "playback" means that, for example, the robotic arm is run at first by a worker corresponding to the work to be executed, whereupon it then often repeats the sequences of motions input into it (Fig. 2). A simple form of learning is established in the sense of simple imitation. More complex and more demanding forms of learning can be derived from this, for example, so that a

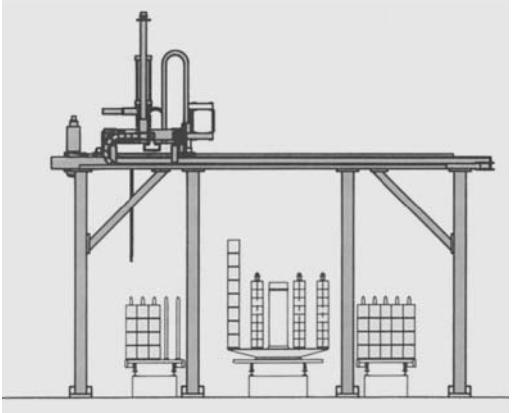


Fig. 7: *The filling of small batches by robot (Pozzi) in the process of yarn dyeing preparation.*

repeated sequence of motions is made dependent on momentary effective geometric ratios or force influences. These kinds of processes have been partly developed in perfection and were already familiar a long time ago from machine tool technology. The robots of class 4, which are also called "intelligent robots", are the really interesting ones. Their "intelligence" lies in the fact that they have diverse sensors at their disposal, which enable them to adapt jobs, which are given and/ or pre-programmed in their essentials, to given conditions. Combined with the "capability for learning", functional specimens result in high flexibility and efficiency (in accordance with Mey).

The use of robots in the field of yarn dyeing is considerably more advanced than in spinning (used for the handling of rinsing in this comparison). Italian firms gathered a lot of experience in this field early on. All round operating classic robots may probably use too much space in the necessary circular arrangement of the machines to be operated (ABB) (Figs. 3–4). Solutions in which the robot moves on rails (OBEM) (Figs. 5–6) or crane-like on racks (Figs. 7 + 8) (Bellini and Camel robot, chiefly for small batches as also with Pozzi) seem more sensible. The intermediate plate to stabilise the material carrier during centrifugation (Figs. 9–10) is essential in robotisation by Bellini.

Fig. 9: The stabilization of a yarn dyeing carrier suitable for manipulation by robot (Bellini).

Rocket packages (bottle packages). Rocket-shaped packages with an axial structure. Are used as dye packages, as opposed to normal crosswound yarn packages, for dyeing on special material carriers. Also as a reference package on shuttle-less weaving machines.

Rock salt Extracted from natural deposits, more or less pure → Sodium chloride. Is either extracted from

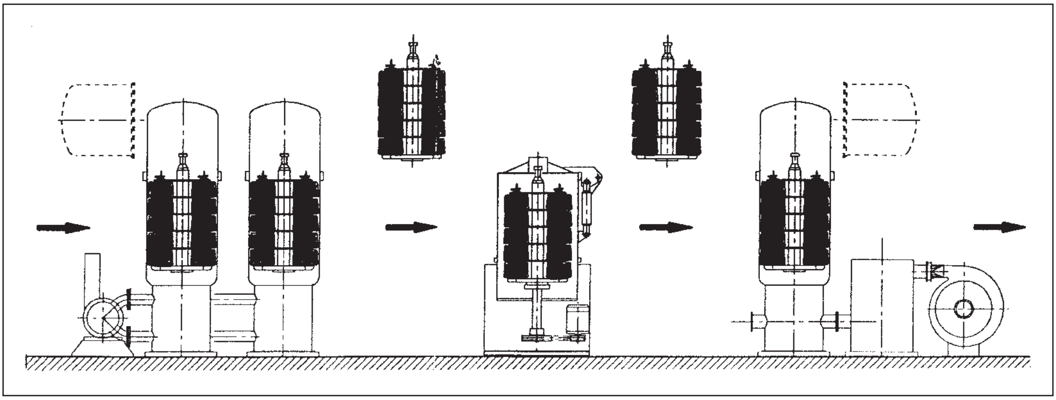


Fig. 8: The sequence of operations in small-batch dyeing, automated by the use of robots (Bellini).

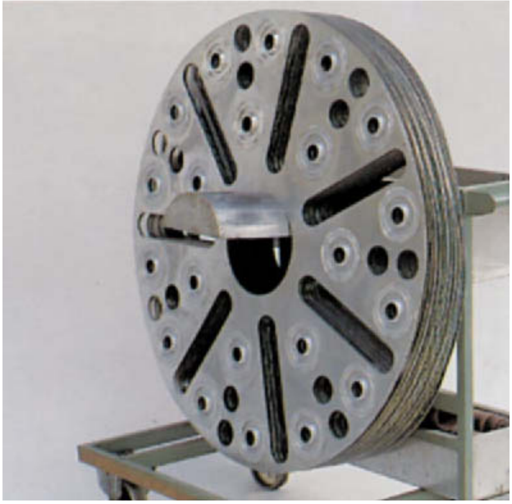


Fig. 10: Large separating disks for use in the robotic handling of yarn dyeing batches during the centrifuging of entire carriers (Bellini).

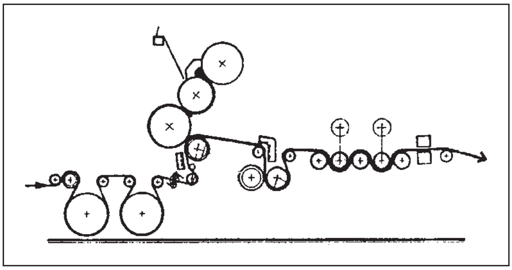


Fig. 1: Saueressig melt coating with roller grinding mill (above) and fabric path (below).

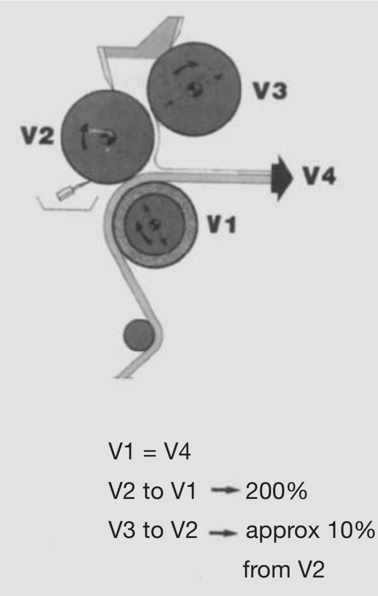


Fig. 2: Reverse roll coater (Kleinewefers KTM).

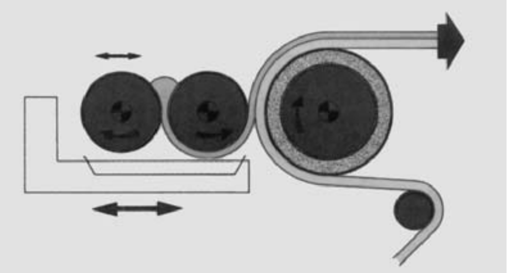


Fig. 3: Smooth roller coater, synchronous (Kleinewefers KTM).

salt-works by miners (ground, recast, refined, etc.) or via evaporation from saline springs.

Rock wool → Mineral silicate fibres.

Rod squeegee → Doctor blade.

Rod teasel machine → Raising teasels.

Roll batcher Device for fabric batching for storage in → Package. Varieties: →: Paternoster batcher; Swivel batcher; Rising roll batcher; Surface batcher; Centre drive batcher. → Batching drives.

Roll batching machine Automatically operating machine made of two rising roll batchers acting in parallel (→ Rising roll batcher). If the desired diameter of a yarn package has been reached, the roll batching machine cuts through the fabric and lays the start on the following empty roller.

Roll carpets (carpets),

I. Carpets in roll make-up.

II. In accordance with DIN 61 151: only in the width, for example, machine-conditioned, measured carpets.

Roll Coater → Reverse roller coating.

Roll/er application in coating processes is carried out in accordance with melt coating. Fusible polymers are heated and sealed in a roller until a film from the roller grinding mill capable of application (top in Fig. 1) is applied to the fabric to be coated (e.g. in PVC coatings of car covers). Coating pastes can generally be applied with the aid of a spreader, sieve or roller application systems. Roller application technology includes

- reverse roll coater (Fig. 2),
- smooth roller coaters (Fig. 3),
- grid roller application devices (Fig. 4),
- nip padding machines (Fig. 5) and immersion impregnation (Fig. 6).

In the broadest sense, a roller bearing element for paste or substrate is also in the cylindrical spreading process,

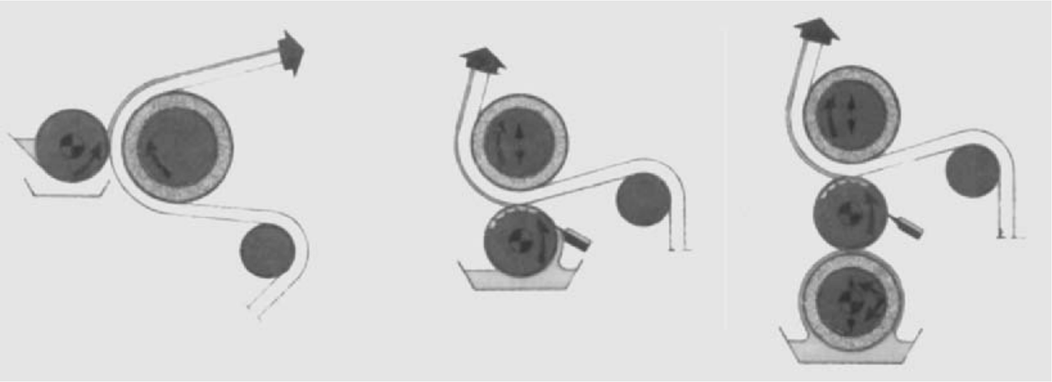


Fig. 4: Grid roller application devices (Kleinewefers KTM).

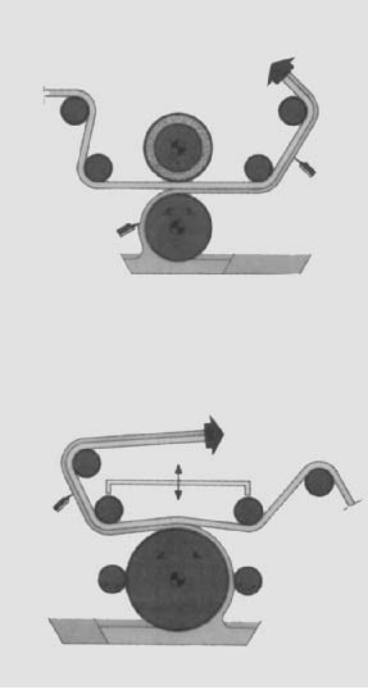


Fig. 5: Nip padding (Kleinewefers KTM).

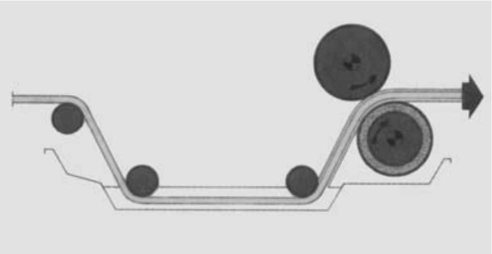


Fig. 6: Immersion impregnation (Kleinewefers KTM).

in the roller coating around a magnetic roller and in the reverse application system. The reverse roll coater has proven to be a versatile application system because it is applied independent of fluctuations in starch in the coating substrates of the mass film and not, as is usual in roller blade coating systems, do carrier substrate and coating starch have to run through a common gap. The applicable viscosity range is also broad provided that the coating pastes do not coagulate under the effect of the shear forces. The application polymer mixture should be stressed at the moment of the metering and levelling through shear forces so that the thixotropic pastes are converted into a homogenous, uniformly strong film of constant flow properties. The coating starches vary from insignificant dry application weights to high mass coatings and are a function of the viscosity and dye content of the coating paste. The coating starch is essentially determined by the gap between applicator roller and metering roller as well as by the speed ratio between applicator roller (operating in the opposite direction to the transmission roller and operating with a speed of rotation of 15% to +200% of the nominal speed of the plant) and substrate roller (the metering roller runs in the opposite direction to the applicator roller with a speed of rotation, which is different to the applicator roller by up to 10%).

The gap adjustment may be regarded as coarse metering and the variation of the applicator roller speed to the tool path feed rate as fine metering. It is thereby important that the path totally adsorbs the mass supplied and the applicator roller enters the metering gap cleanly. Rheological paste properties and speed ratios between metering roller, applicator roller and fabric transport as well as the metering gap width should be precisely co-ordinated with each other, if a smooth, thin film is to result (in accordance with Patermann).

Roller arrangement Depending on the functional principle of a machine, operating rollers are positioned together. When mercerizing (Fig. 1), the rollers

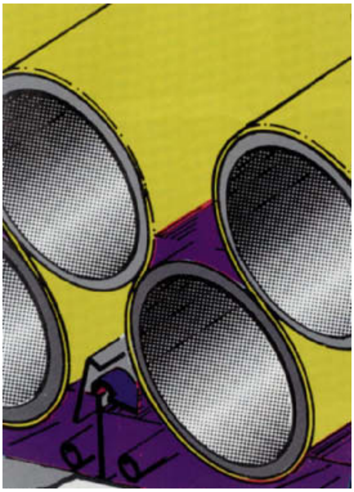


Fig. 1: Roller arrangement on a Goller mercerizing machine.

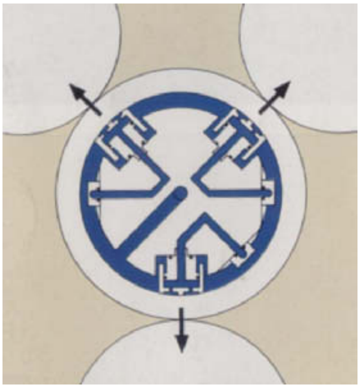


Fig. 2: Roller arrangement in the case of a Kleinewefers KTM calender.

are in a displaced arrangement so that the cloth under tension runs in a controlled manner. The L arrangement or the 3 zone arrangement may be of interest when calendering (Fig. 2).

Roller-bed steamer Broad steamer for continuous shock bleaching of cotton and polyester/cotton cloth. Fabric runs vertical via steam/air level (intensive heating from superheated steam), then falls onto a slowly driven roller bed (water spray system on top).

Roller card raising machine Roller card raising machines (→ Raising machines) have two central cylinders; one central cylinder rotates against the cloth run and the other with it. There are also machines with only one central cylinder, in which the piece has to be turned after several passages, i.e. raising of the number-free end of the piece firstly takes place and then with the number end forwards. The spindles used in card raising are secured on the central cylinder in rows and each individual card raising spindle is supported radially (see Fig.).

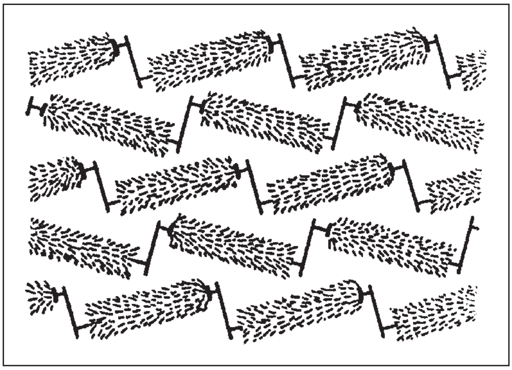


Fig.: Typical roller card raising machine arrangement.

Roller chisel is used for mill engraving (→ Pattern die) on printing rollers.

Roller defects in roller printing result from improper treatment of the printing roller, which has to be corrected or even engraved again.

Roller deformation When rollers are pressed together deformation can occur (Fig. 1) so that the linear pressure is unequal in the gap. Attempts are made to even out this roller deformation through specifically applied corrective forces (Fig. 2).

Roller systems with active bending correction operate

- with bending compensation by transposing the axes (axcrossing),
- with suspended hooks and bending moment (roll bending),
- with mechanically, pneumatically or hydraulically supported roll shells (Variflex-S roller from Babcock; floating roller from Küsters; Hydrein and Bicoflex roller from Kleinewefers KTM or Nippco roller from Sulzer Escher Wyss).

Monforts displaces both squeeze rollers side by side against each other in the Matex colour roller with a special S profile (Fig. 3) and so produces specific nip profiles.

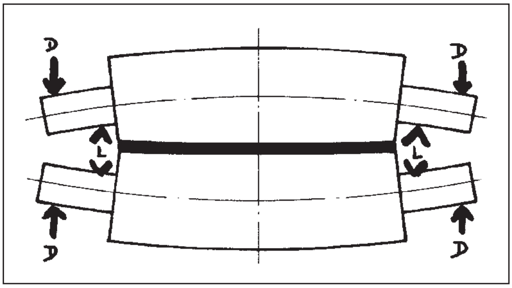


Fig. 1: Roller deformation. L = bearing; D = pressure.

Roller deformation

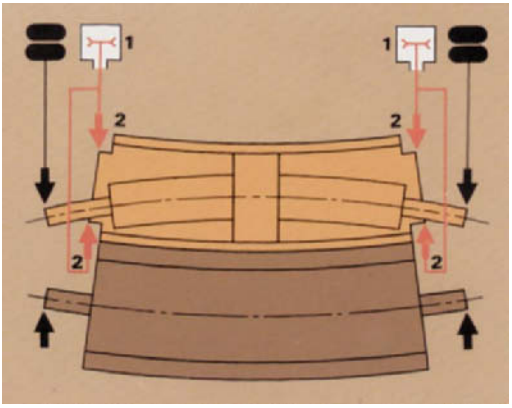
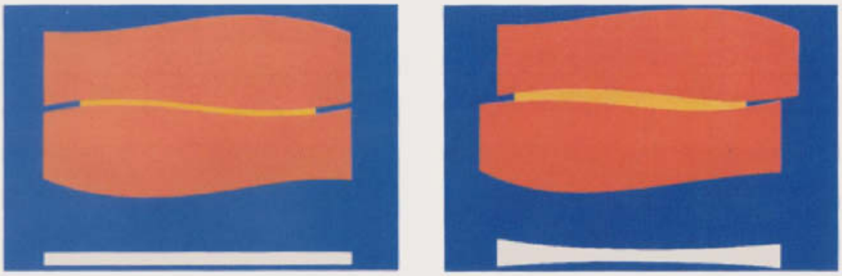


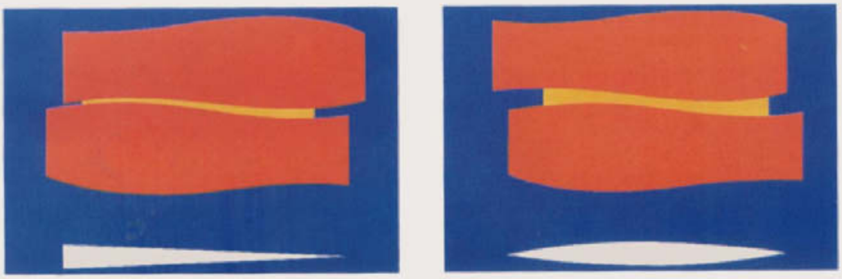
Fig. 2: Function principle of a correcting unit for roller deformation (Benninger).
1 = correcting cylinder; 2 = correcting force.

A very even stress load characteristic (Fig. 4) can be achieved by using individually controllable pressure zones as normal in the Hydrein roller (Figs. 5 + 6). This functions as follows: across the entire operating range of linear loads from 1 : 10 (Thermo-Hydrein roller as an under roller), e.g. between 15 N/mm and 150 N/mm, the hydrostatic pressure in the bearing elements (c) is automatically set by the system so that an even clearance pressure exists across the entire roller width (Fig. 7). The oil is used as a coolant at the same time. The axial feed (d) causes the oil to reach the inside of the roller housing with practically no loss in temperature. The high oil velocity in the gap between the bearing elements and the inside of the roller housing causes turbulence, which ideally causes heat transmission to the roller housing (b).



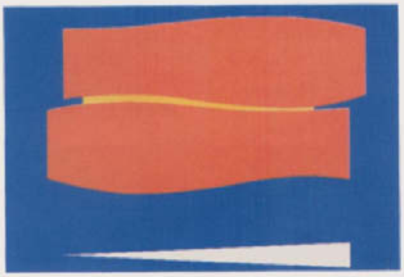
nip pressure constant across full width of rollers

nip pressure greater at right and left than in centre



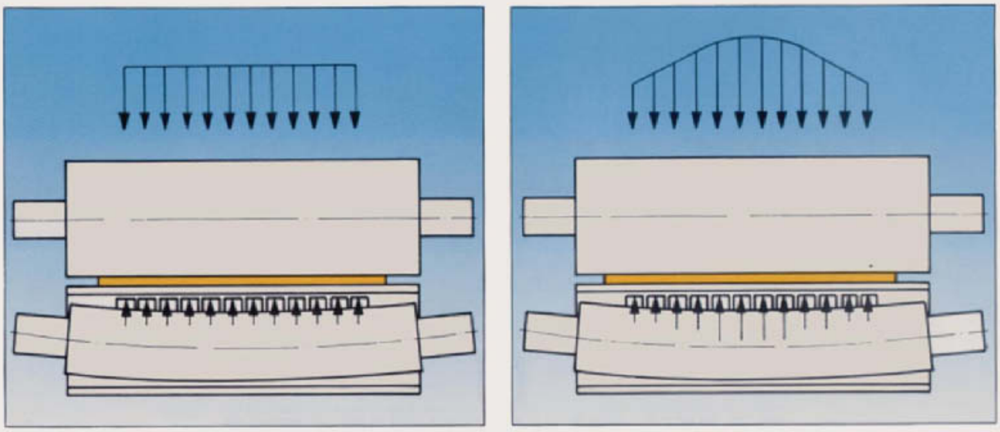
nip pressure greater at left than at right and at centre

nip pressure lower at right and left than in centre



nip pressure greater at right than at left and centre

Fig. 3: Monforts rollers with S-contours for the creation of particular nip forms according to the position of the rollers.



achievement of the ideal nip load profile by using a Thermo-Hydrein roller complete with a pressure zone

any desired distribution of nip load across the width of the roller may be achieved by differentiating pressure settings

Fig. 4: The distribution of nip load in a Thermo-Hydrein calender (according to Kleinewefers KTM).

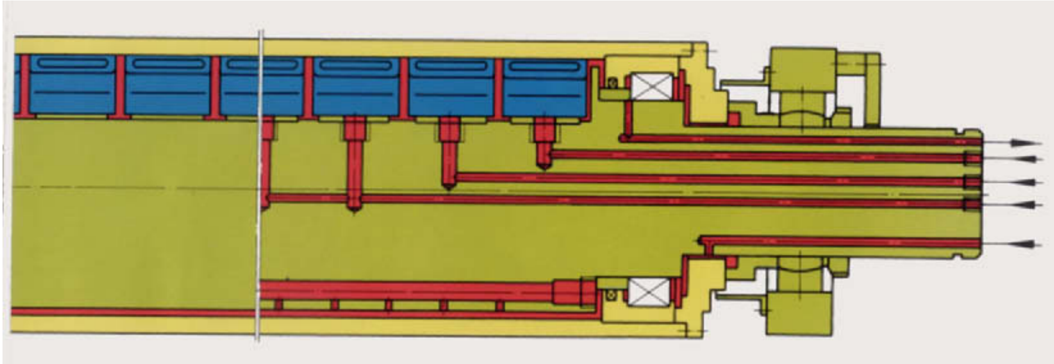


Fig. 5: Multi-zone control of pressure forces with a Hydrein roller (Kleinewefers KTM).

Fig. 6: Hydrein roller system (Kleinewefers KTM).

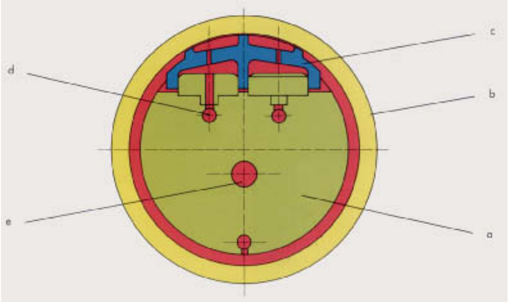


Fig. 7: Roller deformation compensation in the case of a Hydrein roller (Kleinewefers KTM).
a = fixed axis; b = roller housing; c = double ram bearing element; d = pressure lubrication feed; e = oil return

Roller engraving Electronic: small bowls are cut with a sharp diamond chisel from the copper surface of the printing form in gravure printing cylinders. The diamond chisel is electronically controlled (electronic signals control position and depth of insertion of the chisel). The small bowls (which are pyramid shaped at the tip) have smooth walls due to the sharp cutting edges of the chisel, which has a positive effect on the transmission of the print paste to the printed goods. Chisel control signals are obtained through optical-electronic scanning of a black and white pattern (extract from a multicoloured design), which also contains developments as grey-scale values. → Engraving.

Roller fabric spreader → Expander.

Roller grinding and polishing Grinding and polishing of roller printing rollers is carried out on the polishing bench. This is a lathe-like device, in which the print roller rotates and is moved across a rotating disc. A water tank forms part of the polishing bench, in which the roller body is immersed by approx. 5–10 mm during the polishing process. The following are used as polishing materials: polishing stone, grinding stone, charcoal sized at approx. (5 x 12 x 25) cm^3 .

Roller grinding mill is used in printing for grinding print pastes. Chiefly for vat dyes, pigments or pigmented discharge print pastes.

Roller grinding of print paste causes finest grinding of the material, i.e. of dye, thickener, etc. Distinctions are made between roller grinding machines with one roller and one or two grinding bars and those with two rollers and three bars or three rollers. The grinding process results from differential speeds between rotating roller and fixed bars or between rollers running at different speeds. The grinding material is transmitted from one roller to the other in a three roller machine, whereby each subsequent roller circulates more quickly than the preceding one. The grinding material is wiped from the last roller by a doctor blade.

Roller hardness The description of the hardness and/or softness for companies at home and abroad is in accordance with different scales for rubber or plastic rollers for finishing machines amongst other items, whereby confusion continually arises. It should be especially emphasised that the terms → DVM softness and → Shore hardness conflict with each other and are handled differently to some extent.

Roller mangle → Mangle, which contains batch rolled piece goods in one and/or two magazines (double roller mangle).

Roller press (cylinder press) →: Rotary clothpress; Pressing.

Roller printing,

I. Distinctions are made according to the type of roller printing area:

1. Gravure printing using → Roller printing machines: almost exclusive mode of operation using gravure printing rollers, on which print paste is transferred from the print paste container (colour box) by a running roller (furnisher roller). Removal of the surplus print paste by a doctor blade moving to and fro at the side. Such print paste application devices are arranged around the printing cylinder corresponding to the number of print pastes. The fabric runs on a back grey (undercloth) with lappings and a continuous rubber cloth (printing blanket) between the elastic support and the engraved printing rollers. Joint drive of the printing rollers by a repeat wheel.

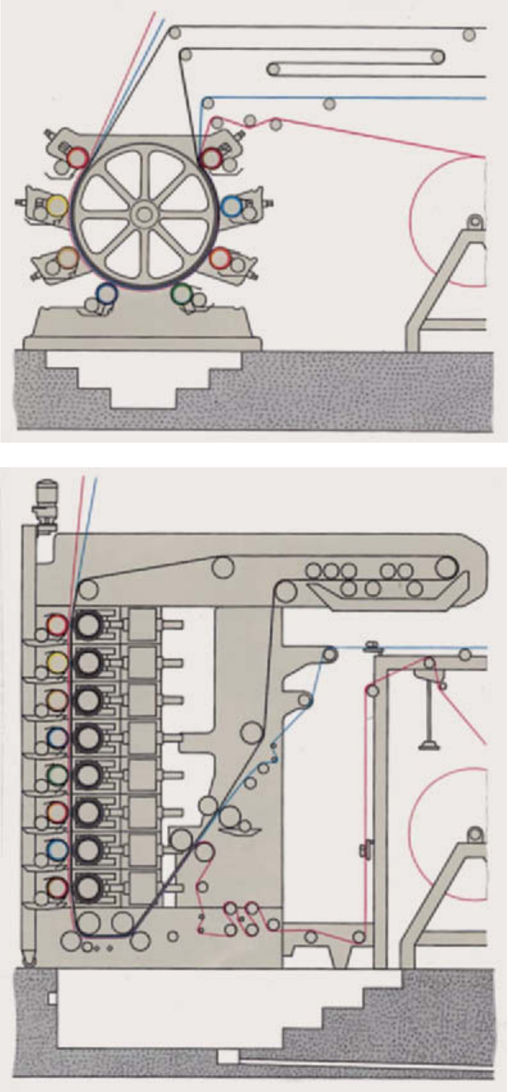


Fig.: Comparison of the run of material through a classical roller printing press (above) with that of a Saueressig-Portal roller printing press (below).

2. Relief roller printing (high pressure): of less importance. Printing rollers with raised samples (print paste application using continuous felt tapes for example) are used. Still used partly for carpet and wallpaper printing.
3. Mosaic printing, e.g. →: Conversion print; Orbis printing.

II. Regarding the type of print paste application through the print rollers, distinctions are made between deeply engraved pressure rollers, roller printing (see Fig.) and relief printed effects, in which the rollers contain the raised pattern. The latter may no longer be found in material printing. Only vigoureux and carpet printing machines still operate using relief rollers. Roller printing is a gravure printing. The sample is etched on the rollers made from copper, copper-plated steel and photo mechanical copper-plated light metal. The term "engraving" is no longer applicable. The transmission of the colour arrangement onto the rollers has been eased by electronics (scanning process). Roller printing machines are particularly suitable for the printing of large batches. They run at speeds of up to 100m/min.

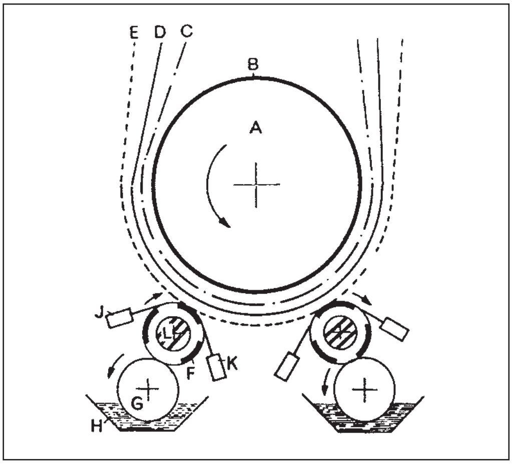


Fig. 2: Diagram of a two-roller printing press.
A = print cylinder; B = lapping; C = endless print blanket; D = back grey; E = goods; F = engraved zone; G = print paste feed roller; H = print paste trough; J = doctor; K = lint doctor; L = print spindle.

Roller printing machines The print paste applicator is composed of the print paste tank (colour box) and the tank in the rotating applicator roller, which transmits the print paste onto the engraved roller (printing roller) (Fig. 1). A doctor blade lying on top of the latter wipes off the surplus paste so that only the deep engravings still contain print paste and transmit this onto the material. The doctor blade has a moving capability of 5–25 mm and moves to and fro sideways 10–50 times per minute. The depth of the engraving is different. Shallow engraving up to 0.09 mm deep is sufficient for surface printing; this increases to 0.2 mm for good imprinting. The depth of the engraving is a criterion for the quantity of absorbed print paste and thereby a cost-determining factor. Shallow engravings give a rather smooth printing. For patterns, which go beyond the extent of fine lines or points, the doctor blade would remove the print paste. In order to prevent this, the figures are divided into fine grooves side by side, so-called hatching, which are at an oblique angle to the direction of motion of the fabric. The rollers corresponding to the colour number to be printed using the print paste application device are arranged on the perimeter of a large cylinder, of the print cylinder or printing cylinder (Fig. 2). They are pressed onto the cloth running between the printing cylinder and the engraved rollers by highly sprung spindles.

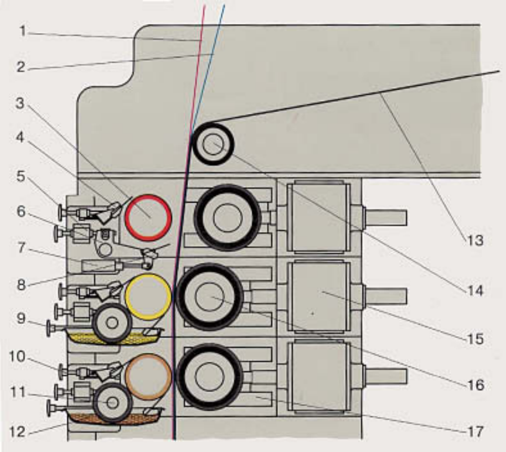


Fig. 1: The printing machinery in a Saueressig-Portal roller printing press.
1 = print material; 2 = back grey; 3 = printing roller; 4 = lint doctor; 5 = print paste doctor adjustment; 6 = print paste doctor bearing; 7 = doctor cylinder; 8 = print paste doctor; 9 = print paste roller adjustment; 10 = lint doctor adjustment; 11 = print paste application roller; 12 = print paste trough; 13 = printing blanket; 14 = deflecting roller; 15 = printing cylinder; 16 = printing roller; 17 = printing roller guides.

It can easily be seen that a thixotropic behaviour of a print paste may be desired with rapid movements (particularly in roller printing). The thinner and lower its viscosity, the quicker the break contours run into a homogenous, smooth surface and the easier the penetration of the fabric surface will be. The following results in the adhesion of the print paste to the printing roller, i.e. in the hatching: The thinner the thickening, the less it sticks. The thickness of the remaining layer is a function of a suitable flow characteristic (with low, very possibly thixotropic viscosity and low adhesiveness). If the part already printed is now touched by another new surface, it is understandable that this part is the less sensitive to squeezing of prints

- the more thoroughly the fabric surface is already homogeneously penetrated by the print paste and
- the less print paste adheres to the new contact surface of the printing roller.

Seen physically, this fact is a function of the flow characteristics within parameters of surface tension and adhesiveness; thus, the adhesion forces between the contact media.

The Kauschka-Brückner roller printing machine system departs from the conventional design with a central printing cylinder and arranges the individual print paste plant, consisting of colour box, printing roller, doctor blade and printing cylinder, lying diagonally. The print paste plant is arranged vertically in the machine from Saueressig. The printing rollers do not have spindles. They are mounted directly and held in bearings by compressed air. The contact pressure is low compared with conventional machines. The “Sari Roller” printing machines built in England are a speciality for printing large registers. The design is distributed on three rollers in these machines, whereby two rollers print the middle section and the 3rd the border.

An elastic base should be available under the cloth during printing, which consists of a thick wool union material (lapping) and a rubber cloth continuously running across and protecting the lapping wound in several layers around the printing cylinder. Modern printing machines are provided with a rubberised printing cylinder. The continuous rubber cloth (printing blanket) then becomes no longer necessary. A cotton back grey absorbs the surplus print paste, which penetrates the material to be printed. In order to be able to use this on both sides without interrupting the printing function, a back grey turning device has been constructed. The continuous washing off on the printing machine can be carried out itself on existing roller printing machines with continuous rubber printing blanket using polyamide/cotton blend fabrics as continuous back grey. Küsters has constructed such a device, in which a special water calender (Aquaroll calender) de-waters the back grey so severely that it is unnecessary to dry it. The back grey is replaced by a continuous, ultrafine grooved plastic printing blanket in the “Darex” printing process. This is continually washed using a particular device. The washing off of print pastes with water-soluble thickenings does not cause any difficulties. The rotor should however be provided with a particular protective layer against solvents in pigment printing pastes and emulsions. The trend from fabric to knitgoods also becomes noticeable in printing. A roller printing machine was constructed in a portal type of construction (“tricot print”), on which tubular knitgoods can be printed.

The precise calibration of the register is a difficult job, especially for multicoloured printing. The printing rollers can be rotated forwards and backwards on their axis for this, moved to the side and also positioned higher and deeper on the sides. The repeat on modern printing machines can be adjusted electro-mechanically during printing by means of pushbutton control. In order to make the repeat easily visible for print pastes with a low natural colour, so-called sighting colours are added to them. These are dyes, which have no affinity to the fibres in question and can consequently be washed off again later. Compounds, which light up in ultraviolet light (fluorescent brighteners), can also be selected for this with the use of corresponding lamps.

The risk of spreading the printing dye pastes exists in wet-on-wet printing of multicoloured designs. The print pastes printed first stain off from the material onto the print cylinder below. The fitting of counter doctor blades or lint doctors or the insertion of non-engraved rollers, which are continuously washed (water rollers), has a counter-effect. In addition, the brighter, more delicate shades, i.e. in “forehand”, are printed first and the darker ones last (“the smallest colour in the first hand”).

A good printing result depends on many parameters in roller printing. The individual factors have hardly been recorded in detail in their effect until now. Even today experience therefore still plays an important role in printing. The relatively low number of installed roller printing machines is mainly due to the fact that engraving the rollers is a costly job. Only large firms have their own engraving department; the rest have the rollers engraved outside. The printing orders should reach a particular minimum quantity for the amortisation of the engraving costs; the metre lengths of the printing design become shorter and shorter however. Roller printing is still of interest chiefly for multicoloured discharge printing.

Roller printing preparation trolley facilitates the preparation of print paste units outside the printing machine, while the machine itself is still producing. Setting-up times can be reduced.

Roller printing, pressure adjustment is still used to adjust the printing pressure in older printing machines. It facilitates resetting of the contact pressure on both sides even during printing with the aid of pins. Frequently replaced by → Plate springs in roller printing.

Roller printing, quality parameters Amongst machine-independent parameters, which lie in the hands of the printer, the print paste dependent dimensions have particular practical significance, of which, it is known that this essentially concerns interface problems, i.e. the laws, which apply to water transport in fabrics/knits, should also be authoritative for the printing process. The following are important:

1. influence of the contact period and centrifugal acceleration (printing speed).

2. influence of isolation effects due to variably rapid migration of print paste components in the course of the printing process.

While the first dimension, and also initial and limit conditions, is influential to a certain extent, both effects govern the continued course of the transfer of thickeners and dye on fabric within a short contact period as well as during the subsequent drying. Knowledge of the rheological properties of thickeners alone is not sufficient, however, for the interpretation of complex dye transfer processes, in which threshold stress and surface tension play a no less important role. For the interpretation of phenomenological facts, mechanically conditioned factors should be just as carefully considered as fabric data and physical/chemical as well as rheological print paste properties.

Roller raising → Raising.

Roller recutting Repair work to the roller after mill, panto and photo-engraving (→ Ruling).

Rollers, rolls Rotatable cylindrical bodies.

I. For the guiding or transporting of cloth, either undriven or driven as → : Guide rollers; Draw rollers. Deflecting rollers may contain the roller pins sealed in a hollow cylinder as a simple equipment practice (Fig. 1).

Fig. 1: Roller pins with welded-in double bottoms.

There are various bracing measures, e.g. filling with expanded foam, if high working widths are to be handled by rollers (Fig. 2).

Fig. 2: Internal bearing method complete with special bearing.

If there are guide rollers in open-width washing machines, the rollers in the gusset as well may be regarded as washing or liquor exchange elements (Fig. 3).

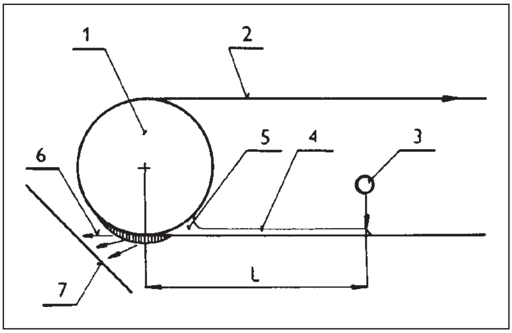


Fig. 3: Guide roller as a washing element.
1 = guide roller; 2 = textile fabric; 3 = liquor application unit; 4 = liquor film; 5 = liquor wall; 6 = spray;
7 = collector; L = distance between application point and tip of stuffer/compression wedge.

II. For the processing of cloth: squeezing rollers, pressure or calender rollers (→ Calender), →: Printing rollers; Applicator rollers.

Squeezing rollers are rubberised. The sequence of operations in Fig. 4 is the same for new or retreadings:

1. registration and initial inspection.
2. removal of an old coating possibly present.
3. sand rays: pretreatment to achieve a perfect adhesion. Covering all parts not to be rubberised such as spindle ends, etc.
4. application of the adhesive system: arranges the adhesion between rubber and metal; if the mixture is adapted, takes place in several machining operations.
5. application of the coating: by hand or on special machines, without bubbles.
6. tying with tape: prevents the running off of the rubber during subsequent vulcanising and ensures good adhesion.
7. vulcanisation: crosslinking of the rubber molecules under heat and pressure, approx. 145°C, 2–10 h. Transfer of the material texture from the plastic into the elastic state, physical/chemical connection with the core at the same time.
8. removal of the bandages.
9. processing of the coating: looping and/or rotating and attaching of possible structures.
10. check: inspection of the specification demanded such as diameter, roundness, hardness, surface quality and surface cleanliness, for example.

Fleece rollers produce special squeezing effects (Fig. 5). The lower the speed of a fabric guide roller (Fig. 6) in roller vats or in roll steamers, the lower is the risk of rope creases due to the fabric wrapping around the rolls in a semicircle. Increased fabric guide rollers with a large diameter are therefore used in these plants (Fig. 7).

Roller scratches in roller printing

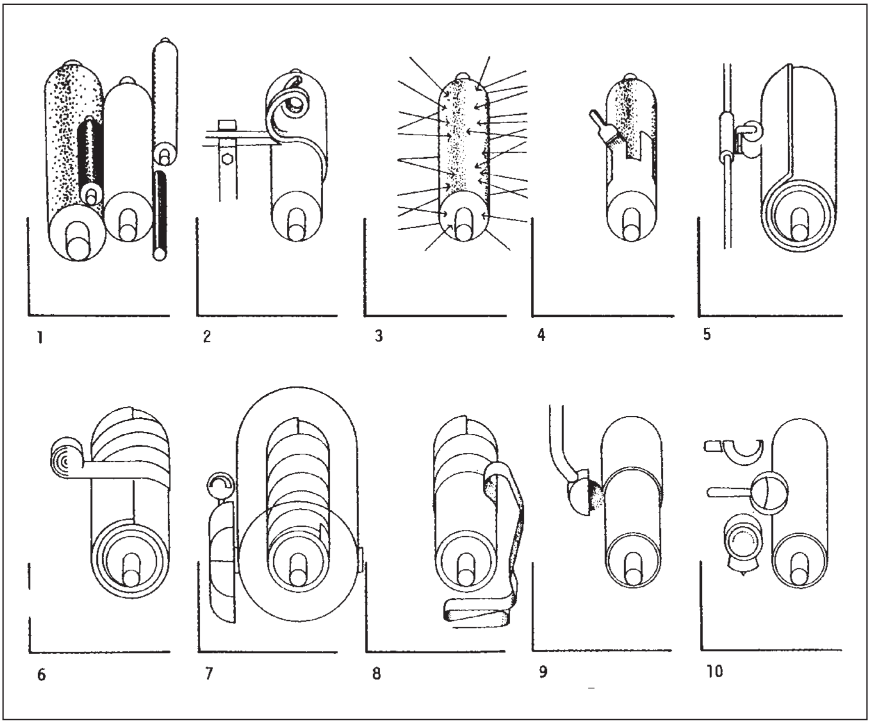


Fig. 4: The application of a rubber roller covering (Zeppernick).

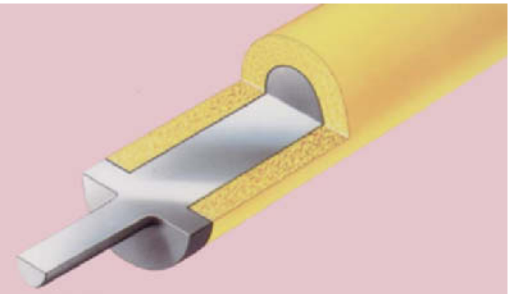


Fig. 5: Roberto roller with special adhesive.

Roller scratches in roller printing result from hard foreign bodies, which were usually only briefly jammed between doctor blade and printing roller and produce a more or less deep tear on the printer roller exterior. Also result if the grinding burrs of the doctor blade are not completely removed.

Roller storage in roller printing The printing rollers are normally stored horizontally on top of each other in several tiers in special shelves in the so-called roller store. On each shelf, a printing roller rests on three to four moving wooden rollers laid down to avoid scratches on the roller when being taken out and pushed

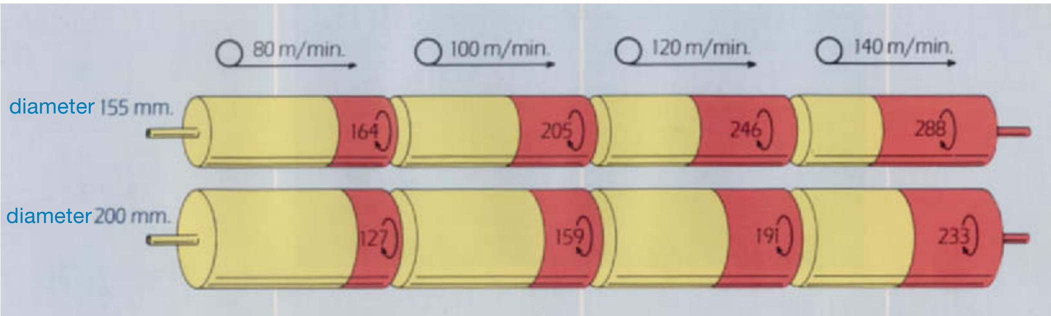


Fig. 6: The speed in revolutions per minute of guide rollers of different diameters for goods moving at different speeds.

Fig. 7: Fabric guide rollers in the Brugman steamer.

back in. Each roller must be numbered for filing and the shelf compartment correspondingly labelled as well.

Roller strike-off machine is used for production-independent design, for the testing of roller engravings and similar. The roller strike-off machine contains a printing station, on which the printing cylinder driven by the printing roller is started up. The printing cylinder is kept spindle-less by spindle sleeves. The repeat is precisely adjusted by means of a pitch pin. A filling doctor is used for the print paste feed. A water roller connected in series to the printing unit squeezes off the printed print paste.

Rollers, wrapped Elastic calender rollers made of paper, cotton, jute, special spiral fabric and similar. The elastic material is pushed onto a steel axis (sufficient diameter avoids bending of the wrapped roller) in the form of separate disks (e.g. approximately 20 000 per metre of roller), hydraulically pressed under high pressure (up to 100 t) and held together on the head ends by iron rim discs. Such wrapped roller surfaces are exceptionally tough and can only be re-surfaced to the desired diameter using diamonds (e.g. → Roberto rolls).

Roller vat, roller beck Basic form of all open-width washing machines. Principle (Fig. 1): Rectangular dyeing vats (approx. 1.1 m wide, 1.2 m deep, 3.5 m long) with guide roller system installed top and bottom, across which the piece good is carried in the zig zag by the liquor after passing an expander (speed of 15–100 m/min).

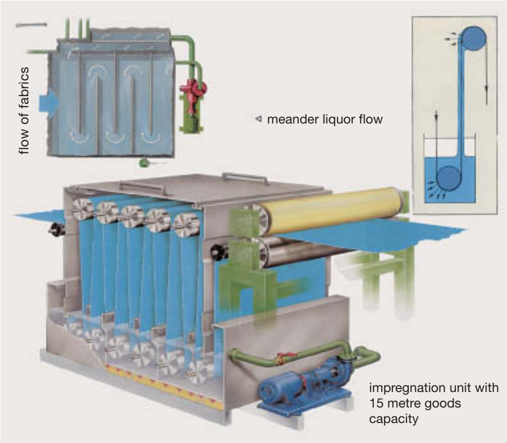


Fig. 1: Meander liquor flow in counterflow direction and throughflow of goods in a Brugman roller vat.

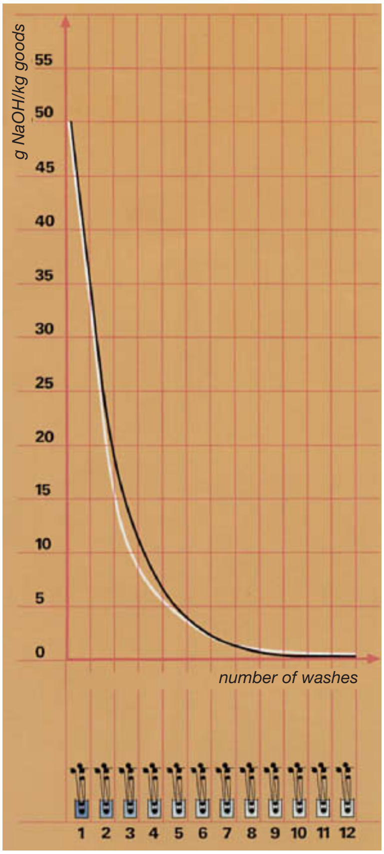


Fig. 2: Comparison of the calculated concentration curve with measurements obtained in practice during the washing out of mercerization liquor in twelve roller vats (black = calculated values; white = measured values).

3–8 such dyeing vats are arranged in combination as required. Large (diameter) deflecting rollers in the roller vat reduce the risk of rope creases. The efficiency of several roller vat washing steps shows the washing off curve of mercerized cotton fabric (Fig. 2). In order to optimise the liquor exchange and thereby increase the washing effect:

- double fabric thread-up (Fig. 3),
- supporting rollers (Fig. 3),
- mote rollers (Fig. 4),
- meander liquor guide (Fig. 1),
- counter current principle (Fig. 5)

can be used.

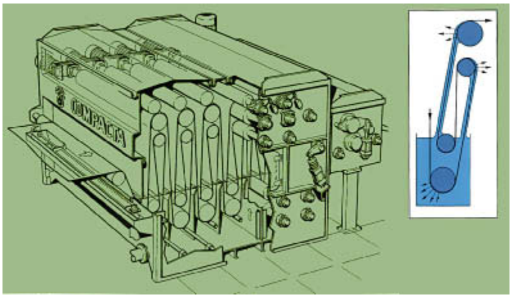


Fig. 3: *Increased liquor exchange by using double immersion of fabrics and supporting rollers in the Küsters roller vat.*

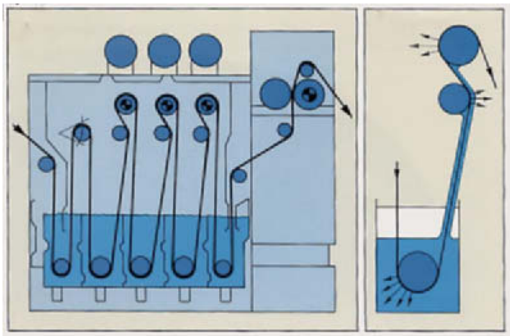


Fig. 4: *The Supra Nova roller vat with mote roller and the single immersion of fabrics, together with top roller drive and horizontal squeezer (Kleinewefers KTM).*

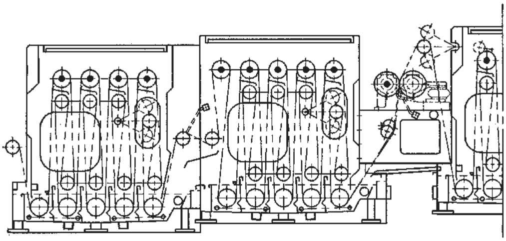


Fig. 5: *The flow of fabrics is from left to right, the flow of liquor from right to left: the principle of counterflow in a Babcock roller vat array.*

Rolling,

I. Drum movement on machines (e.g. washing machines) in one or both directions without stoppage, in contrast to → Reversing action.

II. Hemming of handkerchiefs, for example.

Rolling machine For the rolling of textile fabrics during storage, further transport (and also for their protection). Particularly for voluminous textiles or those of such large width, such as carpet lengths for example, special rolling machines are required for the rolling of a polished technique into shape, which form regular yarn packages kind to material on corresponding carriers (tubes).

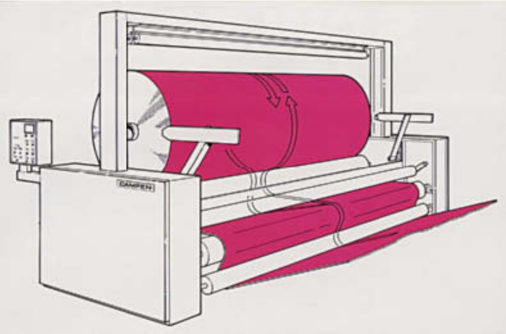


Fig. 1: *Carpet rolling machine SCW 5000 (Campen).*

The rolling unit from Campen shown in Fig. 1 shows the following features and working options:

- driven thread-up rollers (contact rollers) support the carpet from the dead centre to the rolling rollers;
- 2 tiltable driven roller guideways for carpet transport alternatively for exterior and interior pile;
- double dead centre device with rotating shearing blades;
- driven guide roller and 2 driven “rolling head rollers” for starting automatic rolling on cardboard tubes without staples, etc.;
- 2 rubber-coated rising rollers each with a separate drive for the setting of the desired roller strength;
- measuring system with electronic length counter with length preset;
- cardboard tube dispenser with automatic tube insertion;
- pneumatic roll ejector by means of lifting the rear, rising roller;
- seams can be cut out and expelled as required.

With a rolling machine for light, 150 cm wide outwear fabric (Fig. 2), the operator merely has to bring the

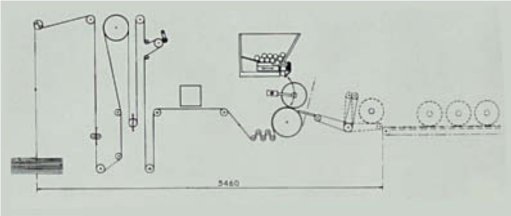


Fig. 2: Rolling machine for fabric (Biella Shrunk).

tubes and the material to be wound. The machine is controlled by a microprocessor. Many variants are possible for controlling the measuring and winding processes. The machine carries out the following machine operations without intervention from the operator (speed of 10–120 m/min, production: 50 rolls at 50 m/h):

- batching of the material into small and medium rolls (max. Ø 500 mm);
- measuring the length;
- readout of marked errors;
- print-out of weight and error marks on a label;
- attaching the label;
- cutting off the material in accordance with given length count;
- piling the roll onto a conveyor belt;
- insertion of a new tube;
- start of a new roll.

Roll test → Levelling property test.

Romaine raw wool weight loss in scouring Weight loss (= loss from washing) from → Raw wool in the laundry.

Röntgen Designation for the unit of ion dose until 1977, the SI unit valid from 1978 is Coulomb per kilogram C/kg: $1\ \text{R} = 2.580 \cdot 10^{-4}\ \text{C/kg} = 258\ \text{C/kg}$. For ion dose rate or output, the derived SI unit is correspondingly the ampere per kilogram A/kg:

$$\text{ion dose rate} = \frac{\text{ion dose by irradiation}}{\text{duration of irradiation}}$$

Roof heat recovery system Radial fan with integrated heat recovery (principle of regenerative heat exchange); as fresh air and exhaust air fan, a bladeless capillary blower, which transports the two separate air streams (fresh air and exhaust air) at the same time; the capillary heat exchange thus extracts approx. 50% of incoming external air from the used, warm, exhaust air. The power saving due to the use of accumulated heat is around 40%, and this figure is even higher where there are large internal heat sources (e.g. laundries).

Root-Tip-Levelling-Kinetics in wool dyeing Prevents skittery dyeing in wool. Sunlight-damaged wool fibres invariably dye first at the tips, probably because the hydrophobic scale layer becomes hydrophilised through cystine oxidation. In the dyeing process the tip and root colour gradually levels out, but can be accelerated by the use of amphoteric levelling agents based on ethoxylated fatty amines (dye and fibre affinity).

During dyeing, the dye needs to diffuse through the laminar boundary layer and the hydrophobic cuticula into the woollen fibres (Fig. 1).

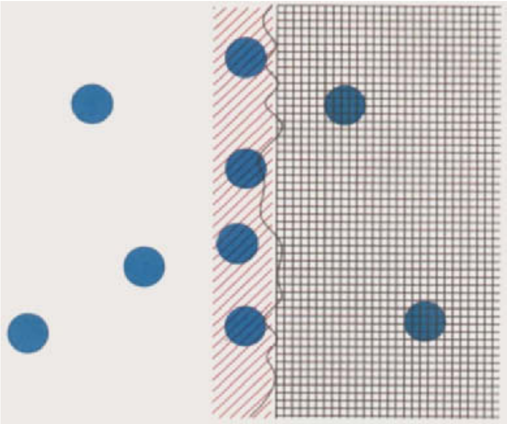


Fig. 1: The blue dye molecules diffuse through the laminar boundary layer (diagonally hatched in red), are adsorbed onto the hydrophobic cuticula and then diffuse into the cortex (cross-hatched) of the wool (by Ciba Geigy).

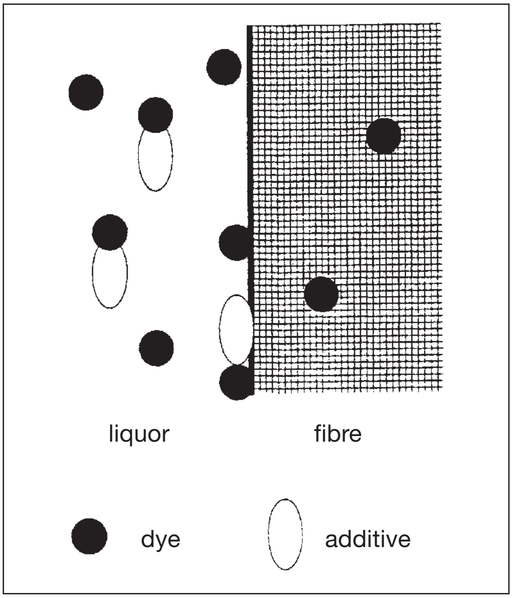
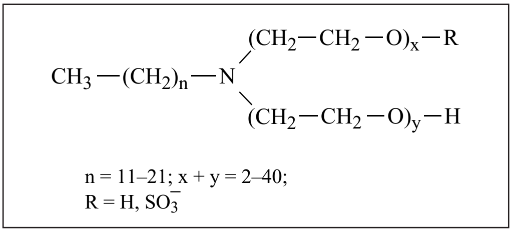


Fig. 2: Possible auxiliary exchange, particularly between additive and dye (by Ciba Geigy).

Root-Tip-Levelling-Kinetics in wool dyeing



$$CH_3-(CH_2)_n-N\begin{matrix}(CH_2-CH_2-O)_x-R\\(CH_2-CH_2-O)_y-H\end{matrix}$$

n = 11–21; x + y = 2–40;
R = H, SO_3^-

Fig. 3: The general formula for ethoxylated fatty amines as used in many levelling additives for wool. The nitrogen atom may be additionally quarternated.

In the dyebath, dyestuffs and auxiliaries can form a complex which has different properties (Fig. 2). The damaged tip is significantly more hydrophilic than the hydrophobic root. In the case of the auxiliary illustrated in Fig. 3, the resulting dye-auxiliary complex is more hydrophobic than the dye alone, and ought therefore to possess a higher root affinity, and therefore level the differences. An interesting question is why a substantially larger dye/auxiliary complex diffuses more quickly into the fibres than a smaller dye molecule.

The auxiliary surfactant is concentrated at the phase surfaces, thus enhancing the wetting properties of the wool (Fig. 4). As the wool fibre roots and tips have different hydrophilic properties, it is quite plausible to assume that auxiliaries are taken up in different amounts at the root and tip, thus changing the hydrophilic properties of the fibres. This change could result in improved dyeability levelling of fibre root and tip.

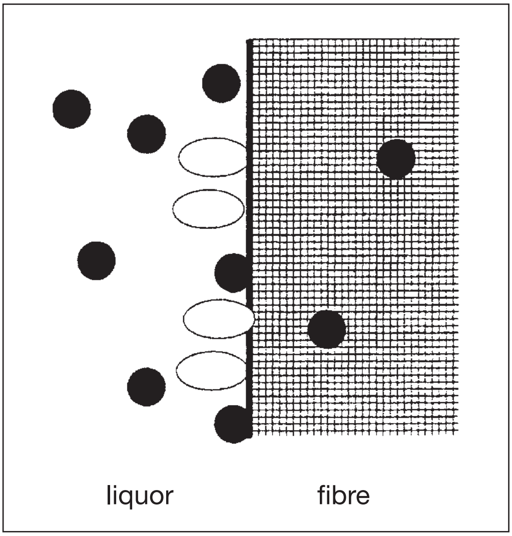


Fig. 4: Possible auxiliary exchange at the fibre surface (by Ciba Geigy).

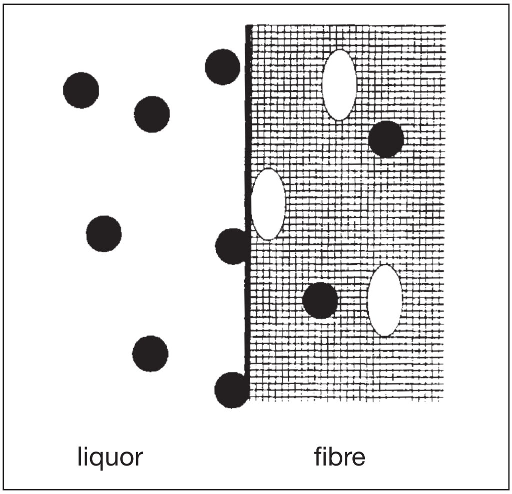


Fig. 5: Possible auxiliary exchange between additive and the interior of the fibre (by Ciba Geigy).

It is widely known that non-ethoxylated anion surfactants are taken up by the wool, enter the fibre and affect the fibre properties relatively quickly. Accelerated levelling of root/tip differences can be brought about by a change in the charge density, competition for bonding points or increased fibre swelling (Fig. 5).

Damaged wool fibre tips are always dyed first. Levelling from the tip to the root occurs during the dyeing process in the dyebath. With reactive dyes, this levelling process stops at a relatively early stage due to the chemical bonding of the fibres, resulting in skittery dyeing. As suitable levelling agents overcome skittery dyeing, the question is whether the auxiliary brings about even dyeing from root to tip from the outset, or whether it accelerates the process of levelling from root to tip, enabling more dye to diffuse to the root, before the reaction with the fibre takes place.

Chlorinated wool is damaged on the surface by chemical treatment, similarly to the way the wool tips are damaged by climatic influences. The simultaneous dyeing of chlorinated and untreated wool in a single dyebath (Fig. 6) is a system where the varying dyeability corresponds approximately to the root and fibre properties of a wool fibre.

Without auxiliaries the dye is taken up relatively quickly by chlorinated wool (tip model) with a damaged surface. Although there still is a slight redistribution of dye in favour of untreated wool (root model) at higher temperatures, the fundamental preference for damaged wool remains. However, with auxiliaries, the process of dyeing is different: although an initial preference for damaged wool is observed, it becomes less and less pronounced. At temperatures above 70°C the dye starts to re-distribute from the chlorinated to the

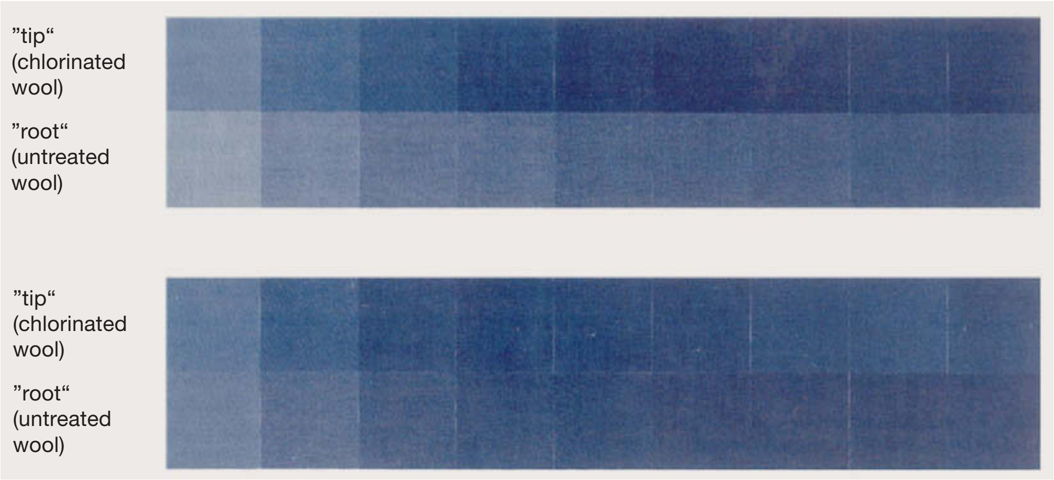


Fig. 6: Model system for correcting root/tip differences: dyeings of untreated and of chlorinated wool in the same dye bath with 1.5% Lanasol Blue 3G (Ciba Geigy). Above without and below with Albegal B (Ciba Geigy).

untreated wool. At this time the dyeing process is almost complete. When boiling point is reached, the process is largely finished, and the untreated wool is more strongly dyed. On the one hand, this reduces the preference for damaged wool at the beginning of the dyeing process, and the absolute colour intensity shows that the dye uptake of the chlorinated wool has not been influenced by the addition of the auxiliary, while the dye absorption rate into the untreated wool is markedly increased by the surfactant. On the other hand, the levelling agent ensures that after the dye has been taken up, it is re-distributed from the damaged to the untreated wool.

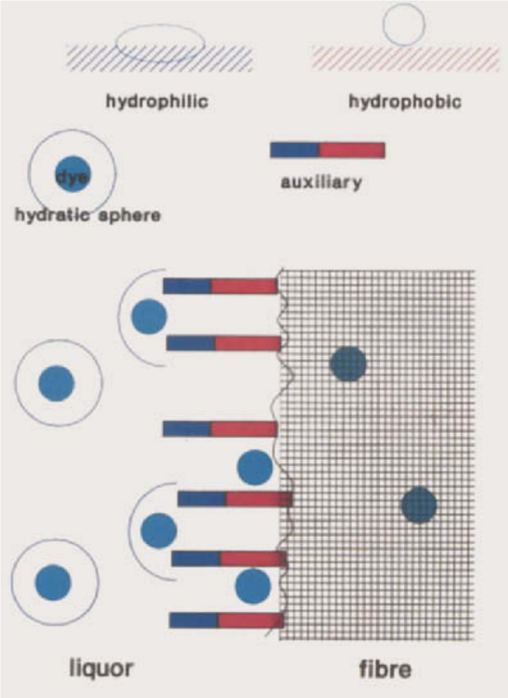


Fig. 7: Hydrophobic and hydrophilic exchanges as an explanatory model for the acceleration of dyeing (by Ciba Geigy).

The fibre levelling effect of formulated ethoxylated fatty amine derivative-based levelling agents of varying structure, charge and active substance content, when applied on a mass concentration scale, is directly dependent on the surfactant quantity taken up by the fibre (Fig. 7).

Studies of sorption using different fatty amine polyglycol ether derivatives, some using equal mass concentrations, others using molar initial concentrations, provide a fairly clear picture of the influence of the structure (hydrophile-lipophile balance (HLB), molecular weight, surface activity) on the exhaustion kinetics and the quantity of surfactants taken up by sorption. The number of monomeric surfactant molecules which can be taken up by sorption is determined by the surfactant’s critical micelle concentration (CMC) and its dependence on the outside electrolyte content (the amount of sodium sulphate in the dyebath during blank dyeing fluctuates during the adsorption of the electrolyte by the wool) and by the temperature. Hydrophobic surfactants (with a low HLB) have a tendency to more rapid sorption while having a lower CMC, i.e. a lower supply of monomers. Regardless of structural influences, at relative low temperatures (25–50°C), considerable quantities of the added surfactant (between 30 and

90%, depending on the initial concentration and structure) are absorbed. The potentially suppressive influence of these surfactants can be shown by velocity potential measurements. There is no simple correlation between the quantity of surfactants taken up by sorption or cation charge density (molecular weight) and the measurable zeta potential: the architecture of the surfactant layer taken up by sorption affects the shearability of the potential-defining ions (according to Hannemann).

Rope creases Disruptive, longitudinal marks; a problem that occurs in fabric and knitted goods finishing, particularly where dyeing takes place in rope form at higher temperatures. It has been shown in practice that crease inhibitors can minimise this fault. Where impregnation is carried out with plaiting, folds, creases occur either in the padder, when plaited, in the steamer or later during piling.

Rope detwister The product rope (Fig. 1) passes between two spring-loaded rollers of the detwister basket (1), the deflecting roller (2) and the two sensor rollers (3) before proceeding to the spreader. When the rope is opened, the torsion direction of the product causes a response in the sensor rollers, and their lateral position is sensed by a proximity actuator. The proportional output signal is amplified and passed on to the induction drive motor which rotates the detwister basket, thus unravelling the rope. The deflecting roller may be equipped with an additional drive or a pneumatic brake. This prevents tensile stress and run-on from developing in the product when the machine is shut down. Finally the system plaits down the product (Fig. 2).

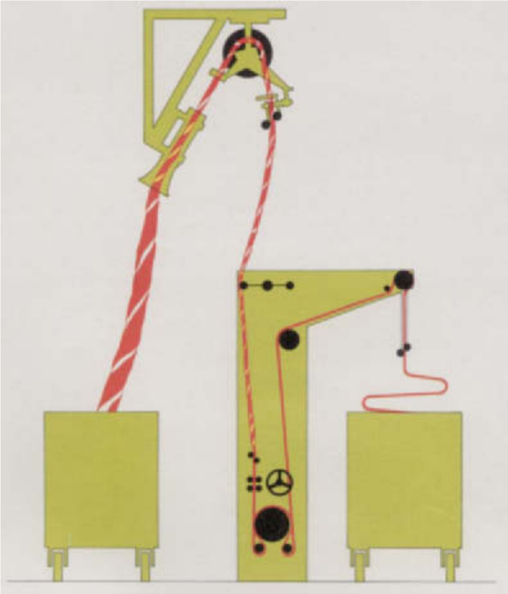


Fig. 2: A rope detwister system (Hemmer).

Rope dyeing machines Dyeing machines in which the textile product is dyed in the form of hanks or ropes, e.g. jet or overflow dyeing machines.

Rope form Textile fabric which has been gathered loosely into the form of a rope in the warpwise direction (woven fabrics) or wale direction (knitted

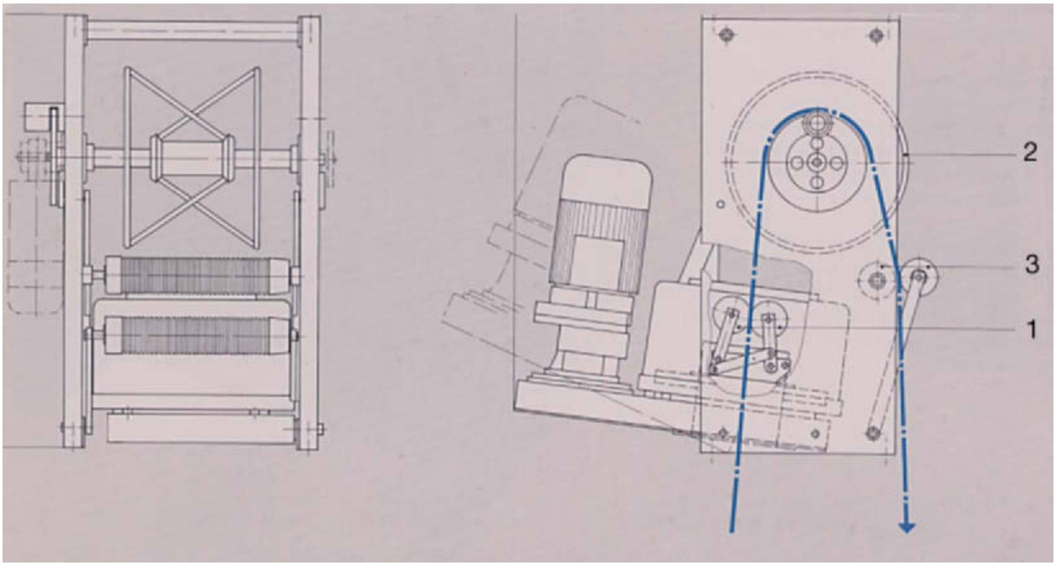


Fig. 1: Contact sensor (numbers explained in text) on the head of a rope detwister (Erhard and Leimer).

fabrics), usually by passage through a ring or pot-eye of suitable diameter for pretreatment and dyeing processes (as opposed to open-width processing).

Rope form handling Device for guiding goods in rope form →: Rope opener; Rope guide wheel; Rope ring.

Rope guide wheel A rotating element in → Rope form handling device which guides and supports rope piece fabric. It may or may not be driven.

Rope marks Bursts in the weft yarn during → Milling in tube form when selvedges which have been sewn together do not allow the air to leave the tube (hose) sufficiently quickly.

Rope opener This spreads all piece goods which are pre-treated in rope form by means of beater rollers, scrollers and spreader rollers.

Rope opening/plaiting device A device for unravelling, spreading and plaiting down fabric ropes.

Rope piler At the end of a wet rope treatment section the rope leaves the machine and is squeezed before being placed in intermediate storage (see Fig.).

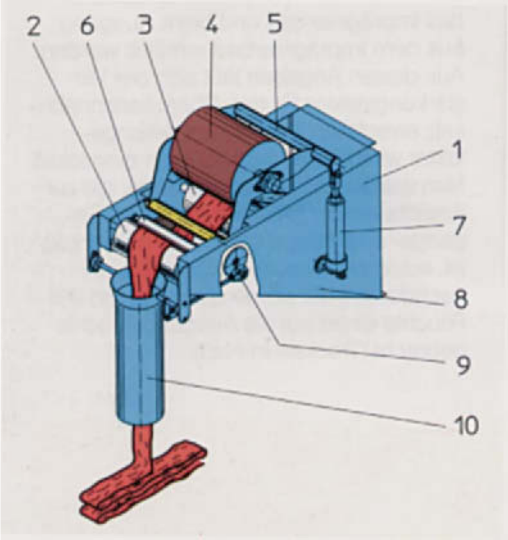


Fig.: Goods run-out with intensive squeeze rollers and a rope piler (Brückner).
1 = run-out housing; 2 = traction roller; 3 = deflection roller; 4 = Aeroflex squeeze roller with frame (5) and pneumatic cylinder (7); 6 = deflection roller; 8 = moving-magnet drive (not shown); 9 = crank drive for plaiting device; 10 = plait pipe.

Rope piler, trunk rope piler Device for feeding rope-form piece goods into bleaching vats. It is usually fed in together with a wetting-out liquor. Electric-hydraulic rope pilers have a telescopic tube which can be used for round bleaching vats. Even with varying product speeds from 30–150 m/min (infinitely variable) it ensures an even rope speed without twisting at a variety of rope speeds.

Rope plaiter Hydrodynamic piece rope plaiter which feeds the rope into the fabric accumulators by means of a rope piling device.

Rope ring (pot-eye). A ring-shaped component forming part of the → Rope form handling device for guiding and supporting the product rope.

Rope soaper (rope washer). Washing, rinsing and finishing device consisting of e.g. 3–5 adjustable pressure squeeze and guide rollers. As well as the washing, rinsing and blueing of bleached goods, it is also used in particular for the chlorine finishing of e.g. the Ce-Es bleaching of fabrics.

Rope squeezing machines (rope mangles). Are designed to extract water from piece goods treated in rope form. They can be incorporated into some manufacturing systems as intermediate devices (squeezing units), e.g. washers or autonomous devices (squeezing machines). In the latter case they are usually full-width squeezers.

Rope washing machines (rope scourers). Are washing machines for washing piece products in rope form. Unlike discontinuous rope washing machines, which consume large amounts of water, continuous rope washing machines operate with smaller amounts

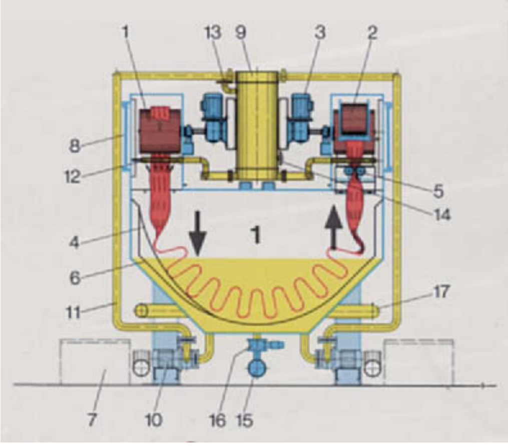


Fig. 1: The construction of a rope treatment machine (“Delphin” according to Brückner).
1 = transport drum; 2 = squeezing roller; 3 = drive;
4 = filling level control; 5 = guide rollers for rope laying;
6 = smooth Teflon coated bath; 7 = servicing stage;
8 = viewing window; 9 = heat exchanger; 10 = liquor pump;
11 = liquor circulation system; 12 = rope spraying system;
13 = steam connection; 14 = condensate connection;
15 = main drain; 16 = individual chamber drains;
17 = liquor counterflow system.

Rope washing machines

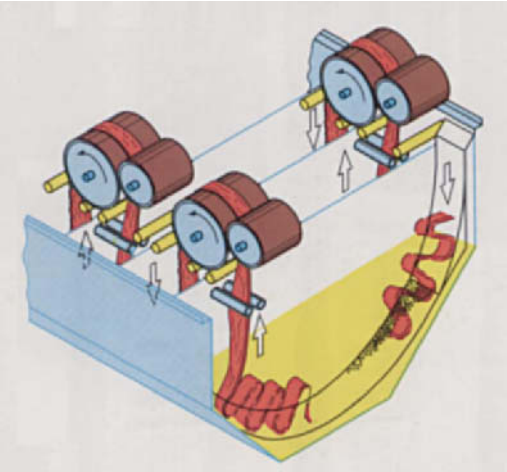


Fig. 2: The arrangement by which the rope is passed from side to side for immersion treatment while travelling along the rope treatment facility ("Delphin" from Brückner).

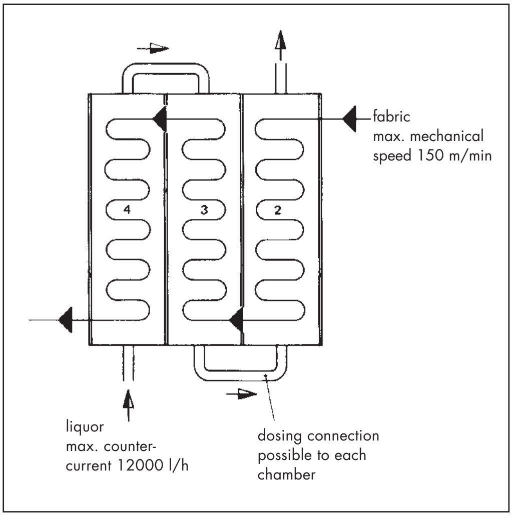


Fig. 4: Fabric path in a rope treatment machine ("Delphin" from Brückner).

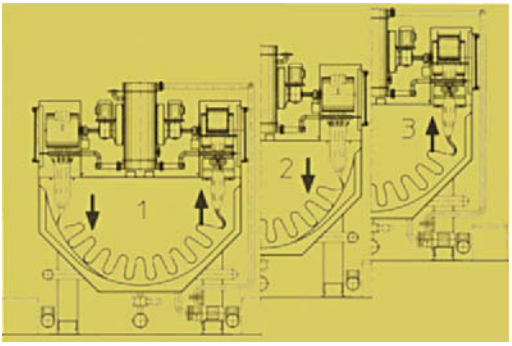


Fig. 3: Section through three chambers in the liquor interchange zone of a rope treatment facility ("Delphin" from Brückner).

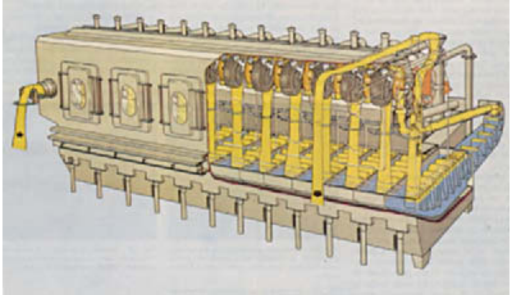


Fig. 5: The WR rope washing machine from MCS (Italy) for the continuous wet treatment of woven or knitted goods.

of liquid and a specific liquor flow. They almost invariably function on a counter-current basis.

In a continuous rope washing machine there needs to be a balance between the stationary product zone and the liquor interchange zones so that the arrival and departure of the laminar boundary layer and subsequent diffusion from the fibres into the laminar boundary layer are sequentially matched. Rope washing machines must be designed in order to make optimum use of available space. In the "Delphin" by Brückner this is achieved by positioning the stationary rope settlement area prependicular to the main product travel direction (Figs. 2 and 4). The liquor exchange zone in the Delphin consists of squeeze rollers (Figs. 1 and 3), while in the MCS rope washing machine (Fig. 5) it is made up of jet tubes. In this system the jet tube transports the rope from one chamber to the next (Figs. 6 and 7), thus enabling the goods to be passed through 8 settlement areas and 8 liquor exchange zones within a single machine. If different pretreatment stages are required, more settlement and liquor exchange zones are required (Fig. 8).

The advantages and disadvantages of rope washing machines produced both by machine manufacturers and by textile finishers are as follows:

Advantages:

- product width does not matter;
- ease of guiding ropes, even over long distances;
- higher product speeds possible than when in expanded state (150 m/min);
- the ability to keep large quantities of material in a small space, particularly in dwell processes;

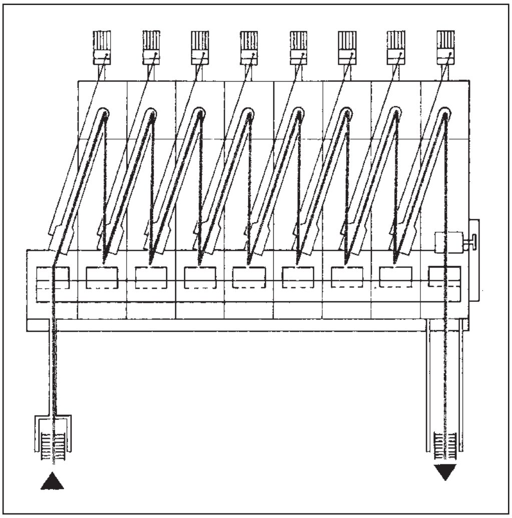


Fig. 6: The transport of goods in the Argathen rope washing machine, which has routing of goods typical for that type of system.

- less tension of goods than with open-width wash machines;
- less space requirements;

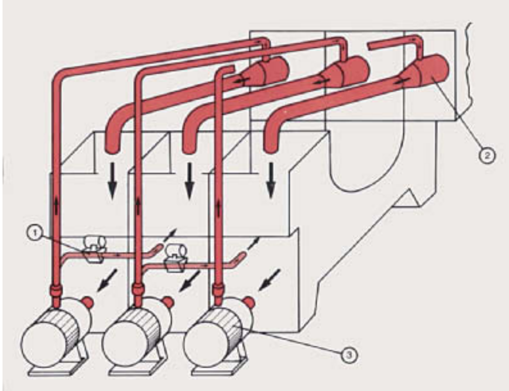


Fig. 7: The liquor interchange zone and the flow of liquor in the Argathen rope washing machine. 1 = counterflow; 2 = jet; 3 = circulation pump.

- reduced capital and maintenance costs;
- better relaxation of goods, a fuller and deeper handle, less pilling (depending on product);
- particularly good appearance for crêpe fabrics, in particular bark crêpe;
- saves time and water consumption, particularly when used with the consistent counterflow principle.

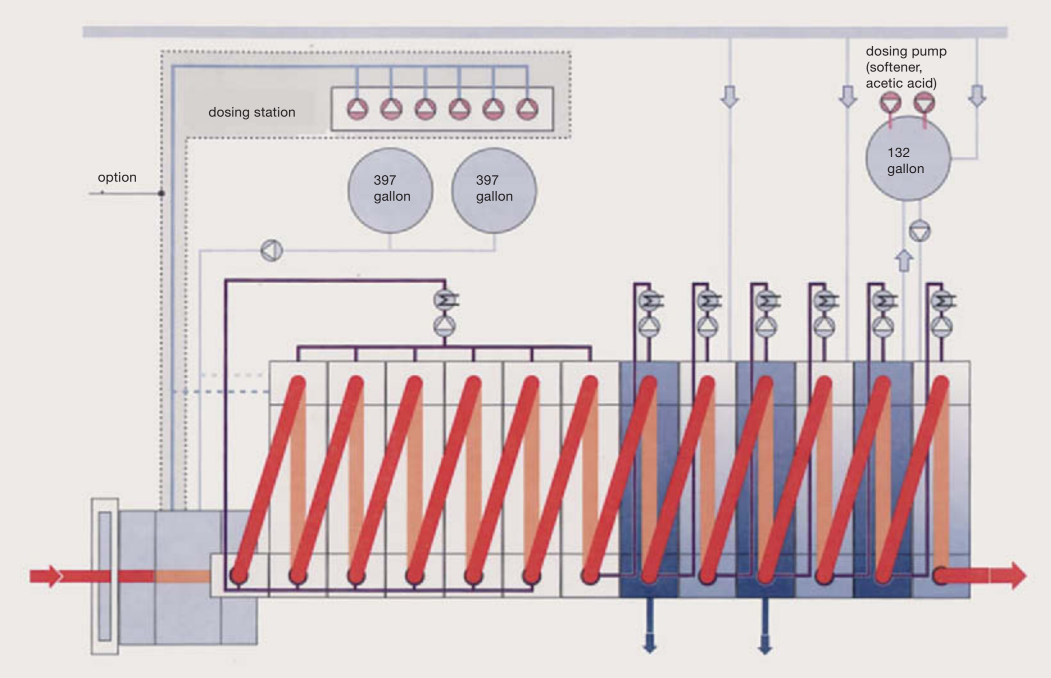


Fig. 8: The twelve compartment "Edelweiß" rope washing machine based on a Rotostream (Thies) for the continuous rope bleaching of cotton.

Disadvantages:

- not every product (due to construction and weight) can be rope-treated for reasons of unlevel dyeing, breaks or fold marks; unsuitable for pure synthetic woven fabrics;
- the product needs to be re-opened after rope treatment;
- danger of ghost prints during the after-treatment of printed goods;
- danger of skewing product;
- fluffy product appearance depending on goods;
- uneven flow of thin articles, occasional knotting;
- idling of individual sections due to incorrect adjustment.

Rosaceae rubber → Vegetable gums from cherry, plum, almond and other trees. Often in large, luminescent lumps, which look red or amber against the light. It contains gum arabic and about one-third ceresine which accounts for its inability to be diluted evenly and fully in water. Although when dissolved it consists of a thick mucilage, it has a lower viscosity than solutions of → Gum arabic. Pulvarised rosaceae rubber can be dissolved in water in the following manner, similar to gum arabic: soften by soaking in water (remove impurities) and then leave to swell for 36 h; then heat the mucilagenous mass for 2 h in autoclaves at 3.0199 bar, leave to cool, filter and if required concentrate by evaporation. Rosaceae rubber from almond trees and wild plum trees is usually used to imitate tragacanth. Decomposed cherry gum is used as → Industrial gums and sometimes as a thickener for printing.

Rosaniline → Fuchsin dyes.

Rosella A bast fibre originating in South-East Asia and similar to → Kenaf. The length of the basic fibre is about 2–5 mm; its per hectare yield is higher than jute, but it requires more processing. Used as a packaging material.

Ross-Miles method (modified) →: Foam test methods; Foam evaluation criteria.

Rot Rot is chemical decomposition with a mainly alkaline reaction (in contrast to → fermentation) and unpleasant odour. It encompasses a variety of indeterminate chemical reactions with the formation of intermediates and soluble end products, which are also released by aerobic and anaerobic bacteria. Putrefactive agents include in particular unstable, easily decomposable proteins, the rotting of which introduces enzymes which dissolve peptide bonds (peptidases). The next stage is the formation of albumoses, peptones or simple amino acids (leucine, tyrosine etc.). As the process progresses, other enzymes (carboxylases) cause CO_2 to split off from the amino acids. Successive splitting-off of CO_2 causes a progressive shortening of the carbon chain. The sulphur contained in sulphurous amino acids (cystine) is released as foul-smelling hydrogen sulphide. The final stage of the rot is mineralization, i.e. decomposition to water-soluble minerals (nitrates, chlorides, phosphates). In comparison with proteins, pure celluloses, fats, resins, waxes and related substances are much less prone to rot. The bacterial or enzymatic decomposition of carbohydrates (sugars, starches, celluloses) gives rise to particularly acid-reacting decomposition products (lactic, butyric and acetic acids), which in the presence of protein lead to the neutralization of the ammonia formed during decomposition of the protein, thus prolonging the rotting process. If dry substances contain a lot of carbohydrates and few proteins, there is only a low level of decomposition under the influence of simple mould fungi. Fats are also much more resistant to bacteria if, for example, they are decomposed by lipases in glycerine (often decomposes quickly) and fatty acids (often resistant to decomposition or only slightly susceptible).

Rotary cloth-press It should theoretically be possible to achieve a press effect in wool fabrics during continuous processing using calenders that are used in cotton finishing. However, rotary cloth-presses are predominantly employed in the continuous dry finishing of wool (see Fig.), in order to compress fabrics. The aim of pressing is to smooth the surface of the fabric. The rotary cloth-press, the Contipress (Menschner) and the flat press are suitable for this purpose; mangles can also be used to smooth fabric surfaces. With the rotary cloth-press, the product is passed without creases between a heated steel roller and a trough. The roller draws the product in and pulls it over the trough, which is held in place by means of hydaulic devices or spindles.

The rotary cloth-press consists of a rotating heated cylinder and a static heated trough which is pressed against the cylinder; care needs to be taken when seams are passed through. The pressure is adjustable. Although this system means that some pressure is exerted on the surface, the area pressed is relatively small and the exposure time is short. Cylinder diameters range from 400 to 800 mm depending on the machine, with a similar pressing surface. In order to avoid excessive loss of product moisture during pressing, the trough and the cylinder are heated at 0.2–0.3 MPa, corresponding to a steam temperature of 120–134°C. If the product moisture is reduced excessively, the product quality deteriorates, and a slight alteration in hue also occurs. Rotary cloth-presses also stretch the material slightly lengthwise, thus reducing its breadth. This occurs more where a rigid pressure is applied to the trough than if flexible pressure is applied. On the other hand, sliding the product over the trough surface results in a delaying friction which the highly-polished nickel silver turning does to some extent reduce, but it cannot be completely eliminated. Rotary cloth-presses are fitted with a momentum raising device allowing the trough to be promptly lowered when folding or other disruptions occur.

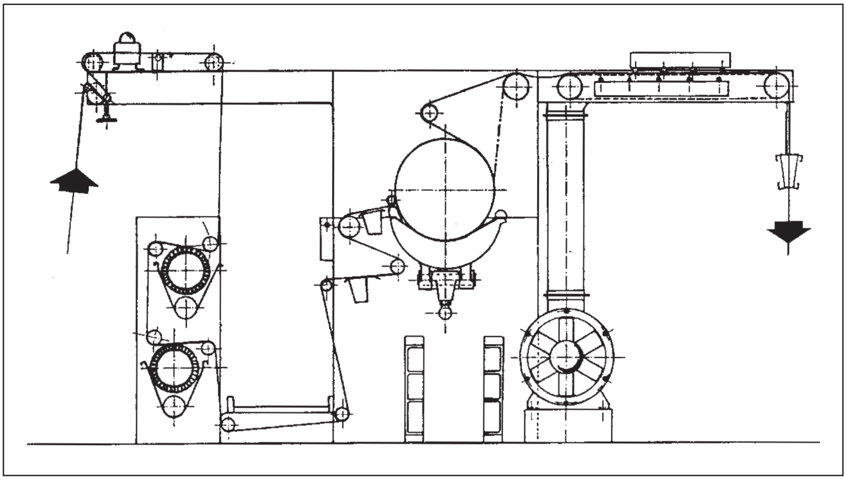


Fig.: A typical rotary cloth pressing machine.

Rotary drum drier A sieve-drum drier where the fabric is guided almost all the way around the drum, for the dry treatment and/or thermal treatment of tubular and/or web qualities. Their compact, high-productivity design with little space requirements make them particularly suitable for small and medium-sized shops.

Rotary irons A further development of → Ironing machines and steam ironing dummies used for finishing outerwear in one fully automated process (→ Steam ironing dummy).

Rotary milling machine → Cylinder rolling milling machine.

Rotary press A combination of 4 ironing presses for transfer printing. The transfer printing processes are cyclic, and hence continuous. There are 4 stations: 1. uptake of the material; 2: uptake of the thermal transfer paper; 3. transfer; 4. cooling and removal of the transfer material.

Rotary screen coating machine A device to provide an even coat of screen lacquer to rotary screens. The lacquer is applied in a single process using a variety of different lacquer types on rotary screens from the top downwards with the help of a rubber doctor roll.

Rotary screen printing The process of → Screen printing using rotary screens. The screen is not placed flat in a frame, but takes the form of a hollow roller. The advantage over automatic → Flat screen printing is a substantially higher level of continuous production (similar to → Roller printing). The advantage over roller printing is greater ease of changing dye and design, as rotary screens can be inserted and removed by hand, without the need for lifting blocks.

Rotary screen printing machines Design features:

I. Stork rotary screen printing machine (Fig. 1): During printing the cylindrical screens are supported by rollers, over which runs an endless printing blanket. The squeegee, which is fitted with a flexible coating blade, is inside the screen. The continuous adjustment of the squeegee pressure makes precision adjustment of the print paste coating possible for each individual screen without making it necessary to stop the printing machine. For long-pile fabrics requiring complete print penetration, an “air blade” which increases the penetrating pressure three-fold has been developed.

II. Zimmer rotary screen printing machine: this uses a magnet roll squeegee, which guarantees steady rolling of the screens and also makes it possible to use a screen stretching device which is independent of the machine. This makes it possible to fit narrow screens for narrow printing widths on wide rotary printing machines without the need to fit additional units.

III. Buser rotary screen printing machine: a significant design feature of this machine is the product feed. The Buser feed stand makes it possible to process fabrics of different qualities. Buser also supplies combined

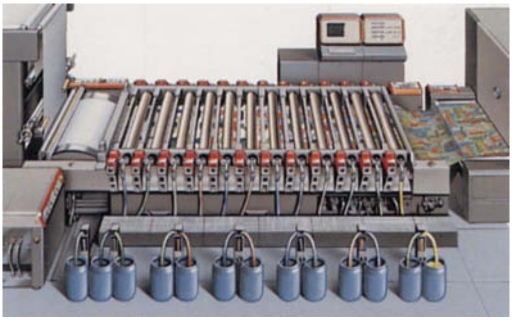


Fig. 1: A Stork rotary screen printing machine.

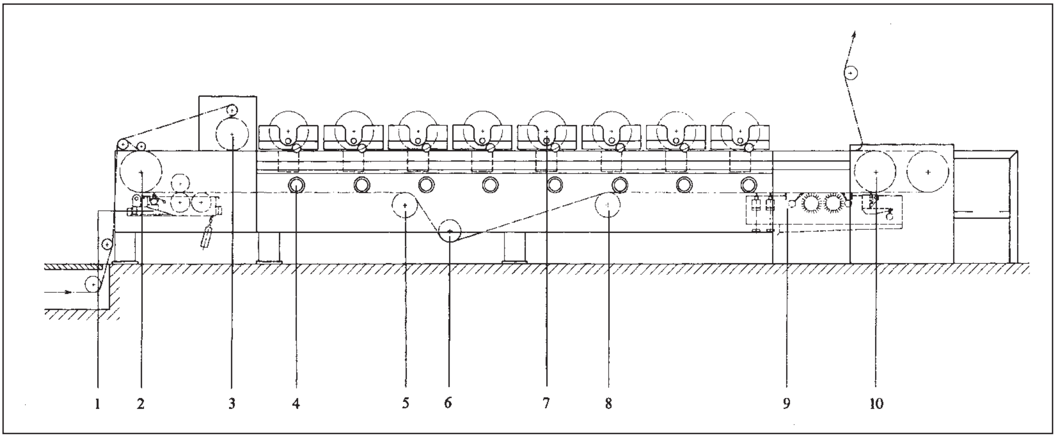


Fig. 2: An MKB rotary screen printing machine.
1 + 3 = gluers; 2 = deflection roller; 4 = pattern repeating wheel; 5 + 8 = supporting rollers; 6 = control roller; 7 = printing system; 9 = printing blanket washer; 10 = drive and tensioning rollers.

rotary screen printing machines, i.e. a flat screen printer with a rotating part.

IV. Aljaba rotary screen printing machine: unlike other rotary screen printing machines, its design is similar to the roller printing machine. However, unlike roller printing, it is the printing cylinder that is driven, while the rotary screens revolve only with slight pressure. They are stabilised and adjusted at the ends by a free-running cog. The product, together with the back cloth, is fed in at a constant tension, but not stuck on.

V. In the MKB machine, the rotary screens can be inserted neatly into the open guide units (Fig. 2).

VI. Reggiani's Futura rotary screen printing machines make it easy to observe products running at a speed of 25–50 m/min between the rotary screens, which is important for ensuring quality control on the part of the printing machine operator (Fig. 3).

Rotary screen printing of carpets → Carpet printing machines.

Rotary screens for screen printing are metal

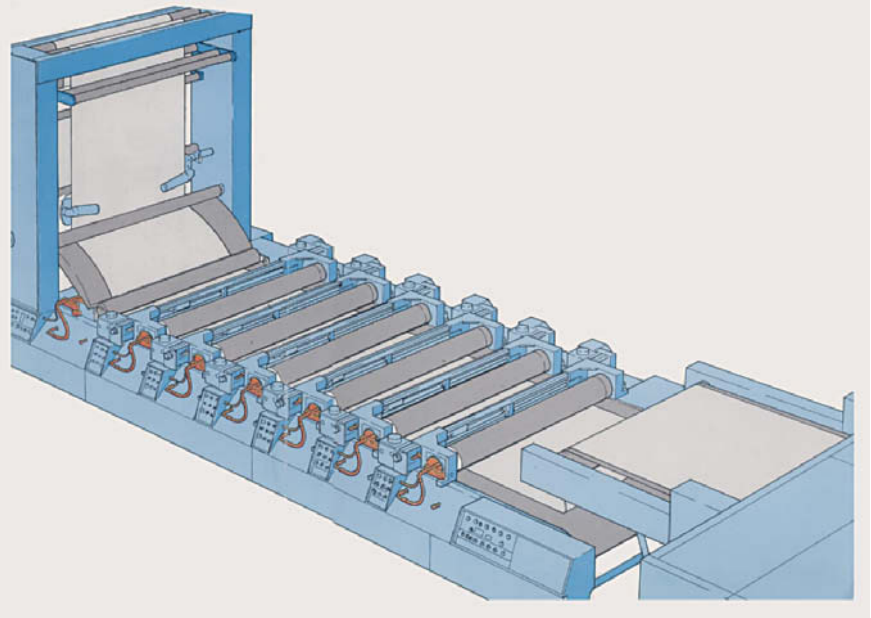


Fig. 3: The Reggiani Futura screen printing machine for circular screens.

cylinders containing fine pores whose walls have a thickness of 0.08–0.15 mm and which can be more than 3 metres in length.

I. Perforated lacquer screens: engraving lacquer screens is one of the classical methods of creating rotary screens. They are based on a seamless perforated cylinder on to which the design is transferred by photomechanical means. After cleaning, a photosensitive coating is applied to the screen, and the positive image is copied to the rotary screen. This is then developed, dried and baked. Finally the end rings are inserted into the engraved rotary screen.

II. Directly patterned galvanised screens: with this other classical method the screen is also produced by galvanisation, but it is engraved at the same time. This is done by transferring a negative film of the grid design, which is prepared and transferred to the master roller. The grid points then remain open or closed depending on the hue in the galvanised nickel coating. A 150-mesh rotary screen with a wall thickness of 0.085 mm and a length of 3 500 mm produced by galvanisation (matrix produced electronically) makes it possible to print half-tones.

III. Discharge screens: another possibility that rotary screen production offers is transferring the screened design to un-perforated nickel cylinders and etch them on, which again makes it possible to achieve screened printing. This process is rarely used.

IV. Laser engraving: this process dispenses with the exposure, development and polymerisation stages needed for other processes. The engraving only needs a time of 15–30 minutes.

Rotary screen printing was first developed at the turn of the century, and perfected in the 1930s. This can be seen from early patents. However, it was only put into practice in the 1950s by Almerindo Barros of Portugal (Aljaba). In the early 1960s, the Stork company was the first to employ galvanisation to manufacture good quality rotary screens in sufficiently large numbers. It was this, rather than the design of the first rotary screen printing machine which was presented in 1963, that was the real technical breakthrough. The rotary screens are the medium for the printing pattern. As such, the size of the perforations determines the graphic resolution, and this decides what the image to be printed will be. The fineness of the perforations, combined with the open perforated surface, also doses and distributes the print paste. The quality of coverage and the levelness depend on them. However, the screen also has mechanical functions. The evenness of the circumference, the torsion strength and flexural resistance of the rotary screen all help to determine the register. The latter two are particularly important when blade squeegees are used. Finally, the screen is also subjected to chemical and mechanical stresses during operation and handling.

The galvano procedure makes use of the ability to produce perforated hollow cylinders through electrodeposition of metal. In galvanoplasty (also known as electroforming), the electro-deposition of metal on suitable bases makes it possible to produce relatively thick metal layers. These tend to be self-supporting and make it possible to produce complex hollow cylinders. Typical of galvanoplasty is the exact reproduction of the surface structure of the medium, which gets lost increasingly as the thickness of the metal wall increases. A metal tube forms the basic element, which is normally electrolytically copper-plated and turned on a lathe so that the outside diameter has as fine a tolerance as possible. In the next stage the copper surface of the tube, which is known as the master roller or die, is mill engraved. The copper coating of the tube is ideally suited, as it is a metal that is easy to emboss. At the same time, unlike steel, a copper coating can be renewed and re-embossed. This is necessary when a master roller has reached the end of its life, for example. Mill engraving is a process in embossing engraving which originally was used in the manufacture of textile gravure cylinders. It involves rolling the relief, an embossing tool which is cylindrical and small in relation to the master roller, and which is prepared in special processes, on to the drive master roller under mechanical pressure (Fig.1). The relief resembles a hedgehog, as it is fitted with a multitude of seamless miniature embossing elements (needles) which are geometrically equal. Often the embossing elements resemble small skittles or pyramids, with a height of approximately 40 µm.

In practice the term → Pattern die-mill engraving is often mistakenly used in place of relief; Jakob and Weissberger summarised the issue: in mill engraving (which is used primarily in preparing rollers for roller

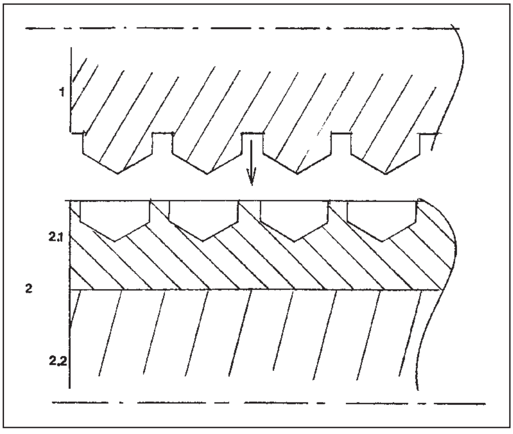


Fig. 1: Embossing the master drum.
1 = embossing tool (relief); 2 = master drum with copper sheath (2.1) and steel core (2.2).

printing), which is suitable for (low-pitch) and geometrical designs, the design is engraved into a small soft steel roller. All production stages that (in mill engraving) involve the creation of deep-set pictorial elements come within the concept of mill engraving. When it has set, the pattern die, i.e. the relief die or “relief”, is rolled at high pressure onto a soft steel roller. The relief therefore has the imprint of the pattern die, the pictorial elements being raised. All processes in mill engraving that create raised pictorial elements are therefore reliefs. When the relief has hardened, it can be transferred, i.e. mill engraved, on to the copper roller or the master roller, resulting again in inset pictorial elements.

The way in which this embossing procedure is able to transfer an almost totally uniform embossed image all the way around the roller, and along its entire length (which can be over 3 m) is as follows: when it is engraved on the outside edge of the master roller the first time around, the relief is embossed on to the roller surface. Here the transfer from the “end” to the “beginning” of the embossed pattern is vital. It must be ensured that the embossed elements of the relief coincide exactly at either end. If this has been achieved, the non-driven embossing of the relief into a forced rolling is a process which can be compared with the intermeshing of two cogs. Due to the extremely small picture pitch (i.e. the distance from one element to the next), the master roller circumference does not need to be a complete multiple of the relief circumference.

All the requirements for fitting the embossed image on the roller circumference also applie to the width. The relief is embossed in such a way that its pattern does not only match the circumference of the master roller, but also the width of the roller parallel to itself. This is achieved by slightly inclining the relief, which means it has a very slight spiral pattern, which is also “force-fed”. When embossing is complete, various processing stages are carried out, which vary from one manufacturer to another – for instance, the nickel-plating of the master roller in order to give stability to the copper margins around the inset picture elements. The next stage involves filling the inset picture elements with a material that does not conduct electricity. At this stage there is hardly any difference between the different processes. However, the coating process and the choice of filler material is one of the best-kept secrets of every manufacturer of rotary screens. They use artificial resins that are liberally applied, and which, when set, are removed (ground off) until the margins are blank metal and the inset picture elements remain filled with plastic and have an even surface (Fig. 2).

Other stages may follow to ensure the mechanical stabilisation of the entire structure, but these are insignificant for the manufacturing process of rotary screens. The master roller, once processed, proceeds to the nickel plating bath. The electrochemical process that takes place here deposits nickel at all parts of the master roller which conduct electricity and therefore permit a current to be created between the electrolyte and the master roller at this point. It is now obvious how the two-dimensional configuration of the master roller creates a three-dimensional screen. This screen wraps around the surface of the master roller and gets thicker and thicker during the electrolytic process (Figs. 3–4).

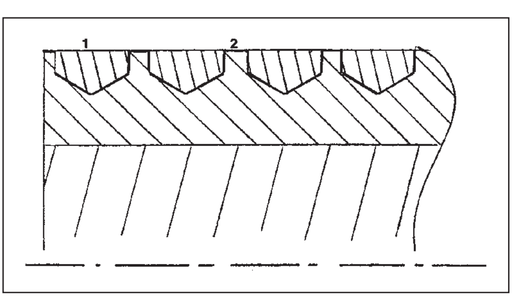


Fig. 2: The low-relief picture segments are filled with plastic (1) and then the ridges are exposed by grinding (2).

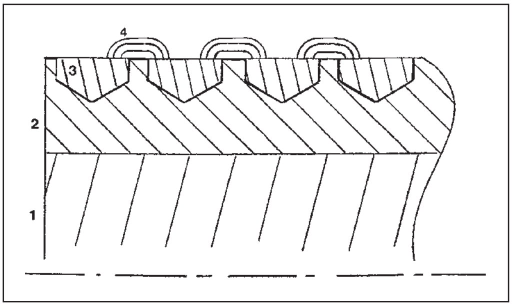


Fig. 3: The build-up of a rotary screen by galvanizing the surface of the master drum.
1 = steel core; 2 = copper sheath; 3 = plastic-filled pattern elements; 4 = the rotary screen, whereby the “contours” indicate progressive deposition with time and also the increase in width of the nickel ridges that is unavoidable under this procedure.

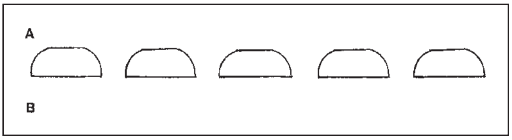


Fig. 4: Section through a first-generation rotary screen after the master drum has been removed. A = the outer surface; B = the inner surface of the screen.

In the past attempts have been made to use plating materials other than nickel to create rotary screens. However, none of these have proved suitable in practice. This is because the metallurgical and chemical properties of nickel make it best suited to the purpose, it is relatively inexpensive and can be galvanised onto thick walls in a relatively short time. The only question is which chemical composition of nickel electrolytes should be chosen. The choice is between sulphamate electrolytes and sulphate nickel electrolytes. The former creates a highly ductile (i.e. flexible, non-brittle) form of nickel, which can almost be classed as soft, whereas sulphate nickel ensures rigidity while ensuring a high level of ductility.

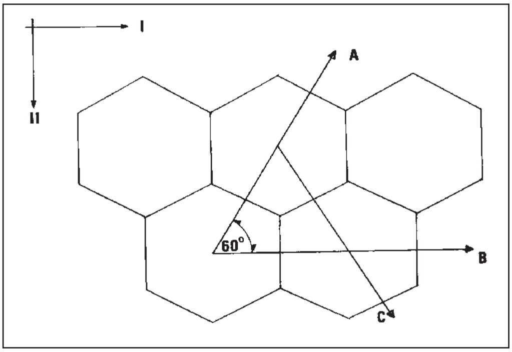


Fig. 5: The basic geometry of a rotary screen (first and second generation). The mesh index is determined by measuring out the screen perforations using a Piece glass. Only the counting axes A, B and C are used. Use of other axes leads to deviations in the result; it must be noted that the mesh index represents a nominal value which may vary. I = orientation of the longitudinal axis of the screen; II = direction of the screen circumference.

The relief is generally applied in such a way that a honeycomb pattern forms which is also imprinted in the rotary screen (Fig. 5).This geometry is both a technical and a historical development. The hexagonal apertures form an equal border width on the master roller and rotary screen in the "metering direction", which applies equally to "metering directions" in square patterns. This means that the screen can take mechanical loads in those directions (which it cannot in other directions). If the openings were circular, for instance, nickel borders of unequal width would form in the metering directions, which in theory would mean a disparate load capability.

Stork's → Penta-Screens are second-generation rotary screens. The word "Penta", derived from the Greek for "five", denoted the change from an increment of 10, which started off as 20, down to an increment of 5. The new screen type is based on the same master roller as the lacquer screen, as is the fact that it uses the hexagonal embossing method. However, it differs from the conventional process in the following way: whereas in the conventional process the rotary screen is deposited on the master roller until it has reached the required thickness, in the new process the galvanisation process is carried out in two stages. In the first stage, a skeleton screen is deposited with a wall thickness of about 30–40 µm. This screen is then removed from the master roller with extreme care, as it is highly delicate, and then increased to the required wall thickness in a second nickel plating process. What distinguishes this process is that the screen margins increase in size both from the outside and the inside of the screen simultaneously (albeit at different rates). This results in a significant decrease in the increase in breadth, which is vital for increased screen fineness with sufficient wall strength. If certain additives are added to the electrolyte in the secondary nickel plating process, and its currents are properly guided, the increase in breadth is limited even further. This makes it possible to produce screen materials of e.g. 300 mesh. However, these are not used in textile printing, but have found their application in technical screen printing.

The second galvanising process "rounds off" the originally precise hexagonal structure of the screen skeleton. It is scarcely recognisable as such, having instead a circular aperture shape. The process makes it possible to achieve a screen fineness of 125, 155, 185, 215 and higher mesh. The new second-generation screens are further distinguished by an enhanced wall thickness accompanied by a greater open screen area. As far as the extreme fineness of this type of screen is concerned, 185 mesh is very rarely used, and higher meshes are almost never used. With an open screen surface of 11.5%, 185 mesh offers a mesh width of 46 µm, while 215 mesh with an open screen surface of 9.5% offers a mesh width of 36 µm. Both these widths hinder the flow of print paste, and tend to cause dye loss during printing. 125 mesh (breadth d_1 with an open surface of 15% 79 µm, compared with 80 mesh with a d_1 of 95 µm with an open surface of 9%) has become the standard for screens. It allows an adequate flow of print paste, has advantages as regards micro-evenness, has a higher graphic resolution than 100 mesh, is more stable and does not tend to cause dye loss during printing.

Rotary screen washing is carried out in a screen washing cabinet by means of a spray ring on the outside and a spray head fitted with a nozzle on the inside. The washing operations in the system illustrated in the Fig., which can either be additionally installed in a printing machine or is already fitted in new machines, are made up in the main of the following stages: at the end of printing the print paste tube has to be detached and cleaned as usual. Then, by pressing a button on the main control system, all screens are washed in parallel, after which the print paste tube has to be re-fitted. The next printing operation can now be carried out. In a special process the doctor removes about 95% of the residual print paste from the surface of the screen into the trough of the internal cleaning device without the need for water. This leaves only a small residual amount of print paste that requires washing, thus economising on water. The main advantage of automatically washing all screens simultaneously is the time saving involved. It also simplifies operation of the machine and helps prevent screen breakages due to handling during removal and insertion.

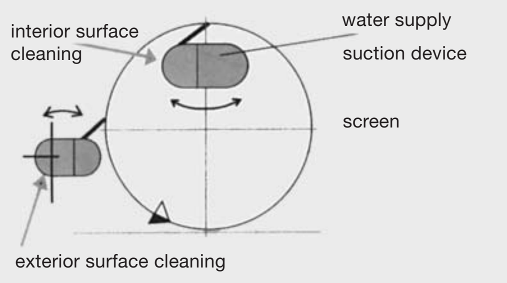


Fig.: The RSR stationary rotary screen cleaning device (Hassler HWB Textile Machines).

In the majority of systems rotary screens are removed and cleaned in the conventional manner using detergents. This involves trained staff, the use of large amounts of water, and associated equipment. On the other hand, cleaning is carried out in the printing machine itself, where the print paste tube and screen are cleaned by more or less the same method as when they have been removed; however, this entails "flooding" the machine.

Rotating rod drier A continuous hank yarn drier with rotating yarn rods which rotate while passing through the machine and which are closely spaced and allow air to flow between them so that the circulated air is fully utilised and the yarn is well aired. Dry treatment in a misty atmosphere at stepped temperatures up to the infeed of the wet product (resulting in the maximum possible protection, easy handling yarn with an even residual moisture content and low vapour consumption).

Rotating rod drier for hanks A continuous drier for drying hanks in a thermal chamber. The hanks of yarn are supported on rods which rotate slowly during their passage through the drier so that the position of contact with the hanks changes constantly. This type of drier is similar to the → Rotation rod drier.

Rotation (Lat. rota = wheel), revolution, turning.

Rotor atomizer This coating system basically consists of a rotor support, hydraulic control device, liquor container unit and centrifugal pump. The rotors turn at approximately 5000 rpm and distribute the treatment liquid over the product with droplets of approximately 30 µm (see Fig.).

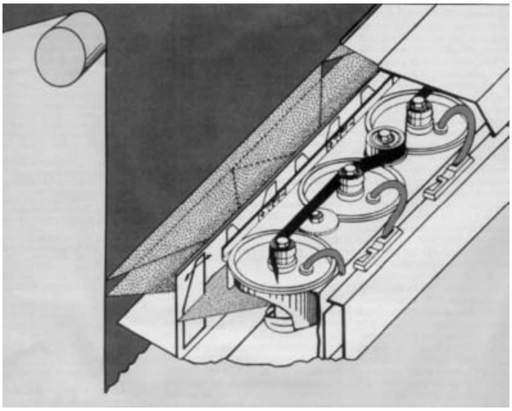


Fig.: Rotor atomizers (WEKO) for dampening a material across its width as it travels past.

Rotor damping A method for damping fabric and for → Low wet pick-up. It operates without jet nozzles. The equipment consists of a rotor support, a hydraulic control unit, liquor container and centrifugal pump (Fig. 1). The liquor is finely dosed. The rotors (approx. 500 rpm) spray a part of the liquor as very flat spray in the form of tiny droplets (diameter approx. 30 µm) at a vertical sheet of fabric. The spray width is approximately 100–400 mm (Fig. 2). The staggered sprays and overlapping zones result in a spray width of 180–280 mm for approximately 800 ml/m/min. Higher application levels are possible by having several rotor sup-

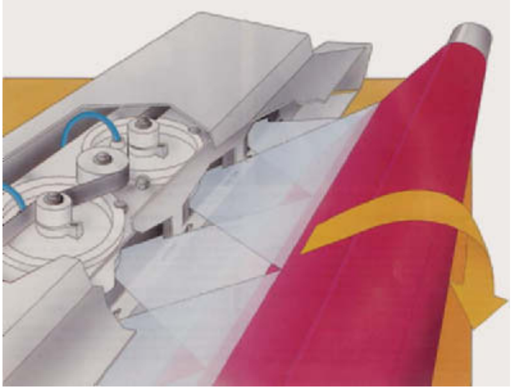


Fig. 1: The WEKO rotor dampening system.

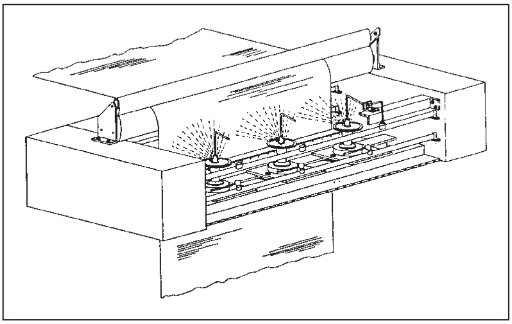


Fig. 2: The Proeco rotor dampening system.

ports, either on one or both sides. The wet absorption depends on the speed, and can be 0–25%, allowing for the product weight. Rotor damping can, because of its convenient size, be integrated into existing machines without much trouble, e.g. into the entry and exit of stretching machines, calenders, pole rotors, sanforising machines, etc. Wet-in-wet application is possible.

Rotor-spun yarn (OE yarn). Fibre yarn produced by means of rotor or turbine spinning process (→ OE spinning process). Individual fibres are removed from slubbings and are continuously added to a spinning open yarn end by an air current from a rotating turbine. This method of spinning results in carded -type yarn with typical qualities differing from those of ring-spun yarn → Ring-spun/rotor-spun yarns, properties of.

Rotor washing machines Washing machines with a divided inner drum uni-directional. Used in the multi-bath or → Flow washing process. Advantages: idle time for reversal of drum rotation is eliminated, thus ensuring a shorter washing process (= levelling for compression treatment reduces washing requirements) and smooth inner drum rotation.

Rot-protective finishing →: Fungicidal finishes; Antimicrobial finishes.

Rottability of textiles Refuse (wet household refuse). Rotting is done on an industrial scale in composting plants by the following heat process: 36 hours heating at a temperature of 70°C; 4 weeks of additional rotting with aeration (and eventual rotting of residual waste). This involves aerobic and anaerobic bacteria, which break down the waste product with the help of enzymes. Synthetic materials such as polyester, polyamide, polyacrylnitrile or polyolefins, however, are not broken down. What is important in the rottability of textiles, is that only cellulose fibres or protein-based fibres rot during composting. A year-long rotting test revealed the following order of textile degradability:

- wool > cotton > viscose > linen > polyamide > polyester > polyacrylnitrile > polyurethane > polyvinylchloride.
- natural/synthetic fibre mixes > synthetic fibres > reinforced rubber.
- carton/packing card > polythene bags > polypropene bags.

The DIN 53 933/part 1 test is the measure of rottability for these textiles. In this test, the criterion is 80% loss of the sample's initial maximum tensile strength (Fig. 1).

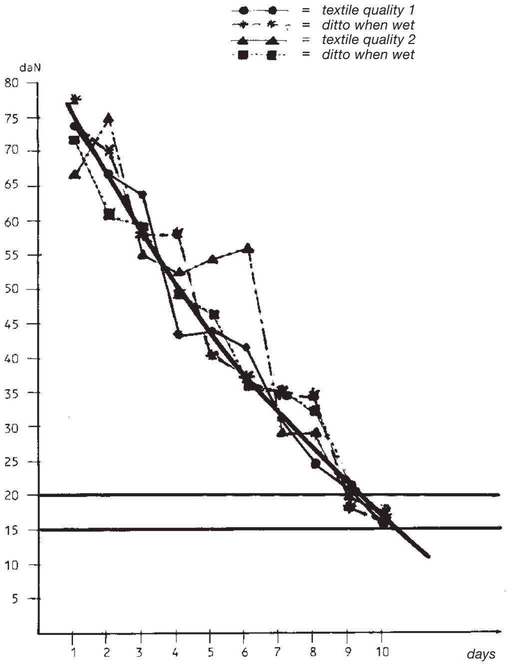


Fig. 1: The strength performance of unfinished cotton fabric in the burial test (DIN 53 933/part 1); drop in maximum tensile force of 80% with respect to the initial maximum tensile force (according to Hemmpel).

If a fall in maximum tensile strength of a cellulose textile product is taken as the criterion for the final rotting point, dependent on the action of the soil, a certain rotting period in days until the final point is reached is designated by f_1.

If a non-finished textile product is used to obtain the starting and reference values, the drop in the maximum tensile strength in a comparative tear strength test according to DIN 53 857 provides a fairly precise indication of the rottability that can be expected of a textile product.

It should basically be assumed that a non-chemically finished cellulose textile product will rot to 80% of its original (maximum) tensile strength within 5–8 days under the test conditions defined in DIN 53 933. Multiples of the rotting time f_1, $f_2 - f_5$, are only important in testing the durability of textiles treated against rotting according to DIN 53 933/part 2 (in preparation).

To rot a product until it loses more than 80% of its maximum tensile strength is pointless, as a tensile strength loss of over 80% is impossible to differentiate exactly. If total rotting (100% tensile strength loss) were used it would no longer be possible to establish the required time factor f_1 for later tests with treated material.

The time it takes for a textile product to rot completely in composting depends on the composting method. Untreated cellulose fibre can be composted in the same time scale as ordinary wet refuse.

If the basic value for the drop in the maximum tensile strength of untreated fabrics is given as 80%, and the product is described as "100% rottable", where a specified number of days until this is achieved is given for the burial test, then with treated fabrics the effect of the treatment can be shown by the reduction in this rottability under the same test conditions (same number of days in burial test according to DIN 53 933 (Fig. 2).

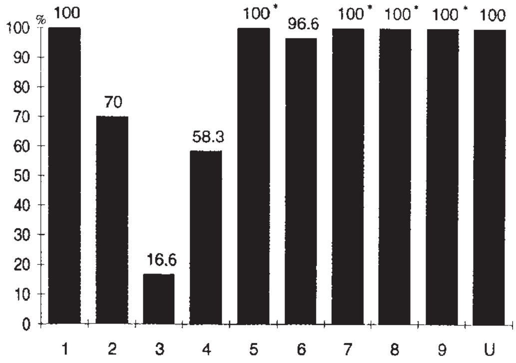


Fig. 2: The influence of finishing agents on the rottability of cotton (tested similarly to DIN 53 933).
1 = water-repellent finishing agent (fluorocarbon and silicon based); 2 = water-repellent finishing agent (paraffin based); 3 = curing agent; 4 = flame retardant agent; 5 = nonconserved softening agent; 6 = conserved softening agent; 7 = anti-electrostatic agent; 8 = handle improving starch; 9 = anti-slip finishing agent; U = untreated goods.
**improves rottability (according to Hemmpel).*

Textile finishing processes affect the rottability of cellulose textiles as follows:

a) Antimicrobial finishing: up to 5% of the rottability of an untreated sample in 7–12 days.
b) Vat dyeing, reactive dyeing, direct dyeing: no reduction in rottability.
c) Resin finishing materials reduce the rottability to zero, depending on the amounts of resin used:
  - modified dimethyldihydroxyethyleneurea: 100 g/l.
  - N-methylol compounds (which below 1500 ppm formaldehyde is not subject to labelling under the German Directive for Use of Dangerous Substances (GefStV – Gefahrstoffverordnung), according to DIN 54 260): 150 g/l,
  - self crosslinkers modified as methylolurea: 100 g/l.
d) Flame-proof materials behave differently according to type, but as wash-fast crosslinking finishes are no longer rottable.

Other finishing agents, e.g. softeners, antistatics, handle modifiers or anti-slip agents appear to accelerate rotting in the burial test (reaching 80% tensile strength loss in less than 8 days). If the finishing agents used in the cellulose textiles contain preservatives, the rottability is reduced (according to Hemmpel).

Rotting resistance test A method of determining the tensile (tear) strength of a textile sample either by the →: Soil burial enzyme test; Soil burial test or by inoculating (infecting) the sample with the spores of one or more moulds in a test chamber where tropical humidity and temperature levels are maintained.

Roughness is understood as the unevenness of a surface. It can be described geometrically by the size of the roughness elements, or mechanically by the friction coefficient. When touched with a finger, the roughness is not noticeable. However, if a finger is moved across the surface at a constant speed (approx. 3–4 cm/s), the movement receptors in the finger are rhythmically stimulated. These groups of impulses are perceived as roughness, the time between the individual impulses reproducing the roughness. The contact pressure is close to the contact threshold so that the roughness is identified from the friction caused.

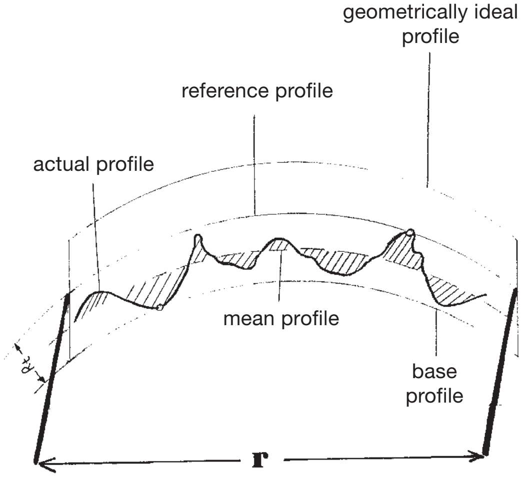


Fig.: Roughness: the relation of the reference profile to the actual profile.
Mean profile, roughness depth R_t (r = roughness reference length).

“Raising” is the processing stage where roughness is achieved. The result is a surface which is distinct from smooth surface of a solid, both regularly and irregularly. In mechanically produced items, roughness affects the appearance (visual surface) and function (surface resistance). It is the result of the production process. The surface structure can be grooved, hollowed, spongy or scaly. In textiles processing, → Raising means bringing fibre ends out of the fabric to the surface in order to obtain a fluffy surface.

Roulette The upper pressurised milling cylinder on a → Cylinder rolling milling machine.

Roving Condenser cable, usually of doubled spun glass yarn, but also of other fibres, e.g. woven and pieced together, for industrial matting. Rovings can, for example, be used as reinforcment in cylindrical composites (see Fig.) and are therefore used as semi-finished products in non-steel constructions, e.g. bicycle frames.

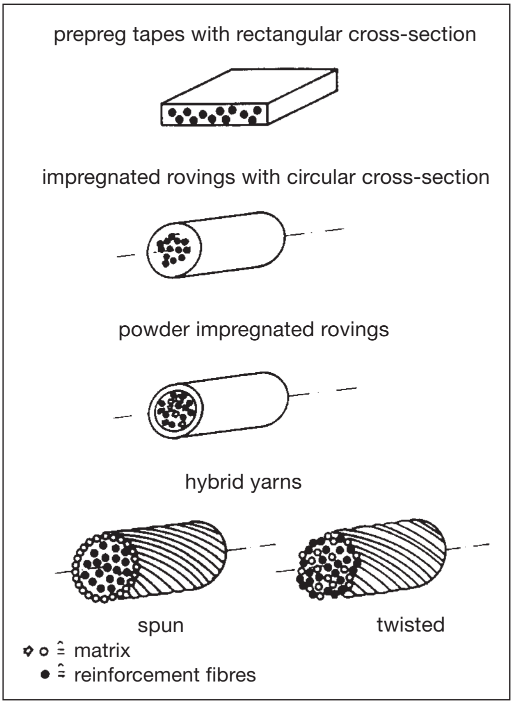


Fig.: Rotationally symmetrical composites as semifinished products; roving reinforced thermoplastics.

Royal-Axminster carpet A velvet pile machine-woven carpet. The pattern does not penetrate to the back of the carpet.

Ru Symbol for ruthenium (44).

Rubber →: Caoutchouc; Vegetable gums.

Rubber covered rollers for textile finishing The problem is to find the right rubber quality to match the particular finishing processes in each textile finishing machine. Selecting the correct rubber quality requires details on the type and concentration of chemical agents used in the process, the bath temperature and mechanical load. The chemicals to which the rubber is exposed are of particular importance. Even small amounts of chemical additives and traces of certain substances can play a role.

Rubber fibres (rubber threads, latex threads), are latex fibres with the elasticity of rubber: they either have a circular cross-section (extruded) or a square cross-section (cut from rubber sheets). The properties of cut threads are: density 0.92–1.05; strength 25–30 N/mm^2 (injected 35–45 N/mm^2), elongation at break 700–900%. They are susceptible to damage (softening and brittleness) from: atmospheric oxygen, ozone, sunlight (10 h of intensive solar radiation degrades elasticity), dry heat (should not be dried at high temperatures or shaped in dry heat), rubber toxins, oils, fats, protective skin creams, dry cleaning solvents, many spotting agents (including benzine, benzol, chlorinated hydrocarbons, etc.). Modern alternatives are → Elastomer fibres. They are dyed with pigment dyes. Not all rubber fibres are resistant to boiling. Treatment liquors should be alkali-free (permutit water can cause damage).

Rubberizing,

I. Sometimes used to describe the application of finishes.

II. Coating a fabric with rubber, on one or both sides, either in a solution of benzol and other hydrocarbons, or as an emulsion. Coating is applied in several layers on a coating machine; finally it is hot or cold vulcanized. Fabrics to be rubberized must be free of acids, fats and metals (rubber poisons), as these cause premature ageing and tackiness of the coating. Synthetic rubber can be used in place of natural rubber. However, nowadays rubberizing has largely been replaced by the use of film-forming plastics.

Rubber-metal connection Bearing elements of rubber and metal which are tightly bonded together chemically at contact points. The binding strengths in respect of tear strength are at the level of the quality of the rubber used (natural rubber or synthetic rubber). The soft rubber element between metal parts functions as a vibration and sound damping elastic shock absorber, which means that with proper application they can provide great stability for machine beds and damping for couplings, joints, buffers, etc. Rubberized metal is also widely used for finishing machines, as well as for centrifuges, washing, printing and raising machines, for electric motors, sensitive lamps, ventilators, switches, testers, etc. For heavier machines, rubberized metal rails are usually used, with a U-profile to provide vertical suspension, and buffers for parts subjected to pressure and shear forces. Special suspension elements are used to support sensitive instruments and devices, which feature rubberized metal dome nuts. Also of importance are various kinds of rubberized metal buffers and couplings.

Rubber thread inlay Rubber thread threaded between textile stitch courses.

Rubber threads → Rubber fibres.

Rubber varnish → Shellac.

Rubbing fastness, wet Tests were carried out with a crockmeter to investigate the force required when rubbing. The rubbing strength for dry rubbing fastness depends more on the fibre material than the profile of the fabric. With cotton textiles the spread of results obtained is significant, while the spread is less with woollen textiles and negligible with man-made fibres. With wet rubbing fastness, almost double the rubbing force is required as with dry rubbing fastness across all fibre types. With wet, in contrast to dry, rubbing fastness, the spread of results is remarkably low, although again it is highest with cotton textiles.

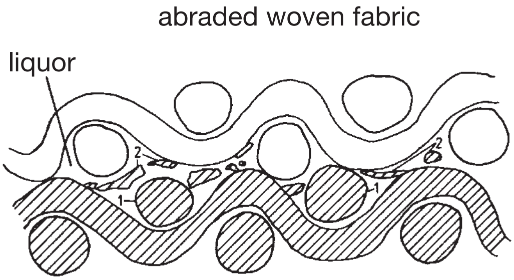


Fig.: Possibilities of dye extraction in the event of wet rubbing:
1 = from the damaged woven fabric; 2 = form abraded fibre fragments.

Microscopic examination has shown that during wet rubbing tests, cotton fabrics are significantly damaged (see Fig.). The cause of this damage is the rubbing coefficient, which is almost twice as high. This means that a significant part of the mechanical work done causes damage to the material.

Rubbing reaction (from P.-A. Koch) used to identify types of polyamide fibre. → Rubbing reagents I and II cause extremely characteristic swelling of the polyamide fibre. At first, fine fibre lacing occurs (name of reaction), which merges again as the depth increases until deliquescence occurs in the final stages, similar to the melting process. The difference between polyamide 6 differs and polyamide 6.6 is due to rubbing reagent II.

Rubbing reagents For polyamide fibre verification using → Rubbing reaction.

1. Rubbing reagent I: 5 parts by volume of zinc chloride solution (from 100g of water-free zinc chloride and 50 ml of water, density adjusted to 1.9) is mixed with a proportion by volume of methanol.
2. Rubbing reagent II: 5 parts by volume of zinc chloride (from 100g of water-free zinc chloride and 100 ml of water, density adjusted to 1.566) is mixed with a proportion by volume of methanol.

Rub fastness testing (crock fastness testing). A test to check the resistance of textiles and their dyes against soiling and crocking during use; in accordance with DIN 54 021. The guidelines apply to all fibre types. For dry fastness, dry dye is rubbed with dry cotton fabric; for wet rub fastness, dry dye is rubbed with wet cotton fabric; it can be carried out with a special rub tester (crockmeter). The fabric is rubbed to and fro 10 times over 10 cm for 10 seconds, at a load of approximately 1000 g. The staining of the cotton rubbing cloth is then compared against the grey scale/stain.

Rub off, to (crock, to). Transfer of dye to white fabric, which often happens with saturated colours, in particular naphthol and pigment dyes, and with some dyes it is practically unavoidable. This rubbing off (dry rubbing) is not colour loss in the sense of fading or insufficient dye; it is rather due to superfluous dye particles (excessive dyeing).

Ruby number A value used for protective colloid effects of textile auxiliaries. It is based on protection against precipitation of a sodium chloride solution, with a solution of Congo ruby A being used as a indicator. The ruby number is the protective colloid in mg, which is just able to prevent the colour change to violet after 10 minutes.

Ruling After precutting in mill engraving, the pattern die is coated with a thin layer of acid-resistant asphalt varnish, into which the → Hatching is scratched on the ruling machine. Finally the pattern die surfaces lying outside the pattern contours are additionally coated with asphalt varnish (reinforced) and the hatching is etched in with nitric acid. The varnish is then washed off with solvents, the pattern die is re-cut, ground, polished and finally hardened. In this way the master pattern is ready. → Engraving.

Rumal An old Indian art still practiced today, where fine cotton headscarves and wedding cloths are silk embroidered with figures.

Run American numbering system for carded woollen yarns. 1 run = 1 hank of 100 yards/oz.

Runic coating The addition of modified rune-type points (point coating) with polyamide paste which is beneficial in preventing mock moiré effects in outer material. Runic coating when applied in even quantities (20 g/m^2), in contrast to dot coating, ensures softness of nonwovens which have been coated, thus reducing the danger of breaking through with a thinner coating of the adhesive mass.

Running creaser Permanent creases in wool products occurring during washing, dyeing and milling in longer runs along the same fold length, and which can only be partially removed by crabbing and decatizing.

Running speed The speed at which a textile product being treated passes through a section, e.g. a finishing machine. It is measured in m/min, while the rotational speed is given in rpm; in weaving machines running speed is measured by weft insertions/min.

Run-off control A program control whereby the unit being controlled relies on certain process parameters. The operating program, which depends on parameters entered by a programmer, follows a pre-set procedure in which each stage is dependent on the process stage reached (feedback system). → Process control engineering.

Russian hemp Identical to Pita fibre; → Mauritius hemp.

Rust consists of iron (III) oxide Fe_2O_3 or iron oxide hydrate (hydroxide) $Fe_2O_3 \cdot H_2O$. The coating is typically red to red-brown. It occurs through the attack of atmospheric oxygen, hydrogen and carbonic acid and is aggravated by acidic vapour, ammoniac, flue gas, etc. It does not occur in alkaline water.

Rust forms according to the following formula:

$$Fe + {}^{1}/{}_{2}\, O_2 \rightarrow FeO$$
$$2\, Fe + {}^{3}/{}_{2}\, O_2 \rightarrow Fe_2O_3$$

This corresponds to an iron pipe that corrodes after a few weeks in a damp atmosphere. Rust forms in the following stages: 1. Adsorption of oxygen (from the air). 2. Iron atoms migrate to the surface, forming oxide, which causes gaps in the crystal lattice of the metal. 3. Further rust forms on the surface. In this way the originally compact crystal structure gradually dissolves (according to Fornelli).

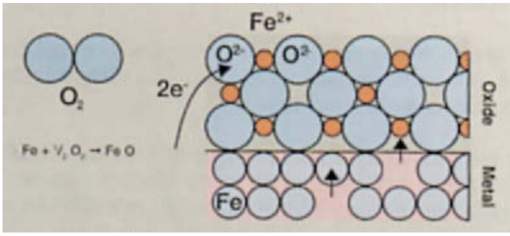


Fig.: The mechanism by which rust is formed (Sandoz).

Rust, laminar →: Keratin sheet structure; Pleated sheet structure.

Rust remover stick Usually → Oxalic acid in stick form for removing rust stains.

Ruthenium red solution 0.02–0.05 g of ruthenium red (ruthenium ammoniumoxychloride) is dissolved in 9 ml of water, 1 ml of ethylenediamine and 10 ml of concentrated glycerine is added. Uses: in microscopy and for fibre testing. It results in a red colour with lignified membranes, resins, pectins, fibroin, chlorinated wool and solids. Silk (sericin) and flax acquire a pink colour, while jute and hemp acquire a pink-red colour.

Rutile A modification of → Titanium dioxide. Used as a white pigment in textile pigment printing.

Rya carpet Scandinavian long-pile carpets in characteristic colours and patterns. They were originally hand-knotted from rough wool (genuine Rya). They are now machine-woven by various processes.

S

S The chemical symbol for sulphur (16).

SABS South African Bureau of Standards → Technical and professional organizations.

Saccharides → Carbohydrates.

Saccharification Saccharification is the process of starch decomposition during desizing. End products: starch sugars (maltose, glucose), which can be removed by washing as they are easily water soluble, and therefore enable starches to be removed from fabrics.

Saccharomycetes → Yeasts.

SAD SAD is a measure for soil pick up which is obtained by reflection measurement (→ Soil adhesion).

$$\mathrm{SAD} = \log \frac{R_{\mathrm{unsoiled}}}{R_{\mathrm{soiled}}}$$

R = reflection according to the wavelength.

Safety belts → Automobile safety belts.

Safety data sheets (SDS). The ecological behaviour of commercial products, together with aspects relating to application, are playing an increasingly important role for manufacturers, processors and consumers, as legislation and authorities are increasing pressure to use environmentally friendly products. On the other hand, however, this is clearly accepted, as individuals are taking measures on their own initiative in order to minimise the impact on the environment by converting to other products and/or altering processes. The ETAD (Ecological and Toxicological Association of the Dyestuffs Manufacturing Industry) has been issuing safety data sheets to affiliated dyestuff manufacturers since 1974 in order to support these efforts and to provide information on the regulations to be complied with, details of the physical, toxicological and ecological properties, together with handling, transport, storage and safety aspects. In the meantime, the ETAD data sheet has been superseded in the dyestuffs sector by the German DIN safety data sheet (SDS)[the German DIN Sicherheitsdatenblatt (SDB), i. e. SDS], which has resulted in a higher intensity of information. Methods to establish the necessary data, which are influenced, amongst other things, by chemical legislation, are also increasingly being normalized or standardized. The ecological details are listed under point 8 in the SDS, i.e. whether substances are biodegradable, toxic to fish, harmful to waste water bacteria, and details of the water pollutant toxicity classification of the product. More information concerning the exact chemical composition of the products, proper disposal and the by-product level present will be desired in future. According to the Directive for Use of Dangerous Substances the manufacturer, importer or marketer has a duty to supply the recipient with a safety data sheet with the first delivery. If the content of the safety data sheet should change within twelve months of delivery, the supplier must automatically forward the client an updated version of the safety data sheet.

Safety signs With the ever increasing risk of litigation, the need for state-of-the-art safety signs and labels has become virtually mandatory for equipment manufacturers. Lawsuits based on “inadequate warnings” have become the predominate form of product liability litigation in the United States. The fact is, if a personal injury occurs during the use or service of equipment and it did not have a state-of-the-art safety sign, there is a significant chance that the equipment manufacturer will be brought into a product liability lawsuit. To prevent this from happening, the best remedy is to design the hazard out of the product or environment. If this cannot be done, effective guarding is the second option. Often guards are removed or circumvented. Using warnings under guards acts as a second line of protection, both for the product user and for the equipment manufacturer. Designing out of guarding hazards should always be the first choice, but because of its function some equipment can be dangerous. Blades cut, gears crush, heated surfaces are hot. Such equipment can have hazards associated with its use and/or service. This is where warnings become an integral part of the product’s design. Safety signs can serve to warn about residual risks, thereby helping to prevent accidents from occuring. If an accident does occur, warnings can provide an equipment manufacturer with a better defence in court. Safety signs and labels should be located in the appropriate place to alert persons to the hazard in time for them to take proper evasive action to avoid the hazard. Sometimes this location is at the point of control for equipment and other times it is

Fig.: Safety signs.

immediately near the potential hazard. In some cases, the hazard does not exist while a guard or protective door is in place. But once the guard is removed or door opened, a possible hazard exists. In this instance, a safety sign or label is often placed on or next to the guard or door and another label is placed on the equipment under the guard or door to alert people to the fact that a hazard exists (Fig.).

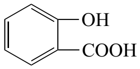
Sail test Combined wear and laboratory test for → Static charge. A test subject wearing a waist slip made from the fabric to be tested passes a polyester sail fixed in an air conditioning chamber. The slip rubs against the sail and is charged. A second person assesses and records the charging and discharging per unit of time.

Sailcloth (canvas, duck). Dense and tight, impregnated heavy fabric (linen, cotton, hemp, synthetic fibres) in plain weave. Used for tarpaulins, awnings, sails, window blinds, etc.

Sakellaridis Valuable Egyptian → Maco cotton.

Sal-ammoniac → Ammonium chloride. A term used commonly in practice, yet incorrectly, for → Ammonium hydroxide.

Salicylic acid (o-oxy-benzoic acid), C_6H_4OH COOH. Density 1.443; melting point 156°C. White crystal needles, sweet and sour to the taste, strong acid, sublimates when heated gently, decomposes (into phenol and carbon dioxide) when heated rapidly. Soluble in fatty oils, alcohol, ether, hot water, barely soluble in cold water. Inhibits the growth of bacteria. Use: as a preservative (coloured ferrous salts), carrier, to increase light fastness of direct vat printing (aftertreatment with 10 g/l).



Salt accumulation When recycling e.g. rinsing water which is sometimes still cleaned in in-house waste water treatment plants, the salts remain dissolved in the water and are not removed. When the recycled water is reused as process or rinsing water, more salt is added to the salt concentration already present from the first use of the water. If part or all of the water is used several times, the salt water concentration continues to increase imperceptibly and may become a source of interference.

Salt addition in dyeing This is used for the following:

I. Dyeing cellulosic fibres with direct dyestuffs: Addition of salt (sodium sulphate or sodium chloride) increases the affinity of the dyestuffs to the cellulosic fibres. The salt affects the agglomeration of the dyestuff molecules in the liquor and the fibre, displacing the equilibrium to the fibre.

II. Dyeing protein fibres: the addition of salt is used to dye the fibre evenly in the acid medium. Due to its negative charge, the dyestuff has a high affinity to the positively charged wool fibre. The essentially smaller anions of the salts also invade the positive areas of the wool, preventing the dyestuff molecules from being absorbed. As the affinity of the dyestuff molecules to the fibre is higher than that of the anions, the dyestuff is absorbed slowly. The slow ion exchange results in an even dyeing.

Salt content monitor Electrical monitoring device to check the salt content of solutions, e.g. bleaching liquors, washing water. The high measuring accuracy is only slightly affected by deviations in temperature. The salt content can be kept constant by means of control equipment.

Salt dyes → Direct dyes.

Salting out This refers to incorrect precipitation of dissolved dyestuffs or textile auxiliaries as a result of excessive addition of electrolytes which results in bronzing and insufficient fastness to crocking.

Salt linkages (salt bridges) → Wool chemistry.

Salt on dyed goods as a source of fibre damage Viscose which has been badly rinsed after dyeing and immediately dried can suffer losses in strength when residues of sodium sulphate (Glauber's salt) from the dyeing process crystallize out on and in the fibre thereby causing some mechanical fibre breakage through pronounced swelling.

Salt resins → Cationic resin.

Salts Reaction products from acids and bases (alkalis) with removal of water; e.g. hydrochloric acid and sodium hydroxide solution form sodium chloride and water. Salts dissociate in electropositive base radicals or metal cations and negative acid radicals or non-metallic anions. Depending on the number of hydrogen atoms exchanged, polyvalent acids form a) neutral salts: all hydrogen atoms are replaced by metal ions; b) acid salts: only a portion of the hydrogen atoms present are replaced by metal ions, e.g. sulphuric acid H_2SO_4, sodium sulphate $NaHSO_4$ (→: Primary salts; Secondary salts; Tertiary salts); c) basic salts: only a portion of the OH-ions present are replaced by acids, e.g. basic chromium chloride $CrCl(OH)_2$, instead of $CrCl_3$; d) double salts: by mixing different salts or by H atom exchange using different metals e.g. sodium potassium sulphate $NaKSO_4$; complex salts, e.g. chromium potassium sulphate $KCr(SO_4)_2 \cdot 12\,H_2O$.

Salts for dyeing applications →: Aluminium chlorate; Aluminium ammonium sulphate; Aluminium potassium sulphate; Calcium carbonate; Potassium dichromate; Sodium acetate; Sodium bisulphite; Sodium chloride; Sodium hexametaphosphate; Sodium nitrite; Sodium phosphate; Sodium silicate; Sodium sulphate, (beta-naphthol), (copper sulphate), (mordanting), (oxygen products), (zinc oxide).

Salt wash (salting out process). Washing process for wool fibres, also removal of mineral oil lubrication stains; whiteness degree and handle are extremely good. Corrosion of iron parts possible. Carried out using non-ionic detergent and sodium sulphate, 10–20 g/l at 25°C liquor temperature, approx. 10 g/l at 45°C. Cold fresh water below the wash temperature is added for rinsing.

Sal volatile → Ammonium carbonate.

Sample Samples in textile testing, in the form of an individual or collective sample, should correspond to the representative section of the goods to be tested in terms of composition and properties. →: Random sampling; Technical textile sampling.

Sample cutter A sample cutter is used to take samples from the fabric.

Sample drier Cabinet drier for textile samples.

Sample dyeing Preparing a colour which, to a large extent, matches a colour sample under various sources of light (day light, artificial light). Assessing a shade or whether it matches the sample and any adjustment using the eye are subjective processes and can be influenced by various factors. Assessment of compatibility with or deviation from the sample for adjustment is therefore carried out using colour measuring devices.

Sample lengths Small quantities are required for dyeing or printing when preparing collections. The relevant sampling machines should anticipate the production ratios as accurately as possible so that the samples manufactured can be reproduced if the client places an order.

Gali manufactures a screen-printing machine to print small sample lengths. The short printing background is bonded to a rotating steel belt (Fig. 1). The next colour is printed with a new screen for each precise repeat cycle. Minox produces a sample overflow dyeing machine with a liquor capacity of 60 l for 5 kg of fabric (Fig. 2).

Fig. 1: A short-run rotary printing machine using an endless steel band (Gali).

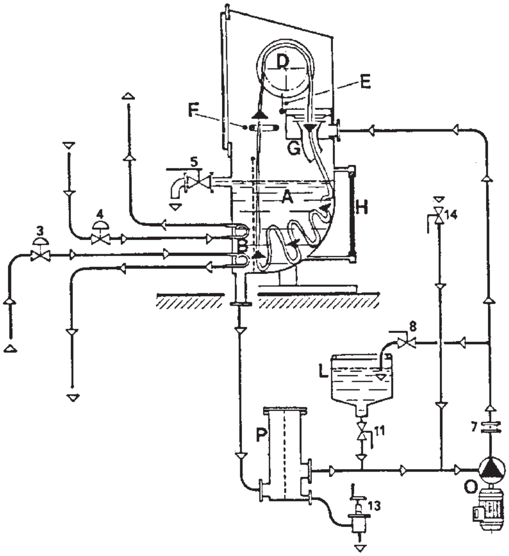


Fig. 2: Minox Overflow, a sample dyeing machine. A = dye liquor; B = heat exchanger; D = transport winch; E = goods sensor; F = goods guide; G = overflow system; H = filling level indicator; O + P = liquor circulation system.

Sampling controller A sampling controller is a discontinuous, scanning or analogue controller which contains a sampling element in the input channel which samples deviations at specific time intervals and provides a specific signal.

Sampling lock E.g. the patterning attachment on a HT yarn beam dyeing autoclave with which it is possible to insert small quantities of yarn or piece goods into the dye and extract them during the matching process by means of a twin lock without altering the treatment conditions (see Fig.).

Sampling vessel This is a small vessel attached to the dyeing machine, in which quantities of sample are switched to the secondary liquor cycle. These are connected to the dyeing machine so that the test specimens (samples) can be incorporated into the liquor circulation during dyeing. The interconnecting valves between the dyeing machine and the sampling container should be closed to remove the sample. The liquor should then be drained off from the sampling vessel and this must also be vented if necessary.

As with many dyeing machines, it is possible to open the sampling vessel even without taking these measures, and then scalding often occurs. According to

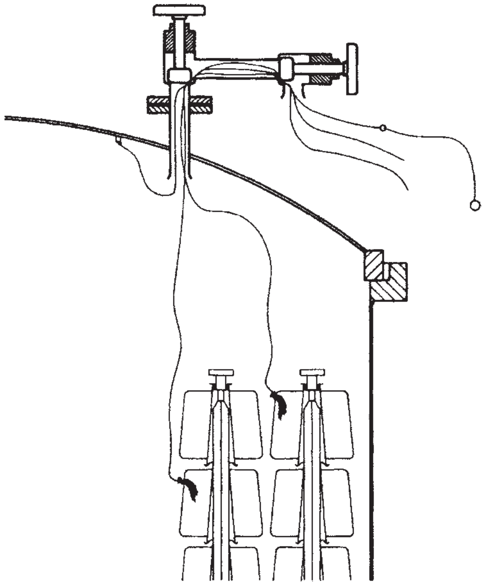


Fig.: A sampling lock on a yarn dyeing autoclave.

the draft of the future European and international safety standard for textile machinery, sampling vessels must be constructed in such a way that it is not possible to open the cover before the feed and outlet connections are closed and the vent is open. It is possible to achieve this using a single shaft connected to the cover which activates the interconnecting valves together with the vent connection (see Fig.).

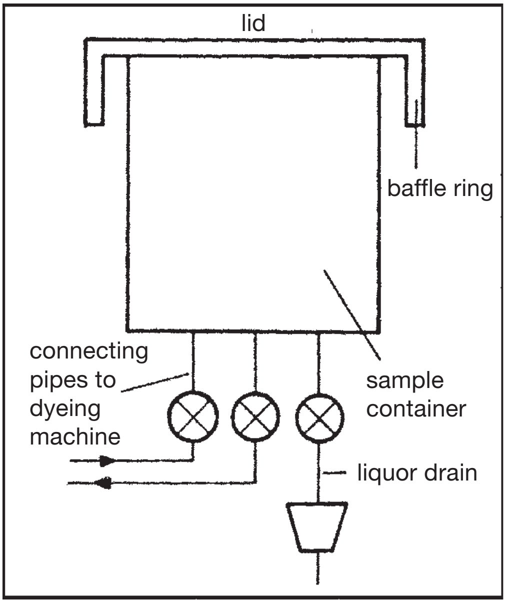


Fig.: A sampling vessel with a safety device to avoid danger when opening.

Sancowad-Process Short liquor dyeing process (Sandoz) for fully fashioned articles, stockings, socks, etc. with liquor-to-goods ratios of 1 : 1 to 1 : 2, using special textile auxiliaries which produce microfoam.

Sandarac gum Natural → Resin from the bark of a North African cypress. Lemon yellow pieces, powdery, fresh surface fracture with glassy lustre. Melting point approx. 135°C. Soluble in alcohol, chloroform, distilled oils. Only used occasionally for silk ribbon finishes and lacquers.

Sand crêpe → Crêpe Jersey.

Sanding Sanding is distinguished from → Emerizing in that only one roller is used as a tool per machine, whereas several rollers work on the fabric in emerizing. A guide roller advances the fabric as close as possible to the abrasive roller which operates at high speed (Fig. 1). The distance determines the sanding effect and must therefore be accurately adjusted. The resultant frictional forces are discharged in the abrasive grinder by cooling the roller. The effect can be intensified, as shown in Fig. 2, by looping the abrasive grinder more.

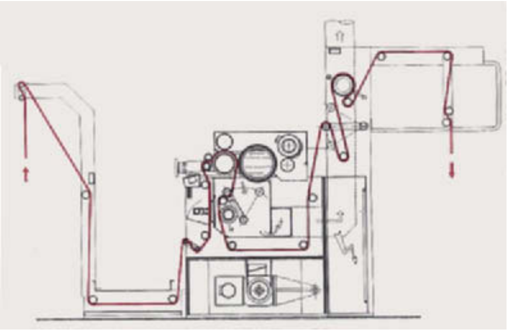


Fig. 1: The Sperotto Rimar SM1 sanding machine.

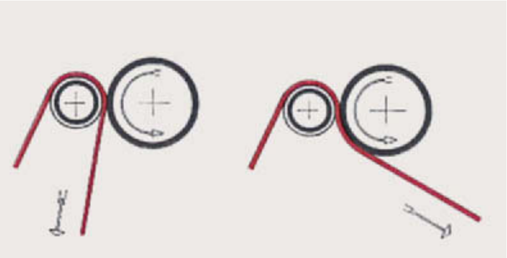


Fig. 2: Two ways of introducing goods to the grinding roller. Left: proximity; right: tangential.

Sandwash silk The sandwash finish of silk fabrics was launched as a response to the fashionably successful "peach-skin" articles made from polyester microfibres. Firstly, the silk is treated with an enzyme (protease) in the drum washing machine in a weak alkali bath with a low liquor-to-goods ratio. This causes the fabric to peel slightly and at the same time, the mechanical strains on the fabric cause a slight napping of the silk fibres. Together with the appropriate final finish, this achieves the characteristic sandy soft handle. Sandwash fabrics display a faded character in contrast to machine wash finishes and have (intentional) white marks (extremely napped, lighter areas, generally lengthways and in folds). Ready-to-wear items are often finished in this way.

Sandwich In sandwich structures, the filling is found between the two layers. Sandwich structures arise e.g. macroscopically, if a fabric which is to be treated enters between a printing belt and a cylinder (Fig. 1). Sandwich structures on a textile basis (Figs. 2–3) may reduce the weight of a fibre-reinforced synthetic material e.g. as a nonwoven.

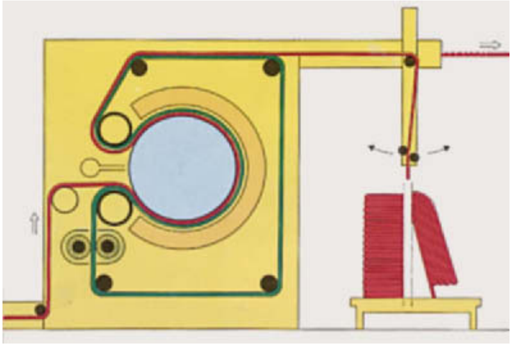


Fig. 1: A typical sandwich working method: the goods (red) are fed between the heated cylinder (blue) and the pressure band (green) in the Sperotto Rimar Multidecat 2.

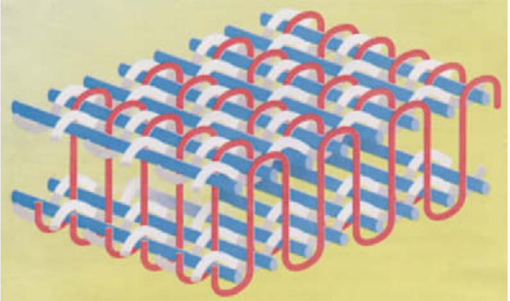


Fig. 2: A textile constructed with a sandwich structure to serve as the core for lamination.

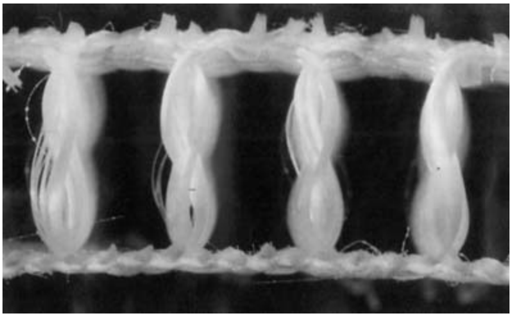


Fig. 3: A three dimensional fabric seen in warp section.

Sandwich structures are also formed in → Laminating, with e.g. an "inner sandwich" (lining inside, top cloth outside) or an "outer sandwich" (lining outside, top cloth inside) being formed. When transport tarpaulins are laminated, the sandwich structure is as follows:

outside	lacquer coat
	top coat
	base coat
inside	fabric

In transfer printing, the paper and the polyester material between the heated pressure plate and base (discontinuous) or in the calender between the roller and belt form a sandwich themselves to enable the disperse dyestuff to sublimate well.

Sandwich dyeing Method of impregnating used predominantly for synthetic fibrous material, mainly to dye light shades whereby the material, rather than being fed through the liquor and squeezed, passes in close contact between two endless absorbent cloths which constantly absorb liquor. Dyestuff from these liquors is thus transferred to the material to be dyed.

Sandwich effects in dyeing (greyness) A dye migration phenomenon in continuous dyeing. The dye migrates from the surface to the interior of the textile material or the dye is washed off the textile surface. As a result, the textile material only appears to be dyed in the middle whilst the surface has a whitish appearance which is often referred to as "greyness". The problem can be remedied or prevented by using appropriate dyeing systems.

Sandwich laminating → Laminating an expanded sheet between two textile webs.

Sanforize A no longer protected brand name for cotton and cotton-mix textiles with shrink-proof finishes made by specific mechanical processes, e.g. shirts, pyjamas, workwear, etc. with a shrink resistance of max. ± 1% tested according to prescribed standard regulations → Compressive shrinkage processes.

Sanforizing oils Sanforizing oils are finishing oils used to provide the fabrics to be sanforized with sliding properties on the shoes of the progressive shrinkage device. Sanforizing oils must not become resinous, and must have good rewetting properties and act as softeners at the same time.

Sanfor-Knit Brand name, which is no longer protected and which is a control standard, relating to cotton knitwear. The standard is achieved by → Compressive shrinkage with additional light synthetic resin finish.

Sanfor-Set Brand name which is no longer protected which is a control standard. Limited to effects of textiles which have been finished using the → Liquid ammonia process and are characterized by good shrink resistance under drying conditions in a tumbler drier. This process can also be used for lighter cotton qualities.

Sanitary wear In the broadest sense, sanitary wear refers to so-called anti-rheumatic clothing. The alleviating effect is provided in conjunction with electrostatic properties and high thermal retention (heat retention). Woollen items are one example, as are particularly air-permeable woollen blankets, continental quilts, travel rugs which are also widely commercially available e.g. polyvinylchloride fibres. Medical aspects of such clothing: has the effect of promoting perspiration and the release of other toxins, encourages the skin to breathe and cleanse itself, guarantees healthy perspiration, removal of grease and salt and has the effect of accelerating the neuronal response time, i.e. it activates a neutral reaction, and therefore prevents colds, rheumatism, inflammation and is prophylactic. Angora underwear is also recommended for rheumatic illnesses.

Sanitation Process to control the germ count with the aim of avoiding the risk of undesired germs spreading, achieving an inhibiting effect and/or counteracting damage to material caused by microbes. →: Antimicrobial finishes; Sanitized finishing.

Sanitized chemical cleaning Complete chemical cleaning and disinfection process in the solvent bath with the addition of bactericidal agents.

Sanitized finishing (→ Antimicrobial finishes). Protects textiles against the growth of bacteria and mycotoxins, achieving a deodorizing effect at the same time (sanitized finish). Currently used for lining fabrics, stockings, socks, etc. Sanitized finishing is achieved using e.g. quaternary ammonium compounds, halogenated phenols, salicylanilide derivatives, neomycin sulphate, etc. To disinfect cotton items following a hypochlorite wash, zinc fluosilicate is used in the USA, for example. The intensive strain on functional clothing such as cycling shorts or body suits results in increased deposits of excrement such as perspiration, fat and traces of faeces and urine. These can form an ideal breeding ground for micro-organisms found on the skin. The high degree of moisture and body heat provide optimal conditions for growth for most micro-organisms. They can double in number every 20–30 minutes. When oxygen is present, i.e. in aerobic conditions, the nutrients (perspiration, soil) and the textile itself oxidize to form carbon dioxide and water. Nitrogentated nutrients (urea, skin particles) decompose to form ammonia. Where oxygen is not present, i.e. in anaerobic conditions, the bacteria are not able to oxidize the nutrients sufficiently to form carbon dioxide. In this case, acids such as lactic acid, acetic acid and butynic acid (odour of perspiration) may be produced. Certain micro-organisms such as the mould fungus aspergillus niger form pigments in addition to carbon dioxide, water, ammonia and acids (black-brown specks in the case of aspergillus niger).

Now that synthetic fibres are used, washing practices have also changed fundamentally. Washing at high temperatures, which has a germicidal effect, has been replaced by washing at low temperatures. Mild, alkali-free detergents are also used which do not substantially increase the death rate of bacteria. Often the laundry is hung up while still wet, esp. items which have a wash-and-wear finish. Due to the almost ideal conditions, the bacteria may increase during drying, in particular in the area of the shoulders and the crotch. All this leads to a deterioration in the standard of hygiene, unpleasant odours resulting from microbial metabolic products and, in the case of sports socks and shoes, athlete’s foot. Permanence must be guaranteed in order to ensure sustained hygienic freshness and the desired material protection. Moreover, it must not be too high due to excessive fixing of the antimicrobial active substances, as they are only effective if there is a certain migration of a minimal concentration in the surface moisture film. The antimicrobial finishing agent must be simple to apply and must be able to be combined with other materials such as softeners, antisoiling agents and water repellents, etc. Fastness to colour, perspiration, ironing, etc. must be preserved. The entire microbial spectrum normally present when using functional clothing must be covered with minimal additive concentration. If a standard concentration of a monosubstance is used as an antimicrobial finish, individual types of bacteria may survive and reproduce all the more quickly. With an optimal combination of carefully selected monosubstances, the individual additive concentrations can be kept low and the entire spectrum is nevertheless efficiently covered by the bacteriostatic and fungistatic effect. Ready-made combination formulae offer the most practical solution. The finish should be kind to the skin, non-toxic as far as possible and environmentally friendly. Pentachlorophenol, for example, which is repeatedly found in imported articles (e.g. sports socks) and products containing arsenic, for example, should not, therefore, be used. A wide range of ready-made formulae are commercially available. These enable an antimicrobial finish which is simple to apply and permanently effective and is also kind to the skin and the environment (according to Kehrli and Mebes).

Sansevieria fibre → Hard fibres similar to manila fibre (tropical Africa, Ceylon). The sansevieria fibre from Ceylon is finer than the African equivalent, similar to Mauritius hemp. Use: for string, matting and coarse cloths.

SANZ New Zealand. Standards organization; → Technical and professional organizations.

Saponide Term used abroad, especially in France, to refer to anionic organic detergent base materials, with the exception of soaps.

Saponification,

I. → S-Finish.

II. Chemical reaction to convert fats into → Soap by a base reaction. With fatty acids, saponification is in the form of simple neutralization. When neutral fat is saponified, glycerine is also produced.

Saponification dyeing process This is used for acetate/cellulose mixes. The aim is to achieve simultaneous → Saponification and dyeing with direct dyestuffs, vat dyestuffs, etc. Disadvantage: more difficult to achieve uniformity of shade (higher dye affinity of cellulose fibre), encourages uneven dyeings where there are different acetate grades (colour stripes).

Saponification number The saponification number indicates how many mg of potassium hydroxide are required to saponify 1 g fat. Using the equation

$$C_3H_5(COO–C_{17}H_{35})_3 + 3\ KOH =$$
$$3\ C_{17}H_{35}–COOK + C_3H_5(OH)_3$$

3 mol KOH (= 168 g) are required for 1 mol tristearine (= 891 g), i.e. approx. 0.189 g pure KOH is required to saponify 1 g tristearine. The saponification number provides an indication of the average molecular size (molecular weight) of the fatty acids involved in forming fat. From this, the → Fats are divided into those with very low saponification numbers (80–130 = beeswax, spermaceti, wool fat), low saponification numbers (171–181 = castor oil, rapeseed oil), those with average saponification numbers (approx. 193 = olive oil, groundnut oil, palm oil, cotton oil, poppy seed oil, hempseed oil, neat's foot oil, bone oil, beef dripping, whale oil, etc.; most fatty acids with 18 C-atoms) and those with high saponification numbers (205–290 = coconut oil, palm nut oil, japan wax, certain train oils). Paraffin oil or mineral oils or fats have a saponification number of 0. Adulterated or diluted fats can therefore be recognised by decreasing saponification numbers.

Saponification of acetate fibres As acetate fibres are esters of cellulose, they are easy to saponificate. This process gives rise to hydrocelluloses. Advantages: improved dyeing properties of regenerated cellulose which may now be dyed using direct dyestuffs, unlike acetate. Disadvantages: reduced brightness and reduced breaking strength. Saponification is nevertheless common where necessary. Principle: partial saponification (unmodified core of acetate cellulose and a saponified surface layer of hydrocellulose which is as fine as possible) with alkali and levelling agent and fibre preserving agent if necessary.

Saponification value (ester number) → Acid value (for fats and oils).

Saponin Pulverised, evaporated aqueous extract from soaproot or → Panama soap. Non-alkali detergent. Group of complex plant glucosides of tigogenine, gitogenine, etc. in Panama soap, soaproot or Senegal root, horse chestnut, etc. Contain amongst other things the particularly toxic sapotoxins which can be separated using a special process. Saponins provide colloidal, foaming solutions, similar to soap. Adding approx. 1% saponin when dry-cleaning with white spirit acts as an anti-static agent.

Saprogenous system → Water quality classification.

Saprophytes Dead organic matter. The term saprophytic bacteria (putrefactive bacteria) is used.

SAQ Swiss Association for the Promotion of Quality, Zurich; → Technical and professional organizations.

Sarcina Sarcina are earth- and air-borne bacterial microbes (in coccus or cuboidal form, sporadically forming spores). Also occur in perspiration (up to 45% on the upper arm). Sarcina can be harmless but also pathogenic.

Sarcosine → Methylaminoacetic acid.

Sari A sari is a wrap-around robe native to India which is often printed with large patterns.

Sarong A Sarong is a Malaysian item of clothing for women which often has large characteristic batik patterns.

SARTEX SARTEX is a Swiss association for textile labelling. Office based at the Gesamtverband der schweizerischen Bekleidungsindustrie [General Association of the Swiss Clothing Industry] (GSBI), Zurich; → Technical and professional organizations.

Satin,

I. Name derived from atlas or satin weave. Generic term for various, mainly lustrous materials, predominantly manufactured using 5-weave satin. Worsted satins are either napless (e.g. satin de Chine) or finished with a fine nap; carded satins almost always have a napped finish. Fabrics with a particularly napped finish have an intense shine which is further emphasised by the weave.

II. Smooth fabric (silk, viscose, wool, flax, cotton, etc.) with high sheen, in atlas or satin weave, e.g. → Duchesse satin, cloth; liberty, etc., see I.

Satinette Satinette is a combination of → Satin and finette (cotton twill napped on one side in linen goods). The warp consists of lustrous viscose filament, the weft is cotton; the weave is in the form of 5-weave warp satin. The lustrous warp is generally found on the fabric face, whereas the cotton warp on the reverse side of the fabric is very napped. Used for night-shirts and pyjamas.

Satin weave → Weave.

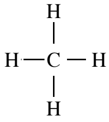
Saturated hydrocarbons Methane hydrocarbons, paraffins, alkanes, saturated aliphatics, of the form C_nH_{2n+2}, characterized by the final syllable -ane, e.g.

methane	CH_4	butane	C_4H_{10}
ethane	C_2H_6	pentane	C_5H_{12}
propane	C_3H_8	hexane	C_6H_{14}, etc.

These are saturated to the limit of their chemical absorbency by hydrocarbons, hence the name saturated hydrocarbons (contrast → Olefins). Together with basic substances, they form aliphatic compounds which arise by substitution and can be recognised as such by their altered final syllables. E.g. the following derived alkyl radicals, each having one H fewer, enabling bonding with other elements of equivalent valency:

methane	CH_4	→	ethane	C_2H_6
methyl	$–CH_3$	→	ethyl	$–C_2H_5$ (alkyls)
methene	$–CH_2–$	→	ethene	$–C_2H_4–$
			(alkylenes or olefins)	

Saturated organic compounds These are compounds where all available bonds (corresponding to their valencies) of the atoms are mutually saturated, e.g. methane:



$$\begin{array}{ccc} & H & \\ & | & \\ H— & C & —H \\ & | & \\ & H & \end{array}$$

Contrast: → Unsaturated organic compounds.

Saturated solution → Solution.

Saturated steam → Steam at a temperature corresponding to a water boiling point of 101°C and there is no water present in the vapour.

Saturated steam fixation (Saturated atmospheric pressure steam fixation). Saturated steam (e.g. in printing steamers, see Fig.) is 100% water vapour at atmospheric pressure with a temperature of 101°C. When the dry and cool fabric reaches the steamer (1), the steam condenses on it, and the energy released (heat of condensation) warms the fabric (2). The absorption phase (3) begins at the same time as the condensation phase. The absorption phase lasts until a physical equilibrium between the moisture content of the fabric and the moisture in the steamer has been reached. The heat of condensation and absorption released together with the exothermal reaction increase the temperature of the fabric to above the temperature of the fixation atmosphere (4). The fixation medium is thereby heated above saturation temperature: the steam is superheated. As the steam is superheated, the absorbing ability of the fabric decreases as the moisture content of the superheated steam is reduced (5). The moisture content of the steam decreases with superheat. As optimal fixation is only achieved when the steam is saturated, the effect of superheating must be nullified (6). In the steamer, this occurs with the minimum possible energy costs as the steam is circulated in combination with a water injection system. The large difference in the dyestuff concentration between the fibre and printing paste causes the dyestuff to diffuse under the influence of saturated steam in the direction of the fibre (7) until a diffusion equilibrium has been reached. The dyestuff is then fixed (8).

Saturated vapour pressure → Steam pressure.

Saturation,

I. → Solution.

II. The so-called saturation of a colour (in contrast to the so-called → Whiteness index) i.e. the extent to which a body colour differs from an equally bright → Achromatic. This is also referred to as depth of shade or grey scale (→ Grey series) and corresponds to Ostwald's black component. Physically obtained indirectly as spectral colour density from the CIE tristimulus values. Also colour saturation (→ Colorimetric measures) as a difference of the → Type of colour from the → Achromatic point. The lower the saturation, the duller/flatter the coloration at the same lightness and the same shade, and the higher the saturation, the brighter/more brilliant the coloration.

Saturation, degree of → Saturation point.

Saturation factor The saturation factor is a constant which is specific to the dyestuff used to calculate the → Saturation value (principally for cationic dyestuffs).

Saturation point Also known as saturation value S_{max}. Particularly important for synthetic fibres. Expresses the maximum dyeing potential of the fibre. If more dyestuff is added to the bath, then either the fibre is no longer able to absorb any more dyestuff or blocking effects arise. Alternatively, non-fast dyeing may occur. The saturation point may vary from dyestuff to dyestuff for any given fibre type.

Saturation value Max. absorption of dyestuff and/or levelling agent by a fibre.

Saturator → Impregnating machine (saturator also padder with large liquor bowl) for intensive wetting with treatment liquor in continuous open-width bleaching, mercerization, etc.

Saueressig printing machine The Saueressig machine represents one of the most popular developments of → Roller printing machines in the 20th century. In this machine, the printing heads are arranged vertically one above the other, unlike conventional roller printing machines where they are positioned around a central

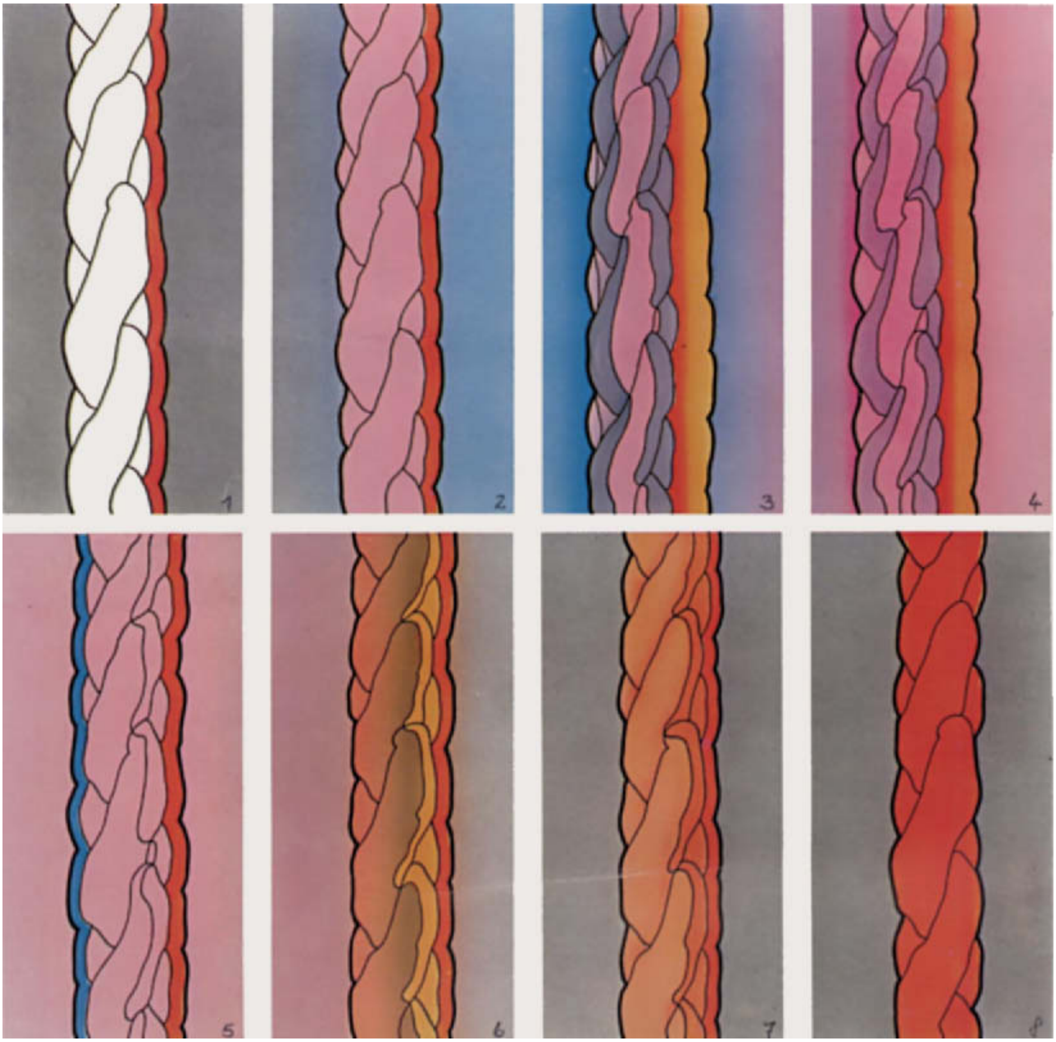


Fig.: Saturated steam fixation in a printing steamer (by Babcock).

cylinder. The colour boxes, doctor blades and furnisher rollers are all mounted on a hinged sub-frame which can be swung to one side of the Saueressig roller printing machine to facilitate the changing of printing rollers. This arrangement allows more rapid colour and design changes than conventional roller printing machines.

Saueressig roller printing machine Roller printing machines in which the central cylinder is replaced by individual cylinders for each printing roller.

Saw-tooth effect Defect in screen printing in the form of graduated (stepped) repeated profiles of fine pattern details which run askew; particularly undesirable with fine floral designs or figured patterning, etc. Correction: e.g. by using even finer gauze screen, use of photosensitive screen coatings with a crossed mesh effect and by correctly developing illuminated screens.

SAWTRI (South African Wool Textile Research Institute) → Technical and professional organizations.

Saxony Woollen cloths made from high quality fine merino carded yarn with soft, flannel-like handle. Predominantly in sporty patterns (e.g. shepherd’s check, glen-check). Finish varies between smooth and a slight melton finish. Used for ladies’ and men’s suits and lightweight coats.

Saybolt Universal viscosity American measure of → Viscosity.

Sb The chemical symbol for antimony (51).

Sc The chemical symbol for scandium (21).

Scaffolding effect A mixed fabric sample (e.g. cotton and polyester) has different burning properties (e.g. in a vertical flammability test) than a corresponding sample made from one of the pure fibre components. Therefore the fibre portion made from polyester fibre for example promotes better burning of the associated cotton as it is worked and spun into the blended yarn almost as a stable scaffold. The scaffolding effect therefore benefits the relative low combustibility of the polyester fibres (at best melting), whereas the relative high flammability of the cotton is increased still further by the "loose" distribution in the scaffolding, which increases the oxygen available.

Scala d'Oro Italian → Quality symbols which covers Rhodiatoce quality testing on finished goods and ready-made garments made from cellulose acetate, polyamide and polyester fibres for in-house products.

Scale structure of wool The scale structure of the outer covering layer of wool has an effect on the felting and dyeing behaviour. If the wool fibres are non-felted, the original hydrophobic scales are either rendered hydrophilic by a polymer or by oxidation (or a combination of the two in the Hercosett process) in such a way that a water film significantly alters the friction between the fibres (Fig. 1).

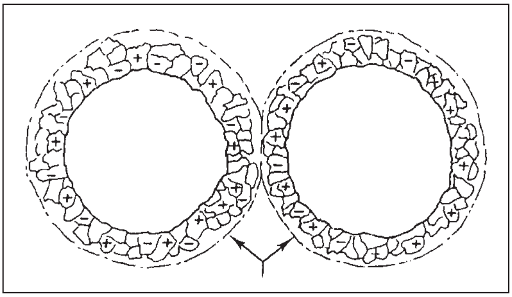


Fig. 1: Hydrophilically treated wool fibres (through felt-free finishing), each with an adhered water film (arrows) at the fibre surface (according to Meichelbeck).

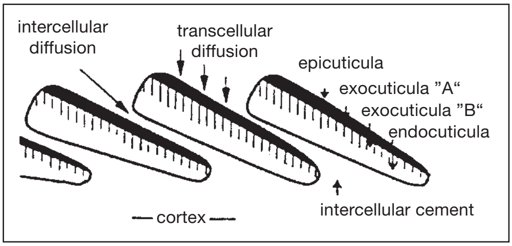


Fig. 3: Diffusion routes into a wool fibre (according to Zollinger).

The scale layer consists of (Fig. 2)

1. The outer epicuticle: hydrophobic, low cystine content, i.e. low degree of crosslinking.
2. Exocuticle: hydrophobic, high cystine content or degree of crosslinking, division into a-layer (extremely high in cystine) and b-layer (high in cystine).
3. Endocuticle: low in cystine, i.e. low degree of crosslinking.
4. Intercellular cement: globular proteins, low in cystine.

The high sulphur content of keratins, i.e. a high cystine content and high degree of crosslinking, in addition to the increased content of hydrophobic amino acids, is regarded as a cause for the hydrophobic nature of the scales. For this reason, the exocuticle (with approx. 35% cystine content) is regarded as a diffusion barrier for dyestuff molecules during the dyeing process. The high sulphur content causes reduced swelling capacity of this layer of fibres. Consequently, changes to the wool fibre by splitting the cystine links causes acceleration of the dye absorption. If the wool is untreated, the dyestuff does not diffuse vertically (Fig. 3) through the exocuticle (so-called "transcellular diffusion") into the wool fibre, but migrates via the intercellular cement/cellular membrane complex (Fig. 2), i.e. between the scales, into the fibre (so-called "intercellular diffusion"). This intercellular diffusion path can be observed at the beginning of the dyeing process.

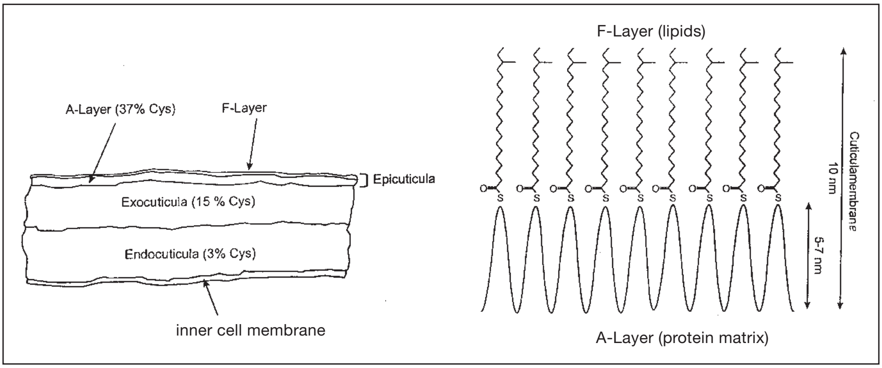


Fig. 2: Scale structure of wool.

Scanner Sensor in electronics, e.g. for colour measuring instruments. Important for electronic sample preparation, electronic colour separation and colour correction devices to make colour separations for multicolour textile printing (transfer printing).

Scanning In contrast to integral imaging using photography, scanning consists of linear recording, with the image elements forming consecutively.

Scanning drum The scanning drum is an integral part of a scanner. The colour transparency is found by the transparent, rotating scanning drum. Focused light is irradiated axially onto the drum and deflected by 90° using a mirror so that the light penetrates both the scanning drum and the colour transparency.

Scanning Electron Microscope (SEM). An electron microscope, which linearly scans the surface to be inspected using a sharply focused electron beam. During this process, electrons are emitted from the object which are collected using an electron collector. The electron flow of these secondary electrons controls the intensity of the electron beam of a television monitor, so that there is an enlarged image of the surface on the monitor. SEM images are characterised by a particular definition and plasticity. The electron beam of the device releases x-rays as well as electrons from the surface. X-ray fluorescent analyses make it possible to define the material of the object being examined (Figs. 1–2).

The development of an electron microscope is based on the 1924 discovery (de Broglie) that electron beams can be assigned a wavelength. The wave describes the periodic movement which radiates from a transmitter, e.g. an electron source, in a specific direction. The wavelength indicates the distance between two successive points in the same phase, i.e. if a rope is swung periodically to and fro, a wave runs across it, and the amplitude creeps along the entire rope until it reaches the end, where it is reflected and creeps back. By taking a photograph of such a wave, it can be seen that the amplitude of the rope is repeated at specific distances. These distances are the wavelength. The same applies to the electron source - according to de Broglie, electrons and protons behave as if they are waves.

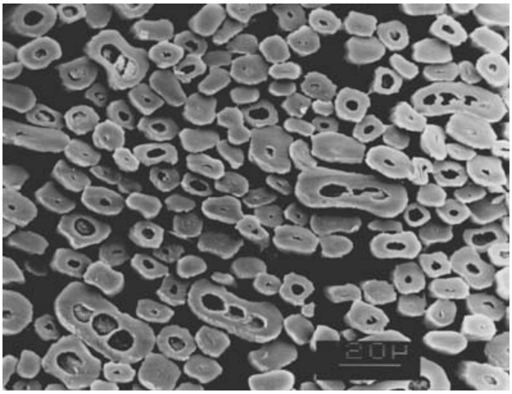


Fig. 1: A scanning electron microscope image of angora fibres in cross-section.

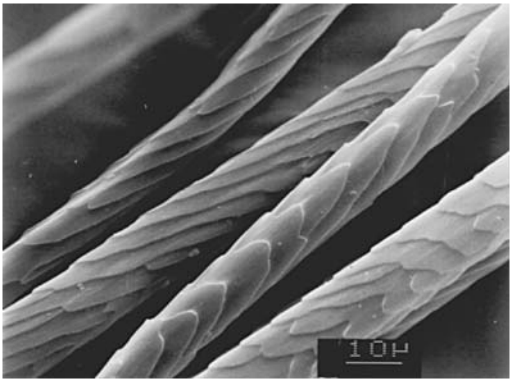


Fig. 2: A scanning electron microscope image of angora fibres in side orientation for the purpose of comparing several fibres of the same type.

The wavelength of the electron beam (0.004 nm at a beam potential of 100 kV) cannot be compared with the wavelength of visible light. The extremely short wavelength of the electron beam enables better definition or greater enlargement compared with a normal optical microscope. With the SEM, the surface of the sample is bombarded by a small (narrow) electron beam. This causes secondary electrons to be released from the surface of the sample, i.e. the sample used must be conductive, otherwise it is not possible to carry out the experiment. The intensity of the secondary electrons is dependent amongst other things on the inclination of the surface in question to the primary beam. The secondary electrons are collected by a detector (rectifier for electron beams), amplified and displayed on a screen. The fine electron beam only reaches one point of the sample at each moment, therefore the beam must be passed across the sample in a fine grid pattern in order to record the entire surface of the sample line by line. In this way, the finished image of the surface of the sample is formed on the screen. The intensity of the secondary electrons gives the brightness.

The principal elements of a scanning electron microscope can be seen in Fig. 3. The electromagnetic lenses are not only used for the imaging, but also as condenser lenses (focusing lenses) to produce the extremely finely focused electron beam on the sample surface. Deflection points for scanning are integrated into the second condenser lens. As mentioned earlier, samples which are not conductive cannot be used and must therefore be specially prepared. In order to conduct the electric charge which arises on the non-con-

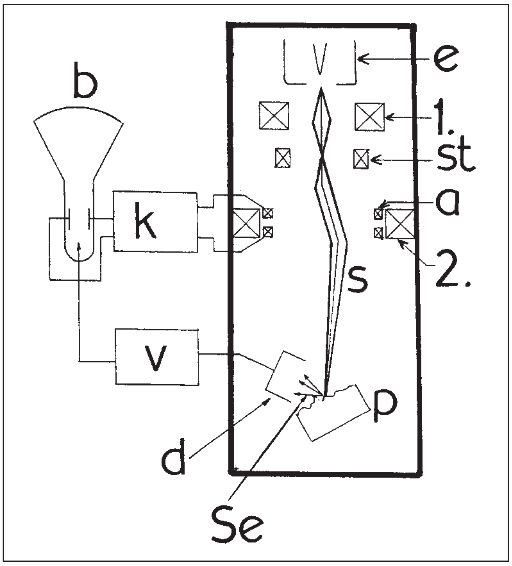


Fig. 3: A simplified diagram of a SEM.
a = deflection coils; b = image tube; d = electron detector; e = electron gun; k = beam deflection; p = sample; s = electron beam path; st = stigmator; Se = secondary electrons; v = signal amplifier; 1. + 2. = 1st and 2nd condensing lens.

ductive samples, they are vacuum coated (sputtered) with a thin contact plating (using a conductive metal like gold). The advantages of the SEM are improved resolution and therefore better enlargement and enhanced definition in comparison to the optical microscope.

Scanning element A transmission element which transmits an input signal at irregular time intervals (during the scanning period) and, by this means, delivers a sequence of impulses as a signal.

Scanning in photo-engraving This process refers to the breaking up of coloured areas into colour points of varying sizes, which when observed give the optical impression of different colour intensities due to blending of the colour lying between the points on the printbase.

Scanning, optoelectronic Optoelectronic scanning causes colour separation (in automatic electronic production of colour separations for textile printing by a scanner) using a scanning drum. Next, the particle beams are converted into signals using electron multipliers. The signals are then sent to the colour computer for the shade and tristimulus values to be corrected. The master copies are illuminated by the optical head which intercepts the reflected light. Further processing is then carried out in the same way as with transparencies.

Scanning process This is a printing method in which a multicoloured design is directly transferred electronically using film or paper copies without the need for screens or printing blocks. The scanning process (as a natural process in image generation) consists of linearly scanning a copy, with the entire image being sampled at close linear intervals which can be selected within limits. This can be carried out continuously, with the copy (image) being fastened around a cylinder and scanning along a spiral by advancing the optical head, with the cylinder turning. Discontinuous scanning uses parallel lines which are staggered at the reverse point by the linear interval selected. A distinction is made between → Colour scanner for paper printing and typical → Textile scanner.

Scarf cutting machine After the fringes of scarf fabric have been twisted and set, the individual scarves must be cut longitudinally or transversely along the unwoven warp or weft thread (see Fig.).

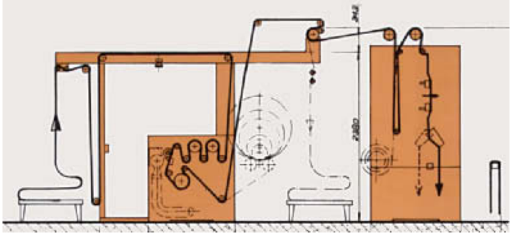


Fig.: Scarf cutting machine by Lafer.

Scarlet →: Kermes; Cochineal.

Scatter coating (Scatter granules coating). Procedure used for interlinings. The granular adhesive (polyamide or polyethylene) is irregularly scattered on the base material and then heated until the granules sinter to form beads (see Fig.). Alternative → Powder-dot coating.

Scatter coating is also used in the manufacture of formed mats for automobile inner fittings to laminate a decorative polyester fabric using the copolyester powder coating with polyester fibre web. Only recyclable polymers are therefore used so that the moulded formed mats can be shredded after the used car has been recycled. The resultant polyester agglomerates can be recycled, i.e. a portion can be added when manufacturing new formed mats.

Scattered light measurement Where dyestuff has been dispersed, a certain portion of the measured extinction is always caused by scattered light. For particle sizes with a radius of r < λ/20, the scattering intensity can be described:

$$l_s = l_0 c r^6/\lambda^4$$

l_s = intensity of scattered radiation,
l_0 = intensity of incident radiation,
c = concentration of scattered particles,

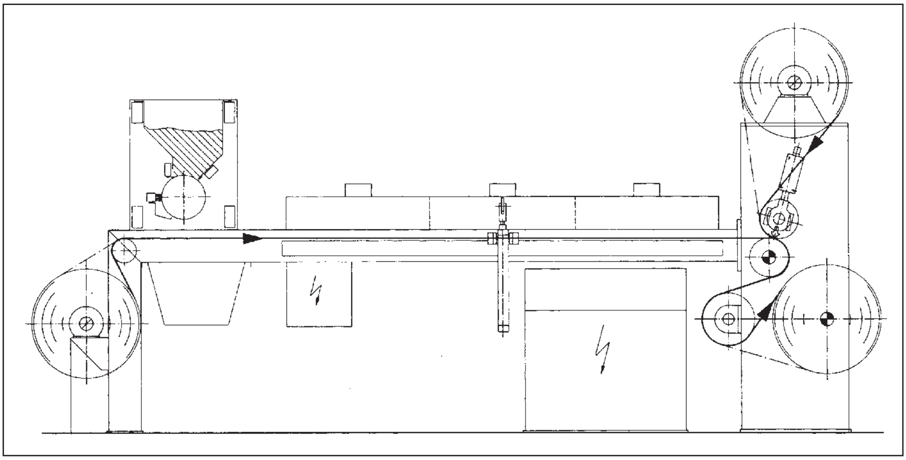


Fig.: A compact scatter coating machine.

r = radius of the scattered particles,
λ = wavelength.

Shortwave radiation is therefore scattered to a greater extent than longwave radiation. For larger particles of radii in the range of the wavelength of the incident radiation, the scattering intensity increases and spatially becomes particularly anisotropic. The ratio of forward to backward scattering increases. Commercial dyestuffs generally have particle sizes in the range of 0.1–1 µm diameter. Their dispersions spatially scatter the light extremely anisotropically and predominantly in a forward direction. For extraction measurements on dyestuff dispersions, this does not have a negative effect on the validity of the measurement of scattered light as long as the distribution of particle sizes of a dispersion is not dependent on concentration. The relative number of agglomerates with larger diameter at increased concentration, for example, may therefore increase. To a remarkable degree of accuracy, dyestuff dispersions act in line with Lambert-Beer's law (→ Extinction). When measuring transmission of dispersions with defined, close particle size fractions, it has been seen that there are different gradients in the extinction-concentration diagram for the same dyestuff depending on the particle size fraction, although the relationship remains linear. For a mix with constant portions of the different fractions which are not dependent on concentration, a linear relationship can also be expected.

Schappe (silk) (Chappe, Floret silk). This is taken from the beginnings and ends of the cocoon which can no longer be unwound after the vegetable glue has been decomposed in a putrefaction process. The schappe undergoes further processing in a similar spinning process to that used for worsted yarn. The comber waste which falls away provides → Bourette. Schappe is used e.g. for machine sewing silk and for strong silk fabrics. → Silk.

SCHEK, SEK Swiss fastness commission → Technical and professional organizations.

Schiff's Reagent Colourless aqueous solution:

I. Fuchsine with some sodium sulphite, sodium disulphite or potassium metadisulphite and the addition of a little hydrochloric acid or sulphuric acid. In this state, the fuchsine is reduced to a colourless compound. Use: as a test for aldehyde (acetaldehyde), formaldehyde: after the addition of aldehyde, there is an immediate or gradual red violet colouring.

II. Sulphur dioxide in 1% fuchsine solution results in an almost colourless solution. Damaged cellulose turns red.

Schreiner calender A Schreiner calender is a 2-roller calender with 30–50 t printing capacity consisting of an upper engraved steel roller (fluted roller) and an elastic roller positioned beneath (hard-pressed covering made from special paper, or very occasionally a cotton roller) (see Fig.), whereas the 3-roller calender has an additional printing roller for printing with 50, 80, 120 t. The heatable fluted roller contains numerous fine grooves (8–22/mm) which run at angles. These, together with the combination of a high heating temperature, 100–200°C depending on the quality of the material, and pneumatically adjustable pressure, produce the silky lustre on moist cotton fabrics. Heating is generally a combination of steam/electricity or gas. Multi-purpose Schreiner calender with exchangeable rollers include the 2-roller embossing silk finishing and chintz calender, the 3-roller silk finish and simili mercerizing calender. The position of the grooves in the fluting is important as the warp and weft twist need to have uniform direction so the fluting doesn't run at an angle through the fibre lay and cut into the fibres. Depending on the direction of the fluting, a distinction is made between: 1) Cross fluting parallel to the roller axle; no longer common due to excessive wear;

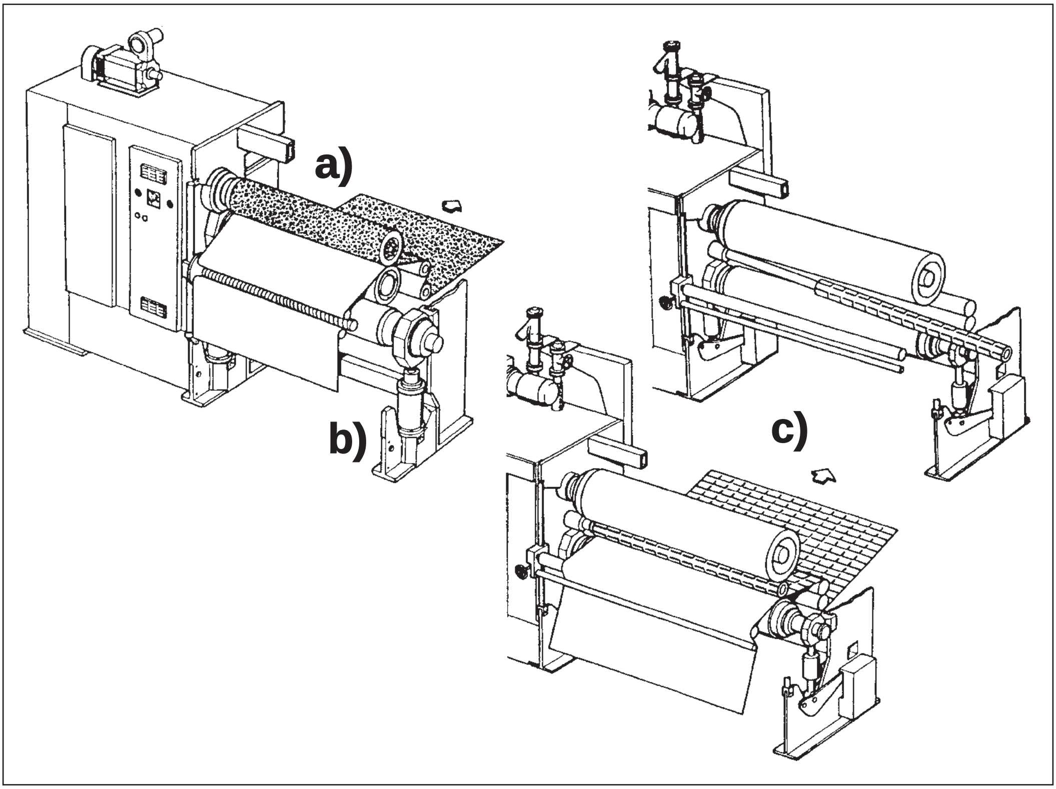


Fig.: Küster's three-roller multi-application calender.
a) upper gap = Schreiner finish or other effects; b) lower gap = matt, rolled, smooth, glossy or chintz effects; c) auxiliary roller with quick change for embossing.

2) Round fluting: grooves around the roller, e.g. silk finish on warp satin; 3) Diagonal fluting: grooves running from the bottom left to top right (when looking at the roller from above). As regards the diagonal gradient, for fabric surfaces with dominant weft yarns (weft satin), gradients of 12–25° are selected, and gradients of 70–80° are selected for fabrics with dominant warp yarns. It is necessary to resharpen the fluting after approx. 6–9 months assuming 8 h daily use.

Schreiner effect, Schreiner calender → Schreiner calender.

Schweizerischer Verein der Chemiker – Colorist (SVCC), similar function as the → SVF, therefore joint efforts to merge the associations.

Schweizerische Vereinigung von Färbereifachleuten (SVF), Basle; task: Intensive promotion of the chemical/technical and professional endeavours of experts in dyeing and the entire textile finishing, for the good of the profession and advance of its members, for the benefit of the textile industry. Members of all countries with significant textile industries belong to the SVF. Principal divisions of the association are the general assemblies and the executive committee. Publishing division: textile finishing. → Technical and professional organizations.

Scleroprotein →: Keratin; Fibre proteins.

Scorch test American test method (AATCC) to determine the amount of damage to hardenable synthetic resin finishes due to → Chlorine retention on cellulose textiles. Also records the specific buffer capacity for each synthetic resin and each catalyst. Working principle: chlorine treatment (2.5 g/l active chlorine, liquor ratio 1 : 50, 25°C, pH 9.5, 15 min), rinse, dry, condition, scorch or press between two metal plates with constant pressure and temperature (185°C, 30 s), condition. Assess by comparing the percentage average decrease in breaking strength and any yellowing which may occur.

Scouring of cellulose fibres and their blends (Scouring of cotton with alkaline boiling). Preparative process for bleaching and dyeing, esp. for cotton, to remove the primary wall of cotton. Can be used for cotton and cotton/synthetic blends both in long liquor (→ Kier-boiling) and in the continuous process (→: Alkali shock process; Extraction scour/extraction bleach). Pretreating with weak acids, e.g. acetic acid, to remove alkaline earth pollutants is not necessary when the extraction method is used. Alkaline boiling is increasingly concentrating on saving time, energy and water in the subsequent rinsing. Polyester/cotton fabrics are boiled in rope form or open-width, depending on the quality, with the tendency being towards open-width treatment. Efforts are increasingly being made to combine desizing, boiling and bleaching in one process. Shock methods at high alkali concentrations are not recommended for polyester/cotton fabrics as this would have a negative effect on the polyester portion.

Boiling and scouring should

- saponify fats and waxes (0.4–1%);
- split proteins and pectins (1.1–1.9%; 0.7–1.2%);
- complex mineral substances with Ca, Mg, Fe, Cu (0.7–1.6%, more in some cotton derivatives), to avoid these reacting with saponification products;
- prevent the formation of oxycellulose and associated damage;
- increase the absorptive capacity (test using capillary rise method);
- improve the degree of whiteness and reduce the seed husk content;
- extract reaction and by-products after impregnation and following the reaction phase at a high temperature where suitable dispersing agents are used and intensive liquor exchange takes place;
- prevent fold marks if strong swelling process occurs.

For this, the following are required:

- up to 25°Bé NaOH (20–80g/l);
- the addition of a reducing agent;
- an anionic surfactant with wetting and detergency power, expressed as a HLB value (hydrophile-lipophile balance which states whether the surfactant tends towards an oil-in-water emulsion or a water-in-oil emulsion; the higher the HLB value, the higher the oil/water ratio with good detergency power; the lower the HLB value, the higher the water/oil ratio with good wetting effect);
- a complexing agent (electron donator) to sequester the metallic cations (electron acceptor). The resulting complex is characterized by its pK

$$pK = -\log K;\ K = \frac{[M^{+n}] \cdot [L^{-m}]}{[ML^{+n \cdot -m}]}$$

The aim of alkali scouring is to produce an absorbent material with an average degree of whiteness and extremely low mechanical and chemical damage for textile dyeing and finishing. To achieve this aim, the substances used on the fibre must be removed as completely and as quickly as possible.

During the impregnation process, the alkali initially moves towards the textile surface by convective diffusion. It is assumed that the liquor then diffuses into the pores filled with air. As this process involves a pure exchange of concentration between the pores of the fibre which are filled with air and the alkali liquor, the process is extremely slow without any external effect. If the liquor is diffused into the fibres, the substances used are partially emulsified (chemical reaction). Next, the extraction of the hydrolized substances from the fibre into the liquor takes place. This diffusion takes place as rapidly as the exchange between fresh, unused and used liquor. It is not clear whether this is a reaction controlled by diffusion in which the speed of the reaction is only dependent on the diffusion of the liquor into the fabric and back out again. In the case of a reaction which is self-controlled, its rate is only dependent on the speed of the reaction between the primary wall of cotton and caustic soda liquor. In order to increase the reaction rate of a diffusion-controlled reaction, the flow-rate must be increased (Fig. 1). In addition to this increase, the following influencing variables have an effect on the extraction rate of the alkali scouring:

- temperature,
- concentration of soda liquor (Fig. 2),
- time,

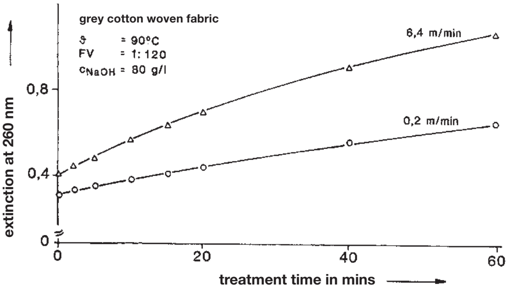


Fig. 1: Effect of liquor exchange on alkaline cotton boiling speed (0.2 m/min = inferior liquor exchange; 6.4 m/min = intense liquor exchange).

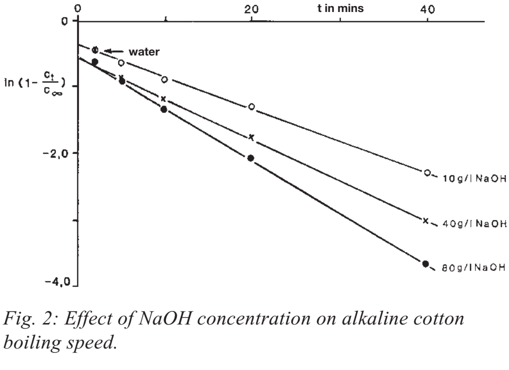


Fig. 2: Effect of NaOH concentration on alkaline cotton boiling speed.

- auxiliary,
- pretreating the cotton with acid.

On the assumption that this is a chemical reaction of the 1st order (rate dependent on the concentration of the starting material, as well as on the temperature), the reaction rate of the boiling and scouring process is as follows:

$$\frac{dc}{dt} = \beta^* (c_\infty - c).$$

If the concentration at the time t = 0 is defined as the initial concentration $c = c_0$ and the concentration at the time t is defined as c_1, the rate of the boiling and scouring process can be derived from:

$$\ln \frac{c_\infty - c_t}{c - c_0} = -\beta^* \cdot t$$

$$\ln\left(1 - \frac{c_t}{c_\infty}\right) = \ln\left(1 - \frac{c_0}{c_\infty}\right) - \beta^* \cdot t.$$

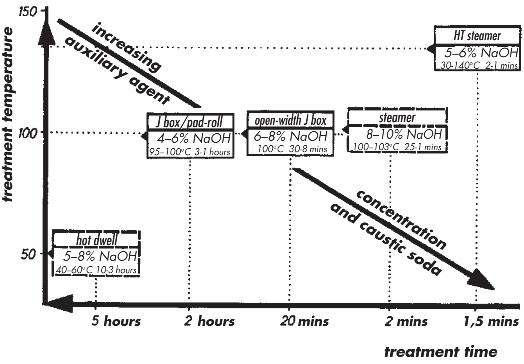


Fig. 3: Standard formulation for alkali treatment with Lufibrol KB and Leophen U (BASF).

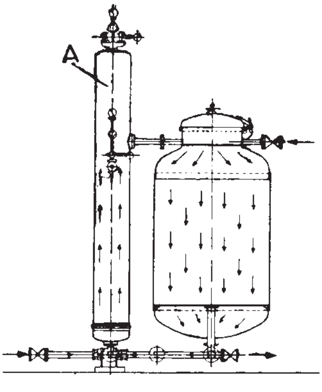


Fig. 4: Kier for alkaline high pressure boiling and scouring (A = lye heater).

The quickest boiling and scouring results are therefore achieved when diffusion is used (Fig. 3) as a result of:

- high temperatures,
- high alkali concentration,
- rapid material flow.

A distinction is made between the two processes: discontinuous boiling and scouring (kier boiling) (Fig. 4) and continuous boiling and scouring (mainly with steamers). The alkali-shock process is used under extreme conditions in terms of soda liquor concentration, temperature and time (Fig. 5).

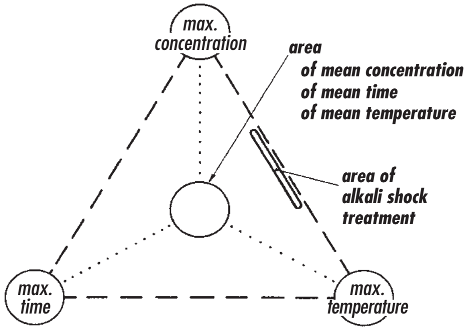


Fig. 5: Alkali shock stage: dependent on concentration, temperature and time.

Screen Grid system of points or lines which intersect at right angles. If a photograph is taken of an original image through this type of screen which is located at a certain distance from the photographic plate, the light spreads conically behind the screen. This causes a dissection of the image or dispersion of the brightness on the plate in the form of numerous points. Using this principle of dissecting extremely small areas, photographic negatives are produced which are copied onto a metal plate and then etched, used as so-called autotypes in paper printing and similarly for → Half-tone printing on textiles.

Screen coating The rotary printing screen system (see Fig.) is based on seamless rotation screens (2). A doctor blade (1) presses the print or coating paste (5) into the screen through the perforated screen wall onto the substrate (4). A pump and level control guarantee constant supply of paste. If the perforations in the rotary screen are sealed in places using a spec. lacquer (the rotary screen is then engraved) the coating unit can be used as a single-colour printing unit for a pattern. Light squeegee pressure makes it possible to apply a small amount of paste for vertical passage of the cloth. The quantity applied to the substrate can be increased by increasing the squeegee pressure or if the doctor blade applies pressure behind the centre of the counter roller (3). Fabric may also be introduced horizontally. This

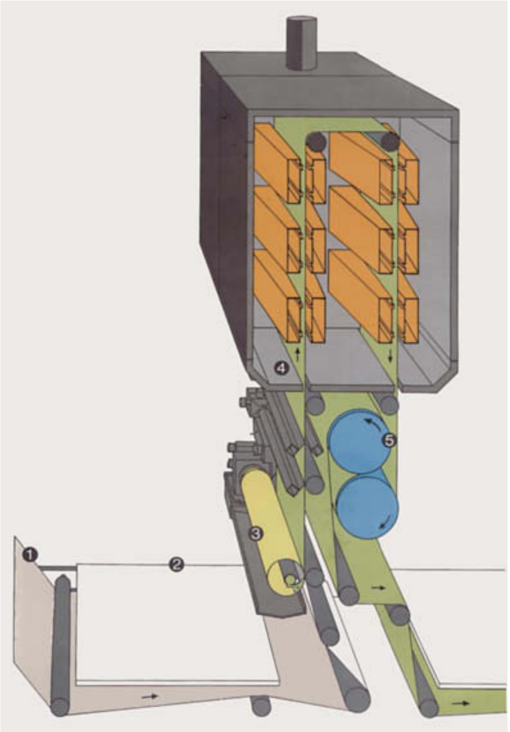


Fig.: A rotary screen coating system (Stork).

may be necessary if the substrates are inflexible and cannot be bent. The wide coating unit has a horizontal fabric feed system as the material and the screen must be well supported. Stork X-cels technology makes a new development in coating processes possible: coating both sides of an open fabric in one passage through the machine using only one screen. In this process, the counter roller operates at a variable speed in relation to the substrate, so the paste which remains on the roller is applied to the reverse of the substrate. The substrate is then guided across a double levelling blade (both on the fabric face and the reverse) which smoothes the surface. Next, non-contact gelling takes place in the vertical drier. The advantage of screen coating for this application, compared with a dip coating process, e.g., is that the amount applied can be accurately controlled. The substrate (1) to be coated or printed passes under the platform (2) through the coating/printing unit (3); this is generally a rotary printing unit which is suitable for both printing and coating processes as well as for partial coatings. The non-stop screen alternating system can be used for short lengths. Additional finishing techniques can also be integrated into the plant if necessary. In this case, the coated material is dried in the vertical drier (4). These driers are also used as intermediate driers in multicolour printing machines, e.g. when manufacturing floor or wall coverings. The drier generally comprises one section for each coating or printing station. A second drying section can be used for particular applications, whereby the length of the drying path is doubled in each section. The substrate is drawn through the drier by means of a pair of cooling rollers (5). After cooling, the substrate is coated or printed.

Screen engraving for printing The textile industry has seen many changes over the years but one constant has been the continued pressure to get new designs printed quickly and economically. One basic reason for this situation is that once the screen is on the printing machine there is very little one can do to increase productivity. Thus, the design and screen imaging area are where savings must be made. The most significant technical innovation introduced in the mid-1980’s was laser engraving of lacquer screens, offering substantial reductions in the production process steps required to achieve a print-ready screen. Coupled with this, the more recent introduction of computer generated design and graphic creation systems based on personal computers has brought great creative and production advantages over conventional methods. In the future textile designers will be able to make rapid design changes to meet market pressures with laser engraving, providing accurate, repeatable and fast, print-ready rotary screens. Some early investors into this technology are now well on the way to their second (or third) engraving machine, and with hardware and software enhancements to generate half-tone screens from continuous tone inputs, the days of Galvano engraving are numbered. Considerable advantages are realised over conventional film engraving, and some of the total system advantages are outlined as follows:

1. Pre-coating: As laser engraving does not require photo sensitive coatings, numerous screens can be coated and baked. The blank screen can be inspected for pinholes prior to engraving, then stored ready for instant engraving when required.

2. End-rings: Engravings may now be made with end-rings already glued in place. Coupled with pre-coating, this can save an enormous amount of down-time on a printing machine. Glueing the end-rings takes up to 30 minutes per screen. It is common for a printer to order a set of remakes with an original set of engravings in anticipation of screen breakage. If the printer has his own laser he can engrave the original set and bypass the remakes. Should he have a screen break, and as he has a coated, end-ringed screen ready, the only time lost will be engraving time. The screen is ready to print straight out of the laser.

3. Film elimination: Film is expensive and it can physically distort over time. Wrinkles, due to handling, are likewise inevitable. As the laser’s powerful computer holds a motif in digitised form, not only costs, but most problems associated with film disappear, includ-

ing step and repeat machines, contact frames, cameras, processing units, etc., all of which take up expensive floor space. The major savings day-by-day through the elimination of colour separation films cannot be overemphasised. Additionally, the creative designer is allowed to concentrate on texture, shapes, colours and text. Tones need only be represented as continuous tone values, not dots. Corrections and amendments are also greatly simplified by the ability to trap, retouch, edit, merge and engrave line and tone files.

4. Seamless designs: Join lines no longer exist.

5. Instant precise remakes: All engraving parameters are stored together with the motif, ensuring that a precise remake can be made at a later date. Archiving can take the form of print-outs, optical disc, floppy disc, half-inch tape or tape cassette.

6. Memory factor: A single motif, once scanned from Zedco's scanner or received from a design computer (Scitex, Hell, Epicad, etc.), can be manipulated (stretched, distorted, jointed, stepped and repeated) in many different ways without re-scanning or returning to the design computer. For example, a motif can be stepped and repeated twice around the circumference of a 640 mm screen and say 72 inches engraving width. Then after suitable distortions, 3 times onto a 860 screen, any engraving width is feasible. These parameters can be changed in seconds. Using this technique memory space is relatively small compared to the storage requirements of a full stepped and repeated design. Registration marks, legends, etc., can be engraved in the selvedge as a separate procedure or engraved automatically with the motif. A job number can be typed directly onto the rotary screen from one of the computers.

7. Continuous tones: By reading a grey wash from the scanner or directly from an imaging system (Hell, Scitex, etc.) either a random stipple or a conventional regular screen can be computer generated at any screen count at any percentage at selectable angles. The engraver can change the gradation curve without going back to the original design or artwork. This is particularly useful for creating platforms. These changes can be made in seconds, then laser engraved immediately. Simulation of a Galvano screen is achieved by using the above method.

The impression has arisen in recent years that the laser technique is dominant as far as direct engraving is concerned. The units for laser erosion rotary screen engraving (ZED, Baasel Scheel, CST, Stork-STK) and for the laser exposure of rotary or flat screens (Stork-STK, MS) seemed to be the only solution. At the last ITMA, the Swiss Lüscher AG showed in fact that, in addition to the laser technique, there is another suitable process for producing economic and environmentally conscious, high quality rotary and flat screens: the ink-jet technique. With the use of the ink-jet technique in "JetScreen" type equipment, Lüscher has been successful with a development which is worth presenting in detail, and can be compared with the laser technique. With the "JetScreen", rotary screens or flat screens are patterned without the use of transparencies, the producer combining familiar, tried and tested processing elements with new ones. The units operate in conjunction with a CAD system. The colour separation to be transferred to the screen is therefore produced in the Lüscher "ImagBox" CAD unit in the form of a graphics file or is available as the compatible or convertible data file of another CAD system.

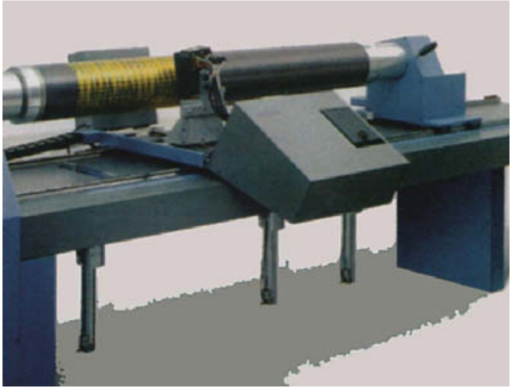


Fig. 1: The parallel layout of 96 spray jets in the "JetScreen" for rotary screens results, with high definition, in short engraving times (Lüscher AG).

The screen is first of all conventionally photosensitively coated, the familiar engraving units, photoelectric layers and coating processes being usable. Instead of the then subsequent film montage with subsequent exposure, the flat or rotary screen is 'shot' according to pattern with the finest wax droplets with the aid of the ink-jet technique. In the case of the rotary screen, this is done with a cylinder rotating about its longitudinal axis, along which the ink-jet head is guided (Fig.1). Flat screens on the other hand are inserted in a vertical machine frame, and the ink-jet head "removes" the screen areas to be engraved line by line (Fig. 2). The graphics file, which is retrieved directly from the CAD machine via a LAN or by an integral computer, serves as the control data file. The spray technique used is the so-called "Drop-On-Demand" process where the droplet is expelled only when it is needed in accordance with the pattern. The wax particles adhere to the screen surface, forming a layer impervious to light. It assumes the function of the transparency. It is then exposed in the "JetScreen", developed away from the machine, and finally produced in the familiar engraving environment.

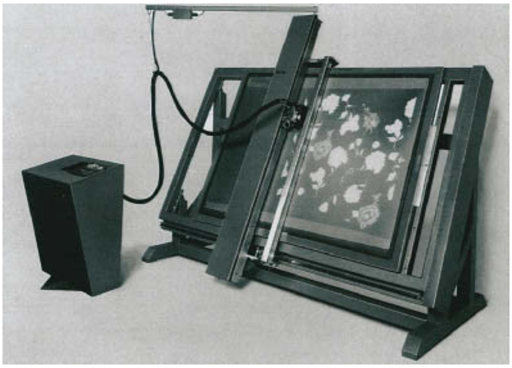


Fig. 2: In the "JetScreen" for flat screens, the spraying head scans the screen surface line by line (Lüscher AG).

The printing head does not spray aqueous dyestuff, for example, but wax. This material is thermoplastic. To prepare it for spraying, it is heated in the printing head. The heated wax has a higher viscosity than a dyestuff formulation dissolved in water or solvent for example. While a less viscous drop would flow in undefined form over the screen surface on impact, the wax droplet changes its round shape very little in cross-sectional terms; it just becomes bigger. Its viscosity is already increasing in the flight stage as it begins to cool, finally hardening in contact with the screen surface. Actinic light absorbent additives, which reliably prevent irradiation of the wax particle, can be introduced into wax. Currently used waxes have 10^4 opacity, which reduces light penetration to 0.01%. There is a further aspect for material choice. Wax can in fact cool down and harden in the spray jet, but does not dry in, since it is composed of 100% solids. Its extrudability is achieved via thermoplasticity. There are therefore no clogged nozzles, even when a nozzle expels no droplet over a long period. Dirt in the nozzle piping system is insignificant, since filters there ensure exceptional wax purity. Furthermore, the wax recommended by the "JetScreen" manufacturer is an environmental-friendly material, which can easily be filtered out of the effluent. The wax develops natural adhesion to all known photoelectric layers, without "sticking" too hard. In this way, it adheres securely to the screen photoelectric layer on the one hand, and on the other can be washed off easily enough in the developing process.

The ink-jet technique imposes minimal requirements on screen positional accuracy, because, in contrast to the laser technique, no focal range has to be adhered to. For this reason, the "JetScreen" for rotary screens has a simply designed screen mounting (cone), and requires no specialised screen guides such as air bearings or guide rings in the working area. The screen is very simply pneumatically stabilised with a minimum overpressure of 0.02 bar. In contrast, the flat screen is brought into the plane position by means of a partial vacuum. Screen positional tolerance has very little effect on picture detail representation. This is due to the very favourable relationship between droplet flight speed and screen rotational speed and spraying head feed speed. The bigger the difference between the two speeds, the smaller the representational error resulting from positional tolerance. A rotary screen running at a relatively low speed or a relatively slow spraying head feed with the flat screen prolong engraving times in principle of course. The current ink-jet technique however permits the parallel layout of a large number of nozzles. There are 96 in the "JetScreen" unit. The number of nozzles more than offsets the low rotary or feed speed relative to engraving time. In contrast to this, a rotary screen laser engraving unit, for example, operates in fact at a high screen speed (400 rpm and above), but only with a focal ray. This can of course be multiplied, but the process founders on cost grounds. With the ink-jet technique on the other hand, the already large number of nozzles can easily be increased as part of the further development of this technique (and retrofitted). The ink-jet technique produces no seam, as is familiar from conventional film engraving, and is dreaded with certain patterns. This process can produce no 'hollow copies', another difficulty not always to be avoided with the conventional process. Another interesting new test and correction process, the "JetScreen" units produce on the screen an image (graphic) almost identical with the subsequent print with this screen. Therefore when in doubt about the resultant print of a critical half-tone, for example, it can be printed out on paper which has been laid on the screen by way of a proof. Since the engraving unit is linked with the design computer, corrections are made in a very short time. This is therefore a significant checking and correction possibility for the engraver, which has not been provided in this form up to the present time.

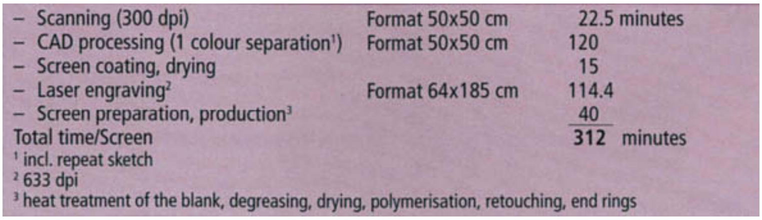
Basically, "JetScreen" units only apply to the screen the conventional engraving transparency, though by a new method. All other processing stages, i.e. exposure, development, thermal or chemical hardening if necessary, through to retouching, remain unchanged. For this reason, all photoelectric layers are immediately usable whatever the make. How appropriate this concept is, is proved by comparing the ink-jet technique with the laser exposure technique for rotary or flat screens. The short-wave laser sources used there are low in performance, and therefore need extremely sensitive photoelectric layers. Their development is only in the initial stages. Thus, there is of course already a series of "ultra-fast" photoelectric layers on the market, but many limitations are apparent in practice. Apart from the fact that these layers need extremely subdued light for processing, there are still difficulties as regards durability in printing. Moreover, the fast photoelectric layers have to be applied within strict limits as regards layer thickness (which also applies to laser erosion engraving units, so that, basically, exclusively mechanised application processes come in question). If the layer thickness is exceeded, full hardening suffers in laser exposure, or the layer is not completely burned off. All these limitations, which of course seem individually controllable, but can as a whole represent troublesome fault sources, are excluded from the onset with the ink-jet technique.

Laser engraving	"JetScreen"
scanning	scanning
colour separation (CAD)	colour separation (CAD)
srcreen coating polymerization	screen coating
laser engraving	"JetScreen"
retouching end ring	exposing, developing, polymerization, retouching, end ring

Fig. 3: Comparison of processing cycles with laser engraving and the "JetScreen" (Lüscher AG).

Laser/ink-jet comparison: Apart from the technical differences in the systems, the practical man is interested above all in the performance aspects. In Fig. 3 the (erosion) laser engraving process and the "JetScreen" are compared for rotary screen patterning. In addition to the colouristic configuration of a textile design, print quality means above all the graphic harmony of colour separation and resultant print. Engraving affects this harmony primarily with its graphic definition capacity. Fineness of contour and screen, freedom from moiré or from "saw toothing" in figure outlines are criteria which, in addition to the photoelectric layer and the screen gauge used, are determined by the engraving process and equipment definition capacity. Thus one would expect better engraving and printing results from the process offering higher effective definition. In this connection, effective means the relationship between graphic definition and engraving time. Higher definition is unusable or less usable, for example, if it leads to unreasonable engraving times. With both processes, therefore, picture definition in printing depends on scanner definition capacity, on the photoelectric layer, and ultimately on mesh count and screen model. These influencing parameters are assumed to be identical in the comparison: identical datafile, identical photoelectric layer and screen.

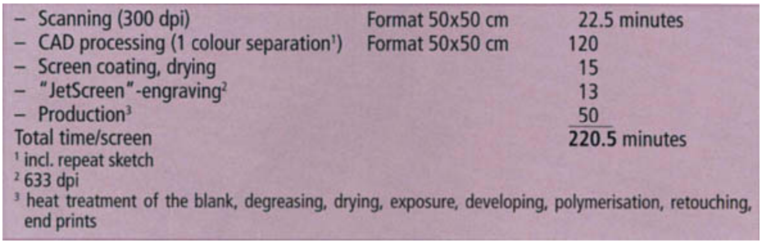
The lengthy time requirements for laser engraving needs brief explanation (Figs. 4 and 5).The engraving time results from screen speed (403 rpm) and horizontal definition (633 dpi), which is equivalent to an engraving head feed of 40 µm per screen revolution. Under these conditions, the total engraving time is 114.4 minutes. This time requirement is too high in practice. In order to keep engraving time within limits, a compromise is made, definition being reduced in the horizontal engraving direction, while it can be selected at a high level in the vertical direction within the bounds of the possible. With a horizontal definition of 245 dpi, for example, (this is equivalent to a feed of 104 µm per revolution), the engraving time is 44 minutes at a speed



– Scanning (300 dpi)	Format 50x50 cm	22.5 minutes
– CAD processing (1 colour separation¹)	Format 50x50 cm	120
– Screen coating, drying		15
– Laser engraving²	Format 64x185 cm	114.4
– Screen preparation, production³		40
Total time/Screen		**312** minutes

¹ incl. repeat sketch
² 633 dpi
³ heat treatment of the blank, degreasing, drying, polymerisation, retouching, end rings

Fig. 4: Time requirement/screen in laser engraving (Lüscher AG).



– Scanning (300 dpi)	Format 50x50 cm	22.5 minutes
– CAD processing (1 colour separation¹)	Format 50x50 cm	120
– Screen coating, drying		15
– "JetScreen"-engraving²		13
– Production³		50
Total time/screen		**220.5** minutes

¹ incl. repeat sketch
² 633 dpi
³ heat treatment of the blank, degreasing, drying, exposure, developing, polymerisation, retouching, end prints

Fig. 5: Time requirement/screen with the "JetScreen" (Lüscher AG).

of 403 rpm. With a horizontal definition of 200 dpi, the engraving time is then about 36 minutes. In this way, practicable engraving times are achievable. Presupposing suitable designs, the engraving result is acceptable. If of course highly detailed designs are to be produced with large half-tone areas or other difficult parameters, this process cannot meet requirements without having to take account of loss of quality or longer engraving times. (according to M. Klemm and W. J. Burrow).

Screen films in photo-engraving These are used:

I. In film printing to copy texture or grid effects into the sample pattern.

II. In photo-engraving for printing rollers to copy the → Hatching into the negatives of the colour separations by contact printing.

Screen frames (film screen frames). The screen gauze is supported by the screen frame. Wood, metal, plastics and combinations of the above, e.g. metal/plastic, are suitable for the production of screen frames.

Screen frames in screen printing In contrast to rigid frames (as used in yuzen, spray and brush stencil printing), various special materials are used as film bases in screen printing. These are supported by a stable screen frame. Types of screen frame include: wooden frames, metal frames, plastic frames and combined frames (e.g. metal and plastic).

Screen gauze → Screen mesh, screen gauze.

Screening test OECD 301 E This test is used as an initial test of the biodegradability of a textile auxiliary (→ Surfactant biodegradability, evaluation of) and should be regarded as a particularly stringent test as it simulates the conditions of river water, rather than those of a biological waste water treatment plant. This test is described in the form of a diagram in Fig. 1.

The substance to be tested is added to an open container, together with nutrient salt solution and a bacterial suspension from a municipal waste water treatment plant with approx. 1 mill. germs/ml. This container is shaken at room temperature for 28 days in a shaking device and a sample is tested for its rate of biodegradability (reduction in DOC) every 7 days. It is, of course, also possible to test the reduction in BiAS analytically, but this gives higher values. If the limit values (DOC 60%) are not achieved, a continuous test is prescribed (Fig. 2). This test is also known as the "confirmatory test". In this, the substance to be tested is tested in an

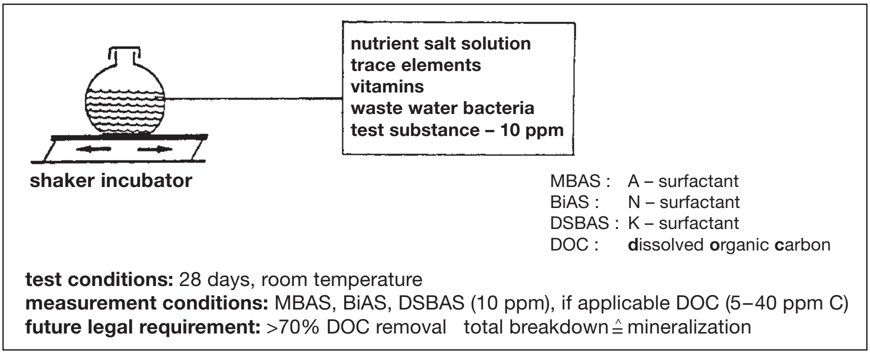


Fig. 1: Test methods for the selection test – screening test OECD 301 E.

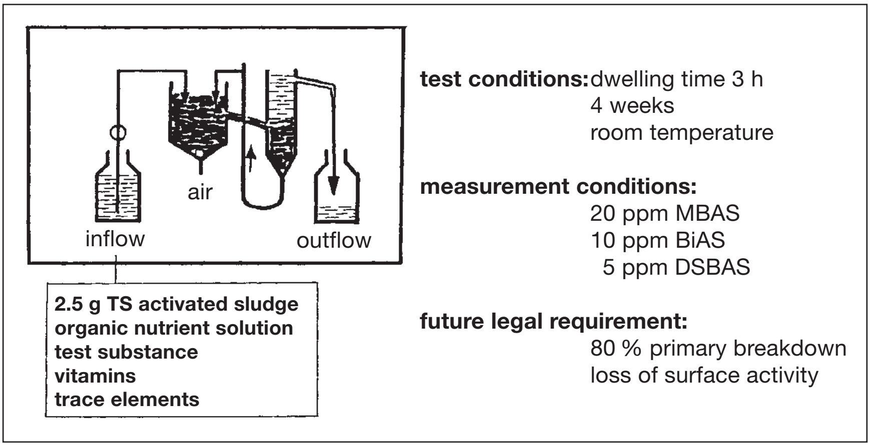


Fig. 2: Test methods for the confirmation test – confirmatory test without OECD number.

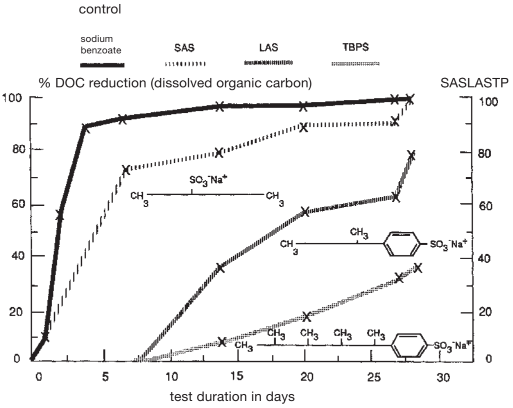


Fig. 3: The total breakdown of anionic surfactants, sec. alkane sulphonate SAS, alkylbenzene sulphonates LAS, TPBS, total breakdown according to modified OECD screening test 301 E.

activated sludge device in which the conditions are adapted to those in a waste water treatment plant. Nutrient salt solution is continuously added to the test substance in an aeration tank. This is where the essential biodegradation takes place. The required 2.5 g solid matter/l activated sludge comes from the municipal waste water treatment plant. The bacterial sludge migrates into a sedimentation tank, where it is pumped back into the aeration tank. At the infeed, approx. 5–20 mg/lxh of anionic surfactant or 5–10 mg/lxh non-ionic surfactant is allowed to flow through the device. The biodegradation can be calculated taking into consideration the concentration of the surfactant at the infeed/outflow. Using this method, the primary degradation should be 80% and above. The biodegradability of the surfactants which are generally used in pre-treatment can be described as good, as shown in the examples in Fig. 3.

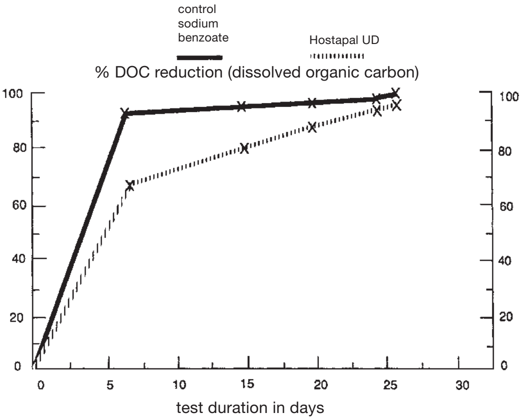


Fig. 4: The total breakdown of nonionogenic surfactants, alkyl (C 16-C 18)-polyethylene glycol ether (11 EO), total breakdown according to modified OECD screening test 301 E.

With SAS, it is extremely easy for the bacteria to carry out biodegradation (Fig. 3). The LAS will exceed the 60% limit after a sufficiently long adaptation time. The delayed degradation could be due to the structure of the benzene ring. Fig. 4 shows the biodegradation of nonionogenic surfactants.

Screen lacquer This is used for prelacquering (preparation) in → Screen making, as a support for photosensitive layers and as a reinforcement coating.

Screen magazine for screen printing Screen magazines were placed to the side of or in front of the printing table in the first screen printing machines (Hikisch, Teximpex). They are divided into sections which can be raised and lowered in order to bring the desired screen to printing table height. Before printing, the movable screen frame is removed from the screen magazine and is slid back into the same compartment afterwards.

Screen making The repeat must be specified before the screens are made. Flat or rotary screens are manufactured by specialist companies or in separate departments within printing works. After the printing repeat has been designed and the colour separation has been produced, a flat screen is manufactured using the photochemical method, or alternatively a rotary screen is manufactured using the galvano-plastic method (or less often using the photosensitive lacquer process). The photochemical method is based on the fact that gelatine together with chromium salts forms water-insoluble compounds (chrome gelatine) when subjected to intensive exposure. The carrier layer is formed by coating with gelatine, which contains ammonia and potassium dichromate. During exposure, the unexposed layers may continue to swell and can be rinsed out at a later stage.

The galvano-plastic method to manufacture rotary screens uses seamless, thin nickel foil cylinders which are perforated and must be of uniform thickness. There is a sealed nickel layer on the areas which are not printed, while the screen is located on the patterned area. The sequence of procedures in the galvano-plastic method is such that a light-sensitive layer must be applied to the carrier roller. A negative film with screen resolution is then copied onto the carrier roller. The photosensitive layer must be developed and hardened before a separation layer is applied to the carrier roller (see Fig.). In the galvanising process, the cylinder is nickel-plated using nickel sulphate before the nickel screen is separated from the carrier roller. Nickel foil cylinders can also be patterned using → Laser screen engraving. →: Engraving; Positive process for screen making.

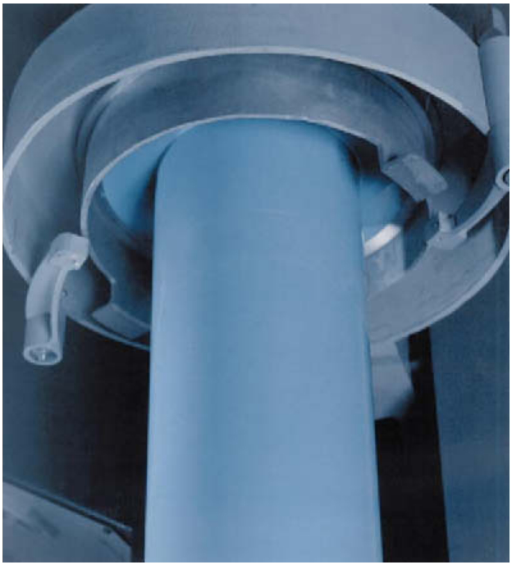


Fig.: Coating a rotary screen by dipping (Stork).

Screen mesh, calendered Crossover points are flattened during calendering and the thickness of the fabric is reduced, while the stitch width remains more or less unchanged. The volume of print paste in the dye paste channel and therefore the quantity of print paste applied is thereby decreased.

Screen mesh materials (→ Screen mesh, screen gauze), a) Silk: elastic, insensitive to pressure and impact, durable, sensitive to strong alkalis; b) Phosphor bronze (alloy consisting of 93% copper, 6.75% tin, 0.25% phosphorous): extremely fine wires (0.09–0.03 mm), high resistance to alkalis and acids, low elasticity gives high accuracy of registration, sensitive to pressure and impact (bulges); c) Polyamide, polyester: fine, even and durable fabric, resistant to chemicals, low moisture absorption, sensitive to highly concentrated caustic soda solutions.

Screen mesh, precleaning In → Screen making, the mesh must be cleaned of dirt, grease, etc. before the cover layer is applied. There are various methods available: for meshes made of silk or synthetic fibres, the screen is merely brushed down with hot water. Metallic meshes must be cleaned using chemicals. The screen can be cleaned with 10% sodium carbonate solution, diluted ammonia or caustic soda solution. However, the cleanest screens are obtained by using diluted organic acids or brushing down with 10% chromic-sulphuric acid (10 parts sulphuric acid, 20 parts water, 1 part potassium or sodium dichromate) followed by thorough rinsing.

Screen mesh, screen gauze (screen-printing fabric). Fabric covering for the screen frame which also serves to support the printing pattern in → Screen printing. Materials used include synthetic monofilaments and fine wires.

Screen plates in screen production These are required when producing → Half-tone autotype screens to help divide an image with differences in shade into a grid network of different sized dots.

Screen print This term is used instead of → Screen printing predominantly in the graphics industry. Screen print denotes the printing process in which the dye paste is pressed through the substrate as through a sieve.

Screen printing (film printing, correct: film screen printing, silk-screen printing). Printing process for textiles, etc. in which the printing block consists of patterned areas which are permeable to print paste, whereas the areas which do not have a design are impermeable to print paste. A distinction is made between → Flat screen printing and → Rotary screen printing. The screens consist of screen mesh (with recessed patterns) which is coated (on both sides) with lacquer, and which is mounted in the screen frame (wood, light metal). The print paste is poured into this and is pressed through the patterned areas which are free from lacquer onto the substrate below (which is fastened to the screen printing table) using the → Doctor blade. Repeat printing is used. The screens, which are generally each used for one print paste (i.e. there is generally one screen for each colour used) are positioned according to the repeat. This simplifies the repeat device which is applied along the screen printing table (bars with pins, etc.). Use: in particular for high quality novelty prints, for rapid colour matching with frequent colour changes and a large number of patterns and for suitable, especially smaller, yardage. → Roller printing and → Rotary screen printing are cheaper, however, especially for large print runs.

Screen printing adhesives When bonding the fabric, the printing table must be covered with a width of rubber, synthetic or wax cloth. Dextrines, gum solution, cellulose derivatives, starch ethers, alginates and even suitable combination detergents are used as adhesives. The adhesive application requires particular care as the adhesive coating must be completely even. The fabric should also be placed on the table as soon as possible after the adhesive has been applied. A glueing carriage has been developed for this in table printing. On screen printing machines, the adhesive is applied using a glueing unit.

Screen printing carriage This was the first step in the partial mechanisation of the printing process in screen printing. Printing table on each side with sliding bars as the contact surface for the screen printing carriages. In principle, this is a rigid frame with four runners which are positioned in such a way that the frame can be raised vertically to a height of approx. 100 mm by operating levers. During printing the screen printing carriage is moved along the table with the screen until the repeat device locks into place. After this has engaged, the carriage and screen are lowered so the screen lies against the goods to be printed. After printing, the screen is lifted off again by operating the lever and the carriage is moved to the next repeat or the next repeat but one.

Screen printing carriage for rotary and flat screens Automatic printing table for either rotary or flat screens to accurately print awkward fabric qualities. The printer moves along with the production carriage which is fitted with a platform (monitoring, exact adjustments).

Screen printing carriage, lever-controlled The first construction of a screen printing carriage occurred in 1935 during the course of the partial mechanisation of hand screen printing. The printing table has sliding bars on each side which form the contact surface for the screen printing carriages. In principle, this carriage consists of a rigid frame with four runners. These are positioned in such a way that the frame can be lifted vertically to a height of approx. 100 mm by operating levers attached to the runners. The frame also has locking devices which lock onto the bars at appropriate repeat limit stops and therefore guarantee accurate repeats. This frame supports the screen. During printing the screen printing carriage is moved along the table with the screen until the repeat device locks into place. The carriage and screen are then lowered so the screen lies against the goods to be printed. Printing takes place using double tilting or double rod squeegees. After the screen has been lifted again by operating the lever, the carriage is moved to the next repeat or the next repeat but one and the printing process is repeated. With the original printing carriages, it was necessary to raise and lower the carriage using two levers with both hands. The development of the lever-controlled screen printing carriage enables the working speed to be increased as the printer does not have to change grip from the lever to the doctor blade handle. Instead, the lever is left in position as the carriage moves forward enabling doctor blade movement to be initiated immediately after the screen has been lowered.

Screen-printing fabric → Screen mesh, Screen gauze.

Screen printing machine, automatic These are machines which carry out the entire printing process automatically when the screens are fixed in a stationary position while the fabric moves. Goods to be printed are affixed to an endless rubber blanket using a gumming device and are moved over the printing table. Screens are arranged next to each other above the table and are raised and lowered at the same time. Doctor coating takes place mechanically, either in the direction of the warp or the weft depending on the design of the machine. This doctor coating process can be carried out once or several times. After the screens have been raised, the fabric is moved forward by one repeat. A washing device, which is used to clean the printing blanket, is located beneath the machine. At the end of the machine, the fabric, which is moist from printing, is fed into a drying chamber, dried and cuttled down as it exits the chamber. The machines can be designed for 12 colours, for example, if there is sufficient space. In 8h, production is between 3000–4000 m, if the colour design for the pattern to be printed remains the same over 1000 m (totally independent of the number of screens). Colour design refers to the colour combination of a pattern which can be modified as required without changing the number of screens.

Screen printing squeegees →: Doctor blade; Squeegee systems in printing.

Screen printing table The table, in hand screen printing, on which the item to be printed is affixed, whilst with screen printing machines, the endless printing blanket runs over the screen printing table, on which the piece good, with a backing cloth if necessary) is affixed. Wool felt is often used under the printing blanket as an flexible layer.

Screen print steamer Designs follow the principle of fabric circulation, with only the reverse of the fabric sitting close to the guide rollers (to prevent haloing effects and smudging). Fabric always guided in a spiral, either a) in the Krostewitz steamer from the outside to the inside, with the fabric being turned by 90° in the centre of the steamer and being delivered at the side or b) in the Gerber or spiral high-speed steamer, with the fabric being guided in the same way, but with the fabric passing in the opposite direction through the tunnel, i.e. from the inside to the outside or c) in the double spiral steamer with the fabric firstly passing at the bottom from the outside to the inside, then turned by 90° and guided upwards, followed by another 90° turn and guided at the top from the inside to the outside. As in cases a) and b) it is always only the unprinted side of the fabric which comes into contact with the guide rollers, there is absolutely no risk of haloing. Other designs include: → Universal loop steamer and the → Continuous steamer.

Screen roller in screen printing These are used to facilitate the transport of screens on the printing table.

Screens, dimensional stability This depends on the material used for the → Screen frames, the type and tension of the screen gauze, → Screen making, environmental conditions in the preparation and printing rooms, treatment and care of the screens. Strong metal frame profiles are useful in providing the required cloth tension. To reduce fluctuations where the frame is permanently bowed, the following is recommended:

– Frame should be sufficiently bowed into a convex form before the fabric is affixed.
– When the frames are being manufactured, the trans-

verse leg (or also the broad leg) may each be bent convexly by approx. 4mm/m and be welded together at this angle which is slightly above 90°.

→ Stretching frames for screen making.

Screen sequence in screen printing Particular care should be taken with the sequence of screens or print pastes as this can have a major influence on the printing result, especially if fine outlines, overlaps or resists are being printed.

Screens for screen printing (film screens). Continuous, fine screens made from → Screen mesh which contain the desired patterning and therefore act as a carrier for the printing pattern. → Screen making.

Screens, fully lacquered → Screens produced using the → Negative process. The face and reverse of the screen are lacquered with a spec. appropriate coating. The advantage of the fully lacquered screens is that it is possible to produce extremely precise designs and that the screens are particularly simple to make.

Screen silk Spec. → Screen meshe, in screen printing is referred to as screen silk to distinguish them from standard → Bolting cloth. They are characterised by more careful selection of material, material treatment, control, particularly good and even material penetration and low swelling capacity when strong alkali print pastes are used. In places, guide threads are woven into the warp and weft at intervals of approx. 20–25 cm. These serve to ensure the mesh is fixed evenly in line with the threads on the screen frame. Mesh count is mainly between 6–16; 6–9 for blotch prints, pigment colours and bronze prints; 4–16 for finer outlines, streaks and screen effects.

Screens, stencils (design, form). Patterned support to enable reproduction of textile fabric patterning. Printing screens consist of the → Screen mesh and the → Screen frames.

I. Metal screens where the designs have been punched out are laid on the untreated material and enable the fabric to be partially brushed.

II. Paper screens where the designs have been cut out are laid on a fabric, and pigment dyestuff dispersions and binders are sprayed onto the fabric to form designs (→ Yuzen printing).

III. Negative films are screens which allow partial light transmission onto the printing screens which are to be exposed.

IV. Gauze cloths, which are stretched on frames and stopped with lacquer as per the design, and allows print paste to permeate the open area of the screen in → Flat screen printing using a doctor blade.

V. Rotary nickel screens, the perforations of which are partially blocked electrochemically with another metal or in which the completely sealed perforations have been previously opened using lacquer treatment in line with the design are used as → Rotary screens for screen printing.

Screen storage in screen printing To prevent damage, it is important that screens are stored in separate compartments, either one above the other, or next to each other (upright). For upright storage, small rollers are fixed in the floor in order to make it easier to manoeuvre the screens. The frames can also be suspended for storage. Rotary screens are kept horizontally in cardboard tubes, or upright if they are oversized.

Screens, subdivided (partitioned). This is used in screen printing to print several colours at the same time using a limited number of screens. To achieve this, the screen frame has a series of cross strips and the mesh is fastened as tightly as possible to the external frame and to the cross links to create individual fields which are totally separate from one another. A comb-type device with notches is used as a doctor blade.

Screen to screen coating A double foam application station can apply the same or, if preferred, different finishes (either wet-on-dry or wet-on-wet as preferred) to both sides of the fabric in a single process. In addition to foam application, paste coatings are, of course, also possible.

The horizontal design (Fig. 1) is used for double-sided coatings and finishes and operates with enclosed doctor blades, Drying takes place in a stenter or conveyor drier. This model can be used for combined use if the lower screen is operated using an enclosed doctor blade; it is therefore possible to combine paste coating on the upper side with impregnation on the underside, for example.

The vertical design (Fig. 2), in which the material is guided upwards, is used for paste coatings, which are dried using infra-red plates, and is used, e.g. with PVC

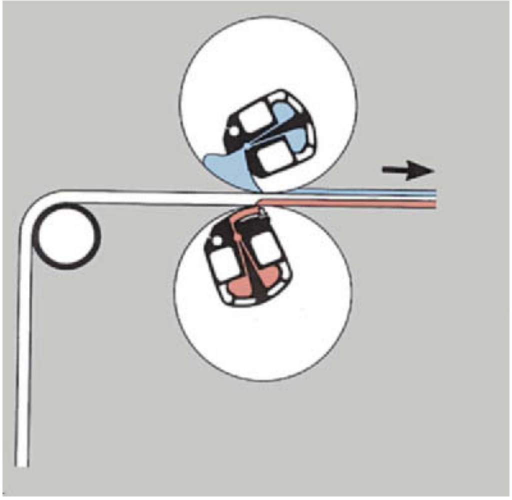


Fig. 1: Screen to screen coating in horizontal layout (STS by Stork).

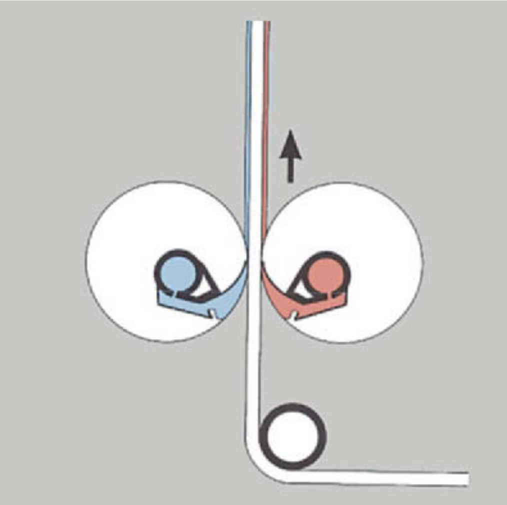


Fig. 2: Screen to screen coating in vertical layout with goods moving upwards (STS by Stork).

coatings for tarpaulins and nets. It can also be used for combined treatments with a stenter, conveyor drier or infrared drier positioned above. The vertical design in which the material is guided downwards is generally used for impregnating textiles/nonwovens and to chemically bond nonwovens. This version of the vertical design can also be used for combined treatments, although it must always be noted that the impregnated side of the material needs to be turned and should be dried in a stenter.

The principle element in screen to screen coating systems is the seamless rotary screen. The doctor blade presses the paste through the perforated screen onto the fabric which has an open fabric structure. A pump and a level controller ensure the paste is applied uniformly. The quantity of print paste applied on the substrate can be altered by choosing a different type of screen or altering the doctor blade pressure. The substrate then passes a double levelling blade (with a face and reverse side) which smoothes the surface.

Screen washing Rotary screens are generally cleaned in the vertical position. The outer screen wall is cleaned using a spray ring, and the inside is cleaned with a spray head with jets (see Fig.). Another possibility is the turbo spray washer which is attached to the central wash water feed on the inside of the screen: there are polyamide fibres on the rotating part which are hydroextracted on the screen wall due to the rotating centrifugal force in order to mechanically intensify the washing effect of rinsing with water.

Scroller → Selvedge uncurler.

Scrooping agents,

I. Common as a finishing agent on fibres to produce

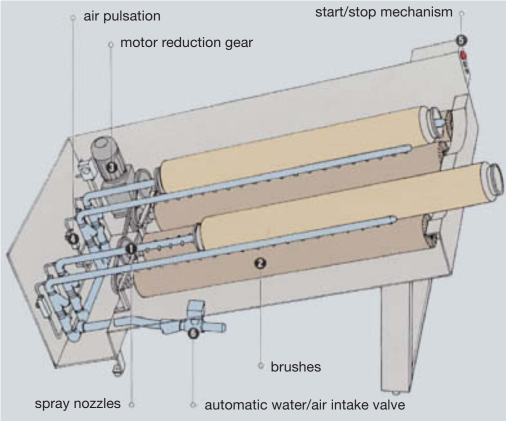


Fig.: A screen washing facility (Stork).

specific finishing effects. Different types of scrooping agents are available to take into account water, fibre, type of fabric and intended use. → Softening of textiles.

II. These are used to produce a scroopy handle (craquant, → Silk scroop). The textile fabric is treated with Marseilles soap, followed by an aftertreatment with lactic or tartaric acid. More recent methods are based on the use of ethoxylated fatty acids or paraffin emulsions.

Scroopy handle → Silk scroop.

Scrubbers for exhaust air For systems dealing with → Exhaust air, cleaning of using scrubbers, a distinction is made between:

a) Scrubbers: centrifugal washer, Prött system (Fig. 1); vortex chamber, Babcock system (Fig. 3); spray absorber (Fig. 2).
b) Heat exchangers (indirect cooling process): Lamella heat exchanger, alternatives between air/air and air/water, Behr system; bare-tube heat exchanger with mechanical tube cleaning, air/water, Radscan system; plate heat exchanger with wet cleaning of the plate, air/water, DEG system.

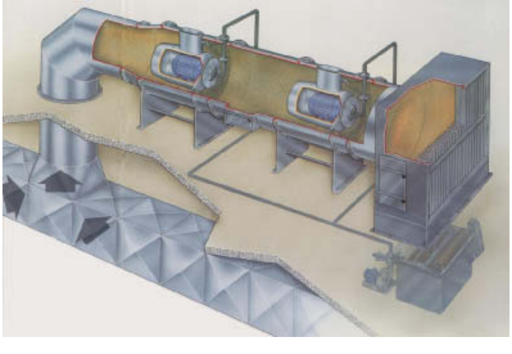


Fig. 1: Section through a Prött exhaust air scrubber.

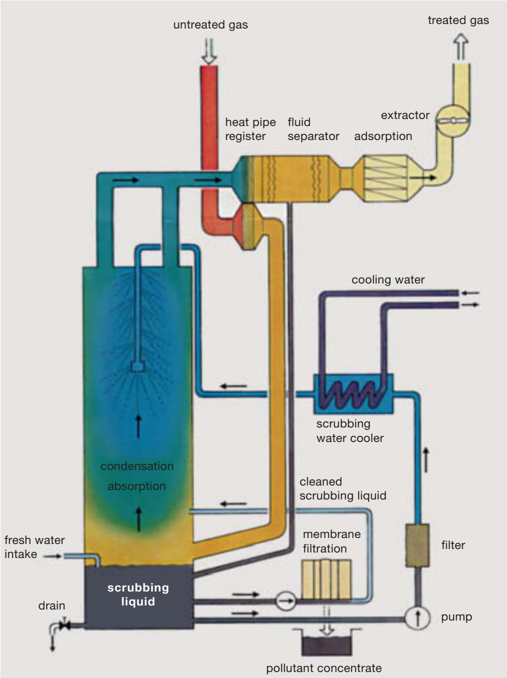


Fig. 2: Heraeus spray absorber.

c) Combination of scrubber and heat exchanger, Behr system.

In Prött's centrifugal washer (Fig. 1), the exhaust air is conveyed through the water curtain in a cross current. The exhaust air is thereby cooled to approx. 50°C, causing the pollutant vapours to condense, thus absorbing the pollutants, e.g. the odorous substances, to a certain extent. Soluble pollutants are partially dissolved in the water droplets. The air is fed to a mist eliminator after it has flowed through the water curtain. Droplets of water, condensation products and pollutants are here separated out. A water reservoir with a filter is used to separate the non-soluble pollutants back out of the water. If necessary, these must be disposed of as special category waste. The cleaned water is then fed back to the atomiser as part of the cycle. It is also possible for the atomised water to be removed from wet treatment machines and fed into the exhaust air cleaning systems.

The pollutants which are separated out are fed into the plant's waste water. This necessitates either a special treatment or transfers the problem to either the in-house or municipal waste water treatment plant.

Prött has a make-up water requirement of 700–5000 l/h with a max. air volume of 32 000 m^3/h for the two-stage system. The two centrifugal discs operate at 4700 l/h and 15 000 l/h; the pump motor capacity is 2 · 18.5 kW.

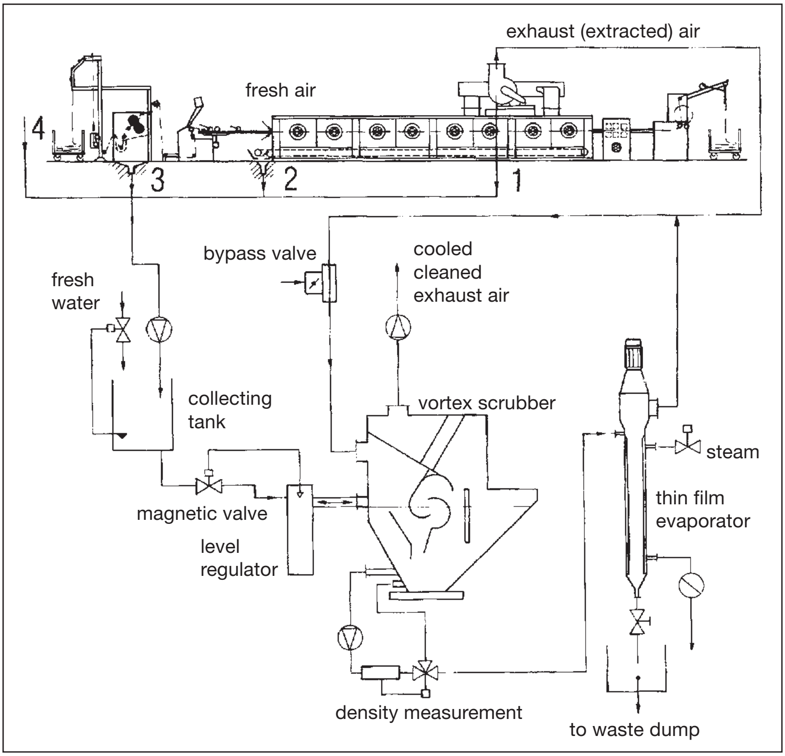


Fig. 3: Exhaust air cleaning system with the evaportion of residual liquor and waste water in a vortex scrubber (Babcock). 1 = water from the automatic cleaning system for a heat exchanger wheel or other recovery devices; 2 = water from automatic screening belt cleaning; 3 = residual liquor and pad cleaning water; 4 = other waste water arising, e.g. from washing or dyeing.

The figures for a two-stage Krantz system of the same size are 700 l/h make-up water at 13 200 l/h and 26 400 l/h water spray for both centrifugal discs. The max. airflow is 35 000 m³/h. Babcock produces a vortex scrubber which has a vortex chamber in the place of one or two centrifugal discs. The waste air is thoroughly mixed with water in this chamber, thus cleaning the air. It is configured directly on a stenter. The max. air volume is 10 000 m³/h. Its method of operation is explained in Fig. 3.

The exhaust air from the stenter is fed into a vortex scrubber where it is cleaned in a rotating air/water vortex and the ensuing water curtain (Fig. 4).

- particles, lints and aerosols are surrounded by water droplets which precipitate as they become heavier.
- water-soluble gases and vapours are absorbed into solution.
- cooling the exhaust air to wet bulb temperature, i.e. to 50–65°C causes the majority of the vapours to condense into fine droplets.

Mist eliminators are provided after the vortex chamber so that no water from the air stream is entrained into a subsequent electrostatic precipitator (Fig. 5). The energy extracted from the exhaust air by cooling can be used to evaporate the wash water. Two examples are given to explain the extent of this: the first example is for a drying process, and the second for a setting process. Example 1: the drying process (assumed figures):

Fig. 4: View of the interior of the swirl chamber of the Babcock exhaust air scrubber.

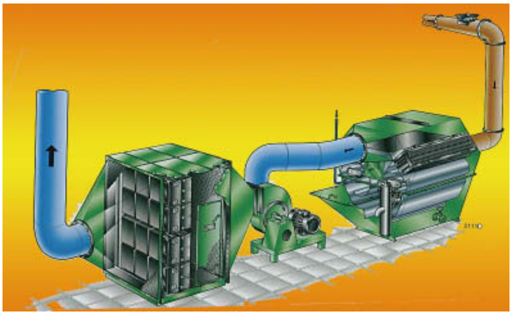


Fig. 5: Exhaust air purification system (right side: scrubber; left side: electrostatic precipitator).

- exhaust air temperature 130°C,
- exhaust air moisture 100 g/kg,
- exhaust air volume 10 000 m³/h = 8759 kg/h.

This gives a wet bulb temperature in the washer of 57°C and exhaust air moisture of 132 g/kg. According to the i-x diagram, 32 g of water/kg air and thus 280 kg water/h are therefore evaporated. Fig. 6 shows the progression in the i-x diagram.

Example 2: the setting process (assumed figures):

- exhaust air temperature 160°C,
- exhaust air moisture 30 g/kg,
- exhaust air volume 7000 m³/h = 5706 kg/h.

This gives a wet bulb temperature of 48°C and an exhaust air moisture of 75 g/kg. According to the i-x diagram, 47.5 g of water/kg air and thus 271 kg water/h are therefore evaporated.

The liquid level of the vortex scrubber is controlled by a level controller and the amount of water evaporated from the reservoir is replaced. The wash water may originate from the residual liquor in the padder or from the dyehouse, for example.

Processes with heat exchangers: in a similar way to the process using washers, cleaning of exhaust air with heat exchangers is based on the reduction of the exhaust air flow temperature, which causes condensable materials to separate out. In comparison to direct washers, the filtration efficiency for dust-like or fibrous pollutants is lower, thus generally necessitating a filter to be provided in addition to the heat exchangers required. The type of heat exchanger (recuperative or regenerative) can vary; whether air/air or air/water exchangers are used is dependent on the operating conditions. With these methods, it is important that attempts are always made to make use of the exhaust heat in order to achieve economic efficiency.

The principle of the washer is shown in Fig. 7: the exhaust air is cooled in an air/air or air/water heat exchanger. This causes fresh air to be heated on the secondary side of the heat exchanger. This air is fed to the thermal treatment machine. This enables heat to be recovered. By cooling the exhaust air in the heat exchang-

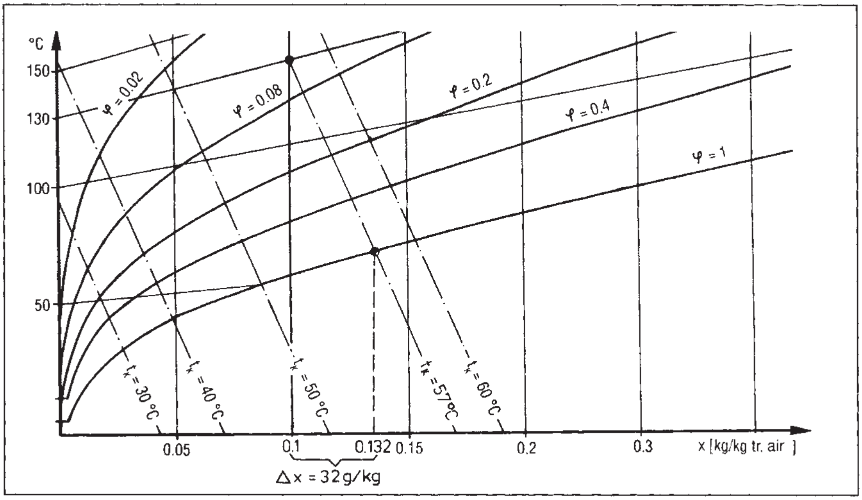


Fig. 6: i-x diagram (example illustrated: drying process).

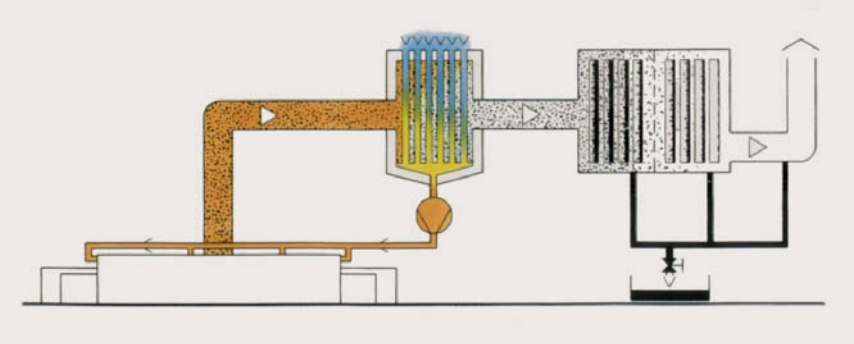


Fig. 7: Diagram of a washer with heat exchange facility (cooling principle).

er to below 60°C, the pollutant vapours are condensed. The condensed pollutants are then filtered out of the exhaust air using mechanical or electrical filters. Heat exchangers and filters must be cleaned with water. The water washes the condensed pollutants off the filter surface and the surfaces of the heat exchanger. The polluted water is collected in containers and must be disposed of in waste water treatment plants. In contrast to exhaust air scrubbers, water-soluble substances and odorous substances cannot be removed from the exhaust air using this system. It is possible, however, to combine this system with the exhaust air scrubber system.

A general problem with this process is the formation of deposits on the elements of the heat exchanger, which necessitates cleaning, and thus indirectly results in further pollution of the effluent. Three variations of the process represent the current practical situation. Behr produce aluminium air/air heat exchanger modules in plate form in addition to stainless steel air/water heat exchangers. Cleaning aluminium heat exchanger elements which have stubborn stains poses a problem. Using aggressive alkali cleaners which are probably used at too high a concentration or for too long a period, causes damage to aluminium parts. It is therefore recommended that more resistant materials are used. This increases the cost of the system. Behr produce aluminium/stainless steel elements which are identical in construction at a price ratio of $^{1}/3$ (DM 850 : 2500).

Radscan's cleaning system allows deposits to be abraded during operation. These cleaning systems have annular scrapers which are positioned around each individual tube in the heat exchanger and which can be moved vertically along the tubes. This can result in contact between the elements and the tubes, as there is naturally no real symmetry to the deposits. Damage to individual tubes also occurs gradually and it is then necessary to plug them to prevent cooling water passing into the airflow. The life-span of a heat exchanger is given at approx. 10 years due to this phenomenon.

A system which originated in the chemical industry is used by DEG-Engineering for heat exchanger elements. Fig. 8 shows these elements in a plate heat ex-

Scrubbers for exhaust air

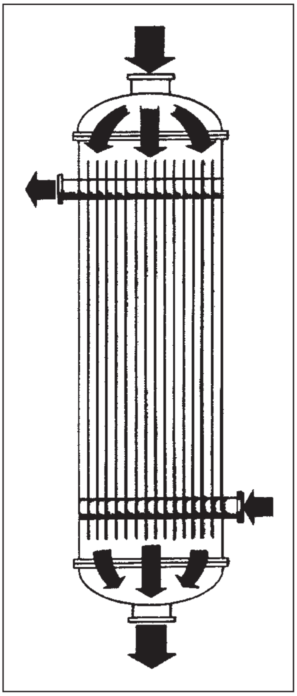


Fig. 8: Plate heat exchanger (DEG).

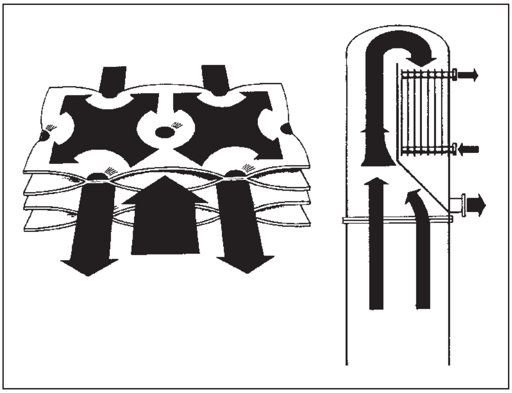


Fig. 9: Plate heat exchanger surfaces (DEG).

changer. It is important that the surfaces are relatively smooth (Fig. 9) and therefore easy to clean and that stainless steel is used. According to the manufacturers, cleaning can be carried out during operation by spraying with a cleaning fluid. As this is sprayed on by jets, there is no risk of mechanical damage. DEG provides for a transfer of energy from the exhaust air to the fresh air. An internal water cycle is set up for this; the heat exchanger on the fresh air side should be designed in a copper/aluminium alloy. The filtration efficiency of the heat exchangers will not be higher than when using a scrubber; as long as efforts are made to achieve comparable reductions in the temperature of the exhaust air (50–60°C). A better effect can be achieved using the scrubber because soluble gases or condensates can also be separated off in the water. This is not possible with a heat exchanger.

Combination scrubber/heat exchanger: the exhaust air passes through a distributor box in the Behr system. It is then routed via a spray system which is fed by circulating water, via packed heat exchangers. The exhaust air is therefore brought into extensive contact with the wash water. At the same time, the exhaust air temperature is reduced in the air/air heat exchanger and the wash water is kept at a lower temperature. After leaving the heat exchanger, the exhaust air is diverted by 90° and passes into the open air through a mist eliminator via a stainless steel filter and an exhauster. Condensate and wash water are collected in the settling basin and are then conveyed to the spray system via a pump (Figs. 10 and 11). By condensing the water vapour in the exhaust air in the scrubber or heat exchanger, approx. 150 kg of condensate/h are collected in the system collecting tank. A second pump conveys the excess scouring solution into an emulsion separating plant for further disposal. The cooling air is extracted by a dust filter. The cooling air then passes into the air/air cross flow plate heat exchanger where it is heated by the exhaust air or the wash water before being blown

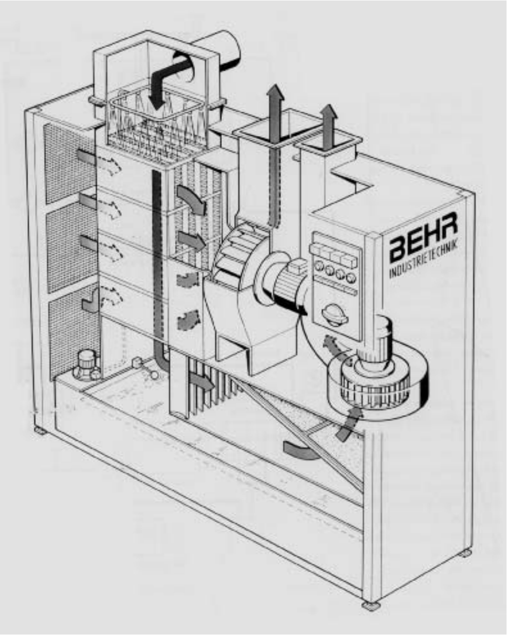


Fig. 10: Exhaust air scrubber for yarn finishing machines (Behr).

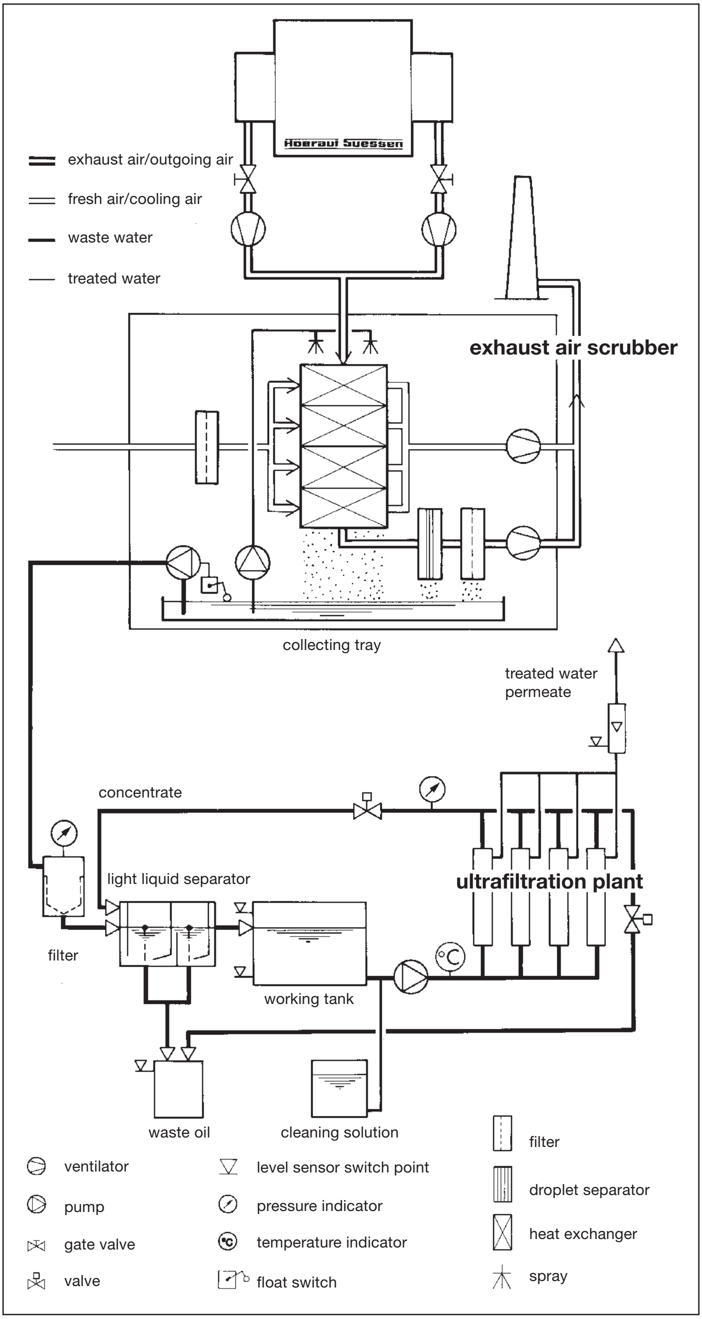


Fig. 11: A yarn finishing facility with exhaust air scrubber and an ultrafiltration plant (Behr).

into the open air by a radial fan. The heated cooling air and the exhaust air emerging from the washer can be collected in the system casing and released into the open air via a collecting main. If the energy from the heated cooling air is to be reused, this is possible by means of a separate channel.

Biowashers: if the exhaust air contains strong odours, it is recommended that it is washed with water which contains bacteria to break down the odorous substances (Fig. 12).

Scutched flax → Scutching.

Scutcher Also known as a stamping machine, used for → Engraving grooved rollers. Using a scutcher, the → Hatching is imprinted into the coat of lacquer on the master mill before the acid-resistant lacquer in which this is coated has fully hardened.

Scutcher oils → Textile lubricants.

Scutchers, breaking machines → Mechanical breaking.

Scutching Scutching is the second stage in preparing flax stems after retting, drying and breaking (flax scutching). The purpose is to separate the wood shavings as much as possible, a process which gives rise to tow in the form of short, snarled fibres. It can be carried out either manually or on a machine (scutching turbines). Scutched or swingled flax (approx. 15–25 % from flax straw, depending on source) are the coarsest long-fibre flaxes which can actually be spun. It is followed by the hackling process. → Flax processing.

Scutching (flax) (breaking). This is the first stage in → Flax processing after retting and drying, and involves breaking down the brittle woody tissue into shavings. It can be carried out either manually or mechanically using a pair of fluted rollers. It is followed by the scutching process.

SDC dyeing control system (Synchron Dyeing Control). As sensitive fabric surfaces can be damaged in rope dyeing if the mechanics (reel, liquor circulation) in the liquor exchange zone of a jet dyeing machine are too high, it is possible to optimise the number of passages through the nozzle system based on the length of

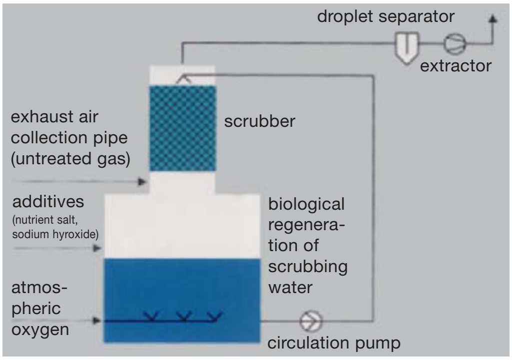


Fig. 12: The principle of a bio-scrubber. The exhaust air is sprayed with scrubbing liquid which dissolves the odorous substances; the scrubbing liquid is then regenerated biologically and returned to the process.

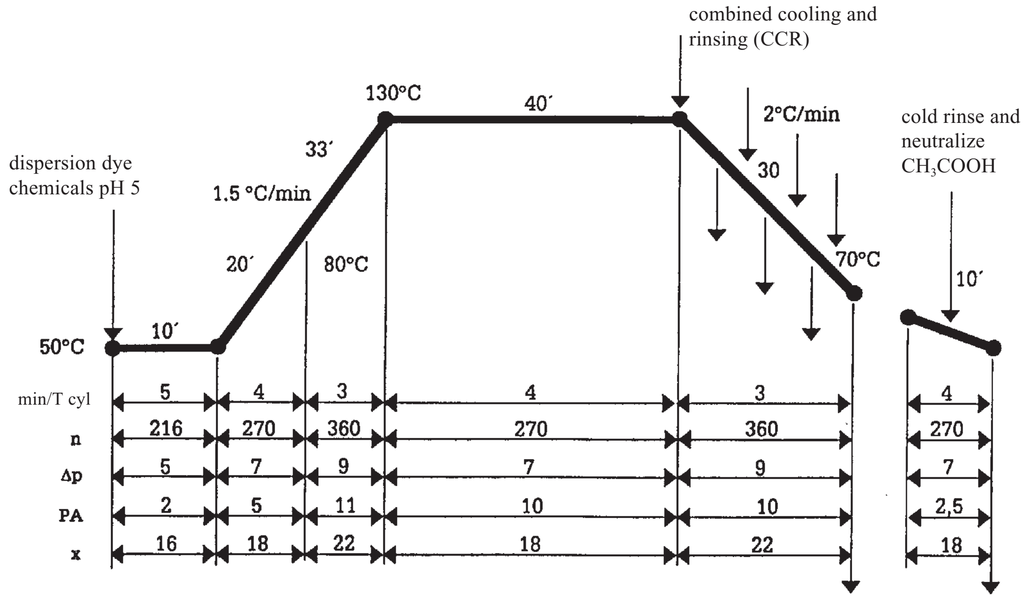
the hank per jet by using appropriate control programs (see Fig.). The reeling speed and the pump capacity should always be adjusted to the current dyeing conditions (affinity of the dyestuffs at the acute dyeing temperature) so that uniform absorption is guaranteed. On the other hand, max. reeling speed in the migration and fixation phase is not necessary. The "Synchron Dyeing Control" system therefore allows the fabric speed to be adjusted to the dyeing process by reducing the number of passes through the nozzle systems and the capacity of the circulating pump to be optimised in each case. Not only does this protect the fabric, it also reduces energy consumption by savings on electricity.

SE → Silk (mulberry silk), → Textile fibre symbols, according to DIN 60 001 T4/08.91.

Se The chemical symbol for selenium (34).

Sea jute A brown, brittle fibre composed principally of lignocellulose (→ Lignin) and similar to → Peat fibres and being obtained from dead plant material on the Southern Australian coast, where it is obtained in great quantities.

Used mainly for insulation and packing. Its utilization in textiles is of secondary importance, though it



min/T cyl	5	4	3	4	3	4
n	216	270	360	270	360	270
Δp	5	7	9	7	9	7
PA	2	5	11	10	10	2,5
x	16	18	22	18	22	18

min/T cyl = rope circulation time
n = speed of drive winch in m/min
Δp = differential pressure in water column metres
PA = nozzle passes/time
x = electricity consumption in kW/h

total process time 143 min

A. number of nozzle passes using
normal process with 2 minutes per cycle = 71.5
electricity consumption for 36 kW/h = 85.8 kW

B. number of nozzle passes
using the SDC system = 40.5
electricity consumption = 43.7 kW

Fig.: The polyester/cotton dyeing process when using the SDC process (by Thies): polyester dispersion dyeing (rope length per accumulator = 1080 m).

used to be mixed with wool in the manufacture of cheap carpets.

Seal → Heat sealing.

Sealskin (musquash). An imitation sealskin. Fur-like plush consisting of a backing fabric with pile on one side, 3-5 mm thick, extremely lustrous, made from Tussah or Schappe silk.

Seam detector This is a mechanically or electrically controlled automatic device to monitor and control the passage of cloth at seam points at machine bottlenecks, e.g. in calenders, rotary cloth presses and shearing machines. As the hank of cloth passes through the annular sensor (inside the dyeing machine), a small, Teflon-cased magnet (which has previously been sewn onto the seam point) in a pouch causes an induced voltage in the toroidal coil as it passes over the seam point. This is processed into an output signal using amplifiers and interference blanking and enables the circulating hank of cloth to be stopped exactly at the seam points for sampling or for seam unpicking when emptying the machine. Also used to display the rotational frequency and cycle time to monitor the dyeing cycle.

Seam detector for jet dyeing machines This is used for fabric control (monitoring the dyeing process), to stop the passage of the cloth (for sampling), to count the piece cycle and to determine the cycle time. The seam detector consists of a sampling probe, electronic kit and a display unit. As the sampling probe passes the jet pipe (secondary cradle mounting also possible), through which the goods are being transported in rope form in the liquor, the premarked seam (marked using a ferromagnetic body Ø 50 mm, 0.1 mm thick) causes the impulse which controls the passage of the goods and stops the piece circulation.

Seam protection If a fabric with a seam is passed through the cutting device of a shearing machine, the shearing blade will destroy the fabric along the seam. The cutting device therefore raises up from the shearing table (or preferably vice-versa). As the seam passes through, a seam protection plate automatically slides between the fabric and the cutting device and covers the shearing point until the seam has passed. Only a minimal length remains unsheared on either side of the seam. The function of the seam protection device is adjusted to the rate of the passage of the goods (see Fig.).

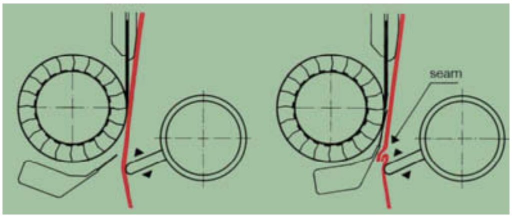


Fig.: Seam protection (Monforts).

Seam welding → Fusible seaming.

Sea silk → Mussel silk.

Sea water salt content Important information for the critical assessment of → Fastness to sea water for (export) swimwear, particularly in view of the increasing trend towards long distance travel to destinations with low and high sea water salt content. The sea water salt content is defined as the total amount of salts/kg sea water. Reference values given in g/l:

The Baltic Sea	8–10
The Caspian Sea	13
The Black Sea	22
The North Sea	28–35
The Adriatic	30–38
The Atlantic	35–37
The Mediterranean Sea	41
The Red Sea	41
The Persian Gulf	39–42
The Dead Sea	250–275

1 kg of ocean water contains on average (in wt.%):

$NaCl$	77.93
$MgCl_2$	5.59
$MgSO_4$	6.12
$CaSO_4$	4.03
KCl	2.11
$MgBr_2$	0.22

Sebacic acid, $HOOC(CH_2)_8COOH$. Starting material for plastics, synthetic fibres (e.g. polyamide 6.10). Used in England and the USA to produce castor oil.

Secondary acetate fibre → Acetate fibres (2 $^1/_2$ acetate).

Secondary backing (carpets) These are used in particular to improve the dimensional stability of tufted carpets (body and border carpets). Polyester spunbonded fibres, e.g., are used for initial base material and secondary backing (see Fig.); the secondary backing is bound to the undercoat which is bonded to the tufts by a polyester spun bonded fabric. Method: pad the laminating compound on the carpet backs from the undercoat chassis and in the same step, feed the laminate material, press together between calender rollers, drying process in the coating machine.

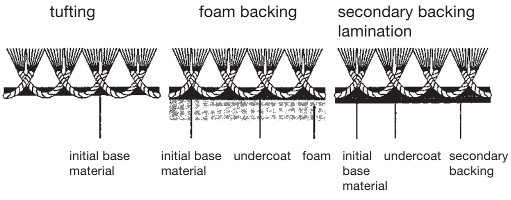


Fig.: Constructional elements in tufted pile carpets.

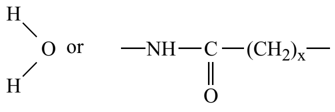
Secondary raw material This is a term applied to waste from spinning, weaving, garment manufacturing, the manufacturing of nonwovens, used textiles, etc. which is reused for fibre extraction, e.g. → Reclaimed wool.

Secondary salts Acid salts of polybasic acids where two hydrogen atoms are replaced by metal; e.g. secondary acid sodium phosphate Na_2HPO_4, derived from phosphoric acid H_3PO_4. →: Primary salts; Tertiary salts.

Secondary valency forces (intermolecular forces, intermolecular attraction forces, cohesive forces). Adhesive forces between molecules acting as → Co-ordinate atomic bond, which is generally liable to dissociation, which is not the case with → Principal valency. According to current opinion, secondary valency forces form a complex group of forces with interactions (micellar forces) for the lateral cohesion of principal valency chains (strength and elasticity properties), in the broadest sense as a group of additional linkage forces, for example in finishing processes. This relates to → Van der Waals forces and → Hydrogen bonds for example. The range of secondary valency forces is approx. 0.5 nm (the range of principal valency forces is approx. 10nm). They are defined and divided into: ε = potential energy; α = polarizability; I = ionizability; r = distance between the molecules; μ = permanent dipole moment.

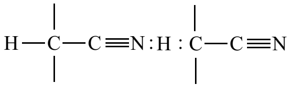
a) Dipole forces: orientation forces between two dipole molecules with permanent dipole moment. These are proportional to the fourth power of the dipole moment and inversely proportional to the absolute temperature.

$$\varepsilon = -\frac{2\,\mu 4}{3\,r^6\,kT} \quad \text{e.g.}$$



$$-NH-\underset{\underset{O}{\|}}{C}-(CH_2)_x-$$

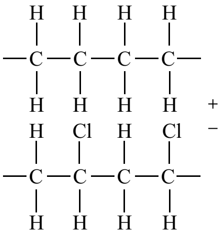
b) Hydrogen bonds: Special case of a) if dipoles come particularly close together so that the H-atoms oscillate to and fro, for example in the polyacrylonitrile molecule:



$$H-\underset{|}{\overset{|}{C}}-C\equiv N:H:\underset{|}{\overset{|}{C}}-C\equiv N$$

c) Induction forces occur as small additional forces if one of the molecules has a permanent dipole and the other is covalent. They increase in proportion to the second power of the dipole moment and are not dependent on temperature.

$$\varepsilon = -\frac{2\alpha\mu^2}{r^6} \quad \text{e.g.}$$

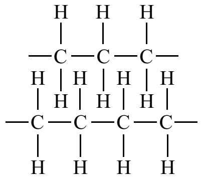


$$-\underset{H}{\overset{H}{C}}-\underset{H}{\overset{H}{C}}-\underset{H}{\overset{H}{C}}-\underset{H}{\overset{H}{C}}- \quad +$$
$$-\underset{H}{\overset{H}{C}}-\underset{H}{\overset{Cl}{C}}-\underset{H}{\overset{H}{C}}-\underset{H}{\overset{Cl}{C}}- \quad -$$

(polyethylene/polyvinyl chloride)

d) Dispersion forces (London forces) create the cohesion between covalent, identical or similar molecules. They are, independent of temperature, linked with the number of electrons and electron dissociation via the ionization constant:

$$\varepsilon = -\frac{3\alpha^2 I}{3r^6} \quad \text{e. g.}$$



(polyethylene)

It can be seen from this that the potential energy of two molecules located at a distance decreases much more quickly related to the distance than to the coulomb force:

$$K = -\frac{e_1 \cdot e_2}{r^2}$$

The secondary valency forces above, which have been intentionally schematized are in practice difficult to distinguish from one another. Therefore dispersion and induction forces arise between polyamide chains in addition to pure dipole forces. The relative proportion of these three forces will therefore vary from case to case. The relative size and importance of these types of orientation and dispersion forces varies; in contrast, induction forces may be disregarded.

Second order transition temperature This is the term used to denote the temperature under defined pressure conditions at which a material changes totally from one phase or state into another.

Sectional warp beams Ready warped beams supplied by the chemical fibre manufacturer, for chain effect and raschel machines as well as for strip looms.

Sectional warping The parallel winding of several warp threads to produce the warp beam. The yarn is stretched on large frames and guided through grid-like devices in such a way that the threads are wound parallel to one another on the warp beam. For particularly high warp settings and fine material, cone sectional warping machines are used. In sectional warping, it is important to achieve an absolutely uniform tension when winding the individual warp threads. → Warping.

Sediment Deposit, precipitate. The sedimentation of solid, suspended particles follows the law of gravity, with the coarsest particles being deposited first, extremely quickly, and the finest particles being deposited the most slowly at the end. The particle size of sediments can be determined in the sedimentometer (turbidity meter) from the turbidity and rate of settling.

Sedimentation This refers to the concentration of dispersed particles (sediment) in a liquid medium due to the effect of gravity or centrifugal force.

Seed fibres → Fruit wall hairs.

Seed hair fibres → Vegetable hair fibres, which can be found on the seed husks of various plants. These include → Cotton and → Akund.

Seepage propagation This is the difference between the level reached and the original position given in cm in → Chromatography.

$$R_f = \frac{\text{dyestuff seepage propagation}}{\text{mobile solvent seepage propagation}} \qquad (0 \le R_f \le 1)$$

Integer values only, especially in → Thin layer chromatography.

$$hR_f = 100 \cdot R_f$$

Seepage wash Cold pad batch bleaching process where the bleach liquor is transferred by pumping (see Fig.). The subsequent rinsing process pumps fresh rinsing water through the perforated beam. The rinsing liquor from the rotating package is drained away in contrast to conventional bleaching, where the liquor is pumped back into the cycle.

Seersucker,

I. Cotton crimp crêpe with vertical stripes, also → Craquelé. Fabric with linear or continuous bark – like effects. Genuine seersucker gets its puckered appearance from warp threads which are stretched tightly or loosely; the loosely stretched threads provide the effect. To achieve a varied tension, two warp threads are necessary. The crease effect is permanent.

II. From synthetic fibres, e.g. patterned interwoven, shrinkable synthetic spun yarns with different shrinkage properties. At increased temperatures, the high-shrinkage material shrinks and creates the embossed design together with the more shrink-resistant adjacent material.

III. Similar nonfast effects can also be obtained by

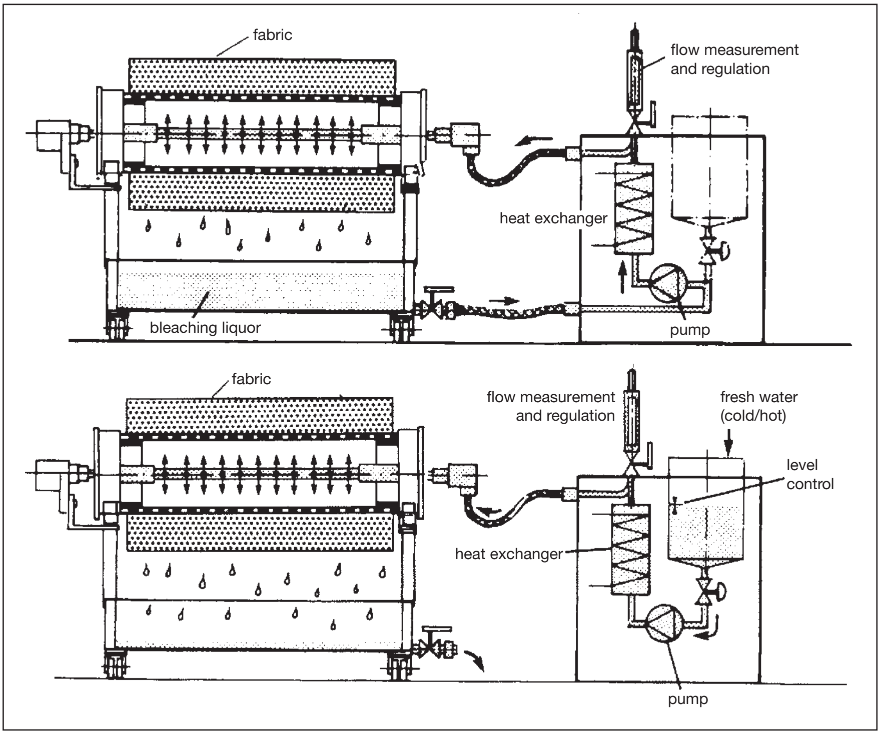


Fig.: Perfo-Roll liquor control (according to Schuierer) in the dwell process (top) and liquor control in rinsing (bottom).

local application of substances which cause the fibres to swell. When producing a garment made from → Crêpe prepared by steeping in caustic soda, a resist print paste which contains a water repellent agent is overprinted in the direction of the warp (as the crêpe effect is only possible in the direction of the warp). The garment is then padded using caustic soda liquor. During this process, a distance of 1–1.5 m should be maintained between the trough and the padding roller so that the caustic soda solution can create a water repellent effect on the areas for resist printing.

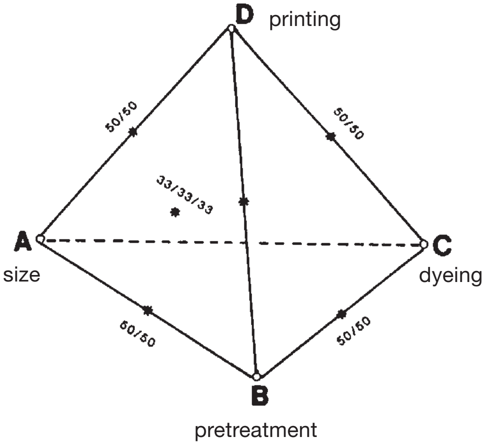
Segregated stream The definition of a segregated stream is controversial. The textile refinement industry has proposed a definition which defines segregated streams as waste from integrated production areas, e.g. from dye-works apparatus or finishing process facilities. The production area should be determined in individual cases and the parameters specific to the particular operation, such as use of systems, production sequence, changes in use of substances, etc., need to be taken into account. However, removal of harmful substances from waste is only economically justifiable from polluted segregated streams.

If the pollution carried by individual segregated streams resulting from textile production is analysed, it will be found that plain pre-treatment waste, for example, carries a high polysaccharide load which constitutes the pre-condition for anaerobic processes. Exactly the same goes for many printing plants. In the reactive printing process, alginates are used almost exclusively as thickening agents, which can be disposed of biologically. The task is therefore to modify the processing techniques within the framework of process-integrated environmental technology with a view to minimizing unnecessary, non-decomposable COD loads and to replacing inhibiting or toxic substances by bio-compatible ones.

The complexity of bio-technical problems demands solution strategies which can represent multi-dimensional variables in such a way that the problem remains adequately transparent. Experience shows that statistical models are very well suited to acquiring the basic knowledge for improved and possibly physical models. For this reason a four-dimensional vertex space was set up which is defined by the four segregated streams (option ranges):

X_1 = plain waste flow,
X_2 = pretreatment waste flow,
X_3 = dye-works waste flow,
X_4 = printing plant waste flow.

The trial vertex represents a tetrahedron (Fig. 1) whose corners correspond to 100% of a segregated stream in each case. The trials at the edges of the tetrahedron are mixtures of segregated streams which flow together at the edges. The boundary surfaces of the tetrahedron contain mixtures of three components of the appropriate waste streams while the interior of the tetrahedron contains a mixture of the four component segregated streams.



e.g.				
point	x_1	x_2	x_3	x_4
A	100	–	–	–
B	–	100	–	–
C	–	–	100	–
D	–	–	–	100

it is true that: $\sum_{i=1}^{i=4} x_i = 100$

Fig. 1: Diagram of the test space (according to Marte and Keller).

One of the significant results of the calculation model is the “screening” parameter which represents a relative measure of the influence of the individual segregated streams on the overall anaerobic decomposition process. The relative impact of the printing plant and the dye-works of 10% and 12% respectively points to considerable non-decomposable and inhibiting pollutants. The pretreatment flow of 27% and the plain flow of 51% have an even greater impact on the overall decomposition process.

Fig. 2 shows the high bio-compatibility of the sizing waste flow (left-hand corner of the phase diagram). The degree of decomposition, measured by the COD-relief of the pure sizing waste, is 75%. The pretreatment flow shows a maximum decomposition rate of approx. 40% (right-hand corner of the phase diagram). This is due on the one hand to a considerable surplus load of surfactants and on the other hand to the surplus peroxide remaining from the bleaching stage. As far as the overall achievable decomposition quota of approx. 17% is concerned, the dye-works flow is problematical. As it will scarcely be possible to increase the bio-compati-

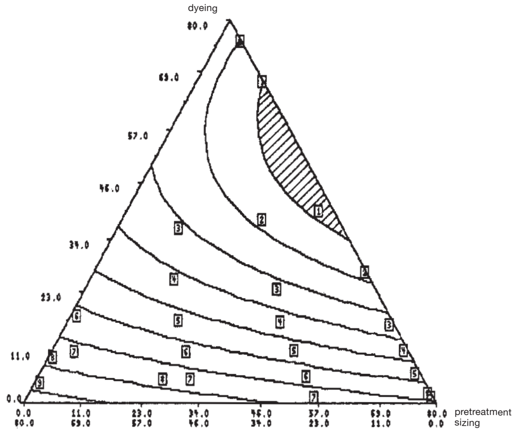


Fig. 2: The anaerobic breakdown of the segregated streams from pretreatment, sizing and dyeing (the COD demand contributed by the stream from printing is 20%) (according to Marte and Keller).
Isoline diagram for the quantity COD-AB. Isolines: 1 = 0.0; 2 = 5.0; 3 = 10.0; 4 = 15.0; 5 = 20.0; 6 = 25.0; 7 = 30.0; 8 = 35.0; 9 = 40.0. Minimum = –3.6278 at 0.0/50.4663; maximum = 42.4915 at 80.0/0.0.

bility of the dye-works flow significantly in the near future, precipitate and flotation techniques should be given preference. If it is assumed, for example, that the sizing and pre-treatment waste flow contains approx. 65% of the COD load of a textile refinement plant and that this load can be pre-purified at a decomposition rate of 80% in an anaerobic stage, this already represents a COD-reduction of approx. 52% of the overall flow of waste to the waste purification plant. It is necessary to revise the pretreatment techniques in order to achieve this goal. The printing-works flow could also be improved significantly if emulsion thickeners were replaced by alginate thickeners and the recipes were reviewed with regard to improved bio-compatibility (according to Marte and Keller).

Segregated stream treatment The continuing increase in the stringency of environmental legislation is having its impact on the textile refinement industry. Appendix 38 of the German Water Management Legislation demands a significant reduction of polluting waste substances. It prescribes limits for COD and BOD values, concentrations of heavy metals and halogenized hydro-carbons. When certain limit values are exceeded, segregated stream disposal is specified. However, the concept of the segregated stream has not as yet been adequately defined. It leaves open the question of whether a segregated stream is the total waste from a facility (e.g. dyeworks apparatus) or whether it means the waste from all existing similar production systems in a plant. All known techniques of waste cleansing can be used for treating the segregated streams if they lead to a reduction of the concentration of the harmful substance which exceeds the permitted limits.

Microbe decomposition of harmful substances can also be executed in segregated streams. Another possibility is to reduce the quantities of textile aids used or to use more easily biologically decomposable substances with low COD values. This was investigated thoroughly using the example of sizing. Cyclodextrines are being considered as a possible substitute for surfactants in washing and dyeing processes. They are easily biodegradable as sugar molecules. As they are similar in effect to micelles, composed of 80–100 surfactant molecules, they can be used in lower concentrations as a surfactant which has a favourable effect on the COD value of the waste.

Due to the high extinction coefficients of many dyestuffs, their presence in the waste can be established by visual means, even if their concentrations are low. Also the degradability of some dyestuffs is low and they are therefore, at worst, absorbed in sludge from the waste when treated in sewage plants.

Physical and chemical techniques are proposed for removing dyestuffs from waste. In some cases it is possible to separate the dyestuffs by means of ultra-filtration. They can also be absorbed by active carbon. If the absorbed dyestuffs are bio-degradable, appropriate biochemical treatment can be carried out. The harmful substance can be destroyed reductively by means of chemical reaction. However, this process is not successful with every dyestuff. This also results in sulphate pollution of the waste with constant COD values. Destruction of dyestuffs by oxidation results in reduction of the COD values as well as in reduction of dye. A disadvantage of this technique is that the oxidation strength of hydrogen peroxide is not adequate to destroy dyestuffs. Destruction of dyestuffs by oxidation is

segregated stream		
residual liquor + 1st rinsing bath + 1st hot bath 3 baths with > 80 % of total hydrolysate		
colour stripping	auxiliary agent/kg of dyestuff used	problem
oxidative	1 kg of active chlorine	AOX, toxicity
	ozone, H_2O_2, Fenton's reagent	cost
reductive	1 to 2 kg of sodium dithionite	COD, sulphate
precipitation	0.3 to 0.6 kg of cationic special flocculation	sludge

Tab. 1: Segregated stream treatment for reducing the colour in reactive dye effluent.

only possible using Fenton's reagents (iron(II) salts) (Tab. 1). By attaining an optimum pH value using calcium carbonate, a precipitate of iron hydroxide and calcium carbonate is created in the form of sludge. This absorbs organic compounds and dyestuff molecules and therefore has to be disposed of separately, possibly as hazardous waste. Another possibility of destroying dyestuffs consists of using oxygen for oxidation. This reaction can be catalysed by the presence of poly oxadiazol; otherwise catalysis takes place through ultra-violet light. This process also destroys other organic compounds in the waste so that a significant reduction of the COD values can be expected. Ozone can be used as a suitable oxidation agent.

Waste can also be cleansed by using organic precipitate and flocculation agents. Dyestuffs can be removed from the waste in this manner. However, it must be seen as a disadvantage that this results in voluminous foam which contains up to 70% water and has to be disposed of as hazardous waste. Under these circumstances the percentage of dyestuff in the precipitate is low. Also some of the precipitate and flocculation agents are toxic to fish. As a certain quantity of precipitate and flocculation agents remain in the waste, the COD values of the waste are also increased. An overdose of the organic precipitate and flocculation agents in some cases results in the dyestuff dissolving again which means it cannot be removed.

The heavy metals which occur in the waste of the textile refinement industry are restricted to cobalt, nickel, copper, chrome and zinc. These heavy metals are contained in metal complex dyestuffs and reduction agents or they get into the waste during the after chroming of wool. The removal of heavy metals from waste is mainly carried out by precipitating as hydroxides. The remaining residue concentration in the waste depends on the pH value of the solution. The solubility of the hydroxides increases again in strong alkaline solution due to the formation of hydroxo complexes. At low heavy metal concentrations flocculation materials have to be added to the waste in order to separate the hydroxide precipitate. When complex organic forms are present a hydroxide precipitate is not possible. As most metals form sulphides which are difficult to dissolve, they can always be separated in this manner. Hydrogen sulphide and sodium sulphide are highly toxic, however, and surpluses have to be removed from the water after precipitation. Trimercaptotriazine also forms compounds which are difficult to dissolve. Among other things it is used in the metal processing industry. To improve sedimentation flocculation materials frequently have to be used. The resulting sludge is classified as hazardous waste, as its reuse is prohibited due to its heavy metal content. Only in the case of silver precipitates is reprocessing carried out to reclaim the pure metals.

Electrochemical methods of separating heavy metals with ion exchangers are possible. If the ion exchanger has chelate forming groups, it binds multi-value ions with high affinity and is particularly suited to binding heavy metals. For example, it is possible to separate copper from waste during copper fibre production by using ion exchangers in the presence of sodium and ammonium ions. It is possible to extract organic metals into an organic phase by means of polymer-bound and water-soluble complexes. Re-extraction results in an enriched solution of heavy metals. This technique is also suitable for waste cleansing. The selectivity of complexes is intensified considerably in comparison with the chelate forms by the use of macrocyclic (crown ether) and macrobicyclic ligands (cryptands). This is particularly significant with regard to recycling of the separated heavy metals. If the ligand used is not water-soluble, it can be used as an extraction agent. Polymer fixing of these ligands is, however, also possible. Due to the high complex image constants, it is possible to remove even the slightest trace of heavy metals. Heavy metals from dye-works waste can also be removed selectively by means of polymer-fixed crown ethers.

The occurrence of organic compounds containing halogen in waste produced by the textile refinement industry can mainly be attributed to the following causes:

- use of carriers containing chlorine during dyeing,
- use of dyestuffs containing chlorine,
- chlorinated pretreatment of wool
- chlorine bleaches.

Carriers containing chlorine are, however, only used in rare cases. Some dyestuff molecules contain halogen atoms. As the dyestuffs only enter the waste in relatively low concentrations, they scarcely increase the concentration of compounds containing halogen in the waste. If the dyestuff molecules are destroyed by chemical reaction, fragments of chlorine remain in the waste. Chlorinated pre-treatment of wool is important for felt free equipment and for printing pre-treatment. Bleaching processes based on hypochlorite result in more hydro-carbons containing halogen than with chloride bleach. In addition, the degree of pre-treatment when bleaching cotton has an important impact on the quantity of hydro-carbons containing halogen which are formed. In addition to other organic compounds containing halogen, hypochlorite bleaching produces mainly chloroform. As the current state-of-the-art does not allow all textile refinement processes to be carried out in such a way that no volatile hydro-carbons containing halogen result, their removal from the waste adopts a particular significance. A possible means of separation is to absorb them using active carbon. However, all other non polar compounds in the waste are absorbed simultaneously by the active carbon. This technique is very unspecific.

hydrolysate quantities as a % of total hydrolysate				
	on the fabric	In the bath	In the effluent	In the carry-over
residual liquor	50	50	37.5*	12.5
1st cold bath	31	32	24*	8
2nd cold bath	30	10	7.5	2.5
1st hot bath	3.5	29	22*	7
remaining baths			8–9	

hydrolysate quantity in the baths with * (for colour stripping) 83.5 % of the total hydrolysate quantity, calculated for Levafix-E dyes (Bayer), liquor 10 : 1, carry-over 250 %, * estimated figures.

Tab. 2: Breakdown of unfixated dye (hydrolysate) in washing.

Several chemical and physical techniques are available for dye removal from waste segregated streams from a dye-works. It is possible to separate wastes from reactive dye works in such a way that approx. 80% of the non-fixed dyestuff (hydrolyse) are contained in only three treatment baths, i.e. in less than a third of the dye-works waste (Tab. 2). The residual liquor, the 1st rinsing bath and the first bath have to be collected and the dye removed at almost boiling point. Concentrations of 100–200 mg/l are to be expected in the separated segregated stream. Depending on the liquor to goods ratio, in which the dyeing and rinsing processes are carried out, the water quantity is 20–40 l/kg of fabric.

The rejected, strongly-dyed waste is transferred to a suitable system of mixing and treatment tanks where the dye is removed and then returned to the remaining waste (see Fig.). The dimensions of the tanks depend in the first instance on the volumes of segregated streams expected. There are various possibilities for the design depending on the structure of the plant and the dye removal agents used. For small dye-works in which strongly varying segregated stream volumes are expected, it is advisable to use a large mixing tank for at least four hours at maximum input and a treatment tank, the minimum volume of which corresponds to the maximum segregated stream during the necessary treatment time in addition to the filling and emptying times. Large tanks with mixing facilities (circulation pumps but no ventilation) are useful as far as dosage and impact of dye removal agents are concerned as well as short filling and emptying times. For largely automated plants in which a large number of baths take place regularly during the main operational period (e.g. 5 or more baths per hour), dosage is particularly simple if the baths are collected and mixed in the treatment tank. Treatment begins when the tank is full. There is no intake to the tank for the duration of the treatment. The baths occurring during this period are transferred into an appropriately proportioned storage tank. After completion of the treatment the treated waste flows out and the treatment tank is again filled with new baths from the preliminary tank. A large mixing tank then becomes unnecessary (according to Beckmann, Sewekow, Schollmeyer).

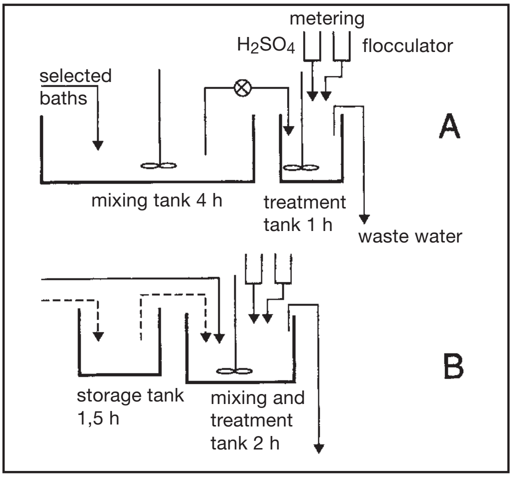


Fig.: Possibilities of the automatic segregated stream colour stripping of effluent from a reactive dyehouse, tank size after effluent accumulation during the times indicated.
A = for small dyehouses with widely changing segregated streams, B = for uniformly accumulating types of segregated streams.

SEK, SchEK Swiss commission for fastness; → Technical and professional organizations.

Selection criteria for dyes and dyeing method These criteria provide guidance based on the requirement profile which defines the dyestuff and the fastness requirements needed to select (see Fig.) the possible dyestuff group or groups. It is then possible, paying particular attention to economic factors, to define the application method to be used (in particular also from an ecological viewpoint).

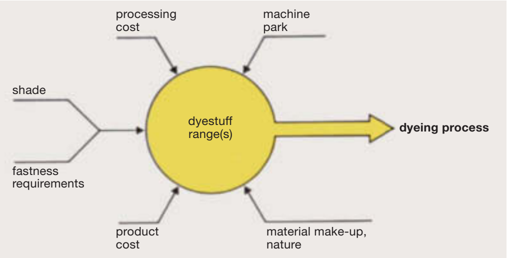
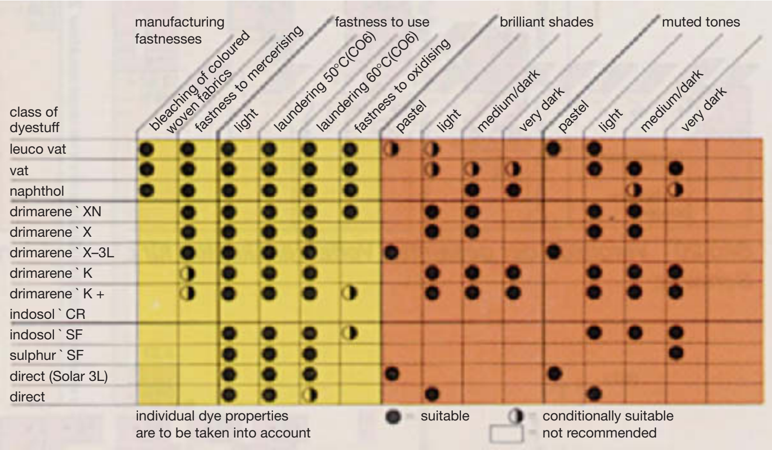


Fig.: Selection criteria for dyes and dyeing.

Selection criteria for dyes and dyeing method

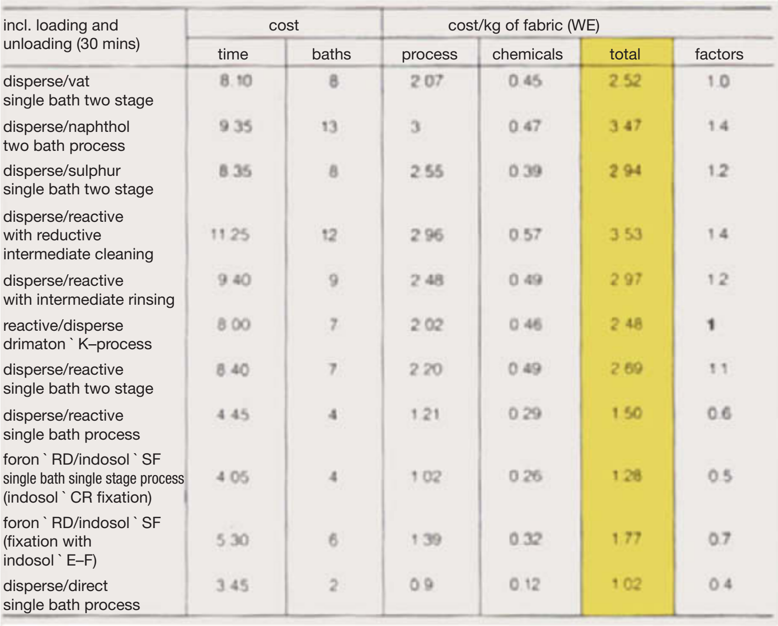


class of dyestuff	manufacturing fastnesses		fastness to use				brilliant shades				muted tones			
	bleaching of coloured woven fabrics	fastness to mercerising	light	laundering 50°C(CO6)	laundering 60°C(CO6)	fastness to oxidising	pastel	light	medium/dark	very dark	pastel	light	medium/dark	very dark
leuco vat	●	●	●	●	●	●	◑	◑			●	●		
vat	●	●	●	●	●	●		◑	◑	◑		●	●	●
naphthol	●	●	●	●	●	●			●	●			◑	◑
drimarene ` XN		●	●	●	●	●		●	●			●	●	
drimarene ` X		●	●	●	●			●	●			●	●	
drimarene ` X–3L		●	●	●	●		●				●			
drimarene ` K		◑	●	●	●			●	●	●		●	●	●
drimarene ` K +		◑	●	●	●	◑		●	●	●		●	●	●
indosol ` CR														
indosol ` SF			●	●	●	◑						●	●	●
sulphur ` SF			●	●	●									●
direct (Solar 3L)			●	●	●		●				●			
direct			●	●	◑			●				●		

individual dye properties are to be taken into account

● suitable ◑ conditionally suitable ☐ not recommended

Tab. 1: Dyestuff classes, taking account of shades and fastness requirements (Sandoz).



incl. loading and unloading (30 mins)	cost		cost/kg of fabric (WE)			
	time	baths	process	chemicals	total	factors
disperse/vat single bath two stage	8.10	8	2.07	0.45	2.52	1.0
disperse/naphthol two bath process	9.35	13	3	0.47	3.47	1.4
disperse/sulphur single bath two stage	8.35	8	2.55	0.39	2.94	1.2
disperse/reactive with reductive intermediate cleaning	11.25	12	2.96	0.57	3.53	1.4
disperse/reactive with intermediate rinsing	9.40	9	2.48	0.49	2.97	1.2
reactive/disperse drimaton ` K–process	8.00	7	2.02	0.46	2.48	1
disperse/reactive single bath two stage	8.40	7	2.20	0.49	2.69	1.1
disperse/reactive single bath process	4.45	4	1.21	0.29	1.50	0.6
foron ` RD/indosol ` SF single bath single stage process (indosol ` CR fixation)	4.05	4	1.02	0.26	1.28	0.5
foron ` RD/indosol ` SF (fixation with indosol ` E–F)	5.30	6	1.39	0.32	1.77	0.7
disperse/direct single bath process	3.45	2	0.9	0.12	1.02	0.4

Tab. 2: Processing costs (machine occupation, water, energy, chemicals) without dye costs (Sandoz).

Tab. 1 is used as the basis for a decision in the initial stage of selection. Based on the specific requirements of the article in question, i.e. the shade, depth of shade, wear fastness properties and fastness requirements in manufacturing, it is possible to determine which dyestuff category should be used to fulfil the given requirements. In practice, this Tab. will differ especially with respect to the definition of the colour spaces and the relationship of fastness to concentration, but in future also in terms of environmental compatibility. If several possibilities are given, the costs of the procedures and the reliability of the method will be used as the decisive selection criteria. The costs of the dyeing processes are shown in Tab. 2. The machine utilisation times, bath contents and chemical costs listed are based on typical operating conditions and can be compared with each other (this includes the time required for loading and unloading and filling and emptying the baths). If these conditions are altered, the absolute figures may vary, although the ratios remain unchanged. The cost factors listed in the last column of Tab. 2 indicate the extent of the cost differences between the individual processes and the importance of selecting the optimal application process in each instance.

– machine occupation time:	dyeing process 7.30 hours loading and unloading 0.30 hours 8 h x 96.00	768.00
– water cost:	7 bath fillings 7 x 5 m^3 = 35 m^3 à 2.50	87.50
– steam cost:	$\frac{5000 \times 4.19 \times 270}{2400 \times 1000} \times 51$	120.20
– cooling water:	$\frac{5000 \times 110}{30\,000} \times 0.5$	9.20
– electricity:	0.12 x 30 x 7.5	27.00
		1011.90
– cost for 1 kg of fabric		2.02
– chemical cost: sodium sulphate calc. (60 g/l)		92.00
– sodium carbonate (2.5 g/l)		5.00
– others (3 %)		75.00
– (dispersing agents, lubricants, pH setting)		60.00
		232.00
– cost for 1 kg of fabric		0.46

Tab. 3: Procedural costs (1 batch of 500 g fabric).

When stipulating the various stages, the modular principle should be followed as far as possible, so that the same modular elements are always used for procedural sections which occur equally in several stages. This should ensure comparability. The overall procedural costs are composed of the machine costs together with the variable, process-specific expenditure on water, steam and electrical energy (Tab. 3). The assumed machine costs per hour are 96.00 monetary units.

Using this selection mechanism factor 0.4 would be chosen, for example, as the most cost effective dyeing method (according to Jakob and Tiefenbacher).

Selectivity Limited to preferred selection. Selective membranes are, for example, permeable for specific substances, and impermeable for others (→ Semipermeable). When dyeing polyamide fibres, selective absorption occurs if monosulphonic acids are absorbed by preference due to the displacement of disulphonic acids (→ Blocking effect in the dyeing of polyamide).

Selective separation of fibres from fibre blends by working methods which use solvents or release agents for individual components. Selective bleaching of black hairs in wool: premordanting with ferrous salts which are chemically bound to melamine pigment, rinsing; peroxide bleach catalyses in the black hairs without any effect worth mentioning on the colourless wool.

Selenium (Se). Atomic weight 79.2. Present in sulphur ores. Grey metallic selenium is a poor conductor of electricity, but its conductibility is increased when illuminated by approx. one thousand times, decreasing to its original value again in the dark. Used as selenium cells, bridges, barriers, photoelectric cells, etc.

Self-bonding fibres → Bicomponent fibres consisting of polymers with different melting points. If they are heated to the temperature corresponding to the fibre with the lowest melting point, this acts as an adhesive for the other components.

Self-cleaning Rotating filter basket with a rinsing self-cleaning effect to discharge any lint present.

Self-cross-linker In contrast to reactive resins, which tend to react more with cellulose and crosslink these, self-cross-linkers tend to react more with themselves and form resin deposits in the pores of the fibre which promote crease resistance. → Self crosslinking resins.

Self crosslinking →: Crosslinking; Self crosslinking resins.

Self crosslinking resins Resin finishing agents which predominantly react with themselves under specific crosslinking conditions (self crosslinkers, self

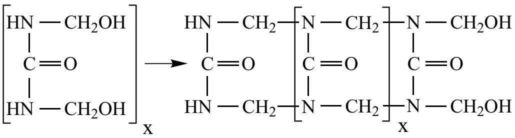


Fig.: Resin former self crosslinking mechanism in resin finishing.

crosslinking agents; see Fig.), which therefore also only enter into low crosslinking reactions with cellulose (in contrast to → Reactive resin) such as → Urea and → Melamine-formaldehyde compound. → Cross-linkers.

Self-extinguishing Term used in the → Flammability test: after the ignition flame has been removed, the test fabric continues to burn for a short time, although the charred area does not increase significantly. The flame extinguishes itself, although there is still non-burned test fabric which could fuel the flame.

Selfil yarn This is a single yarn consisting of fibre slubbing (e.g. wool) and two fine synthetic filament threads which loop in alternating directions offset phase around the yarn compound which has been subsequently formed, and thus has the effect of strengthening the yarn.

Properties: overall, fewer areas of yarn defects than with conventional spun yarns, tighter, more elastic, finer yarn, has relatively higher strength than coarser yarn, higher shrinking properties (generally 5–8%). Use: predominantly for fine knitwear. Selfil yarn no longer needs to be after twisted, steamed or respooled before dyeing. For light and mid-shades spin top-dyed wool with unbleached polyamide fibres. Yarn-dyed selfil yarn has a low tendency to relaxation due to the dyeing process. Garments made from selfil yarn can be dyed perfectly on the beam.

Self-polymerization → Self crosslinking resins.

Self shade (solid dyeing, plain dyeing). Monochromatism; occurs in fibre blends as → Tone-in-tone dyeing.

Self-smoothing fabrics Fabrics with an → Anticrease finish.

Selvedge,

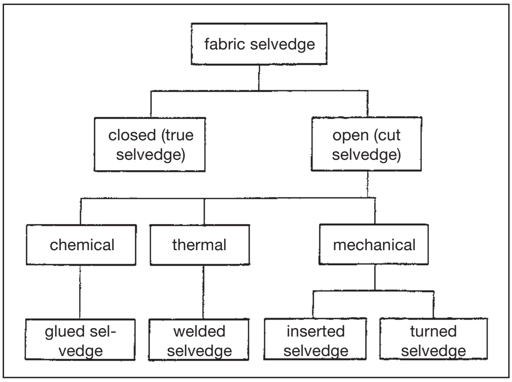


Fig. 1: A systematic classification of the possible methods of forming selvedges using the bonding principle.

I. With the introduction of shuttleless → Weft insertion systems it was necessary to adapt spec. mechanisms to fasten the → Selvedge on the looms in order to ensure the ground warp thread was firmly fixed. Numerous devices are available for this which differ in terms of the fastening principle and construction.

Fig. 1 shows a systematic classification of the possible methods of forming selvedges.

a) Fabrics produced on looms with shuttles have a closed selvedge which is formed by the continuous to and fro motion of the weft yarn.

b) Due to their nature, welded selvedges are limited in terms of the warp and weft material used. For fastening using a resistance wire, the warp and weft material must be made of thermoplastic materials, and when the selvedge is to be fastened using ultrasound, the fabric must have a thermoplastic content of at least 50%.

c) Laid-in selvedges are characterised by high stability. However, due to their complex mechanical structure, laying-in devices are expensive and limited in

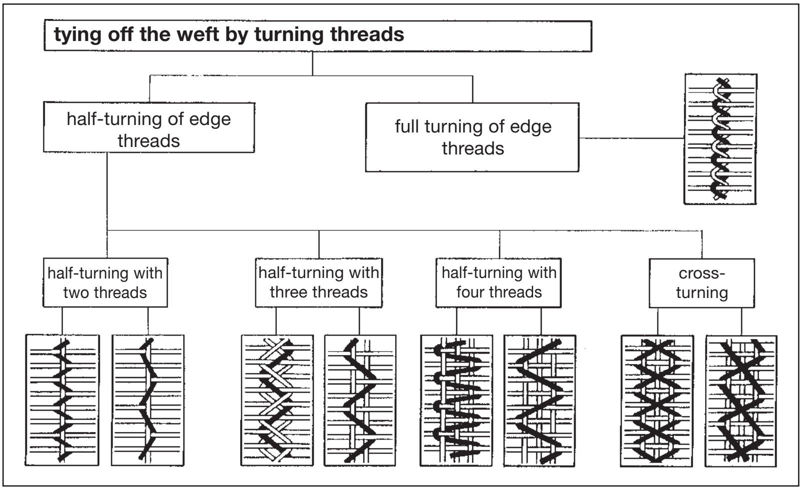


Fig. 2: Creating selvedge by means of turning threads (according to Wulfhorst et al.).

terms of the number of twists that can be made. For closely-woven fabrics, the principle reaches its technological limits as the procedure involves doubling the weft density in the area of the selvedge. For this reason, laid-in selvedges are predominantly used where this is necessary for stability reasons or where the selvedges are being made up during the garment-making process.

d) The turned selvedge is the most commonly found selvedge structure due to its high flexibility and to the comparatively cheap price of the turned selvedge device. These devices can be adapted to almost any loom and can be used for almost any type of fabric due to the variety of weaves. Fig. 2 shows a systematic classification of the different leno weaves. The weaves differ in terms of the number of crossing threads and stationary threads used and the type of tie thread. The most common are devices for two and four-thread half-cross turned weaves and those for full cross turned weaves. (Maetschke, Obolenski, von Thenen, Wulfhorst).

II. (edge, selvage). A distinction is made between the edge selvedge (list, selvage) and the centre selvedge (inside selvedge, split selvedge). The first is formed on the loom by reversing the shuttle or on shuttleless looms, by twisting or laying-in devices. The centre selvedge is formed similarly in the centre of the fabric (if several fabrics are being produced next to one another at the same time, which are later to be cut). The selvedge area is generally reinforced by regulating the relevant warp threads more closely, through tighter warp threads and/or another weave.

Selvedge cutting device This is a device which is used to cut the selvedges and remove the edge waste.

Selvedge feeler Non-contact scanning device which operates mechanically or photoelectrically to guide the cloth, particularly on stenters.

Selvedge gassing machine This is used to remove loose threads on the selvedge by gas singeing.

Selvedge guider → Expander.

Selvedge monitor This is a safety device which switches the machine off if one or both of the selvedges is no longer held by clips or the needle bar.

Selvedge printing machines (selvedge printers). These are generally combined with inspection machines on measuring machines, or less commonly with fabric batching machines. Company logos or advertising slogans are printed on the selvedges using heat transfer printing units.

Selvedge trailers Floating threads on fabric selvedges (→ Selvedge trimming machine).

Selvedge trimming machine This is used to remove from the selvedges loose, overhanging non-bound selvedge trailers which occur in weaving. The thread ends are cut off using a special shearing tool and extracted.

Selvedge uncurler (scrollers). This is a device to uncurl, unfold and stretch fabric and knitwear selvedges which have been rolled or turned up. Generally fluted metal or plastic fingers arranged in pairs, rotating rapidly in opposite directions, between which the fabric is guided. Selvedge uncurlers on stenters are generally combined with cloth guidance devices. Rolled selvedges in knitwear and folded edges in woven textiles are normally opened by selvedge uncurlers with motor driven spindles. Where these are not sufficiently effective, it is necessary to "intervene" from time to time and smooth out the selvedges manually as the fabric advances. This gives rise to the risk of injuries to fingers or hands by the operating spindles. On the other hand, there is no risk of injury or becoming caught in the device when a mechanical → Selvedge unroller is used. These smooth out the selvedges using fixed metal strips arranged helically at an angle to the direction of the cloth. Pneumatic selvedge unrollers, which use air nozzles to smooth out the selvedges, have no danger points either. These are suitable due to their high smoothing effect and low material strain, especially for sensitive fabrics.

Selvedge unroller These are used to open, unroll and stretch surface sensitive wovens and knitwear with folded edges or rolled selvedges. The operation involves no contact whatsoever (regardless of whether the fabric is dry, moist or wet). The nozzles are arranged in such a way in relation to the surface of the cloth guide that the stream of air emitted optimally smoothes out the rolled selvedges. This creates an insulating air cushion which guides the batch of cloth forward which has been unrolled without contact.

SEM → Scanning Electron microscope.

Semi-automatic Certain machine work stages are initiated manually but run automatically. Only part of the processes are automatic.

Semi-circle tester → Flammability test.

Semi-continuous bleach Open-width boiling and bleaching process for larger batches of cotton and cotton/synthetic blends which are uneconomical for continuous plants. Device: impregnating device, Benteler batching device and open-width scouring machine.

Semi-continuous bleaching → Semi-continuous bleach.

Semi-continuous operation If sections of a production line (e.g. washing ranges) need to operate discontinuously due to the nature of the process being carried out (e.g. rope washing machines for woollens to achieve sufficiently long washing time) it is sensible to use machines which allow at least semi-continuous operation.

An example of a semi-continuous operation is the high-capacity washer for rope washing fabrics with wool content (Fig. 1); it is equipped with a spec. rope handling device which helps to improve the performance of the washing system. Instead of feeding the hanks individually, positioned next to each other, and

Semi-continuous operation

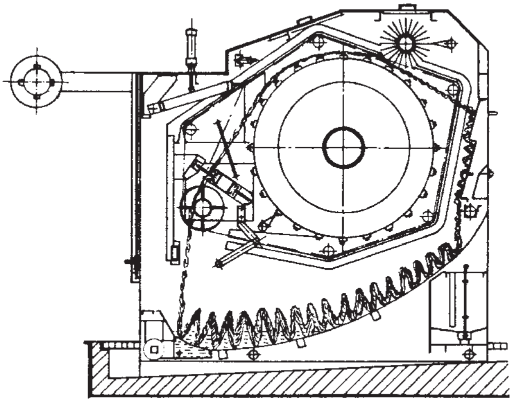


Fig. 1: A rope washing machine (the Menschner Lavarapid) with rope guide systems for semi-continuous operation.

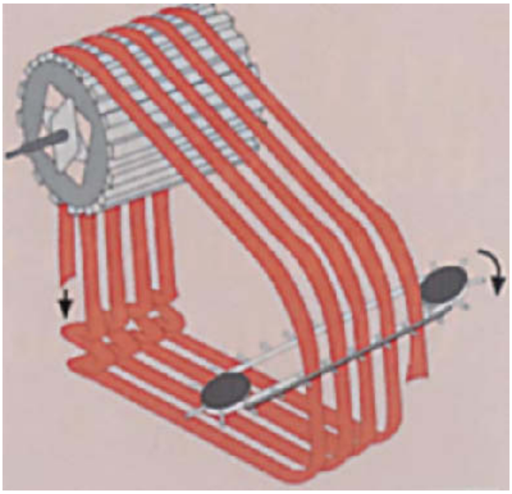


Fig. 2: Three-dimensional diagram showing the rope guiding system inside the Menschner "Lavarapid" washing machine.

sewing the hanks separately, this device feeds the fabric into the machine as one single rope which has been previously sewn together. The rope handling device moves the hank which has been sewn together along a helical line across the washing cylinder and finally through the entire machine (Fig. 2). Using this device, the hank is transported along in such a way that it is necessary to carry out any winding required in confined spaces. It is sensible to integrate this machine into a process such as that shown in Fig. 3.

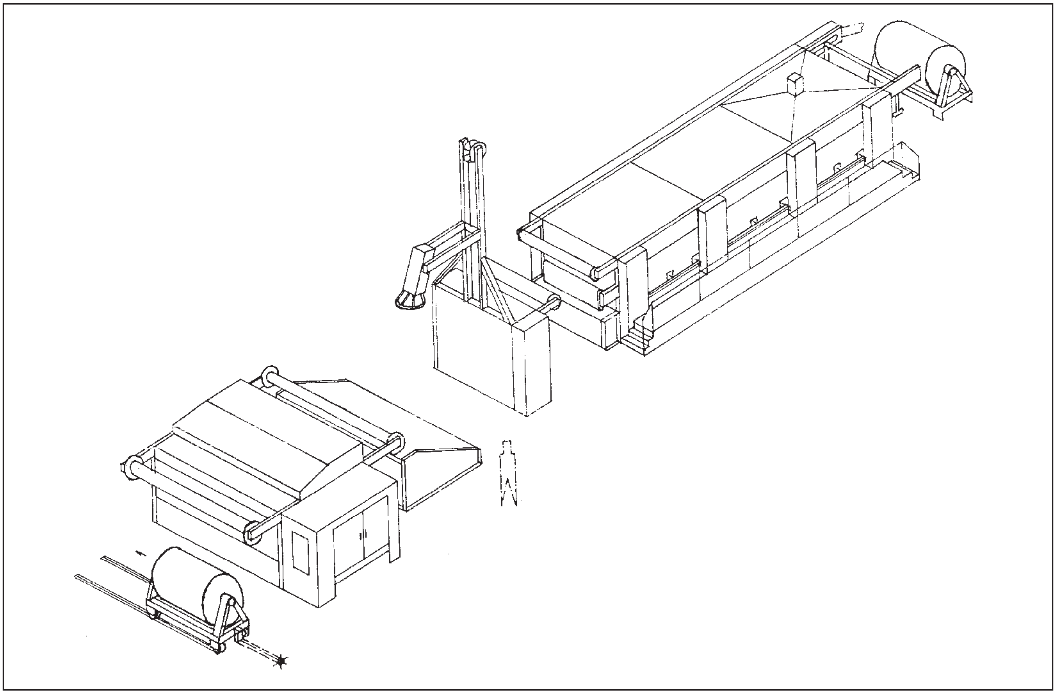
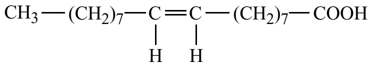


Fig. 3: Semi-continuous operation in wool fabric washing with rope (left) and open width (right) washing machines together with a rope opener (centre) from Hemmer-Menschner.

Semi-decatizing (semi-decating). A milder finishing process than full decatizing applied to wool and worsted piece goods to improve the lustre, handle and finish. The process involves crabbing followed by steaming of the goods wound on a perforated cylinder.

Semi-drying oils These include → Cottonseed oil, rapeseed oil, colza oil and soybean oil. They consist in particular of oleic acids and (to a lesser extent) linoleic acids. Due to the presence of unsaturated fatty acids with double bonds which are capable of oxidation and which are of the oleic acid type.



$$CH_3-(CH_2)_7-\underset{\underset{H}{|}}{C}=\underset{\underset{H}{|}}{C}-(CH_2)_7-COOH$$

Their drying power is significantly higher than that of → Nondrying oils.

Semi-felting raising machine → Wire raising machine which guides the napping cylinder in the opposite direction to that of the direction of the cloth by moment reversal.

Semipermeable This refers to the characteristic of a membrane which is permeable to specific molecules or ions, and to be impermeable to others. →: Osmotic pressure; Diffusion.

Semi-pigmentation dyeing process → Vat dyeing.

Semi-pigmentation process for vat dyes Principle: the dyebath is prepared cold with finely dispersed dyestuff, alkali and sodium dithionite and then heated slowly to vatting temperature, if necessary later to temperatures above 100°C (HT process) after reducing agents have been added.

Semipolar bond A co-ordinate bond which plays a particular part in → Chelation.

Semi-solid fats Bone fat, palm oil, also hardened fats (e.g. caster oil and coconut oil) and train oils. Obtained synthetically by reducing (hardening) unsaturated fluid oleic acids (by the catalytic hydrogenation of fats) in saturated solid stearic acid. Used as a basis for soaps, give more viscous working solution (preferred in milling for example), particularly effective at temperatures of 60°C. Glycerides from oxy fatty acid (caster oil) have similar properties.

Semi-solvent Mixtures of solvents whose individual components do not dissolve certain substances, but which together have the effect of a solvent; e.g. benzene and alcohol on acetate-cellulose. Particularly important in textile printing and stain removal.

Semi-worsted yarn,

I. This refers to soft, full-bodied yarn, loosely or tightly twisted, produced in the semi-worsted spinning process for weaving, knitting, warp-knitting. Intermediate stage between → Worsted yarn and → Carded yarn. Is fuller bodied, but less strong than worsted yarn, as the short fibres are not separated using combs. Semi-worsted yarn is stronger, but less full-bodied than carded yarn, on the other hand; clear finish.

II. Fabric with a) a worsted warp and a carded weft or b) twisted carded and worsted yarn, in the warp and the weft or c) alternate worsted and carded yarns in the warp and the weft.

Senegal gum African → Vegetable gums with predominant acacia content. Properties similar to those of kordofan gum, described under → Gum arabic, but with less adhesive strength. Main varieties: poorest qualities: pador gum, (dark amber to brown, often contaminated with sand and vegetable matter). Galam gums are purer and more water-soluble. The best qualities are found in salabreda gums which can be ground (most similar to kordofan, the purest form, colourless or slightly coloured).

Senneh carpets (Senna carpets). The finest and most well-known → Knotted carpets from Iran. Extraordinarily finely linked patterning in finely graduated, modest colours. 250 000–600 000 Turkish knots/m^2.

Sensor (Lat.: sensus = feeling, perception), measuring device (sampling probe, electronic sensor, signal measuring device, detectors) for physical values which are to be passed on for evaluation. Important in process control engineering, e.g. simple on/off contacts, water meter flow impulses, residual moisture measurement, etc. Used in computer-controlled finishing processes.

Sensor engineering International specialist designation for the field of generating process signals. → Sensor is another word for the terms measuring probe, measuring head, detector, transmitter, probe. Sensor engineering is the method of obtaining readings and both preparing signals and converting them into standard interface properties. Monitoring analysis with redundant measurements has taken the place of representative individual experiments, enabling an analysis of trends to be carried out and meaningful prognoses to be made. A chemical measuring technique in the reaction vessel (the “in process control”, “in-line” analysis and chemical process and quality control) is therefore possible, increasingly negating the need for quality control of the end product which is based on a deeper technical and scientific level, and which is therefore more complicated.

Until now, electricity has been the only technology of any importance in measuring and control technology when transmitting a signal. Optical fibres and other energy carriers, as well as fluid material systems are becoming increasingly important in analysis. They help to shift the analytical test methods out of the specialist laboratory and into the factory, where the practical applications are actually taking place. Analysis is therefore becoming more common.

A conventional thermometer has a sensor section, the bulb, which is filled with alcohol (Fig. 1). It connects with the capillary vessel which amplifies the sig-

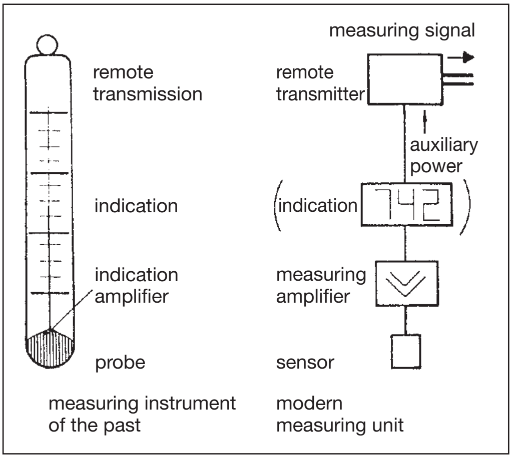


Fig. 1: Comparison: temperature measurement today and in the past.
The modern measuring unit has the same function as measuring instruments in the past but with remote output for the measuring signal in addition (according to Rüttiger).

nal for the temperature reading through the reduction in diameter and its lens effect. The liquid column in front of the scale indicates the reading. The modern measuring device has the same functional elements, only the form, which has been adapted to the new purpose, has changed. A significant difference is that the reading is no longer stored in the memory of the observer, but is converted into signals by means of amplifiers which are suitable for remote transmission. The sensor, or the sensing element, is the main focus. A physical value (temperature, in this case) or a physico-chemical quantity (such as the pH value) is converted into an electrical value either directly or indirectly. In most cases, the signal is a weak current or a voltage which is so low that amplification is required. A measuring amplifier is required for this. It must be matched to the sensor both in terms of amplification and input resistance, amongst other parameters. Often auxiliary power needs to be fed to the measuring amplifier of the sensor. It is important that the sensor and measuring amplifier are completely compatible, and they should therefore be procured as a set from the same manufacturer. The readings are transferred by various types of remote signals.

The transmission lines vary from simple bell wires to twisted wires (pairs of wires) through to coaxial cables if larger distances or higher transmission rates are required. Optical waveguides (glass fibre cables) and wireless transmissions (infrared transmitters and receivers, similar to television remote control) are modern forms of transmission elements. The "content" of the data supplied by the measuring signal is more important for the receiver. It may be a "raw" measuring signal, without range alignment or zero point adjustment, or it may be a "processed" signal where even the non-linear characteristic curve of the sensor is evened out and the standard temperature drift for sensors is compensated using an additional temperature sensor. Between these two extremes, all variations are possible, even sensors in which the range alignment takes place automatically (autoranging) or is switched remotely by a central exchange. On-off switches and phased signals are classed as digital signals in terms of the way in which the remote signal represents the reading.

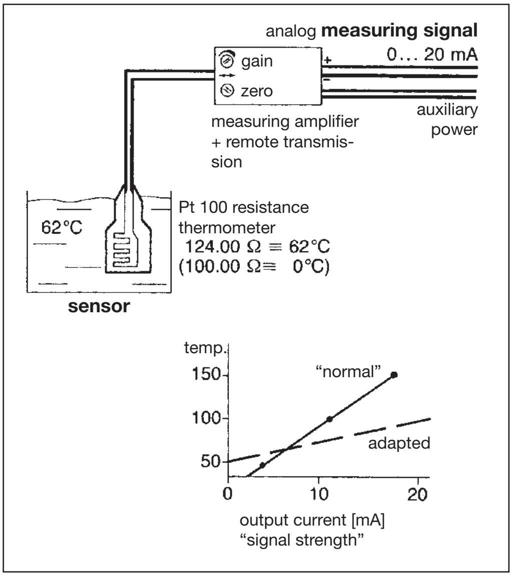
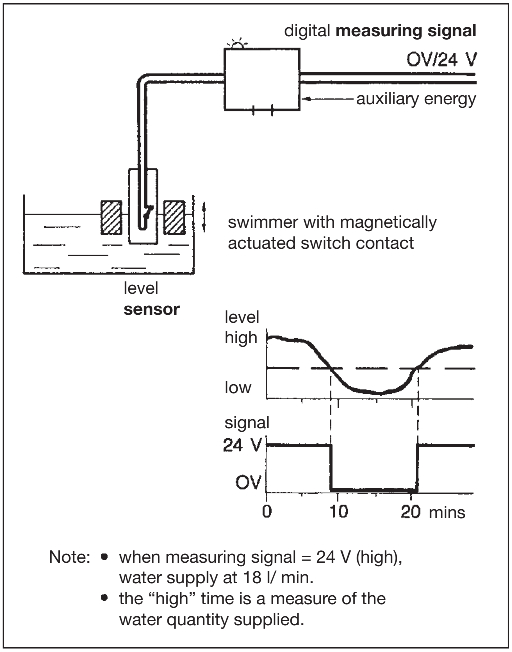


Fig. 2: Analogue measuring signals (according to Rüttiger).

The analogue signal is still the most similar to previous "readings" (Fig. 2). The electrical resistance in a resistance thermometer (Pt 100) varies with the temperature. It is connected to an ohmmeter or a "resistance meter", which operates in conjunction with a tele-transmitter by superimposed current. The advantage of the so-called "superimposed current" is that it is forcibly maintained by the amplifier. Even if the contacts corrode slightly and long cables have high resistance, the signal current does not change. Fig. 2 shows the calibration curve in addition to the connection diagram. This calibration curve can be recorded even with a simple multimeter or service digital voltmeter. The sensor is moderated, the auxiliary power is connected to the amplifier and the current is measured using the remote signal output. The unbroken line, "normal", shows that the amplifier is obviously adjusted for HT devices. The calibration curve can be modified by means of regulating screws; in this example, the zero point (temperature value at 0 mA) and the gradient of the curve. The broken line indicates modification to an open device in which the liquor temperature does not exceed 100°C. What is significant in this example is that the signal current generated from the tele-transmitter increases, the higher the temperature. Current and temperature have an analogous relationship, hence the name "analogue signals". Adaptability is also significant. A sensor can be adapted favourably (broken line) or unfavourably (unbroken line) using analogue signals. Favourable adaptation is very time-intensive and is therefore rarely used.



Note:
- when measuring signal = 24 V (high), water supply at 18 l/ min.
- the "high" time is a measure of the water quantity supplied.

Fig. 3: Digital measuring signals (according to Rüttiger).

Digital measuring signals (Fig. 3) are remote signals which only have two states or two levels, e.g. for current/no current or high voltage/low voltage. Fig. 3 shows this type of measurement system. A simple level sensor is upgraded as a "measuring device". For processing in a computer, all signals which register a process state are in the first instance measuring signals. Using the levelling probe, it is possible to measure a level at a point. This is again shown in the calibration curve section. Physical connection of the sensor effect: the auxiliary energy (24 V d.c.) is in direct contact with the level sensor. If the float rises with the liquor, it closes the contact at a level of 80 cm. The + 24 V voltage is looped to the remote output. The remote signal leaps from 0 V to + 24 V. If the level drops, the float also falls and the contact is opened. 0 V appears in the transmission line again. An indicator lamp is often utilised which displays the switch status of the float. This is useful for maintenance and fault finding.

Typical sensors in textile finishing are as follows:

a) Thickness gauge for fabrics and knitwear. Sensor: distance sensor, micrometer. Measurable variable: thickness of textile in mm.
b) Residual moisture gauge for fibres. Sensor: conductivity (insulation) gauge with contact rollers. Measurable variable: relative moisture in %.
c) Surface temperature of textile fabrics. Sensor: series of thermometers with rotating apertures to measure the heat radiation of fabrics. Measurable variable: textile fabric residual moisture (indirectly using the wet bulb temperature).
d) High humidity measurement during application of product. Sensor: microwave transmitter (10 GHz) with horn antenna attached for multiple transmission with receivers for the microwave radiation transmitted by the fabric. Measurable variable: fabric moisture.
e) Residual moisture in textile fabrics. Sensor 1: intensity of an infrared water band reflected in front of the fabric. Sensor 2: intensity of generally reflected infra-red light. Measurable variable: for thick fabrics, the relative moisture, for thin, open fabrics, the absolute moisture.
f) Residual moisture in textile fabrics. Sensor: condenser; variation in capacity across water in the field. Measurable variable: absolute moisture per m^2 converted into %.
g) Oxygen content of a gaseous phase. Sensor: oxygen molecules are attracted into a homogenous magnetic field in the direction of higher field strength due to their paramagnetism. If two gases with different oxygen content (one of which has a high moisture content, for example, which "dilutes" the oxygen content) meet in a magnetic field, a difference in pressure forms between them. Measurable variable: moisture content of steam (in comparison to air).
h) Hydrometer. Sensor: buoyancy of a body in solutions (measuring range 0–1.6 g/ml). Measurable variable: liquor concentration.

Constant development has taken place in the field of chemical sensors. Mass spectrometry, associated with gas chromatography, dominated the field of advanced analytical instrumental methods for approx. 20 years. This was followed by liquid chromatography, associated with mass spectrometry, together with various other instrumental methods which have been simplified into detectors, such as Fourier transform infrared and mass-specific detectors which are suitable for gas chromatography. These are all now in use and have enhanced the range of resources available to analysts. Molecular beam technology is impressive due to its high separating capacity and sensitivity. Conventional element analysis and microanalysis have been replaced by higher performance instrumental techniques. These coupling systems cover everything from individual analytical devices to complete analysis systems to sensor technology.

Monitors designed on the basis of gas chromatography, which can be regarded as automated, modular instruments and as complete analysis systems, carry out all the stages of an analytical experiment coherently. They enable automatic chemical monitoring of parameters relating to hygiene at work and safety issues as well as ongoing monitoring of emissions relating to the environment. They can be used to control and monitor processes. If the analytical principles in fluid systems realised in these monitors are transferred from the gaseous phase into a mobile phase, the technology of Flow Injection Analysis (FIA) results. This not only enables an extraordinarily high analytical flexibility to be combined with a high sample sequence, but also enables solutions which are simple to achieve.

Although ion-selective electrodes are sensitive, they are only definitely able to measure certain ion concentrations continuously if their technical use is defined at the same time as potentiometric sensors are being developed. Biosensors are still in the process of being developed, while electrochemical “Field Effect Transistors” (FET) based on semi-conductor technology, probes or photoacoustic sensors, piezo oscillators, phonon sensors and thermistors represent another important area of development and application for sensors in textile finishing (according to Widmer and Rüttiger).

The number of ion-selective electrodes has increased considerably over recent years as it is now possible to produce selective complexing agents for some cations. In the meantime, commercial electrodes have become available which correspond selectively to surfactants. The electrical signal arising with a potentiometric measurement system can be used for control purposes. In recent years, a number of sensors have been developed which supply an optical signal. These are referred to as optic sensors or optrodes. Their operation is based on the fact that a dyestuff or other molecule is immobilised on a carrier material. This molecule forms a complex with the compound to be identified which has a different absorption spectrum to that of the initial compounds. The spectral range at a given wavelength can be measured using a spectrophotometer when optical waveguides are used.

Sensor technology Recording parameters which are spatially difficult to access without contact, and processing the values obtained in computers. → Sensor engineering.

Separating course A gap created in the knitting of tubular fabric caused by omitting one or more needles in the relevant knitting system. This can also be used as a guide for opening tubular knitwear (→ Tubular fabric slitting machines).

Separation of mixtures Mixtures can be divided into solid mixtures, solid/liquid mixtures, solutions, gas mixtures, impure gas and liquid mixtures, according to their state of aggregation. The decisive element when choosing the separation method to be used is the state of aggregation of the mixture and its physical and chemical properties. In the separation processes, the reaction partners involved are not in pure form, but are mixed with other substances such as solvents.

One of the most significant separation processes is thermal separation. It is used in distillation, evaporation and rectification to separate homogenous materials and is carried out by addition or absorption of heat, using thermal molecular movement for the separation process. This causes a change of state in the component of the mixture which is to be separated. In the case of liquids, thermal separation is used for the processes of crystallising out, salting out, precipitation and evaporation. The prerequisite for evaporation to be used as a separation process to reduce the effluent pollution is a large difference in boiling point between the water and the pollutants. In other cases, the more expensive method of rectification should be selected as the thermal preparation method (see Fig.).

Separators Clarifying centrifugal machines. Heavy dirt particles adhere to the drum wall through centrifugal force, whereas clarified fluids and solvents drain off. Use: e.g. to clarify mercerizing liquor and organic solvents. As separators have a better effect the lower the density of a solvent, separators tend to be recommended for lighter, combustible solvents rather than for heavy, non-combustible solvents.

Septic Rotten, fostering decay. Contrast: aseptic. → Antiseptics.

Sequestering agent This is the term used for chemical compounds which remove polyvalent metal anions from water and are able to combine to form an anionic complex (sequestering, → Complexing agent); e.g. polyphosphate, ethylenediaminetetraacetic acid (EDTA). Inorganic polyphosphates are used as sequestering agents and builders in industrial and domestic detergents. From an ecological point of view, the use of this group of substances must be reduced as the phosphate load is one of the most significant contributing factors for the eutrophication of ground water. The potential applications for sequestering agents in wet textile processes of all types are diverse and, for the most part, have not been adequately researched.

The use of sequestering agents in water treatment, for example, can be useful e.g. when pre-treating cotton even when softened process water is being used, as a considerable amount of water-hardening substances are introduced by the untreated fabric. Some types increase the soil carrying capacity of surfactant liquors

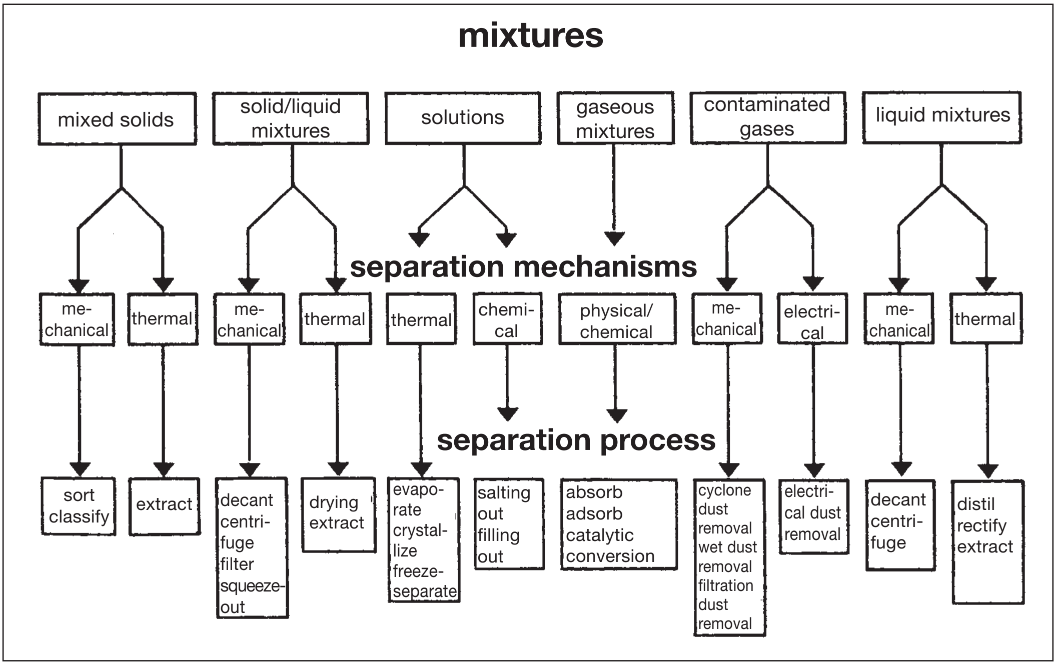


Fig.: Overview of processes for the separation of mixtures.

due to their dispersibility and therefore, may cause greying and hardening of the textile substrate for example, by redepositing the soil or sizing agent as loading substances from the wash liquor, even when only small quantities are used. The ability to dissolve solid deposits or to subject them to colloid-disperse distribution is utilised as an after-treatment to improve the fastness of dyes as dyestuff molecules and agglomerates which have not been fixed can be removed easily and thoroughly from the fibres. The delayed crystallization effect of some types not only delays the formation of inorganic deposits, it also has a positive effect on the separation of polyester oligomers.

Sequestering agents have three important properties:

1. Sequestering power: in the textile industry, "sequestering" is understood in the broader sense to mean the removal or the neutralizing of harmful metal ions (water hardening substances, heavy metal ions) from the water. The quality of water used in the textile finishing industry plays a significant part. In addition to undesired excess consumption of textile auxiliaries and dyestuffs, water hardness can cause disruption to processes, incrustations on the textile substrate, on the machines and pipes and inferior final fabric quality. Neutralizing the calcium and magnesium ions present in the water as water hardening substances can, in principle, take place either by removing them from the water before the actual process occurs (permutit process, ion exchangers) or adding materials which prevent their harmful effect. The alkali builders or sequestering agents used for this deactivate the water hardening substances and other harmful cations in the water such as iron, copper or manganese by precipitation, ion exchange, chelating or adsorption on the seed crystal surface. Even if the process water is softened before the liquor formulation, the addition of a sequestering agent brings certain clear advantages in respect to the reliability of the process.

The pretreatment of cotton, which is the most important example of this, should be described in more detail here. Over recent years, the content of non-cellulose contaminants in raw cotton has increased drastically. The main reasons for this are:

- the use of chemicals when cultivating cotton (insecticides and growth modifiers),
- harvesting machines, processing plants and packaging machines (pollutants from soil and husks)
- higher processing rates at all stages such as ginning, opening, carding, drawing, spinning, machine knitting, knitting and weaving (higher metal abrasion, poss. rust particles).

As the amount of additives can vary considerably depending on the origin of the cotton and its past history (in some cases up to 2 or 3 times the average values), it is becoming increasingly difficult for those carrying out the pretreatment to guarantee uniform, reproducible quality of the fabric which is ready for dyeing, printing or finishing. If in addition the standard 3-stage pretreatment sequence (scouring, degumming, bleaching) is shortened for economic reasons, a sequestering agent should always be added. Correct dosage ensures that the water hardening agents and heavy metal contaminants, which could result in catalytic damage, are thoroughly removed, and also offers other advantages, depending on the product group.

2. Dispersibility: the term “dispersing” (Lat.: diffuse, scatter) means that solid particles are distributed in a liquid. Due to the fact that the surface, which is large in comparison to the overall volume, is generally unfavourable in terms of its energy, particles in a dispersion tend to settle together to form agglomerates and aggregates. When added to the particle surface, certain types of sequestering agents (e.g. polyacrylate) cause an increase in the electrical charges of the same sense and thus increase the repulsive powers between the particles. In a similar way to when dissolving and emulsifying fatty or oily pollutants in liquors containing surfactants, it is beneficial as far as their energy is concerned for the surface of the solid particles to be increased. Consequently:

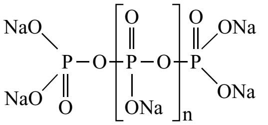
- Solid particles are prevented from settling.
- Agglomerates are split due to the repulsive powers and distributed more finely.
- The formation of flocculent and crystalline deposits and their coagulation is delayed.

3. Buffer capacity: buffering means that the pH of a solution can be maintained at a constant level in a narrow range when a moderate amount of acid or alkaline solutions is added. The preferred sequestering agents used in the textile finishing industry are weak acids, which are generally commercially available products in either completely or partially neutralized form (generally in the form of sodium salts). In solution or when strongly diluted, they decompose into ions; they dissociate. Hydrogen ions are added to the free acid ions, the sodium or alkaline earth hydroxides remain dissociated, however. When adding acids or alkalis which originate from, e.g. organic (fatty acids) or inorganic pollutants, or which could arise from (bleach) reactions, the buffer balance is shifted. Sequestering agent anions absorb excess protons or release them where there are insufficient quantities. The pH is kept relatively constant. Sequestering complexes with polyvalent metal ions do not dissociate as the sequestering effect is based on this. Accordingly, they are ineffective as buffers.

Properties of various groups of sequestering agents:

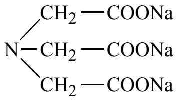
I. Inorganic condensed polyphosphates:

Advantages: ability to increase detergency efficiency and soil carrying capacity of surfactants; complexing power for calcium, magnesium and heavy metal ions.



Disadvantages: disadvantageous in hot, strong alkali liquors due to their low stability at temperatures of > 80°C and pH > 11 and in strong acid media. In these areas, it is possible that insoluble deposits will form. No selectivity for heavy metal ions when calcium and magnesium ions are present.

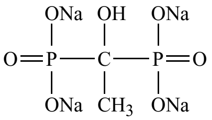
II. Amino-polycarbonates, e.g. ethylene diamine tetra-acetate (EDTA) or nitrilotriacetate (NTA; the following formula):



Advantages: high selectivity for heavy metal ions, therefore well-suited as a regulator for hydrogen peroxide bleach; good stability at increased temperatures; good alkali resistance.

Disadvantages: only resistant to oxidizing agents to a limited extent in hot and strong alkali media; practically no detergency efficiency and soil carrying capacity; at high alkali concentrations, diminishing complexing power; only effective in the stoichiometric region, therefore large quantities are required.

III. Phosphonates, e.g. hydroxyethylene diphosphonate:



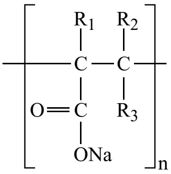
$$\begin{array}{ccccc} & \text{ONa} & \text{OH} & \text{ONa} & \\ & | & | & | & \\ \text{O}= & \text{P} & — \text{C} — & \text{P} & =\text{O} \\ & | & | & | & \\ & \text{ONa} & \text{CH}_3 & \text{ONa} & \end{array}$$

Advantages: high calcium, magnesium and iron binding capacity; high stability in cold and warm alkali baths and in strong alkali, oxidizing liquors; very selective effect on polyvalent heavy metal ions; effective in the lower stoichiometric region.

Disadvantages: only average detergent and dispersing action; may result in alterations in shade and dyestuff being dissolved out of the fabric due to the formation of hard complexes with the central atoms of dyestuffs containing metals.

IV. Polycarboxylates, e.g. polyacrylate:

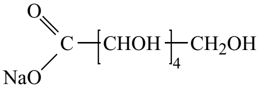
Advantages: excellent dispersing properties: solid soil, deposits, husks, etc. are removed from the fabric and stabilised in the liquor; high calcium, magnesium and heavy metal binding capacity; threshold effect: by adsorbing the polycarboxylate on the seed crystal sur-



face (e.g. of slightly soluble hard water salts), they are prevented from continuing to grow and being deposited on solid surfaces; due to the threshold effect, they are already in the lower stoichiometric region and therefore effective even when only small quantities are used; have the effect of delaying crystallization, thereby also avoiding or reducing silicate deposits in combination with sodium silicate; do not form hard complexes and therefore do not tend to corrode the central atoms of dyestuffs containing metals; by varying the monomer components used and the degree of polymerization, products with spec. property profiles can be synthesized.

Disadvantages: resistance and efficiency in strong alkali and strong electrolytic liquors are limited.

V. Polyhydroxycarbonates, e.g. gluconate:



$$NaO-C(=O)-\left[CHOH\right]_4-CH_2OH$$

Advantages: high sequestering power at limited acid/alkaline concentration.

Disadvantages: efficiency is very dependent on pH.

Sequestering agents and ion exchangers are shown in the Fig. (according to Plendl).

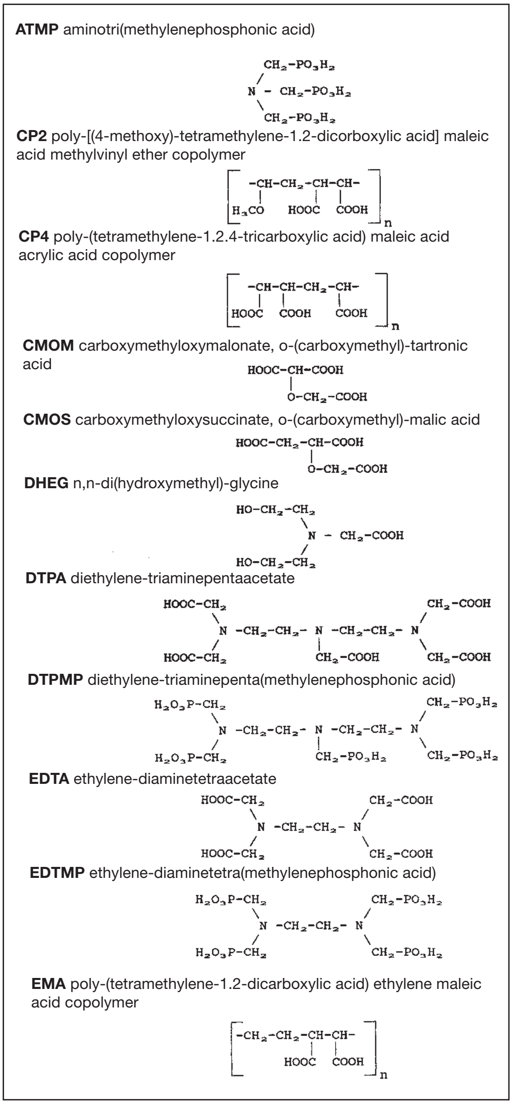


Fig.: Sequestering agents and ion exchangers (according to Plendl).

Sequestration According to DIN 53 900, the masking of dissolved metal ions which can form deposits with certain reagents, particularly surfactants. The effect is based on the formation of complexes which remain soluble in the medium in question. Sequestering agents are generally compounds which form chelates with the cation in question. Chelates (Gk. chélé = claw) are a special type of complex or co-ordination compound in which the cation is surrounded as if by a claw or a pair of tongs. Co-ordination compounds are higher order compounds. In the case of sequestration, a polyvalent cation is tightly surrounded as a “central atom” by other oppositely charged ions or by neutral molecules, known as ligands. Ligands must be able to supply at least one non-binding electron pair and the central cation must have a number of empty orbitals of a suitable energy level to accommodate these electron pairs. A ligand which is only able to supply one electron pair is referred to as a monodentate. The number of monodentate ligands which are able to be grouped around the central ion determines the co-ordination number of the relevant ion. For a chelate to form, it is necessary to have a ligand which can supply at least two pairs of electrons which are sufficiently far apart from each other in the ligand molecule to be able to form a bridge. This type of ligand is a bidentate or a ligand with two co-ordinate bonds. The majority of sequestering agents are polydentates with 4-8 co-ordinate bonds (Fig. 1)

Ion exchangers, which are either dissolved or suspended in water, are, in water insoluble suspended products for which the matrix consists of either an inorganic grid of Na-Al silicate (SASIL = Sodium Alumin-

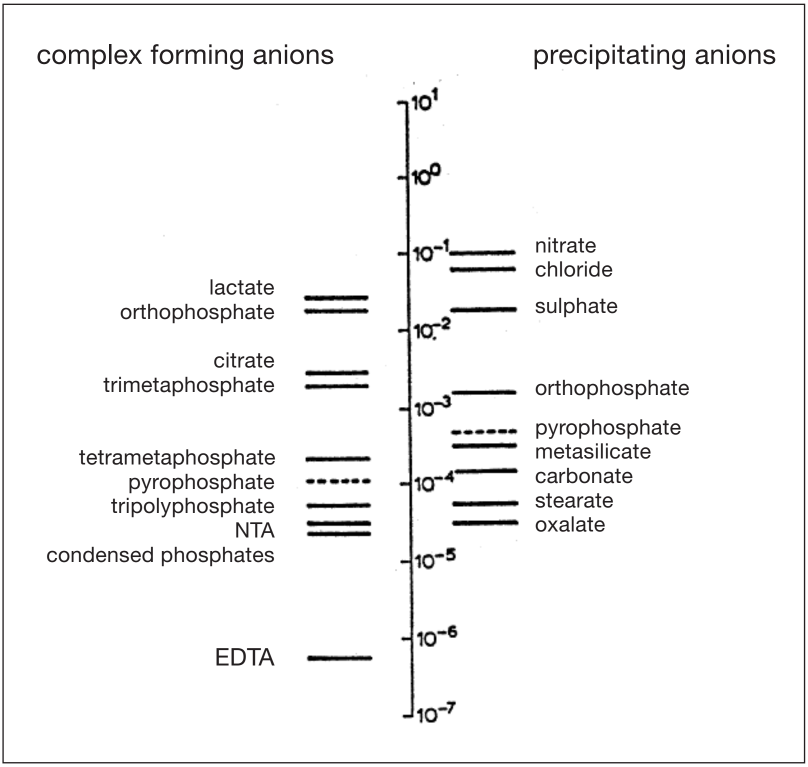
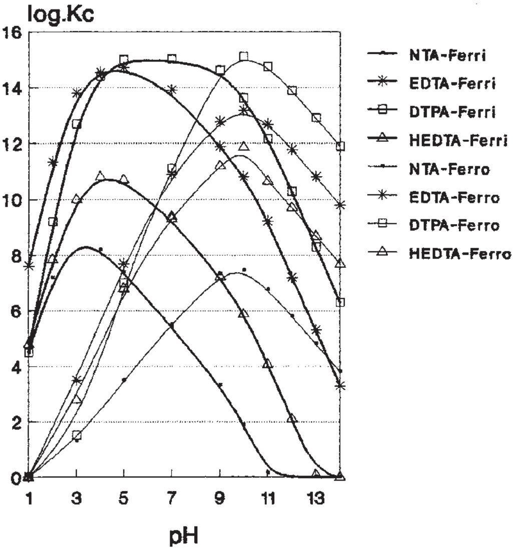


Fig. 1: The concentration of free Ca^{2+} ions following the formation of complexes with certain anions compared to the concentration following precipitation. The concentration of free Ca^{2+} ions is calculated for the dissociation of a 0.01 m solution of the 1:1 complex.

ium Silicate or HIB = Heterogeneous Inorganic Builder) or of a scaffold of partially crosslinked polycarboxylic acids. Products which are soluble in water, which are generally used in finishing processes, are polycarboxylic acids such as polyacrylic acid, polymaleic acid, copolymers of acrylic acid and maleic acid. When dissolved in water, these polymers form balls or helices, inside which the counterions can be exchanged.

The bonding capacity of the sequestering agents for metal ions is given by the stability constant K_S or the relationship between sequestered and free metal ions is represented by log K_S. The higher the value of log K_S, the more powerfully the cation in question is sequestered. The stability constant is not the only factor which determines the adhesive power of the cation in the chelate, however; the temperature, pH and electrolyte concentration are also significant. The effect of the pH value is determined by the calculation of the stability constants across the overall pH range. The stability constant corrected according to the pH is known as the conditional stability constant (log K_C). It is only possible to specify whether and to what extent a sequestering agent is suitable for a specific process with the aid of the conditional stability constant and an understanding of the effect of temperature and electrolyte concentration. Unfortunately the necessary reliable information



source: BASF.Trilon ES-8803.
T = 25 C . μ = 0.1

Fig. 2: The conditional stability constants ferrichelate and ferrochelate for polyaminocarboxylic acids.
Ferri = iron (II); ferro = iron (III).

is often not available and it is necessary to test at a later stage to ascertain which sequestering agent has the optimal effect and whether the use of a sequestering agent is actually economically justifiable.

Fig. 2 shows the extent of the effect of pH on the stability of the complex compound. Although the ferric EDTA complex has a much higher stability constant (log $K_S = 25$) than the ferrous EDTA complex (log $K_S = 14.3$), the latter is more stable at pH > 8. The influence of temperature on the Ca-EDTA complex can be seen e.g. as a decrease in the stability constant by approximately a factor of ten when the temperature is increased from 20°C to 60°C. Increasing the electrolyte concentration also results in a decrease in the stability constant. The rate of sequestration is generally relatively high; exceptions are those metal ions whose inner orbitals exchange electron pairs, e.g. Cr and Co. It takes several days for an equilibrium to be reached where the Cr-EDTA complex is used.

In addition to their complexing power, various sequestering agents also have the ability to stabilise dispersions, hinder the agglomeration of particles and prevent the accumulation of newly formed crystals. This last property is generally referred to as the threshold or swelling effect. It is not easy to determine and calculate the stability constant, and in some cases, it is not even possible. It is also difficult to make calculations in practice using these constants. Another option to determine the efficiency of a sequestering agent is therefore often detailed in fact sheets, namely by giving the binding capacity, generally for Ca^{2+} but also for other cations such as Mg^{2+} or Fe^{3+}. This binding capacity is based on the ability of the auxiliary in question to prevent the precipitation of a particular cation which is under the influence of an anion which causes precipitation (Hampshire test) or alternatively to prevent a freshly precipitated deposit from being dissolved once again (modified Hampshire test). In both test methods, other specific properties of the sequestering agents in addition to the stability constants also play a significant role, so care is required to ensure this data is not incorrectly interpreted in practice. (according to Engbers).

Serabend carpets (Mir carpets), Persian → Knotted carpets from the Sarawan region. Typical flame-effect patterning about the size of an egg on a red, blue or cream background. 120 000–250 000 Turkish knots/m^2. Mir from Mirabad has particularly fine patterning.

Serge (Fr.: serge = twill). Diagonally striped materials in twill weave. Name derived from the type of fibre (alpaca, woollen serge) and use (costume serge), also warp printed (serge vigoureux).

Serge de Nîmes Denim fabric for jeanswear; sail cloth trouser fabric, warp printed in indigo, originally white or brown. Specially sewn and riveted garments which are artificially aged (stonewash; sandblasted, biowash process). First jeans manufacturers to use serge de Nîmes: Lewis, Lee, Wrangler.

Serial washing machine → Continuous washing plant for laundry separated into batches consisting of 4–10 machine units (each with a capacity of 24 kg) in series which are separate from each other (modular construction principle) and have separate liquors. Counter current operation at timed intervals, with (in contrast to the conventional inner drum) horizontally partitioned “laundry agitators” which scoop the laundry from the lower trough (outer drum) and allow it to fall back freely into the bath after a half turn. Whenever the timing changes, the laundry agitators and transport valve ensure the laundry is passed into the next unit. Each unit serves as a treatment station for the programmed washing operation, each batch of laundry for the programmed washing operation remains alone until unloading. Hydroextraction using squeezers/calenders or a connected hydroextractor.

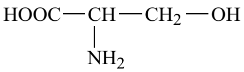
Sericin (silk gum). A silk gum substance which surrounds the fibroin filaments up to 19–28% and with them forms raw silk (→ Silk). A distinction is made between the white cocoon, which is known as “white bast” and that from yellow cocoons, “yellow bast”. Composition: 45% carbon, 32% oxygen, 17% nitrogen, 6.5% water. Sericin has a different amino acid structure to that of fibroin (→ Silk structure, see Tab.), i.e. basic and particularly acid groups in higher concentration (aspartic acid, glutamic acid, serine, threonine, tyrosine). Its isoelectric point is therefore pH 4.1, whereas that of fibroin is pH 4.9.

Sericin content of natural silk determination Accurately weigh out approx. 20 g of a sample, boil for 1 h in a 1% Marseille soap solution, squeeze out, hydroextract, rinse with water, squeeze out, dry for 4 h at 105°C and when calculating the sericin content use:

$$\text{sericin content in \%} = \frac{G_1 - G_2}{G_1} \cdot 100$$

G_1 = weight of the completely dry sample before degumming (original weight less the water content detected on the second sample);
G_2 = weight of the completely dry sample after degumming.

Serine Monoamino monooxycarboxylic acid. An → Amino acid which is present in wool (9.4%) and silk (16.24%).



$$\mathrm{HOOC{-}\underset{\displaystyle NH_2}{\underset{|}{CH}}{-}CH_2{-}OH}$$

Serviceability of carpets This is difficult to specify; in addition to fastness of colours/prints, the following need to be taken into consideration: abrasion resist-

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is often not available and it is necessary to test at a later stage to ascertain which sequestering agent has the optimal effect and whether the use of a sequestering agent is actually economically justifiable.

Fig. 2 shows the extent of the effect of pH on the stability of the complex compound. Although the ferric EDTA complex has a much higher stability constant ($\log K_S = 25$) than the ferrous EDTA complex ($\log K_S = 14.3$), the latter is more stable at pH > 8. The influence of temperature on the Ca-EDTA complex can be seen e.g. as a decrease in the stability constant by approximately a factor of ten when the temperature is increased from 20°C to 60°C. Increasing the electrolyte concentration also results in a decrease in the stability constant. The rate of sequestration is generally relatively high; exceptions are those metal ions whose inner orbitals exchange electron pairs, e.g. Cr and Co. It takes several days for an equilibrium to be reached where the Cr-EDTA complex is used.

In addition to their complexing power, various sequestering agents also have the ability to stabilise dispersions, hinder the agglomeration of particles and prevent the accumulation of newly formed crystals. This last property is generally referred to as the threshold or swelling effect. It is not easy to determine and calculate the stability constant, and in some cases, it is not even possible. It is also difficult to make calculations in practice using these constants. Another option to determine the efficiency of a sequestering agent is therefore often detailed in fact sheets, namely by giving the binding capacity, generally for Ca^{2+} but also for other cations such as Mg^{2+} or Fe^{3+}. This binding capacity is based on the ability of the auxiliary in question to prevent the precipitation of a particular cation which is under the influence of an anion which causes precipitation (Hampshire test) or alternatively to prevent a freshly precipitated deposit from being dissolved once again (modified Hampshire test). In both test methods, other specific properties of the sequestering agents in addition to the stability constants also play a significant role, so care is required to ensure this data is not incorrectly interpreted in practice. (according to Engbers).

Serabend carpets (Mir carpets), Persian → Knotted carpets from the Sarawan region. Typical flame-effect patterning about the size of an egg on a red, blue or cream background. 120 000–250 000 Turkish knots/m^2. Mir from Mirabad has particularly fine patterning.

Serge (Fr.: serge = twill). Diagonally striped materials in twill weave. Name derived from the type of fibre (alpaca, woollen serge) and use (costume serge), also warp printed (serge vigoureux).

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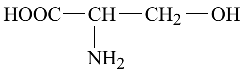


$$HOOC-\underset{\displaystyle NH_2}{\underset{|}{CH}}-CH_2-OH$$

Serviceability of carpets This is difficult to specify; in addition to fastness of colours/prints, the following need to be taken into consideration: abrasion resistance, tuft anchorage, soiling capacity, electrostatic charge, etc. Individual factors can be determined using test devices, provide a considerable amount of information on the actual serviceability and should be substantiated by treading tests.

Service life of textile plant and equipment As a valuation for depreciation, a distinction is made between a) the original cost (= cost value, book value, carrying value), b) present useable value (current value, i.e. value at the point the annual profit, profit or loss account or cost system is to be drawn up), c) replacement value (is always replaced by the present useable value in cost systems). The depreciation used for in-house cost system or annual profit or loss accounts cannot simply be based on the present useable value (replacement principle, sustaining productivity), as accounting principles alone would give a false basis for calculation. On the other hand, the commercial balance sheet or the tax balance sheet is used for the depreciation shown by the balance which is based on the original cost and guarantees the capital sum invested. For this depreciation, the service life is equated with the useful life and, as this cannot be accurately determined in advance due to the various associated factors of probable stress, activity and wear and ageing, this is estimated for specific years of operation. This assumes depreciation of the plant after expiry of the estimated service life, at which point the allowance for the reduction in useful value is deemed complete. In addition to the so-called annual linear depreciation, which is based on original costs, there is also degressive depreciation which is calculated from the relevant book value (remainder of investment as shown on the balance sheet). With the linear method, the depreciation quota remains the same until the final year; with the degressive method, it decreases annually. This corresponds to a large extent to the decrease in the useful value of the plant, and thereby, also to the practical trend in wet finishing companies for example, where higher depreciation in the early years make it possible for a replacement purchase to be made at an earlier stage.

Service life of textiles From experience in processing complaints, the term "service life" can be defined as the length of time for which the textile can be worn or used in terms of fashionable and aesthetic aspects. A highly fashionable item will therefore be suitable for use for considerably less time than a timeless article subjected to the same strains.

Servo component Element of the control system or regulating system. Operation to control a physical quantity in a mass or energy flow as required for the particular operation is known as "regulating". Regulating takes place at the regulating point. Servo components which are used to control an energy flow are known as "actuators".

Servo-hydraulic Machine components which are difficult to operate can be controlled more easily using oil pressure. The aid (servo) using oil (hydraulic) operates, e.g. with a gear chain, as follows (see Fig.): a pump which is part of the gear chain, supplies oil to the hydraulic control unit. The control valve controls the oil supply in the pressure cylinder of the disc assembly. Oil exerts a pressure to the conical disc in the chain, for axial transfer of the displacement disc and to forcibly move the driving gears. Servo-hydraulic makes it possible to preselect the speed of the driving motor while the gears are immobilized.

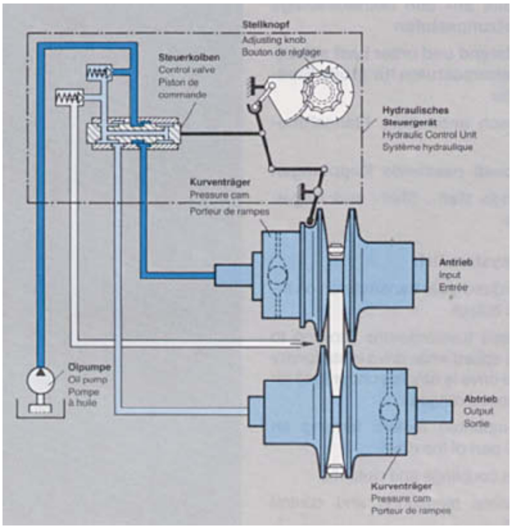


Fig.: Servo-hydraulic.

Sett The number of warp and weft yarns in fabrics (the number of stitches in knitwear) per unit of measurement, i.e. per 1 or 10 cm, often per cm^2. Magnifying glasses or yarn counters are used to determine the sett. The sett therefore corresponds to the distance from the centre of one yarn to another. Whether the yarns lie closely together or form open stitches is insignificant. Not to be confused with → Fabric density.

Setting,

I. Setting textiles in the sense of fixing dimensions or shape. →: Crabbing; Decatizing; Hosiery setting; Heat setting (→ Fixation), wet setting. The degree of setting, i.e. modification to the structure as a result of the influence of heat, can be defined in the case of polyester by determining the solubility in phenol/tetrachloroethane; this can also be achieved using differential thermal analysis (DTA) which can also be used for polyamide.

II. Setting colorations. This is achieved e.g. by fastness improvement agents and → Developer.

III. Setting prints: developing process to promote setting. This preferably takes place on a steamer.

IV. Setting dyestuffs generally using hot air (→: Thermosol single-bath processes; Thermosol two-bath processes), direct contact (hot roll fixation machines) or steamers.

Setting of carpet yarns This is necessary if yarns with high pile and low density are to be processed. Discontinuous steaming in rope form or as special packages in autoclaves is labour-intensive. A number of devices are available for continuous operation.

Setting-up time Proportional → Order processing time as work involved in preparing the fabric, which also includes the necessary transport. Subdivided into setting-up time and setting-up allowance. Example: in screen printing in the pressroom, manual stentering, gluing, etc. represents a setting-up time which places a considerable burden on order planning, which can be significantly reduced by the mechanisation of screen printing. The setting-up time is followed by the → Execution time.

Settlable solid pollutants in waste water According to the Abwasserabgabengesetz (waste water levy law), the solids measured in ml/l (soil components, fibre abrasion, etc.) in a water sample which settle to the bottom within a specific time.

Set yarns → Textured yarns which are pre-set, in contrast to highly elastic yarns. Fabrics manufactured using set yarns shrink considerably less in wet finishing.

Sewability Sewing threads can be described as having excellent sewability if they guarantee problem-free production, minimal downtime and optimise the efficiency of production plants. Other individual contributing factors include: the construction of the sewing thread, tensile strength, elongation at break, abrasion resistance, sliding properties and softness. Maximum stress is caused by modern high-speed seamers which convey the sewing thread through the eye of the needles up to 80 times, at speeds of up to 8000 stitches/min. at approx. 200 km/h until the loop formation is completed. This stress on the sewing thread (particularly when starting and stopping) is considerably higher than when used subsequently in the seam. Ensuring good sewability is a particular problem when developing suitable softeners and additives to improve the sliding properties of the thread in relation to the sewing needle (sewing thread lubricant). Suitable auxiliaries include polyethylene emulsions, paraffin emulsions and → Silicon elastomers. In extreme circumstances (depending on the speed, material to be sewn, needle gauge), needle temperatures of 280–300°C may occur. There are certain sewing sectors with high needle temperatures in which it is not possible to use synthetic spun yarns. The only solution is reduced sewing speed (lower temperature, longer sewing times, increased piece cost).

Sewability, improvement of → Sewing thread lubricant.

Sewerage filter (clarification filters). Precoated filters for dry cleaning are used to clarify the contaminated solvent circulating in the machine with a “separating barrier” of filter aid which is constantly replenished; these are so-called precoated clarification filters in which the filter residue (filter cake) is deposited on a supporting substrate. A clarification filter consists of a pressure-resistant housing with a tight fitting lid. The supporting substrate, which exists in a variety of types, arrangements and forms, is accommodated inside the housing. When compared with other older, clarification processes (especially those with separators), the fact that modern clarification filters not only offer a greater throughput but also have a greater clarifying capacity is decisive. Clarification filters should ensure a continuous, trouble-free and uninterrupted initial filtration performance and should be easy to clean in the shortest possible time without much servicing. An adequate filtration capacity is a further requirement; if the surface area of the filter is too small, the clarification performance per unit time is reduced.

Some terms specific to clarification filters include:

a) Filter cake discharge: removal of the contaminated filter cake accumulated at the base of the vessel from the filter; this is particularly important for single-batch filters. The removal of obstinately adhering sludge can be assisted by a built-in agitator in the base of the filter or by the application of pump pressure.

b) Filter cake sinking time (in single-batch filters): the time required for the filter cake detached from the support medium to collect on the bottom of the filter vessel and its subsequent discharge. This takes 5–30 min depending on height of filter, type of filter aid, solvent used, and the concentration of grease in the solvent.

c) Filtration surface area: the surface area of clarification filters available for precoating with the filter coating. In the case of multi-batch filters, its size in m^2 serves to determine throughput performance (e.g. 1200–1500 $l/m^2/h$) and therefore the pump capacity. For the same throughput performance, this can be considerably lower for single-charge filters.

d) → Filter auxiliaries.

e) Filter cake: a deposit consisting of filter aid and filtered-out suspended matter (soil) which builds up on the supporting substrate after precoating (ground coat, initial coat) and subsequent use in clarifying filtration.

f) Button trap and lint filter: this is a coarse filter installed between the machine and the pump to prevent the passage of pins, buttons, hooks, coins, etc. which could damage the pump. This filter should also be fine enough to retain lint since the latter can only be removed from the actual filter by opening the lid due to the fact that it floats to the surface and cannot be discharged with the filter cake.

g) Backrinsing: this involves pumping solvent through the filter in the opposite direction to that used in filtration. Backrinsing is carried out with filters that are not self-cleaning or when operational breakdowns occur with self-cleaning filters. It is only carried out when there is no danger of blocking the supporting substrate beyond repair from inside. For filter models with plate-shaped elements where the connecting sleeves have small cross-sections, backrinsing can only act on a small part of the filtration surface area.

h) Self-cleaning: a filter in which the filter cake is detached completely from the supporting substrate and sinks as soon as the pump pressure falls to zero under normal operating conditions (i.e.: average batch contamination, low concentration of grease and water in the solvent, and the use of a filterable dry cleaning detergent). Plastic filters are also self-cleaning even with high water concentrations.

i) Rinsing action: during cleaning processes with solvents, the cleaning effect increases with increasing quantities of (uncontaminated) solvent flowing through the material per unit time, i.e. by a rinsing action. Intensive rinsing through the material saves dry cleaning detergent. It is for this reason that efforts are made in dry cleaning to achieve optimum filter performance.

k) Precoat (ground coat, initial coat): the quantity of filter aid pumped into the filter with the uncontaminated solvent which precoats the supporting substrate before the actual filtering operation is carried out. The precoat forms a separating barrier between contaminated and filtered solvent. During subsequent clarifying filtration, a filter cake is gradually deposited on the precoat.

Sewerage filter aid → Filter auxiliaries.

Sewerage filtering → Solvent filtration in dry cleaning.

Sewerage-filter system (clarification filter systems),

I. Filter screens (mainly multi-batch filters).

a) Textile sieves: filter bags or screens usually made from synthetic fibres (formerly cotton), fluted cloth filters (saves space due to greater surface area) as well as candle or column filters. For cleaning purposes, filter bags must be removed from the filter housing. Filter disks, of circular shape and covered with synthetic material, are attached in series to a rotating hollow shaft mounted in bearings through which the filtered solvent can flow out. Rotation causes the filter coat, mixed with contaminants, to be detached from the filter elements through centrifugal force.

b) Metal sieves: woven metal mesh (openings approx. 0.01 cm) or perforated metal sheets. Plane metal sieves can be cleaned with mechanical squeegee systems. Circular metal sieves, candle or tube filters consist of filter tubes suspended above a plate floor inside a filter cylinder. Diameter approx. 2–4 cm. Cleaning is carried out by backrinsing. Flexible metal mesh filters in tubular form are kept under tension by means of springs which are released to discharge the filter cake.

II. Leaf filters (mainly single-batch filters): the filter elements consist of layers of relatively thin leaves (metal or plastic mesh). During filtration, solvent flows through the filter elements, precoated with filter powder, into drainage channels between the leaves.

a) Plastic leaf filters. These are composite self-cleaning coated filters built up by the superimposition of single rectangular leaves. Spacers and central perforations facilitate throughput and solvent drainage.

b) Metal leaf filters. Single filtration through rectilinear leaf elements made with wire of a specific thickness, the distance between which determines the size of the lamellar spacing. The latter is also achieved by stringing together a slightly coiled wire and a straight wire to form a composite structure. Metal leaves of this kind are built up from bent leaf elements. As filter elements, compressed spiral metal springs are used. Through appropriate construction of the spirals, e.g. a staggered hexagonal arrangement, adequate lamellar spacing between the compressed spiral rings is made available. Filters of this type are cleaned by simple expansion (“expanding filter”) which allows the filter cake to be discharged. The expanding filter is ideal both as a single-batch and a multi-charge filter.

III. Cartridge filters: these are multi-charge filters consisting of a fluted paper filter with a filter aid and activated carbon in granular form. They are firmly enclosed in perforated sheet metal to provide a suitable size of insert cartridge for the filter housing. When the filtration pressure becomes too high, the filter must be replaced and the old cartridge is either disposed of or discarded.

Sewing silk Tightly twisted strong silk yarn made from degummed reeled silk or schappe silk by twisting 2 to 3 silk strands together and then combining several of the resulting threads by applying twist in the opposite direction. Uses: hand and machine sewing.

Sewing technology The sewing together of individual pieces of textile fabric to make up a batch for processing is an important operation in a textile finishing plant (Fig. 1), as is the sewing of end-cloths to the beginning and end of the batch. The adjoining ends must not be sewn on top of one another, i.e. the seam must not be thicker than the fabric itself. For this reason, pieces are sewn end-to-end using butted seam sew-

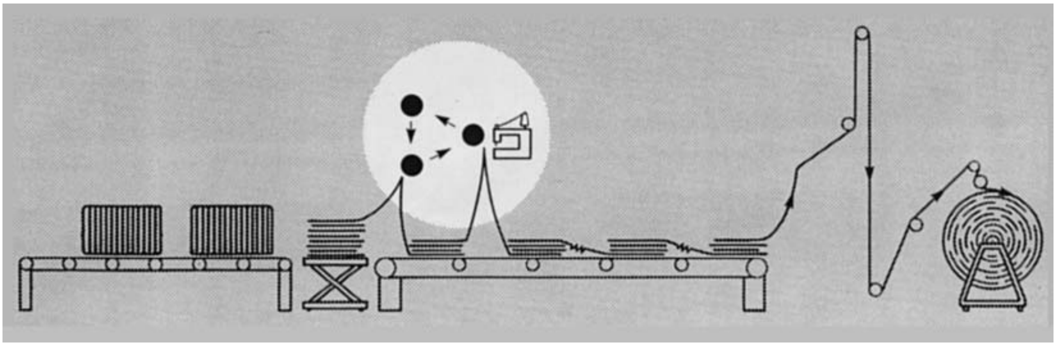


Fig. 1: Composing a batch by sewing the items piece to piece and rolling the batch together.

ing machines (Fig. 2). The seams need to be carefully sewn so that they do not tear during processing and cause break outs. Torn seams seriously reduce production. If, for example, a seam breaks during the passage of a fabric through a steamer, the machine has to be shut down completely and it may easily take more than 30 min before the machine is cool enough for an operative to enter the steamer and sew the broken out fabric ends together again. The steamer must then be heated up to the required temperature once more before production can be resumed which incurs even more downtime. Moreover, the guide rollers in processing machines can often be damaged by bending or warping due to piece ends from broken seams becoming wrapped around them.

Whilst seams must be strong in order to withstand the stresses and strains of processing, they must also be easy to separate. There are many sewing machines on the market capable of fulfilling this requirement. Special types of machines are also available for sewing wet goods. In order to produce individual seams in a textile finishing plant, portable machines are essential, and convenient transportable models are readily available for this purpose.

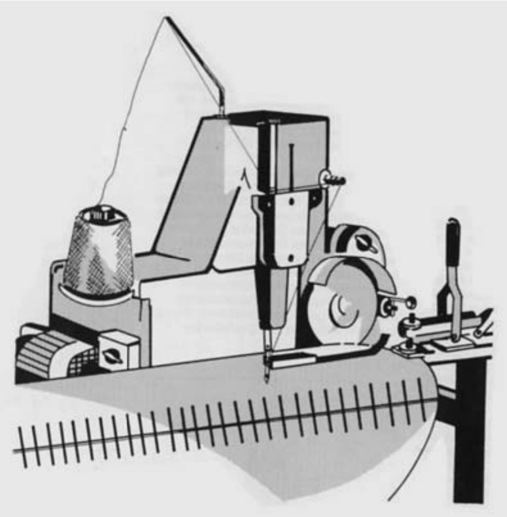


Fig. 2: Butt to butt sewing (Dohle).

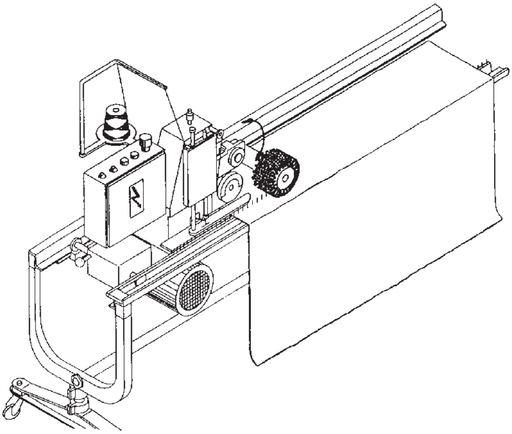


Fig. 3: Securing two piece ends in order to sew them together using a carriage-type sewing machine.

Apart from stationary, fixed head, high-speed sewing machines capable of 1500 stitches/min, so-called carriage type sewing machines are also used for sewing piece ends together. With this type of machine, both piece ends to be joined are held on parallel rows of pins (Fig. 3) and the sewing head travels along rails during the sewing operation. After the process is complete, the machine automatically sews back to the starting point. This type of sewing machine is particularly suitable for elastic materials since, in this case, it is not necessary to pull the material through a stationary sewing head by

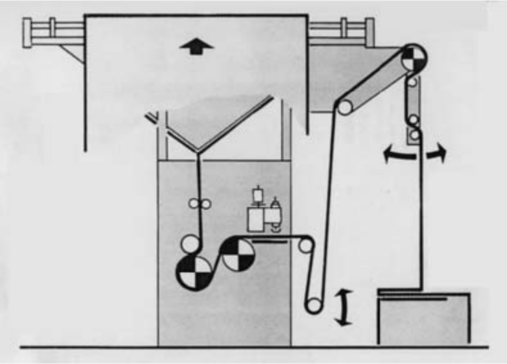


Fig. 4: Tubular sewing of both fabric selvedges.

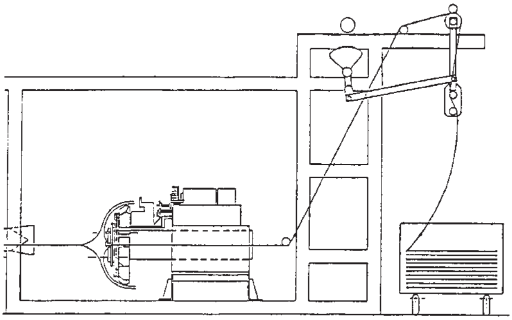


Fig. 5: Round stitching sewing machines for knitted tubular goods.

hand which could easily distort the fabric. By means of fabric scrays, the sewing operation can be integrated into a continuous finishing process. Various, particularly sensitive, woven and knitted fabrics have to be treated in so-called tubular form whereby the fabric is folded together (doubled) in the lengthwise direction and stitched edge-to-edge with special sewing machines, either continuously over the entire length (Fig. 4) or with individual stitches at periodic intervals. Circular sewing machines specifically designed for tubular knitgoods are also available (Fig. 5).

Sewing test in listing → Shade variation test for continuous dyeing.

Sewing thread A variety of textile yarn used for hand or machine sewing. The most important types of sewing thread include: mercerized cotton, silk-spun polyester, core-spun polyester (a core of polyester filament yarn with a cotton covering) and polyester staple. Sewing threads are numbered for size according to various systems (e.g. ticket number) where, generally speaking, the higher the number, the finer the sewing thread. → Sewability.

Sewing thread finishing An appropriate → Sewing thread lubricant is often applied to sewing threads as a finish in order to improve → Sewability performance.

Sewing thread lubricant Due to the increased demand for sewing threads made from synthetic fibres and the use of higher sewing speeds in industrial applications, sewing thread lubricants based on simple organic substances such as waxes or stearates are no longer sufficient to control the development of heat in the sewing needle, i.e. to provide a heat shield. For high sewing speeds, silicone-based products have been found to be particularly suitable.

Sew together In order to pass large batches made up of a number of pieces efficiently through the production process of textile finishing, the individual pieces are sewn together (→ Sewing technology, see Fig. 1). This is carried out on an industrial sewing machine.

S-Finish A term originally applied to the partial surface saponification of cellulose ester fibres (acetate and triacetate) by alkaline hydrolysis to reduce static charge and improve fabric handle.

→ Alkali treatment of polyester. Nowadays the term has also been adopted for an analogous treatment of polyester fibres in which a controlled partial saponification with alkali (NaOH) is carried out to achieve a silk-like lustre and handle, reduce the build up of static charges and improve anti-soil properties. Degradation of the fibre surface layer typically results in a weight loss of 12–14%. Precise control of the process is necessary in order to prevent excessive loss of tensile strength. Quaternary ammonium compounds are used as accelerators in the alkali treatment.

SFR Abbreviation for "Svenska Färgeritekniska Riksförbundet" = Swedish Association of Textile Engineers and Colourists; → Technical and professional organizations.

SFS Abbreviation for "Suomen Standardisoimisliitto" = Finnish Standards Organization; → Technical and professional organizations.

Shade build-up,

I. To achieve a uniform shade build-up in dyeing, combinations of dyes having similar rates of exhaustion should be used so that they will be taken up by the fibre as uniformly as possible in a specified period of time over a specified rise in temperature. With such combinations, the shade should initially appear lighter (after a short dyeing time and low dyeing temperature) but without any significant preferential exhaustion of one particular component in the combination nor, on the other hand, should there be incomplete exhaustion of one of the combination dyes over longer dyeing times or at higher dyeing temperatures.

II. Dyeing of polyamide or acrylic fibres with dyes or dye combinations at increasing concentrations. The purpose here is to establish the depth of shade which corressponds to the maximum build up of the particular dye or combination.

Shade number The number allocated to each of the 24 hues in the → Chromatic circle.

Shade of colour,

I. (position in colour space). In practice, this involves general sensations to → Colour of all kinds. So-called → Chromatic colour sensations are meant here, i.e. spectral colours defined by dominant wavelengths in contrast to → Achromatic colours. Shades can be specified by reference to visual colour standards, e.g. colour atlases. The → Chromatic circle provides a means of allocating a colour number to one particular shade in a retrogressive range of all shades and allows each shade to be defined with the appropriate letter of the → Grey series. Instead of dominant wavelength, the wavelength derived from its range is specified and the shade T corresponds at the same time to the colour number of the Ostwald chromatic circle. The ratio between the dominant wavelength and T follows from the chromaticity diagram in accordance with DIN draft 6 164. T allows the assertion to be made that the shade between any two colours T_1 and T_2, with the same saturation S and the same blackness value D, is proportional to the difference U and the difference between the respective values of T:

$$\frac{T_1 - T_2}{U} = \text{const.}$$

i.e. irrespective of T_1 as long as $D_1 = D_2$ and $S_1 = S_2$. The same considerations apply to → Lightness and → Saturation.

II. (dyeing) → Colour.

Shade reproducibility The possibility of achieving exact reproducibility of shade from the same dyeing recipe. In practice, two main problems influence shade reproducibility: on the one hand, poor reproducibility may be due to errors in weighing out the dyes specified in the recipe or inaccurate volume metering on the other. Moreover, variations in substrate pretreatment or the quality and/or source of the substrate itself can also influence shade reproducibility.

Shade, to The verb “to shade” is a term used in dyeing to bring about relatively small changes in the colour of a substrate by adding further small amounts of dye/s in order to match a given standard shade more accurately. → Shading corrections in dyeing.

Shade variation A coloristic term for a difference in colour (usually between a particular batch and a standard) which can also be expressed numerically by means of computer colour measurement. A colour difference expressed in ΔE units indicates whether a particular sample is the same shade as a standard pattern, i.e. whether it is a close enough match within specified colour tolerances. Variations in shade between a particular sample and a standard pattern are determined quantitatively.

Shade variation, colour change A change of colour following the completion of an order for a particular shade in dyeing on a continuous dyeing plant, or a colour way in textile printing, or a colour change in the mass coloration of man-made fibres.

Shade variation test for continuous dyeing The (visual or instrumental) assessment of fabric samples to check → Shade variation (side-to-centre shade variation or listing) should only be carried out after dried fabric has been allowed sufficient time to cool down completely. It is essential here to distinguish between genuine side-to-centre shade variation and shade variations caused by optical effects such as:

- colour differences due to lustre or roughness,
- a change in the angle of, e.g. two twill weave fabrics at a seam,
- variations in fabric density,
- optical colour differences due to a flatter or more plastic appearance of the material itself,
- differences in depth of colour in open-weave fabrics,
- differences in depth of colour due to variations in singeing.

A useful method to determine the source of side-to-centre shade variation is to sew various test samples (Fig.)

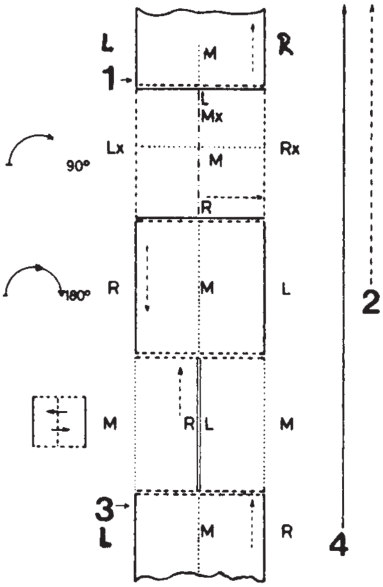


Fig.: Diagram showing the sewing-in of staggered fabric sections in a fabric web.
L = left; M = middle; R = right; Lx = left, rotated by 90°; Mx = middle, rotated by 90°; Rx = right, rotated by 90°; 1 = normal run of goods; 2 = original run of goods; 3 = normal run of goods; 4 = run of goods in test.

of the same fabric, which have been rotated through appropriate angles relative to the normal fabric direction, into the middle of a production dye batch, and then compare the results after dyeing.

Evaluation of the fabric test samples is carried out as follows:

1. Test samples M-R/M-L provide information on differences in shade and depth between the sides and the centre of the fabric.
2. Test samples R-L allow a comparison between the right and left hand sides of the fabric to be made.
3. Comparison of test samples Mx-Rx/Mx-Lx with M-R/M-L: if, for example, the edge Rx of the piece which has been rotated through 90° and R are lighter or darker than the centre Mx and M to the same extent, then the cause of side-to-centre shade variation is most probably due to a) unequal nip pressure of the padder rolls or b) uneven drying or thermosol treatment. If, on the other hand, it is established that the lighter or darker edges of test samples M-R/M-L do not correspond to test samples Mx-Rx/Mx-Lx, then it must be assumed that the fault lies a) in fabric construction or b) in fabric pretreatment.
4. By comparing the test samples M-R/M-L for normal running fabric with the test samples M-L/M-R for pieces rotated through 180°, information is obtained as to whether, for example, a particular defect in the form of a lighter or darker side of the fabric only needs to be sought in a) unequal pressure of the padder rolls or uneven drying resp. Thermosol treatment or b) in fabric construction or pretreatment.

Shading The appearance of colour variations in cut-pile carpets composed of synthetic fibres caused by changes in pile orientation (shadowing); crushing of the pile. The pile density (in the pile direction) of a pile carpet varies between the area of shading and its immediate surroundings due to the rotation of pile threads in different directions about their own axis.

In general, two different kinds of shading are encountered in practice:

a) In-service shading: in this case, the pile density resp. yarn twist is unbalanced over the entire surface of the carpet. Friction between the sides of adjacent pile threads delays the recovery of twist equilibrium; this friction is reduced by treading, brushing and vacuum cleaning. The elimination of friction and the untwisting process are promoted by a change in moisture content so that a reversible change in length results. A state of equilibrium for the individual pile threads is achieved over varying lengths of time dependent on differences in moisture content.

b) Shading in production: localized variations in pile density are produced and fixed, for example, by poor cutting of the pile; these variations are only overcome in final finishing (without any real levelling) by uniform pile processing and may become visible once again when the carpet is in use.

Testing: equipment for carrying out shading tests consists of a modified castor chair apparatus. In contrast to a standardized test apparatus, the castors do not roll over the material but execute milling actions in different directions. The carpet test specimen is moistened to different degrees and covered with film so that the special “shading-promoting” microclimate is maintained during the test. Shading is produced by the milling action of the chair castors within 90 min. If the material is largely resistant to shading, however, the pile will only exhibit a uniform flattening without any localized change in pile direction (Bendt and Huchzermeyer).

Shading corrections in dyeing, shading corrections in dyeing are carried out by “topping” the basic dyeing with suitable dyes as necessary in order to match a given shade more accurately.

Shadow effects → Dyeing of ombré or shaded effects.

Shag carpet A carpet with a long loose pile of manufactured fibres. Shag carpets are made with relatively coarse cut (or a combination of cut and uncut) twisted pile generally 2.5 to 5 cm in length. Because of its height, the pile tends to lie in a somewhat random fashion.

Shaker process → Powder-scatter coloration technique.

Shampoo cleaning of carpets and upholstery → Foam cleaning.

Shampooing → Foam cleaning.

Shampooing, colour fastness to Colour fastness of textile floorcoverings to shampooing or → Foam cleaning.

Shampooing method → Foam cleaning.

Shampoos Products for the → Foam cleaning (shampooing) of textile floorcoverings and upholstered furniture (Fig.).

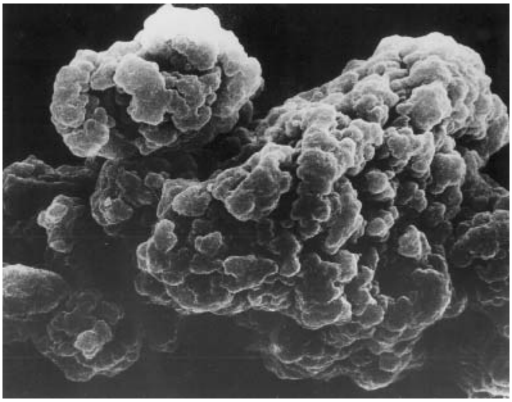


Fig.: 900 x enlargement of a dry shampoo for cleaning carpets.

Shantung Shantung derives its name from the Chinese province where it originated. A rough plain weave silk fabric made of uneven yarns which gives the material an irregular textured appearance due to the use of thicker yarns or long slubs in the weft. Originally made from wild (tussah) silk on hand looms in the Shandong (Shantung) province of China. Nowadays it may be produced from a) pure silk, in which case the yarns retain all knots, slubs and other imperfections, b) synthetic fibres or c) cotton. An imitation silk shantung has also been produced using lower quality bourette silk.

Shape memory The ability of a garment or other textile article to hold its manufactured shape as a result of durable-press finishing. These materials are able to recover their original set shape again after changes induced by e.g. laundering, since the resin finish is only cured after the fabric has been made up into the final shape of the garment.

Shape retention → Dimensional stability.

Shape stabilized cotton shirts

Non-iron shirts, or "Shape Stabilized Shirts", were put on the market in 1993 in Japan and soon enjoyed a boom period for about 3 years. After a short-term selling recession, sales have recovered and are now at a highly stabilized level, as shown in Tab.

SSP is a non-iron process, in which liquid ammonia pretreatment, post-cure resin and a high-level sewing system play important roles. From eight million pieces produced, five million are polyester-cotton 50–50 blend and three million are 100% cotton. The three million means that after a long history of development, 100% cotton non-iron shirts have become daily commodities for consumers. With VP, formaldehyde vapour and sulphur dioxide vapour are applied to make-up shirts in a closed system. Because the crosslinking reactions are performed after sewing, the VP process can be assumed to be a sort of post-cure process. The other non-iron processes are pre-cured types that do not show a high W&W performance compared to SSP or VP. The production procedure for SSP is the combination of liquid ammonia and post-cure resin finishing, shown as follows:

SSP (Post-cure)	Regular finish (Pre-cure)
Bleaching	Bleaching
↓	↓
Liquid ammonia treatment	Mercerisation
↓	↓
Resin application (special recipe)	Resin application
↓	↓
Sewing (with special care)	**Curing**
↓	↓
Pressing	Sewing
↓	↓
Curing	Pressing

Fig. 1 shows a typical liquid ammonia process of an ammonia-dry system. The fabric passes the main chamber, containing liquid ammonia for a few seconds, and then the liquid ammonia is immediately removed by a heat cylinder. Almost all the ammonia is recovered and recycled. No ammonia remains on the fabric at the end of processing.

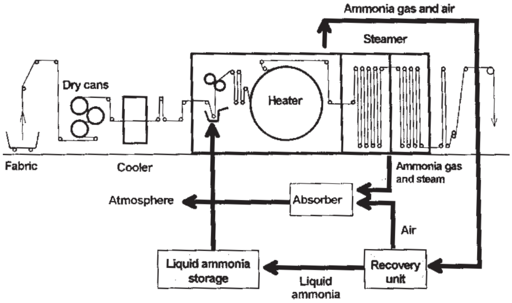


Fig. 1: A typical liquid ammonia processing unit of an ammonia-dry system.

Changes in the cotton fibre after liquid ammonia treatment:

- The fibre becomes deconvoluted and its surface is smoothed.
- The cross section of the fibre becomes round and the hollow space at the centre of the fibre (lumen) becomes smaller.
- The fibrils become ordered and average fibril distances appear.
- The degree of crystallinity decreases.
- The crystal structure changes to a rather expanded state.

Effects of liquid ammonia treatment on a cotton fabric:

- low shrinkage after washing.
- increase in shrink resistance.
- increase in the elasticity of each fibre.
- softer to the touch.
- increase in strength.

Total supply 80	Non-iron 46	Domestic 18	SSP (Nisshinbo)	8
			VP (Toyobo, etc.)	4
			Pre-cured	6
		Imported 28	Pre-cured	28
	Regular 34	Domestic		27
		Imported		7

Tab.: Roughly-estimated yearly supply of shirts in Japan (million pieces).

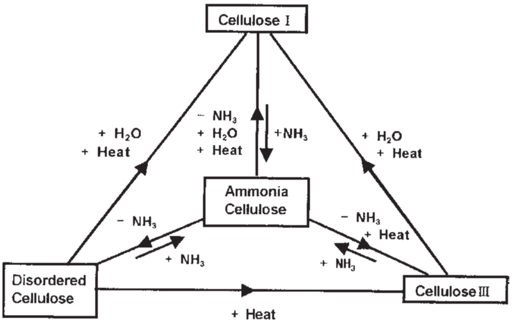
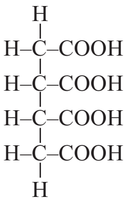


Fig. 2: The changes in the crystal structure.

As can be seen in the model (Fig. 2), cellulose I (natural cellulose) becomes ammonia cellulose through liquid ammonia treatment. Then it changes to cellulose III on removal of the ammonia through heat treatment. Close observation of the model has shown that cellulose III re-converts into cellulose I under hot water and heat treatment.

Formaldehyde-free crosslinking: There is a need to replace formaldehyde-releasing agents now in widespread use for imparting flat drying properties to cotton fabrics. Recent efforts to replace these formaldehyde adducts of cyclic amides have focused on polycarboxylic acids. Butanetetracarboxylic acid (BTCA) and citric acid have been the most successful to date. Formation of ester linkages to cotton is believed to involve intermediate acid anhydride formation. The crosslinking agents must have one more carboxylic acid group per molecule than the number of required attachments to cellulose. Thus, the maximum number of attachments to cellulose for BTCA is three and for citric acid two. The properties of the modified cotton fabrics are good. BTCA, which gives a high level of resilience and more durability to laundering, is still too expensive to compete with the conventional formaldehyde-containing agents. Also the best catalyst, sodium hypophosphite, causes shade changes with sulphur dyes. Citric acid is less expensive but less durable and can have fabric yellowing problems.



$$\begin{array}{l} \;\;\;\;\;\;\;\;H \\ \;\;\;\;\;\;\;\;| \\ H-C-COOH \\ \;\;\;\;\;\;\;\;| \\ H-C-COOH \\ \;\;\;\;\;\;\;\;| \\ H-C-COOH \\ \;\;\;\;\;\;\;\;| \\ H-C-COOH \\ \;\;\;\;\;\;\;\;| \\ \;\;\;\;\;\;\;\;H \end{array}$$

BTCA

Recently improvements have been made to the polycarboxylic acid finishing system. A three component curing system containing triethanolamine, malic acid and sodium hypophosphite substantially increased the strength and abrasion resistance of BTCA treated cotton fabrics. The results suggested that BTCA can esterify hydroxyl groups of triethanolamine and malic acid as well as cellulose to produce a graft copolymer of cellulose with a more open structure and flexible three-dimensional molecular network than is obtainable with BTCA alone. Malic acid is comparable to citric acid in availability, cost and ecological acceptability. When activated by moderate amounts of BTCA it can serve as a non-yellowing formaldehyde-free durable press finishing agent for cotton. The activating effect of BTCA may be due to the esterification of the α-hydroxyl group of malic acid by BTCA, thus eliminating interference of that hydroxyl group with esterification and crosslinking of cotton. Tartaric acid was used as a coreactive additive with citric acid to improve both the textile performance and whiteness imparted by this durable press agent.

Shattering strength → Bursting strength.

Shaving An alternative term for → Emerizing, i.e. a mechanical treatment of loomstate woven cotton fabrics containing a high proportion of husks with fine-toothed blades or emerizing rollers.

Shear force In the case of textile fibres and fabrics, the effect of forces acting at right angles to their longitudinal axis.

With the Kawabata Evaluation System (KES-F-1) for assessing the handle of textile fabrics, a fabric specimen can be gripped by means of two clamping devices (spaced 5 cm apart) with the threads in parallel alignment (Fig. 1). During the test, the front clamping device is released by a coupling so that a pretensioning force is applied to the specimen. A shear deformation is produced by parallel displacement of the rear clamp through a shear angle of ± 8°. Three cycles are allowed to proceed in order to obtain a complete shear angle curve. During the measurement, the rear clamp is displaced relative to, and parallel to, the front clamping device at a rate of 0.417 mm/s. If a shear angle of + 8° is reached, the direction of movement of the rear metal block is automatically reversed and the test specimen relieved of stress up to 0° distortion. It is then subjected to distortion in the opposite direction up to a maximum angle of – 8° and relieved of stress once more.

Three parameters for the shear-elastic characteristics of the test fabric are read off the recorded curves (Fig. 2):

1. Shear stiffness (rise in shear stress/shear angle curve); G [N/m].
2. Spread of shear hysteresis at a shear angle of 0.5°; 2 HG [N/m].
3. Spread of shear hysteresis at a shear angle of 5°, or 3° for knitted fabrics; 2 HG5 [N/m] resp. 2 HG3 [N/m].

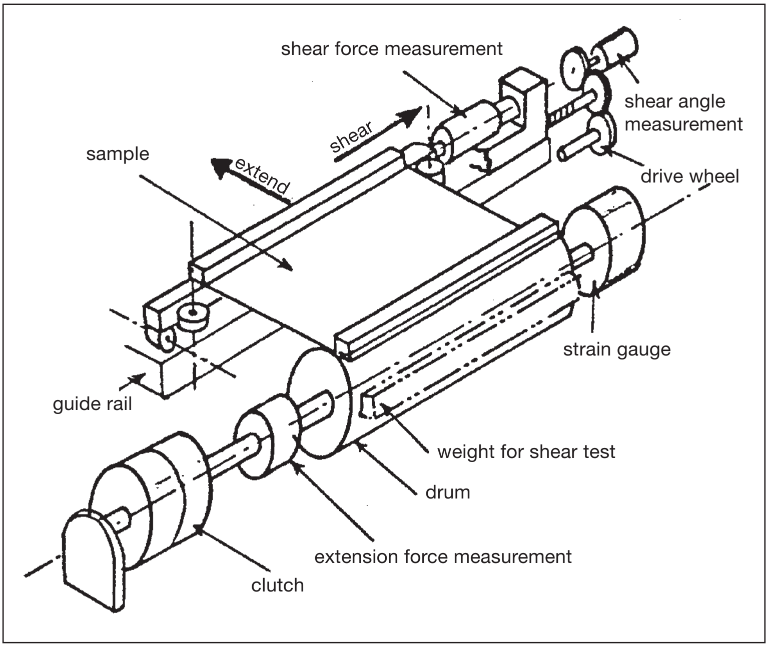


Fig. 1: A testing device for both tensile and shear elastic poperties (KES-F-1).

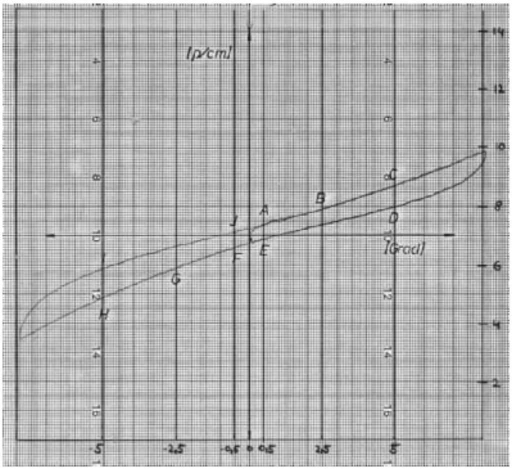


Fig. 2: Shearing stress curves.

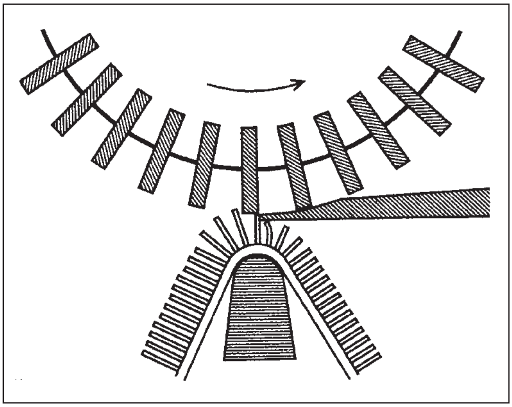


Fig. 1: A greatly simplified diagram showing the shearing process. The pile fabric is guided across the shearing table and is sheared between the shearing blades mounted on a cylinder (wrongly known as spiral blades) and a fixed blade.

The shear stiffness and the shear hysteresis at a shear angle of 5° are taken as a measure for the mobility of the yarns when sliding over one another.

Shearing (cropping). Unlike cutting (→ Cutting in textile finishing), shearing produces a characteristic finish on textile fabrics (Fig. 1). The extent to which a particular fabric is sheared varies according to requirements, e.g.:

- light shearing: e.g. pretreatment of grey cotton fabrics,
- normal shearing: close cropping of light fabrics,
- heavy shearing: e.g. shearing of velour pile or knitted loops.

Shearing usually involves a number of cuts (e.g. twice on the right and once on the left).

The fine projecting fibres present on the surface of flat fabrics may also be removed by cutting, i.e. by shearing, instead of singeing. In addition, the irregular fleecy layer formed during raising treatments has to be trimmed (sheared) to a uniform height. The shearing of

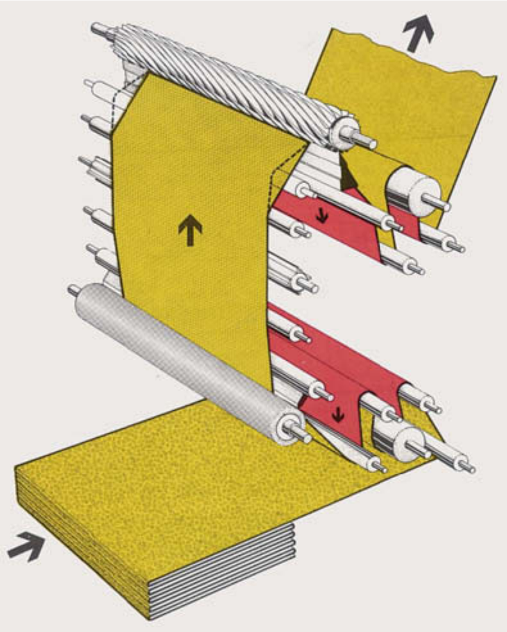


Fig. 2: A Lamperti shearing machine.

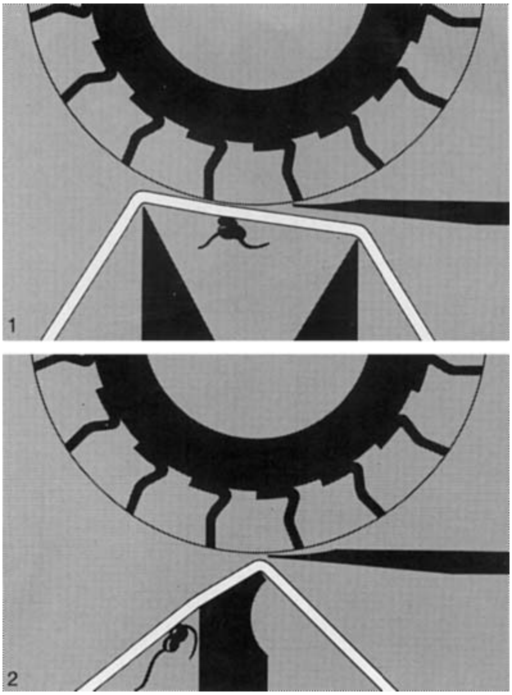


Fig. 3: Types of shearing table (according to Vollenweider): hollow table (1) and pointed table (2).

dry, or occasionally slightly dampened, fabric is carried out on machines with rapidly revolving cutting blades (shearing cylinder) which have a similar action to a lawn mower (Fig. 2). In this operation, the fabric to be sheared is drawn between a shearing bed and the shearing device which consists of a shearing cylinder and a ledger blade. The shearing table may be pointed or hollow (Fig. 3). In modern machines, it is possible to switch from one type to the other.

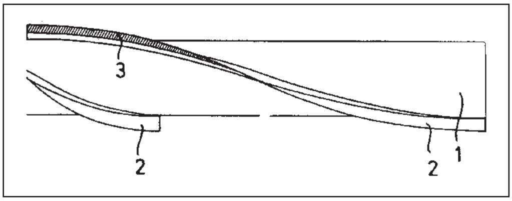


Fig. 4: A shearing roller with helical steel blades (2) and file profile (3) (according to Heusch).

The shearing roller has 24 helical steel blades around its circumference (Fig. 4). The distance between the shearing device and the shearing table is adjustable so that it can be adapted to the thickness of the fabric and the depth of cut required. One or several shearing devices may be provided depending on the particular type of shearing machine. They are arranged in such a way that both sides of the fabric can be sheared at the same time. Rotating brushes are installed both in front of, as well as behind, the shearing device to align the fibres correctly for shearing and remove cut ends after shearing. For velour qualities, a card wire brush roller (velour lifter) is used instead of a normal brush roller. In order to prevent the shearing device heating up during operation, a felt saturated with oil (lubricating felt) is placed against the shearing cylinder. Seams must not be allowed to pass under the shearing device otherwise they would be cut open. For this reason, either the shearing device is raised or the shearing bed lowered before the seam reaches the shearing point. This function is controlled automatically on modern machines by means of a seam detector. Where high productivity is required, several shearing machines are often run in tandem as a continuous production line. This procedure allows both sides of the fabric to be sheared. In some large plants, raising machines and shearing machines are combined in a single production line.

For the finishing of long-pile materials, combined polishing/shearing machines are used. The polishing effect is produced by means of a heated rotating cylinder (pile rotor). With certain structured materials, e.g. curtaining fabrics, the floating warp and weft threads have to be cropped. Suitable shearing machines for this purpose are equipped with a special system to align the threads by means of compressed air. Special models have also been designed for knitted fabrics. In order to cut longitudinal patterns in the pile, Vollenweider has substituted the fixed shearing bed by one composed of metal leaves. Depending on the position of the latter, the shearing knives will only come into contact with the pile in specific areas. In addition to these so-called longitudinal shearing machines, transverse shearing machines are also available. The axle of the shearing cylinder runs parallel to the warp and direction of the running fabric. These machines are regarded as somewhat antiquated. Specially constructed shearing machines are now available for shearing patterns in the material.

The shearing cylinder generally consists of a thick-walled hollow cylinder with a bearing journal firmly inserted at both ends. For small diameter cylinders, however, solid steel cylinders are usually employed. Depending on the particular design, the cylinder has 10–24 or, in the case of carpet shearing machines, up to 40 spiral blades mounted around its circumference. These are attached to the ends of the cylinder with screws in side recesses. The shearing cylinder must not be unbalanced in any way nor should there be any eccentricity in running, otherwise a uniform shearing action can no longer be ensured. The speed of the cylinder during shearing is between 500–2000 rpm depending on the particular article being sheared.

The cutting power of the shearing device is measured by the number of cuts per minute. This figure is obtained by multiplying the number of spiral cutting blades by the rpm of the cylinder. The “specific shear value” is given by the number of cuts per cm of material. It is obtained by dividing the cutting power by the fabric speed in cm/min. The specific shear value required depends in each case on the material to be sheared. In order to achieve the highest possible productivity for a given specific shear value, it is necessary to set both the cylinder speed as well as the fabric speed as high as possible. There is an upper limit to this, however. If the cylinder speed is set too high, a so-called “spoke-wheel effect” occurs: i.e. with a spoked wheel, it is impossible to thrust an object between the spokes when the speed is too high. The same situation applies to fibres during shearing which, at excessively high cylinder speeds, no longer have sufficient time to pass between the spiral blades. The shearing result therefore becomes poor again beyond a certain cutting power due to the fact that the fibres are only turned over, not cropped, by the rapidly rotating shearing cylinder.

Shearing spirals are supplied by machine makers in sizes of 1.1–2.0 mm. They are made in a variety of profiles which include:

- bayonet spirals,
- angle spirals,
- cleaning spirals; breaking spirals,
- mortice spirals,
- U or double spirals,
- knee spirals,
- concave spirals.

Both the knee and concave spirals, as well as the cleaning and breaking spirals are in common use in shearing machines for cleaning and shearing of textile fabrics. In special cases, e.g. for shearing carpets, mortice spirals are also employed in sizes up to 4 mm. Depending on their profile, the spirals have different cutting or wedge angles. Thus, shearing spirals, in which the cutting edges run perpendicular to the cylinder axle, have obtuse cutting angles (> 90°). Spirals, in which the cutting edges run in a straight line diagonally to the cylinder axle, have acute cutting edges (< 90°): e.g. knee or mortice spirals. The concave spiral has an even more acute angle. It is bent in accordance with a specific logarithmic spiral (hollow-ground form), so that the cutting angle does not change during the course of shearing. This fulfils the requirements for constantly uniform cutting characteristics. The shearing force on individual fibres can prove more effective with an acute, well-ground cutting angle. Due to the acute cutting angle, the force supplied by the shearing cylinder acts across a narrow line at right angles to the longitudinal axis of the fibre. With an obtuse cutting angle, on the other hand, the same force is distributed over a greater surface area.

Secure seating of the spirals is extremely important for trouble-free operation of the shearing cylinder. The commonly used angle, knee or concave spirals are provided with an angled foot or support limb which is bent in such a way that it matches the curvature of the cylinder and always points in the opposite direction to the rotation of the cylinder in order to absorb the pressure forces which develop during the shearing of fibres. Because they are wrapped around the cylinder several times, such spirals already have adequate purchase. It is therefore sufficient to secure the spirals simply by means of end screws in the side recesses. For spirals having a narrow gradient, additional screws are used, spaced at regular intervals, in order to attach the foot of the spiral to the cylinder body. In all cases, a more secure seating of the spirals is achieved the more often or more steeply inclined they are wound around the cylinder. At the same time, however, the pitch angle and consequently the cutting angle, is also increased. This can be precalculated from the length of the cylinder and the spirals. The number of windings increases for small diameter cylinders, higher pitch angles, or longer lengths of cylinder. A spiral with a single turn around the cylinder has only one cutting point whilst one with two turns already has two, and so on. Nevertheless, each spiral makes only a single cut during one revolution of the cylinder. For spirals with a single turn, the cut runs once along the length of the ledger blade during one revolution whereas, for a spiral with two turns, each of the two cutting points is only displaced by half the length of the ledger blade, i.e. only one cut per revolution occurs in this case also. A greater number of turns, which may be obtained by increasing the pitch angle, does not therefore bring any increase in performance. A greater pitch or cutting angle still has the disadvantage that the fibres could more easily evade the cutting action under these circumstances with consequent impairment of the shearing effect. With higher cutting angles, the effective cutting force perpendicular to the cutting edge of the ledger blade decreases in favour of the displacement force which acts parallel to the edge of the ledger blade (Fig. 5).

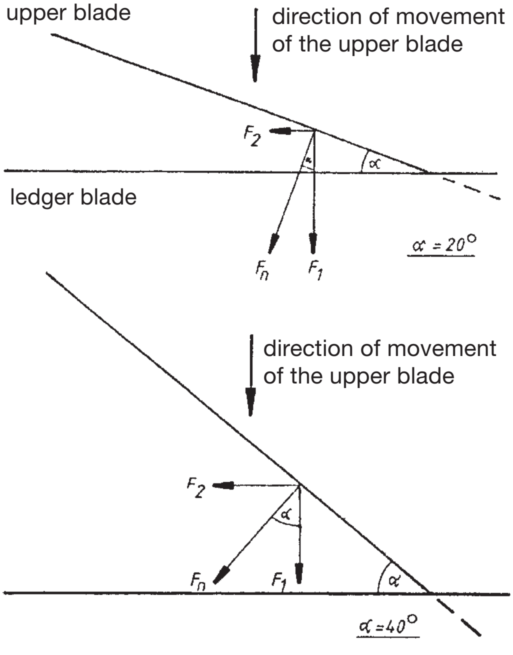


Fig. 5: Cutting and displacement forces during shearing.

During perpendicular movement of the shearing cylinder against the cutting edge of the ledger blade, the normal force F_n which runs perpendicular to the cutting edge of the upper cutting blade is effective. F_n is equally great at all points along the cutting edge of the upper blade. This force is made up of two components, i.e. the cutting force F_1 (perpendicular to the edge of the ledger blade) and the displacement force F_2 (perpendicular to the cutting force and therefore parallel to the cutting edge of the ledger blade). The application lines of F_n and F_1 include the angle again. If the pitch angles or cutting angles are known, the respective ratios of the sizes of F_1 and F_2 may be calculated as follows:

$$F_1 = F_n \cdot \cos \alpha$$
$$F_2 = F_n \cdot \sin \alpha$$

Since the value of F_n is equally great in both cases, it can be said that F_1 and F_2 behave like the cosine and sine of the pitch angle. The frictional forces between the cutting edges of the upper blade and ledger blade and the fibre, as well as the stiffness of the fibres act against the displacement force (Fig. 6).

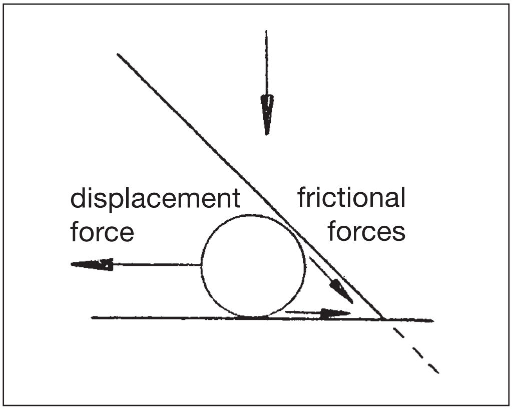


Fig. 6: Opposing forces during shearing which arise because of friction of the fibres and stiffness of the fibres.

Since the frictional forces are, among other things, also dependent on the pressure of the interfaces on one another, they become more effective the higher the cutting force perpendicular to the cutting edge of the ledger blade, i.e. the flatter the pitch angle. At the same time, the displacement force is smaller for a flatter pitch angle. Consequently, the pitch angle must be kept so small that the frictional forces reinforced by the cutting force are stronger than the displacement force. In the case of very soft and smooth fibres, such as cotton or fine synthetic fibres, the pitch would have to be so flat because of the low stiffness and low coefficients of friction, that firm seating of the spirals could no longer be guaranteed. In order to oppose the displacement force in such cases, the cutting edges are milled cut. Depending on the particular design of shearing cylinder, the spirals are secured to the cylinder body at pitch angles of 19–28°. Milled cut spirals with flat pitch angles are chiefly used for shearing low-pile fabrics such as velvet, knitted loop plush, etc. Smooth spirals are only used in shearing devices with a hollow shearing bed as well as for shearing lace and curtaining materials since, in this case, the teeth of a milled cut could scratch the surface of the material.

If the cutting edges have been produced with a milled cut, it is possible to mount spirals intended for shearing smooth and soft fibres at a higher pitch angle. Depending on how many milled cuts there are on the cutting edge of the spiral, a distinction is made between:

– extra coarse milled cut: i.e. approx. 7 milled cuts/cm,
– coarse milled cut: i.e. approx. 9 milled cuts/cm,
– semi-coarse milled cut: i.e. approx. 13 milled cuts/cm,
– semi-fine milled cut: approx. 15 milled cuts/cm,
– fine milled cut: i.e. approx. 18 milled cuts/cm,
– extra fine milled cut: i.e. approx. 22 milled cuts/cm.

The number of milled cuts is guided by the fineness of shearing and the thickness of the fibres to be sheared. Shearing spirals for shearing carpets usually have 9 milled cuts/cm; on the other hand, spirals with 18 or 22 milled cuts/cm are selected for worsted fabrics. As far as the shape of the milled cut is concerned, a distinction is made between milled cuts with a large milled cut spiral angle and those with a small milled cut angle. With the former type (conventional form), the fibres to be sheared slide first of all as far as the wedge-shaped serration where they are then cropped in tufts. In this process, it may happen that before reaching the wedge-shaped serration, the short fibres slip under the leading milled cut edge and are not sheared. Among those fibres that are actually sheared are some that may have had a longer slide path than those which reached the wedge-shaped serration at the outset. The quality of shearing is more uniform the shorter the slide path along the cutting edge of the ledger blade. Such a shortening of the slide path can be achieved with the aid of a finer milled cut or a higher pitch of the spirals.

With a milled cut profile having a small milled cut spiral angle (“patent milled cut” of Heusch in Aachen), the milled cut spiral angle is either 0° or it is kept so small that the frictional forces between the fibre and the cutting edges of the pair of blades are lower in every case than the forces of lateral displacement. The fibres are then cropped in their respective positions without sliding. A more uniform pile height is obtained in this way. Since it is generally only the wedge-shaped serrations that have a cutting function for milled cut profiles with a large cutting angle, and the surfaces of the serrations are hardly used for cutting, the extent of wear within the wedge-shaped serration may, under certain circumstances, be greater because the fibres gathered into tufts at this point require relatively higher cutting forces. With small milled cut spiral angles, the work of cutting is distributed over the entire milled cut wedge cutting area. Wear of the cutting surfaces is, therefore, more uniform and also less marked.

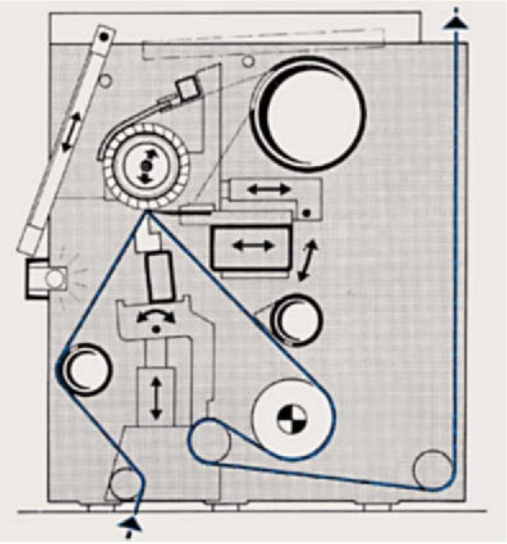


Fig. 7: A Menschner shearing machine.

The ledger blade is a 10–12 cm wide knife blade, 3–6 mm thick, corresponding in length to the width of the shearing machine (Fig. 7), which is ground on its underside for approx. 3 cm towards the cutting edge. In this way, an absolutely uniform contact surface between the cutting edge of the ledger blade and the fabric is achieved. On the side opposite the cutting edge, the ledger blade is attached by screws or clamps to the so-called blade carrier ledge on the ledger blade support beam. It is also important for the cutting angle of the ledger blade to be particularly small in order to obtain the cleanest possible shear. An acute cutting angle is obtained, on the one hand, by bevelling the leading edge by 15–45° depending on the type of machine and, on the other hand, by the hollow ground channel on the upper side of the blade. The greater the bevel of the leading edge, the more acute the cutting angle. An acute angle is more sensitive, however, and wears more quickly. In addition, such a cutting edge is more likely to overheat and burn out since it has a lower thermal capacity (less mass) than a blunt and thicker cutting edge. When the spirals of the shearing cylinder work against the ledger blade, the thinner cutting edge can absorb less heat of friction causing the temperature to rise more quickly. The size of the bevelling angle also depends on the design of the shearing bed. In all cases, the gap between the leading edge of the ledger blade and the shearing bed should increase in size towards the base. If this is not the case, fibre blockages can occur especially during the shearing of pile fabrics with a dense pile. In this case, the fibres already undergo bending prior to shearing and thus escape cutting. The hollow-ground upper channel is obtained by grinding with the shearing cylinder. For this purpose, the shearing cylinder is brought into such a position that the lowest point of the cylinder lies 2 mm behind the leading edge of the ledger blade. It is then allowed to rotate in the opposite direction to normal shearing at approx.

250 rpm and traverse to each side by 5 mm. By moderate pressure of the cylinder on the ledger blade with the addition of a suitable abrasive, it is allowed to work into the ledger blade until its leading edge has been ground to the required height (0.2–1.2 mm). The cylinder is then drawn forward again by 1 mm for shearing.

The hardness of the cutting edge must be uniform along the entire length of the ledger blade. Soft areas wear down more quickly during grinding and shearing so that thinner places develop in the ledger blade in these areas. This produces lengthwise stripes in the fabric during shearing. Since the cutting edge of the ledger blade generally exhibits a lower hardness than the spirals of the shearing cylinder, the wear is mainly at the expense of the former. This makes good sense, since it is less expensive to regrind a ledger blade than a shearing cylinder. During regrinding of the ledger blade, i.e. so-called whetting or sharpening, the shearing cylinder is lifted out of its bearings and, depending on the particular machine, the shearing bed is lowered. Alternatively, the shearing device is raised to allow free access to the ledger blade. A petroleum stone (i.e. a grinding stone moistened with petroleum) is then drawn along the leading edge of the ledger blade. In this process, the stone is applied in the same diagonal position as the original bevel of the ledger blade. This operation is continued until a fine burr has formed on its upper edge which may be detected by feeling with the thumb. After this, the shearing cylinder is lowered into its bearings again and the burr removed by rotating the cylinder in the shearing direction. If it no longer proves possible to produce a good shearing result by sharpening the ledger blade in this way, then the spirals themselves are blunt. In this case, it is necessary to regrind the entire shearing device.

Depending on the fabric, a pileless shearing as with milled cloth or a levelling of the cloth surface as with velvets might be necessary. The shearing task will mostly be conducted at the end of a finishing process. Only pile fabrics such as plushes, velvets, etc. are being sheared in greige state before dyeing. The shearing process influences the appearance of the cloth surface positively in such a way that hairiness of milled cloth such as flannels will be removed, thus avoiding the detrimental pilling effect, as well as providing an even pile appearance on pile articles like plushes, velvets or even milled cloth, blanket fabrics and so on, by levelling the cloth surface. Depending on the fabric to be sheared a shearing cylinder with 18, 20 to 24 spirals will be used. According to the fabric quality and the required shearing result, shearing lines enabling the shearing in several passages right and left are being used. For the finishing of pile fabrics such as plushes, fur imitations and blankets shearing aggregates combined with either a polishing cylinder or a table raising unit are in use. The table raising unit is used for raising and orientating the pile before shearing. The polishing cylinder with the electric heaters and four diagonal beater bars is needed for thermally stretching and arranging the fibres before the projecting fibre ends will be removed by shearing.

The Multicut MC-5 is a compact shearing machine which takes up little space and has short fabric passages, which does away with the familiar problem of edge curling in articles in which fabric tension is a critical factor. The newly designed, basic machine can handle both short- and long-pile articles. In order to avoid the notorious moiré effect especially appearing on low-pile fabrics as velvets, terry cloth, woven plushes, warp knitted velvets, Velveton, etc. the arrangement of the shearing spirals on the shearing cylinder has been changed (Fig. 8). This newly patented shearing cylinder gives the possibility to achieve production increases of up to 100% in comparison to the still usable fabric speeds. The conventional execution of a shearing cylinder shows shearing spirals being fitted onto the cylinder in equal distances regardless of the number of spirals used. This symmetrical arrangement limits the fabric speed especially on velvets, plushes and other low-pile fabrics. An increase of the fabric speed results in an increasing periodic variation of the pile length (moiré) and an obvious visibility of the peaks of this periodic variation. The sheared fabric surface looks uneven and of inferior quality. The new development of the shear-

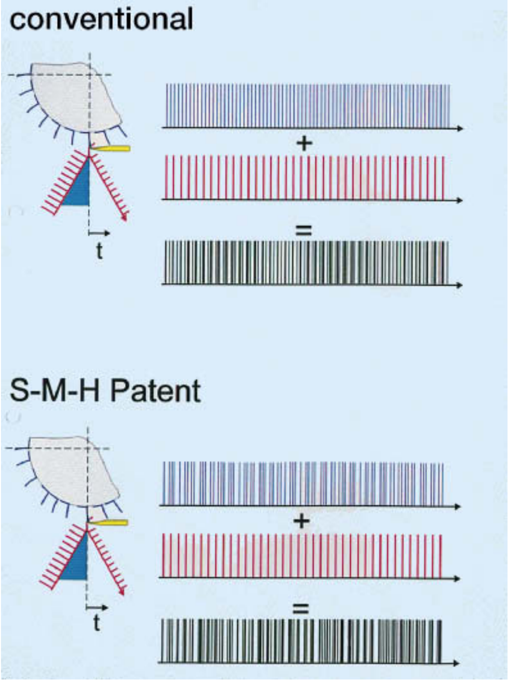


Fig. 8: Comparison of conventional and new shearing cylinders.

ing cylinder with asymmetrically arranged shearing spirals avoids the periodic changes by interrupting the uniform constant cut sequence of conventional shearing cylinders. The peaks of periodic variations are no longer visible, neither at considerably higher fabric speeds.

This new shearing machine is generally computer controlled. At the operating panel, just a fingertip is needed to start or stop production. Automatic adjustment of the shearing height, tension, fabric speed, felt lubrication, automatic fabric retraction at machine stops, e.g. the OP7 takes up all data and the MC-5 reacts automatically. Manual operation by single push buttons is, of course, also possible. The shear unit is within easy reach for regrinding. The felt lubrication is preselected via the OP7 and controls the oil supply and lubrication intervals even more reliably to protect the shearing tool and cut costs in terms of oil consumption. The speed or torque of the take-off roller including the folder can also be controlled to eliminate load alterations as a result of the folder movements, and thus an overstretching of the fabric or slipping of the roller. There are no separate switch cabinets but the electrical equipment is integrated into the side panelling. The fabric tension can be selected either via speed or torque control (for articles requiring different tensions or elongations). The dust extraction system has been revised in the shearing area in order to prevent soiling as much as possible. The drive of the cloth transport is effected by an AC drive. Steeples cloth tension regulation by potentiometer. Execution of the shearing cylinder according to requirements with 18, 20 or 24 spirals. Drive capacity of shearing cylinder 500–16 000 min-1 by AC drive. Rotational direction of shearing cylinder reversible for regrinding within the machine. Pneumatic lift-off of the dust extraction hood as well as shearing cylinder from working position for easy maintenance of the underknife. Shearing cloth rest as pointed, round, segment or roller type upon request. Steplessly adjustable shearing depth, legible from digital display. Mechanical oscillation of shearing cylinder. Safety cover at the shearing unit for accident prevention. Seam detecting unit for the automatic slowing of the shearing cloth rest, the pile lifting cloth rest as well as raising cloth rest. Pile lifting device with pointed cloth rest. AC drive for pile lifting roller. The rotational speed will proportionally be adjusted to a changing cloth speed. Further features are: Segmented cloth rest for the prevention of selvedge damages on worsted fabrics. Maintenance-free bearing of the shearing cylinder. Speedy exchange of shearing unit. Automatic device for quality control at initial cut. High cloth speed at optimum shearing effect by reinforced machine elements. At automatic processing the operation is effected only by means of on and off switch. High air flow at low energy consumption for the dust extraction. The storable programme control guarantees the precise control of all functions. Justomat for automatic adjustment of the shearing gap to the cloth thickness when shearing milled cloth.

Shearing blade A metal cylinder with 12–18 helical knife blades around its circumference is one of the key elements of a shearing machine (→ Shearing). The milled cut of the cutting blades produces an oblique shearing action so that any lateral yielding of pile fibres can no longer occur.

Shearing blades, grinding The ledger blade, which consists of a flat blade 10–12 cm wide, 2–3 mm thick, corresponding in length to the width of the machine, is ground on the underside approx. 3 cm towards the cutting edge. An absolutely uniform alignment of the edge of the ledger blade on the fabric is achieved by this means and the thin cutting edge of 0.2–0.4 mm is more easily obtained during grinding. The spiral blades of the shearing cylinder include straight, knee, and concave profiles. In the case of straight spirals, a right-angled cutting edge is formed by grinding to provide a contact surface for the edge of the ledger blade whilst a more or less acute-angled cutting edge is obtained with knee and concave spirals. The latter is more advantageous for shearing since their cutting performance lasts longer. Concave spirals are used almost exclusively in practice. Spiral blades are also produced with a so-called milled cut so that individual fibres are grasped and conducted more readily to the cutting zone of the shearing device. Milled cut spirals are more suitable than smooth cut spirals for the shearing of fabrics composed of 100% synthetic fibres as well as their blends. Synthetic fibres are harder and smoother than wool fibres and evade the cutting zone more easily if smooth cut spirals are used. → Shearing.

Shearing brush A brush roller to prepare the fabric pile for shearing. A brush with a fabric adjusting device in front of each shearing cylinder to achieve optimum alignment of the fibres for shearing, i.e. a pile laying brush. The drive to each brush roller is provided with reverse gears and settings for forward, off and reverse. These rollers are covered with bristles or card wire in a spiral arrangement. Any cut fibres loosely adhering to the back of the fabric after shearing are removed by beater rolls. In addition to a normal pile laying brush, a card wire brush may be installed before the 1st shearing cylinder for optional selection of either bristle or card wire brushing as demanded by the particular fabric. For velour fabrics, a special velour device is also installed before the 1st shearing cylinder with pile height adjustment as well as a pile laying brush. A brush roller, running in the pile direction, is also installed after the final shearing cylinder. All brushes and pile laying devices are connected to a suction extraction system for the effective removal of fibre dust and cut fibres.

Shearing height adjustment The shearing height on a → Shearing machine is the distance between the shearing device (shearing cylinder and ledger blade)

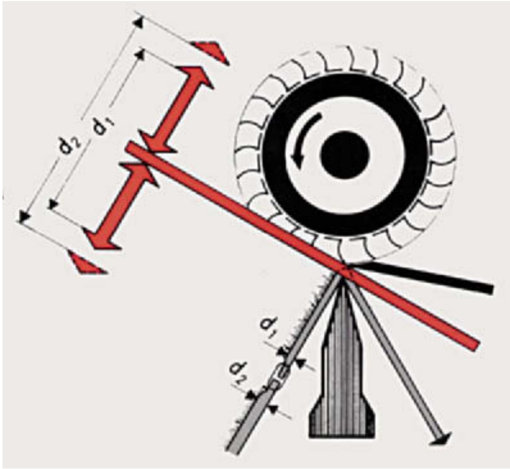


Fig.: Textiles of differing thicknesses (d_1 and d_2) require different shearing height settings in order to achieve the same shearing height.

and the shearing bed (see Fig.); this distance can be varied by adjusting the height of the shearing bed relative to the cutting blades in accordance with the thickness of the fabric. Some modern shearing machines have a thickness measuring device which accurately scans the thickness of the fabric which allows the extra thickness of a seam to be recognized and defined. The fabric speed is reduced to a constant value in order to lift the relevant treatment devices exactly at the seam point. After a seam has passed through the shearing zone, the production speed is automatically increased to the set value again. The thickness measuring device also provides an automatic shearing height adjustment at the same time. The given set value is readjusted and kept constant according to the fabric thickness. Manual adjustment of the shearing gap is therefore unnecessary when processing different articles and fabrics of different thickness.

Shearing machine (cropping machine) → Shearing is carried out with one or several shearing cylinders accommodated one behind the other in older shearing machines. In more modern machines, on the other hand, the cylinders are often mounted one above the other. The steel spirals of the shearing cylinder are usually in the form of concave spirals with either a smooth or a serrated (so-called milled cut) edge. In many cases, both smooth cut and milled cut spiral blades alternate with each other. Milled cut spiral blades have proved particularly suitable for blends with synthetic fibres since the smooth fibres are gripped more readily by the notches and cannot evade the cutting action in the shearing zone.

Two factors, above all, influence the quality of the shearing result in practice: the spread angle of the fabric in the region of the shearing bed and the cutting power of the shearing device during the shearing operation. A faultless shearing effect can only be achieved when these two factors have been optimized. The importance of these two factors becomes apparent whenever real cutting power is demanded, e.g. in the shearing of velour, velvet and similar pile fabrics. Experience has shown that the best results in close cropping are achieved when the specific cutting power is 18–24 cuts per cm. For velour and velvet fabrics, on the other hand, decisions relating to the number of shearing passages required have to be taken on a case to case basis. In general, the shearing of these materials is carried out at slower speeds and with more passages than is required for close cropping, with the depth of cut being adjusted progressively.

Shearing machines are generally quite sophisticated. Improvements to one model or another are perhaps still possible if a) the diameter, width and material quality of the shearing cylinder bearings are more favourably designed, b) if the bearing lubrication and heat dissipation are further improved and c) if the dimensions of the shearing cylinder itself are fully optimized.

Shearing machine circular-knit pile fabric A suitable single-cylinder shearing machine is necessary as a special machine for finishing circular-knit pile fabric. The shearing machine, model HPS, manufactured by Broma, was developed specifically to meet the requirements of elastic warp- and circular-knit pile fabric (Fig.). The final appearance of circular-knit pile fabrics after shearing is determined, first and foremost, by the quality of the shearing device. For this reason, the shearing cylinder in the HPS shearing machine has been designed as a particularly stable unit. This shearing cylinder is carefully balanced both statically and dynamically which guarantees vibration-free running both in the lower speed range for grinding as well as at high working speeds. Robust journals and bearings for the shearing cylinder provide increased reliability of concentric running during continuous operation as well as after frequent dismounting and re-installation. The spiral blades of the shearing cylinder have a milled cut. As a result, the fibres in circular-knit pile fabric are securely gripped and guided to the cutting zone. Sufficient clearance between the spirals ensures that the fibres of the elastic knit loop plush can be aligned with greater certainty. In this way, a maximum number of “sleeping” loops are gripped which reduces the shearing loss to a minimum.

The HPS shearing machine operates as a single shearing unit with a fixed shearing cylinder and a pointed shearing bed which can be lowered. A seam detector monitors seam passages so that the shearing bed is lowered at the appropriate time whilst the shearing cylinder remains in functional mode. This protects the shearing device. A high suction effect is achieved in

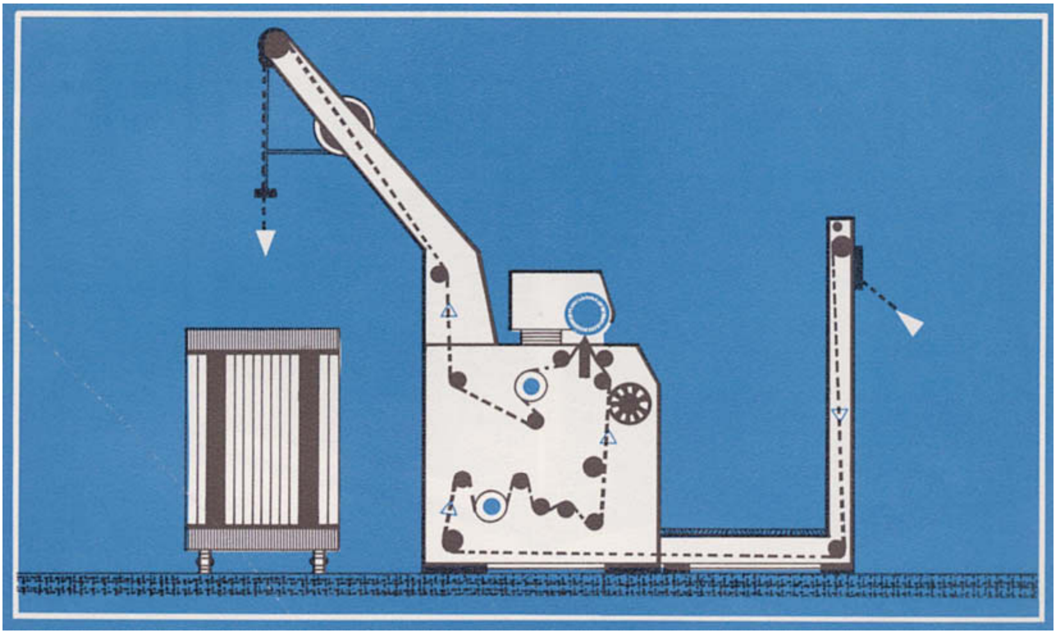


Fig.: Shearing machine circular-knit pile fabric HPS by Broma.

the HPS shearing machine which produces a better alignment of the fibres for shearing and reduces the deposition of shearing lint in the cylinder. In this machine, therefore, the application of suction not only serves the purpose of dust extraction but also assists in the shearing process at the same time. A direction reversing device makes it easier to check the shearing height at the beginning of a shearing run. Consequently, the shearing effect can be checked from the outset without any fabric loss. The fabric speed is adjustable over a wide range. The built-in hydraulic system ensures effortless raising of the shearing cylinder, e.g. for periodic grinding of the easily accessible ledger blade.

Shearing machine for knitted loop plush → Shearing machine for circular-knit pile fabric.

Shearing range A production line consisting of several shearing machines arranged one after the other for continuous → Shearing. This is a much more productive alternative than the batchwise shearing of fabrics which would otherwise require several passages on a single machine.

Shear properties of dispersions In contrast to simple (Newtonian) liquids, the rheological behaviour of dispersions containing solid particles is, in many cases, dependent on the nature of the shear stress to which they are subjected. During processing, dispersions are subjected to a wide range of shear gradients in flowing,

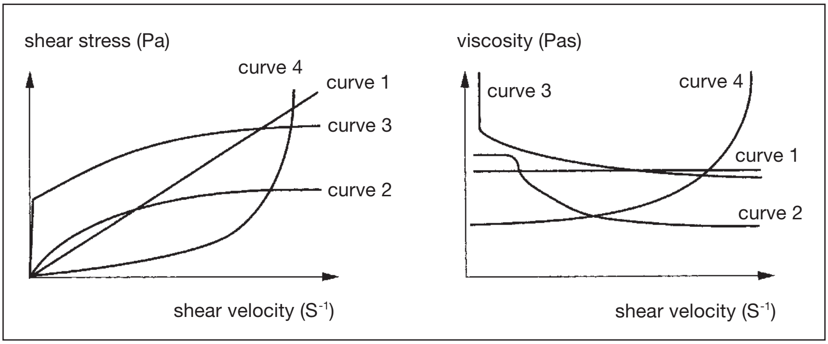


Fig.: The fluid properties and viscosity of different liquids exposed to shear stress (according to Burg and Jeschke).
Curve 1 = Newtonian liquid;
curve 2 = structurally viscous liquid;
curve 3 = plastic liquid;
curve 4 = dilatant liquid.

agitation, pumping and sieving, which is why rheological investigations have been carried out over rates of shear ranging from 10^{-1} to 10^4 m/s. High shear forces are encountered, above all, during the application of dispersions in spraying by rotor damping, so that a high resistance to shear is an essential property of dispersions suitable for this type of application (e.g. softeners).

The Fig. illustrates the theoretical progression of flow properties and viscosity for various liquids subjected to shear stress (→ Rheology). Dispersions often exhibit structural viscosity or pseudo-plastic flow properties. A decrease in the viscosity of such dispersions occurs with increasing rates of shear. Dispersions may also be subject to flow limits which become manifest by the need for a certain quantity of ultimate shear strain (force/friction surface) to be overcome first before the dispersion begins to flow. In this case, the dispersion is said to exhibit plastic flow properties. If, on the other hand, the viscosity rises with increasing rates of shear, the dispersion is said to exhibit dilatant flow properties. This property, which is undesirable in practice, occurs especially in dispersions with a high solid content. In addition to the viscosity behaviour which is dependent on shear-rate, an additional time-dependent flow property, e.g. as in thixotropy, has been established in some cases. The cause of this phenomenon is due to the application of too low a rate of shear in establishing a state of equilibrium as, e.g. in the formation of, or changes to, ordered structures during measurement (according to Burg and Jeschke).

Shear rate → Rheology.

Shear, to Trimming the pile loops of knitted plush fabrics by → Shearing.

Shear viscosity The → Viscosity of a liquid under a specific shear stress (→ Rheology).

Sheath core structure → Covering layer.

Sheathed thermocouples Thermocouple sensors encased in a protective outer steel housing suitable for installation in textile driers or thermofixation units (Fig.).

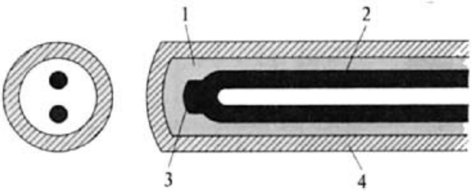


Fig.: Section through a sheathed thermocouple from Philips. 1 = insulating material; 2 = thermocouple wire; 3 = soldered joint; 4 = steel sheath.

Sheath layer fibres → Skin fibres.

Shed The path across the warp in a loom or weaving machine formed when some of the warp threads are lifted by their harnesses whilst others are left down or depressed during weaving to allow the insertion of weft (filling) threads by a shuttle or other picking mechanism.

Sheep's wool The fibrous covering of a sheep classified according to breed and origin (region of cultivation). According to the German TKG (Textilkennzeichnungsgesetz = Textile Labelling Act), only the → Wool from sheep may be described as wool. Wool that is shorn from sheep bred exclusively for wool production represents a more or less coherent → Fleece.

Sheet-dye process (slasher-dyeing process) A conventional continuous dyeing process for the dyeing of cotton warp yarns in open-width form, chiefly with indigo. The main disadvantage is that the process has to be interrupted if just a single end break occurs. For this reason, the → Long-chain dye process is often preferred in practice. In order to eliminate this particular disadvantage, an alternative double-sheet dyeing process, with at least two superimposed open-width warps, is often used. A more uniform liquor uptake is achieved due to the thicker double layers of warp threads.

Combined slasher sizing and dyeing has also been employed for the application of azoic coupling components (naphthols) to cotton warps for subsequent development with a diazo compound after weaving in order to produce warp-dyed effects.

Sheets Special sheets made of nonwoven material (cellulose, polyester) or polyurethane foam used as a support medium for impregnation with active substances, e.g. softeners. They are used as → Tumbler finishes.

Shellac A natural resin secreted by a scale insect Laccifer lacca (Coccus lacca) and deposited on the branches of trees in India. After collection, washing and purification by melting and filtering, it is formed into thin sheets which are later fragmented into flakes of orange shellac. This may be dewaxed and bleached to a transparent product. Commercial grades: (1) orange, TN (impure), fine, superfine, heart, superior and (2) bleached and dewaxed (colourless). Shellac is much tougher than other natural → Resins and has a melting point of approx. 100°C (115–120°C according to other sources). Molten shellac has a typical resinous or turpentine-like odour. It is sometimes adulterated with other resins or colophony. The development of a red-violet colour on addition of a few drops of acetic anhydride and conc. sulphuric acid to a sample of shellac indicates the presence of colophony. Solubility: shellac is soluble in 90% boiling ethanol (a wax-like separation occurs on cooling), the solution is turbid and possibly gelatinous; solubility in ether is 10–18% (a higher solubility = adulteration); if the shellac is of pure quality, an almost clear opalescent solution is obtained on boiling 10 parts of shellac with 5 parts of sodium tetraborate and 200 parts of water. Prolonged storage has an unfavourable influence on the solubility of shellac (especially bleached shellac). Storage under water is favourable. Shellac is soluble after partial saponification in alkalis and borax solution with a (red-violet) colour. Density of shellac = 1.035–1.14; saponification value = 185–225. Use: basis of some special finishes, leather finishing, wax and leathercloth, calico printing, oil sizes, (spray) paints, varnishes, Indian inks, etc.

Shell roller Besides solid copper rollers, on the surface of which a design is engraved by etching to facilitate transfer of print paste to textile fabrics in roller printing, so-called "shell" rollers are also used. Shell rollers are made by the electrodeposition of a 2–10 mm thick layer of copper on to a cast iron or steel cylinder. Shell rollers have also been made by pressing a 10–15 mm thick copper shell on to a steel cylinder. Two end pieces, 200–250 mm in length, are normally sweated into both ends of the cylinder to achieve the required taper and locating tab for the mandrel. Apart from their overriding cost advantage, shell rollers have a number of disadvantages compared to solid copper rollers, e.g. they are less durable, more prone to accidents and are less easily repaired when damaged. Moreover, unless the deposit of copper is fairly thick, they cannot be turned off and used again for another design.

Shepherd's check A small check effect which may be in black and white or in contrasting colours. The check effect generally consists of groups of 4, 6 or 8 yarns of the two colours in even-sided twill weaves, usually 2/2 twill. The term, shepherd's check, probably originates from the plaids worn in former times by shepherds in the hills of the Scottish borders ("pepita" is an alternative term used in Germany and Austria for shepherd's check). Shepherd's check is produced in cotton, wool, silk or man-made fibres. A dogstooth or → Houndstooth check is a particular variety of shepherd's check effect.

Shetland,

I. Originally, the term "Shetland" was a mark of origin for a yarn spun by hand exclusively from the wool of sheep bred and reared in the Shetland Islands. The wool from the Shetland sheep is particularly fine and imparts a soft handle to the textiles produced from it.

II. Currently, the term "Shetland" is applied loosely to all medium to coarse carded yarn fabrics produced from fairly coarse wool qualities (roughly equivalent to C quality), usually with a twill weave construction and a light to medium melton finish. The weave structure should still be recognizable after finishing; generally mottled, i.e. wool-coloured. The shades are principally mottled grey over blue and reddish brown. In general, Shetland fabrics are largely insensitive to creasing and have good resistance to rubbing and abrasion. Occasionally, worsted yarn Shetlands are encountered which are given a smooth finish. Uses: men's jackets, light to medium weight between-season coats as well as winter coats in the form of double cloth; lighter weight qualities are also used for women's jackets, costumes and coats.

III. Where the term "Shetland" is qualified by adjectives such as "genuine", "pure", "real", or any description with a similar meaning, this implies that the wool has actually originated in the Shetland Islands.

Shibori technique A Japanese tie dyeing technique similar to the old → Kasuri method. It differs from the latter, however, by stitching gathers into the woven fabric, either completely or with intermediate spaces before dyeing, often using repeated overdyes and/or resist dyes to achieve a multitude of elaborate patterning possibilities. The final designs include attractive white resist effects. Uses: dresses, kimonos, scarves, shawls, upholstery. The process is carried out in small Japanese factories specializing in this particular technique. Shibori is similar to the Malayan and Indonesian → Plangi.

Shiner picks → Shiners.

Shiners Alternative terms include: shiner picks, tight picks, tight weft (filling) threads, tight ends, fiddlestrings. A shiner is a warp or weft thread, usually consisting of a continuous man-made filament yarn with a higher lustre than its immediate neighbours in a woven fabric. It is a common defect in woven fabrics and is almost exclusively due to a particular thread being overstretched so that it lies more tightly in the fabric structure and exhibits an increased lustre. Causes: cross-sectional variations in individual filaments due to localized differences in drawing, damage by deformation, variations in yarn twist, variations in air humidity during processing, etc. Since the dye affinity of shiners usually differs from that of the normal adjacent yarns in a fabric, uneven dyeings are inevitable.

Shingosen fabrics A Japanese term for "new synthetic fibre" which specifically applies to polyester microfibres with silk-like characteristics used in womenswear. Finishing involves subjecting the polyester material to an alkaline weight loss of 3–5% by the pad-steam process in order to obtain super microfibre products, i.e. fibres with a linear density of approx. 0.1 dtex.

Shiraz carpets Contrary to expectations, Shiraz carpets are not produced in Shiraz itself but in the whole Fars area of which Shiraz is the capital. The various carpets known by this name are, in fact, woven by different nomadic tribes who have lived for centuries on the Fars tableland. The bazaar in the town of Shiraz is the trading centre for these carpets.

Ground looms are used even for those carpets woven by semi-nomadic people living in small Fars communities. The warp and weft are executed in wool except for some types woven by semi-nomadic people who use cotton. The weft can be either single or double, according to the particular tribe, but the pile is always produced with wool. Some tribes use the Persian knot whilst others use the Turkish. In both cases, the number of knots per unit area varies considerably, e.g. 100 000–250 000 knots/m^2. It is however, impossible to be precise about the average knot density of Shiraz carpets because the quality varies enormously from tribe to tribe. The best qualities are those woven by the Arab and Basiri tribes, which are also known as Shiraz Extra.

Shiraz decoration is typically nomad. The motifs are simple and geometric, executed in bold straight lines and bright colours. The most common motif, and one by which a Shiraz carpet may be identified, is a single diamond-shaped lozenge in the centre of the carpet or repeated along the length twice or three times according to the size. The diamond shape is usually light or dark blue and the field is almost always red and decorated with stylized plant motifs.

Shiraz gum → Asiatic gums.

Shirley Institute A well-known British textile research institute based in Didsbury, Manchester, formerly the headquarters of the British Cotton Industry Research Assocation (BCIRA). The Shirley Institute was amalgamated with the Wool Industry Research Assocation (WIRA) in 1988 to form the British Textile Technology Group (BTTG).

Shirting A German term for a type of → Chiffon in the form of a plain weave semi-matt cotton or viscose lining material which is mainly dyed black or grey. It is starched and given a glaze finish. Finer qualities are similar to jaconet. Uses: furnishing fabrics, cloth-backed maps and bookbinding.

Shirvan carpets Provenance: the village of Shirvan is situated near the south-west shore of the Caspian Sea and the district of the same name in the southern part of Azerbaijan.

Technical details: The warp and weft is in wool in antique specimens, in wool or cotton in those woven between 1850 and 1920, and completely in cotton in modern examples. The pile is always in closely-cropped wool. The Turkish knot is used to give a knot density of 150 000–250 000 knots/m^2. Modern examples usually have a higher knot density than the older or antique ones. Shirvan carpets are woven in various sizes but are most commonly produced in small or long narrow shapes. As with other Caucasian carpets, Shirvans have a widely varied decoration which is similar to, but smaller than that of → Kazakh carpets.

Small Shirvan rugs are woven either in prayer rug or normal form. In both cases, the decoration is, for the most part, made up of a design composed of minute stylized diamonds and tulips or boteh motifs. Shirvan rugs are varied in colour. Usually the ground is a sober colour such as dark blue whilst the motifs are quite vivid. White is predominant in the borders.

Shives Short pieces of woody waste in flax which are almost entirely removed during the breaking and scutching operations involved in → Flax processing.

Shock catalyst A strongly acidic catalyst used in the application of resin finishes by the → Shock-cure process, e.g. certain organic acids such as citric acid, mixtures of metal salts of strong acids with complex-forming hydroxycarboxylic acids.

Shock cooling Rapid cooling, e.g. of dyed goods, or a more or less exhausted dyebath, by partially running the dyeing machine and adding cold water. Purpose: to control the temperature, e.g. when making further additions of dye for shading.

Shock cooling is also carried out after the heat-setting of synthetic fibres by impingement with cold air in order to stabilize the heat-setting effect.

Shock-cure process A variant of the → Dry crosslinking process; in this case, crosslinking is achieved by shock curing within a few seconds (20–60 s) either at high temperatures (170–190°C) with conventional resin finishing catalysts, e.g. magnesium chloride or, alternatively, at 140–160°C with so-called → Shock catalyst. Both the drying and curing stages are usually combined in a single pass through a finishing stenter.

Shock drying The shock-like drying of textile fabrics in jet drying (→ Jet driers).

Shock dyeing Rapid transfer of dye liquors into a dyeing machine.

Shock dyeing test A test for the evaluation of dyes and levelling agents in package dyeing. A yarn package of polyester fibres or filaments is heated to 130°C in a dyeing machine. Afterwards, the disperse dye liquor is transferred rapidly into the dyeing vessel and the dyeing process interrupted after 15 min. Samples of dyed polyester material taken from the inside – centre – outside of the package are then knitted into fabric samples to assess the uniformity of dyeing.

Shock filter cleaning Cleaning of clarification filters by a reduction in pressure or the agitation of flexible filter elements.

Shock freezing A process originally operated in Lowell, Mass., (USA) in 1935 which involved a shock-like cooling of wool textiles to between – 30 and – 45°C by spraying with liquid air or nitrogen until freezing occurs. The wool was then dusted vigorously to remove impurities. This process was developed for wools heavily contaminated with vegetable matter but is no longer of any practical importance.

Shock oxidation → Vat dyeings, oxidation of.

Shock setting Dry heat-setting of polyamide and polyester piece goods with hot air. This treatment is usually carried out on heat-setting stenters at high temperatures, e.g. by heat-setting the goods at 190–220°C for 5–20 s depending on the substrate.

Shock treatment E.g. shock bleaching, shock dyeing, shock curing, etc. These terms are commonly used to paraphrase short-duration treatments in finishing such as the direct introduction of fabrics without preheating into a treatment system already heated to maximum temperature.

Shoddy Fibrous material made in the woollen trade by reducing new or old knitted or loosely woven fabrics in the form of → Rags and thread waste to a fibrous state (graded as class I). It is a form of → Reclaimed wool having a staple length which is generally longer than that of → Mungo.

Shore hardness A hardness scale which is in common use internationally for vulcanized materials such as rubber as well as plastic rollers. Measurements are made with a hand-held tester in which the resistance of the material under test to the pressure exerted by a needle is read directly off a scale. This test has the advantage of being simple to carry out and is also suitable for testing rollers already installed in machines. It is, however, not altogether accurate. Measurements range between 40–100 Shore which can, however, represent different degrees of roller hardness for various makes of rubber. There is no correlation between Shore hardness and → DVM softness values. → Roller hardness.

Short bast fibres Cottonized bast fibres; → Cottonized flax.

Short-Cure-Process A 2-stage permanent-press finish. Stage 1: mild curing of finished fabric for a short duration at low temperature. Stage 2: final curing under severe curing conditions after the fabric has been made up into garments.

Short liquor In the sense of liquor with a low amount of liquid, e.g. 1 : 5. Opposite: → Long liquor.

Short liquor jets Waste water quantities and energy use are substantially decreased in dyeing in an exhaustion process using a short liquor-to-goods-ratio (FV).

Winch beck	FV 1 : 30
Short liquor jet	FV 1 : 6
Airflow	FV 1 : 3

Construction features of short liquor jets: In the Roto Stream system (Fig. 1), the cloth is transported over a winch and through the subsequent nozzle. The liquor level is extremely low. The cloth is outside the liquor. It is possible to increase the liquor level and rinse in the overflow however. The transportation of the cloth (feed) is eased by the freely turning, internal drum. The design, with controlled placing (= plaiter), allows a more even and consequently increased loading of the (plaiter) drum.

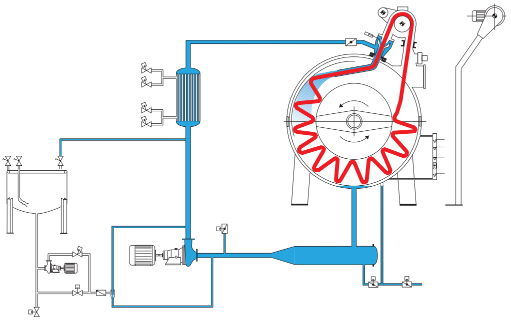


Fig. 1: Roto Stream (Thies).

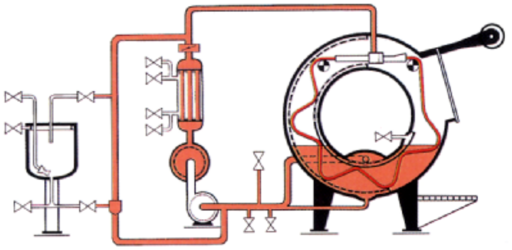


Fig. 2: Ring Soft (Thies).

In the Ring Soft system (Fig. 2) the material is transported via two winches and a wash section. This gentle fabric transportation is beneficial to critical items; the cloth is less roughened and not bobbly. The lowest liquor-to-goods-ratio is approx. 1 : 6. Increase to approx. 1 : 10 is possible. Rinsing can also be carried out in the overflow.

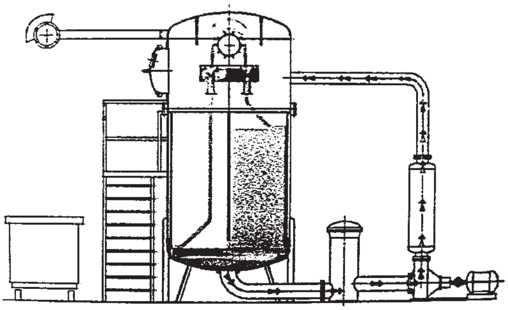


Fig. 3: Pandora (MCS).

Another method is pursued in the Pandora (Fig. 3). The jig technique is called to mind and work is carried out in the Pandora as follows: The cloth runs, driven by a large winch and an overflow nozzle, from one fabric storage tank to the other and back again. The liquor which flows in from the overflow nozzle runs through the cloth into the bath and is pumped to the overflow nozzle again. The cloth also dwells outside the liquor in this machine. The liquor-to-goods-ratio may be adjusted upwards from 1 : 4. It is possible to rinse in the overflow.

The cloth transportation is based on a new system in the Air Flow (Fig. 4). The drive is via a winch and across the strong air flow, in which liquor is injected. Winch speed and air flow are controlled. The cloth lies on a teflon grill outside the liquor and is sprayed with finely atomised liquor.

The liquor level can only be altered a little, as the

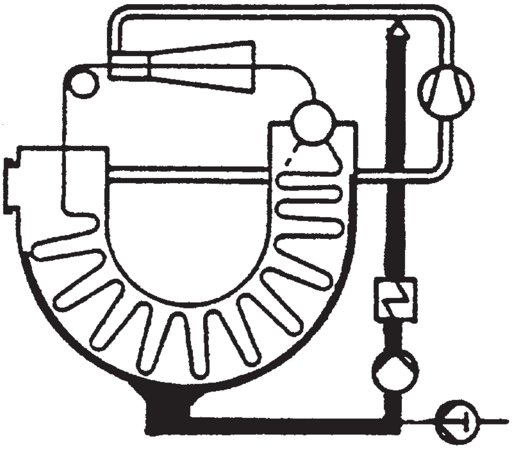


Fig. 4: Air Flow (Then).

cloth should not stand in the liquor or be covered with liquor. Running problems due to the higher weight and due to the resistance in the liquor would result otherwise. On the other hand a certain liquor level should be reached, as no injection circulation is possible if not. Rinsing in the overflow is not possible. Continuous rinsing with an open discharge valve (via extension vessel) is possible (according to Bacher).

Short liquor ratio dyeing Dyeing in accordance with the exhaustion processes in the short liquor-to-goods-ratio, in general 1 : 10 and below, brings the benefit of less water and energy consumption.

Short liquor ratio foam dyeing process Carried out in drum dyeing machines using suitable chemicals with addition of aqueous liquor in the form of foam for various use for all textiles (mild treatment, crease-free finishing) in the extremely short liquor-to-goods-ratio (1 : 1–2). Identical dyeings of good reproducibility result in all processes using conventional dyes. Lowering of water/energy costs, reduced dyebath additions, also reduced waste water quantities.

Short liquor ratio machine Generally have the following characteristics (Fig. 1):

I. Jet dyeing vats with
- winch or conveyor roller unit,
- winch with a nozzle connected downstream and transport stage or nozzle connected downstream, with compressed air feed and transport stage,
- accumulator with low liquor level or freely rotating rotor as a dwell zone or non flooded dwell chamber with stainless steel conveyor belt.

II. Overflow or jet machines with
- winch,
- winch with rinsing funnel or nozzle connected downstream and transport stage,

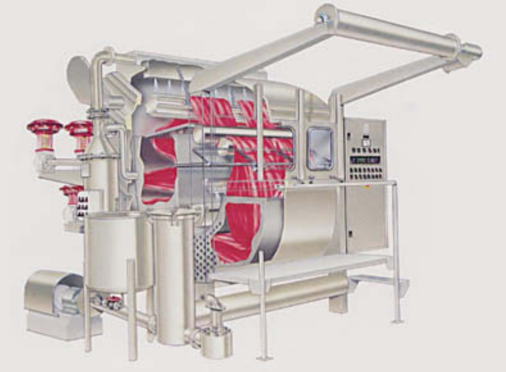


Fig. 1 : "Diplo" model short liquor ratio piece dyeing machine (Sclavos).

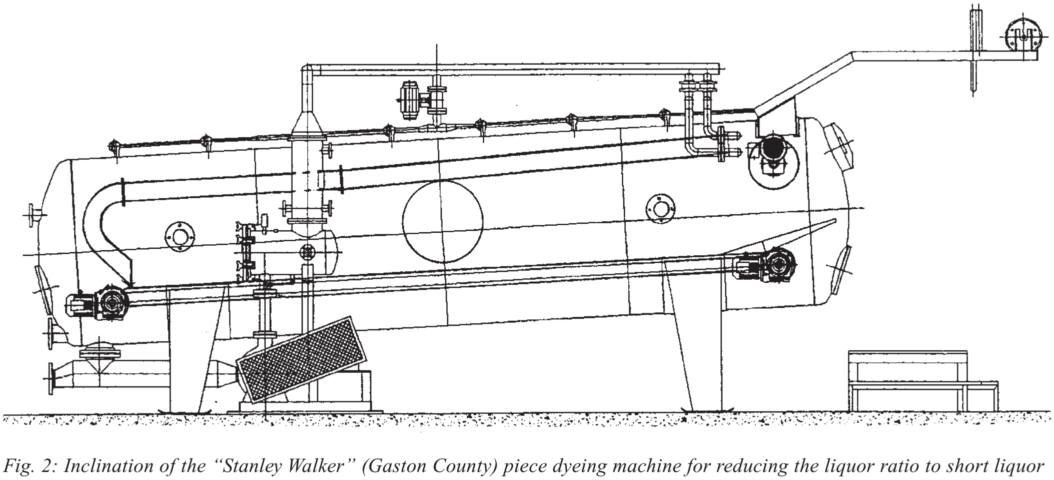


Fig. 2: Inclination of the "Stanley Walker" (Gaston County) piece dyeing machine for reducing the liquor ratio to short liquor level, with fabric transport on a conveyor system from the sump forwards.

- fully flooded storage tube, which guarantees even throughflow of the cloth in treatment liquor.

The smallest liquor-to-goods-ratio possible is approx. 1 : 8.

The horizontal construction (Figs. 2 + 3) accommodates the reduction of the liquor-to-goods-ratio. The dyeing in the bath is supported during rope dyeing by suitable plaiting down systems (Fig. 4).

The reduction in water consumption is to the fore in the short liquor technique; this not only applies to the reduction of the preparation liquors, but chiefly also to the decrease in rinse water quantities required. Solutions for short liquor technique offered by machine manufacturers have the following features:

- mechanical cloth transportation or combined nozzle/mechanical. Previously allocation of tasks varied between nozzle and roller (winch).
- fabric drum arrangement (dyeing vat) of the kind in which the cloth glides and is laid in folds in one place. In some designs, plaited cloth is moved forwards (Fig. 2). It is important to avoid fold formation for too long for most finished tubular knitgoods (removable by opening tube from time to time; mechanically, via liquor circulation or via blowing in air).

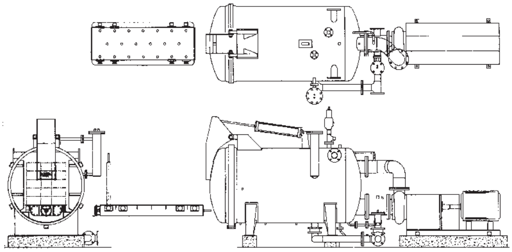


Fig. 3: Different perspectives of the HPD-2000 horizontal short liquor yarn dyeing machine system (Morton).

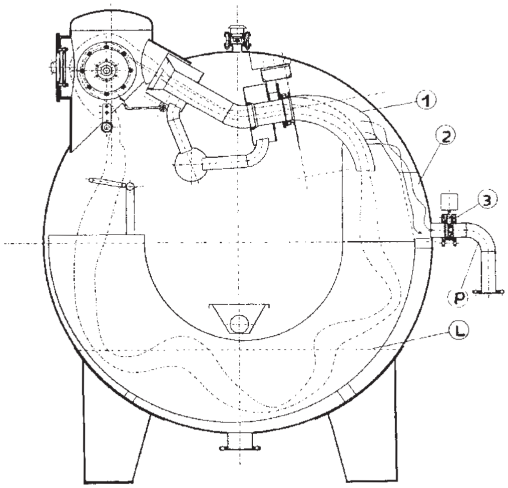


Fig. 4: "Microwash" system in an Apollon short liquor technique piece dyeing machine (Sclavos).
1 = fabric rope plaiting system with liquor bypass;
2 = Microwash drain; 3 = drainage pipe valve (P);
L = liquor level appropriate to short liquor ratio 5–7 : 1.

Advantages of short liquor technique:

- saving of water;
- saving of thermal energy;
- saving of chemicals (chiefly electrolytes, products for setting a particular pH, etc.);
- improvement in the dye yield (in some dye classifications; this means better reproducibility because the dyeing equilibrium is displaced in favour of the material);
- higher operational safety, particularly with regard to levelness.

This allows the process to be simplified or the heating-up speed and the pH-dependent process stages to be accelerated and also results in:

- reduction of dyeing time and/or
- decrease in the number of misdyeings because the number of corrections of faulty dyeings also goes down with increased operational safety and reproducibility.

Short-loop drier (festoon drier). Universal drying machine for delicate viscose fabric, for tubular jersey fabrics and for the gentle pre-drying of resin impregnated fabrics to avoid pre-curing and migration of the epoxy resin. Tension-free transport of the fabrics (see Fig.) in the form of short loops passing in continuous travel over vigorously vibrating rollers, producing constantly changing points of contact. The goods are subjected to air currents on face and back and the fabric is able to shrink without hindrance. If the loops of fabric are long, the term used is festoon drier.

Fig.: Short loop fabric transport of knitted fabric in a Tube-Tex festoon drier.

Short period dyeing technique Process for increasing productivity with the aim of reducing dyeing time to a minimum without jeopardising the levelling of the dyed goods.

Short period heat setting (shock setting), takes place on special stenters, on which synthetic fibres are thermofixed in seconds at very high temperature.

Short period steaming of vat dye → Flash ageing has great importance in the fixation in vat dyes in accordance with the two-phase process. Sodium dithionite and other suitable materials are used as reducing agents. Steam periods of 15–30 seconds. Most familiar machine designs are the flash-ager and the arch steamer (Benteler).

Short-ratio thickener Thickening agent with rheological properties, even at low concentrations, which cause it to run from a glass rod as individual drops, not smoothly in the form of a long strand (→ flow properties of printing thickeners).

Short steaming process → Reactive dyes in direct printing.

Shoulder padding Shaped inserts used as → Interlinings in men's and women's jackets and coats to confer a desired shape. Shoulder padding usually consists of wool or cotton wadding (often lined with muslin) and/or an expanded foam material resistant to dry cleaning.

The use of shoulder padding in garments is very much dependent on the dictates of fashion.

Shrinkage A negative change in the dimensions of textile products which involves a reduction in area (length and/or width) of a fibre, yarn, fabric or other textile due to the influence of various agencies, e.g. wetting, laundering, dry cleaning, etc. The total shrinkage potential of a textile material is a combination of several shrinkage mechanisms. →: Dimensional change of textiles; Compressive shrinkage.

Shrinkage effects A collective term for plastic effects on fabrics produced by localized → Shrinkage process.

The degree of shrinkage is influenced by the construction of the textile as well as the morphological characteristics of the participating fibres. Shrinkage takes place in relation to the external conditions involved in finishing (Fig. 1) or during subsequent use of the textile. Shrinkage is reversible and changes to extension on reversal (Fig. 2). Shrinkage is also a reaction to a previous extension of the material and represents a relaxation of the forces to which it was subjected in earlier stages of processing and which became fixed temporarily, either mechanically in the textile construction, or by physico-chemical mechanisms in the polymer structure. For relaxation to take place, enough energy has to be applied for these latent forces to be released. Machines designed to induce shrinkage must therefore apply mechanical as well as thermal energy in order to neutralize fibre/fibre adhesion by overcoming the frictional forces and other interactions between the polymer molecules such as hydrogen bonds, salt linkages and hydrophobic interactions. The relaxed, shrunken, state is then fixed in the material (albeit only temporarily) by re-formation of the linkages in the relaxed state. Some machines are better able to fulfil these conditions by the treatment of fabrics in rope form (Fig. 3) whilst others are specifically designed to achieve optimum

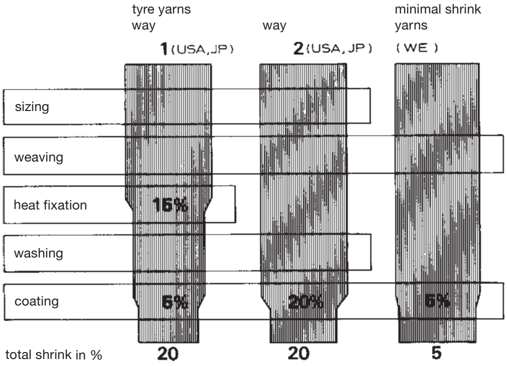


Fig. 1: The controlled shrinkage of different yarns in different finishing processes (by Akzo).

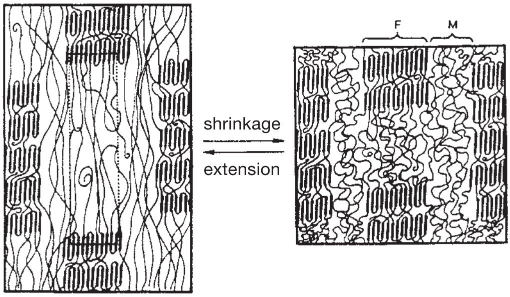


Fig. 2: Proposed model of the structure of synthetic fibres in a stretched and shrunk state by Berndt.
F = fibrils (molecules arranged in crystallized and non-crystallized layers); M = matrix (continuous molecule chains, only crystallized to a small amount).

Fig. 3: Henriksen shrink: a shrinkage drier for tubular knitted goods, which are transported into air jet shafts by drive rollers (2) and thrown against baffle plates (3) by hot air before residing for a period of time in the basket (7) during each cycle of the continuous process.

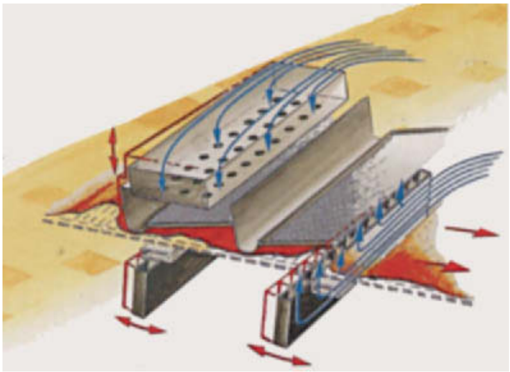


Fig. 4: Obermeier shrink: open-width goods lie on a carrier belt (broken line) and are lifted from below by backwards and forwards vibrating jet boxes while being pressed down from above by fixed jet boxes, resulting in the goods progressing in a sinus-like fashion.

Fig. 5: Controlled shrink between a hot cylinder (right) and thick rubber belt (black) (by Morrison).

shrinkage by treatment in open-width form (Fig. 4). In terms of machine concept, a distinction is also made between those machines where shrinkage of the fabric takes place in a fully relaxed state and those which involve a tight-strand passage (controlled shrinkage) through the shrinking zone (Figs. 5 + 6).

Shrinkage fibres Acrylic, polyamide, polyester or polyvinyl chloride fibres which have not been preshrunk are used for the production of high bulk type textured yarns (e.g. 18% shrinkage reserve) used in the manufacture of needled composites and (up to 40% shrinkage reserve) for artificial furs and similar products.

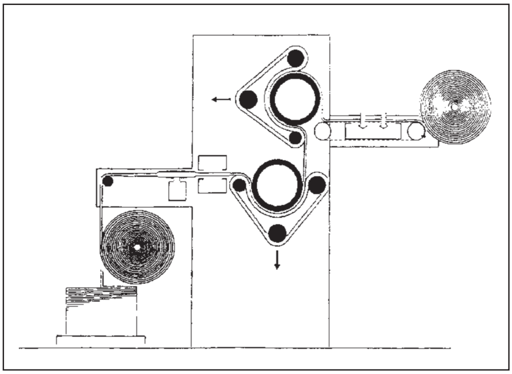


Fig. 6: Controlled shrink on a Sperotto-Rimar machine for cotton knitted goods.

Shrinkage measurement of knitgoods A variety of methods are used in practice, e.g.:

I. Wash test at 60°C as specified in DIN 53 892 and DIN 53 920 with subsequent drying: this procedure is used to simulate the dimensional changes which occur during laundering and subsequent treatment in a tumbler drier. Three representative test specimens are taken for measurement and allowed to condition under standard atmospheric conditions for testing textiles as specified in DIN 53 802 until equilibrium has been reached. The specimens are then removed and marked for measurement on a smooth flat surface in accordance with DIN 53 870. After the test procedure has been completed, the specimens are again allowed to condition before dimensional change is determined. In order to determine the sum of all shrinkage components, i.e. the overall shrinkage potential, it is necessary to carry out this test procedure repeatedly.

II. Wash test as specified by Marks & Spencer. This procedure deviates from the DIN standard test method with subsequent tumbler drying insofar as the underlying principle is based on imitating the shrinkage of a made-up garment and subjecting this test specimen to a laundering and tumbler treatment for the determination of shrinkage. The test specimen is allowed to condition again after the treatment before determining any dimensional changes in length and width between measuring marks drawn on the specimen before testing.

III. Weight/surface area method: this procedure is based on calculating the degree of shrinkage from the change in weight/surface area caused by washing. This method provides the finisher with a measure for the shrinkage stability requirements of a particular fabric in terms of shrinkage per unit area and average linear shrinkage. Test specimens of a specific surface area (A_0 = 100 cm^2) are taken from the fabric with a circular sample cutter. After washing, the weight G_1, without those parts of the test specimen removed by washing, is determined. This enables the weight per unit (FG) area of the test specimen before washing to be known, i.e. weight per unit area:

$$FG = \frac{G_1}{A_0}$$

In order to determine the weight per unit area after washing, a specific surface area ($A_2 = 50\ cm^2$) must be taken from the washed and shrunk test specimen and then weighed. Thus, weight per unit area after washing:

$$FG = \frac{G_2}{A_2}$$

The sampling procedure is explained in Figs. 1–2 as follows:

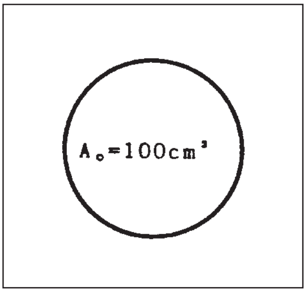


Fig. 1: Sample (A_0) of area 100 cm^2 to be measured before washing.

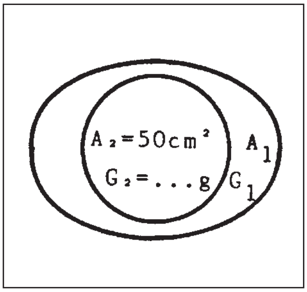


Fig. 2: Sample (A_1) after washing (approximately elliptically deformed) and the second sample (A_2) of area 50 cm^2.

The change in weight per unit area is given directly from the results of weighing the test specimens of specified size prescribed above:

$$FS\ [\%] = 100 - 50 \cdot \frac{G_1}{G_2}$$

The calculated shrinkage per unit area (FS) as well as the mean linear shrinkage (LS) appear as positive values. The mean linear shrinkage of a knitted fabric is defined as the linear change in length of a test specimen (contraction of elliptical axes). The mean linear shrinkage is the average of the elliptical contraction in all directions; it is a measure for the required stabilization of yarn in a knitted fabric:

$$LS\ [\%] = 100 - 10\sqrt{100 - FS}$$

IV. Determination of linear deformation: with this method, it is possible to determine the linear deformation after a test load quite independent from the fabric shrinkage. When circular-shaped knitted fabric specimens undergo a change in shape after application of a working stress, the circular form is transformed into an ellipse. This change in form provides evidence that a contraction or elongation has occurred which corresponds to linear deformation. The percentage elongation or contraction after a wash treatment is determined with the aid of a set of test stencils of 0–25% contraction, divided into 10 measurement ellipses. If the test specimen is smaller than the ellipses, then linear deformation is also accompanied by a degree of shrinkage. The change from a circular to an elliptical form, however, does not imply that the directions of courses and wales coincide with the axes of the ellipses. Deviations in the courses and wales are read off the ellipse axes in angular degrees.

V. In order to measure the geometrical changes in woven and knitted fabrics, markings are drawn on the fabric as described for conventional methods of shrinkage measurement and any change in their dimensions is determined after a treatment by hand. These measurements are, however,

- destructive,
- discontinuous,
- random,
- liable to subjective errors.

Evaluation of the applied markings provides, in each case, an average value of the number of loops per unit length. This raises the question as to how the shrinkage in individual loops can be determined with greater statistical reliability. Since no continuous measurement data is available for the measurement of shrinkage, the following sensors have had to be developed:

a) Measurement of shrinkage by image data processing systems: for this purpose, the light intensity profile of the individual loops is evaluated geometrically and, unlike conventional test methods, a local analysis is carried out. The loop structure of the optically detectable textile surface is described as a periodical process with highly superimposed coincidental variations. The measuring task of the system is based on freeing the fundamental period, i.e. the average loop width, from these variations. The Video Shrink Inspector VSI (Sick) represents a commercially available system based on this principle. This computer-controlled image data processing system analyses close-up images of the textile surface. The dyed knitted or woven fabric is guided loosely over a measuring head containing a miniature infra-red semi-conductor camera and a special stroboscopic source of infra-red illumination. An image section, measuring 2 x 2 cm is digitalized and stored in the computer with a resolution exceeding 250 000 pixels with 256 grey tones per image in each case. A correlation pattern recognition procedure determines a statistically assured mean loop length and width from the highly irregular fabric texture. This is converted into a dimensional change in length and width by comparison with a stored reference or with the results from an additional measuring head and is displayed within seconds to an accuracy of 0.5%. The actual image recorder is housed in a casing together with the illuminant source. A high resolution CCD matrix camera with 500 x 580 pixels is used as the image sensor. The CCD video camera has a high sensitivity in the near infra-red region. The material is illuminated with two infra-red radiators positioned at right angles to each other. These radiators emit 25 pulses/s which are of very short duration, so that sharp images can be captured even with a rapidly moving web of fabric. The times of measurement are sufficiently short to serve as a control parameter. The camera is adapted to the spectral characteristics of the illuminant source with the aid of a built-in infra-red filter. This largely excludes any influence of interfering stray light. A CCD camera provides images which can be resolved into numerous individual elements. Each of these elements can be detected, i.e. they can be digitalized for computer processing. The radiant intensity of the individual elements is recorded and represents the ratio of light intensity to the illuminated surface. Since the illuminated surface is constant at 2 x 2 cm, the radiant intensity is proportional to the light intensity. The measuring sequence is subdivided into four stages:

- Depending on the method of measurement, the cameras are calibrated before measurement begins.
- During the measuring phase, sufficient measurements are taken to obtain the mean values desired.
- Depending on the setting, the measurements are converted into output values.
- The converted and processed results are displayed on a monitor screen and, if desired, transmitted to a printer via a 0–20 mA interface.

These four phases are supplemented by the calculation of statistical results. Provided sufficient measurements have been run, a statistical series is produced. The application of this image processing system for shrinkage control is carried out:

- continuously,
- quickly,
- non-destructively and contact-free.
- measurements of changes in geometrical form are independent of the density and moisture content of the textile materials.
- production statistics can be produced with a statistical reliability which far exceeds that achieved by manual methods of shrinkage measurement.
- because of the rapid determination of measurement data, corrections to the production process can be made immediately and defective production avoided by the adjustment of machine settings.
- the system contributes to the automation of manufacturing stages and quality control.
- image data processing systems represent an additional expenditure for an industrial enterprise, although the purchase price is offset by the considerable advantages which they offer.

b) Shrinkage measurement by radiometric systems: the method of shrinkage determination which involves measurement of weight per unit area (III) shows that the weight per unit area of knitted fabrics is increased and the extent of shrinkage can be calculated exactly. The procedure described in III must, however, be regarded as an experimental detection method. If the control of dimensional change is to be carried out in a production department during processes such as drying or shrinking, then the experimental test proves to be

- time-consuming, and
- residual shrinkage values are not immediately available for the adjustment of machine settings,
- the test is destructive,
- only a relatively small number of random samples can be taken.

These disadvantages can be eliminated with radiometric measuring systems. When radioactive isotopes are beamed through absorbing materials their intensity is reduced in proportion to the material's mass. After passing through a layer of material, the original intensity I_0 falls to a value I, and the following exponential equation may be derived from this relationship:

$$I = I_0 \cdot e^{-KF}$$

I = radiation intensity after passing the absorbing layer,
I_0 = radiation intensity of the isotope,
F = material's mass in cross-section,
K = proportionality factor, linear weakness coefficient.

The weight per unit area, thickness and density of a test material can thus be determined from changes in the amount of energy emitted by a radiation source of known intensity. Isotopes are an atomic species of a chemical element with the same number of protons but different numbers of neutrons and nucleons. The latter exhibit spontaneous radioactive decay. Radioactive radiation therefore describes the property of unstable atomic nuclei in emitting constant energy in the form of α-rays (helium nuclei), β-rays (electrons) and γ-rays (energy-rich photons) without external influence. In β-decay, the emitted particle rays consist of fast electrons. The atomic number of the corresponding atoms changes but not the mass number. The newly created elements are mostly radioactive again and continue to decay in so-called decay chains. The speed at which the radioactive isotopes are converted into their decay products gives the half-life value.

Krypton 85, a β-ray isotope of the inert gas of the same name, is well suited for virtually all weights associated with textiles. This isotope has a half-life of 10.7 years and covers a weight range from 50–1000 g/m^2 with a high degree of accuracy. The β resp. electron-emitting isotope is encased in a solid radiation-proof cast-steel casing, and β-rays are released through a shuttered aperture only when the unit is switched on for measurement. An ionization chamber filled with inert gas serves as a radiation receiver. The incident electron radiation, the intensity of which is attenuated through absorption by the textile web, creates an ionization flow in the receiver. Incoming electrons are carried away by the electrodes. The ionization flow is proportional to the incident radiation, i.e. the heavier the fabric in the scanning gap, the smaller the flow in the ionization chamber. This flow thus represents a measure for the weight per unit area of a textile material.

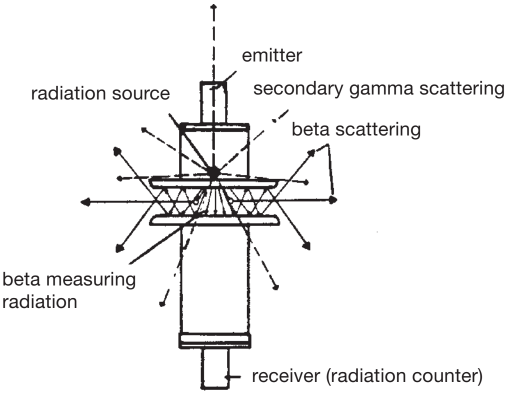


Fig. 3: The flow of radiation from a Gravimat (Mahlo) when the radiation emission window is open.

Gravimetric measurement can be carried out in a shrinkage machine. The radiometric measurement of weight per unit area is used for the continuous control of textile webs on stenters as well as for shrinkage control in compressive shrinking processes. A suitable system for this purpose is illustrated in Fig. 3. This unit consists of the following components:

- measuring head,
- electronic analysis,
- display unit,
- operating panel with set-point adjustment.

For gravimetric monitoring of shrinkage processes, a device for measuring the weight per unit area must be installed at fabric entry and another similar device at fabric exit from the machine. These measuring units determine the actual weight per unit area by differential measurement. If this measurement deviates from a given set value beyond the tolerance limit, then the control unit must obtain information in order to restore the given set condition. Regulation is carried out by means of a servomotor which is actuated by the pressure roll of the shrinkage machine. At the same time, the speed must also be controlled, since more fabric has to run into the machine per unit time to produce an increased amount of shrinkage.

Shrinkage of cellulose The shrinkage of textiles composed of cellulosic fibres and their blends has different causes which are not exactly distinguishable from one another. The low elastic extensibility and dimensional change of fibres during transition from the dry to the wet state by swelling are the main causes of shrinkage here. During swelling, the fibres undergo a change in cross-section which induces shrinkage. Swelling occurs through the penetration of water molecules into the cellulose structure and their attachment to the surfaces crystallites through hydrogen bonding. This process takes place mainly in the less ordered non-crystalline regions of the fibre. Since viscose has a higher proportion of non-crystalline regions, the degree of swelling is greater than native cellulose. During swelling, some existing intermolecular forces can be ruptured. The fibres become shorter due to an increase in volume. The swelling of native cellulose fibres occurs mainly in the width whilst the longitudinal swelling is only slight. Swelling subsides to a large extent on drying. The causes of this anisotropy are the crystalline regions, the orientation of which is parallel to the fibre axis. In the case of long molecular chains, more forces of cohesion are formed and swelling becomes more difficult. With increasing fibre crystallinity, the absolute degree of swelling is lower and, consequently, fibre stability is higher. Linear density, type of yarn and fabric construction have a secondary, but not insignificant influence on dimensional stability.

In each of the individual process stages from spinning, weaving, bleaching, dyeing through to final finishing, yarns as well as woven and knitted fabrics remain under tensile stress from the first to the last stage of processing. These latent stresses are stored in the fibre in the form of new hydrogen bonds and have a considerable influence on the degree of shrinkage. The built-in stresses participate in a gradual re-formation of a change of shape in the elastic region of the fibre when wet processing is carried out under largely tension-free conditions. It therefore follows that fabrics which have not undergone any relaxation during the final stages of finishing will shrink. The extent of dimensional change in the weftwise direction depends on the fabric construction and whether the preceding finishing stages were carried out under high or low tensile stress. Depending on the type of fabric, dimensional changes up to 20% can take place in the warpwise direction.

In → Resin finishing, the stresses stored in the easily ruptured network of hydrogen bonds become fixed through the superimposition of an additional network which may be permanent or temporary depending on the type of crosslinking agent used. Under these circumstances, the stresses can no longer be broken down. They represent stored energy and reduce the ability of the fibres to resist mechanical influences.

Much more important than the influences of weaving are the various parameters involved in the production of knitted fabrics. In this case, it is the knitter who determines the final dimensions of the fabric and not the finisher. He must decide whether the grey width, the inner tensions in the fabric and the finished width are sufficiently well matched to each other that the finisher can deliver the required finished width, the specified shrinkage values, and a uniform weight in the finished fabric. Whatever measures are taken in finishing to adjust the dimensional stability of a fabric so that it corresponds with specified weight and width requirements, their effect is always temporary. During the first laundering treatment after making up, the fabric will attempt to assume a fully relaxed structure. For this reason, the knitter, finisher and garment manufacturer must be aware of the effects of the various knitting parameters on dimensional stability since, in this case, textile finishing actually begins at the fabric manufacturing stage.

Factors in weaving and knitting which have an influence on wet processing include:

- fibre raw material: natural or synthetic fibres;
- fibre structure: orientation, crystalline or no-crystalline regions;
- fibre geometry: length, linear density, crimp, shape of cross-section;
- yarn construction: staple, continuous filament or textured yarn; blend ratio;
- conditions of weaving/knitting preparation;
- set-up of weaving and knitting machines;
- fabric structure.

All measures taken during previous processes must be coordinated in such a way that the fabric exhibits as little shrinkage as possible before final finishing. The shrinkage and propensity to creasing of woven and knitted cellulosic fabrics can be influenced chemically by the deposition of crosslinking resins and subsequent crosslinkage of cellulose molecules via their OH groups. In this process, covalently bound linkages are formed between the fibre and the chemical crosslinker. This limits the mobility and extensibility of the cellulose molecules which leads to brittleness and a loss in tensile strength. The main problem in resin finishing is the need to keep losses in fabric elasticity within acceptable limits whilst, at the same time, achieving optimum easy-care properties and dimensional stability.

Shrinkage testing (shrinkage resistance tests). The purpose of these tests is to control those dimensional changes (→ Shrinkage) of textile products which are of relevance to the consumer. A wide range of shrinkage tests for different fibres and applications are now in use, the procedures of which vary to a greater or lesser extent in different countries. Procedures to determine the dimensional change of textile fabrics are given in the following DIN standards: DIN 53 892, DIN 53 894 and DIN 53 898 (→ Shrinkage measurement of knitgoods). DIN 53 866 deals with the shrinkage behaviour of single and folded yarns.

Shrink fastness test → Shrinkage testing.

Shrink-finishing tunnel A machine for the compacting and → Shrinkage of piece goods in particular. Fabrics are processed continuously in open-width form. The machine consists of two preshrinking units, a vibration jet drier with three open-mesh conveyors and beater rolls, a steaming zone, transport conveyors, hot air nozzles for undulating movement of the plaited fabric, and a cooling zone at the delivery end. This type of machine is particularly recommended for raising the loops of knitted loop pile fabrics before shearing as well as the shrink resistant finishing of knitgoods in general. Residual shrinkage values capable of meeting the ideal standard of below 1% are achieved.

Shrinking machines Machines for the shrink-resistant finishing of textiles by mechanical compression in a moist hot state (→ Compressive shrinkage) or a tension-free treatment in a steam atmosphere (Fig. 1). The objective is to achieve residual shrinkage values up to 1% max. in subsequent use.

The shrinkage calender made by Heliot (Fig. 2) is described below as an example. Fabric first enters a J-box for compacting or automatic feed (A). This is followed by a device for the detection of holes, 2 motorized feed rolls with adjustable speed (B). A device for opening out knitted fabric by means of 2 pneumatic spreaders (C). Illumination of both sides of the fabric in the working area. Adjustable overfeed. Steam box for vertical steaming through 3 double steam rails (D). Extraction of excess steam and removal of condensate (E). 2 shrinkage units each consisting of a heated roller with controllable surface temperature and an endless felt blanket (with controlled contact pressure and automatic centering) (F). Regulating system between both shrinkage units for tension-free treatment. Connecting conveyor to the folding unit (G). Transport conveyor for tension-free feed (H). Suction extraction of accumulated moisture (I). Video monitoring of the folding opera-

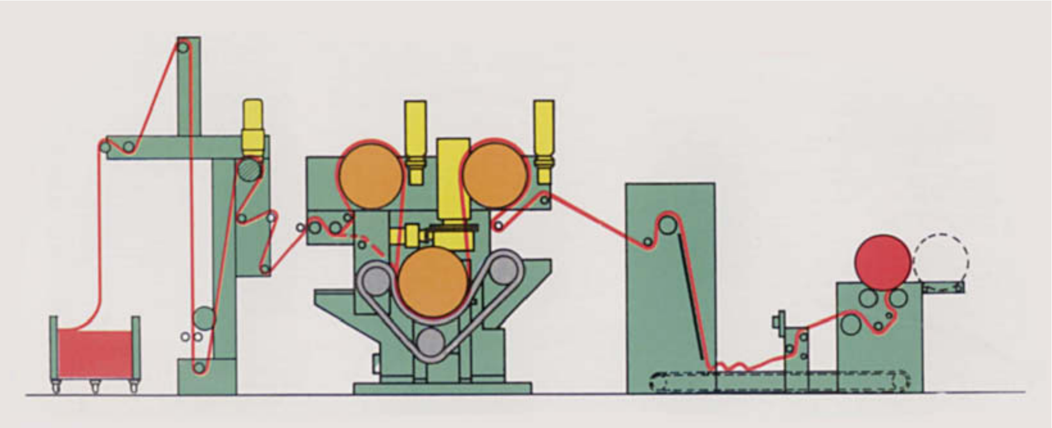


Fig. 1: Top-Tex shrinking machine (Monforts).

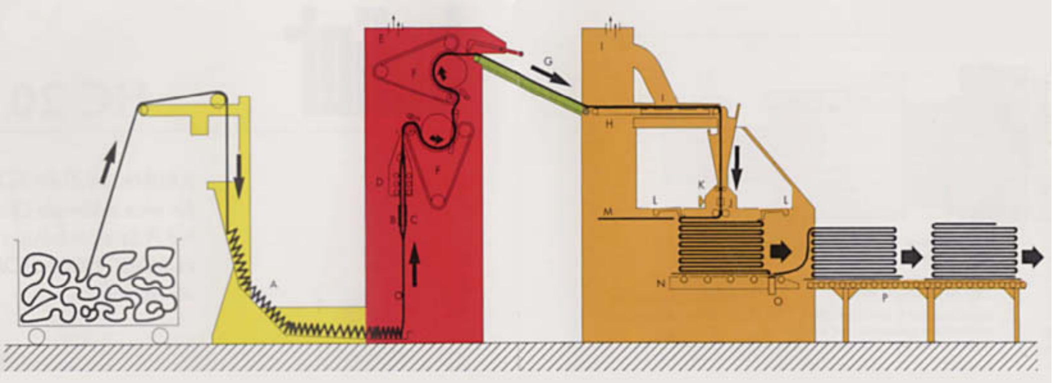


Fig. 2: Heliot shrink calender (left) with integral plaiter (right).

tion. Static eliminator. Feed rollers for the rear spreader (J). Folding device with rectilinear movement (K). Weight application to flatten the fabric for uniform folding (L). Batch-changing unit (M). Moveable folding table (N). Automatic cutting unit (O). Transfer of cut end on to completed batch of folded fabric. Conveyor belt (P).

Shrinking of knitwear One of the most important care and use properties of clothing textiles is shape retention during wearing and washing. A positive influence on the dimensional stability of knitwear made from cotton is possible by means of chemical treatment or also using mechanical processes such as controlled → Compressive shrinkage. Chemical stabilizing is avoided if possible for ecological reasons because knitwear worn close to the skin, which contains urea-formaldehyde derivatives as resin finishing agents, possibly contracts little known interactions with the skin. Terms such as "green cotton" (special tumbling in the Henriksen Tric-O-Dry) or "natural cotton" (treatment using liquid ammonia) make use of the market trend in textiles, which are loaded with as few chemicals as possible. Purely mechanical processes of compressive shrinking such as the Top-Tex-W system (Monforts) for example or compactor types on a shoe shrinkage basis (Hunt & Moscrop) have therefore gained strongly in importance.

The compressive shrinking of textile fabrics is influenced by mechanics, humidity, heat and time. If a parameter is missing or if its effect is inadequate, there is a negative influence on the result of the shrinking process. The unstable knitwear is often stretched longitudinally after wet treatment. These tensions are more or less strongly blocked depending on the magnitude of the frictional forces between the threads of adjacent stitches. The knitwear is compressed by the compressive shrinkage, i.e. the frictional forces within the strained stitches are raised; the stitch can be brought back into its most favourable energetic form. The contact pressure in the rubber cloth/steel cylinder sandwich, i.e. the normal force, should be selected so that on the one hand the fabric adheres on the rubber cloth and the linear change of the rubber cloth can increase; on the other hand the frictional force between shrinking cylinder and knitwear should be overcome. The frictional forces within the bonding points of the stitch and between the fibres should be overcome during the compression process.

The knitwear is carried more loosely across a steam cylinder before the shrinkage process. With an pressure of 6 bar the maximum temperature is 165°C. The steam pressure should be selected so high that a pressure of 0.5-0.8 bar is formed in the cylinder wrapping and the risk of condensate forming in the steam drum is avoided. If the relatively cold knitwear circulates in the steam cylinder, the steam condenses on the fabric surface. It should be assumed that one section of the residual fabric moisture also contributes to condensate formation. The condensate film prevents the coefficient of friction between shrinkage cylinder and knitwear in the subsequent shrinkage process. The rubber cloth is cooled with water when the machine is commissioned. The water is squeezed out until a certain residual moisture has been reached; this moisture content also positively accommodates the shrinkage process. The internal friction of the knits, which the rubber cloth transmits to the fabric, can clearly be overcome because of the moisture, and the knitgoods flow into each other better. The heat and moisture transfer of the steam represents an important task in the preparation of the fabric for the shrinkage process. The condensate splits polar bonds between polymer molecules and thereby causes a fibre swelling. The mobility of the polymer chains is in turn increased. The textile fabric together with the compressed rubber cloth circulates approx. half of the shrinkage cylinder circumference. This phase represents the dwell period of the compressive shrinkage process. Mechanically pushing together the fabric into the new dimension follows. At a machine speed of 20 m/min, the dwell period is approx. 3 seconds. In connection with the shrinking unit, the knitwear is fed to a heated solvent cylinder, which removes the condensate film from the fabric surface; the knitwear is fixed in comparison to the ironing process. Only after passing the solvent cylinder, after the de-swelling, can hydrogen bonds be re-formed and the fibre material stabilised, i.e. the fabric is temporarily fixed using secondary valences.

If a textile fabric is hydrothermically treated and mechanically pushed together longitudinally, a compressive shrinking takes place. The shrinking should be controllable by the clamping of the rubber cloth on the shrinkage cylinder. The compression is achieved via surface elongation and subsequent surface compression of the rubber cloth with a change of curvature at the same time. The soft, elastic material alters its shape due to the clamping of the rubber cloth on the cylinder. The rubber cloth becomes thinner in the area of the clamped point proportional to the contact pressure. The cloth should inevitably be stretched based on the volumetric constancy of the rubber, i.e. its surface is enlarged. The fabric only reaches the stretched rubber cloth surface shortly before the nip. The forced elongation reduces elastically on leaving the pressed area, i.e. the rubber cloth becomes thicker again and thereby shorter. The turning knitwear must recognise the movement of the rubber cloth, as it adheres; the flat, heated shrinkage cylinder, however, may slide by on the fabric. The knitwear is pushed together, which is expressed in an increase in the stitch density.

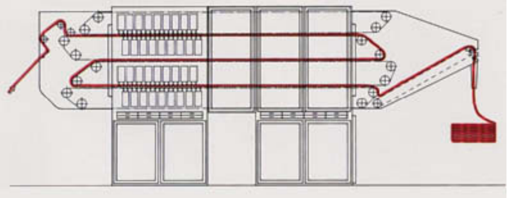


Fig. 1: Santex "Santashrink" shrink drier for the tension-free drying of knitted fabric.

It is also possible to shrink knitwear in special dryers (Fig. 1). Good shrinkage results can be achieved and the residual shrinkage values considerably improved using a special knitted fabric drier. Under the influence of intensive ventilation, the fibres return to their original natural form and a large part of the total tension potential is thereby depleted. The fully relaxed state of a stitch is characterised by an ideally formed stitch, which is then adjusted if the forces from the yarn bending to the stitch loop and the frictional forces in the bonding points, which must have reached a minimum value, are in equilibrium. In order to obtain residual shrinkage values in conformity with market conditions, more variables, which influence the shrinkage potential, should be considered (Fig. 2):

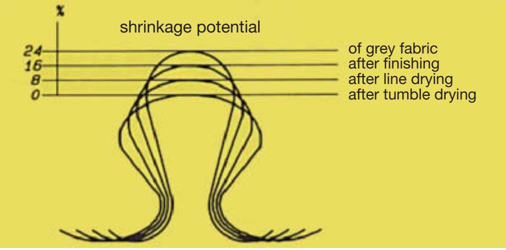


Fig. 2: Shrinkage potential of a stitch in various processing conditions with the absolute round stitch as a system with lowest shrinkage potential.

- stitch structure, bonding forces and yarn material;
- knitting machine setting, lead and material tension;
- separate pretreatment stages and the effects of time and temperature connected with them;
- extended dwelling and sine-shaped fabric movement in the shrinkage drier as well as changing how the fabric is laid;
- finish treatment after the shrinkage drier, storage and packing.

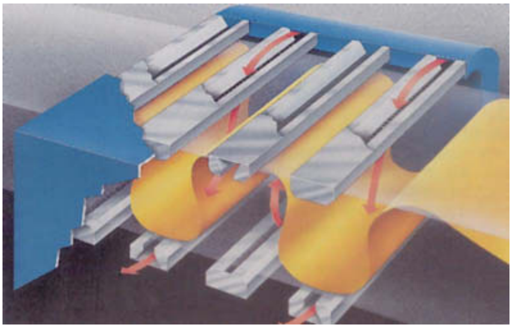


Fig. 3: Obermaier drier with no conveyor belt.

The brace in brace driers (Fig. 3) has offset vibration in the middle and bottom stage between the ventilation zones in order to additionally increase the relaxing process in the fabric. The fabric disengages in the rapid exchange from the brace, due to the vibrations, and drops back again. The fibre bonding is opened by the vibration, loosens up the stitches and encourages shrinkage behaviour until it is a reproducible, dimensionally stable finished good. The untensioned fabric guide and fabric movement are easy on the surface, but encourage shrinkage, and produce a good handle and give the fabric volume.

The knitwear is laid down in even creases, lying close behind one another, using an adjustable rotating brush roller, immediately after the fabric transfer onto the drier strip in the brace drier from Brückner (Figs. 4 and 5). Density and depth are given to the folds corresponding to the shrinkage potential of the knitwear across the possible lead of the fabric transportation device up to 120%. The knitwear is spread by using a brush roller with an arrow-shaped bristle arrangement and rolled up edges are opened at the same time.

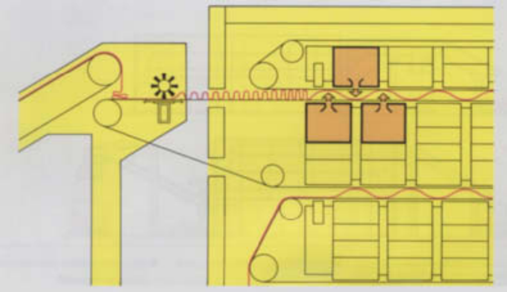


Fig. 4: Brückner conveyor belt drier (diagrammatic).

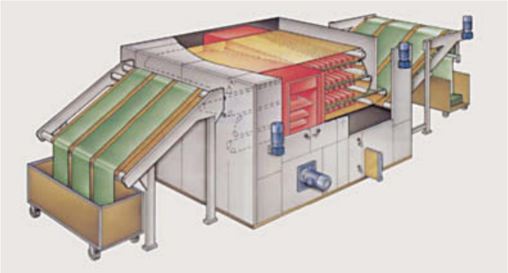


Fig. 5: Brückner conveyor belt drier.

Shrinking of power Concerns → Dimensional stability due to → Non-shrink finish.

Shrinking process Anticipation of → Shrinkage caused by mechanical and/or hydrothermal finishing processes of → Non-shrink finish.

Shrink-proof finish → Non-shrink finish.

Shrinkproof finishing Grammatically speaking, this is a term that should really be restricted only to finishes capable of producing a fabric with a residual shrinkage of zero (an absolutely shrinkproof fabric is not possible in practical finishing) but which is commonly used (erroneously) for finishes which reduce the residual shrinkage of textile fabrics to a level consistent with their fitness for purpose. The correct term for these finishes is → Non-shrink finish.

Shut-off devices Stop-cocks, sliding valves or other suitable valves for stopping or regulating the passage of flowing or stored liquids, gases, steam, etc.

Shuttle A boat-shaped yarn-package carrier, often made of hardwood with a metal tip at each end, used in → Shuttle looms to insert the weft (filling) yarns through a shed formed between the warp yarns during weaving. As the only → Weft insertion systems in a shuttle loom, the shuttle has an aperture to hold a pirn or cop on which a limited supply of weft yarn is wound during weaving preparation. The pirn or cop contains sufficient weft yarn to insert several picks before the empty yarn package is replaced with a full one in order to continue the weaving process.

Shuttle looms (shuttle weaving machines). In a shuttle loom, the weft is inserted by means of a → Shuttle which is propelled over a race plate through the shed of separated warp yarns. The shuttle is propelled from side to side by a wooden shaft called a “picking stick” so that the weft yarn is inserted alternately from left to right and vice versa thus producing a closed selvedge (in contrast to all of the more modern → Weft insertion systems introduced in the meantime). Weft insertion by means of a shuttle is the oldest insertion system on mechanical looms. For many weaving applications nowadays, shuttle looms have been replaced by more efficient shuttleless machines, e.g. air and water jet looms, etc. Shuttle looms are, nevertheless, still widely used for carpet weaving in which heavy, thick yarns are processed at low speeds. → Weaving.

SI,

I. Israel Standard.

II. → Sisal, → Textile fibre symbols, according to DIN 60 001 T4/08.91.

III. → SI system of Units (Système International d'Unités).

IV. Styrene-isoprene (polymer).

Si,

I. → Sisal, → Textile fibre symbols, according to DIN 60 001 up to 1988; this abbreviation was changed in 1991 to → SI.

II. Symbol for the non-metallic element silicon (atomic number 14).

SIC Israeli standards organization. → Technical and professional organizations.

Siccatives, drying agents Desiccants as additives for drying oils, for the preparation of → Varnish and in linseed oils. Insoluble siccatives: compounds of inorganic or low molecular organic acids. Soluble siccatives: metal salts soluble in linseed oil, ether, etc. Molten siccatives are products manufactured by, for example, melting metal oxides and colophony.

Side-by-side fibres (S/S types) → Bicomponent fibres.

Side-to-side shading → Tailing.

Siebenbürgen rugs Small oriental → Knotted carpets, which arrived in Siebenbürgen during the Turkish occupation of South-Eastern Europe and were used to decorate the churches in the manner of the independent principality at that time.

Siemens Derived SI unit of → Electrical conductance, e.g. for electrometric measurements. 1 S is equal to the electrical conductance of a conductor of electrical resistance 1.

Sieve applicator in flock printing For flock coating of small parts, panels, pullovers for sample purposes in manually operated small flock coaters, which work using a spherical sieve for take-up of the flock as well as electrostate sieve applicators.

Sieve-drum drier Loose material, hank yarn, spinning cable, carded strip, woven and knitted fabrics are sucked through a current of hot air to a drum covered with screen fabric and in this way, dried. Sieve-drum driers (see Fig.) are characterised by their high performance over a small area. The principle is also used for thermofixing, steaming, washing, in the smoothing machine and with continuous dyeing. The sieve-drum drier differs from the circular stenter in that the needle tapes are fixed to the drum and have to be detached and reattached if the width of the fabric is changed. Advance devices may also be used. The machine is designed especially for drying nonwovens. The sieve-drum drier is therefore an airing drier with pure fresh air reverse flow and exhaust discharge in the first drying section, in which the initial drying stage takes place.

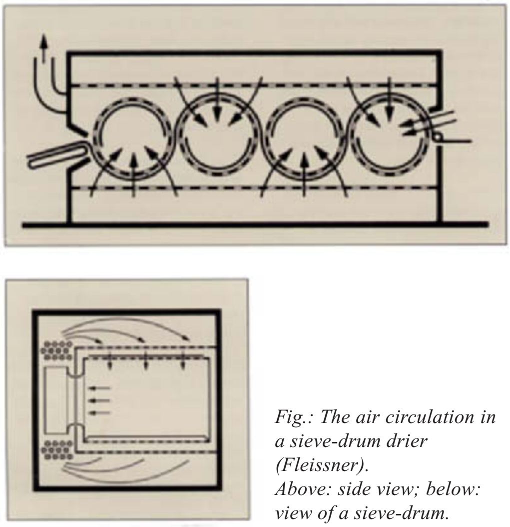


Fig.: The air circulation in a sieve-drum drier (Fleissner). Above: side view; below: view of a sieve-drum.

The single-drum speed is adjustable to the lengthwise fabric shrinkage. The fabric is freely transfered from drum to drum so that shrinkage is also possible crosswise. The drier is therefore well-suited for tension-sensitive fabrics, which is supported on top of the curved sieve-drum surface and so prevents any distortion or gathering. From energy consumption calculations it emerges that the sieve-drum drier performs well within the airing system (compared with the plate conveyor drying machine and the circular tension machine) and has a 30% lower energy consumption in comparison with the jet system with the stenter.

Sieve-drum drier, perforated drum type Revolving sieve drum used for accelerated, gentle drying (e.g. for knitted fabrics). The fabric, fed from the supplier conveyor belt, passes over the surface of the rotating drum to the lift-off device and the cuttler. Through the low air pressure (fan) generated inside the drum, constantly pre-heated air is sucked through the fabric, circulated repeatedly in the drier, reheated again and removed virtually saturated. An economical drying method especially for spinning cable, flock, hank yarn, woven and knitted fabrics. Perforated drum driers have proven their value because the airing component fundamentally affects the drying power. It has since been possible to make the perforated drum drier an equal rival among very economical driers through the arrangement of tension chain feeds or complete tension chains. Nor is there any doubting the fact that, besides the positive ventilation features, the perforated drums also ensure a perfectly safe conveyance of the fabric, both with and without overfeed, with two-way air supply provided by transfer to counter-rotating drums. It is useful if the drum bodies are fitted with coarse and fine mesh covers, in order to both eliminate contact heat and allow certain currents operating below the web to be effective. Perforated drum driers are therefore powerful because the supporting drum body allows them to operate with full air impact and good flow technology guarantees an even arrangement of air over the entire working range.

Sieve-drum drier, reverse flow type An English construction of the sieve-drum drier system, where warm air, unlike with the normal system, is blown from inside to outside.

Sieve-drum steamer Steamer based on the principle of the → Sieve-drum drier, where textile runs are held on rotating sieve (suction) drums by steam.

Sieve-drum washing machine Drum washing machine based on the flow through principle. The liquor flows due to gravity towards the laterally arranged axial pump, which ensures an equal level over the working width to be achieved inside the drum (Fig. 1).

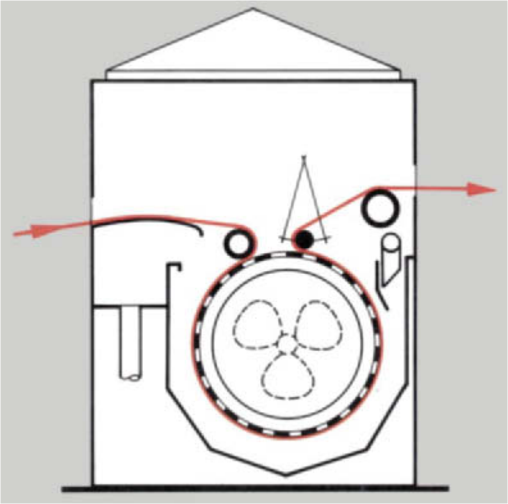


Fig. 1: A sieve-drum washing machine (Babcock).

The differential pressure operates over the entire drum circumference, being mainly the result of the fibre passage resistance and the section of the drum not covered with fabric. The drum shell is finely perforated on the outside with a large open area, and is smaller on the inside towards the liquor flow limit on the side of the web. The fabric entry in the drum section is relatively short compared with conventional roller vats. Sieve-drum washing machines are especially suitable for pure rinsing and impregnating purposes (Fig. 2), as well as for knitgoods (low-tension cloth guide).

Sight glass Built into pipelines, condensate returns, etc. for checking the flow, purity, absence of bubbles.

Sighting (marking, identification dyeing) is aimed at temporary dyeing to prevent confusion of dif-

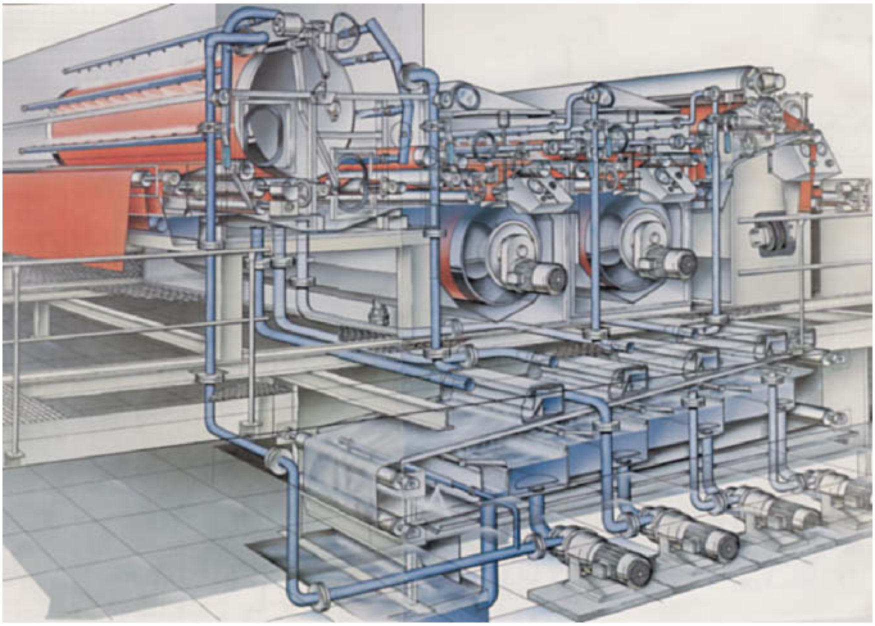


Fig. 2: A sieve-drum washing machine (Babcock) with collection of the washing liquor outside the goods compartments and its re-use through spraying onto the sieve-drums.

ferent yarn twists, yarn types, materials and the like. Sighting frequently also occurs with the manufacture of fancy-ply fabrics to control the distribution of different types of fibres in the design. Requirements: easy to wash off again (even after intermediate steaming, fixing or decatizing) without damage to the material. Application: sprinkle 0.1–0.5 g/l dry dye (mostly concentrated dyes without fibre substantivity) in spooling oil or sizing, distribute well with high-speed mixer, sieve. Impregnate the yarn cold, squeeze out the running thread and dry at a low temperature.

Sighting colours → Textile markers.

Sighting dyes Non-substantive dyes for the particular stubstrate, which can be added to colourless printing pastes to reveal repeat inaccuracies on blades and rollers and later washed off again (e.g. for white discharges, half-tone reserves, leuco vat ester dyes, stabilized azo dyes, phthalocyanine dyes). Frequently also colourless substances (e.g. fluorescent brightening agents) which fluoresce in UV light.

Sighting thread Sensor-exciting metal thread as a separating thread or sewing thread (→ Seam detector).

Sigokki machine There are various possibilities of applying a printing background in resist printing. The easiest is to print the background via the pre-printed resists on a rotation film-printing machine. At the same time, it is recommended to use two blotch printing templates, with one template covering any printing faults of the other template, such as lint markings. One possible way of applying ground dye pastes has been developed in Japan. The Sigokki machine is a mixture of a padding machine and a roller printing machine. The system is simple in construction and design and is in widespread use in East Asia (see Fig.).

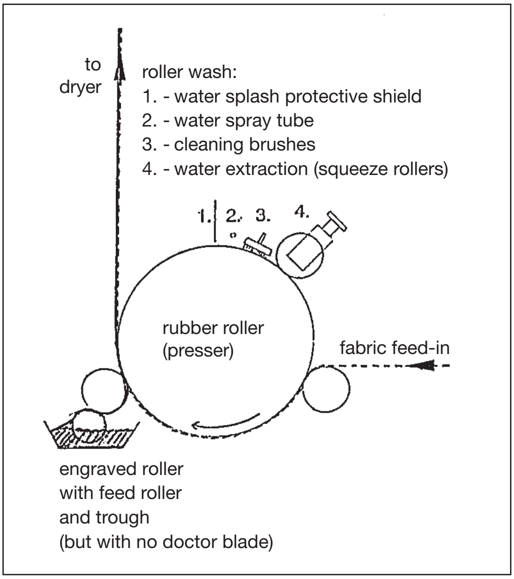


Fig.: Sigokki machine.

Silica gel (active silicic acid), SiO_2, manufactured from → Water glass (sodium/potassium silicates) by conversion by sulphuric acid under certain concentration and temperature conditions. Acidic manufacture: fine-pored A type (bulk density approx. 720 g/l), alkaline manufacture: coarse-pored B type (bulk density approx. 450 g/l), grain sized approx. 2–6 mm. Properties: ability to mechanically link with water and release it again by heating (regenerating above 450°C). Principle: sponge-like structure of numerous extremely fine capillaries (diameter some millionths mm). Use: in absorption systems, A type for drying and cleaning of industrial gases and space air drying with air-conditioning systems, B type for drying liquids, especially liquid hydrocarbons (benzine, benzole, etc.). Distinction: A gel transparent and clear, B gel milky.

Silicate boiler scale (SiO_2), most dreaded modification of → Boiler scale, caused by silicate in boiler feed water (even 5–10 mg/l SiO_2 is a risk to boilers operating at high pressure). Has a particularly low thermal conductivity. 0.2 mm layer thickness causes local overheating, buckling of the tubes, etc.

Silicate ion-exchanger → Zeolites.

Silicate of soda → Sodium silicate.

Silicates Salts of the meta, ortho and polysilicic acids. Not soluble, non decomposed in any solvent. The aqueous solution has a limited service life (tendency to gradual flocculation or drying up). Even a small addition of acid causes gelatinous separation (→: Sodium silicate; Water glass).

Silicic acid Numerous hydrogen-oxygen modifications of silicon (Si); e.g. orthosilicic acid H_4SiO_4, metasilicic acid H_2SiO_3 and polysilicic acids. The salts are called silicates.

Silicon (Si), atomic weight 28.4; melting point approx. 1450°C; density 2.3; non-metal; large, monochrome crystal or grey or brown powder (amorphous form). The former is somewhat chemically inert, the latter considerably reactive. Reducing agent, resistant to acids, boiling alkali forms alkali silicates. Produces with water, hydrogen acids or silicic acids, the latter being more or less hydrous (salts = silicates, e.g. water glass $Na_2Si_4O_9$). Silicates are mostly insoluble in water. Potassium, sodium and associated elements form high-viscosity solutions (water glass). Alkali silicates (fused with aluminium, iron, etc.) are familiar as → Zeolites. Forms with hydrogen silanes (e.g. monosilane H_4Si), with halogens e.g. silicon fluoride SiF_4, fluorosilicic H_2SiF_6 (salts = fluorosilicates). With metals and similar elements of silicides (e.g. + carbon; silicon carbide SiC). Numerous compounds are derived from organic or inorganic silanes, such as halogen silanes, which can alkylate. Alcohols form silanols (R_3SiOH)

or silicols (≡C–Si–OH), whose sodium salts, esters, amines produce silazanes (≡C–SiN=) and, by hydrolysis, oxygen compounds of the siloxane type (–SiR_2–O–). Thus, from organo-siloxanes (≡C–Si–O–), the major → Silicones of the type $[(CH_3)_2SiO]_n$, i.e. "silico-ketones" (Kipping), are produced by polymerization.

Silicon carbide (carborundum), SiC, variously coloured (reddish, greenish blue, black) crystals, very chemical and heat resistant, diamond-like hardness, density 3.2. Is obtained from coal and quartz at over 2000°C. Use: as grinding and polishing material; for fire-resistant bricks and electrical resistance bodies.

Silicone antifelting treatment allows knitwear manufacturers to produce machine-washable woollen articles by the application of → Silicone elastomers.

Silicone-based dyes serve to permanently dye glass fibres in dark shades, as well as to modify the properties of normal silicone oils and resins.

Silicone-based textile auxiliaries → Silicones represent important auxiliaries in the textile industry for processing and finishing. They have many advantages due to their universal application possibilities, problem-free handling, free choice of type of application, gentle cross-linking, great efficiency and slight environmental pollution.

Silicone catalysts Hydrogen methyl polysiloxanes (→ Silicones) require special catalysts for cross-linking, the choice of which creates the possibility of influencing the overall effects of the fabric.

Silicone coating The cross-linking of → Silicone elastomers to lattice-type structures occurs at the reactive points by means of special cross-linkers under the influence of metal organic special catalysts and heat. A cross-linker must have at least three reactive binding sites per molecule so that an elastic lattice structure is produced. Usual cross-linkers are:
- methyl hydrogen siloxanes
- tri or tetra-alcoxysilanes
- triaminosilanes.

The special catalysts are used to accelerate the cross-linking reaction.

The basic substance with silicone coating is in all cases polydimethyl siloxanes, i.e. long, linear polymer chains, which consist alternately of silicon and oxygen atoms. The residual valencies of the silicon are usually saturated with methyl groups. The polymer chains are equipped with a defined number of reactive groups such as vinyl groups. Vulcanization (see Fig.) occurs at these places.

Another essential component of silicone rubber is the active fillers. Active means that the surface of the fillers (gen. highly disperse silicon oxide) interacts with the polymer chains, which reinforces the mechanical properties. However, the viscosity or plasticity of the mass greatly increases with the filler content. With coating processes such as spread coating, dip coating or spraying, certain viscosity limits may not be exceeded, however. For this reason, silicone rubber has frequently been dispersed in organic solvents, the viscosity controlled via the quantity of solvent and the dispersion applied to the textile. At any point in the coating process, however, the solvent must evaporate again, be recovered by condensation, be burnt or, in the worst case, emitted into the environment.

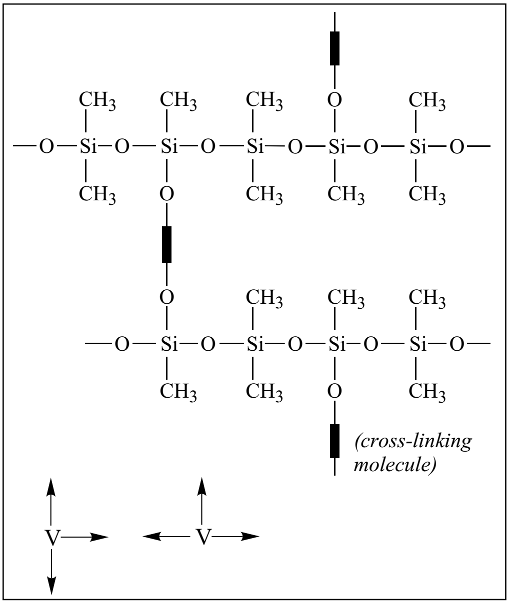


Fig.: Three-dimensinal cross-linking of silicone coatings as vulcanization.

In the automobile, tyre, food and printing industries, as well as in textile-processing systems, silicone-coated conveyor belts for sorting and production lines have been successfully used for decades. Virtually all manufacturers of silicone-coated conveyor belts have since gone over to solvent-free production. For this application, single-component silicone masses, cross-linking at room temperature, have been developed with a low viscosity, as has liquid silicone rubber. Conveyor belts must be flexible in a temperature range from – 50°C to + 250°C. Chemical resistance and abrasion resistance are taken for granted. Special types of conveyance systems with steep angles of inclination have anti-slip properties. For process belts in the food sector, solvent-free silicone rubbers are available. For special working processes, electrically conductive, antistatic coatings are necessary. There are also solvent-free alternatives available for this.

Increasingly, airbags are part of the standard equipment of motor cars. They protect the occupants in an accident against impact with the windscreen, steering wheel and fascia. The fabrics used need to be gastight and temperature-resistant due to the thermal development of the propellant.

The polychlorobutadiene-coated fabrics used exclusively in the years of development are still processed the most often today. Disadvantages such as slow elimination of hydrogen chloride at increased temperatures, distinct blocking behaviour and poor resistance to ageing have become apparent in the course of time. In addition, large amounts of solvents are required in the coating process. This has led to considerations as to how polychlorobutadienes can be avoided. Two main directions have been taken:

1. Yarn manufacturers, weavers and garment manufacturers are working on the possibility of managing with uncoated fabric.
2. Parallel to this, silicone rubber has been tested as coating material and considered suitable.

The development of special types makes for solvent-free coating of polyamide fabrics even using low coating amounts of 20 g/m^2. Both types of airbag, uncoated and silicone-coated, are already used in cars. There are advantages in favour of the silicone-coated airbag. These are, first and foremost, improved gasproofing, which prevents carbon monoxide (propellant gas) from escaping, and great flexibility, which facilitates manufacture and folding and makes for the smallest packing volumes. In addition, silicone coating prevents friction of yarn on yarn with vibration and provides the proper heat protection upon igniting the propellant. As a result of these advantages, silicone-coated airbag fabrics are increasingly accepted.

Silicone cross-linking For the silicone cross-linking of reactive-group → Polydimethylsiloxane at least trifunctional cross-linkers are required so that an elastic network structure is achieved, e.g. methyl hydrogen siloxanes, tri- or tetra- alcoxysilanes and triaminoalkylsilanes. Silicone cross-linking usually takes place in the presence of special catalysts and may drain off as condensation (OH terminal group), addition (vinyl terminal group) and as peroxide cross-linking (methyl terminal group).

Silicone elastomers High-molecular → Polydimethylsiloxane with terminal hydroxyl groups, which cross-link with hydrogen methylpolysiloxanes in the presence of catalysts, e.g. tin alcyl compounds or silicic acid esters. Used in solvents or aqueous emulsions (solvent technique enables better effects) as → Silicones in finishing, e.g. for elastic finishing of knitwear made of synthetic fibres, antifelting finish and the like. Further properties include: soft handle; positive effect of the resistance to chafing, sewability, pilling behaviour and bursting resistance with knitgoods.

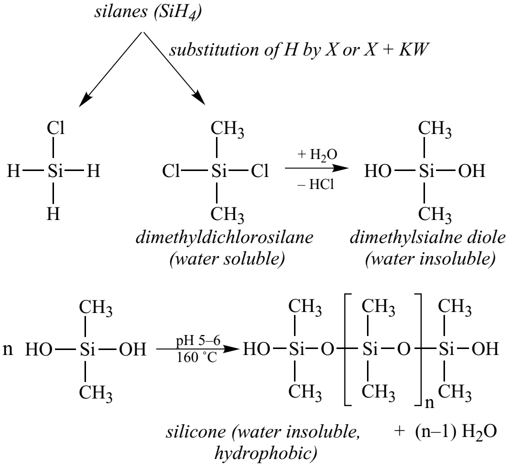
Silicone fibre African → Bast fibres, similar to ramie. Natural colour grey, also bleached. Produces no cold feeling on the skin with sweating. Spun according to the type of combed yarn, especially blended with wool for sportswear, stockings, gloves, etc.

Silicone finishes for textiles Give the textiles, if desired, hydrophobic properties (silicone additive of 1–1.2% of the dry weight of the fabric), protection against wet dirt, a soft handle and improvement to the sewability and abrasion resistance.

Silicone finishes, stripping May be required with defective silicone finishes. Is difficult, however, particularly if the fault is not detected until after hardening. By means of an acid treatment with 60 g/l hydrofluoric acid (alternatively oxyl acid and suitable polyphosphates and acid-resistant wash-active substance) in 60 min at 80–90°C, if necessary with a subsequent chemical cleaning.

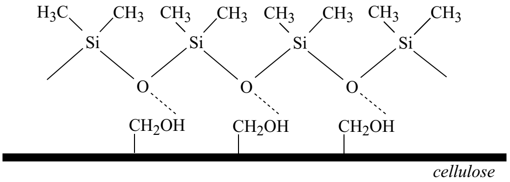
Silicone rubber Synonym for → Silicone elastomers. Poor resistance to abrasion. Resistance to acids is excellent to moderate, to solvents poor (aliphatic/aromatic hydrocarbons), to oxidation, ozone, sunlight ageing, excellent, to flammability moderate to good.

Silicones (polysiloxanes) are, as organic silicon compounds, among the synthetic polymers. They represent important auxiliaries in the textile industry for processing and finishing. They offer advantages due to their universal application possibilities, problem-free handling, free choice of type of application, gentle cross-linking, great efficiency and slight environmental pollution. Starting from dialkyl or diaryldichlorsilanes and water, polysiloxanes or rather silicones are produced by polycondensation.



The properties of the condensates can be affected by the addition of trialkyl or triarylchlorsilanes (chain termination) or alkyl or aryltrichlorsilanes (cross-linking). Application, for both synthetic and native fibres, occurs either according to the exhaustion process or by padding. Precondensated polysiloxanes (as solutions in organic solvents or as aqueous dispersions) are normally applied to the fabric together with catalysts. After drying on the stenter, the actual condensation takes place with temperature (150–160°C, 0.5–3 min). So far hot condensation has had the greatest significance of the various cross-linking options. Addition cross-linking is also usual, however, using siloxanes with vinylene groups and hydrogen siloxane cross-linkers. Zinc, tin, lead, magnesium and zirconium compounds are all suitable as catalysts for condensation. Cross-linking lasts some 30–60 s at 120°C, 15–30 s at 150°C. Usually H-siloxanes (methylhydrogenpolysiloxanes), dimethylpolysiloxanes or combinations of both are used. The H-siloxanes in particular are capable of cross-linking due to their movable hydrogen atoms (catalysts: tin, zinc, lead). The choice of catalysts allows the overall effects of the finishes to be consciously affected.

Silicones are in a position to cross-link with cellulose, whereby the ether groups align themselves according to the primary hydroxyl groups of the cellulose (epoxy resins which condense under temperature and with catalysts having the aligning effect).



The silicones settle advantageously on the fibres in a more or less formed film, so that no gaps which can destroy the properties of the silicone films arise. The fabrics being impregnated need to be thoroughly precleaned.

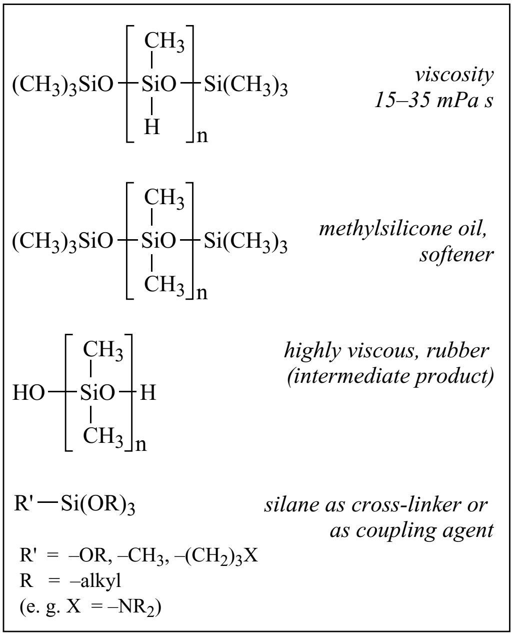
The consistency of the silicones can extend from oily via elastic to a resinous state:

I. Silicone fats and oils: polysiloxanes with a linear chain structure and relatively small average degree of polymerization.

a) Silicone oils are produced from difunctional silanes. They involve liquids with a chain or ring-shaped molecular structure and a silicon component of 36%. Properties: water-clear liquid of varied viscosity with low setting point and good heat resistance, water and adhesive repellent, low surface tension, strong compressibility, soluble in all non-polar solvents, higher homologues are odourless and tasteless, resistant to oxidation. Use: gloss and flow agent in polishes and paints, lubricant, etc.

b) Silicone fats are manufactured from silicone oils; non-drip, heat-proof lubricants e.g. for stenter.

II. Silicone resins: polysiloxanes with reticulated structure and relatively high average degree of polymerization. Manufactured from trifunctional silanes or mixtures of di- and trifunctional silanes.



$$(CH_3)_3SiO\left[\begin{matrix}CH_3\\ |\\ SiO\\ |\\ H\end{matrix}\right]_n Si(CH_3)_3$$

viscosity 15–35 mPa s

$$(CH_3)_3SiO\left[\begin{matrix}CH_3\\ |\\ SiO\\ |\\ CH_3\end{matrix}\right]_n Si(CH_3)_3$$

methylsilicone oil, softener

$$HO\left[\begin{matrix}CH_3\\ |\\ SiO\\ |\\ CH_3\end{matrix}\right]_n H$$

highly viscous, rubber (intermediate product)

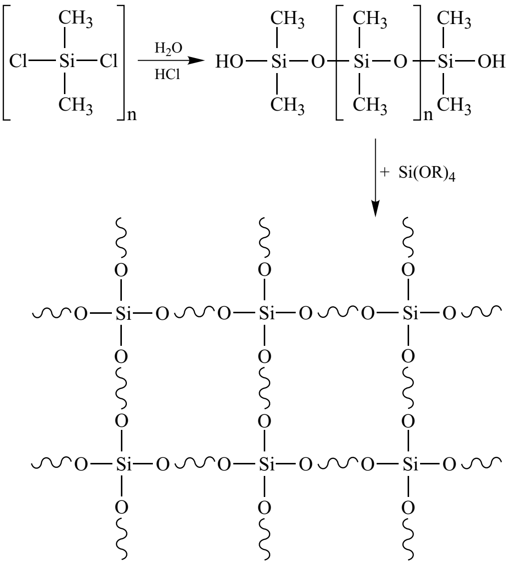
$R'—Si(OR)_3$

silane as cross-linker or as coupling agent

$R' = –OR, –CH_3, –(CH_2)_3X$
$R = –alkyl$
(e. g. $X = –NR_2$)

Properties: silicones are hydrophobic. A hydrophobic effect occurs through the spatial arrangement of the silicone compounds condensing on the fibre surface. Silicones are therefore used for hydrophobing (= water-repellent finishing). This waterproof film allows wash-fast effects to be achieved. Unfortunately, this is frequently accompanied by a deterioration in the fastness to light and rubbing. The effect can be easily verified using rain tests.

In addition, silicones also work as softeners. They allow fibres and threads to glide better in the overall structure. Besides a supple and soft handle, this finishing achieves improved wettability at the same time, which is particularly important for polyamide fabrics for tents or umbrellas. Together with carbamate or glycol resins, silicones are also used for crease-resistant and permanent-press finishes. Silicones are weatherproof since they have no unsaturated groups. They have good elasticity, which is attributable to the helix shape of the chains and can be reinforced still further by slight cross-linkings. The polar Si-O-Si bonds allow any contact to polar surfaces to be made, while the hydrocarbon residues point in the opposite direction. Normal silicones, therefore, have good surface activity and are, as a result of their low volume solubility and high surface solubility, antifoaming agents and separating agents in high concentrations, and foamers in small concentrations. Silicones react sensitively to residues of anion-active auxiliaries. They require careful stor-



age and clean preparation because they split off hydrogen.

III. Silicone elastomers (synonymous with silicone rubber): high molecular polysiloxanes with functional terminal hydroxyl groups which cross-link in the presence of catalysts with hydrogen methyl polysiloxanes.

They provide a soft, supple, surface-smooth handle, improved wrinkle recovery and crease resistance in combination with resin finishing (makes for a 50–60% reduction in the synthetic resin quantity as well as improved abrasion resistance, wettability, etc.).

Silicones in finishing While in the silicon crystal the atoms are arranged regularly in relation to each other, in the amorphous silicon this order is lacking. The transition from the crystalline to the amorphous state, therefore, has some disadvantageous consequences. On the one hand, the mobility of the charge carriers in the amorphous product is clearly smaller than in the crystal; on the otherhand, the amorphous structure produces a high concentration of non-saturated silicon bonds (Fig. 1). These express themselves as defective states in the band gap. One possibility of rendering the free bonds passive to a large extent consists of saturating them with hydrogen. With the manufacture of amorphous silicon layers, e.g. by plasma destruction of silane (SiH_4), the hydrogen passivation of the free bonds occurs almost automatically.

Owing to the large electro-negativity difference between silicon and oxygen, there results in silicon-oxygen compound, a negative partial charge on the oxygen (e.g. silicates, Fig. 2). With corresponding silicic acid esters, which are usual in resin finishing as sewability improvers in the form of dispersions as additives, this charge distribution is symmetrical and makes

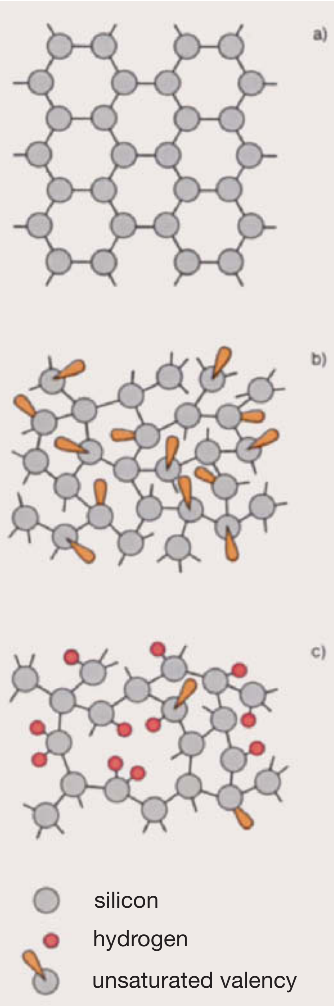


Fig. 1: The (diagrammatic) arrangement of atoms in: a) crystalline silicon; b) pure amorphous silicon; c) hydrated amorphous silicon (a–Si:H).

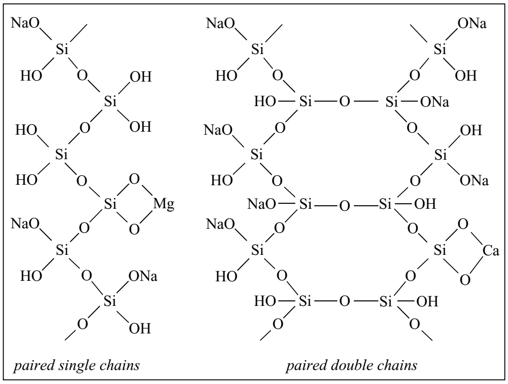
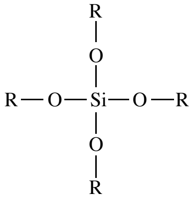


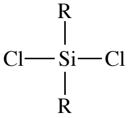
Fig. 2: The structures of single and double chains in silicates (water glass).

the silanes into stable compounds, e.g. tetra-alkyloxysilane (additive for resin finishing):



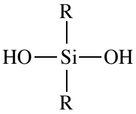
$$\mathrm{R-O-\underset{\underset{R}{|}}{\underset{O}{|}}{\overset{\overset{R}{|}}{\overset{O}{|}}{Si}}-O-R}$$

If dihalogensilane is hydrolyzed



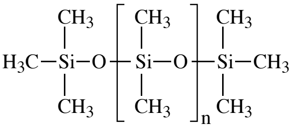
$$\mathrm{Cl-\underset{R}{\overset{R}{Si}}-Cl}$$

in the presence of monochlorsilane (chain stopper) or trichlorosilane (brancher), cross-linked siloxanes are formed by the autocatalysis of halogenhydrogen produced in the meantime via polycondensation of the metastable hydroxysilanes



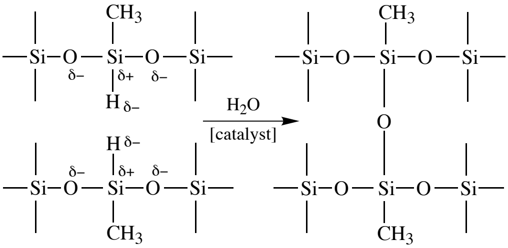
$$\mathrm{HO-\underset{R}{\overset{R}{Si}}-OH}$$

with the brancher and linear siloxanes, e.g. dimethylpolysiloxane (softener), are formed with the chain stopper:



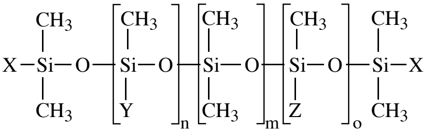
$$\mathrm{H_3C-\underset{CH_3}{\overset{CH_3}{Si}}-O-\left[\underset{CH_3}{\overset{CH_3}{Si}}-O\right]_n-\underset{CH_3}{\overset{CH_3}{Si}}-CH_3}$$

While the Si–O bond of the latter might be polarized, it is only firm enough to preserve the polymer material of the silicones. This basic framework is not only infinitely variable in its chain length; the equilibration ability is so rich in variants with suitable catalysts that any sequence in the main chain and specific terminal groups can be aimed at. In addition, the silicon atom has vacant 3d orbitals in its electron configuration, the result being that, through coordinative expansion, reactions with nucleophiles are possible, which among other things permit all side chain modifications such as condensations, additions and radical reactions as polymer-analogous reactions, especially when hybridic hydrogen (negatively polarized) is present:



methylhydrogenpolysiloxane *cross-linking (hydrophobing)*

In the general formula for silicones (polysiloxanes)

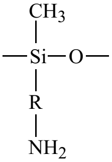


$$\mathrm{X-\underset{CH_3}{\overset{CH_3}{Si}}-O-\left[\underset{Y}{\overset{CH_3}{Si}}-O\right]_n-\left[\underset{CH_3}{\overset{CH_3}{Si}}-O\right]_m-\left[\underset{Z}{\overset{CH_3}{Si}}-O\right]_o-\underset{CH_3}{\overset{CH_3}{Si}}-X}$$

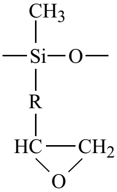
there are three main possibilities of modification with the organic substituents $-CH_3$, –X, –Y, –Z:

a) sequence in the copolymer,
b) terminal group modification,
c) side chain modification.

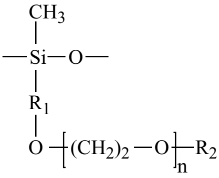
It is possible to build in as side chains:



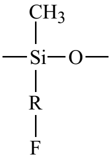
antistatic agent, antifelt finishing



cross-linking agent for fine finishing, antifelt finishing



defoaming agent, softener, hydrophilation, soil release, silicone surfactants



oleophobic finishing

The following requirements result for a defoamer:

- The defoamer must be insoluble in the foaming system. It must not, therefore, dissolve in the liquid lamella.
- The defoamer must spread as rapidly and evenly as possible over the lamella to suppress the surfactant

mineral oil defoamers		silicone oil defoamers	
70–80 %	oil	5–20 %	silicone oil
20–10 %	hydrophobic extenders	2– 5 %	hydrophobic silicic acid
10 %	emulsifiers with stabilisers and conserving agents	3– 5 %	emulsifiers with stabilisers and conserving agents
		90–70 %	water

Tab.: The composition of defoaming agents.

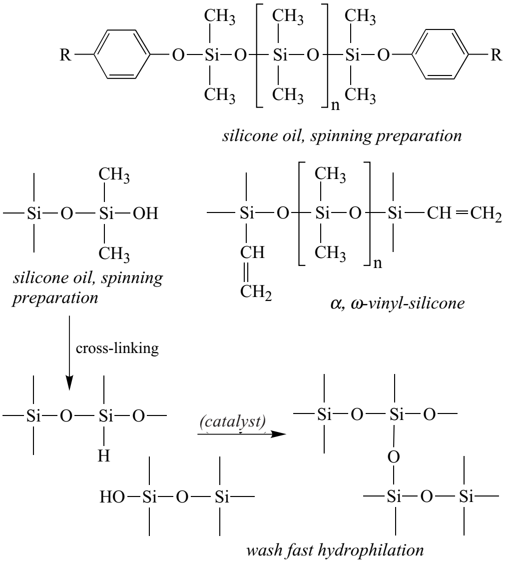
molecules, i.e. it must have a smaller surface tension than the latter.

- The defoamer should also produce lattice defects in the boundary surface, which is achieved by the insertion of hydrophobic fillers.

The Tab. shows the composition of two types of defoamers chiefly used in the textile industry, silicone defoamers being visibly superior to the mineral oil defoamers, in effect, on account of the low surface tension of the silicone oil.

Elementary halogenation produces silicofluorochemicals (Fig. 3).

The following can function as terminal groups:



In this way, a group of trivalent silicones is produced, which can be processed into silicone elastomers (Fig. 4). For the production of silicone elastomers on textiles, the minimum curing temperature is important (Fig. 5).

Silicones can also display a surfactant character (Fig. 6) by being stimulated differently; in this way cationic, anionic and amphoteric surfactants are formed.

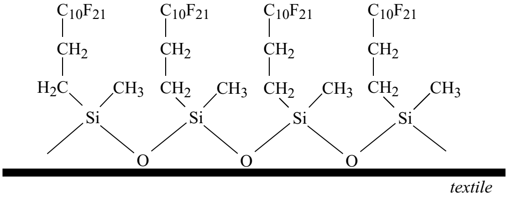


Fig. 3: Textile finishing using silicofluoro chemicals.

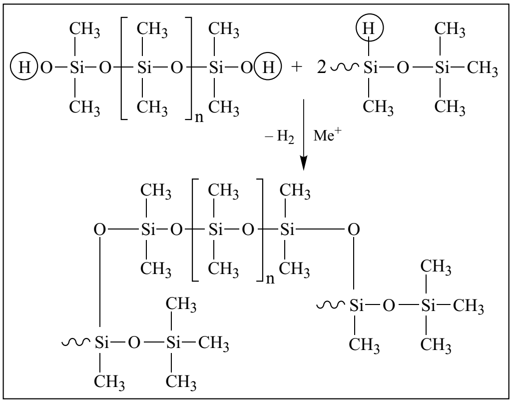


Fig. 4: Three dimensional cross-linking of silicone elastomer.

Siloxane polymers (Fig. 7) can be altered extensively in their characteristic profile, e.g. by modifying of the polyether component.

Emulsions of alkoxy-aminoalkyl terminally modified base oils are also used, which are present in water highly aggregated and sterically inhibited as “dormant prepolymers” since the hydrophobic silicone polymer prevents the access of water to the reaction centres. It is only through water vapour (Fig. 8) that these silicones become monomolecular and not aggregated, and reactivation occurs, e.g. subsequent to a “dry process”, since silicones have great penetration power for gases of any type. Via hydrolysis, release of alcohol and base-catalyzed silanol condensation (primary amino groups), elastomers are formed with outstanding handle properties (amino modified). “Pure” single-component products require neither separate cross-linkers nor external catalysts.

In the course of development, type and degree of the amino modification have been varied, with quaternary groupings also finding access. New types of emulsifying techniques allow for the production of extremely fine-particle “microemulsions”, where the constituents also penetrate the textile substrate via micropores. To the hitherto pure surface effect is added a quantum of “inner softness” so that supersoft properties result. The extreme fine particle nature of these types of emulsions

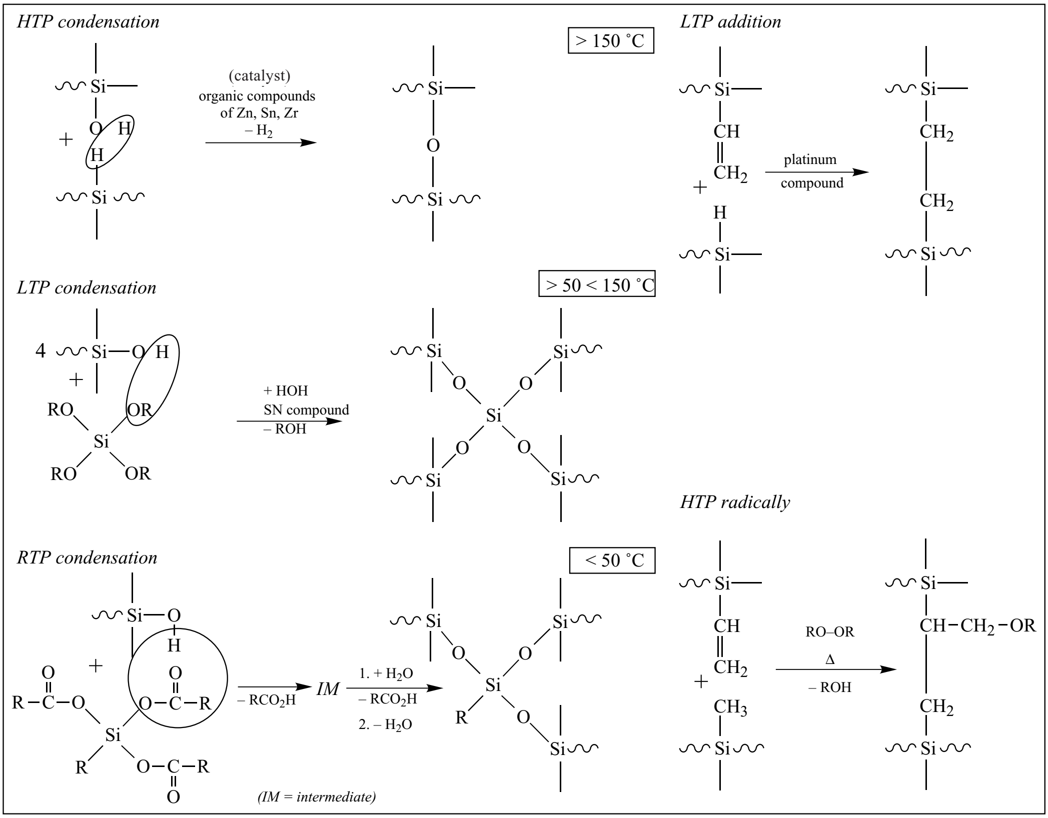


Fig. 5: Hardening temperatures of various silicone elastomers (HTP = high temperature; LTP = low temperature; RTP = room temperature).

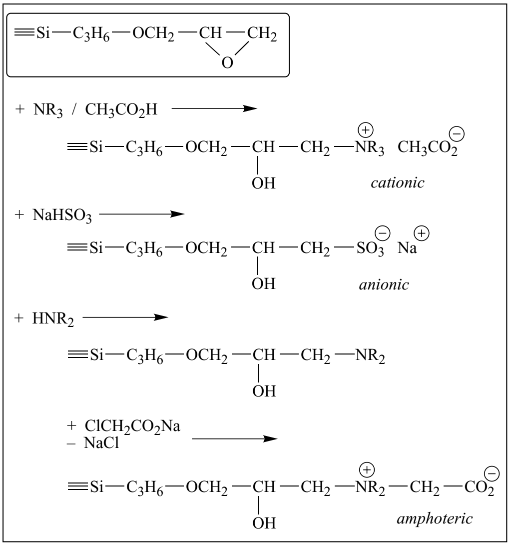
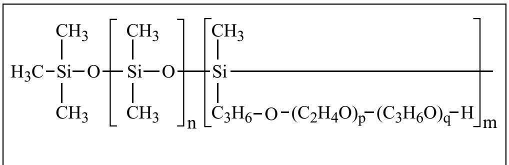


Fig. 6: The synthesis of ionogenic silicone surfactants.



$$H_3C-\underset{CH_3}{\overset{CH_3}{Si}}-O-\left[\underset{CH_3}{\overset{CH_3}{Si}}-O\right]_n-\left[\underset{C_3H_6-O-(C_2H_4O)_p-(C_3H_6O)_q-H}{\overset{CH_3}{Si}}-\right]_m$$

number n/m	0/1	13/5	20/5	20/5	20/5
weight as % EO/PO	80/20	100/0	75/25	35/65	20/80
cloud point (C°)	45	90	65	30	10
HLB value	–	19	18	14	10
surface tension (mN/m)	23	28	28	27	–
Ross-Miles foam depth (mm)	200	110	60	60	5

Fig. 7: The composition and properties of selected polyether-siloxanes.

(the size of the particles are below the wave length of light) brings sustained improvement to their stability in the face of mechanical and flotation stress, with the result that nothing stands in the way of using jet dyeing

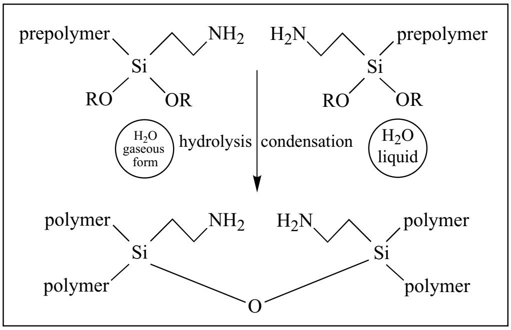


Fig. 8: The reaction mechanism for single-component silicone elastomer.

systems. Multistage syntheses, low production capacities and sophisticated emulsifying techniques mean, however, that the price of amino modified silicon microemulsions is high. Extenders therefore reduce the content of "super softeners" (according to Haug, and Seidel and Kiesling, as well as Hardt, and Gysin).

Silicone softeners Silicones provide textile substrates with a combination of soft handle, smoothness, gloss, fullness, elasticity and sewability with excellent permanence at the same time. A soft, flowing handle can be an influential criterion when purchasing textiles. At a time of more demanding consumer claims, silicones are increasingly common as textile softeners. A decisive share of these silicones in textile finishing is allocated to the amino-modified polydimethylsiloxanes. The softening effect of the silicone oils is based on their slide performance both on the fibre surface and in the fibre itself. Amino-functional groups linked to polydimethylsiloxanes enable an improved orientation and substantivity of the silicone on the substrate. This leads to an optimally soft handle and is often described by the term "supersoft".

The mainly used aminoethylaminopropyl-functional silicones ($–Si(CH_2)_3NHCH_2CH_2NH_2$) may contribute to the yellowing of the textile, especially white goods, at the drying temperatures customary in textile finishing. While the tendency to yellowing of this type of amino-functional silicone may be minimized through optimizing various parameters, such as amine content, viscosity and formulation, it cannot be avoided altogether, however. The soft handle of this type of silicone is accompanied by a certain hydrophobing of the fibres. Since the moisture content of clothing textiles etc. is determined by the transport of the moisture away from the skin, the hydrophilic property of the fibres is crucial to the wearing comfort. Although silicones in textile finishing have originally been valued due to their water-repelling properties, the trend in soft handle finishing is towards more hydrophilic silicones.

Dirt should be easy to remove from textiles. This presupposes a slight affinity of the fibres for oily dirt. The soil-release properties of textiles are affected by the finishing. Generally, with silicone softeners, a parallel can be observed between reduced hydrophoby and improved soil-release values. In the application, amino-functional silicones are generally applied to the textile substrate in the emulsified state. Then the drying and heat setting takes place. At the high drying temperatures found upon contact with atmospheric oxygen, a more or less strong thermal yellowing (dependent on the amino group content) is observed, which is more disturbing on white goods in particular. This thermal yellowing is attributed to an oxidative breakdown of the amino-functional pendant groups under the formation of chromophoric groups. The tendency to yellowing is particularly acute with the aminoethylaminopropyl group and has to do with the arrangement of the two amino groups (bridged primarily and secondarily via ethenes) preferred for oxidative chromophore formation. The sensitivity of amino groups to a thermooxidative breakdown can be affected by the number and type of alkyl substituents on the nitrogen as well as by the use of protective group techniques such as acylation reactions.

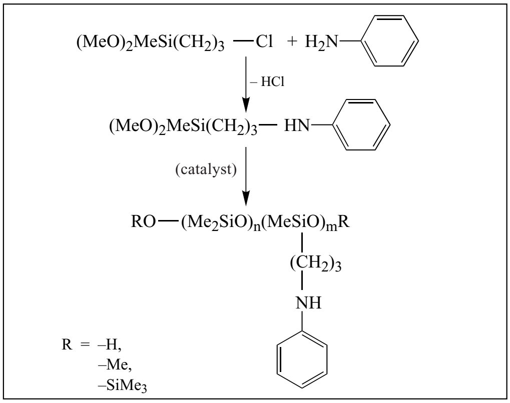


Fig. 1: The synthesis of cyclohexylaminopropyl functional silicone.

Assigned to amino-functional silicone softeners, the following approaches present themselves: synthesis of new, variously substituted amino-functional polysiloxanes. The product class of the cyclohexylaminopropyl-functional silicone oils demonstrates a combination of finishing effects relevant to textile softening. These involve a soft handle, combined with a degree of whiteness at low hydrophoby and good soil-release values. Cyclohexylaminopropyl-functional silicone oils can be manufactured as shown in Fig. 1.

Varying the parameters of polymerization (viscosity), amine content and terminal group reactivity

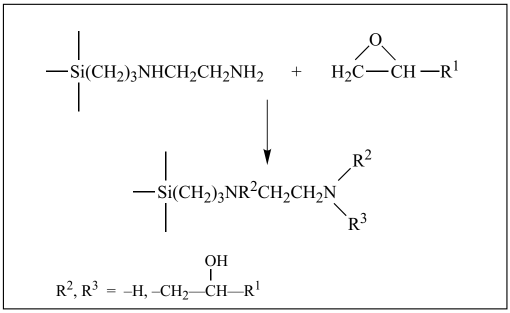


Fig. 2: *Alkalisation of the aminoethylaminopropyl function with epoxides.*

(Me$_3$Si-terminated or MeOHSi/HOSi-terminal) allows product types that meet special requirements to be accessible. Alkylation reactions represent one possibility of increasing the degree of substitution of the aminoethylaminopropyl function. In addition, the reaction with epoxides (alkyl oxides, glycidol, epoxy-functional silanes and siloxanes) is proposed among other things in order to reduce thermal yellowing (Fig. 2).

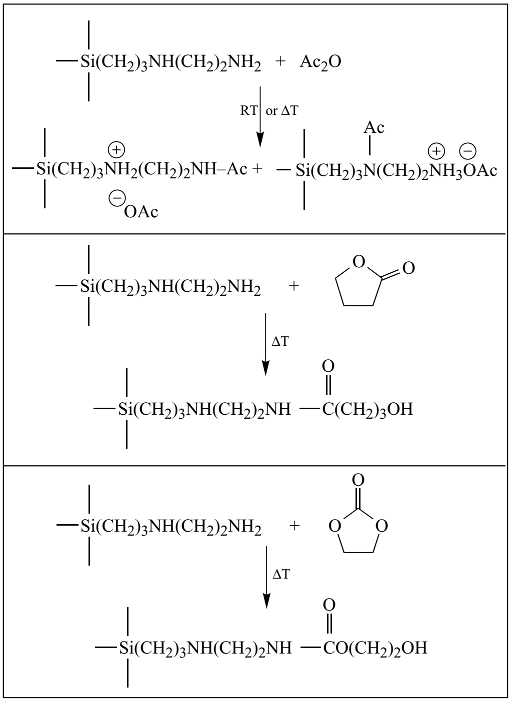


Fig. 3: Acylation in order to reduce thermal yellowing. From top to bottom: acylation with acetic acid anhydride; acylation with g-butyrolactone; acylation with ethylene carbonate.

Alkylation reactions of this type occur relatively unspecifically so that a reaction takes place with both the primary and the secondary amino group while multiple alkylations right down to quaternization may occur. To convert an essential part of the primary amino group into a higher degree of substitution, an overall high degree of conversion is needed. The unfavourable arrangement of the two amino groups with respect to thermal yellowing in the form of an ethane bridge remains intact, with the result that only moderate improvements in whiteness can be expected. It is also a disadvantage in processing terms that a strong viscosity increase occurs with the inevitable pre-reaction of the amine and epoxide components, which can negatively affect the ensuing emulsification. With the finishing, moreover, undesirable roller deposits may come about due to premature cross linking reactions. For the reasons specified, therefore, the direct synthesis of silicone oils containing only secondary amino groups is preferred to the subsequent alkylation of amino-functional silicone oils. The stability of amino groups towards thermooxidative breakdown can be significantly increased by acylation, i.e. conversion into amino groups. This principle is also transferable to amino-functional polysiloxanes. Essentially, this involves acylation with acetic acid hydride, γ-butyrolactone and ethylenecarbonate (Fig. 3) (according to Lauterschläger, Bindl and Huhn).

Silicone surfactants Organic molecules, which comprise the functional lyophilic groups, are bonded with an existing lyphobic silicone back. Silicones containing Si–Cl or Si–OR groups in the fundamental building blocks are assumed here. These might be converted with hydroxyfunctional reaction partners such as polyethers or fatty alcohols. These esterification or transesterification reactions occur invariably with good yields. This represents, besides the equilibration reaction, an important condition for the precise synthesis of customized silicone surfactants. The Si–O–C compound obtained in this way is not permanently hydrolytically stable especially in acidic or alkaline solutions, with the result that the use of silicone surfactants of this type is limited in aqueous media to neutral pH. Such silicone surfactants may be generally used without any problem in anhydrous organic systems. A hydrolytically stable Si-C compound is obtained with the aid of a hydrosilylation reaction. Hydrosilylation may be carried out with precision and good yields. In addition, Si–H functional siloxanes are converted in the presence of transitional metal catalysts (usually platinum complexes) with terminally unsaturated organic reaction partners. These are chiefly used with a certain surplus to guarantee a complete reaction of the Si–H groups.

Among the organo-polysiloxanes, the non-ionogenic polyether polysiloxanes form one of the most important substance groups; reference is also made to non-ionogenic silicone surfactants. The physical properties of these products can be varied to a great extent through changes in the length of the polysiloxane chain, through the polysiloxane/polyether ratio, through the number of polyether side chains and through the ethenoxide/propenoxide ratio in the polyethers, the result being that these copolymers have a large property spectrum (→ Silicones in finishing).

The basic building blocks for the manufacture of silicone surfactants are functional polydimethylsiloxanes, whose reactive centres are formed by Si–Cl, Si–OR or Si–H groups. The equilibration reaction allows the basic building blocks to be manufactured with great precision and reproducibility. Simple types are built up linearly. The functional group is terminally bonded in α-, ω-positions. Proceeding from this type, it is possible to obtain polymer surfactants in which each molecule is defined di-functionally, which therefore produce, in the strict sense, a surfactant with the general structure ABA, where the compatible remainder is designated as A and the polymethylsiloxane component as B. It is also possible, though, to synthesize higher molecular block copolymers with alternating lyophilic and lyophobic sections, if the siloxane building blocks are converted with similarly linear α-, ω- functional reaction partners. Such a surfactant type would therefore be built from repeating AB units. Here the reactive groups are laterally bonded to the linear polymer backs in a comb-shaped arrangement. The distribution of the lateral groups corresponds to the balance established by equilibration reaction. With other types, the siloxane ridge is branched. The surface activity of the copolymers richest in methyl groups is clearly the highest. Accordingly, these also display the best wetting action on polar and non-polar hydrophobic surfaces and are effective foaming agents in water.

Silicone test This simple qualitative test for → Silicones customary in water-impermeable finishes is based on the transferability of siloxanes from the textile material to glass by means of hot concentrated sulphuric acid. Method: pour 1–1.5 ml conc. sulphuric acid over approx. 50–100 mg test fabric in a new test tube, shake in a small Bunsen burner flame (without regard to the dissolution and any blackening of the liquid). Interrupt the shaking every 3–5 s and observe, away from the flame, how the shaken-up acid runs back along the test tube wall. If the acid is brought to the boil after 1–1.5 min at most, and the inside of the tube remains evenly wetted, the result is negative. Should, after approx. 20–40 s when still holding the test tube, a sudden downflow of the approx. 250–300°C, hot conc. sulphuric acid occur prior to reaching boiling point, it needs to cool down again. After pouring away the main quantity, wash out the remaining acid with distilled water, displace the water again with sulphuric acid and reheat. Should the sudden downflow reoccur after 20–30 s, the result is positive. The effect will disappear depending on the amount of silicone either at the start of boiling or only after lengthy heating. 0.5–1 mg polysiloxane can still be easily recognized. The result is negative with silicic acid. A further possible way of testing for silicones consists in reducing the fabric to ashes, with the silicones being converted to SiO_2, melting the ashes with a 6-fold quantity of sodium carbonate/potassium carbonate and dissolving in water. The solution is tested as follows:

a) Addition of some ammonium molybdate, acidification with nitric acid and heating. Yellow colouring indicates silicates or phosphates.
b) Replace solution with a surplus of freshly prepared 5% ammonium molybdate solution, adjust with hydrochloric acid to pH 3 and pour this solution in a surplus of freshly prepared sodium stannate (II) solution. Blue colouring indicates silicates and phosphates.

Silk The production of wild silk and the Bombyx mori type only comprise 0.2% of the world's fibre yield. Owing to fashionable demand, however, global production is growing. Bombyx mori, as the most important silk, is usually processed to grège fibres in the country of production. The seriplane test involves winding it visually on black panels and assessing the evenness of the threads in order to classify the quality of the yarn. Schappe silks are obtained in silk cultures after spinning off the cocoon of Bombyx mori. Wild silks, e.g. Tussah (China) or Eri (India) are obtained from wild caterpillars and processed into fabrics in the country of origin. Japan supplies just below 10% of world production; China is the major supplier of silk with 60%. India supplies approx. 14% of world produc-

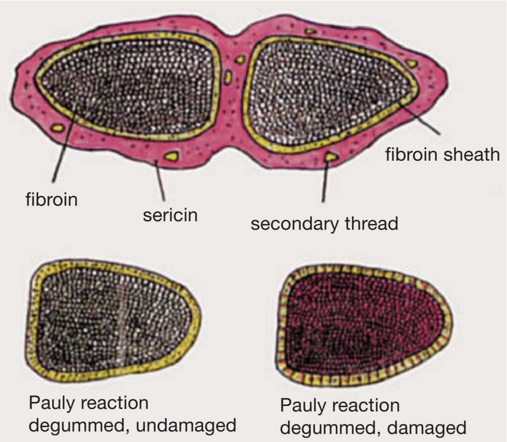


Fig. 1: Cross-section of a raw silk thread, and cross-sections of fibroin both damaged and undamaged following a Pauly reaction.

tion. Russia has a 6% and Brazil a 3% share in silk manufacture.

Silk consists of fibroin threads that are embedded in a sericin gum (Fig. 1).

With wild silks, the → Degumming, i.e. the detaching of the individual filaments from the gum, is difficult and laborious. Schappe silk is usually degummed in the yarn. Approx. 25% of silk gum has to be removed from Bombyx mori, and 5–15% from Tussah silk. Degumming occurs according to four processes (each at pH 9–11.5, 15 min to 5 h):

a) at 98°C with Marseille soap
b) at 98°C with surfactants
c) at 50–60°C with enzymes
d) at 128°C with water.

The average length of the section that can be reeled off varies, however, and is dependent on the genus, size, quality and type. As a rule, 600–800 m are reeled off in a test basin, though under operating conditions the length is only 400–600 m. The trimmings have a length of 250 mm. The length of a raw silk thread may reach 1500 m. The silk thread of a Tussah silk worm reaches a length of 1200–1400 m, of which approx. 600–700 m can be reeled off.

The fibre width and fineness of the raw silk thread differs depending on the origin, breed, sex and size of the cocoon. The fineness of the double thread, i.e. of silk that has not been degummed, is 15–25 µm or 1–3 dtex. The individual threads are 13–28 µm wide and have a fineness of approx. 1 dtex. This makes degummed silk the finest natural fibre. A filament of the Tussah silk worm (Fig. 3) is essentially coarser than that of the Bombyx mori (Fig. 2). It has a cross section of 40–80 µm and a fineness of 3.7–7 dtex. The fineness values can only be specified as an average since the strength within a cocoon shows great variations from beginning to end. The smallest number is found with the silk thread at the beginning. The thickness of the thread increases gradually, gains particularly rapidly in the final layers of the cocoon and is almost three times as large at the end. Such unevenness makes obtaining a uniform raw silk thread especially difficult. To compensate 5–6 cocoons are reeled together to form a multifilament that is subsequently twisted.

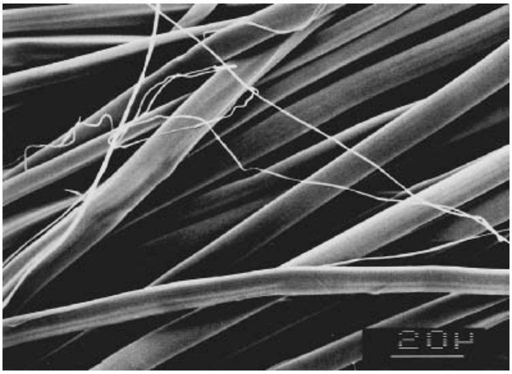


Fig. 2: Scanning electron microscope image of mulberry silk.

Fig. 3: Scanning electron microscope image of tussah silk.

I. Properties: non-degummed silk has a density of 1.37, degummed 1.25. With 2.5–5 cN/dtex, raw silk has a tensile strength which almost that of synthetic fibres. The wet strength is 75–95%. The tensile strength of the yarn is dependent on the length of the fibres, i.e. it becomes smaller with decreasing fibre length. That is why reeled silk has an essentially greater strength than Schappe silk and this in turn has a greater strength than Bourette silk. The abrasion resistance of silk is high. The adhesive silk gum has a negative effect, however, since the fibrous substance can chafe and is thus self regenerated. A loss of abrasion resistance can be seen with loaded silk since the adhesive metal salts make the threads brittle. That is why, with fabrics of this kind, rolling is preferable to folding. In a normal climate, silk will absorb 9–11% moisture, with 100% atmospheric humidity even up to 30%, without feeling damp. The water retention value is 40–45%. In its dry state, silk has a slight elongation of 10–20%. The elongation strength of raw silk is at 29%, that of degummed silk at 24%. Wet elongation 120–200%. Degree of elasticity 70%. The elongation and elasticity values of raw silk are higher than those of degummed or loaded silk. Silk has similar hygroscopic properties to wool. Degummed silk has swelling capacity and absorbency. Characteristic is an anisotropic fibre swelling which lies in the longitudinal direction at 1.65% and in the transverse direction at 18.7%. The sericin alone is the carrier of the natural yellow dyestuff. Depending on the origin, whitish, yellowish or greenish cocoons can be found. The silk fibroin of mulberry silk is either colourless or whitish and transparent, rarely yellowish. Since sericin is released upon boiling off or degumming, the white colour is characteristic of degummed silk. Wild silks are mostly light brown, though sometimes dirty-white or reddish. In contrast to mulberry silk, dyestuffs are also contained in the fibroin of Tussah silk, with the result that no white thread can be obtained with this even by boiling off and intensive bleaching conditions. Silk only obtains its shimmering lustre when the sericin is removed. The lustre depends strongly on the origin. Temperatures which are too high during soaking and insufficient tension when reeling off and drying affect the lustre adversely. Frequently the fibre loses some of its lustre by artificial loading. At the same time, silk gains in fullness as a result of degumming and obtains the characteristic silky handle or “scroop”. This handle should be neither soft nor hard, but rather allow a certain crackle to be felt (Fr. “craquant”). Tussah silk differs from mulberry silk in its harder handle and less exquisite lustre.

II. Chemical behaviour:

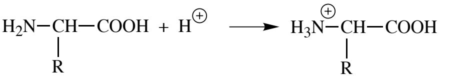
a) Heat: On heating silk to 120°C, no noticeable changes can be detected other than a gradual vaporization. If the temperature is raised to 130–150°C, the following reaction will occur: ammonia from amino acids begins to vaporize; the sericin becomes hard, its solubility in water deteriorates. The silk acquires a dark colouring, which gradually changes into a yellowish grey-brown shade. A change in the properties first occurs with temperatures of 160–170°C. The decomposition of the fibres can be seen from the increasingly darker shade and the smell typical of this reaction. The ash of the silk contains phosphates, sulphates, calcium salts, magnesium and iron. In air, the silk fibre will oxidize, which happens extremely slowly, however, under normal conditions. This process can be accelerated through increasing the temperature, though this is insignificant in a dry atmosphere. With increased atmospheric humidity, silk will oxidize more rapidly.

b) Light: the amino acids are in a position to absorb ultraviolet rays. Under their action, the intermolecular compounds become gradually weaker, thereby reducing the durability of the silk. After ten days of radiation by sunlight under glass, durability is reduced by 19%. With the same amount of radiation without protective glass, this value is 34% and rises in summer to 98%. Sericin has the task of protecting the fibroin from the effect of light.

c) Moisture: when silk is soaked in water, increasingly large quantities of salt and sericin dissolve with rising temperature. The composition of the water has a great effect on this. In boiling water, the fibre becomes rough, loses its lustre and durability, and swells up. Swelling can likewise be observed in a damp environment. Should a cocoon thread be placed in water at 18°C, the diameter increases by 16–18% and the length by 1.2%. When the cocoon cases are washed in warm water at 55°C with a liquor-to-goods ratio of 1 : 20, irregular weight losses of 0.37–3.51% will result. The values are different when boiling them in a 3%-soap solution (liquor-to-goods ratio 1 : 60): they vary according to the genus and type between 22–29%.

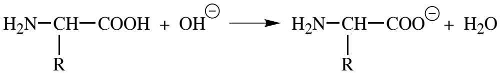
d) Acids and lyes: the silk fibroin is an amphoteric substance, which has binding power for both acids and lyes. It is hydrophilic in character corresponding to its amino acid composition.

acid bond:



$$H_2N{-}\underset{\substack{|\\ R}}{CH}{-}COOH + H^{\oplus} \longrightarrow H_3\overset{\oplus}{N}{-}\underset{\substack{|\\ R}}{CH}{-}COOH$$

base bond:



$$H_2N{-}\underset{\substack{|\\ R}}{CH}{-}COOH + OH^{\ominus} \longrightarrow H_2N{-}\underset{\substack{|\\ R}}{CH}{-}COO^{\ominus} + H_2O$$

The diamine carbon acid content is smaller with silk fibroin than with wool keratin with the result that a max. approx. 0.024 gram equivalents of acid are capable of binding 100 g silk fibroin. The acid-binding power increases, as it does with wool, with increasing pH, whereby a saturation value is initially achieved between pH 1.3 and 0.8. It is only below pH 0.8 that the acid take-up increases rapidly, which is related to the charging and acid-binding power of the carbon amide group of the peptide bond conditioned by it. Warm, diluted mineral acids, such as salt and sulphuric acid, do not attack the fibroin, but dissolve the sericin. With moderately concentrated mineral acids, a shrinkage of the fibre can be seen, which is applicable in finishing (crêpe effect). Concentrated sulphuric acid destroys silk immediately. With cold or especially hot nitric acid, silk turns a yellowish colour. Organic acids have less effect on mulberry silk. Natural silk will dissolve through boiling with glacial acetic acid under pressure.

The max. base-binding power is hard to determine since the fibroin is attacked with increasing hydroxidion concentration. The base-binding power is roughly equivalent to that of wool. The binding mechanism of alkalis on fibroin is explained by the enolization of the amidized carboxyl group, whereby the alkali enters the hydroxyl group of the carbon atom adjacent to nitrogen. Lustre and handle are impaired by the action of diluted lyes while the sericin is dissolved. Through the action of alkalis on mulberry silk, the adjacent polypeptide chains are hydrolytically divided. This results in a shortening of the chains.

e) Pauly reaction as proof of degumming: with wool this reaction is based on the fact that the amino acid building blocks with aromatic groups form a red azo dye with diazotized sulphanilic acid. An amino acid building block of this type with an aromatic group is, for example, tyrosine, which is present in both wool

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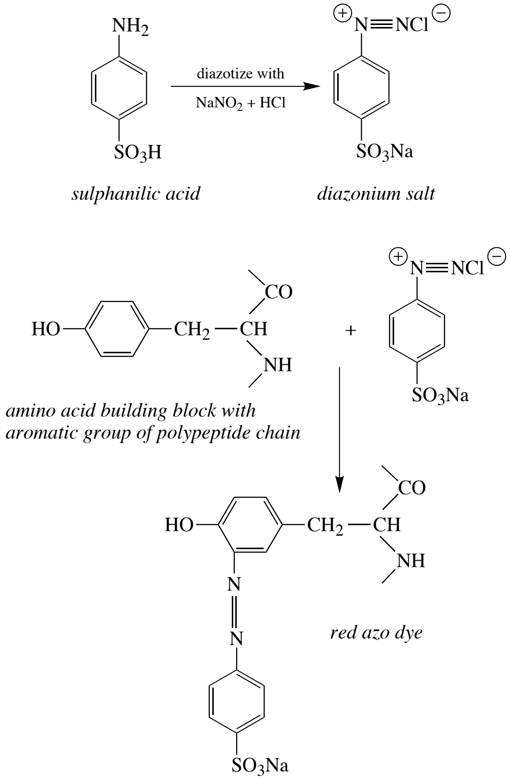
and silk. The dyeing reaction proceeds according to the following:



The Pauly reaction has also been tested on silk. It was found that the gum turns an orange-red with the Pauly reagent (Fig. 1). It can be seen from this reagent whether the silk is degummed or not, i.e. where there is yellowing, the silk is clearly degummed and also undamaged. With orange-red coloration, it needs to be decided microscopically and by subsequent degumming of a test sample that the silk is degummed. If gum can no longer be shown to exist, the orange-red coloration signifies damage to the silk fibroin (white chate marks). Degummed Tussah silk turns a yellowish brown through the Pauly reagent and bleached Tussah silk is stained slightly orange (bleaching of Tussah silk is not possible without some minor damage). Mechanically damaged silk fabrics will also turn red, since the fibroin sheath is destroyed by a little tyrosine and thus the core of the fibre becomes accessible with a high tyrosine content.

Silk bolting cloth → Screen mesh, Screen gauze.

Silk damage Testing for damage to natural silk occurs by determining the viscosity of a solution of natural silk in concentrated aqueous lithium bromide solution.

Silk dusting Occurs due to the splitting up of silk under the effect of alkali or too great a mechanical stress in the working liquors and gives the fabric surface a whitish appearance, as if sprinkled with flour.

Silk dyeing The most important dye classes are acid, metal complex (predominantly 1 : 2), direct and reactive dyes. Cationic, afterchrome, vat (indigo) and vat leuco ester dyes are only used in special cases. In the high-fashion sector, classic brilliant shades in the red, blue and green range cannot as yet be replaced by more genuine products of equal value (Tab.). In contrast to wool and polyamide, the absorption curve for silk is different. Absorption already begins at 30°C and has virtually reached the optimum at 60–70°C. With the moving dye, e.g. on the overflow, this temperature range should be used since the risk of damage to the fabric increases at higher temperatures (dusting). A 60 min dyeing period at 60–70°C is gentler than 40 min at 90°C. To obtain equal dyeings, care should be taken to ensure that a rise in temperature in the dye bath of 1°C/min is adhered to.

I. Dyeing in the pH range of 4.5–7, depending on the dye depth, shade and type of fabric. pH control by means of acetic acid or buffer system of sodium acetate/acetic acid, no addition of salt necessary. Levelling agents are important; fibre preserving agents (lubricants) are advisable when dyeing in the hank.

II. Dyeing in a weakly alkaline soap bath at pH 8–8.5 (e.g. with Marseille soap), addition of sodium sulphate, no levelling agents necessary. Better fibre preservation, better evenness. Depending on the colouring, the shade will turn out slightly lighter. For larger batch-

dye class	area of use	advantages and disadvantages	fastness, 1/1 RT (average value)		
				staining on silk	
			xenon light	water severe	sweat alkaline
direct	piece	simple dyeing process some good light fastness poor wet fastness	4–6	3–4	2–3
acid	yarn piece	simple dyeing process some good light fastness some brilliant nuancing poor wet fastness	2–5/6	2–4	1–4
1 : 2 metal complex	yarn piece	simple dyeing process some good light fastness good degree of exhaustion dull nuancing moderate wet fastness	6	3–4	3–4
reactive for CO	yarn piece	moderate to good light fastness high wet fastness suitable for cold dwelling process	3–6	4–5	4–5
reactive for WO	yarn piece	good light fastness some brilliant nuancing high wet fastness high degree of fixation suitable for cold dwelling process	6	5	4–5

Tab.: The areas of use, the advantages and disadvantages and the fastness of dye classes for silk.

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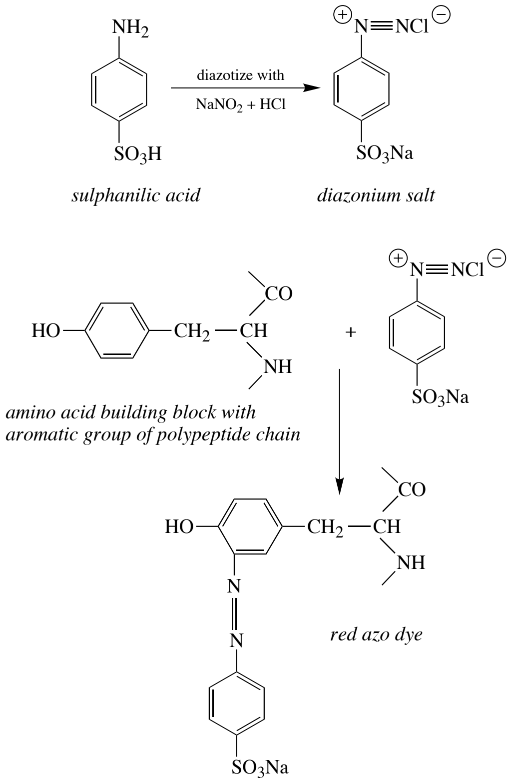

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Tab.: The areas of use, the advantages and disadvantages and the fastness of dye classes for silk.

es and lighter shades, the cold dwell process may be used (pad batch 24 h).

III. Process for reactive dyes: various reactive systems can be dyed on silk. Fixing mechanism and binding stability differ, as do the resistances. With weaving yarns, the demand for resistance to degumming may also be important; then dyes should be selected which are stable in the hot alkaline bath. Two processes are normally encountered:

a) Exhaust dyeing in the alkaline range (sodium carbonate or sodium hydrogen carbonate) at 50–70°C with the addition of large quantities of salt (up to 100 g/l for black).
b) Cold dwell process with alkali (sodium carbonate or sodium hydrogen carbonate), poss. urea, dwell time 24 h at room temperature.

To achieve good wet fastness properties, a subsequent washing treatment at approx. 80°C is important for both processes; care should be taken to ensure that the mechanics are protective (according to Hofstetter, Flensberg and Hammers).

Silk dyeing machines There are dyeing machines specially developed for silk, in which the silk fabric is treated as gently as possible. To this end, driven reel winders with a particularly large radius are used, especially in overflow machines, to prevent slippage of the fabric (see Fig.).

Silk fabric inspection packaging In silk finishing operations, description for areas in which pieces are checked and made ready for consignment.

Silk finish → Silk scroop.

Silk finish for cotton (Schreiner effect), discreetly shimmering “silk lustre” on fabrics (e.g. damasks, satin, linings, shirting fabrics, etc.), also combined with synthetic resin intercalations, as washproof or permanent silk finish (dress and blouse fabrics). In each case, there is a refraction of light effect on the fabric surface of the finest ribs, only visible under a magnifying glass, which has been produced on a silk finish calender. Silk finish is recommended with qualities of fabric which preclude mercerization for cost or technical reasons (linings or certain dress fabrics).

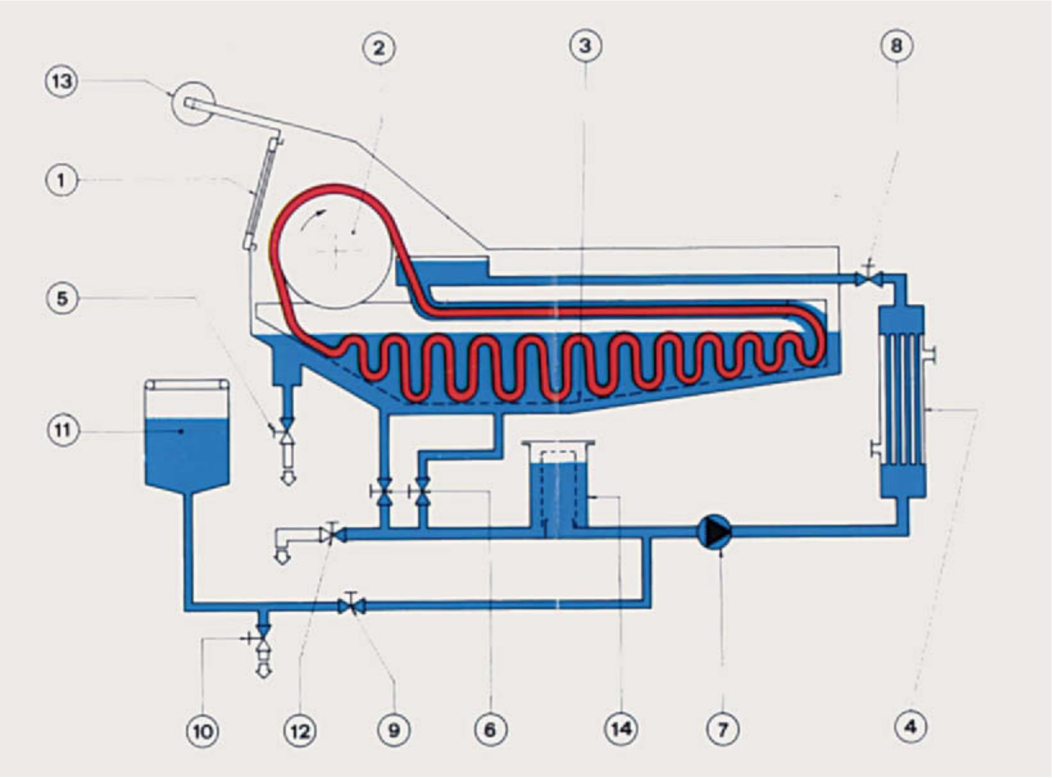


Fig.: A Mezzera overflow for silk.
1 = loading; 2 = guide winch; 3 = channels for fabric transfer; 4 = heat exchanger; 5 = overflow valve; 6 = suction control valve; 7 = main liquor circulation pump; 8 = demand control valve; 9 = product intake control valve; 10 = drain valve for additives; 11 = preparation tank for dyes and additive products; 12 = machine drain valve; 13 = unloading winch; 14 = filter.

Silk finishing The finishing of silk is usually limited to restoring the handle and lustre worsened by other finishing processes (bleaching, dyeing, drying). The finishing of the different silk qualities varies depending on the desired handle. Besides the handle of the fabric, the following finishing effects on silk are important:
- dimensional stability, thread straightness/shrinkage
- no formation of folds, white chate marks, dusting
- resistance to slipping
- resilience
- scroop (crackly feel)
- soft, flowing drape
- hydrophilic property
- non-marking of water drops
- dirt repellence
- oil and water repellence
- antistatic behaviour.

If so far the main focus of attention has been on traditional handle finishing, the question of greater fastness to care and wear of the silk is being raised with increased frequency. As with other fairly easy-care textiles, issues such as crease resistance, anti-electrostatic effect, elasticity, stain removal and the machine-washability of silk up to 60°C and 80°C are being discussed. Problems regarding the wet fastness level of dyed or printed silk have been able to be solved through the use of reactive dyes.

It should not be forgotten that "easy-care" finishing of the silk only represents a real improvement if the outstanding natural properties of this natural fibre are preserved and an improved resistance of the silk to mechanical strains of all kinds is achieved in addition (according to Flensberg and Hammers, Monney and Moreau).

Silk grass (Honduras silk grass) Longest type of bast fibres belonging to the → Bromelia fibres (Central and South America). Cream-coloured, silky bright, fine and soft (surpassing the Cantala and Mauritius fibre).

Silk gum → Sericin.

Silk hardening → Degumming.

Silk printing Besides direct printing, discharging is one the conventional modes of operation. Resist printing has only been able to gain limited acceptance. The printer uses several ranges of dyes, in order to do justice to the demands in discharge printing.

I. Direct printing: acid, acid milling, 1 : 2 metal complex and reactive dyes are taken into account. The first three groups, properly selected and cationically after-treated, facilitate good fastness to water and washing up to 40°C. For greater demands, reactive dyes should be used. There is increased use of continuous festoon steamers compared with the star, as well as the development of better open-width wash machines.

II. Discharge printing: a lot of experience and continuous monitoring form part of the implementation. The choice of dyes and the discharge chemicals under the existing operating conditions are crucial. Process:

a) white discharge;
b) coloured discharge with direct, acid, metal complex or cationic dyes as illumination dyes;
c) coloured discharge with vat dyes.

Direct, acid, metal complex or reactive dyes are considered as background dyes. The dischargeability of each dye delivery should be checked. The choice of the reducing agent is greatly dependent on local conditions as well as the process chosen. Some illumination dyes are not very fast to wet treatment, the upshot being that they cannot withstand one wash (even at low temperature); the fastness to light of some elements is also only moderate. The choice of discharge-resistant dyes increases considerably with tin dichloride. Some elements are at a wet fastness level that permits a wash up to 40°C. The yellow cast of the discharged portion that is added to the illumination shade has a coloristically negative effect, however. Last, but not least, the corrosive effect of tin dichloride on the steaming equipment should be considered (separation from hydrochloric acid). Only the coloured discharge with vat dyes on the reactive ground supplies washable silk prints with wash fastness properties up to 40°C and above. The process is not technically simple, however. In addition, many of the suitable indigoid vat dyes have disappeared from the market so that colorists are limited in their choice of shade.

III. Resist printing: resist printing processes represent an interesting alternative to discharge printing from a coloristic point of view and are particularly well-suited to table film prints on silk. The process is based on the property of special resist agents to resist certain acid and metal complex dyes, while not preventing others from fixing to the fibre. The colorist is thus given the opportunity to manufacture a large choice of ground and overprint shades. In this wet-on-wet process, only one operation is required. The resist printing processes are technically easier to control than discharge printing and offer greater operational safety (according to Hofstetter, Monney and Moreau).

Silk ribbon finish At one time a valued special type of finishing based on resins and ether-soluble gums in benzole and similar for (esp. thread-dyed) pure-silk (taffeta, Liberty) ribbons, to achieve a full, solid handle, without stiffness or hardness. Since then, synthetic resins have been increasingly used for silk ribbon finishing.

Silk scroop (scroopy handle, craquant, crackly finish, crunchy feel, silk finish, silky handle). Crackly handle due to subsequent treatment of textiles with soap or fat emulsion and organic acids (folic, lactic, acetic, tartaric, citric acid). The silk scroop is not usually stable in storage, leaves an unfavourable flabby handle and a slightly rancid odour due to the eliminated fatty acids. Is dependent on the climate (humidity).

Silk structure The microfibrils in the fibroin consist of stretched protein chain molecules that congregate in flat layers via hydrogen bridges. These layers are folded (pleated sheet structure). In the hierarchy of raw silk fabrics, it is recognized that this is a compound structure of fibrils (individual fibroin filaments) in a matrix (sericin) (Fig. 1). The individual fibroin filament is a compound of fibrils and interfibrillar material. The fibrils consist of crystalline domains embedded in non-crystalline material.

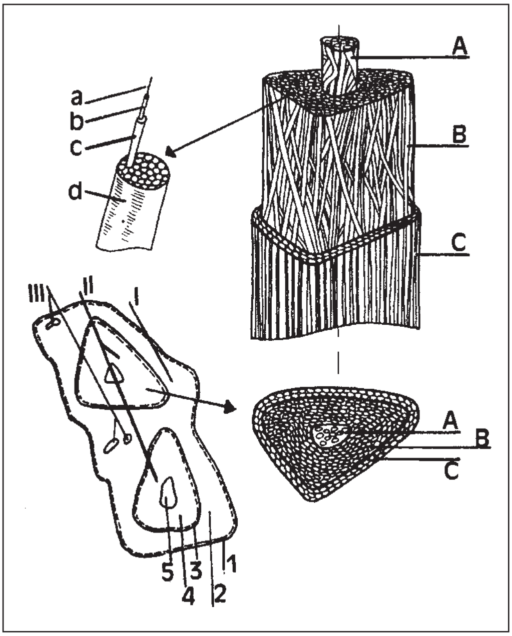


Fig. 1: The hierarchically organized structure of silk from sericin and fibroin.
I = sericin; II = fibroin fibres; III = secondary threads; A = core zone; B = fibre layer; C = skin or mantle zone; 1 = sericin skin; 2 = sericin layer; 3 = fibroin skin; 4 = fibroin layer; 5 = fibroin core; a = elementary fibril; b = microfibril; c = macrofibril; d = fibril rope.

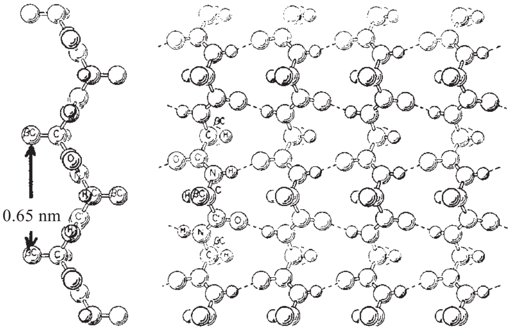


Fig. 2: Pleated sheet structure (according to Pauling) with parallel protein chains and a reflection from the fibre axis (b in the unitary cell) of 0.65 nm as demonstrated by X-ray radiography.

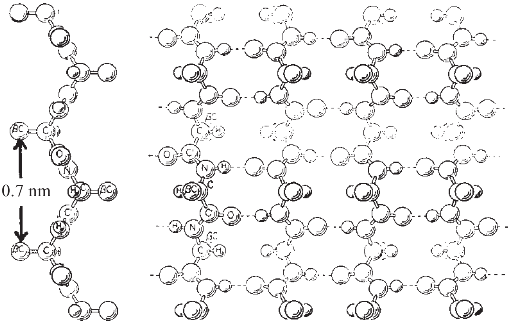


Fig. 3: Pleated sheet structure (according to Pauling) of silk fibroin with antiparallel protein chains with typical hydrogen bridges and characteristic X-ray reflection of 0.7 nm.

Pauling distinguishes between parallel and non parallel pleated sheet structures (Figs. 2 and 3). It is characteristic of the pleated sheet structure of the silk fibroin that the amino acid residue of the glycine is inserted in the polypeptide chains in a regularly alternating manner; hence the reason why all other side chains, e.g. the methyl group of the alanine protrude from one side of the layer; only the hydrogen atoms of the glycine residues protrude from the other side (Fig. 4). The pleated sheets are packed together face to face and back to back. This results in a sandwich structure with methyl groups between the pleated sheets, which in line with the greater space requirement of the methyl groups need to be remote from each other. The methyl group of the inserted alanine residues is the most frequent side chain in the pleated sheet structure. The peptide chains in the crystal lattice of the β pleated sheet structure are usually connected to each other by means of hydrogen bridges between the peptide bonds so that layers are produced.

In hydrolysates of silk fibroin, 18 different amino acids were identified and quantitatively determined (see Tab.). There are precise findings available concerning the amino acid sequence in the fibroin. Approx. 60% by weight of the fibroin can be separated out of a colloidal aqueous fibroin solution by enzymatic hydrolysis with chymotrypsin and be isolated as X-ray crystalline powder. This powder consists of a chemically homogeneous polypeptide in which the amino acids glycine, alanine and serine are present in the molar ratio 3 : 2 : 1. The predominant repeating unit is a hexapeptide that repeats either 8 times $[\text{Ser-Gly-Ala-Gly-Ala-Gly}]_8$ or 7 times $[\text{Gly-Ala-Ser-Gly-Ala-Gly}]_7$.

Silk fibroin is a mixture of two different fibroin

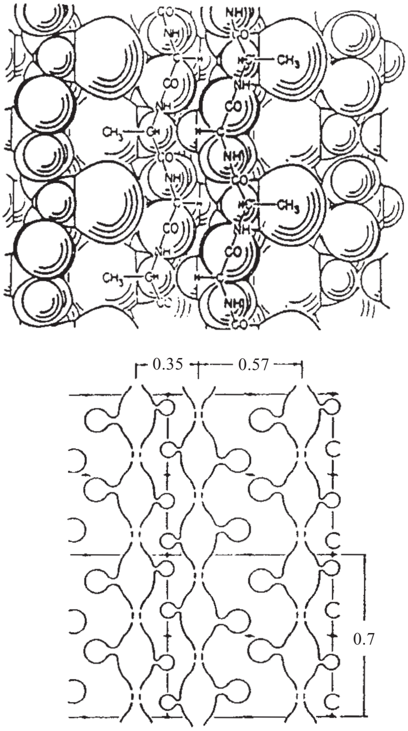


Fig. 4: The different separations (0.35 nm and 0.57 nm) between silk fibroin chains due to the grouping of all methyl groups in hydrophobic pools (0.57) and due to the orientation of the residual hydrogens in other pools (0.35).

amino acid	co-confibroin (according to Lukas)	fibroin from the posterior silk gland (according to Shimura)			sericin (according to Komatsu)
		total	lg. sub.	sm. sub.	
glycine	43.7	42.9	49.4	10.0	13.5
alanine	28.8	30.0	29.8	16.9	6.0
serine	11.9	12.2	11.3	7.9	33.4
tyrosine	5.1	4.8	4.6	3.4	2.6
valine	2.2	2.5	2.0	7.4	2.8
asparagine	1.3	1.9	0.65	15.4	16.7
glutamine	1.0	1.4	0.70	8.4	4.4
threonine	0.90	0.92	0.45	2.8	0.53
phenylaline	0.61	0.67	0.39	2.7	0.53
methionine	–	–	–	0.37	0.04
isoleucine	0.71	0.64	0.14	7.3	0.72
leucine	0.51	0.55	0.09	7.2	1.1
proline	0.31	0.45	0.31	3.0	0.68
arginine	0.46	0.51	0.18	3.8	3.1
histidine	0.16	0.19	0.09	1.6	1.3
lysine	0.31	0.38	0.06	1.5	3.3
cysteine	–	–	–	–	0.15
carboxymethyl-cysteine	–	–	–	1.6	–

Tab.: The amino acid composition of silk protein in mol %. (lg. sub. = large subcomponent; sm. sub. = small subcomponent).

molecules, which differ slightly in their molecular weights. After the reduction of few disulphide bridges, a heavy (H) and light (L) polypeptide chain are formed in the molar ratio 1 : 1. The amino acid compositions of these chains are reproduced in the Tab. (H = large sub-component; L = small sub-component). The H chain occurs in three variants (F, M, S), the L chain likewise in three variants (A, B, C). The composition of the particular variants is genetically controlled. From the table, it can be seen from amino acid analyses of the total fibroin artefacts that a protein mixture is present. Only amino acid analyses of the two sub-units lead to correct results.

Silk union Generic term for fabrics that contain natural silk or filament yarns similar to silk in one thread system.

Silk waste →: Bourette; Schappe(silk).

Siloxanes Oxygen compounds of → Silicon. Polysiloxanes:→ Silicones. The siloxane bond is, on the one hand, solid enough to make silicones useable as materials and still reactive, and on the other, it can synthesize macromolecules of virtually any size and constitution by the aid of diverse chemical processes. A direct consequence of this property is the so-called equilibration capacity, i.e. the thermodynamic controlled reorientation of siloxane bonds in relation to molecular weight, type and effect of the individual building blocks by acid or alkaline catalysts. The greatest advantage of this behaviour consists in the exact reproducibility of all properties of a given silicone and the possibility of subsequent correction. By varying the chain length and the organic groups bonded to the silicon, especially by deliberate modification involving specific terminal and/or pendant groups, a variety of methylpolysiloxanes have been developed that are used in the textiles industry (→ Silicones in finishing).

Silver (Ag). Atomic weight 107.93. White precious metal, soft and tough, can be stretched, hammered and polished, resistant to air (hydrogen sulphide traces cause dark colouring). Good conductor of electricity and heat. Melting point 960.2°C; density 10.5. Soluble in dilute nitric acid, concentrated sulphuric acid and potassium cyanide solution. Compounds: silver is monovalent, as colourless silver nitrate it is soluble in water, as silver chloride (white) it is soluble in ammoniac, not in dilute nitric acid; silver bromide (yellow), silver iodide (yellow) is insoluble in ammoniac. There is a tendency to complex salt formation. All water-insoluble compounds are soluble in excess ammoniac (except for silver iodide). Use: metal for valuable apparatus parts and measuring instruments. Non-metallic compounds especially for volumetric analysis.

Silver-bronze → Bronze printing.

Silver nitrate stains Typically light to dark brown, normally blurred edge. To remove: a) potassium iodide solution 10% takes around 60 min, then sodium thiosulphate solution 10% if necessary; (old stains) pre-soften overnight with fatty alcohol sulphanate solution and potassium iodide solution 10–20%, wash out, continue as above; b) potassium cyanide solution 5%, with thorough subsequent rinsing.

Silver number, silver index Indicates how much silver is reduced and separated from 100 parts test material numerical expression of bleach damage on cellulose fibres.

Silver printing → Graphite prints. Carried out with appropriate → Metal powders.

Silver test with ammoniacal silver solution Solution A: 1 g silver nitrate and 10 ml water. Solution B: 4 g sodium thiosulphate and 100 ml water. Mix solutions A and B, and add sufficient thiosulphate until the precipitate is dissolved. Then add solution C (4 g ammoniac and 100 ml water). Bring everything to the boil, filter and preserve the light-sensitive solution in brown bottles. Application: to test for hydrocellulose, especially with subsequent treatment with dilute ammoniac. Yellow-brown colouring according to the degree of damage. Also to test for wool damaged by sunlight (black colouring).

SIM Malaysian standards organization. → Technical and professional organizations.

Simili → Metallized yarns made from artificial gold.

Simili mercerizing Mechanical glaze finishing of fabrics (white goods, shirting fabrics, damasks, coloureds in fast dyeing) without chemical application, by calenders in the wet state at high thrust and high temperature (up to approx. 300°C, thrust approx. 80–120 t, speed approx. 10–25 m/min) for surface deformation effects. As a cheaper process for manufacturing glazes similar to → Mercerizing, which is very fast to water and, to a certain extent, also washfast.

Simon-Goodwin charts → Colour difference formulae.

Simple cleaning In the context of dry cleaning, cleaning and drying only without a specific stain removal stage (spot removal).

Simple perforation → Drum perforation.

Simple round perforation → Drum perforations.

Simplex fabrics Velour-type surface processing of knitwear made of cotton or synthetic fibres such as polyester, polyamide, acetate and triacetate. Originally limited primarily to glove qualities, for clothing fabrics including sport and leisure articles.

Simulated grass matting Rot resistant, coarse artificial grass matting made from coloured synthetic fibres, usually polypropylene.

Simulated leather foil As per DIN 16 992/1980: Plastics film with simulated leather surface finish.

Simulation tests Degradation test procedure to assess the biological level of waste water treatment plants (see Fig.). The degradation process is simulated in laboratory models under practical operating conditions, as in the aeration tank of a waste water treatment plant. Unlike → Screening test OECD 301 E, simulation tests involve systems with a high bacterial cell density (activated sludge) and continuous dosing, whereby the test substance is tested using high quantities of readily degradable compounds ("synthetic waste water"), i.e. under practical operating conditions. The average residence time of the test substance in the aeration tank of the treatment plant is normally 3 h, being a value that is significantly greater in modern waste water treatment plants and thus conforms to somewhat stricter test conditions. If over a period of several weeks the reduction in the test substance is determined

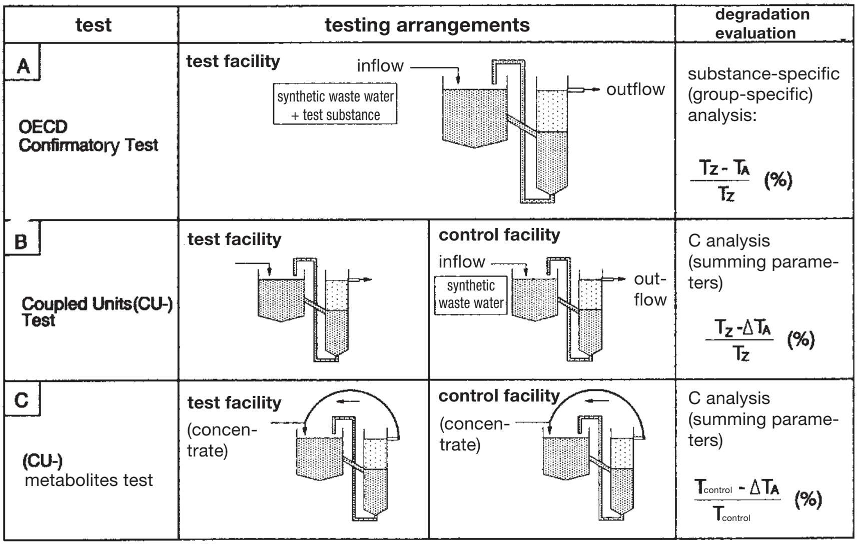


Fig.: Degradation testing system based on sewage treatment simulation tests.

in the inflow and effluent of the test treatment plant from a substance (group)-specific analytical procedure, such as MBAS or BiAS measurement, this will yield the scale of the primary degradation that can be expected under waste water treatment plant conditions. Within the framework of surfactant legislation, the so-called OECD Confirmatory Test constitutes the reference test as to whether the statutory required primary degradation is satisfied at least 80 % by a surfactant, insofar as this has not already been verified by the results of the OECD screening test (according to I. Steber).

Simultaneity factor Term used in electrical engineering for economically comparing the sum of all connected loads of the built-in power users in a (machine) unit with the so-called working load, the maximum sum of all connected loads of power users that are simultaneously operative in the work sequence of such a unit.

$$\text{simultaneity factor} = \frac{\text{connected load}}{\text{max. working load}}$$

Singeing Scorching, gassing of fibre ends protruding from surfaces on yarns, fabrics, etc. if a fluffy fabric is not required. Singeing is predominantly carried out on textile fabrics manufactured from yarns in the form of knitgoods or wovens. The aim is to achieve a smooth and fibre-free surface, which is essential both for subsequent processing in textile finishing and for desired serviceability properties. Knitgoods or wovens made from all types of fibrous materials or their blends can be singed, with singeing having special significance in cotton finishing. The smooth surface obtained exhibits the following improved properties in the textile fabric:

- clearer visualization of the particular textile fabric,
- reduced soiling with subsequent processing,
- more stable fabric appearance in the dyeing with plain colours due to reduced diffuse light reflection,
- sharp contours to the printed pattern with print fabrics,
- antipilling finish obtained, especially with fabrics made of polyester or cotton/polyester.

A distinction is made between direct and indirect processes:

I. Direct: The dry fabric passes a red hot metal radiator (500°C) or a non-luminous gas flame (all types of gas are possible). With contact singeing, the textile fabric is guided over heated plates or rotating cylinders (approx. 750°C). Contact singeing is primarily used to singe velvet. When the machine is idle, the textile fabric is automatically removed from the cylinder. The fabric speed is 70–80 m/min. The singeing effect depends on the contact surface between the textile and the heated element. Risk of fire can be prevented by installing a so-called spark suppressor.

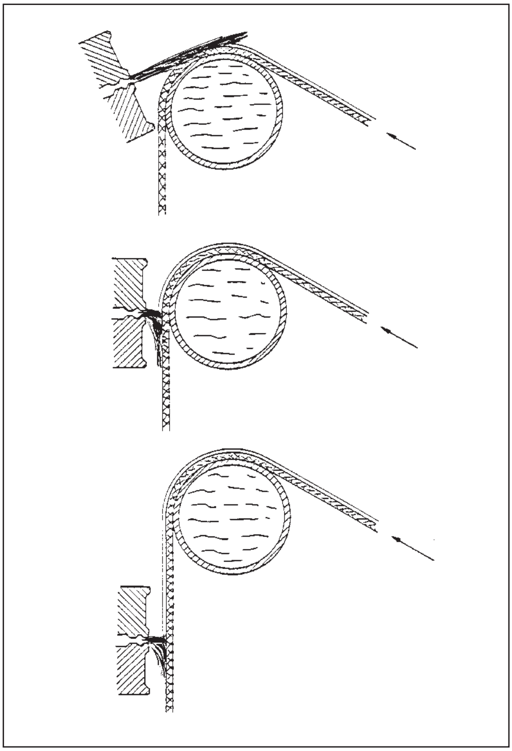


Fig. 1: Singeing positions using an open flame (by Osthoff). Top: tangential singeing; centre: singeing on a water-cooled roller; below: singeing free-moving goods.

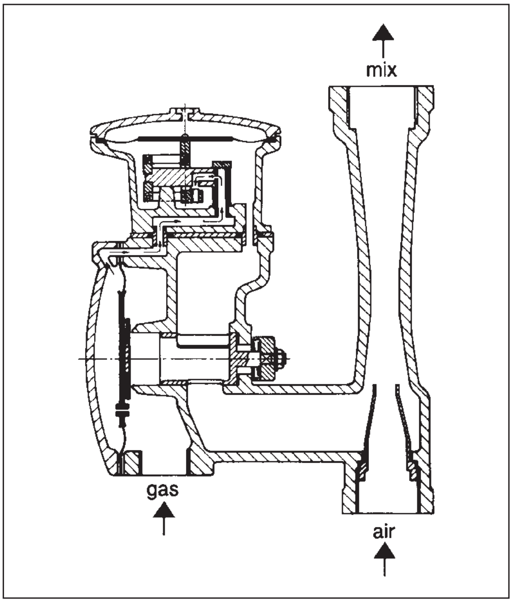


Fig. 2: Producing the gas/air mixture (Parex).

II. Indirect: The fabric passes heated ceramic bodies arranged at intervals and emitting IR rays.

The temperature of the singed fabric is a measure of the singeing effect. The high speed of the fabric protects it from charring (50–200 m/min). Plate singeing is rarely used as a direct process; it has been supplanted by cylinder singeing. The indirect processes have become more significant due to the need to protect the textiles. The textiles are normally singed in the raw state, less often between the stages of scouring and bleaching or dyeing. In practice, wovens are chiefly treated in this way since this pretreatment is too uneconomic for yarns.

The singeing of synthetic fibres assists in reducing the tendency to pilling. Three positions are distinguished between when singeing with a naked flame (Fig. 1).

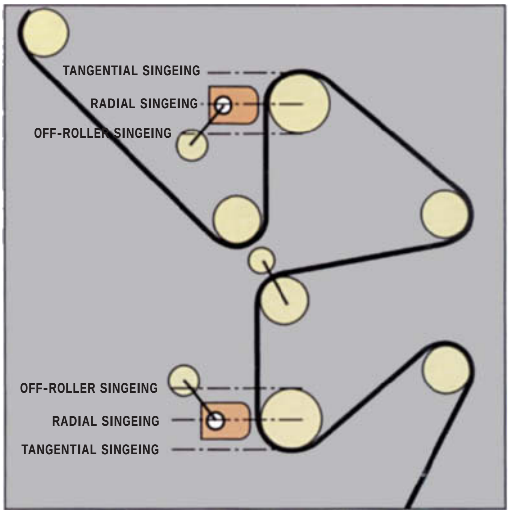


Fig. 3: Fabric flow in a singeing machine (Julien).

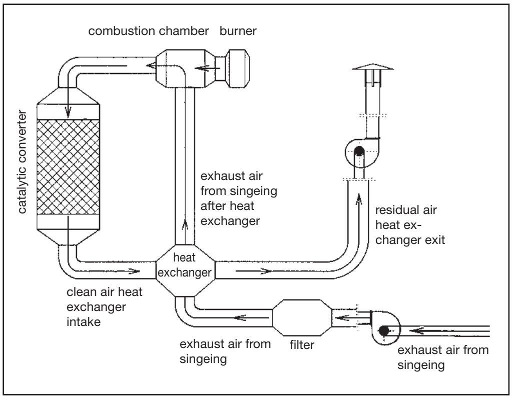


Fig. 5: The thermal afterburning of exhaust air from singeing (Osthoff).

What is important when singeing with a naked flame is the constant mix of air and gas (Fig. 2). At the start of the pretreatment, the cotton fabric passes through the singeing machine (Fig. 3), prior to any sparks being extinguished in a roller beck (Fig. 4).

The exhaust air from singeing can be disposed by after combustion in the existing steam boiler by means of a system depicted in Fig. 5. Other special post-combustion systems are also well known.

Singeing machine Especially used for wovens and knitgoods with low-tension controlled throughput involving several singeing positions: tangential, counter-roll and counter-fabric. Especially used for the technical pretreatment of knitgoods in tubular form prior to mercerization (Fig. 1).

The singeing machine is preferably used for cord,

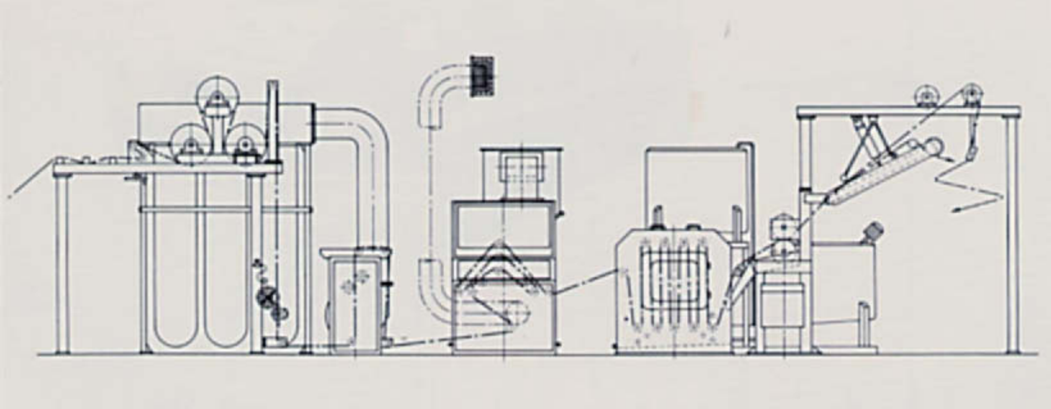


Fig. 4: The beginning of cotton pre-treatment, with singeing and spark suppression.

Singeing machine for tubular knitgoods

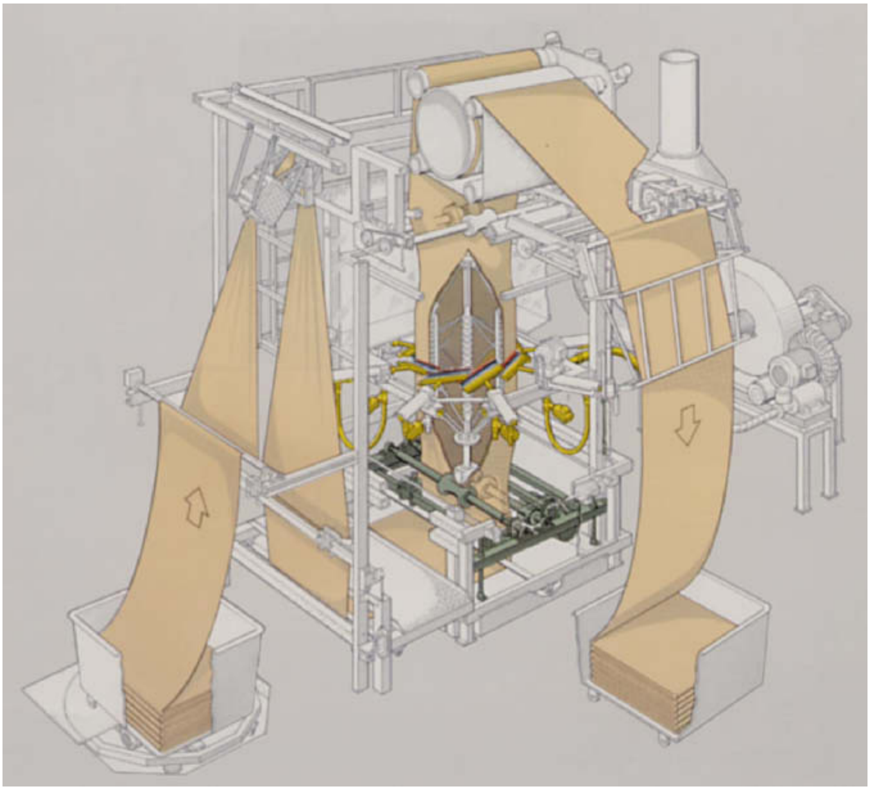


Fig. 1: *Tube singeing for knitted goods (Dornier).*

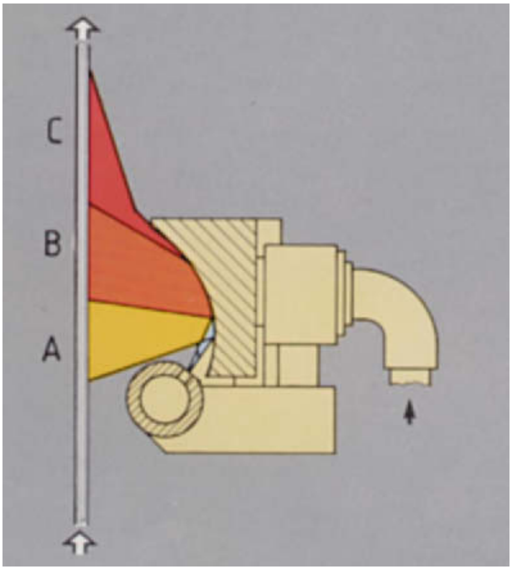


Fig. 2: The way in which a singeing machine works (Julien): zone A = pre-drying by infrared radiation; zone B = the effective working area of the flame across a wide fabric web; zone C = the afterburning zone.

with the avoidance of singeing stripes. To separate fibres on and between the ribs, high burning potential is required. The cord back that is not being singed runs against water-cooled rollers.

Singeing speed: 50–100 m/min (cord), 50–180 m/min (flat woven fabric [Fig. 3]). Predrying, flame singeing and after combustion will occur at these speeds in front of the burner flame (Fig. 2).

Singeing machine for tubular knitgoods A singeing machine with an annular burner designed for knitgoods in tubular form. The singeing of tubular knitgoods is one of the problems for which satisfactory solutions have recently been offered. All previously available systems are fraught with disadvantages, which have prevented the singeing of tubular goods from really gaining acceptance, even though there is no denying the general recognition there has been of the need for this system with many fabrics.

The singeing machine for tubular knitgoods is equipped with one or two rotating burners, i.e. it can be used for two sizes of tubular fabric. The tubular fabric is opened and guided via a conically shaped basket. The basket is carried in rollers similar to the familiar tubular fabric stretcher. The elasticity of the knitgoods allows the diameters of the goods to lie between 10–15% be-

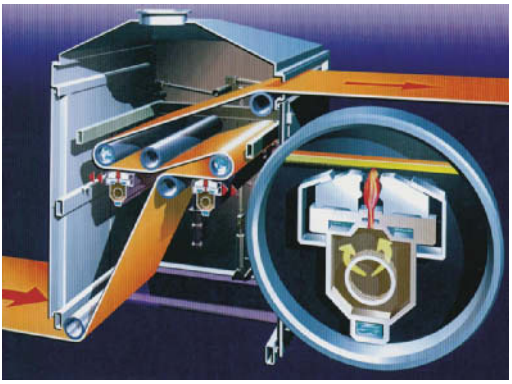


Fig. 3: Singeing unit (Küsters).

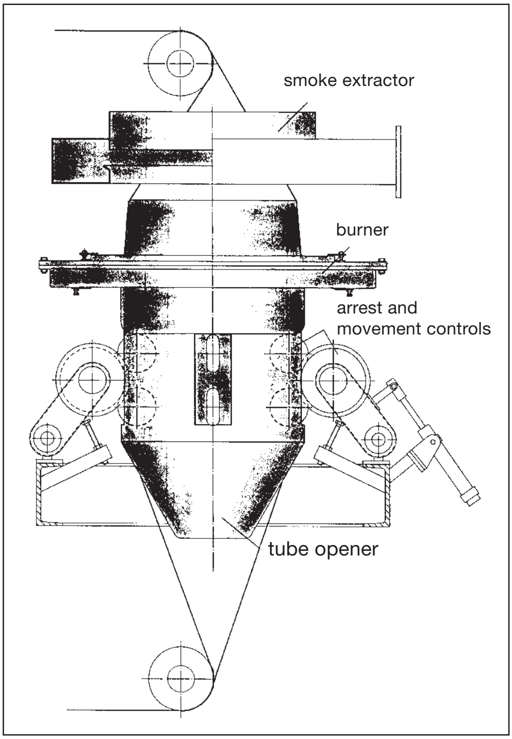


Fig. 1: A singeing machine for tubular knitgoods (Osthoff).

low or above the diameter of the guide basket. At the delivery end, the guide basket is conically shaped. In this area the singeing flame impinges on the tubular fabric, which is completely open at this point. Singe markings are therefore out of the question.

As a burner, the singeing machine for tubular knitgoods in Fig. 1 uses a device which is similar in structure to a double-jet burner. Adjustable drive units allow the singeing speed to be regulated to meet requirements. The operating speed is adjustable between 30–80 m/min. The singeing machine for tubular knitgoods is equipped at the outlet with a plaiter, which is fitted with a spark arresting roller. Converting the singeing machine from one dimension of tubular fabric to another is easy since both the burner and the guide basket can be changed quickly and without much effort by appropriate auxiliary devices. The disposal of the waste gas (Fig. 2) is via a suction channel, which is located above the burner and connected to a fan designed to meet the requirements. The singeing machine for tubular knitgoods depicted in Fig. 3 uses diagonally positioned burners.

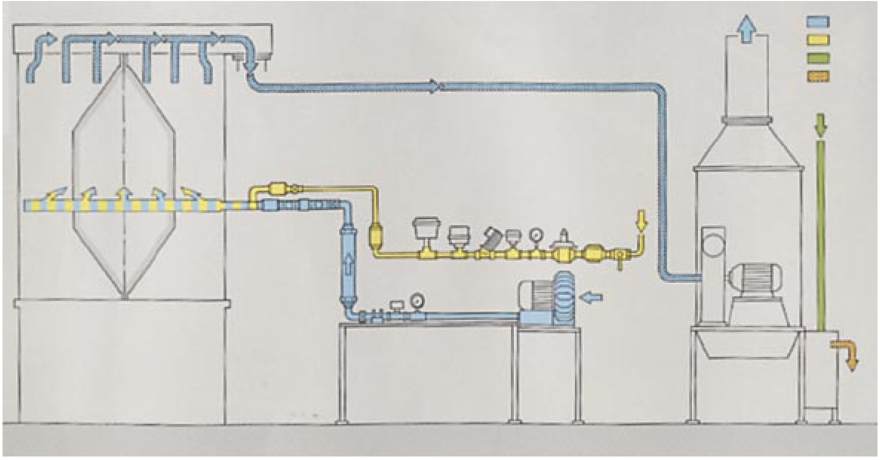


Fig. 2: Flue gas treatment for an Osthoff singeing machine for tubular knitgoods.

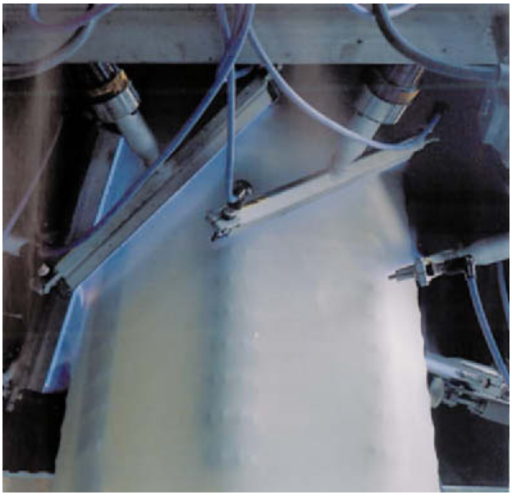


Fig. 3: Machine for singeing tubular knitted goods (Dornier).

Dornier (Fig. 4) has developed a new singeing concept on the basis of the thoroughly proven circular expander from its mercerising machine. It enables tubular knit fabrics of cotton and its blends in all the usual diameters to be singed evenly and free of selvedge marks. The fabric is guided over the circular expander under controlled tension so that

- the stitches are opened and intensive singeing can be performed on the fabric in its circular form,
- with the fabric being singed in its tubular form, selvedge marks are avoided,
- optimum singeing is applied to each tube diameter,
- process reproducibility is guaranteed.

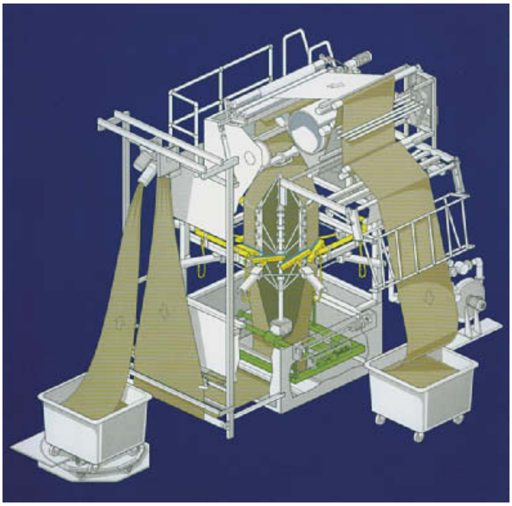


Fig. 4: Circular singeing; technical drawing of Dornier singeing machine, type EcoSinge.

The fabric is guided onto the circular expander via a turntable and untwister. Located around the circular expander are eight swivelling burners. These are mounted on a ring such that the full flame width of each segment can be applied to the fabric irrespective of the diameter setting. The diameter of the circular expander is power-adjusted and coupled to the burner adjustment system. Thus the gap between the burner and fabric remains the same.

Single-bath chrome dyeing process → Chromate dyeing process; Chroming of dyes.

Single-bath chrome mordant → Metal mordants, for mordant and chrome dyes.

Single-bath exhaustion process Dyeing process in which several components are applied to the fibre in a dye bath, e.g. dispersion dyes and cotton, wool or cationic dyes.

Single-bath extended steaming process Continuous dyeing process for various types of fibre and groups of dyes. The padded dye is fixed by prolonged steaming (up to 15 min). With pad-steam systems, the economical steaming period is only 60 s. Single-bath extended steaming processes have only been possible since suitable steamers have been available.

Single-bath/pad/dwell process Reactive dyes are padded together with lye or water glass/lye.

Single-bath process Treatment, especially for dyeing blended fibres, in a bath, i.e. with dyes for each component. Contrasting process → Two-bath process, i.e. treatment in two consecutive baths. Variants: Single-bath single-stage process corresponds to single-bath process. Single-bath two-stage process, whereby, at the end of the first treatment stage, the second stage is carried out in the same bath.

Single-bath single-stage process → Single-bath process.

Single-bath 2-stage process → Single-bath process.

Single-bath steam process for reactive dyes Principle: padding with dye and alkali and steaming with/without intermediate drying.

Single charge sewerage filter Serves as a → Sewerage filter, where in each working charge a fresh filter layer is deposited on the filter elements, the soiled filter cake is cleaned. The filter cake is either maintained under pump pressure (self-cleaning) or has to be stripped off (usually automatically) by backwashing, or by compressed air or mechanical devices. Single charge sewerage filters have, with the smallest dimensions, max. flow, greatest rinsing action, smallest greying risk.

Single coarse raw silk Simple, coarse raw silk thread (8–10 cocoon threads) made from inferior cocoons, e.g. as inlay threads for spun metallic yarns.

Single-component coating system Polyurethane coatings whose mass contains linear polymers with a high molecular weight. They do not require any subsequent hardening after coating and drying.

Single end sizing Process involving guiding threads through nozzles which separate several chambers from each other. Residual drying in heated pipes (< 12 m long), subsequent batching on crosswound yarn packages. Owing to the fast speeds, not suitable for sizing warp ends in industrial standards. Applied to special yarns (e.g. asbestos threads, novelty yarns, sighting thread). Basic disadvantage: nozzle change for each size range. – Manuf.: OPI.

Single face fabrics (plain jersey fabrics) → Knitted fabrics with only right-side loops on one side of the fabric and only reverse-side loops on the other side of the fabric.

Single filaments Monofilament chemical fibres.

Single-layer stenter → Horizontal stenter.

Single-metal machines E.g. double drum machines with inner and outer drum consisting of the same material; almost exclusively stainless steel.

Single package centrifuge Especially for large textured yarn packages. – Manuf.: Frauchiger.

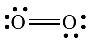
Single-phase printing process The printing paste contains, besides dyestuffs, the chemicals required for the application, e.g. reducing agents with vat dyes or alkalis with reactive dyes.

Single-pole system Hank dyeing equipment where the yarn hanks are treated suspended from only one pole.

Single squeegee Screen printing squeegee with one blade.

Singlet oxygen Referred to as an active molecule in bleaching processes. The oxygen molecule is paramagnetic and has two unpaired electrons. It is therefore a diradical although under normal conditions it is relatively non reactive for homolytic substitutions and additions. For the oxygen molecule in the normal state, the structure

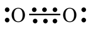
A



$$:\ddot{O}=\underset{\cdot\cdot}{O}:$$

would initially be expected with a double bond. However, the normal state of the molecule has the term symbol $^3\Sigma$, and from this it emerges that two electrons are not paired. Consequently the molecule is very paramagnetic. The structure with double bonds represents the first excited state $^1\Delta$. The atoms in the normal state, stable at 93.8 kJ/mol are held together by a single bond and two three-electron bonds. The number of electrons and orbitals exactly matches the structure

B



$$:O\overset{\cdot\cdot\cdot}{\underset{\cdot\cdot\cdot}{-}}O:$$

where each oxygen atom has occupied one of the four valency orbitals with a free pair of electrons. Another orbital is then available for the single bond, and the remaining two are available for the two three-electron bonds. Since the bonding energy of one three-electron bond is approx. half as large as that of a single bond, roughly the same stability can be expected for structure B as for structure A. Another interaction needs to be taken into account, however, namely the coupling of the two three-electron bonds. Each of these has an unpaired electron. Its spins can consist of either a singlet state or a triplet state. In the first case they are opposed, in the second rectified. These states have different stability. The triplet state is more stable. If the movement of the two electrons is not completely synchronized, they can dwell for a time on the same oxygen atom. Then the interaction between them is greater than when they are found on different atoms. These ideas are further underpinned by the existence of a $^1\Sigma$-state, which is approx. 158.3 kJ/mol, less stable than the normal state. This state also has the structure B, although the two odd electrons here have an opposed spin. Thus the unfavourable energy interaction between the two three-electron bonds is involved. The mean value of the energy of this state and the normal state is not very different from the energy of the state with a double bond.

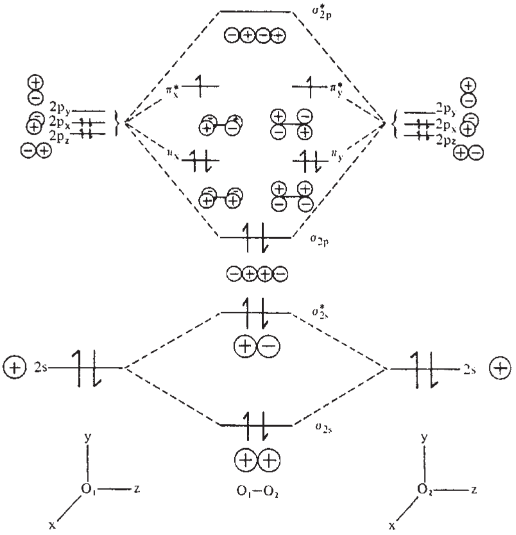


Fig. 1: The molecular orbitals and energy levels of oxygen.

Fig. 1 depicts the states of the electrons involved in the oxygen molecule. It is clear from this that the triplet state has the lowest energy and thus the most stable. The three lowest energy configurations of the oxygen molecule are shown in the Table. The structure of the oxygen atom in the various shells can be seen in Fig. 2.

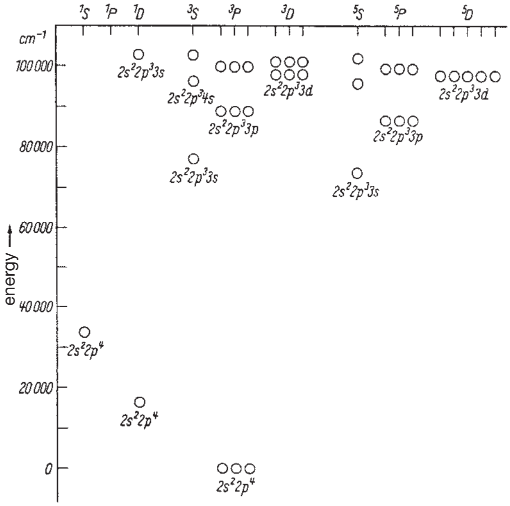


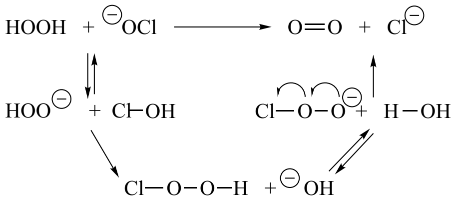
Fig. 2: Energy level diagram of the oxygen atom.

Because the $^1\Sigma$-state is approx. twice as energy-rich as the $^1\Delta$-state, the state $^1\Delta$, with 45 min life in the gas phase, is 500 times as viable as the state $^1\Sigma$ (Tab.).

electron state	$^3\Sigma$	$^1\Delta$	$^1\Sigma$
name	triplet	singlet	singlet
highest occupied molecular orbital	↑ ↑	↑↓ —	↑ ↓
rel. energy content [kJ]	0	92	155
life-time [secs]			
in the gas phase	∞	3 000	7–12
in solution	∞	10^{-3}	10^{-9}
valency linkage electron structure	↑|Ö–Ö|↑	Ö=Ö	↑|Ö–Ö|↓

Tab.: Oxygen molecule energy configuration.

As early as 1927 it was discovered that when mixing a sodium hypochlorite solution with H_2O_2 the reaction showed briefly red. The spectroscopic analysis of this reaction revealed that excited oxygen (singlet oxygen) is the emitting species. A general theory was ultimately postulated, according to which, at least in the majority of reactions involving H_2O_2 or peroxides, primarily excited species of molecular oxygen could be formed which transfer their excitation energy to appropriate acceptors. This is because the energy levels of excited molecular oxygen are in the 250–300 kJ range, which is also required for many organic chemiluminescences. With regard to the mechanism of the H_2O_2 hypochlorite reaction, both radical and heterolytic processes are discussed approximately according to



Essentially, with the singlet oxygen process for stabilizing wool, treatment with formaldehyde is carried out in the presence of hydrogen peroxide. With the reaction between the two compounds, the formaldehyde molecule is activated, as singlet oxygen is formed and therefore becomes extremely reactive. A formaldehyde of this type prefers to react with lysine segments of wool protein and forms cross-bonds. The reactions occurring between peroxide and formaldehyde can be described as follows: in the alkaline medium, formaldehyde is quantitatively oxidized by hydrogen peroxide by developing hydrogen gas and forming sodium formiate. If the medium were not alkaline, methyl peroxide would be isolated. A recorded chemiluminescence spectrum contains the bands characteristic of molecular singlet oxygen.

Single weft carpet Woven carpet, in which each row of knops is fixed in with only one weft.

Sinnerscher Circle Approximate classification of the significance of four washing parameters (chemistry of the surfactants, washing time, temperature and washing mechanics) to define the cleaning efficiency of a drum washing machine (see Fig.).

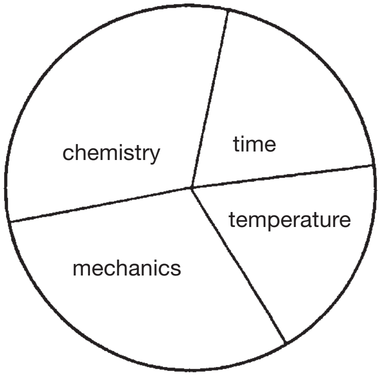


Fig.: The Sinnerscher Circle for representing washing performance.

Sintering Surface method of → Melting, i.e. melting at increased temperature; e.g., with the → Heat sealing of polyethene, the thermoplastic material forms a more or less continuous film, depending on the distribution density, which is capable of being heat sealed with other fabrics. The melting temperature of the material allows conclusions to be drawn as to sintering temperature. The sintering capacity is a function of degree of polymerization, degree of crystallinity and melting point.

Sinter, to → Adhesive-bonded textile.

SIRO "Scientific Industrial Research Organisation", Australian textile research organization; → CSIRO.

Si-Ro-Set colour fastness Method of dyeing with Si-Ro-Set treatment, i.e. possible effect on the shade and possible staining of white wool and cotton as a result of the treatment. The dye should be selected according to the application of the finished goods, i.e., only reduction-insensitive dyes may be used in dyeing.

Si-Ro-Set process Australian process for surface fixing and manufacturing of permanent creases and pleats on woollen articles such as trousers, skirts, etc. by treating with a solution of thioglycollic acid derivatives and subsequent shape fixing by steaming.

SiroSpun process Process developed by CSIRO and IWS, by which a 2-ply yarn is produced at one spinning position, making twining redundant (see Fig.). This process allows a special spun-twisted yarn to be manufactured directly on the ring spinning machine. At the same time, two slubbings are fed parallel through the drafting zone. The technological operation corresponds to the production process for normal single yarn, with the distinction that two slubbings are spun simultaneously per spinning position. With parallel spinning, the permanent control of the Siro yarns with the aid of a mechanical thread monitor prevents unwanted single yarns from being produced. The use of the special SiroSpun thread monitor is the basis for a perfect Siro twist being wound onto the cops.

Spinning process: inside the drafting zone, two specially developed condensers separate the two roves of yarn in the pre- and main drafting zone. Both roves are drawn separately, and the twist is obtained as usual by means of ring and traveller. The parallel-drawn slubbings are joined after the pair of rollers at the drafting-zone delivery end. A thread guide is located in the spinning zone for joining the two bands of fibres drawn in the drafting zone. Between this thread guide and the pigtail thread guide, there is a pair of blocking rollers, which produces a twist back up in this section of yarn. A ring groove is milled in the surface of the pair of rollers on one section of the circumference. It causes the twist arising from the spindle to be blocked on the full diameter and only allows it to reach the upper drafting zone as far as the union junction once it has passed through this groove, with the result that the two bands of fibres are twisted together. The twist travels to the individual components as far as the nip. Both threads combine after the delivery cylinder of the drafting zone with the pre-determined twist to the desired yarn count. Expressed in another way: the resulting yarns are twisted around each other in one operation. Hence a two-ply yarn is produced with the same direction of twist as the individual components. The ever-present uneven qualities balance each other out over the length of the yarn between nip of the front cylinder and winding onto the empty bobbin. The twist of a ply yarn is, therefore, as even as the twist with a single yarn.

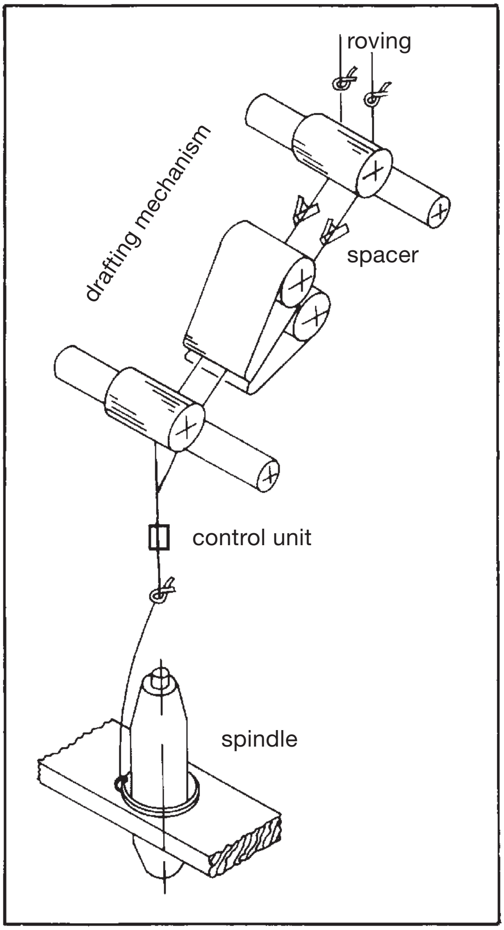


Fig.: SiroSpun spinning position for worsted yarn (Zinser) (spin twist process).

This process produces a false twist or spun-twisted yarn, which conforms to a genuine ply yarn in terms of character and properties. The economic advantages of the SiroSpun process are:

- elimination of the usual twisting process, hence elimination of costs,
- small space requirement,

- greater capacity with the same spindle speed,
- smaller staffing costs.

SIS Swedish standards organization; → Technical and professional organizations.

Sisal → Hard fibres of subtropical agave types (Mexico, Brazil, Africa, Indonesia). Named after the oldest port of exportation of Sisal in Mexico. Snow white to yellowish. Fibre bundle 60–150 cm long. Strength 35–55 cN/dtex. Not very resistant to seawater. Chemical composition: 65.8% cellulose, 10% water, 1.2% lignin, 0.3% fat and wax, 1–4% ash. Dyeable similar to → Manila fibre. Application: binding yarn, cord, string, ropes, sacks, sail cloth, carpet industry, decoration materials, also for finer fabric. Sisal tow for upholstered materials.

Sisal-Manila fibre test → Billinghame's test.

SISIR Singapore standards organization; → Technical and professional organizations.

SI System, conversion factors The conversion factors for the non-metric or Imperial units into the SI system are shown in Tables 1–15. These tables are intended to assist in converting the old units encountered in the USA and Far East.

unit name	unit symbol, abbreviation	relationship	SI equivalent
inch	″		$25.\underline{4} \cdot 10^{-3}$ m
my, micron	µ	$1\ \mu = 1\ \mu m$	10^{-6} m
millimicron	mµ	$1\ m\mu = 10^{-3}\ \mu m$	10^{-9} m
ångström	Å		10^{-10} m

Tab. 1: Length (according to German).

unit name	unit symbol	relationship	SI equivalent
inch	in	$1\ in = \frac{1}{12}\ ft$	$25.\underline{4} \cdot 10^{-3}$ m
foot	ft	$1\ ft = 12\ in = \frac{1}{3}\ yd$	$0.304\,\underline{8}$ m
U.S. Survey foot	ft (U.S. Survey)	$1\ ft\ (U.S.\ Survey) = \frac{1\,200}{3\,937}\ m$	0.304 800 6 m
yard	yd	1 yd = 36 in = 3 ft	$0.914\,\underline{4}$ m
mile	mi	1 mi = 1 760 yd = 5 280 ft	$1\,609.34\underline{4}$ m
mile (U.S. Survey)		1 mile (U.S. Survey) = = 5 280 ft (U.S. Survey)	1 609.347 m

Tab. 2: Length: Anglosaxon units (according to German).

unit name	unit symbol	SI equivalent
litre	l	1 dm^3
standard cubic metre	Nm^3, nm^3, m^3_n	1 m^3

Tab. 3: Volume (according to German).

unit name	unit symbol, abbreviation	relationship	SI equivalent
square inch	in^2, sq in		$6.451\,\underline{6} \cdot 10^{-4}\ m^2$
square foot	ft^2, sq ft, qfs	$1\ ft^2 = \frac{1}{9}\ yd^2$	$9.290\,3 \cdot 10^{-2}\ m^2$
square yard	yd^2, sq yd		$0.836\,13\ m^2$
acre	acre	1 acre = 4 rood	$4\,046.86\ m^2$
acre (U.S. Survey)	acre (U.S. Survey)		$4\,046.87\ m^2$
square mile, section	$mile^2$, sq mile	$1\ mile^2 = 640$ acres	$2.589\,988 \cdot 10^6\ m^2$
square mile (U.S. Survey)	$mile^2$ (U.S. Survey)		$2.589\,998 \cdot 10^6\ m^2$

Tab. 4: Area: Anglosaxon units (according to German).

unit name	unit symbol	relationship	SI equivalent
gamma	γ	$1\ \gamma = 1\ \mu g$	10^{-9} kg
gramme	g		$1 \cdot 10^{-3}$ kg
pound	Pfd, ℔	1 ℔ = 500 g	$0.\underline{5}$ kg
metric hundredweight	Ztr	1 Ztr = 50 kg	50 kg
metric quintal	dz	1 dz = 100 kg	100 kg
metric ton	t	$1\ t = 10^3$ kg	1 000 kg

Tab. 5: Mass (according to German).

unit name	unit symbol	relationship	SI equivalent
UK and US avoirdupois units			
grain	gr	1/7 000 lb	$64.798\,9\underline{1} \cdot 10^{-3}$ g
dram	dr	1/16 oz	1.771 845 g
ounce	oz	1/16 lb	28.349 5 g
pound	lb		0.453 592 37 kg

Tab. 6: Mass: Anglosaxon units (according to German).

unit name	unit symbol	relationship	SI equivalent
dyne	dyn	$1\ g \cdot cm \cdot s^{-2}$	10^{-5} N
gramme, (force)	g^*, g_f, gf		$9.806\,6\underline{5} \cdot 10^{-3}$ N
pond	p		$9.806\,6\underline{5} \cdot 10^{-3}$ N
large dyne	Dyn		1 N
kilopond	kp		$9.806\,6\underline{5}$ N
kilogramme (force)	kg^*, kg_f, kg_p, kgf		$9.806\,6\underline{5}$ N
metric ton (force)	t^*, t_f, tf		$9.806\,6\underline{5}$ kN

Tab. 7: Strength and force (according to German).

SI System, conversion factors

unit name	unit symbol, abbreviation	SI equivalent
foot per hour	ft/h	$84.\overline{6} \cdot 10^{-6}$ m/s
foot per minute	ft/min	$5.08 \cdot 10^{-3}$ m/s
foot per second	ft/s	$0.304\underline{8}$ m/s
inch per second	in/s, ips	$25.\underline{4} \cdot 10^{-3}$ m/s
knot (UK)$^{1)}$	kn (UK)	0.514 772 m/s
mile per hour	mile/h, mi/h	$0.447\,0\underline{4}$ m/s
mile per second	mile/s, mi/s	$1.609\,34\underline{4} \cdot 10^{3}$ m/s

Tab. 8: Speed: Anglosaxon units (according to German). 1) 1 knot (UK) = 1 nautical mile (UK)/h.

unit name	unit symbol	relationship	SI equivalent
dyne per square centimetre	dyn/cm^2		$0.\underline{1}$ Pa
torr	Torr	1/760 atm	133.322 Pa
conventional millimetre column of mercury	mmHg		$133.32\underline{2}$ Pa
conventional metre column of water	mWS	0.1 at	$9\,806.6\underline{5}$ Pa
kilopond per square centimetre	kp/cm^2		$98\,066.\underline{5}$ Pa
technical atmosphere	at, ata, atu, atü	$1\ kp/cm^2$	$98\,066.\underline{5}$ Pa
bar	bar	$10^6\ dyn/cm^2$	10^5 Pa
physical atmosphere	atm		$101\,32\underline{5}$ Pa

Tab. 9: Pressure, mechanical stress (according to German).

unit name	unit symbol	relationship	SI equivalent
metric tonne per cubic metre	t/m^3	g/cm^3	$1\,000\ kg/m^3$
kilogramme/litre	kg/l	g/ml	$1\,000\ kg/m^3$

Tab. 10: Density (according to German).

unit name	unit symbol	relationship	SI equivalent
erg	erg	1 dyn · cm	10^{-7} J
kilopond metres	kp · m		$9.806\,6\underline{5}$ J
kilowatt hours	kWh		$3.\underline{6} \cdot 10^{6}$ J
technical litre-atmosphere	l · at		$98.066\,\underline{5}$ J
physical litre-atmosphere	l · atm		$101.32\underline{5}$ J
15 °C calorie	$cal_{15°}$		4.185 5 J
thermochemical calorie	cal_{th}		4.184 J
international table calorie	cal_{IT}		$4.186\,\underline{8}$ J
electron-volt	eV		$1.602\,189\,2 \cdot 10^{-19}$ J
metric tonne of hard coal units	tSKE		$29.307\,6 \cdot 10^{9}$ J
horsepower hour	PS · h		$2.647\,8 \cdot 10^{6}$ J

Tab. 11: Energy (according to German).

unit name	unit symbol	relationship	SI equivalent
ergs per second	erg/s	1 dyn · cm/s	10^{-7} W
international table calories per hour	$\mathrm{cal_{IT}}$/h		$1.16\underline{3} \cdot 10^{-3}$ W
international watt	$\mathrm{W_{int}}$		1.000 19 W
kilopond metres per second	kp · m/s		$9.806\,6\underline{5}$ W
technical litre-atmospheres per second	l · at/s		$98.066\,\underline{5}$ W
physical litre-atmospheres per second	l · atm/s		$101.32\underline{5}$ W
torr-litres per second	Torr · l/s		0.133 32 W
horsepower	PS		$735.498\,7\underline{5}$ W

Tab. 12: Power and performance (according to German).

unit name	unit symbol	relationship	SI equivalent
stokes	St		$10^{-4}\ \mathrm{m^2 \cdot s^{-1}}$

Tab. 13: Kinematic viscosity (according to German).

unit name	unit symbol	SI equivalent
pound per hour	lb/h	$0.125\,997\,9 \cdot 10^{-3}$ kg/s
ounce per minute	oz/min	$0.472\,492 \cdot 10^{-3}$ kg/s
pound per minute	lb/min	$7.559\,873 \cdot 10^{-3}$ kg/s
ounce per second	oz/s	$28.349\,523 \cdot 10^{-3}$ kg/s
pound per second	lb/s	$0.453\,529\,3\underline{7}$ kg/s

Tab. 14: Mass flow: Anglosaxon units (according to German).

unit name	unit symbol	relationship	SI equivalent
degree	°	1 °C	example: 20°
degree	grd, deg	1 K	temperature differences, temp. intervals
centigrade	cent, cgr	1 °C	
degrees Kelvin	°K	1 K	
degrees Réaumur	°R	$1.2\underline{5}$ K	
degree Fahrenheit	°F	$0.\overline{5}$ K	
Fahrenheit degree	degF	$0.\overline{5}$ K	temperature intervals
degree Rankine	°R, °Rank	$0.\overline{5}$ K	
Rankine degree	degR	$0.\overline{5}$ K	temperature intervals

Tab. 15: Temperature (according to German).

SI System of Units

SI System of Units A system of agreed coherent metric units (Système International d'Unités) proposed for international acceptance in 1960 and which is now in use for all scientific and most technological purposes in many countries throughout the world. SI units are based on the MKS (metre-kilogram-second) system and have now replaced units formerly used in the CGS (centimetre-gram-second) system and the f.p.s system (Imperial units). There are numerous derived units (Newton, joule, etc) and scales of decimal multiples and submultiples, all with agreed symbols. The SI system was accepted as an ISO Recommendation in 1969, incorporated into German Federal Law in 1970 and covered by a DIN Standard under DIN 1301 as well as an EC Directive in 1971. Since 01.01.1978, the SI system with its established base quantities, base units and derived units, has assumed unlimited legal validity throughout the Federal Republic of Germany.

The base units of the SI system are summarized in Tab. 1 and the decimal multiples and submultiples in Tab. 2. For some important derived units of base quantities, or derived quantities in frequent use, special names are used. The derived SI units with independent names are listed (alphabetically) in Tab. 3 and the most important quantities and their corresponding units are given in Tab. 4.

dimension	SI basic unit	
	name	unit symbol
length	Metre	m
mass	Kilogramme	kg
time	Seconds	s
electric current strength	Amperes	A
thermodynamic temperature	Kelvin	K
substance quantity	Mol	mol
intensity of light	Candela	cd

Tab. 1: Basic units of the SI system.

combining form	combining form symbol	factor
exa	E	10^{18}
peta	P	10^{15}
tera	T	10^{12}
giga	G	10^{9}
mega	M	10^{6}
kilo	k	10^{3}
hecto	h	10^{2}
deca	da	10^{1}
deci	d	10^{-1}
centi	c	10^{-2}
milli	m	10^{-3}
micro	µ	10^{-6}
nano	n	10^{-9}
pico	p	10^{-12}
femto	f	10^{-15}
atto	a	10^{-18}

Tab. 2: Decimal parts and multiples of units.

basic dimension	unit	symbol	definition
electricity quantity . .	Coulomb	C	1 C = 1 As
frequency	Hertz	Hz	1 Hz = 1 s^{-1}
energy	Joule	J	1 J = 1 Nm = 1 Ws
luminous flux	Lumen	lm	1 lm = 1 cd sr
illuminance	Lux	lx	1 lx = 1 lm/m^2
force	Newton	N	1 N = 1 kg m/s^2
elec. resistance	Ohm	Ω	1 Ω = 1 V/A
pressure, stress	Pascal	Pa	1 Pa = 1 N/m^2
elec. conductance . .	Siemens	S	1 S = 1/Ω
elec. potential	Volt	V	1 V = 1 W/A
power	Watt	W	1 W = 1 J/s

Tab. 3: Derived SI units with independent names

SI System of Units

size	statutory unit (SI unit)		no longer valid unit and conversion relationship
	name and unit symbol	expressed as a power product of the basic units	
force *F*	Newton N	$1\,N = 1\,m\,kg\,s^{-2}$	kilopond kp $1\,kp = 9.80665\,N \approx 10\,N$ $1\,kp \approx 1\,daN$
pressure *p*	$\frac{\text{Newton}}{\text{square metre}}$ 1) $1\,\frac{N}{m^2} = 1$ Pascal Pa 1 Bar = 10^5 Pascal 1 bar = 10^5 Pa	$1\,\frac{N}{m^2} = 1\,m^{-1}\,kg\,s^{-2}$	metres head of water mWs $1\,mWS \approx 10^4\,\frac{N}{m^2} = 10^4\,Pa$ $1\,mWS \approx 0.1\,bar$ millimetre WS mmWS $1\,mmWS \approx 10\,\frac{N}{m^2} = 10\,Pa$ millimetres head of mercury mmHg 1 mmHg = 133.3224 Pa technical atmosphere at $1\,at = 1\,\frac{kp}{cm^2} \approx 10^5\,Pa = 1\,bar$ physical atmosphere atm 1 atm = 101 325 Pa ≈ 1.01 bar Torr 1 Torr = 133.3224 Pa
mechanical stress σ, τ also tenacity, surface pressure, pressure on the face of a hole	$\frac{\text{Newton}}{\text{square milimetre}}$ 1) $\frac{N}{mm^2}$	$1\,\frac{N}{mm^2} = 10^6\,m^{-1}\,kg\,s^{-2}$ $1\,\frac{N}{mm^2} = 10^6\,\frac{N}{m^2} = 10^6\,Pa$ $= 1\,MPa = 10\,bar$	$\frac{kp}{mm^2}$ $\frac{kp}{cm^2}$ $1\,\frac{kp}{mm^2} \approx 10\,\frac{N}{mm^2}$ $1\,\frac{kp}{cm^2} \approx 0.1\,\frac{N}{mm^2}$
force moment *M*	Newton metre Nm	$1\,Nm = 1\,m^2\,kg\,s^{-2}$	kilopond metre kpm $1\,kpm \approx 10\,Nm$ kilopond centimetre kpcm $1\,kpcm \approx 0.1\,Nm$
work *W* also energy and heat quantity	Joule J 2) 1 J = 1 Nm = 1 Ws	$1\,J = 1\,Nm = 1\,m^2\,kg\,s^{-2}$	kilopondmetre kpm $1\,kpm \approx 10\,J$ kilocalorie kcal 1 kcal = 4 186.8 J
power *P* also energy and heat flux	Watt W $1\,W = 1\,\frac{J}{s} = 1\,\frac{Nm}{s}$	$1\,W = 1\,m^2\,kg\,s^{-3}$	$\frac{\text{kilopondmetre}}{\text{second}}$ $\frac{kpm}{s}$ $1\,\frac{kpm}{s} \approx 10\,W$ horse power PS $1\,PS = 75\,\frac{kpm}{s} \approx 735\,W$

SI Units

size	statutory unit (SI unit)		no longer valid unit and conversion relationship
	name and unit symbol	expressed as a power product of the basic units	
kinematic viscosity ν	$\frac{\text{square metre}}{\text{second}}\ \frac{m^2}{s}$	$m^2 s^{-1}$	Stokes St $1\ St = 10^{-4}\frac{m^2}{s}$
dynamic viscosity η	$\frac{\text{Newton second}}{\text{square metre}}\ \frac{Ns}{m^2}$ $1\frac{Ns}{m^2} = 1\ Pa \cdot s$ Pa · s = Pascal second	$1\frac{Ns}{m^2} = 1\ m^{-1}\ kg\ s^{-1}$	Poise P $1\ P = 0.1\frac{Ns}{m^2} = 0.1\ Pa \cdot s$
temperature ϑ	Kelvin *K* and degrees Celsius °C	basic unit Kelvin K	degrees Kelvin °K 1 °K = 1 K (°K may be used until 31.12.1974 at the atest)
temperature interval $\Delta\vartheta$	Kelvin *K* and degrees Celsius °C	basic unit Kelvin K	degree grd 1 grd = 1 K = 1 °C (°K may be used until 31.12.1974 at the atest)
magnetic flux Φ	Weber Wb $1\ Wb = 1\frac{Nm}{A} = 1\frac{J}{A}$	$1\ Wb = 1\ m^2\ kg\ s^{-2} A^{-1}$	Maxwell M $1\ M = 10^{-8}\ Wb$
magnetic flux density *B*	Tesla T $1\ T = 1\frac{Nm}{m^2 A} = 1\frac{Wb}{m^2}$	$1\ T = 1\ kg\ s^{-2} A^{-1}$	Gauß G $1\ G = 10^{-4}\ T$
magnetic magnetizing force *H*	$\frac{\text{Ampere}}{\text{metre}}\ \frac{A}{m}$	$1\frac{A}{m} = m^{-1} A$	Oersted Oe $1\ Oe = \frac{10^3}{4\pi}\frac{A}{m} \approx 80\frac{A}{m}$
illuminance *E*	Lux lx	$1\ lx = lm/m^2$ $= cd\ .\ sr/m^2$	

Tab. 4: The most important dimensions and their SI Units (according to Böge).
1) All quotients of a statutory unit of force and a statutory surface unit, e.g. N/cm^2, are also admissible.
2) All products of statutory force and length units or of statutory power and time units, e.g. kWh, are also admissible.

SI Units → SI System of Units.

Sivas carpets Are fine, medium-size → Knotted carpets from the north Anatolian city of Sivas. Warp and weft in cotton, pile in low lustre wool; the Turkish knot is used with approx. 280 000 knots/m^2. Although Sivas carpets come from the heart of Anatolia, they bear no resemblance to the primitive nomad-type carpets woven in large numbers in this region. The Sivas motifs are clearly of Persian inspiration and the customary decoration is similar to that of Persian → Tabriz carpets, both in the medallion and corner design.

The colours used for the ground are usually white and ivory. The designs are always in pastel shades such as pink and pistachio green. Sivas carpets can easily be distinguished from Tabriz carpets because of their less solid feel, lack of compactness in the pile despite close cropping, the lack-lustre quality of the wool, and the use of pastel shades.

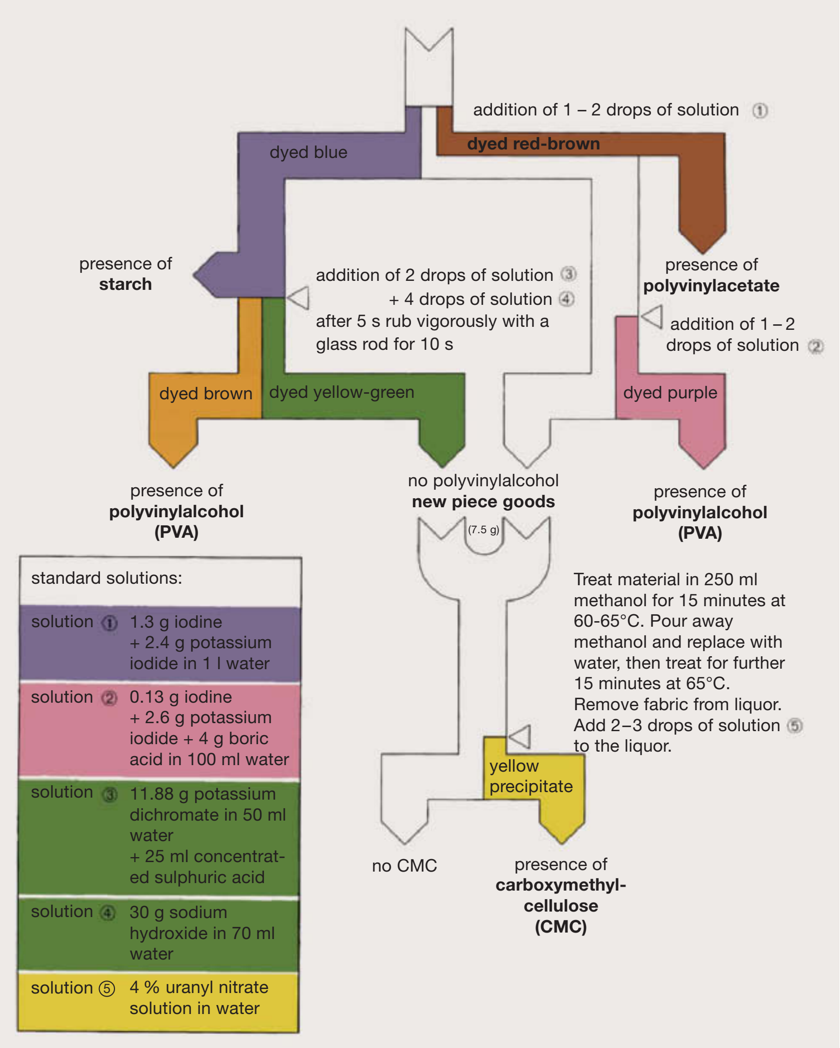
Size bridging The size present between warp yarns applied in machine sizing causes adjacent yarns to adhere together during drying due to the formation of an unbroken size film, i.e. size bridging. In the warp splitting section, after drying, these size bridges are torn apart, i.e. a large part of the size film is broken up at this stage (= increased dust build-up and yarn hairiness). The problem may be remedied by predrying or preheating.

Size content, starch based An air-dried sample of weight M_1 is boiled in dichloromethane, filtered, treated with cold methanol and then with water. Finally, the sample is tested for the presence of a starch based size with iodine solution in potassium iodide. If no more starch is present, the sample is boiled in water with Marseilles soap, filtered, and the weight M_2 determined. This procedure is also suitable for the determination of starch based finishes. The percentage size content is given by:

$$= \frac{M_1 - M_2}{M_1} \cdot 100$$

Size determination, qualitative The analytical scheme illustrated in the Fig. can be followed in order to determine the type of size present on a woven fabric.

Size liquor pick-up This variable is dependent on



Treat material in 250 ml methanol for 15 minutes at 60-65°C. Pour away methanol and replace with water, then treat for further 15 minutes at 65°C. Remove fabric from liquor. Add 2–3 drops of solution ⑤ to the liquor.

standard solutions:	
solution ①	1.3 g iodine + 2.4 g potassium iodide in 1 l water
solution ②	0.13 g iodine + 2.6 g potassium iodide + 4 g boric acid in 100 ml water
solution ③	11.88 g potassium dichromate in 50 ml water + 25 ml concentrated sulphuric acid
solution ④	30 g sodium hydroxide in 70 ml water
solution ⑤	4 % uranyl nitrate solution in water

Fig.: Diagram showing the process for the determination of size (by Sandoz).

most of the parameters involved in → Sizing. It offers a useful means of determining the approximate degree of sizing (usually calculated by multiplication with the size liquor concentration). Because of the diverse influences in individual cases, however, size liquor pick-up values determined under specific circumstances are not transferable to different sizing conditions (see → Sizing, degree of).

Size recycling Since the polymers used for sizing textile yarns lead to high levels of waste water pollution during desizing, the importance of size recycling is clearly demonstrated by means of a materials balance of the sizing process (Figs. 1 and 2). As environmental pollution regulations become ever more stringent, textile companies are confronted by legislation with the choice either to recover sizing agents from the waste water or to pay for disposal costs.

Synthetic sizing agents are now available which can be recycled. The recovery of these products is also economically viable for small textile plants who are able to take advantage of this technology collectively.

For size recovery, suitable sizing agents must, among other things, exhibit the following properties to facilitate recovery by ultrafiltration:

- water-solubility,
- thermal and mechanical stability,
- biological resistance,
- easy removal by washing,
- low to medium viscosity.

Experience in various production units has shown that a range of PVA sizes, certain acrylate sizes, CMC sizes, and mixtures of these components, meet these requirements.

The advantages of size recycling may be summarized as follows:

- reduced environmental pollution,
- reduced waste water and fresh water costs,
- cost savings due to repeated use of the sizing agent,
- more economical use of high-quality sizing agents,
- improved weaving efficiency,
- high economy due to the short pay-back time for the required plant.

Sizes are selected according to the following criteria:

- dusting propensity,
- film characteristics,
- clinging tendency,
- moisture absorption,
- increase in yarn strength,
- ecological aspects (waste water pollution, capable of recycling),

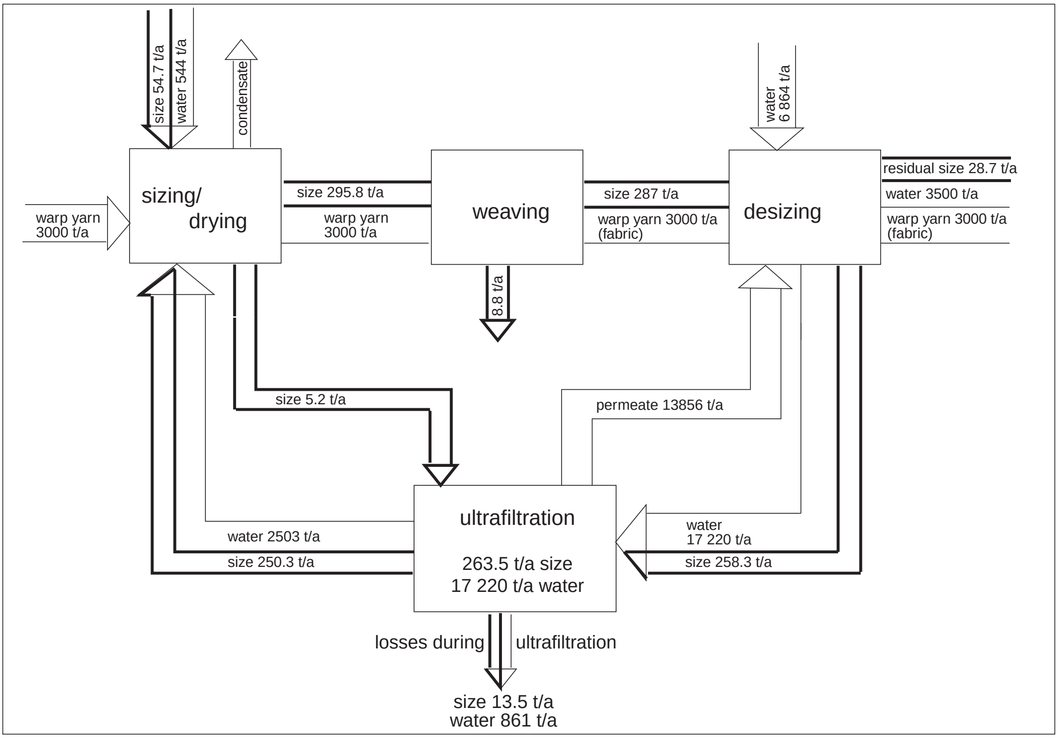


Fig. 1: Balance of resources with recovery.

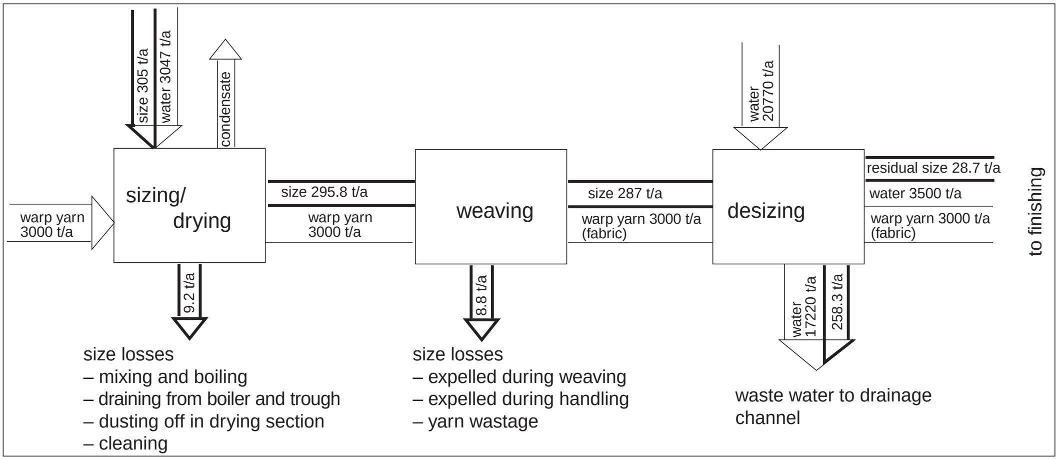


Fig. 2: Balance of resources without recovery.

- ease of removal in desizing,
- price,
- sizing conditions (process technology).

The synthesis of a size in the form of copolymers, e.g. from acrylic acid derivatives and ethylene, which can be eliminated in waste water treatment plants, could be based on the principle illustrated in Fig. 3.

As an example, three characteristic monomers, as possible segments in an acrylate polymer size, will now be referred to:

a) Polyacrylic acid: characteristic component carboxyl group; high affinity for water, the polymers have very good dissolving properties in water;
b) Polyacrylonitrile: characteristic component cyano group film hardener, good size adhesion to the fibre;
c) Polyvinylether: characteristic component ether group; low affinity for water; hydrophobic component and softening element depending on the chain length of R_2.

Since the properties of the polymers combine additively with the properties of the monomers used, it is e.g. possible to produce a polymer specifically from the three monomers alone with the desired hydrophilic-hydrophobic balance, a predetermined degree of hardness and appropriate adhesive properties.

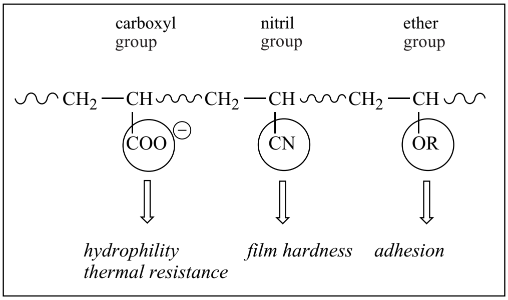


Fig. 3: The structural principle of eliminable sizes in the form of copolymers.

The substances used as sizing agents originate from the macromolecular region; they are either natural materials or entirely synthetic polymers. A decision to use a particular sizing agent should, in principle, be based on the intended application, and should not only influence the sizing process itself as favourably as possible, but also the subsequent finishing stages as well. It is highly probable that, with today’s state-of-the-art technology, both these objectives can be realized at the same time, especially with regard to the ecological aspects of size recycling (Tab. 1).

However, for all those operations which follow sizing and weaving, another property of these polymers is of decisive importance; i.e. their complete removal from the fabric during suitable washing processes and, as a prerequisite for this, the highest possible tendency for solvation (Figs. 4 and 5).

A consideration of the chemical structure of the most important compounds used as sizes leads to an appreciation of their different physical behaviour towards the “agent of removal”, i.e. water. The interrelation of their functional chemical groups to water molecules is decisive for the swelling capacity and ease of removal of the polymers under washing off conditions as well as their suitability for recycling. Due to their own dipole characteristics, OH groups react towards the dipole water with the formation of relatively labile hydrogen bonds whilst substances containing carboxyl groups enter into ionic bonds with polymer salt characteristics under the inclusion of water molecules. This is the reason for the high tendency of polyelectrolytes for solvation, e.g. of polyacrylates. This results, for exam-

sizing agent	moisture absorption by size films [%]		recovery (ultrafiltr.)	special remarks
	65 % r. m.	86 % r. m.		
PVAL partially saponified	10	20	present technology	usually in combination with CMC
PVAL fully saponified	5	20	present technology	usually in combination with CMC
PVAL ”new“	10	25	yes	not used in combination
CMC	20	40	yes	iin combination with PVAL
polyester resin	2.8	6.0	(yes)	investigation not yet completed
NH_4 polyacrylate	40	62	(yes)	tied to use in conjunction with starch
Ca polyacrylate	26	60	(yes)	tied to use in conjunction with starch
polyacrylic acid ester	14	27	(yes)	recovered size has different film properties

Tab. 1: The relative importance of recoverability compared with other properties of selected sizes.

ple, in the ease of removal of size or mixed size films by washing. In association with less soluble sizing agents, the solvating properties of polyacrylates are responsible for triggering extremely welcome water transport phenomena.

In the case of a starch/polyacrylate mixture, the acrylic component swells much faster than the starch, and finally breaks open the entire structure of the size film due to its highly swollen state, thereby promoting the transport of water into the size film. This has important consequences in pretreatment, i.e. in the presence of polyacrylates, the enzymatic degradation of starch can be accelerated and, in many cases, an enzyme treatment can even be replaced by a considerably shorter and much simpler oxidative desizing. In this case, however, the possibility for size recycling is lost.

The wet processing stages of woven fabric pretreatment carried out prior to dyeing, such as scouring, boiling off, bleaching, mercerising, etc. are carried out in alkaline media. The cellulose is swollen by alkali and thereby made accessible for chemical reactions. The presence of sizing agents on the fabric has a very variable influence on the accessibility of cellulose to alkalis and therefore their swelling capacity.

Polyvinyl alcohol and polyacrylates are typical water-soluble sizing agents. Polyvinyl alcohol sizes can be easily recycled (Tab. 2).

Polyester can also be made dispersible in water by the introduction of sulpho groups. Water-dispersible polyester-based sizes are produced by the polycondensation of several products such as dicarboxylic acids, diols, polyethylene glycol, sulphonated aromatic dicarboxylic acids. The following polyethylene terephthalate with sulpho-isophthalate groups can be mentioned as an example:

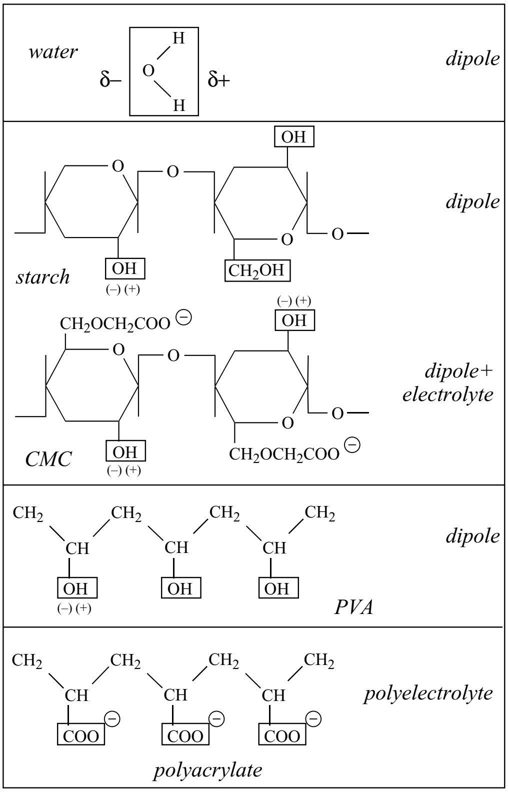


Fig. 4: Chemical structure of the most important partners during desizing.

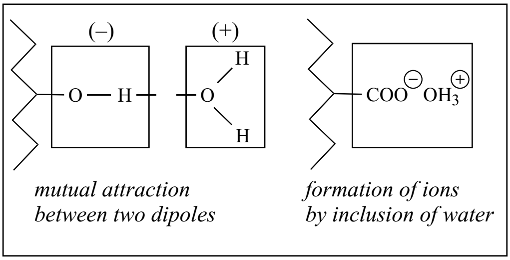
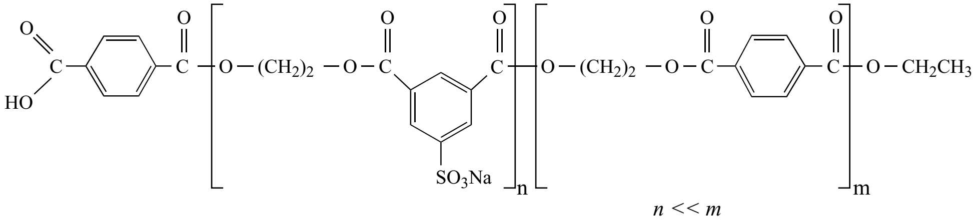


Fig. 5: Solvation of sizing agents.

Tab. 2 Properties typical of recoverable sizing agents.

polyvinylalcohol	polyacrylates
test	
iodine reaction with boric acid iodine spot test	spot test on PES fabric spot test with Merck mixture indicator
elimination	
breakdown: possible only with adapted bacteria	breakdown: very poor elimination of between 30 % and 80 % by agglomeration or precipitation
precipitation: not good due to dispersants, e.g.: – borax + sodium sulphate – ferric salt	precipitation: good, e.g.: – H_2SO_4 or other strong acids – Na^+, Cu^{2+}, Al^{3+} precipitated with sodium borates
recycling: possible and effective	recycling: possible and effective
advantages	
– very high mechanical properties – mixes with almost all sizes – strongly elastic film – little impact by ambient humidity	– readily soluble – resistant to alkalis – no boiling – does not form skin – low dusting – easy to handle
disadvantages	
– forms skin – forms foam – sensitive to alkalis – sensitive to peroxide – dissolves slowly	– hygroscopic – not thermally resistant to ammonium salt polyacrylates (NH_4) – odour (NH_3) – sensitive to changes in climate



Starch is the most important sizing agent worldwide, and derivatives of starch are also used as sizing agents. As natural products for sizing, the galactomannanes are also employed. Such natural sizing agents, however, cannot be recycled since they lack the necessary water solubility (Tab. 3) and must therefore be removed by enzymatic degradation (according to Lamprecht, Schönberger, Langer, Dachs and Schlüter).

Size residues The presence of size residues on textile fabrics always gives rise to faulty dyeings and prints. Effective control after → Desizing is therefore indispensable. Size residues may be determined analytically.

Sizing,

I. The sizing of warp yarns involves 3 stages (Fig. 1):

1. Selection and preparation of a suitable sizing liquor (size cooking).
2. Saturation of the yarn sheet with sizing liquor in the padder.
3. Temporary fixation of the size on the yarn (the application of size is temporary since it is removed

starch and starch derivatives	galactomannanes	carboxymethylcellulose
test		
iodine/starch spot test TEGEWA colour scale	iodine test not possible ninhydrin colour reaction	precipitation with uranylnitrate or cationically active substances
elimination		
biological breakdown > 90 %, even for starch derivatives (poorer breakdown only for starch ether) precipitation: possible but not effective	biological breakdown > 80 % precipitation: possible but not effective	biological breakdown insignificant; higher breakdown rate may be obtained by mixing with starch precipitation: not good, better for example at pH 2–3 or using multivalent cations
recycling: not good	recycling: not good	recycling: possible
advantages		
– favourable price – withstands high humidity – withstands alkali – breaks down biologically starch derivatives – water soluble – reduced retrogradation – altered viscosity	– washes out well – smooth film – not sensitive to electrolytes and alkali – adheres strongly – free from salt	– washes out well – does not form skin – can also be used at low humidity – strong, clear films – adheres well
disadvantages		
– recycling only with conserving agent – high use of product for starch or modified starch: – highly viscous – forms skin – builds up on rollers – adhesion reduces with ageing	– recycling only with conserving agent – high price (product use lies between that of starch and synthetic size) – no iodine test – has own colour – deposits on rollers – may form lumps – variable viscosity	– possible corrosion damage if salt content too high – deposition/build-up – sticky soiling if humidity too high – precipitates at too high temperature

Tab. 3: Non-reusable natural sizes.

again during desizing) by drying (e.g. on a cylinder drier).

The objective of sizing is to improve the running properties of the warp during weft insertion. In the weaving process, the frictional behaviour of the yarns against each other (and consequently their surface properties) is decisive for increased weaving performance (reduction in broken ends and picks). If the yarns are regarded as porous solids with a loose structure, the capillary system of small cavities associated with each other can be described as pores into which the size liquor diffuses by displacement of air. The hairiness of the yarns, which is a feature of yarns produced from staple fibres, represents a characteristic irregularity of the yarn surface which is influenced by sizing (Fig. 2). The sliding surfaces of the yarns being sized are therefore reduced by the deposition of size between the surfaces (this also applies to filament yarns).

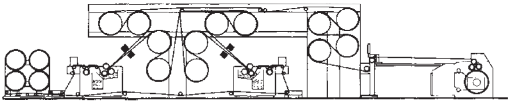


Fig. 1: Sizing line with 2 sizing troughs, 12 cylinders for drying the assembled warps, and beaming unit (SMH)).

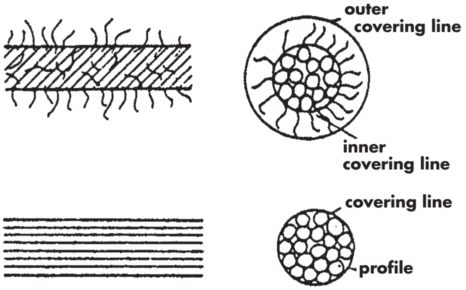


Fig. 2: Difference in the sizing of staple fibre yarn (top) and continuous filament yarn (bottom).

Besides this sheath effect, the yarn cross-section is so strongly bonded in the form of a core effect by loading with the sizing agent that the strength of the yarn is increased for the duration weaving until the subsequent desizing process. In spite of this, tensile forces also arise during shed formation, in addition to the "clinging" effect (through hairiness), caused by tension on the warp which the warp yarn must be able to withstand. Size add-on in the size box depends to a considerable extent on the viscosity of the sizing liquor. The viscosity of the size depends greatly on the temperature and is, of course, also influenced by the type of polymer. The degree of sizing can be determined and controlled by the continuous measurement of water uptake by the warp and the liquor concentration (Fig. 3). Variations from the target add-on are compensated by controlling the nip pressure, i.e. if the size pick-up is too high it is increased and if the size pick-up is too low it is reduced.

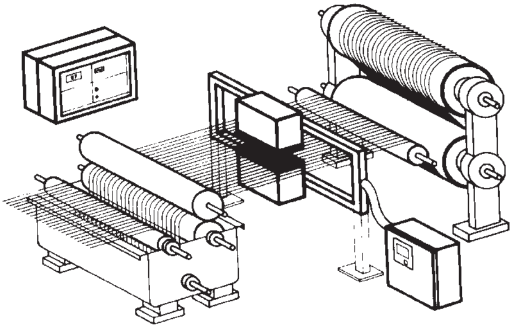


Fig. 3: AS 120 material moisture content meter (Pleva).

II. Wet sizing (Fig. 4 and 5) is a pretreatment for yarns to be processed as warps for weaving into textile fabrics. Sizing protects the yarns against mechanical stresses in the weaving process by the application of a film of → Sizing agent which envelops the yarn and which subsequently must be mainly removed again in finishing (see Tab.). The composition and quantity of application of the size must be adapted to the type of yarn. Weaving efficiency is highly dependent on sizing. The type of sizing agent (see Fig. 6) is also important in finishing which is why close cooperation between the weaver and the finisher is desirable. Sizing is carried out in hank form (hank sizing) but mainly in the warp from beam to beam (warp sizing) or from a warper's creel or a section warper (tape sizing).

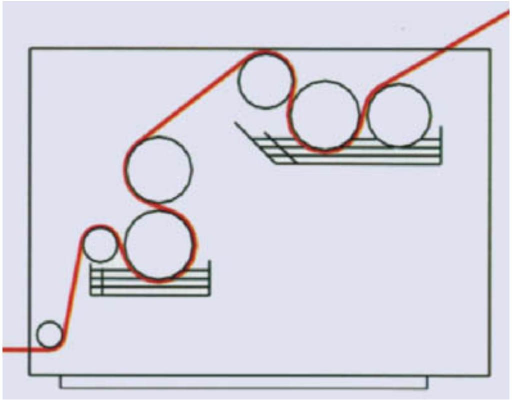


Fig. 4: Wet sizing with prewetting and subsequent sizing of the outer part of yarn.

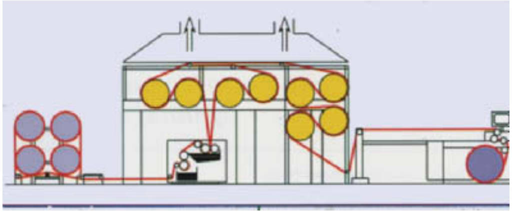


Fig. 5: Wet sizing plant (SMH).

For the classic warp sizing process, the size has to be cooked in a kettle after which the size liquor is trans-

characteristic	removal	size type
degradable	enzymatic oxidative	starch modified starch
soluble in water	swelling	polyacrylate PVA CMC specially modified starch
"water fast"	neutralization + dispersal	special polyacrylates "PES"

Tab.: The spectrum of sizing agents.

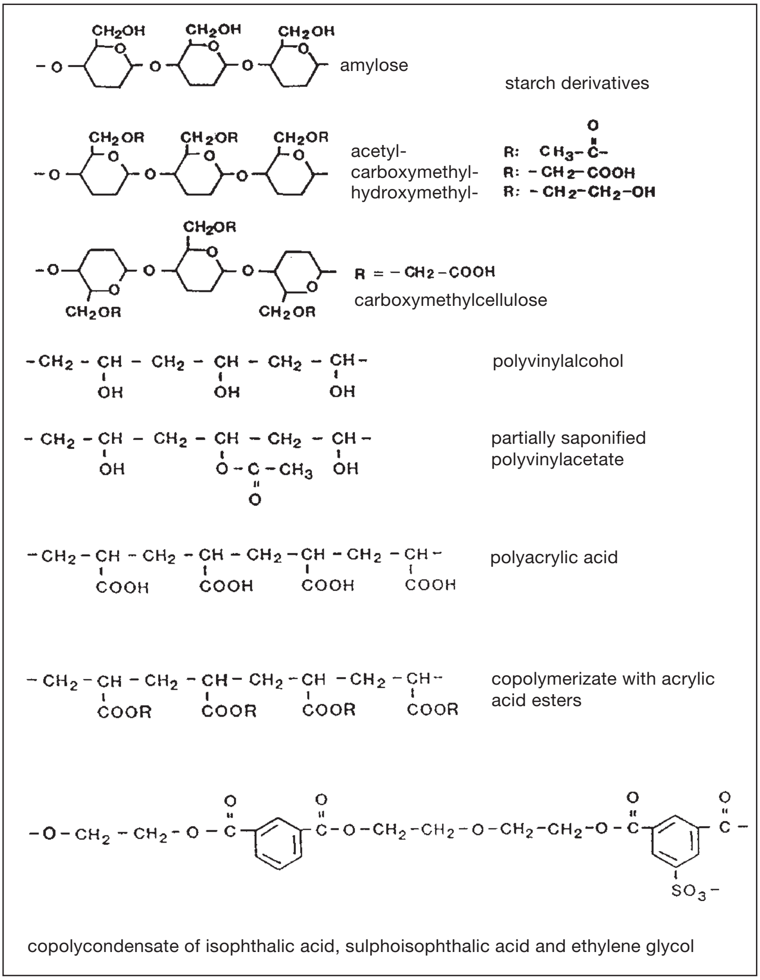


Fig. 6: The chemical structures of sizes.

ferred to a heated storage vessel from where it is finally delivered to one or several size boxes for application to the warp sheet. The wet yarn is subjected to “wet extension” whereby the individual yarn fibres slip against one another and the yarns are stretched. This wet extension in the process is often necessary in order to be able to control the behaviour of the yarns; it is, however, not desirable since the strength of the yarn is generally reduced as a result. Excessive extension of the yarns during sizing is a common cause of broken ends in weaving.

The warp is squeezed between one or several pairs of rollers at pressures of 300 kg to (in high pressure size boxes) 10 000 kg. The impregnated warp then passes over drying cylinders supplied with superheated steam. During this stage, water evaporates from the still wet yarns into the surrounding air which is normally collected under a hood and discharged by means of an extractor fan into the atmosphere through the roof. In order to expel the water quickly enough to achieve high processing speeds of, e.g. 100–125 m/min, the yarn is “cooked” on the drying cylinders. This rapid drying often leads to size bridging between individual yarns. The layer of warp yarns is peeled off the cylinders as a result of which individual fibres or hairs protrude from the fibre bundles. If the working speed changes, drying is either excessive or insufficient since the system inertia cannot be overcome quickly enough to compensate for changes in temperature/speed. After leaving the drier, the yarns are separated with the aid of lease rods.

In some cases, waxes are recommended instead of sizing. Moreover, efforts have been focussed on developing methods for the recovery of sizes and heat from sizing machines. The type of sizing agents and additives, application quantities, and the drying method have also been thoroughly investigated. Difficulties have been encountered in measuring the concentration of the size liquor. Measurements made with refractometers are regarded as problematic. Furthermore, the possibility of size recovery and biodegradability are receiving increased consideration in the selection of suitable sizing agents. In addition, efforts are being devoted to the control of size add-on by means of appropriate measurement and control systems. →: Sizing agents selection criteria; Size recycling.

Sizing agents The role of a sizing agent is to provide yarns for weaving with the necessary smoothness, compactness, pliability and strength in order to make them more suitable for further processing in the loom or weaving machine and more resistant to mechanical stresses. Basis of sizing agents: mainly degraded starches, animal glues, water-soluble cellulose and starch derivatives, mucilages from plants, water-soluble polymers and plastic dispersions as well as drying oils (see Tab.).

I. Water-soluble sizing agents: these are chiefly used for warp sizing on sizing machines: a) Natural products: mostly based on starch or proteins and, less frequently, on sodium alginate. These sizing agents are preferred for hydrophilic fibres. b) Modified natural products, such as cellulose or starch derivatives of the starch and cellulose ether resp. starch ester type, which are likewise preferred for hydrophilic fibres. c) Synthetic products specifically for hydrophobic fibres which can be classified into the following types: vinyl derivatives mostly in the form of polyvinyl alcohols in different viscosity ranges and varying degrees of saponification, as well as polyacrylate derivatives with an acidic character or neutral polymers resp. copolymers with outstanding suitability for practically all man-made fibres. Modified polyesters with water-solubilizing sulpho groups

II. Aqueous sizing agents based on plastic dispersions: specifically designed for application together with water-soluble sizing agents for hank sizing. These products contain water-insoluble plastics finely dispersed in water, e.g. mainly vinyl derivatives, chiefly polyvinyl acetate dispersions and polyacrylate resin dispersions.

III. Oil sizes and organic glues.

IV. Water and glue-free sizing agents.

Sizing auxiliaries These include products based on fat components used as additives to → Sizing agents in order to improve the softness and smoothness of warp yarns for subsequent weaving, e.g. animal and vegetable fats and oils as well as sulphated or emulsified fat and oil compounds, water-soluble synthetic waxes as well as paraffin and wax emulsions.

Sizing control systems In order to ensure reproducible sizing even, e.g. when running at extra slow speeds, attempts are made to measure and control as many parameters as possible in the size box (see Fig.).

The concentration of the size liquor may be controlled by refractometry. Temperature influences the refractometer measurements (refractive index) as well as the viscosity of the size liquor, consequently the liquor pick-up changes according to the speed of running, which is why attempts are made to regulate the nip

	natural				synthetic				
size / substrate	starch	CMC	galactomannane	glue	polyacrylic acid B	polyacrylic ester B	PVA	PES	vinyl copolymer
yarn									
cellulose	+	+	+		+	+	+		
cellulose/PES	○	○	○		+	+	+		+
cellulose/PA	○	○	○		+	+	+		
wool	○	○		+		+	+		+
wool/PES	○	○				+	+		+
PES, PA	○	○				+	+		+
filament									
viscose rayon		+		+	+	+	+		+
acetate						+			+
triacetate						+			+
polyamide					●	●	●		
polyester						+	+	+	+

\+ alone or in combination ● alone ○ only in combination with synthetic sizing agent

Tab.: Sizing agents related to their substrates.

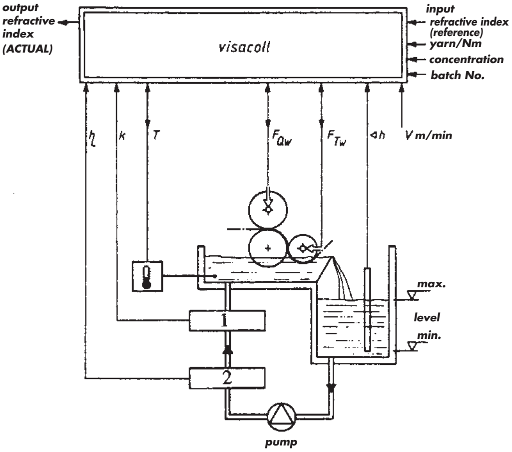


Fig.: Visacoll sizing meter (SMH) for sizing control.
1 = refractometer; 2 = viscometer.

pressure. The liquor level in the size box is also controlled.

Sizing, degree of The running properties of warp yarns in weaving is highly dependent on the quality of warp sizing. Thus, the incidence of broken ends only remains low within a limited range of "optimum sizing" conditions. When warps have been over-sized or under-sized, the number of broken ends increases (see Fig.).

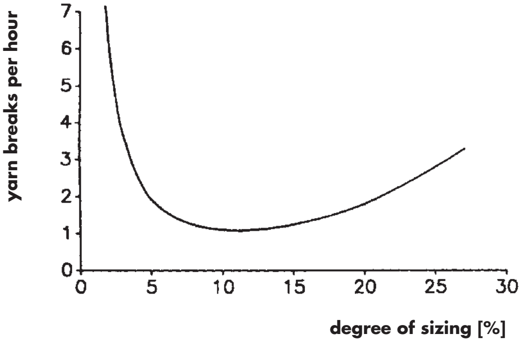


Fig.: Effect of degree of sizing on yarn breakage rate.

Because of its large contribution to weaving efficiency and fabric quality, considerable efforts have been made for a long time to adjust the degree of sizing to a value known to be optimal and maintain this value at a constant level. However, this can only be achieved with difficulty for the following reasons:

- the degree of sizing can only be measured directly with considerable outlay (e.g. by radiometric methods);
- the degree of sizing is dependent on many parameters which can change, depending on the article, from batch to batch and/or change within a batch depending on time.

Moreover, the degree of sizing is dependent on several factors, e.g.:

- parameters of the warp, i.e. warp yarn density;
- parameters of the warp yarn, i.e. spinning technology, type of fibre, fat and wax content, linear density, twist, hairiness;
- parameters of the sizing agent, i.e. affinity of the sizing agent for the yarn;
- parameters of the size liquor, i.e. concentration, viscosity and temperature (here the viscosity is not only a function of the sizing agent and the prescribed liquor concentration, but also the processing involved in size cooking);
- parameters of the sizing machine, i.e. number of sizing troughs, constructional features, warp passage and speed, pressure and adjustment of the squeeze rolls, warp tension in the wet zone (according to Trauter).

Sizing machines Are used for machine → Sizing of rapidly running individual yarns (between yarn packages), of hank yarns (hank sizing is of secondary importance only because of inadequate capacity; the process is carried out on hank dyeing machines), the sizing of already warped tape warps and, for large scale production reasons, of warp beams. This latter involves the open-width passage of warp yarns from back beams resp. a multiple beam frame (usually in a step-by-step arrangement), through the size box and the drier for beaming. Sizing machines are equipped with high performance control and regulating systems for almost all working parameters up to automated monitoring, the

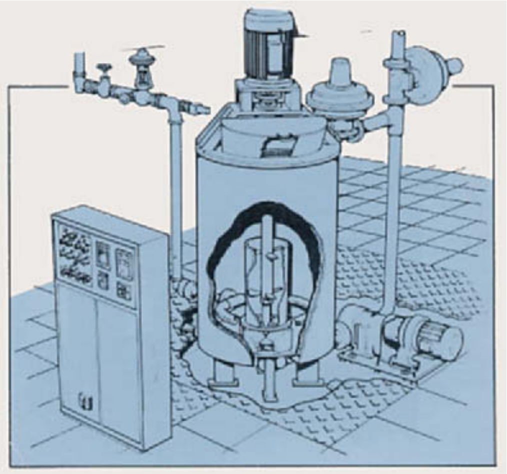


Fig. 1: Size boiler (SMH).

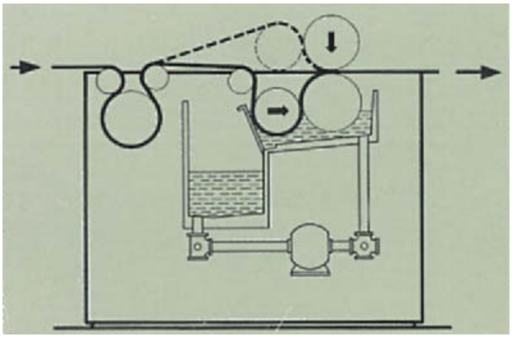


Fig. 2: Size trough (SMH).

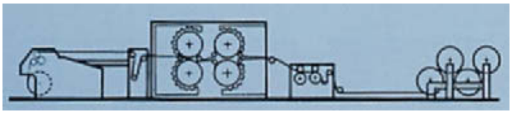


Fig. 3: Cylinder drier.

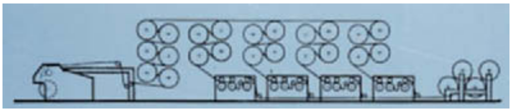


Fig. 4: Warp division machine.

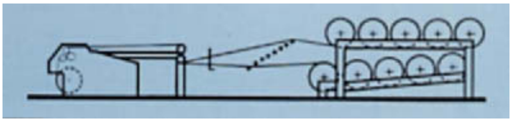


Fig. 5: Assembler machine.

size box (trough) with one or two rollers or with double immersion and squeeze rolls. Useful control and regulating systems to achieve a constant level, viscosity and temperature of the size liquor are technically important features of modern sizing machines.

The following equipment is necessary for sizing:

- a size boiler to swell the polymers (Fig. 1),
- a size trough with high-performance squeeze rolls (Fig. 2),
- a cylinder drier with optimum heat utilization (Fig. 3),
- in certain circumstances, a section warp division machine (Fig. 4),
- in certain circumstances, an assembler machine (Fig. 5).

Sizing selection criteria During shedding on the loom, the strength of the warp yarns is subjected to severe tensile forces on the one hand and the clinging together of hairy yarns on the other. This clinging of the yarns occurs to a greater extent in the temple and selvedge area since the tensile forces acting on the warp yarns are lower here. High tensile forces on the warp yarns are more likely to open up yarns which have clung together. It is therefore difficult to set the optimum tensile force on the warp yarns particularly since the level of warp tension is not constant across the width of the warp. On the one hand, the yarns must not be subjected to excessive tension and, on the other hand, if the tensile load is too low the yarns will cling together. A compromise must therefore be found which will appear somewhat different for each type of yarn and each type of article (Fig. 1). For a certain tensile load on the warp yarns, which lies between clinging and overloading of the warp yarns, the number of end breaks are at a minimum.

In order to produce a textile fabric on a high-performance weaving machine, the warp yarns have to meet the following requirements:

- the yarns must have adequate abrasion resistance and yarn strength,
- the yarns should have a high and uniform residual elongation as well as uniform warp yarn tension,
- the yarns should have a low degree of hairiness and a low snarling tendency,
- the yarns should run without any crossing of the yarns.

With shuttleless weaving machines, good shedding performance of the warp yarn sheet is decisive for high weaving efficiency. Sizing sticks down the projecting hairs on the yarns and increases the strength of the yarns by bonding the core of the yarns.

To achieve this, sizing concentrations of approx. 100 g/l size are applied in the size box. Because of the viscosity of the size liquor, warp separation is necessary under certain circumstances in order to obtain better penetration. For this reason, the sized warps must be assembled (united again) afterwards. The warp con-

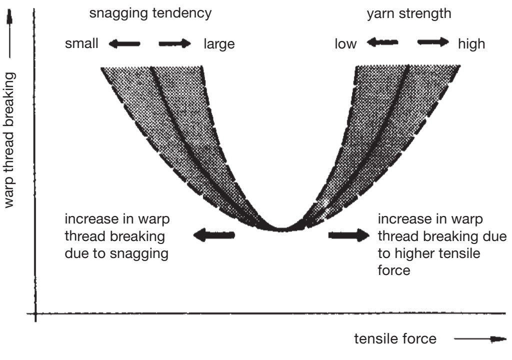


Fig. 1: The optimum for warp thread tensile force between tensile stress and snagging stress.

Sizing selection criteria

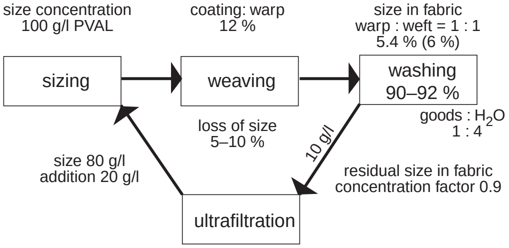


Fig. 2: Schematic showing work required for size recovery.

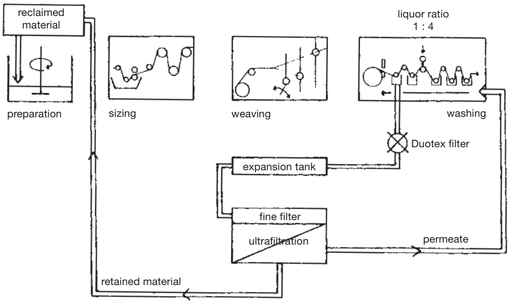


Fig. 3: A real example of size recycling.

tains an add-on of approx. 12% size after sizing or, in other words, the woven fabric contains approx. 6% of size. In recent years, efforts have been directed towards size recycling from desizing baths (Figs. 2–3).

Sizing has assumed considerable importance for a variety of reasons:

1. Fabric quality and the unit capacity of weaving machines are dependent to a large extent on the type of size used. Weaving plants are under pressure to increase the unit capacity of their weaving machines, e.g. by optimization of the sizing process through the application of synthetic sizing agents.
2. In order to partially offset higher wages, productivity has been increased by the introduction of high-performance weaving machines. These high-speed weaving machines subject the warp yarns to a considerably higher strain than the former conventional weaving machines which, again, demands improved sizing agents.

The type of sizing agent used, and the quantities of sizing agent necessary to ensure satisfactory weaving performance, are a function of several parameters (e.g. fabric construction, type of weaving machine, type of fibre and yarn quality); consequently, these parameters

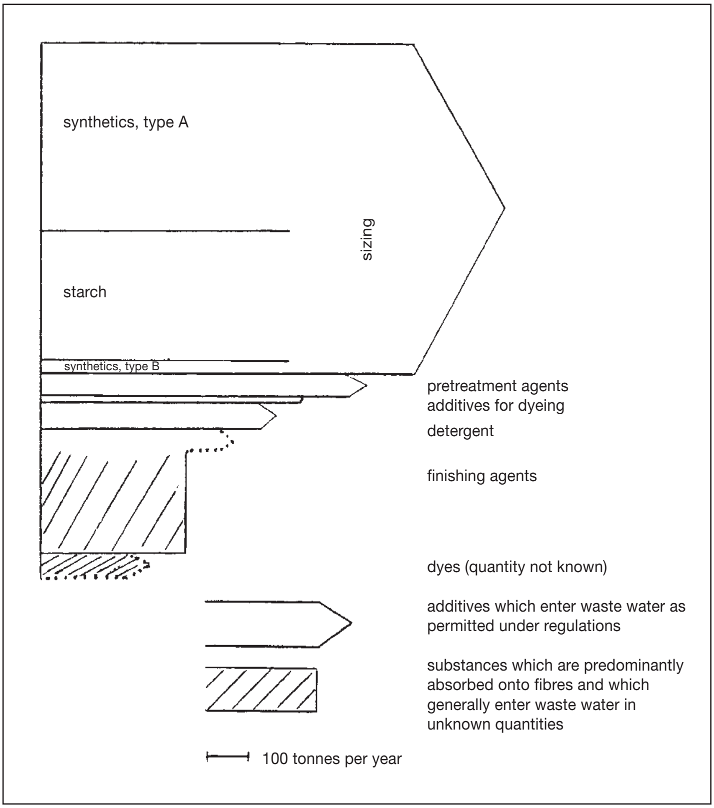


Fig. 4: An extremely simplified list of materials used by a textile finisher with a waste water output of approx. 1000 m³ per day and a COD of 1800 g/m³; TOC utilization is approx. 25%.

must be individually established for each weaving plant. In Germany, about 150 products for sizing (sizing agents and additives) are currently available in the market. Annual consumption is approx. 20 000 t of sizing agents.

Sizing agents for textile sizing are produced from 5 different basic raw materials:

- starch (chiefly potato starch),
- carboxymethylcellulose (CMC),
- polyvinyl alcohols (PVA),
- acrylates (A),
- polyester (PES).

Unfortunately, the environmentally-friendly starch sizes exhibit the lowest sizing efficiency so that weaving plants are often compelled, for the reasons given above, to use synthetic products in order to ensure the required quality standards. As a consequence, the proportion of synthetic sizes has risen to 45%.

For a textile finisher, sizing agents account for approx. 50% and more of the total organic pollutant load (determined as COD) in the waste water (Fig. 4). In view of this quantitative importance of sizing agents in waste waters, it seems reasonable, from an economic aspect, to question:

1. What level of pollutant load does desizing contribute to the waste water?
2. To what extent can the sizing components be degraded/eliminated in a biological waste water treatment plant?
3. What measures can be taken to effectively reduce waste water pollution from this process in the textile finishing industry?

The above questions can be answered as follows:

1. Random sample analysis of desizing liquors from 5 different finishing plants gave the following results:

- pH: 6–7 resp. 11–13 depending on the process,
- COD: 500–20 000 mg/l,
- hydrocarbons: < 0.1–5 mg/l,
- AOX: < 0.02–1.3 mg/l,
- arsenic: 0.01–9* mg/l

(* source unknown, but probably due to biocide/pesticide residues).

2. Apart from potato starch and its derivatives with a low level of substitution, none of the common synthetic sizes for staple fibres currently available in the market are biodegradable to a satisfactory degree. Non-biodegradable means that the sizing agent is neither biodegradable nor can it be adsorbed or stripped by sewage sludge.

Synthetic sizing agents therefore remain to a large extent in the water courses. Sizing agents are officially not (yet) included as hazardous substances in the corresponding lists (e.g. 129th EC List etc.). Whether synthetic sizing agents will be included in such lists is not foreseeable at present. In any case, not all sizes are biodegradable (Fig. 5).

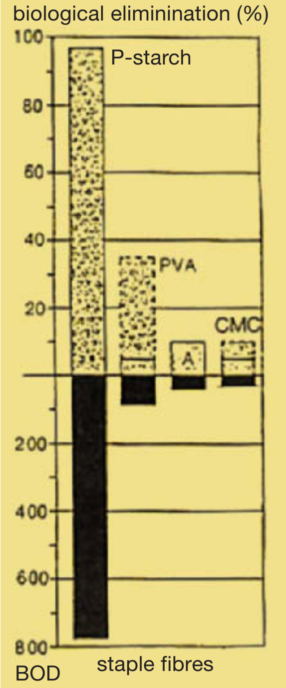


Fig. 5: The BOD values and ease of biological elimination of sizes. P-starch = potato starch; PVA = polyvinylalcohol; A = polyacrylate sizes; CMC = carboxymethylcellulose.

The Chemicals Law (ChemG – Chemikaliengesetz) is concerned with the control of new products as a first priority. It contains, however, an authorization for the limitation/banning of so-called “old substances”. Nevertheless, it cannot be assumed that the legislator will make use of this as far as synthetic sizing agents are concerned.

The Detergent and Cleaning Agent Law (WRMG – Wasch- und Reinigungsmittelgesetz): under the heading “Definitions”, it is stated in the WRMG under § 2, paragraph 1, clause 3: “detergents and cleaning agents are given equal consideration and, according to definition, are applied to surfaces and, with a single cleaning using products for the purpose of clause 1 (surfactants) are largely removed and, according to experience, can enter water courses”. Sizing agents fall within the scope of the WRMG for which a fundamental requirement of biodegradability resp. at least a high degree of biological elimination applies. This fundamental requirement, however, requires a concrete preparation by a statutory order in accordance with § 3, paragraph 2. Serious considerations with regard to making use of this regulatory authorization do not exist at present.

Waste: sizing agent residues from preparation vessels and size boxes are industrial wastes and must be disposed of as such. The “disposal” of such residual concentrates by the waste water route is forbidden by Appendix 38 of the German Water Resources Law (WHG – Wasserhaushaltsgesetz).

Waste water: a fundamental distinction has to be made here between the federal and regional water laws and municipal regulations.

With regard to sizing agents in particular, it is stated accordingly in the German Water Resources Law (WHG) under its § 7a, among other things that the sources of origin of waste water containing hazardous substances are subject to statutory regulations. This is enforced by the Waste Water Origins Regulation. The requirements placed on waste waters from such sources are intended to be defined in the amendment to the administrative regulations in accordance with § 7a of the WHG. The corresponding administrative regulation for textile manufacture/textile finishing is therefore expected. A draft is, however, already available (Appendix 38). These administrative regulations are in one part:

– minimum requirements in accordance with generally recognized state of technology which only apply to direct polluters and, in one part:
– minimum requirements in accordance with the current state-of-the-art (for hazardous substances) which are applicable both to the direct polluter as well as the indirect polluter. For the indirect polluter, however, a further regulations by the German states is necessary.

As far as sizing agents are concerned, the amended draft contains

– the fundamental requirement for synthetic sizing agents to be retained with recycling resp. disposal by state-of-the-art measures;
– concrete threshold limits for the obligation to treat segregated streams of waste water by state-of-the-art technology; one of these parameters is the degree of biological elimination (determined by the so-called → Zahn Wellens Test).

Waste water from desizing must be treated by present state-of-the-art technology in order to meet these threshold limits if the COD exceeds 5000 mg O_2/l and the COD elimination lies below 75% in the aforementioned test. If the COD concentration lies above 30 000 mg O_2/l, a COD elimination of 90% is stipulated. These values imply that the usage of water corresponds to the state of production technology and a falling short of the COD concentration by "dilution" is not involved. As far as COD elimination in the Zahn Wellens Test is concerned, no experience is yet available for segregated waste water streams from desizing. The execution of this ordinance, i.e. the waste water analytical tests, shows how many and which industrial plants are affected. The first-mentioned fundamental requirement for the recovery of synthetic sizes is first of all intended to be carried out, above all, by so-called vertical plants since, in this case, the size recovery can be associated with economically advantageous recycling.

3. Wherever possible, readily biodegradable products should be used as sizing agents. The problem here, however, is that such products often do not satisfy technical application requirements. Attempts are currently being made to develop biodegradable and, at the same time, high-performance sizing agents (new starch and galactomannan derivatives); however these products have either not yet been perfected or they do not allow a complete substitution of synthetic sizes which are difficult to eliminate biologically.

For the use of sizing agents which are readily biodegradable, investigations should be carried out with the effect of treating the desizing liquors by anaerobic means since, for energy reasons, it is senseless to degrade the energy in the sizing agents with aerobic energy again; it is much more sensible to recover anaerobic energy in the form of biogas. Attempts to introduce biologically eliminable sizes (new acrylate sizes) with adsorption as the predominant elimination mechanism have not proved satisfactory since a problematic displacement in the sewage sludge takes place.

So long as the use of readily biodegradable sizing agents is not possible for technical application reasons, increased efforts must be devoted to the development of recyclable sizes. A 100% recycling is not possible. The technology for the recovery of synthetic sizes based on PVA, CMC and PAC is ultrafiltration. With this membrane technology, reusable concentrates are produced from desizing liquors of relatively low concentration by the selective extraction of water. For pure PVA sizes, this method of recovery and reuse is already an established technology. Efforts must be made to push the larger weaving plants to desize their woven fabrics themselves so that desized goods can be offered to the market in order to exploit the economic advantages of recycling. The commission finisher should also be encouraged to go over to receiving desized goods or to stipulate the type of sizing agent to be used (even for fabrics from the Far East and overseas) even though this measure does not appear feasible at present.

SKE A German abbrev. for "Steinkohleneinheit", i.e. coal equivalent. It is the quantity of heat produced by 1 kg of coal with an average → Thermal value of 29 400 kJ (7000 kcal). The use of this unit is no longer permissible.

Skeins A form of yarn package consisting of an unsupported coil of yarn. Each → Hank is twisted several times, folded in half, and the end tucked through a free opening.

Skew straightener A device for straightening skew distortion in textile fabrics, e.g. with the aid of rollers.

Skin burns,

I. Burns caused by acids: the affected area should be treated immediately with water and sodium bicarbonate.

II. Burns caused by alkalis: the affected area should be treated immediately with water and boric acid.

Skin compatibility of antimicrobial finishes The question concerning the purpose of an antimicrobial or hygienic finish is based on the physical condition of human beings. On the one hand, consideration has to be given as to how an active substance to be used in such finishes should be classified with regard to its toxic properties towards the animal and plant world whilst, on the other hand, there is the question of its skin compatibility. In this regard, it is clear that only those substances with a low degree of toxicity are suitable for antimicrobial finishes. Completely non-toxic substances for this application are unknown. On this basis, suitable products are selected if a test for skin compatibility carried out beforehand has revealed no negative aspects.

The largest organ of the human body with approx. 18% of the body's weight is the skin, the boundary layer (1.6–2 m^2) with a defensive and protective function. The horn layer of the skin protects the body against the penetration of chemical substances and microorganisms. The surface of the skin is covered with a film of skin fat which is composed of free fatty acids, bound fatty acids, triglycerides and components such as squalene, cholesterol, wax alcohols and other substances. The surface pH of healthy skin lies between 4–7. This "acidic covering" provides a defence against disease-causing microorganisms. These pH conditions must therefore be taken into account in the selection of an active substance for antimicrobial finishes. The pH of human perspiration in the sweat glands lies between 5.5–6.75. Salts, lactic acid, pyroracemic acid, uric acid, amino acids and ammonia are the main components of human perspiration. Perspiration is decomposed by microorganisms and the volatile decomposition products are responsible for the typical odour. Perspiration and the fat film are nutrients for bacteria and fungi on the one hand whilst, on the other hand, substances are also present on the skin which inhibit the growth of microorganisms. Healthy skin is therefore in a state of equilibrium with the microorganisms present on it and their action. The frequency with which this equilibrium is disturbed, however, is revealed by the fact that approx. every 5th patient seeking the services of a medical practitioner appears to be suffering from a skin disease. In some parts of Germany, more than a third of the inhabitants suffer from athlete's foot, a type of fungal infection which, in turn, can be a source of subsequent bacterial infections. Every skin has its own microflora. Due to the influence of an active substance on the fibre of a textile which is contact with the skin, there is a danger that the body's own microflora will change since the equilibrium is disturbed. As a result germs, including those causing disease, would achieve predominance and lead to interference of the skin's function. Moreover, as a consequence of a long-lasting action of the active substance, germs could develop resistance and resist a subsequently desired growth inhibition. With long-lasting action of a substance, sensitization reactions can also occur. Finally, the phenomena of allergies must be considered. Not every human being is able to tolerate certain substances. Because of these expected negative influences of antimicrobial active substances, an antimicrobial finish for textiles worn for long periods in direct contact with the skin e.g. underwear is, for hygienic and microbiological reasons, generally avoided.

Skin diseases (dermatitis) can be caused by certain finishing chemicals, organic solvents, disinfectants and preservatives, dyeing carriers, textile auxiliaries, dyestuffs, etc. by handling the products on the one hand, and by wearing textiles containing residues of these substances on the other. In most cases, a certain hypersensitivity (→ Allergy) of the skin towards a particular substance mentioned above exists which is, however, tolerated without any reaction by the majority of subjects who come into contact with it. An individual hypersensitivity can either be an inherited predisposition or may be acquired by constant contact with a particular agent. Specific measures for skin protection have a preventative effect (e.g. the wearing of rubber gloves and the use of skin protection ointments or barrier creams). The factor/s responsible for triggering a skin reaction is difficult to determine in individual cases. With → Textile eczema, a distinction is made between non-specific non-allergic and allergic contact eczemas. A causative connection can exist for persons with sensitive skins, e.g. towards particular items of clothing produced mainly from coarse materials. Textiles made from synthetic fibres can also cause skin irritations since the hydrophobic surfaces are not able to soak up perspiration. Skin irritations due to purely mechanical effects may also be caused by tight-fitting garments. On the other hand, allergic contact eczemas originate, in the majority of cases, not from textiles themselves but from the residues of finishing chemicals applied to textile fibres. The following eczema-inducing agents have been discussed in the literature: urea-formaldehyde derivatives, some azo and disperse dyes, chromates and rubber components. The detection of agencies which trigger eczemas is carried out by skin patch tests with textile constituents and types of materials, exposure tests and chemical analysis. For atopic subjects, it is recommended to give newly-purchased textiles a domestic wash before they are worn on the body.

Skin effect → Covering layer.

Skin fibres,

I. Fibres with a → Covering layer.

II. → All-skin fibres.

III. → Core-spun yarns.

Skin incompatibility Possible causes of skin incompatibility reactions with regard to clothing include the following from a dermatitis point of view:

I. Irritative reactions (wool sensitivity): textile incompatibility which manifests itself by itching and scratching, occasionally accompanied by reddening, to eczema symptoms in more severe cases, are understood to be caused by irritations of the skin by specific types of textile fibres. It is an expression of so-called wool sensitivity as encountered much more frequently in atopic patients with neurodermatitis than with control subjects and patients with eczema of a different origin. Wool intolerance occurs more frequently on moist skin and with younger rather than older patients. The irritations are triggered via peripheral nerves, especially pain receptors.

II. Allergic reaction (hypersensitivity reactions): for the demonstration of allergic reactions to textiles, two types are important:

1. Type I reaction: with this type of immediate allergic reaction, the triggering allergen contact takes only seconds or minutes. A skin reaction in the form of nettle rash (urticaria), in the mucous membranes as hay fever, conjunctivitis or bronchial asthma can then occur. The disease symptoms are caused by the meeting of the allergen (antigen) with specific antibodies present in the body of sensitized patients which are attached to the surface of mast cells. If antigens and antibodies in the skin or mucous membranes come into conflict with each other, signal or messenger substances (preformed mediators) are released which results in the formation of the above-mentioned inflammatory reaction.

2. Type IV reaction (late reaction): in this case, the skin reactions reach their peak after 24–72 h and, from time to time, even after 4–6 days. The changes in the skin correspond clinically to allergic contact dermatitis with reddening, formation of lumps and blisters, discharges and scaling, accompanied by itching. The type IV reaction is promoted by specific sensitized T-lymphocytes which are formed after contact with the allergen in association with the Langerhans cells of the epidermis in lymph nodes and other immune cell-forming organs, and enter the skin via the bloodstream where they are present for sufficient time for a reaction to occur.

Allergic reactions to textiles are mainly contact resp. type IV reactions and, less frequently, type I reactions (according to Klaschka).

Skin rug A hand-woven → Flat carpet in the form of a weft-figured carpet produced from a single weft consisting of narrow cut strips of skin at a predetermined width (also includes those rugs where the strips of skin are used in the warp with a yarn weft). The edges and ends of the rug are bonded.

Skins The untanned outer skins of particularly large agricultural animals (e.g. cattle, horses, pigs) as well as smaller land animals and large aquatic animals (e.g. fish, lizards, snakes, whales, crocodiles). →: Pelts; Tanning; Leather.

Skin wool (fellmongered wool, lime wool, pelt wool). Produced from the skins of slaughtered sheep (as well as other domestic animals). Production: as enzyme wool, as sweated wool (Mazamet wool, lime wool, slipe wool) by a) shearing, or b) by extraction with the hair roots, or c) as b) but after a prior treatment with milk of lime to dissolve the hair roots to give so-called lime wool which must consequently always be regarded as chemically damaged wool. → Recovered wool.

Skittery dyeings An irregular speckled appearance in dyed goods produced by colour differences between adjacent fibres or parts of the same fibre due to a variety of causes (→ Skittery dyeing wool).

Skittery dyeing wool The uneven dyeing in the region of individual fibres which can be more pronounced in blended wools is described by the terms skitteriness, tippy dyeing, → Dichroism, etc (→ Tippy dyeing). Beyond a certain threshold value of dichroism (this term is used in respect of polychromatic effects as in a series of standard dyeings), the eye detects such dyeings as weaker in shade and uneven in appearance even with the best blending of the individual fibres. The skittery sensation thus depends on several factors, not least from the observer himself and from the form of the textile material.

Skitteriness is due to the fact that individual wool hairs exhibit differently dyed areas and is caused by uneven damage, especially during the growth phase. The most severely damaged parts are on the outside and are described as tips; the entire remaining part of the fibre is often described as the root. That part of the wool hair which can be unambiguously recognized coloristically, e.g. with cationic dyes, as the tip usually amounts to 5–35%. Wool from different sources differ markedly in this respect. As far as the fact that it is often difficult to decide where the tip (i.e. the most severely damaged part of the hair) stops, this will only be referred to in passing. Even though one generally only speaks of the tips and roots, all possible gradations exist between them. In the case of dyeings with more strongly dyed tips the term “positive dichroism” is used whilst the reverse situation is described as “negative dichroism”. The eye reacts more acutely to the positive variant, which is not only due to the fact that the strength differences may be more pronounced in this case, but also because the proportion of tips is less percentagewise than the proportion of roots.

A test for the quantitative determination of skitteriness is shown in the Fig. This is achieved by the mixing of different dyed slivers of known dye concentration and assessment of the resultant felts by experienced colourists. In this experimental procedure, negative dichroism was produced by keeping the root/tip ratio constant at 70 : 30. The total dye content of the blend, consisting of roots and tips, was likewise kept constant so that, theoretically, no differences in colour strength

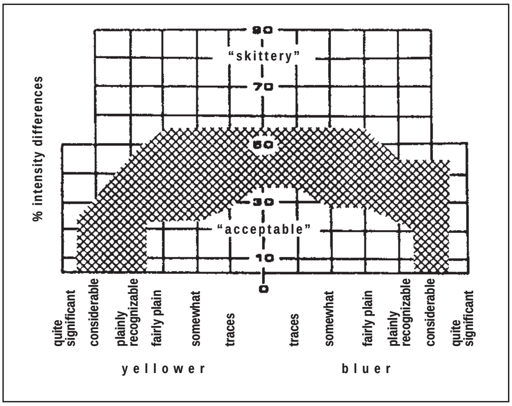


Fig.: Visual assessment of the skitterines of wool felts relative to intensity and shade differences in the admixtures (Ciba-Geigy).

should occur. This was achieved by the fact that in the case of pre-existing negative strength difference of the tips, the roots must have been dyed correspondingly darker. In strength terms, the same measures were adopted for the shade variations "yellower" or "bluer". The hatched area in the Fig. represents the skitteriness sensation threshold which was established from the different assessments of the colourists. Within and without the hatched zone, the assessments were uniformly acceptable or skittery. With negative dichroism, differences in colour strength greater than 40–50% occur relatively seldom. Pronounced skitteriness is therefore to be feared when the elements relating to dichroism vary in dye combinations, so that shifts in shade between roots and tips occur (according to Hertig and Scheidegger).

Skittery roller printing May be caused by, for example, poor engraving, excessive viscosity of the printing medium, excessive wiping of the medium out of the engraving or through clogging of the engraving. It can be alleviated by improving the engraving, or thinning the printing medium, by use of a stiffer doctor blade or reducing the pressure on the blade, or else by using rotary brushes for applying the printing medium.

SKT An abbrev. for "Schweizerische Klassifikation Textil", i.e. Swiss Textile Classification. A committee for textile documentation in Switzerland. The association for documentation is responsible for preparing a classification system for the textile finishing sector. The structure of the SKT is based on the decimal system.

SL → Slag wool, → Textile fibre symbols, according to DIN 60 001 up to 1988.

Slack mercerization → Mercerizing of cotton textiles on chainless mercerizing machines without tension. Fundamental requirements: suitable construction of the textile material (floating weaves), no tension during the mercerization process, the stretch effect is set by subsequent resin finishing.

The process is mainly employed to produce weft stretch cotton fabrics and is sometimes referred to as "chemical stretch" or it is applied as part of the process for crease-resistant linen. Dye affinity is increased but there is no increase in lustre.

Slag wool Synthetic → Mineral fibres (also crimped) produced from liquid blast furnace slag, used mainly for sound and heat insulation. Despite its good fire resistance, it has not been taken up by the textile industry, even in fibre blends, because it is very brittle and breaks easily; an irritant to the skin. Moreover, the oxidizable sulphur content (2–5%) readily leads to the formation of highly corrosive sulphuric acid in the presence of moisture.

Slaked lime → Calcium hydroxide.

Slasher dyeing → Warp sizing and dyeing.

Slasher dyeing machine A continuous plant for combined dyeing and sizing of warps for weaving (with diazo dyes or indigo) in the open-width state by means of a two-bath single-stage process for dyeing, development and sizing. From the warp beam frame the plant consists of: a dye trough (low liquor content), intermediate drier (15–30% residual moisture content), sizing unit for dye development and sizing (2 pairs of squeeze rolls and 2 immersion squeeze rolls), main drier, storage compensator, drier splitting section to separate the warp yarns for weaving. Yarn tension is measured at the entry to and exit from each unit with infinitely variable control.

Slasher-dye process A synonym for the → Sheet-dye process.

Slatted expander Expander combinations consisting of wood laths to maintain a fabric web in the fully open-width state. Depending on requirements, the wood laths are available with or without a rubber covering.

Slat-type black out For this application, special fabrics are given a light-impenetrable blackout coating. After finishing has been completed, the fabric is cut into strips and can, in this form, be assembled in predetermined constructions for windows so that they can rotate about their longitudinal axis as so-called roller blinds. The required stiffness of the individual slats is also achieved by means of the blackout coating which consists of several coats (e.g. white latex, latex with carbon black, white latex.).

Sleeved roller → Shell roller.

Sliding-oscillating centrifuge A type of centrifuge which, instead of pendulum feet, has a so-called sliding-oscillating bearing mounting (see Fig.). Its particular advantages include a low space requirement, better accessibility, only horizontal vibrations, and therefore less stress on the foundations, and considera-

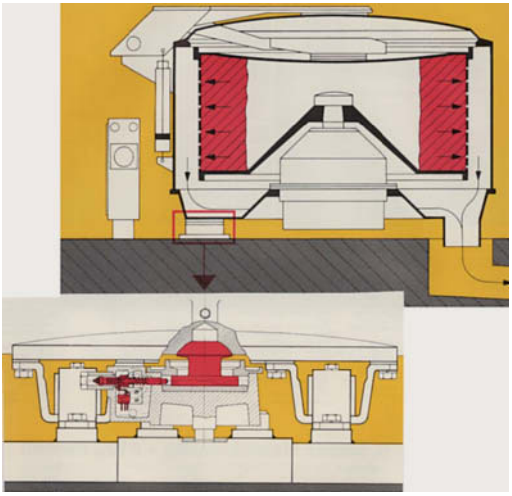


Fig.: Sliding-oscillating centrifuge with pneumatic lid- and frame opening (Krantz).

bly less loading sensitivity. The rimless model is fitted with a failsafe locking device and compressed air lid safety device; electronic speed control > 200 rpm, which can be used to set the desired end speed according to fabric type in a step-less rate (via inductive sensor in centrifuge's outer casing). Pneumatic lid opening after drum stop. Basket diameter 1200 mm, basket height 600 mm (according to Krantz).

Sliding valve A stop device used in wide diameter pipelines for steam, heating, liquids, etc. Similar to → Valves, but designed for horizontal flow, with hand wheel (operated hydraulically or electrically by means of auxiliary current push-button control), screw-threaded spindle and sliding gate. The contact faces are somewhat inclined to each other, sealing is by means of a stuffing box. The material used is generally similar to valves. Depending on the particular application, numerous designs are available, e.g. as stop valves, channel valves, membrane and quick-acting sliding valves, etc.

Slip resistance,

I. An important serviceability property of carpets, rugs, mats, etc. is that they do not slip on floors. This property calls for considerable attention with regard to the different types of floorings and the cleaning products used. In terms of finishing, slip resistance is primarily a function of the binder used (→ Backcoating of carpets). Slip resistance is most pronounced with non-filled coatings. The addition of pigment significantly reduces the slip resistance and is all the greater, the more the pigment particles are concentrated on the surface of the coating film.

II. The resistance to slippage of warp over weft threads, or vice versa, in a woven fabric. Slippage resistance mainly involves a comparative assessment. One test method provides approximate numerical values by comparison of the stress-strain curves (breaking load/breaking elongation) of two strips of textile material torn in a tensile strength tester, as well as a further strip which has been cut through at right angles and then sewn together again to form a simple seam. In this connection, the elongation of the sewn strip is greater than that of a normal strip without a seam due to slippage of the threads. For the same load, the difference in elongation values is a measure of the slippage resistance. Standard test methods include BS3320 : 1988 and Marks & Spencer test method P12.

Slipe wool Recovered wool obtained by treating pelts with lime and sodium sulphide or some other depilatory. This treatment loosens the wool which can then be pulled away without damaging the hide.

Slippage The slippage of e.g. drive belts on a pulley, or ropes of fabric in dyeing and processing machines, etc. are typical of this kind of slippage. If, for example, the reel of an overflow resp. jet dyeing machine runs faster than the rope of fabric being transported, the resultant slippage puts a lot of strain on the material. Synchronization of the fabric speed with the reel is therefore a necessary requirement. Particular attention must be paid to continuous control of fabric running in such machines and the effective circulation speed of the material should be indicated. In addition, a small free and lightly running control reel can be installed between the main reel and the acceleration tube of the machine (see Fig.) which is only driven by the fabric rope, so that its peripheral speed always corresponds to the effective fabric speed. The rotation speed of the control reel can be evaluated electronically and transmitted to a display

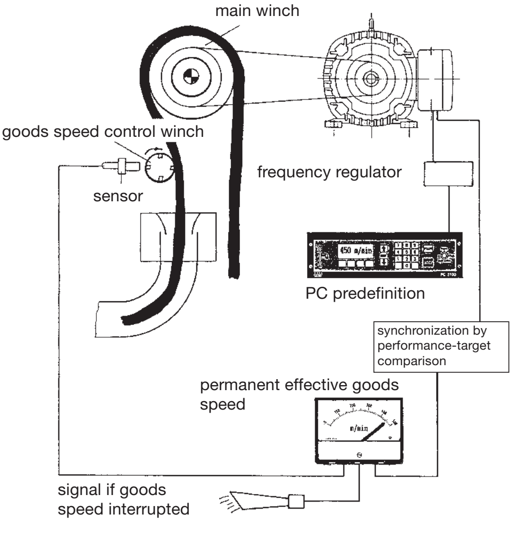


Fig.: The automatic synchronization of both winch speed and goods speed (Scholl).

unit which then provides an analogue or digital display of the effective fabric running speed. This not only allows the effective fabric running speed to be read directly at all times during the treatment, but also enables the fabric running to be optimally adjusted manually or automatically at all times so that the speed of the material and the main reel, as well as the jet pressure, are precisely matched and synchronized with one another. By this means, good running properties and minimum strain on the material is achieved.

A second, no less important, task of this system is the continuous monitoring of material transport. In contrast to other systems that monitor the fabric run with the aid of the magnet in the seam detector, which can only detect running malfunctions after each fabric circulation (which can take several minutes), the described system reacts immediately, i.e. without delay. If the circulation speed of the fabric falls below a freely adjustable limit value adapted to this speed, the machine stops immediately and a warning light or acoustic signal draws the operator's attention to the malfunction. The seam detector installed below the service port between the storage compartment and the main reel serves only its intended function, i.e. to stop the fabric run for sampling or unloading when the seam containing the magnet reaches the area of the service port.

Slit dye tube A flexible → Dye tube made of perforated stainless steel which is cut longitudinally in order to provide radial flexibility.

Slot clearer A special squeegee developed for rotary screen printing in the form of a narrow rectangular colour box (with print paste feed from outside) which is placed inside the rotary screen. The floor consists of two plastic lips which seal the slot on the inside of the screen by pressure on the squeegee.

Slow centrifuging A short centrifuging only, which is not carried out at full revolutions, i.e. the machine is switched on for a short period and immediately switched off again and the brake applied (centrifuge wet); 10–12 centrifuge revolutions are given whereupon, e.g. net curtains must be immediately suspended since each intermediate storage in the wet state leads to the formation of creases.

Slow motion, inching (extra slow speed, inching). Slow running of high production machines to allow time to make necessary adjustments, e.g. fabric tension, seam passage, etc.

Slub fabrics are produced (entirely or partly) from → Slub yarn.

Slub or knot density (knotted carpets) → Knot density.

Slub yarn A fancy yarn containing → Knops.

Sludge disposal With many aerobic and anaerobic biological waste processing methods, the question as to how best to dispose of the accumulated biosludge arises again and again. The growing microorganisms in biological processes die off at some time and must, just like an excess of microorganisms, be removed from the system. Usually, the microorganisms themselves build large voluminous flock-like structures which settle out relatively easily. However, the large voluminous structure results in an enormous water-binding capacity, i.e. in addition to the cell water, a typical biosludge contains between 98–99% water. Such a mixture is not easily disposed of. By adding 10–20 g/m^3 of a cationic flocculant, biosludges can be concentrated by pure sedimentation or sieving to levels of up to 6% dry substance content. Since such a biosludge with 94% water has a paste-like structure, any further separation of water is technically difficult. To achieve further water extraction in screen presses, centrifuges or chamber filter presses, therefore, a further addition of 50–100 g/m^3 of

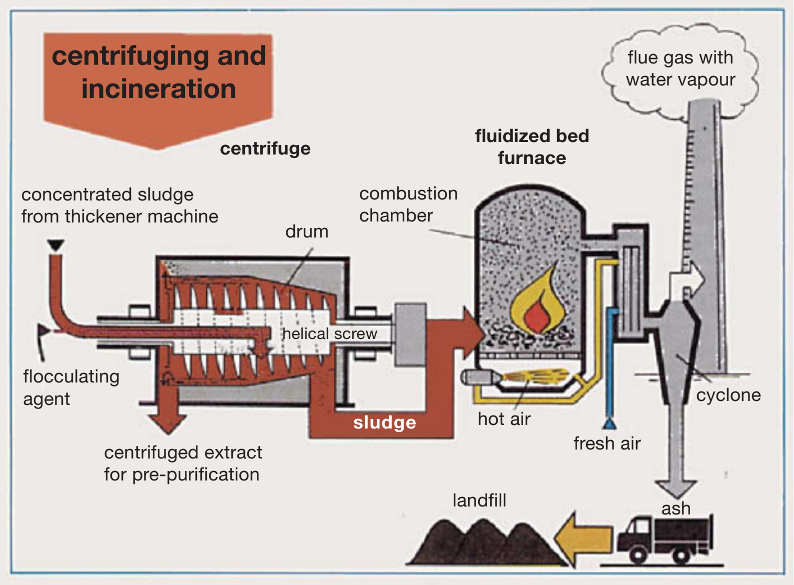


Fig.: Sludge treatment by incineration.

flocculant is necessary in order to obtain a sludge with a 15–20% dry substance content. A biosludge with a 20% dry substance content feels like wet cardboard and has a corresponding firmness. A further water extraction by machine is not possible. Consequently, this biosludge containing 80% water must be incinerated (see Fig.). Disposal by land-fill is forbidden because of the biological activity still present in the sludge, which can lead to unpleasant smells and other possible damage.

Sludge distillation An auxiliary or second still for dry-cleaning machines specially designed for the cleaning of workwear, hides and leather. Its purpose is to distil off the (chlorinated hydrocarbon) solvent as extensively as possible which, due to heavy contamination with oils and grease, therefore has a higher boiling point.

Sludge drier The principle of a sludge drier is based on the function of a thin-layer evaporator. A rotor distributes the material to be dried as a thin layer on a tube-shaped, indirectly heated, exchange surface at an appropriately high speed. Between the exchange surface and the material being dried, a layer of steam forms in ideal conditions which prevents caking and allows the material being dried to rotate without frictional losses. The thinner and more uniform the layer, the quicker the steam can diffuse through the material and the higher the drying capacity. If the material to be dried has a tendency to cake (this is dependent on the type of sludge and therefore cannot be excluded), appropriate constructive devices can be built-in to prevent such incrustations (see Fig.).

Sm Symbol for the element samarium (62).

Smeared prints Are formed by inadequately ground doctor blades in roller printing so that the print paste is insufficiently removed locally next to the engraved areas of the roller. The problem can be remedied by regrinding the doctor blade and/or by adjusting the position of the doctor blade against the printing roller.

Smog Consists of a mixture of smoke and fog and represents a visible pollution of the atmosphere (usually in the presence of considerable haze) over large cities and highly industrialized areas. It is largely the result of reactions between organic compounds and lies predominantly close to the ground during unchangeable weather conditions. Above a critical concentration, smog causes respiratory problems, eye irritations and the gradual destruction of dyes and colouring matters on textiles, which may also be accompanied by damage to the fibres. Olefin-based hydrocarbon pollutants from motor vehicle exhausts and their photochemical reaction products, together with the participation of nitro-

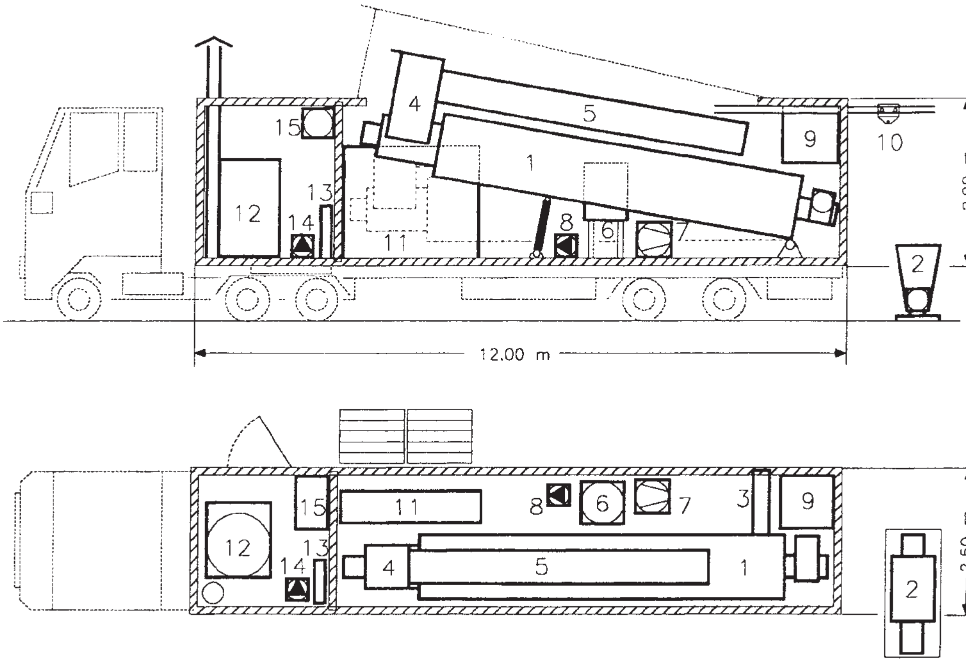


Fig.: A mobile sludge drier.
1 = thin layer drier; 2 = sludge metering pump; 3 = dried sludge output compacting screw; 4 = water lock; 5 = evaporator condenser; 6 = phase separator; 7 = vacuum pump; 8 = evaporator condensate pump; 9 = adsorption filter; 10 = extensible assembly device; 11 = central switch cabinet; 12 = steam generator; 13 = feed water preparation / process water injection; 14 = boiler feed pump; 15 = feed water barrel.

gen oxides in the air, make a particular contribution to smog formation as well as local concentrations of sulphur dioxide, nitrogen oxides and soot-laden fog. The principle of smog formation is based on the following reactions:

$$NO_2 \xrightleftharpoons{\text{sunlight}} NO + O \xrightarrow{O_2} \text{oxidant}$$

$$\text{oxidant} + \text{hydrocarbon} \longrightarrow \text{peroxides, aldehydes, acids}$$

$$+ \; SO_2 \longrightarrow \text{sulphur trioxide}$$

These reactions proceed quite quickly in most cases, and involve new free radicals with possibilities for polymerization and chain reactions.

The primary ingredients of photochemical smog are often non-toxic and include certain hydrocarbons and oxides of nitrogen. The phytotoxic products of photochemical reactions are peroxyacetyl nitrates, ozone and nitrogen. They are initiated by the energy of sunlight and are injurious to vegetation and some animals, even when present only in minute quantities (0.1 parts per million) and for a short duration (e.g. 8 hours exposure).

The clear links between many health problems and smog has led to several governments in the developed world introducing legislation to promote the use of smokeless fuels and reduce the emission of noxious and toxic gases into the atmosphere, e.g. → TI-air (TA Luft, Germany), British Clean Air Act (U.K.) and the Federal Clean Air Act (USA).

Smoke is a visible cloud of airborne solid/liquid particles resulting from incomplete → Combustion, or chemical reaction; the smoke particles are generally smaller than 1 µm. Smoke is an important constituent of → Smog.

Smoke development Different quantities of smoke are generated by textile fibres during combustion and is measured by the density of the smoke (see Tab.). Fibres such as wool or acrylic generate less smoke than, e.g. polyester or cotton so that the risk of being overcome by toxic smoke is less. The application of flame-retardant finishes should reduce the generation of smoke from textile fibres.

fibre material	smoke production (cm^3/g)
polyester	410
cotton	121
polyacrylnitrile	84
wool	57
aramide	2

Tab.: The smoke production of various fibres.

Smooth backing (smooth coat). A smooth, less structured, backcoating with a lower degree of foaming applied to textile floorcoverings for the purpose of achieving good resistance to slippage and cutting.

Smoothen, to A term used in laundering for → Mangling and → Pressing. In wool finishing, the term is used for steeping (wet setting, crabbing).

Smooth foam backing (flat foam). A smooth, non-structured, foam carpet backcoating.

Smoothing agent is a special type of textile softener in which the smoothing effect is based on reducing friction between individual fibres or particles of finishing agents. Cationic products are more effective as smoothing agents than anionic or non-ionic products.

Smoothing and calibrating calender A special calender for the thickness calibration and surface smoothing of needlefelt nonwoven filters for liquid media (see Fig.).

Smoothing index → Smoothness number.

Smoothing machine Consists of an oil-heated steel cylinder with 4 transverse grooves (temperature

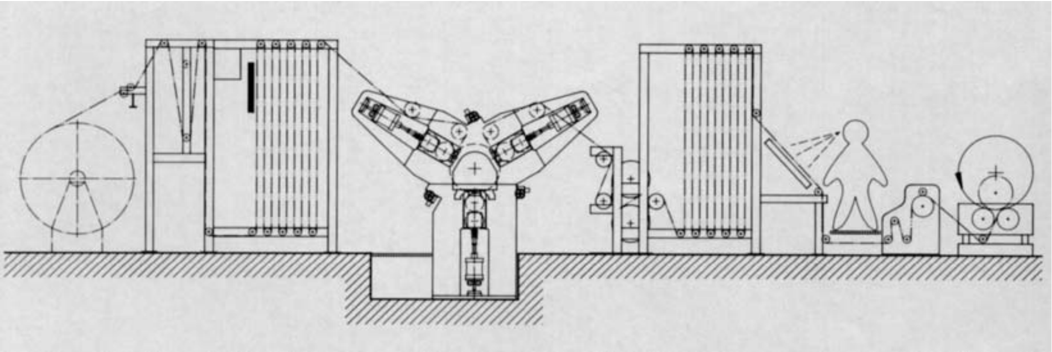


Fig.: Calibrating calender (WUMAG) for nonwoven textiles.

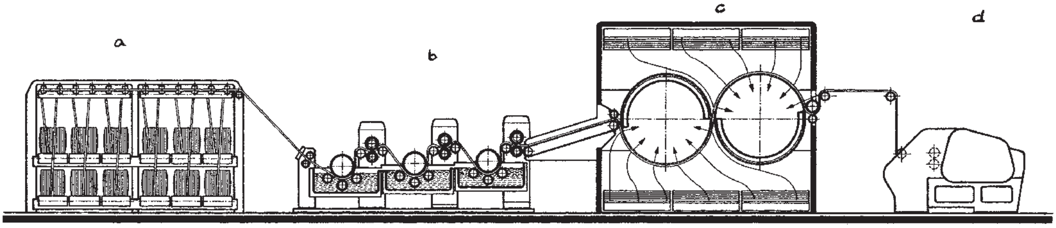


Fig. 1: Wool top treatment on a smoothing machine (Fleissner).
a = entry; b = washing/smoothing machine; c = air-smoothing; d = pin drafter.

up to 250°C) which runs against the fabric at 150–1500 rpm, with various fabric positions (effected by means of a felt blanket to control the wrap angle of the fabric) and flattens protruding fibres (by splicing). This flattening can, in certain circumstances, be permanently set with the aid of a previously applied fixing agent (applied by brush) in a subsequent thermal treatment.

Smoothing machine, backwashing machine (ironing machine, pressing machine). Washing machine for combed tops. Consists of unwinding frame for combed sliver packages, 2–3 washing and 1–2 rinsing vats (each with squeeze rollers), drying rollers, pressing rollers and a combing device at the outlet. Scouring baths are generally neutral or alkaline with ammonia with synthetic detergents (Fig. 1).

A backwasher with agitating scouring drum and associated support and working rollers (Fig. 2). In the form of individual or twin steeping baths with a side propeller pump situated by each of the slowly rotating drums (scouring liquor taken from inside the drum replaced by fresh liquor flowing from out to in). Drying is normally carried out in a perforated drum drier (air polishing).

Fig. 2: Fabric entry and exit top sheets in a suction drum back washing machine (Fleissner).

Smooth leather → Leather, with a smooth surface, e.g. morocco and nappa leather.

Smooth loops In tufted (pile) carpets where the loops have been produced from bulked filament yarns with little or no twist in contrast to twisted loops.

Smoothness appearance A subjective assessment criterion for the appearance of textile surfaces, especially for durable-press (DP) articles after household washing. The smoothness appearance is assessed by comparison with 3-dimensional standards (Wash-and-Wear Standard, DP-Rating and the Monsanto Crease Formation Standards as photographs). The smoothness appearance depends on a range of influence factors and the quantity of resin finishing agent as well as the degree of crosslinking exercise a decisive influence here.

Smoothness effect → Smoothness appearance.

Smoothness number This may be defined as the relative fibre-to-fibre resistance to friction where a low smoothness number corresponds to a smoother effect achieved by the application of → Smoothing agent. Examples: smoothness numbers of various products (2 g/l) related to the untreated fabric (smoothness number = 100):

glycerol	128
castor oil fatty acid sulphate, highly sulphonated	134
sulphated castor oil, medium degree of sulphonation	113
paraffin, emulsified	88
oleyl alcohol sulphate	54
sulphated olive oil, low degree of sulphonation	48
wax alcohol sulphate	42
triethanolamine-stearic acid ester, neutral	39
acidic	35–27

Smoulder To burn slowly without flame but with visible light.

Smoulder, to → Smoulder.

Smyrna carpets (→ Oriental carpets),

I. A general trade name for → Turkish carpets exported to Europe via the Turkish port of Smyrna (today's Izmir). For more than a century, Smyrna (Izmir) was the centre of the oriental carpet trade. European buyers, each with their own particular requirements, went to Smyrna where those requirements were met by local merchants who would accept orders for any type of design at very reasonable prices. These were usually copies of other well-known types of Turkish carpets produced in designs to satisfy European and American preferences and were often woven with inferior materials with a relatively low knot density. They were made principally in Ushak, Isparta, Sivas and Smyrna itself.

II. Coarse, soft, not very durable, deep-pile → Medallion carpets of Greek origin.

SN Sunn → Standard abbrev. for textile fibres according to DIN 60 001 T4/08.91.

Sn,

I. Sunn → Standard abbrev. for textile fibres according to DIN 60 001, in use until 1988. After 1991, changed to → SN.

II. Symbol for the element tin (50).

Snag,

I. A loop which has been pulled out of fine-knit hosiery due to the smoothness of the fibres (ladder). Drop stitches in smooth weft-knit fabrics are wales which, as a result of a broken thread or needle damage, are present as unformed threads. Drop stitches can be eliminated by "taking up" the loops in their old form with opposing interlacing. The prevention of drop stitches by a change of the loop formation in smooth weft-knit fabrics, generally by loop transfer or by pressing-off loops (i.e. transfer of half the loops from one needle bed to the other with crosslinking of adjacent loops) provides an assurance against laddering. Anti-snag finishes also provide some degree of protection against snagging. An anti-snag finish is a collective term for any finishing treatment which is intended to reduce the risk of laddering in fine hosiery by bonding the threads. This type of finish has nothing to do with so-called "ladder-free stockings" since the special characteristics of the latter are created by the type of thread interlacing in the knitted fabric as shown in the Fig. (according to Hofer).

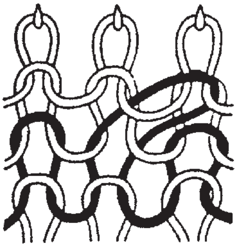


Fig.: Diagram showing ladder prevention by snagging.

II. (pulled thread), a slub-like structure consisting of individual capillary fibres, 2–8 mm in length, which has been pulled out of the whole thread. It occurs mainly with polyamide yarns and knitted fabrics (hosiery).

Snagging Box (ICI). A laboratory instrument for testing the sensitivity of knitted fabrics, e.g. women's outerwear, to snagging (formation of → Snags). Each of two rectangular fabric samples, cut out of the material in the lengthwise and widthwise direction, are shaped into tubes and pulled on to a rubber roller. The edges of the samples are stuck to the rubber roller with adhesive tape and the test specimens are treated for 5 h in a rotating (60 rpm) cube-shaped box with a steel spike in each wall. Assessment is by comparison against a photographic standard with 4 progressive stages of snagging.

Snapper in roller printing This is a printing defect consisting of a double stripe of colour with a white centre running vertically up the piece. It is caused by a small, relatively soft, foreign body becoming trapped between the edge of the doctor blade and the printing roller during printing thereby lifting the doctor edge at this point. As a consequence, the foreign body itself prevents any print paste from penetrating at the centre of the "lift" but allows excess print paste to pass on either side of it (i.e. on the non-engraved surface of the printing roller) from where it is transferred to the fabric. The foreign body is generally a loose thread from the fabric being printed, or particles of dried thickener from the print paste. The problem is remedied by washing off the doctor blade, printing roller and colour box and straining the print paste.

Snarl (twist). The twisting of e.g. a rope of fabric as an undesired effect in, e.g. winch dyeing. The term also applies to single and ply yarns (see Fig.).

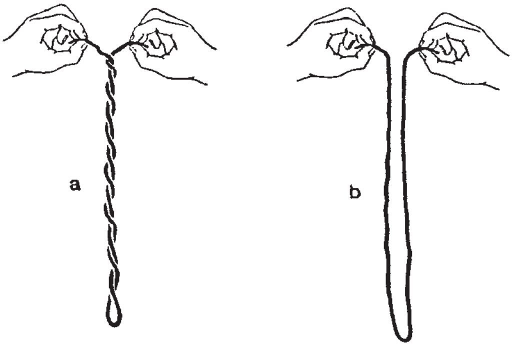


Fig.: Snarling in a snarling FZ yarn (a), twist-free yarn (b).

Sniffing method An olfactory test for determining the odour threshold in the microbiological decomposition of organic substances on textiles (→ Antimicrobial finishes). It is of limited application, however, since individual sensitivity to the smell of ammonia varies greatly. The blow-through test, in which the presence of ammonia is determined with the aid of → Nessler's reagent, is more precise.

Soap Alkali salts of fatty acids with a minimum of 12, and a maximum of 18, carbon atoms. The first signs of surfactant properties are already apparent from 8 carbon atoms upwards. The hydrophilic part of an anionic surfactant is due to the presence of COO– groups, and the hydrophobic part is due to the presence of an alkyl residue, e.g. sodium stearate $C_{17}H_{35}COONa$. All sodium, potassium and ammonium salts of fatty acids exhibit good solubility in water; all magnesium, calcium and aluminium salts are insoluble in water. The latter accounts for the fact that, in the presence of water hardness salts (e.g. magnesium, calcium), soaps form insoluble precipitates. Saponification of fatty acids with caustic soda or sodium carbonate yields soda soaps (curd soaps, hard soaps), whilst saponification with caustic potash or potassium carbonate yields potash soaps (semi-solid or soft soaps).

Properties: the anionic and surface-active substance is subject to a reversible hydrolytic breakdown in water which results in an alkaline reaction. Advantage: excellent washing effect which can be attributed to the action of soap as a protective colloid. Disadvantage: soap is not resistant to water hardness which means a loss of washing agent in hard water due to precipitation of the insoluble soap. This precipitated soap is deposited on textile materials which results in unlevel dyeings and an unpleasant handle on the goods. Soap is not resistant to acids and is therefore not very suitable for processes carried out in an acidic medium (e.g. wool finishing). Soap is not stable to electrolytes and salting out can occur in the presence of salts. For this reason, it is not stable to sea water. Some of the drawbacks of soap can be eliminated by condensation with condensed phosphates. The unsatisfactory properties of soap have led to the development of synthetic → Surfactants.

Importance in textile processing: originally, soap was only used for washing. Later on it was also used for cleaning oily textiles, milling, scouring, bleaching, as a wetting and levelling agent, emulsifier, degumming, desizing, water repellency, and as a spotting agent, etc. Because of their negative properties, soaps have been displaced by synthetic surfactants in commercial and household detergents. In general, it can be assumed that soap is precipitated out by calcium and magnesium ions in waste water treatment. In the case of biological waste water treatment, however, soap breakdown is more difficult.

Soap flakes are produced from dried, cut, hard soap.

Soap handle The preferred handle for worsted yarn wool fabrics which, in former times, was achieved by using soap in scouring and milling.

Soaping aftertreatment of dyeings and prints Improves the quality of the fabric when given as a final process before the goods are sent for finishing.

I. (Fast) dyeings: not only genuine fast dyeings but also, e.g. acid wool dyeings and blended wool yarn dyeings are soaped to achieve better rub fastness. Contrast dyeings, or white and coloured effects on different fibres, are also frequently soaped; in the latter case, it is preferable to use slightly acidic surfactants. Diazo dyeings are also soaped (at approx. 50°C) to improve the colour fastness to washing. In this case, and especially with vat, reactive, vat leuco ester, sulphur and naphthol dyeings, the loosely-adhering dye particles are removed from the fibre by an aftersoaping treatment thereby giving cleaner fabrics with improved colour fastness to rubbing and fully-developed brilliant shades.

II. Prints: an aftersoaping treatment serves to produce prints with higher colour fastness by removing dye particles adhering to the surface of the fibres (e.g. naphthol and vat dyes) or unfixed dye (e.g reactive dyes). The shades are more brilliant as a result. The optimum temperature depends on the class of dye. Synthetic detergents are mainly used for aftersoaping.

Soaping machine This type of machine consists of a vat with squeeze rolls for wetting out wool piece goods that only require a short milling treatment. When the addition of milling agent is made by pouring it into the machine, this does not result in satisfactory distribution of the product.

Soaping of vat dyeings and prints This treatment is essential for the achievement of correct shades and optimum colour fastness to light and rubbing. After oxidation, the vat pigments are present in a finely divided form on the substrate. During the soaping treatment, however, aggregation occurs to form large crystallites which are more resistant to physical and chemical influences. The soaping treatment is carried out at the boil in each case with soap, soap and sodium carbonate, synthetic detergents or synthetic detergents and sodium carbonate. Where only hard water is available, the addition of water softeners is necessary.

Soap paste (soap glue) → Pasting.

Soap powder Dried, pulverized → Soap (produced from soap paste and sodium carbonate) with a total fatty acid and resin acid content of 5–40%.

Soap regeneration in processing baths The effectiveness of soaping baths is easily reduced during use. The main causes (apart from the obvious consumption of soap in binding soils of various kinds) include, e.g. water hardness, turbidity, and a drop in pH. Although often overlooked, the carry over of undesired chemicals from previous treatment baths also plays a part here. In many cases, a renewed, increased, efficacy of the soap bath is assured by refreshing the liquor or raising the pH again. Variations in pH may be compensated by the careful addition of caustic soda liquor.

However, the use of sodium carbonate for this purpose is undesirable in order not to load the state of equilibrium unnecessarily.

Soap residues (fatty residues). Coarse agglomerated residues of soap, fat, lime salts, and dark pigment soils, often appearing as numerous spots which are deposited on garments during washing. They are caused by using a soap with an excessively high fat content or (usually) by carrying out the first rinse with cold water. They can be eliminated by using → Syndets or a slightly acidic rinse water.

Soap steamer A processing unit for the treatment of piece goods at the boil after dyeing or printing. The running fabric is immersed in the soaping bath and then steamed. With this system, several wash compartments in an open-width washing range can be saved.

Soaps with modified fatty acid residues Besides the carboxyl group –COOH, the hydrophobic hydrocarbon residue is modified (modified alkyl chain) in these soaps, which inhibits hydrolysis and increases the resistance to acids and water hardness salts. Such soaps are of interest in milling.

Soda → Sodium carbonate.

Soda ash → Sodium carbonate.

Soda bleach lye → Sodium hypochlorite.

Soda cellulose (alkali cellulose). Represents the first stage in viscose rayon manufacture. Cellulose pulp is steeped in warm caustic soda liquor (17–18%) for 1–2 h, and then pressed to remove excess solution. The treated cellulose is broken up in a shredder to form powdery crumbs. The crumbs are then aged for several hours during which time the caustic soda reacts with the cellulose to form soda cellulose.

Sodalite, cage zeolite A blue, grey, yellow or colourless mineral consisting essentially of sodium and aluminium silicates with sodium chloride in a cubic crystalline form of the type Na[Cl(AlSiO)], which occurs in certain basic igneous rocks. The hollow structure of sodalite is important as a lattice unit in → Zeolites.

Soda vat → Fermentation vats.

Sodium → Alkali metals. Sodium, symbol Na, is a soft, silver-white metal which oxidizes rapidly in air. It is wax-like at room temperatures and brittle at low temperatures. Atomic weight 23.05, m.p. 97.6°C. Sodium is lighter than water (density 0.97) and has the typical properties of an alkali metal; the positive sodium ion forms water-soluble colourless salts with colourless acid ions.

Severe fire risk in contact with water in any form (stored in air-tight containers or under naphtha or similar liquid that does not contain water or free oxygen), ignites spontaneously in dry air when heated.

Sodium acetate (acetate of soda, sodium ethanoate). CH_3COONa; molecular weight 136. Colourless odourless crystals or anhydrous salt. Solutions in water are weakly alkaline. Uses: neutralization of mineral salt esters on cellulosic textiles; reduction of acetic acid acidity (buffering); neutralization of naphthol diazo solutions; aftertreatment of sulphur black (prevents tendering); additive for diazo solutions in dyeing and printing with naphthols, etc.

Sodium alginate Sodium salt of → Alginic acid, $C_{10}H_{18}O_{10}(COONa)_2$; soluble in cold resp. warm water under rapid stirring (it is advisable to allow freshly prepared solutions to stand overnight). Boiling in water reduces the viscosity. Solutions are non-foaming. Stable to alkalis but sensitive to acids (especially below pH 3). The addition of a complexing agent (5–25% of the weight of alginate) is recommended in hard water. Solutions are sensitive to bacterial decomposition (the addition of 0.2% salicylic acid, formaldehyde, etc. can be used as a preservative). Uses: sizing agents, finishing agents, water-repellent impregnations. The main use of sodium alginate is as a thickener for textile printing (discharge pastes, roller and screen printing, easy to wash off, uniform viscosity, excellent penetration in printing, non-foaming, flows readily, good colour yields, sharp outlines). Suitability as a thickener for textile printing: especially important for reactive dyes, azoic diazo dyes, vat leuco ester and vat dyes; not suitable for cationic dyes, chrome dyes and naphthols. The viscosity of sodium alginate thickeners is determined by the degree of water hardness and the alginic acid content.

Sodium aluminate (aluminate of soda). Na_3AlO_3 or $Al(ONa)_3$, molecular weight 144.25. Colourless small lumps or fine powder with 35% Al_2O_3 (stable to air) or 50% Al_2O_3 (somewhat hygroscopic, store in air-tight containers); both forms are readily soluble in water. Uses: waste water treatment, water softening, oil removal from feed water and desilification; mordant for dyeing alizarin red (on cotton), etc.

Sodium aluminosilicate (sodium silicoaluminate). A series of hydrated sodium aluminium silicates with the approx. formula $Na_2O–Al_2O_3–3\,SiO_2 \cdot 5\,H_2O$. Available either as a natural or synthetic product; crystalline, insoluble in water. The use of sodium aluminosilicate as an inorganic ion-exchange compound (→ Zeolites) is well-known. By exploiting this property, it is also used as a builder in classic detergent compositions in addition to pentasodium triphosphate. During the transport phase from the user through the sewer system to the waste water treatment plant, the concentration of harmful heavy metal ions is reduced.

Sodium bicarbonate (bicarbonate of soda) → Sodium hydrogen carbonate.

Sodium bisulphate $NaHSO_4$; molecular weight 120. White fused lumps, colourless crystalline mass or coarse-grain powder, readily soluble in water with an acidic reaction. Uses: finds considerable use in wool dyeing instead of sodium sulphate/sulphuric acid.

Sodium bisulphite $NaHSO_3$; molecular weight 104. Colourless crystals, powder (both readily soluble) or as a commercial solution with a density of 1.33–1.38. Odour of sulphur dioxide. Alkaline reaction. Uses: as a reductive bleach (for protein fibres); as a spotting agent (especially for permanganate resp. manganese dioxide stains); as a substitute for sulphurous acid; as an afterbleach with potassium permanganate; as an antichlor; often substituted with → Sodium dithionite; as a discharging agent in discharge printing (with zinc dust), etc.

Sodium borate (borax, sodium tetraborate, sodium pyroborate). $Na_2B_4O_7 \cdot 10\,H_2O$; molecular weight 382; density 1.7. White crystals or anhydrous powder. Soluble in water; the solution is fairly strongly alkaline. Uses: mild alkali, textile printing, application of alkali blue (wool dyeing); manufacture of hat proofs; addition to finishing liquors (as a preservative); solvent for alizarin dyes and casein; flame-retardant impregnations; component in soaps and gloss starches; flux.

Sodium carbonate (soda ash, soda, soda crystals, Leblanc soda, Solvay soda, carbonate of soda),

I. Anhydrous sodium carbonate (soda ash), Na_2CO_3; molecular weight 106.01; density 2.5. White powder soluble in water.

II. Crystalline sodium carbonate, $Na_2CO_3 \cdot 10\,H_2O$; molecular weight 286, density 1.45. Colourless crystals, effloresces readily, forms hard lumps when stored under damp conditions; water-soluble. Solutions are strongly alkaline.

Uses: water softening; alkali scouring, bleaching, degreasing, washing, etc.; additive to dyebaths; component in detergents and washing powders; soap filler; cleaning agent for metals, etc.

Sodium chlorate (chlorate of soda). $NaClO_3$, molecular weight 106.5; density 2.5. Colourless crystals, hygroscopic, toxic; water-soluble. Powerful oxidizing agent; textiles moistened with sodium chlorate are readily ignitable. Uses: powerful oxidizing agent especially in textile printing and aniline black dyeing.

Sodium chloride (common salt, cooking salt, table salt, sea salt, rock salt). NaCl; molecular weight 58.5; density 2.164. White crystals readily soluble in water; saturated solutions boil at 107.7°C. Uses: chiefly as an addition in dyeing, especially with substantive dyes to increase the rate of dye exhaustion on the fibre; spotting agent on coloured silk (prevents bleeding); regeneration of base-exchange filters (water treatment); salting out soaps; tanning; electrolyte addition in developing baths for 2-phase printing (prevents bleeding); addition to water baths in the dyehouse laboratory to achieve a higher boiling point, etc.

Sodium chlorite $NaClO_2$; molecular weight 90.5; white crystals or crystalline powder, odourless, very stable product. Dilute neutral and basic solutions can be heated to 100°C without decomposing. Acidic solutions decompose very rapidly:

$$\begin{array}{llcl}
(1) & NaClO_2 + H_2O & \rightleftharpoons & HClO_2 + NaOH \\
(2) & HClO_2 & \longrightarrow & HCl + O_2 \\
(3) & NaClO_2 + HCl & \longrightarrow & HClO_2 + NaCl \\
\text{or} & 5\,NaClO_2 + 4\,HCl & \longrightarrow & 4\,ClO_2 + 5\,NaCl + 2\,H_2O
\end{array}$$

The associated bleaching action is therefore pH-dependent. Uses: bleaching agent for cellulose (chiefly linen and cotton), cellulose pulp, paper, cupro, acetate and viscose fibres, as well as polyamide, acrylic, polyester and polyvinyl chloride fibres, waxes and straw products, edible and inedible oils, etc.; oxidation of vat and sulphur dyeings.

Sodium chlorite bleach,

I. Cellulosic fibres: sodium chlorite produces excellent bleaching effects with a high degree of fibre protection. It can be applied by full bath treatments or by discontinuous and continuous padding methods. Also suitable for acetate and triacetate (→ Bleaching agent, sodium chlorite). Sodium chlorite itself has no bleaching action but only that of the chlorine dioxide formed during its decomposition which further decomposes into chlorine and oxygen. This reaction only proceeds quickly enough in acidic media below pH 5. Damage to the fibre can occur at pH < 3. For full bath bleaching, organic acids (acetic or formic acid) are preferred to adjust the pH. In addition, diammonium or sodium phosphate are added as stabilizers. In pad-steam processes, organic acids are substituted by products which split off acids by the action of heat, i.e. so-called activators (e.g. ethyl acetate, chloral hydrate). Commercial liquid forms of sodium chlorite can also contain an activator addition already.

II. Synthetic fibres: with the exception of polyurethane and some individual acrylic fibre types, the sodium chlorite bleach is the most suitable bleach for synthetic fibres in which the material is treated exclusively in a long liquor. Applications on the padder are not suitable in this case. The bleaching effect is not equally good on all fibre types and staple fibres are more easily bleached than continuous filament yarns. Traces of metal salts (iron, manganese) in the fibre can lead to discoloration of the bleached material. After bleaching, complete removal of the often obstinately persistent chlorine is essential; if rinsing proves insufficient, an antichlor bath with sodium dithionite or sodium bisulphite must be used. A chlorite-resistant optical brightener may be added to the bleaching bath if a maximum white effect is desired.

Disadvantage of the sodium chlorite bleach: environmentally problematic process because of the toxicity of the gases liberated during bleaching as well as chlorine pollution of the waste water (AOX).

Sodium citrate (trisodium citrate). $Na_3C_6H_5O_7$; molecular weight 258.15; white crystals or granular powder, odourless, stable in air, pleasant acid taste, soluble in water. Combustible. Uses: inactivating addition for complexing water hardness salts (the action of sodium meta and polyphosphates is inferior in this regard).

Sodium dichloroisocyanurate → Chloroisocyanuric acids.

Sodium dithionite (sodium hydrosulphite, "hydros"). $Na_2S_2O_4$; molecular weight 174. Sodium dithionite is a white, water-free, powder which is readily soluble in water and should only be stored in a completely dry state in a cool place. Solutions decompose readily into sodium thiosulphate; it is a powerful reducing agent; alkaline solutions eagerly absorb oxygen. Uses: the most important reducing agent for stripping dyeings; reducing agent for the dyeing of vat, indigo and sulphur dyes; reducing agent for the printing of vat dyes by the 2-phase process; bleaching agent (especially for wool); antichlor; spotting agent (for dye, fruit, perfume, rust and ink stains, perspiration, etc.). Sodium dithionite-formaldehyde compounds (so-called sulphoxylates) are used for stripping dyes, and as more stable reducing agents for the dyeing and printing of vat dyes, and discharge printing.

Sodium dithionite dissolving station In many dyehouses, large quantities of sodium dithionite ($Na_2S_2O_4$) are used. This chemical compound is difficult to handle manually because it is harmful to health and also gives rise to unpleasant fumes and irritating dusts. Above all, it is dangerous because of its property of spontaneous ignition if it comes into contact with moisture. For these reasons, the van Wyk company (Holland) has developed a sodium dithionite dissolving station (see Fig.) in which this chemical can be dissolved automatically at the required concentration. Moreover, caustic soda liquor and 2 auxiliary products can also be added automatically at the desired dosage. The process is continuous keeping the small mixing tank at a pre-determined level. From this tank, the dyeing machine(s) are fed automatically. Since the mixing tank has a small capacity and is completely enclosed, the sodium dithionite is handled very efficiently with minimum loss by oxidation. A completely self-controlled system can be realized with the aid of new sensors for measuring the redox potential. The dissolving station can be installed with automatic loading systems to suit customer requirements, e.g. a sack emptying and conveyor system as well as an automatic emptying system for large containers.

Fig.: Sodium dithionite dissolving station (van Wyk).

The dissolving station consists of: (a) measuring hopper, (b) dosing screw transporter, (c) weighing system with 2 load cells and weight transmitter, (d) 4 dosing pumps with adjustable stroke volume and frequency, (e) 1 water dosing system with volume meter and pulse transmitter, electromagnetic water valve and flow control valve, (f) 1 mixing tank, and (g) stainless steel mixer. The control system is based on an "Intel Bitbus Microcontroller System" and is operated by means of a Burr Brown TM 2700 microterminal installed near the dyeing machines. The operator selects a recipe and the unit automatically produces this recipe for the period required. A warning lamp indicates when the measuring hopper needs refilling; at the minimum level an alarm sounds at the operating terminal. Preparation is continuous during the refilling stage. The standard system has a storage capacity for 30 recipes.

Sodium exchanger → Ion exchanger.

Sodium formaldehyde sulphoxylate → Sulphoxylates.

Sodium hexametaphosphate (→ Graham's salt, metaphosphate). $NaPO_3$ also as $(NaPO_3)_6$ or $Na_2[Na_4(PO_3)_6]$. Density 2.4; mol. wt. 612. White powder, hygroscopic, soluble in all proportions (visco-colloid). Reacts as a weak acid, 1% solution ca. pH 6.5. In solution with an excess of Sodium hexametaphosphate and in the presence of hard water salts and heavy metals forms soluble complexes (also at higher temperatures; optimum effect at approx. 70°C). Dissolves Calcium soaps and similar compounds. On standing in hard water: turns turbid and forms flocks without salt precipitation. Reaction: → Complex phosphates. Application: water softening to 0° German hardness; scouring, degreasing, milling, after-soaping, desizing, bleaching, dyestuff dissolving and rub fastness improvement of dyebath additions; builder for laundering detergents, etc.

Sodium hydrogen carbonate $NaHCO_3$; mol. wt. 84; density 2.2. White powder, soluble in water; solution is weakly alkaline (phenolphthalein is an indicator); over 65°C breaks down to form CO_2, Na_2CO_3 and H_2O. Usage: Neutralization of naphthol-diazo solutions; buffer; in printing, etc.

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Sodium hydrogen sulphite → Sodium bisulphite.

Sodium hydroxide (caustic soda, caustic lye). $NaOH$; molecular weight 40.01; density 2.13. White crystalline mass (flakes, lumps, pearls, sticks) hygroscopic, absorbs CO_2 from the air (to form sodium carbonate). Water soluble, also soluble in alcohol: heat strongly evolved on solution; solution strongly alkaline. Viscous lye: density 1.357 = 32.5 wt.% = 44.1 vol.% (1 litre = 441 g). Concentration in aqueous solution determined by aerometer or titration. Below 100 g/l NaOH sodium hydroxide solution is in the form of hydrated ion hydrates. These ions have a hydrodynamic diameter of 1.5–2.0 nm. With increasing concentration of sodium hydroxide and a reduction in the amount of available water molecules, and from 150 g/l, an increasing presence of hydrated ion pairs is found, with a diameter of 1.0–1.5 nm. Finally from 200 g/l there begins an increase in the solution of hydrated dipole hydrates and eventually dipole hydrates. These ions have a diameter of 0.5–1.0 nm. Applications: Caustic boiling, mercerizing (Fig.), degumming, crabbing, causticizing, vat dyeing, naphthol dyeing (base application), boiler water softening, etc.

Sodium hydroxide process Used to determine microscopic evidence of light damage to wool fibres. Chopped fibres are placed on a slide between the object carrier and the cover slip and flushed with 0.1N sodium hydroxide. Under the microscope, damaged fibres show as swelling strongly with twisted fibres and deep surface fissures.

Sodium hypochlorite (bleach lye, chlor soda, bleaching soda, Eau de Labarraque, sodium bleach liquor, sodium salt of hypochlorous acid). $NaOCl$; mol. wt. 74.5. white powder (anhydrous condition), Crystalline (hydrated, $NaOCl \cdot 6\,H_2O$). Normally used as the hypochlorite lye: clear, yellow-green, free from calcium salts, stabilised (stable for cool storage during months); density 1.21–1.23 with 140–160 g/l active chlorine, equivalent to 147–168 g/l NaOCl. Storage conditions: a) if possible at lower temperatures : 10–20°C; b) store (according to storage temperature) for maximum of 1–2 weeks. Applications: bleaching of cellulose; scouring agents → Bleaching agent, sodium hypochlorite.

Sodium hypochlorite bleach In comparison to → Calcium hypochlorite has an advantage in the absence of calcium, hard water salts. Therefore easier rinsing, weaker acidification (cost), softer fabric handle, also retains white effects better and helps to avoid local fibre damage by calcium chlorite particles. Clear disadvantage: AOX loading in effluent.

Sodium hypochlorite liquor (hypochlorite lye) → Sodium hypochlorite.

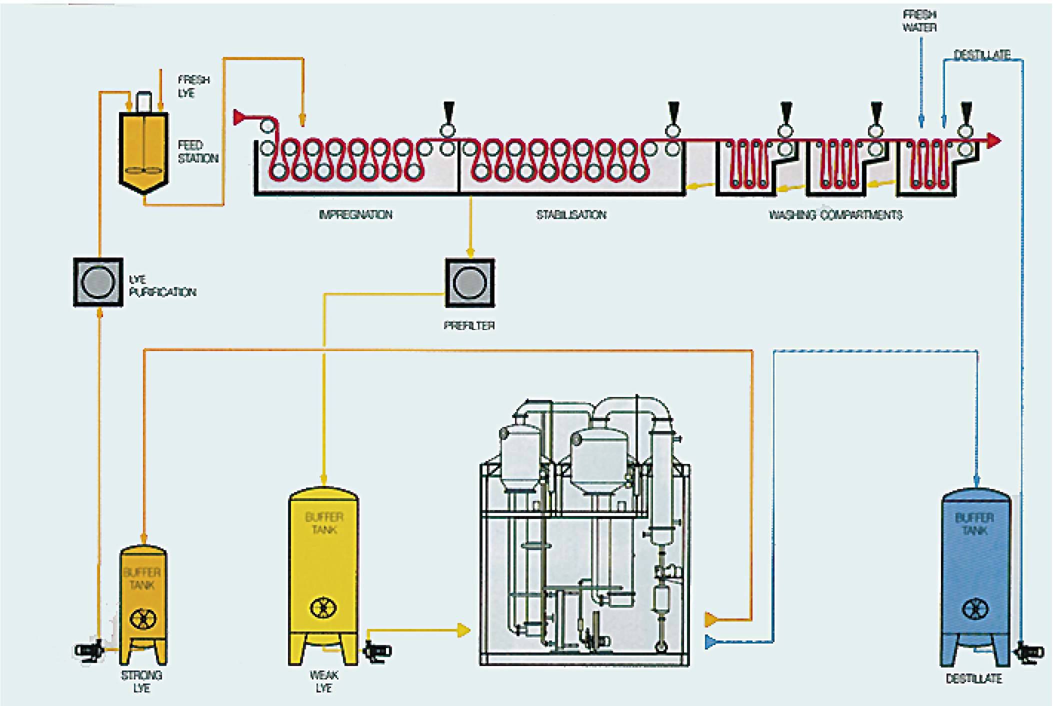

Fig.: Caustic soda recovery system from GTV based on an evaporation process.

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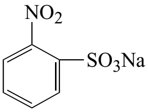
Sodium hyposulphite → Sodium dithionite.

Sodium metabisulphite Common name for sodium pyrosulphite $Na_2S_2O_5$. Results from splitting off water from sodium hydrogen sulphite $NaHSO_3$ or saturating a solution of sodium hydrogen sulphite with sulphur dioxide SO_2.

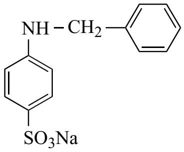
Sodium metaphosphate → Sodium hexametaphosphate.

Sodium metasilicate Na_2SiO_3, $Na_3[HOSiO_3] \cdot 5\,H_2O$; Alkaline silicate; anionic. Protective colloid, dispersing and scouring auxiliary; alkaline; temperature stable; somewhat hard water stable; alkali stable.

Sodium m-nitrobenzene sulphonate Used to inhibit the reductive effects of caustic and soda boiling, (bleaching dyed goods), as reserving agent for vat dyestuffs in discharge printing and similar methods.



Sodium N-benzylsulphanilate Fine white to yellowish powder, easily soluble in water with neutral reaction. Extensively used in dissolving hydrotropic dyestuffs and as a dispersing agent, especially for vat and leuco-vat dyestuffs in printing: effective as a levelling agent, increases the yield and improves fixation.



Sodium nitrite (nitrite, saltpetre). $NaNO_2$; molecular weight 69; density 2.17, white to pale yellow crystals, weakly hygroscopic, easily soluble in water, slightly soluble in alcohol. Applications: Diazotising azo dyestuffs (1 part sodium nitrite and 3 parts nitric or sulphuric acid; ratio is important to produce the required nitrous acid); dyeing with leuco-vat dyestuffs; in printing, etc.

Sodium nitroprusside (nitroferricyanide). For the identification of wool. 2 crystals of sodium nitroprusside ($Na_2[Fe\{CN\}_5\{NO\}] \cdot 2\,H_2O$) are dissolved in a little water. Some fibres are dissolved, with boiling if necessary, in 5% sodium hydroxide solution; a few drops of sodium nitroprusside solution are added. In the presence of sulphur (wool) an intensive red-violet colour forms. Natural silk and regenerated protein fibres do not give a colouring.

Sodium number (SN). Expression for the required minimum alkalinity (to avoid hard water deposits) of feedwater in mg/l of NaOH. For very low salt-content water 200–500; for phosphate containing water 400–2000; for phosphate-purified water 100–400. Application of the SN limiting value also covers the presence of 4000 mg/l chlorine, 8000 mg/l SO_3, 1500 mg/l P_2O_5 and higher values. Calculation:

$SN = \text{mg NaOH} + 0.222 \text{ mg } Na_2CO_3 + 0.667 \text{ mg } Na_3PO_4 \cdot 12\,H_2O + 0.222 \text{ mg } Na_2SO_3$.

Sodium perborate (peroxyborate, perborate, peroxy sodium). $NaBO_3 \cdot 4\,H_2O$; molecular weight 154, colourless crystals or fine powder, stored as a dry powder, water soluble; in pure form contains 10% active oxygen that is slowly released on warming (→ Sodium percarbonate). Application: Laundering detergent formulation component (10–20%); bleaching (oxygen bleach methods); oxidation of high fastness dyeings; de-sizing; purification of starch, solubilising of algae, seaweeds, etc.

Sodium percarbonate (sodium percarbonic acid). $NaCO_3 \cdot {}^1/_2\ H_2O$; molecular weight 149.13. Contains 21% peroxide = 10% active oxygen. White powder, water soluble. Breaks down to evolve oxygen and form sodium carbonate. Application: Oxidation and bleaching agent (normally with a stabiliser), additive to washing detergent formulations especially as a replacement for → Sodium perborate.

Sodium peroxide (sodium superoxide). Na_2O_2; molecular weight 78; density 2.81. Pale yellow, fine particulate powder (or compact granules of 0.3–1.5 mm ∅) 19–20% active oxygen, very hygroscopic, odourless; 97% purity; ignites in damp conditions in concentrated form and also in the presence of flammable material (paper, wood, etc.) water soluble with emission of heat (decomposes to hydrogen peroxide and sodium hydroxide. Application: Oxidizing agent for vat and sulphur dyestuffs; bleaching agent for silk, wool, cotton, linen, viscose, etc.) In soluble form after the addition of sulphuric acid (to neutralize) and addition of phosphate to make weakly alkaline, stabilizer etc. to produce a non-yellowing full white product (softer fabric handle and less fibre damage).

Sodium phosphate, dibasic Better named disodium hydrogen phosphate. → Sodium phosphates.

Sodium phosphates (→ Monophosphates),

I. Primary sodium phosphate (monosodium phosphate, sodium dihydrogen phosphate) NaH_2PO_4. White salt, easily soluble; slightly hygroscopic when fully dry. Reacts acidic, 1% solution pH 4.2, Anhydrous form exists (with 15% bound water) as monohydrate ($\cdot 1\,H_2O$, density 2.04) and dihydrate ($\cdot 2\,H_2O$, 34.5% H_2O, molecular weight 138). Application: Water preparation especially for boiler feed as corrective method after base exchange. Dosing ca. 20 g. sodium phosphate crystals/m^3/l° hardness whereby there is a minimum 1° carbonate hardness from sodium hydrogen carbonate.

II. Secondary sodium phosphate (disodium hydrogen phosphate). $Na_2HPO_4 \cdot 12\,H_2O$; density 1.53; molecular weight 358. Colourless crystals; readily efflorescent; water soluble; solution is weakly alkaline, 1% solution ca. pH 8.5 – 9.2. Crystallises with 2 molecules of H_2O; resistant to weathering. Application: Water preparation especially for boiler feed (60 g/m^3 and residual hardness) especially after the softening stage; weighting of silk, dyebath additive as a mild alkali (substantive sulphur dyestuffs), fixing agent for aluminium mordant (alizarin red), flame retardant impregnation, builder for laundering detergents.

III. Tertiary sodium phosphates → Trisodium phosphate.

Sodium polyacrylate → Polyacrylate sizes.

Sodium pyrophosphate, acid → Disodium hydrogen phosphate.

Sodium pyrosulphite $Na_2S_2O_5$; mol. wt. 190. White powder, water soluble. Has similar properties and application (although higher SO_2 content of 67.37%) to sodium hydrogen sulphite.

Sodium sesquiphosphate $Na_3H_3(PO_4)_2$. Known as a polyphosphate; changes on heating to a neutral mixture of alkaline mono-phosphates at 300–500°C. Application: as detergent and boiler de-scaling agent.

Sodium silicate (sodium salt of silicic acid, water glass). $Na_2SiO_3 \cdot Na_2Si_2O_5$; molecular weight 304. Solid mass, powder or clear, highly viscous solution (strongly alkaline) with 35–40°Bé (contains 27% SiO_2 together with 8% NaOH); store in air tight conditions. Application: Degumming of silk; caustic and keir boiling; stabiliser for peroxide bleaching; silk weighting; dyeing of alkali blue (wool); flame retardant impregnation; in printing; matting of viscose; soaping assistant; component in washing powder and liquid soaps; adhesives, etc.

Sodium stannate (preserving salt, tin soda). $Na_2SnO_3 \cdot 3\,H_2O$; molecular weight 267. Easily water soluble crystals, solution (hydrolysed) strongly alkaline. Used as a swelling agent e.g. for viscose filament yarn (by diffusion of salt solution into the fibre) and, by thermal decomposition for the stabilising and storage of stannic acid gels (similar effect and improved by a treatment with barium chloride solution with the formation of barium stannate), as matting pigments. Application: weighting of silk; flame retardant impregnation (textile finish); matting of viscose.

Sodium stearate (sodium salt of stearic acid). $C_{17}H_{35}COOH$ molecular weight 306.46. Saponified stearic acid. White flakes; soluble in water and alcohol. Application: manufacture of household soaps and tallow soaps, finish component, etc.

Sodium sulphate (Glaubers salt, sodium salt of sulphuric acid, sulphate). $Na_2S_2O_4$ molecular weight 142; density 1.46.

I. Anhydrous, known as “Duisburger sodium sulphate”, white powder, iron free and 99.5–99.8% pure, water soluble with gentle heating.

II. Crystalline, colourless crystals of high purity, easily efflorescent, water soluble with temperature lowering. Application: Salt in the dyehouse (neutral baths: like sodium chloride for salting out dyestuffs, increases dyestuff rate of exhaustion; acid baths: reducing acidity, slows the rate of exhaustion of dyestuffs); in standing baths for increasing the salt content and raising the boiling point; component in many powder-form dyestuffs (diluent); additive in weighting formulations, etc.

Sodium sulphide (sulphuretted sodium). $Na_2S \cdot 9\,H_2O$; molecular weight 240. Fused mass or crystals (ratio 1 : 2), colourless (also weakly yellow), smell of hydrogen sulphide, hygroscopic, water soluble with alkaline reaction; gradually decomposes in the presence of air; reducing agent. Application: dissolving and dyeing with sulphur and vat-sulphur dyestuffs; de-hairing agent (tanning), etc.

Sodium sulphite (sodium salt of sulphurous acid). $Na_2SO_3 \cdot 7\,H_2O$; molecular weight 252. White crystalline powder, ca 25% SO_2, easily efflorescent (with oxidation to sodium sulphate), water soluble, weakly alkaline solution. Application: antichlor; reducing agent (printing); preservative; corrosion inhibitor in process water (binds acids), etc.

Sodium tetraphosphate $Na_6P_4O_{13}$. Anhydrous sodium tetraphosphate contains ca. 60.4% P_2O_5 and 36% Na_2O, is hygroscopic and reacts weakly alkaline. In contrast tripolyphosphate will bind more calcium ions. Used as builder for paste/highly viscous synthetic detergents.

Sodium tripolyphosphate (TPP, triphosphate, tripolyphosphate, sodium polyphosphate). $Na_5P_3O_{10}$; washing powder additive. Application: chelating agent for water softening; feed-water preparation; hot water supply systems; laundering; milling; after-rinsing, etc.

Sodium tungstate (sodium salt of wolframic acid), $Na_2WO_4 \cdot 2\,H_2O$); molecular weight 330; density 3.25. Colourless crystals, water soluble. Application: flame retardant and water repellent finishes.

Sodium Xylenesulphonate $C_6H_3(CH_3)_2SO_3Na$. Highly effective hydrotropic agent for fat free soaps, scouring agents, washing powders and similar.

Soft dyeing technique Term used for gentle handling of fabrics in the dyeing process with overflow or jet dyeing machines having controlled liquor flow.

Softener formulations Textile softeners are used to vary the handle of fabrics (similar to filling, stiffening and weighting finishes). They should demonstrate a positive effect on the handle of treated textiles; many textiles require softer, smoother, supple handle for the best sales potential. They may also serve to improve the processability and wear characteristics of the textiles.

Most textile processes, according to their intensity, *the influence of handle modifiers*

- textile characteristics:
  handle, volume, softness, fall, odour
- mechanical properties:
  stretch, elasticity, abrasion resistance, tensile strength, tear strength, smoothness, pilling tendency, sewability
- functional properties:
  moisture management (hydrophilic / hydrophobic), antistatic, flame retardant, dirt resistant, sewability, rope crease prevention, antimicrobial
- aesthetic properties:
  colour nuance, fastness, permanence, whiteness, thermal migration

influencing factors specific to production

- environmental acceptability (manufacture and use):
  biological breakdown, toxicity, irritant potential, corrosiveness, bath exhaustion, transport
- resistant to:
  storage restrictions electrolytes, water hardners, acids, alkalis, jet suitability (foam, shear forces), storage stability (heat, frost), drying and fixation processes
- handling:
  viscosity (suitable for metering), concentrate, stock emulsion, solubility
- compatibility:
  bleach liquor, dye liquor, reductive post-cleaning, optical brighteners, synthetic resins, catalysts, chemical finishes

Tab.: Requirements profile for textile softeners.

will more or less lead to the removal of oils and the enbrittlement of textiles. The softeners must replace this natural softness and suppleness. Often, a softener must also reduce the tendency of textiles to build electrostatic charges. A wide variety of chemical compounds of differing constitutions are used for formulating textile softeners. They often contain a hydrophobic molecular component. The hydrophobic part is usually an alkyl chain of 16–18 carbon atoms length if it is to contribute a softening effect. The varied application possibilities for softeners is further complicated by the variety of subjective assessments possible with so many different chemical types. The requirements profile for softeners establishes another set of criteria (see Tab.).

Handle modification may be considered according to the following usage criteria:

- functional softeners where the use above all is based on the correction of unwanted side effects of formaldehyde based cross linking finishes;
- process aids to improve the ease of make-up of knitted goods (especially for avoiding needle damage in high speed industrial sewing);
- handle modification to correct harsh handle effects, establishing a handle effect in the sense of a full, smooth and voluminous handle goods.

The following generalisations apply without regard to fibre types:

- the hydrophobic group should be as linear as possible, not branched.
- the number of C atoms in the hydrophobic chain component should ideally lie between 16 and 18.

Each substance has specific properties that are dependent on the ionic group. Substances with the same ionic character have varied properties entirely dependent on the type of hydrophobic group they are attached to. There are substances that give the best smoothing effects and substances that give the best softening effects. It is possible to differentiate between these products by determining their corresponding static and dynamic friction characteristics.

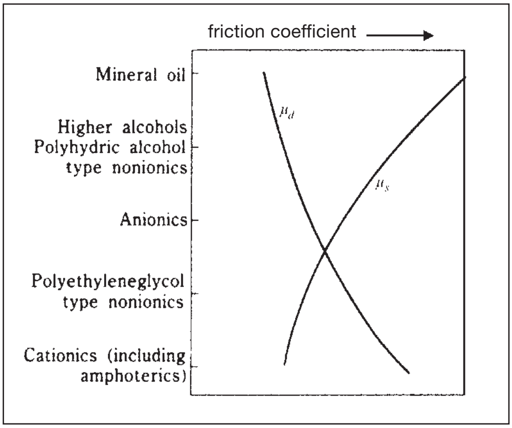


Fig.: The influence of the hydrophilic group on the reduction of the coefficients of friction.
μ_d =dynamic coefficient of friction, μ_s = static coefficient of friction.

It can be seen in the Fig. that mineral oil and a higher alcohol are good lubricating agents on account of their specific friction values but are poor softeners. In contrast, cationic softeners have low static and high dynamic friction values.

I. Non-ionic products have been widely used as textile softeners over many years. They form products that are typical for the ionic character but cannot however form salts. In the case of non-ionic bodies, a fatty chain of high molecular weight provides the softening effect, solubility is provided by condensation with a ethylene oxide chain. In comparison to anionic and cationic softeners, as a group they show the best resistance to heavy metal- and alkaline earth-salts.

The length of the ethylene oxide chain is variable; it determines the solubility as well as playing a part in the softening effects. A higher ethylene oxide content gives a lower softener effect. To produce non-ionic softeners a saturated compound is used with a carbon chain length between 16 and 18.

To produce softeners on this basis:

a) Condensation of a fatty acid with ethylene oxide. This produces a fatty acid polyglycol ester with the following formula (R = hydrophobic tail):

$$R–COO–(CH_2–CH_2–O)_n–CH_2–CH_2–OH$$

They give textiles a soft silk-like, scroopy handle.

b) Compounds that are made from fatty acid amines and amides that give, in comparison to the previous fatty acid polyglycol esters a distinctively softer handle. They have the general formula of:

$$R–NH–(CH_2–CH_2–O)_n–CH_2–CH_2–OH$$

alkylamine polyglycol ether

or

$$R–CONH–(CH_2–CH_2–O)_n–CH_2–CH_2–OH$$

fatty acid polyglycol ether

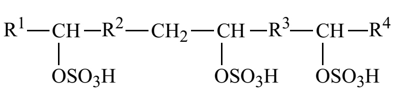
c) Between these 2 types are found, in softening effect, the condensation products of fatty alcohols with ethylene oxide. They have the general formula:

$$R–CH_2O–(CH_2–CH_2–O)_n–CH_2–CH_2–OH$$

Non-ionic softeners find application on all fibre types (both natural and synthetic). They may be combined with anionic and cationic products and can, with pale shades that do not require after-soaping or rinsing, be added directly into dyebaths. Without substantivity, they are principally used for working in short liquors, for padding or standing baths. Softeners on a non-ionic basis have an advantage in their universal applicability but have the disadvantage in their lesser softener effects in comparison to anionic and cationic products.

II. Anionic softeners are composed of a high molecular weight fatty chain with their notable solubility conferred by $–COONa$, $–OSO_3Na$ and $–SO_3Na$ groups. The basis for many anionic softeners are soaps. Their general chemical constitution is $R–COONa$, whereby R is an alkyl chain with 16 to 18 carbon atoms.

One possibility for the manufacture of such softeners is in the treatment of oils, fats or fatty acids with strong sulphuric acid or chlor-sulphonic acid. Important for the quality of such products is the degree of sulphonation. Higher levels of sulphonation lead to improved chemical stability although the softening effect may be somewhat reduced. They have the following general formula:



$$R^1-\underset{\substack{|\\ OSO_3H}}{CH}-R^2-CH_2-\underset{\substack{|\\ OSO_3H}}{CH}-R^3-\underset{\substack{|\\ OSO_3H}}{CH}-R^4$$

By suitable blocking of the carboxyl group of fatty acids it is possible to produce the so-called → Fatty acid condensation products, which find common usage in textile finishing as effective softeners. The masking of these groups is made by condensation with amino- group containing and also by condensation with oxygen group containing alkyl sulphonic acids. These are known by the general formula (where R^1 = higher molecular weight fatty acid residues; R^2 = alkyl sulphuric acid):

$$R^1–COO–R^2 \qquad R^1–CONH–R^2$$

Fatty alcohol sulphonates are further used by blocking the carboxyl group or completely replacing it. In this way, carboxyl-free softeners are produced as higher sulphated fatty alcohols.

These are represented by the general formula (R = high molecular weight fatty residues):

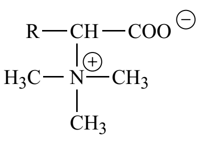
$$R–CH_2O–OSO_3Na$$

Whilst these substances are not substantive, they must be exhausted onto the fibres.

III. Cationic softeners form the major part of the total market for textile softeners. They rely on the typical high molecular weight fatty chain for their softening effects but their solubilising group is not based on sulpho- or sulphate groups, instead a quarternary group is used to form a soluble salt. They obtain their capillary activity from the cation and the positively charged cation is attracted to the fibre surface, so that they are aligned with the fibre to give the best effects. Due to this additional electrostatic attraction cationic softeners have clear advantages over anionic softeners and can give wash durable effects. Similar to all softeners, the chain length of the hydrophobic tail plays an important role. The special character of the → Quarternary ammonium compounds give them a dominant position in the range of textile softeners based upon good water solubility, high adsorption on the fibre surface, anti-microbial effect, good smoothing effects.

Cationic softeners are mainly produced by replacing the long chain fatty acid with → Polyamines or ethanol amines (→ Fatty acid ethanolamides).

IV. Amphoteric softeners: Quarternary ammonium salts, based on derivatives of betaines are, under certain conditions, good softeners. If they have a suitable fatty chain next to a basic or acidic group then they may be used as textile softeners. Products with amphoteric character have the following general structure:



$$\begin{array}{ccccc} & R- & CH & -COO^{\ominus} & \\ & & | & & \\ H_3C- & & \overset{\oplus}{N} & -CH_3 & \\ & & | & & \\ & & CH_3 & & \end{array}$$

V. Softener dispersions are differentiated from the foregoing surface treatment products in not containing hydrophilic groups to provide water solubility, instead they are combined with a suitable → Emulsifying agent to bring them to a form that allows their use in finishing liquors. The starting point for softener emulsions a usually →: Waxes; Paraffins; Fatty acids or other fatty chain groups and also silicones. Similarly polyethylene waxes can be used in emulsion form.

A special product group in the softener dispersions are silicone emulsions, usually high molecular weight α, ϖ-dimethyl-polysiloxane (→: Silicone in finishing; Silicone softeners). Both primary and secondary silicone emulsions are identified. With these emulsions are very soft, smooth, silk-like handle is achieved, also known sometimes as the silicone handle.

Softeners Used to increase the suppleness and to achieve a certain character in fabric handle by an end finish applied to yarn, wovens, knit-goods, etc. also as additives in sizing and finishing liquors, etc. Products used are normally surface active substances, mostly cationic, or preparations based on oils and fats.

Softening of textiles (avivage, softening, lubricating), sales directed, working practice of softening bleached and dyed goods to confer an advantageous handle and possible lustre. Hank yarns have an improved value in the ease of unwinding. In silk dyeing it is the term used for treating dyed goods by a warm bath containing organic acid (acetic, formic or lactic). It is used during bleaching or as an after- or end-treatment, in finishing during dipping, impregnating or nipping between rollers or through spraying on a spraying machine.

1. softening = softness of handle stressed
2. firm or hard handle = lubrication without softening of handle
3. handle finish = → Silk scroop

Softening in this context is most important for fibres and yarns that will be used in needling processes, e.g. non-wovens, tufted carpets and sewing threads. For the spinning of synthetic continuous filament yarns, the control of the applied amount of lubricant is a prime process criteria.

Softening of water → Water softening processes.

Softening range The temperature range for synthetic fibres (according to each fibre type) that lies between becoming thermoplastic and the true melting point. It is not identical to the → Transformation temperature but lies somewhat above.

Soft fibres Term for → Bast fibres in contrast to → Hard fibres.

Softflow rope dyeing machines Fabrics with a sensitive surface character that may be subject to creasing or surface roughening during the dyeing process are dyed on machines using the oveflow principle in soft flow dyeing machines (see Fig. 1). Here the goods are not moved through a jet pipe but fall onto a smooth plate or are twice overflow-treated (Fig. 2).

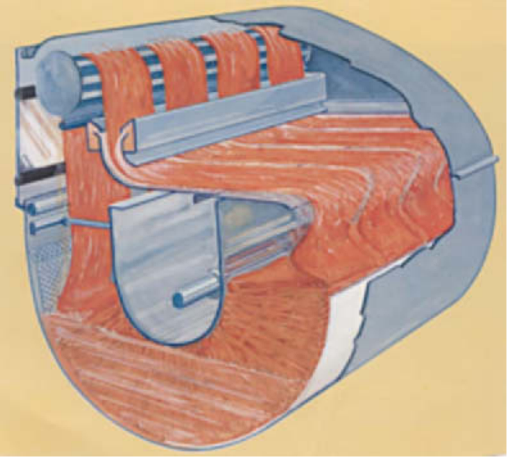


Fig. 1: The principle of a softflow rope dyeing machine.

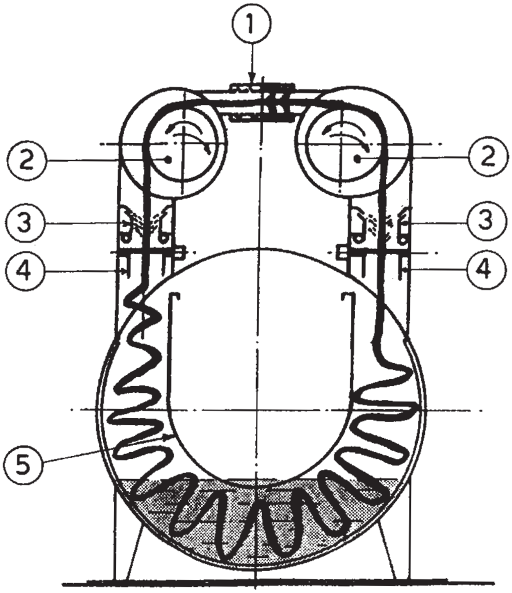


Fig. 2: Counter-flow piece rope dyeing (Caber Toboga). 1 = jet; 2 = dragging reel; 3 = flow and counter-flow; 4 = plaiter; 5 = container.

Soft handle treatment The final required handle for textiles is also linked to ease of processing and enhanced ease of use. A soft, smooth and supple fabric handle is a market demand for many textiles. Fibres of all types go through many different process stages and will lose the greater part of any contained fats, oils and preparations on the way. Fabric handle modification is

physical/chemical properties
- – solubility in water
- – vapour pressure curve
- – distribution coefficient (oil/water)
- – hydrolysis
- – viscosity
- – density
- – metabolites formation

effects on biological systems
- – algal growth
- – fish toxicity
- – reproduction
- – fertiliser effects

breakdown and accumulation
- – screening tests for biological breakdown
- – extended tests for biological breakdown
- – sewage sludge
- – soil
- – fish tests

effects on health

a) short term toxicology
- – acute toxicity
- – aquatic toxicity
- – skin irritation, eye irritation
- – skin sensitization
- – sub-chronic toxicity
- – teratogenic properties

b) long term toxicology
- – carcinogenic properties
- – chronic toxicity among many others

Tab. 1: Environmental perspective on the relevant factors in the evaluation of soft handle agents.

usually from an additional process and should also contribute to avoiding any tendency to build electrostatic charges.

An environmental requirements profile for → Softeners can be seen in Tab. 1. Starting materials for classical fabric softeners include natural oils and fats that can be chemically modified. Selected silicones used as softeners in microemulsion form are considered to be “supersofteners”. The following technical application factors are used to differentiate between the effects of different softeners (Tab. 2);

a) Ionic charge: increasing effect from non-ionic to anionic to cationic.

b) Nitrogen content: Fatty amine, fatty acid amine and quarternary ammonium compounds show that increasing softener effects come with increasing nitrogen content. Quaternary ammonium compounds, however, show problems linked to alkyl group substitution. There are risks from factors such as carcinogenicity, toxicity, mutagenicity, allergenic potential, irritant effects and explosion risk (see Tab. 1)

c) Chain length of the hydrophobic residues: Softeners often show a pronounced similarity to hydrophobic agents, especially cross linkable softeners. Hydrophilic softeners have no straight chain backbone and are not as critical.

d) Softeners in dispersion form: The nature of dispersions from fats, oils, waxes, paraffins, or polyethylenes are varied.

e) The application method: Softeners are applied by various methods and these have a large effect on the end results:
   - – add-on method (padding),
   - – spraying,
   - – exhaust methods.

	softness	smoothness	yellowing	low foaming	substantivity	hydrophilic
anionic sulphurated fats, oils, fatty acid condensates, containing sulphonated groups	–	+	+	–	–	+
non-ionogenic oxethylated products of fatty acids, fatty alcohols, fatty amines, fatty amides	–	–	(+)	–	(+)	+
cationic salts or quaternized compounds of tertiary amines, aminoesters, aminoamides	+	–	–	(+)	+	–
amphoteric betaines, amino oxide	+	–	–	–	+	+
dispersions of fats, oils, waxes, paraffins, polyethylenes, ailicones, polyurethanes	–	+	(–)	+	(+)	–

Tab. 2: Implementation concept for hydrophilic soft handle agents.

The assessment of softening effects can only be made according to subjective criteria by questioning experienced (in handle assessment) persons. A standard fabric (100% cotton – rotor spun yarn) is padded with a series of softening finishes. The test patterns are identified only by codes and assessed by a large sample of assessors. Each candidate uses a numbered pattern that meets the handle criterion. The samples are then sorted in comparison to this sample.

Softness index Calculated from the factors of surface smoothness or friction, yarn thickness and compressibility. Fabrics are tested as 1 cm. wide strips. Evaluation is based upon a 10 batch. The softness index indicates e.g. treatment with dist. water 1; with 0.5 gpl soap 1.10; after acidic bleach on cotton 1.36.

Softness number → Softness index.

Soft velours carpet Velvet like tufted floor covering based on fine denier yarns. Finishing is based on the use of combined shearing and polishing machinery.

Software System data and also application based service for electronic data processing. It includes the operating system, compiler, service programmes produced by computer manufacturers or specialist firms who control and service the → Hardware.

Soil Everything that must be removed from the goods e.g. pigment soiling, chalk deposits, fat and oil flecks from the loom, excess dyestuff from the dyeing process, over dyeing, diazotisation, from naphthol dyeing, from print thickeners and similar.

It may be differentiated:

I. water soluble organic and inorganic soiling:

a) sugar, syrup, starch, flour, urea;
b) organic acids, fruit acids;
c) proteins (blood and egg white);
d) inorganic salts.

II. water insoluble inorganic soiling:

a) cement, plaster dust, soot;
b) earth pigments such as clay and silicate.

III. water insoluble, non polar, organic soiling:

a) hydrocarbons (grease, asphalt, tar);
b) colour pigments and lacquers;
c) plant and animal fat.

IV. water insoluble, polar organic soiling:

a) fatty acids (perspiration);
b) polymers.

Soil adhesion Most fibres, under normal atmospheric conditions, have an electrochemical double layer built as a surface skin around the fibre that, because of its polarity, influences the soil adhesion potential of the fibre. There is thus a correlation between the → Zeta potential and the soiling behaviour of the fibres. Fibres without this surface zone have their → Soiling behaviour influenced by their polar molecular groups.

Soil burial enzyme test For the testing of substances e.g. textiles, and their biological degradation under rotting conditions (→ Soil burial test). The test is performed (according to Giesen-Wiese) as follows:

1. Pre-dried earth is prepared at 37°C to pH 8.0 with a phosphate buffer and 30% moisture content.
2. 0.5% by weight of an enzyme preparation cellulase activity is mixed in.
3. Non-woven samples are damped-off in buffer and laid sheet-wise in the earth-enzyme medium.
4. The samples are stored in a closed container at 28°C.
5. After removal, the samples are rinsed in cold water and then dried.
6. The effect of biological degradation on the samples by weight loss is assessed.
7. E.g. “Bio-inlay” (100% viscose fibres) shows a loss of weight of ca. 40% after 8 weeks burial.
8. A viscose content of 50% shows a loss of more than 50%.
9. A fully synthetic, binder-free inlay fleece in the same period of time will show a loss of less than 5%.

Soil burial method → Soil burial enzyme test.

Soil burial test (burial strength test, earth rotting test, → Soil burial enzyme test), testing of textiles for resistance by rotting by bacteria and fungi. Made by burying test samples in moist active earth mixtures (30% moisture; e.g. garden soil with 1/3 humus, rotted leaves and sand or earth, horse manure and sand), with pH and temperature suitable adjusted; after days or weeks the tensile strength is assessed. Comparison is made with a blind sample that has undergone similar treatment. A normal cotton fabric would be completely degraded after 5 days, whereas a cyanoethylated cotton (3.8% residual nitrogen content) would after 22 weeks show no signs of degradation. More exact methods, under laboratory conditions, involve using sterilised earth , inoculation with selected moulds and the burial of samples in closed containers under constant temperature and moisture. In the USA the estimation of fabric strength is made on a sample four times wider. In comparison to strip testing the comparable loading to break point gives higher strength values.

Soil hiding The soil hiding effect is based on fibre cross-section and decitex. Trilobal profile yarns with lower decitex show greater soil hiding effects than round cross-section fibres with higher decitex. Trilobal soil-hiding, hollow fibre types show weaker dyestuff yields, require more dyestuff for the same depth of shade than normal types. Reduced soiling effects are also possible through matting effects; e.g. the result of matting polyamide and polyacrylonitrile fibre is double the soil uptake in comparison to non-matted fibres with the same apparent degree of soiling. A high level of soiling is frequently due to incorrect choice of dyestuff.

Soiling → Soil adhering to textiles, most frequently caused by mechanical effects (fibre attraction) or electrostatic effects. →: Soiling behaviour; Anti-soiling finishes.

Soiling behaviour Soiling behaviour of textiles is extremely dependent on the type of fibre; → Soil release. No standardized tests exist for the soiling behaviour of carpets, because there are so many different types of soiling (dust, mud, lint of all types), and different colours and patterns. However, institutes use internal testing methods that permit absolute conclusions under specified conditions, and there is a method of testing stain soiling in Switzerland.

Soiling, staining,

I. Accumulation of → Soil, usually localized.

II. In mixed fibre dyeing, tainting of surrounding fibres by dye that is only intended for a specific area of fibre. The problem can frequently be alleviated by an intermediate reduction clear.

III. Unintentional dyeing of adjacent fibres (white or coloured) during wet finishing processes.

IV. Unintentional dyeing of white adjacent fibres during fastness tests. → Staining.

A polyester-wool mix can be used as an example of wool soiling in mixed fibre dyeing: Dispersion dyes colour the wool in the fibre mix by means of direct adsorption from the dye bath, or as a result of the dispersion dyes migrating from the polyester fibre onto the wool. This type of soiling can be restricted by using appropriate agents (resist agents). Alternatively it can be removed with an intermediate reduction clear, using reduction agents and/or surfactants. The following definitions apply:

1. For polyester fibre:
    a) Dispersion with non-ionogenic products: the quantity of dye adhering to the surface depends on the type of dye used, and is usually greater in the first dyeing phase. As the dye temperature increases, the quantity decreases and generally disappears after a boil period of 30 min, so that the polyester fibre has virtually no dye left adhering to its surface.
    b) Dissolving with acetone: the proportion of dye adhering to the surface is relatively smaller than the quantity of dispersible dye, and with this method it reaches almost zero during the course of the dyeing process.
2. For wool:
    a) Dispersion with non-ionogenic products: The observation of superficial dye presence is carried out in the same way as 1a), although the quantity will always be larger than on the polyester fibres. Depending on the dye used, this quantity will be at its highest when the temperature is between 60 and 80°C.
    b) Dissolving with acetone: although the influence of the dyeing sequence on the quantity of dye bonded to the surface is similar to 1b), the quantity of dye that is soluble in acetone is proportionally larger in comparison with the dispersible dye. This is an indication that the non-ionogenic products are not absolutely efficient.

Soiling test Wash or dry clean a test sample of a textile that has been artificially soiled, so that the level of optical brightening (→ Whiteness, degree of) achieved after washing or dry cleaning can be comparatively assessed. In principle, the soil test incorporates a combination of three soil types, such as carbon pigment, saponifiable fat, mineral oil (standard soil types).

	A	B	C
METALS			
Cr		250	800
Co	20	50	300
Ni		100	500
Cu		100	500
Zn		500	3000
As		30	50
Mo	10	40	200
Cd		5	20
Sn	20	50	300
Ba	200	400	2000
Hg		2	10
Pb		150	600
INORGANIC COMPOUNDS			
NH_4-N	-	-	-
F		400	2000
CN_{free}	1	10	100
$CN_{saturated}$	5	50	500
$S_{saturated}$	2	20	200
$Br_{saturated}$	20	50	300
PO_4-P	-	-	-
AROMATIC COMPOUNDS			
benzene	0,05(d)	0,5	5
ethyl benzene	0,05(d)	5	50
toluene	0,05(d)	3	30
xylols	0,05(d)	5	50
phenols	0,05(d)	1	10
aromatic compounds	-	7	70

d = limit of determination

Tab.: Limiting values of the Dutch soil pollution list.

Soil pollution (ground pollution). In 1983 the Netherlands passed an interim Contaminated Land Clean-Up Law threatening or requiring the necessity to clean up soil or ground pollution. This Law contained a requirement to identify the risks to health from contaminated land. The Law contained a "Contaminated Land Clean-up Instructions Manual" that set out the limiting concentrations, as well as administrative and practical requirements for cleaning up of contaminated land and water resources. Three aspects were addressed in the definition of the hazard assessment:

– type and concentration of hazardous material.
– the local contamination situation.
– the land use.

The points were not used singly but also considered was the scale of the hazardous material pollution and the possible impact of a clean-up operation defined, and if the clean up were possible and would not extend the scale of the problem or if a land use accepting the risks were possible.

Assessments were not to be made on the basis of any individual aspect but in consideration of all aspects. The working manual contained details of a large range of organic and inorganic hazardous substances with well-known effects on land and ground water. To give only the land values as an example, they were grouped in 3 concentration areas, A, B and C (see Tab.). Group A contains values that are typical for background land concentrations in the Netherlands. They are dependent on the land conditions and must be individually determined. Exceeding the limiting values of

Group A indicates a clean-up. Group B contains test values that, if exceeded, require an on-going investigation. A criterion applied here is the possibility of continuing risk to public health or the environment. If the limits of Group C are exceeded it is necessary to determine if a clean up can be carried out in the short term or should be evaluated with a view to being started. If a clean up is to be carried out it will not base solely on the limiting values but also on an evaluation of the use of the land in the context of the surrounding area. In Germany there are no regulations defining such limiting values for land. At the time of writing the Environment Ministry has not decided if it will apply a Regulatory or Land Protection Law approach. (according to Schollmeyer).

Soil redeposition Redepositing of removed dirt onto the goods during washing or dry-cleaning processes. Anti-soil redeposition: Counteracts the re-deposition of dirt during washing.

Soil release The property of dirt, especially oil-based, being more easily released from textiles during cleansing processes. Synthetics and resin finished synthetic/cellulosic mixtures are poor in this respect in comparison to natural fibres.

Soil release finish Application of finishing processes that are specifically designed to ensure more efficient laundering of soil and stains. Soil release products currently in use can be based on the following chemicals, for example: Silicium compounds, carboxymethylcellulose, ethoxylated compounds, polyglycol ester of terephthalic acid, acrylic acid polymers, and fluorochemicals. Frequently utilized in combination with resin finishing agents under the conditions specified for crosslinkers. Generally speaking there are no conditions of application specific to soil release finishing. The level of permanence of the soil release effects achieved is dependent on the product used. Good soil release effects are achieved through application of the → Dual action principle, using fluorochemicals that are oleophobic and hydrophilic. → Antisoiling finish.

Soil repellency Resistance to soiling as a finishing effect, which prevents soil penetration, or makes it difficult. Examples of soiling include dry soil (dust), wet soil (fruit juice, ink), oils and fats (engine oil and skin grease). → Anti-soiling finishes.

Soil repellent finish Alternative term for → Antisoiling finish. Prevents dry soil deposits on synthetic fibre textiles. Should not be confused with → Soil release finish.

Soil Resistance Merit Rating (SMR). Factor of soil resistance for carpets, taking into account the influence of colour. SMR indicates how high the soil concentration should be in a white test sample, so that the same apparent level of soiling as a specific colour can be achieved. The higher this value is, the greater the soil resistance of that colour. These values are defined on the basis of reflection measurements using a green filter (y value).

SMR examples:

white	1.0	mid-blue	33.0
light yellow	2.1	red	18.0
light grey	1.9	violet	17.0
mid-grey	9.5	olive green	21.0
beige	4.7	dark green	63.0
lemon yellow	3.6	dark brown	97.0
light green	4.4	coffee brown	190.0

Evaluation:

1.0–3.9	very bad
4.0–7.9	bad
8.0–15.9	fairly good
16.0–30.9	good
> 31.0	very good.

Soil-resistant Resistance against water-bound soil, fatty substances and pigment soiling.

Soil suspending property The extent to which a product is able to hold insoluble particles in → Suspension and/or prevent them from redepositing on the clean surface of the textile. Most synthetic washing agents have poorer soil suspending properties than soap; however non-ionogenic surfactants in particular (such as alkylphenolglycolether) can be far superior. The soil suspending properties can be improved by the addition of → Builders (soil suspenders).

Calculation of soil suspending property:

$$\%STV = \frac{\%WG_b - \%WG_w}{\%WG_0 - \%WG_w} \cdot 100$$

STV = soil suspending property,
WG = white content,
WG_0 = white content of white (unwashed) test textile,
WG_w = white content after washing in soil liquor without wash-active substance (water value),
WG_b = with wash-active substance.

Sol Colloidal substance in solution, such as glue in water. In this instance, it can be termed a hydrosol, because it is a water-based “solution”.

Solar cell Semi-conductor photoelement for converting radiated energy into electrical energy.

Solar collector Device for converting radiation from the sun into heat and conveying it to a heat transfer medium.

Solar radiation and materials Outside the Earth’s atmosphere, solar radiation shows a continuous spectrum in a wavelength range of approx. 0.5–3500 nm. A range of 280–3000 nm eventually reaches the Earth’s surface because of absorption processes in the atmosphere (oxygen, ozone, carbon dioxide, water vapour, etc.). The radiation strength of global radiation (= direct and dispersed radiation) and its spectral distribution are determined by the geographical extent and the daily/seasonal position of the sun. The radiation strength and wavelength limit of UV radiation are determined by ozone levels in the stratosphere, which are also subject to seasonal and geographical variations. A certain amount (quantum) of the energy present in sunlight can be absorbed by molecules. The energy level of absorbed radiation is dependent on the wavelength. Absorption in the short wave UV range is higher than for longer wavelengths or in the visible spectrum, but even at 500 nm it is 239 kJ/mol. Both the corpuscular theory (light is described as particles) and the quantum theory (light is described as energy in the form of waves) can be applied to sunlight.

Energy absorption from light alters the electron structure of the affected molecule, which in turn affects its readiness to participate in chemical reactions. This means that conditions are very different in comparison with the molecules in their basic state. The fact that chemical conversions are usually only on a small scale can be explained by the fact that the high energy level of individual molecules is only concentrated for a very short period. In other words, the energy absorbed is discharged again rapidly, and the molecule returns to its basic state (see Fig.).

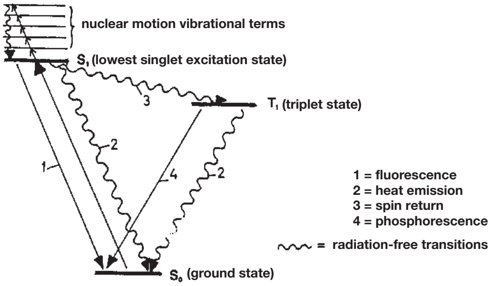


Fig.: Molecular excitation and intramolecular deactivation (BASF).

When a molecule absorbs energy, it transforms from a singlet ground state S_0 to a vibrational term of the agitated singlet state S_1. Even higher energy states cannot be achieved by the wavelengths discussed here, or they undergo "inner conversion" within an incredibly short time (10^{-12} s) and revert to the lowest level of the S_1 state without radiation. Deactivation of the S_1 state can occur in various different ways: it can occur intramolecularly, as a result of energy transfer to adjacent molecules, or by means of chemical conversion with other substances. There are three different possibilities for intramolecular deactivation:

1. Light emission, fluorescence (transition 1): this effect can be utilized beneficially, for instance with optical brighteners. When this happens, the basic state S_0 is reached in the nanosecond range (10^{-8}–10^{-9}), which means that the lifespan of an agitated S_1 state is approx. 1000 times longer than that of the high-energy S_1 level.
2. Deactivation by means of radiation-free transition to the basic state with heat emission (transition 2): the lifespan of the lowest singlet agitated state in this case is significantly shorter than one nanosecond.
3. Radiation-free deactivation by means of spin reversal, i.e. by means of conversion to the triplet state T_1 (transition 3): the energy level of this condition is lower than that of the S_1 state; however its lifespan, in the millisecond range up to approx. 100 s, is many thousand times longer than that of the S_1 state. For this reason it is particularly important for further chemical conversions, even when concentration of the partners is low.

The T_1 state can transform back to the basic state S_0 in the presence of radiation (transition 4). This type of radiation is known as phosphorescence. Subsequent deactivation can also occur without radiation (transition 2). However, intramolecular deactivation is not the only possibility for S_1 and T_1 states, they can also be deactivated by means of processes involving other molecules. The most significant of these processes is energy transfer to other molecules in the same environment (acceptors). This energy transfer can occur without radiation, or with light emission from the first molecule, with subsequent absorption by the second. This can occur as singlet-singlet transition and triplet-triplet transition. This type of energy transfer is the basis of all photosensitized processes. Example of energy transfer (D = dye; A = molecule in the environment [acceptor])

singlet-singlet transition:
$D^* (S_1) + A (S_0) \rightarrow D (S_0) + A^* (S_1)$

triplet-triplet transition:
$D^* (T_1) + A (S_0) \rightarrow D (S_0) + A^* (T_1)$

Measurement of the radiation of the sun at outdoor exposure stations is usually carried out using a pyranometer. The measured values are stated in Langley units (1 ly = 4.19 J/cm^2). Pyranometers record all the radiation from the sun that reaches the Earth, consisting of direct solar radiation and diffused radiation from the sky (wave range approx. 300–3000 nm). In test reports it is the recorded dose of radiation that is stated instead of (or as well as) the duration of exposure, when establishing the cause of a particular property change in a fabric. Examples of these altered properties are colour change (visual or colorimetric definition), or percentage loss in breaking strength of a non-illuminated fabric. The relationship of the Langley units to the property changes of exposed materials is problematic with results from different test stations, or materials that have been illuminated at the same place but at different times of the year. Comparison of Langley data can lead to incorrect interpretations due to solar radiation conditions that vary seasonally and locally (according to Baumgarte and Wegerle).

Solid fats In particular they contain → Stearic acid and palmitic acid (palm nut oil, pig lard, beef tallow, etc.). Beef tallow in particular produces very hard, solid (tallow) soaps with good cleaning properties but less foaming. These soap products are particularly effective at temperatures of 80–90°C. Tallow soaps can also be used for proofing.

Solidify → Freezing point.

Solids content Dry substance content (in g) per kg of thickener, e.g. locust bean flour 20–25, locust bean flour derivatives 20–250, guar derivatives 40–250, starch ether 100–400, carboxymethyl cellulose 40–200, hydroxymethyl cellulose 15–40, crystal gum 250–330, carragheenates 50–100, polysaccharides 40–200, alginates 30–120, tragacanth 65–80, starch 80–100, polyvinyl products 100–200, polyacrylic products 200–250, British gum 500. For less noticeable stiffening (thickening of pad liquors for pad dyeing), a low solids content is preferable – the most suitable for this purpose are alginate, locust bean flour and tragacanth. Thickeners can have a high or low solids content.

Solubilising power Ability of dissolved → Surface-active compounds and compounds that are heavier than water or insoluble to behave organotropically, i.e. to appear soluble. → Solubilization.

Solubility Can be achieved in a water-based medium with hydrophilic groups; in a non-polarized solvent it is the hydrophobic part of the molecule or ion that is responsible for solubility. The solubility depends on the size of the groups in question. As a basic principle it can be said that similar substances will form a solution (Liebig).

Solubility of size films The solubility of sizing agents in water is a flexible term. A product that takes 20 hours or a week to dissolve must still be classified as water-soluble. Because of the water solubility, the dresser assumes that the size will wash out easily. The person responsible for pretreatment has to prove that the opposite is true under certain circumstances. In sizing, there could be anything from starch that will wash out easily, to starches that are decomposed by enzymes or by means of oxidation. In addition to this, some of the modified starches, of which the chemical compositions are rarely known, can for instance become as soluble as pure potato starch if overdried. For this reason it is usually recommended for a commission textile finisher to desize using enzymes or by means of oxidation in cases of uncertainty.

Fully synthetic sizes include polyacrylate and polyvinyl alcohol sizes, which can be used on cellulose fibres as well as warps made totally of synthetic fibre, and “polyester sizes”, which are usually used on polyester filament warps. There is also CMC size (carboxymethyl cellulose), which is semi-synthetic and is usually used in conjunction with a fully synthetic size. Synthetic sizes have considerable advantages for the weaver, and similarly there are advantages in pretreatment. Although the sizes are based on water-soluble polyvinyl alcohols and acrylates, in practice one wash is not sufficient to remove the sizes. There are three major reasons for this:

1. As well as any sizes that are easily soluble in water, there can be additional sizing fats and waxes (in the size recipe formulation and/or developing subsequently on the warp). This slows the solubility because water penetration is reduced.
2. The sized warp can sometimes be overdried, which is also linked with water penetration worsening.
3. Synthetic sizes may have been combined with modified starches with poor solubility or no solubility at all.

In addition to these reasons, water-soluble sizes behave like thickeners with a low solids content; in other words their solutions still have a considerable level of viscosity even in low concentrations. If size is mixed with water, it does not become a solution immediately but goes through a gel phase first. Sizes will only dissolve if enough water is available, and enough time is allowed for diffusion. If the allocated time within the wash period is too short, it is recommended that the fabric is desized after the impregnation-dwell process. Double impregnation is also advantageous. This ensures that enough liquor is always available for the diffusion and swelling processes of fibre/size. Apart from the level of water solubility, synthetic sizing agents have the following distinguishing characteristics:

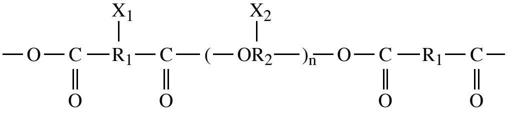
a) Acrylate sizes for staple fibre warps have ionic characteristics, and as salts they form true solutions of low viscosity. For this reason they are easily and rapidly soluble, i.e. washable.
b) Carboxymethyl cellulose sizes act in the same way as thickeners, and because of this they can also be used as wallpaper paste. A large amount of water is required for them to form a solution, and a specific thickening time. They are not acid/alkali sensitive.
c) Polyvinyl alcohol sizes form solutions that disperse colloids and have a higher viscosity than acrylate sizes. In contrast to acrylates they are precipitated with alkali instead of acid.

Polyvinyl alcohol sizes can be decomposed and removed in an alkaline medium, by means of oxidizing agents such as persulphate or peroxide. The oxidizing agent causes the macromolecules of the size to split into smaller units so that they can be washed off.

To summarize, for the successful desizing of synthetic sizing agents the following rules apply:

- fast wetting, liquor absorption > 80%;
- sufficient thickening time;
- sufficient water availability during the washing process;
- no alkali presence with polyvinyl alcohol, or if so, only in combination with oxidation agents;
- for acrylate sizes no acid must be present (pH not below 5.5).

Sizes based on polyester condensation products: polyester condensation products are usually present in the form of sodium salt. For this reason they are less suitable for warp sizing on water jet weaving machines (see Fig.).

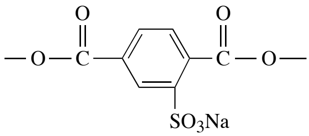


$$-\mathrm{O}-\underset{\substack{\|\\ \mathrm{O}}}{\mathrm{C}}-\overset{\substack{\mathrm{X}_1\\ |}}{\mathrm{R}_1}-\underset{\substack{\|\\ \mathrm{O}}}{\mathrm{C}}-(-\overset{\substack{\mathrm{X}_2\\ |}}{\mathrm{OR}_2}-)_n-\mathrm{O}-\underset{\substack{\|\\ \mathrm{O}}}{\mathrm{C}}-\mathrm{R}_1-\underset{\substack{\|\\ \mathrm{O}}}{\mathrm{C}}-$$

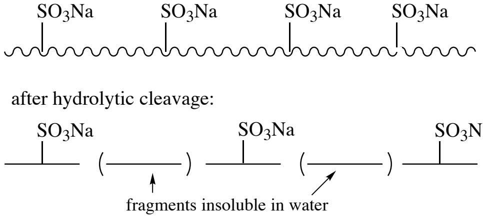
R_1 = aromatic, cycloalipathic and aliphatic hydrocarbon residuum with 2–6 C atoms
R_2 = C_2H_4 (n = 2–10), C_3H_6 (n = 1 or 2), CH_2–cycloalkyl–CH_2
X_1 = SO_3, $OC_3H_6SO_3$, $CO_2CH_2CH_2SO_3$ of aromatic R_1
X_2 = $CH_2O–(CH_2)_3SO_3$– of alipathic R_2, X_1 = H

Fig.: Polyester condensate.

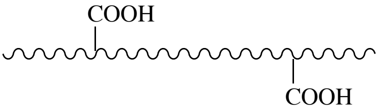
The structure of polyester condensate can be shown in a simplified form:



When these sizes are washed off, a pH of 9 must not be exceeded. If the concentration of alkali is too high, it will result in hydrolytic cleavage of the polyester condensation product, with the result that fragments without sulpho groups to trigger solubility will remain on the warp as insoluble residue.



Ammonium acrylates and ammonium methacrylate copolymers are present on the warp after drying as insoluble polyacids.



This type of size is well suited to water jet weaving machines. However, more alkali is required for washing off than with polyester condensates (according to Angstmann and Bassing).

Solubilization Ability of a water-based liquor containing surfactants to completely dissolve water-insoluble substances and organic solvents/water. This process can be explained by micelle formation of the surfactants (see Fig.) and their orientation towards the interface between the substance to be dissolved and the solvent. This is of practical significance in textile finishing and dry cleaning.

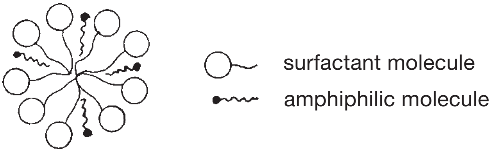


Fig.: Model illustrating the solubilization of amphiphilic substances through placement in the micelle, similar to surfactant molecules (according to Lange).

Solution (true solution), even distribution of one substance in another (by means of diffusion), or a → Phase consisting of several different particle types (components), that cannot immediately be converted into each other (from Pauling). The principal component of a solution is the solvent, and the other components are classified as the solute. Some of the best-known types of solution are the following:

I. Gas in gas (gaseous solution).

II. Gases or liquids in a liquid (liquid solution). Unlimited (e.g. water/alcohol) or limited (e.g. 7% ether).

III. Solid substances (salts) in liquids, with temperature dependency: at max. solubility (saturation) = saturated solution. The opposite is a non-saturated, dilute solution, with a low level of the dissolved substance.

IV. Solid substances in solid substances (e.g. metal alloys as a solid solution, or if crystal mixes occur as a crystalline solution; this category also includes polyester dyeing with dispersion dyes, or inter-penetrating polymer networks, for example).

Solution pressure (solution tension), the tendency of solid soluble substances to deliver ions or molecules into a liquid. Similar to so-called electrolytic solution tension, where every metal exhibits a greater or lesser tendency to discharge ions into water.

Solution process Substances such as surfactants, salts or dyes dissolve in liquids, without a chemical process, to form solutions. The solute particles impart specific properties to the solution, such as lowering vapour pressure or raising the boiling point in comparison with the solvent in its pure state.

1. Lowering of vapour pressure: Raoult's Law is the principle behind the lowering of vapour pressure, which is directly proportional to the mole fraction of the solute:

$$\Delta p = x_2 \cdot p_0$$

p_0 = vapour pressure of pure solvent,
x_2 = mole fraction of solute.

This equation is a limit rule applicable to dilute solutions, and it describes the process of vapour pressure lowering when substances are dissolved at a constant temperature. Since the vapour pressure curve of a solution will always run below the vapour pressure curve of the solvent, the boiling point should rise if the pressure is constant (see Fig.).

2. Raising of the boiling point: a substance dissolves under constant pressure, which causes the boiling point to be raised. Both of these physical properties are directly proportional to each other. The following equation applies for raising of the boiling point at constant pressure:

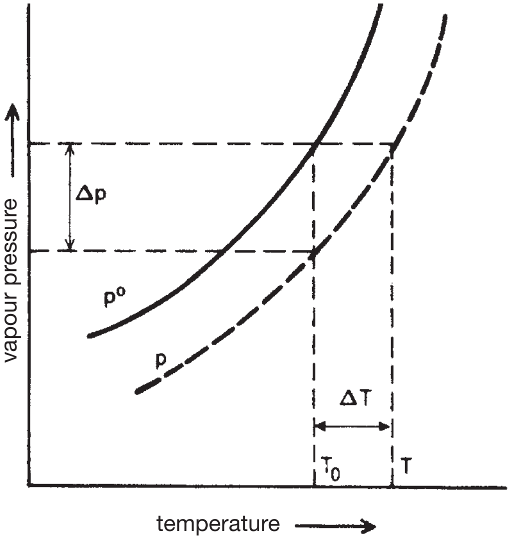


Fig.: The reduction of vapour pressure Δp and the elevation of the boiling point ΔT of a solution as shown in a diagram of pressure against temperature.
—— pure solvent, – – – solution.

$$\Delta T_s = E_s \cdot n$$

n = number of solute moles,
E_s = molar raising of boiling point.

Raoult's Law is equally applicable to the raising of the boiling point as it is to the lowering of steam pressure.

Solution wash processes Consisting of two phases:

Phase 1 (reaction-monitored): dissolving of the water-soluble substance.

Phase 2 (diffusion-monitored): removal of solution (liquor exchange).

On this basis, the solution wash processes are labelled by the following criteria:

- At the beginning of the wash process, the substance to be washed off is in a solute state in the textile.
- There are no chemical bonds or affinities between the substance to be washed off, the textile, and the wash liquor.
- The wash process is a diffusion process that tends towards a concentration equilibrium.

However, in practice these criteria are never fulfilled completely. One reason for this is that not all of the substances to be washed off are present in a solute state at the start of the wash process (example: when washing off after cold-dwell bleaching). The second reason is that chemical bonds exist between the textile and the chemicals, for instance in the case of caustic soda liquor, the most widely used chemical in textile finishing.

The basic equation for substance migration during the washing process is as follows:

$$G \approx \gamma \cdot (c_1 - c_2)$$

G = chemical exchange quantity per time unit,
γ = substance exchange value,
c_1 = alkali concentration in fabric,
c_2 = alkali concentration in wash liquor outside fabric.

The substance exchange value γ is defined as D/h, where D is the diffusion constant of the electrolyte to be washed off, and h is the diffusion path. From the above equation, conclusions can be drawn for washing machine design. The diffusion coefficient D is dependent on the chemical. The following proportionality applies:

$$D \approx \frac{T}{\eta_w}$$

T = absolute temperature of wash liquor
η_w = dynamic viscosity of wash water, which becomes significantly lower as the temperature increases.

Both influence factors result in an increase in the diffusion coefficients of approx. 400% in a temperature range of 20–100°C. It is therefore important to keep the temperature of the wash liquor in all wash compartments as high as possible, i.e. close to boiling point, as far as the substrate and/or the process permit. Since the diffusion path h is the denominator in the definition equation for the substance exchange value γ, the objective is to keep this path as small as possible, to ensure that a high substance exchange value is achieved. The diffusion path extends from the position in the chemical in individual cellulose fibres to the turbulent flow of the wash water surrounding or flowing through the fabric. External deposits on the fibres, close to the continuous flow channels, are easier to wash off than the substance inside the fibres, because the diffusion path is shorter. Therefore it is clear that the diffusion path does not remain constant throughout the wash process. Short diffusion paths can be achieved if the wash water flows through the fabric as perpendicular as possible to its surface. This consideration can be confirmed by the well-known, high-performance specific effects achieved by suction drum washing machines in which the water is sucked through the fabric. In washing machines where the roller fabric feed is over alternating rollers, there is a throughflow at each looped roller, if the wash water on the side of the fabric facing the roller is at least partially forced through the fabric by the wedge pressure between the fabric and the roller. On the rollers beneath the liquor, the water has to be forced through the fabric against the pressure of the water surrounding it. If the liquor trough in which the lower rollers are dipped, which is always the case in roller vat washing machines, is missing, there will be no back pressure, and fabric throughflow will be more efficient.

In order to achieve the best possible washing effect, the strongest concentration rate possible must be maintained between fabric and wash water, according to the equation stated previously. Since wash water economy is one of the most important requirements of a washing machine, maintaining a high concentration rate must not be at the expense of an increased water throughput. Instead the solubility and soil suspending properties of the wash water must be utilized more effectively, by bringing the same wash water into deliberate direct contact with the fabric many times. As the concentration difference at the end of a washing machine is nearly 0, it is only possible to wash off the water-soluble chemical fully after an infinite period of time (see Fig.)

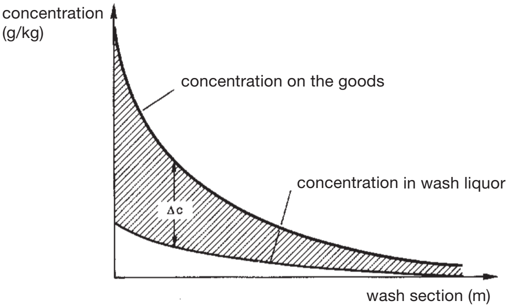


Fig.: The concentration profile within the wash section of a roller vat.

Concentration curves from a wash session can be drawn for the chemicals being washed off the fabric and the chemicals in the wash water for the duration of the wash in a roller vat washing machine. This shows that there is a considerable gap between the two curves at the point where the water enters the fabric (due to the counter-flow principle = discharge side of the wash water). This simply means that the dissolving and soil suspending properties of the wash water are not being utilized efficiently enough. The wash water clearly does not come into contact with the fabric being washed frequently enough or intensively enough. If the relatively large flow cross-section of the wash water in a roller vat washing machine is analysed, it becomes clear that at least some of the wash water flows straight through the machine without coming into close contact with the textile (according to Tischbein).

Solvation Term for the formation of dissolute additive compounds (solvates) between solute particles and any solvent (water, ammoniac, alcohol). Where water is present → Hydration.

Solvay soda Term relating to the extraction process used for manufacturing soda (sodium carbonate).

Solvent application of softeners → Softening of textiles in organic solvents during → Dry-cleaning or → Solvent milling.

Solvent bleaching Oxidation bleach with sodium chlorite in organic solvents. Peroxide bleaching of wool using tetrachloroethylene liquors was an example of an exhaustion process in → Solvent technology in textile finishing. Aqueous emulsions of H_2O_2 in tetrachloroethylene have 100% attraction to hydrophobic wool, which they bleach during the drying phase, continuing for 24 hours until bleaching is complete.

Solvent carbonizing In a process developed by Sperotto-Rimar for carbonizing fabric (Fig.), the woollen cloth is first treated with tetrachloroethylene, so that the water on the surface of the hydrophobic wool fibre is exchanged for tetrachloroethylene. Immediately after the solvent treatment, an aqueous sulphuric acid bath flows through the fabric. According to Sperotto-Rimar, the sulphuric acid/water mix should primarily be attracted to the hydrophilic burrs (it should be remembered that the burrs consist of approx. 60% cellulose and 40% lignin). After the burn phase in a heat recovery oven, there is often no neutralizing process, since woollen textiles only retain a low amount of residual acid in this system.

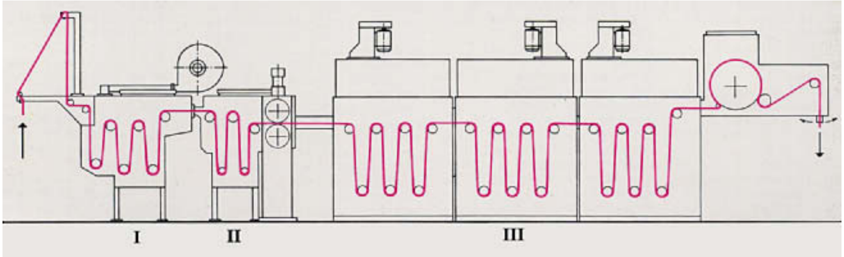


Fig.: A Sperotto-Rimar solvent carbonizer. I = loading with tetrachloroethylene; II = impregnation with dilute sulphuric acid; III = drying and burning of the wool fabric.

Solvent distillation can be carried out in large-scale plants (see Fig.). The solvent containing impurities is routed to the first distillation still. The rectifying power of the column above separates the solvent into low-liquor and distillate, which is condensed. The remaining exhaust vapours that do not condense have to be adsorbed. → Solvent recycling.

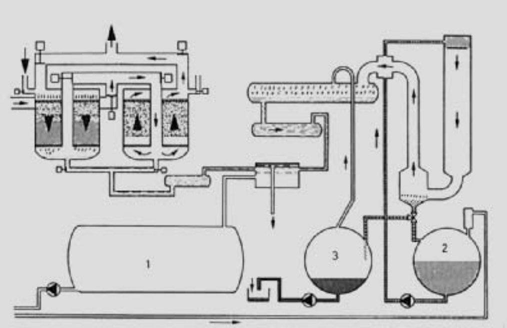


Fig.: A Brückner solvent recovery system (scaled for a distillation throughput of 2800 litres per hour).

Solvent dyeing This means dyeing without water, i.e. using solvents. This is only possible for light shades with no fastness, and is therefore of little significance.

Solvent dyeing (organic solvents) A process developed in the 1970s, which was designed to replace water as a dyeing medium with suitable solvents, because water was becoming more and more expensive and scarce. Solvent dyeing is only used in specialist dyeing areas as a complementary process for existing aqueous dyeing processes. Areas of application are:

I. Fully fashioned dyeing, where the process operates according to the principle of dry-cleaning.

II. Polyester dyeing, particularly the dyeing of high-tension polyester sewing thread.

Both of these process types are exclusively discontinuous processes, in which tetrachloroethylene (perchloroethylene) is used as the solvent. Process advantages: No fabric pre-cleaning is required; several finishing phases can be combined; the drying process is simplified. There are two different types of dyeing process:

1. Ionic dyeing process for polyamide and wool: water-soluble acidic dyes and special tetrachloroethylene-soluble acidic dyes are used for both fibre types. Since hardly any dyeing occurs without the addition of a "solvent aid", it is essential to add water, because otherwise no ionic bond will be able to form between the dye and the fibre.
2. Non-ionic dyeing process for polyester: in this process, the coloristic advantages and the process advantages stand out particularly in comparison with the aqueous process. Tetrachloroethylene, ethylene glycol, diethylene glycol and glycerine are all examples of a possible solvent medium.

Overall it can be concluded that this type of solvent dyeing has not become well established, because the appropriate dyes have not been developed, and the primary solvent, tetrachloroethylene, is associated with environmental problems.

Solvent dyeing processes → Solvent dyeing (organic solvents).

Solvent evaporation rates from wool Wool retains traces of water as well as tetrachloroethylene during the drying process. A woollen fabric was soaked with 20.8% water, and a parallel sample was soaked with 20.8% tetrachloroethylene. The samples were dried at 60°C in a slow air current. Tetrachloroethylene was expelled from the wool considerably more rapidly than water. The table depicts the rate of evaporation and the residual quantities of water/tetrachloroethylene in relation to wool:

	start	after 5 min	after 10 min
water	20.8%	9.3%	2.8%
tetrachloroethylene	20.8%	2.3%	0.9%

Solvent filtration in dry cleaning During dry cleaning operations, filtration is necessary for the continuous removal of suspended, insoluble and, where possible, even dissolved impurities from the contaminated solvent. Solvent clarification is mainly achieved through the use of filters with the addition of special filter aids, e.g. filter powder. This technology is far superior to former methods based on, e.g. separators, as far as the supply of clean solvent and rate of throughput is concerned.

Solvent flammability Flammable liquids that are used as solvents and have a boiling point of up to 150°C generally have a flash point below 55°C. According to German classification of flammable liquids, liquids that are not water-soluble and have a flash point between 21°C and 55°C belong to the hazard classification AII. Light heating oil, for example, falls into the hazard classification AIII. Where flammable liquids are used, it is assumed that the application temperature is not higher than the flash point for that liquid. For AII liquids, the application temperature must be well below the flash point. Because of this, these liquids are subject to much more stringent safety measures than liquids in hazard class AIII. The latter usually have a boiling point higher than 150°C, meaning that they are less volatile. This can be disadvantageous with regard to the drying temperature and distillation. However, they tend to be used in preference to the more volatile, flammable solvents. When assessing the explosion hazard, it was assumed in the past that it was sufficient to avoid an explosive atmosphere if the application temperature of a flammable liquid was at least 5 K below its flash point. That was based on the assumption that the flash point was identical to the lower explosion point. However, if the flammable liquid is distributed in a fine mist of droplets, for instance if the solvent is evaporated and condensed during recovery, this safety interval is no longer adequate. The reason is that the explosion point can only apply to the flammable substance in vapour form. For solvent mixes with no halogenized components, including benzine hydrocarbons, the explosion point is about 15 K below the flash point. The application temperature should not exceed the lower explosion point. On that basis, the maximum application temperature of a flammable solvent mix with a flash point of 55°C would be 40°C. This temperature would be too low for drying cleaned textiles. To raise the drying temperature, the fabric being cleaned would have to be dried in a protective atmosphere of inert gas, such as nitrogen or carbon. If distillation is carried out under atmospheric pressure, the flash point will certainly be exceeded. This will result in areas where there is an explosion hazard, in which more stringent safety regulations will be applicable. It is possible to reduce the boiling temperature of the flammable solvent by means of a vacuum. However the installation of a vacuum pump introduces mechanical moveable parts into the system, which should be avoided in an area where there is an explosion hazard.

Solvent health hazards The directive for use of dangerous substances (→ Legislation on environmental protection) is applicable for classifying solvents according to their level of influence as a health hazard. The following liquids are considered to be an extreme health hazard: benzene and its homologens where the boiling point is below 150°C (toluene, xylene), methanol, dioxan, organic halogen compounds (→ Chlorinated hydrocarbons) where the boiling point is below 200°C (e.g. carbon tetrachloride, symmetrical dichloroethane, di-, tri and tetrachloroethylene, chlorobenzene and chlorofluorocarbons) and carbon disulphide. The directive also provides information concerning limitations of use, and states that any solvents to which the directive applies must be clearly labelled in black writing with a black warning border on an orange background, with the following text:

CAUTION!
Hazardous vapours – do not inhale!
Observe safety regulations!

Solvent impregnation agents For → Solvent impregnation of certain specialist products that are soluble in hydrocarbons or chlorinated hydrocarbons. Base materials are particularly solid hydrocarbons, such as paraffin (oil), ceresin, synthetic wax, chlorinated rubber, organic metal compounds in the form of solute metallic soaps of higher fatty acids or metallic polyoxides, with solid hydrocarbons, waxes etc; synergetic copolymer-hydrocarbon compounds; silicon polymers; aluminium alcoholates.

Solvent impregnation (solvent waterproofing). Specialist technique for waterproofing in organic solvents (benzine, heavy benzine, tetrachloroethylene, etc.) with → Solvent impregnation agents. Important in dry-cleaning for re-impregnating garments after cleaning.

Solvent milling → Milling in solvents.

Solvent naphtha Specific purposes of these products are as solvents for lacquer manufacture, to dissolve resins, rubber, fat, dyes, etc. Boiling point ranges from approx. 140°C–200°C. Together with an emulsifier and an active substance, they are also a component of carriers.

Solvent recycling Requirement for working with tetrachloroethylene economically. In comparison with soft water, tetrachloroethylene is currently 700–2000 times more expensive. In addition to this, there are unintentional waste water costs, whereas the cost of solvent recovery for re-use is nowhere near as high as the cost of the tetrachloroethylene itself. For this reason, solvent technology can be economically efficient if recycling is used to its full potential, taking into account the following points:

a) Solvent distillation: principal method in continuous circulation, made easier by 2 significant facts: the low evaporation heat of tetrachloroethylene (at 220kJ/kg less than 10% of the heat of vaporisation of water) and a higher boiling point. Solute impurities in tetrachloroethylene remain in the still sump, and need to be separated easily as a concentrate.

b) Solvent volatilization: recycling method for fabric that has been wetted with tetrachloroethylene after cleaning, or application of tetrachloroethylene-based finishing chemicals. The fabric is dried in warm air, and the vaporized solvent is condensed at the same time in water-cooled heat exchangers. The low specific heat of the tetrachloroethylene (= 0.85 kJ/kg) in relation to water, and a low heat of vaporisation of the tetrachloroethylene provide favourable conditions for volatilization. In most plants, the clean, hot cooling water (40–65°C) generated during the distillation and drying processes is also recycled by utilizing it for specific purposes.

c) Solvent adsorption method: method of diverting the used tetrachloroethylene back into the circuit for reuse, which is also a necessary measure for environmental reasons. When the fabric is cooled and ventilated, ambient air is used to flush solvent gas residues out of the fabric (final phase). The air is then passed through an activated carbon filter, where the residual gases are transferred to the carbon. When the carbon becomes saturated, the solvent is driven out by water vapour and re- condensed.

Solvent retention Characteristic of solute substances, where they bond physically with components of the solvent when the boiling point is raised. As the solvent is extracted from the solution by vaporization, the remaining solution will gradually become more concentrated. The more concentrated the solution becomes, the more effective the solvent.

Solvents Main component of this type of → Solution. According to this definition, water acting as a solvent in an aqueous salt solution is considered to be a solvent, for example. However the popular definition of solvents is organic solvents. There are specific requirements for solvents used in textile finishing:

The principal chemical requirement is that a solvent is a relatively inert, stable liquid, which does not react with any of the (textile) substances with which it comes into contact. The physical requirements are much more differentiated. The solvent should have good solubilizing properties concerning fats and oils. Common commercial surfactants should be soluble in it. These surfactants should have sufficient dispersion stability for pigment soiling, so that there is no subsequent uptake of detached soil by the textile (known as soil suspending properties). In addition to this it should be possible to solubilize water as a solvent with these surfactants, so that the removal of water-soluble soil can be improved in this way. On the other hand, the solvent should not have such extreme solubilizing properties that fibres and synthetic substances swell or even dissolve in it. In order to ensure that the solvent can be recovered economically, it should be slightly volatile, and also colourless and as odourless as possible. The level of purity should be as high as possible, and the boiling range as narrow as possible. If solvents are flammable, a compromise must be reached with respect to the boiling temperature. The ideal physical properties are related to viscosity and density. The solvent should be fluid, and its density should be significantly above or below 1. The density is necessary so that the solvent can be easily separated from water after recovery because of the difference in mass.

From a physiological point of view, the important requirements are that the solvent is neither carcinogenic nor does it cause mutation, and if possible it should not resorb through the skin. The maximum concentration permitted in a workplace (TLV value), where there will be long-term effects on humans, should be 50 ppm – in other words 50 ml of solvent vapours in 1 m^3 of inhalable air.

Ecological requirements have now become so manifold that this list can only include a few of the main points. In Germany, any liquids that constitute a hazard to water are allocated to classes 0–3, where the class number denotes the level of hazard to water. The highest class number is the most hazardous. Solvents are classified according to acute toxicity for mammals, bacteria and fish. Since tetrachloroethylene falls into water hazard category 3, it would not fulfil the requirement. It is not only the atmospheric lifespan of the solvent that is crucial regarding degradability in the troposphere (the lowest layer of the atmosphere), it is also important to assess the breakdown products as to whether or not they constitute an environmental hazard. The only solvents with potential to decompose the ozone layer are compounds that contain chlorine and have a high level of atmospheric stability. Their chlorine atoms react with the ozone layer in the stratosphere. The greenhouse effect occurs due to the fact that the atmospheric layers nearest the Earth are gradually heating up and the higher layers are cooling down slowly because the reflection of radiated heat is obstructed. This effect has not been measured yet for most substances, apart from the anthropogenous substances carbon dioxide, methane, dinitrous oxide and fluorochlorocarbons. The breakdown products of these substances must also be considered. One ecological requirement that has become very relevant at the moment is the recycling potential of the used solvents from distillation residues. In general it is more economical to recycle solvents than to dispose of them by incineration.

Solvents and fibre swelling As an example, loose wool fibres, yarn or woven fabric can be immersed in distilled water, with parallel samples in tetrachloroethylene. After a short length of time, a swelling or adsorption equilibrium is reached. The standard centrifuge method is used at a speed of 3500 rpm. After 5 minutes the centrifugal weight (centrifugal swelling) is record-

	increase in cross-section in %	increase in length in %
viscose fibre	6–7	8–12
cotton	0	8.7
wool	3.5	6.1

Tab.: The dimensional changes to different fibre materials in tetrachloroethylene.

ed, which is then used to calculate the quantity of liquid in the fibres as a result of swelling or adsorption. The result for wool is that it adsorbs approx. 40% water, but only approx. 19% tetrachloroethylene. If the molecular weight of water and tetrachloroethylene is taken into account, it can be concluded that the adsorbed quantity of tetrachloroethylene, which has significantly larger molecules, is equivalent to only about 10% of the quantity for water. This small quantity of tetrachloroethylene has a slight swelling effect on wool, and the fibres only adsorb it superficially. The Tab. shows how certain fibres exhibit dimensional changes in tetrachloroethylene. Dimensional changes in tetrachloroethylene are significantly less than for water.

Solvent scour Washing off scrooping or solvent preparations (solvent finishing). In the treatment of polyester, it should be remembered that this type of fibre is capable of solvent sorption, which accelerates dye diffusion.

Solvent scour process for wool → Raw wool scouring using organic solvents, usually only to extract lanolin. Australian method: spray with benzine (white spirit), squeeze off, and then rinse with water jets. Swedish method: (Laval oil or petroleum scour) with petroleum fraction boiling at 170–270°C. The solvent is filtered after use, cleaned and recovered by means of distillation.

Solvent sizing Sizing of warp ends (widthwise) using organic solvents. It is carried out in a completely sealed pressure system in a suitably constructed solvent sizing machine. Polystyrene, for instance, is applied cold, can subsequently be removed from the fabric by means of tetrachloroethylene (desizing; extraction possible using ultrafiltration), and long-term experiments in the weaving industry have shown that this method is well suited to sizing.

The solvent sizing machine shown in the Fig. is a sealed-system machine with a partial vacuum (to prevent solvent vapours from escaping). Path of warp yarn, starting at the warping beam: a) air lock; b) sizing unit with an observation window running across the width of the machine, height-adjustable immersion roller, pneumatic squeezing units, liquor level control, low pressure/vacuum monitoring, solvent spray device for roller cleaning; c) drying chamber for hot-air drying at approx. 120°, 132–138° contact drying on 2 Teflon-coated drying cylinders, automatic pressure/temperature (atmosphere) in a deodorizing zone; d) drying zone and preparation unit for final scouring with wax or paraffin (2 heated troughs with water-cooled application rollers, freely-adjustable immersion depth and circumference speed), beaming machine, pre-selectable yarn tension control (yarn run-off, sizing, drying, dry dividing zone, winding). Solvent-saturated drying air circulates around water-cooled condensers, any other air is removed by suction using solvent recovery equipment (activated carbon filter), where it is blown out into the atmosphere after the solvent has been adsorbed (the proportion of solvent must be below the permitted TLV level of 30 ppm). This causes a partial vacuum, which prevents solvent vapours from escaping. Solvent regeneration is carried out using separate distillation equipment.

Solvent soaps → Fat-solubilising detergents. Incorrect expression for → Dry-cleaning detergent.

Solvent-soluble dyes Analogous to → Oil-and-fat soluble dyes.

Solvents – thermal decomposition At the following temperatures, solvents are liable to thermal decomposition:

tetrachloroethylene	150°C
trichloroethylene	120°C
1,1,1 trichloroethylene	160°C
CFC 113, CFC 11	150°C

Solvent technology in textile finishing,

I. Addition processes: finish with solvent-soluble organic products, usually for final finishing of dyed or printed fabric, e.g. discontinuous solvent methods:

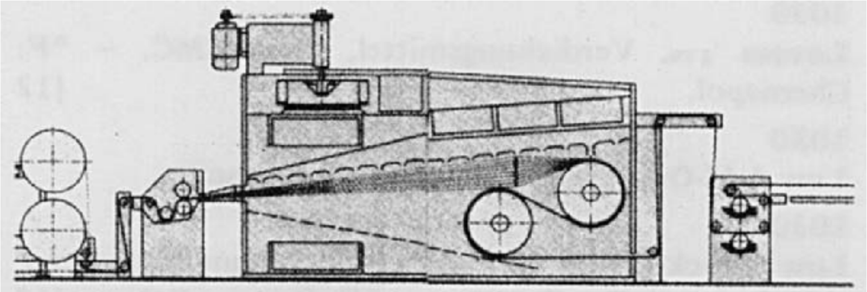


Fig.: Solvent sizing machine

- improved handle resulting from the use of softeners in machine-knitted goods;
- antifelt finishing of woollen knitted fabric with silicon elastomers.

Examples of continuous solvent methods with full-width treatment:

- anti-static finishing of synthetic knit and weave fabrics;
- finishing of pretreated synthetic print fabrics with wetting agents;
- application of optical brighteners;
- finishing with filling agents;
- hydrophobization both with silicon and oil-repellent products, and with metal salt/ wax formulations;
- finishing with silicon elastomers;
- solvent carbonizing.

II. Exhaust processes: adsorption of dispersed liquid phase on hydrophilic fabrics (wool, cotton), usually emulsified aqueous product solution in tetrachloroethylene, which has a quantitative fabric uptake if fabric movement is discontinuous, e.g. in solvent bleaching and solvent milling (= 5–30% water to dry wool weight).

III. Pigmenting processes: breakdown of insoluble product additives into pigments, using mechanical pressure, they are then removed mechanically, for instance by after-print cleaning (polyester, polyamide, triacetate weaves and knits). For fixed prints a high-pressure tetrachloroethylene liquor jet is applied, causing insoluble (acrylate) films (print thickeners and synthetic sizes) to be broken down into pigments, which, in an insoluble state, are washed off and flushed away as unfixed print dye residues. Operating speeds in solvent continuous technology are > 50m/min. The print thickeners or sizes accumulate with dye in the form of a thick solvent-free sludge, which is disposed of as hazardous waste.

IV. Subtractive processes: dissolving of solvent-soluble substances (oils, fats, waxes, preparations) and associated insoluble impurities (pigments). The residues subtracted from the fabric (texturizing, spinning and winding oils, preparations/non fixed dispersion dyes, etc.) that occur through distillation and are easy to dispose of, account for 8–10% of the fabric weight, which means large plants running at least several shifts per week.

V. Displacement processes: subtractive purification using mechanical displacement and emulsification of the liquid phase. First, swelling and dissolving of water-soluble products is triggered using minimal quantities of water on the fabric, then the aqueous solution is driven or emulsified off the fabric surface by means of intensive high-pressure tetrachloroethylene jets and the fact that tetrachloroethylene is not water-soluble. The solvent emulsion or mix is subsequently distilled, and the resulting concentrated residue is free of waste water.

Solvent usage in dry-cleaning A historical parallel can be drawn between the status of environmental legislation and the state of solvent technology in dry-cleaning (Fig. 1).

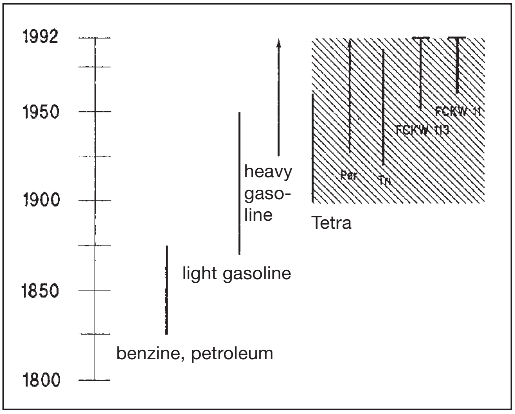


Fig. 1: The history of the usage of solvents in dry-cleaning. Tetra = carbon tetrachloride; Per = tetrachloroethylene; Tri = trichloroethylene; FCKW 113 = trifluorotrichloroethylene; FCKW 11 =trichlorofluoromethane.

During the exhaust and door-opening phases (Fig. 2) in dry-cleaning machinery, the exhaust, which contains tetrachloroethylene, used to be passed through a filter and out of the machine. The filter bound the tetrachloroethylene vapours by adsorption. If the filter capacity was exhausted, the solvent had to be recovered by means of activated carbon evaporation. After the filter had been air-dried, it was ready for use again. In addition to the positive aspect of exhaust cleaning and solvent recovery, daily use of activated carbon filters caused many different types of problems in the plant. Regeneration of activated carbon systems required input from employees in the evening, since the equipment was usually set up to cope with a daily capacity. There was also extra consumption of energy during the

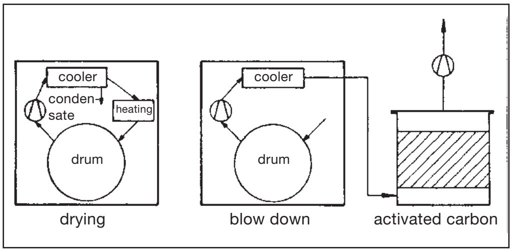


Fig. 2: The classical system with blow-down on dry-cleaning machines.

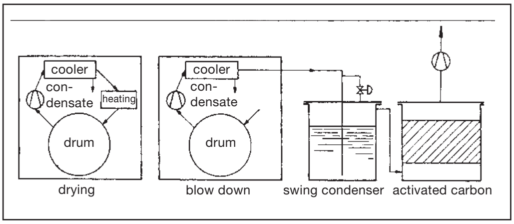


Fig. 3: The classical system with a swing condenser.

evaporation process, as well as censure by the industrial inspector if the equipment was overloaded or badly maintained.

In order to improve this situation, the back pressure condensation system was developed in the mid-1970s (Fig 3.). During the exhaust phase, the exhaust flowed against a standard hydraulic seal, which caused the solvent vapours to condense in the cooling machine rather than reach the filter. If the access door was opened, the seal was bypassed by means of a butterfly valve, and the exhaust was allowed to freely pass through until it reached the activated carbon. The advantage of this combination was that the adsorption capacity of the activated carbon was multiplied by a factor of 2 or 3, so that it only needed to be regenerated every second or third day, thereby saving energy, solvent and man hours. This was basically the first step towards sealed cleaning machines, which were launched on the market in the early 1980s (Fig. 4).

This type of machine did not discharge exhaust into the atmosphere. During the drying and exhaust phases, the air was routed through a closed circuit across a cooler with coolant throughflow, where the tetrachloroethylene vapours were condensed as far as possible. Even when the access door was opened, the exhaust-free characteristics of the machine were retained. It was during this phase that the weak point of the process became apparent. The tetrachloroethylene concentration in the drum was approx. 4000 ppm. At the edge of the drum, concentrations of up to 2000 ppm were measured. Since there was no removal of the solvent by suction to atmosphere, the escape of tetrachloroethylene vapours into the room could not be ruled out.

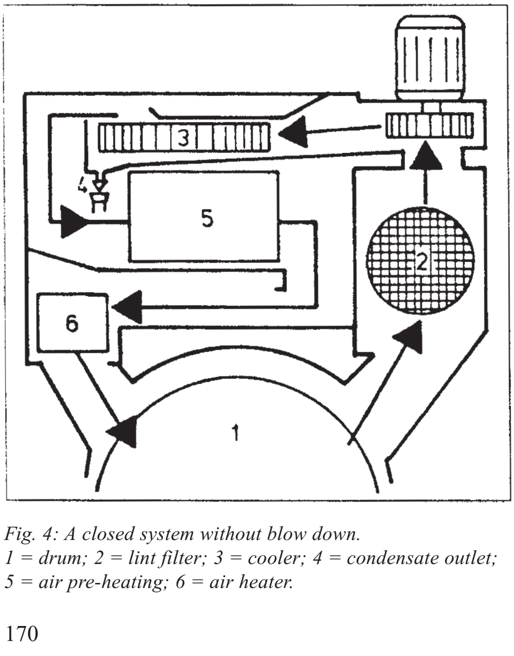


Fig. 4: A closed system without blow down.
1 = drum; 2 = lint filter; 3 = cooler; 4 = condensate outlet; 5 = air pre-heating; 6 = air heater.

For this reason it is not surprising that traces of tetrachloroethylene were found in foodstuffs stored in rooms adjacent to dry-cleaning machines. In Germany, foodstuffs containing a level of tetrachloroethylene higher than 0.1 mg/kg must be withdrawn. The legislation covering this can be found in the directive on maximum solvent values (Lösemittel-Höchstmengenverordnung) dated 01.01.1990. The usage of tetrachloroethylene also has to be regulated legally, because it is a potential toxic and ecological hazard. At an international level there is not such precise legislation for chlorinated hydrocarbons, including tetrachloroethylene, as there is for chlorofluorocarbons. There is one legislative declaration, albeit a specific one, the Declaration of the 2nd International North Sea Protection Conference in 1987. This regulates the burning of solvent waste at sea, as well as any depositing of hazardous substances in the form of waste water into the North Sea, which includes CFC solvents. Further directives are contained in various different parts of the EC guidelines, relating to the protection of water and the disposal of rubbish. In 1991 in Germany, the use of tetrachloroethylene was about to be banned. It was not until the professional unions protested emphatically, explaining that there was no alternative at that time, that the directive banning the substance was rescinded. However, this retraction was only on the condition that new directives were followed, which stated that tetrachloroethylene emissions had to be drastically reduced. For instance, the tetrachloroethylene concentration in adjacent premises where food is manufactured or sold was allowed to be a max. 0.1 mg/m^3, and from 01.01.1996 this applied generally to all adjacent premises [second directive for execution of the German pollution law (March 1991)]. This is an immense requirement, considering that the TLV value is 345 mg/m^3. The limits for waste water are also similarly stringent. Although they are set at a national level in Germany, there are also parameters at a super-regional level – CFC solvents as an independent substance must not exceed the threshold value of 0.2mg/l.

The new directives also state that in a dry-cleaning plant using tetrachloroethylene as a solvent, the concentration in the drum where the fabric is cleaned must not exceed 2g of tetrachloroethylene per m^3 of air. Previously the permissible limit was approx. 15g/m^3 of air. Understandably, a cleaning machine requires more time to achieve a target of 2 g/m^3 as opposed to 15g/m^3. However, longer drying periods with the machine drum rotating mean that mechanical effects exerted on the textiles are automatically more pronounced, which can lead to surface raising in sensitive fabrics, such as parts of micro-filament fabrics that are particularly liable to wear, or stiff parts. In addition to this, there is also a problem which has gone unnoticed in the past, caused by stiffening, linings and padding. For example an anorak with proofed outer material and thick non-woven fleece padding requires twice as much, if not three times as much drying time as normal garments. Furthermore if the anorak only dries when the drum is rotating it means that the anorak's outer material and padding are subjected to mechanical effects for twice or three times as long. In situations such as this, it is often a better idea to wash the garment in water (if the fabric care label and garment properties will tolerate this).

A further problem affecting textile manufacture in the broadest sense that has arisen as a result of the new legislation in the second BImSchV (Bundes-Immissionsschutzverordnung – German Federal Immission Protection Regulation) is the fact that pre-trials are no longer possible in the textile cleaning industry, because the open use of tetrachloroethylene is no longer permitted. Neither is it possible to carry out a pre-trial to establish whether textiles, dyes, finishes and accessories are resistant to tetrachloroethylene. This means that the fabric care label becomes more significant when it comes to a clear definition of the fabric care instructions. Sealed machines certainly make matters easier for the textile industry when it comes to dealing with environmental legislation:

- Solvent usage is significantly reduced,
- Working hours for regeneration are not necessary,
- There are energy savings.

However, sealed machines relocate the emissions from the atmosphere to the work room. This happens:

- During the loading and unloading phases,
- When high pressure in the machinery is released via the water separator,
- Through broken seals.

In order to comply with TLV values in ppm for tetrachloroethylene in the future, the exhaust fumes from the machinery released during loading and unloading must be discharged through a filter into the atmosphere. However, if that is the case, there is a requirement for a new process for exhaust purification and recovery, that combines the advantages of the old process and avoids the disadvantages caused by the main emissions (Fig. 5).

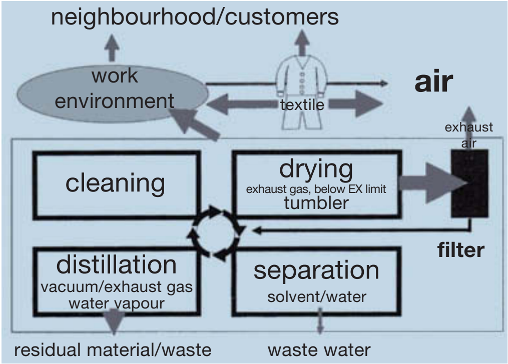
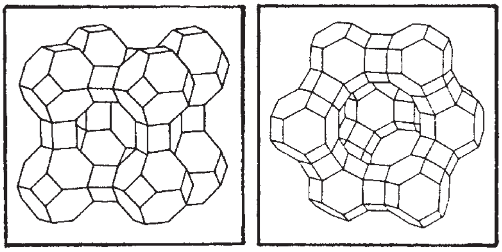


Fig. 5: The main sources of emission from dry-cleaning.

It is possible to filter solvents out selectively using molecular filters (Fig 6.), because of their crystalline structure and precisely defined pore diameters. A tailor-made type of molecular filter is selected for each solvent. As regards adsorption capacity, molecular filters provide an internal surface area of more than 1000 m^2/g. During the exhaust phase of the cleaning machinery, the exhaust fumes flow against a hydraulic seal. The back pressure condensation principle ensures that most of the solvent vapours present in the exhaust are recovered in the cooler.

A low-level partial airflow that is necessary for fabric ventilation is passed over the filter insert into the atmosphere. If the access door is opened, the exhaust bypasses through a butterfly valve via the filter and then straight into the atmosphere. Whilst the machine is almost sealed during the exhaust process, the system is open during loading and unloading. The number of loading and unloading operations is counted electronically, and constitutes a critical measurement for achieving the capacity limit of the filter. If this limit is reached, the machine operator is alerted by means of a visual signal that desorption is now necessary. Regeneration is carried out in a sealed circuit with hot air. To do this, circulated air is routed from the fan to the molecular filter insert via the heating unit, which can either be electrically or steam heated according to pref-



type 0.3–0.5 nm $Na_{12}[(AlO_2)_{12}(SiO_2)]\cdot xH_2O$

type 1 nm $Na_{86}[(AlO_2)_{86}(SiO_2)_{106}]\cdot xH_2O$

Fig. 6: Molecular sieve = sodium aluminium silicate.

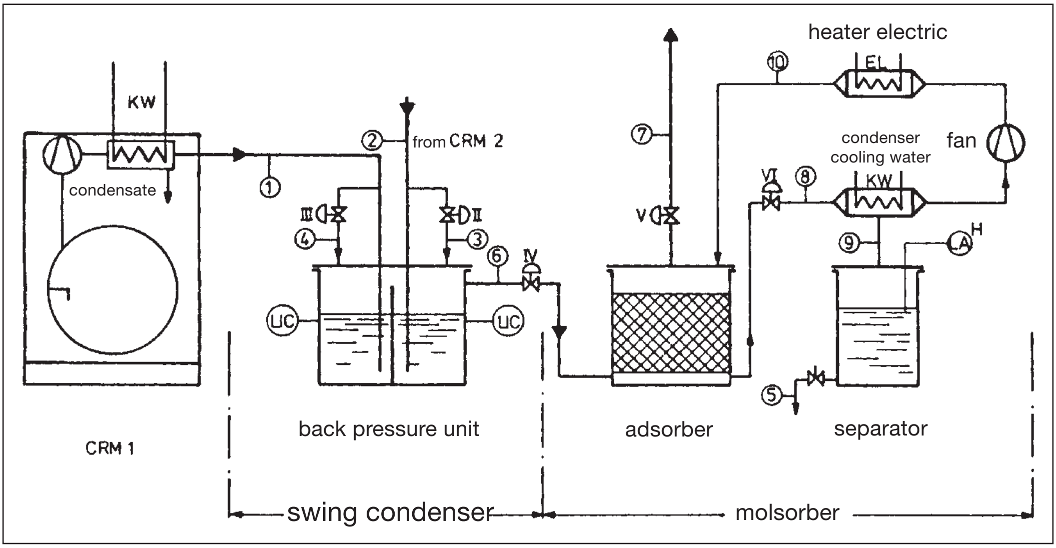


Fig. 7: Diagram showing the principle of the HKN process of the molsorber type.

erence. This air circulation forces the solvents out of the pores of the molecular filter and picks them up. After they have left the filter, they are cooled down in a heat exchanger, and the solvent vapours are condensed. The solvents flow into the separator, where they accumulate. The air circulation is sealed again, and the process is repeated. If solvents are recovered the heater switches itself off, and the plant is run cold as a sealed circuit (Fig. 7).

There are three aspects that are important for future cleaning techniques and associated textile requirements from a global point of view:

1. Effect of withdrawal of availability of CFC 113 (trichlorotrifluoroethane, which has been banned in Germany since 1991) as a solvent: so far the only solvent available as a replacement that can be accommodated in fabric care labelling is non-aromatic heavy benzine. As opposed to CFC 113, treatment with this type of hydrocarbon must be clarified on two points:

- drying must be carried out at 60°C, instead of 40°C, as was the case previously,
- the duration of dyeing is extended.

The resistance to temperature of sensitive textiles becomes a more important factor, as does the resistance to increased mechanical action.

2. Extension of the mechanical period where tetrachloroethylene is used as the solvent: taking into account the extent to which emission-reducing measures become established on a global basis, it should be assumed that the drying period could be extended by as much as 100%. Resistance to mechanical action takes on more importance.

3. Increasingly more wet treatment in commercial textile cleaning plants: “Wet treatment” should be strictly differentiated from household washing conditions. Specialist textile cleaning plants have washing machines and washing auxiliaries at their disposal that are designed to cope with the requirements of particular textiles. The number of revolutions, the direction of revolution, and the effective temperature can be adjusted appropriately depending on the sensitivity of a particular textile, and the optimum drum size can be used. Drying occurs at a temperature ranging from warm to hot, either with the article hanging up, or if appropriate, in a tumble-dryer, which is certainly a possibility for synthetic fibre textiles.

To establish whether cleaning in the future should be done using water or solvent, the following parameters should be taken into account:

- degree of soiling,
- tetrachloroethylene retention properties during drying,
- availability of tetrachloroethylene at commercial dry-cleaning plants.

Overall, wet treatments in textile cleaning will increase proportionally over the next few years. Dimensional stability and colour-fastness are gaining in importance. The current level of knowledge and constantly changing parameters mean that it is no longer a straightforward matter to decide whether to wash or dry-clean. Because of the current legal situation, both cleaning methods require cost-intensive extras, which applies in general to dry-cleaning with tetrachloroethylene or heavy benzine. For washing this applies in a more specific sense (particularly in the case of heavily soiled workwear).

Solvent volatility → Evaporation number.

Solvent/water interface In dry-cleaning and solvent finishing: where there is a solvent/water mix (e.g. tetrachloroethylene), the water proportion in the separation system, where the tetrachloroethylene, having a greater specific weight, separates from the lighter water. If the water separator is not functioning properly, there will be an odour of tetrachloroethylene, for instance. In dry-cleaning, the solvent/water interface accounts for approx. 10% of the fabric weight; however the tetrachloroethylene content can vary.

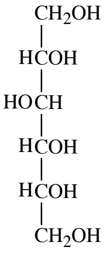
Sonator Sonic generator for rational generation of sonic waves (rhythmically generated surges 6000 per min) for intensive subsequent impregnation, wet aftertreatment, rinsing, and for more thorough dyeing of dense fabrics, seams, etc. If the working liquor is subjected to ultra-sonic pressure surges, the fabric is kneaded, which should achieve significantly better penetration within a short time, and is also gentle on the fabric.

Sonic velocity as a measure for exhaust air moisture →: Exhaust air moisture measuring systems; Fluidic oscillator.

Sorbate, Sorbent → Sorption.

Sorbitan fatty acid esters These are generated as a result of → Sorbitol (glucose alcohol) dehydration. The resulting anhydrous sorbitols are esterized with fatty acids. Depending on the fatty acid used, sorbitanes are water-soluble (palmitic acid and stearic acid) or dispersive (lauric acid and oleic acid), and they have excellent emulsifying properties.

Sorbitol Hexahydric alcohol. Manufactured by reducing d-glucose or dextrose derived from starch or maize. There are different forms: a) white powder or colourless needle-shaped crystals, melting point 100–120°C, easily soluble in water, pyridine, methanol, acetic acid, phenol, not so easily in cold alcohol; b) syrupy solution with 70–80% sorbitol content, density greater than 1.26, neutral, non-reducing, odourless, non-toxic, sweet taste.



$$\begin{array}{c} CH_2OH \\ | \\ HCOH \\ | \\ HOCH \\ | \\ HCOH \\ | \\ HCOH \\ | \\ CH_2OH \end{array}$$

Application: alternative to glycerine for sizing, finishing, dyeing, printing; for plasticizing rubber and glue; for softening the gelatinous layers on print rollers.

Sorption Addition, uptake. The substance carrying out the sorption is known as the sorbent, and the substance undergoing sorption is known as the sorbate.

I. Adsorption: enrichment of a substance in the interfacial layer of two adjacent phases. The components being adsorbed are known as adsorptives, and the solid interacting with the adsorptive is known as the adsorbent. In the adsorbed state, the adsorptive phase that is held onto the surface of the adsorbent by adhesion becomes the adsorbate. The opposite process, the release of the adsorbate, is called desorption.

II. Absorption: inclusion of a substance into the chemical structure of another substance, during which the interface between the phases is lost. As well as physical absorption, there is also chemical absorption, in which a chemical bond is formed at the interface.

The word sorption is used for processes in which it is difficult to distinguish between absorption, adsorption, chemical sorption and physical sorption, or if absorption and desorption are indistinguishable as separate processes.

Sorption isotherms Graphical representation (→ Isolines) of a fibre sorption situation, e.g. for water (vapour) from the surrounding air, for non-ionic dyes as a constant distribution between the liquor and fibre/ dispersion dye (→ Nernst's distribution law), for ionic dyes on fibres with ionic groups as isothermic dependency on concentration and pH (Langmuir isotherms), for ionic dyes on fibres with non-ionic groups using the empirically-identified adsorption isotherm (direct dye on cellulose: Freundlich isotherm).

Sorrel salt → Potassium tetroxalate.

SOTP "Second Order Transition Point", temperature limit for synthetic fabrics, which is below the melting point, above which there are no further significant changes to loss of breaking strength, degree of shrinkage and fibre elasticity at treatment temperatures. Strongly crystalline fibres have a low melting point, and less crystalline ones have a high melting point, such as:

polyester fibre	79°C
polyamide fibre	79°C
wool	> 120°C

Sound From a physical point of view, sound consists of mechanical oscillations in an elastic medium. The occurrence of sound is linked with the existence of material. Sound can occur in solid bodies as well as in a liquid or gas medium. Sound that uses air as its medium is the most common form of sound in everyday life. It can be triggered as a direct result of activating a solid body, as long as the oscillating bodies are in contact with the air, and an effective contact with the air is possible. Air particles that have been triggered to oscillate, in turn activate further adjacent particles, and so on. This results in a periodic sequence of the air becoming denser and thinner, and spreading out in waves. At certain intervals, the same activation status repeats itself in

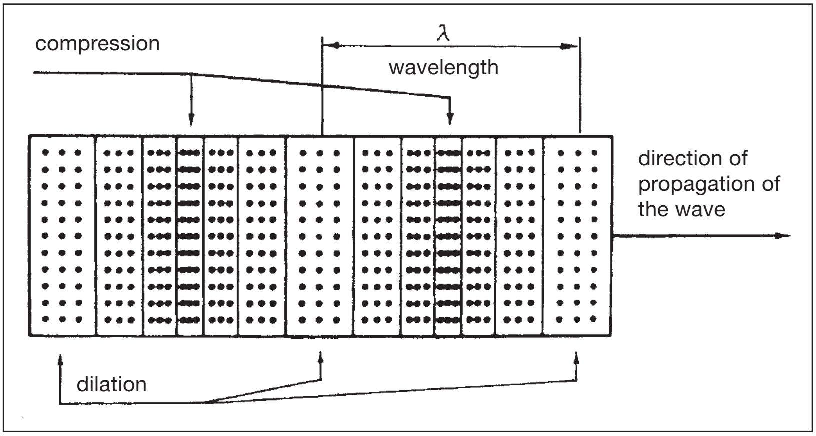


Fig.: Diagram showing the propagation of sound in the form of a longitudinal wave.

the direction of propagation of the wave movement. Since particle excursion follows the wave dissipation direction, it means that the resulting waves are longitudinal in direction.

The activity originating from a point source of sound spreads out in all directions in space. All particles that are the same distance from the sound source are on the same point of a spherical shell and have the same phase length (spherical waves). This type of wave is always found in close proximity to the sound source. Further away from the source, small parts of the spherical shell converge in planes (plane sound wave). If the oscillating air particles are replaced by highly elastic mass points for experimental purposes, the situation shown in the Fig. arises.

If the chronological sequence (frequency f) of activation is constant, it means that the interval between two states of activation of the same type that follow on from one another is of an equal size. These intervals are the wavelength λ. The product of the frequency and the wavelength gives the speed of dissipation.

The speed of dissipation is a characteristic value for each substance, and in the case of gases it is dependent on pressure, density and other factors. Where the air pressure is normal and the temperature is 0°C, this speed is 332 m/s. At the upper limit of human hearing at approx. 18 kHz, the corresponding wavelength is then approx. 1.6 cm. It is possible to generate ultra-sound waves at frequencies of up to 10^9 Hz (hypersound). The length of the path in air is approx. 0.6 µm (path length of visible light, average free wavelength of molecules in the dissipation medium). When sound dissipates, the particles only oscillate about their equilibrium positions, there is no further directional movement. During wave movement, the particles are only responsible for spreading the sound energy, no transmission of material takes place.

The space filled with material in which the sound dissipates, is known as the sound field. The sound field can be described quantitatively by means of sound field dimensions, based on which the speed of the sound is the speed at which the wave dissipates in that area. In contrast to sound speed, sound velocity expresses the speed at which individual particles in the sound field move about their positions of equilibrium. Both these measurements describe different physical situations. In air, the oscillating air particles manifest themselves as a chronological change in air pressure. The changes in pressure represent the changes in acoustic pressure, which by definition is the deviation of the overall pressure from the state of equilibrium. The acoustic pressure, a measurement that is subject to change, overrides normal atmospheric pressure, and has a chronological value of zero. The sound of normal speech at a distance of 1 m from the speaker causes an acoustic pressure of approx. 10^{-2} to 10^{-1} N/m^2 (according to Schollmeyer).

Sound-absorbing panels Usually made of cork or composites, designed to absorb noise, in other words, to lower the noise level.

Sound insulation Acoustic protection and heat insulation in modern buildings, achieved by means of floor coverings (carpets).

Sound level (sound pressure level), expressed on a scale in dB = decibels ($^1/_{10}$ bel). Human hearing ability forms the basis for measurement, which has a sound pressure range starting at the minimum audible level of $2 \cdot 10^{-5}$ Pa (Pa = Pascal) up to the pain threshold at $2 \cdot 10^2$ Pa (at 1000 Hz). → Industrial noise pollution.

Sound level measurement The German industrial standard for noise measurement applying to machinery and driving units is DIN 45 635. Fig. 1 shows an example of how points are arranged for the measurement of noise emission for a textile machine in line with DIN 45 635 T32, where the measured distance from the machine represented here with the letter d is usually 1 m.

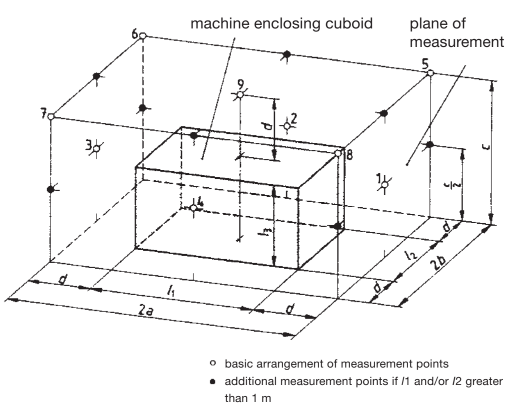


Fig. 1: Sound level measurement: the plane of measurement, the locations and the total of measurement points meet the requirements of DIN 45 635 T 32 for textile machinery up to 2 metres in height.

The sound pressure level is usually measured according to evaluation A. This sound pressure level L_A is defined as the time/space-related sound pressure level evaluated according to A, recorded on the enveloping surface of an imaginary cuboid at a distance of one metre from the surface of the drives. If necessary, this measurement must be corrected to compensate for external noises and influence factors caused by the room itself. The acoustic capacity level L_{WA} [dB(A)] can be calculated by the addition of the dimension L_S to L_{PA} using the following equation:

$$L_{WA} = L_{PA}\ 1\ m + L_S$$

The following applies for the average value of L_S: approx. 10–12 for smaller drives up to 3 kW, and for larger drives up to 100 kW approx. 12–15. This can be used as a basis upon which to predict noise development (Fig. 2). It is becoming increasingly easy to obtain definite information from the manufacturers of the machinery. The VDI directive 2159, which was developed to cover toothed gearing and also includes quality classification, provides guidelines on the state of the technology (VDI is an abbrev. for the Society of German Engineers = Verein Deutscher Ingenieure). There is also the VDE standard 0530, containing specifications for electric motors. An overview is available for some types of helical gearing, taking this standard into account. The overview shows that the gears conform to the VDE standard, and that it is possible to implement categories B and C of the VDI directive (high and very high rate of production).

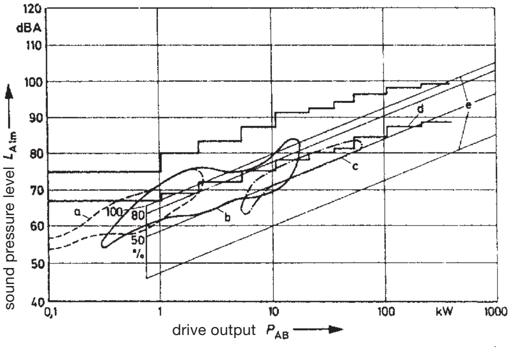


Fig. 2: The sound pressure levels of different drive systems. a = spherical washer drive; b = laminated chain drive; c = all-metal contact drive; d = permitted level according to VDE 0530 for surface cooled motors; e = quality classification according to VDI 2159.

The following steps must be followed to establish the acoustic capacity level:

- recording of the machinery noise level at each point of measurement L'_{pi}
- calculation of the mean value L'_p
- recording of the external noise at each point of measurement L''_{pi}
- calculation of external noise correction K_1
- definition of environmental correction K_2 (e.g. using a comparative sound source or measuring the echo interval)
- calculation of the sound pressure level for the area being measured
  $L_p = L'_p - K_1 - K_2$
- calculation of the area being measured L_s
  $L_s = 10 \cdot \lg S/S_0$
- calculation of the acoustic capacity level
  $L_w = L_p + L_s$

Furthermore the standard usually requires definition of the emission value in relation to working areas, for one or more workstations allocated to the machine. For most textile machinery, a measurement at a distance of 0.5 m from the machine profile, and 1.6 m in height is defined in the appendices to Part 32. The value obtained must be corrected to compensate for external noise (K_1) and environmental influences (K_2), in the same way as the sound pressure level for the measured area.

For some other types of machine, an "indirect" process is described for defining the emission level with respect to the working area, which enables the acoustic capacity level to be used for calculation. This process is basically the same as the calculation of the sound pressure level for the measured area L_p for a specific distance, e.g. 0.5 m, by subtracting the appropriate dimensions from the acoustic capacity level. This method is particularly advantageous for measuring compact hand tools, because the dimensions of the measurement area can always be given as a constant value (the measurement area is the same for all types of machinery). The emission value relating to the working

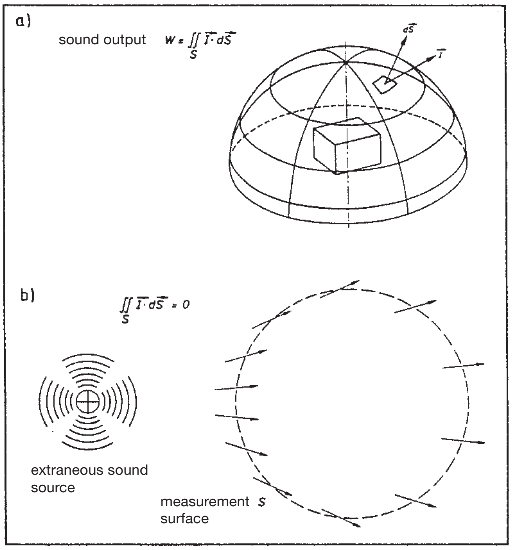


Fig. 3: Determining the noise emission from a machine by the measurement of sound intensity.
a) on the measurement surface S; b) suppression of an extraneous source of noise lying outside the measurement surface.

area can therefore be calculated by subtracting one of the constant values published in the measurement regulations from the acoustic capacity level.

Since noise measurement can often not be carried out until the machine has been installed at its permanent location, and under comparatively unfavourable environmental conditions, the conditions of measurement stated in DIN 45 635 T 1 and the corresponding ISO standard can not always be adhered to. It is only possible to correct environmental influence factors and the effect of external noises up to a certain point. To tackle this problem, there are ways of using measuring devices based on sound intensity measurement technology, which allow the recording of noise emission from machinery independently of environmental influences, even where the external noise level is relatively high. Specialist measuring devices are necessary for sound level intensity measurement. They usually consist of a measurement probe with two sound pressure microphones that can measure the energy flow of the sound using vectors, i.e. taking both quantity and direction into account. This means that the non-directional diffused proportion of the sound (environmental influence) is not included in the measurement. External noise influence is eliminated by measuring in the usual sealed area (Fig. 3), as long as the external noise level remains constant during measurement.

Sound pressure (acoustic pressure, sound pressure change), refers to the periodical changes in pressure that occur in a sound wave. The unit of measurement is Pascal.

Soundproofing Achieving reduction of noise emission is a significant aspect of textile machinery construction. In order to achieve this successfully, the construction engineer has to assess the noise level generated by individual components of the machine during the design phase, and when the machine is under construction he has to implement specific measures to combat noise. To design low-noise machinery, it is essential to have knowledge of the principles of machine noise emission, the physical context, and the rules governing low-noise construction.

Noise can be defined as any type of sound that constitutes a disturbance or a nuisance to people, or is detrimental to health. Machine noise falls into two categories, depending on how it is distributed – airborne sound and solid-borne sound. If the airborne sound is generated directly by sound oscillations caused by a flowing medium, a combustion and explosion process, or the sound of an explosion, it means that it is purely airborne sound transfer.

Examples of airborne sound generation:
- air flow,
- flow around edges and rods,
- suction and exhaust openings,
- flow in pipes,
- rotating parts,
- belt drives or blowers and ventilators.

If the sound is transferred indirectly, i.e. oscillation is first triggered in a solid body, which then transmits the oscillation onwards causing airborne sound to radiate from its external surfaces, it is called solid-borne sound. Solid-borne sound in machinery is generated when solid bodies collide, e.g.
- stopping,
- meshing,
- cam/tappet.

As a result of interactive forces on machinery components, e.g.
- bearings,
- cam gears,
- chains,
- couplings,
- brakes,
- friction wheel gears.
- mass forces caused by an out-of-balance situation.

As a result of interactive forces involving a sealed medium, e.g.
- hydraulic equipment,
- pneumatic equipment.

Noise development in machines is primarily influenced by changing the applied forces and their ranges, and secondly by preventing sound from dissipating. For solid-borne sound, the solution is to insulate and dead-en the machine parts, for instance by encapsulating them. With textile machinery in particular, the noise is caused by a large number of moveable parts and comes from various different sources. The total volume of two equally loud sources of sound is only 3 phon higher than a single one. For this reason, anti-noise measures must always be applied to the loudest noise source of a machine. Any measures applied to the lesser sound sources will make no difference to the overall level as long as the loudest source remains unchanged, because the loudest source determines the overall level. → Noise protection.

Sour off Adjustment of pH after alkaline processes, using acids, usually to pH 7 (neutral).

Southern Regional Research Center (SRRC). American organization for textile research; part of the Agricultural Research Organization, and therefore also representing cotton cultivation and Research into Textile Use for Cotton. → Technical and professional organizations.

Soybean oil Semi-drying oil obtained by pressing or extraction from soya beans; brown to greenish-yellow, odour/taste similar to olive oil. Easily soluble in ether. Saponification number 189.5–212.6; no non-detergent fatty matter. Use: oil sizes.

Space dyeing Sectional printing or dyeing of yarn and cable in varying stages of processing, various colour shades, as well as in different intervals and lengths. In space dyeing it is scarcely possible to differentiate between dyeing and printing. The space dyeing process provides an opportunity to create interesting types of pattern. Multi-coloured, irregular motifs and imaginative effects on the fabric can be achieved by using yarn with partially bordered patches of colour. The washed-out looking, asymmetrical patterns on upholstery covers and domestic textiles (floor coverings) are particularly dominant. Also, this type of printing also occurs in knitwear and ladies'/gentlemen's wear made from multi-coloured yarn. Outerwear made out of multi-coloured yarn is always dependent on current fashion, and for this reason they only appear on the market at irregular intervals. Depending on the process, the patterns produced are either reproducible or random, which can not be reproduced identically. Space dyeing is the collective term for several different types of process (continuous or discontinuous), which usually carry an imaginative brand name.

There are 6 different groups for yarns, each with different working methods:

I. Printing on knitwear: The knit-deknit process is the most economical space dyeing process, and it has gained much importance at an international level. The process was patented by the F. Whitaker company, Philadelphia (USA). The following manufacturers have produced machines under this patent: Fleissner (Germany), Murphy (USA), Ilma (Italy), Radici (Italy). The principle of this process is based on applying the dye liquor onto tubular knitted fabric. First a tubular knit is manufactured, which is then sent to the printing machine as a batch for ground dyeing, where the first stage is passing it through the padder for ground dyeing. It is always the palest colour in the required colour scheme that is applied during the padding process. The next stage is to print the required patterns and colours onto the tubular fabric with print rollers, using the wet-on-wet printing process. The print rollers have a specific pattern (engraved or relief), to avoid patterning faults after tufting. The most common type of machine used for this purpose is the duplex printing machine, which prints both the upper and lower sides of the tubular fabric at the same time, because with normal print rollers it is not possible to achieve good print penetration. After the printing process there is a continuous fixing process in saturated steam, after which the printed fabric is washed and dried. Finally the printed tubular knit is rewound, and it has crinkle arcs in the knit layers that are not set fast. The type of crinkling is dependent on the stitch size of the fabric knit. If the crinkle arcs of the thread are not required they can be removed. The wound yarn is then batched onto cones and routed to the tufting machine. The knit-deknit process (Fig. 1) is primarily used for coloration of floor coverings.

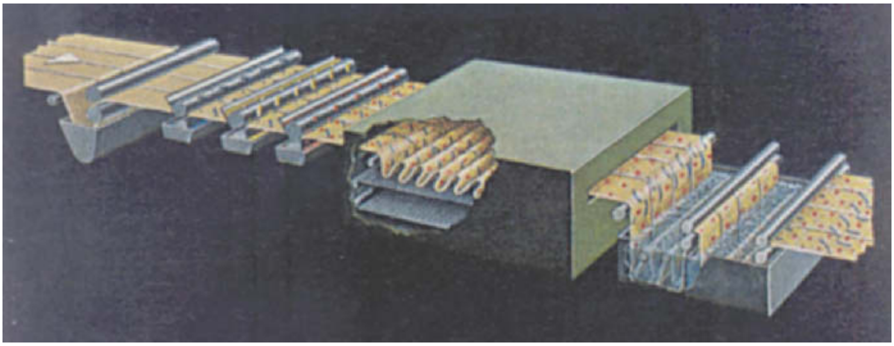


Fig. 1: The knit-deknit process (by Bayer).

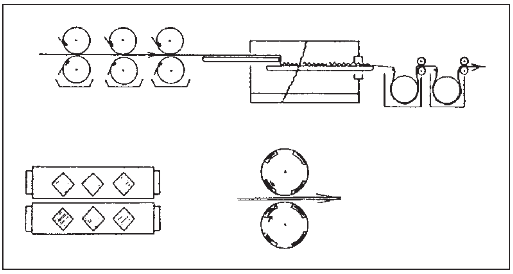


Fig. 2: A Fleissner space dyeing machine.

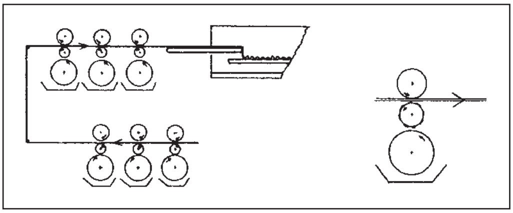


Fig. 3: A Murphy space dyeing machine.

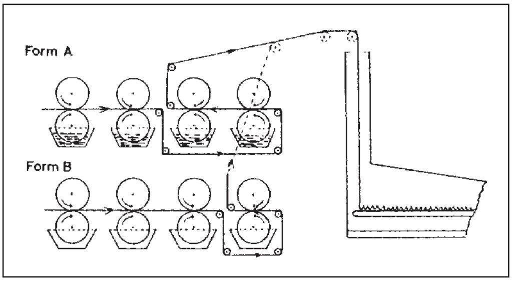


Fig. 4: An Ilma space dyeing machine.

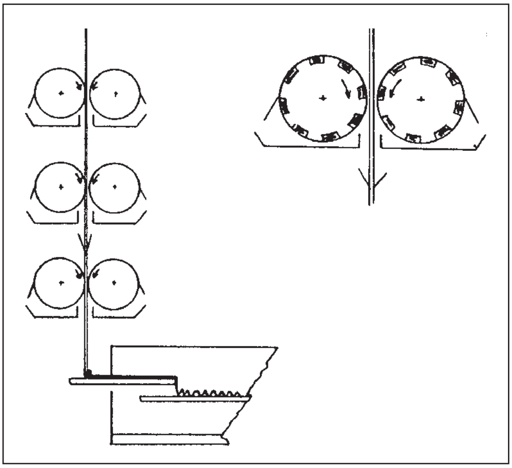


Fig. 5: A Radici space dyeing machine.

The main factor that differentiates between the types of process is the different printing systems used, i.e. the print rollers and their arrangement. The rollers can be manufactured from steel, rubber or wood. If steel print rollers are used, the patterns are engraved, if they are made of rubber, the patterns are embossed in the form of a full rubber relief facing of the rollers, or with wooden rollers, foam rubber patterns are stuck to the rollers. Depending on the type of machine, either both sides of the fabric are printed simultaneously, or first one side is printed and then the other. The arrangement of the print rollers is dependent on the machine, and can either be horizontal (Figs. 2–4) or vertical (Fig. 5), and this is a significant factor for print precision.

II. Warp printing: This is another space dyeing method that is used globally, and its characteristic feature is that warp yarns can be both padded and printed. In the Laing process (Fig. 6), warp yarns (up to 500 threads running concurrently) are first padded (in the same way as the knit-deknit process) and subsequently printed. There are two rollers of different sizes for printing, and the lower of the two, which is the smaller, is positioned so that it dips into the dye trough. The dye paste is only transferred to the yarn when the relief patterns on the upper and lower roller meet together, so that a perfect pattern profile is guaranteed, without any patterning faults, during the subsequent tufting process. If the print roller pairs are arranged in series, multicoloured effects can be achieved. The warp yarn is continuously steamed after printing, and it is then washed, dried and wound onto section beams.

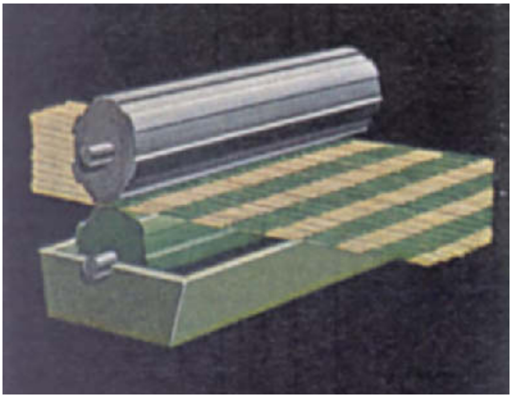


Fig. 6: The Laing process (by Bayer).

The Stalwart system (Fig. 7) is similar to the Laing process, the main difference being that smooth rollers are used instead of relief rollers. With this system, the lower roller is also positioned to dip into the dye trough. The dye paste is only transferred to the required point on the yarn when the upper and lower rollers are

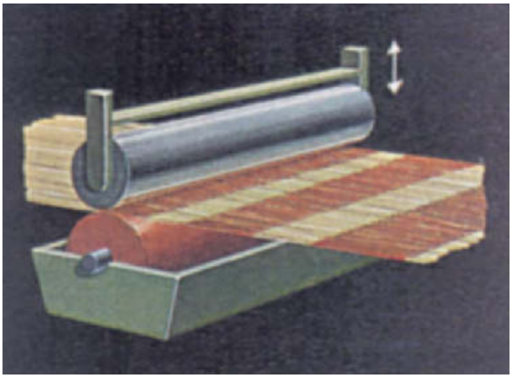


Fig. 7: The Stalwart system (by Bayer).

pressed together, until the upper roller lifts again. The print contact time governs the length of the colour stripes – a shorter contact time produces a shorter stripe, and vice versa. It is possible to set up a series of several printing machines. This equipment can be used to manufacture long space patterns on a large scale, or self-shades.

The Martin process is also comparable with the Stalwart system. However, this process does not just use a single smooth roller per colour for printing the entire width of the warp yarn; instead it uses several rollers that can be operated independently of each other. This provides scope for greater variation.

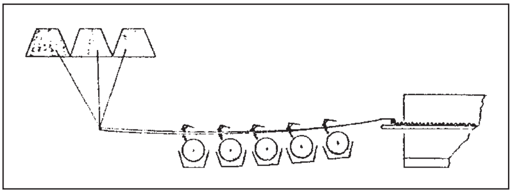


Fig. 8: A Fleissner space dyeing machine for threads.

The Fleissner space dyeing process (Fig. 8) has a certain level of similarity to the Martin process. Warp yarns are printed with the space effect in this process as well. The yarn, depending on pattern, is pressed onto the dyeing rollers by means of impulse controlled irons, where it is wetted with the dyeing liquor (printed). Depending on the yarn speed, the impulse control can determine the length of printed colour stripes. The maximum possible number of colour print rollers that can be used at any one time is six. After the printing process, the yarn is set in a perforated steamer using saturated steam.

The equipment used for Zaza printing (Fig. 9) works on the principle of a Vigoureux printing machine. The warp yarn is passed between an upper relief roller and a lower felt roller, which is supplied with dye paste from the dye trough via a rubber roller. The relief rollers can produce geometrical repeated patterns as well as horizontal and diagonal stripes. In sections where the raised areas of the relief press the warp yarn onto the felt rollers, the dye passes through the yarn from below through to its upper side. In this situation, the relief roller only has patterning properties. The machine operates with four pairs of rollers, in other words five colour shades can be produced including the ground colour and the four shades that can be printed onto the yarn. The Zaza system is mainly used for space dyeing fine titre yarn for outerwear and knitwear.

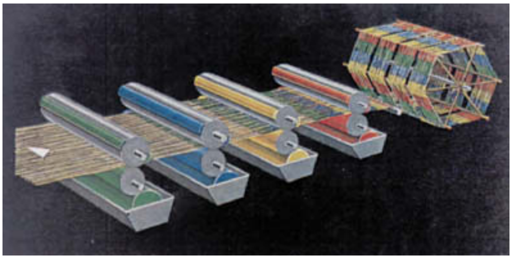


Fig. 9: Zaza printing (by Bayer).

Using the SWA space dyeing process (Fig. 10), it is possible to print warp yarns with up to 40 threads at an operation speed of 110–115 m/min. The dye liquor is applied by means of a metal roller that transfers the dye liquor in the trough onto a felt roller. Above the felt roller there is a smooth roller, the upper roller (which can also be substituted by a relief roller with a regular pattern sequence). The yarn passes between the felt roller and the upper roller; if any dye paste needs to be transferred, the upper roller is pressed onto the felt roll-

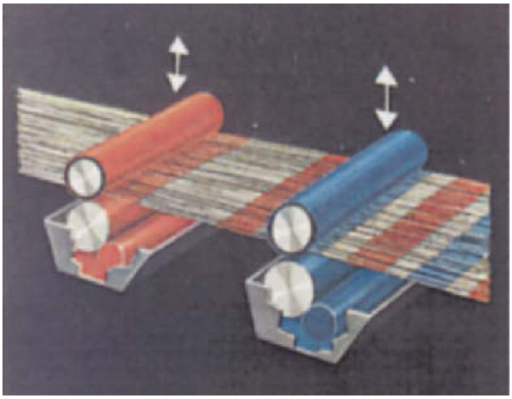


Fig. 10: An SWA space dyeing machine (by Bayer).

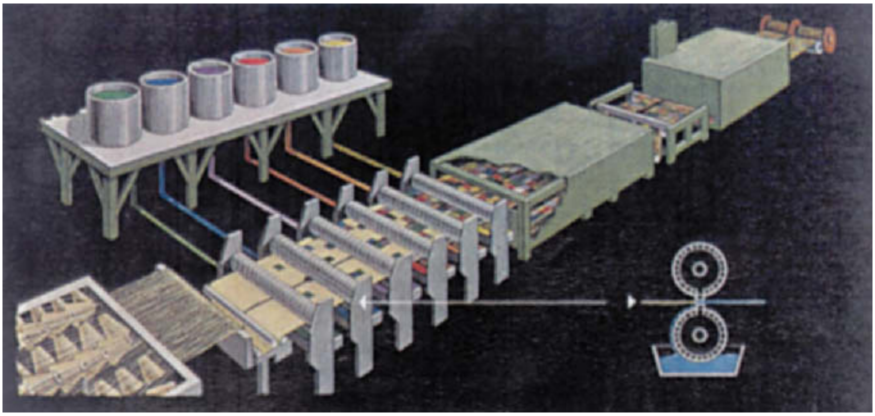


Fig. 11: The Crawford-Pickering multicolour process (by Bayer).

er. The print process is controlled via a monitor, which communicates the required impulses to the print rollers. A separate print unit is required for each dye paste applied. After printing, the yarn is partially dried in a hot air duct and then wound. The dyes are set in saturated steam.

With the Crawford-Pickering multicolour process (Fig. 11), patterns can be applied to warp yarn with a high level of precision, for the production of tufted carpets. It operates according to the principle of a continuous programmed print. In the printing system, each colour paste (usually 6 shades) has an allocated print unit, consisting of two rollers positioned vertically over each another. Both rollers are equipped with a large number of mechanically controlled stamps. The lower roller is for the purpose of applying the paste, and the upper one provides resistance. Each stamp on the dye roller prints 4–5 threads at a time. After the continuous steaming, washing, vacuum extraction and drying processes, the yarn is divided up into threads printed by the same stamp onto 4–5 identical beams, each with a total of 126 threads. If a tufting machine with 5/32 inch partitioning is used, 126 threads will result in a pattern repeat of 50 cm. If the process is combined with a patterning system, it is possible to apply the design to the carpet with the same level of precision.

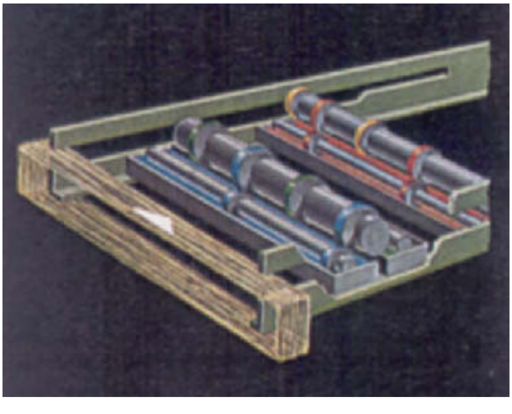


Fig. 12: A Timmer hank yarn printing machine (by Bayer).

The entire process, from carpet design to pattern printing can be exemplified as follows: A geometric pattern is tufted so that a 4 cm length of thread results in a 1 cm pattern length in the finished carpet. The printed pattern has pulled together after tufting with a ratio of 4 : 1.

III. Hank yarn printing: The Timmer hank yarn printing machine (Fig. 12) can be used to print woollen, polyamide, cotton, viscose and silk yarns in hank form. The printing process is divided into four phases, and $^1/_4$ of each hank is printed in each phase. The hanks are automatically moved lengthways, so that the next quarter of that phase can be printed. Moving along in a crosswise direction and pausing are also controlled automatically. In this way, the hanks are guided 4 times through four pairs of rollers. Patterns can be created by means of colour combination, and by printing patterns onto the hank yarn using the rollers. Care should be taken that only the specified hank size (1371 mm) is used. Any differences can be bridged up to 50 mm.

The VH-Syn-O-Flow process (Fig. 13) enables multi-colour dyeing of yarn in hank form in a single process, in contrast to the previous system. The hanks are arranged moderately densely around a stainless steel drum provided with a slit. In this way, 60 separate colour stripes in any combination can be applied to the hank. The dye is applied automatically, by applying the dye liquor to the hank yarn through the slit in the stainless steel drum. All the dye liquors being used in the process are applied at the same time. The dyeing process lasts approx. 30–90 s, depending on the fineness of the yarn. After dyeing, the yarn is removed by hand and set, depending on the dye used. The total machine charging process takes about 5–6 min. The machine capacity is approx. 50–75 kg/h.

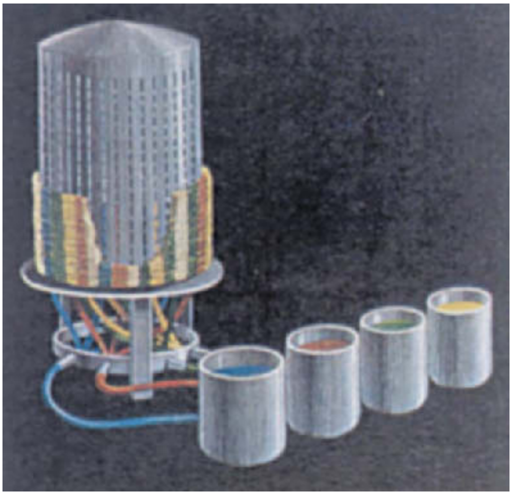


Fig. 13: The VH-Syn-O-Flow process (Hendricksen) (by Bayer).

A multispace dyer (Fig. 14) is a plant for continuous dyeing and steaming of yarn and hank yarn. The essential machine components are:

- jet beam with 40 jet nozzles (the distance from the yarn is variable),
- steel perforated conveyor belt,
- steamer,
- exit table,
- four dye containers to supply the jets with dye liquor.

For the dyeing process, the yarn hanks are arranged on the conveyor belt one after another, at right angles to the direction of transport. They are then passed beneath the jet bar, which sprays 40 jets of dye liquor at the yarn. Stripes are produced on the hanks, which are perpendicular to the hank length. Space dyeing effects using four or five colour shades can be created, including the ground colour of the yarn. If two or more adjacent jets are charged with dye liquor in the same colour, broader stripes in that colour will result. Full penetration dyeing of the hanks can be controlled by the amount of liquor, viscosity and auxiliaries used. After dyeing, the hank yarn is carried through the steamer on the perforated belt, where it is steamed for 6–8 min. Immediately after steaming, a continuous or discontinuous scour and scrooping are carried out. The performance capacity is 200–280 kg/h. This type of plant is an alternative for smaller carpet manufacturers, both from a qualitative and a quantitative point of view, because of the relatively low space dyeing costs.

IV. Multi-colour effect on individual threads: it is inexpensive to set up the equipment to achieve this effect, however the production capacity is not sufficient for it to be able to compete against knit-deknit space dyeing and warp yarn processes. For this reason it is used for outerwear and hosiery.

The Eastern Colour Yarn Dyeing process (Fig. 15) provides a method of partially dyeing yarns using a centrifuge supplied with dye liquor. For dyeing, the yarn is rapidly unwound from a reel, routed past 1–3 dyeing centrifuges, sprayed and rewound (yarn winding machine principle). In the next stage, the yarn is shock-heated and rewound again. Setting is carried out by steaming. Up to three colour shades are possible, because there are three centrifuges arranged one above the other. This process is used exclusively for the outerwear and hosiery sectors.

The Superba process (Fig. 16) is similar to the previous process, but the dye liquor is applied vertically as the yarn is routed past on rapidly turning centrifuges. The drops of dye liquor that are spun out hit the yarn and produce small spots (speckled effect). 8 threads can be processed at a time. If longer spaces occur, perforated discs can be used. The decisive factors in this technique are the length of the perforations, the number of revolutions of the centrifuge, and the dyeing speed. The

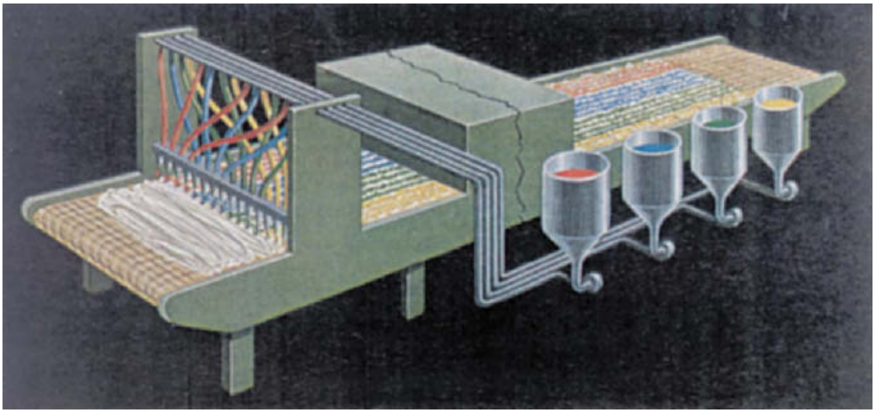


Fig. 14: A multispace dyer (Callebaut de Bliquy) (by Bayer).

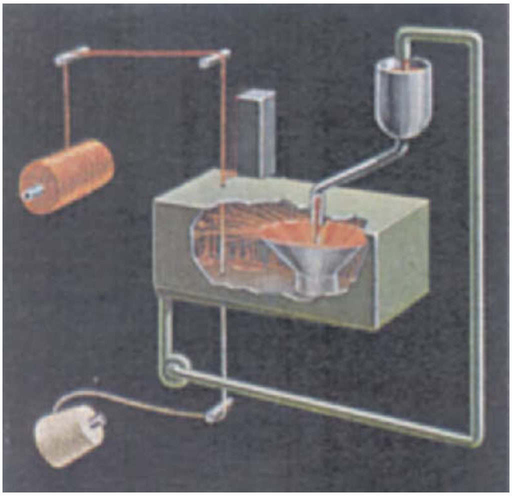


Fig. 15: The Eastern Colour Yarn Dyeing process (by Bayer).

Fig. 16: The Superba process (by Bayer).

maximum yarn speed possible is 800 m/min, at which speed it is possible to apply three colour shades using three centrifuges. After the dyeing process the yarn is plaited up in spirals on 4–8 perforated belts, and it passes through the setting chamber and drying box in this arrangement. The important aspect of this technique is that in most cases no aftertreatment is required since thickeners are not usually necessary. Depending on the planned subsequent processing, the yarn is wound straight onto large cones or put into cans (one can per thread). Yarns dyed using this method are made into outer garments and used for the microspace in tufted carpets.

The OPI process (Fig. 17) is used to create reproducible space dyeing effects on yarn. The length and spaces of the spray effects are variable using this method. There are three different functions in the process that produce the effects:

1. Spraying the dyeing liquor onto the yarn, which runs at speeds of up to 1000 m/min.
2. Removal of water from the soaked yarn using specially designed compressed air jets.
3. Dye setting using steam.

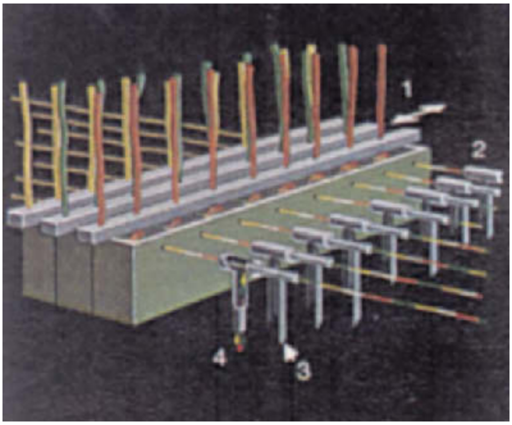


Fig. 17: The OPI process (by Bayer).
1 = nozzle bars; 2 = squeezer device; 3 = compressed air; 4 = excess dye.

The space dyeing effect is created by moving a jet beam back and forth. Each jet beam is equipped with 8 jets, and is positioned at a perpendicular to the direction of thread run. Depending on the required colour arrangement, up to three jet beams can be used in series, to enable rapid changeover between three colours, or so that 2–3 colours can be applied simultaneously. The equipment can be adjusted to create long and short space dyeing effects, which are dependent firstly on the running speed of the thread, and secondly on the speed of the alternating movements of the jet beams. These two factors can be adjusted independently of each other, providing the option of unlimited variation depending on how they are adjusted. The machine operates at speeds of 1000 m/min. Moisture is continuously removed from the thread by means of compressed air, which is done by passing the thread through a tube sealed by special jets. The pressure of 24 Pa ensures that superfluous dye liquor, when the thread enters the jet, is forced out. The advantage of this principle is that the outline of the sprayed colour area remains clear-cut because the water is removed suddenly. For this reason the dye liquor can be applied without using thickening agents, rendering scouring unnecessary. The water has been removed from the yarn to such an extent that it can be wound without the need for an interim drying process. After winding there is a continuous steaming process, followed by drying and rewinding. The OPI system does not occupy much space, and it operates at a high production rate. Because of this, there are several possible points in yarn processing where it could be incorporated, such as before a rinsing machine or before setting equipment, in other words continuous operation is possible.

Parallels can be drawn between the operation techniques used in the Unitika-Mixy process (Fig. 18) and Eastern Colour Yarn Dyeing, as well as with the Superba and OPI systems. Before the yarn is sprayed with dye liquor, it is stripped at high speed (up to 550 m/min) and heated. Then it is dried and rewound. The setting process is carried out discontinuously in saturated steam. Multi-colour effects as well as self shades can be created on the same equipment.

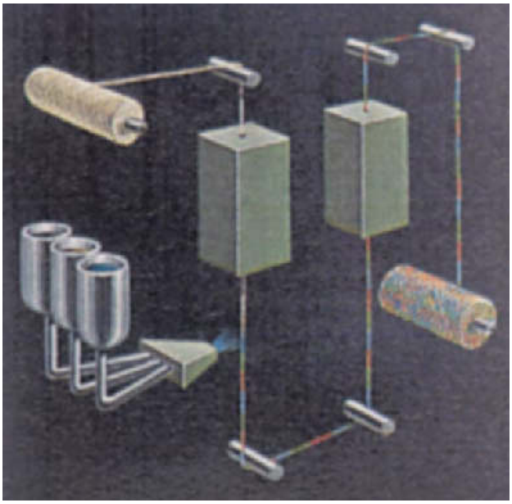


Fig. 18: The Unitika-Mixy process (by Bayer).

The Hörauf process (Fig. 19) can be used to create the space dye effect by means of a liquor application system that is relatively easy and safe. A pump for each dye liquor is used to spray a jet of liquor onto the yarn, which is running past at a high speed. The jets are interrupted by rotating punch tapes. Depending on the length of the spaces, perforated discs are used. The determining factors for creating the space area are the length of the perforation and the interactive control of the three spray stations. The process (which in this respect is similar to the OPI process) helps to reduce the level of applied dye liquor after spraying to meet the required liquor uptake percentage. As 2–3 dye liquors are applied consecutively, all the surplus liquor is simply removed. It is not possible to re-use it in the system. After the application of liquor, the yarn arrives at the winding device (and setting device), which is a Buddecke system. There are two or four continuous rubber belts that transport the yarn in a tension-free state along a cloth beam at right angles to the direction of transport through the steamer. The dwell time in the setting chamber is variable, depending on the winding density and yarn type. Finally the yarn is stripped off the carrier and wound onto reels. Any aftertreatment, such as washing and scrooping, can either be carried out continuously or separately depending on the type of machine.

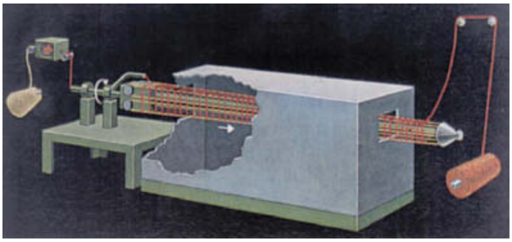


Fig. 19: The Hörauf process (by Bayer).

The Hirschburger process (Fig. 20) operates on the same principle as the Hörauf process, but in this process two threads can be wound simultaneously with one winding head. In the Hörauf process the beam is rigid, but in the Hirschburger system the beam rotates about its own axis. This method of construction means that no squeezing, vacuum extraction or jetting off of surplus liquor is necessary after liquor application. The winding head has three speeds of operation, adjustable between 600–1000 m/min. In this process the dwell time of the yarn in the steamer is also dependent on winding density, as well as the type and strength of the yarn.

The essential feature of the Spirovap space dyeing system (Fig. 21) is the perfect path of the plaited yarn along the conveyor belts. Up to 8 threads are plaited up in spirals on a perforated belt. A second belt covers the yarn from beneath at the turning point, so that the yarn

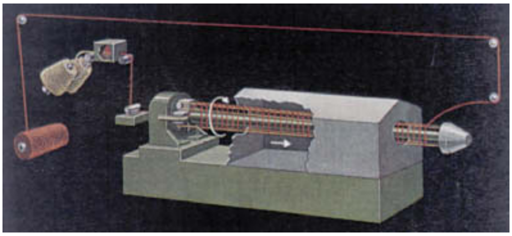


Fig. 20: The Hirschburger process (by Bayer).

is transported between two belts and any changes in direction will not affect the yarn. While the yarn is being transported in this way, it is printed from underneath with four print roller units. Next it is passed through the steamer, and the upper perforated belt is changed. There is a separate perforated belt for printing, and a belt for steaming. When the yarn has passed through the steamer it is rewound. The system has a maximum operating speed of 550 m/min.

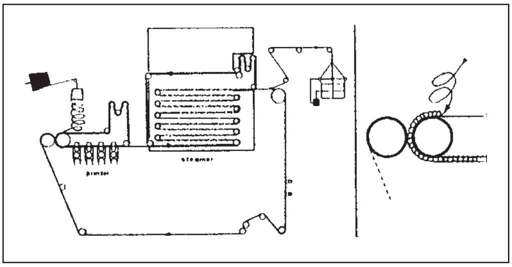


Fig. 21: A Spirovap space dyeing machine.

The Unispace process (Fig. 22) is used for treating manufactured garments as well as yarns in hank form or from a yarn package. 12 threads from the bobbin creel are fed simultaneously through the humidifying system, over the yarn plaiting device and piled up in layers to a certain height on a small printer's blanket. Once the yarn hanks have been treated they are spread out on the printer's blanket. For printing, the layer of yarn or fabric is fed slowly through the printing system (print saturator). The print saturator consists of print rollers that are equipped with several horizontally moveable jets, which are electronically programmed to charge the rollers with dye liquor. After spraying, the yarn is transferred from the print blanket to the conveyor belt, where it is plaited up and passed through the steamer. After the steaming process, the yarn is rinsed and squeezed off by a compressed air process. 12 threads at a time are plaited with a yarn plaiting device and then passed through the dryer. Finally the threads are rewound individually.

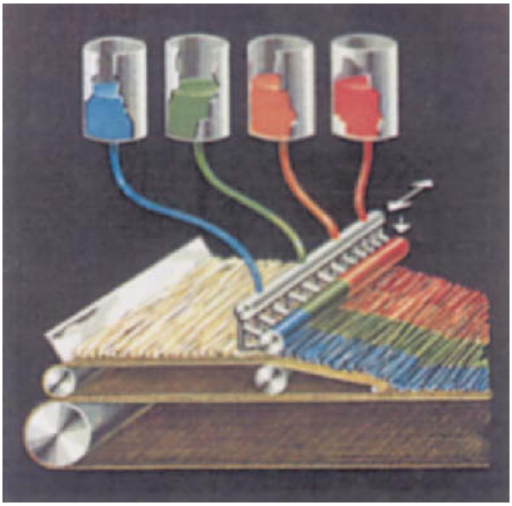


Fig. 22: The Unispace process (by Bayer).

V. Multi-colour effect on hank yarn: this can be achieved by using ombré dyeing techniques, for example. With this method, the first stage is to dye yarn hanks completely with the lightest colour shade, and then dip-dye them in a second dye liquor. The process can be repeated using a further liquor. Dye setting is done in the dye bath, since dyeing is done at boiling temperature. Usually two different colour shades are applied using this technique. Care should be taken that the boundaries between the individual colour shades are as sharp as possible, so that one shade does not blur into another. Ombré or shaded effects are highly dependent on current fashions and for this reason they only appear on the market from time to time, particularly in hand-knitted goods.

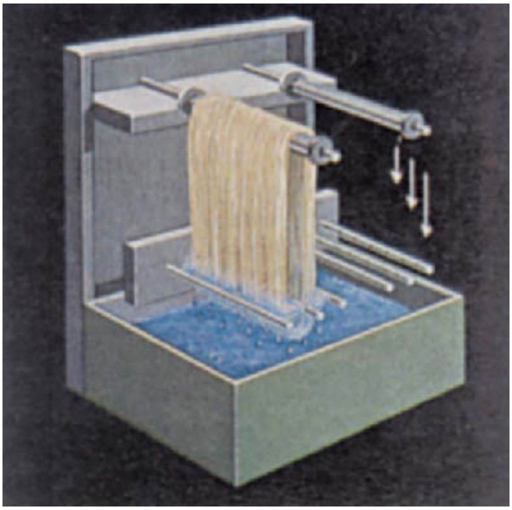


Fig. 23: The Hussong-Walker-Davis process (by Bayer).

The Hussong-Walker-Davis process (Fig. 23) is basically a mechanized version of ombré dyeing. This piece of equipment has several arms that can rotate about their longitudinal axis, upon which the yarn can be hung in hank form. Parallel with these arms, to the right and left of the hank, there are spray tubes that spray the almost boiling dye liquor through openings

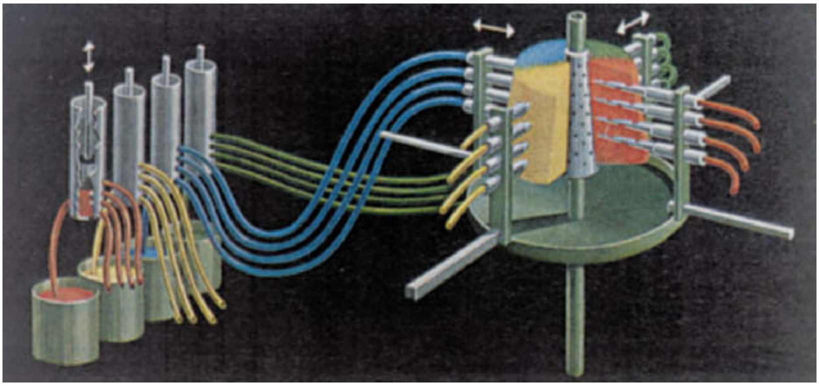


Fig. 24: The Astro-Dye process (by Bayer).

onto the yarn. The excess liquor drains off the yarn hanks and is caught in a liquor reservoir so that it can be routed round to the spray tubes. This sequence is repeated until all the dye has been taken up. The arms that hold the yarn hanks are adjustable in height, which means that the spray tubes reach a greater or lesser part of the lower section of hank. The dye is set in a way that is similar to the dye bath. Various different shades can be applied; however, the dye liquor must be changed each time. The yarn hanks on the arms are turned further by the interval defined previously, so that the second dye liquor can be sprayed on. This process is repeated until the hanks are completely covered. Self shades can also be created in this way, if the yarn is continually rotated past the spray tubes.

VI. Multi-colour effect on wound yarn packages: a specialist space dyeing technique has been developed by Astro Dye Works (Calhoun, USA). Using the Astro dyeing technique of injecting liquor into yarn reels (Fig. 24) it is possible to create variegated dyeing effects with a maximum of four different shades. The injection device consists of four star-shaped spars arranged at equal intervals around the winding, each having four vertically arranged perforated injection needles. In the dyeing process the injection needles, which are linked to the liquor containers via flexible tubes, are embedded in the reel and inject the dye liquor by means of compressed air. Depending on requirements, each of these 16 injection needles can be charged with one of the four dye liquors being used, which means that there is a wide spectrum of possible patterns. However there are certain tried and tested methods to achieve particular effects. The following requirements must be fulfilled if similar results are to be achieved:

- The yarn should be free of soiling.
- The cone should be tightly wound, in order to achieve the required capillary effect.
- The cones should be even in firmness and weight.
- Suitable dyes should be used, the important factors being good solubility and cold liquor stability.
- Exact metering of liquor.
- Suitable setting method, depending on fibre type and process.

Yarns dyed using the space dyeing method are characterized in particular by the fact that dyeing is truly random, i.e. the yarn is dyed at different points with varying intervals, without any regularity. There is no overall rigid design for the dye pattern. Textiles made out of this type of yarn also have an arbitrary effect (appearance), or there are colour zones at irregular intervals (colour image) of varying sizes (source: Bayer Colour Review).

Space printing As an analogy to the knit-deknit process (→ Space dyeing), this is a weave-deweave process or a lease-delease system (also used for yarn setting and bulking). A continuous warp yarn is woven on a loom without a shuttle, and on one side of the fabric a loop system is created. This method has advantages over the knit-deknit process: High production speed (approx. 1500 m of carpet yarn per min) and the fact that there is no yarn tangling.

Spacer Spacers are for supporting and sealing the yarn layers in yarn package dyeing.

Spark detection systems These are devices to protect against fire. They detect short visual impulses, caused by flying sparks, for example, and immediately implement appropriate action to combat the fire. Because of the risk level in a situation like this, they are combined with automatic fire extinguishing systems. Dry extinguishing substances such as halon or CO_2 are stored in accumulators in the middle or at the end of a textile processing chain. There are built-in radiation detectors in the feeder circuit, which provide constant monitoring of the duct and report passing sparks to the signal switchboard. In the event of an alarm, it shuts down the feeder ventilation system and triggers the dry extinguishers via a delay device.

Spark generation in electrical equipment Possible reasons for spark generation include: the insulation between two lamellae being worn (solution: short-circuit both lamellae and solder the problem area), the collector being out of true (solution: switch off or sand down), excessive revolution count, poorly centred anchor, damage to magnetic coils, using the wrong material for brushes, and a bad choice of lubrication for the collector. Solution: appropriate action must be taken on a large scale.

Spark quencher Spark quenchers extinguish sparks generated during singeing, which occur in pressure rollers, steam boxes or water immersion.

Sparta carpets → Isparta carpets.

Spatial formula → Configurational formula for spatial representation of chemical substances, using the → cis-trans- isomerism method.

Spau press Cold → Flat press.

SPC → Stored program control.

Special finishes on textiles Numerous special finishes have been developed in addition to the normal → Finishing process, due to the variability of fashion influences and higher quality requirements. Examples: anti-static finishes, anti-soiling finishes, burn-out printing articles, crush finishes, flame-retardant impregnation, embossing, anti-odour finishes, rubberizing (laminating), water-repellent finishes, non-crease finishes, crimped crêpe finishes, crepon printed effects, shrink-proof finishes, crêpe prepared by steeping in caustic soda, matt finishes, metallic finishes, moiring, moth-proof finishes, permanent finishing, pleating, friezing, sanforizing, slip-resistant finishing, anti-mould/rot/termite proofing, Si-Ro-Set process, brushed finishes, transparent and opal finishes, water-proofing, etc.

Specialist organizations → Technical and professional organizations.

Special soaps → Soap manufactured by saponificating alkalis, alkaline earths, ammoniac or amines, or by converting alkaline soaps with heavy metals. This type of soap is used for personal hygiene or for technical purposes.

Special washing agents These are for specialist washing processes and/or for certain textiles, such as detergents for coloureds, fine fabrics or wool, biological detergents, workwear detergents, detergents for institutional laundry and highly soiled laundry. They are also used in the commercial sector, where they are known as → System detergents. Special washing agents for fine and coloured fabrics do not contain any bleaching agents, and in many cases there are also no optical brighteners. Sometimes they contain cationic substances as well as non-ionogenic surfactants, which draw on the fibre during washing and result in an anti-static preparation as well as a scrooping effect in synthetic filaments. Cellulose ether, in particular, prevents dispersed soil particles from being reabsorbed by cellulose and synthetic fibres.

Special waste classification In line with a directive covering waste definition, there are specific requirements for waste of industrial origin that contain substances such as chlorinated hydrocarbons, because it is not possible to dispose of this type of waste with domestic waste. A company disposing of material containing solvent residues that have not been reprocessed has a basic obligation to identify them. It is particularly important to label any waste or residues with exact information. Hazardous waste is becoming very significant because disposal is so difficult, and because of the associated environmental dangers. Disposal takes place in incineration plants for hazardous waste or at hazardous waste disposal sites. → Waste management.

Special water consumption in open-width wet process plants can be calculated using the following equation:

$$\frac{\text{water consumption l/h}}{\text{fabric run kg/h}} = \text{l/kg}$$

Specific, essentially characteristic.

Specific action Suitable for a specific purpose, (usually) without any side effects; e.g. diastase action, where “specific” carbohydrates or proteins undergo water-soluble decomposition, with no side effects that damage the fibre.

Specific conductance Electrical → Conductivity of a cube with 1 cm edges made from the substance for which conductivity is being measured. Unit: S/m.

Specific gravity → Density.

Specific heat Heat energy in J (Joules) required to heat 1 kg of a substance to raise its temperature by 1°C.

Specific moisture content → Air humidity.

Specific pressure Linear pressure in relation to → Nip (during squeezing). The determining calculation with respect to liquor uptake is:

$$\text{specific pressure} = \frac{\text{squeeze pressure [bar]}}{\text{squeeze area [cm}^2\text{]}}$$

In order to calculate the specific pressure, the relationships between the roller cross section, the hardness and thickness of the roller covering, linear pressure and fabric speed must be known. If the roller has a smaller cross section, the specific pressure will be higher, and water removal will be more efficient to a certain extent. Hard, thin roller coverings made from soft rubber with a uniform thickness of 3–60 mm on low-diameter rollers, where specific pressure is low, are efficient at extracting water. The higher the fabric speed, the less efficiently water can be removed.

Specific strength → Tensile strength.

Specific water retention Quantity of solute water in relation to 1 g of → Dry-cleaning detergent. Specific water retention usually becomes lower as the concentration of dry-cleaning detergent increases (this tendency can reverse at a very high concentration).

Speckled → Mottled.

Speck printing The → Specks that are usually not required in printing are produced artificially by using encapsulated dyes, so that the resulting print profile consists of dots of equal sizes in a mono or multi colour way. This print effect can be carried out on various different types of fibre if suitable dyes are used, for example in transfer printing on polyester.

Specks,

I. Pitch tips or skin particles in wool.

II. In textile printing: dotted sprinklings in one or several colours of a colour way, usually caused by poorly dissolved or insufficiently dispersed dye, or print paste precipitation due to incompatibility of print paste ingredients, dye or thickeners. Specks can be produced deliberately in → Speck printing.

Specky print pastes Pre-mixed print pastes that instead of having even colour distribution are interspersed with little specks of dye known as colour specks.

Spectral Relating to the → Spectrum.

Spectral analysis Spectral analysis is based on the fact that each element has its own characteristic → Spectrum. This means that the presence of a particular element can be detected if its characteristic emission or absorption spectrum occurs. For this purpose equipment containing prisms is used, such as spectroscopes and spectrographs (with which the resulting spectrum can be photographed). Simplified spectral equipment can be used to carry out spectral analysis in the space of a few minutes, for instance to detect metal traces. Emission spectroanalysis provides accuracy levels of nearly 0.001%, and sometimes even greater accuracy can be achieved. This means that spectroanalysis is certainly a suitable method for identifying heavy metal traces in textiles, where this information is important and needed quickly. However, spectral analysis is rarely used in dye laboratories for dye testing. →: NMR Spectroscopy; Spectrophotometer.

Spectral colorimetry → Colorimetry.

Spectral colour density Physical measurement of → Saturation or → Depth of shade.

Spectral energy factor Corresponds to the level of → Reflectance.

Spectral lamps Small gas discharge tubes with oxide electrodes, in which metal vapours are caused to emit light. When the power is first switched on, only the inert gas glows. After sufficient heat has built up, when enough metal is present in vapour form, the inert gas ceases glowing, and a → Spectrum of metal appears that is easily activated. Sodium spectral lamps are supplied that run on alternating and direct current for colorimetric measurement. They produce almost monochromatic light, and any additional lines can be filtered out if required. Cadmium spectral lamps are constructed in a similar way, and are usually used for standard optical measurements because of their sharpness and intensity. The green and blue cadmium lines in conjunction with the red ones in → Spectrophotometer measurement form an ideal complement to mercury lines produced by frequently used mercury lamps (→ Ultraviolet lamp).

Spectral line The wavelength range resulting from the absorption or emission of light, for example for mercury there is the so-called mercury line 2536, which corresponds with the light emitted by a mercury atom on the same wavelength. The spectral colour is the (monochromatic) light of uniform wavelength defined by single spectral lines, on the basis of which the true colour valency of additive colour compounds should be identified.

Spectrofluorimeter → Blocking filters.

Spectrophotometer Instrument used for → Colour measurement according to the spectrophotometric principle (Fig. 1). The wavelength used to measure the reflectance or transmission can be continually changed. Either the whole reflectance curve is recorded or point measurements are taken at selected wavelengths depending on the automation. Prisms or diffraction gratings are used as monochromatic filters.

I. Non-fluorescent samples: the reflectance is measured as a ratio of the energies reflected from the sample and a white standard at the same wavelength. This ratio is independent of the light source. The standard colour

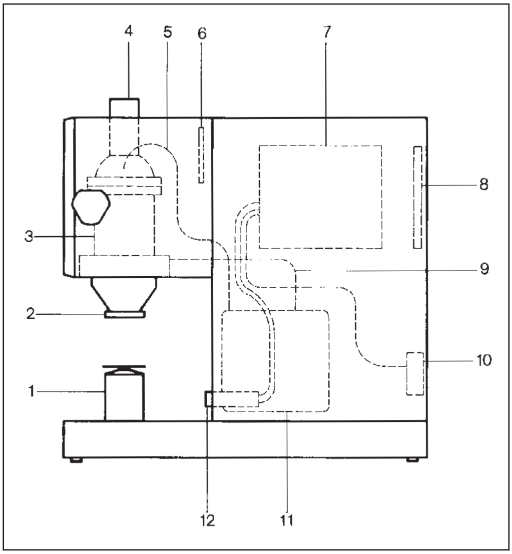


Fig. 1: The Datacolor-Texflash spectrophotometer in section view.
1 = sample table; 2 = measurement shutter; 3 = measuring geometry; 4 = UV calibration; 5 = signal light guide; 6 = ignition unit; 8 = data interface; 9 = reference light guide; 10 = mains connection; 11 = monochromator; 12 = reset key.

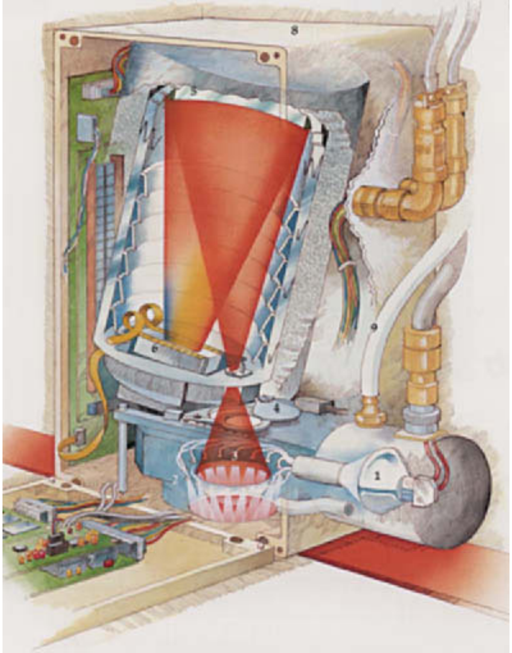


Fig. 2: View of the inside of a spectrophotometer (Hunter Lab, Spectraprobe).
1 = halogen lamp; 2 = light guide with 16 glass fibres; 3 = lens; 4 = filter; 5 = holography; 6 = 76 channel silicon detector; 7 = microprocessor; 8 = housing; 9 = optical external viewing system.

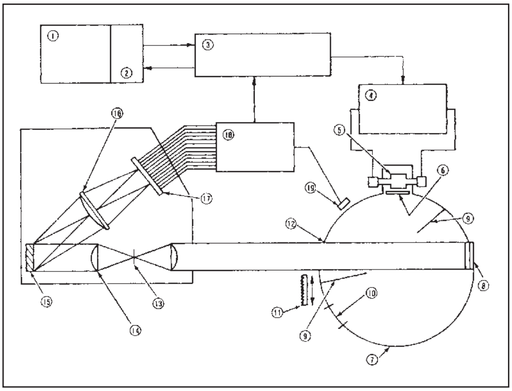


Fig. 3: The light path in a spectrophotomer with xenon flash and diffraction grating with no moving parts.
Diagram of measuring head d/8° MS 2020: 1 = keyboard and display; 2 + 3 = microprocessor; 4 = flash activation circuit; 5 = xenon flash; 6 = D 65 conversion filter; 7 = sphere; 8 = sample; 9 = deflector; 10 = mirror point; 11 = beam switch; 12 = observation point; 13 = entry slit; 14 = collimator lens; 15 = diffraction grating; 16 = condenser; 17 = silicon detector; 18 = electronics; 19 = reference detector.

values X, Y and Z are calculated from the reflectance curve for a chosen light source and observer. Application: for all purposes for which either the reflectance curve without standard colour values X, Y and Z (such as colour formulation calculations using dye selection, the evaluation of colour in artificial light and colour intensity comparisons, etc.) is sufficient or a high level of accuracy is required (necessary standard colour values X, Y and Z in depth of shade comparisons or colour differences on metameric pairs of samples are better calculated by using the reflectance curve rather than by measuring directly in a three-filter photometer). The path of the light ray in spectrophotometers is shown in Figs. 2 and 3.

II. Fluorescent (optical brightener) samples: measurement conditions:

1. The reflectance value is dependent on the spectral distribution of the light source. For this reason, the distribution must include the long-wave part of the UV range.
2. Polychromatic measurement set-up: the sample must be placed between the light source and the monochromatic filter as the fluorescence can only be properly excited by exposing the sample to the whole spectrum. Non-fluorescent samples can also be measured using a monochromatic arrangement (i.e. with the sample placed between the monochromatic filter and the detector).

Spectrophotometer, filter type Instrument used for → Colour measurement according to the spectrophotometric principle. Instead of one continuously operating monochromatic filter, a → Spectrophotometer has a large number of filters for particular wavelengths. The reflectance curve can therefore only be measured at the number of points corresponding the number of filters in the instrument. Narrow-band interference filters are used as monochromators and, in rarer cases, interference overlap filters. The number of filters ranges from 16–31 distributed at regular intervals over a range a 400–700 nm. Knowing the reflectance for a minimum of 16 wavelengths is sufficient for many applications.

Spectroscopy,

I. Nuclear Magnetic Resonance Spectroscopy (→ NMR spectroscopy) is used for routine monitoring of the chemical structure, configuration and purity of compounds. A prerequisite for this technique is that the sample must be soluble in deuterated solvents at room temperature.

II. Electron-Spin Resonance Spectroscopy (ESR spectroscopy) is a high frequency spectroscopic method used for examining paramagnetic compounds. This analytical method supplies information about the structural characteristics of radicals such as those which may be formed as a result of external effects, for example radiation and temperature. Using ESR spectroscopy, it is possible to investigate the chemical changes which occur during radiation or thermal treatment of polymers or textiles.

III. Infrared and raman spectroscopy supply information about molecular oscillations and can be used to elucidate the structure of compounds as well as supplying qualitative and quantitative evidence of chemical changes. The range of application has significantly widened particularly because of the development of the FT technique (Fourier-Transform Infrared and Raman Spectroscopy). In recent years, the application of FTIR spectroscopy has been especially successful in the following areas:

– elucidation of the chemical modification of fibres and other materials caused by finishing, radiation and weathering processes;
– examination of the uniformity of radiation treatments, softener applications and coatings, etc. on various substrates (such as natural and synthetic organic polymers and inorganic minerals and rocks).

In addition, various recording techniques are used depending on the sample material and approach to the problem:

– The recording depth during surface analyses can be varied between the limits approx. 10 and 0.1 µm by measurements using attenuated total reflection (ATR).
– Transmission measurements can also be performed on viscous materials with good reproducibility using the optical anvil diamond cell in the measurement.
– The crystallinity and orientation of polymer materials can be determined by using polarised light.

In addition to these, photoacoustic spectroscopy, FT raman spectroscopy and measurements for micro and emission infrared spectroscopy are also available.

IV. Fluorescence spectroscopy: computer-controlled recording luminescence spectrometers can be used to measure fluorescence, phosphorescence, chemiluminescence and bioluminescence. Apart from this, the fluorescence polarization option also allows examination of the rotational movement of molecules in solution.

V. Scanning photometric microscopy is a measurement technique which can be used in carrying out spectral analyses on microscopically small objects (such as textile fibres or fibre cross sections). Using → Photomicroscopy, it is possible to detect dyes, UV absorbent or fluorescent substances among other substrates, and the absorption and distribution of dyes among other substances can be determined in fibrous materials. Knowledge of the dye absorption and the distribution on, or in textile fibres provides a glimpse into textile dyeing processes and systematic analyses make it possible to optimise the dyeing formulations.

VI. X-Ray photoelectron microscopy (XPS) is a method used to determine the elements and their bonding states in the surface of solids (the recording depth is a few nanometers). The advantages of this analytical method, (almost free of interference, reliable bond data and the possibility of quantitative measurement) particularly apply to natural fibres and synthetic fibres. The following are examples of applications of the method:

– verification and identification of surface coatings,
– examination of changes resulting from surface treatment or ageing,
– recording of depth profiles (in combination with a method involving the removal of material; ion-sputtering or mechanical erosion in UHV).

VII. → Atomic absorption spectroscopy (AAS): the atomic absorption spectrometer is used for heavy-metal analysis. The instrument is equipped with various atomising devices which are used for example, in flame and flameless atomisation in a graphite resistance furnace.

Spectrum The spectral lines or → Light wavelengths resulting from the splitting of light. This concept communicates itself to other physical phenomena. There are optical spectra (in the visible wavelength range), infrared, ultraviolet and x-ray spectra depending on the range of wavelengths covered by the spectral lines. In each case, they are distinguished by:

1. Lines or discontinuous spectra (composed of many individual coloured lines which, when photographed, appear as dark stripes).
2. Band spectra (composed of groups of many individual line bands crowded within the range of black or almost black = band head).
3. Continuous spectra (e.g. the continuous rainbow spectrum of sunlight).
4. Emission spectra (of luminescent substances or substances which emit light when excited, consisting of coloured lines, bands or a continuous coloured spectrum appearing on photographic plates as pale and dark areas).
5. Absorption spectra (are incomplete, i.e. thin bands or lines are missing in the spectrum to give a characteristic pattern - the absorption spectrum is like a negative form of an emission spectrum (for example, when white light passes through a cupra ammonium hydroxide solution, the yellow and orange parts of the absorption spectrum are missing).

Spectrum locus → Chromaticity diagram.

Speed In physical terms, speed is the distance covered divided by the time taken for it to be covered ($v = s/t$) measured in m/s or km/h. Textile finishing machines are differentiated from each other by:

I. the production speed, where the fabric speed is measured at the exit (in m/min.)

II. the nominal speed or max. production speed (according to DIN draft 64).

III. the differential speed or the difference between the local fabric speed and the production speed as a percentage of the production speed, e.g. forward slip on a shrinkage line.

Speed indicator → Tachometer.

Speed measurement of yarns and fabrics In many processes, the speed of textile materials has a significant effect on product quality. Speed measurement is also suitable for the open-loop or closed-loop control of processes. Examples of measurement applications are:

- movement of fibres in an air stream,
- processing of fibre slivers,
- speed of filament and fibre yarns,
- speed of nonwovens, knitwears and fabrics.

The speed signal can also be used for measuring length, for example, the length of yarn from the package and the length of textile webs. The classical mechanical length and speed measurement methods operate using measurement pickups, the accuracy and reliability of which, in many cases, is insufficient. The measurements are mainly affected by two types of error:

1. Surface errors result from the penetration of the measurement wheel into the often soft surface which is being measured because the contact pressure is too high. In this case, the measurement wheel is picking up the length of the bow in the surface resulting from the contact pressure so the length of the test material corresponds to the chord of this arc. The measurement errors which result are positive. Especially in the case of sensitive surfaces, damage may result or at least undesirable effects which reduce the value of the goods.
2. Slippage errors result from insufficient friction between the measurement wheel and the goods being measured which gives rise to slipping between the surfaces. The wheel slippage has a series of effects, the errors from which, are in many ways, not reproducible.

With the development of micro- and optoelectronics as well as laser technology which took place at the end of the sixties, an extensive amount of research work was devoted to this area. These methods are contactless and do not give rise to the sources of error found using the mechanical speed and length measurement techniques. Suitable marks can be applied at regular intervals to the test surface for measurement of speed and length using contactless sensors. The number of marks passing the measurement site gives the length of material and this, in relation to the period of measurement, can then be used to determine the speed. It is also possible to measure the length and speed of moving objects using a contactless method without adding the marks. There are four different methods available for this approach.

The Doppler method makes use of the effect produced by a moving object of reflecting an electromagnetic or sound wave at a different frequency to that of the wave, before meeting the object. The amplitude of the frequency is directly proportional to the speed of the object. In the case of the laser-reference beam Doppler method (Fig. 1) the light emitted by the laser is split into a reference beam and measurement beam by a beam splitter. The measurement beam meets the moving surface at a velocity v and is reflected as diffused light. The scattered light at the new frequency is collected via a lens and superimposed on the reference beam reflected from a mirror (→ Laser Doppler Effect). The resulting pulse signal gives rise to fluctuations in intensity which are then recorded. The speed is obtained by counting the Doppler oscillations. With a differential laser Doppler method, the light emitted by the laser is split into two beams which are intersected again at the surface of the moving test material. Superimposing the two signals with displaced frequencies produces a pulse which a photodetector records as intensity fluctuations. The pulse frequency is directly proportional to the surface speed.

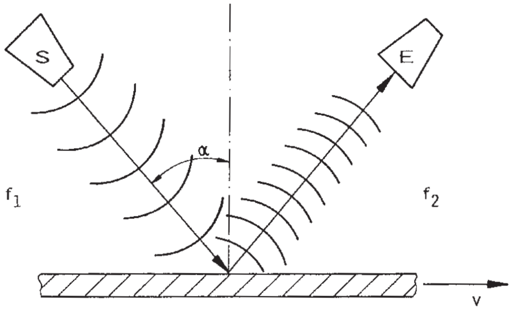


Fig. 1: Principle of the Doppler method for speed measurement.

With the interference (Speckles) method (Fig. 2), a laser beam reflected from a rough surface shows intensity inhomogeneities which are caused by interference phenomena (so-called "granularity"). If the object is moved, the light pattern also. When the moving light pattern is observed using a diffraction grid, an alternating frequency appears which is proportional to the speed of the object.

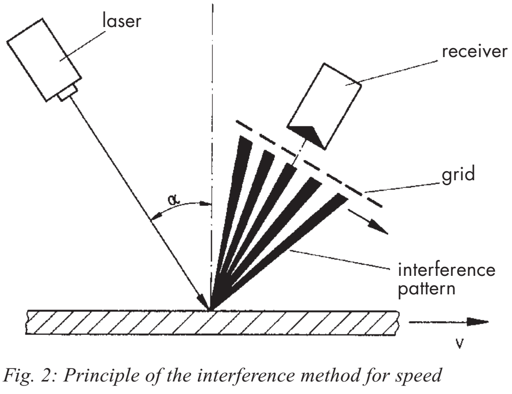


Fig. 2: Principle of the interference method for speed measurement.

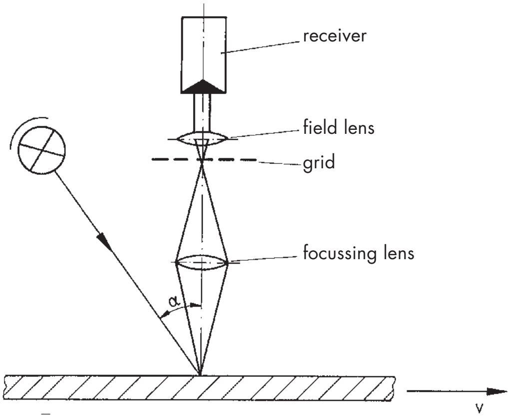


Fig. 3: Principle of the local-filter method for speed measurement.

In the case of the local-filter method (Fig. 3), the light (coherent or incoherent) reflected from a stochastically rough surface is allowed to fall through an optical grid, with the slits aligned vertically to the direction of motion, and the beam is summated accordingly. As the surface moves, a signal is produced yielding a spectrum which has a frequency proportional to the speed.

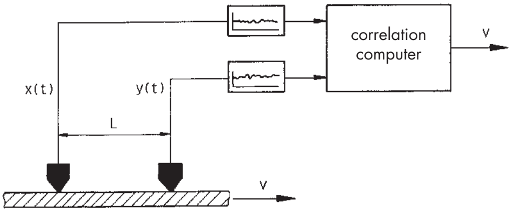


Fig. 4: Principle of the correlation method for speed measurement.

The correlation methods (Fig. 4) use the stochastic fluctuating characteristics of the test object (such as the surface structure, degree of reflection and diameter of electrostatic charge), which are otherwise perceived as disadvantageous, as marks for the speed and length measurement. The correlative speed measurement is based on the measurement of the time required for a certain test material to pass between two sensors arranged one after the other at a distance L in the direction of motion. The two sensors produce the signals x(t) and y(t). Ideally, both signals are of identical shape and are only displaced towards each other by an amount equal to the running time Δt.

$$y(t) = x(t-\Delta t)$$

If a cross-correlation of the two signals is now used to determine the time shift $\tau = \Delta t$, then the speed of the test object can be found from the relationship $V = L/\tau$. (according to Wulfhorst).

Spent fish or train oil → Tanning.

Spermaceti The fat of species of whale, scaly, crystalline, purified white, greenish white transparent, fracture appears like mother of pearl, glossy. So-called synthetic spermaceti (in most cases hardened sperm oil): friable; weak smell (unlike train oil) greasy; poor quality: harder, resembles stearin. Adulterated: frequently by stearin (harder, fine crystalline structure). Melting point: 42–54°C. Solubility: soluble in 7 parts hot or 35 parts cold alcohol; freely soluble in ether and chloroform, etc.; slightly soluble in petroleum spirit; turns pale yellow and rancid after prolonged boiling (calcium carbonate addition). Unsaponifiable matter 49–54%. Use: sizes and finishes, etc.

Spher- (Gk.: spaira = sphere; circle), ball-shaped.

Spherical float Controller for → Steam trap.

Spherical molecules → Colloid.

Spherocolloids → Colloid.

Spherulites Spherical or toroidal shape crystalline structure in high polymers composed of groups radiating from a point. Usually small but easily recognizable under a polarization microscope, where the illumination of each cell is restricted by a dark interference cross. They are caused by “inhomogineities” and arise e.g., while the liquid phase cools down. They are in most cases undesirable in synthetic fibres. They are not always a problem in coarse fibres but slightly impair the strength of fine fibres (fibre fracture) and impart a light coloration.

S-phrases (safety phrases). Safety instructions for the handling of hazardous substances (in Germany, in accordance with the ArbStoffV – Arbeitsstoff Verordnung – Working Materials Ordinance) in accordance with EC directives. In each case, the phrase is assigned a number or number combination for the substance in question, for example, S 36 = Wear suitable protective clothing (standard phrase). → R-clauses.

Spider silk Product of silk spider (Madagascar). Without silk glue. Extremely light. Strength, glaze and elasticity similar to genuine silk but finer.

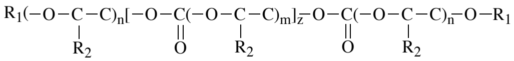
Spin dyeing → Mass coloration.

Spin finishes “Oiling agents” consisting of oils or fats and surfactants the behaviour of which, depending on the task in hand and composition, comes somewhere between textile lubricants and textile softening agents. The finish should give the fibre a glaze which is adjusted to the preparation process. It also suppresses the build-up of electrostatic charges on the fibres and produces a certain degree of thermal protection at the same time. Finishes which are suitable for these requirements should be simple to handle and easy to dissolve or emulsify. They should wet as spontaneously as possible and spread well on the fibre surface. They must be physiologically and ecologically harmless and not corrode metals, plastics or other operating materials.

During the manufacture of synthetic fibres, auxiliary agents are applied to the filament yarn during spinning, imparting to it the properties needed for processing. These fibre spin finishes, the composition of which is known only to the supplier of the auxiliary agent or the filament-yarn manufacturer, are usually water-based systems and are applied to the synthetic fibres at a rate of 0.1–1.0%, by weight. Spin finishes used in industry in fibre manufacture are, as a rule, multi-component systems which may contain the following constituents depending on the type of fibre and the task in hand: adhesives or lubricants, emulsifiers, wetting agents, fibre finishing agents, antistatic agents, moistening agents, bactericides and anticorrosive agents among others. At 40–70%, lubricants make up the main part in the mixture. Taken together, the emulsifiers, fibre finishing agents and the antistatic agents almost make up a complete spin finish up to a few percent. Here, mineral and ester oils act as lubricants although other components such as emulsifiers and surfactants may also have friction-reducing properties. The function of the fibre finishing agents, i.e. of holding the individual filaments together in the yarn, is specifically fulfilled by castor oil ethoxylates or sarkosides. The emulsifiers perform the necessary dispersal of hydrophobic components in the water-based system for the application, with alkylphenyl and alkyl alcohol ethoxylates being regarded as the most important surface-active substances. All ionic or polar substances, such as the alkali and ammonia salts of organic and inorganic acids or amine oxides, act as antistatic agents.

Knowledge of the effectiveness of the individual classes of substances named, i.e. the association of their chemical structures with certain functions and the application of a spin finish makes it possible to target the developing new spin-finish systems to their application. However so far, no results are known to have been acquired of the relationship between application behaviour and the effectiveness of a finishing preparation, which point to a relationship between the structure and the physical properties of a practical preparation, on the one hand, and the preparative effectiveness of this "aqueous auxiliary agent preparation" on the other. Especially in the light of filament-yarn manufacture using increasing spinning speed, particularly good take-up, distribution and adhesive properties on the filaments are required. The physical state and the physical properties of the water-based spin-finish preparations are decisive in satisfying these requirements. Small amounts of side products which cannot be considered safe in terms of their toxicity, at least in the case of not-particularly refined grades of mineral oil, and the restriction on the loading of effluent with these relatively slowly broken down mineral oil fractions, lead to a limitation in their use, especially in Germany, if not indeed to a total ban in future on the resulting hydrocarbons in effluent.

Thermostable, easily biodegradable emulsified ester oils represent a compromise. However, in the case of heating processes such as drawing or fixing, problems arise due to uncontrollable cracking reactions leading to the formation of residues in, for example, the texturizing heater. Further development has led to the use of special polyalkeneglycolethers. These products which are generally described under the collective term EO/PO products, represent a large proportion of modern texturizing spin finishes. A range of viscosities which have a favourable level of friction for the texturizing process, is obtained by selecting a series of base products with graded molecular weights. These types of spin finishes are characterized by a high lubricant-film stability, high thermal stability and the formation of the least amount of cracking residues. A serious disadvantage of these products is their low susceptibility to biological decomposition. The statutory requirements being prepared in Germany with regard to the biodegradability of textile effluents (biodegradability > 80% in the OECD simulation test) has forced the development of product alternatives which are more favourable in terms of their toxicological effects on the ecology. Starting from the idea that an appropriately high molecular weight is necessary to achieve both good lubrication properties and sufficiently high thermal stability and that the resulting viscosity of the spin finish systems largely determines the level of friction, certain sizes of molecule have to be obtained. On the other hand, it must also be taken into consideration that for cracking behaviour to be favourable over the whole molecule, potential cleavage sites must be incorporated evenly and, in order to achieve a high level of biodegradability and physiological safety (skin tolerance, etc.), functional groups which are relatively easily attacked biologically (e.g. by hydrolysis) must be introduced while enlarging the molecule. Here, carbonyl groups are available for use as links. Compounds are formed in this way to give the following polyether/ester structure:



$$R_1(-O-\underset{\underset{R_2}{|}}{C}-C)_n[-O-\underset{\underset{O}{\|}}{C}(-O-\underset{\underset{R_2}{|}}{C}-C)_m]_z-O-\underset{\underset{O}{\|}}{C}(-O-\underset{\underset{R_2}{|}}{C}-C)_n-O-R_1$$

R_1 = linear or branched, saturated or singly unsaturated alkyl residue with 3–22 C atoms
R_2 = hydrogen or low alkyl residue with 1–2 C atoms
n = total number from 0–10
m = total number from 4–16
z = total number from 0–3

Freely water soluble, self-crosslinking thermostable products are obtained with lubricating properties and good cracking behaviour. These base products biodegrade well and skin-tolerance tests have shown that due to the ester structures formed, skin irritation is no longer observed in the case of the starting products (EO alkyl alcohols). With a result of 95% from the OECD simulation test, the biodegradability of the classes of substance described must be considered high and therefore comply with the strictest requirements in contrast to EO/PO-based lubrication components of similar molecular weight. The sum of aquatoxic test parameters such as fish, bacteria and daphnia toxicity leads to the conclusion that these are less aquatoxic than comparable groups of surfactants with similar surface actions or wetting properties, such as certain alkyl alcohols x EO, sulphosuccinic acid esters or alkyl sulphonates with LC_{50} of 1–10 mg/l. With an ascertained toxicity of $LD_{50} > 5000$ mg/kg, these products are categorised as non toxic. The high skin tolerance may be regarded as another advantage as a large number of other surfactants used as spin finish components are evaluated as “skin intolerant”.

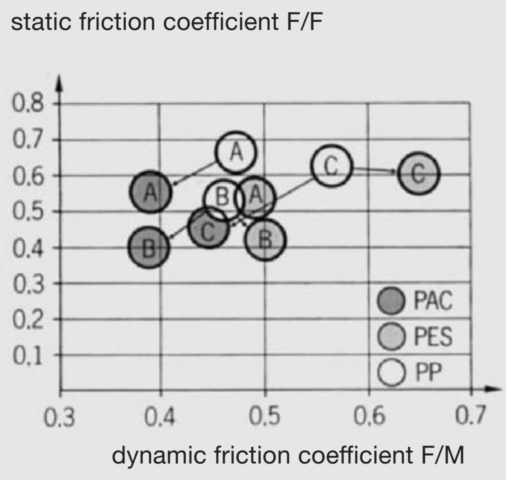


Fig.: Diagram showing the adhesion /slippage behaviour of various finishes (A–C) by the arrangement of frictional locations within the smoothness nomograph.
A = fatty acid polyglycol ester; B = phosphoric acid ester; C = fatty acid amidoamine; PAC = polyacrylonitrile; PES = polyester; PP = polypropylene.

A not altogether problem free representation of the adhesion/lubrication behaviour of spin finishes is offered by the assignment of friction sites in the so-called smoothing monogram (Fig.). In this, the fibre-fibre friction measured within the speed range of a few mm/min is delivered via a dynamic fibre-solid coefficient of friction (usually thread-metal at around 100 m/min). As a rule, the measurements are carried out on filament yarns using, for example, the Rothchild F meter under standard atmospheric conditions. Although the diagram offers no information on the effects of fibre crimping, spin-finish additives or climate, it can be used for comparative assessments.

The diagram shows the friction sites of different spin finishes as circles. The friction effects produced by the same spin finishes vary from fibre to fibre. A no less important criterion for the workability of, for example, polypropylene spun fibres is the potency of the antistatic effect of the spin finish. Dynamic testing methods are frequently used for the measurement of a charge on the fibre substrate immediately after a process involving friction, e.g. on the running card. The charge can be reliably recorded after spinning using an electrostatic induction voltmeter. Defined climatic conditions are a prerequisite for reliable results.

Spin finishes have a large influence on the processing of synthetic fibres for needle-punched felt. These type of nonwovens are encountered in a large number of different applications, for example, in floor coverings and wall coverings, car furnishing fabric (boot and parcel shelf), lining materials, geo-non-wovens (road building and landscape gardening) as well as blankets. The problem, which cannot be solved by mechanical means or choice of fibre alone, presents fibre spin-finishing with important tasks: reducing needle resistance forces, increasing non-woven density, reducing fibre damage and facilitating neater structure formation during pol needling in loop and velour production (according to Veitenhansl, Winck and Herlinger).

Spindle,

I. Device on spinning and twisting machines for holding packages and the like for imparting a twist to or roll-batching yarn.

II. → Hydrometer.

III. Threaded shaft for the transmission of turning motion.

Spindle cells Inner cell layer accounting for the largest proportion of matter in → Wool structure.

Spindle crown → Spinning cake.

Spinnability of wool Spinnability is improved when wool is dyed at the isoelectric point, i.e.

- lower losses at the setting, less attack at the combing noils on recombing, less suction waste on the ring-spinning frame, i.e. a total of around 0.5–4% (worsted yarn: 2%; carded yarn: 3.5%) higher yield,
- improved run properties of the slub yarns and fewer yarn breaks during ring spinning.

Spinning Formation of yarns or threads from fibres.

I. Natural fibres: three stages depending on the type of fibre and properties:

1. Aligning the (loosened and mechanically pre-

cleaned) fibres in parallel to form a sliver (combed top; card sliver) or slub-yarn threads, pulling out and drawing.
2. Twisting to form the threads or yarn.
3. Winding up to form the hank or package or something similar.

→ Spinning processes for staple fibres.

II. Man-made fibres: fibre formed by passing the spin solution or dope through spinnerets (with numerous fine holes) into a regenerating bath which causes the fibre to harden (wet spinning) possibly stretching the fibre at the same time (stretch spinning) or the fibre may be hardened by evaporating the solvent (dry spinning). Different synthetic fibres (such as polyamide) are spun from a melt and then stretched (→ Melt-spinning process). → Spinning processes for man-made fibres.

Spinning bath additives Used during the spinning of man-made fibres:

1. To improve the spinnability and, if necessary, to modify the properties of the spun product (→ Modifier). Spinning bath additives for the spinning solution are surfactants or preparations made from surfactants, e.g. sulphonated oils, alkyl sulphates, aliphatic acid condensation products of alkyl amines and onium compounds. Spinning bath additives for spinning melts are chiefly pigments (dye pigments and delustring agents), optical brighteners, antioxidants and light-stability agents.
2. To clarify spinning baths and prevent build-up at the spinnerets and spinning-bath pipework. These are surfactants or preparations made from surfactants, e.g. sulphonated oils, alkyl sulphonates, aliphatic acid condensation products, oxalkylation products of alkyl amines and onium compounds.

Spinning cake (spindle crown), a yarn package which has been spun according to the centrifugal or so-called can or pot spinning method (rotating pot resulting in the shape of a ring-shaped cake with the characteristic hole in the centre. These slightly conical spinning cakes occur in different sizes but they are always in the form of compact blocks of yarn tightly wound in almost parallel layers.

Spinning lubricants (spinning oils),

I. Combinations of mineraloil based chemicals with the addition of lubricants, antistatic agents and emulsifiers, etc. used for the fault free running of spinning and stretching processes for synthetic fibres. Spinning oils must be removed before dyeing as they, or their residues, will have an effect on the levelness of dyeing. Not to be confused with → Coning oils.

II. Suitable additives are added to the spinning solution instead of applying the spinning oil to the filament afterwards.

III. Lubricating agents applied to natural or man-made fibres depending on the type of → Textile lubricants which ensure stretching and spinning in all spinning-mill operations. The preferred raw materials are surface-active polar compounds derived from aliphatic alcohols and aliphatic acids. Their chemical nature allows them to be easily removed during the wet processes which follow and makes them ecologically compatible. A modified spinning oil has been successfully used in dust control during cotton spinning. → Spin finishes.

Spinning preparations → Spin finishes.

Spinning preparations for friction texturizing Preparation problems mostly arise in association with changes to yarn titre or speed. With high machine speeds, the usual mineraloil- and esteroil-based spinning preparations, problems have not increased. Particularly in regard to thermal stability, the more recent spinning preparations are differentiated according to two principles:

I. Substances which change under the influence of heat by decomposing rather than melting and are then extracted in the form of gaseous products (such as carbon dioxide, carbon monoxide, aldehydes and water vapour).

II. Thermally stable products additional to the fibre surface with high adhesion, and which may be in the compound itself or can be applied by so-called bonding agents.

Spinning preparation for high polyester and polyamide delivery speeds are:

a) Spinning preparations for the magnetic spinning process:

– mixtures of mineral oils and ester oils such as butyl stearate as the lubricant

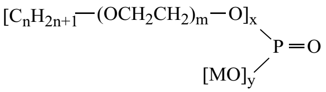
$C_{17}H_{35}–COO–C_4H_9$ *butyl stearate*

– emulsifiers and antistatic agents

$C_nH_{2n+1}–CO(OCH_2CH_2)_m–OH$ *aliphatic acid ethoxylate*
n = 9–17, m = 4–12

$C_nH_{2n+1}–(OCH_2CH_2)_m–OH$ *aliphatic alcohol ethoxylate*
n = 8–16, m = 4–12

$C_nH_{2n+1}–SO_3M$ *alkylsulphonate*
n = 14–17; M = Na, K, amine



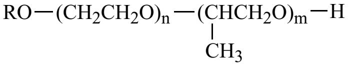
$$\begin{array}{l}[C_nH_{2n+1}{-}(OCH_2CH_2)_m{-}O]_x \\ \qquad\qquad\qquad\qquad \searrow \\ \qquad\qquad\qquad\qquad\quad P{=}O \\ \qquad\qquad\qquad\qquad \nearrow \\ \qquad\qquad\qquad [MO]_y\end{array}$$

phosphoric acid ester
n = 6–18, m = 0–10
x = 1–3, y = 3–x
M = Na, K, amine

b) Spinning preparations for friction texturizing:

– mixtures of co-polyethylene oxide polypropylene oxide alkanols with random distribution and as block copolymers

$RO–(CH_2CH_2O)_n–(CH_2CH_2CH_2O)_m–H$



$$RO-(CH_2CH_2O)_n-(\underset{CH_3}{\underset{|}{C}}HCH_2O)_m-H$$

- mixtures of aliphatic acid and aliphatic alcohol ethoxylates

$C_nH_{2n+1}-CO(OCH_2CH_2)_m-OH$ *n = 9–17, m = 4–12*

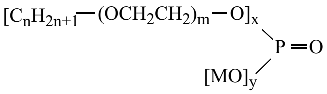
$C_nH_{2n+1}-(OCH_2CH_2)_m-OH$ *n = 8–16, m = 4–12*

- endbonded aliphatic alcohol ethoxylate

$C_nH_{2n+1}-(OCH_2CH_2)_m-OR$ *n = 4–12, m = 4–15; R = alkyl group*

c) Spinning preparations for magnetic and friction texturizing:

- specifically phosphoric acid esters



$$\begin{array}{l}[C_nH_{2n+1}-(OCH_2CH_2)_m-O]_x \\ \qquad\qquad\qquad\qquad\qquad\quad \searrow P=O \\ \qquad\qquad\qquad\qquad [MO]_y \nearrow \end{array}$$

n = 6–18, m = 0–10; x = 1–3, y = 3–x; M = Na, K, amine

- mixtures of aliphatic acid and aliphatic alcohol ethoxylates

$C_nH_{2n+1}-CO(OCH_2CH_2)_m-OH$ *aliphatic acid ethoxylate n = 9–17, m = 4–12*

$C_nH_{2n+1}-(OCH_2CH_2)_m-OH$ *aliphatic alcohol ethoxylate n = 8–16, m = 4–12*

In the spinning mill, these concentrates are applied as emulsions or solutions (above or underneath the discharge duct near to the winding machine), either using conventional rotary preparation rollers (usually sintered ceramic) or by means of jets.

Spinning processes for man-made fibres differ according to whether they are melt-spinning, wet spinning, dry spinning, gel spinning or dispersion spinning. Wet-spinning processes are expensive to use and dry spinning processes are expensive in terms of investment. Melt spinning is the most economic method:

I. Melt-spinning: the polymer chips are placed in a spinning pump. The melt is forced out through spinnerets and the threads cooled in the air. The threads are drawn at a rate of 1000–6000 m/min. Melt spinning can only be carried out on thermostable and fusible polymers (thermoplastics). Polyamide, polyester, polyolefins and glass fibres can be spun depending on the process. →: High-speed spinning; Microfibres.

II. Wet spinning: this method is used for polymers which decompose on melting. 5–25% solutions are forced through spinnerets by means of a spinning pump. The threads are coagulated in a regenerating bath and stretched in a stretch bath. The method operates with drawing speeds from 50 to 100 m/min. The cost of recovering the solvent makes this method expensive. Viscose, cupro- and polyvinylalcohol fibres are drawn using this method.

III. Dry spinning: In this case, 20–45% solutions are used. After leaving the spinnerets, the threads enter a 5–8 metre channel in which they are blasted with a counter current of hot air so that the solvent evaporates. This method allows drawing speeds up to 300–500 m/ min. Only polymers which dissolve in volatile solvents can be used. The method is used with polyacrylonitrile (25% in dimethylformamide), chlorinated polyvinylchloride (45% in acetone) and cellulosetriacetate fibres (approx. 20% in dichloromethane).

IV. Gel spinning: 35–55% solutions are used with this method. Because of the low solvent content, the shape of fibres produced is very stable. The drawing speed is around 500 m/ min. Polyacrylonitrile and polyvinylalcohol fibres are spun using this method.

V. Dispersion spinning: this is a special process for insoluble and non-fusible polymers. Inorganic polymers are added to the dispersions of the polymer to be spun in order to raise the viscosity and stabilise the fibre. After the thread has been formed, this polymer is burnt off while the polymer particles forming the fibre fuse together. This process is used to spin polytetrafluoroethylene fibres.

All spinning processes run in four stages, according to the same scheme. The first stage involves extruding the spinning solution or fluid through a spinneret, the lengths of the threads produced being controlled by their spinnability. During the second stage, the threads begin to harden while internal stresses are equalized. The still semi-fluid threads pre-stretch under their own weight in the third stage while the chains are already becoming weakly aligned. During the fourth stage, the threads are finally stretched and achieve their final characteristic properties (strength, etc.).

The ability to form long continuous threads varies with the material. For any given material, the achievable fibre length depends on the viscosity η of the fluid and speed v of the spinning process. The length L of the fluid fibre goes through a maximum as the product $v \cdot \eta$ increases. The maximum achievable fibre length is called the spinnability. It can be seen from the curve $L = f(v \cdot \eta)$ that the spinnability is controlled by two processes: cohesive failure and capillary failure. A certain amount of elastic energy can be stored in every viscoelastic fluid. Among other things, this phenomenon leads to the Barus effect. When a certain value has been exceeded, the fibre breaks due to cohesive failure. This fracture process has derived its name from the fact that it depends on the cohesive energy of the material as well as the viscosity of the fluid, the speed of the process and the modulus of elasticity. The capillary fracture is the fusion fracture and is dependent on the surface tension as well as viscosity and speed. The mechanism which sets in earlier, leads to fracture. For this reason, the optimum value is sought for L for any particular value for $v \cdot \eta$.

The function $L = f(v \cdot \eta)$ has the following consequences: if the speed and/or viscosity during spinning is too low then a capillary fracture will result. The fibre disintegrates into individual droplets. Viscosities which are too low occur, for example, when the solution is dilute or if the spinning temperature is too high. A cohesive fracture on the other hand occurs when the relaxation times are too long, which happens, for example, when molecular weights are high or when gel formation during wet spinning is too rapid. Cohesion fracture is brittle fracture (according to Elias).

Spinning processes for staple fibres Unlike the conventional ring-spinning frame, which has 6 or 3 process stages in its optimized form, the non-conventional spinning processes for producing rotor-spun yarns, air-jet-spun yarn, friction yarn or covered yarn manage with fewer process stages (Tab. 1).

new automatic ring spinning	present day automatic rotor spinning	rotor spinning of the future
carding	carding	carding and drawing
drawing 1st passage	drawing 1st passage	
drawing 2nd passage	drawing 2nd passage	rotor spinning
roving production	rotor spinning	
ring spinning	linked and automated	
winding		
= 6 processing stages	= 4 processing stages	= 2 processing stages

Tab. 1: Ring and rotor spinning processing sequences.

Each one of the five processes mentioned is characterized by a special principle in fibre bundling and the respective method of applying the twist which results in the different yarn structures producing the characteristic properties of the spun yarn.

I. Ring spinning frame: due to the good fibre guidance system, this method is capable of processing practically all fibres within a wide range of titres. The ring-spinning frame is therefore very flexible. The high yarn tension and control of fibre orientation during spinning means that ring-spun yarns are firm and even (Fig. 1). Only when the proportion of short fibres is high is the uniformity of the yarn not at its optimum.

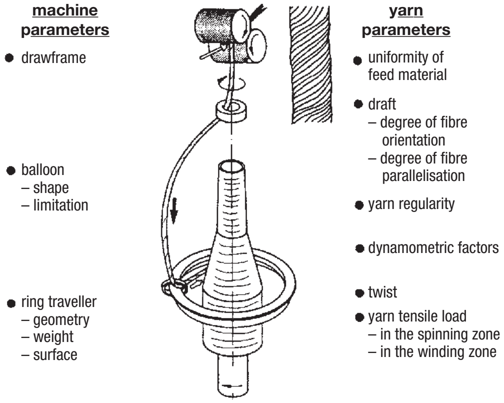


Fig. 1: Parameters affecting quality and ascertainable yarn features for ring spinning.

Because the card sliver is uniformly successively stretched and twisted as the ring-spun yarn is made, all the fibres are arranged in a spiral of uniform pitch parallel to the yarn axis. At the same time, all fibres are constantly kept under tension and have little or no opportunity to become randomized.

The fibres which are partially anchored in the core of the yarn and partially project out of the yarn account for the high level of hairiness of ring-spun yarn. The difference between this yarn and other yarns is that practically all fibres contribute to bearing the tensile load of the yarn. For this reason, a high proportion of the fibre strength is transferred to the strength of the yarn (substance utilisation). Because the fibres are well aligned, the ring-spun yarn can be fully untwisted and the twist factor can be measured precisely. The individual steps in the ring spinning process can be brought together in an integrated process (Fig. 2).

II. Rotor spinning: this process is fairly flexible in regard to the fibre length but is most suitable for processing short to medium staple lengths and is restricted to coarse to medium fine yarn (Fig. 3). The

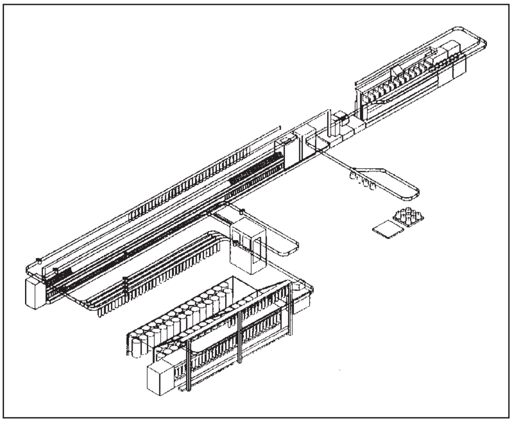


Fig. 2: Fully automated ring spinning machine.

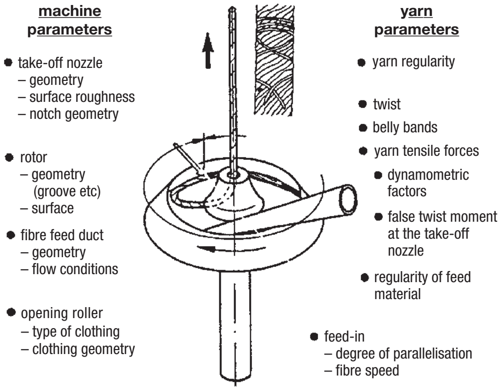


Fig. 3: Parameters affecting quality and ascertainable yarn features in rotor spinning.

yarn has less strength than ring-spun yarn depending on the process. Formulae for yarn torque and tension:

– required yarn torque:

$$M_{Btorque} = f\,(\text{fibre strength, etc.})$$

– actual yarn torque:

$$M_B \cong P_B \cdot r \cdot \alpha$$

P_B = yarn tension at point B
r = yarn radius
α = torque coefficient

– yarn tension:

$$P_B < \mu \cdot \text{tex} \cdot \frac{l_f}{2} \cdot R \cdot \omega_R^2$$

μ = coefficient of friction fibre/rotor wall
l_f = average fibre length
R = radius of rotor
ω_R = angular velocity of rotor.

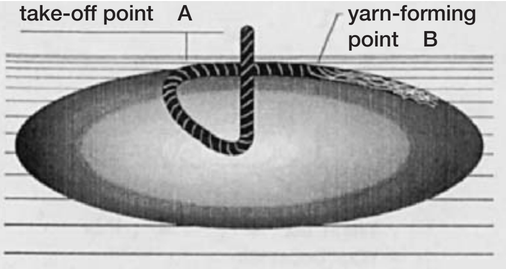


Fig. 4 Take-off point and yarn-forming point in rotor spinning.

As the run of fibre fed into the rotor grooves (Fig. 4) periodically crosses the yarn-discharge area, randomised fibres or fibres wrapped around the yarn as a covering cannot be avoided. The core of rotor-spun yarn has a constant twist which is comparable to that of ring-spun yarn. However, it is in the nature of this spinning method, that fibres wrapped around the yarn are twisted in both directions which prevents the sliver from opening up completely when the yarn is untwisted. The deviation of the measured twist value from the actual twist value is labelled T%. The value may be anywhere between 0 and 50% depending on the choice of fibre and the machine specifications. When rotor-spun yarn is under tension, the load is not or is only partially borne by the randomized fibres and fibres wrapped around the yarn. It is therefore clear why a rotor-spun yarn is not as strong as a ring-spun yarn using the same fibres (→ Ring-spun/rotor-spun yarns, properties of). Fig. 5 shows the functional parts of a rotor spinning machine.

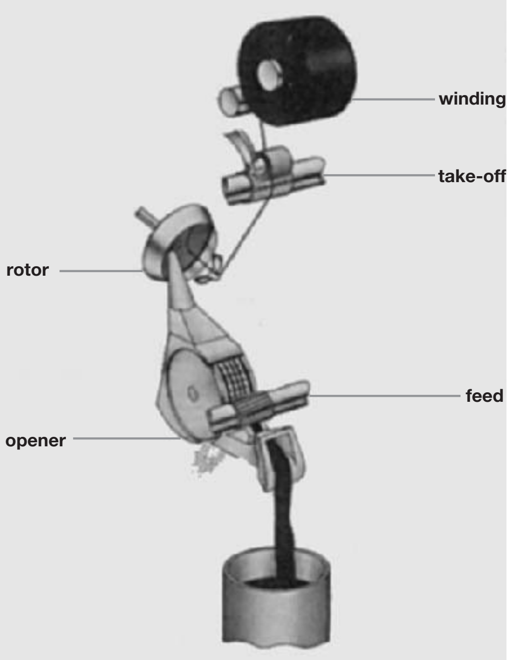


Fig. 5: Rotor spinning (SKF).

III. Air jet spinning: because the fibre control is good, this method is suitable for processing medium sized to long fibres, i.e. combed cotton and man-made fibres of medium to fine titres (Fig. 6). However, it is not possible to spin carded cotton of relatively high short fibre content or use it to manufacture fine yarn.

Spinning processes for staple fibres

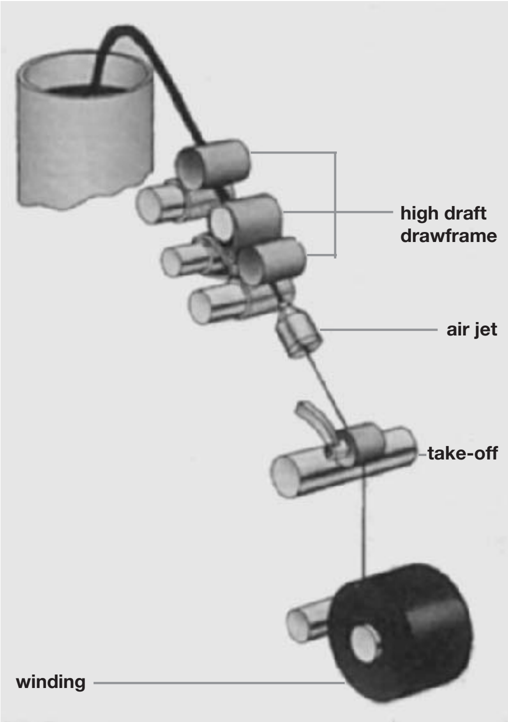


Fig. 6: Air jet spinning (SKF).

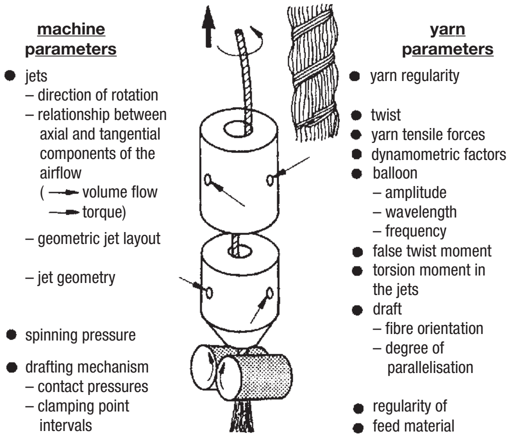


Fig. 7: Yarn parameters affecting quality and ascertainable yarn features in air false-twist spinning.

Air jet spun yarns are covered or wrapped yarns with a specified proportion of external bonding fibres which are wrapped around a core of parallel fibres. If only a single jet is used, the covering fibres are mechanically separated from the core fibres at the exit of the stretching roller. If two air jets are used, one after the other, the first jet winds the loose surface fibres around the rotating core of the yarn. The second air jet produces a false draught. As soon as the yarn passes the second jet, the core twist returns to zero while the covering fibres wind tightly around the core, strengthening the yarn by cohesion friction.

The optimum yarn strength is achieved (Fig. 7) when the proportion of covering fibres is around 10–25%. This means that the presence of a smaller percentage of the covering fibres or loosely wound fibres leads to soft yarns of lower strength, and conversely, a correctly measured percentage of tightly wound covering fibres yields stronger and harder yarns. This principle of yarn formation also explains why polyester fibres with higher friction values and standard staple lengths can be processed using this method while cotton fibres with lower friction values and shorter fibre lengths present problems.

IV. Friction spinning: from the technical details it follows that this method is fairly flexible with regard to fibre length but is more suitable for fibres with short and medium staples. As with rotor spinning, friction spinning is restricted to coarse to medium titres (Fig. 8). Yarn strength may be even less than it is for rotor-spun yarn, and may be problematic, depending on the system.

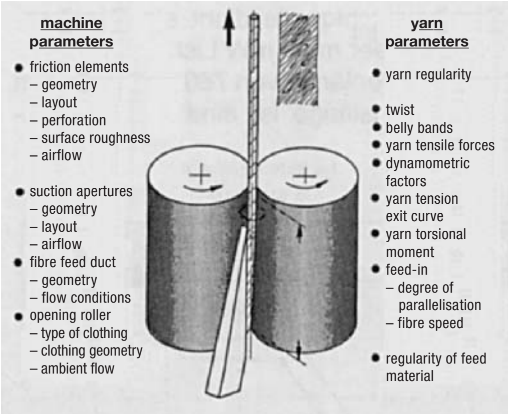


Fig. 8: Yarn parameters affecting quality and ascertainable yarn features in friction spinning.

Feeding the individual fibres to the nip of the friction drums (Figs. 9 and 10) produces a type of random-fibre zone but no covering fibres. The combining up of the fibres and introduction of the twist occurs simultaneously (a process which takes place once and is the cause of a few structural problems). The yarn take-off at right angles to the friction surfaces gives rise to a corkscrew arrangement of the fibres in the yarn. Under tension, the fibres on the circumference of the yarn

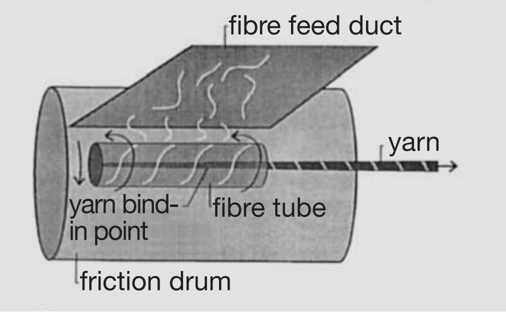


Fig. 9: Fibre transition from feed duct to yarn in friction spinning.

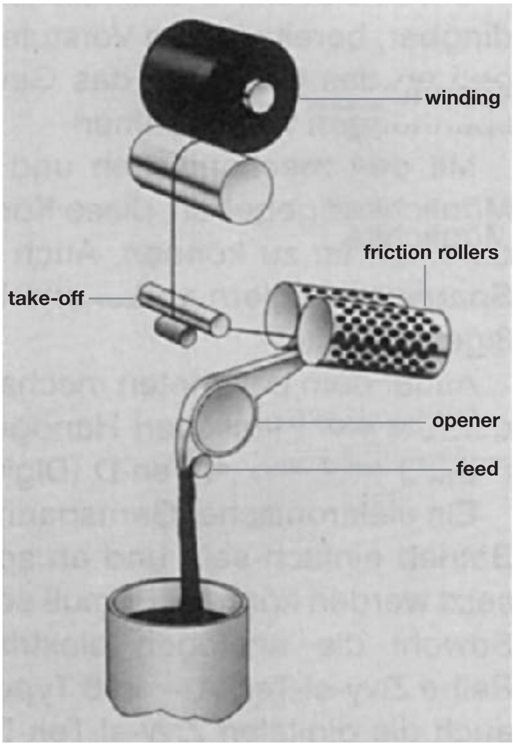


Fig. 10: Friction spinning (SKF).

must first orient themselves to the essentially coreless axis of the yarn. Protruding fibres which give the yarn a high level of hairiness and good covering properties can be more easily drawn out of the sliver. A twist can be established in friction yarns but the uniform twist produced by this method in the core of the yarn does not allow an objective comparison of twist values.

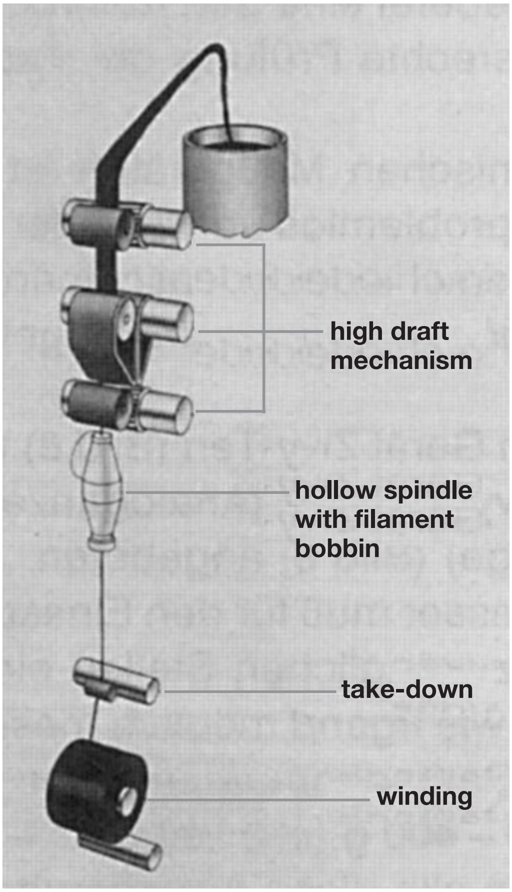


Fig. 11: Wrap spinning (SKF).

V. Wrap spinning: unlike the false-twist yarns, wrap-spun yarns are reproduced from a continuous sliver with a different composition to the yarn core (Fig. 11). Filament yarns are usually used which are spun around a yarn core composed of parallel staple fibres all running in the same direction in spiral twist. By making an appropriate choice of size and type of both components and different wrap densities, yarn structures can be produced with properties which can be varied within a wide range. However, in the interest of giving the yarn a pleasing appearance, the wrap components should not represent more than 5–10% of the total weight of the yarn. In the case of wrapped yarns, it is the core which takes up most of the tension. The larger this is, the tighter the strangle hold the wrap has on the parallel fibres in the core. This produces the cohesive forces which resist the load. It therefore follows that the tension used to apply the filament wrap to the core is more important than the number of loops in the wrap themselves.

In a productivity comparison (Figs. 12 and 13), the difference between the ring spinning method and the other high-performance methods becomes clear. Ring

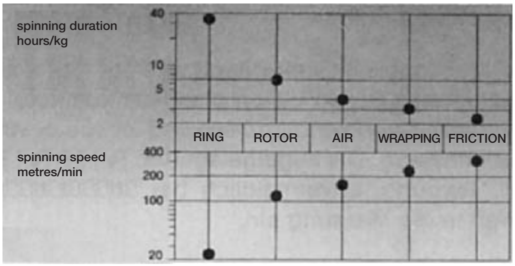


Fig. 12: Productivity comparison between various spinning methods.

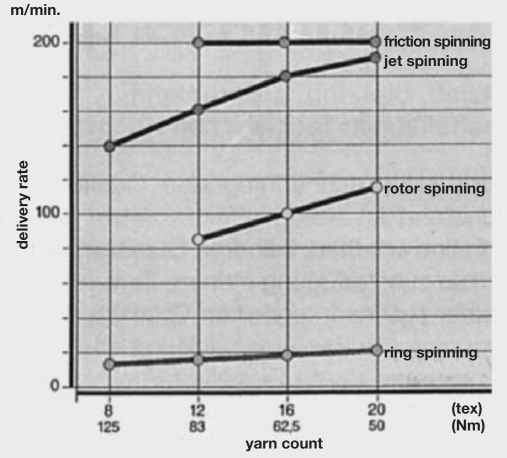


Fig. 13: Possible delivery rates of individual spinning methods relative to yarn count.

spinning is the slowest method but, by optimization, it becomes the fastest spinning method by a considerable degree. Particularly when processing polyester for example, attention must be paid to the danger of damaging the yarn. Jet spinning is faster than rotor spinning but, depending on the yarn count, friction spinning achieves the highest values with a constant delivery of 200 m/min.

A technological analysis of the different spinning systems with regard to quality of yarn and flexibility leads to the following conclusions: a critical aspect of yarn quality for new spinning systems is the yarn strength (Fig. 14). Strength comparisons of the different systems show that ring-spun yarn always produces the highest values. Rotor- and friction-spun yarns achieve relatively good values with short fibres, whereas air-jet-spun yarns achieve relatively good strength with man-made fibres. On comparing the yarn count ranges of the different spinning methods, ring spinning again proves to be the superior method. With regard to

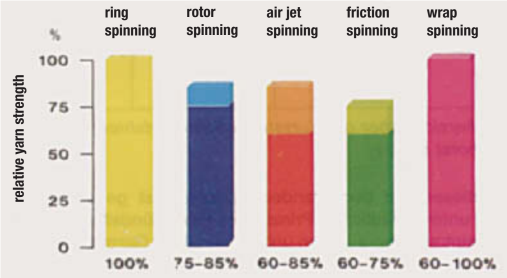


Fig. 14: Comparison of achievable yarn strength in various spinning methods.

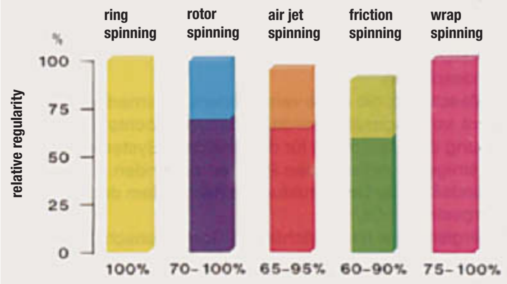


Fig. 15: Comparison of achievable yarn uniformity in various spinning methods.

yarn uniformity, friction-spun yarn is somewhat less uniform than the others (Fig. 15). The possible ranges of application can be derived from these quality and flexibility comparisons. It is clear that non-conventional spinning systems are not as universally applicable as the ring spinning system. In spite of this, these yarns

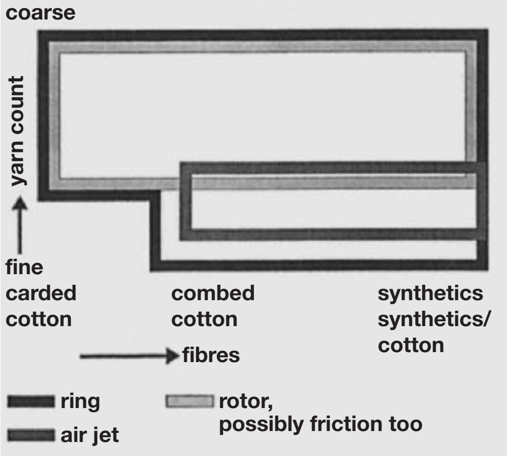


Fig. 16: Schematic application ranges for different spinning systems.

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processing stage	feature	spinning technology ring spinning	OE rotor spinning	OE friction spinning	air false twist spinning
before entry into the spinning machine: feed material	regularity	o	o	+	o
drafting zone formation zone opening and individualising zone	fibre opening – drafting – orientation – speed	–	+	o	–
consolidating zone consolidation point	moments of torsion	–	o	+	+
winding zone	yarn tensile forces	+	++	o	+
	dynamometric values	+	+	+	+
	twist angle of inclination	+	+	++	++
	belly bands wrapping fibres	–	+	+	++
	yarn regularity	++	++	++	++
	hairiness	+	+	+	+

++	well suited or on-line quality monitoring and process control
+	well suited for random sample type controls in the laboratory or on the machine
o	conditionally suitable for quality control, unsuitable for process monitoring
–	unsuitable for quality control and process monitoring

Tab. 2: Property profile of different types of spun yarns.

can be produced economically and with sufficient quality to manufacture a number of end products. In future therefore, several spinning systems will compete with each other on the market (Fig. 16) as the property profiles of the yarns are so different (Tab. 2):

- ring spinning: indispensable for high-strength yarn and structurally durable yarns.
- rotor spinning: of interest particularly for the processing of coarse and medium fine fibres for a wide range of end products. The application range can be increased by combing the cotton.
- air jet spinning: most suitable for long fibres, i.e. combed cotton and mixtures in medium to fine titres (area of application chiefly shirts and bedding).
- friction spinning: the softness of friction yarns means that they can be used in knitted fabrics in spite of their reduced strengths.

(according to Wulfhorst, Stalder, Hartmannsgruber, Schönung and Denssen).

Spin texturizing Targeted effect on structure during the spinning of filaments leading to, for example, higher elasticity and bulk.

Spiraldo system Device on → Winch beck. The winch is in the form of a spiral which enables the perfect control of a batch sewn together to form a continuos rope. Different piece lengths do not matter. However, the individual loops have the same lengths, which can be selected. Loading and discharging is much faster than if each piece is sewn together in a loop.

Spiral steamer (Krostewitz steamer or Gerber system). Universal steamer for printed goods (dry fabric fixing): spiral-shaped fabric feed-through (guide-roller contact on one side only), centrally located Teflon guide blade and fabric exit to the side. Fabric content 43–200 m.

Spirit → Ethanol.

Spirit-soluble dyes Used as so-called “brightening dyestuffs” in leather dyeing for dyeing greases, plastic, many types of lacquers and metal foils, etc. Also used for retouching. The light fastness of spirit-soluble dyes is dependent on fastness of the dye and lacquer composition.

I. Cationic dyes (selection): spirit solubility and strength good; light fastness moderate.

II. Acid dyes: spirit solubility and strength somewhat less but light fastness better. Selection rather restricted.

Splicer Controllable ancillary device on automatic bobbin winders which carry out the splicing operation at the winding head when there is a thread break.

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consolidating zone consolidation point	moments of torsion	–	o	+	+
winding zone	yarn tensile forces	+	++	o	+
	dynamometric values	+	+	+	+
	twist angle of inclination	+	+	++	++
	belly bands wrapping fibres	–	+	+	++
	yarn regularity	++	++	++	++
	hairiness	+	+	+	+

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Splicer Controllable ancillary device on automatic bobbin winders which carry out the splicing operation at the winding head when there is a thread break.

Automatic bobbin winders with knotting devices can be fitted with splicers as an upgrade.

Splicing Intense intermingling/interlooping of the thread ends of two overlapping slivers (yarn) by means of a targeted stream of compressed air. Splicing technology is regarded as a genuine alternative to knot-free joining technology.

The knot-free spliced joining of yarn ends is carried out by an automatic splicer. Particularly in the case of the worsted yarn sector, knot-free thread joins have proved themselves particularly valuable in knitting and weaving in comparison to knots which, due to their tendency to catch, cause the threads to break or overstretch at the thread guides. Apart from this, knots have an unpleasing appearance due to their differing dye affinities during piece dyeing. Spliced joins can be used universally and practically never fail. At the join, the thread ends are compacted so that diameter of the join is only 1.2 times that of the thread. The strength of the join is about 80% of that of the yarn. In the fabric, spliced joins in the yarn are invisible or almost invisible in comparison to knots.

Split fibres (splice fibres). Manufactured from polyethylene-based polymer films (melting point 130°C) (depending on longitudinal cut, mono-axial heat-stretched and thermoset) or polypropylene-based polymer (melting point 165°C) (mono-axial or bi-axial heat-stretched, thermoset and longitudinal cut), subsequent splicing or splitting as well as crimping and staple cutting. In principle, mechanical separation into elements while stretching, whereupon the disintegrated film is subjected to a powerful stream of air or high-frequency sound. This produces a fine parallel gossamer layer of very fine fibres of high breaking strength and abrasion resistance. Narrow fibre strips are separated from the initial fibre veil and twisted into small slivers or fibrous yarn. Split fibre yarn has the appearance of a continuous, voluminous, multi-filament yarn of synthetic fibre with short protruding fibre ends. Coarse split fibres are suitable for the manufacture of chenille-type yarns for the carpet industry.

Splitting Two-component fibre systems which are spun as such and should be thermally or chemically treated during the finishing stage so that the two components separate from each other and the fibre titre becomes significantly finer. A flock coated warp velvet made from two-component fibres must be thermoset before splitting in order to avoid creasing during chemical splitting. Splitting is carried out from long liquor with 10% caustic soda at boiling point for 30 min. A second thermosetting process must then be carried out to sinter the split fibres (210–220°C for 30–40 s).

Sponge rubber → Foam rubber.

Spontaneous combustion → Combustion without the application of heat from external sources.

Spontaneous ignition temperature (SIT, ignition point), lowest temperature at which spontaneous ignition occurs due to gas formation (→ Flammable liquids).

Spores Reproductive and permanent form of → Bacilli and (→ Moulds) which are produced by the same fungus. No other → Bacteria produce spores. Spores such as those found in the soil are not harmful to the human body. Anthrax spores on the other hand are harmful. After the spores are formed, the rod-like body decomposes, releasing the spores. Properties: extreme resistance to heat, cold, drying out (over periods of years) and high pressure.

Sporicide → Spores annihilation. → Sterility.

Sports clothing → Functional clothing for special requirements (→ Active wear); not to be confused with → Sportswear.

Sports jacket Fashionable men's jacket with sack-shape cut; without shape, used as a summer jacket; shaped, used as a sports jacket (also high-quality, elegant designs, 250–500 g fabric weight) with shape-retaining interlining also used as a holiday jacket (→ Topper).

Sportswear Leisure sports and town and weekend clothing in the form of → Casual wear in a functional but smart genre, with sports-like attractive details; includes knitted wear and imitation leather.

Spot-bonded nonwovens Spot-shaped welded nonwovens made from a mixture of thermoplastic and non-thermoplastic fibres reinforced by passing through a calender. The rollers have helical engraves lines, the raised parts of which are distanced from each other so that the welded area accounts for no more than 13% of the whole area. → TCF process.

Spotting,

I. Pouring several portions of treatment liquors manually on to goods during dry cleaning.

II. Behaviour of short thickeners (usually structurally viscose thickeners). The portions of printing paste transferred from the valleys of a printing roller in Rouleaux printing, or through the perforations of a rotary screen, or through the interstices of a flat-screen gauze onto the textile substrate, which do not spread into each other, to give a level film of printing ink. Instead, the small spots left behind result in a cloudy printing image after fixing.

Spotting agent Used for removing local contamination (spots, etc.) on textile goods. They differ as follows (Fig.):

1. Dry spotting agents: all organic solvents (mixture); used with the total exclusion of water.
2. Wet spotting agents: used with water. Essentially a solvent-containing surfactant combination including emulsifiers with washing or cleaning properties such as amine soaps, alkyl sulphates, alkyl sulphonates, fatty-acid condensation products, alkyl-aryl sulphonates or oxalkylation products.

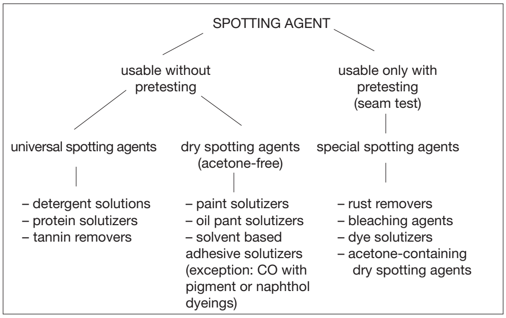


Fig.: Spotting agent differences.

Spotting powder Used to absorb moisture during spotting in order to prevent the appearance of the feared stain borders. Active components: talcum, kaolin, fullers earth and gypsum.

Spray additive Method of softening textiles in the dyed-fibre flocks.

Spray application Handle-modifying finishing or moistening of textiles carried out by spraying finishing liquor on to the textile web (Fig. 1). In contrast to other application methods, the goods are not immersed. Finishing liquors are mainly applied in concentrated form < 40% and preferably 10–20%. Special spraying machines are available for finishing fabrics according to the → Low wet pick-up method, especially for wash-and-wear finishing (Fig. 2). With this unit it is possible to apply a uniformly distributed thin layer of liquid over the whole width of the goods on the right side which then soaks thoroughly into the fibres.

Spray applicators → Spray finishing machine. Also used for applying plastics to fabric or nonwoven webs by spraying the plastic onto the substrate without contact instead of applying it with a doctor blade, for example, in the case of floor coverings.

Spray bonding spraying plant used for bonding polyester- or siliconized-fibre based nonwovens. Web transport using circulating conveyor belt. Spraying performed using traversing spray guns across the textile

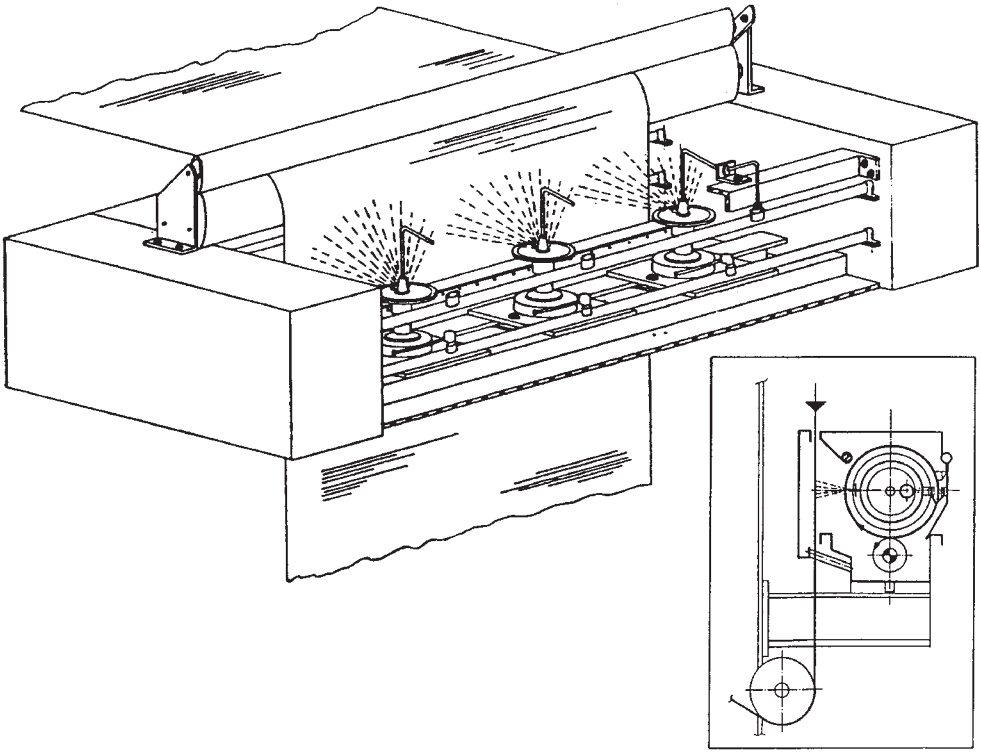


Fig. 1: The Mutschnik spray application system.

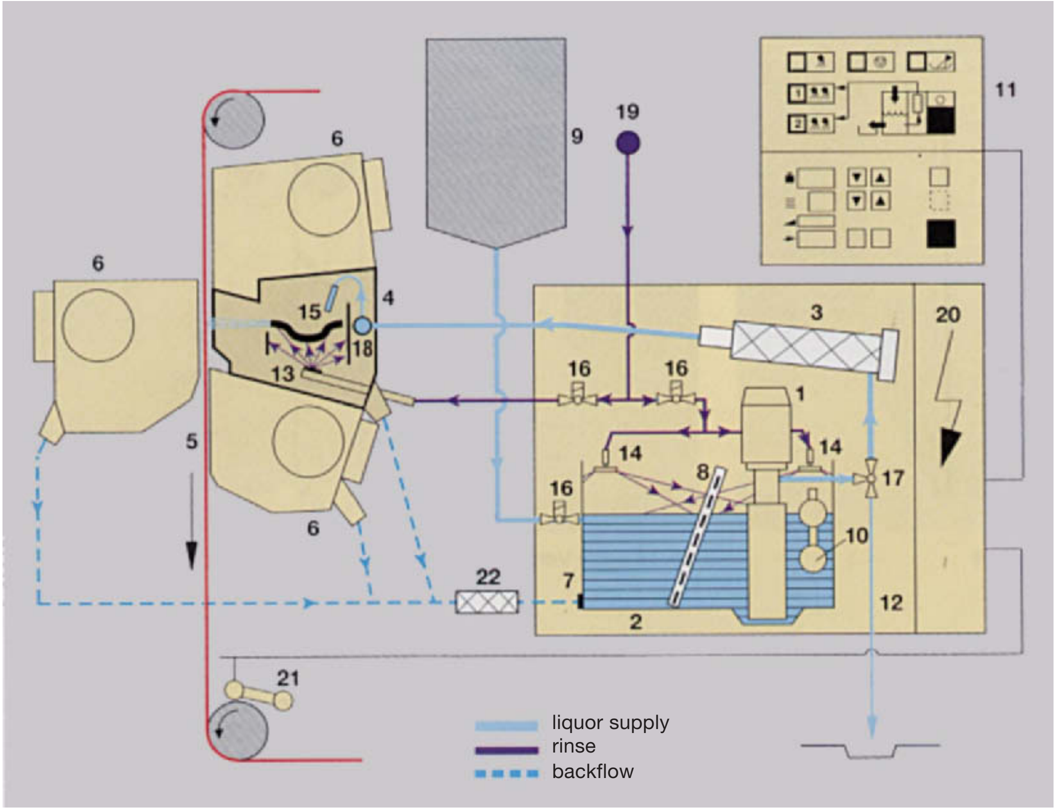


Fig. 2: Construction principle of the complete spray application facility with RF-Compact II by WEKO.
1 = immersion shaft pump; 2 = liquor tank; 3 = filter; 4 = rotor mounting; 5 = fabric web; 6 = suction module; 7 = backflow opening; 8 = backflow filter; 9 = mixing tank; 10 = float; 11 = operating unit; 12 = run-off pipe; 13 = spray nozzle; 14 = turbo jets; 15 = rotor; 16 = magnetic valve; 17 = pneumatic three-way valve; 18 = liquor distribution rotor; 19 = fresh water supply; 20 = electrical and electronic elements; 21 = digital tachometer; 22 = plug-in filter.

web, switching off automatically at the edge of the web. Water cascades in the spraying booth for washing down spray droplets and recombines in an separator/collector located at the side.

Spray coating,

I. Method of polyurethane coating by chemical foaming as graded coating on, for example, (tufted) carpet backs, in which all agents are mixed in a mixing head and then sprayed immediately on to the back of the carpet through special nozzles. The spray coating is controlled by the precise maintenance of mixing ratios and temperature so that during coating, a part of the mixture penetrates into the back of the carpet before foaming and anchors the knops. Not until after this does the chemical foaming take place by the isocyanate reacting with the small amounts of water residing there to form urea derivatives and carbon dioxide, which serves as the gas component for turning the sprayed coating into a foam. Pre-coating and fillers are not ab-

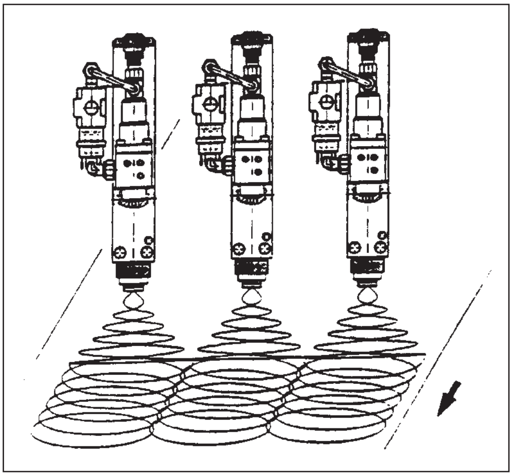


Fig.: Spray coating extruders in action (Nordson).

solutely necessary. After applying the chemicals: heating by infrared heating line (compensated heat losses) and hot embossing calendering. → Polyurethane preparation plants.

II. Meltable polymers (hot-melt adhesives) can be extruded from nozzles arranged next to each other across the width of the textile (see Fig.). Two threads of the polymer are laid in accordance with a specified principle before hardening thus forming a coating of initial substrate which receives a second substrate later and which is laminated on.

Spray-dampening Finishing character work; particular usual for washing cloths and wool cloths and the like in order to impart the desired moisture content and heavy, soft handle to the fabric. In most cases with non-supersaturated moist air after the drying frame (stenter drying) on the spraying machine by spray jets or rotating brush rollers according to the so-called "natural moisture" principle.

Spray dyeing machine A form of → Hank dyeing machine for dyeing hank yarn on perforated yarn-carrier tubes with firmly connected rotating hanks. The machine gently turns suspended hanks. The liquor is sprayed on the hanks through the perforations. Units are available with up to 30 carrier tubes. The hanks of yarn are suspended next to each other and behind each other on the perforated tubes (Fig. 1) which turn cyclically in order to move the hank in a repeat fashion (according to a register). The pumped dye liquor sprays out of the perforated tube (Fig. 2) through the yarn and flows down the hank into the heated sump from which it is pumped round and used again.

Another type of hank dyeing machine, dyes, centrifuges and dries hanks of wool and wool blends in a single process. The triangular shaped carrier arms which carry the hanks of yarn are attached to a rotor (Fig. 3). During dyeing, the liquor circulates through the arms into the yarn, is captured in the liquor tank and delivered to the dyeing process via filters, circulation pump and heat exchanger. After dyeing, the yarn is centrifuged on the carrier arms and then dried by the introduction of hot air via a secondary circuit. A blower circulates the air which has been heated in the heat exchanger.

Fig. 1: Fong's rope dyeing machine.

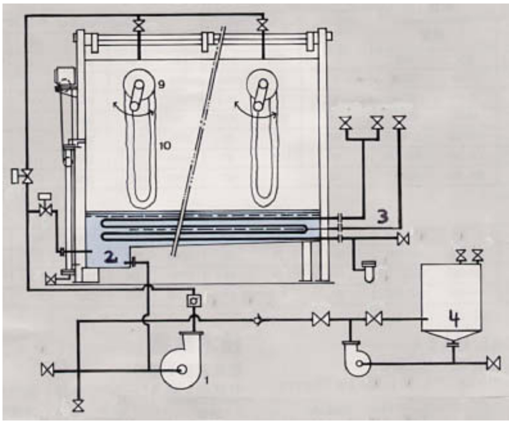


Fig. 2: Diagram of a Fong's rope dyeing machine.
1 = pump for liquor circulation; 2 = liquor sump;
3 = heating system; 4 = additive tank with additive pump;
9 = perforated rotating pipe with transport shackle;
10 = yarn rope.

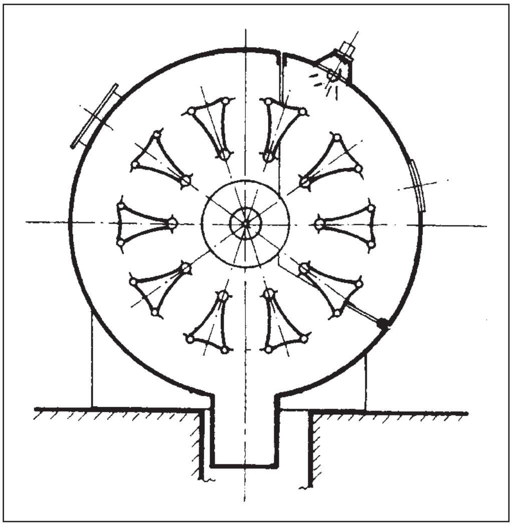


Fig. 3: Diagram of a rope dyeing centrifuge; the triangular forms for carrying material are clearly to be seen (MCS).

Spray finishing Finishing with → Spray dyeing machine, used particularly for pressure-sensitive silk, viscose filaments and blended fabric articles such as crêpe de chine, marocain crêpe, flamisol crêpe, georgette crêpe, bark crêpe, moss crêpe, blister crêpe, matelassé, hammer blow and even for taft and similar smooth articles as well as for dress fabrics and linen fabrics for correcting the final handle. The advantage over padder finishing is that only a small amount of finishing liquor is applied. The aqueous film which is squirted or sprayed on in most cases also offers advantages during subsequent manufacture. Appropriately low viscosity finishing solutions are used as the spray liquor, if necessary, in combination with glycerine or something similar or with softeners, organic acids (for scroopy silk finish), matting agents and fragrant finishes, etc. Quickly and easily applied solutions are then mostly applied directly on the stenter dryer otherwise the goods are left rolled up beforehand. → Jet impingement.

Spray finishing machine Special machines derived from older spray dampening machines which apply finishing liquors in the form of powders or low viscosity mists through nozzles either on one or both sides as a form of → Spray finishing. There are different designs such as those with an open arrangement (additional extraction equipment or improved supply of fresh air reduces exposure to personnel), those in separated chambers (the goods passing in and out through wall slots) up to high-performance machines with integrated, enclosed atomising chambers through which the goods pass vertically up past batteries of air nozzles arranged on both sides across the web at a speed 6–36 m/min. Continuous closed loop speed control, crease and tension-free passage with all the necessary monitoring equipment; can also be used for moistening or dampening purposes.

Spray guns Used for moistening (spraying) textiles, during stain removal, dry-cleaning or re-touching (wardrobe) and used for leather dyeing, spray finishing, spray printing with printing ink solutions and lacquering, etc. Various different designs, in most cases using a push button valve (instantaneous shut-off), for example, at mains water pressure as a water-spray gun and used with compressed air for dye solutions and lacquers, etc. particularly in the case of leather spray dyeing, and used without compressed air, with electric drive, automatic boost pump, finger-control and nozzle regulation, etc.

Spray impregnation Application with device for → Low wet pick-up of synthetic-resin pre-condensate solution, by spraying. Advantage: energy saving and improved utilization of the condensation equipment.

Spray printing The pattern is produced by → Stencils for spray printing. The thin and finely matched printing ink solutions are sprayed through the fine stencil voids on to the goods using nozzle atomizers (Fig.) or compressed-air spray guns (air extraction and safety spectacles required). In principle, all classes of dye are suitable; fixing and washing as in the usual applications. → Chromojet printing of carpets. Nozzles are controlled by a computer program for applying an uneven, non-systematic pattern to fabrics.

Spray systems Spray the treatment liquor on to the goods over a broad front via nozzles in order to intensify the liquor exchange. Fig. 1 shows how the

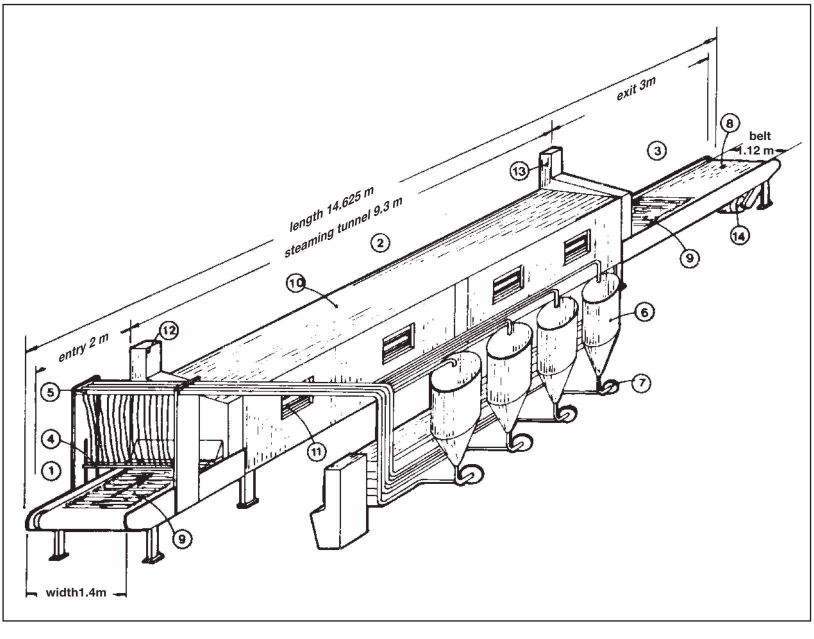


Fig.: Spray printing machine (Texinox).
1= entry table;
2 = steaming tunnel;
3 = exit table;
4 = impregnating ramps;
5 = distributor;
6 = dye vats;
7 = injection pump;
8 = conveyor belt;
9 = fabric;
10 = steamer housing;
11 = observation hatch;
12 = entry chamber;
13 = exit chamber;
14 = drive to 8.

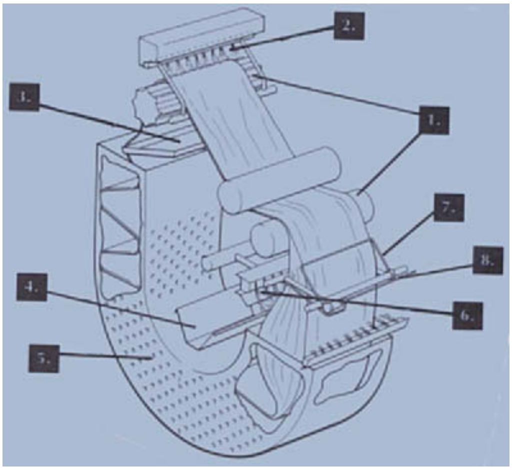


Fig. 1: Dye liquor spray application (Diplo system from Sclavos); the numbers are explained in the text.

goods are moved by the two carrier rollers (1) in the Diplo system from Sclavos. The spray nozzles apply the liquor (2) before the folder (3) takes off (plaits) the goods into the J-box (5). As the swollen rope leaves the goods storage chamber, the front cascade (6) sprays the goods with liquor again while the air nozzles (8) blow on to the goods.

In the Spray-Tex spray washing unit (Babcock, Fig. 2), contamination adhering to the surface, non-fixed dyes, chemicals and textile auxiliaries are loosened by spray jets with adjustable pressure and washed away. The wash water which is re-circulated via filters (temperature regulation adjustable up to 98°C) is sprayed on to the goods through flat jets with a high degree of evenness over the entire width of the goods (Fig. 3).

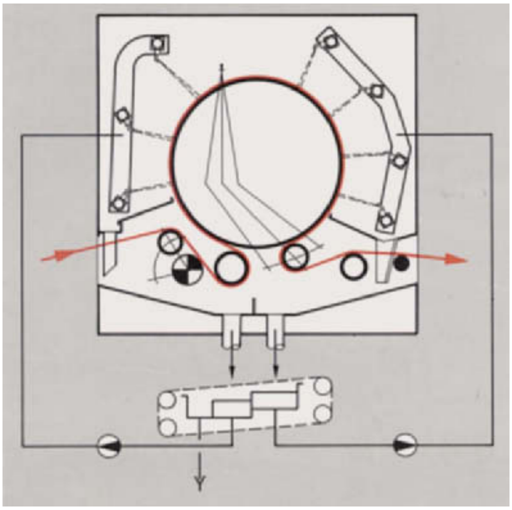


Fig. 2: Spraying during washing (Babcock) through both the perforated drum and through the goods.

Fig. 3: A suction drum wash compartment with a spraying system (Babcock) covering the full width of the goods.

Steam/water mixtures are also suitable for spraying. Thus, in 1987, the technical world was made aware of this method through the "Shock steam" pretreatment of cotton fabrics (Fig. 4).

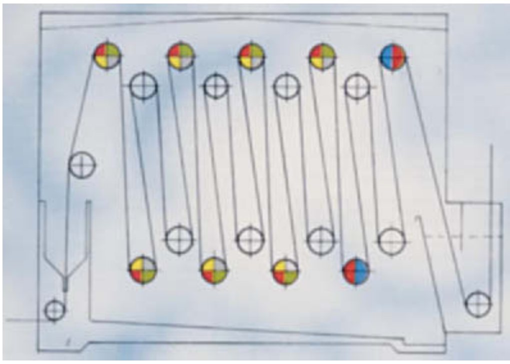


Fig. 4: Shock steam (Asisa).

The goods were intensively sprayed through with the treatment medium through perforated deflection rollers. At ITMA 1991, Kleinewefers KTM introduced the Raco-Yet spray system (Figs. 5 and 6) which operates according to this principle. Finally, there is also the wash system which uses the Injecta principle from Benninger which is a spray unit (Fig. 7).

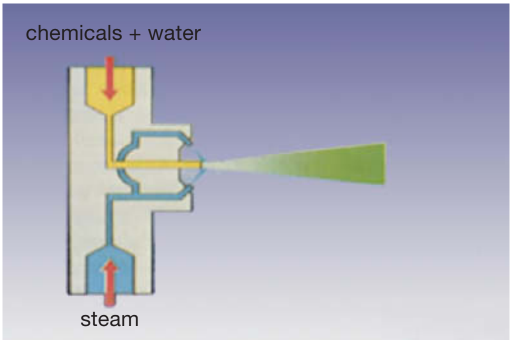


Fig. 5: A two-component mixing nozzle with external mixing (Kleinewefers KTM).

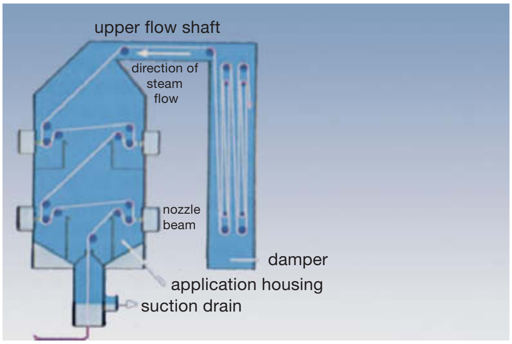


Fig. 6: Application housing with nozzle beam and connection to the damper (Kleinewefers KTM).

Spray test American test method for waterproof impregnation, by sprinkling artificial rain using a funnel-shaped sprinkling nozzle on to a stretched test sample. Excess water is removed by rolling a metal cylinder over the surface once, and weighing and drying to a constant weight (precisely controlled conditions). The Swiss Standards Specification and the → Pfersee-testing instrument are based on this test.

Spray washing machines Preferably used for the first phase of after-print washing of printed goods for the gentle acceleration of prints when removing thickeners and excess dye at low temperatures (Fig. 1). The machines significantly reduce the danger of ground contamination or shade modification due to staining in the treatment baths which follow, in which temperatures and times must be adhered to. The power and water consumption is justified because experience has shown that stains which appear during the first stage can only be removed during the following stages at considerable extra expense (residue problem). High-pressure spraying and low-pressure spraying have different and specific effects. Because the effect of high-pressure systems is almost purely associated with the surface, they are used at the start of the wash line during the after treatment of printed goods. Low pressure systems should not be applied until later.

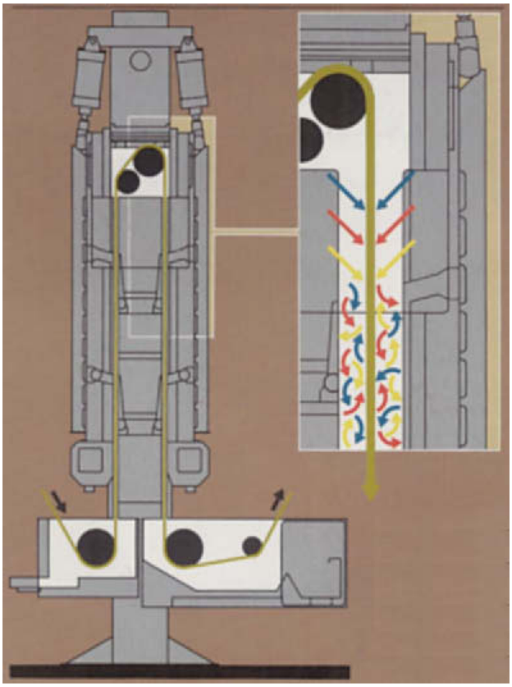


Fig. 7: Section through an Injecta wash system with funtional diagram (Benninger).

I. High-pressure spraying: the washing effect is good between 10 and 30 bar, but below 10 bar good performance can only occasionally be achieved (depending on the thickener). Above 30 bar, the increase in effect is no longer justifiably related to the water and power demand for pumping. As high pressures and large volumes of water require pumping powers which are no longer justifiable on economic grounds, interest is focused on small volumes of water through small diameter high pressure jets. However, the jets are susceptible to contamination and tend to block. The best processing method is to have the printed side facing down while spraying it from underneath at a slight tangent with the goods almost lying on top; liquor which has sprayed can fall freely from the goods, so there are no blocking effects, and filter effects and redeposition practically never occurs. Changing the angle of the jets has a pronounced effect. Because they act as a “surface plane”, thickeners and excess dye are removed from the surface of the goods but the effect is less pronounced between the threads (depending on the weave and thickness of the goods) and is almost non-existent be-

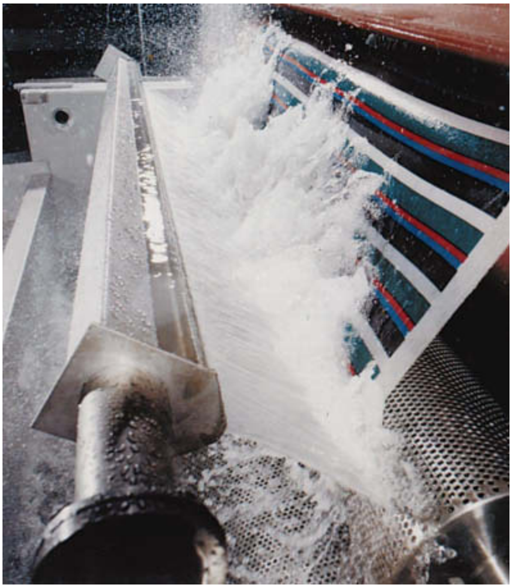


Fig. 1: An Arioli spray system in the first washing bath of an after-print washing of printed goods.

tween the fibres. Depending on the power, the effect is much greater for intense/saturated surface print than it is for intense penetrating print. Under the same working conditions, blank print thickeners are better removed in all cases, using high pressure sprays, than the same thickeners when fully immersed in a bath followed by padding. The spray effect is dependent on the preceding softening or dwell time due to the effect of the print-fixing conditions: over about a minute, there is no improvement, in fact, some thickeners get worse. Hot wetting followed by cold spraying is better than cold wetting alone.

II. Low-pressure spraying (e.g. as in a ribbed-drum washing machine, Fig. 2, with cycle rate at 120 m^3/h (2000 1/min) at 0.6 bar): surface effect for thickener which has not yet been loosened is significantly less than it is for high-pressure spraying. The cleaning effect (where surface cleaning is anticipated) is greater on thickener and excess dye lying between threads and in some cases between fibres. Blank surface printed thickeners are better removed using the full bath padding method. Taking also the risk of redeposition into account, low-pressure spraying with circulation during the after treatment of printed goods should not come first in the washing line. Unsuitable temperatures or chemicals will shift the equilibrium, contaminate the goods and may reverse the washing effect. In extreme cases, the machine becomes an applicator. High circulation powers result in fast and good distribution of fresh water and, possibly, chemicals; low-foaming products must be used otherwise circulation will be impaired.

Even for this machine, assembling several units one after another means less of an improvement in the cleaning effect from machine to machine because the effect achieved is more strongly dependent on speed than it is on the high-pressure spraying process. After successful cleaning of the surface, a slow time dependent transfer begins.

Jet spraying of goods plays a very important role in the unit in Fig. 3 showing a modified roller vat. All wash liquor is fed by separate pumps from the base vats which has not come into contact with the goods, by horizontal pipes provided with spray jets. The wash liquor is sprayed across the width of the goods as they pass. Otherwise it is only in the sump at the lower deflection roller that the goods come into contact with the liquor. Ballast liquor, which does not act as wash liquor in the liquor exchange, therefore does not come into contact with the goods.

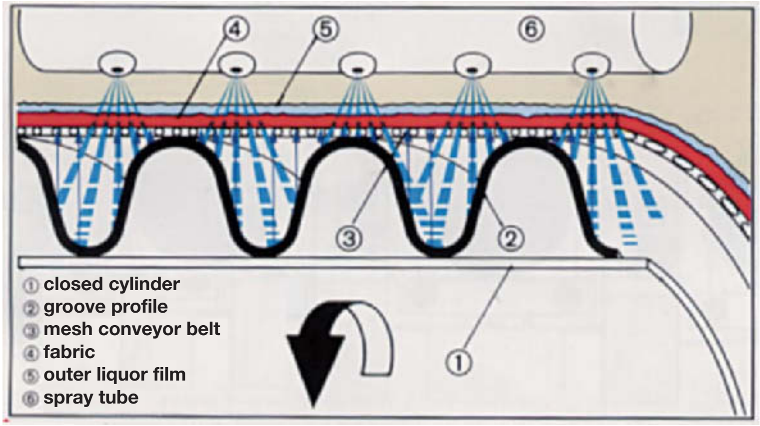


Fig. 2: Kleinewefers KTM ribbed-drum washing principle diagram.

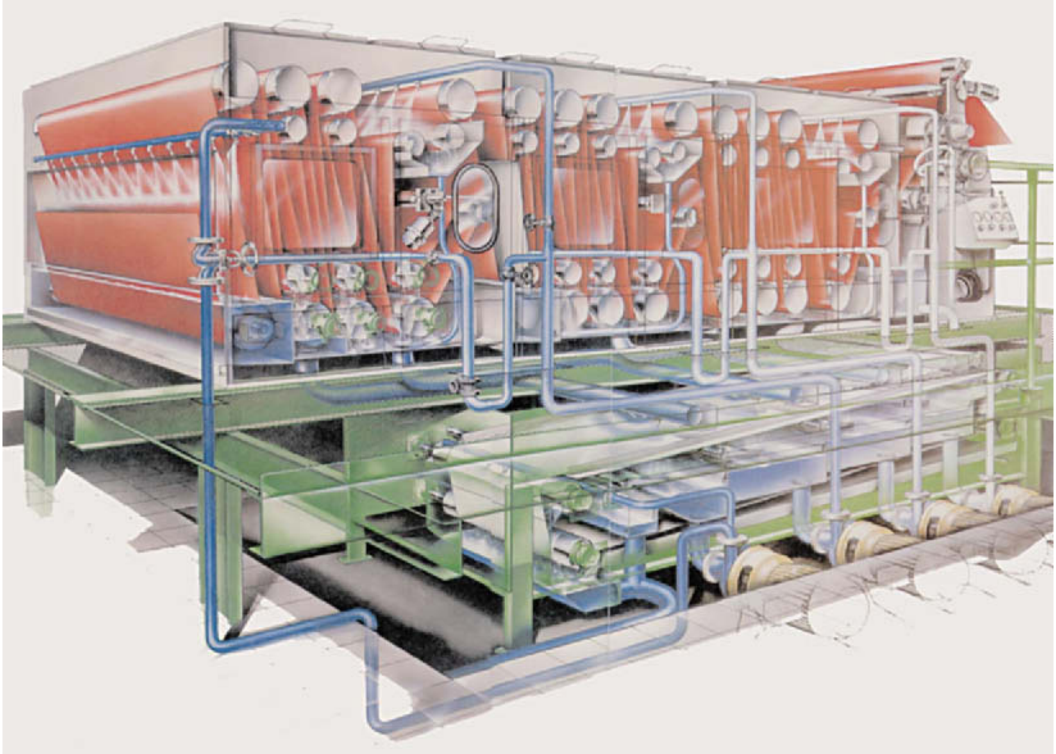


Fig. 3: The spray system in the Econ-Tex open width washing machine from Babcock.

Spread-coating (finishing). Application of thickened finishes using a → Doctor blade.

Spreader reel Special winch with slanting stainless-steel hoops for improved spreading of piece goods on the winch beck.

Spreading capacity Property of a fluid, particularly of a → Surface active compound which enables a drop of this fluid to cover the surface of another fluid or solid body spontaneously (→ Wetting).

Spreading coefficient In the case of surfactants, used for the determination of → HLB values. Within the HLB range of 7–15, the relationship between spreading coefficients and HLB values is linear. The spreading coefficient S_1 is determined from the surface tension σ_{WL} of a 1% surfactant solution in water, the surface tension of the organic phase alone σ_{OL} (preferably castor oil) and the surface tension σ_G of this solution against the organic phase:

$$S_1 = \sigma_{WL} - (\sigma_{OL} + \sigma_G)$$

The HLB value is found from a calibration curve which has been constructed from the spreading coefficients of a number of emulsifiers with known HLB values.

Spreading tension (→ Spreading coefficient), the tendency of a fluid to spread out over a solid surface is determined by the difference between its → Wetting tension and its → Surface tension. This parameter is called the spreading tension and is expressed in N/m. A positive value signifies that the fluid spreads on the surface spontaneously.

Spring sleeves consist of elastic, compressible metal springs used to facilitate the shrinkage of man-made yarn during the finishing process.

Sprinkler systems Automatic fire-extinguisher systems. In the event of a fire, the caps, made of solder which cover the sprinkler heads of the extinguisher system, melt (e.g. at 70°C) releasing the water, carbon dioxide or tetrachloromethane through the heads. Use: in stenters, raw material storage areas or throughout the whole factory.

Sprinkling process Dye powder is added directly to the stock thickener without first dissolving or making it into a paste. Dispersion, reactive and a few acid or metal-complex dyes are most suitable for this purpose.

Spunbond → Random webs.

Spunbonded fabric Compacted → Spunlaid fleeces.

Spun-dyed fibres Man-made fibres dyed in the spinning paste (spun-dyed).

Spunlaid fleeces → Nonwovens manufactured by spinning fibres in a melt, solution or wet spinning process and then laying on a conveyor belt (Fig.).

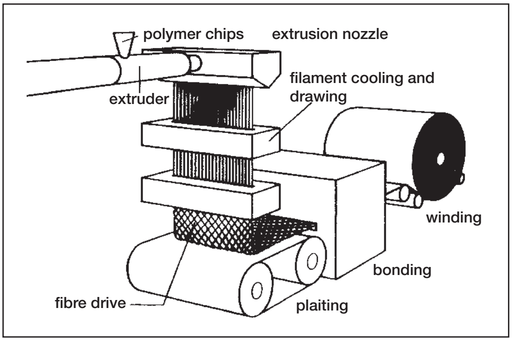


Fig.: Spunlaid fleece production principle (Freudenberg).

Spun yarn → Yarn spun from fibres.

Spun yarns According to DIN 60 000 strand-shaped structure made from → Staple fibre which is held together by twisting (spinning) as opposed to → Continuous filament yarn.

Sputter coating Using this technique, it is possible to apply defined coatings with the desired properties to the surfaces of flexible, sheet materials. Reflecting, conductive, insulating and magnetic properties are some which can be achieved. The main application at the present time is foils and films but some possibilities have emerged in regard to the application of sputter coating textiles.

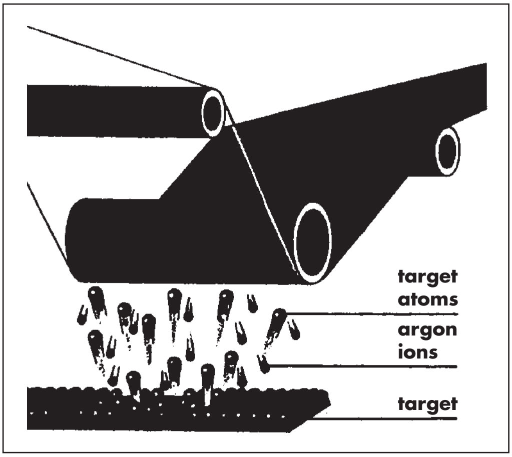


Fig. 1: Sputtering process (Heraeus).

Sputtering (cathodic atomization) is a vacuum coating method used for the production of thin coats. During the sputtering process, a corona discharge is created by an electrical field between the material source (target) and the substrate in an inert-gas atmosphere (Fig. 1). A plasma is produced which is an electrically conductive gas consisting of neutral particles, free electrons and positively ionized inert-gas atoms. Positive inert gas ions are accelerated from the plasma on to the target. When the ions collide with the target surface, atoms are released from the target material which hit the substrate at great speed to form a coating. The large number of target materials used (metals, alloys, ceramics and glasses) makes it possible to apply coatings with the required properties.

Sputter coating differs from alternative thin-layer technologies such as galvanizing, thermal or electron-beam vaporization and has the following advantages:

- a large number of materials can be precipitated,
- different materials can be precipitated simultaneously,
- the adhesion is better due to the kinetic energy of the atoms hitting the substrate and this produces a genuine bond between the substrate and coating,
- the coating properties are highly reproducible between tight tolerances,
- the process is environmentally friendly.

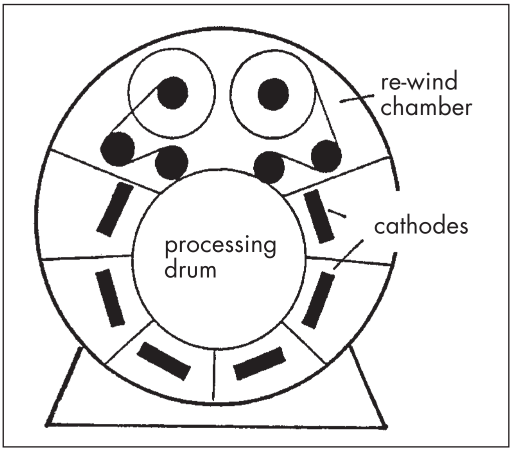


Fig. 2: Sputter coating machine (Heraeus).

The reeling mechanism is located in the upper part of the vacuum vessel (Fig. 2). The substrate is guided past 6 coating chambers by means of deflection rollers in the upper part of the vessel and then reeled up again. All 6 coating chambers can be pumped separately. The maximum possible width of the web is 1.68 m. The web on a single roll may be as long as 10 000 m depending on the substrate thickness. Before coating, the individual chambers are pumped out to a pressure below 10^{-5} mbar in order to leave as little residual gas as possible. After the working gas, typically argon, is allowed into the vessel, the working pressure is adjusted to 10^{-3} mbar. To precipitate a metallic coating of 10 nm thickness, it is possible to run the process at a web speed of around 10–20 m/min with a single cathode. When oxygen is added to the inert argon, the metal atoms react in a reactive sputtering process to produce an oxide which is then precipitated. Reactive sputtering requires time for the chemical reaction to take place and is therefore significantly slower. Typical web speeds range from 0.1–1 m/min for a single cathode (according to Siefert).

Squeegee contact angle Angle formed between the squeegee blade and the flat screen or the tangent to the rotary screen. In the case of the rod squeegee, it depends on the diameter (the smaller the diameter the greater the squeegee contact angle) but in the case of the blade squeegee, it is dependent on the angle at which the blade has been set. Together with the → Squeegee pressure, the squeegee contact angle affects the amount of print paste applied (→ Squeegee systems in printing).

Squeegee lifting mechanism in flat-bed screen printing If one-man operation is used in screen printing, the squeegee, providing it is not a tilting or double squeegee, has to be lifted above the printing paste on the side adjacent to the printer so that it can take the paste with it again on its return. Lifting devices are used for this purpose which come in various designs.

Squeegee pass The movement of the doctor blade from one side of the screen to the other. This movement can be carried out once or several times depending on the substrate, print style and printing press.

Squeegee pressure Together with the → Squeegee contact angle, this controls the amount of printing paste which is applied during flat and rotary screen printing. In the case of the magnetic-rod squeegee system, it is established by differences in the strength of the magnetic field, but in the case of the blade squeegee, it is determined by appropriately adjusted spring pressure (→ Squeegee systems in printing).

Squeegee profile The squeegee profile is characterized by the cross-section of the squeegee rubber. Depending on requirements, synthetic rubbers of different thicknesses are used which lead out on the side turned towards the screen gauze with the edge rounded off or cut flat or steep. → Squeegee systems in printing.

Squeegee setting Characterized by the → Squeegee contact angle.

Squeegee stroke → Squeegee pass.

Squeegee stroke length Distance travelled by the squeegee in screen printing in a single → Squeegee pass.

Squeegee systems in printing,

I. Rouleaux printing: the squeegee is used to scrape excess printing paste off the surface of the printing roller. It is mounted between the printing ink transfer roller and the printing surface and is attached via steel pins in bronze or brass bearings. These can be adjusted in a horizontal direction via threaded spindles screwed into the bearing head. Adjustments can be made in the vertical direction after these have been released. Thus, the angle of contact to the printing roller can be adjusted at will. The squeegee consists of a squeegee holder, a doctor blade and, if necessary, a support blade.

II. Screen printing: the squeegee is in the form of a sliding bar made of wood or metal with a straight scraping edge usually consisting of a rubber profile. Depending on the pattern, printing paste, gauze density and type of fabric, one, two or more → Squeegee passes will be necessary to apply sufficient ink paste to the surface of the goods. Improved designs of this blade squeegee are in the form of a double squeegee, double tilting squeegee and multi-colour double squeegee. The (magnetic) rod squeegee is gaining in importance.

III. Rotary-screen printing and rotary-screen printing of carpets: blade squeegees, rod squeegees and combined blade and rod squeegees are used in rotary screen printing and blade squeegees, rod squeegees and double rod squeegees are used in the flat-screen printing of carpets. The rod squeegee (with or without friction) is used in the rotary screen printing of carpets. The fan, box and split squeegees are special rod-squeegee designs.

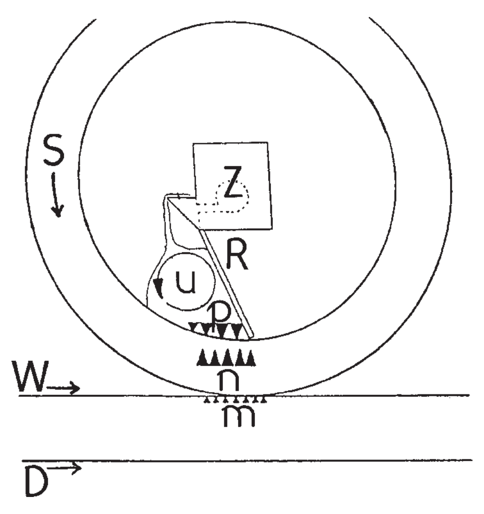


Fig. 1: Sketch showing the principle of print paste application with a blade squeegee in rotary screen printing.
m = penetration resistance; n = flow resistance; p = back pressure; u = circulation flow; D = direction of movement of printing blanket; R = blade squeegee; S = direction of screen rotation; W = direction of movement of goods; Z = paste feed pipe in the distribution duct.

Along with the traditional blade squeegee, the magnetic rod method is also becoming increasingly important in its use in textile screen printing. The discussion about the properties of both squeegee techniques is not only fired by arguments associated with patents but, more astonishingly, there is also a huge variety of opinions and views about where each system should be used. The user who is forced to decide on one of the two squeegee techniques has so far been basing his decisions on cost factors.

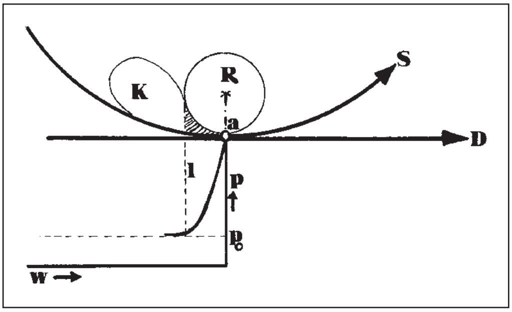


Fig. 2: The contact zone and back pressure diagram for a magnetic-rod squeegee in rotary screen printing.
a = contact point; l = border line; w = direction.
D = direction of movement of printing blanket; K = print paste wedge with hatched contact zone; R = rod squeegee; S = direction of screen rotation.

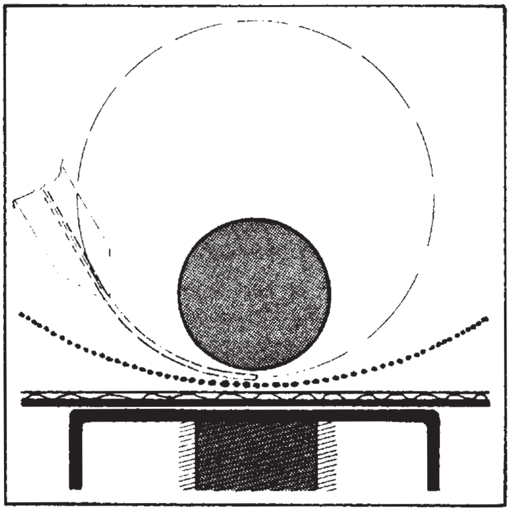


Fig. 3: Magnetic-rod squeegee of 25 mm diameter with a flat accumulation zone analogous to a flat-angled blade squeegee.

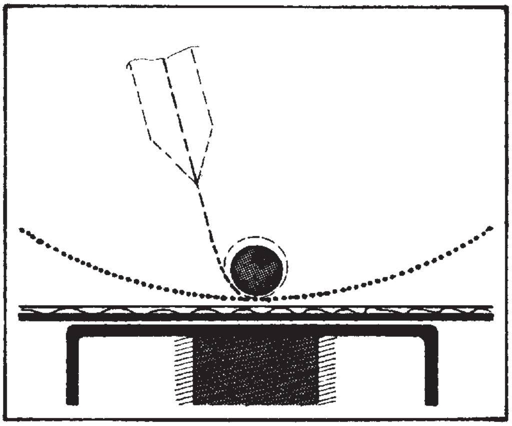


Fig. 4: Magnetic-rod squeegee of 8 mm diameter analogous to a steeply-angled blade squeegee.

The coating which is applied using the blade squeegee (Fig. 1) is more superficial; rod squeegees (Fig. 2) generally press the coating into the substrate more. Blade squeegees require a relatively coarse screen and printing pastes with relatively low viscosity for deep penetration. The rod squeegee is characterized by the type of coating (the rod behaves in a similar way to a roller and the contact pressure is relatively high) which resembles roller printing. Fine pattern details can be printed more clearly using the magnetic rod squeegee because its rod squeegee characteristics make it possible to use finer screens and printing pastes of higher viscosity. Large- or full-area patterns or ground prints can be printed more evenly by using a rod squeegee than by using a blade squeegee. It is preferable to install two rod-squeegee stations in existing blade-squeegee machines – one for the fine details (contours) and one for the large areas (blotches) (see Figs. 3 and 4).

Left/middle/right – when using the blade-squeegee technique, achieving a uniform coat on the left, middle and right becomes more difficult as the working width increases. On the other hand, evenness across the width is easy to obtain using the rod-squeegee technique because the magnetic field attracts the rod uniformly across the width – the greater the coating width, the greater the advantage of the magnetic-rod squeegee.

Blade-squeegee contact pressure: low to medium contact pressure; contact pressure produced mechanically (pneumatic, hydraulic or spring pressure and lever effects); risk of distortion – the force required for producing the contact pressure is introduced, or the squeegee is supported, via the ends of the squeegee unit. The capacity for adjustment and the reproducibility of the contact pressure depend on several factors. Adjustment can be corrected, or correction must be applied, on both sides of the machine.

Rod-squeegee contact pressure: medium to high contact pressure; contact pressure produced electromagnetically; distortion-free coating; contact pressure is produced by a magnetic field parallel to the rod without applying any load to the squeegee-unit mountings or the ink-paste feed pipe. The contact pressure is very easy to adjust and reproduce – adjustment is carried out by means of a printing pressure step switch at each printing station or continuously by using a rotary potentiometer.

The active wedge area is crucial for the determination of the contact time. In the print diagram, this area corresponds to the zone stretching from the initial rise in impact pressure, through the penetration resistance zone, to the squeegee contact point. The pressure behaviour in this area, which is known as the contact zone, has a significant effect on the amount of printing paste applied. A prerequisite for a uniform coating is a constant and defined level of ink paste over the entire printing width in order to keep the length and ratio of the two wedge areas constant. The discharge speed is dependent on the size of the impact pressure and the flow resistance of the screen. The size of the impact pressure is determined by the geometry of the squeegee, the squeegee force, the print speed and the flow properties of the printing paste. The flow resistance is determined by the percentage of the gauze area which is open.

The parameters which affect the process are divided into those which are variable and those which are constant as follows:

a) Variable parameters:
- squeegee geometry,
- squeegee force,
- print speed,
- level of printing paste,
- printing paste;

b) Constant parameters:
- screen,
- substrate,
- print cover.

Either the constant parameters can be adjusted at considerable expense in terms of time and money or they cannot be adjusted at all. They are used as the basis for selecting the variable parameters which can or must be adjusted at little cost during the printing process in order to achieve the desired result.

Squeegee geometry: the wedge area is characterized by the angle between the squeegee and the screen (squeegee angle) and the amount by which it extends in length and height (Fig. 5). The squeegee geometry describes the shape of the wedge area bound by the squeegee.

When observing the back pressure over the entire length of the printing paste wedge, it will be seen that it is not constant but increases in the direction of the point of contact of the squeegee and falls to zero at the squeegee edge (Fig. 6).

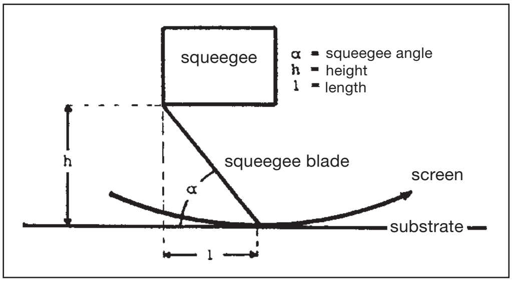


Fig. 5: Diagram of the squeegee angle.

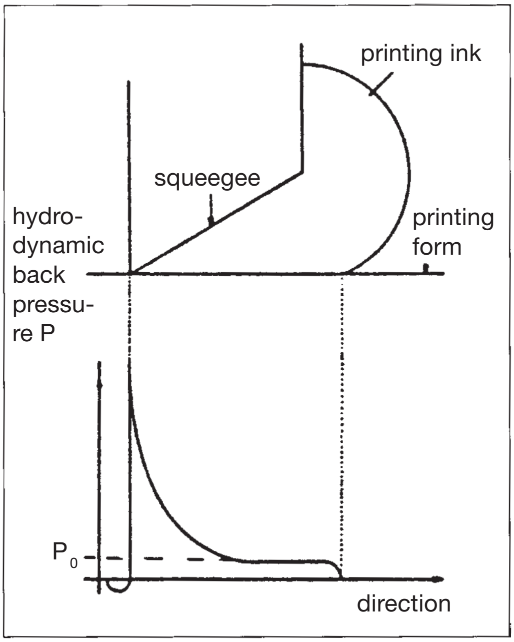


Fig. 6: The distribution of back pressure in the print paste wedge, P_0 = penetration resistance.

Theoretically, due to the suction effect of the substrates, it has to be assumed that transient negative pressures arise behind the edge of the squeegee. A variation in squeegee geometry alters the height of the back pressure and the width of the contact zone. In the case of large squeegee angles, relatively short term increases in pressure appear with steep flanks and low peak values. With small squeegee angles, the increases in pressure which arise are relatively long term with more gradual inclined flanks and relatively high peak values (Fig. 7).

The area under the curve can be taken to represent the amount of printing paste applied. According to this, the amount of printing paste applied increases as the squeegee angle decreases. These curves also show

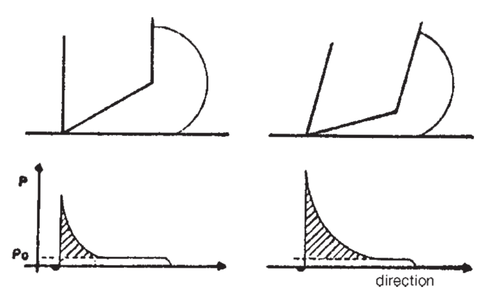


Fig. 7: The distribution of back pressure in the print paste wedge for large and small squeegee angles.

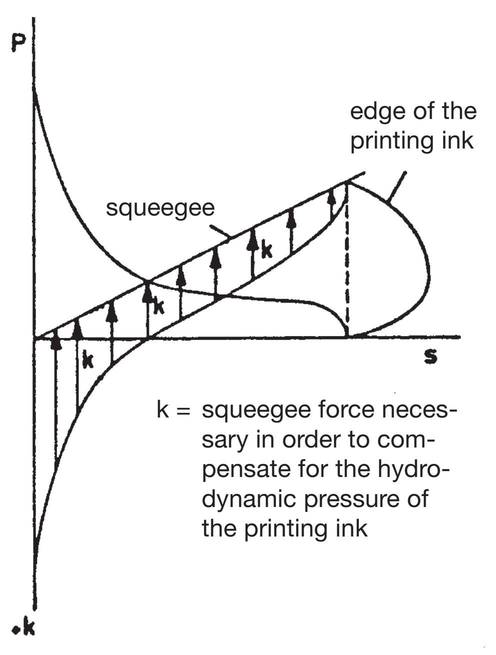


Fig. 8: Load on the squeegee resulting from the back pressure.

clearly the change in the width of the contact zone: in the case of a large squeegee angle, the contact zone is narrower but, with a smaller squeegee angle, the contact zone is wider provided the printing paste is kept at a constant level. This shows that clearly defined geometric proportions in the squeegee/screen/substrate region must exist in order to optimize the printing paste application and that this geometry is constant over the width of the printed area. The back pressure is not only felt by the screen and the substrate, but also by the squeegee. The squeegee force which presses the squeegee against the inside of the screen acts against this pressure loading (Fig. 8).

The different squeegee forces explain the better edge-middle-edge uniformity of the magnetic bar squeegee. In the case of the blade squeegee, the mechanical force exerted on the squeegee comes from above. The squeegee forces required in the blade-squeegee method, ranging from 100–400 g/cm, produce a squeegee loading of up to 74 kg for a print width of 185 cm. Under the stress of this loading, the squeegee housing distorts to produce variations in the squeegee angle. This problem does not arise in the case of magnetic rod squeegees. A corresponding design and arrangement of the magnetic bar produces a higher squeegee force which acts uniformly over the entire width of the print. In spite of this greater squeegee force, the screen loading caused by bar friction, which is produced by the squeegee bar, is less.

Under certain limiting conditions (such as high penetration resistance and low absorption capacity of the substrate) the blade squeegee exhibits vibration phenomena due to the residual elasticity of the squeegee lamella. The printing paste is not able to migrate into the substrate and the squeegee blade presses away towards the back so that application of the printing-paste becomes uncontrollable. Providing the squeegee bar is not bent, this situation cannot arise in the case of the magnetic bar squeegee. Here, the bar is seen to “float” under the limiting conditions mentioned above. The insufficient contact between the bar and the screen which results leads to a reduction in impact pressure and an increase in the residual film on the inside of the screen.

In the case of the blade squeegee, a contact zone of 30 mm and more is produced by the squeegee lamella. The squeegee geometry is varied by the angle adjustment and this produces both a broadening of the contact zone and an increase in the impact pressure. Squeegee kinematics: the movement of the screen alone has an effect. With the magnetic bar squeegee, vibration in the

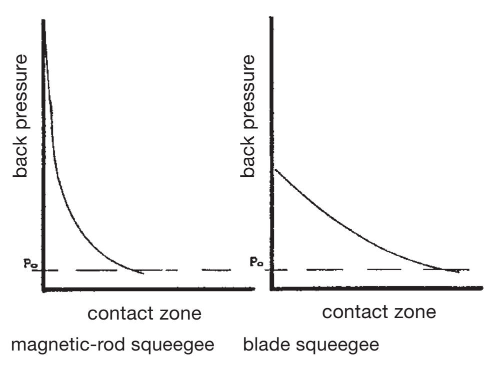


Fig. 9: Back pressure diagrams.

parameter	squeegee system	
	roll squeegee	blade squeegee
process parameters: contact zone	narrower	wider
contact time	shorter	longer
back pressure	higher	lower
print paste extrusion speed	higher	lower
changes in application by varying squeegee geometry	linear	progressive/linear, substrate dependent
changes in application by varying squeegee force	none	slight
changes in application quantity by – low speed – high speed	 large small	 large large
print result: metering – for PES knitted goods – for PES woven goods	 50… 150 g/m^2 50… 100 g/m^2	 20… 160 g/m^2 20… 85 g/m^2
colour depth for the same application quantity	less	more
penetration	higher	lower
macro evenness micro evenness	higher higher	lesser lesser
edge definition	poorer	better
susceptibility to pump smears	lower	higher
marks from creases in screen or folds in substrate	fewer	more

Tab.: Comparison of the most important parameters of roll and blade squeegees (according to Ferber and Hilden).

squeegee geometry is produced by changing the bar diameter. For the diameters usually used in practice (10–30 mm), this leads to a contact zone ranging from 5–15 mm and the squeegee angle remains constant, depending on the design of the magnetic-bar. Squeegee kinematics: two sources of movement act on the printing paste – the squeegee bar and the screen. The different types of squeegee geometry and kinematics lead to the different back pressure diagrams shown in Fig. 9.

To summarise: qualitatively, neither of the two squeegee methods can be judged to be better (Tab.). Both the magnetic-bar and blade squeegees have their specific advantages and disadvantages. As long as no squeegee systems are built which show neither of the disadvantages mentioned but show all the advantages, the printer, who wishes to produce a sophisticated pattern at the appropriate quality, must be able to master and apply both techniques (according to Ferber and Hilden).

Squeegee washing machine After use, i.e. when changing the colour way or the design, both screens and squeegees must be washed down. Special washing

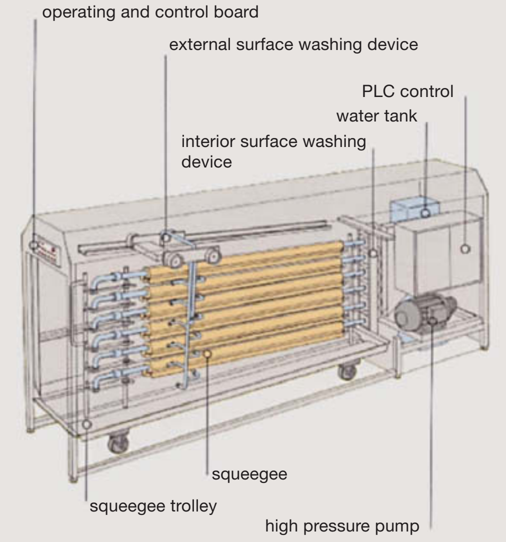


Fig.: A Stork squeegee washing machine.

machines are available for this purpose such as the Stork washing machine (Fig.).

Squeeze off Removal of water or other liquids adhering to the surface of the running webs by pressing between rollers, padder, water calender, aero-flex roller or Roberto roller. → Water extraction.

Different methods are available for uniform squeeze off (Fig. 1).

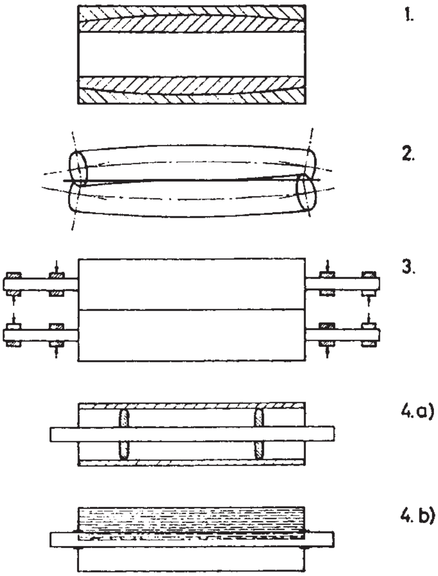


Fig. 1: Possibilities of homogeneous extraction. 1 = cambered core rollers; 2 = skew-positioned rollers; 3 = counter-moment loaded rollers; 4 = internally supported rollers, a) mechanical, and b) hydraulic (swimming roller).

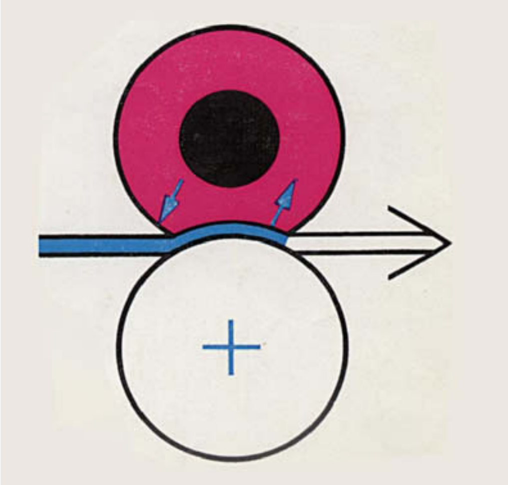


Fig. 2: Menzel Roberto roller principle (top roller).

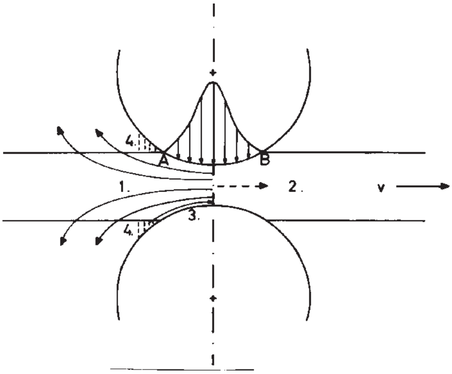


Fig. 3: Diagrammatic view of the squeezing-off process in the nip. 1 = return liquor flow; 2 = capillary transport; 3 = return adherent flow; 4 = extracted liquor.

The Roberto roller can be employed to intensify the squeeze off (Fig. 2).

The actual squeeze off process used for textiles produced in different liquor streams when the textile passes through the nip (Fig. 3).

Squeeze roller,

I. Squeezing for the purpose of, for example, water extraction on the → Padder and the like.

II. → Squeezing units.

Squeezers,

I. → Squeeze roller.

II. → Handkerchief printing machine.

III. Squeezing machines (squeeze off padder) usually used in combination with continuous washing and dyeing processes.

Squeezing effect In practice, this is actually a term incorrectly used for the → Liquor pick-up during padding as a % of liquor left behind (after squeeze off) in relation to air-dried goods. The squeezing effect expresses the % amount of liquor in relation to the unknown amount of liquor picked up in the colour box and which is removed during subsequent passage through the squeeze off rollers.

Squeezing units should squeeze off fabrics uniformly (Fig. 1). They are used for roller-press water

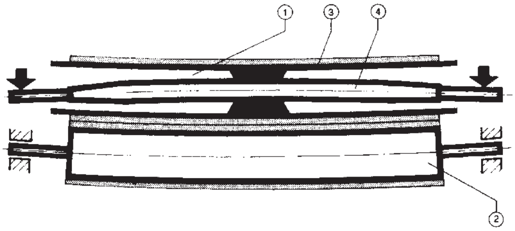


Fig. 1: A pair of squeezer rollers in the Variflex-S pad dyeing system from Babcock. 1 = variflex roller; 2 = solid core roller; 3 = tube casing; 4 = axle-like core.

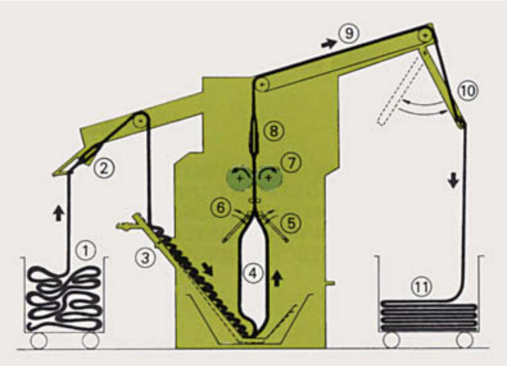


Fig. 2: A Heliot squeezing unit for knitted goods.
1 = wet goods; 2 = ring expander; 3 = automatic feed trough; 4 = balloon for straightening knitted rows and ribs; 5 = air injection; 6 = guide and water-addition rods; 7 = squeeze rollers; 8 = advancement roller/expander; 9 = back grey; 10 = piler device; 11 = folded goods.

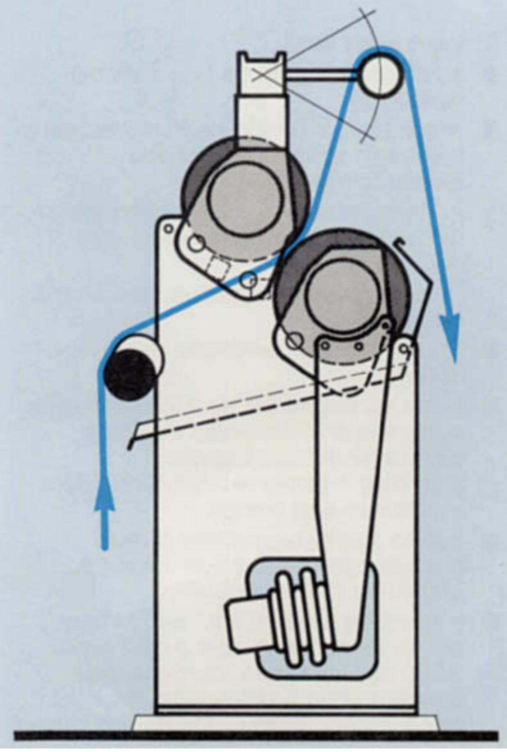


Fig. 3: A final squeezing unit from Babcock.

extraction, particularly for piece goods (Fig. 2). Squeezing units located at the end of the plant (Fig. 3) draw the goods through the machine while extracting water from them at the same time. → Squeeze off.

Sr Symbol for the element strontium (38).

S roller → Swimming roller.

SRRC Abbrev. for Southern Regional Research Centre, also known as the SRRL (L = Laboratory). Well known cotton research institute in the USA.

SRWT Abbrev. for Stress Relaxation Wrinkle Tester. Test instrument for determining the crease behaviour of cotton.

S-S bonds → Cystine links (bridges).

s/s type fibres side-by-side, → Bicomponent fibres.

S-substances → S-phrases.

ST,

I. → Tussah silk, → Textile fibre symbols, according to DIN 60 001 T4/08.91.

II. → Mineral silicate fibres, → Textile fibre symbols, according to DIN 60 001 until 1988.

St → Stokes.

Stability test Used for the preliminary determination of the expected amount of damage from a temperature at 195°C for three hours (particularly in the case of linseed-oil sized viscose filaments) followed by tensile strength test. A drop of 15–20% in tensile strength indicates damage. The stability test allows the speeding up of lengthy processes on the fibre, it being possible to get a early glimpse of the workability of the affected material later.

Stabilization time (yarn mercerizing), time during which cotton ropes are rinsed after → Mercerizing under tension in order to prevent loss in glaze due to shrinkage.

Stabilized naphthol combination dyes Mixtures of naphthols and fast salts usually used in printing.

Stabilizers Bleaching auxiliaries for → Oxidative bleaching processes. These substances are used to regulate the release of oxygen, help prevent oxygen decomposition by catalysts such as copper, manganese and iron, etc. and prevent the loss of oxygen and prevent local fibre damage. Stabilizers are usually not needed in hard water.

A good stabilizer should be sufficiently effective in small amounts at low and high temperatures in alkaline, neutral and acid liquors. Waterglass is frequently used but does not work in soft water. → Magnesium silicate is the most effective stabilizer and even has a significant stabilizing effect in hot baths. Examples of commercially available stabilizers are fatty-alcohol sulphates, fatty-alcohol phosphates, fatty-acid condensation products or even ethylenediaminetetraacetic acid.

The following model should serve to explain how stabilizers work. The symmetrical peroxide molecule, H–O–O–H, is activated by the addition of caustic soda and forms the perhydroxy anion $^{-}O_2H$ by heterolysis. Homolytic decomposition of the peroxide is also possible (·OH). Both reactions compete and this steers the stabilizer towards the bleaching superoxide anionic radical [$\cdot O_2^-$].

The peroxide can be regarded as a weak acid which dissociates according to the following reaction (acid constant $K_a = 2.5 \cdot 10^{-12}$):

$$H{-}O{-}O{-}H \rightleftharpoons H^{\oplus} + H{-}O{-}O^{\ominus}$$

Hydrogen peroxide acts both as an oxidizing and a reducing agent depending on the medium:

oxidative:

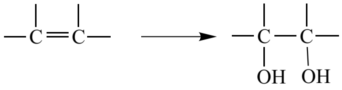
$$H_2O_2 + {}^{\ominus}OH \rightleftharpoons {}^{\bullet}O_2^{\ominus} + H^{\oplus} + H_2O + e^{\ominus}\ (E = -0{,}08\ V)$$

reductive:

$$H_2O_2 \rightleftharpoons O_2 + 2\,H^{\oplus} + 2\,e^{\ominus}\ (E = +0{,}7\ V)$$

The bleaching process gives rise to three effects:

1. Oxidation of the natural pigments in the cotton. These colour pigments, molecules with chromophor groups, can be oxidized by the peroxides and lose their original colour as a result.



$$-\overset{|}{C}=\overset{|}{C}- \longrightarrow -\underset{OH}{\overset{|}{C}}-\underset{OH}{\overset{|}{C}}-$$

(original colour) *(colourless)*

The stabilizer controls the peroxide reaction during the bleaching process by limiting the rate of oxidation while blocking the reactions which damage the substrate. Thus, the peroxide is aimed at bleaching alone. The result which is achieved, therefore, is the max. degree of whiteness without a significant decrease in the degree of polymerisation in the cellulose.

2. Formation of molecular oxygen. This side reaction causes a loss in oxidizing agent and results in a drop in the degree of whiteness as too little peroxide remains available for the bleaching process. The reaction is irreversible.

The stabilizer blocks this process in favour of the required bleaching effect, so that it can be ignored.

3. Oxidation of cellulose. The formation of atomic oxygen is dangerous to cellulose if it is not protected by an organic stabilizer. The stabilizer is effective in blocking this reaction and, as a catalyst inhibitor, protects the cellulose from catalytic damage.

Stabilizing section (stabilizing zone). Section of the piece mercerizing machine in which the caustic liquor is diluted by hot rinsing (to a density of less than 6°Bé) so that shrinkage of the goods (= loss of gloss) is effectively prevented. While the goods are in the stabilizing section, they must remain under tension.

Stabilizing stage Part of the → Mercerizing process. The most important factor during this part of the process is that the impregnated cotton is kept under tension while it is rinsed. X-Ray analysis is used to monitor the transition from cellulose I into Cellulose III. Once the caustic concentration in the goods has dropped below a certain level, rinsing can be continued without the item being kept under tension.

Stain blocking Finishing effect. Active stain blocking prevents penetration of stains and dirt into the substrate (oil-repellent finish). Passive stain blocking eases the removal of dirt which has got on to, or stains which have penetrated into the substrate (→ Soil-release finishing). Basic requirements: from a chemical point of view, it must be ensured that the perfluoroalkyl residue contains at least 4 carbon atoms and one CF_3 end group. The optimum effect is achieved when the perflouro chain contains 8 carbon atoms. The effect of the physical limiting conditions must not be underestimated – uniform distribution of the agent and optimum orientation of the perfluoroalkyl chain will have a beneficial effect, even in the case of small additions. Adhesion to the fibre is imperative for the effects to remain permanent.

Stain breakdown in clothing for dry-cleaning After critical examination, these contain on average:

60%	food and protein stains,
10%	fruit, coffee, inks, water colour and rust, etc.
15%	oil stains,
10%	old fat
5%	other stains.

Staining (colour bleeding) → Soiling:

I. The staining of adjacent undyed textile fabric (or multifibre strip) in colour fastness tests to water, washing, perspiration, etc., caused by the transfer of colorant from a test sample to the adjacent material. The degree of staining is assessed by comparison with the → Grey scales for fastness testing.

II. Staining (bleeding) on to white or coloured accompanying textile fibres during wet processes in finishing which is often caused by the presence of unfixed or inadequately fixed dyes on dyed or printed goods.

III. In textile printing the soiling of white grounds in the print afterwash.

Stainless steel,

I. Steel with special, chemical, physical and mechanical properties manufactured by special steel production techniques (usually in electric arc furnaces) with or without additions of alloying elements (alloy steels). In addition to numerous non-alloyed or slightly alloyed construction steels and tool-grade steels, stainless steels also include corrosion-resistant steels with high resistance to a wide variety of chemical agencies achieved by the addition of chromium, nickel, molybdenum and other metals. A remarkable property of stainless steels with a high nickel content which deserves mention here is the fact that their heat conductivity is only about 1/3 that of usual steels. Stainless steels are very important in textile dyeing and finishing as construction materials for the manufacture of processing machinery and equipment. All non-rusting steels are traded under various names (e.g. Remanite steels, VA steels, etc.) together with a commonly used numbering system to indicate the carbon content and/or type of alloy steel. V4A steel is mainly used in the textile dyeing and finishing industry. The resistance of V4A steel, which contains molybdenum, is particularly good to organic acids and bleaching liquors containing chlorite, etc. For resistance to salts, however, the machine maker's instructions must be observed.

II. (non-rusting steel). Alloy steels which do not corrode in water or in air with a high moisture content, even after long exposure, are described as non-rusting types. Alloy steels of this kind contain more than 12% chromium (chrome steel), e.g. typical formulation: 70–90% iron, 12–20% chromium and 0.1–0.8% carbon.

Stainless steel fibres (non-rusting metal fibres). Stainless steel metal filaments, e.g. metal filaments produced from stainless steel 18/8 or other stainless variants.

Stainless steel pickling The resistance of stainless steels to corrosion always demands clean metal surfaces. Consequently, after each welding operation, all oxide scale or blooming must be removed without fail. For large surfaces, this is achieved by treatment with steel brushes, emery abrasives, sand or glass blasting followed by a subsequent chemical treatment (so-called pickling process) until the oxide scale is completely removed (without roughening the surface). For the manufacture of textile dyeing and finishing machinery, it is sufficient to treat the stainless steel parts with an acid mixture of hydrochloric acid, nitric acid and water.

Stain removal → Stain removal dry-cleaning.

Stain removal dry-cleaning Stains are removed from garments after dry cleaning by means of an aftertreatment with suitable spotting agents. This differs from so-called stain removal processes carried out on materials which are not dry cleaned. The use of spotting agents involves a localized dry cleaning treatment, a wet afterclean, or a bleaching treatment etc., i.e. the art of applying all kinds of physico-chemical reactions to the smallest areas of a textile material in order to remove stains successfully in the shortest possible time whilst, at the same time, protecting the material, the dyeing and the finish as far as possible.

Stain removing, spot cleaning → Stain removal dry-cleaning.

Stain removing table A work table provided with a steam gun for wet and dry steam and air for drying the treated area as well as spray guns, vacuum extraction, etc. Work tops are of various designs but a stainless steel construction with perforations is generally preferred; stainless steel mesh work tops are also used. The table is usually operated with the aid of foot pedals. Virtually all stain removing tables are equipped with a swivelling sleeve board which also has a vacuum connection to an automatic vacuum vibrating valve which switches on when in use and is automatically switched off again when swivelled away from the working area. Most of the work on stain removing tables is carried out with the steam gun. Spotting brushes are reserved for special purposes only.

Stain-repellent finishing → Antisoiling finish.

Stains A collective term for the local discoloration of a textile which is usually undesirable. Stains are caused by chemical bonding between a particular → Soil and the fibre which, in the strictest sense, is not representative of a typical average soil removed by detergents in laundering. In contrast to such easily removed soils, stains must either be decolorized or destroyed with the aid of chemically-active compounds. According to this definition, typical stains produced on textiles are caused by fruit, wine, inks, coagulated blood, heavy metal salts, catalytically-oxidized and hardened lubricating oils, rust, etc. According to other definitions, however, stains are also regarded as a form of localized soiling on textile materials.

Stalagmometer An apparatus consisting of a glass capillary with a specified orifice which is used to measure the → Surface tension of a liquid by the drop method: suitable for dilute aqueous solutions (1–3 g/l). Measurements are based on a comparison, usually against the drop count of pure water: the results can also be converted into absolute values. Principle: low surface tension = smaller drops = a higher drop count. The apparatus is particularly suitable for determining the efficacy of surface-active textile auxiliaries in terms of the drop count and dependence on concentration (at the same temperature).

Stalk fibres A synonym for → Bast fibres.

Stamping inks → Marking inks suitable for marking textile fabrics with identification/reference numbers, etc. capable of withstanding the various treatments involved in finishing. Especially useful for duty-free textile imports to be finished and re-exported, etc. Rapid drying is very important.

Stamping machine,

I. Used for loose-stock dyeing. Loose fibres are press-packed into a dyeing cage by wet stamping, i.e. with the addition of water to wet out the fibres (see Fig.). These machines are available with a single, double or triple ram depending on the cylinder diameter, in order to press-pack the fibres for processing in a bleaching or dyeing cylinder. A homogeneous and densely packed block of fibres is necessary for optimum and uniform dyeing results. A special model is also available for the simultaneous and automatic loading/stamping of synthetic tow material, gauze bandaging and bast fibre tow.

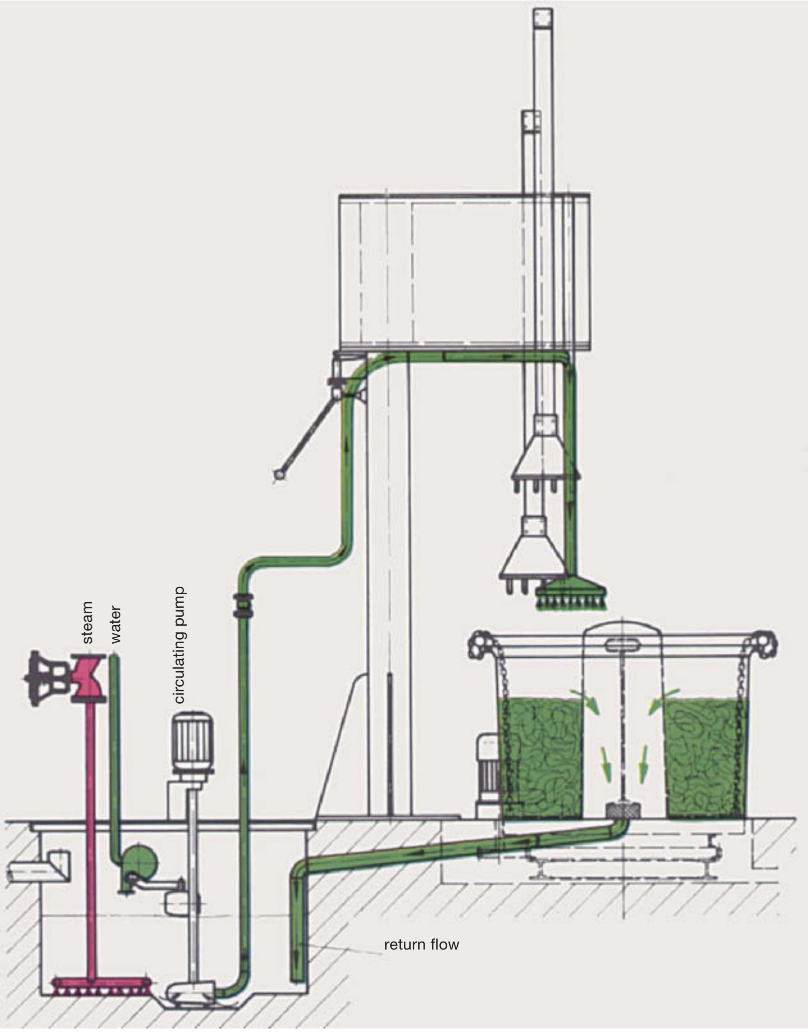


Fig.: Jasper stamping machine.

II. Used in mill engraving for textile roller printing. The first stage is to case-harden and temper the engraved die in order to make it tougher than the cylinder against which it has to be pressed. The hardened die is then placed in the clamming machine against a soft steel cylinder known as a "mill" which will subsequently be used to transfer the design on to a copper printing roller. The mill is either the same size as the die or larger. A specially prepared acid-resistant black paste is applied between the die and the mill in the machine. On rotation, this paste is then left in the engraved lines (hatching) and the roughened edges of the die grip into the soft metal of the mill. With gradually increasing pressures, the pattern lines are gradually transferred on to the mill as raised images coated with black paste. This frictional contact in the machine alternates with several passages through baths of acetic acid, and the acid-resistant coating protects the raised pattern lines which are gradually formed on the mill during immersion in the acid. When the correct depth has been reached by this etching treatment, the raised edges of the mill are turned by hand or on a lathe so that they are smooth and well below the patterned surface.

Standard abbrev. for textile fibres → Textile fibre symbols.

Standard atmosphere →: Air humidity; Air conditioning.

Standard cell A galvanic cell capable of delivering a fixed and constant electromotive force (emf) over a long period of time (when manufactured to exacting standards and used with due care). Uses: calibration of potentiometers and all other voltage measuring devices.

Standard depth dyeing A dyeing produced on a textile substrate from a series of graduated concentrations for the purpose of illustrating an individual dye in a dye maker's → Pattern cards.

Standard depths A series of arbitrarily chosen depths of colour, each of which is judged to be equal for all hues. Standard depths allow dyeing, colour fastness or other properties to be compared on a uniform basis. Also referred to as International Standard Depths as defined in DIN 53 235 and BS 1006: A01: 1978. Since pale dyeings fade sooner than deep dyeings, the colour fastness to light of a dyeing is expressed at different strengths (from 1/25 to 2/1) corresponding to light, medium and deep dyeings of a particular dye. The strength of a dyeing which has been exposed to a light fastness test can be ascertained by comparison with these standard depths. Standard depths are also used in all tests where the same depth of shade is a requirement (e.g. comparative colour fastness tests). The DEK standard depth scale contains about 20 shades produced in the following standard depths (on bright and matt fabrics for viewing under standard illuminant C): 2/1, 1/1, 1/3, 1/6, 1/12, 1/25 (DEK – Deutsche Echtheitskommission – German Fastness Committee). In addition to the foregoing, data for the blue and achromatic shades mainly involved in the production of navy blue and black colours is often given at depths greater than 2/1 SD; these are designated as navy blue/light (N/L), navy blue/dark (N/Dk), black/light (B/L) and black/dark (B/Dk).

Standard depths, colorimetric standardization Dye makers and textile dyers need to measure the dyeing properties and colour fastness of new dyes against available products. For this purpose, a generally accepted basis of comparison must be available. At the end of the 1920's, the first standard depths came into being through collaboration between the major German and Swiss dye manufacturers, who by 1930 had agreed on 10 physical colours of approximately equal depth, together with higher depth navies and blacks. These standard depths, which had been visually adjusted to the same depth of shade, were produced on different materials in order to make visual assessments easier to carry out. In 1935, the German IG Farben and the Swiss dye makers made a commitment to carry out light fastness tests at these depths and assess the results with the → Blue scale on wool which had just been introduced at that time.

By 1960, the 1/25, 1/12, 1/6, 1/3, 1/1 and 2/1 series of standard depths commonly used for textile dyes had already been established very much in their present form. Data on colour fastness and other properties on textiles is published by dye manufacturers at an arbitrarily fixed depth, known as 1/1/ standard depth (SD), which most colourists regard as being of approximately equal depth. Unfortunately, although it had long been taken for granted that this depth of colour had really been determined with some precision it had, in fact, only been vaguely defined. Thus, according to DIN 54 000, 18 dyeings in various colours are prepared which "appear to be of equal depth to the eye of a person with normal colour vision". This depth of colour is described as 1/1 standard depth. Obviously, considerable leeway exists as to what constitutes a standard depth dyeing for the production of these 1/1 standard depth dyeings. This is particularly so when a particular colour does not correspond to one of the 18 colours in the colour sample collection of "1/1 Standard Depths" (Fig. 1) as specified in DIN 54 000 (traditionally referred to as the "barrel organ"). Even here, however, colourists also have different opinions as to the "real" colour depth of these dyeings. For this reason, a colorimetric and unambiguous definition of the 1/1 standard depth for all colours has become an urgent necessity.

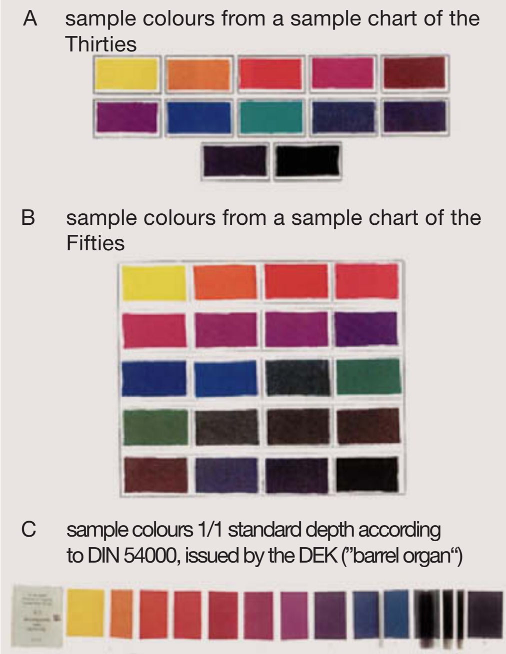


Fig. 1: Sample dyeings on colour charts compared with the DIN "barrel organ" of 1972.

A colorimetric definition for various colour depths in which the 1/3, 1/9 and 1/25 standard depths form the basis of the German Standard 53 235 was drawn up by L. Gall. The Gall formula for a 1/1 standard depth is indeed often used although it has not been widely accepted because it deviates too much from the average perception of experienced colourists (Fig. 2). In view of this situation, colourists of Sandoz AG likewise developed a formula which, in addition to the "barrel or-

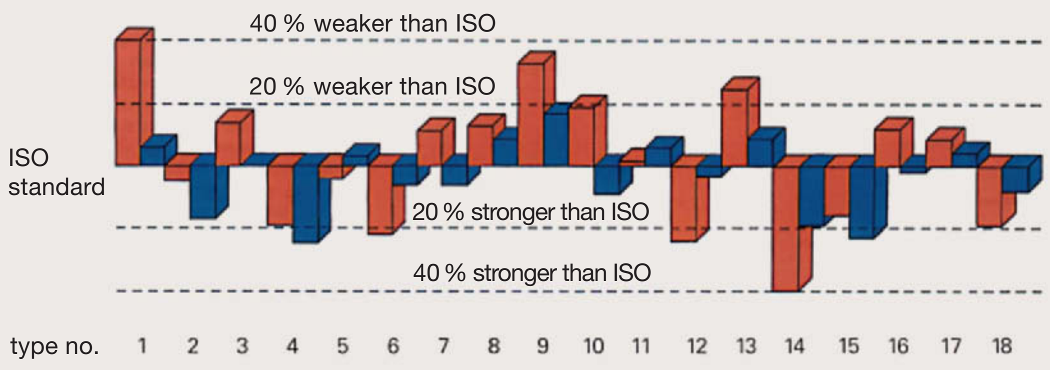


Fig. 2: Deviations of the Gall and the Sandoz standard depth formulations from the ISO standard. Orange = Gall formulations (mean deviation 21%); blue = Sandoz formulations (mean deviation 12%).

gan", was based on more than 100 dyeings spread over all colours and which, according to the consensus of several colourists, had been carefully adjusted to 1/1 standard depth.

The formula defines the space in which the colour loci of all dyeings at 1/1 standard depth lie in CIELAB colour space. This space takes the form of a shell over the C/H plane, i.e. for each purity C and each hue H, the standard depth lightness L_{RT} is given. The function $L_{RT} = f(C,H)$ meets all sensible mathematical conditions:

- it is unambiguous,
- it is continuous overall and continuously discriminating,
- the lowest value lies at C = 0, i.e. on the lightness axis. At this point, the space runs horizontally (parallel to the C/H plane).

With increasing purity, there is a monotone rise in all directions although this is not equally pronounced for all colour angles. The extent of this rise is given by the polynomial P as a function of the colour angle H. P is a cyclic spline function which at H = 0 is also constantly differentiable. The dependence of function P on hue supports the well-known Tatsache Rechnung which also exhibits poor equality of spacing in CIELAB colour space in terms of colour perception.

For a direct comparison with DIN standard depths, the 18 shades were dyed on a similar wool quality to that which had been used for the DIN standard, both according to the DIN model as well as according to the Sandoz formula. This provided a very good approximation to the still obligatory DIN standard depths. Uniformity within the colorimetric series was, however, judged to be better by comparison with the ISO standard depths. The absolute deviations of the new formula nevertheless lie below those which could, for example, have a negative effect on colour fastness tests (according to Christ, Griesser, Meyer and van Diest).

Standard deviation (s). A measure of the dispersion of a distribution or the scatter of a series of numbers or measurements about their mean value which is used in → Statistics. Standard deviation is defined as the square root of the average of the squared deviations of the observations from the group average. Squaring the deviations eliminates negative signs and concentrates attention on the magnitude of the deviations and not their sign.

Standard dyeing time [t_{70}-value, t_{70} (0.5)]. A parameter characterizing the dyeing process which is roughly inversely proportional to the dye diffusion constant. It gives the time in min at 100°C (at a liquor ratio of 40 : 1) required to achieve a bath exhaustion of 70% when dyeing is carried out at half the saturation depth (according to Hoffmann).

Standard electrode potential (E°). Standard electrode potentials are defined by measuring the potential in volts relative to a standard hydrogen half cell using a 1.0 molar solution at 25°C:

$$H_2 \rightleftharpoons 2\,H^+ + 2\,e^- = 0.00 \text{ volt}$$

Electrode potentials cannot be measured absolutely and are usually specified by comparison against a hydrogen electrode which is assumed to have an electrode potential of zero. In practice, a number of more convenient electrodes of known standard electrode potential are used. These are calibrated against the standard hydrogen electrode.

A so-called electrochemical series is established when metals are arranged in decreasing magnitude of their standard electrode potentials. The use of the series allows some qualitative generalities to be drawn. Thus, for example, the higher the metal is in the series the greater the tendency for it to be oxidized. The greater the negative value of the potential, the greater is the tendency of the metal to pass into the ionic state. A metal will normally displace any other metal below it in the series from solutions of its salts. Metals with a negative standard potential release their outer electrons more readily; are converted into the ionic state; easily remove oxygen from other metal oxides (therefore acting as powerful reducing agents); oxidize very rapidly and become very hot in the process. They convert the hydrogen ions of acids into electrically-neutral hydrogen gas and combine with the acid residue, etc. The reverse situation applies to metals at the other end of the series with a positive standard potential where powerful oxidizing agents are to be found; these metals are no longer attacked by non-oxidizing acids (hydrochloric acid, dilute sulphuric acid) and are insoluble in them (at room temperature with exclusion of air); they oxidize reluctantly and with a slight development of heat; the oxides are readily decomposed again, i.e. with the evolution of oxygen. These properties decrease more and more towards the higher end of the electrochemical series and vice versa. In each case, baser metals higher in the series precipitate more noble metals that are lower in the series from solutions of their ions and are themselves converted into the ionic state. From the standard potential, the corresponding values for any two metals may be calculated, e.g. in the electroplating of an iron nail with copper (in $CuSO_4$ solution) some of the iron goes into the solution and the nail is covered with a reddish brown layer of deposited copper since the copper gives up its electrical charge through a shift of electrons to the iron:

$$CuSO_4 + Fe \longrightarrow FeSO_4 + Cu$$

$$Cu^{++} + Fe \longrightarrow Fe^{++} + Cu \downarrow$$

$$Cu^{++} \rightleftharpoons Fe + 0.78 \text{ volt}$$

Standard illuminants (standard light sources). The reliability and reproducibility of any → Colour measurement is highly dependent on the spectral energy distribution of the particular illuminant employed, i.e. on its “colour”. In order to minimize the increasing difficulties of colour matching and colour measurement, so-called standard illuminants (DIN 5033) have been introduced in order to provide standard conditions of illumination which are unambiguously characterized by their standard chromaticity coordinates x, y and z (see Tab.). Thus, when the international system of colour measurement and specification was set up by the Commission Internationale de l’Éclairage (CIE) in 1931 it was recognized that standardized sources of illumination would have to be defined, and three such sources (CIE Standard sources A, B and C) were adopted at that time as approximations to three common conditions of illumination.

illuminant	x	y	z
standard illuminant E	(0.3334	0.3334	0.3332)
standard illuminant A	0.4476	0.4075	0.1449
standard illuminant B	0.3485	0.3518	0.2997
standard illuminant C	0.3101	0.3165	0.3736

Tab.: Standard illuminants and their standard colour value components x, y, z.

In terms of its spectral energy distribution, standard illuminant A was designed in 1931 to be representative of indoor artificial illumination and corresponds to a gas-filled coiled tungsten filament lamp. Standard illuminant B was supposed to represent daylight plus sunlight (lamp with filter) and standard illuminant C was intended to represent average daylight, resp. from a clear northern sky (artificial daylight produced by a lamp with filter) (see Fig.). Standard illuminant C is also specified for use with the → DIN colour chart. Both standard illuminants B and C are now largely redundant in favour of the standard D illuminants which have been introduced subsequently. Indicator colours on various chromaticity diagrams are used to check the spectral composition of a light source. The former standard illuminant E represented a → Standard white in the form of magnesium oxide, i.e. “pure white” light based on the equal energy spectrum.

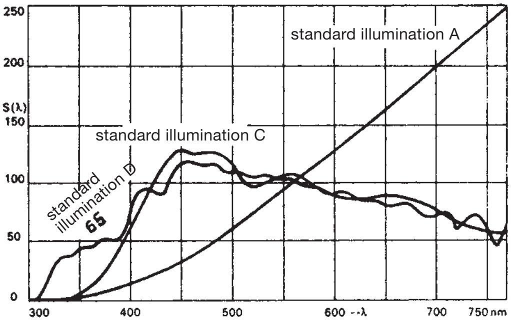


Fig.: Comparison of standard illuminant spectra.

The most important standard illuminants for textiles are:

1. A = tungsten filament light with a colour temperature of approx. 2800 K. An actual source corresponding to this illuminant is readily achieved, and calibrated standard tungsten lamps are available from standardizing bodies in most countries.
2. C = average daylight with a correlated colour temperature of 6774 K.
3. D_{65} = daylight with a UV component (daylight illumination). Studies have shown that standard illuminant C, which was formerly commonly used alone

to represent average daylight had too little energy in the invisible UV region of the spectrum to be of value in assessing fluorescent brightening agents (optical brighteners). Standard illuminant D_{65} was therefore introduced to overcome this problem and, with an approx. colour temperature of 6500 K and standard chromaticity coordinates of $x = 0.3127$, $y = 0.3290$ and $z = 0.3583$, it was accepted by the CIE as a standard illuminant in 1986. Its spectral energy distribution provides a good approximation of average daylight, taking into account the following types of variation:

- from early morning to late evening,
- from a blue sky to completely overcast conditions,
- different latitudes.

Standard light source → Standard illuminants.

Standard observer The standard observer may be defined as the perceptive functions representative of an observer with normal colour vision in → Colour measurement. In the CIE system of colour measurement, the relative amounts of three defined stimuli, mixed additively, required by the average observer to match spectral light at each wavelength under defined viewing conditions. The original 1931 CIE standard observer was based on experiments using a 2° field of view. This is a much narrower field of view than that normally used for critical colour assessments. Subsequent colour matching experiments therefore led to the development of the supplementary 10° standard observer in 1964. The 10° standard observer is recommended whenever a more accurate correlation with visual colour matching of fields greater than 4° is required and, since it is based on conditions of observation which more closely approximate those encountered in practice, it has gained increasing acceptance in recent years (see Fig.). It is used for the calculation of CIE coordinates.

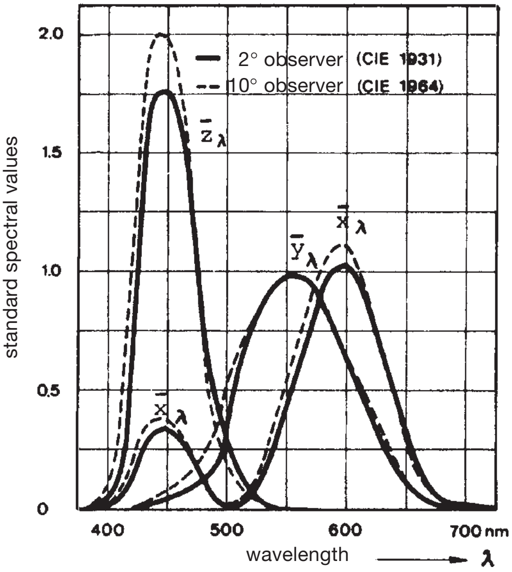


Fig.: Differently defined standard observers for colorimetry.

Standard reactions of man-made fibres Combinations of reactions for each class of fibre which allow a particular fibre to be clearly identified. For conclusive identification, however, all the reactions given for a specific class of fibre must be carried out in each case. The necessity to check these standard reactions constantly against new fibres coming on to market is a disadvantage.

Standard shades In textile dyeing and printing, these are shades in frequent demand, especially black, navy blue, brown, etc.

Standard soil → Soiling test.

Standard soiled fabric → Soiling test.

Standard solutions → Normal solutions.

Standard spectrum values and colour distribution curves characterize the sensitivity of the human eye to the red, green and blue components of visible light. The retina contains three stimulation centres with varying spectral sensitivity, each of which is particularly sensitive to one of the above-mentioned components of visible light. The sensitivity distribution of each of the three stimulation centres, arranged according to the wavelength of light, gives the standard spectral distribution curves (standardized by the → CIE in 1931): $\bar{x}$ (for red light), $\bar{y}$ (for green light) and $\bar{z}$ (for blue light). The light energy of all visible wavelengths falling on the stimulation centre in the retina is integrated according to the sensitivity for each wavelength and transmitted to the brain. The size of this signal, the standard tristimulus value (→ Colorimetric measures) X, Y, Z, is therefore the sum of the products of the light energy falling on the eye and the sensitivity for all wavelengths. → Colour measurement).

Standard strength dyes Dyes which have been adjusted in strength to customary commercial concentrations by the addition of appropriate diluents or extenders. Standard strength dyes are the standard products of a particular dye maker as illustrated in their pattern cards. →: Dyestuff commercial forms; Dye formulations.

Standard times A standard time is the time required for a motivated operative with an appropriate skill level to complete a work task including allowances for relaxation, machine breakdown and interruptions. If technological modifications to machines and production processes are introduced which have a positive or negative effect on already established standard times, the standard times must be checked again and/or recalculated.

The techniques of work study are applied in order to obtain a precise understanding of work flow, work loads and capacity utilization. Central to these timings is the observation of actual work flow undertaken by a work study engineer in order to record observed times for each work element measured in $^1/_{100}$ min units. A sufficient number of these timings allows reliable individual values to be obtained for each work element which is absolutely essential for the fixing of standard times. The results of the observations must be carefully recorded and the record of various timings, i.e. the figures on the time sheet, must be reproducible.

The particular circumstances under which the timings have been measured must also be recorded just as carefully as the times themselves. Since the work performance of the operatives integrated into the production process is subject to continual variation, the time and work studies must be carried out at various times of the day and over an extended period of time.

Starting from the combined time and work study results, individual values for each task to be undertaken are fixed and summarized in a manual. The individual entries are to be understood as net values only and include no allowances. These individual values allow the work study engineer to make cross comparisons against the same tasks carried out in other production departments or they can be used to make individual time comparisons with similar companies elsewhere.

The standard time determination (tA) serves to fix the times which the employee needs for the proper execution of an order assigned to him with normal performance. The standard time (tM), on the other hand, identifies the machine utilization time for a particular order without any contingency for possible waiting times.

For a machine operated by a single person, a standard time and work load calculation is required for optimum machine allocation. The frequencies are multiplied by the appropriate time values from the manual and entered in the corresponding columns tA and tM. For dyeing processes, the frequency values, e.g. for additions and sampling, are already fixed on the basis that a batch is dyed under normal operating conditions with one addition and three sampling operations (according to Hauser).

Standard time t70 A parameter in heat transfer printing. It denotes the time after which 70% of the quantity of dye initially present on a carrier substrate (paper) is transferred on to the textile material and therefore represents a measure of the dye's propensity for sublimation.

Standard white (→ Ideal white). For comparative reflectance measurements, only those pigments capable of giving a full matt white of 100% white content with as near complete reflection of the incident light rays are used. Relatively few substances are able to satisfy these requirements in practice however. For colour measurement applications, the following two pigments are used as standard whites: (1) barium sulphate, where the theoretically almost 100% white content applies exclusively to the chemically pure compound produced from a dried slurry, or (2) freshly prepared magnesium oxide where the degree of whiteness has been set at exactly 100 (%) for all wavelengths although it is, in fact, somewhat lower and decreases still further at increasing wavelengths.

Standards Organizations → Technical and professional organizations.

Standfast molten metal dyeing process (molten metal dyeing). A process developed in England mainly for the continuous vat dyeing of piece goods. It is based on the shock-like development of steam at the interface between an aqueous dyebath and a hot liquid metal bath. The fabric passes through a cast iron U tube (approx. 1.5 m high; walls approx. 3 cm apart) with both legs of the tube being connected at the base via a guide roller (distance approx. 16 cm). The extremely small dyebath (e.g. 4.5 l of vatted dye; temperature approx. 75°C; controlled liquor level 18–20 cm) is located at the fabric entry side and is open at the bottom so that fabric passing through the dyebath runs immediately into the steam-heated molten metal bath contained in both legs (normally maintained at 95–105°C by thermostat control; passage approx. 3 m) after which it leaves the other opening of the tube (fabric exit side) through a bath containing 10% sodium sulphate solution (approx. 18 l). Working principle: a) cylinder pre-drying; b) saturation with dye liquor in a hot dyebath; c) shock-like fixation and simultaneous application of pressure (120–200% pick-up, i.e. lower for a large surface area of fabric) in the hot molten metal bath with exclusion of air; d) removal of unfixed dye in the hot sodium sulphate bath together with any metal particles still adhering to the fabric (achieved by means of a rotating angular roller). The usual oxidation and soaping stages complete the process. At fabric speeds of 25–110 m/min (experimental recommendations for light to medium depth shades are 55–27 m/min) the immersion times in the dyebath are 0.5–0.1 s and in the molten metal bath 7–2 s. The normal working speed is 50–60 m/min. The average production capacity of the process is 27 m/min (including washing-off, colour changes, etc.). Working widths are usually 150 cm up to approx. 240 cm. Colour changes are easily and quickly executed in circulation without stopping the machine (5–10 min). It is also possible to establish dyeing recipes on a laboratory pilot machine. Metal charge: Lipowitz' alloy or Wood's metal usually with a melting point of approx. 70°C (in principle, the temperature of the molten metal bath is kept 20°C above its melting point; less adherence of metal to the surface of the textile). The quantity of metal required is approx. 2 t, and metal losses of the order of 0.11% or more per m of fabric are usual. Advantages: ideal for both small and large batches, suitable for many types of fabric (including those with uneven surfaces), quick colour changes, small volume of dye liquor (favourable for minimum dye consumption), accurate pre-matching of shades is possible in the laboratory, no differences in shade between the beginning and end of a batch, side to centre uniformity, good tone-in-tone dyeings on blend fabrics, no nip creases. Disadvantages: the problem of achieving well-penetrated dyeings on tightly woven fabrics has not been solved (it is advisable to apply the dye first by pigment padding), certain limitations exist with regard to maximum dye yields in deep shades, the process is only recommended for absolutely sulphur-free vat dyes to ensure reliable results, the liquor pick-up cannot be controlled, high investment cost plus licensing fee and metal losses. The process has, unfortunately, not lived up to its early expectations.

Standing bath dyeing In this method of dyeing, where batches are dyed in sequence, the dyebath is not changed during exhaust dyeing and only the exhausted dye is replaced after each batch has been dyed in order to restore the dyebath to its original state and ensure reproducible results. Despite its still secondary importance, the technique has attracted some interest on environmental protection grounds since economic exploitation of the fresh dyebaths is, in any case, largely assured. For all practical purposes, shades are matched in conformity to sample by laboratory matchings or computer colour matching. Dyeing from standing baths is still an important method in → Garment dyeing for the production of standard shades.

Standing dyebaths Dyeing from a standing bath makes use of exhausted dye liquors to produce further dyeings and therefore represents a worthwhile recycling technique. → Standing bath dyeing.

Stannic chloride (pink salt, tin tetrachloride, tin perchloride, tin (IV) chloride), $SnCl_4$, molecular weight 260, density 2.229–2.26. Colourless, water-free, corrosive, fuming liquid, almost chemically pure with a 45.4% tin content. Evolves heat on contact with water. Uses: mordant for alizarin dyeing, weighting of silk, clearing and softening of silk, manufacture of fuchsin, colour lakes.

Stannous acetate (tin (II) acetate, acetate of tin), $Sn(C_2H_3O_2)_2$, molecular weight 236. Aqueous solution. Used as a reducing agent in discharges on substantive dyes (especially black).

Stannous chloride (tin crystals, tin salt, tin dichloride, tin (II) chloride), $SnCl_2 \cdot 2\,H_2O$, MW 225, density 2.71. White salt, hygroscopic, soluble in water, powerful reducing agent. Uses: discharge printing, tin mordant (for shading alizarin red and pink on the yellower side to give fiery shades); aftertreatment (with soap) of alizarin red; resists (wool resists); spotting agent.

Stannous oxalate (tin (II) oxalate), SnC_2O_4, molecular weight 206.5. Uses: dyeing and printing of textiles; mordant for alizarin print pastes and dyeing (more vivid pink and red shades).

Staple fibre Unlike a continuous → Filament, a man-made staple fibre is produced in predetermined short lengths (cut into short lengths) for spinning into → Spun yarns (see Fig.).

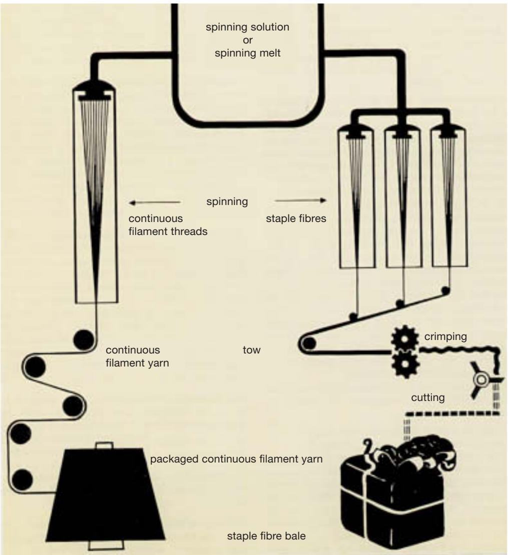


Fig.: Production of man-made continuous filament yarns and man-made staple fibres (simplified diagram).

Staple gun Used in screen making with → Staples.

Staple length is the average length of → Staple fibre which, in the case of man-made fibres, can be any predetermined cut length. The staple lengths (in mm) of some natural and regenerated cellulose fibres are as follows:

1–5 = jute
5–50 = recovered wool
10–25 = hemp
0–50 = cotton
15–50 = bourette silk
25–45 = flax
30–150 = viscose staple fibre
60–150 = schappe silk
70–200 = ramie
50–300 = wool
approx. 1000 = raw silk

Staples Used to attach screen gauze to the wooden frames of flat printing screens.

Starch occurs as microscopic granules in the roots, tubers and seeds of plants. The structure of starch is based on α-glucose residues resp. maltose groups, unlike cellulose (which is built up from β-glucose residues). The chief components of starch and some of their characteristics are given in the Tab. This clearly

Starch

characteristics	AMYLOSE	AMYLOPECTIN
in the starch granule	inner constituent	sheath constituent
potato starch	approx. 20 %	approx. 80 %
maize starch	approx. 30 %	approx. 70 %
chemical	mixture of linear polysaccharides in maltose bonding of 60–400 glucose residues, different chain lengths	mixture of intensively branched polysaccharides in isomaltose bonding of 600–6000 glucose residues, containing approx. 0.075 % P (as phosphate group, ester- like)
electrochemical	non-ionogenic	anionic (elec.conductive, reacts with lyes etc)
in hot water	colloidal soluble	insoluble, slowly swells to a paste, congeals on cooling
with iodine solution	blue colouration	violet to brown colouration

Tab.: Starch constituents.

reveals why potato starch in particular is used in Europe for sizing purposes whilst maize (corn) starch, on the other hand, is used for textile printing.

Arrowroot, potato, maize (corn), rice and wheat starch are important commercial sources. Starch products based on degraded starches for sizing and finishing are usually produced as more or less soluble starches. In the broadest sense, starch products may also include those based on fruit seed grains (carob seed grain), mucilages from algae, mosses, etc. which are also used as sizes, finishes and thickeners for textile printing.

Starch belongs to that group of polysaccharides characterized by the linking together of a more or less large number of sugar building blocks through glycosidic bonds to form macromolecules. The build up of starch from glucose molecules may be described by the following empirical formula:

$$n\,(C_6H_{12}O_6) \rightarrow (C_6H_{10}O_5)_n + (n{-}1)\,H_2O$$

In addition to the polysaccharide substance which is present as the chief component, starch grains also contain small proportions of lipoid-like compounds (0.04–0.63%) depending on the type of starch, as well as ash-forming constituents, especially phosphate. This is bound to the polysaccharide substance by ester-like linkages in potato and root starches. Native starch also contains 12–20% water. Starch consists of two structurally different polysaccharides, i.e. amylose and amylopectin. Because of their structure and average molecular weight, these components are responsible for the properties of starch. The amylose fraction which, depending on the type of starch, accounts for 14–27% of the starch, is built up in the form of a linear chain. The glucose units in amylose are connected by α-1,4-glyco-

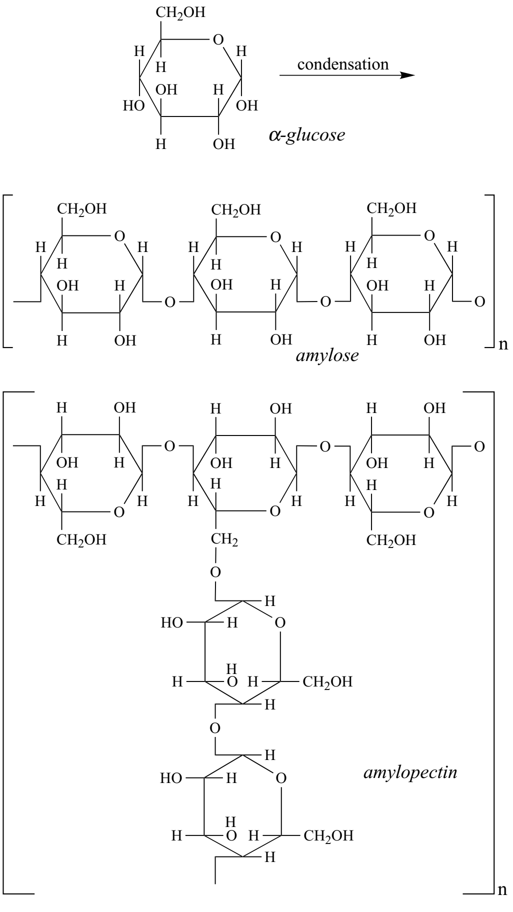


Fig. 1: The structure of amylose and of amylopectin.

sidic linkages so that each amylose molecule contains a reducing (aldehyde) and a non-reducing group. Amylopectin, on the other hand, has a branched structure resulting from the presence of additional α-1,6-glycosidic linkages (Fig. 1).

Chains of D-glucose units with α-glycosidic linkages such as those of amylose tend to assume a helical arrangement in which the glucose units are fixed in a chair configuration. This arrangement results in a compact shape for the amylose molecule even though its molecular weight is quite large (150 000–600 000). Amylose forms a blue inclusion compound with iodine in which a complete helix is formed from 6 glucose units, each with one iodine atom included in the hollow space (Fig. 2).

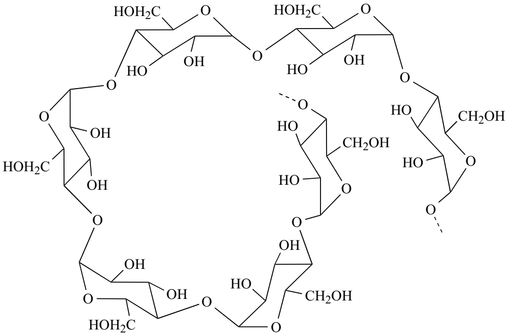


Fig. 2: Helical amylose structure.

Amylopectin has a structure similar to that of amylose (i.e., α-1,4 linkages) with the exception that in amylopectin the chains are branched. Branching takes place between C–6 of one glucose unit and C–1 of another and occurs at intervals of 20–25 glucose units. Physical measurements indicate that amylopectin has a molecular weight of one to six million. The branched amylopectin exhibits a largely globular spatial arrangement which becomes manifest in the high hydration capacity of the molecule. The complex structure of amylopectin may be explained by association between the free ends of the molecule branches by hydrogen bonding. In native starches, amylose and amylopectin are present alongside each other in the layers of starch grains. These are associated in a radial direction through hydrogen bonding and produce microcrystalline micelles. Even when starch is boiled in water, the cohesion within the micelles is so strong that they do not completely dissolve but form a loose network of associated molecules. During swelling in water, the free polysaccharide branches are solvated first, and then the ordered regions of the micelles (Fig. 3).

The term "modified starches" includes all those starch products whose properties have been modified by physical, chemical or biochemical means, whether this has been achieved by a change in the physical state, process of degradation, the introduction of functional groups into the starch molecule or a combination of various means.

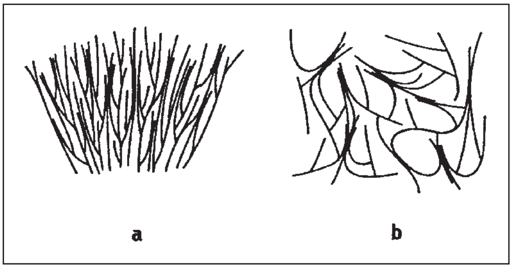


Fig. 3: a = the radial layered structure in a native grain of starch; b = the disintegration of the layered structure during swelling.

The aim of the sizer is to degrade starch on boiling to an extent where it develops a sufficiently stable viscosity. In this regard, care must be taken to ensure that the viscosity of the starch size does not decrease further under the action of shear stresses in the nip of the squeeze rolls in the size box and in the circulation pump. With a stable size viscosity the degree of sizing (→ Sizing, degree of) on the warps is constant.

Native starch is insoluble in cold water. This is due, to inter and intramolecular hydrogen bonding between the hydroxyl groups of the starch molecule on the one hand, and between the hydroxyl groups of bound water on the other. With a bonding energy having an order of magnitude of 10 kJ/mol, hydrogen bonds are weaker than valency bonds (approx. 100 kJ/mol). However, because of the great number of hydrogen bonds in this case, the bonding energy of a valency bond is reached in the starch so that the hydrogen bonds are not broken down in cold water and only a reversible swelling of the starch grains occurs. With an increase in the temperature to approx. 60°C, the amorphous regions of the starch micelles begin to swell first and, with a further increase in temperature, the crystalline regions also swell until the maximum viscosity is reached. Under increasing swelling pressure the amylose goes into solution whilst the amylopectin remains in a gel form. The conversion of swollen starch from the microgel state into a sol state is only achieved at temperatures above 100°C (pressure cooking). Solubility can also be achieved at temperatures below 100°C with the simultaneous application of mechanical energy by stirring or shaking. Under intensive stirring and the simultaneous introduction of atmospheric oxygen, oxidation of starch takes place and the swollen starch grains begin to collapse with a consequent reduction in molecular weight. The result is a colloidal solution consisting of swollen starch fragments, hydrated starch agglomerates and dissolved starch molecules. During storage at reduced temperatures, the starch paste sets again to a porridge-like consistency. This so called retrogradation is due to a recrystallization of the amylose fraction and presents several disadvantages to the sizer such as limited shelf life, reduced adhesive power, etc.

A number of different compounds have a hydrotropic effect on potato starch. This effect manifests itself by an increase in solubility, a reduced viscosity of the starch solutions, and a marked suppression of their thixotropic properties. The viscosity-dependence of potato starch on electrolytes is due to the phosphate groups of the amylopectin. Whilst native potato starch first begins to swell in aqueous solution at temperatures above 60°C, swelling already occurs at lower temperatures in the presence of hydrotropic substances and, with a further increase in temperature, a colloidal solution is obtained. A reduction in viscosity has been observed in the presence of water-soluble ionic substances (salts) such as potassium bromide, potassium iodide, calcium chloride and ammonium thiocyanate as well as water-soluble non-ionic compounds such as urea and thiourea. With ionic compounds, the action is induced by the anion. The effect of hydrotropic agents may be explained in a similar way to the influence of increased temperatures on the swelling of starch grains. At increased temperatures, the association of water molecules (cluster formation) is reduced so that the molecules can penetrate the starch grains more easily and cause swelling. When hydrotropic substances are added to the solvent, a hydrate formation of the ions resp. molecules of the hydrotropic agent occurs. Free hydroxyl groups are formed which cause the water molecules to become more hydrophilic so that they can penetrate the starch grains and bring about swelling followed ultimately by their solution. Some of the hydrogen bonds between the starch molecules are broken down so that the hydrated ions are now bound to the hydroxyl groups of the amylose by hydrogen bonds. Rupture of the hydrogen bonds between the starch molecules causes a considerable reduction in the viscosity of the solutions.

Starch/acids → Starch degradation with acids should normally be avoided (→ Starch decomposition, loss of starch substance); the formation of dextrin is more rapid and the rate of saccharification varies depending on the particular acid. Oxalic acid is an exception (0.1% of the weight of the starch) where hydrolysis proceeds as far as soluble starch and no dilution of the starch solution occurs even without neutralization.

Starch decomposition The degradation of starch proceeds through starch hydrolysis to complete breakdown of the starch molecule firstly to dextrin and then to starch sugar. In → Desizing processes, enzymes, e.g. → Diastases, are used for this purpose. However, in the preparation of starch solutions for sizing and finishing applications, other conditions are present so that in this case the greater quantities of starch exercise a protective colloid effect with the result that the optimum temperature lies somewhat higher; at lower temperatures any further degradation is inhibited. In the desizing process, the situation is different insofar as practically starch-free solutions are involved here and degradation of the starch can therefore proceed unhindered.

Starch degradation When aqueous suspensions of starch are heated, the following processes take place: firstly, the starch grains begin to swell and enlarge, then absorb water after which starch separates from the layers forming the grain, and the outer skin bursts. The soluble internal components of the grain swell out and are distributed in the water in colloidal form. The resultant → Starch paste consisting of coarsely dispersed starch particles is of no value for sizing or finishing in this form. A further diminution of the particles takes place without any significant degradation (molecular weight from approx. 150 000–15 000) by: a) increasing the temperature (110–120°C) with superheated steam under pressure; b) by stirring, forcing through fine nozzles, homogenization, and treatment in a colloid mill; c) through chemico-colloidal additions, i.e. inorganic or organic salts (urea, sodium salicylate, wetting and dispersing agents; d) oxidation products → Starch oxidation products. The end products of starch hydrolysis are valuable soluble starches. → Starch decompsition.

Starch degrading agent These products are used in → Starch degradation, especially for the production of textile sizes and finishes. Product basis: substances capable of liberating oxygen or preparations containing such substances, as well as → Enzymes. → Desizing agent.

Starch degrading enzymes → Diastases.

Starch esters These are starch products esterified with acetic anhydride, phosphoric acid or other acids which can be used as textile sizing and finishing agents. Starch esters produce more or less free-flowing pastes.

Starch ethers Mainly oxypropyl or carboxymethyl starches formed by the action of propylene oxide or monochloroacetate on starch. Monochloracetic acid gives the much used carboxymethyl ether which is anionic in character. Starch ethers are soluble in water to give more or less viscous solutions which exhibit good resistance to acids and metal salts. They are used as sizing and finishing agents, thickening agents for textile printing and, in combination with synthetic resins, also for resin finishing. As thickeners for textile printing, they have been recommended for use in mixtures with galactomannans or alginates to increase colour yields.

Starch film → Starch (sizing, finishing) films.

Starching machine,

I. Finishing mangle usually with a large trough (pad box).

II. → Yarn liquoring machine.

Starch modifications → Modified starches.

Starch oxidation products → Starch degradation resulting from the use of these products leads to the formation of soluble starches. Further → Starch decompsition is excluded. For textile sizes and finishes, an addition of approx. 10–20 g of a product capable of liberating oxygen (sodium perborate, percarbonate, persulphate, sodium or hydrogen peroxide, or products containing chlorine) is made per 1 kg of starch followed by boiling for about 10–20 min. Any weakening of the solution through dilution is excluded with this procedure. The addition of such catalysts accelerates the hydrolysis of starches (perborate gives a higher viscosity index; white content 89%) Under certain circumstances perborate causes yellowing. For starch hydrolysis, oxidation products (previously with additions of fats, waxes and glue if required) are superior to the → Diastases. For the → Desizing of starch-based sizes, on the other hand, the reverse is (usually) the case.

Starch paste External characteristics: opaque, sticky; iodine reaction: dark blue; solubility: insoluble in water; technical qualities: fibre adhering, pore blocking (suitable for use as a printing thickener), good covering properties, subject to chalking, readily forms dust. The starch films are non-transparent, of average strength and low elasticity.

Starch size Starch is still the most commonly used sizing agent for the weaving of cotton and viscose fabrics and has the advantage of being biodegradable. The question of → Size recycling, as in the case of synthetic sizing agents, does not arise with starch sizes. → Sizing selection criteria.

Starch (sizing, finishing) films The addition of wetting agents, softeners, etc. to starch solutions reduces the strength and extensibility of starch films. The addition of glue increases the strength but reduces the extensibility: the latter can be increased, however, by the addition of oil or glycerine at the expense of strength. The addition of vegetable gums (→ Locust bean flour) results in a firmer handle and greater stiffness, but with reduced tensile strength and increased resistance to abrasion.

Starch, soluble (soluble starches). This is not a starch product with a definite composition but represent a series of similar starch modifications which are completely soluble in hot water to give solutions of different viscosities which can be used for various applications in sizing and finishing. Solution characteristics: a) external appearance: transparent, thick, creamy, with coherent flow properties; b) iodine reaction: blue; c) solubility is only possible in hot water; d) technical qualities: good fibre penetration, good filling, stiffening properties, does not affect dyed or printed shades. Starch films produced from soluble starches are quite transparent and exhibit high strength and elasticity.

Starch sugars (starch syrup). As the end product of starch degradation, starch sugar is identical to → Maltose (malt sugar) and → Glucose (grape sugar). External characteristics: aqueous, without body; iodine reaction: colourless; solubility: readily soluble in cold water. Technical qualities: starch sugar has neither a stiffening nor a hardening effect and is hygroscopic.

Star dyed A term used to describe dyeings produced on the → Star frame.

Star dyeing A process for dyeing (usually delicate) textile fabrics in → Star dyeing machines, especially velour upholstery fabrics and other pile fabrics made of cotton, natural silk, acrylic, polyester, acetate, etc.

Star dyeing machines These machines are particularly suitable for dyeing delicate textiles (e.g. chiffon, cotton velvet, velour upholstery fabrics, chenille furnishing fabrics, and natural silk). In conventional star dyeing (vertical machine), the → Star frame to which the fabric is attached is lowered into the dyebath contained in a kier and moved continuously up and down with a gentle reciprocating motion (see Fig.). In the vertical type of star dyeing machine, the dyeing vessel is fully flooded with liquor. Consequently, this method of dyeing requires a relatively high consumption of energy as well as a considerable volume of dye liquor, and can therefore lead to relatively high environmental pollution.

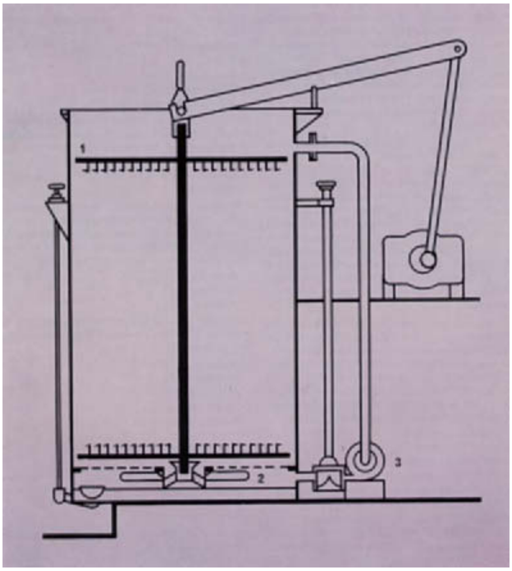


Fig.: Diagram of a suspension star (by Bayer).
1 = material carrier; 2 = heating coil; 3 = liquor circulation pump.

In the horizontal star dyeing machine, on the other hand, the fabric is supported on both edges between two parallel star frames fixed on a central axis to form a spiral batch. After the dual star frame, loaded with fabric, has been introduced into the dyeing machine, it is reciprocated mechanically in a half-flooded dyebath.

Star frame A frame having radial arms resembling the points of a star with hooks placed fairly close together on each arm. It is used to suspend delicate fabrics in the open width state in → Star dyeing machines, either from one edge (vertical star dyeing machine) or both edges (horizontal star dyeing machine). Starting from the centre of the frame, the fabric is suspended from the hooks to form a spiral batch. For fabrics with sensitive edges, a narrow cotton or linen strip is first sewn along the edge/s to be suspended. Star frames loaded in this manner are either moved up and down vertically (vertical machine) or horizontally about their axis (horizontal machine) in the dyebath so that, in the latter case, only half of the star frame is immersed in the dye liquor at any one time (advantage of shorter liquor ratio).

Star steamer → Batch steamers.

Start up (e.g. machine). The action of starting up a machine in order to set it in motion.

Star washing machine (X machine). A drum type washing machine with a → Compartmented drum.

Statex thread An elastic rubber (sheath) thread with the initially wrapped textile core thread dissolved out.

Static charge Whenever two different materials are separated an → Electrostatic charge builds up between them. A triboelectric effect is involved here and materials can be arranged in order according to their interactions. The more dissimilar the materials, e.g. carpet materials, the greater the charge produced. The intensity of the charge is influenced by several factors, e.g. type of carpet, shoe sole material, relative humidity and the person. An electrostatic charge which has built up remains on the shoe sole and the carpet, and a means of discharging it has to be found. This build up of an electrostatic charge on the shoes is distributed over the entire person and finally discharged to earth via a door handle, heating element or other metallic elements. This discharge can be unpleasant and, in some cases, can damage sensitive electronic equipment. The simplest solution to the problem is to increase the conductivity of the carpet so that when the surfaces are separated the charge is conducted away rapidly and cannot build up further.

Test methods for measuring the static charge:

1. Walk test (AATCC Test Method 134 – 1979): in this test a person walks backwards and forwards in a specified manner with specified soles and heels over a carpet which has been conditioned for at least 3 days in dry air (23°C and 25% relative humidity). The test person carries a sensor connected to a static voltmeter which registers the voltage absorbed by the body. The test is carried out with three standardized shoe soles: a) BAM = natural rubber; b) Neolite = synthetic rubber, and c) polyvinyl chloride = a typical synthetic shoe sole material. If the voltage exceeds the sensitivity threshold, the carpet has not withstood the Walk Test. The sensitivity threshold is the voltage at which only few people are aware of any static shock or discomfort. In general, 2000–3000 V has been agreed upon and, for this test, the limit has been fixed at 2000 V.

2. Electrical resistance test (volume resistivity): this test involves measuring the electrical resistance of a carpet – a property which is indirectly connected with its antistatic behaviour. A direct current voltage is applied via two electrodes in contact with the carpet which allows a direct measurement to be made of the volume resistivity. When the electrodes are placed on the back and face sides of the carpet, the mass or volume resisting force is measured; however, if they are placed on the surface only, a measurement of the surface resistance is involved. Several test methods are available and each method is based on its own electrode system. The two most well-known methods are the IBM/ICL Test and the test according to DIN 54 345 Part 1. The IBM/ICL method contains guidelines which state that the resistance of carpets in rooms where computers are used should be at least $5 \cdot 10^5$ and a maximum of $2 \cdot 10^{10}$ ohms. It is assumed that no static charge would arise between these values which could be conducted away through sensitive instruments.

In reality, no direct relationship exists between the volume resistivity of a carpet and its propensity to develop an electrostatic charge (according to Smith).

Static discharge A static discharge prevents the build up of an → Electrostatic charge. → Ionizers.

Static loading resistance The test according to DIN 54 316 is designed to simulate indentations on textile floorcoverings caused by furniture. The thickness of the specimen is determined before the application of a heavy load (2200 cN/cm^2; a_{2200}) = normal thickness a_{20}, as well as after a specified recovery time (60 min; $a_{20,E}$). The compressibility Z ($Z = a_{20}–a_{2200}$) and the depth of the indentation after the load is released e ($e = a_{20}–a_{20,E}$) provide a measure of the indentation propensity of the carpet. The appearance of the indentation is also assessed visually under specified illumination and viewing conditions after a specified recovery time. The test apparatus measures the thickness of the carpet and applies the required load by means of a pressure piston (circular support surface 10 cm^2).

Static pressure The equilibrium pressure which, in the dyeing of loose stock, wound yarn packages and hanks in HT dyeing machines, ensures safe treatment at temperatures above 100°C (high temperature conditions) as well as well-penetrated and level dyeings in a short period of time.

Statistical analysis All measurements or tests involve the accumulation of measurements in the form of individual values (or a series of measurements). We are concerned with measurable variables here (e.g. length, pressure, temperature, moisture content, etc.) which, in the main, obey a normal distribution. In contrast to these, however, some numerical results (e.g. for defects, rejects) obey a Poisson distribution. The most frequently used statistical measures applied to a series of measurements include calculation of the arithmetic mean $\bar{x}$, the standard deviation s, as well as the mean range R if necessary. Undoubtedly, the most generally useful statistical measure is that known as the mean, or average, obtained by adding together the individual values of the variable, and dividing the sum by the number of individuals. It is often referred to as the arithmetic mean and the word "mean" by itself always signifies the arithmetic mean. In order to compare a series of measurements where the mean values differ greatly from one another with regard to their mean variation, it is necessary to determine the variation coefficient v since the standard deviations are smaller for a series of measurements with small mean values and greater for a series of measurements with large mean values. The variation coefficient gives the standard deviation in % of the mean value.

Further information on a series of measurements gives the confidence limits resp. the relative confidence interval of the mean value at a selected confidence level. In technical statistics, a confidence level of 95% has become widely accepted in practice. The relative confidence interval of the mean value is given as a % of the mean value and, together with the selected confidence level, gives the range within which the true mean value lies. The distribution of individual values is also of particular interest and, in this case, it is not only the test for normal distribution but also the concrete form of the distribution (histogram) which provides important information relating to a series of measurements. The histogram (bar chart) is a graphical representation of a frequency distribution which in some respects is very similar to the frequency polygon. The x-axis is marked in the same way with the values of the variable being measured. The frequencies in the groups, however, are not represented by a point at a height proportional to their frequency, but by a rectangle with an area proportional to the frequency, having as base the x-axis between the group limits.

1. Arithmetic mean $\bar{x}$: as the most important parameter for a normal distribution the arithmetic mean gives the centre of the frequency distribution. Although it is the most familiar statistical measure, it should be emphasized that it only provides a partial description of the frequency distribution from which it is calculated. Distributions of very varied shape and spread may yet have the same mean. Nevertheless, it is an exceedingly useful measure, and provides enough information for many purposes:

$$\bar{x} = \frac{1}{n} \sum x_i$$

2. Variance s^2: a measure of the dispersion of a distribution of a random variable:

$$s^2 = \frac{1}{n-1} \sum_{i=1}^{n} (x_i - \bar{x})^2$$

The variance of a random variable is usually written s^2 and is the square of its standard deviation.

3. Standard deviation s: a measure of the dispersion of a distribution given by the positive square root of the variance:

$$s = \sqrt{s^2}$$

4. Variation coefficient v: a relative measure of dispersion:

$$v = \frac{s}{\bar{x}} \cdot 100\,\%$$

5. Absolute confidence interval of the mean value q: this parameter gives the range in which the mean value of the populations lies:

$$q = \pm t \cdot \frac{s}{\sqrt{n}}$$

6. Correlation coefficient r_{xy}: a measure for the linear relationship between x and y. The value always lies between the two limits –1 and +1.

$$r_{xy} = \frac{\sum_{i=1}^{n} (x_i - \bar{x})(y_i - \bar{y})}{\sum_{i=1}^{n} (x_i - \bar{x})^2 \sum_{i=1}^{n} (y_i - \bar{y})^2}$$

7. Coefficient of determination B: this parameter identifies the percentage of dispersions of a characteristic which correlate with those of others:

$$B = (r_{xy})^2$$

8. Existence test t: this test is carried out in order to establish whether the correlation coefficient of the population can be zero or not:

$$t = \frac{r_{xy}}{\sqrt{1 - r_{xy}^2}} \cdot \sqrt{n-2}$$

The t-test is a test used on the means of small samples of one of these null hypotheses:

– that the sample has been drawn from a population of given mean and unknown standard deviation (which has therefore to be estimated from the sample)
– that two samples have both been drawn from the same parent population.

F-test: (1) A test applied to the variances of two samples, of the null hypothesis that they have both been drawn from the same parent population. (2) A test applied to the variance of a single sample, of the null hypothesis that it is drawn from a known normal parent population.

The t test involves the investigation of the variability of two mean values whilst the F test is defined as a dispersion test. For the practicing engineer it is important to know that the following procedures can be carried out with the F and/or t test:

– difference between target and mean values in a series of measurements,
– difference between two mean values/distributions,
– difference between two numerical values,
– poisson distribution.

In principle, all variants of the comparison between two variables with a freely selected confidence level have a common relationship (as a rule, a figure of 95% is adopted for technical applications). In this way, a tabulated value of a distribution (F or t) is always compared at a selected confidence level with the respective degrees of freedom and a calculated value. The following cases can arise: a) calculated value ≤ tabulated value (e.g. $F_e < F$), i.e. the difference between the observed variables (e.g. mean value and target value) is coincidental; b) calculated value > tabulated value, i.e. the difference between the observed variables is significant (according to Hörl).

Statistical certainty →: Confidence factor; Statistical analysis.

Statistical process control (SPC). In most organizations it is necessary to measure and establish the so-called “capability of a process”. In many industries this requires the use of certain procedures which are grouped under the general heading of statistical process control (SPC). In addition to measuring capability, controlling and improving processes through the use of statistical techniques, it might also be necessary to identify and classify lots of batches of material by their characteristics, select samples, determine any rules for acceptance or rejection of material or for adjusting the severity of inspection and the segregation and screening of rejected materials. The system should refer to the statistical procedures used and give the areas of their application. SPC is not only a tool kit, it is a strategy for reducing variability, the cause of most quality problems: variation in products, in times of deliveries, in ways of doing things, in materials, in people’s attitudes, in equipment and its use, in maintenance practices, in fact, in everything involved in the production process. With its aid, the statistical variability of processes and work flows is predictable. This contributes to better planning as well as the objective and rapid evaluation of data. On the one hand, undesired variations can be recognized in the form of a trend and promptly corrected and, on the other hand, positive aspects can be specifically reinforced. The SPC method (see Fig.) is supported by the control chart which provides a graphical representation of measurements dependent on time.

Statistical quality control An aspect of → Quality control which involves inspecting and testing a sample of a raw material, component or product in order to reach conclusions concerning the quality of all the output of that material, component or product. Where inspection or testing involves destruction of the product, statistical quality control based on sampling is the only means of monitoring quality. It is achieved by the application of mathematical statistical procedures, e.g. with the aid of → Control charts for acceptance tests on manufactured products by → Random sampling.

Statistics The mathematical manipulation and analysis of numerical data in order to quantify and interpret trends and frequencies in industry, manufacturing and technology. Statistics involves the objective evaluation of empirically determined measurements and analytical data. The results of statistical analysis provide reference points for a production department or measuring procedure with regard to its inherent limits of accuracy and inaccuracy. The science of statistics is used in industry to optimize production, e.g. in statistical → Quality control.

Status nascendi (Lat.). A nascent state (e.g. → Active oxygen).

Statutory units (in metrology) → SI system of units.

Steam (water vapour). Steam is normally generated at constant pressure in boilers. The heat content per kg, or specific enthalpy, of steam depends on pressure and temperature. Steam may be either saturated or superheated. Saturated steam is a vapour and, at a particular pressure, has a definite temperature, the saturation temperature. Superheated steam is a gas and, at a particular pressure, may have any temperature in excess of

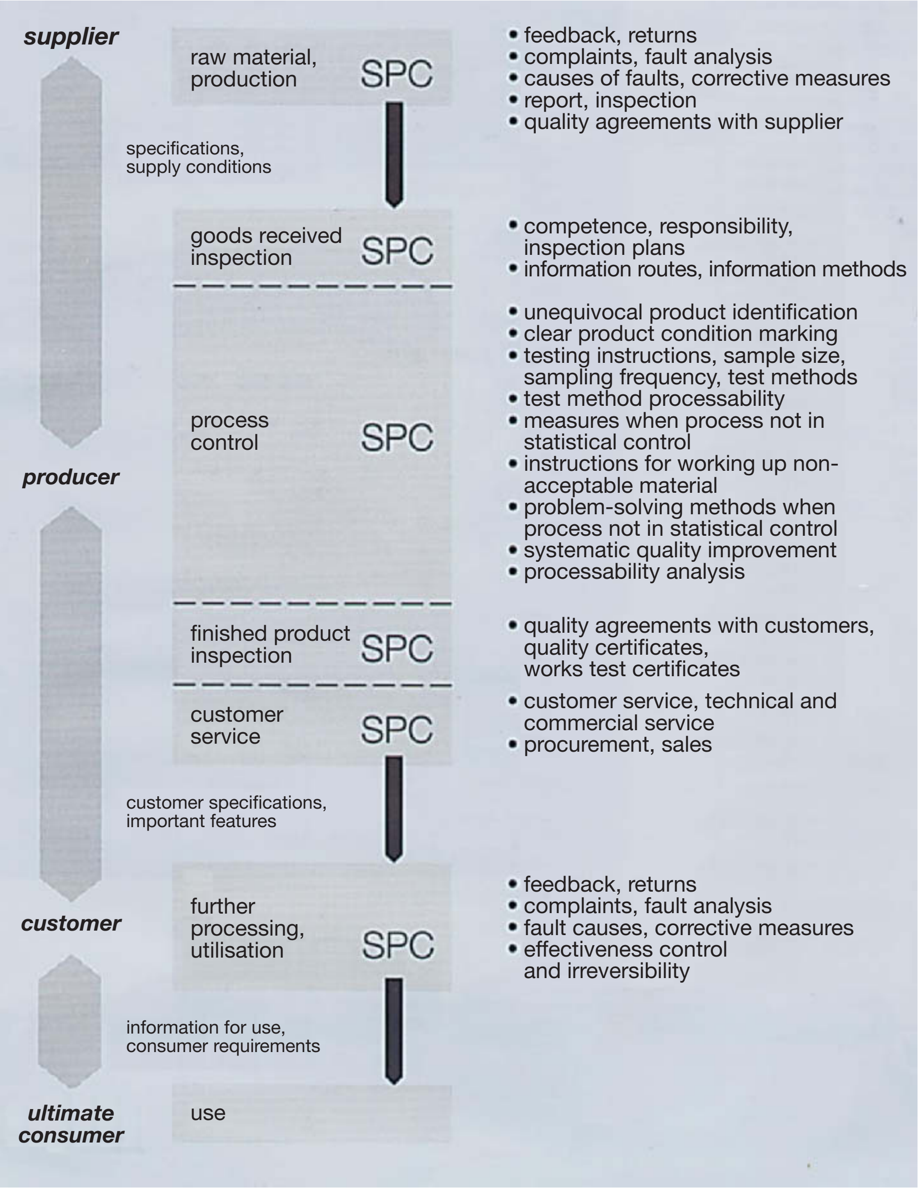


Fig.: Statistical process control system (SPC).

the saturation temperature. At normal air pressure (1.0133 bar) the temperature of water increases gradually to its boiling point at 100°C through an exchange of heat between a burning fuel and the water. With rising temperature there is also an increased development of steam, i.e. the rate of evaporation of water increases. When a further 2250 J (so-called heat of evaporation) is supplied to 1 kg water at 100°C in an open space (steam boiler), steam at 100°C is produced with an absolute pressure of 0.981 bar which represents a useful source of energy because of the high amount of bound (latent) heat energy it possesses,. If further heat is supplied, the steam pressure obviously rises above 0.981 bar. At the same time, the volume of 1 kg steam increases and the weight per m^3 in kg decreases (saturated steam). When steam is extracted rapidly from the boiler there is a sudden decrease in the steam pressure, i.e. the water temperature is higher than its pressure-related boiling point. A rapid development of steam therefore occurs, the water and steam are in a state of reciprocal equilib-

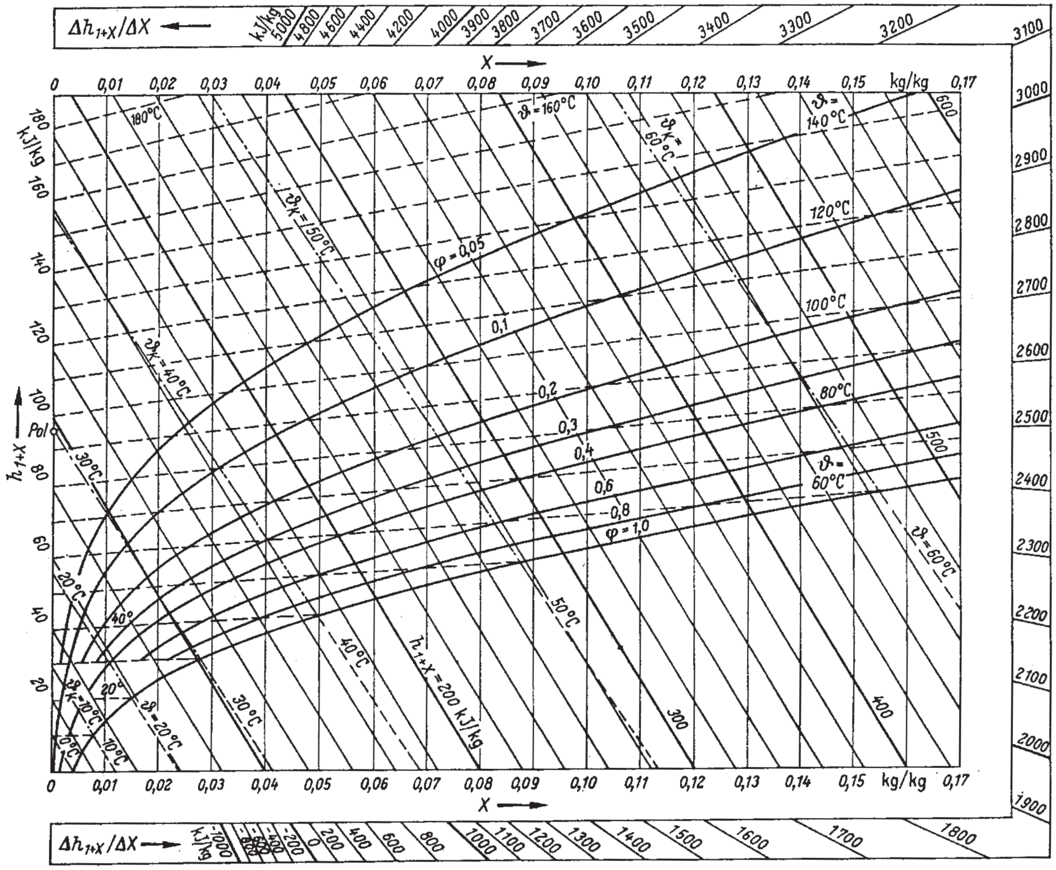


Fig.: Mollier – h, X – diagram for steam with a total pressure of p = 1 bar.

rium and the steam is said to be saturated (saturated steam). Since, the equilibrium shifts in favour of water at low pressure, unsaturated steam, i.e. wet steam, is formed under these conditions. On heating saturated steam without water its temperature increases, as well as the pressure in a closed boiler, whilst the weight of the steam remains unchanged. As a result, superheated steam is formed which can also be created in the distribution network (steam superheater).

Changes of the condition of this kind can be visualized for moist air, i.e. for the evaporation of water in the surrounding air in the Mollier-h, X-diagram (see Fig.). The absolute water vapour content X is plotted on the abscissa and the enthalpy on the ordinate. Both values are related to 1kg of dry air each time. The quantity of moist air per kg of dry air is 1 + X kg and its enthalpy is described as follows:

$$h_{1+X} = 1 \cdot h_L + X \cdot h_{WD}$$

h_L = enthalpy of dry air (kJ/kg),
h_{WD} = enthalpy of water vapour (kJ/kg).

For any temperature ϑ [°C], the enthalpy is:

$$H_{1+X} = c_{p,L} \cdot \vartheta + X\,(r = c_{p,WD} \cdot \vartheta)$$

$c_{p,L}$ = specific heat of air [kJ/kg/K],
r = evaporation enthalpy of water at 0°C [kJ/kg].

If the relationship h = f (X, ϑ) is represented as in the Mollier diagram, the region of unsaturated wet air (steam) would be crowded into a narrow wedge in the right-angled coordinates. For this reason, Mollier chose an oblique-angled coordinate system in which the X axis is so inclined that the isotherms of the wet unsaturated air for ϑ = 0°C lie horizontally.

As parameters, the temperature ϑ and the relative humidity of air φ are entered in the Mollier diagram. The saturation line φ = 1, represents the state of air saturated with water vapour (saturated steam). Next to it, the lines of constant dew point temperature ϑ_K are found. The points for conditions corresponding to pure water vapour lie at infinity in this diagram.

Steam as a liquor heating medium The heat transfer relationship between saturated steam and water is much more favourable than that from superheated steam. Superheated steam, being a gas, is a poor heat transfer medium and has a low film heat transfer coefficient. When direct heating is carried out with superheated steam, the steam outlet holes must be kept very small and at a sufficient depth below the surface of the liquor. When direct heating is carried out with saturated steam, the steam should not be too wet (dilution and overflowing of becks; considerable reduction in the transfer of heat) (see Tab.).

Heating method	Advantages	Disadvantages
Direct steam (under high pressure)	Small heating coils, small pipe diameters, small valves, dry steam	Poor heat utilisation frequently leaking flanges and valves
Direct steam (under low pressure)	Good heat utilisation	Large diameter piping, with poor steam traps (wet steam!) liquor dilution
Indirect steam (under high pressure)	Cheap piping system	Poor heat utilisation. Frequently leaking flanges and defective steam traps
Indirect steam (under low pressure)	Good heat utilisation	Large diameter pipes, large valves
(Hot water)	Best heat utilisation, permanently cleaner pipelines	No direct heating possible. High plant costs

Tab.: Advantages and disadvantages of steam heating methods.

Steam black → Aniline black produced on the fibre with sodium chlorate as oxidizing agent and yellow prussiate of potash (potassium hexacyanoferrate II) as aniline black catalyst. Steam black is also referred to as prussiate black.

Steam boiler Various types of steam boiler can be classified a) according to the steam pressure (low-pressure boilers up to 1.5 bar, high-pressure boilers above 1.5 bar); or b) according to the construction (natural circulation; controlled circulation boiler; forced flow-through boiler).

Steam boiler can be a packaged type, 3-pass fire-tubes steam boiler suitable for pressurized combustion of liquid or gaseous fuels (Fig. 1). The high efficiency, the steam quality, the high reliability are basically due to the following features:

- 3 smoke pass with the second and third pass inside the tubes,
- lagre furnace with low thermal load,
- wetback smoke reversing chamber,

Fig. 1: Steam boiler.

- large heat exchanging surfaces,
- large evaporating surface and steam chamber.

For small to medium-size generating plants, e.g. from 0.13–12.60 kg/s, the most frequently used construction is the treble-pass packaged boiler (natural circulation boiler): a free standing unit with minimum floor space requirements compared to the earlier walled-in corrugated fire tube boiler. These boilers have an adequate water capacity resp. steam space and therefore a good steam reserve. In spite of the adequately large water capacity, this type of boiler offers short heat-up times, e.g. within approx. 20–25 min at 11 bar in the case of oil-fired boilers, with a good steam quality. They are mainly constructed for operation with an overpressure as oil-fired boilers, i.e. a forced draught fan is no longer required. As a result, good CO_2 levels are achieved, there is a good utilization of flue gases due to the treble-pass construction and, therefore, favourable exhaust gas temperatures between 180 and 260°C depending on the pressure, load and clean heating surfaces; operating efficiencies up to 92% can be achieved with oil-firing; good water-side and flue gas-side cleaning access. Treble-pass boilers, together with a superheater, are also particularly suitable for the in-house generation of electricity. Treble-pass boilers are preferably heated by oil or gas or a combination of both. Theoretically, any treble-pass boiler can be heated by solid fuels with a grate installed in the fire tube. Because of the small fire tube, however, only a relatively small grate area can be accommodated. For this reason, a conversion from oil to solid fuel only gives approx. 60% of the steam capacity of an oil-fired boiler. If the boiler is to be fired specifically with solid fuels, treble-pass boilers with larger diameter fire tubes must be selected. Travelling grates with automatic belt charging are generally used as firing systems for high boiler capacities, or internally-fired plane grates with automatic belt charging or hand-firing for low to medium boiler

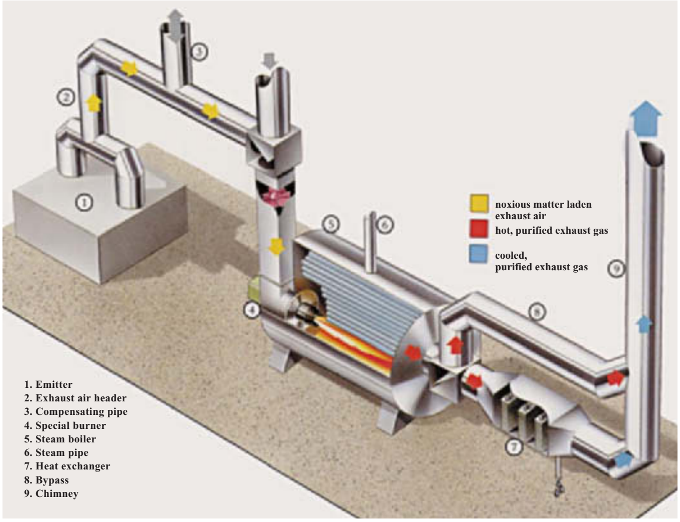


Fig 2.: Exhaust air combustion in a König "Sparal" system steam boiler.

capacities. Alternatively, sloped grate firing should be chosen specifically for wood waste supplemented by a blower unit for wood, dust and shavings. Treble-pass boilers are always pre-assembled in the factory as complete units before delivery, at least as far as low and medium capacity models are concerned. Advantage: no time-consuming on-site erection; installation is simply a case of mounting the unit on a level hard standing, connecting it to fuel, power and water supplies and to the steam system, and the boiler is ready to operate. Provision must also be made for disposal of the "blow down". Small treble-pass boilers are also available in the market as so-called product boilers, i.e. due to the water content, these boilers fall under the product number 10 (water content up to nominal diameter in m^3 x working pressure in bar; the number 10 must not be exceeded). These boilers can be erected in working areas and under residential areas. For small-sized plants, quick-acting boilers (forced through-flow boilers) are mainly used.

The main element is the tube coil which can be installed either vertically or horizontally. A vertical or horizontal construction is chosen depending on the height of the boiler room. Advantage: minimum floor space requirements, quicker readiness for service (approx. 2–4 min). Great attention must be paid to water treatment. Type of firing: oil or gas. Water-tube boilers are increasingly being used for lower capacities (natural circulation boilers); these are mainly constructed as vertical multiple-pass boilers (3 or 4 passes). Advantage: minimum floor space requirements, water content, short heat-up times (approx. 6–10 min). Type of firing: oil or gas. These boilers have frequently replaced the former vertical cross-tube boilers which are only occasionally found nowadays (high flue gas temperature, low efficiency). Traditionally, burners with the lowest possible excess of fresh air are used. Large quantities of hot exhaust air laden with pollutants can be satisfactorily processed in the burner of a steam boiler with a consequent saving of energy at the same time (Fig. 2).

Steam calender A machine used after the drying of finished knitgoods for steaming, compacting and stretching the fabric to the desired tubular width (see Fig.).

These machines are available in two versions:

I. Vertical steaming and compacting calender (European design) for vertical running fabrics: minimum floor space requirements, blind fabric passage, high running speeds not possible up to now.

II. Horizontal steaming and compacting calender (US design) for horizontal running fabrics: requires considerably more floor space, high running speeds possible (due to more intensive fabric steaming) and continuous working. Control and inspection of the fabric is easier than in I.

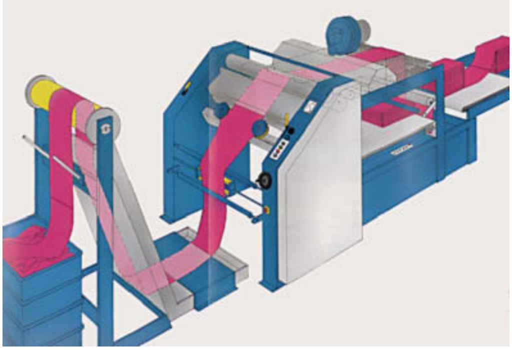


Fig.: Typical steam calender for tubular knitted fabric.

Steam colours An obsolete term formerly used in textile printing for all dyes requiring a steaming treatment after printing in order to fix the colours. Insoluble colorants, such as those used in metal powder and pigment printing were a typical exception.

Steam conditioning In order to ensure reproducible effects in pretreatment and dyeing at all times, the

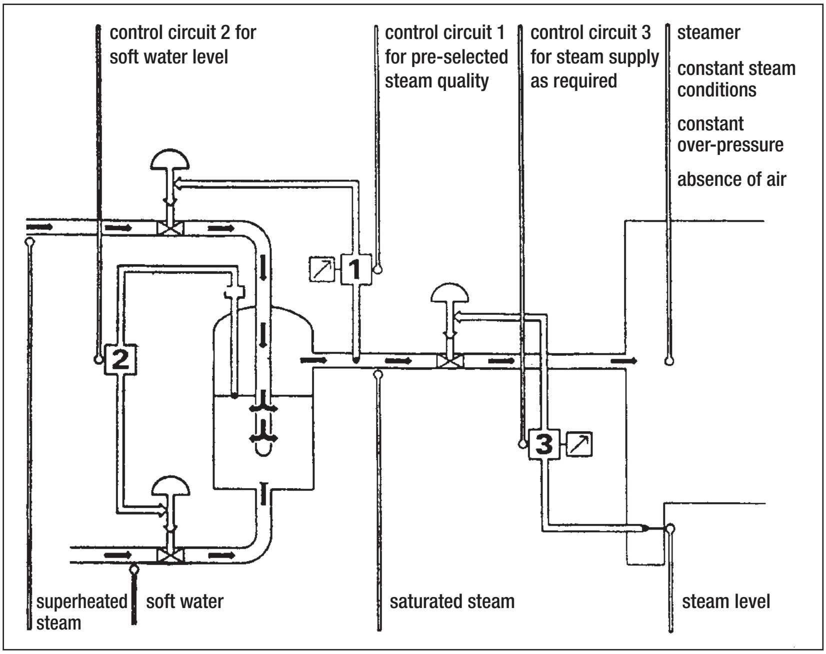


Fig.: Steam conditioning station with three automatic control circuits.

steam conditions inside the steamer must be absolutely constant. This means that a steam conditioning station must fulfil the following requirements:

It must be able to ensure a constant light overpressure and consequent absence of air in the steamer

- with a constant quality of saturated steam,
- for any length of time,
- irrespective of variations in the steam distribution network,
- irrespective of the surrounding temperature,
- irrespective of variations in operating conditions with varying steam consumption (fabric speed, nature of material, etc.).

Constancy of the steam conditions is, in the main, ensured by three different control circuits (see Fig.): both control circuit 1 (superheated steam supply from the distribution network) and control circuit 2 (soft water level in the mixing vessel) together ensure a constant quality of saturated steam. Control circuit 3 is responsible for the consumption of the corresponding steam feed to the steamer. An important point here is that the steam level passes in a special measuring tube underneath the steamer. Because of the easily measurable change in the steam level, the control unit can react immediately and exactly. The plant operates without an excess of cooling water.

Steam conditions In textile finishing plants, steam is generated in different types of boiler at high or low pressure. The steam is often further superheated in a turbine before leaving the boiler house for the generation of electrical energy, then reduced to a lower pressure and stored in the distribution network. The steam gives up its superheat to a greater or lesser extent in the steam main depending on the length of the main to the point of consumption and the quality of insulation. If the steam stored in the distribution network has a low degree of superheat, the steam soon reaches a state of saturation. Further release of heat leads to the formation of condensate and the steam becomes wet.

Depending on the technical execution and length of the steam main, as well as the steam throughput, losses of pressure occur which can be calculated with the following formula:

$$\Delta p = \xi \cdot \frac{\rho}{2} \; w^2 \; [\mathrm{N/m^2}]$$

ξ = loss correction value,
ρ = density [kg/m^3],
w = flow rate [m/s].

The condition of the steam at various points of consumption can therefore differ from the condition of the steam stored in the distribution network. The above-mentioned changes in the condition of steam may be represented in the so-called Mollier diagram (h, X diagram). → Steam. The enthalpy is defined as:

$$h = u + p \cdot V$$

where u is the internal energy, i.e. the sum of all the energy supplied to a stationary body in any form, and p · V is the work done by e.g. expansion against the surrounding pressure during heating. Entropy is a measure of the reversibility of a thermodynamic process. On release of the steam pressure (throttling), the enthalpy remains constant and corresponds to a horizontal line in the Mollier diagram. The entropy increases during throttling since a non-reversible process is involved.

If the steam was allowed to flow in the opposite direction, then no pressure increase would be obtained but the same pressure drop would have to be overcome in the other direction only. The following examples serve to demonstrate changes in steam conditions:

1. A release of the pressure of saturated steam at 6 bar to 1 bar gives superheating to approx. 139°C.
2. Cooling of superheated steam at 3 bar, 200°C to saturated steam condition. Approx. 147 kJ/kg (0.04 kWh/kg) has to be dissipated. Further release of pressure to approx. 1 bar and cooling to saturated condition. Approx. 50 kJ/kg (0.014 kWh/kg) has to be dissipated.
3. Wet steam at 4 bar with approx. 3% water content, which corresponds to 97% steam content, is already dry on releasing the pressure to 1 bar.

The development of superheating, the quantities of water necessary for cooling superheated steam, or the moisture content produced in the steam, can all be taken from the Mollier diagram.

The development and maintenance of constant steam conditions is very important for the trouble-free operation of each process where steam is required as a treatment medium. Pressure fluctuations, such as those which occur in all distribution networks, should first be controlled with a pressure regulator or pressure reducing valve. Wet steam should be passed through a separator which can also filter out coarse contaminants such as rust from pipelines as a rule. If the steam is superheated, then cooling to virtually saturated steam conditions is necessary in many cases (according to Tischbein).

Steam content tester A device for determining and controlling the steam content in a steam/air mixture. With this device the wet bulb temperature (= temperature of the wet bulb thermometer in a psychrometer) can be measured continuously thereby enabling the steam content to be determined. Other devices are based on determining the oxygen content in steam/air mixtures. (→ Zirconium sensor).

Steam-cure process A process for the continuous moist crosslinking of cotton with a nitrogen-methylol compound in the presence of a highly active catalyst mixture (magnesium chloride and citric acid) in a steamer supplied with superheated steam for drying and crosslinking (6–10 min at 130–140°C). Reaction takes place in the 15–5% moisture content range. Subsequent neutralization is not necessary.

Steam decatizing A process in which decatizing is carried out with steam (also known as blowing) in contrast to → Wet decatizing.

Steamer,

I. A program-controlled yarn steamer with radial through flow to ensure uniformity of the steaming effect.

II. An apparatus for steaming (Fig.) printed or padded piece goods, yarns, tops, hosiery, garments, etc. These steamers are of two types, a) batchwise or discontinuous steamers and b) continuous steamers.

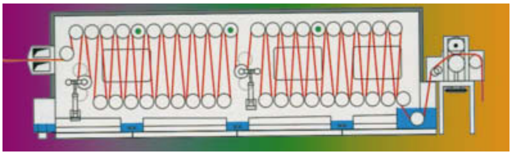


Fig.: Brugman steamer for dyeing.

Steamer for two-phase printing A special type of continuous steamer with a built-in padder, preferably with a small fabric capacity and a high steaming performance, e.g. rainbow or arch steamer, loop steamer, spiral steamer or → Flash ager.

Steamer grey A light woven fabric which is run into a steamer together with printed goods to prevent the dried print pastes on a printed fabric from marking off on to adjacent layers of the same fabric during the steaming process.

Steam finisher A steaming cabinet or steaming tunnel for batchwise or continuous steaming of outerwear garments in laundries and dry cleaning establishments. A notable finish effect is produced by movement of the garments in the steam/air flow especially in the case of blended fabrics.

Steam generator → Steam boiler.

Steaming Finishing process causing general increase in moisture levels, increased swelling, and therefore, further effects, such as improved washing. There are further specific effects on wool-based fibres, including partial alleviation of tension (tension-free steaming), fluffing and raising the pile, removal of creases caused by laying, storage, pressing and decatizing, stripping of shine caused by pressing, etc. The best method to use is to steam for approx. 3 min with saturated steam, but complete saturation of the fibre should be avoided (detrimental effects to the handle).

Steaming at atm. pressure, fastness to Capacity of the colour shade to resist being affected by steam (e.g. during steaming). The sample is placed between undyed cotton and the adjacent fabric for colour fastness testing. After rolling, the test sample is placed in the neck of a glass cylindrical flask, which is filled with boiling water. It is boiled for 30 min and then dried in warm air (< 60°C) without being touched. Any staining of the undyed adjacent fabric is evaluated using grey scales for fastness testing.

Steaming dummies → Steam ironing dummy.

Steaming of fibrous materials The purpose of steam treatments in textile finishing is to achieve rapid heating, if, at the same time, the fabric is required to have a high moisture content, and/or it must not be allowed to dry out. If the temperature of the fibre and its moisture content is raised, chemical reactions that occur during pretreatment and finishing can be accelerated, as can physical processes such as dye diffusion and molecular transpositions in the fibre that occur during setting.

Condensation takes place when the cold fibre first enters a steam atmosphere, and latent heat of 2250 J/g is released by the condensed steam. In de-aerated steam at atmospheric pressure, the fibre temperature quickly rises to 100°C. It can increase even further if there is a subsequent exothermic reaction. The quantity of condensate depends on the original temperature, specific heat and moisture content of the fibre. Saturated steam at a temperature of 100°C condensing on cotton at a temperature of 20°C with 7% moisture increases the moisture content of the fibre by 5.5 g/100 g. This increase will be of approximately the same proportions for other fibres. An acceptable solution and diffusion speed can often be guaranteed under these conditions. In the case of polyester however, diffusion into the fibre at 100°C occurs only very slowly. In order to achieve better mobility of the polymer chains and higher diffusion rates, saturated steam should be used at higher temperatures and higher pressure, or the steam should be superheated. Cellulose and wool fibres adsorb more water out of the steam once the temperature has reached 100°C, until the adsorption equilibrium is reached.

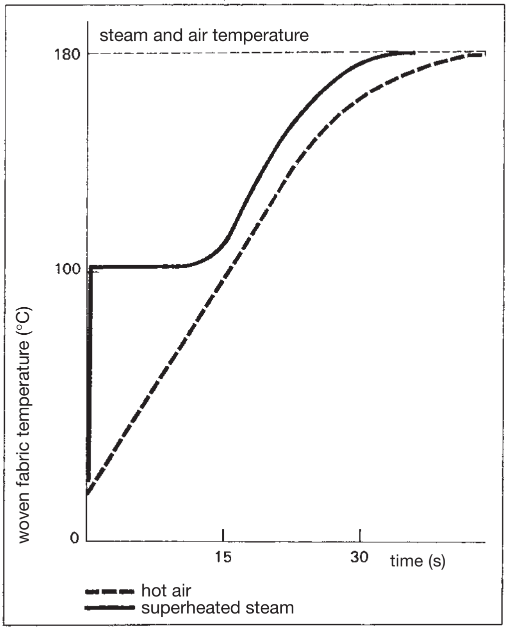


Fig. 1: Substrate heating rate in hot air and in superheated steam.

Steam condenses on cold dry fabric, causing its temperature to rise rapidly to 100°C (Fig. 1). The moisture content will increase less than in steam at 100°C due to the additional inherent heat, which is transfered from steam to the fibre. However it will be enough to split hydrogen bonds, cause swelling in thickening layers, and reach the glass transition temperature in thermoplastic fibres. The moisture level is then balanced by steaming. For cotton the level of equilibrium is approx. 1% at 150°C (20% residual heat), and for polyester 0.2% at 180°C (10% residual heat). However these levels are only reached relatively slowly, so that the fibre structure remains more penetrable than it would if heating was carried out in dry air.

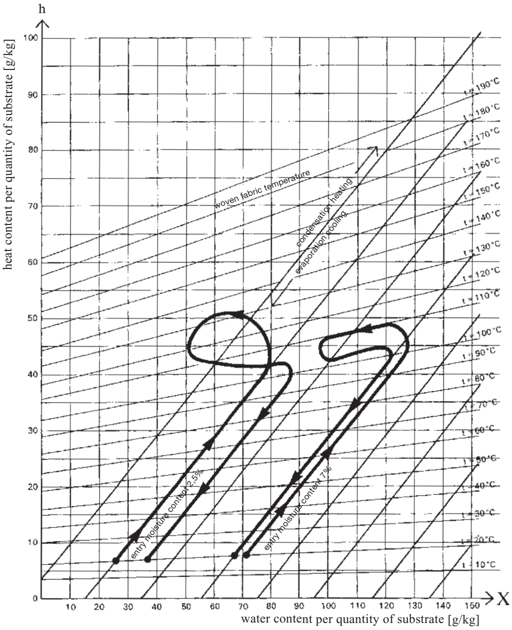


Fig. 2: h-X diagram for wet woven fabric.
[$C_{m\ woven\ fabric}$ = 1.34 kJ/kg°C]

The so-called h-X (heat content/moisture content) diagram (Fig. 2) provides a graphic representation of the changes that take place during the steaming process.

If there is a low initial moisture content of 2.5%, maximum heat is developed, resulting in a solution with a high boiling point. Temperatures in excess of

110°C cause pointless decomposure of the reduction agents used in discharge printing, for instance. For this reason the dye is only partially reduced and set, even if enough water has been adsorbed to ensure internal diffusion within the fibre. At the opposite end of the scale, a high initial moisture content of 7.5% leads to minimal heat development and a solution with a relatively stable boiling point of approx. 110°C. After the exothermic reactions have ended, this temporary temperature equilibrium can no longer be maintained. If the vapour is vaporized and cooled, the temperature of the fabric is reduced to the same temperature as the vapour to enable further water uptake. This will continue until either equilibrium is restored, or the printed fabric is removed from the vapour (according to Miles).

Steaming of garments One aspect of textile care when manufacturing finished garments from clean textiles is blocking, using →: Steaming tables; Steam finisher, garment shaper, etc. The finish can be improved if the garment is subsequently pressed, either by hand or mechanically. If the textile is steamed, the fibre becomes warm and damp, and therefore flexible and easy to shape. A smooth finish can be achieved using presses, brushes or by tensioning. The setting process is done by means of vacuum extraction or with a blower (drying).

Steaming of prints Prints are usually set or developed by steaming the various different substrates (details can be found under the relevant dye classification). The steaming process is carried out in open or sealed systems, either at atmospheric pressure or at pressure for temperatures in excess of 100°C.

Steaming of yarns, twisted yarns etc. This process is carried out by means of steam in a steam box under pressure. It is done to improve softness, quality and to avoid shrinkage (curling) during dyeing, etc. Crêpe yarns in the form of yarn packages or on weft bobbins should be steamed with extreme care (crêpe quality). When yarns are steamed, they are heat-treated, whilst at the same time being affected by moisture. If the fibre temperature and moisture level are raised, chemical reactions occur in the fibre structure. The yarn tension reaches a state of equilibrium, in other words the yarn is relaxed, stabilized, set to the correct twist, and prepared for an even dye uptake if the yarn is to be dyed. Saturated steam is an essential requirement in any temperature range for optimum thermal treatment. There are three distinctive types of steam in thermodynamics (Fig. 1).

It should be noted that even where the same type of steam is used, or at the same steam temperature, the vapour state can vary. Each time water is boiled, saturated steam is generated. In this situation the temperature at which vaporization takes place, or at which the steam becomes saturated, is dependent on the pressure. At atmospheric pressure and at sea level this temperature is approx. 100°C. When saturated steam is cooled, wet steam is formed. This type of steam has already begun to condense, making the steam visible. This type of condensate can cause staining or even water inclusion in the yarn, which damages it and prevents steam penetration. If the steam is heated further, or if the pressure is changed, superheated steam is produced. This type of steam is a poor conductor of heat. The main problem is the lack of moisture, rendering it unsuitable for yarn steaming. Superheated steam can also be produced by taking saturated steam from a steam generator and reducing its pressure. The transition phase between saturated steam and superheated steam is denoted by the saturated steam line. At this point the steam is in a state that will not cause any damage in yarn treatment. However, many yarns do not tolerate heat treatment at a temperature of around 100°C. For this reason it is necessary to create conditions in which water will vaporize at a low temperature. This can be done at a low pressure in an autoclave. According to the laws of physics, water will vaporize in a vacuum at a temperature of 50°C, for example. However the vacuum also causes the air to escape from the yarn, creating "free space" for the steam. Penetration is thus encouraged. The vacuum also removes oxygen with the air. In practice, either direct or indirect steaming (depending on the manufacturer) is used in this context (Fig. 2).

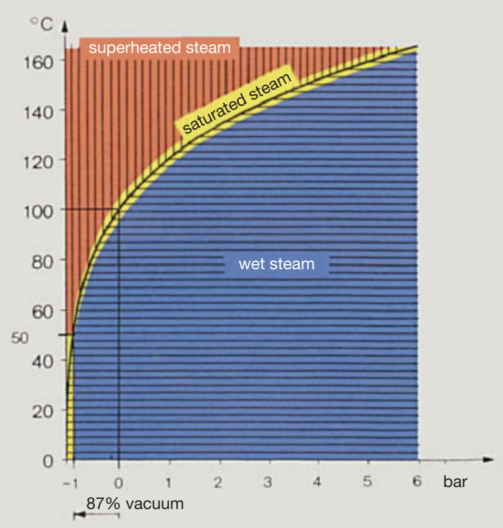


Fig. 1: Types of steam.

If the direct steaming process is used, steam will flow directly into the autoclave. With indirect steaming, steam is generated from a sealed water reservoir in the bottom of the steamer (Fig. 3). The water reservoir may also be equipped with electric heating elements, in which case a steam generator would not be required (Xorella).

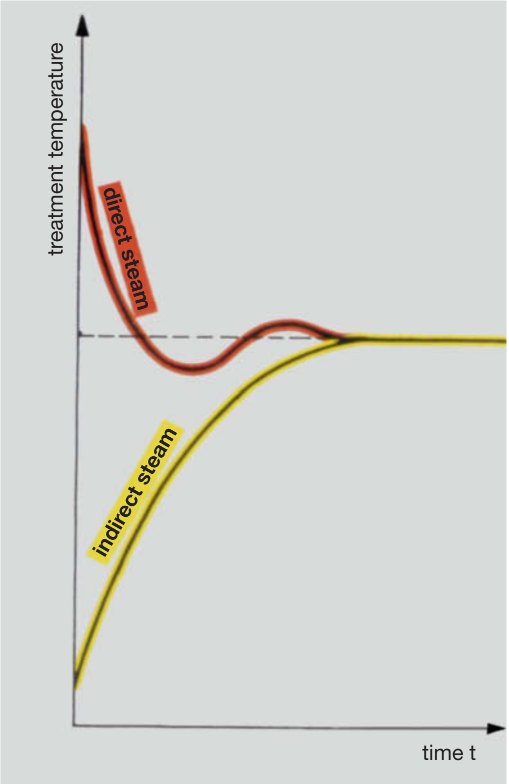


Fig. 2: Effect of indirect steam and direct steam in yarn steaming.

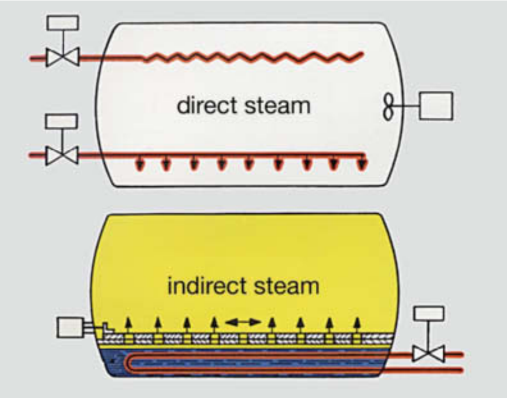


Fig. 3: Production of direct steam and indirect steam in yarn steamers.

The period of treatment in the autoclave is controlled by a program and runs automatically.

Example:

	direct	indirect
preheating	approx. 10 min	not required
vacuum	approx. 3 min	approx. 3 min
steaming	approx. 10 min	approx. 5 min
vacuum	approx. 3 min	approx. 3 min
steaming	approx. 10 min	approx. 15 min
evacuation	approx. 3 min	approx. 3 min
	approx. 39 min	approx. 29 min

Charging the equipment with cops or yarn packages is usually done automatically. Continuous running equipment and various different charging systems can be integrated into the transport system.

Steaming pad → Steam ironing dummy.

Steaming table For steaming piece goods, which are drawn across a perforated table top (with a textile cover).

Steaming temperature control Control of superheated steam with spray water as a control variable.

Steaming under pressure, fastness to Capacity of the colour shade to resist being affected by steam at high pressure, such as during setting or pleating. The sample is wound onto a copper cylinder (with adjacent fabric) and steamed under pressure in a pressure steamer or an autoclave. After steaming the steam is released over a 2 min period. Then the specimen is dried in warm air (< 60°C) without touching the individual components. There is a 4 h acclimatization period (20°C, 65% relative air humidity). Any change in colour or staining of the undyed adjacent fabric is evaluated using the appropriate grey scale for fastness testing. Steaming conditions:

light	5 min	108°C, 1.35 kPa absolute pressure,
medium	10 min	115°C, 1.70 kPa absolute pressure,
extreme	20 min	130°C, 2.76 kPa absolute pressure.

Steam ironing dummy A device which allows the steaming and drying of dresses, skirts, jackets and coats in their normal shape as worn on the body by blowing steam or hot air through them when fitted on to the dummy. Various automatic models are also available. Capacity 30–60 garment pieces per h. Mounted on a low pedestal with operating controls (lever or push-button control). With movable shoulder supports and automatic length adjustment. Grips are provided for fastening the garments and adjustment for all normal sizes is possible. Some models have exchangeable bust supports for women's dresses and jackets. Simple constructions, often in groups up to 3–5 garments on a common base (fan air supply) for drying dyed or wet impregnated pieces.

Steam jacketed pan (double-cased pan). A formerly indispensable item of equipment in the colour kitchen of a printworks to prepare thickeners for textile printing by boiling. The interior of the vessel, made of copper or stainless steel, is surrounded by a cast-iron sheath. The well-sealed space between both inner and outer walls is fed with steam in order to heat the contents of the pan. After the boiling operation is complete, the steam supply is shut off and substituted with cooling water for rapid cooling of the prepared print thickener. Steam jacketed pans for this purpose are usually provided with two mechanical agitators which keep the thickener paste in constant motion, and thus ensure a smooth consistency and uniform mixing of the ingredients. The agitators turn on their own axes and, at the same time, travel continually around the interior of the pan so that every particle of thickening agent is thoroughly mixed. These agitators work on the well-known sun and planet principle and are actuated by bevel gearing.

Steam jacketed pans are seldom required nowadays since many of the natural gums and native starches formerly used as thickeners for textile printing, and which required boiling, have been largely replaced by cold-water soluble thickeners such as alginates, starch-ethers, galactomannans, etc.

Steam lye extractor A system for the removal of caustic lye with steam after the mercerization of piece goods.

Steam mansard A type of continuous steamer which works on the Krostewitz steamer principle.

Steam precipitation A problem caused by steam coming into contact with → Condensate at a considerable lower temperature (usually in a steam main). Result: a very rapid condensation of steam occurs associated with a considerable reduction in volume thereby forming a void so that water streams in from various directions at high speed, causing a sudden braking effect and frontal collision or → Water hammer. Such events can occur, for example, in heat exchangers if an accumulation of condensate is present which has either been cooled excessively or when the steam pressure in the main is considerably higher than the steam pressure in the heat exchanger.

Steam pressure (saturated vapour pressure). The pressure (often expressed in millimetres of mercury, mm Hg) exerted by a vapour, either by itself or in a mixture of gases. All solids and liquids give off vapours, consisting of atoms or molecules of the substances that have evaporated from the condensed forms. These atoms or molecules exert a vapour pressure. If the substance is in an enclosed space, the vapour pressure will reach an equilibrium value that depends only on the nature of the substance and the temperature. This equilibrium value occurs when there is a dynamic equilibrium between the atoms or molecules escaping from the liquid or solid and those that strike the surface of the liquid or solid and return to it. The vapour pressure is then said to be a saturated vapour and the pressure it exerts is the saturated vapour pressure. There is an inverse relationship between the vapour pressure and the → Evaporation (number) since solvents evaporate resp. vaporize more quickly at increasing vapour pressures and correspondingly more slowly at a low vapour pressure. Consequently, solvents which evaporate readily have high vapour pressures and vice versa. The measurement of vapour pressure is based on the principle of the mercury barometer with the test solution in an air-free space, whereby the respective vapour pressure can be expressed directly in mm of mercury. The pressure exerted by a liquid or solid at equilibrium at a specified temperature is termed the vapour pressure at that particular temperature. Thus, at increasing temperatures, the vapour pressure obviously increases as well which, for all liquids or solvents, is always 1.0133 bar at the → Boiling point. When non-volatile salts are dissolved in water (e.g. sodium chloride), the vapour pressure decreases whilst the boiling point increases (i.e. the so-called boiling point elevation of solutions). Substances which sublime readily also exhibit a significant vapour pressure even at room temperature (e.g. camphor, naphthalene).

Steam saturation, degree of The degree of water vapour saturation in steamers.

Steam setting → Heat setting processes.

Steam starvation A partial inactivation of a steamer due to the build up of excessive condensate.

Steam trap → Steam traps. A self-acting device which, operating under steam pressure, automatically ejects condensed steam (condensate) from steam pipes, etc. without permitting the escape of steam. Various designs and systems are available, e.g. with float valve, ball valve or slide valve, bimetallic strip control (valve opens with a drop in pressure resp. temperature and closes with a rise in temperature).

Steam traps A steam trap is a device into which → Condensate from steam pipes, etc. is allowed to drain, and which automatically ejects it without permitting the escape of steam. Whilst there are many different types of steam trap, some are more suitable for a particular application than others. The condensate ejecting element and, if applicable, the actuating mechanism (float valve, thermostat, etc.) are combined in some steam traps. The various types of steam trap can be classified according to their control principle: e.g. by float valve (closed spherical float, inverted bucket type); by temperature and/or pressure (bimetallic strip, rod or liquid expansion, liquid evaporation); by temperature and flow (self-acting or non-self-acting moving internal elements); ejecting systems with self-acting variable cross-section (valves, sliders, cocks); with non-self-acting variable cross-section (nozzles, labyrinths, capillaries); ejection not self-acting (hand-operated) or self-acting (continuous and outlet venting); with purging device for clearing the entire cross-section of the ejection system by an arbitrary external influence. It is important to check the steam trap regularly for seat leakage since a gap of only 1 mm^2 allows 90

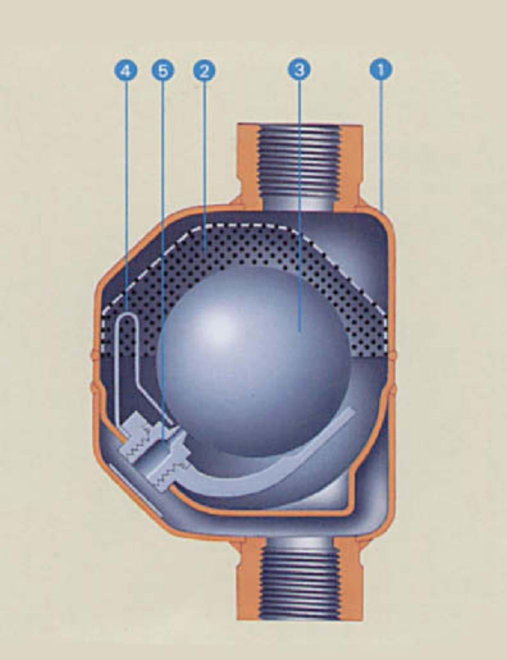


Fig. 1: Float ball condenser.
1 = housing; 2 = dirt filter; 3 = float ball; 4 = bimetal strip; 5 = valve seat.

kg of steam at 7 bar working pressure to escape in 24 h. Strainers should be fitted on the inlet side of all steam traps to prevent the entry of dirt, rust and other foreign particles, which can block orifices and cause the trap to malfunction. Sight glasses are available for fitting on the downstream side of a steam trap so that it can be seen at any time whether or not the trap is working correctly and discharging condensate.

The Float ball condenser (Fig. 1) is suitable for installation in vertical pipes (max. working overpressure 21 bar; max. operating temperature 350°C; differential pressure gradation 5/10/16/21 bar). It's working principle is demonstrated in Fig. 2.

1. During the starting phase, the bimetallic strip keeps the float ball away from the valve seat so that air and cold condensate are rapidly ejected.
2. Incoming hot condensate causes the bimetallic strip to bend which keeps the valve seat free. The float position adjusts itself according to the accumulation of condensate. The condensate is ejected continuously.
3. Due to the loss of buoyancy and the pressure gradient, incoming steam causes the level of condensate to drop and the float-ball is drawn to the exit nozzle which seals its tight. A hydraulic seal is therefore formed above the valve seat. The bimetallic strip remains below the valve seat and is not in contact with the float.

Steam trap test station A mobile production service for testing and demonstrating the working principle of various types of steam traps and systems under practical conditions at different pressures and with different quantities of condensate with/without counter pressure. Such test stations can also be installed as fixed units (see Fig.).

The test chamber is installed immediately before the steam trap. The small quantity of steam which is necessary to cover radiation losses from the pipeline and steam trap flows through a hole in the dividing wall of the test chamber. When the steam trap functions correctly the test chamber is filled with condensate. If a steam trap is blown through, the water level in the test chamber falls and the steam flows through beneath the dividing wall. The sensor of the test chamber is therefore in contact with condensate or steam. Accordingly, there is a change in the electrical resistance at the sensor. This change is fed as a signal via the sensor cable to a hand-held electronic test instrument for analysis.

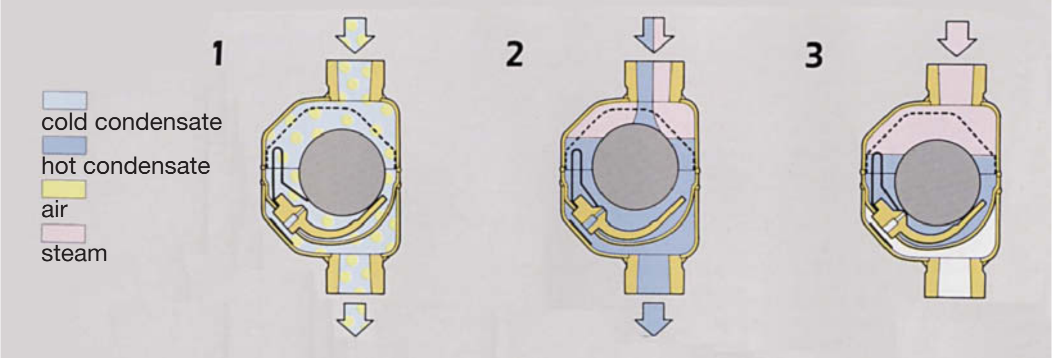


Fig. 2: Float ball condenser function principle.

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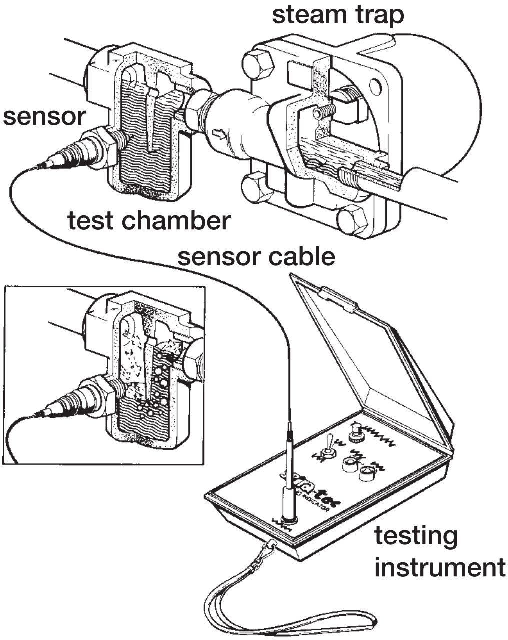

Fig.: Steam trap test station for checking whether a condenser is in working order (Sarco).

Stearates Stearic acid salts, e.g. aluminium stearate, which is used as a water-repellent treatment.

Stearic acid soaps Manufactured by saponificating stearic acid ($C_{17}H_{35}COOH$). Used for scrooping in sizing and finishing (proofing grease).

Steatite, soapstone Mineral mass with a greasy feel, a derivative of → Talcum consisting of 60–85% talcum, 5–7% magnesium carbonate, 0–24% barium carbonate, 0–2% lime, 0–2% beryllium oxide. Used to remove grease stains and as tailor's chalk.

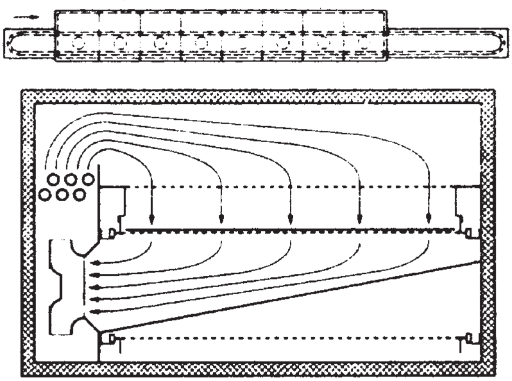

Fig.: Diagram of a steel plate conveyor drying machine.

Steel Forgeable iron, high level of strength and hardness, with 1–2% carbon and possible additives of non-iron metals (to increase corrosion resistance → Stainless steel), elastic properties.

Steel fibres → Metal fibres.

Steel plate conveyor drying machine Ventilation dryer with a high level of transport stability, consisting of edge supported perforated plates; fixed to reinforced sections with chains running along the sides. A fan blows heated air for drying over the heater into a retention chamber in which there is an even distribution of air over the whole width. (see Fig.).

Steiner Tunnel Test Method for testing the burning properties of carpets. The specimen is exposed to open flames in a tunnel. → Flammability test.

Stencil brushing Pile processing machines which can be equipped with a variety of tools for structuring the surface of imitation fur, such as stencil brushes for use after fabric has been preheated (Figs. 1–3).

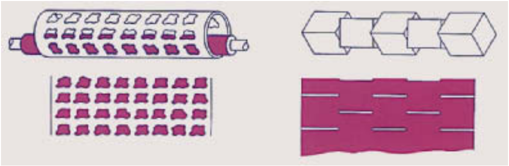

Fig. 1: Stencil brushes.

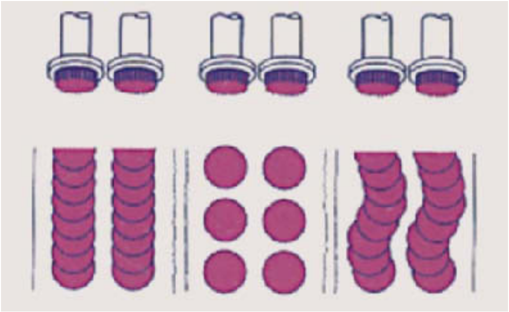

Fig. 2: Rotary brushes.

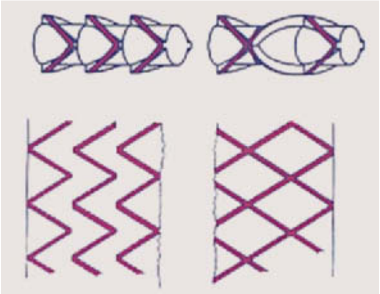

Fig. 3: Patterning devices, with drives, for geometric and floral designs.

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Stencil raising/shearing machines The pattern is cut out of a stencil that partially covers the fabric, so that only the cut-out stencil area of the fabric will be raised or sheared.

Stencils for spray printing This type of stencil is usually made from 0.2–0.6 mm thick zinc sheet cut out in the shape of the pattern. There are various different methods of manufacturing spray stencils. The pattern can be a) cut out using a saw; b) chiselled out; c) etched (hydrochloric acid). Polyvinyl chloride film is sometimes used instead of zinc sheet, in which case etching of the pattern is not possible.

Stenter dryer → Drying systems.

Stenter emissions Emissions from thermal treatment of textile fabrics have been tested using a portable FID in numerous textile finishing companies. These tests have shown that significant mass concentrations of foreign substances can occur, particularly during thermal setting processes. For practical reasons the entire stenter is considered to be a source of emission, and this means that the overall mass flow of exhaust has to be analysed for foreign substances, which should never exceed the threshold values prescribed by TI-air for substances in categories II and III.

Experience shows that a textile treatment, which becomes volatile under process conditions, produces the most emissions during grey fabric setting. A suitable washing process can significantly reduce the level of volatile substances in the fabric, even at a high setting temperature of 220°C. However if the wash process is difficult, the volatile content of the textile is still relatively high, at 3.2 g/kg, even if the mid-range setting temperature of 185°C is used. Proofing finishes also contain a certain level of volatile substances.

A significant proportion (sometimes the greater proportion) of stenter emission is caused by the so-called constant load, which is made up of unburnt hydrocarbons from the burner. Constant load measurements are between 20 and 120 mg per normal m^3, depending on stenter age and type, the number of fields and the exhaust capacity (FID measurement, verification gas: propane). The constant load is itemized in the emission declaration in line with the 11. BImSchV (Bundes-Immissionsschutzverordnung – German Federal Immission Protection Regulation) as overall carbon levels per year. Example:

base load:	70 mg per normal m^3
average exhaust vol:	13 500 normal m^3/h
no. of operating h/year:	4500/year
annual exhaust quantity:	60 750 000 normal m^3/year
annual emission quantity from base load:	4252.50 kg/year

Suppliers of textile auxiliary substances used in resin finishing provide information in safety datasheets as to whether they contain certain substances and in what quantities, complying with:

– categories I–III of the TI-air appendix,
– the list of TLV values.

Individual emissions must be stated together with their annual quantities, in line with TI-air categories I–III, in the emission declaration. This information should be limited to the most important emissions, in other words limited to finishing chemicals used in the largest quantities, which must be itemized as individual substances in line with TI-air categories I–III. For any toxic or carcinogenic substances (TLV list) the following restriction must be observed:

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a) cancerogenic compounds according to Number 2.3 TI-air (1997) (anorganic materials):

  class I: 0.002 g/kg with a mass flow of 0.5 g/h or more;
  class II: 0.02 g/kg with a mass flow of 5g/h or more;
  class III: 0.1 g/kg with a mass flow of 25 g/h or more;

b) organic compounds according to Number 3.1.7 TI-air (1997):

  class I: 0.4 g/kg with a mass flow of 0.1 kg/h or more;
  class II and III: 0.8 g C/kg with a mass flow of 0.8 kg C/h or more.

Stenter exhaust air treatment TI-air was published in 1986, causing more stringent emission values for volatile and gaseous organic compounds to be enforceable. Textile finishing plants must comply with the regulations stated in TI-air, because of the equipment they use, e.g. stenters.

In comparison with the version of → TI-air that was previously applicable, permissible emission values have been reduced drastically, i.e. if hourly solvent loads are exceeded, the mass concentration (mg/m^3) of the corresponding categories must be adhered to. The latest version of TI-air is a directive with stringent limitations. In textile finishing, substances in categories 2 and 3 are frequently used, which must be disposed of properly in line with TI-air. That also includes substances with strong odours, because companies are under obligation to run their plants in such a way that local residents are protected from air pollution.

In order to analyse exhaust air concentration, suitable measuring methods must be selected, among other reasons so that the plant size can be measured accurately enough for exhaust purification. A suitable method of measurement is to use an FID (flame ionisation detector). This measurement process analyses the overall carbon content of the exhaust flow and gives no information relating to individual components. Measurement should be carried out over a fairly long period. A

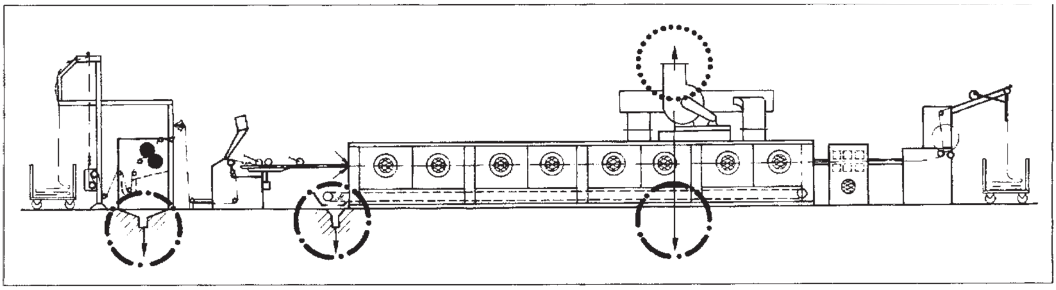


Fig. 1: Soiling of water and air in a dyer-stenter combination (by Babcock).

more accurate method of analysing individual components is to use gas chromatography in combination with mass spectroscopy. Individual components are defined selectively. To assess the measured values, the products used should be observed from a theoretical point of view based on the manufacturer's statistics. Measurements to analyse dioxins are time-consuming and cost-intensive. Waste water impurities generated by peripheral stenters should also be considered (Fig. 1).

When deciding how to dispose of stenter exhaust, the emitted category 2 and 3 contaminants should be considered in series, and because of the high volume of exhaust, the resulting overall emission of contaminants will be significant. Consideration should also be given to a suitable exhaust system (Fig. 2). The following methods are available for exhaust air cleaning:

1. Activated carbon adsorption: use of activated carbon is a state-of-the-art technique, which can be used in any situation where there is only solvent and water adsorption. Heavily polluted exhaust flows leave a deposit on the activated carbon, reducing its adsorption capacity and/or causing regeneration problems.

2. Exhaust washers with hyperfiltration: since stenter exhaust emissions consist of lint, softeners, resin and other reaction products, the use of an exhaust washer including heat recovery equipment, connected in series, is an economically viable solution. A particular point in favour of this is that it almost completely eliminates the "blue fumes" generated during fibre preparation and the associated odour problems. The high temperature of the stenter exhaust is cooled down if heat recovery equipment is used. Any lint, resin and softener content can be condensed depending on concentration, vapour pressure or saturation pressure. External air, or air from inside the room, which is passed over the heat recovery system in counter flow, preheats the system and can be directly re-routed to the stenter. Depending on the temperature of the exhaust, 22–33% of primary energy can be saved. The heat recovery equipment has a built-in cleaning system, which is cleaned during operation without interrupting production. The cooled exhaust (after it has been through the heat recovery system) is passed through an airwasher and is sprayed in counter flow with suitable washing liquids. The emit-

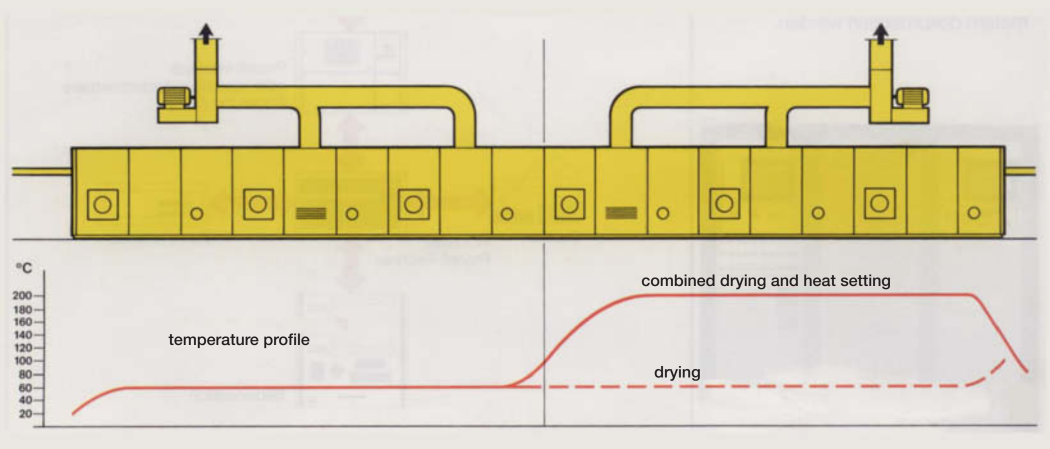


Fig. 2: Exhaust air separation as per temperature profile in the stenter (Monforts).

tents in the exhaust react with the washing liquid and are eliminated from the exhaust. The washing liquid in the washer is used as circulation water. The contaminants that have been picked up are diverted to a hyperfiltration system on the second circuit, where the solid particles are removed and the clean washing liquid is piped back into the washer circuit again. Water can be partially removed from the concentrate once it has been extracted, either by vacuum extraction or by evaporation, making it suitable for disposal.

3. Thermal post-combustion: thermal post-combustion of stenter exhaust is another method of disposing of the by-product of stenter drying.

The process of flue gas cleaning in an existing steam boiler enables combustible contaminants and odorous substances that are not naturally components of air to be removed from process exhausts, whilst recovering energy at the same time. Combustion usually has to take place with a high level of excess air, creating larger quantities of exhaust. Exhaust fans are used to remove the exhaust that is generated by means of induced draught (3000–30 000 m^3/h). During this process the stenter can reach temperatures of 50–200°C. The exhaust is piped through a specially designed circuit from the process plant to the boiler house. There is an air vent so that preheated air can be routed from the boiler house to the burner during boiler operation or used for exhaust-free heating. The burners are designed for exhaust or fresh air operation. A special burner is installed in the boiler for variable and high excess air, and it is also equipped to cope with high air temperatures, a high level of contaminants and high air humidity. The main requirement of the burner system is to optimize combustion by reducing contaminants, taking optimum levels of carbon monoxide and nitrous oxides into account. After the boiler, a heat recovery process is carried out, so that the temperature of the flue gas is kept as low as possible, thereby maximizing the recovery effect. Under certain circumstances a new chimney system is necessary for the flue gases to escape after heat recovery, because the chimney has to comply with TI-air specifications (Tab.).

There are many input and output signals to be recorded in plant control. The control system must be freely programmable to allow for variable operation and to provide adaptability to new operating conditions. It is appropriate to use this type of post-combustion if the following requirements are met:

- existing steam or hot water boiler of an appropriate size,

substance	I (mg/m^3)	II (mg/m^3)
organic hydrocarbons: paraffins, wax, spinning and texturing oils, softeners	200–2 000	< 5
dust, fibres	150– 500	< 3
carbon monoxide	0– 500	< 40
nitric oxides		< 150
formaldehyde	0– 50	< 5
hydrochloric acid	0– 10	< 10

Tab.: Stenter exhaust air measuring results (reference quantity = 3% O$_2$).
I = stenter exhaust air measured value; II = measured value in boiler exhaust gas according to Sparal machine.

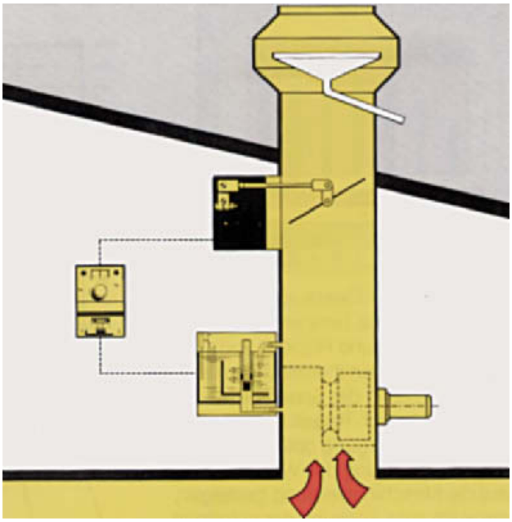


Fig. 4: Exhaust air valve control by Brückner.

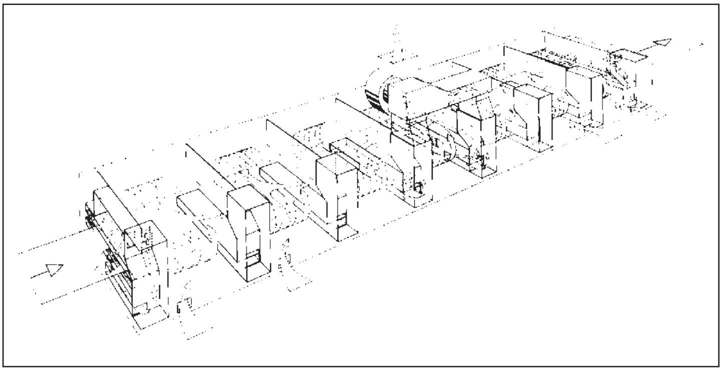


Fig. 3: Differentiated exhaust air streams in the Krantz stenter.

Stenter exhaust air treatment

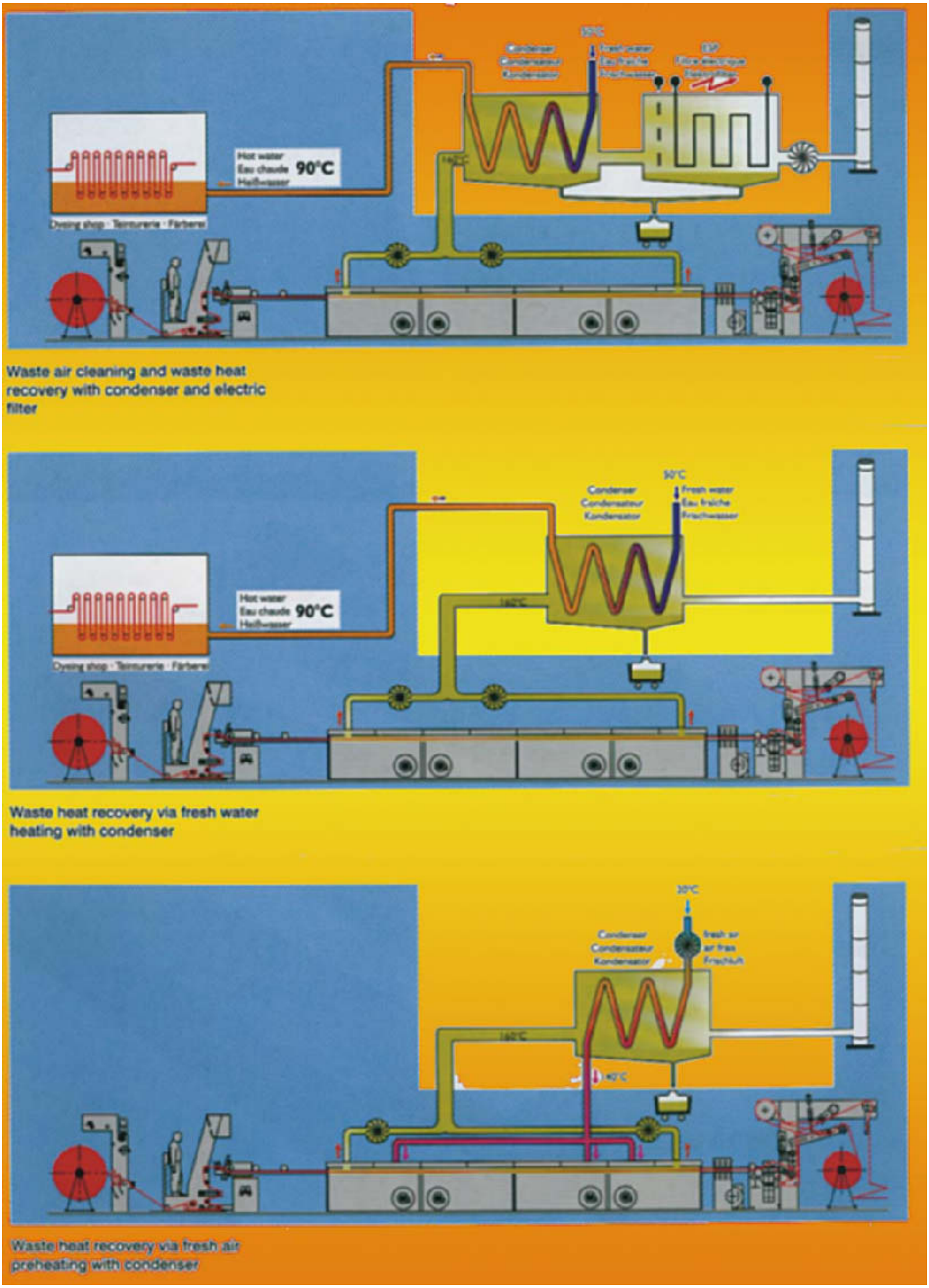


Fig. 5: Waste air cleaning and waste heat recovery.

- combustible exhaust from industrial production plants (contaminants in the form of organic compounds),
- the steam boiler must be operating while the process is running and contaminants are being emitted.

The exhaust from pure drying processes, as well as from combined drying/setting/condensation processes, can be piped away without disrupting the process by installing two fans. If the entire machine is being used for drying, both fans supply a controlled amount of humid exhaust. If drying and setting processes are being carried out simultaneously, the first fan supplies a controlled amount of humid exhaust, and the second one, oil or scrooping damper controlled, supplies enriched exhaust.

One way of achieving more economical use of energy (Fig. 3) is by combining the uniflow principle (fabric and air from front to back) up to the middle point, with the counter flow principle (fabric to back, air from back to middle). With regulation of exhaust air dampers (Fig. 4), the humidity of the surrounding air (exhaust) is detected and drying conditions can be optimized. Very low amounts of exhaust can be achieved if the behaviour curve of drying is matched. The exhaust quantity can be controlled by means of the revolutions of the exhaust mototr. Waste air cleaning/water heat recovery systems and components for waste air cleaning and waste heat recovery specially matched to Monforts machines and ranges, opening up new possibilities for energy-optimized operation of the plant as a whole (Fig. 5).

Stenter infeed assembly Device for pick-up of fabric guiding system elements at the machine's infeed point. This is an essential device for feed into the stenter entry zone. Usually consists of → Variable-tension rolls, infeed fingers and selvedge curlers to straighten out selvedges, a sensing element to make sure the fabric width is maintained accurately, and a needle device to define the fabric selvedges on a needle chain.

Stentering The process of drying textile fabrics on stenter driers; → Stenters.

Stentering and drying machine Tensioning and treatment of fabric runs with drying chambers, air supplies either vertical or parallel to the fabric, horizontal or vertical stentering chain redirection.

Stentering fabrics for printing (tensioning and straightening), to avoid pattern distortion after printing, the printed fabric is tensioned to finished size. This process involves straightening the warp and weft threads to a perpendicular position. Simple → Stenters are used, set up so that the fabric can be tensioned under slight steaming. If horizontal stripes have to be printed, such as in roller printing, these stripes are engraved approx. 2 cm askew, and the fabric has to be stentered askew to compensate for this.

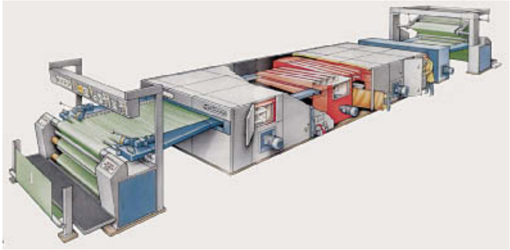


Fig. 1: A Brückner stenter frame.

Stenters Units for thermal treatment of textile fabrics, that retain and set the fabric width. They consist of an entry zone with an edge guide, one or several drying or setting zones, cooling devices for shock cooling, and an exit zone with a batching device and possibly an edge cutting device (Fig. 1). The retaining device consists of pin or clip chains, or combination chains. The air circulation and air impingement systems are comparable to those of other drying systems. However in practice there are considerable differences, because a stenter's chain system enables it to be set up specifically to suit the fabric being treated (e.g. with/without width control, with/without overfeed, clips/pins, ducted air system, etc.). Typical stenter options are varying air supplies and varying impingement types (round, oval or slit jets). Apart from essential components, a stenter dryer should have short air circuits, practically arranged heating systems, easy accessibility, and be easy to use. For knitwear finishing for instance, as well as an over-

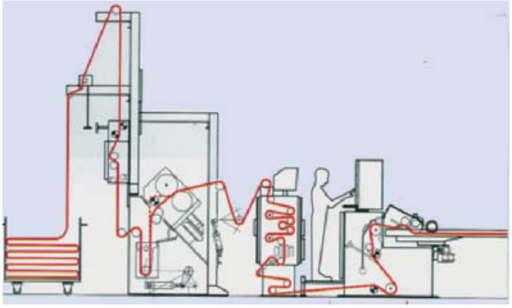


Fig. 2: Fabric preparation in front of a stenter frame.

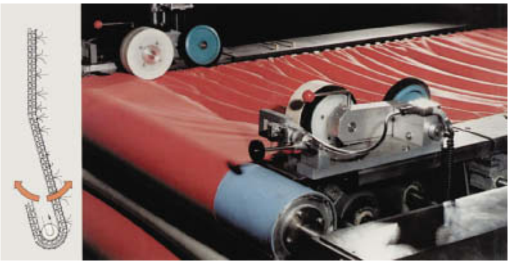


Fig. 3: Multifunctional entry zones can be modified at short notice (e.g. for coating).

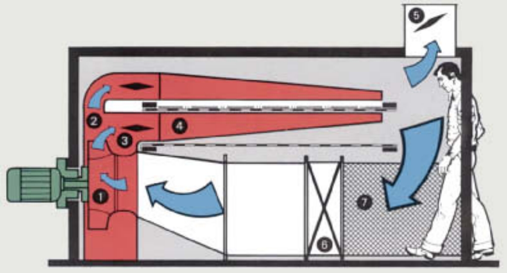


Fig. 4: A Brückner constant pressure ventilation system, here with oil circulation heating.
1 = circulation fan; 2 = distributor for upper and lower airflow; 3 = throttle valves; 4 = nozzle boxes; 5 = exhaust air vanes; 6 = heater; 7 = fibre trapping sieve.

feed device (Fig. 3) the fabric guiding system should be relatively tension and flutter-free. Air flow control (Fig. 4) should be clear, simple and easy to use, because multi-speed motors often do not allow enough margin. If low friction tools are used, chain lubrication, which often causes oil splashes, will not be necessary. Direct gas heating can be used to direct air and any vapour in the circuit through the burner, so that any foreign substances present in the surrounding air are burnt. However this results in unknown cracking products.

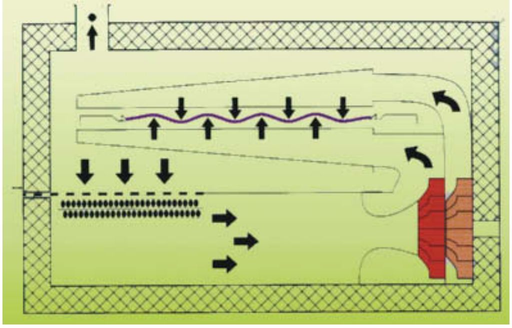


Fig. 5: TWIN-Air system.

The TWIN-Air-system (Fig. 5): Separately controlled air flow for top and bottom air. Also available with separate temperature setting for top and bottom air to supplement the system. Advantages: Reproducible fabric results at any time. Individual exact setting by speed-controlled fans even at low speeds. Ideal for delicate fabrics such as knitted goods, coated fabrics, viscose, microfibres, pile goods and silk. The TWIN-Air system is based on a Monforts patent.

There are measurement and control devices to ensure even quality of the tensioned fabric. The stenter can be equipped with electronics, which will automatically set target values for the relevant finishing process, which guarantees reproducibility for that process and the required effect (Fig. 6). Stenters are fitted with heat recovery systems, enabling approx. 80% of the exhaust heat to be put to further use. Heat exchangers usually operate on the air/air principle.

Fig. 6: A stenter control bridge with the Babcock "Dasy-Tex" process control system. The "Dasy-Tex" hardware includes local autonomous control loops, a higher-order computer, the program memory, the operator's keyboard, a monitor and a page printer.

In textile finishing, stenters cause a logistic problem in almost every factory. It is an essential prerequisite that the machine is operated properly (shrink-free fabric, exact final fabric width) to ensure fabric quality (weaves, knits). A stenter is an expensive piece of equipment, because the original purchase cost is high, it requires plenty of space, and it consumes large amounts of power. For this reason it is the only textile finishing machine to have such highly developed measurement and control systems. The stenter is one of the most highly polluting systems, next to machines that produce waste water, because of its high air throughput containing vapour that picks up diverse contaminants. Stenter emissions are regulated by TI-air specifications, but gaseous waste products are more difficult to deal with than textile finishing by-products dissolved in waste water. At the moment, stenters operating in Germany are required to be licenced, because they produce exhaust (→ Exhaust air segregation in stenters). The technical requirements for cleaning the exhaust are significant, and cost as much again as the actual purchase price of the equipment. In some areas, a licence for a new stenter is only granted if there is evidence that processes for cleaning the exhaust effectively (condensation, absorption, washing, post-combustion) have been implemented (→: Exhaust air heat recovery; Stenter exhaust air treatment).

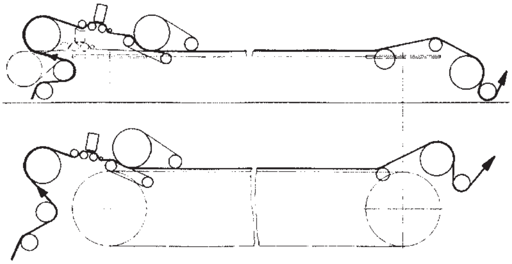


Fig. 7: *Entry and exit pin-wheel sections on horizontal and vertical chain layouts on stenters.*

Fabric should not be under tension in a stenter, they should be de-swollen, drained and dried in clearly defined dimensions, under as little tension as possible (in width and length). The selvedge grip elements necessary for these processes are not in a fixed position, but form continuous mobile chains around a vertical or horizontal axis (Fig. 7). At the inlet the chains are near to each other, gradually becoming further apart to correspond with the intended width of the fabric (Fig. 8). In stenters for drying and tensioning, the chains run through sealed boxes with heat circulation, and may be accommodated over three levels (Fig. 9). Multi-storey stenters are used almost exclusively for finishing woollen weave fabrics. The continuous chain runs in and out of several levels that are arranged one on top of the other. Straightening devices are also fitted at the fabric entry zone, to ensure that the fabric is tensioned in line with the warp or knit.

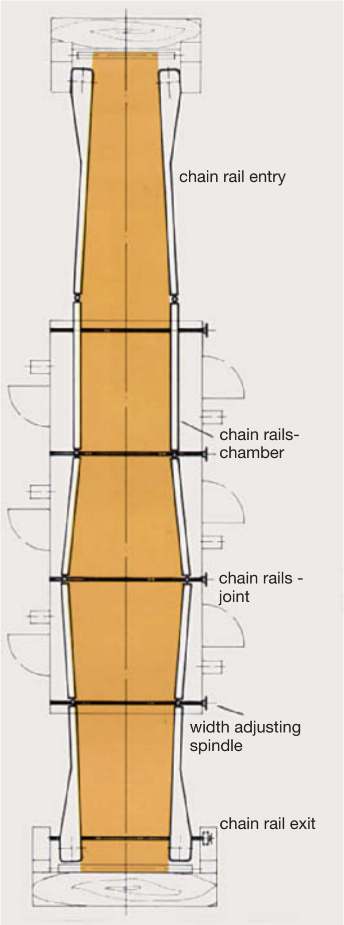


Fig. 8: Individual width adjustment in the various stenter chambers of a Brückner machine.

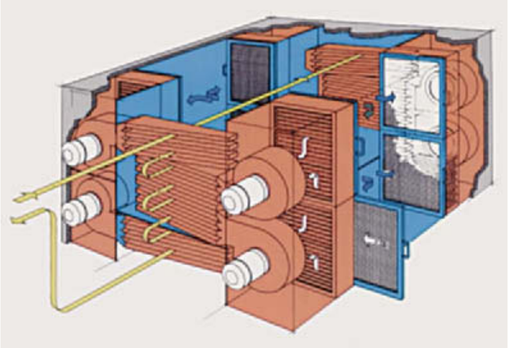


Fig. 9: The Santalucia multi-layer stenter. (yellow arrows = movement of goods; white arrows = fresh air; blue arrows = air circulation).

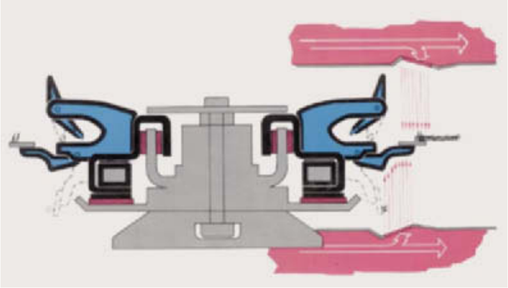


Fig. 10: Chain guides in a Krantz stenter, with flow (right) of the chain carrying goods on pins through the aerated zone and horizontal return (left) of the combination chain (pins alternating with clips).

There are various different construction methods of stenter grip elements. Depending on the type, stenters are known as clip or pin stenters (Fig. 10). The former are fitted with hammer or feeler clips. Hammer clips, a dated option, are clipped through a guide rail without taking the position of the fabric edge into account (false selvedge).

If feeler clips are used, the edge of the fabric can be

	advantages	disadvantages	main application
A horizontal stenter	entry and exit optimum with clips, highest possible tensioning forces, pins and clips possible	wide chain rails, complicated transmission, problems of curling selvedges and in selvedge trimming	universal machine, clip operation, heavy-weight woven fabrics, carpets
B vertical stenter	entry and exit optimum with pins, short spacing, highest possible drying capacity, simple and cost-effective	hardly suitable for feeler clips, higher chain bolt loading, less rigid chain rails	knitted and woven fabrics in pin operation, plastic coating, hammer clip operation
C tier stenter	high drying and heat setting capacity with little floorspace, gentle drying and aeration, 1 man operates entry and exit	fabric contact with return drums, limits to temperature separation, only hammer clips possible	heavyweight woven fabrics, especially wool fabrics, knitted fabrics, time processes
D double return stenter	high capacity, low floorspace requirement, no return drums, 1 man operates entry and exit	no feeler clips, both fabric faces once to the underside	all applications except with feeler clips

Tab.: Main applications of stenter chain versions plus advantages and disadvantages.

located by means of small rollers or hoops. They do not close until the fabric edge is in the right position between the upper and lower gripping jaw. Pins are used in the following situations: For knits, for weaves needing warp shrinking, and for woollen fabrics where clip marks are not wanted. To enable warp shrinkage during fabric tensioning, the stenter chains are set to overspeed. The fabric is fed into the machine at a slightly higher speed than the running speed of the chains. There is a special device to crimp the fabric in pleats on the pin selvedges (Fig. 11).

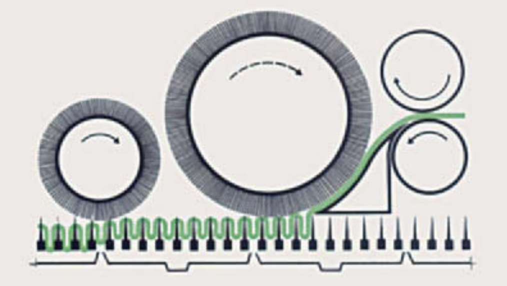


Fig. 11: Overfeed setting (Monforts).

Since the pin or clip chain is continuous (out = fabric transport; return = running empty to the single-needle area), a horizontal or vertical chain return is necessary (Tab.). This type of chain arrangement influences the design of the stenter (Figs. 12 and 13).

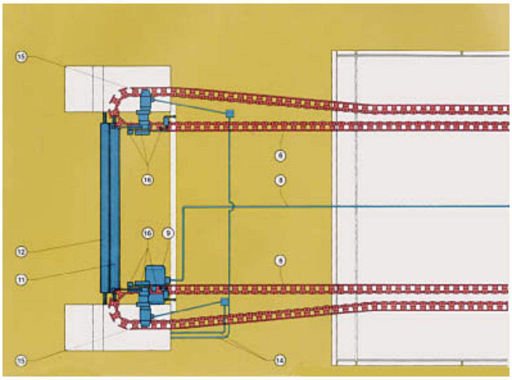


Fig. 12: A Babcock stenter with horizontal chain layout. 6 = chain; 8 = control cable; 9 = main chain drive motor; 11 + 12 = traction rollers; 14 = control cables for coordinating overfeeding and chain speed; 15 + 16 = shrinkage machine (overfeed setting).

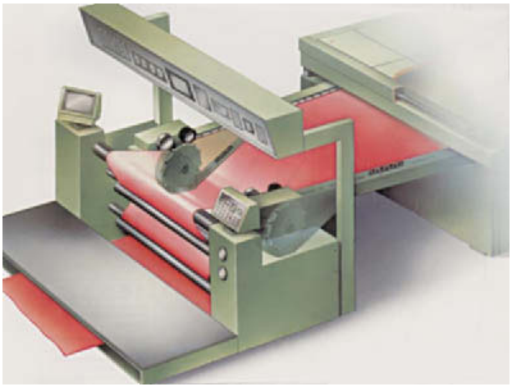


Fig. 13: Monforts Montex stenter with vertical chain layout.

If the stenter is being used as a multi-purpose system (cloth drying, knit treatment, coating), it is practical to have an adjustable operating platform in front of the entry zone (Fig. 14). Chains are often available with a combination of clip types, so that there is a choice between feeler clips or pins. To prevent the edges breaking loose from the pins, clips have been designed that hold the selvedge in position during tensioning. Combination clips can, for instance, consist of two feeler clips, one above the other, and a pin clip underneath. The fact

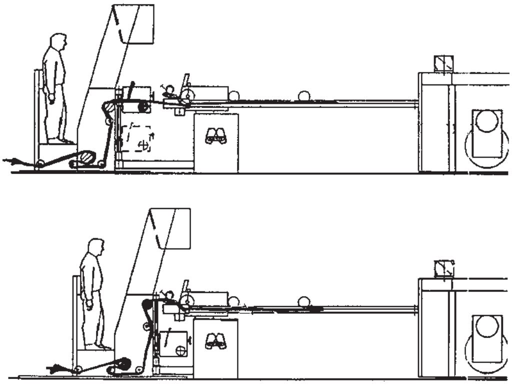


Fig. 14: The adjustable operating platform on the Monforts stenter.
Above: for coating; below: for normal drying operation.

that there are two feeler clips means that it is possible to run two lengths of fabric simultaneously in exceptional circumstances. The small holes created in the edges, caused by tensioning on needle bars, can be removed during a subsequent process, such as decatizing or calendering. The perforated edges on knitted goods can be cut off at the exit zone, using a cutting machine.

A levelling frame is a shorter version of a stenter, and they are used mainly in printing, where they are fitted with brush elements and dust filters. They operate at high speeds of up to 100 m/min and even higher, and are used for alignment of fabric with low moisture content. Jigging or Organdy stenters have side elements with continuous clip chains that move backwards and forwards (approx. 20–30 times per min).

At high fabric speeds (for clip stenters up to 200 m/min, pin stenters up to 120 m/min), the stenter must have an effective heating system. Because of the high level of water evaporation (150–300 kg/h) and the length of the heated area (3 m), the only effective method is jet ventilation, in which warm air is blown directly onto the moving fabric from above and below (Fig. 15). It is effective because the high air speed continually removes the vapour layer that forms on the fabric during drying and acts as insulation (approaching laminar flow barrier through high environmental turbulence). In general the jets are at a right angle to the fabric (Fig. 16). Counter position of the air tunnels is possible (Fig. 17).

Specialist stenters for raised and pile fabric have the option of having the jets angled so that they blow from

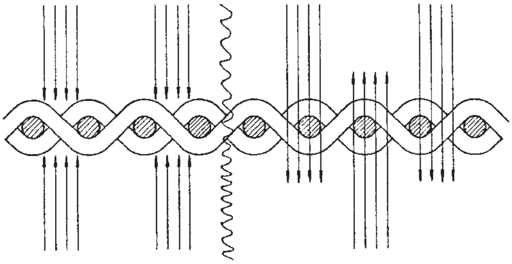


Fig. 15: Optimum (right) and less satisfactory air jet effects in the jet zone of a jet stenter.

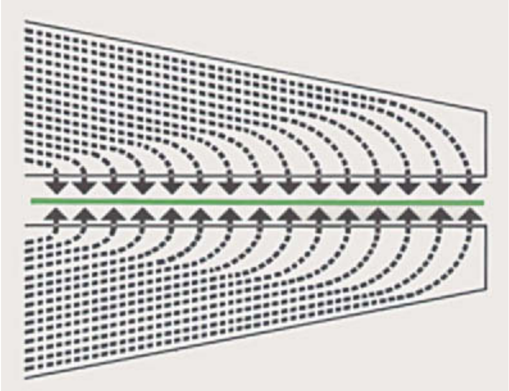


Fig. 16: Tapering jet boxes ensure that an equal quantity of air, blown at ninety degrees onto the goods, is provided at all points across the fabric web (green).

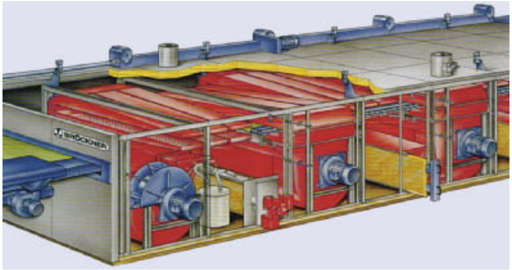


Fig. 17: Counter position of air tunnels in a stenter frame.

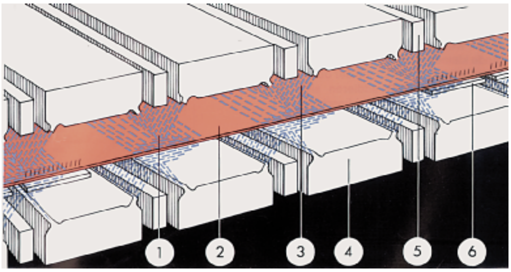


Fig. 18: The goods are transported through this Monforts drier by the air cushion generated by the angled jets.
1 + 3 = hot air jets; 2 = fabric web; 4 = jet box; 5 = throttle rod; 6 = needle slat.

a diagonal position, enabling the fabric surface to be treated without disarrangement (Fig. 18). Depending on design, the air is blown through slits or holes in the jets (Fig. 19), which affects the air path (Fig. 20).

The type of heating is always selected to suit local circumstances. Many stenters are used not only for drying, but also for hot air treatment (thermostabilization, thermosol treatment, heat setting, etc.). For machines that are often used for intermediate drying, in addition to specialist dryers, the air flow is frequently designed in such a way as to ensure even drying across the entire fabric width. For elasticated fabric, stenters with "carrier jets" are used, which carry the fabric on a cushion of air (Fig. 18). The heating system of a stenter is divided up into zones, each of approx. 3 m in length. A specific temperature can be used in each zone, independent of the other zones, enabling counter-flow drying. One method of heating the fabric up rapidly as it enters the stenter is to use infrared heating units. There are several different methods of air heating, the most effective being direct gas heating. Efficient utilization of heat is only possible in stenters that are set up to accommodate a specific width of fabric, where the same type of fabric is always run. Where high temperatures are required, such as for heat setting of woven fabric made from synthetic fibre, extra heating units can be installed. Fine mesh filters are fitted across the air flow to remove fibre dust. Nonwoven fleece can also be used as a filter. Meshes and filters require frequent cleaning.

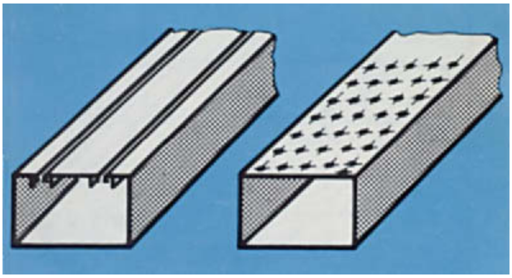


Fig. 19: Slotted and perforated jet boxes as alternatives for use in a stenter (e.g. the Facetta air conveyor jets from Brückner Trockentechnik).

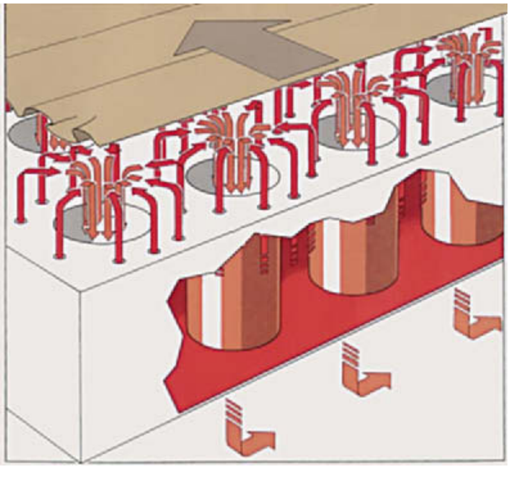


Fig. 20: The Babcock special air direction system using perforated nozzles.

Stenters for knitgoods One of the main purposes of knit finishing is to stabilize the knitgoods: the latent tension, caused by fibre type, yarn manufacture, knit structure type and quality, must be neutralized. The washing process, in which the fabric is alternately stretched and shrunk by means of fibre compression and elongation, starts to neutralize the fabric tension. This shrinkage process is important, in order to ensure that the resulting knit is free of residual shrinkage. Depending on the hydrophilic fibre content, a strong restoring force may be present after wetting/drying. This restoring force can be neither suspended nor eliminated by using a low-tension wet finishing process. For this reason deformation to length and width must be carried out in order to achieve stitch compression in the final drying process. With synthetic knits, the fibre properties have to be permanently frozen, for instance by means of heat setting followed by rapid cooling. For all other finishing processes it is essential to use as little tension as possible, and to have short fabric paths that are as direct as possible. This is the only possible way to achieve permanent shrinkage. Chemical finishing agents assist the setting process, but they cannot completely suspend latent surface tension. It is the stenter that plays a central role in this aspect.

The short, direct fabric paths required for the finishing of knitgoods limit the use of chains for fabric transport. For this reason, vertical edge guiding allows a shorter distance between the upper tensioning roller (Fig. 1, position 1) and the needle-punching device (Fig. 1, position 2) than horizontal chain guiding. In practice a 4–finger edge uncurling device (Fig. 1, position 3) ensures that the fabric is guided safely until the point of needle punching, and that the edge is fully uncurled. A homogeneous fabric appearance ensures that needle punching is carried out precisely. Needle punching is done cleanly using the vertical chain guiding method (Fig. 2), despite chain oscillation occurring after the change in direction, which is unavoidable. Vertical chain guiding requires a slimmer construction, enabling the distance between the textile and the jets to be shorter.

The machine arrangement shown in Fig. 1 is suitable for cut knitgoods that are batch rolled, batched on a dye beam or tabled. If continuous fabric is used, or if several small batches are being treated, it is practical to install a trough between the padder and the fabric feed.

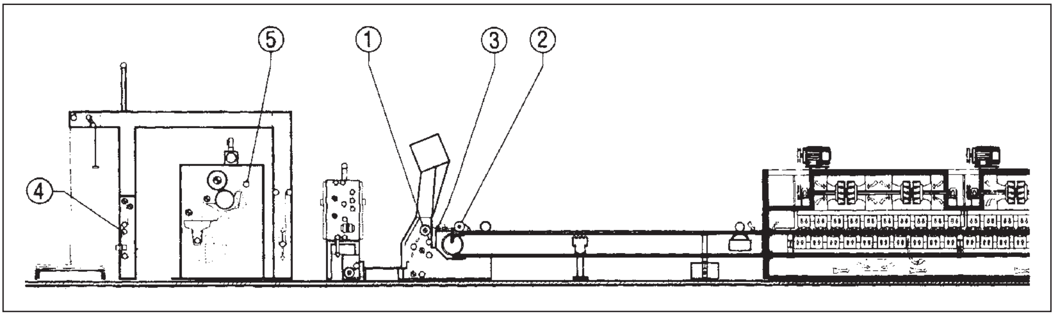


Fig. 1: Side view of a Krantz wide stenter with vertical chain layout (numbers explained in the text).

In order to achieve an even, low-tension fabric feed, the guide rollers operate at a point after central fabric control (Fig. 1, position 4). They consist of adjustable expander rollers, and ensure that the fabric is both expanded initially, and that it is in a central position. Finishing padders for knit finishing are available, and are fitted with two multi-level adjustable expander rollers as standard, one each to be used before the fabric is fed into the trough, and one before the nip. There is a compensator for light operation, developed specifically for knit finishing, which regulates speed with minimum fabric tension in comparison with standard combinations of roller compensator devices. To prevent light fabrics from sticking or wet fabrics from wrapping, an extra powered roller is installed in series to ensure a low-tension fabric path to the nipping unit (Fig. 1, position 5). In this way, the knit fabric is transported at low tension to the straightening device, which should preferably be equipped with fabric tensioning control and driven curved rollers. After the straightening process, the fabric is transported to the stenter entry zone at low tension. A powered, controllable tensioning roller assists this process. There are several expansion rollers along the fabric path, which are in a variable combination to ensure that the fabric is expanded correctly. Fine straightening of the fabric, which is frequently necessary shortly before the actual shrinking process, can be done precisely using motorized straightening rollers, or complete curved/diagonal straightening combinations with electronic sensors. The knitted fabric is guided from the driven, controllable, tensioning roller via a short route to the overfeed device (shrinkage unit) with a brush belt (Fig. 1, position 2). The specially developed brush belt pushes the fabric edges evenly into the needle bar, even at overfeed speeds > 40%. The edge tensioning can be adjusted on both sides independently or together, by means of several potentiometers. This ensures that the knit surface is even across the width of fabric, without distortion at the edges or stitch compression in the centre of the fabric.

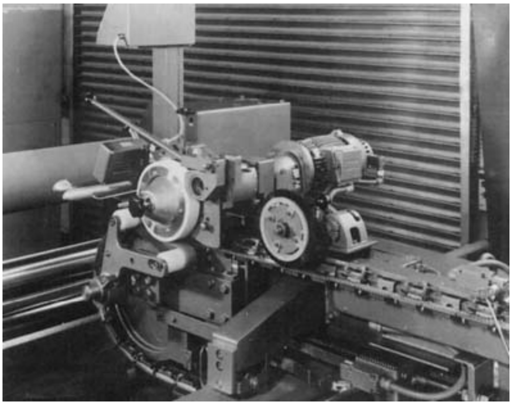


Fig. 2: A shrinkage unit.

Total relaxation of the knitgoods before drying or setting is an essential factor for residual shrinkage. It is important to maintain the correct level of fabric moisture for relaxation. When tabling dry fabric the recommended method is to install a saturated steam steamer in series with the shrinking unit. This enables even, homogeneous moisture distribution across the width and length of the fabric. At this point, applied optical brighteners can be set before the actual drying process. This method is practical in particular for finishing processes using temperature-sensitive brighteners that tend to yellow. In the entry zone infinitely variable width adjustment is carried out to stretch the fabric width slowly. In particular, articles that have undergone extreme shrinkage during pretreatment (e.g. raising, dyeing) need to be stretched without distorting the knit appearance. Fabric that has undergone shrinkage of up to 50% can be stretched properly without centre or edge breakages that must be avoided. This can be safely carried out with an entry zone length of between 4.5 and 6 m.

The spindles in the entry zone are arranged in a significantly lower position than in the dryer, to prevent contact with sagging fabric. There is a central rope to assist the transport of heavy or sagging fabric, which

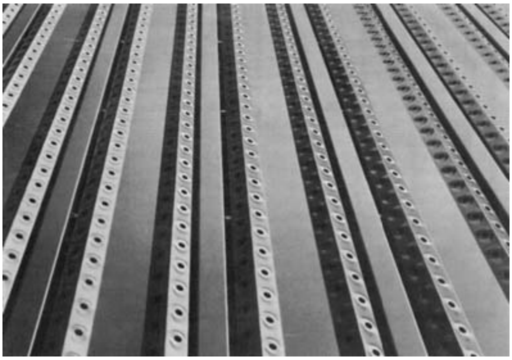


Fig. 3: View of the convey air nozzle system.

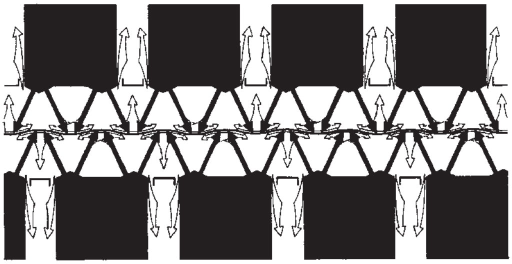


Fig. 4: Diagram showing the points of impingement of the hot air jets in the convey air nozzle system.

runs at the same speed as the chains. The edges are glued before the fabric enters the drying zone. This process is either done at the sides, or it can be done in the centre under certain circumstances, such as if the fabric has been separated into two runs. The glue is evenly dispensed onto the fabric in exact amounts, so that it can be partially dried by means of an IR drying unit connected in series.

The jet arrangement in the drying area, which operates on the basis of the convey-air system (Figs. 3 and 4), ensures a special fabric transportion. This effect causes the fabric to “float” evenly, enabling a permanent, immediate stretch and relaxation of the fabric before the actual setting process. Fabric transported in this way is relaxed during drying, setting, and also when it is cooled by the vibration caused by the air flow. Compression and shrinkage during the drying process ensures that the fabric is evenly and fully shrunk.

The arrangement of the air jets (Fig. 5), and also the vertical air outlet in a transverse position to the fabric, prevent surface fading of the knit, which is mechanically very sensitive. The quantity of air blown out can be controlled by means of speed control of the fan, and there is also a throttle valve situated on the suction side, which can be used for infinitely variable adjustment of the air quantity. The quantity of air dispensed above or below the fabric can be selected mechanically using a control valve. This valve can also be used to select unilateral air flow (Fig. 6). If the fabric run is interrupted, if there is an emergency cut-out, or when the fabric is changed, there is an automatic air flow cut-out to prevent the fabric being dried, whilst maintaining the temperature. This protects the fabric from being subjected to a direct air flow. The selection of a heating system (direct gas heating or indirect steam, oil or electric heating) is not only based on available energy resources, but also on the volatility of substances emitted from the fabric during textile finishing.

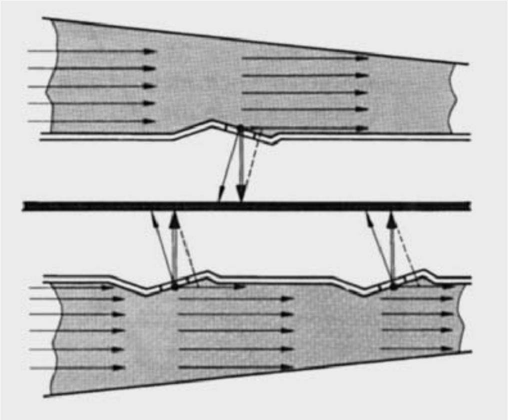


Fig. 5: Diagram of the arrangement of nozzles in the drying zone.

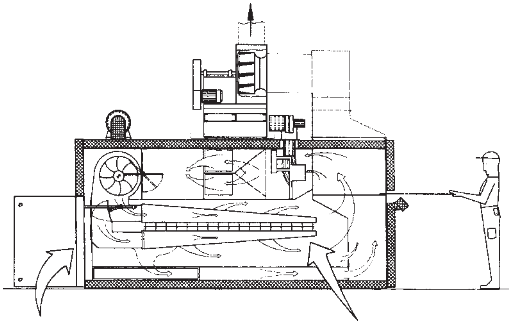


Fig. 6: Cross-section through a drying zone.

The fabric is frequently not set before washing. There are two reasons for this: the production sequence is shortened by one phase (in other words the product is completed in a shorter time), and ideally fabric should be as soft and open as possible. Generally speaking, cotton knitgoods are finished using a particularly large amount of textile auxiliaries. This can cause condensation to occur in the exhaust channels, despite effective insulation. Condensation stains on the fabric can be avoided by means of a specially designed exhaust channel system underneath the fabric run. Goods with cotton content or raised fabric generate a large quantity of lint, which can be efficiently removed from the surrounding air by the installation of a changeable filter. The filter can be cleaned during production. The drying sections have a door on both sides of each zone. Firstly the doors allow general cleaning to be carried out inside the dryer, and secondly they allow access to the jet boxes, which have openings at the ends so that they can be cleaned internally. In the transition zone between the drying room and the exit zone, there is a buffer zone with a suction slit. This is to prevent hot air escaping at the end of the dryer and the condensation of textile auxiliaries. The cooling zone in the Babcock stenter is fitted with the convey-air jet system. Relaxation is carried out with the help of vibration, and the final stage of shrinking is set by means of shock freezing. At the end of the exit zone the fabric is cut at the edges. At maximum production speed the system cuts the fabric directly at the selvedge. The cutting device pins the cut selvedge with a pinning form and sends it to a suction device. As cutting occurs directly on the selvedge outside the chain, the fabric loss is minimal. Selection of a batching device depends primarily on the production stage, the ultimate intended use of the treated textile, and the diameter of the batcher. All batching devices (Figs. 7–11) should roll the fabric consistently, keeping the edges straight, maintaining a low tension level, and without any edge curling. This objective can be achieved by;

- short distances between the point of removal after the pinning process,
- an even pressure on the batching rollers, assisted by the roller power if necessary,
- batching with defined low fabric tension.

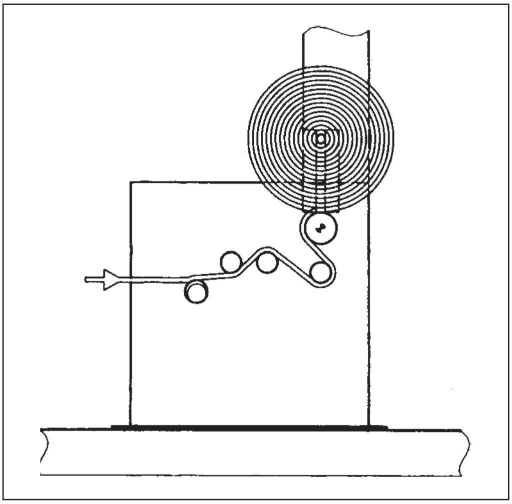


Fig. 7: A vertical rising roll batcher (Krantz).

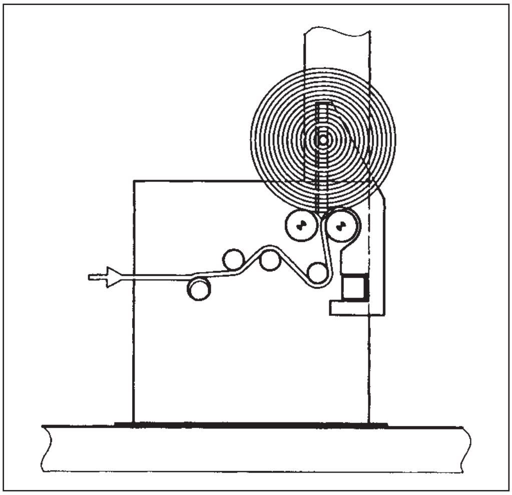


Fig. 8: A double-roller rising roll batcher (Krantz).

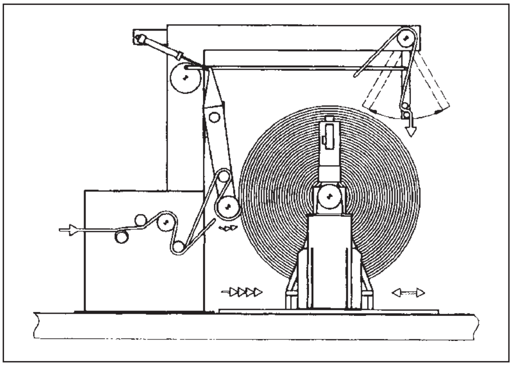


Fig. 9: A giant batch roll contact batcher (Krantz).

For batching finished knitgoods that are ready for despatch onto cardboard tubes (batch diameters of up to 400 mm), a vertical rising roll batcher is used (Fig. 7). If large runs of fabric are being roll batched, a double-roller rising roll batcher (Fig. 8) is recommended, which is powered separately to ensure even batching. If a giant batch roll of knitted fabric is being produced, a combination of a centre drive batcher and a surface batcher is used, which is known as a giant batch roll contact batcher (Fig. 9). The batching device is situated on a sliding platform, resulting in a constant, short feed path between the swivelling pressure roller and the increasing diameter of the batch roll, which is vital to en-

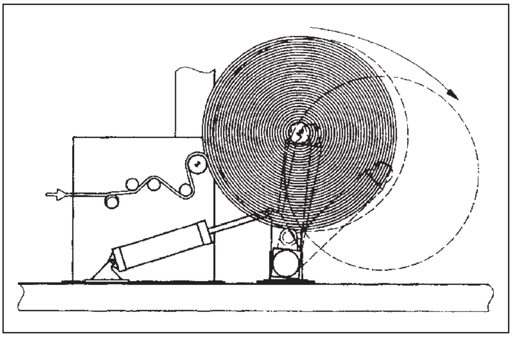


Fig. 10: A universal batcher (Krantz).

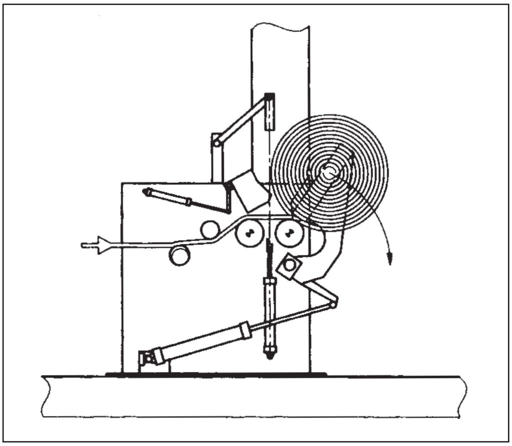


Fig. 11: A nonstop piece roll batcher (Krantz).

sure constant smooth batching. There is a tension controller to adjust the tensioning of this device. A universal batcher (Fig. 10) is used in any situation where batches of varying diameters are required. The fabric feed process is assisted by pneumatic or hydraulic pivoting arms. This batching process is suitable for all standard batching packages, from cardboard tubes to dye beam, even entire giant batch roll carriages. Batching can be carried out even at maximum production speed, without stopping the sequence or reducing the speed, by using a non-stop piece batcher (Fig. 11) for batching rolls of up to 800 mm diameter onto cardboard tubes or wooden batch rolls. Fig. 12 shows a typical two-level stenter for knitgoods, with a generous fabric area (Krantz, Bollig, Hampel and Souren); a multi-layer stenter is shown in Fig. 13.

Step-and-repeat machine The step-and-repeat machine has a print roller pre-prepared with light-sensitive paint, upon which the positive slide is placed and exposed.

Step washing For bleaching processes to be carried out properly, residual quantities of hydrogen peroxide must be present on the fabric after the reaction phase in the steamer. It is practical to immediately utilize these residues and the bleaching auxiliaries, such as surfactants and sequestering agents, in the washing process that follows. This was not possible using the counter flow washing method, which was popularly used in the past. The water flow (see Fig.) is in the same direction at the start of the washing process, with the addition of a small quantity of the overall fresh water supply depending on the type of fabric. This means improved cleaning where residual chemicals are present, and the released impurities can be completely detached

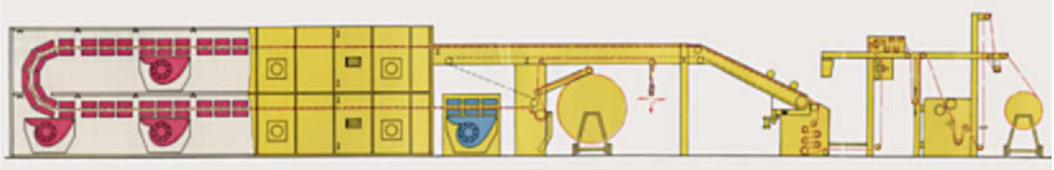


Fig. 12: A Brückner two-level stenter for the final finishing of knitted goods.

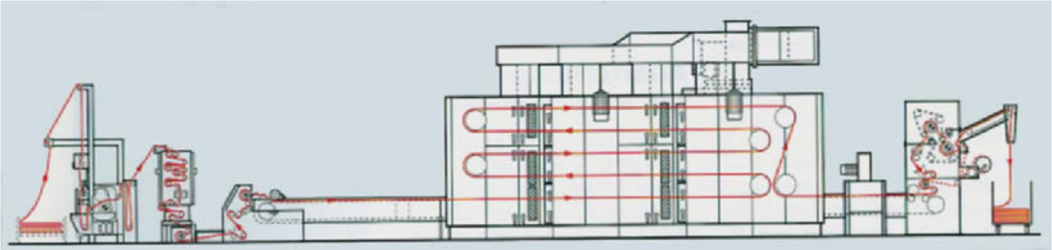


Fig. 13: Knitwear finishing (KM 16 H, Krantz).

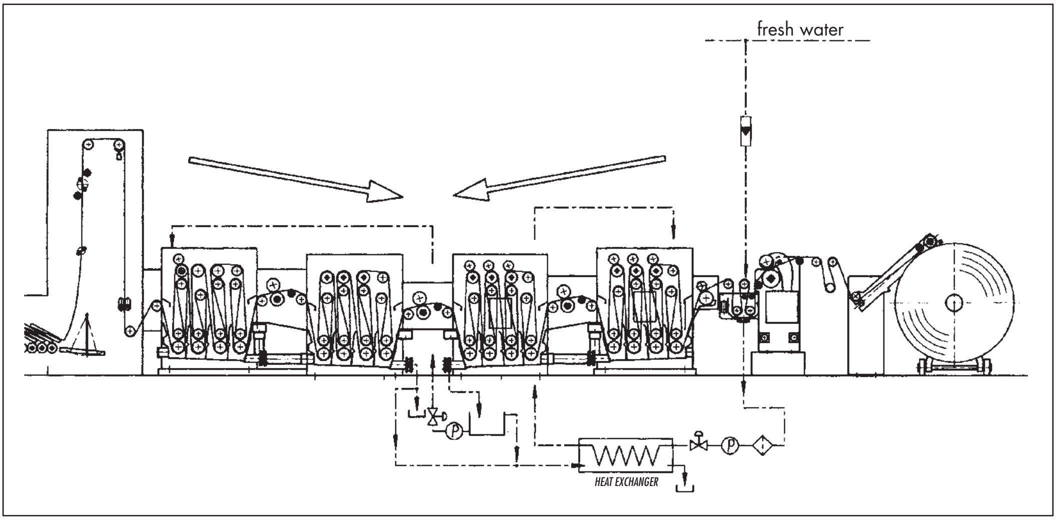


Fig.: Diagram showing the principle of step washing (Küsters).

and emulsified. It is only when this process is finished that the counter flow principle is applied, using the entire fresh water supply for subsequent soil removal.

The advantages of step washing are:

- Utilization of the residual bleaching chemicals left on the fabric after the steaming process, as well as efficient emulsifying of dissolved substances in the same flow direction, and removal and washing off of all soiling in the counter flow.
- Further improvement of reaction conditions in the steamer because of the high liquid content (if flexnip is added to counter the impregnation vat application), thereby creating better conditions for washing, which results in higher levels of absorbency.

Stereochemistry applies to the spatial arrangement of atoms within the molecule structure, e.g. →: Stereoisomerism; Isomeric compounds; Isotactic polymers.

Stereoisomerism applies to compounds having identical empirical formulae and constitutions, where the atoms are in a different spatial arrangement (spatial isomerism), and they possess different properties. There are different types of stereoisomerism, optical isomerism (→ Optical Activity), → cis-trans isomerism and conformation isomerism.

Stereoscan images If an object being examined is metallized with certain metals, it will appear almost three-dimensional under an → Electron microscope, and is caused by systematic scanning of the object during the irradiation and deflection of electrons to create the impression of a stereo image (see Fig.).

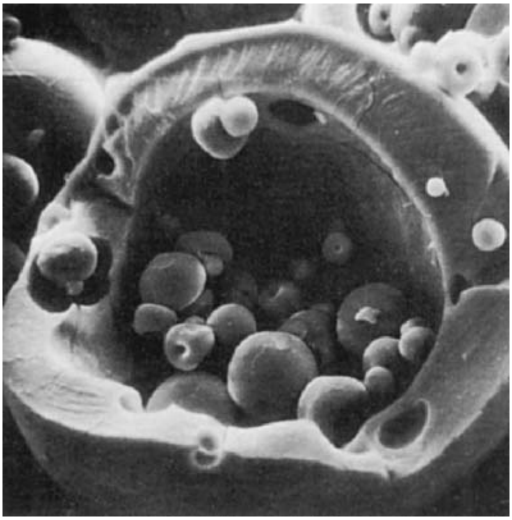


Fig.: A stereoscan image of the microgranulate formulation of an indanthren dye.

Stereospecific polymers These are → Isotactic molecules and Syndiotactic molecules, whose spatial arrangement during synthesis is formed with the aid of specifically acting catalysts.

Sterility An absence of germs (known as asepsis), i.e. no living germs are present at all. Depending on the fabric this can be achieved by dry or moist heat treatment. Usually 8 min at 120°C in an autoclave is enough (for cotton wool and bandage material), strong disinfectant can be applied (preservative), or germ-free filtration can be used (water treatment), etc. Radiation treatment is also a possibility. → Sanitized finishing.

Stick lac → Shellac.

Stiffened fabrics Stiffening → Interlinings between the top cloth and the lining, → Front fusing.

Stiffened linen Extremely strong → Buckram, board-like, hard, barely flexible, used for stiffening uniform collars.

Stiffening agents Used specifically for finishing and sizing. There are different types

I. Vegetable colloids: starches, mucilages, mosses, algae, gums.

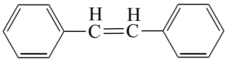
II. Animal colloids: glue, gelatine, casein, protein sizes.

III. Synthetic colloids: polyvinyl products and similar, cellulose derivatives, synthetic resins.

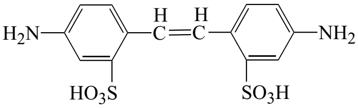
Stiffness (rigidity, flexural rigidity). Flexural rigidity is a measurement of the resistance exhibited by a material when subjected to bending. It can be defined according to DIN 53 864.

Stilb Unit of → Radiant intensity per unit area. Radiant intensity is defined as the quotient of candela and square metres: $L = 1\ cd/m^2$.

Stilbene (trans 1,2 diphenylethylene)



Stock substance of stilbene dyes and numerous valuable optical brightening agents, for instance in the form of a detergent additive. The latter are usually derived from diamino stilbene disulphonated acids (a by-product of the dyeing industry), which in itself does not exhibit any fluorescing effects, but it does, if for instance the chains are extended on both sides to NH_2 groups.



Stilbene dyes → Direct dyes.

Stimulus → Colour stimulus.

Stipple engraving Dotted recesses in the pattern engraving on printing rollers. Synonymous with → Hatching.

Stitch-bonded carpets → Loop pile carpets manufactured using the stitch-bonding technique. The stitch-bonded fabrics are then bonded on the reverse side and coated.

Stitch-bonded composites (stitch-bonded fabrics), textile fabrics consisting of fibrous nonwovens or loose criss-crossed thread layers piled on each other, which are bonded with the stitches formed by warp threads that are sewn in, or they are bonded with other fabrics. Stitch-bonded composites can be sub divided into →: Stitch-bonded fabrics; Stitch-bonded thread-layer fabric; Stitch-bonded pile fabric; Stitch-bonded weft pile fabrics.

Stitch-bonded fabrics,

I.→ Stitch-bonded composites.

II. Fibrous nonwoven fabric bonded by forming stitches from warp threads that have been sewn into the fabric.

Stitch-bonded nonwovens Nonwoven fabric bonded with chain-stitch seams (stitch-bonding technique using long fibres, not sewing thread).

Stitch-bonded pile fabrics In principle the many different qualities of stitch-bonded pile fabrics can be divided into the following categories:

- type used for floor coverings,
- type used for rear window shelves,
- type used for car boot upholstery.

The requirements posed by these different uses, in a general, mechanical and specific sense, together with aesthetic and cost-related aspects, led to the development of the following range of variations. There are

- single layer needle-punched nonwoven coverings,
- multi-layer needle-punched nonwovens with a basic utility layer (reclaimed fibre),
- (single layer) pile fleece coverings with loop pile or velour-type upper side,
- combinations of single layer coverings with hard stitch-bonded fabric (reclaimed fibre).

Production technology for stitch-bonded pile fabrics is mainly based on techniques used generally in the textile fleece industry. However these techniques are modified or extended. The process sequence can basically be represented as follows:

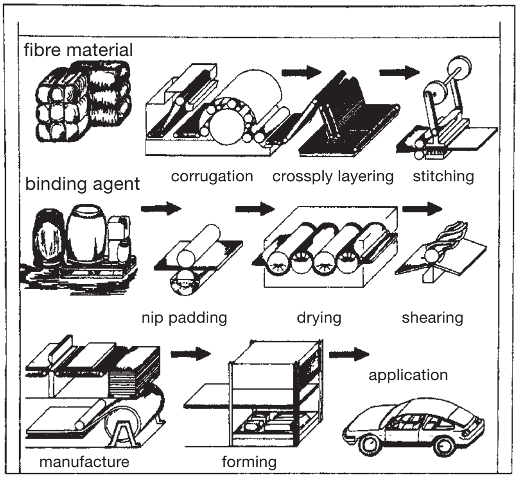


Fig.: Stitch bonded pile fabrics in a simplified flow diagram (according to Eisele).

- preparation of raw materials,
- mechanical bonding,
- finishing,
- garment manufacture
- final inspection.

The Fig. shows a flow chart.

Stitch-bonded thread-layer fabric → Stitch-bonded fabrics made from criss-crossed thread layers piled on each other as a backing material, bonded with the stitches formed by warp threads that are sewn in.

Stitch-bonded weft pile fabrics Stitch-bonded fabrics (→ Stitch-bonded composites) in which threads formed into pile loops are bonded to the backing material by means of sinker loops created by a pillar stitch chain.

Stitch bonding Mechanical oversewing of fibre nonwovens, thread-layer fabrics or textile fabrics with two parallel chain stitch seams sealed together. To carry out this oversewing, there are numerous adjacent sliding needles that are moved at the same time (with sharp points designed to pierce holes), which work with closing wire bars. The appearance of the seams, which consist of stitches, depends on the type of stitch bonding used for the warp knit fabric (→: Pillar stitch; Tricot weave).

Stitch course → Stitches arranged adjacently to one another. In standard knitting they are formed consecutively, in warp knitting they are formed at the same time. The number of stitches in the stitch course is dependent on the stitch size.

Stitch density Construction characteristic of all knit fabric types; calculated as the product of the stitch course count and the stitch wale count. This figure represents the number of stitches within an area of 100 cm^2.

Stitches Thread loops that are linked together and constitute the smallest units of → Knitted fabrics. They consist of 1 head (upper part), 2 shanks (middle part) and 2 feet (lower part); each having 4 bonding points (2 upper and 2 lower, i.e. at the top and bottom). Stitches arranged horizontally are known as stitch courses, and those in a line vertically are called a stitch wale. Depending on the side of the fabric, there can be “purl” stitches (where the stitch heads are emphasised), and “rib” stitches (where the stitch shanks are emphasized).

Stitch gauge This is the total stitch count (= needle count) per $1^1/_2$ inch (Engl.) = 3.81 cm fabric width. This stitch fineness is known as → Gauge (g), which can also be abbreviated to gg. The higher the gg number (usually between 36 and 66), the more stitches there are in the knitted fabric, it is finely woven and therefore has better elastic properties. → Cover factor.

Stitch sewknit fabrics Variant of → Malimo fabric, manufactured for instance from weft layers sewn (using pillar stitch) with woven fabric, Malimo fabric, expanded foam, fleece or knitted fabric as a basis fabric. Synthetic sewing thread is usually used. Use: imitation fur fabrics, friezé for coats, suedette, corduroy, upholstery fabrics.

Stitch wale → Stitches arranged above each other made by the same needle. The stitch wale count is dependent on the distance between the needles.

Stitch width The distance between two → Stitches, also characterized by the number of stitches per cm or inch. → Mesh number. This is important in screen gauzes, for instance.

Stochastic (Gk.), an approach based on analytical → Statistics, in which any conclusions drawn about mass phenomena or repeat sequences must take → Probability into account. Random events that occur with a certain level of stability during the course of sufficient experiments are stochastic.

Stock colour Print paste with a high concentration of dye (large quantities are usually kept in stock), used in combination with other stock colour pastes or → Reduction thickeners as mixes.

Stock pastes in printing Print pastes consisting of all the necessary chemicals except for the dye.

Stocks Solid silicon rubber compounds, which can, for example, be forced through calenders to coat fabrics.

Stock solution Analytical term for the weight of a substance dissolved in a solvent, e.g. 10 g/1000 ml.

Stock thickener (stock thickening). → Printing thickeners containing setting chemicals (large quantities are usually kept in stock), to which dye is added at a later point, in powder, paste or solution form.

Stock vat It is not possible to vat individual vat dyes in a dye bath, they need to be dissolved in concentrated form. This method is known as stock vatting.

Stock vat dyeing process Inaccurate term for → Variable temperature dyeing processes.

Stoichiometric formula (substance formula), refers to the conclusive formula of the relative atomic number in → Chemical compounds, e.g. for sodium perborate $NaBO_3$ = 1 : 1 : 3, and for sodium peroxide Na_2O_2 = 1 : 1.

Stoichiometry (Gk.: stoichos + metron = primary matter + measurement), concerns the quantitative calculation of chemical reactions that result from individual formulae or are basically derived from the same moles; e.g. 1 mole iron Fe (= 56 g) and 2 moles hydrochloric acid HCl (= 73.02 g) = 1 mole iron (II) chloride $FeCl_2$ (= 127 g) and 1 mole hydrogen H_2 (= 2.02 g), therefore the initial 129.02 g results in 129.02 g again. Stoichiometry plays an important role in the practical analysis of all chemical processes. → Titration (quantitative analysis).

Stokes (St), a unit of kinematic viscosity that is no longer used. The current SI unit is m^2/s. 1 St = 10^{-4} m^2/s.

Stone polishing In print roller manufacture, the polishing process on copper print rollers during → Copper electroplating. It occurs when agate stones (rolls) are pressed onto rotating rollers, causing the copper crystals that form vertically to be polished.

Stone-Washed-Finish Denim fabrics (→ Jeans) dyed with indigo or other dyes are sized with a large quantity of starch and manufactured into garments. Once the textile has been made into a garment it is desized immediately (30 min at 60–70°C) and then treated with sodium hypochlorite. The technique is known as "Stone-Wash" or denim finishes because pumice stones are used as an abrasive agent to achieve special effects (1 kg of stone or sand per kg of fabric). The bleaching effects can be altered by varying the pH and liquor temperature of the sodium hypochlorite bath. The higher the temperature and the lower the pH (pH 8), the stronger the bleaching effect and the attack on the fibre. There must be a compromise between the sodium hypochlorite concentration, the pH and the temperature to ensure that the fibre is not damaged too severely (see Fig.).

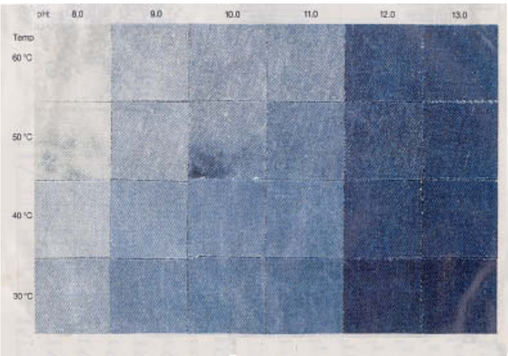


Fig.: Stone-washed finish of jeans, effect of pH and temperature (Sandoz).

The strongly abrasive effect of the pumice stones should also be taken into account; it can cause damage to the fabric, the seams and the machinery. In addition, the use of pumice stone can cause unwanted dust generation in the working environment, which generates further problems. Also the diameter of the pumice stones reduces rapidly with each wash, making it relatively expensive. Bleaching with hypochlorite is also becoming more controversial because of the waste water problem. This is a possible alternative: cellulases (enzymes) can be used for a "non-stone" technique. In this method, the jeans are desized first and subsequently treated with cellulase. Thanks to this specific effect, oxidative bleaching and the use of pumice stone is not necessary. The final result is comparable to that of the stone-wash process.

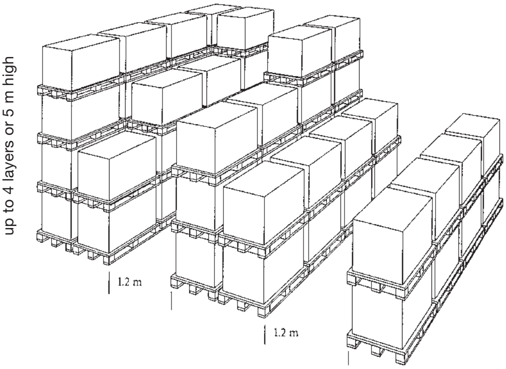


Fig. 1: Block storage, either 4 layers or up to 5 metres high.

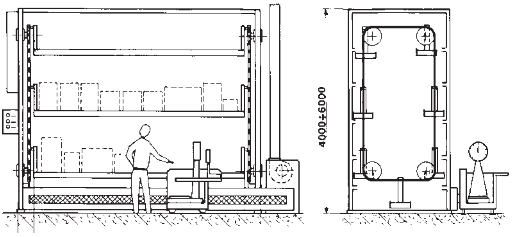


Fig. 2: A typical paternoster store for the storage of dye containers.

Storage Storage should be organized logistically; e.g. block storage (Fig. 1), high-shelf store, paternoster store (Fig. 2), etc.

Storage regulations Storage products in chemical form are categorized in storage categories according to:

1. Fire and explosion hazard: in line with the Comité Européen des Assurances (CEA) code relating to fire hazards. The criteria are the flash point, the combustion test, the drop-weight test and additional specific tests.
2. Toxicity: any properties of substances and their breakdown products in the event of fire that are toxic, detrimental to health, irritant, corrosive and caustic.
3. Eco-toxicity: Substances with properties that present a hazard to water (water hazard categories) or air (foul smelling), with respect to both the actual substances in storage as well as breakdown products in the event of fire.

The German Water Resources Law (Wasserhaushaltsgesetz) makes a distinction for stored chemicals between "hazardous substances" (§ 7a) and "substances that present a hazard to water" (§ 19g). There are specifications applying to this type of substance, relating to storage, bottling and spillage. There are also specifications for the handling, treatment and use of these chemicals, referring to how they should be handled for instance in the event of a fire, and suggesting improvements to the infrastructure.

Storage sublimation → Sublimation fastness during storage.

Storage time One element of → Throughput time. Storage time is a period during which the goods are part of a process, but do not undergo any change, i.e. there is no work in progress. This period frequently constitutes up to 80% of throughput time. Storage time is made up of the time spent physically in storage, out-time caused by technical reasons relating to the process (quality control), out-time caused by mechanical problems (defective machinery), and out-time resulting from human error.

Stored program control (SPC). The control element (in the switch box) of textile finishing machines has undergone a major change from relays to SPC, making the switch boxes visibly smaller. In practice the control valves fitted actuators must react to electrical signals. For this purpose there are electropneumatic converters, i.e. pneumatic valves with electromagnetic operation. A coil acts as a magnet, triggering a mechanism within the valve to switch from one position to another. This type of electropneumatic control system is a basic component of controlled function sequences for the appropriate unit in standard textile machine switch boxes. Occasionally a control system is made up of elements using standardized technology. Usually hybrid systems are used, e.g. pneumatics with electronics, electrics with hydraulics, etc. For this reason however, the signals need to be converted from one technology to the other within the control system, at the interfaces between each element. This means that a hybrid control system can consist of purely electrical sensor and processor elements, with a purely pneumatic or hydraulic actuator. Solenoid valves form the links between two different technologies, converting electrical signals into pneumatic signals. The electromagnetic relay is the essential factor in signal conversion, and the way in which it functions is based on efficient utilization of the magnetic effect of an electric current. As soon as current flows through a coil, it assumes magnetic properties and attracts the solenoid, which then closes the contact via the lever mechanism.

The electric relay circuit is being increasingly replaced by stored program control in modern textile machine design. In the control system (see Fig.), input signals come from the sensors, which are routed to the central unit via input boards. The signals generated by this unit are processed by output board assemblies and transferred to the actuators. The program is written using an external programming device and transferred to the program memory. The programming languages used most frequently in SPC are the contact schedule, the function schedule and the list of instructions.

Stored program control technology has become a central aspect of automation technology since its introduction at the beginning of the 1970s. It has provided

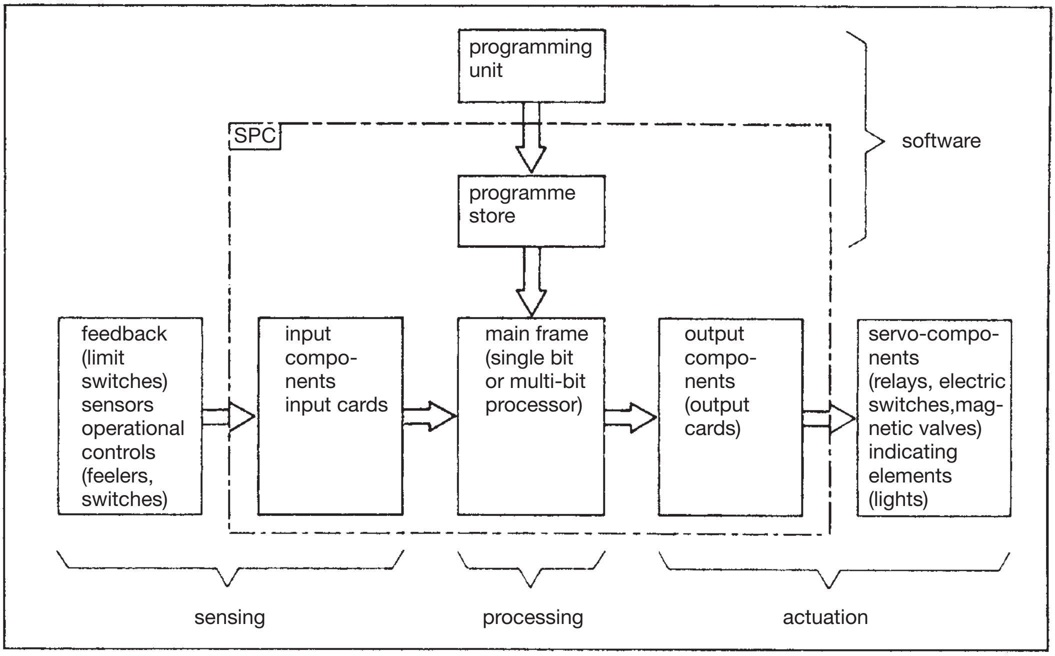


Fig.: SPC system unit.

much new impetus in automation. SPC is a computer that has been specifically optimized for "control technology". Data input into the control computer is done by means of binary signals (position switches, switches, limit potentiometers, light barriers, etc.). Data output is also in the form of binary signals, for instance via control devices that switch over, e.g. motor protection that shuts off a motor, or a solenoid valve that allows a cylinder to be released. Data in the control computer is processed using a program. In other words the SPC program is not fixed in wires or circuits, it is stored in electronic memory. A programming device is required to program this memory, as it is not self-programmable. Programming can be carried out on-line or off-line. Obviously the machine must be designed so that technicians anywhere in the world carrying out maintenance or repair to systems equipped with SPC will have portable programming devices, so that they can access factory-programmed controllers on site and modify them if necessary.

The sensors that supply the SPC with signals and the reactors that receive the signals need to be wired onto the SPC, and the pneumatic and hydraulic elements need to be connected to the solenoid valve by tubes. However this wire/tube connection is uncomplicated because it is not based on logic. There is no logic integrated into the wiring system, apart from external safety devices for humans and machinery. This means that circuit diagrams are simple and clearly defined.

Input of the actual program is done by the programming device, so it needs to be abstracted from the visible wiring to form an image that can be viewed on a monitor. Even if this image bears a resemblance to old-style circuit diagrams, the operator must be aware that it is only an image of the logical functions, a graphic representation of a Boolean logic system. Although a visual representation of a contact switch can be seen on the monitor, it does not attract a contactor. This abstraction becomes more apparent in the form of a programming tool or programming language in the application list.

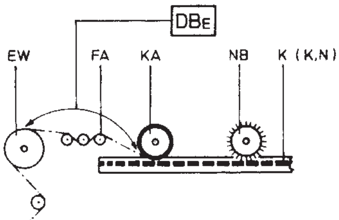
Re-wiring is made considerably easier, firstly because the programming device makes it easier to carry out changes in comparison with physical re-wiring, but in particular because it is easy to keep a record of the new program using the programming device. The state of SPC technology permits extensive documentation of SPC programs, which means that the current program version is always accessible (according to Bocksnick and Plagemann).

Store lighting (TL 84), type of lighting for colour-matching booths, defined as cool, white fluorescent light at a colour temperature of 4400 K. → Colour matching of dyed/printed samples.

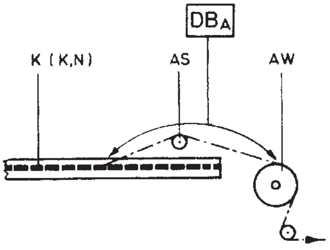
Stoving fastness Level of resistance against the influence of sulphur dioxide. The guideline applies to wool and silk, even when mixed with other fibres. The fabric sample undergoing testing must be wetted for 5 min at 25°C in soap solution and squeezed at 100% liquor uptake. Fabric sample and control sample is then exposed to an environment containing sulphur dioxide for 16 h. Fabric samples are hung for 2 h in air without rinsing. Textile mixes are rinsed for 10 min after sulphur treatment and then dried at 60°C. The result is analyzed using the grey scale method.

Straightening machine So-called fabric flattening and straightening machine, either with a horizontal span or as a tension wheel, as a type of a twin star frame. They are used for width tensioning and yarn straightening of dry fabrics and are especially important for all types of lighter fabric. Straightening machines are equipped with steam appliances and an automatic fabric entry zone (→ Expander).

With regard to the straightening machine (see Fig.) it is assumed that a long piece of fabric, e.g. 1000 m, with a constant slant "set back to the right" of only 2°, conforming to approx. 6 m by 1.80 m fabric width, is submitted to the stenter. A scanner is installed either just in front of or behind the drawing roller of the automatic straightener. As long as it is switched off, the fabric is still inclined as it leaves the stenter. When the automatic straightener is switched on, it detects the distortion and generates correction impulses in such a way that the right hand chain runs faster for a short time until the fabric is even. Then the automatic devices do not



entry (schematic)



exit (schematic)

Fig.: Stenter/straightening frame, entry and exit (schematic). DB_E = elongation area at entry; EW = intake roller; FA = finger unrolling and selvedge guider; KA = shrinkage device; NB = needle brush; K (K, N) = chain (clips, needles); DB_A = elongation area at the exit; AS = de-needling rod; AW = drawing roller.

call for any more correction; both chains run at the same speed again for a time. Then the stretched incoming fabric again exits, is detected as stretched, and correction starts afresh. In reality the correction is carried out more neatly. An even correction is permanently achieved, i.e. the right chain permanently runs somewhat faster, with correct, i.e. optimum controller adjustment. The right edge of the fabric runs 0.2% faster on average than the left, and so undergoes 0.2% more elongation.

The fabric enters into the stenter permanently stretched. During the throughput time of a point on the fabric only 12 correction impulses are given in total on 30 m in 1 min. During an impulse time of, for example, 0.3 s the right hand chain runs at 31 m/min, which corresponds to a straightening effect of 5 mm/impulse. So these 12 impulses achieve a straightening effect of 6 cm. The right hand chain covers 30.06 m on average in 1 min, the left hand chain only 30.00 m. While the left edge is pinned down with, for example, a lead of exactly 10%, it is only 9.8% on average on the right side. Then, no more elongation or shrinkage is carried out in the stenter itself, only an angular displacement. The drawing roller in principle inevitably produces a slight drawback tension, which, for example, is obtained by a lead of 1%. The left edge of the fabric is run by the chain at a speed of 30 m/min, is then stretched by 1% between de-needling point and drawing roller. The right edge of the fabric however runs at an increased correction speed of 30 m/min + 0.2%, but is then stretched between the de-needling point and drawing roller by only 0.8%. So in reality one edge of the fabric does not become longer than the edge.

Straining machine →: Yarn liquoring machine; Print paste sieving machine.

Straining of print pastes In printing the sieving or straining of print paste and thickeners before use, to remove any impurities that could cause problems.

Stramin (Italian: straminga = cheesecloth), cotton woven cloth similar to cheesecloth, usually with strong threads (made from strongly spun yarn). → Canvas.

Straw In the form of braiding straw for trimmings (on bristles, galloons, etc., sewn together for hats, bags, etc.). Straw types used are mainly wheat (light-coloured), rye (dark), maize, rice and barley. Imported from Eastern Asia and Italy. The raw material should be pale in colour and as close to white as possible. Other factors that affect the quality are, shine, matting, evenness and fineness. The only straw processed is knot-free cut straw approx. 10 cm in length (the lower part of the straw is called "pedal" and the upper part is called "punta"). Either whole straws can be processed, or they can be split into 3–7 pieces as "Liserét" (outer and pith straw), sorted according to colour, shine, length and fineness.

Streaky dyeing → Barriness.

Strength Strength is the level of resistance exhibited by a material against separation into individual pieces. In textile testing, strength usually means → Tensile strength (breaking strength, limit strength, tear strength). Depending on the type of separation process, there are different types of strength, such as → Bursting strength; Flexural strength or resistance; Tear strength; Resistance to tear propagation; Crease resistance; Flexing abrasion resistance; Loop strength, Torsional strength; Wet strength.

Strength per unit linear density The highest possible tensile force of linear density or → Tensile strength of fibres or yarns.

Stress cycle Term for load/relief cycles in the context of textile elasticity tests, e.g. knitgoods. The elasticity of a fabric can be analyzed by repeatedly measuring the force required to achieve a specified level of elongation

Stress-strain behaviour The stress-strain properties of individual fibres are frequently used to describe the condition of the fibre or to quantify fibre damage. The measurement procedure used for this is designed to analyze tension and elasticity modules in the same measurement procedure.

The resulting stress-strain curves (Fig. 1) cover three ranges:

- an elastic range according to Hooke's law (up to approx. 5% elongation),
- a plastic range (up to approx. 25% elongation),

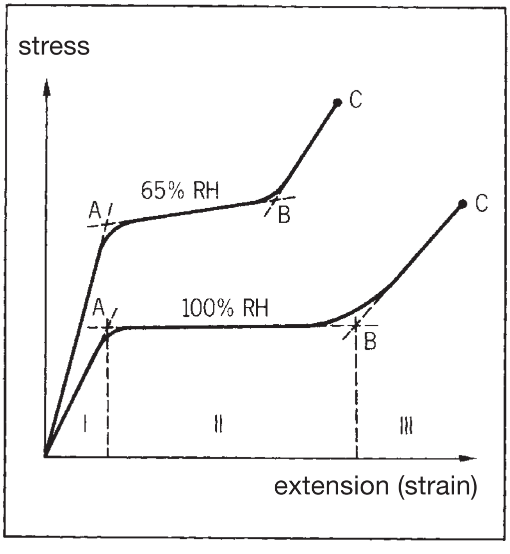


Fig. 1: The stress-strain curves for hair under differing conditions of relative humidity (RH).
I = the Hooke region; II = the plastic deformation region; III = the non-plastic deformation region; A = the Hooke limit; B = yield point; C = fracture point.

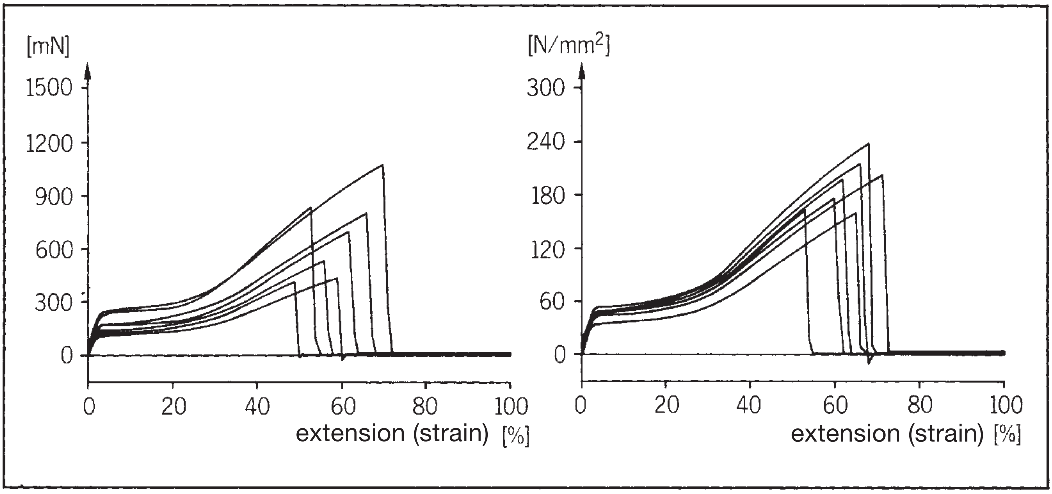


Fig. 2: Stress-strain curves. Left = tensile force; right = tensile stress.

- a "post-plastic range" characterized by a relatively sharp increase in force up to the fibre tearing point.

All three ranges are used to establish the material characteristics more precisely (Fig. 2). Hooke's law (Fig. 3) provides the elasticity module, the index values are found in the plastic range, in particular the 15% value, and the final and most important parameter constitutes the tearing point. In addition, the point of change between the plastic and post-plastic range, the gradient of the post-plastic range and the area under the different curves are all stated. These areas show the working potential of the material. For this reason, stress-strain curves provide more information than the analysis of tension and elongation.

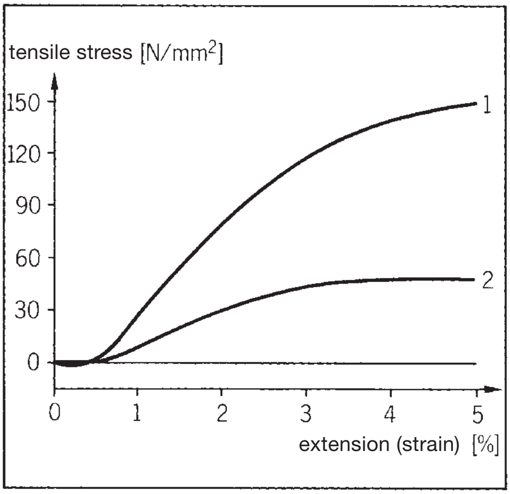


Fig. 3: The Hooke region of stress-strain curves as used to determine the elastic modulus (= Young's modulus). Curve 1 = dry hair; curve 2 = wet hair.

The stress-strain curves can be used to determine the elastic modulus. Fig. 3 shows the curves in Hooke´s law for wet and dry hair. The E-modulus are as follows:

- dry hair (60% relative air humidity): 5744 ± 469 N/mm^2
- wet hair: 2156 ± 228 N/mm^2.

(according to Busch and Schumann).

Stretch General term for elastic textiles made from stretch yarn or stretch fabric, for instance. Slimline clothes are frequently fashionable, which means that stretch garments are popular in the ladies' outerwear fashion sector. Polyurethane elastomer fibres have a better chemical resistance, a higher level of elongation and better recovery properties than rubber thread, which was commonly used in the past. For this reason polyurethane elastomer fibres have almost totally replaced rubber thread in the manufacture of particularly elastic textiles such as corsetry, support stockings and elastic tapes. They provide a new potential for swimming costumes, sport and leisure clothing, and also for the fashionable outerwear sector, because of their fineness and better textile characteristics. Elastomer fibres are primarily used as thread with other fibres wound or spun around them, e.g. in corsetry and warp-knits in general, but they can also be used in their pure form, e.g. in → Stretch cord or other stretch fabrics. The type of finish is usually dependent on the intended final use of the garment and the properties of the additional fibre used. The heat sensitivity of elastomer fibres means that the choice of finishing processes and chemicals is extremely limited. The main objectives in finishing are to produce optical elasticity, a pleasant, soft fabric handle, and sufficient dimensional stability.

Softeners that have particular lubricating properties contribute towards stretch and recovery characteristics, as well as sewability. This type of softener is particularly important for knitgoods. Effects are permanent; a high level of softness is also achieved. Non-silicone softeners that produce a soft, smooth handle should be selected in order to achieve an optimum compromise between a soft handle and lubricating effects in fabrics containing elastomer threads. The reason for this is that an excessive level of fibre smoothness can lead to slipping and also cause the polyurethane thread, which is usually not dyed, to protrude from the fibre compound. Further finishing objectives are for instance creating fullness and stiffness in corsetry, preventing cut edges from curling inwards when making up garments out of raschel fabric, and also water-proofing swimwear to speed up the drying process.

Stretch cord Collective term for different qualities of elastic cord. Depending on elasticity they are ideally woollen or cotton and textured polyamide, in addition the warp contains 2–6% elastic thread covered with textured polyamide. Example: Warp – approx. 85% textured polyamide and 15% elastomer yarn (elasticity 15–30 % depending on quality); overall composition: 80 % cotton, 16–17% polyamide, 3–4% polyurethane (elastomer fibre). Stretch cord articles need to be arranged with as little tension as possible in the warp. Pad-steam processes are a suitable and efficient dyeing option. Sulphur and naphthol dyes should ideally be used.

Stretch fabrics (elastic fabrics), elastic textiles with comfortable wearing properties (retain shape and are crease-resistant), elasticated either lengthways/ warp (ideally) and/or crosswise/weft. The yarns used for this are highly-elasticated synthetic textured yarns, elastomer and rubber thread wrapped with yarn, or core-spun yarns, frequently in the form of synthetic mix yarns, with/without natural or synthetic fibres, and also specialist wool and cotton yarns (e.g. with → Slack mercerization), etc. They can be divided into two categories:

1. Power stretch: high level of elasticity, with body-shaping properties, for corsetry, swimwear, surgical stockings.
2. Comfort stretch: lower elasticity, yield on stretching, no body-shaping properties but mould to fit the body, used in ladies' hosiery, underwear, sportswear and outerwear.

Average elongation (according to DuPont) includes reversible stretch (R%) and max. irreversible stretch (I%):

outerwear:	R = 15–25%; I = 2%.
sport-style outerwear:	R = 20–35%; I = 5%.
form-fit garments:	R = 30–40%; I = 5%.
active sportswear:	R = 35–50%; I = 6%.

Stretching and drying machines For fabric in runs:

a) for stretching without a drier → Straightening machine;
b) for stretching and drying treatment with a drier as a simple stretching and drying machine, double stretching and drying machine, multi-storey stretching and drying machine. → Stenters.

Types of stretching and drying machine:

conveyor drier,
air-stream drier,
felt calender,
stenter drier,
loop drier,
hot flue,
channel/cabinet drier,
sieve-drum drier,
drying loft,
other drier types,
stretch-drying machine,
radiation drier,
heat setting machine,
cylinder drier.

Stretching frames for screen making To ensure that screen is taut (see Fig.), the following stretch guidelines apply: Silk 2% (only when wet), polyester 3%, polyamide 5% (more practical when wet). Stretch dimensions should always be checked.

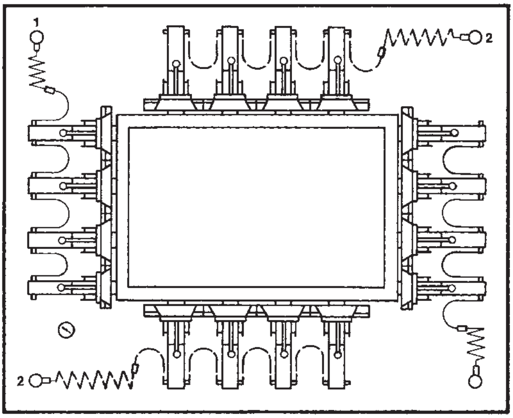


Fig.: Stretching frame for screen making.

Stretching frame systems: pneumatic with an air circulation system that supplies an equal air pressure to individual chambers simultaneously (ensures that each chamber will tension evenly). The clip carriages, which run on ball bearings, adapt automatically even at high pressure by matching the fabric stretch laterally (= necessary tension balancing). The warp and weft can also be tensioned separately. The stretching frame incorporates a manometer, so that a toothed rod on each side of the machine can be used to ensure precise mechanical tension monitoring/ overload. Tensioning clips run on ball bearings, and they adapt automatically by matching the fabric stretch laterally. The tension level can be monitored, either by recording the percentage fabric stretch using a metre stick, or by means of mechanical or electronic sag measurement. The important factor is the tensioning force applied (rather than the linear stretch as a percentage). Example: in a pneumatic stretching frame the linear density of polyester with an expansion value of 2.9 bar is tensioned; this is equivalent to exactly 10.1 N/cm warp and 10.1 N/cm weft, measured using electronic sag determination. This means that complete tensioning equilibrium is achieved. If the percentage stretch is now measured, the result will be + 2% for warp and +1.2% for weft. If this process had been done in reverse, i.e. if both warp and weft had been stretched by 2%, the weft would have had much higher N values than the warp, meaning that no equilibrium had been reached. This means that the weft yarn would have been overstretched. If this happens, the fabric recovery properties are reduced, i.e. the fabric tension achieved is relatively rapidly affected by fatigue. Measurement procedures for fabric tension/stretch:

1. linear extension and recorded stretch in %.
2. fabric tensioning forces/recording in bar.
3. electronic measurement of fabric sag in N/cm.
4. mechanical measurement of fabric sag.
5. mechanical measurement of fabric sag based on a specific weight.

Stretch principle When fabric is being dried on a stenter, its width is regulated, during which varying stretch levels can occur from the edge area to the centre of the fabric. These discrepancies have a negative effect on the fabric quality, and cause problems during subsequent processing. This discovery led to the development of a machine that ensures even stretching independently of the width before stenter drying. The fabric adheres to the roller surface, where it is stretched by the penetration of each of the two comb rollers (Fig. 1, 2b = stretched), and after it has been orientated in this way it

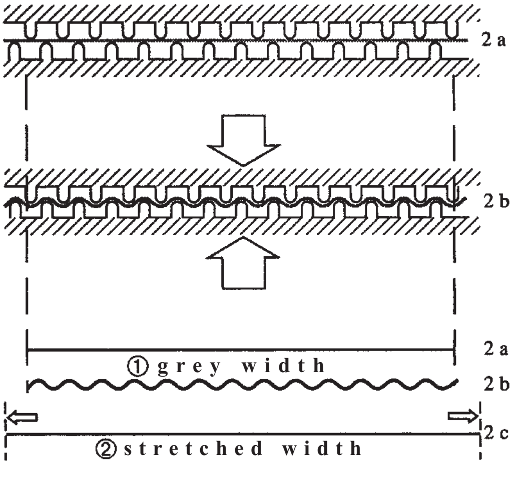


Fig. 1: Memotex process stretch principle. The woven fabric runs in between two profiled rollers (Küsters).

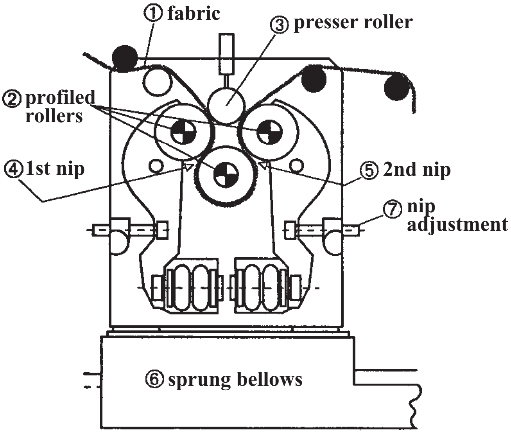


Fig. 2: Fabric path over the Memotex machine profiled roller (Küsters).

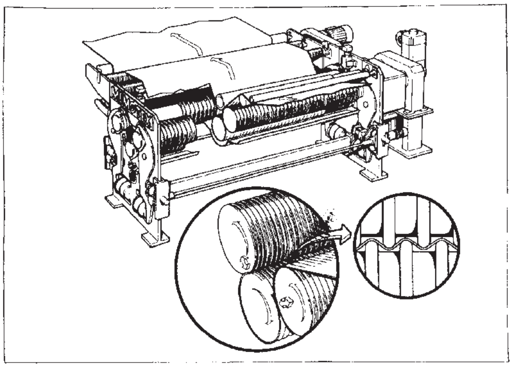


Fig. 3: The run of goods in close-up and in perspective view.

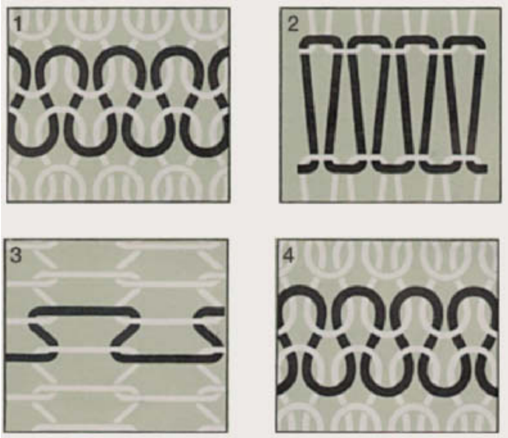


Fig. 4: The stretch principle in the stretching of knitted goods tubes in order to correct longitudinal strain.
1 = after knitting; 2 = after wet treatment; 3 = during the stretching process; 4 = final state.

field of application	Memotex operation process activation in the finishing stages	Memotex process product quality optimisation
pretreatment: Memotex fibre and woven fabric orientation	– reorientation of fabric and fibres – affecting woven fabric properties	– evening out fabric tension by averaging weaving tension, with consequently better fabric run on subsequent machines – higher tear strength and therefore use of more cost-effective weft yarns (e.g. OE instead of ring yarns) – tenacity improvement – tear strength improvement – stabilising elongation, particularly with woven cotton/PES fabrics – levelling warp and weft contraction – softer, smoother handle – print quality dimensional stability
pretreatment with bleaching stage	– intensifying the bleaching process by better liquor penetration	– increasing absorbency – more uniform bleach appearance
mercerisation	– intensification of lye uptake – feeding of a narrower grey fabric width	– improving the mercerising effect by opening out the woven fabric – achieving a wider final width stable to shrinkage, i.e. better dimensional stability
chemical finishing	– more efficient chemical finishing – reduced chemical use with identical residual shrinkage – less mechanical loading of the stenter entry section	– uniform setting of the required fabric width with uniform fabric density before final chemical finishing by stretching with the Memotex machine

Tab.: Possible fields of application for a woven fabric stretching machine in the pretreatment and chemical finishing of cotton.

is passed over spreading devices and unrolled to the new width (2c = stretch width). This principle of numerous small stretch areas results in the required even stretching across the entire fabric width. A machine of this type is shown in Figs. 2 and 3.

The Tab. shows possible areas of application for cotton fabric stretching.

The realization that the fabric run has been given stretch properties as a result of a swelling process is essential if a lasting effect is to be achieved. The macroscopic orientation (paralleling) of the cotton fibres alone or in combination with synthetic fibres is almost completely set by the swelling process. Knitgoods also take up warp tension during the manufacturing process (Fig. 4), which can be compensated by overstretching of the weft. To do this, the tube of knitted fabric is stretched when wet using deflecting bars with an adjustable width (Fig. 5).

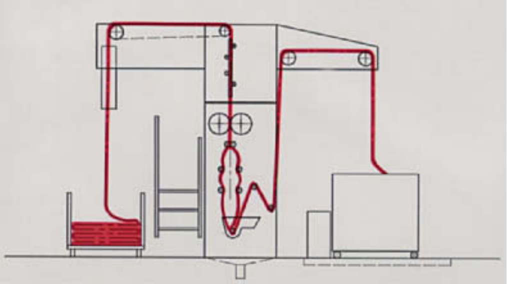


Fig. 5: A Santastretch machine for handling knitgoods tubes (Santex).

Stretch-spun fibres Synthetic threads that have been stretched during wet spinning to increase their strength and fineness, e.g. cupro filaments and high-strength viscose fibres.

Stretch yarns Yarns with exceptional elasticity, e.g. →: Textured yarns; Core-spun yarns.

Stretch yarns, dyeing Usually in the form of tubeless cross-wound yarn packages (muff) on pack system dyeing machines with a cylindrical yarn carrier in the pack dyeing system (brick-type) or a packing system onto dye tubes.

Strike Term referring to the speed of dye uptake on the substrate (→ Half-dyeing, time of). First strike is the ending, which depends on substantivity, in padder dyeing.

Strike migration test (exhaust level test), → Levelling property test. Phased dyeing in constantly boiling dye liquor to analyse absorption speed and levelling properties of dyes, as a specific type and also in combination (retarding, blocking), possibly with and without levelling agents. Method: the dye liquor is charged with dyes and additives and brought to boiling point. Then 40% of the fabric is added, with a further 10% being added after 2, 4, 8, 16, 32 and 64 min, and boiled for a further 60 min. After rinsing and drying, the levelling of each fabric sample added at different times is analysed (colour depth, shade, levelness). Variation: add 50% of the fabric to the boiling liquor, add a further 10% after 2, 4, 8, 16 and 32 min, boil for a further 30 min.

Strike-off (knocking-over), term originating from old-style hand or block printing. Colour is applied to the print block in the colour trough, and the print is then positioned on the fabric. The print is strengthened by hitting the block with a small hammer, which transfers the dye onto the fabric. Nowadays the term strike-off is used to mean the printing of a repeat run.

Strike-off machine, Impressioning machine → Roller strike-off machine.

Strike-through A phenomenon that occurs during the setting of interlinings, where parts of the bonding substance appear through the lining material.

Striking off → Strike-off.

Stripe coating In addition to the one-colour coating method for self-shaded tarpaulins (Fig.), this is another method of coating runs of awning fabrics, which is suitable for multi-colour finishes. The top coat is applied using print pastes of different colours in stripes. It is possible to vary the width of the stripes (at least 9 cm in width).

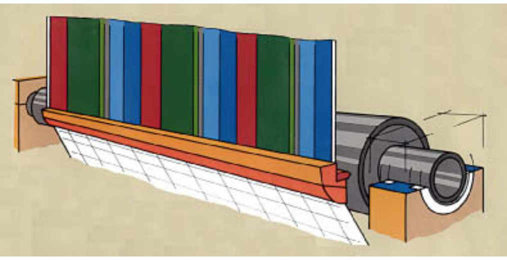


Fig.: The Zimmer Magnoroll '92 for stripe coating.

Stripiness (stripy dyeing), term for a stripy finish in dyed knitgoods, which is equivalent to warp or weft striping in wovens. It is caused by differences in yarn quality.

Stripping agent (decolourizing agent), a product for → Stripping of dyeings and prints. Reduction bleaching agents on a sodium dithionite basis are usually used.

Stripping auxiliary is used to aid the → Stripping of dyeings and printing. Has the task of supporting the brightening effect in the stripping reduction process by restricting the re-uptake of reduced, dissolved dyes. Sometimes also combined with → Fibre protective agents, principally in wool. The addition of anthraquinone might be recommended in the stripping of naphthol, vat dyes, etc.

Stripping of cationic preparations Alkaline treatment (ammonia or sodium carbonate) with 2–3 g/l of complexing agent, non-ionic wash-active substance (WAS) and anionic WAS is often successful: start cold, heat to 80–90°C within 30 min, treat for 30 min, then rinse well. Acid treatment such as in → Stripping of resin finishes is more effective. The same also applies to cationic softeners and cationic aftertreatments.

Stripping of dyeings Partial or complete stripping is used to brighten or level dyeings which turn out uneven or for re- and/or new dyeings into other, in particular, brighter or faster shades of colour. This is, however, often only possible with difficulty and incompletely, in particular for dyeings on man-made, acetate and viscose fibres. The stripping is carried out, depending on the fastness of the dyeing and stripping effect required, using processes which remove the dye again (hot soap solution, blank vat) or which destroy the dye, in which, depending on fibre type and dye class, reducing (sodium dithionite, sodium formaldehyde sulphoxylate or zinc formaldehyde sulphoxylate) or oxidising (sodium hypochlorite, sodium chlorite or potassium permanganate) agents are used. The correct setting of the pH is important to avoid fibre damage. Protein degradation products should be added for fibre protection in wool and silk. An addition of sequestering agents improves the stripping effect in metal-complex dyes. The stripping of dyeings is also possible in organic solvents. Disperse dyes in particular can be stripped easily in trichloroethylene. Tetrachloroethane is less effective.

Stripping of resin finishes for redyeing Intermicellar stored synthetic resins and/or crosslinkings of cellulose can usually only be removed with difficulty, or not at all. With fresh finishings, successes may be achieved through treatment with 4–6 ml/l of hydrochloric acid and 2–4 g/l of non-ionic washing agents at 50–60°C within 30 min, then neutralise and rinse thoroughly. At 95°C, formic acid, instead of hydrochloric acid, may also be sufficient. After removing resin, possible additional light → Stripping of dyeing.

Stripping of silk,

I. → Degumming.

II. Removal (complete or partial) of the dyes applied to the silk. The stripping process is selected in accordance with the dye used, for which the high sensitivity of the silk should be considered in particular.

Strip-Tester American device for → Shrinkage testing.

Stroboscope (oscilloscope), optical device (with tachometer) to observe fast running machine parts in operation (gearing, electric motors e.g. during spinning, winding, weaving) up to 120 000 rpm, in which motion appear stationary to the observer and/or reduced to 1% of actual speed. Device for discovering irregularities. The stroboscope also facilitates the examination of printing speeds through illumination with a regularly visible flash of light. If the frequency of the flashlight and process correspond, the illuminated article, e.g. the printed material running in the printing machine, appears to be stationary, as every flash illuminates the same printed motifs.

Strontium Sr, atomic weight 87.6, compounds of those similar to → Calcium. Properties: → Alkaline earth metals.

Structural formula In contrast to the → Configurational formula, the two-dimensional representation of the arrangement of atoms in molecules.

Structural models for man-made fibres As diagrammatically represented in Fig. 1, the various synthetic fibres can be explained with regard to the orientation of the macromolecules and their crystallinity using different structural models. In most thermoplastic polymers the groups of macromolecules can be freely rotated around their bonding axes, from which flexibility of the molecular chains results. If these fi-

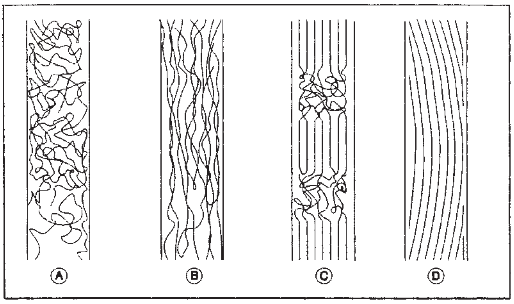


Fig. 1: Diagram showing the possible arrangements of chain molecules in the fibrils within man-made fibres as proposed by Rossbach.
A = non-orientated non-crystalline fibre polymer;
B = orientated non-crystalline fibre polymer; C = orientated partially crystalline fibre polymer; D = orientated highly crystalline fibre polymer.

bres are produced in the melt-spinning process at low spinning speeds without aftertreatment steps (drawing/heat setting), an extensively amorphous fibre polymer with completely disoriented polymer chains is obtained (Fig. 1, A). High spinning speeds and an additional drawing of the fibres firstly disentangle the polymer chains and orientate the macromolecules in the direction of the longitudinal axis of the fibre. In addition, crystalline zones are formed in the fibre, in which the extent of the crystallite formation depends on the degree of drawing (Fig. 1, C). The supramolecular atomic states in such partially crystalline polymers are characterised by the alternate arrangement of disordered and crystalline regions (→ Supramolecular structure of polymers).

The characteristic dimensions of such atomic states are in the magnitude of 3–50 nm. Certain polymers, such as poly-(m-phenyls-n-2.2-to[4-(3.4-dicarboxyphenoxy)]-phenylpropanimide) (PEI) amongst others, do not show any crystallisation power however, so that oriented, non-crystalline fine structures appear in these materials in a stretched state (Fig. 1, B). High crystalline fibre structures are chiefly produced in fibre types, in which no free rotatability of the atoms around the bonding axis is possible due to steric inhibition. This results in rigid rod-like macromolecules, which can be oriented to a stretched chain configuration in a paracrystalline order (Fig. 1, D). Typical examples are poly-p-phenyls-terephthalamide (an → Aramide fibre) and liquid crystalline polyesters. The liquid crystalline properties, which appear in these materials in solution or in melting are important in this context.

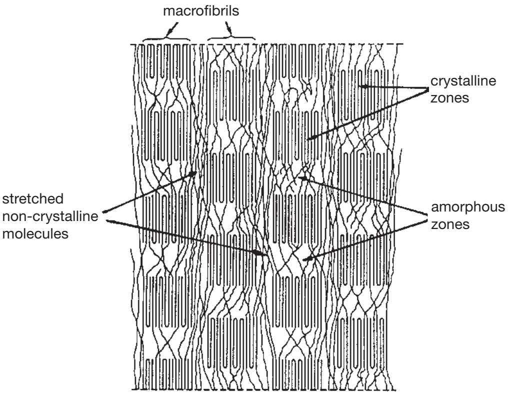


Fig. 2: The structural model of polyester fibres proposed by Prevorsec.

The individual fibrils from Fig. 1 are arranged in a three phase model in the structural model from Prevorsec (Fig. 2), consisting of unordered, amorphous zones, crystalline zones with excess chain folding and semi-crystalline interfibrillar gaps. This structural model in the main gives a good explanation of the dyeing behaviour of heat set polyester.

Structural viscosity In isothermal and reversible conditions, a reduction (without hystereses) of the apparent → Viscosity by ultimate mechanical shearing strain.

Structural viscosity behaviour Pseudoplastic behaviour, → Rheological behaviour of solutions.

Structure of textile materials Textile products, chiefly composites, have a typical structural arrangement, knowledge of which is important for the textile finisher in order to co-ordinate the finishing process of individual components on the overall concept. Floorcoverings (Fig. 1) and chiefly tyres (Fig. 2) represent complex composites in their structure.

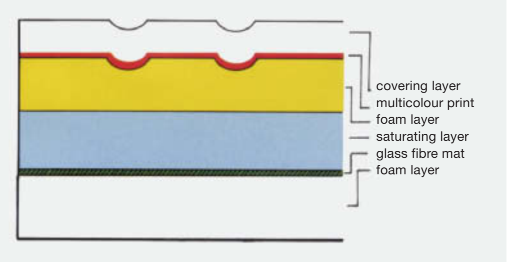


Fig. 1: Heavyweight floor covering structure.

Structure tester Measuring instrument for flat textiles, which determines the relation of fibre content to gaps using a simple throughflow measurement (air). The device reproduces a structural conductance, with which, together with fabric weight and fabric thickness, the stationary state of a fabric can be determined numerically.

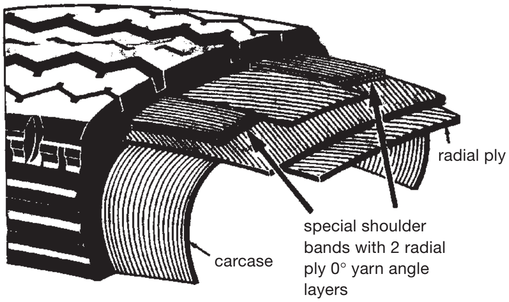


Fig. 2: Radial-ply tyre structure.

Stud roller breaking machine → Mechanical breaking.

Stuffer-box crimping → Crimp, types of.

Stuffer channel (compression channel). Is used for compressing the piece goods together in a longitudinal direction when milling on a rotary milling machine for rope treatment (Fig. 1) or in open-width washing machines (Fig. 2) to relax the fabric.

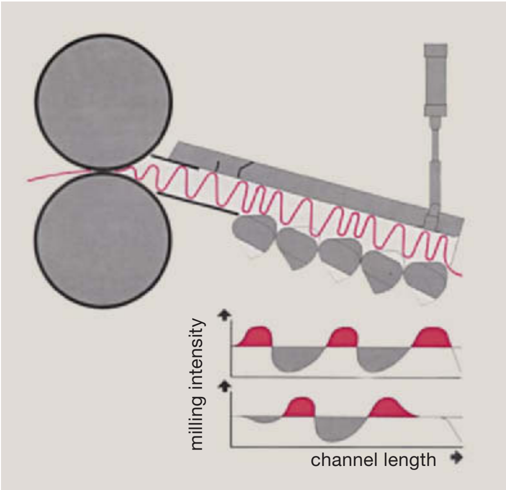


Fig. 1: Diagram of a stuffer channel in milling (Hemmer).

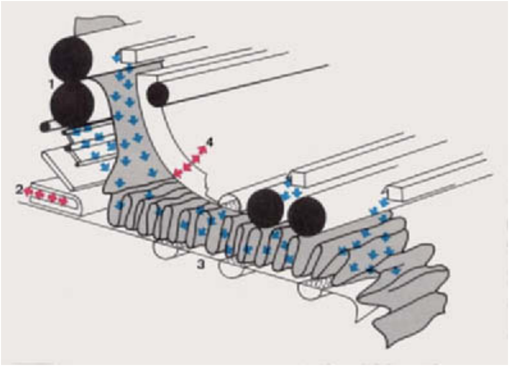
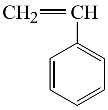


Fig. 2: The stuffer channel of an open width washing machine (Hemmer).
1 = squeeze roller pair which feeds the goods into the stuffer channel; 2 = hammer for stuffing the folds of goods;
3 = spray nozzle beam in the stuffer channel; 4 = moveable top plate for reducing the size of the stuffer channel.

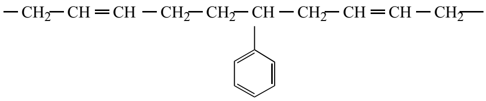
The channel floor of a stuffer channel in a milling machine may consist of milling media, which create compression and relaxation zones through an up and down oscillation motion. Its special shape and its work rhythm cause short, but intensive compressions and relaxation of fabric forms. Fig. 1 shows both final working positions of a milling channel and the corresponding compression and decompression curves, measured on the textile. The comparatively gentle increase in the pressure curve and the sudden relaxation is of particular importance. The elasticity of the fabric package is considerably increased and also its elastic recovery capability.

The even and slow increase in the pressure curve and the following steep fall show the typical behaviour of the elastic recovery in textiles containing wool. The relaxation phase, clearly flatter and longer timewise, increases the after-absorbency for liquor by opening the entire yarn and fibre lattice. The number of pressure and relaxation cycles, to which the textile is subjected in the channel, can be adapted to the desired effect by pre-selecting the working speed of the milling media. Shorter milling times are the result. The pressure and relaxation cycles during washing are expressed in a higher washing performance through the intensive, thorough kneading of the fabric.

Styrene (vinylbenzene, phenylethylene), colourless, unsaturated liquid. Technically important starting material for → Polystyrene and numerous polymer blends (especially with acrylic acid esters and/or butadiene) for coatings, chemical finishings and similar.



Styrene-butadiene rubber From a copolymer of →: Butadiene consisting of styrene; Man-made rubber.



Distinctions are made between polymerisation root and reaction temperature in these polymer blends: warm polymers and/or hot latex (at 50–80°C). Properties: shore hardness 40–90; fabric-like strength, good; abrasion resistance, good to excellent; resistance to acids, average to good; to solvents, poor (aliphatic/aromatic hydrocarbons); to oxidation, average; to ozone, solar ageing and flammability, poorer. Chiefly used for vehicle tyres.

Subcutaneous (Lat.), located under the skin (→: Cutis; Cuticle).

Subdivision of process technique in textile finishing Can be carried out in accordance with different standpoints, e.g. in accordance with type of fibre to be treated, article-specific or in accordance with the processing machines. Following a suggestion from Rüttiger, a vertical subdivision can be carried out: all processes in the basic physical operations (unit operations) and basic chemical operations (unit processes) are triggered and described by so-called primary functions. The horizontal subdivision is carried out article-specifically at the finishing processes. The processes are naturally described by very complex total functions. The advantage of the horizontal subdivision lies in the clear process description; it is, however, applied very broadly due to the variety of articles needed in textile finishing. The advantage of the vertical subdivision lies in the abstraction of coincidental process conditions to generally applicable functional correlations.

Vertical subdivision of process engineering in textile finishing:

1. Finishing areas: completed areas in the textile finishing industry, e.g. pretreatment, dyeing, printing, finishing, coating. They are characterised by type and sequence of processes to be carried out.
2. Finishing processes: extensive treatments of textiles (preparation, material conversion, processing of reaction products), according to which the textile has a particular finishing effect, e.g. alkaline scouring, peroxide bleaching, pigment dyeing, beam dyeing, thermosol dyeing.
3. Finishing steps (treatments): separate treatments of a textile, which usually run in a finishing machine or are characterised by a particular recipe formulation, e.g. padding, drying, rinsing, steaming, cold dwelling, hot dwelling under tension, hot dwelling on skeins. Represented in schematic flow diagrams by material, energy and flow.
4. Process elements (smallest indivisible functions of processes): parts of a treatment in which only an individual function or a group of positively coupled functions operate, e.g. immersing, squeezing off, controlling fabric mechanically, inking, maintaining temperature.
5. Basic functions in finishing: always recurring individual functions in the various finishing processes, e.g. heat exchange, mass transfer, stretching, wetting, swelling, shrinking. Can be described using basic general scientific and technical laws.
6. Areas of help for finishing processes: measuring and test technology (including intelligent sensors), finishing machines, automation, estimates, optimisation, systems engineering.

Sublimate Product of → Sublimation.

Sublimation,

I. (Lat.: sublimis = fine in the sense of “refining”), conversion of substance from the solid state into the vapour and/or gaseous state and vice versa without → Melting beforehand. Important behaviour of disperse dyes.

II. Sublimation of a dye printed onto a textile substrate is understood as more or less strong change in shade of colour, which can usually be put down to reductive influences of the vapour itself or even of contents of the substrate, e.g. of hemicellulose, during the steaming process or exposure to steam for too long.

Sublimation fastness during storage Resistance to dye migration (sublimation) during storage. For the test (→ Sublimation transport mechanics) the sample is laid between two metal plates with adjacent fabrics and loaded. The test specimen is treated at 120°C in the heating cabinet. The change in colour and the staining are assessed using the grey scales.

Sublimation fastness test → Sublimation transport mechanics.

Sublimation fastness tester Developed by Hoechst AG for determining the dry heat setting fastness and the temperature at the start of the sublimation. Using heating on both sides of the test specimen and 8 pairs of hot plates, between which the test specimen is laid. The weight loading can be adjusted and the temperature for each hot plate pair can be selected between room temperature and 300°C. A control device monitors and controls the temperature accurately. – Manuf.: Klaus Fischer, Bad Salzuflen, Germany.

Sublimation fastness to heat treatment Some disperse dyes (chiefly on polyester) have the capacity to enter the gaseous state directly from the solid under the effect of heat. These are thereby coloured or discoloured in blends with other fibres. On the other hand, in the heat setting of dyed polyester/cotton blend fabric it can be observed that the colouring of cotton by disperse dye under the effect of heat more or less disappears (→ Dry heat setting fastness). The temperature has a greater influence on the sublimation than the period of heating.

The evaporation and sublimation of disperse dyes play an important role during production (dyeing/finishing) and in garment manufacture. They can be described as process-determined parameters in thermosol dyeings, while they are basic prerequisites for implementing transfer printing successfully. In testing the factors which influence the sublimation of disperse dyes, it has been shown that the determination of the dry heat setting or sublimation fastness (really simple in itself) is more complex than expected.

Basis for implementing the sublimation tests (→ Sublimation transport mechanics): a sample of the dyed material is heated together with undyed adjacent fabrics by close contact with a medium, which is set at a particular temperature. The change in colour of the sample as well as the staining of the adjacent fabric are assessed using grey scales. But colorimetry can also be called upon for precise assessment. Sublimation curves, which show the course of the temperature dependent sublimation, can be obtained in this way. A disadvantage of these curves lies in the fact that the colorimetric assessment of the depth of shade deviates from the visual rating, as the human eye judges the depth of shade differently depending on the colour range. Besides the colorimetric assessment, there is the possibility of extracting the sublimated dye using dimethyl formamide and subsequent determination of the sublimated dye quantity using the colorimeter (according to Somm).

Sublimation ghosting → Ghosting in transfer printing.

Sublimation in thermosol treatment In thermosol treatment, the disperse dye is distributed differently in the fibre depending on process conditions.

Case 1 (Fig. 1): this case corresponds to a thermosol treatment on a contact fixation unit. Sequence of operations: a) setting (30 s on ironing press) using polyester adjacent fabric on both sides at 180–230°C; b) determination of the sublimated dye. Extraction using dimethyl formamide and colorimetric determination. Control type: dried dyeing. During the sublimation test, sorption, diffusion in the fibre as well as evaporation/sublimation run in parallel.

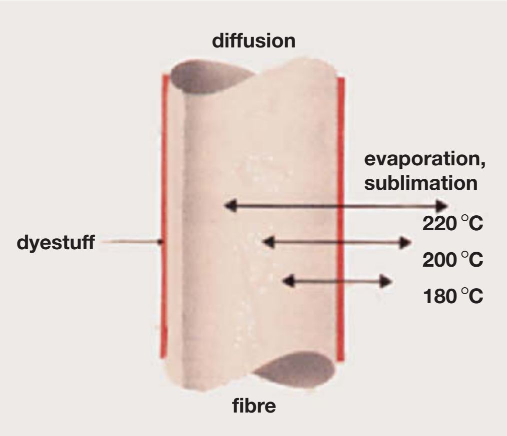


Fig. 1: Model case 1: after drying, the dye is found on the fibre (according to Somm).

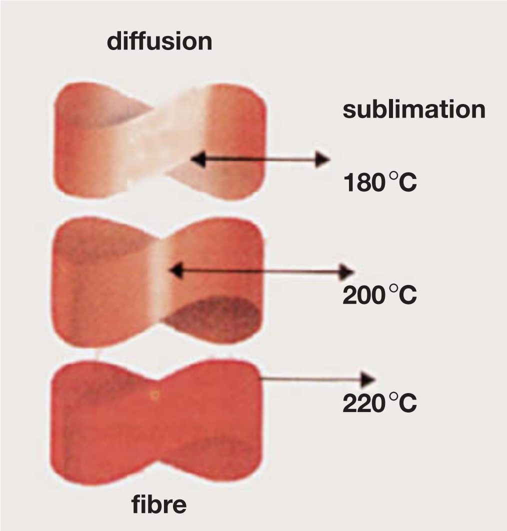


Fig. 2: Model case 2: the dye is found as ring dyeing in the fibre in accordance with the thermosolling temperature employed (according to Somm).

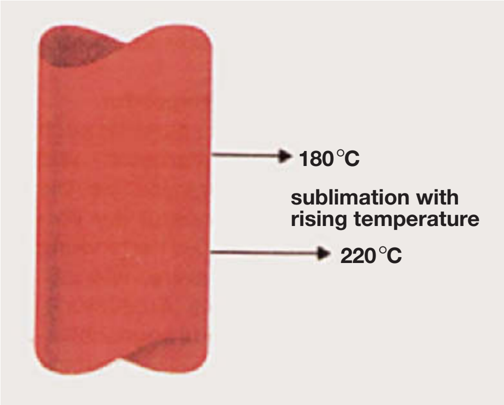


Fig. 3: Model case 3: the dye is optimally fixated in the fibre (according to Somm).

Case 2 (Fig. 2): this shows the sublimation behaviour of ring dyeings. Sequence of operations: a) setting (30 s on ironing press) without adjacent fabric, 180°C; b) reductive intermediate reduction clear; c) aftersetting (30 s on ironing press), using polyester adjacent fabric on both sides, 180–230°C; d) determination of the sublimated dye (as in case 1). In the area of ring dyeing, besides the sublimation a diffusion into the fibre core also leads to an even dye distribution. A practically ideal distribution is achieved at 220°C.

Case 3 (Fig. 3): sequence of operations: a) setting of the dyeing (215°C, 60 s on Benz dryer); b) reductive intermediate reduction clear; c) sublimation tests (30 s on ironing press), using polyester adjacent fabric on both sides, 180–230°C; d) determination of the sublimated dye (as in case 1). This case shows the ideal dye distribution and with it the actual sublimation fastness of a dye with increasing temperature.

Sublimation transport mechanics In normal sublimation fastness tests (SE-Test) an intimate sandwich is formed from a polyester sample dyed using disperse dye and a similar undyed sample. The package is heated. In the dyed fabric and in the dyed tape respectively of thickness d is the initial dye concentration c (g/m^3). A part of the dye (characterised by the hatched surface in Fig. 1) migrates into the originally undyed fabric and/or the tape during the test.

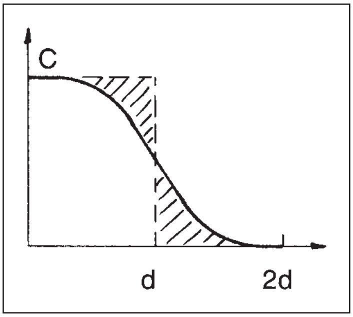


Fig. 1: Dye distribution in the sublimation fastness test (according to Gerber).

The percentage migrated is given, using the formula

$$S\,(\%) = 100 \cdot A \cdot \rho \cdot \sqrt{\frac{D \cdot t}{\pi}}$$

S = migrated dye (%);
A = contact surface (cm^2/g);
ρ = density (g/cm^3);
D = diffusion coefficient (cm^2/s);
t = contact period (s).

and corresponds to the transport mechanics by sublimation. This formula forms the theoretical background to the experimental findings, for which the percentage dye quantity migrated S increases in proportion to the square root of the experiment period t. The proportionality constant and/or the gradient of the S-R(t) lines is therefore:

$$\frac{d\,S}{d \cdot \sqrt{t}} = 100 \cdot A \cdot \rho \sqrt{\frac{D}{\pi}}$$

For its part the gradient is consequently proportional to the root of the diffusion coefficients. The mass transfer is carried out through diffusion in the polymer.

The SE-Test concerns a mass transfer in a porous body. This can be carried out both through diffusion in the polymer (direct contact of the fibres) and by diffusion in the gas phase within the pores or between the fibres. How strongly the two processes are proportionally involved in the mass transfer essentially depends on the vapour pressure of the dye in the pores and/or across the dyed fibres. Of course, the fabric structure and the pressure with which the fabric samples are pressed together also play a particular role.

The two transport processes can be distinguished in the following way in order to assess their relative importance. A stationary diffusion process is observed through a sintered glass filter (Fig. 2).

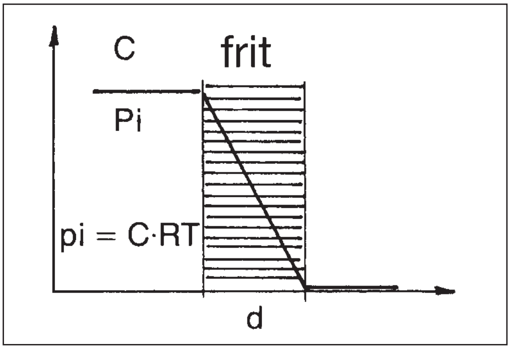


Fig. 2: Stationary diffusion through a frit (according to Gerber).

A dye solution in concentration C or a gas with partial pressure p_i is located on the left side of the sintered filter. If this is flushed with a solvent or gas on the right side so that the concentration of the diffusing components remains almost zero, a linear concentration gradient is set within the sintered filter. According to definition, the diffusion flow J (g/cm^{2}s) is proportional to the concentration gradient C/d and proportional to the diffusion coefficient D (cm^2/s).

$$J = D \cdot \frac{C}{d} \; [\text{g/cm}^2\text{s}]$$

If one then specifically assumes that the transport mechanics are carried out as gas in the pores of the sintered filter with porosity ε, the formula for the diffusion flow J_G is

$$J_G = \varepsilon \cdot D_G \cdot \frac{p_i}{RT \cdot d} \cdot \frac{M}{q} \; [\text{g/cm}^2\text{s}]$$

Sublimation transport mechanics

D_G is the diffusion coefficient of the diffusing gas in the pores and p_i/RT represents the concentration C in mole/cm^3. In order to express the diffusion flow in g/cm^2 as well, multiplication M (g/mole) is required. In order to give J_G in g/cm^2 s of the commercial dyestuff, a correction, using the diluting ratio q should be carried out as well.

If the diffusion flow J is regarded as gas diffusion

$$J = J_G$$

should thus be put. The expression:

$$D = \frac{\varepsilon}{RT} \cdot \frac{D_G \cdot p_i \cdot M}{C \cdot q} \quad [\mathrm{cm^2/s}]$$

thereby results for the macroscopically observable diffusion coefficient D.

This is consequently proportional to partial pressure p_i across the fibre, which contains the dye in concentration C (g/cm^3). It is naturally also dependent on how quickly the dye molecules diffuse in the gas and/or how large the diffusion coefficient D_G is. The gas theory makes the formulae available for the calculation of D_G. In order to determine the diffusion coefficient D, the equilibrium vapour pressures p_i should also be stated across the fibres dyed in the depth of shade C. Fig. 3 shows the apparatus used to determine p_i.

This apparatus is located in a thermostatically controlled bath. A flow of nitrogen is guided across the dyed polyester combed top, located in the tube. The equilibrium pressure p_i of the dye can be calculated from the dye quantity precipitated in the upper part. The saturation pressure p_s can also be determined according to the same process if the tube is loaded with a mixture of quarry sand and dye instead of with dyed fibres. The vapour pressure determination only succeeds however in low sublimation fast dyes. The p_i/C ratio is constant and can be replaced by the ratio of saturation value p_s/C_s. A few of the values calculated for the diffusion coefficient in the gas phase D_G and vapour pressures measured across dyed polyester fibres are compiled in the Tab.

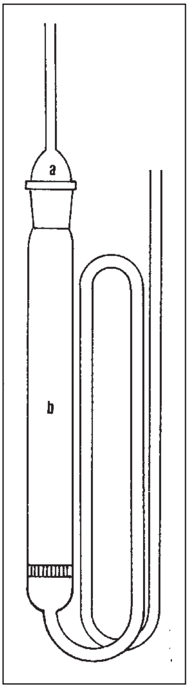


Fig. 3: Apparatus for measuring vapour pressure.
a = dyed polyester fibres;
b = undyed polyester fibres for absorbing the evaporated dye.

dye C. I. disperse	D_G [cm^2/s]	C [g/kg]	$p \cdot 10^{-3}$ [mbar]
yellow 23	0.11	68	18.66
orange 20	0.10	38	8.79
red 53	0.10	115	6.39
blue 56	0.12	62	0.93
violett 27	0.12	39	19.99
		20	11.99
		10	6.66

Tab.: The diffusion coefficients and vapour pressures of some less sublimation – fast dyes at 210 °C (according to Gerber).

The migration process may be regarded as a diffusion process in a porous body. The diffusion mathematics provided the 1st formula for the percentage dye quantity migrated. Only the expression derived for the diffusion coefficient can still be entered in this formula. If the ratio p_i/C is replaced by p_s/C_s , the following expression results for the sublimation fastness S_G (%):

$$S_G = \frac{100}{\sqrt{\pi}} \cdot A \cdot \rho \cdot \sqrt{\varepsilon} \cdot \sqrt{\frac{t}{R \cdot T}} \cdot \sqrt{\frac{D_G \cdot p_s \cdot M}{C_s \cdot q}}$$

S_G is the expression for the percentage of dye migrated across the gas phase. This expression produces the correlation between sublimation fastness and vapour pressure. Besides the dye vapour pressure p_s, a few other dye-specific parameters determine its sublimation fastness. When comparing two dyes with regard to their sublimation behaviour, not only is the vapour pressure p_s altered, but inevitably also the diffusion coefficient D_G, the molecular weight M, the saturation value C_s and the diluting ratio q. In addition to this, dye transport through the gas phase S_G, a migration through direct contact $S_{C,}$ can be considered. With a test period of 60 s this amounts to:

$$S_C = 2\,000 \cdot \sqrt{60} \cdot \sqrt{D_p}$$

The total dye transport observed in the experiment during the SE-Test is the sum of these two effects.

The sum of contact and gas phase transport calculated correlates amazingly well with the values S_{expr} determined in the experiment. The proportion S_C transferred by direct contact is also always crucial in sublimation non-fast dyes, against which the proportion S_G migrated across the gas phase can be ignored in sublimation-fast dyes. The activation energy of the migration process can be derived from the results of migration tests from the Arrhenius representation. The gradient of the Arrhenius lines is:

$$\frac{d \ln S}{d\, 1/T} = -\frac{E_A}{R}$$

whereby E_A represents the activation energy. If this concerns a sublimation-fast dye, which can practically only migrate through direct contact, the following applies:

$$S_C = 100 \cdot A \cdot \rho \cdot \sqrt{\frac{D_p \cdot t}{\pi}}$$

According to Arrhenius, the following applies for the temperature dependency of the diffusion coefficient D_p:

$$D_P = D^\circ \cdot \exp(-E_D/RT)$$

in which E_D represents the activation energy of the diffusion process. The relation

$$E_A = \frac{1}{2} E_D$$

can thereby be derived for the activation energy of the migration process E_A (in accordance with Gerber).

Sublistatic printing process → Transfer printing processes especially for several man-made fibres (in particular polyester, triacetate; less from polyamide and polyacrylonitrile). Printing on paper is carried out as a trichromatic pattern, for example, or even in customary fashionable designs and then transferred onto the fabric at temperatures of 200–210°C. Disperse dyes capable of sublimation are used as dyes, which are printed on paper as solvent-containing coloured inks by means of shallow photo-engraving rollers. The prints transferred onto the fabric from the paper are already set and do not need to be washed.

Submerged centrifuge Textile material is moistened in the basket of the → Sliding-oscillating centrifuge and then spun. It is used for soaking, impregnating, rinsing, acidifying and neutralizing. Net liquor is taken up and reused.

Submerged network test Testing of the network capacity of a surfactant on a standard cotton sample in the form of a round-cut dry substrate which is drawn under water hanging by a thread on a hook. The time that the sample requires to submerge to the bottom is measured. The network effect of various surfactants can be compared by ascertaining the particular concentration which is necessary to attain a 25 second network time. One can plot these values (log C_{25}) against the chain length abcissa of the surfactant and this yields straight lines in homologous rows. In the submerge network test, intersections in the surfactant molecule and greater chain lengths result in a reduction of the "C_{25}". However, a minimum concentration is always required for a certain network effect, irrespective of the structure of the surfactant.

Submerged path Length covered by piece goods in, for example, foulard and impregnation machine troughs in order to obtain adequate moisture.

Submerged spin process Used for dyeing continuous yarn and cross spools with reactive dye substances using the cold residual process. Cross spools are impregnated in a dye bath by a centrifuge. Commercial interest is limited to → Space dyeing.

Submerged test Testing method for water repellent impregnation of textiles (particularly yarn, activity products and knitted fabrics). Technique: weigh textile to be tested, submerge in sieve 10 cm under water for 5 minutes whilst agitating sieve to free trapped air, remove from water, allow to drip for approx. 10 minutes, weigh and ascertain water absorption.

Submerged thermosol process Follow-on process for (bleaching and) whitening synthetic fibres (also cotton mixtures): stretching process 2–5 min in hot fluorescent brightening liquor in the residence device (immersion accumulator), then squeeze out, dry and thermo fix. When fixing the fibre non-bound or diffused, whitener is thermosol fixed.

Submicroscopic fibre channels Identical with so-called intermicellar zones (→ Crystallites).

Substance (Lat.: substantia), synonym for material, "matter", constituent.

Substantive dyes → Direct dyes.

Substantivity Term originally derived from substantive dye (→ Direct dyes), which can be equated with (up)take of a dye or an auxiliary, i.e. with its ability to uptake from a liquid medium onto a textile substrate and to set. The dimension for the force with which the dye and/or the auxiliary is captured from the substrate is however, described as → Affinity. A dye must have affinity to a textile substrate so that it can show substantivity, i.e. can uptake and be set in the substrate; but it should conversely not be substantive inevitably in order to have an affinity to the substrate. Often used as a qualitative description of the affinity of a dye for a particular fibre. Substantivity is quantitatively the difference between the chemical potential of the dye in its standard state in the fibre and corresponding chemical potential in the dyebath. Affinity (μ) consists of enthalpy (H) and entropy (ΔS) in accordance with $\mu = H - T\Delta S$; if μ is negative, the reaction for temperature T runs voluntarily.

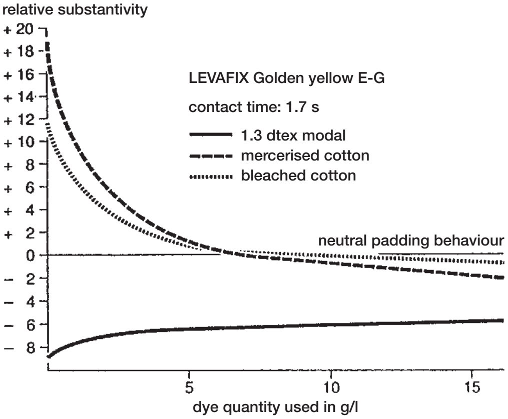


Fig. 1: Contact substantivity (%) in the squeeze nip (Bayer).

The substantivity in the nip is an important parameter in the cold-dwell process, as it causes the selective uptake of dye in the padding process and endings. Two fundamental substantivity effects can be distinguished in the pad process: positive substantivity and negative substantivity. The difference in the substantivity between cotton and regenerated cellulose is dye-specific. Dyes with higher substantivity on cotton basically result in a neutral substantivity ratio on cellulose regenerated fibres, while less substantive dyes are displaced into the negative range. Positive substantivity means that the dye concentration on the fabric is higher than in the padder liquor after the squeezing off process. Negative substantivity means that the fibre uptakes more water than dye from the padder liquor. The ratio of liquor and dye in the squeezed off liquor is constant if the substantivity is neutral. Besides the dye type, the availability of positive and negative substantivity also depends on the depth of shade, i.e. the dye concentration of the padder liquor (Fig. 1).

The negative substantivity which can be observed on viscose in certain reactive dyes also indicates a high association of dye molecules in this range for low padder liquor concentrations. Graphs, which show the percentage increase in dye uptake of the fibre as a function of padder liquor concentration, are consequently obtained when determining the substantivity. In high molecular dyes, the affinity in small concentrations outweighs the normal preference of source water uptake. These types of dye are substantively positive in bright shades.

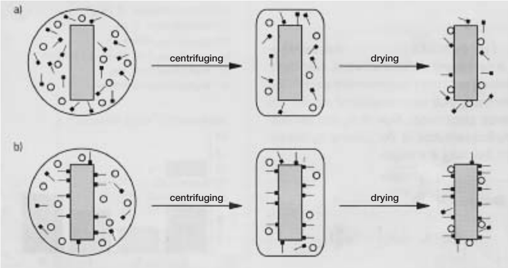


Fig. 2: Schematic diagram of the method of operation of a substance with no affinity for fibre (a) and one with affinity for fibre (b) (Henkel).

Even smaller molecular substances such as surfactants have substantivity. The action of a substance compatible with the fibre and a substance not compatible with the fibre is schematically shown in Fig. 2. No adsorption can be recognised in case a). It means that the solution constituents also remain evenly distributed when cotton samples are present in the solution. The substances compatible with the fibre are, however, adsorbed on the fibre surface (case b, filled out symbols). This results in an impoverishment of the solution of affine molecules, while the non-affine molecules (open circles) are also present in the original concentration and with the same distribution. The state after centrifuge hydro-extraction is also shown. The fibres are still surrounded by a liquid film. Both types of molecule are evenly distributed in case a). The molecules are in adsorbed and dissolved form in case b). The concentration of dissolved molecules is reduced corresponding to the adsorption. After drying, the dissolved molecules remain behind on the fibre. That is why values, which are different from zero, are also measured in case a) when determining activity, although no adsorption took place. The sum of the activities is determined from the adsorbed and non-adsorbed substance in case b).

Traditionally, the after-washing of dyeings was carried out using reactive dyes in accordance with exhaustion processes through repeated cold rinsing, scouring off and soaping and finally through hot and cold rinsing again. The reactive dye hydrolysates to be washed off, accumulate in the separate wash baths in different concentrations, but generally in a properly diluted form. The hydrolysates are very hard to eliminate in the biological wastewater treatment plant and may therefore stain the outlet channel. To remove the hydrolysates from the wastewater, they should be in concentrated form, which can only be achieved by changing the afterwash processes. Diffusion and substantivity have a large influence on the dyeing:

- The higher the substantivity, the more dye disappears and the higher the fixation yield is.
- The higher the diffusion, the quicker the equilibrium dye in the fibre/dye in the liquor will be adjusted and the quicker the dye reaches the reaction site.

A compromise has to be adopted for exhaust dyeings, as both dimensions depend on the temperature in opposite ways (Fig. 3). The diffusion speed is increased with increasing temperature and the substantivity decreases. A high substantivity and a high diffusion speed would

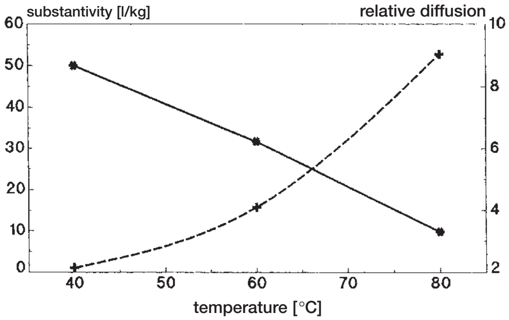


Fig. 3: Temperature dependency of substantivity and diffusion (Sigrist and Haelters).

be ideal for dyeing, but cannot be realised at the same time as a result of the opposite temperature dependency of both parameters. A high diffusion speed and a low substantivity is however required for the washing off of hydrolysates. These conditions can only be fulfilled for both parameters at higher temperatures.

Substantivity factors Auxiliaries in calculating the addition boosting of dyes in continuous dyeing to obtain end-to-end uniform dyeings.

Substituents → Substitution.

Substitute Substitute material with a similar effect to the original product no longer fit for use.

Substitution (Lat.: substituere = to replace), exchange of equivalent atoms and/or atom groups (radicals, alkyls). Example of inorganic substitution: $CuSO_4$ (copper sulphate) and H_2S (hydrogen sulphide) → CuS (copper sulphide) and H_2SO_4 (sulphuric acid). Example of organic substitution: (methane) CH_4 → $CC1_4$ (carbon tetrachloride). The exchanging atoms or atom groupings are called substituents. The product obtained is called a product of substitution.

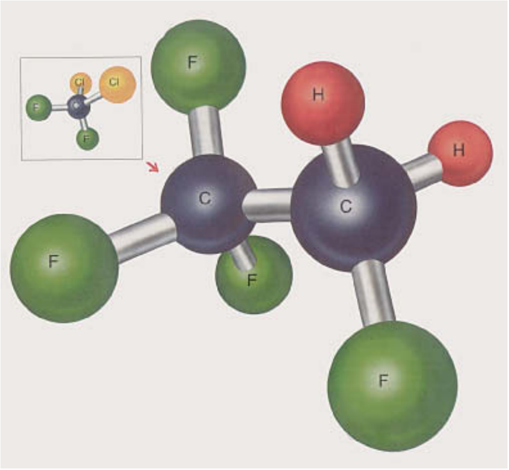


Fig. 1: The substitution of chlorine by hydrogen in a CFC compound. One fluorine is also substituted by a CF_3 group.

A chlorine and halogen substitution has taken place in Fig. 1. The new partially halogenised CFC compound is ecologically optimised and has the same technical properties as the fully halogenised CFC compound.

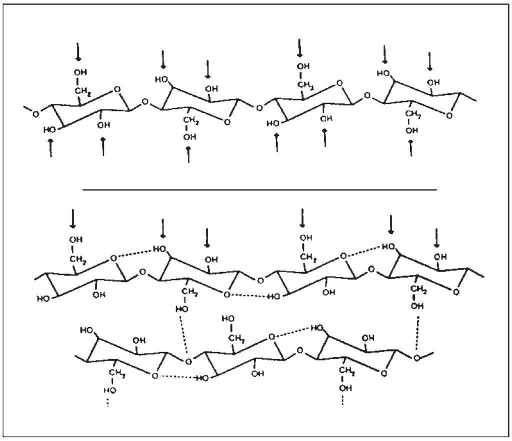
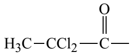
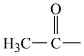
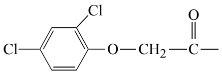
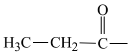
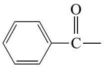
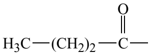
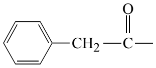
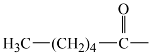
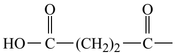
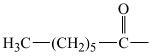
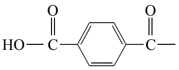
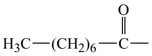


Fig. 2: The difference between the substitution of cellulose in dissolved form (above) and as cotton fibre, in which case only a part of the hydroxyl group can be substituted because the remainder participates in hydrogen bridges.

In the case of the chemical modification of cellulose, it is also called substitution in so far as the three hydroxyl groups in position C_3, C_2 and C_6 (Fig. 2) available from a chemical reaction can only be 100% converted into the diluted form of cellulose: the hydrogen of the hydroxyl groups is substituted, e.g. by an acetyl group, which results in cellulose triacetate.

Not all hydroxyl group hydrogens can be substituted in cotton cellulose because they are integrated into interchenar and intrachenar hydrogen bonds in the heterogeneous system. That is why the availability of cotton cellulose for substitution reactions is restricted.

Substitution, degree of Measurement for the complete substitution of all groups available for the substitution (100%) in a polymer module (monomer in the polymer). So when a polymer is substituted, i.e. converted, compared to the polymer (without breaking the main chain) to the available lateral chain, the degree of substitution is given in %. In cotton cellulose the degree of substitution statistically describes the conversions carried out across all the polymer chains of the three available hydroxyl groups in C_3, C_2 and C_6 position. So, a maximum degree of substitution of 3.0 can be achieved in the dissolved form of cellulose through substitution, which depends very largely on the reaction partner (see Tab.).

substituent	*DS*	*substituent*	*DS*
 $H_3C-CCl_2-C(=O)-$	*0.5*	 $H_3C-C(=O)-$	*2.4*
	*2.7*	 $H_3C-CH_2-C(=O)-$	*2.6*
	*2.8*	 $H_3C-(CH_2)_2-C(=O)-$	*2.7*
	*2.8*	 $H_3C-(CH_2)_4-C(=O)-$	*2.8*
 $HO-C(=O)-(CH_2)_2-C(=O)-$	*1.4*	 $H_3C-(CH_2)_5-C(=O)-$	*2.4*
	*0.35*	 $H_3C-(CH_2)_6-C(=O)-$	*2.2*

Tab.: The degree of substitution DS of cellulose dissolved in LiCl/dimethylacetic acid (according to various reactions).

Substrate (Lat.), basis, base, substance carrier; e.g. the fibre as a substrate for dyeing and/or dyestuff.

Subtilisine So-called extra-cellular, proteolytic enzymes (→ Proteases) made from cell walls of bacillus subtilis and amyloliquefaciens (bacillopeptidases). Have proteolytic and esterolytic activity. Hydrolytic activity qualified by an intermediary serinester involving a histidine residue and a complex network of hydrogen bonds. Temperature stability is particularly important technically (at approx. 60°C, optimum pH 10–11) under washing process conditions. Behaviour towards non-ionic surfactants relatively stable; clear activity losses in the presence of anionic surfactants or soaps.

Subtractive colour mixing → Colour mixtures.

Succinates Salts of → Succinic acid.

Succinnic acid (Lat.: acidum succinicum; therefore succinic salts: succinates), $(CH_2COOH)_2$. Large-scale technical extraction from λ-butyrolactone by oxidation with nitric acid. Is used as an initial base for dye syntheses, (ester) for malleability agents and resins. The most interesting are the sulphone succinic acid esters (sulphonated polycarboxylic acid esters and amides) for wetting and partly also washing agents.

Sucrose sebacic acid esters Sucrose mono sebacic acid esters are produced by converting 3 mole of sucrose and 1 mole of fatty acid esters (e.g. methyl stearate). The products are colour- and odourless with good detergency and emulsifying power and good biodegradability. The foaming power is lower than in → Alkylbenzene sulphonates. The products are resistant to hard water.

Suction-air drier → Drying systems.

Suction cooling In order to cool fabric or knitgoods after steaming, the fabric is passed through a cooling zone directly connected to the actual finishing operation. The cooling unit (see Fig.) consists of a circulating air fan, which blows air above the fabric guide through a nozzle system, which is drawn through the fabric by another nozzle unit below the fabric. A porous conveyor belt delivers the fabric to the plaiting down roller.

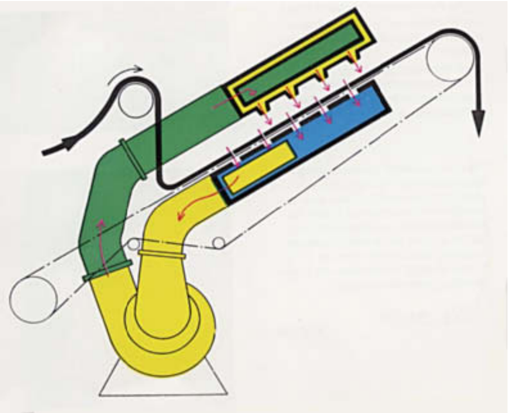


Fig.: Suction cooling at a rotary press-process (Kettling & Braun).

Suction damping of wool fabrics is used for the re-humidification by water vapour of wool and wool blend fabrics, which are completely drawn out, guided on perforated cylinders.

Suction-drum backwashing machine This works with the suction-drum system. Combed tops are washed off in the dyeing machine after being dyed and are given a subsequent softening treatment. They are also softened again before being pressed dry (in order to give them a shiny effect). Combed top washing machines are often suction-drum washing machines (Fig.).

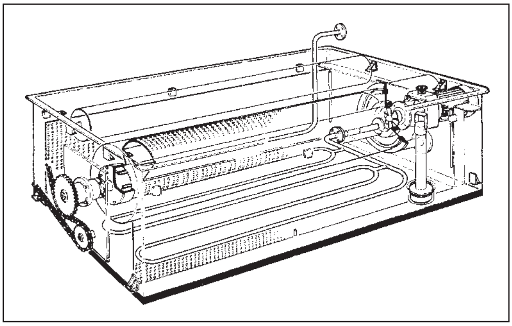


Fig.: Suction-drum backwashing machine from CMT.

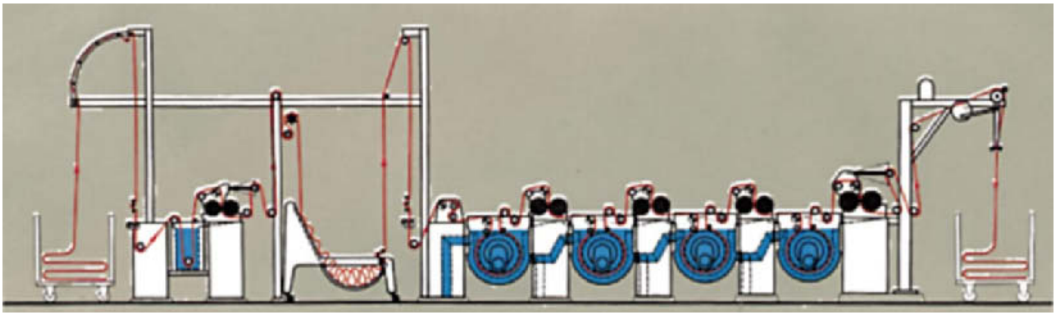


Fig.: Suction-drum washing machine (Babcock).

Suction-drum drier → Sieve-drum drier. Hot-air dryer for loose material, tow (fibre manufacturers), hank yarn, cloth and knitted fabrics. The material is sucked in through the perforated, rotating drum by airflow, soaked heavily and then dried. – Manuf.: Fleissner.

Suction-drum wash compartment This works according to the → Suction-drum washing machines principle. It is a double covered sieve drum; the interior is wide-meshed, the exterior is fine-meshed. The design of the suction-drum surface and the magnitude of the flow resistance through the holes in the drum and the screen fabric inhibit the flow of the liquor on the surfaces not covered with fabric.

Suction-drum washing machines Drum type washer with a pumped flow from the outside of the drum through the fabric and the drum covering in the interior, i.e a suction-drum with through suction. It is possible to feed through correctly fabric which has been overfed with a controlled driven drum, resulting in the tensionless transport of fabric through the drum (see Fig.).

Suction extraction system for shearing The suction (see Fig.) has 3 functions:

1. suction of the shearing dust from cutting devices and brushes.
2. straightening of the fibres suitable for shearing in the cutting device.
3. cooling of the shearing cylinder.

Suction extractor Also referred to as a suction slot device. The fabric passes across a suction slot with a slot width of a few mm. Air is drawn through the fabric by means of a vacuum pump. A suction roller, mach nozzle, Hikosaka roller, jet squeezer and OPI processes are similar suction extractors, with modified designs, for stretch fabrics.

Suction extractor for printing screens is used to remove surplus varnish during the manufacture of printing screens by dissolved solvents.

Suction of pumps Pumps work either with a suction lift or positive suction head (see Fig.).

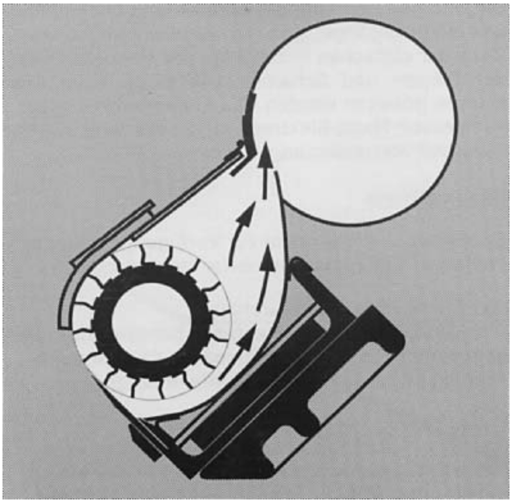


Fig.: Vollenweider Peerless three-function shearing extraction unit with fan and dust filter (straight connecting pipe between machine and fan).

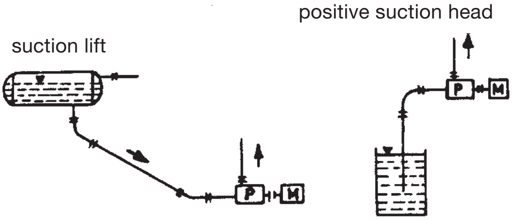


Fig.: Pumps: left with suction lift; right: with positive suction head.

Suction roller for textile webs A finely perforated stainless steel pipe, functions on both sides to transport the fabric. Fabric passes over a suction slot, with adjustable width, in the suction roller. The slot can be adjusted during a run. It can be installed either as an independently or as an inbuilt unit, complete with a water extraction machine and with a vacuum pump driven

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by a variable speed motor (a compensator roll arrangement by which fabric is transported at a speed of < 60 m/min). → Water extraction throughflow method.

Suction slot device Suction slot holder (beam) on the → Suction extractor.

Sudan Red test Microscopic detection test on fats, oil (including linseed oil, sulphonated oil) and soap that have been coloured red.

Sueded cloth A velvet-like raised cotton, wool, or wool/cotton union fabric which may also be printed. It is used for jackets, dressing gowns, etc.

Suède fabric → Imitation suede. This is an example of a simple fabric manufactured for making gloves by caustic treatment and the emerizing of cotton-warp knitted fabrics. In order to obtain a smooth surface ultra fine synthetic fibre-yarn is used.

Suède leather,

I. Roughened → Leather and is also called genuine suède leather (for example leather made from deer). It is either polished grain (e.g Nubuk) or polished velour (e.g lamb, sheep, calfskin, cow velour). Imitation suede leather → Imitation suede.

II. (suède) → Leather with a velvety rough or fluffy surface. The flesh side is cut and worn on the outside (for example Danish, suède leather). The grainy side is smoothed to obtain a special soft velvety texture (e.g Nubuk Leather).

Suède-Look “Swedish Leather” with suède characteristics, for example Duvetine and rough suede jeans material with flocked variants.

Suedette This is a five or eight stem reinforced satin material. A velvety effect is obtained by strongly roughing the right side of the fabric. Another name for this is fabric is Duvetine.

Suedine This is an imitation leather fabric with suède characteristics.

Suèding (emerizing). This is performed on the surfaces of cloth or knitted fabrics. During emerizing the fabric is covered by a thin pile that does not damage the machine or the structure of the fabric. The effect is dependent on the structure of the yarn and the surface. The shorter and thinner the fibre in the yarn, the lighter and easier it is to obtain the pile. The initial emerizing refining materials are also influenced by this.

Two different types of machinery are usually available for the mechanical variation of the surfaces: a multi roller machine for emerizing the surface or a single roller machine for → Sanding the surface. In the first instance the fabric is tensioned over four to seven rollers with emery papered rollers that turn against or with the direction of the fabric. In this way, adjustable pressure creates friction between the fabric and the emery surface. With emerizing any protruding fibre splits and results in a velvety but nonetheless lower fibre pile. The size of the emery grains is larger or smaller for each emerizing effect. Many articles are initially emerized on relatively rough wheels and are finally emerized on smaller emery rollers. A further set of rollers is needed for micro fibre-material. In practice multi roller emery machines offer more advantages for embossing than single roller emery machines:

- Knots in yarn can be eradicated and are not pulled or loosened by any subsequent adjustments.
- The emery rollers seldom heat up. This results in a longer life for emery paper.
- Power consumption is reduced because it is shared between a number of emerizing positions.

It is certainly still possible to work in a controllable sanding position with single roller machines, however in this process all differences in thickness are sanded down. This means that yarn knots are loose, and faulty fabric and selvedge can be sanded down and destroyed. Natural differences in thickness (for example tight chain thread and differences in creases) are increased. The possibilities of using this machine are decreased as a result of this. Multi roller emery machines offer more variation possibilities. Only a portion of the total power needed to emerize is transmitted to each roller. Single rollers can be used with different granules and it is also possible to choose different directions of feeding the fabric. Multi roller machines should, from now on, be predominantly used with equipment that has continually changing article programmes and that deal with specific customer requirements.

The technology employed in emerizing is largely based on that employed in sueding and it has its own individuality. The figure shows the attainment of an optimal emery effect as well as the direction of rotation relative to the direction of the fabric. For most articles the first roller runs in the opposite direction to the direction of the fabric. The weft thread is raised as a result. The second roller moves in the direction of the fabric and emerizes the raised weft thread. The third roller moves against the fabric again in order to intensify the process. The fourth and fifth rollers rotate in the direction of the fabric in order to give the emerized pile a light nap. An equally high fabric tension is employed when dealing with micro-fibre and fine fibre material.

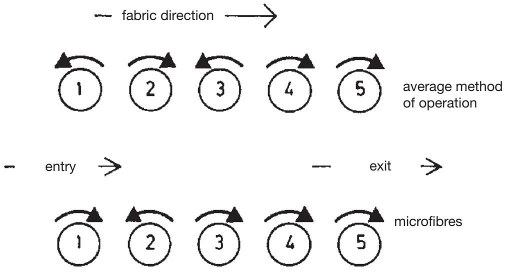

Fig.: Optimum emerizing effects; direction of emerizing roller rotation relative to fabric direction (Menschner).

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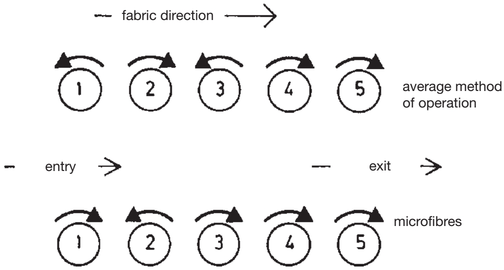


Fig.: Optimum emerizing effects; direction of emerizing roller rotation relative to fabric direction (Menschner).

The emery rollers only slightly touch these fabrics (tangentially touching).

Single roller emery machines may have either round or lattice rollers. A lot of mechanical power is used in raising, emerizing and putting a nap on the weft when using lattice rollers. Around 80–120 suitable pieces of emery paper are required for the lattice rollers. This process is not recommended for modern women's outerwear fabric. The range between being "too weak" and having "good tensile strength" is so narrow that it is no longer safe to control.

Lattice rollers, if at all necessary, are more advantageous for emerizing smooth cotton, viscose or woollen articles to make them "woolly". Round rollers are used for microfibre materials. There is less mechanical pressure on the fabric. Silk or high on Jacquard material can only be emerized with round rollers. Emerizing machines with round rollers are so quiet that only the noise level of the suction can be measured. In practice they are more beneficial whenever the single roller needs to be replaced on emery machines. The Tab. shows a summary and a comparison of the operation data.

	cylinder roller	lattice roller
fields of application	silk, low-high jaquard woven fabric lightweight women's outerwear products (100–180 g/m^2)	plain cotton/viscose or wool piece goods over 200 g/m^2 (mainly coarse graining: 80–120)
noise	very low level	high level
grain size	280/320 with lightweight women's outerwear qualities, 400/500/600 with fine-fibril polyester yarns and microfibres	80–120

Tab.: Comparison of cylindrical and lattice emerizing roller operating data.

The emerizing machine is a "cutting" tool. The hanging weft thread can be grasped and raised by large tools (80–120 granules). Result of processing using coarse grain is a denser, longer pile. If cotton or wool fabric result is too boardy and the aim is a "woolly surface", a particle distribution between 80 and 120 should be used. Wooden rollers produce the best effects here. They are therefore usually obtained using coarse paper. Light women's outerwear items between 100 and 180 g/m^2 in fabric weight should usually attain a short, dense pile. Particle distributions between 280 and 320 have proved their worth in such fabrics. Fine fibrillar polyester yarns and microfibres are emerized using 400/500/600 particle distribution. Even finer particle distributions around 600–800 are not normally used because they actually "polish" rather than emerize.

The tension of the fabric in the area of the actual emerizing field is of prime importance for a good emerizing effect. It must be adjustable and readable depending on the item. Adjusted tension values should be kept constant and automatic re-adjustments should be carried out if the material is stretched. It is especially important that tensile elements, which may take place at the input and output of the machine, do not influence the emerizing effect (according to Riedel).

The emerizing can be carried out after bleaching and before dyeing. This has the advantage that the dye result is no longer altered by subsequent emerizing (sudden change in shade). A disadvantage could be that the dyeing machine is polluted by emerizing dust or the fabric has an altered colouring behaviour. Other users carry out this dry finishing as the last processing step on the finished goods. Changes in colour are thereby partly attempted effects. The effect of a change in colour does not occur in patterned woven fabrics, shirting for example. It should rather be observed here that a subsequent resin finishing reduces the emerizing effect. A correspondingly more intensive processing during emerizing should compensate for this.

On denim fabrics the emerizing process should be carried out before the preshrinking in order to guarantee residual shrinkage values < 1% demanded. The preshrinking effect would be reduced by the fabric tension within the machine. Another area of use for emerizing is the preparation of the fabric for a subsequent raising process. The fibre capillaries loosened in the processing from the twisted yarn can be packed in the subsequent raising process more easily by the card wire point of the raising belt and further processed. This reduces the number of raising passages required. Knitted interlinings are a classic example of this case. From a textile technology point of view scrooping agent applications are required for the raising and the emerizing. These softeners may, amongst other things, already be applied in the spinning process.

Various stages, in which emerizing can take place:

1. After bleaching, before dyeing, e.g. filament woven fabrics made from polyester microfilament.
2. After bleaching, before dyeing or in the finished item, e.g. finish emerizing of outerwear materials. Depending on the organisational structure of the plant and/or the type of the effects attempted.
3. Emerizing only in the finished item, e.g. washed silk.
4. Emerizing as preparation for the raising process, e.g. interlinings.

Suèding machines (emerizing machines). Material with suède leather characteristics is produced on the emerizing machine by the emerizing rollers which split and emerize the fibre. The role of the emerizing machine can be illustrated by using the Suker and Müller SF machine as an example. A pair of draw rollers transport the fabric into the feed end as well as from the delivery end. A carrier roller ensures the cloth is guided correctly under constant tension. This is particularly advantageous in the machining of stretch fabric. The machine is built as low as possible in order for the operator to be able to carry out good visual checks on the passage of the cloth and the operational processes. Over five parallel adjustments can be made by the scaled handwheels so that fabric can be used on the emery rollers.

The setting of the fabric tension is carried out by means of the PIV-gear by a handwheel with a scale indicator, in order to provide reproducible values. The tension regulating system is tested on extremely sensitive articles and the basic machine equipment operates with a pneumatic coupling. Thin turned over seams with a thickness of only 0.25 mm can be detected without any difficulty by using the seam detection system. The process of automatic seaming can also be triggered.

Adjustments for different fabric thicknesses take place automatically. In order to keep the loss of fabric, that has not been machined, as low as possible the motors of the emery rollers are fitted with brakes which stop the emery rollers immediately when the transport of the seam is lost and accelerates the nominal revolutions per minute after the passage of seam. The part of the fabric that has not been machined is reduced to a minimum.

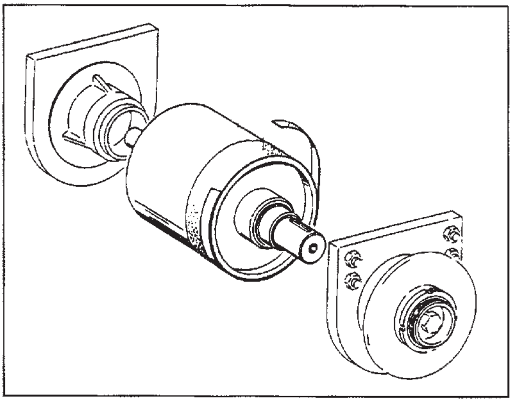


Fig. 1: A cylinder suèding roller (SMH).

The emery rollers which are wrapped in a spiral with emery paper (Fig. 1) are driven by a high performance motor and can be rotated, as desired, with or against the passage of fabric. The number of revolutions can be chosen from (950, 1200 or 1600 rpm). High frequency of contact between the fabric and process occurs as a result of the high number of revolutions and the use of the lattice roller (Fig. 2).

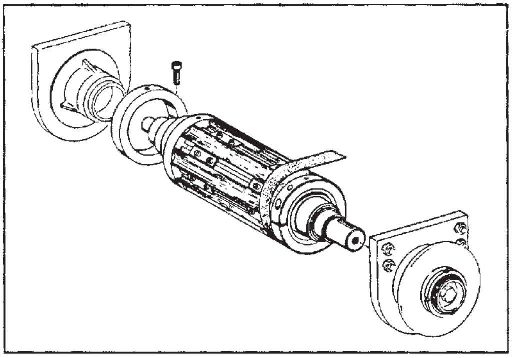


Fig. 2: A lattice suèding roller (SMH).

The emery band is classified by:

- Granulation, i.e the fineness of the granules, which limits the amount of granules per unit of area. Granulation influences the effect of emerizing.
- The type of granules influence the life of the emery coating as well as the machining effect obtained.
- Above all the embedding of the granules influences the life of the emery band.

Around 40–800 granules per unit of area are inserted. The fineness of the granules increases with an increase in numbers per unit of area. In coarse emery bands granules in textile material are embedded in fine paper. A choice is made between flocky and wet emery coatings when joining the granules to the carrier. Besides solid rollers, there are also lattice rollers that are only mounted on ledges. In addition to these rollers there are emery machines that operate according to the principle of wire roughing machines which rotate the emery machines in alternate directions (Fig. 3).

Limitations on the effects of emerizing:

- the design of the emery machines,
- the emery and grain coating,
- the speed of transport of the fabric,
- the number and direction of rotation of the emery machines,
- the fabric tension,

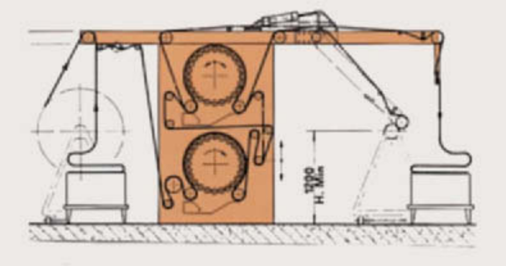


Fig. 3: A Lafer duplex raising machine with suèding rollers.

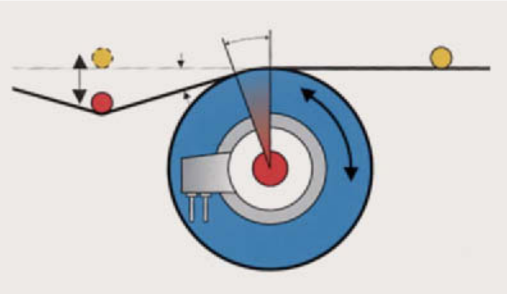


Fig. 4: Arrangement for feeding fabrics tangentially to the suèding roller.

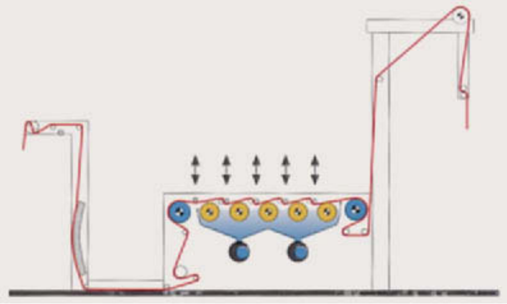


Fig. 5: Diagram of the transport of fabrics through the SF suèding machine (Menschner).

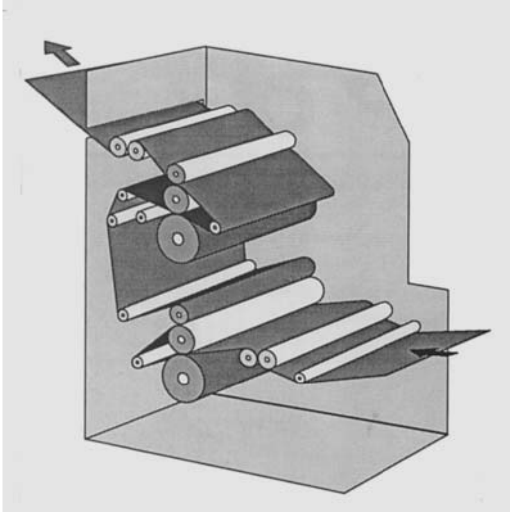


Fig. 6: A Wesero grinding machine.

– the installation of the fabric onto the emery machine (Fig. 4).

During emerizing the friction that occurs between the emery rollers and the fabric is continually measured in the emery system designed by Menschner and is kept at a constant value by a closed-loop control (Fig. 5). The power consumption of the motors on the emery roller is given as a “specific effect set point”. The angle at which the fabric enters through the emery rollers is automatically adjusted and mechanically positioned because of attrition of the emery coating and/or a change in the tension of the fabric. These adjustments continue until the optimal frictional effect between the fabric and emery roller is reproduced. One analogy draws upon the possibility of an early diagnosis of a change in the emery coating. If the required frictional is no longer obtainable, an acoustic signal indicates that there has been a change in the emery coating. Good quality reproducible fabric is continually guaranteed as a result of this. Traditional wire raising rollers can also be wrapped with emery bands instead of wire raising bands. Grinding machines work in a similar way (Fig. 6).

Suffix (Lat.: suffixus = attached). A suffix is added after the stem of a word for different chemical compounds. For example: -ase, -ate, -ide, -ite, -ose, etc. Opposite → Prefix.

Sugar alcohols (sorbitols), tetravalent-hexavalent aliphatic → Alcohols.

Sugar fibres Cuban. Raw material fibre from the waste from sugar production.

Sugars,

I. The traditional name for syrup and sugar cane.

II. Food relating to glucose, fruit, milk, maltose, etc.

III. Chemistry: can be easily combined with → Carbohydrates, mono and oligosaccharides when polysaccharides (for example starch, cellulose) do not contain sugar but consist of many simple sugars. Each type of sugar can be classified in two isomers α and β forms (→ Glucose, d-,α-, β-). Sugar and → Aglycone form → Glycosides. Simple sugars (Monosaccharides) combined with a group of aldehydes are called aldoses (C-number = bioses, trioses, tetroses, pentoses, hexoses), to which dextrose/glucose and most natural sugars also belong. Sugars within the keto group are called ketoses (for example, fruit sugars/fructose).

Suint Mainly from → Wool fat and Wool grease suint (consists of between 8 and 58%).

Sulphamic acid (sulphuric acid amide). NH_2SO_3H. Colourless crystal, odourless, non-volatile, non-flammable, disintegrates at 250°C. It has a density of 2.126 and a molecular weight of 97. It is a strong acid (very sour) and is soluble in water and alcohol. It destroys excess nitrates during diazotising: $NH_2SO_3H + HNO_3 \rightarrow H_2O + N_2 + H_2SO_4$. It is used during diazotisation and also before the coupling of naphthols (cleaner, stronger shades). Use: to analyse the presence of nitrates; boiler scale removal material (instead of H_2SO_4) in foam extinguishers where the acid carrier releases carbon dioxide from carbon.

Sulphamide ($-SO_2NH_2$), → Acid amides.

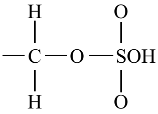
Sulphatases → Esterases.

Sulphate hardness → Water hardness salts.

Sulphates Salts from sulphuric acid (H_2SO_4; → Sulphur oxyacids), generally easily soluble (difficult in calcium, insoluble in barium and lead).

Sulphation (sulphating),

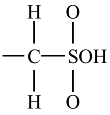
I. A reaction introducing the → Sulphonic (acid) group ($-SO_3H$) into an organic compound whereby ester originates from sulphuric acid i.e, → Sulphates with ester characteristic looping of sulphur to oxygen to carbon –C–O–S–:



$$-\overset{\displaystyle H}{\underset{\displaystyle H}{\overset{|}{\underset{|}{C}}}}-O-\overset{\displaystyle O}{\underset{\displaystyle O}{\overset{|}{\underset{|}{S}}}}OH$$

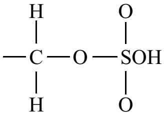
as for example is the case with fatty sulphuric acid esters. A choice is basically made between Sulphation and → Sulphonation. We only speak of → Sulphation in cases of doubt.

II. A reaction introducing the → Sulphonic (acid) group ($-SO_3H$) into an organic compound. Originating from this group are either a) sulphates by "real sulphation" or "carbon sulphation" which have a direct carbon-sulphur-bonding (they are also illustrated here as carbon-sulphonates):



$$-\overset{\displaystyle H}{\underset{\displaystyle H}{\overset{|}{\underset{|}{C}}}}-\overset{\displaystyle O}{\underset{\displaystyle O}{\overset{|}{\underset{|}{S}}}}OH$$

or b) sulphates i.e, esters from sulphuric acid by an ester type bonding of sulphur to oxygen to carbon (also called oxygen-sulphates):



$$-\overset{\displaystyle H}{\underset{\displaystyle H}{\overset{|}{\underset{|}{C}}}}-O-\overset{\displaystyle O}{\underset{\displaystyle O}{\overset{|}{\underset{|}{S}}}}OH$$

The concept of sulphation is often used in the generalised sense especially if it has not been made clear if → Sulphonation or sulphation or both should be used at the same time.

Sulphatoethylsulphone dye One of the most important treatments from the → Vinylsulphone dyes:

$$F-SO_2-CH_2-CH_2-O-SO_3Na.$$

Sulphenic acids A type R–SOH compound. It results, for example, from the effect of alkali on wool from the splitting of the cystine bridges:

$$R-CH_2-S-S-CH_2-R \rightarrow R-CH_2-SOH$$

and disintegrates in the separation of hydrogen sulphide from aldehyde:

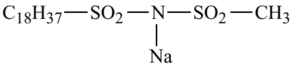
$$R-CH_2-SOH \rightarrow R-COH + H_2S$$

Sulphenic acid is very reactive.

Sulphidation (sulphidating). A reaction introducing sulphur into an organic compound whereby it forms into a sulphidation product consisting of mercaptane (R–S–H), thioether ($R-S-R_1$) and disulphides ($R-S-S-R_1$), etc.

Sulphides Salts from hydrogen sulphides (H_2 S) for example → Sodium sulphide (Na_2S). It is also an organic alkyl sulphide radical.

Sulphimides ($-SO_2-N(H)-SO_2-$), a product that originates from paraffin hydrocarbon (→ Acid amides). They are similar to sulphamides and are a high quality textile resource which has wetting and washing properties, for example:



$$C_{18}H_{37}-SO_2-\underset{\displaystyle Na}{\underset{|}{N}}-SO_2-CH_3$$

Sulphite-cellulose waste lye originates from the production of cellulose. It contains hemicelluloses, sodium lignin sulphite as an effective protective colloid, rubber, resin, glucose, tannin. Characteristics: it slows down the absorption of dyestuffs especially in light colours. Its protection colloids give wool, in high temperature alkali baths, its "weak" tanning characteristics and also in the scouring of silk.

Sulphites Salts from the sulphuric acids (H_2SO_4; → Sulphur oxyacids). They are either acid salts (e.g. → Sodium bisulphite) or normal salts (→ Sodium sulphite). Only alkali salts are soluble, and as a result have an alykaline hydrolysis reaction. Usage: they are reducers, bleachers and separators.

Sulphito- The name for the SO_3^{2-} ion coordinated as a ligand in → Complex compounds.

Sulphitolysis The separating of sulphites from disulphide compounds (→ Cystine bridges):

$$\begin{aligned} &R-S-S-R + SO_3^{2-} \rightleftharpoons R-S-SO_3^- + R-S^- \\ &R-S^- + H^+ \rightleftharpoons R-SH \\ &SO_3^{2-} + H^+ \rightleftharpoons HSO_3^- \end{aligned}$$

The maximum sulphitolysis that can been performed on wool cystines and thiol compounds (→ Cystines) is approximately pH 3.5 when unprotected and pH 4.5–5 when protected. Under similar conditions, alkali chlorinated wool with sodium sulphite and sodium dithionite is produced after treatment. The optimal bleaching of chlorinated yellow wool is also achieved.

Sulpho-acetate of alumina (aluminium sulphuric acid), which is produced from a double reaction of 1 Mol aluminium sulphate with 1 Mol of lead acetate = $A1_2(CH_3COO)_4\,(SO_4)$ or by the dissolution of aluminium hydroxide in acetic acid = $Al(SO_4)(CH_3COO)$. Alkaline salt originates from the addition of sodium bicarbonates $Al_2(SO_4)_3$ or the double reaction of alkaline sulphate with lead or calcium acetate = $AI_2(SO_4)(CH_3COO)_2\,(OH)_2$. Usage as a mordanting fluid for alizarin and Turkey red colours (especially alkaline salt) for the acid neutralisation of aniline black dye.

Sulphobetaines Used for high grade finishing. Examples include → Triethylsulphateamine, disodium salt.

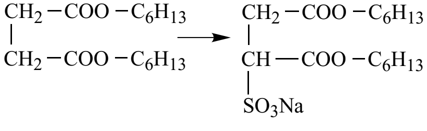
Sulphonated fatty acid esters → Fatty acid-condensation products.

Sulphonated fatty acids (fatty sulphonated acids) → Sulphonated surfactants. The reaction product of fatty acids/sulphuric acids in so doing, finally react (with the efflux of water) with a CH_2-group and which explains, with → Sulphonic acids, the direct bonding of carbon-sulphur ($–C–SO_3H–COOH$) with the fatty acids-carboxyl group. Sodium salts possess a high level of resistance to acid and alkali, form very soluble lime salts and are (for example with a mixture of → Fatty sulphuric acid esters) very active in the processes of saponifying, rinsing, dyeing, softening and modifying finishes. They are also resistant to bitter salts.

Sulphonated oil Sulphonated surfactants and similar products.

Sulphonated polycarboxyl acid esters and amides A group of high quality wetting and washing auxiliaries.

1. a) sulphonated succinic acid esters (sulphosuccinates) form the largest subgroup with extraordinary varying possibilities. $C_{6–8}$-alkyl residue have the best wettability. C_7-alkyl residue also have good washability. They are very resistant to hard water, alkali and acids. Types:

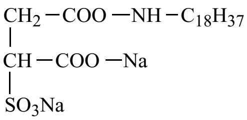


$$\begin{array}{l} CH_2-COO-C_6H_{13} \\ | \\ CH_2-COO-C_6H_{13} \end{array} \longrightarrow \begin{array}{l} CH_2-COO-C_6H_{13} \\ | \\ CH-COO-C_6H_{13} \\ | \\ SO_3Na \end{array}$$

-ester *-sulphosuccinate*

Sulphuric succinic acid esters are average to good washing auxiliaries. They are used as mild washing agents and are degradable (by comparison to other products). Sulphuric succinic acid esters from stearic acid monoethanolamides are useful for special after washing in many countries. Washing can be performed without additional electrolytes or alkali to neutralise weak acid. It can also be carried out in hard and saline water. They can be used to scour off other predominant surfactants. Disadvantages: they are in the form of a paste, sensitive to alkali, substantivity (controllable handle). $ROOC–CH_2–NaOOC–CHSO_3Na$.

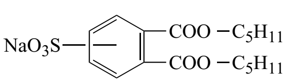
1. b) Sulphuric succinic acid amides are very active in washing. They are designed on the following principles:



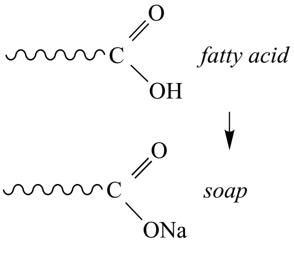
$$\begin{array}{l} CH_2-COO-NH-C_{18}H_{37} \\ | \\ CH-COO-Na \\ | \\ SO_3Na \end{array}$$

2. Sulphonated esters from tricarballylic acid ($[CH_2–COOH]_2–CH–COOH$) are very strong wetting auxiliaries.

3. Sulphonated phthalic acid esters and amide wetting auxiliaries are also very good for washing. Their design principle is as follows:

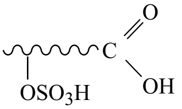


Sulphonated surfactants (sulphonated oils). The carboxyl (COOH) group is recognised as being the main insufficiency of soap:



In order to retain the features of the fats as much as possible, a corresponding change in the molecules of the → Fatty acids or → Fats (mainly castor oil or olive oil) must be made.

I. Turkey red oils: serve, above all, auxochrome dyestuff compositions. This involves the classical implementation of the sulphonic acid group $–SO_3H$ through sulphonation. The products become water-soluble and exhibit chemical → Fatty sulphuric esters wherever the sulphonic acid group has been placed in the long fatty molecules such as castor oil acids-sulphuric acid esters:



The products have uncombined chemical reactions (different degrees of sulphonation, partly C–SO_3H–bonding). The sulphonated oil from the Turkey red oil is formed through emulsifying (the name originates from its once outstanding contribution to the dyeing of Turkey Red). It is soapy, loosens up dirt, but does not possess any washing capabilities. With increasing degrees of sulphonation we may choose between a) low sulphonated oil (approximately 3–7% SO_3); b) high sulphonated oil (approximately 10–12% SO_3) c) highest sulphonated oil (approximately 19–22% SO_3), which increasingly possess wetting and emulsifying capabilities as well as increased resistance. The latter members of this formation are resistant to hard water salts, bitter salts ($MgSO_4 \cdot 7\,H_2O$), acid and alkali. Usage: are used in the dispersion of lime soap, excellent (bitter salt), finishing oils and dyeing oils (also in the boiling of liquid acids to remove colour). It is also used for wetting, levelling, full dyeing, scouring, kier boiling, desizing, chlorine bleaching, mercerization, carbonization as an emulsifier and so forth.

II → Sulphonated fatty acids: fatty sulphonated acid sodium salts are worth mentioning. They are also found in the fatty molecules of the sulphonic acid group. The sulphur is, however, directly bonded to carbon (–C–SO_3). There are also many different oils that easily form soluble lime salts in hard water besides numerous ones which have similar characteristics to fatty sulphuric esters.

III. Sulphonated tallows: These possess a proportionally low degree of sulphonation. Usage: special finishing, chemical finishing, as fat for padder tarnishing and so forth.

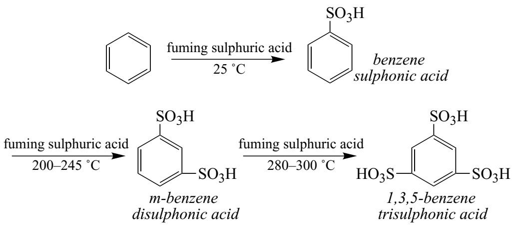
IV. Other oil products: mainly unsulphonated olein and acid oils, olive oil, ground nut oil, mineral oil or paraffin produced for the melting of wool and viscose spun fibre and when required in emulsifying combinations. Similar oil products can be used for the oiling of viscose filament yarn. Mineral oil and linseed oil can also be used as components for viscose-filament yarn-finishing as well as other oils.

Sulphonated tallows Tallow product with usually low degree of sulphonation; its natural fat properties are retained to a large extent. It is usually soluble in water. Anion active. Utilized as an avivier agent, as finishing and smoothing additives and as grease basis for matt finishing of foulards.

Sulphonation It was once a general reaction that introduced the → Sulphonic (acid) group (–SO_3H) into an organic compound. Sulphonation is only referred to in the narrowest sense if sulphur from the sulphonic acid group is immediately bonded with the carbon; type –C–SO_3H (sulphonated – type –C–SO_3Na). This structure exists for example in → Sulphonic acids, dyestuffs such as auxochrome and generally in all → Sulphones. The basic choice is made between sulphonation and → Sulphation and in cases of doubt the term sulphation is used.

Sulphonation, degree of A percentage of the organic bonded sulphuric acid and SO_3 in → Fatty alcohol sulphates and similar sulphates. Fats are water-soluble during contact with the → Sulphonic (acid) group. Acids, lime and bitter salt resistance as well as the resistance to wetting and emulsifying power increase with the degree of sulphonation. Synthetic washing materials practically have one hundred percent sulphonation and means that every active molecular substance is washed and eradicated by a soluble group. Proportionally lower degrees of sulphonation groups are sulphonated tallows which consequently obtain their softening ability from the fat characteristics. Consequently the required fatty effects are achieved by the addition of unsulphonated fatty alcohol.

Sulphonation of aromatic compounds Sulphuric acid sulphonation of aromatic compounds results in arylester sulphonation. Sulphur trioxide in sulphuric acid is joined to an aromatic ring by an electrophyllic substitution. Sulphonation occurs by the following means:



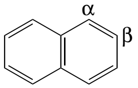
Sulphonation results over a transitional period that exists during the formation of a π complex. The attacking ion interacts with the π electron shell of the attacked aromatic compound. This reaction is reversible. The dilute sulphuric acid allows the sulphonic acids form to desulphonate. Sulphonation is easier as a result of this. An increase in time and temperature of sulphonation causes an increase in the degree of sulphonation. Previously prepared substituents (Tab.) influence the process in the normal way i.e top quality substituents direct in ortho and para positions. Second quality substituents direct in meta positions. During temperature increase the para-positions are mostly opposite to the ortho-positions. An overview illustrates the possible reaction positions during sulphuric acid sulphonation from formerly substituted aromatic compounds. Only those from the used dyestuffs are listed.

substituent	o-	p-	m-
$-SO_3H$		5%	95%
-OH	15%	85%	
$-CH_3$	15%	80%	5%
-Cl		100%	
-NH-Ar		100%	
-COOH		14%	86%

Tab.: The formation of sulphonic acid as a percent according to the availability of substituents.

The following requirements must be adhered to in sulphonation:

- Never put two sulphuric acid substituents in an ortho-para position to each other.
- Two or more substituents can become strengthened or weakened. In the latter case isomers are mainly formed side by side.
- The influence of the hydoxyl group outweights all the other substituents.
- Amide groups lead the sulphonic acid groups into their para and ortho positions.
- Second quality substituents make sulphonation harder. There is very seldom a substitution in the meta position.
- Phenol that leads the sulphonic acid group, initially into a para position and finally into an ortho position, can easily be substituted.
- Naphthalene sulphonation is strongly influenced by temperature; below 65°C the sulphonic acid group forms the α position, under 120°C it forms the β position.



1- naphthol becomes 1-naphthol-4-sulphonic acid; sulphonation of 2-naphthol takes place in mild conditions to 2-naphthol-1-sulphonic acid vigorous under conditions 2-naphthol-8-sulphonic acid and 2-naphthol-6-sulphonic acid.

- Sulphonation of anthraquinone takes place in vigorous conditions. Disulphuric acid forms as well as monosulphuric acid. The second sulphonation always takes place on the other benzene nucleus. Further sulphonation does not occur.

Sulphones (R_2–SO_2). Oxidation product of → Thioethers.

Sulphonic (acid) group (SO_3H). Monovalent. Characteristic of many textile auxillaries and numerous dyestuffs (auxochrome).

Known as a → Sulphuric acid extract of an hydroxyl group. Interaction of the sulphonic acid group occurs during → Sulphation (sulphonation). It consists of mainly water insoluble organic compounds which effect its water solubility.

Sulphonic acids Aliphatic and aromatic compounds have a wider variety with the water-soluble sulphonic acid group ($-SO_3H$). They are in acidic form, for example, as acidic dyestuffs, sodium salts, direct dyestuffs and are very valuable textile auxiliary components (→: Fatty acid condensation products; Sulphonated fatty acids). In contrast to fatty sulphuric esters, sulphur is directly combined with a carbon atom (–C–S–). These also include “C- sulphonates”, alkyl sulphonates, “real” sulphuric acid and alkyl sulphuric acid metals in the form of sulphonates (as salts). They are made up from paraffin carbo-hydrogen (through sulphonation with SO_2 and CO_2 or sulphuric chloride SO_2Cl_2) and initially change to sulphuric chloride (Mersol.-type: $R–SO_2Cl$), which are saponified with caustic alkali to form Mersolate (cleaning auxiliaries, wetting auxiliaries, etc).

Sulphonium compounds Sulphur-complex, similar to → Oxonium compounds in which oxygen interacts with sulphur. Sulphonium compounds are taken from the coordinative four-valency sulphur and are substituted three times with alkyl. As a high-grade finishing product Sulphonium compounds contain a lot of cellulose (e.g. disodium salts from tris (β-sulphurethyl) sulphonium). sulphonium compounds behave similarly to quarternary ammonium compounds and form strong hydrate bases similar to sodium hydroxide. The colouristic characteristics of sulphonium compounds have until now been similar to phthalocyanine-complex in sulphonium compounds (→ Phthalocyanine dyestuffs).

Sulphonyldiethanol Originates from di-vinyl sulphone when poured into a watery alkali solution:

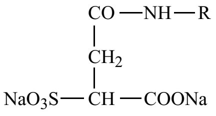
$$CH_2{=}CH-SO_2-CH{=}CH_2 \xrightarrow{OH^-}$$

$$OH-CH_2-CH_2-SO_2-CH_2-CH_2-OH$$

Sulphonyldiethanol serves as a linking auxiliary for cellulose, for example for the non-iron finishing of cotton. (→ Bis(β-hydroxyethyl)-sulphone).

Sulpho salts Known as double sulphides. They originate from oxygen salts produced by changes in sulphur as opposed to oxygen, for example urea $CO(NH_2)_2$, sulphur urea $CS(NH_2)_2$.

Sulphosuccinamates Foaming agents and emulsifiers of the general formula:



$$\begin{array}{l} \quad\;\; CO-NH-R \\ \quad\;\; | \\ \quad\;\; CH_2 \\ \quad\;\; | \\ NaO_3S-CH-COONa \end{array}$$

sodium sulphosuccinamate
(R = organic residue)

These differ from most surface-active compounds through two ionisable groups: sulphonic acid group and carboxyl group. The consequent bifunctionality in interaction with the amide group yields specific characteristics which predestine them for use in emulsion systems. Thus certain sulphosuccinamates are used alone or in mixtures with e.g. potassium oleate sulphate or sodium lauryl sulphate as an emulsifier for latex compounds, as well as as an emulsifying and foaming additive in the manufacture of foamed carpet backing coatings.

Sulphosuccinate → Sulphonated polycarboxylic acid esters and amides.

Sulphoxides (R_2–SO), oxidized → Thioethers.

Sulphoxylates (formaldehyde sulphoxylates, formaldehyde sulphoxylic acid salts, oxymethane sulphinic acid salts) formed from formaldehyde and sodium dithionite or (in acid solution) through the reduction of formaldehyde disulphite with zinc dust. Used as highly effective reducing agents – frequently used in heat – for stripping, in vat dye printing, as discharge agents, as kier boiling assistants (preventing oxycellulose), etc.

I. Sodium formaldehyde sulphoxylate: ($NaHSO_2 CH_2O \cdot 2\,H_2O$) mostly 98–99%, stable (if protected against moisture and heat), soluble in cold water; used as: deoxidant in cloth printing (vat dyes), discharging of direct and naphthol dyeings.

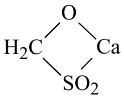
II. Sodium sulphoxylate stabilised with acetaldehyde and ammonia. At around 70°C it already exceeds the upper vatting limit of vat dyes. Has a higher negative redox potential than sodium dithionite, i.e. not suitable for dyes sensitive to over-reduction.

III. Zinc formaldehyde sulphoxylates:

a) Primary salt [$Zn(SO_2CH_2OH)_2$], water-soluble; used for: stripping of dyeings, deoxidant in vat-dye printing, discharge printing of acetate fibres, etc.
b) Secondary salt [$Zn(SO_2CH_2O)$], not soluble in water, soluble in ethanoic acid or formic acid bath; used for: stripping of dyeings, discharge agent.

IV. Zinc acetate aldehyde sulphoxylate: oxyethane sulphinic acid zinc: [$ZnSO_2(CH_2OH)_2$], difficult to dissolve in water, used for: stripping.

V. Calcium formaldehyde sulphoxylate: deoxidant for printing with vat dyes.



VI. Glucose sulphoxylate.

Sulphur (Lat.: sulfur). Chemical symbol: S. Atomic weight 32.06. Sulphur is bivalent, quadrivalent and hexavalent. Yellow rods, chunks or powder (always containing sulphurous acid), brittle, stable in air (density 2.06). Insoluble in water, low solubility in alcohol, ether, benzene; soluble in carbon bisulphite; burns when ignited with a blue flame (melting point at 114.5°C) (to form sulphur dioxide SO_2). Used as bleaching agent (wool, straw), vulcanisation, etc.

Sulphur bridges →: Cystine bridges; Wool chemistry.

Sulphur determination for wool → Benedict-Denis reagent.

Sulphur dioxide SO_2. Molecular weight 64. Colourless gas (steel cylinders) with a suffocating odour, toxic, non-combustible (occurs when → Sulphur is burned); also liquid (H_2SO_3, molecular weight 82, salts: sulphites, hydrogen sulphites). Colourless, weak acid, pungent odour. When air is included, slow oxidation to form sulphuric acid (store well sealed). Addition of small amounts of alcohol improves storage properties; acid reaction. In the dissolved state, SO_2 is present in water, only to a small extent $SO_2 + H_2O \rightarrow H_2SO_3$. Used for: bleach (wool, silk, cellulose, etc.); antichlor; after-treatment after potassium permanganate bleaching (dissolving manganese dioxide); stain remover (for berry and fresh fruit stains). Must be well rinsed out of cellulose goods (formation of sulphuric acid).

Sulphur dyeing A distinction must be made between normal and modified types of sulphur dyes. For normal types, storage time is limited. Even when stored in cool, dry conditions, auto-oxidation can occur with individual products. Individual dyeings likewise have limited lives; changes of shade. In the case of modified types, observe the manufacturer's instructions. Dissolving regulations: observe the details provided by the manufacturer. Normal types should be boiled with 1 to 3 times the amount of sulphur sodium crystals. This solution must be filtered before being added to the dye bath. Modified types, on the other hand, are water-soluble or can be diluted with water. Dye baths: use soft water. In the case of standing baths, monitor the salt content. Sulphur dyes take up relatively slowly, and therefore pose no levelling problems, unlike vat dyes. Oxidation: where rinsing and/or hanging are not sufficient, baths with hydrogen peroxide are used. The use of dichromate is prohibited by law in Germany. Oxidation through steaming does not occur often. After-treatment: for some dyes, metal salts (copper) increase fastnesses, although changes of shade occur. Metal salts reduce the absorbency of the goods. Improvements in fastness which are resistant to washing can be obtained through after-treatment with nitrogen condensation products. Sulphur black dyeings should be alkaline finished (pH 8–8.5), or else sodium acetate or sodium formiate should be added to the last rinsing bath. In this type of dyeing, there is the risk of sulphur separating, which converts into sulphuric acid, causing a weakening of the fibre. Sulphur dyes can be applied by both the exhaust method and the pad dyeing method. However, there is little interest in the discontinuous pad dyeing method. Modified types are recommended for pad dyeing methods.

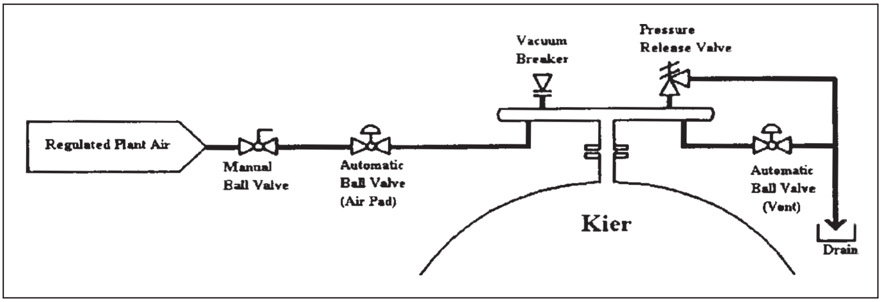


Fig. 1: Typical jet dyeing machine for the "Nitro"-process of sulphur dyeing.

I. Dyeing of cellulose fibres:

a) Exhaust dyeing. Normal types: observe the manufacturer's details precisely. Additions of sulphur sodium and salt vary depending on the dye, as does the dyeing temperature. Modified types: partly reduced and leuco forms behave like normal types during dyeing. Additions of reducing agents can be reduced. Thiosulphuric acid derivative types have no affinity; this occurs only when sodium sulphide or sodium sulphydrate are added, through reverse transformation to the mercapto form. Baths with sulphydrate are less alkaline, which has a favourable effect on the handle of dyed goods, this being particularly important in the dyeing of regenerated cellulose fibres (cupro, viscose). Instead of sulphide, glucose can also be used as the deoxidant. However, it must be noted that the dyeing must then take place in a closed system at a minimum of 90°C, since glucose can only develop its reducing characteristics under these conditions. A further reduction of the sulphur content in waste water is possible through the choice of low-sulphur dyes, but their substantivity to cellulose is less than that of normal sulphur dyes. This situation is solved in terms of process engineering in that after dyeing, before oxidation, the dye liquor with the low-sulphur dyes is cooled to at least 60°C before the rinsing process is started.

b) Pad dyeing method. Normal types: the preparation of dye solutions is so laborious that liquid sol types are preferred for this process. An important method for this is the pad-steam method: padding with dye, intermediate drying, padding through polysulphide solution, steaming, rinsing, oxidation and rinsing again. Further possibilities are provided by the thiosulphuric acid derivative types: in the pad-roll, cold dwell and thermosetting methods.

II. Dyeing of wool and silk: sulphur dyes have not found practical use for either wool or silk. Lowering the dyeing temperature and adding fibre preserving agents do not entirely prevent poor handle and fibre damage.

III. Nitrogen inerting during sulphur dye application: The "Nitro" exhaust dyeing process (Fig. 1) utilises nitrogen, one of nature's most abundant and inert elements, in order to minimise the amount of chemical reducing agent required for the application of sulphur dyes.

Nitrogen makes up 78% of the air and is used in a number of industries to protect various materials from the detrimental oxidative effects of atmospheric oxygen. For example, nitrogen is used in packaging by the food and beverage industry, for the preservation of coffee, snack foods, juices and wine. Controlled atmosphere technology employs nitrogen to maintain the freshness of fruits and vegetables during storage and transportation.

Oxygen in the air hinders at the chemical reducing system in the dyebath lowering the stability of the "leuco" dye and thereby increasing the likelihood of premature oxidation leading to bronzy unlevel dyeing. As in the case of vat dyes, excess reducing agents are generally required to avoid these problems. By simple inerting methods, the "Nitro" process purges the dyeing vessel of atmospheric oxygen and thus decreases the amount of chemicals required for dyestuff reduction. The nitrogen purging process can be implemented for as little as $0.0025/lb. of fabric dyed while reducing chemical cost by approx. $0.03/lb. as compared to many Sandozol RDT type applications. The decrease in chemical usage leads to lower BOD and COD loads while nearly eliminating sulphides in the waste

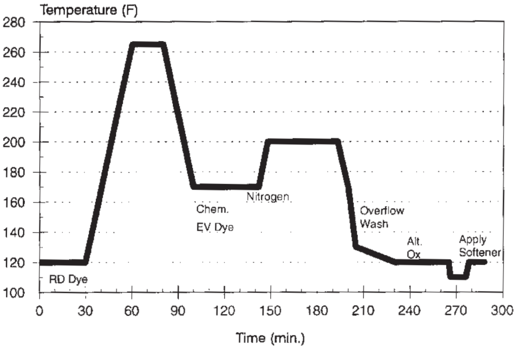


Fig. 2: Diresul Black 4G-EV-Jet application: Foron RD/ Diresul EV 1 bath, 2 step dyeing procedure.

streams. In addition to chemical cost savings and minimal environmental impact, the "Nitro" application process utilises fast chemical and dye additions as well as rapid heating rates to cut as much as 1 hour 15 min off typical classical sulphur dyeing cycles (Fig. 2).

Sulphur dyeing from standing bath Even with salt, sulphur dyes exhaust only incompletely, which is why in the case of deep shades, one usually works with standing baths. Analysis of the cooled liquor by spindling with areometers. Experimental values for medium dyeings up to 3–4° Baumé, for dark ones up to 5–6° Baumé, and for black liquors up to 8° Baumé.

Sulphur dyeings (black)-storage stability testing Moisten a dye sample of at least 10 g with as small an amount of distilled water as possible (beaker), centrifuge, dry at 90°C (drying chamber), moisten again and then continue in this way (repeat the whole procedure 10 times). Then place the sample in cold water and boil for 30 min (replace evaporation loss), take out, add barium chloride solution to the water used for boiling; any clouding which occurs indicates sulphuric acid ions, and thus endangered storage stability.

Sulphur dyes Due to its favourable price, combined with good fastness of dyeing (exception: fastness to chlorine), this class of dyes is still of great importance, despite the environmental problems associated with the dyeing method. The range of dyes covers, above all, muted shades; more lively colours are missing, particularly red shades. Manufacture of sulphur dyes through fusing together elemental sulphur and aromatic compounds containing nitrogen, or boiling them with polysulphides in water or solvents. Usually, this results in mixtures of various products, or more rarely well-defined compounds. The reaction mechanism is not clear in every case, nor is the precise constitution. Sulphur dyes are insoluble in water and are dissolved through alkaline reduction with sodium sulphide or sodium dithionite and caustic soda, the so-called sulphydryl form, generally also called the leuco form (principle: $=C=O \rightarrow \equiv C{-}OH \rightarrow \equiv C{-}SH$). The sodium salt which forms ($\equiv C{-}SNa$) goes onto the fibres and is once again fixed, water-insoluble, on the fibre through subsequent oxidation. With sulphur dye types as dyes which had already been partly or wholly reduced, and mixed with dispersants and stabilisers (so-called sol types), laborious dissolving was no longer necessary. Sol types are on the market mainly in liquid form. These types were followed by the thiosulphuric acid derivatives (→ Bunte salt dyes) as the non-affinity form, which only goes onto cellulose after the addition of sodium sulphide or sodium sulphydrate.

Sulphur dyes, field of application Of great significance for cheap staple goods or heavy fabrics of cotton in muted shades (Manchester, velvet, rucksack fabric, tent fabric, lining materials, apron materials, work clothing, etc.) which are fast to washing, light and abrasion. Of less importance on regenerated cellulose fibres (losses in handle and lustre).

Sulphur dyes in printing Their use is restricted mainly to black brands. Printing paste similar to that for → Vat dyes.

Sulphur dyes in resist printing → Vat dyes in resist printing.

Sulphur oxyacids $H_2S_2O_3$ = thiosulphuric acid. Salts: → Thiosulphates ($Na_2S_2O_3$) as antichlor, for titrimetric analysis, etc. $H_2S_2O_4$ = (formerly) low sulphurous or hydrosulphurous acid, or (these days) dithionic acid. Salts: hypo- or hydrosulphides, these days dithionites ($Na_2S_2O_4$), as strong reducing agents. H_2SO_3 = sulphurous acid. Salts: → Sulphites (Na_2SO_3), hydrogen sulphites ($NaHSO_3$), as reducing agents. H_2SO_4 = sulphuric acid. Salts: → Sulphates (Na_2SO_4), hydrogen sulphates ($NaHSO_4$), potassium aluminium sulphate [$KAl(SO_4)_2$]. H_2SO_5 = oxysulphuric acid, peroxy(mono) sulphuric acid (→ Caro's acid). $H_2S_2O_8$ = poly- or persulphuric acid, peroxydisulphuric acid; salts: → Persulphates ($K_2S_2O_8$), as oxidation agents. $H_2S_{2(-5)}O_6$ = polythionic acids.

Sulphuric acid (oleum), H_2SO_4. Molecular weight 98.04. Salts: sulphates. Thick, oily liquid; colourless to weak brown colour, odourless, highly corrosive to the skin (wounds difficult to heal), highly hygroscopic (store well sealed); strong acid, displaces (due to its being not easily volatilised) most other (more volatile) acids from their salts; dissolves metals (with hydrogen formation). When sulphuric acid is diluted with water, always add the sulphuric acid slowly into plenty of cold water in a thin stream and not the reverse; heating (up to 120°C) , sometimes explosive spraying around. Used for: carbonisation; wool dyeing (besides sodium sulphate); developing of leuco vat ester dyes; frequently for acidifying (particularly in bleach); as accumulator acid (20–30%), etc.

Sulphuric acid solubility test,

I. In cold concentrated sulphuric acid, the following are soluble: natural silks, cellulose fibres; acetate, triacetate, polyamide, polyurea, polyester, polyacrylnitrile fibres; some modacrylic fibres, polyvinyl alcohol fibres, polyurethane fibres, rubber threads. Insoluble: wool; casein, PVC, polyvinylidene chloride, polyethylene, polypropylene, polytetrafluor ethylene fibres.

II. In boiling concentrated sulphuric acid, the following are soluble: wool; natural silk; cellulose, acetate, triacetate, casein, polyamide, polyurea, polyester, polychloride, polyacrylonitrile, copolymer, PVC, polyvinyl alcohol, polyethylene, polypropylene, polyurethane fibres; rubber threads. Insoluble: polytetrafluor ethylene fibres.

Sulphurized phenols → Fat-free aromatic products.

Sumach Products containing tanning agents, ground leaves of varieties of rhus, or viscous light brown solution of 20–36°Baumé (= sumach extract), also solid mass. Originates from southern Europe. Tannin content 18–28%. Used as a tanning agent similar to → Tannin; for weighting silk.

Summation parameters Textile waste water can contain a large number of different substances which are alien to water; these include inorganic substances, e.g. neutral salts such as sodium chloride, but also heavy metal ions and – not least – ions from sulphur chemistry, such as sulphide, sulphite and sulphate, which frequently occur as secondary products of reducing agents. These inorganic substances can usually be identified and determined at reasonable expense using classical methods. However, for the analytical characterisation of the numerous organic individual substances in the waste water, one of the so-called summation parameters are frequently used (→ Waste water evaluation).

Organic water pollutants consist of numerous individual substances which can be determined only at considerable expense, if at all. The advantages in using summation parameters lie in considerable savings in work and costs, but the corollary disadvantage is undifferentiated information.

Some of the important summation parameters for assessing waste water are:

- → TOC: total organic carbon. Method: combustion analysis.
- DOC: dissolved organic carbon.
- COD: → Chemical oxygen demand. Method: oxidation with dichromate.
- BOD: → Biochemical oxygen demand. Method: biochemical oxidation.
- → AOX: Adsorbable organic halogen. Method: adsorption on carbon, combustion, determination of HCl or HBr.

Provided below is a list of the most important determination regulations for summation parameters, adherence to which in accordance with the DIN standard is to be regarded as relevant in relation to water analysis from textile areas. The expenditure on measurement and the measurement methodology is not discussed here.

– pH	[1]
– determination of acid and base capacity	[2]
– Suspended matter	[3]
– chemical oxygen demand (COD)	[4]
– biochemical oxygen demand (BOD)	[5]
– determination of halogen compounds (adsorbable organic halogen: AOX; purgable organic halogen: POX; extractable organic halogen: EOX)	[6, 7]
– carbon (total organic carbon, total inorganic carbon, total carbon)	[8]
– total nitrogen, phosphorous, sulphur	[9]
– heavy metals content	[10]
– hydrocarbons and aromatic compounds	[11]
– surfactants	[12]
– colour	[13]
– toxicity to fish	[14]
– other substances which pollute waste water	[15]

[1] DIN 38 404–C-5.
[2] DIN 38 409–H 7-1-1; 38 409-H 7-1-2.
[3] DIN 38 409–H 9-2; 38 409–H 10, (“sedimentary substances”).
[4] DIN 38 409–H 41-1; H 43-1; (“chemical oxygen demand”).
[5] DIN 38 408–H 51 (“biological oxygen demand”).
[6] DIN 38 409–H 14, 1985, “Determination of adsorbable organic halogen (AOX)”; DIN 38 409–H 25 (POX); DIN 38 409–H 8, (EOX).
[7] DIN 38 407, part 4, “jointly detectable substance groups (group F), determination of volatile halogenated hydrocarbons (1984)”.
[8] DIN 38 409–H 3-1, (“total organic carbon, TOC”).
[9] DIN 38 405–D 10 (“nitrite”), DIN 38 405–D 19 (“nitrate”), DIN 38 406–E 5-1 (“ammonium”), DIN 38 409–H 11 (“organically bound nitrogen”), DIN 38 405–D 19 (“sulphate”), D 11-4 (“phosphorous, total”), D 26 (“sulphide, dissolved”), D 19 (“sulphite”).
[10] DIN 38 406–E 1, (“iron”), E 8 (“zinc”), E 9 (“aluminium”). E 19-2 (“cadmium”), E 12-3 (“mercury”), E 21 (“lead, total”), E 22 (“chromium, total; copper, total; nickel, total; tin”), DIN 38 405–D 18 (“arsenic, total”), D 24 (“chromate”).
[11] DIN 38 409–H 18 (“hydrocarbons”), DIN 38 407–F 9-2 (“benzene and homologues”).
[12] DIN 38 409–H 23-1 (“anionic surfactants, non-ionic surfactants”).
[13] DIN 38 404–C 1-1.
[14] DIN 38 404–L 31 (“toxicity test”), L 30 (“daphnia toxicity”).
[15] DIN 38 409–H 16-2 (“total phenols, phenol index”), DIN 38 405–D 4-1 (“fluoride”), DIN 38 409–H 15 (“hydrogen peroxide”).

As summation determination, these methods are largely sufficient for monitoring adherence to the limit values which are required by law. However, they cannot make meaningful statements about which chemical type leads to the measurement result, i.e. it is not possible to trace back to a process stage the cause of the pollution of the waste water. The methods listed are to some extent very time-consuming, and not suitable for in-line or on-line process monitoring. Further methods for identifying and characterizing pollutant substances are essential. Determination of the summation parameters does not permit any statements about the possibilities for specific removal of any pollutants. Only the use of specific methods of analysis enables a diagnosis of which stage of a production sequence results in pollution of exhaust air or waste water. (according to Schollmeyer).

Sunflower pectin as thickener The pectin obtained from sunflowers is of interest for technical purposes on account of low prime costs. For printing with dispersion, acid and reactive dyes, sunflower pectin with a finishing level of 33% and a uronic acid content of 73% can be used rheologically. When flowing, sunflower pectin solutions behave as non-Newtonian liquids with plastic-pseudoplastic viscosity in a broad span of speeds and transverse stress. At concentrations of over 5%, solutions lose their flowing properties and convert into gels. The apparent viscosity has a negative temperature coefficient, and reduces with storage time. Neutralization lowers viscosity.

Sunn fibre South Asian → Bast fibres, water-retted, coarse and hard. Used for cords and ropes.

Superabsorbers → Absorbent compounds such as highly absorbent polyacrylate powders, can be used in the hygiene sector for the absorption of wetness which occurs suddenly (see Fig.).

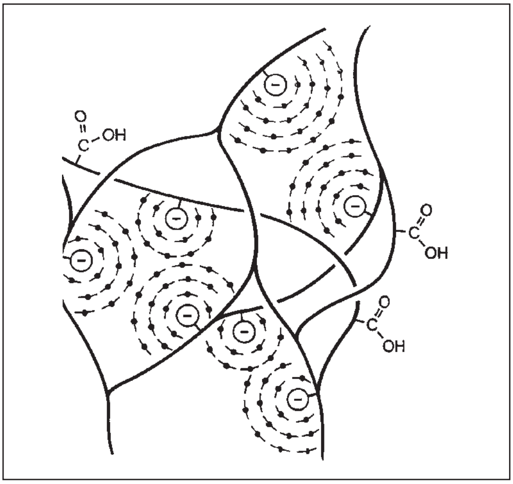


Fig.: Structure of a superabsorber (Favor-Hydro-Gel).

Supercontraction Shortening of (e.g.) fibres to less than their original length (see Fig.). Can be reversible or irreversible. In the case of keratin fibres, it is based on the splitting of cystine and hydrogen links. The starting points for the various theories concerning the chemical reactions which occur during fixing are based on the observations by Astbury and Woods (1933). They investigated the behaviour of wool fibres which were stretched by 40%, exposed to steam for varying lengths of time, and then relaxed in steam. If the steaming time in the elongated state was less than 15 min, after 1 hour's relaxation in steam the fibre shrank to a length which was shorter than its original length. Astbury and Woods called this phenomenon supercontraction. In the case of a steaming time of more than 15 min, after relaxation the fibre length was longer than the original length. This phenomenon was termed permanent setting.

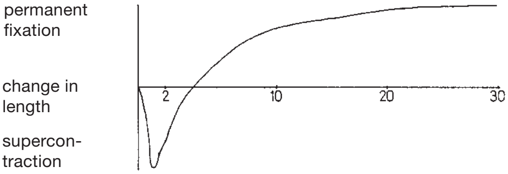


Fig.: The change in length of wool fibres, which have been stretched by 40%, following immersion in steam and subsequent relaxation in steam (according to Astbury and Woods).

Astbury and Woods explained supercontraction and permanent setting as follows: When boiling water or water vapour act on a stretched wool fibre, they quickly break up the links which stabilise the unstretched state, because they are under tension as a result of elongation. If the fibre is relaxed at this stage, then the remaining stabilising links are no longer sufficient to maintain the unstretched state; the fibre contracts to less than its original length. If the steaming time in the elongated state is extended, new crosslinks form, which stabilise the elongated state. With increasing steaming time, the stabilising crosslinks predominate, giving rise to permanent setting. However, Astbury and Woods did not state which crosslinks might be involved in the setting mechanism.

In 1936, J. B. Speakman proposed a theory of the chemical mechanism of wool fixing. Following his experiments, in which he investigated the influence of water, steam, alkalis and reducing agents on the setting of wool fibres, he concluded that the disulphide links are split by the action of steam:

$$R{-}S{-}S{-}R + H_2O \rightarrow R{-}SH + R{-}S{-}OH$$

Through this splitting, the wool fibre becomes capable of being deformed, because stabilising crosslinks between the individual polypeptide chains are eliminated. The setting of the fibre takes place via new stabilising cross-links between the sulphonic acid residue which is formed during splitting, and free amino acids.

Supercritical systems Certain gases such as CO_2 or NH_3 whose normal boiling points lie at low temperatures (e.g. NH_3 at –33.4°C) can, through compression at high pressures (p_k 111 bar, critical density 0.24 g/cm^3 for ammonia), assume relatively low viscosities which are comparable with gases.

In the Fig., pressure p_E, at which liquefaction begins, is the vapour pressure. According to the second law of thermodynamics, the areas above the line CDE and below the line ABC must be equal. If for each isotherm, in each case the points E at the beginning of liquefaction of the gas and the points A for the end of liquefaction are connected to one another, then the result is a range within which a conversion from the gaseous phase to the liquid phase takes place (shaded zone in

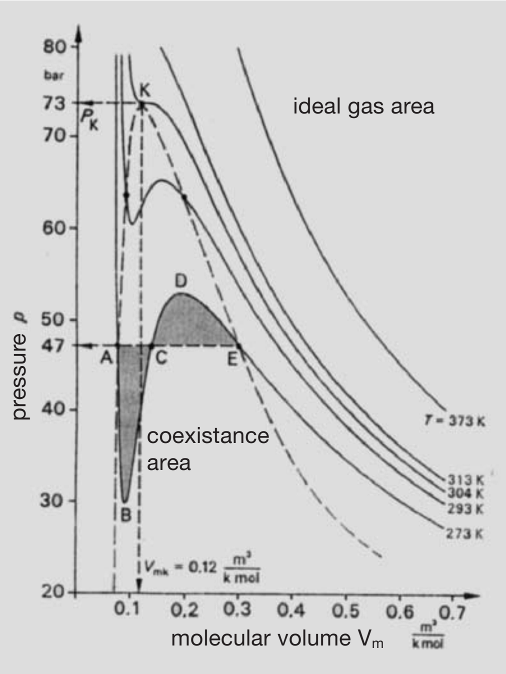


Fig.: Isotherm progressions for carbon dioxide in the p,V diagram.

the Fig.). To the left of this area there is only the liquid phase, and to the right, the gaseous phase. In the coexistence zone, both phases are present. In the case of water, these zones are: superheated steam (pure gaseous state), dry saturated steam (binodal curve) and wet steam (within the liquefaction zone). The highest steam pressure point is the critical point K. The corresponding temperature is the critical temperature T_k. This is the turning point of the corresponding isotherms. The corresponding values are the critical pressure p_k (for CO_2, p_k = 7.38 MPa) and the critical volume V_k (for CO_2, V_{mk} = 0.1275 m^3/kmol). Above point K, liquefaction solely through compression (smaller volume and higher pressure) is not possible.

In the development of environmentally friendly finishing processes in the textile industry, using supercritical carbon dioxide, essentially only the solvent characteristics of the supercritical fluid are exploited (e.g. in the dyeing of polyester with dispersion dyes from supercritical CO_2). However for some applications, for example in pre-treatment, a supercritical system should be chosen which itself has a chemical reactivity. The critical data for ammonia lies in a technologically manageable range, so that it can be used as a reactive and simultaneously solvent medium. One could expect that, for example, with waxes and lignin constituents, ammonolytic reactions could be achieved, which would lead to easily soluble (i.e. extractable) products. Beyond that, structural changes in cellulose towards mercerization effects are conceivable. (according to Schollmeyer).

Superheat Specific heat of → Steam at constant pressure and superheat temperature, less the saturated steam temperature.

Superheated steam → Steam.

Superheated steam dyeing Continuous dyeing of woven cotton fabrics with reactive dyestuffs is normally carried out by either a pad-dry chemical pad steam or pad-dry-thermofix process. In both cases the dye liquor is applied in a pad trough, and the fabric passed through the padder. Infrared driers are used for predrying and hotflues for final drying. Fixation of the reactive dye is then achieved by a second stage of chemical padding or steaming or a further hotflue treatment of thermofixing (Fig. 1). The pad-steam route is a difficult process to control. In both these processes, to ensure high quality dyeing results (level appearance, no side-to-centre shading, no two-sideness), the dyeing dryers or hotflues work with low-intensity air circulation. Drying and thermofixation take place in an air atmosphere.

The Babco-Therm drier developed by Babcock is a superheated-steam drier. It continuously dries and fixes dyed cotton fabrics in 100% superheated-steam atmosphere. As can be seen from Fig. 2, as the fabric enters the drier it is heated to 100°C dew-point temperature within 1 second by condensation of the superheated steam. Unlike air drying, the drying here takes place at this temperature of 100°C. Thanks to the constant

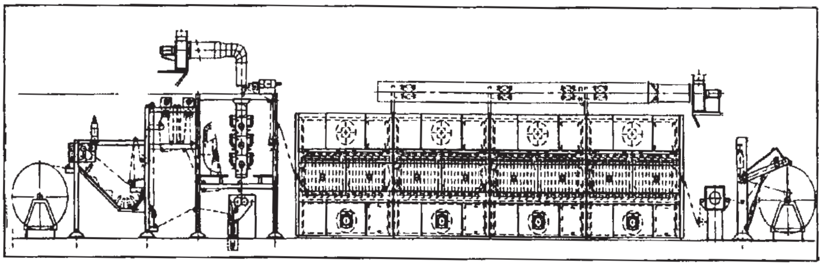


Fig. 1: Conventional pad-dry-thermofix range with infrared drier and hotflue.

Superheated steam in the print steamer

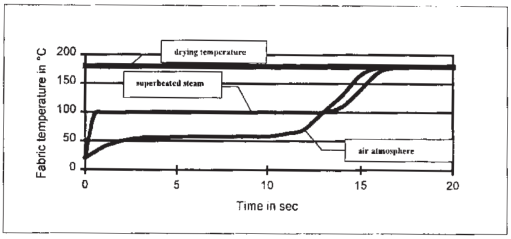


Fig. 2: Fabric temperature curves for air drying and superheated-steam drying.

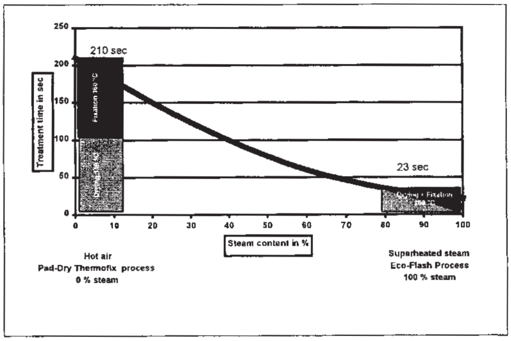


Fig. 3: Correlation between treatment time and steam content.

high temperature of the fabric, dyestuff fixation proceeds so quickly that the process takes place in parallel with the drying process and is completed by the end of the drying process. The correlation between total treatment time and steam content is shown in Fig. 3. Drying and fixation are reduced from 210 s. in air drying with the pad-dry thermofix process to 23 s. in superheated steam drying, the so-called Eco-Flash process. This process (Fig. 4) was developed in co-operation with BASF. The significant reduction in treatment time to around 20 s. as a result of the new process is of great importance for process management, production costs, etc. Special mention must also be made of the reduced tendency to migration.

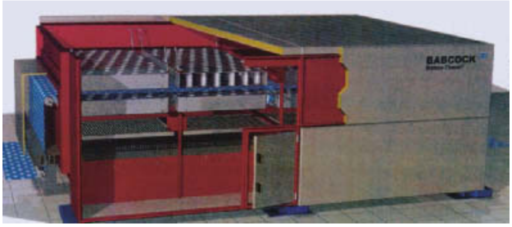


Fig. 4: Inside of the Babco-Therm.

Superheated steam in the print steamer This is 100% water vapour at an atmospheric pressure of 1 bar and a temperature of over 100°C. This steam is not saturated.

In the steamer, the dry and cool goods are heated up rapidly to 100°C through the superheat energy of the steam and the condensation heat which is released.

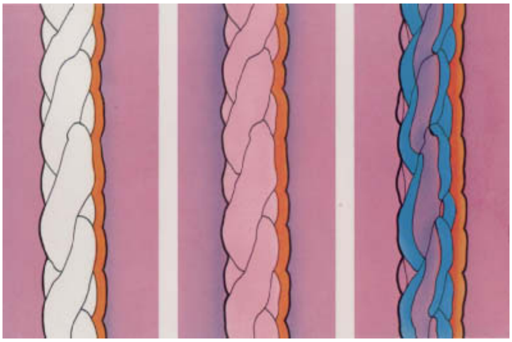


Fig. 1: The warming-up phase: the result of condensation from the steam onto the substrate during its entry into a steamer (by Babcock).

Then the excess condensation evaporates (the evaporation speed is determined by the degree of superheat of the steam), with the temperature remaining constant, until the moisture content of the printed goods has reached an equilibrium with 100 % relative humidity at a temperature of 100°C (Fig. 1). Only then does the temperature rise, with the dampness of the goods decreasing, until the set fixing temperature is reached (Fig. 2). The dampness of the goods is then in equilibrium with the absolute humidity of the setting atmosphere. Once the goods have reached the temperature of the fixing medium, which is rapidly the case under the influence of steam, the setting phase has been reached. No hard and fast boundaries can be drawn between the heating and setting phases. In almost all cases, these two phases will overlap.

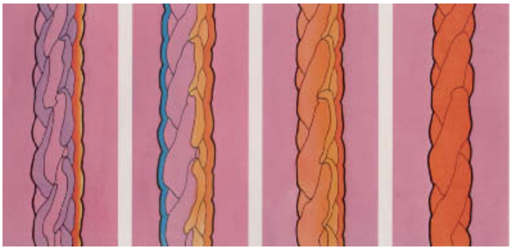


Fig. 2: The fixation phase: both the humidity and the temperature of the goods are in balance with the analogous parameters for the steam (by Babcock).

Superimposed yarn layer Bonded yarn fabrics which are arranged randomly or deliberately.

Supermicrofibres The so-called supermicrofibres are finer than → Microfibres by a power of ten; supermicrofibres are obtained by dissolving out the polyester "islands" in "islands in the sea" technology (see Fig.).

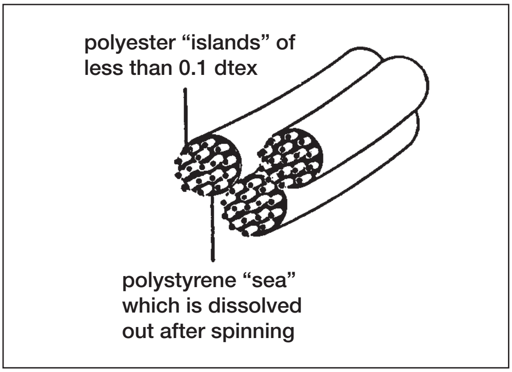


Fig.: "sea island" technology for producing super microfibres (0.1–0.3 dtex).

Superpolyamide fibres Carothers (the inventor of the polyamide 6.6 fibre), used this name to denote all fibre-forming polyamides with a molecular weight over 10 000.

Super-Sat system In the impregnation device developed by Babcock, the reduction of the liquor content is achieved by means of a liquor nip between the goods and the deflecting roller (see Fig.). The liquor is fed into the nip, with sufficient excess and distributed evenly over the width. Through the excess pressure in the liquor, which arises when the goods travel around the deflecting roller, the liquor is forced through the goods. This takes place by guidance of the goods, once from the reverse and once from the right side of the goods. This way, despite the short contact time, intensive liquor exchange is achieved. There is no longer any need for a penetration section following on from impregnation. This in turn enables the combination of the "Super-Sat" system with various steamers as reaction chambers. As a result of the low liquor content and the rapid liquor turnover which results, the goods can flow from the hot pre-wash into the impregnation unit, without cooling. Heating the liquor encourages its penetration into the fibre, but as a result of the rapid liquor renewal, this causes auto-decomposition of the liquor. The fabric can be loaded with liquor to between approx. 100% and its maximum carrying capacity. The amount of liquor carried along can be limited by means of a squeezer mechanism, a laying-on roller or a doctor blade. The excess liquor which is not taken up by the goods in the liquor nips is fed back, by a manually operated or automatic filter, into a small liquor collection vessel, and from here it is pumped back into the unit. Also, the liquor which drips off the goods on the way to the steamer and in the steamer inlet is fed back to the liquor collection vessel. No chemicals are lost. The level in the liquor collection vessel is kept constant through controlled addition of fresh water. The impregnation liquor is mixed and diluted in a mixing vessel through which the fresh water and a partial flow of the recirculated liquor is directed. The desired concentration, related to the weight of goods put through, is achieved by means of a dosing device. Manuf.: Babcock.

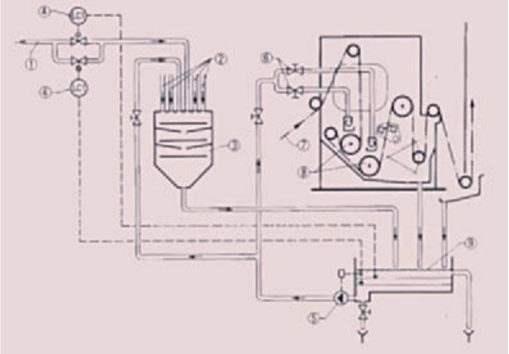


Fig.: Diagram showing the function of the "Super-Sat" system (Babcock).
1 = fresh water; 2 = chemical solutions; 3 = mixing vessel; 4 = level regulation; 5 = circulation pump; 6 = quantity setting valves; 7 = goods; 8 = impregnation roller; 9 = lint filter.

Superwash A quality term defined by the International Wool Secretariat (IWS) for wool articles which have been finished to be resistant to machine washing. These articles must fulfil certain conditions in relation to their fastness to light and wetness, relaxation shrinkage and felting shrinkage. Articles which conform to the Superwash standard (Tab.) can be washed in any washing machine at up to 40°C without suffering any impairment to their appearance, handle or dyeing.

In the class of possible care labels (see Fig.), truly felt-free woollen articles are only those which have the term Superwash added to the wool seal.

Superwash process Synthetic resin-based finish for felt-free and low-shrinkage wool articles, which enables the → Superwash standard to be fulfilled. The basis is the IWS-CSIRO chlorine/Hercosett process and the Dylan GRB and GRC processes. In comparison with the oxidative methods, based on synthetic resins a felt-free effect is achieved which was previously unobtainable without impairment of the fibre characteristics (→ Antifelting finish). The designation Superwash ap-

Property	Test method	Minimum requirement
lightfastness	spec. 3, appendix 1	rating 4, pastel shades rating 3
washing fastness	193	shade change rating 3–4 bleeding on ®Hercosett wool rating 4 bleeding on cotton rating 3–4
excepting piece dyers	193	shade change rating 3 bleeding on ®Hercosett wool rating 3 bleeding on cotton rating 3
fastness to perspiration (exclusively for patterned products)	174	shade change rating 3–4 bleeding on ®Hercosett wool rating 4 bleeding on cotton rating 3–4
relaxation contraction		length max. 10 %, socks 15 %
single jersey	9	max. width expansion 5 %
double jersey (excepting hand-knitting yarn)	186	length 5 %, width 5 %
felting contraction	185	single jersey area max. 10 % socks length max. 5 % double jersey area max. 5 % 180 min, 15 L Cubex
hand knitting yarn	192	area max. 10 %, 180 min, 15 L Cubex

Tab.: Obligatory specifications for Superwash knitted fabrics and hand-knitting yarns.

Fig.: The relationship between the care symbols and the additional information supplied beneath the woolmark for pure virgin wool (reading from lower right to upper left, the quality increases up to nonfelting wool in washing).

plies to all woollen articles which conform to the IWS machine washing test conditions, regardless of what method was used to achieve the effect. Since the trend is increasingly away from dry cleaning towards washing, Superwash finishing for trousers is gaining in importance.

Suppleness Suppleness is a characteristic property of a material; the opposite characteristic is brittleness. The suppleness resp. brittleness of a material is dependent, among other things, on the transverse strengths of a material. →: Knot breaking strength; Loop breaking strength; Torsional strength. Flexurally limp fabrics are very supple.

Supramolecular structure of polymers Synthetic fibres exist in the glass state and – depending on their previous thermal history and the acute temperature – represent viscoplastic, plastic or highly viscous supercooled melts. Their textile mechanical or dyeing behaviour depends heavily on the supramolecular structure of the polymers, large numbers of which form layers together to form the fibre. There are notional models of the supramolecular structure, which result from various physical-chemical measurement methods. The older notion of the “fringed micelle” has been superseded by the model of chain folding over and the notion of the crystal with statistically distributed imperfections (→ Structural models for man-made fibres).

Fig. 1 shows a schematic 2-dimensional representation of the supramolecular structure of oriented polyester after crystallisation at high and low temperatures (tempered). In principle, the non-crystalline areas are made up of the following types of chains (see Fig. 2): chains which connect the crystallites (t_1, t_2), those with

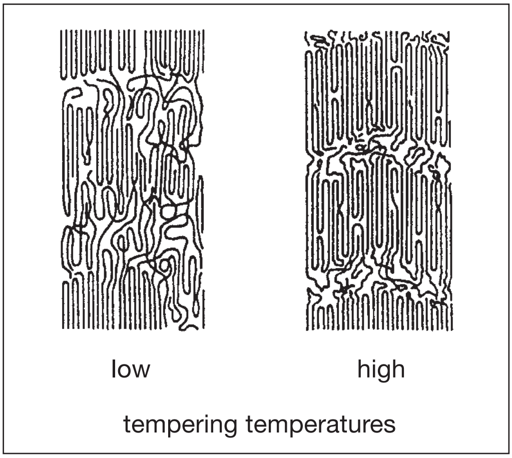


Fig. 1: Schematic illustration of the structure of oriented polyester after crystallisation at different temperatures (according to Fischer and Fakirov).

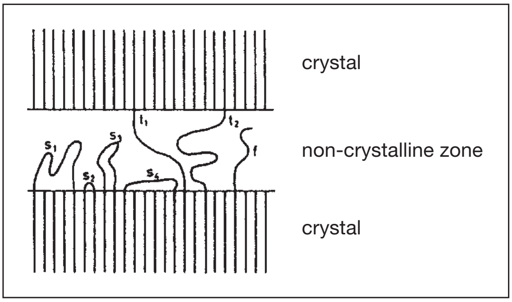


Fig. 2: Schematic illustration of the different chain types of the non-crystalline zone.

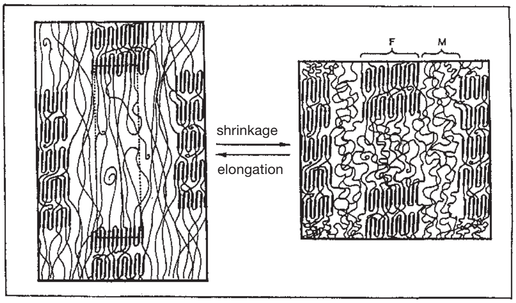


Fig. 3: Model presentation of the structure of synthetic fibres in the stretched and shrunken state (according to Berndt). F = fibrils (molecule chains arranged in crystalline and non-crystalline layers); M = matrix (continuous molecule chains only partially crystallised).

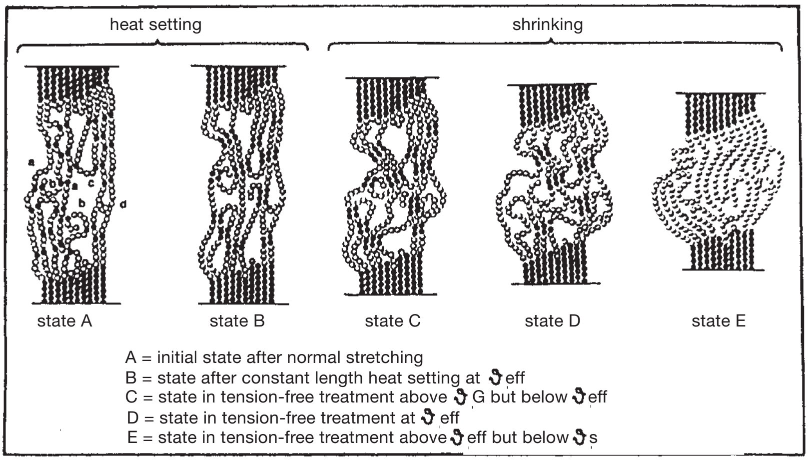
a free end (f) and loops (s_1–s_4), with the borderline case of sharp folds being included.

The fibre structure model shown in Fig. 3 provides a schematic representation of the arrangement of the molecule chains in the fibre interior in the stretched and shrunken state. Since the long period of a fibre, i.e. the main focal distance between the crystal layers, does not change analogously to the fibre in the shrunken state, it must be assumed that for most synthetic fibres, the fibre structure model shown in Fig. 3 applies. According to this, a synthetic fibre can be thought of in structural terms as a matrix (M) with more or less well-ordered molecule chains running in a longitudinal direction, integrated into which are fibrils (F) in which molecule chains run through crystallised and non-crystallised regions in layers. Shrinkage of up to 50%, which can be reversed again by stretching, can be explained by the convolution of chain molecules in the matrix between the fibrils.

Fig. 4 illustrates the synthetic fibre structure in the bead model according to Berndt. The crystalline layers of the fibrils are symbolised in the model by black beads, whilst the white ones represent non-crystalline areas. Directly after fibre manufacture, in general, state A pertains: the molecule chains, which in the melted mass are present in the convoluted state and which is more favourable in terms of energy, are oriented during spinning and stretching. Besides the relatively large and thus stable partially crystallised fibrils, crystallites which are less thermally stable also form in the matrix. Furthermore, the majority of the tensions applied during stretching are blocked by freezing of the chain movement.

State B describes a thermoset fibre after length-constant thermal treatment and cooling. In the case of fixing, generally no uniform crystal size spectrum forms, since the stable crystallites remain preserved and the relatively high cooling speed as well as the tensions acting from outside prevent place-changing processes in the molecule chains, through which distorted crystallites with low thermal stability also arise.

States C to E illustrate the current state of the set



A = initial state after normal stretching
B = state after constant length heat setting at ϑ_{eff}
C = state in tension-free treatment above ϑ_{G} but below ϑ_{eff}
D = state in tension-free treatment at ϑ_{eff}
E = state in tension-free treatment above ϑ_{eff} but below ϑ_{s}

Fig. 4: Model presentation of the change in state of the non-crystalline fibre proportion between the fibrils in heat setting and in thermomechanical analysis (shrinkage measurement) according to Berndt.

specimen (B) in the case of tension-free treatment with successively rising temperature.

State C shows clearly that where the transformation temperature is exceeded, the chain segment movement increases, through which the blocked restoring forces in the molecules are released. The molecule chains aim towards the convoluted state, which is more favourable in terms of energy, and which is associated with place-changing processes for the chain segments, i.e. with material shrinkage. With further temperature increases, these place-changing processes proceed further, until the fibrils and the cross-linkage points formed during setting prevent further shrinkage.

In state D, the crystallites which are initially less thermally stable during further heating are melted open, and the tensions which were blocked are released. The result is renewed shrinkage.

In state E, the heating process is continued with a rate of heating which lies above the speed of crystallisation, through which the thermally more stable cross-linkage points are also dissolved. The material between the fibrils can become disoriented and tend towards optimum convolution. In this state, only the crystalline layers in the fibrils prevent deliquescence of the fibre, which is finally reached after the fibre-specific melting temperature ϑ_s has been reached. (according to Schollmeyer and Berndt).

Surface active compounds Chemical compounds which are dissolved or dispersed in a liquid, and are preferably absorbed at a boundary surface. The molecule of these compounds has at least one group which effects an affinity to surfaces with an expressed polarity, through which the solubility in water is limited, as well as a residue which has little affinity to water. The products which are used in practice are mostly mixtures of such compounds (→ Surfactant).

Just as at the water/air and water/oil interfaces, the surface tension at the water/solids interface also is lowered through the absorption of surfactants which are dissolved in the aqueous phase. The solid/liquid interfacial surface tension cannot be measured directly, but the lowering of it, which is caused by surfactants, is expressed in the effect on wetting (→ Wetting process). Since a wetting process is equivalent to the formation of a solid/liquid interface instead of a solid/gaseous interface, this process is encouraged by a lowering of the solid/liquid interfacial surface tension. In the specific case of a drop of liquid lying on a flat solid surface, this can easily be shown using Young's equation, which places the spontaneously occurring wetting angle in relation to the interfacial tensions which are present in the system (see Fig.).

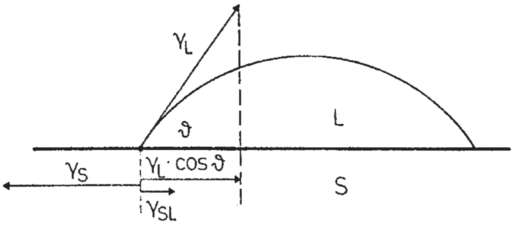


Fig.: Explanation of Young's equation of interfacial tension.

$$\gamma_S - \gamma_{SL} = \gamma_L \cos \vartheta$$

γ_S and γ_L are the surface tension of the solid S or the liquid L, whilst γ_{SL} stands for the interfacial surface tension between S and L. If the liquid is water and a surfactant is dissolved in it, then γ_L and γ_{SL} are lowered by the adsorption of the same, whilst γ_S remains unaffected. From the equation, it can be seen that the wetting angle thus becomes smaller. This can lead to the situation where $\vartheta = 0$, and the liquid thus spontaneously spreads over the surface.

Surface active detergent Within a detergent or washing powder, the pure organically active components: → Detergent raw materials or → Soap (→ Surfactant). The proportion of a surface active ingredient is given in %; e.g. 30% pure alkyl-aryl-sulphonate or alkyl-sulphonate or aliphatic alcohol sulphonate, etc. Although the presence of surface active ingredients plays an important part in the effectiveness of → Detergent it would be a mistake to judge a detergent in practical or even theoretical terms according to this aspect alone. Significant differences exist between surface active ingredients derived from the same group of substrates. Further, the mixing of surface active ingredients may result in a synergistic improvement in the washing performance of the individual components, or conversely a decline in the washing performance. Finally, other components (→ Builders) in particular may produce an improvement in performance. Objectively conducted washing or cleaning investigation with → Soiling test is decisive in arriving at a comparative assessment of value.

Surface activity Characteristic of → Surfactant, which occurs at the interfaces of two phases. → Capillary activity.

Surface analysis Strictly speaking, the surfaces of textiles represent 3-dimensional formations, with a thickness of a few nm, which is sufficient for accommodating a few molecular layers. This surface also determines a range of characteristics such as wettability, adhesion, diffusion, bio-compatibility and optical characteristics such as lustre. Analytical methods exist for characterising these surfaces. → Photometer microscopy allows the analysis of fibre surfaces and fibre cross sections, and the detection of dyed or fluorescent substances on these surfaces, or of materials marked with fluorescent dyes. Thus the evenness of the distribution of polymer UV absorbers on the surface, or of polymer coating add-ons for wool with a Superwash finish can be analysed, just as the silicone or fluorohydrocarbon coating add-ons can. For measuring the size of the specific surface of materials, there is the Brunauer, Emett and Teller nitrogen absorption/desorption method, which also provides information about pore size distribution, e.g. depending on the pretreatment of the material. The → Scanning Electron Microscope permits visualisation of the surface, with high depth of field, and quite specifically permits determination of the scale edge height of keratin fibres. With the addition of energy-dispersive → X-ray fluorescence, electron microscopy also allows the detection of elements such as sulphur and chlorine, but also of heavy metals such as chromium on the surface. → Infrared spectroscopy, which provides detailed information on the chemical structure of compounds, can be carried out in a surface-sensitive technique, that of attenuated total reflectance. Thus in particular the effect of a bleach on wool fibre can be tracked kinetically. Using polarised infra-red radiation, information about the orientation of macromolecules in thin layers can be obtained. The method with the least depth of information is → X-ray photoelectron spectroscopy. It allows tracking of the decomposition of fatty acids bound in an ester-like manner on the surface of the wool, as well as the UV damage to the surface of the wool through the effects of weather, and the modification of the surface of the wool in the case of chlorine treatment compared with corona treatment. → Spectroscopy.

Surface batcher,

I. Used for the production of → Giant batch rolls, the drive for which operates tangentially at the periphery of the winding machine and thus, regardless of the size of the yarn package, ensures the same speed and tension of goods.

II. Winding device with the drawing roller, held in two swing arms, rising with increasing diameter of the yarn package. → Batching drives.

Surface energy, free Work which needs to be performed in order to structure the surface of a liquid isothermically or reversibly, or to enlarge it. The result is in the form of an increase in the free energy of the system. Expressed in joules. → Surface tension.

Surface finishing The fundamental construction of the handle and quality of fabrics is effected by working methods in wet finishing which are adapted to the type of goods. Dry finishing tasks, on the other hand, have to develop further the effects created by wet finishing, and complete them. It is only through the combination of wet and dry finishing that aspects (appearance and handle) and wearability of the finished goods are ensured. Although the operational sequence in dry finishing for achieving “needle readiness” of e.g. wool is fairly firmly associated with “shearing, pressing, shrinking, decatizing”, at least with the bare-finished worsted goods, which are important in terms of quantity, and gives rise to continuous line concepts, fashion influences nevertheless demand new process steps or other sequences in dry finishing. The goods can come into contact with dry finishing not just at the end of textile finishing; in pretreatment too, special surface finishing steps such as singeing, emerizing, brushing or roughening can be applied to the dry or wet goods, in order to shape the quality.

If one disregards singeing for the moment, then all aspects in the surface finishing of woven fabrics are achieved by means of mechanical influences on the fibres. If the results of shearing and roughening are perceived mainly by touch, then human beings register aspects which come about through pile rotation (lustre) or friezing primarily visually. If the skin is a sense organ for perceiving complex sensations such as the handle of goods, then when inspecting the surface, the eye perceives a certain surface with the aid of its two-dimensional matrix of light-sensitive elements. Through an irregular displacement of this area over the entire surface in rapid sequence, there arises in the optic nerve an assessment, based on comparison, of the evenness or unevenness of the surface of the textile. Here, the optic nerve acts as a complex computer, which can record certain structural features at high speed, and which conveys to the conscious mind strongly reduced data such as “matt, glossy, silky, sandy, grainy, rough, smooth, level, unsettled, with islands”, as designations for aspects. These visual perceptions are supplemented by the aspects perceived in a tactile manner by the skin (and possibly acoustically by the ears), such as “hard, soft, full, thin, limp, wiry”, etc., to form impressions of the goods, which are principally brought about by surface finishing. The fact that in the literature concerning finishing machines and processes no uniform sequence is to be found, is connected with the fact that individual work sequences (dry and wet treatments) overlap one another in multiple ways. The fabric, which is often used as a “guide” for arranging the treatment steps, sometimes passes through the same machine several times in different stages of its manufacture (e.g. in wet or dry roughening). The DIN 61 704 specification has therefore been proposed as a classification principle. In the case of the processes of providing aspects, which include e.g., wet brushing, this type of classification can result in problems. In the systematization of the finishing processes for woven fabric, the concept of surface finishing with mechanical means is therefore used only in the processing of dry goods (singeing, shearing, brushing, roughening, emerizing, pile rotation, friezing) (Fig. 1), whilst wet roughening and wet brushing are classified under fixing processes, since the inevitable drying process is important for the preservation (fixing) of the finishing effect of this fixing process.

Surface finishing

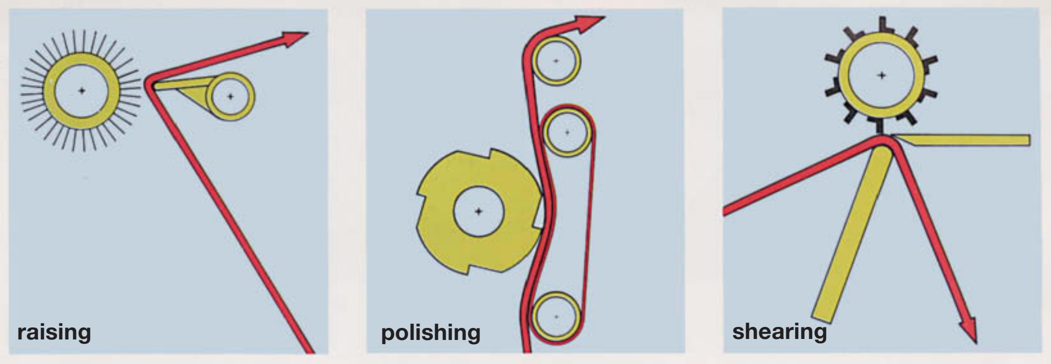


Fig. 1: A comparison of the processes for finishing surfaces by raising, rotary polishing and shearing (by SMH).

In the case of shearing, pile rotation and singeing, these are separation processes of individual fibres, whose countless macromolecules are split or slide past one another by the action of external mechanical forces and/or heat. In the case of a knife cut, the wedge surface of a blade forces the material "fibre" apart, as happens in practice e.g. when pile tubes, which are formed by the pile weft during weaving, are cut open to produce corduroy (Fig. 2). In the shearing cut, two blades are used, which move relative to one another (i.e. in absolute terms, one blade can be stationary). Shearing forces bring about the separation of the fibre material which is to be processed, with frictional energy occurring in the form of heat. In shearing, there is a separation into processed work piece and waste, through the flow of the material. In this way, the result is either a shortening of the projecting fibre pile of a woven fabric, or – in the case of improper work – a splicing of the fibres lying in the direction of the force which is applied. The situation for pile rotation is similar. With the aid of grooves which are milled into a rotating heated cylinder, fibres which rest tangentially on the pile rotor along their fibre axis, are very often caught, and therefore split and flattened (Fig. 3). This mechanical "flattening" of the surface of the woven fabric causes higher light reflectance, and thus lustre.

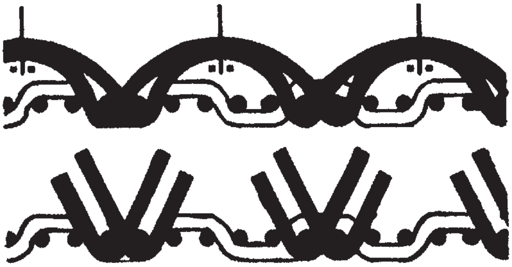


Fig. 2: Corduroy with V-ties.
above = not cut open; below = cut open.

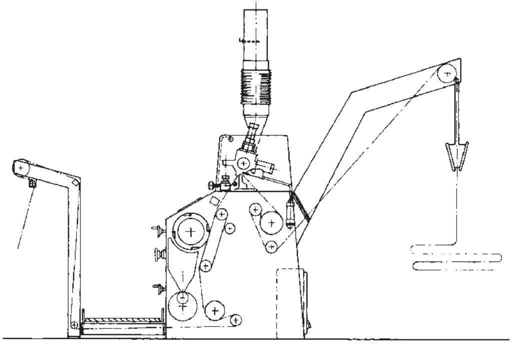


Fig. 3: A Sellers polishing and shearing machine.

Since fibres naturally burn relatively poorly, for singeing off fibre ends which project from the surface, high ignition temperatures have to be used, in the form of an open flame. On ignition, there is then briefly a chemical equilibrium between combustion (exothermal oxidation with flame formation through ignition of the gases which have occurred in the fibre interior through pyrolysis) on the fibre surface, and endothermic decomposition of the fibre substance (pyrolysis) in the fibre interior. In order to keep the flame out of the fabric body and restrict it to the projecting fibre ends, air has to be blown through the fabric against the flame, on account of the necessary high temperature. One can thus state: surface finishing of woven fabrics can be effected by mechanical means and/or by heat (Tab.).

One method of structuring the surface of the woven fabric is screen shearing, where a rotary screen with apertures left open rolls over the textile fabric like a rotary printing roller, and the parts which are not pressed down are shorn more or less heavily. The use of brushes opens up an almost unlimited field of effects which can be achieved. Brushing can be rotating,

finishing process	the effect of heat	the effect of mechanics
cutting	–	++
shearing	+	++
rotary polishing	+	+
singeing	++	–

Tab.: The effect of heat and/or mechanics during surface finishing.

changeable, on the spot, anti-clockwise and clockwise, acting jointly or alternately, and also with or without a screen, with rotation and belt brushes being used. Brushing can be with the nap or against the nap, and optionally also in the warp or weft direction. The numerous furnishing fabrics with patterns in different pile positions, as well as the endless diversity of fake furs, in combination with the variables of the fibres and colorations used, yield goods whose final appearance – once processed – are hard even for an expert to distinguish from natural fur.

In contrast to embossing on an embossing calender, where work is carried out with a heated roller, the embossing of pile articles is in accordance with a different scheme. The goods being treated are heated with an infra-red field on the pile side, to a temperature which makes deformation of the pile possible, and are then structured under pressure with a cold embossing shell. The pattern which is thus obtained has affected only the pile, and left the back of the goods in its original state. The goods remain soft and flowing. A prerequisite for this process is the use of pile fibres which permit plasticisation. Included in the field of suede embossing are the silk finish embossings or crêpe patternings. For silk finish embossing, the steel roller is given the finest flutings at a certain angle to the warp or weft thread. On the fabric, the embossing of the finest lines yields a refraction of light which lends the goods a silk-like lustre. A polyamide fabric or product, for example, only becomes usable for underwear in the first place with a silk finishing roller and a corresponding temperature. The transparency of the fabric is lowered and at the same time the handle is improved. The term “chintzing” is used for making something glossy. In the original sense, the gloss effect on the fabric was achieved through the friction of a steel roller against a flexible roller, e.g. cotton or paper roller. Since the introduction of polyamide roller casings as a counter roller for a steel roller, through the use of corresponding temperatures and contact pressures an effect is achieved which is similar to chintz, with a corresponding compression of the goods.

Recently an important finishing process has made its mark, which – in accordance with the effect achieved – is called “peach skin finish”. This is a soft, pliable and velvety effect, e.g. on the following fibre materials: for pure cotton and for the blends polyester/cotton, polyester/viscose, polyamide, polyamide/cotton, polyamide/viscose, wool and blends of polyester/wool. The mechanical effect is achieved through emerizing. On cotton articles and denim, a soft handle and the desired suppleness can be achieved through processes in which the weight of the product is reduced. This process includes the action of cellulose enzymes (stoneless stone-washing process), or the enzymatic decomposition in accordance with the Knit-Elle-es process from the firm Shikibo, in which a smaller loss of strength is noted. In the case of textiles produced from polyester fibres, the aforementioned effect can be achieved through controlled hydrolysis of the surface, on the basis of a treatment with alkaline solutions. Besides the better handle, strength is reduced, the pilling tendency is likewise reduced, and the wetting capability is increased to some extent (alkalisation).

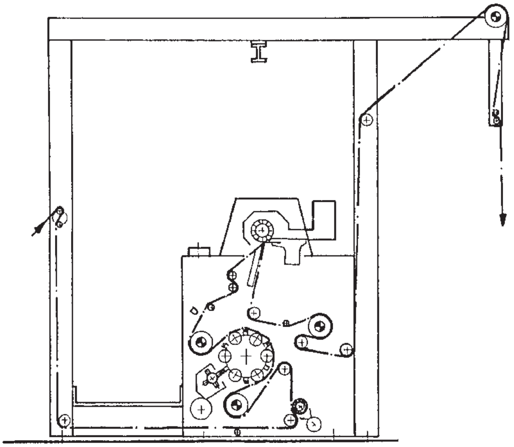


Fig. 4: The combination of central cylinder raising and shearing in a Sistig-Menschner raise-and-shear unit.

Also popular among users are warp-knitted velvets of viscose, acetate or triacetate, which can be printed after emerizing or roughening (Fig. 4), shearing and thermosetting; embossing effects on the surface of the goods can also be achieved through goffering or calenders. Crêpe effects on cotton textiles are already known from the nineteenth century; on textiles made of synthetic fibres, similar effects can be achieved through the application of strongly swelling chemicals, e.g. phenol-based. For textiles made of synthetic fibres, predominantly mechanical methods are employed. Embossalon is the name for a goffered warp knit fabric manufactured from polyamide; in appearance, it resembles fabrics (satin and crêpe) of textured filament yarns. A flat surface is usually achieved through calenders.

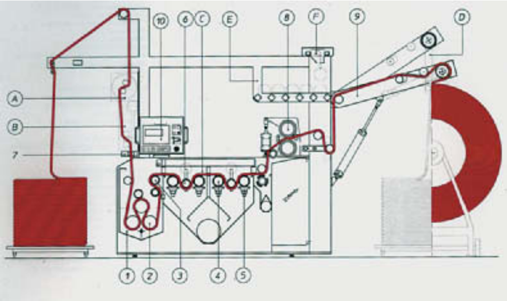


Fig. 5: Wet suèding (Sperotto Rimar, Plurima). Composition of the machine: 1 = impregnation tank; 2 = drawing rollers; 3 = tension control device; 4 = suèding rollers; 5 = tanks for the dipping of the suèding rollers; 6 = penetrating rollers; 7 = automatic seam detector; 8 = squeezing unit; 9 = fabric delivery and collecting unit; 10 = control panel. Optional devices: A = double fabric spreader positioned on the inlet side; B = centering device positioned on the inlet side; C = oscillating transverse motion of the suèding rollers; D = fixed-length flat and variable length "A" frame plaiter (it can be combined with the batcher); E = spare suèding rollers complete with relevant roller holder suitable for storage; F = hoisting unit for the rapid replacement of the suèding rollers.

A range of surface effects is achieved through special printing pastes which foam up under the action of temperature, through printing with delustring products, possibly in combination with a high-lustre surface. Through printing with special resins and hydrophobic products, chintz or crêpe effects with colour nuances and the like are achieved. Textiles which are patterned with a metal film are regularly in demand. This film is applied to the textile with a technology similar to thermoprinting. An appearance similar to brocade can be achieved in e.g. knit fabrics with a relief-like surface, in that a metal film is fixed only on the thread sections projecting upwards. Technologies with which one can achieve a crumpled or broken visual appearance on woven fabrics of synthetic and natural fibres are widespread. The term "crash" is used to refer to textile fabrics which have marked folds or break surfaces, with these being less parallel and more or less running in the warp direction. For the so-called "crinkle" effect on woven fabrics of synthetic fibres, an unsettled "rumpled" appearance without marked fold breaks is characteristic. This effect is achieved on various types, from mechanical, repeated wrinkling with steam by means of a so-called "cannon", down to processing in a hank dyeing machine under specific conditions. Woven fabrics with a crinkle finish, manufactured from polyester microfibres, are particularly sought-after for sports clothing. Very soft handle can be achieved by wet suèding (Fig. 5) (according to Schiffer and Rothova, as well as Kittan).

Surface fluoridation For increasing the substrate adhesion in manufacturing processes such as gluing, coating, laminating, lacquering and printing. Adhesion depends on various factors, above all on the polar nature of the surface, which enables mechanical bonds. For this reason, polymer materials are treated with oxidation processes, which are divided into corona discharge, low-pressure plasma and chemical processes. All methods have more or less disadvantages. Chemical methods have proved their worth only in tightly circumscribed applications (e.g. liquid mordants), or else they require a high expenditure on monitoring and maintenance (such as ozone treatment). Low-pressure plasma technology is characterised by a complex combination of vacuum, high frequency and gas technology, which comes down to careful training of plant operators. The continuous plasma pre-treatment of runs of materials has not yet been sufficiently investigated. Depending on the condition of the run of material (above all in the case of thicknesses > 1 mm, or with higher porosity), corona pre-treatment is very susceptible to faults. In the area of the dielectric, fires frequently occur, which bring with them short circuits in the pre-treatment station. Furthermore, only one side of the run of material can be activated by the corona discharge. Often, the desired high surface energy is not achieved.

Another pretreatment method is continuous surface fluoridation of runs of materials (see Fig.). The surface of textile runs is briefly exposed to elemental fluorine, diluted by an inert gas, in a continuous process in a reaction chamber suitable for the process. The parameters of contact time and fluorine concentration influence the surface energy of the textile. The surface effect which can be achieved additionally depends on the chemical condition of the fibres. Due to the high reactivity of the element fluorine, all textiles which consist of polymer fibres and which have substitutable hydrogen atoms can be activated with fluorine. Through this, the surface energy of the textile material is raised in such a way that excellent adhesion to other polymers (e.g., printing dye pastes, adhesives) is achieved. What is decisive for this effect is the extremely high oxidation potential of fluorine, which can develop extremely effectively even when heavily diluted. The polymer surfaces are permanently atomically changed, with the hydrophilic nature rising up to non-wettability with

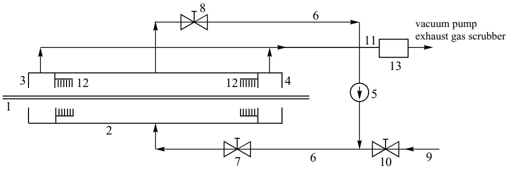


Fig.: Sketch showing the principle of a system for double sided surface fluoridation.

water. The intensity is comparable only with that of plasma gas. The high reactivity is explained by the interaction of the low dissociation energy of the fluorine molecule and the very strong bonds which fluorine achieves with other atoms. Furthermore, the fluorine atom is relatively small, so that the spatial relations in compounds of fluorine permit high co-ordination numbers of the respective central atom. The fact that this fluoridation technique is feasible on an industrial scale is due to the astonishing development in chemical engineering over the last 20 years, which enabled fluorine to become, not just an important starting material, but even a great technical event. However, to categorise fluorine as "hazardous" reflects a widespread prejudice which arises from lack of knowledge about this chemical element. No mention is made of the hazardous nature of the ozone which is released in the corona pretreatment, for which, incidentally the same maximum threshold limit value in air (0.1 ppm) has been set as for fluorine or hydrogen fluoride. But ozone (as animal experiments have shown), is far more toxic than fluorine or hydrogen fluoride. Since fluorine makes its presence felt well below the permitted limit concentration of 0.1 ppm in the ambient air, through its intense, characteristic smell (reminiscent of heavily chlorinated water), there are no references to incidents of poisoning in relevant literature.

The fluorine, which is purchased in steel pressure bottles, is diluted in a corresponding extraction and dosing device with inert gas (nitrogen, inert gas or compressed air) to a certain concentration. This fluorine /inert gas mixture is supplied to the system via the line (9). After the reaction chamber (2) has been filled with diluted fluorine, the mixture of fluorine and inert gas is circulated through the reaction chamber (2) by means of the pump (5) via the line (6) and the two shut-off valves (7, 8). The textile goods which are to be subjected to surface pre-treatment are fed into the chamber (2) via the entry air lock (3), and leave it via the exit air lock (4). Via the line (11), the air locks (3, 4) are kept at low pressure, via an intermediate catalyst (13) followed by a vacuum pump with a connected gas scrubber, in such a way that neither fluorine nor hydrogen fluoride can get into the ambient air. The flow resistors (12) which are placed upstream of the airlocks also contribute to this (9 = fluorine gas supply; 1 = fabric; 10 = dosing valve) (according to Milker and Koch).

Surface hairs → Kemp.

Surface lacquering Surface lacquering of membrane materials is a measure for extending life; it extends the service life of stationary membrane roofs to 15–20 years, depending on the place and manner in which they are deployed, and also has a positive influence on the visual aspects and the cleaning behaviour. Compared with the overall thickness of the material, the lacquer layer consists only of a thin skin of approx. 4–20 µm (see Fig.), and as a rule is constructed of polyacrylates. Advantages:

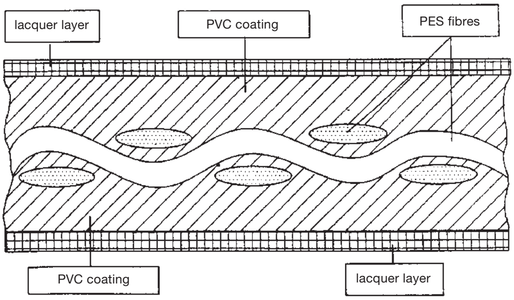


Fig.: Diagram of the structure of a membrane material with surface lacquering.

- protection of the membrane from environmental effects,
- improvement of the dirt-repellent effect,
- protection of the PVC mass against losses of formulation constituents, such as softeners,
- good scratch resistance of the surface,
- good high frequency heat-sealing properties,
- good temperature stability of –30° to +80°C,
- good adhesion on PVC coating.

Surface modification of fibres Due to their great variability, physical processes are increasingly opening up possibilities for specific modification of surface characteristics. For technical textiles in particular, such techniques can be of great interest, since through UV laser radiation, plasma modification and plasma polymerisation, adhesive, adsorptive, biological and visual fibre characteristics can be influenced or achieved (→: Plasma treatment; Corona treatment). In laboratory trials, methods using radiation with → Lasers have proved their suitability, and in principle have the advantage over plasma technology that they are simpler in terms of equipment, and more variable. Treatments of fibre material using UV lasers result mainly in morphological modifications, besides a few examples of laser-chemical treatments (graft co-polymerization). On the other hand, CO_2 lasers in the infra-red spectral range represent powerful systems, suitable for industry, which in commercially available forms are suitable for heat treatment of textile fibre materials; pure surface treatments and surface modifications have not yet been achieved, due to the low absorption of the polymers at the laser wavelength. All important fibre substances and many reactive substances, however, have strong absorption bands in the spectral range of 3–10 µm, e.g. polyethylene terephthalate is highly absorbent at 9.7 µm. One possibility for making use of these absorption characteristics is seen in the emission spectrum of CO_2 lasers: CO_2 lasers have two broad emission bands in the range of 9–11 µm (in the interests of a high performance yield, commercial lasers are adjusted to 10.6 µm), which are technically variable through corresponding modification of the laser resonator. In this case, one may anticipate considerably higher absorption of the optical energy by the fibre substance or by reactive substances. On this basis, three possibilities for deliberate surface modification are conceivable:

1. Through optical activation of the substrate surface, for example, there is the possibility of a laser-induced deposition of reactive substances with specific desirable characteristics, from a gaseous or liquid environment.
2. With a corresponding adaptation in the infra-red spectral range, it is conceivable to achieve depositions of surface-active media through activation of reactive gases.
3. In conjunction with a pulsed operation of the laser, one can reckon on morphological surface modifications, similar to known effects which are achieved with UV lasers. (according to Schollmeyer).

Surface phenomena of fibres for composites The interactions between reinforcing material (high-modulus fibres) and polymer matrix (ductile with high fracture toughness) determine to a large extent the processing and end characteristics of the resulting composite material. Interfacial or boundary layer characteristics are due on the one hand to morphological parameters (e.g. specific surface of the reinforcement material, coarseness), and on the other hand to the nature and size of the interacting forces originating from the components. Deliberate influencing of the boundary layer characteristics via the interacting forces presupposes the allocation of the nature and size of the interaction to the chemical and physical structure of the components. The significant role of boundary layer characteristics in relation to the manufacture of composite materials and characteristics is shown in Fig. 1. Here, the considerations start from the basis of a three-phase model, of reinforcement material/boundary layer/matrix. In this model, the interaction is achieved on the one hand via adhesion processes (or chemical reactions) at the interface between the fibre and the boundary layer, and on the other hand via the mutual influence of the boundary layer/matrix [e.g. hydrophobic interaction, diffusion processes, formation of quasi-IPN (inter-penetrating polymer networks)].The model thus follows theoretical concepts, according to which a high composite material strength presupposes a strong adhesion to the reinforcement material/boundary layer and boundary layer/matrix interfaces. It should be possible to influence the fracture toughness of composite materials with ductile matrices and high-modulus intercalation components through boundary layers whose modulus of elasticity lies below that of the matrix.

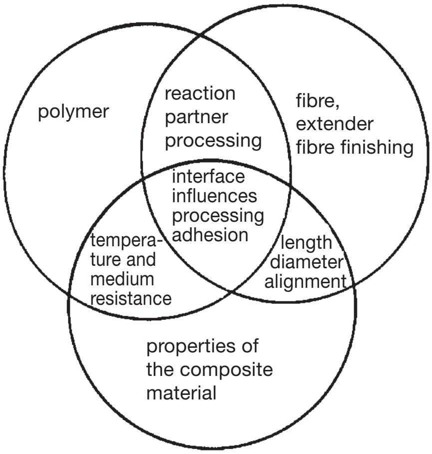


Fig. 1: The effect of influences operating at the interface on processing properties and composite properties.

The attempt to implement this concept takes account of the influence of surface parameters of the reinforcement materials on boundary layer characteristics. Targeted alteration of the surface characteristics of reinforcement materials can be effected through suitable modification (microscopic characteristics), influencing the characteristics of the boundary layer through compatibility mediators and modified binders (mesoscopic quantities), matrix modifications and their correlation to macroscopic composite material characteristics. Physical-mechanical modelling of interacting forces is currently under development. The multi-component systems which are to be investigated are difficult to access. In order nevertheless to make the composite material characteristics accessible to scientific investigation, it is necessary to work with approximation methods which are not completely secure.

Above all, electrostatic interactions at solids boundary surfaces are accorded importance for adhesion, as the effective surface forces of polymers which come into contact. For this, the presence of a potential difference at the phase boundary is necessary. The energy of corresponding interactions is due e.g., to the acidity or basicity of the components involved.

$$\mathrm{MOH} + \mathrm{HXR} \rightleftharpoons \mathrm{MOH_2^+} + \mathrm{XR^-}$$

$$\mathrm{MOH} + \mathrm{YR} \rightleftharpoons \mathrm{MO^-} + \mathrm{YHR^+}$$

MOH = inorganic oxide or hydroxide
HXR = organic acid
YR = organic base

According to the Lewis theory, in the event of contact between electron acceptors and electron donators, an electron migration takes place, which leads to electrostatic interaction between the partners. In the case of adsorption of surface-active substances from aqueous

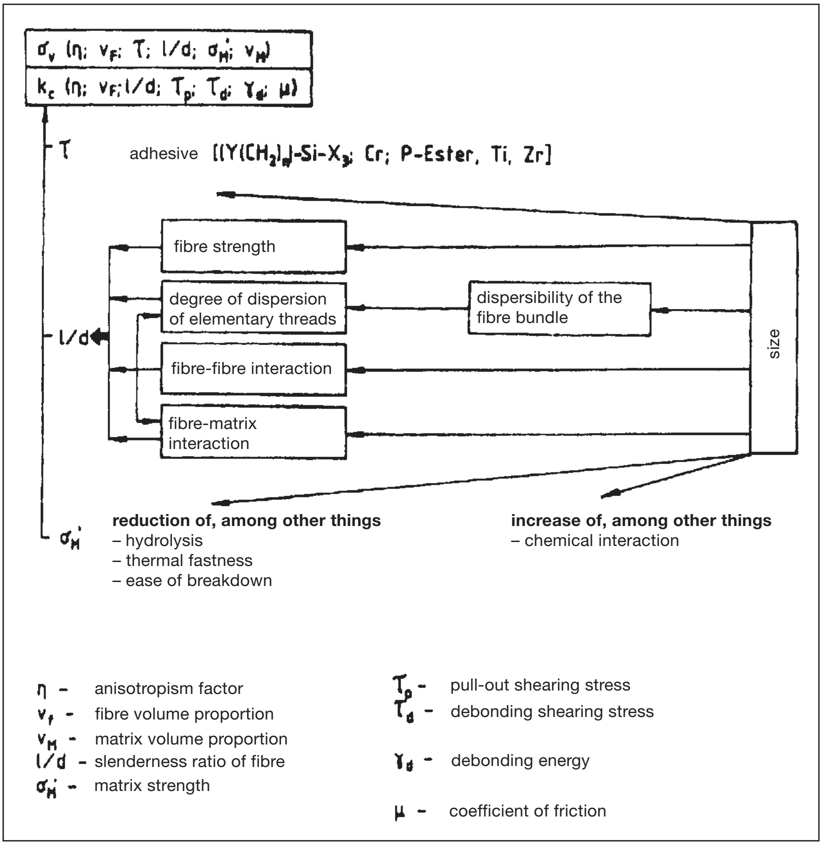


Fig. 2: The influence of the size on the properties of fibre and composite.

media onto polymers or reinforcement materials, interactions play a role in which the decrease in free enthalpy is based on entropic effects. This entropic effect is attributable to the fact that in the immediate surroundings of polar molecule groups, there are water structures with a higher order than in pure water. Since under normal conditions, reinforcement materials retain adsorbed water in a swell layer in their surface, the presence of surfactants is associated with an influence on these hydrophobic interactions. Wetting measurements and electrokinetic measurements (zeta potential) can be applied for surface characterisation.

The surface modification of reinforcement materials must fulfil two tasks:

1. First and foremost, modification is necessary in order to enable textile processability of the fibre substances. Thus in general it is necessary to apply gliding agents and binders, as well as anti-static agents.
2. In composite material, modification represents the connecting link between fibre and matrix. It thus influences the working of fibres into the matrix (wetting, dispersion, fibre disintegration), the fibre/matrix interaction via adhesion agents, as well as – in some cases – the matrix characteristics themselves.

For this reason, each sizing agent and/or each finish represents a system (Fig. 2), which consists of at least, adhesive media, gliding agents, binders and film formers, and which must be optimised in accordance with the complex profile of requirements. With the amounts of these substances which are usually applied, the result is modification layer thicknesses of the order of 100–500 nm. This layer thickness can no longer be neglected in a real composite material.

To achieve fibre/matrix adhesion, hydrosilicons are used as reinforcement materials. Fig. 3 shows the primary reactions which take place. First of all, hydrolysis of the trialkoxy groups takes place. The hydrosilicon groups formed react with the glass surface via hydrogen links, and then form covalent bonds. The second function (–Y) of the hydrosilicon must be selected such that a strong interaction with binder and matrix, and thus a mutual penetration, is possible. The resulting boundary layer with chemi- and physio-sorbed hydrosilicon and an interdiffusion layer is shown schematically in Fig. 4.

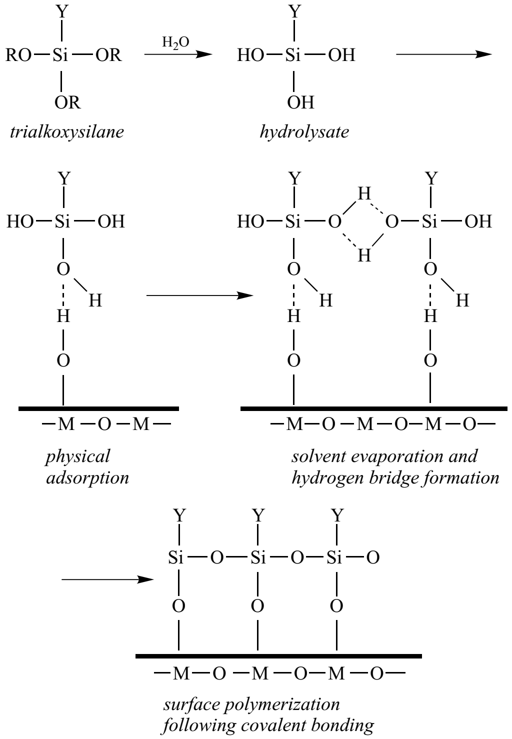


Fig. 3: The binding of silane adhesives to mineral surfaces.

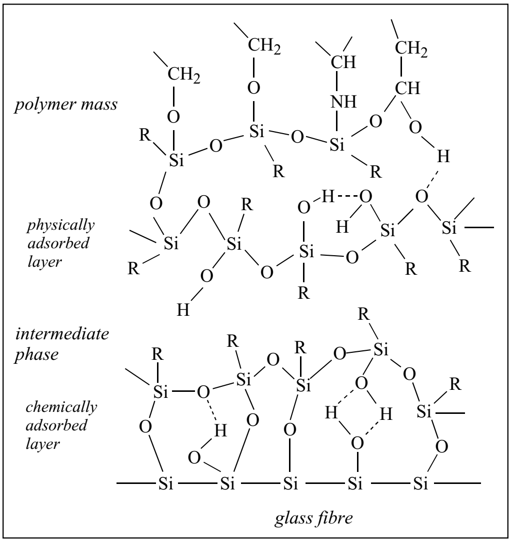


Fig. 4: Structure of the interface between fibre and polymer. (left) = description of layer; (right) = chemical structure (diagram).

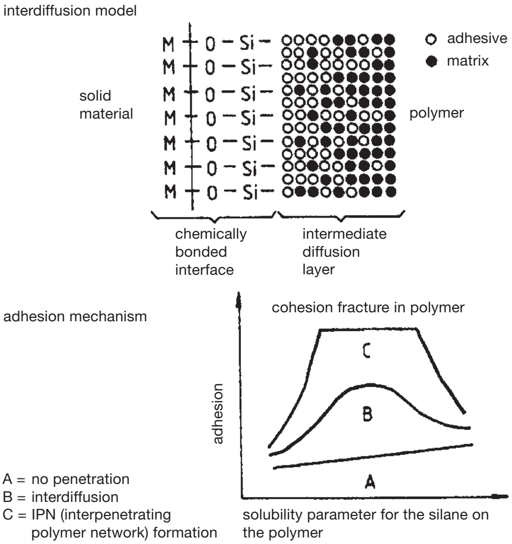


Fig. 5: Model of interdiffusion and mechanisms of adhesion.

In this concept, Fig. 5 shows the connection of adhesion and the solubility parameters of sizing agent and polymer matrix. It is clear that good adhesion is achieved through interdiffusion or the formation of quasi-IPNs. Interaction, interdiffusion and IPN formation are influenced by the structure of the adhesion agent. (according to Jacobasch).

Surface potentials The properties of the fibre and soil during washing (greying) determine the surface potentials of fibres, which are dependent on the medium used.

In tetrachloroethylene, the negative surface potential becomes greater as the concentration of anionic dry-cleaning detergents increases (Fig. 1, RV.OR I). However, when the fabric‘s greying behaviour is interpreted, it must be taken into account that dry-cleaning

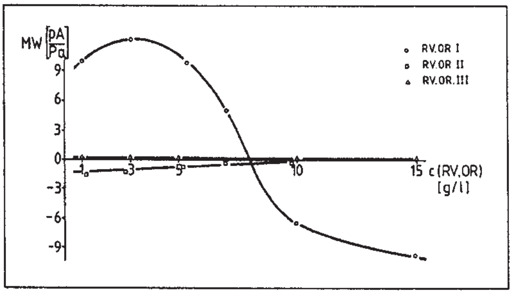


Fig. 1: Measured surface potential values for cotton in tetrachloroethylene in relation to the type and concentration of the dry-cleaning detergent (RV.OR I and II are anionically active, RV.OR III is cationically active).

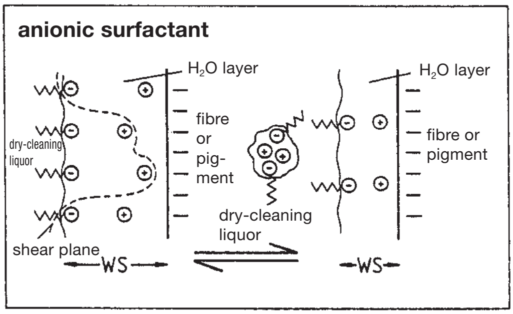


Fig. 2: Proposed model of the structure of surface charge in the adsorption layer (WS) of water at the fibre surface and its shearing due to dry-cleaning mechanics.

liquor also contains small quantities of water, which could exert an influence on the surface potential (Fig. 2). This can lead to the surface potential deviating from the expected values (Fig. 1, RV.OR II and III).

Surface print Prints with a greater colour intensity resulting from the concentration of dye printed onto the fibre surface. This effect is achieved by using suitable thickeners, which should be in combination with semi-emulsions if reactive dyes are used. For any other type of dye, thickener combinations containing starch should be used.

Surface printing machine The pattern is printed by means of raised relief-type printing elements. In contrast to → Roller printing machines, the surface printing machine can print all wovens using the same rollers. The only difference is that print paste application to the print rollers is varied with a paste application device. In addition to this, a surface printing machine requires less pressure than a roller printing machine. Up to eight dyes can be used. The main components of the machine are: printing cylinder, lift lever for printing cylinder, print rollers, colour box for dye pastes, and felt for paste transfer (dye cloth). Hollow cylinders with the pattern in relief (raised) are used as print rollers. Relief printing technology is not important in the textile printing industry any longer; however it is still used frequently for printing wallpaper. The same principle is also used for carpet printing machines.

Surface, specific This term is applied to fibres, and is used to define dyeing properties, for instance. The surface of crystallites in polyamides or polyurethane (see Fig.) to which test dyes (e.g. acid dyes with certain chemical structures) can be applied.

Surface temperature measuring instruments,

I. → Pyrometer for contact-free temperature measurement on any type of surface (rollers or fabric runs).

II. → Thermometer.

Fig.: Proposal for the localization of dye molecules among partially crystalline polymers.
Left: chemical fibres composed of continuous polymers (e.g. polyamide, polyacrylonitrile, viscose, cellulose); right: fibres composed of segmented polymers (e.g. polyurethane) (according to Flath).

Surface tension,

I. The tension present at different interfaces (soil/wash liquor, fibre/soil, fibre/dyeing liquor, water/benzine), which is as a force acting against the wetting/penetration process. This could be the surface strength of a water droplet, which causes cohesion and prevents it from breaking up. Another example is penetration of air bonded to the fibre capillary into the fibre surface (for 1 g of cotton cellulose approx. 5000 m^2). A high level of surface tension at the interface therefore causes poor wetting. The wetting/penetration properties are increased proportionally as a result of the surface, interface and capillary-active products counteracting the tension. Interfacial tension is defined as the force per linear unit resulting from free interfacial energy, which is numerically equal to free interfacial energy/interfacial unit, expressed in N/m or mN/m. It is measured using →: Electrokinetic interface potential; Interfacial tensiometer.

The interface tension can be lowered in some substances using sodium oleate solution, soap (30.4 g/l at 22°C), etc. a) compared with water; b) compared with soap in mN/m:

air	a) 72.4; b) 30.4
chloroform	a) 29.4; b) 2.09
carbon tetrachloride	a) 43.4; b) 1.64

Lowering of surface tension at interface (in mN/m) and wetting angle of:

1. Ceresin/water using the following additives:

solution	wetting angle	surface tension (mN/m)
pure water	110°	72.8
5 g/l anionic wetting agent	65°	38.1
5 g/l soap (sodium oleate)	46°	26.0

2. water/acetate spun fibres:

solution	wetting angle	surface tension (mN/m)
pure water	55°	72.8
5 g/l anionic wetting agent	35°	38.1
5 g/l soap (sodium oleate)	0°	26.0

Surface tension is defined according to German standard DIN 53 914, using a tensiometer with a plate, ring or bar and a film is formed with liquid. The tensiometer is moved in such a way that increasing tension is exerted on the film, which is ultimately broken. The force acting at this moment is measured. Calculation formula:

$$\sigma = {}^{K}/_{2L}\ \text{mN/m}$$

K = force measured,
L = circumference of plate/ring, or length of bar.

II. Force resulting from free → Surface energy, per linear unit. Numerically it corresponds to the free surface energy per surface unit, expressed in J/m^2 or N/m. The liquid state forms the transition phase between the gas state and the solid state. A liquid consists of particles (atoms, ions, molecules) in relatively free motion. Forces of attraction, which are stronger than in a gas, cause a certain level of order. The particles move together as closely as their specific volume will permit. The forces of attraction in liquids are known as cohesive forces. One effect of cohesion is the ultimate tensile strength of a liquid film. Liquids have viscous properties, which means that they resist flow. Unlike gases they have a stable volume, can barely be compressed, and usually have a phase interface (surface).

Since particles in the surface layer are unilaterally attracted inwards, the liquid tends to form the smallest surface possible (Fig. 1). Surface tension is a measurement of the forces that cause reduction in surface size. It can be defined as the quotient of an increase in energy and an increase in surface area:

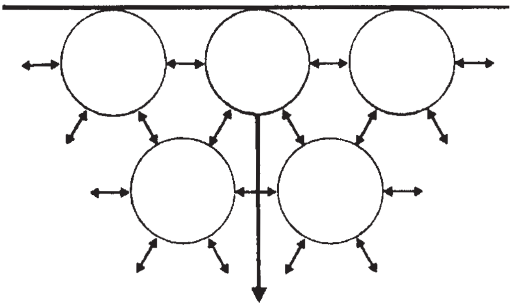


Fig. 1: The forces of attraction between water molecules. A molecule at the surface is affected only by forces from the side and from within the liquid. The resultant force on the molecule is one that is directed inwards, and represents the surface tension.

$$\sigma = \frac{\text{increase in energy}}{\text{increase in surface area}}$$

If there are differences in concentration within a solution, the heat migration of the dissolved particles causes any differences in concentration to balance out eventually. This levelling of concentration is known as diffusion. Surface tension counteracts concentration levelling by evaporation of the liquid molecules as they move into the gas phase. In other words, surface tension is the force that counteracts expansion of a liquid surface, because the molecules within the liquid are subject to inward forces of attraction caused by interactive molecular forces. In an ideal situation, this means that droplets will be spherical in shape, i.e. the smallest surface area for the maximum volume (Fig. 2).

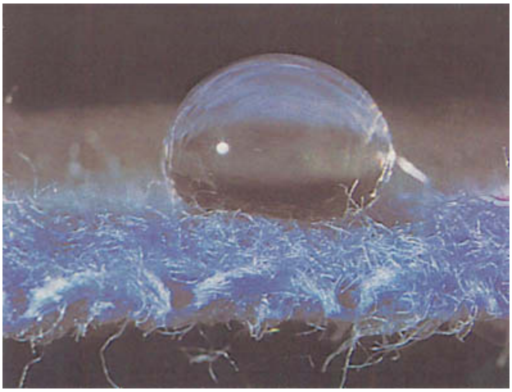


Fig. 2: A water droplet retains its surface tension when in contact with a waterproofed fabric, i.e. in the absence of wetting (by Wunder).

The high surface tension of water can be lowered by adding surfactants in low concentration. The degree to which surface tension is dependent on temperature is lower than its dependency on vapour pressure or viscosity. For this reason it can be observed that liquids with a high surface tension will evaporate more slowly at the same temperature than those with lower surface tension. The concentration dependency causes considerable interfacial tension gradients at the point where surface/interfacial tension is generated (Fig. 3). These gradients in turn cause interfacial currents. This phenomenon is known as the Marangoni effect. A simple example to illustrate this is n-heptane (surface tension

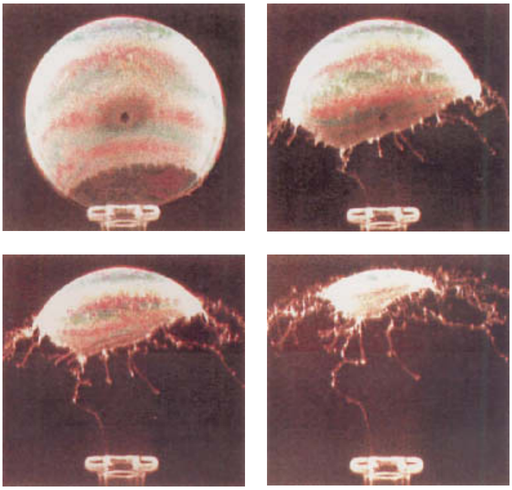


Fig. 3: High-speed cinematography is used to observe phenomena resulting from surface tension (here, the bursting of a bubble) (by Henkel).

$\sigma = 0.0203$ N/m) and benzene ($\sigma = 0.0288$ N/m). A drop of benzene on a thin film of n-heptane will not spread out, because benzene has a higher surface tension than n-heptane, even though both liquids can be completely mixed. In reverse, the benzene film spreads out almost explosively as a result of the n-heptane droplet spreading. If an interfacial tension gradient occurs, it causes surface currents, which result in surface renewal. The above phenomena can be systematically classified, the surface renewal being a micro-effect, and where the interface is affected it is a macro-effect. Surface renewal or micro-effects arise if the depth of the liquid layer is significantly greater than the depth to which interfacial currents occur.

The static surface tension can be measured using the Wilhelmy method. The dynamic surface tension is measured using a device based on the maximum bubble pressure method in an aqueous solution, depending on the speed at which the new preparation/air interface (measured in Hertz as bubble-forming frequency) is formed (Fig. 4).

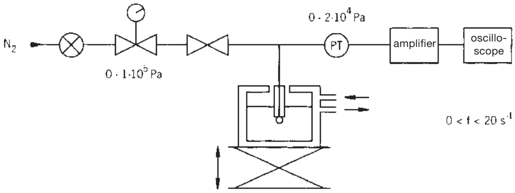


Fig. 4: Measuring dynamic surface tension by the maximum bubble pressure method.
PT = pressure transformer (induction system).

Surface tension meter Measuring instrument for determining the → Surface tension of liquids and solid matter. In order to determine the dynamic surface tension of liquids two capillaries of varying lengths are placed in the solution to be measured, releasing a defined flow of air. The differential pressure between the capillaries is recorded electronically and transferred to a computer for evaluation (Fig. 1).

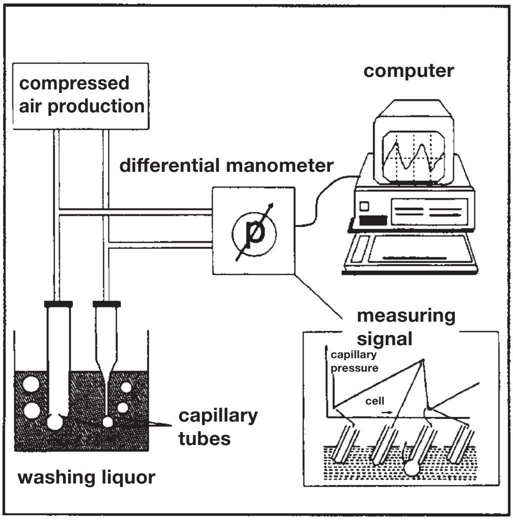


Fig. 1: On-line surface tension meter, design and measuring principle (wfk).

The measuring technique is based on the change in the maximum bubble pressure. When a capillary with gas bubbles escaping from its lower end is submerged into a solution containing a surfactant, the shape and size of the bubbles change according to the surface tension of the solution. High surface tensions, i.e. low surfactant concentrations, produce large bubbles, whereas low surface tensions produce small bubbles. Also the pressure which is necessary to create bubbles changes, high pressure being associated with a high dynamic surface tension. The use of an additional wide capillary means that measurements can be taken independently of the submersion depth.

Tensiometers are suitable for measuring in washing liquors, as they enable changes in concentration above the critical micelle formation concentration (CMC) to be recorded, as opposed to measurements of static surface tension (Wilhelmy or ring method). Also, in addition to the surfactant quantity, other parameters concerning the technical application of the washing liquor can be measured such as the amount of dirt, dirt-bearing capacity and remaining amount of washing power (reserve washing power).

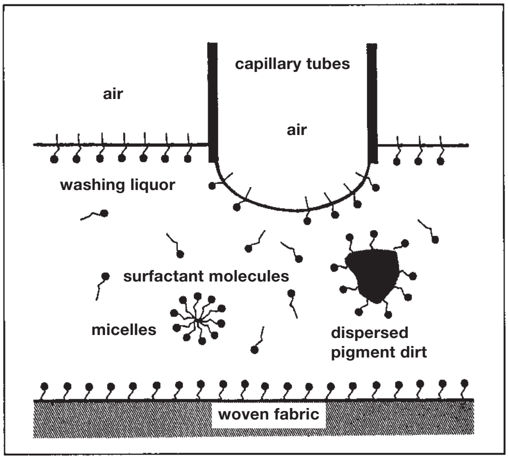


Fig. 2: Adsorption behaviour of surfactants in washing liquors (wfk).

Surfactant molecules in the washing liquor occur individually as well as in the form of micelles (Fig. 2). Free surfaces at the interface between air and water, water and fabric, and water and dirt are occupied by surfactants in physical-chemical balance. The gas bubble forming constantly at the end of the capillary represents an imbalance due to the enlarging interface. Surfactants continuously accumulate at this interface. This process is diffusion-controlled; the more surfactant is present in the solution the more quickly the process takes place. The micellar-bound surfactants also participate in this dynamic process, whereas the surfactant elements in the liquor are adsorbed to a greater degree by the dirt. This explains why increasing pollution of the liquor increases the measurable dynamic surface tension at an initially identical operating concentration. The differential pressure recorded with the on-line tensiometer increases with falling dirt-bearing capacity accordingly (Fig. 3) (Krüssmann Principle).

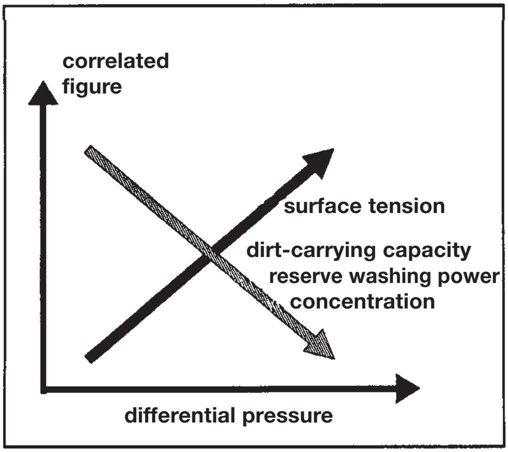


Fig. 3: Qualitative correlation between differential pressure, dynamic surface tension, surfactant concentration, reserve washing power and dirt-carrying capacity (wfk).

Surface water,

I. Fresh water originating from natural or artificial sources above ground (e.g. stream, river, lake, pond, reservoir). Temperature and composition are usually extremely varied (self-cleaning frequently takes place with the help of bacteria and fish. Some impurities dependent on origin, season, temperature, water management, usually has more organic substances and less salt than → Ground water. Floating colloid substances that cloud the water originate from micro-organisms, dirt, clay, earth, humus, products of protein decomposition, etc. Colour and reaction varies greatly depending on the level of impurities and the type of ground.

II. → Adhering water.

Surfactant Surface active substance.

Surfactant additives Additive in a detergent that causes the product to have further properties, but has nothing to do with the washing action. Examples are optical brighteners, corrosion inhibitors, anti-electrostatic products, dyes, perfumes and bactericides.

Surfactant analysis Surfactants are used in almost all processes in textile manufacture, pre-treatment and finishing. Examples of problem areas in surfactant analysis are:

- The analysis of surfactants in textile auxiliaries during inspection of raw materials, with the objective of analysing both qualitative and quantitative product composition. One advantage is that it is possible to analyse extraneous substances, the other is that it is possible to compare two products.
- The importance of checking the concentration of surfactants in aqueous liquors becomes greater when waste water is being monitored. But it is also essential to be aware of surfactant concentration in this type of medium during production, so that errors can be avoided.
- Investigating changes in the chemical structure of surfactants, for example during drying and setting processes, plays a crucial role in waste water and exhaust analysis. It is also important for detecting alterations in behaviour to surfactant properties in textile process sequences.
- If the surfactant distribution during softening is checked for evenness, it is possible to optimise the process parameters and thereby minimise application of the product.
- Analysis of residual surfactants on the fibre surface is useful, meaning, for instance, that problems arising after washing phases in process sequences can be avoided.

With regard to minimizing contaminants in waste water, there will be new, more stringent requirements for specific surfactant analysis in the future (→ Surfactant biodegradability, evaluation of). The law applying to detergents and cleaning agents stipulates stricter requirements for products “that have been applied to surfaces in line with specifications, which are for the most part removed in a single cleaning process using the products implied in paragraph 1, which in practice can subsequently be detected in water” (and this includes numerous substances used in textile finishing). Because of the composition of aqueous liquors or fabric coatings used in the textile industry, methods of analysis must be found that are minimally intrusive, or other possible methods must be found, such as the selective separation of surfactants from the medium concerned. The Fig. illustrates one possible separation method, using solid phase extraction as an example. In the case of normal liquid/liquid extraction, the distribution equilibrium of the substance being analysed in two non-mixable liquids is utilized as a separation effect. However, in solid phase extraction, the selective interactions occurring between the substances under analysis and a chemically modified silica sorbent are used. This process is already used for biochemical purposes, e.g. for separating surfactants from proteins. The surfactant molecules are smaller, and are therefore retained in the gel, whereas the protein molecules can pass through almost without hindrance. The contents of the column are eluted with methanol, for example, making it possible to recover the surfactants for specific analysis.

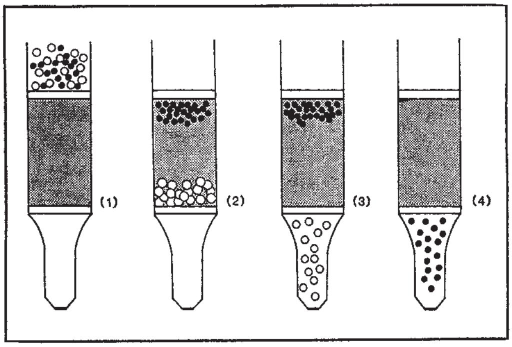


Fig.: The principle by which surfactant and macromolecules are separated using solid phase extraction (DTNW).
Black dots = surfactant molecules; white dots = macromolecules; 1 = delivery of the solution containing the substance;
2 = separation of surfactant and macromolecules;
3 = rewash; 4 = elution of the surfactant molecules.

These molecules are chemically dipolar, and utilizing this characteristic property, as well as the associated physical/chemical property changes, where the critical micelle concentration is exceeded, is one possible method of surfactant analysis. Another method is to use the criteria that are dependent on the chemical structure of the surfactants for analysis. The table shows the methods that are usually used, and ways in which they can be implemented for qualitative and quantitative analysis.

methods		analytical quality	analytical quantity
spectroscopy	ultra-violet	x	x
	infra-red	x	(x)
titration process	two-phase titration	–	x
	surfactant electrodes	–	x
dye complexes	absorption behaviour	x	x
	fluorescence phenomena	x	x
chromatography	HPLC	x	x
	gas chromatography	x	x
	thin layer chromatography	x	(x)
electrochemical methods	tensimetry	–	x
	conductivity	–	x
gravimetry	precipitation	(x)	x
	solid content	–	x

Tab.: Surfactant analysis methods (DTNW).
HPLC = High pressure liquid chromatography

It is difficult to analyse detergents and cleaning agents using a generalized formula. As ion exchangers, there are some types that are suitable for surfactant exchanger chromatography. To use this method, it is assumed that the detergent product containing the surfactants is alcohol-soluble, and exchanges ions at double rate (dissolved in an isopropanol/water mix). Non-ionogenic surfactants are contained in the fluate, while the anionic components released into free acid by cation exchangers can be found in the sorbate. The acids, which are bonded at different levels of firmness, can be released by means of eluation agents of appropriate strengths, and then analysed. This separation process provides the four fractions without the need for a preliminary qualitative/semi-quantitative test: (fluate) non-ionogenic surfactants, (1st eluate) soap, (2nd eluate) hydrotrope and chloride, (3rd eluate) anionic surfactants. The components are extracted in their entire form (i.e. not broken down), and the first step is an optical inspection (IR, UV). Multi-component mixes in the individual fractions can be differentiated for instance by hydrolysis and inspection of the cleavage products, separation of components for which saponification is not possible, etc. (according to Knopf and Denter).

Surfactant biodegradability, evaluation of In order to discuss the biological degradability (→ Biodegradation) of a substance, it is essential to understand what is meant by it. There are two important terms that have been used as analysis criteria for a relatively long time, especially for surfactants: primary degradation and ultimate degradation (see Fig.).

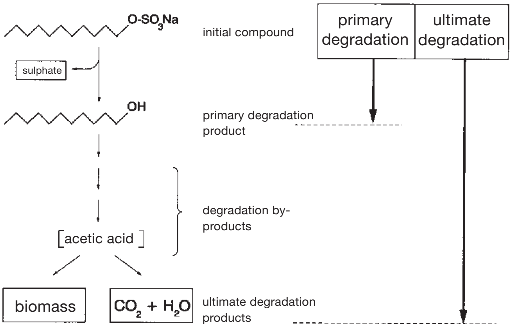


Fig.: Terms of evaluation of biological degradability (example: fatty alcohol sulphate).

The degradation of any chemical compound is a multi-phase process, in which the first stage is conversion of the initial compound into the first degradation product by the degradation organisms. Since the initial substance loses its chemical identity and usually also its primary matter properties (e.g. for a surfactant its surface-active effect and therefore its foaming properties) in the very first phase, the disappearance of the initial compound is referred to as primary degradation. Surfactants form an excellent example because even primary degradation frequently has significant ecological consequences. It has been proven that for a number of anionic and non-ionogenic surfactants, the loss of surface-active effects, i.e. primary degradation, is linked to a drastic reduction in toxicity affecting aquatic organisms. This means that it is certainly of ecological relevance with respect to the European minimum degradation specification of at least 80% for anionic surfactants (under defined test conditions). However the aim should, of course, be to achieve total degradability of any chemical compound released into the environment, rather than simply ensuring that any undesirable properties become ecologically non-toxic.

Ultimate degradation means the biodegrading process up to its final stage, in other words up to the point at which the initial compound is converted to the final product of biodegradation. The final products are mineral oxidation products – carbon dioxide, water, possibly inorganic salts, and the organic material converted (assimilated) into bacterial biomass. Proof of the ultimate degradation of a chemical constitutes a reliable basis for the assumption that neither the initial compound nor any by-products generated during degradation will remain in the environment, thereby representing a long-term ecological risk.

Analytically, the primary degradation of a test compound can be tracked by means of an appropriate (group) specific analytical process. Ultimate degradation however is analysed using substance-specific → Summation parameters.

1. Primary degradation: analysis specific to substance (groups).
   a) a-surfactants (anionic surfactants): MBAS degeneration (methylene blue active substance);
   b) n-surfactants (non-ionic surfactants): BiAS degeneration (bismuth active substance);

legal foundation	degradation	screening test	simulation test
EEC instructions or national laws for a-, n-surfactants	primary degradation (≥ 80 %) – MBAS degeneration – BiAS degeneration	screening test OECD 301 E	OECD confirmatory test
EEC instruction 79/831 or chem. law (1982) for new substances	ultimate degradation	OECD test for ready biodegradability:	
	– C degradation	modified screening test OECD (> 70 %)	coupled units test
	– BOD	GF test (> 60 %)	–
	– formation of CO_2	CO_2 evolution test(> 60 %)	

Tab.: Important degradation test methods of surfactants.

   c) c-surfactants (cationic surfactants): DSBAS method (disulphine blue active substance).
2. Ultimate degradation: Summation parameters.
   a) mineralization: O_2 consumption (BOD); formation of CO_2;
   b) mineralization + assimilation: DOC degeneration (Dissolved Organic Carbon).

Test methods have been developed for evaluating surfactant biodegradability that can be used universally, are recognized internationally, and are based on standard test specifications. They can be divided into two categories, screening tests and simulation tests (Tab.).

Surfactant biodegradability tests Surfactant biodegradability (→ Biodegradation of surfactants) is usually analysed according to two biological processes:

1. Selection test (screening test OECD 301 E).
2. Confirmation test (OECD confirmatory test).

Both of these tests feature in the Detergent and Cleaning Agent Law in Germany, for instance. Any surfactant achieving at least 80% biodegradability in the selection test is considered to be biodegradable. The selection test is a simple static version of the “shake-flask” test. The concentration range is quantified in mg/l. The substance is set off with a mineral-based nutrient salt solution and then injected with waste from a purification plant. The concentration curve of the surfactants is monitored over a period of 19 days. At the same time, the biodegradation properties of two standard substances are tracked (lauryl alcohol sulphate after 14 days 92%, tetrapropylene benzene sulphonate after 19 days 35%). If the surfactant biodegradability is lower than 80% in the selection test, or if the test result is unclear, the confirmation test must be carried out. The confirmation test is a model based on a biological purification plant, which represents a continuous process. An artificial nutrient base is used (meat extract + peptone). In this test, concentrations are higher by a factor of 4 than in the selection test. Waste from a purification plant is injected into the test environment, in the same way as the selection test. After approx. 2 weeks activated sludge is formed, and the remainder of the surfactant is monitored analytically (mean value of 14 measurements over a period of 3 weeks).

Anionic surfactants can be detected by means of methylene blue in the form of methylene blue active substance (MBAS). Non-ionogenic surfactants are recorded as bismuth active substances (BiAS). The methylene blue method is based on the fact that where anionic substances are present, cationic methylene blue forms blue salts that can be extracted using chloroform. The concentration can be determined photometrically. Surfactants on a phosphoric acid ester basis form an exception. To analyse non-ionogenic surfactants, they are enriched by blowing through acetic ester, and then precipitated in a bismuth complex with a modified Dragendorff reagent (sodium bismuth iodate + barium chloride + acetic acid). The bismuth content is analysed after being dissolved using pyrrole idinthiocarbamate, by means of potentiometrical titration. The limits and accuracy of this test have recently been discussed in great detail.

It is not only the level of biodegradability that is analysed in the confirmation test, the elimination potential can also be partially analysed. If surfactants are properly adsorbed by the activated sludge, the test method does not detect them. This phenomenon occurs with alkylphenolethoxylates (APEO), and for this reason they were believed for a long time to be biodegradable. Adsorption of surfactants into sewage sludge should in principle be regarded positively, and is usually required. It is one of the essential cleaning mechanisms in the purification plant. However it is only acceptable if the by-products resulting from decomposition are harmless.

Surfactant degradation → Biodegradation always begins with an oxidative attack (see Fig.). Non-branching side chains can rapidly be split up into units of acetic acid. The rings are opened at a slower rate, and finally desulphonation occurs.

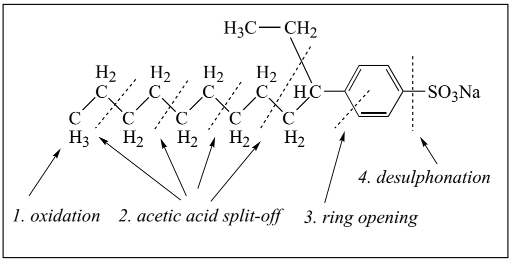


Fig.: Biological surfactant degradation.

If the biodegradability potential is being tested, the “chocolate marshmallow – black bread” model should be used for test nutrients: mixed nutrients, derived from surfactants that biodegrade easily and those that do not, provide realistic results in a simulation test, i.e. biodegradability levels similar to those occurring in practice. The → Screening test OECD 301 E is actually cheaper than simulation tests, but very stringent conditions are required. Examples of these are:

- modified OECD test;
- GF test (water-soluble);
- block test (not easily soluble).

In the screening test there is only one C source; mineralization is only necessary if a few bacteria are present. For this reason, screening tests are designed for long-term use. It is often claimed that surfactants can be “biodegraded rapidly and easily under real environmental conditions”. This comment relates to primary degradation, which causes the substance to lose its surfactant characteristics. However, this needs to be followed directly by secondary degradation down to CO_2 and H_2O, in other words it must be completely degraded to waste water that contains no metabolites. “Hard” metabolites, which exhibit resistance to secondary degradation, can increase in concentration. For this reason, a metabolite test acts as a “magnifying glass” to home in on an area that was unclear in the standard test (see above), all of which serves to highlight primary degradation.

Using the compost method is not a suitable way of measuring surfactant biodegradability, because adaptation is possible within this microbiological zone, because the timescale is greater. Adsorption can take place while surfactants are still in the settling tank, before they even arrive at the biodegrading stage of the purification plant. Therefore a distinction must be made between adsorption into the sewage sludge and elimination. Since cationic surfactants adsorb efficiently, they can be deposited together with the sludge without the need for a biodegrading process.

Surfactant foaming capacity → Foaming power of surfactants.

Surfactants As defined by the German Detergent and Cleaning Agent Law (Waschmittelgesetz), organic polar compounds with at least one hydophobe residue and a hydrophile group. The term identifies water-soluble compounds which are used for wetting, washing, emulsifying and dispersing, accumulate on border surfaces and which reduce the border surface tension. The term surfactant is not identical with detergent, as the latter are washing agents which, among other substances, contain surfactants. Surfactants are therefore → Surface active compounds whose molecules demonstrate a lipophile (hydrophobe, i.e. water repellent = fat tolerant) organic residue, symbolized in Fig. 1 by rods, and a hydrophile (lipophobe, i.e. water friendly, fat intolerant) group, symbolized in Fig. 1 by a circle.

Fig. 1: Diagram of the structure of a surfactant. Sphere = hydrophilic; rod = hydrophobic.

The hydrophobe group is usually understood to contain a hydrocarbon residue with alkyl and/or aryl components. Characteristic of the hydrophobe group, as a component of the surfactant molecule, is that it behaves in a watery medium as if it were being forced out. It should be remembered that in any case van-der Waalssche attraction forces are in play, between a hydrocarbon chain as the preferred model of a hydrophobe group and the water molecules which are in contact with it. On the other hand the water molecules exert even stronger attraction forces on each other and therefore have the tendency to displace the hydrocarbon chain. This explains why the size of the hydrophobe groups plays an important role in the solubility of the surfactant.

According to the molecule structure, surfactants have an ionogenic or a non-ionogenic character which is determined by the hydrophile group in the molecule. Products are therefore classified as ionogenic and non-ionogenic. The former are divided into anionic, cationic and amphoteric surfactants. These all contain a hydrophile group which is able to dissociate into ions which are known as tensiodions and gegenions. The surfactant acquires a hydrophobe and a hydrophile residue and bears surfactant properties.

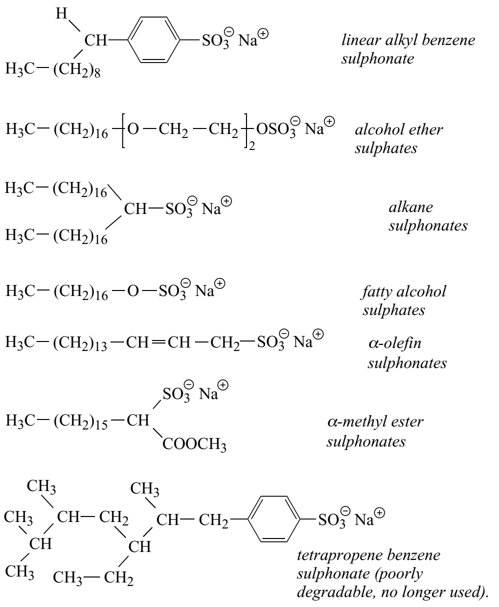
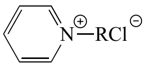


Fig. 2: Examples of anionic surfactants.

Anionic surfactants (Fig. 2) are identified by the fact that they contain an anionic, usually a $–COO^-$-, $–SO_3^-$-, $–OSO_3^-$-group, at the last constant carbon atom of a hydrophobe chain. They are therefore salts of alkyl carbonic acids ($R–COO^-H^+$), alky sulphonic acids ($R–SO_3^-H^+$) or sulphuric acid with higher alcohol levels ($R–O–SO_3^-H^+$). Cationic surfactants are predominantly derivatives of ammonia, generally alkylamines or substituted pyridine compounds which are usually quaternized.

e.g. $R{-}\overset{\oplus}{N}(CH_3)_3Cl^{\ominus}$ *or*



The amide acid, polyalcoholester (sugar ester) groups belong to the non-ionogenic surfactants (Fig. 3), as well as the ethane oxide adducts group, which is very important as far as application techniques are concerned, and whose polarity is based on the accumulation of ether groups in the polyethene oxide chain.

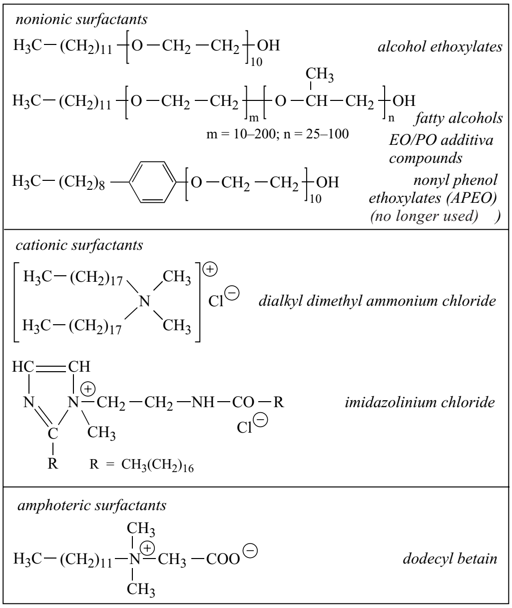


Fig. 3: Examples of nonionic, cationic and amphoteric surfactants.

Amphoteric and hermaphrodite ionic surfactants contain an anionic and a cationic group in the molecule (see Tab.). If both ionic groups are strongly disassociated, they are referred to as hermaphrodite ions. The degree of their dissociation in water is only influenced slightly by the pH value of the solution. In the case of slightly dissociated groups, the molecule reacts in acetic solution like a cationic surfactant, whereas in alkaline solution it reacts like an anionic surfactant and is known as amphoteric.

hydrophobic	hydrophilic	counterion	type	examples
alkyl-, alkyl aryl-	$-COO^{\ominus}$	$Na^{\oplus}$	anionic	soaps carboxylate
alkyl-, alkyl aryl-	$-SO_3^{\ominus}$	$Na^{\oplus}$	anionic	sulphonates
alkyl-, alkyl aryl-	$-O-SO_3^{\ominus}$	$Na^{\oplus}$	anionic	sulphates
alkyl-, alkyl aryl-	$-NH_2 \cdot H^{\oplus}$	$Cl^{\ominus}$	cationic	amine salts
alkyl-, alkyl aryl-	$-N^{\oplus}R_3$	$Cl^{\ominus}$	cationic	invert soaps qac
alkyloxy- alkyl aryl oxy-	$-(CH_2-CH_2O)_n-H$		nonionic	ethoxylates
alkylamino-	$-(CH_2-CH_2O)_n-H$		nonionic	ethoxylates
acyloxy-	$-(CH_2-CH_2O)_n-H$		nonionic	ethoxylates
acylamino-	$-(CH_2-CH_2O)_n-H$		nonionic	ethoxylates
acyl-	sugar residue		nonionic	ethoxylates
alkyl-	$-\overset{\vert}{\underset{\vert}{N}}\longrightarrow O$		nonionic	aminoxides
alkyl-	$-\underset{R_3N^{\oplus}}{\underset{\vert}{CH}}-COO^{\ominus}$		amphoteric	betaines
alkyl-	$-\underset{R_3N^{\oplus}}{\underset{\vert}{CH}}-SO_3^{\ominus}$		amphoteric	sulphaines

Tab.: Surfactant classification with examples.

The → HLB value describes the intensity relationship between polar and apolar molecule elements of a surfactant. It is determined by the type and size of the hydrocarbon chains as apolar representatives and the height of the dipole in the polar element. Thus a long straight-chained hydrocarbon element has a greater intensity than a short branching hydrocarbon chain. In the polar range an ethene oxide group is less intensive, carboxyl, phosphate, sulphate and sulphonate groups being more intensive, in descending order of intensivity. The HLB value determines:

- solubility of the surfactant
- emulsion properties of the surfactant
- dirt-bearing properties of the surfactant.

With non-ionogenic surfactants the HLB-value can be registered quantitively by codes for the hydrophile as well as for the hydrophobe (lipophile) ranges. With ionogenic surfactants, this has to date not proved to be adequately possible, as in this case other properties also determine surfactant-typical behaviour, which are not included in the HLB value. The HLB value is mainly of qualitative significance. Dividing the HLB value into a scale of 20, textile washing agents have an HLB value of 13–18 (1 = water insoluble, 20 = water soluble).

The solubility of surfactants is defined as saturation concentration in balance with a second phase, which either consists of the pure surfactant or of a defined hydrate of the same, or at least is surfactant-rich and low in water. Thus the second phase can be

- crystallized surfactant or stoichiometric surfactant hydrate or
- a fluid mixing phase of constantly variable composition.

The first of these is found mainly but not exclusively with ionogenic surfactants, the second particularly with non-ionogenic surfactants. The solubility of surfactants in water depends above all on the hydration of the hydrophile group. Thus the following characteristic behaviour of surfactants towards water as a solvent can be expected: the hydrophile group tries to achieve solubility of the surfactant in water and is successful if the hydrophobic residue is not too large. The hydrophile group therefore prevents separation of the hydrocarbon phase. The system tries, however, to reduce the energy-filled interface between hydrocarbon and water to a minimum with simultaneous maximum contact between water and the hydrophile group which leads to accumulation at the interface areas or to aggregate formation (micelle formation). The solubility of surfactants depends on both concentration and temperature. Typical surfactant phenomena are the Krafft and cloud points.

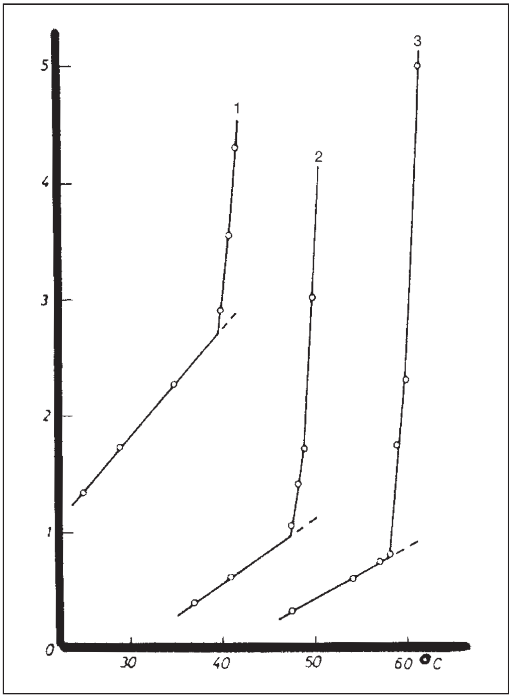


Fig. 4: The solubility in water (in 10^{-3} mol/litre) of sodium alkane sulphonates as a function of temperature. 1 = C_{14}; 2 = C_{16}; 3 = C_{18} .

The solubility temperature curve of ionogenic surfactants (Fig. 4) demonstrates a peculiarity which is connected with the formation of aggregates (micelles). The curves demonstrate turning points which move towards higher temperatures and smaller concentrations with increasing chain length. This turning point of the solubility curve is known as the Krafft point. It indicates the temperature above which the solubility of surfactants increases enormously. This increase is caused by the fact that above this Krafft point micelles are created which are considerably more soluble than surfactant monomers. The solubility curve is “cut” precisely at the Krafft point by the critical micelles concentration curve (Fig. 5).

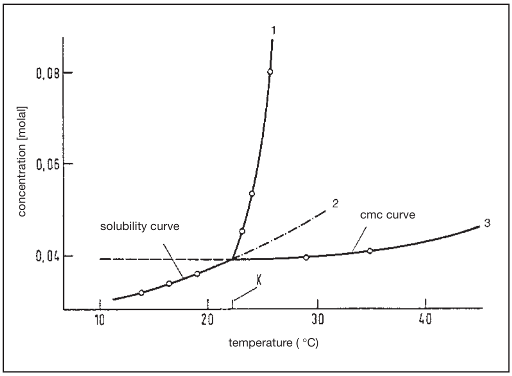


Fig. 5: Schematic phase diagram of a surfactant near the Krafft point.

The use of surfactants is only viable above the Krafft point temperature. The height of the Krafft point increases with increasing chain length of the hydrophobe group. The height is reduced if the hydrophobe group is branched. The type of hydrophile group and its inverse ions also has an impact on the location of the Krafft point. The addition of electrolyte increases the temperature of the Krafft point.

Non-ionogenic surfactants, which form a clear solution in water, demonstrate particular properties as opposed to other surfactants. When the temperature is increased and when a certain relatively precisely-defined temperature characteristic of that particular surfactant is exceeded, the solution becomes cloudy and the solution separates into two fluid phases. This temperature is known as the “cloud point”. The reason for the occurrence of this phenomenon probably has to do with hydration of the hydrophile non-ionogenic groups. This hydration is exothermal; with increasing temperature partial dehydration takes place and this causes formation of a new phase (Fig. 6). The fact that the cloud point is almost independent of the overall concentration of the surfactant confirms this explanation. The cloud point can be influenced by additives. This can be caused by additives being stored in the micelles, thereby changing their properties, or by changes to the properties of the water, i.e. the environment of the micelles. This mechanism applies in particular to the addition of electrolytes which generally transpose the cloud point to lower temperatures with increasing concentration.

The impact of the hydrophobe and the hydrophile group is due to the fact that the cloud point increases with increasing length of the ethene oxide chain (hydrophile group) and decreases with increasing length of the hydrophobe element. Interface activity is the prop-

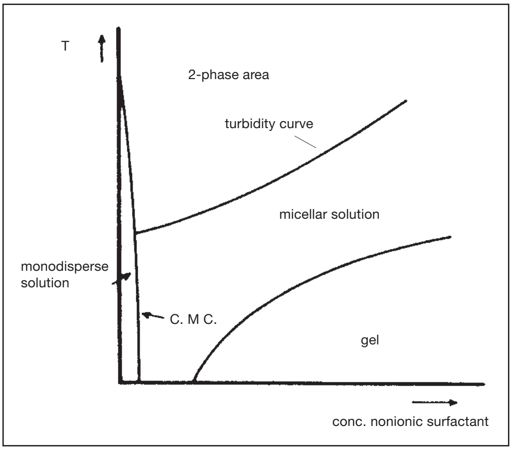


Fig. 6: Surfactant/water phase diagram (schematic).

erty of drifting out of a solution to the border area of a liquid and reducing the surface tension. The bifunctional structure of surfactants means that their concentration at the interface is up to several thousand times as great as in the solution. Orientation of the surfactants occurs simultaneously. The apolar molecule element is constantly directed towards the apolar medium, whereas the polar molecule element is constantly directed toward the polar medium. Due to the interface activity of surfactants, the surface tension of water is, for example, significantly reduced. In addition, hydrophobe, largely apolar solids in watery media are hydrophiled to a greater or lesser extent by the attraction of the hydrophobe group of surfactants, caused by van der Waals interaction. With polar solids (such as metal oxides) the hydrophile group can react directly with the solid surface during adsorption of surfactant ions, causing the hydrophobe group to be oriented towards the aqueous phase. In the case of higher surfactant concentrations a second layer can build up on the hydrophobe absorption layer, the hydrophile groups of which tend towards the aqueous phase.

The adsorption of surfactants depends to a large extent on the class and the constitution of its hydrophile and hydrophobe elements. Quantitative relationships between surfactant constitution and marginal activity have not been established in any numbers, the most important of those established being the rule defined by Traube. This rule states that an n-alkyl surfactant in aqueous solution, in which only the alkyl chain was extended by a CH_2 group, reduces the surface tension in the same way as the non extended surfactant in triple concentration. The Traube rule applies to non-ionogenic and ionogenic surfactants alike. It works on the assumption that chain extension does not cause any significant differences in hydration. The validity of the rule is limited to a certain chain length, above which surface tension increases again. A further limit is formed by the critical micelle formation concentration (aggregate formation), as the surface tension does not change above this concentration. Comparison of homologous rows of alkyl sulphates and alkyl sulphonates has shown that, with alkyl sulphates, the oxygen atom derived from the fat alcohol contributes as much to reducing the surface tension as a CH_2 group of the alkyl chain. Fig. 7 shows the surface tension curves of sulphate and sulphonate with identical alkyl chain lengths.

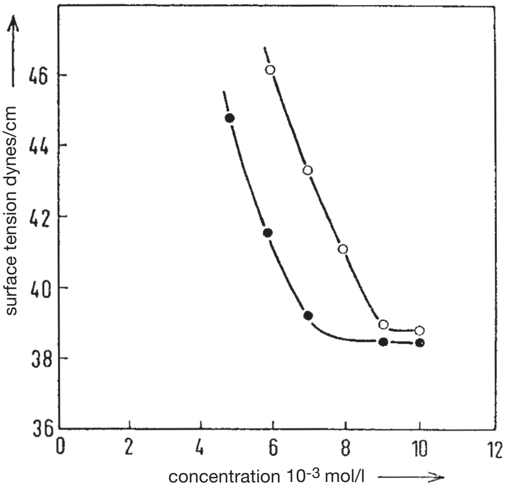


Fig. 7: Surface tension of aqueous solutions of sodium dodecyl sulphate (black dots) and sodium dodecyl sulphonate (white dots) at 27°C relative to concentration.

In addition to adsorption capability in marginal areas in order to keep the contact surface of the hydrophobe element as small as possible, dissolved surfactants beyond a certain concentration and beyond a temperature which is specific to each surfactant, i.e. the Krafft point, can amalgamate. A characteristic of micelle forming surfactants is that they form micelles in solutions at a certain concentration which corresponds approximately to the concentration at which adsorption in the phase margin has reached its saturation point. This concentration is known as the micelle critical formation concentration (CMC). Micelle formation is an expression of the fact that, with concentrations above the CMC, it is more favourable in energy terms to remove the hydrophobe chains of the surfactant from contact with the hydrophile volume phase, by bringing the surfactant molecules in the volume phase together, instead of bringing further molecules into the already saturated adsorption layer. According to a standard criterion, a surfactant is counted as being adequately pure

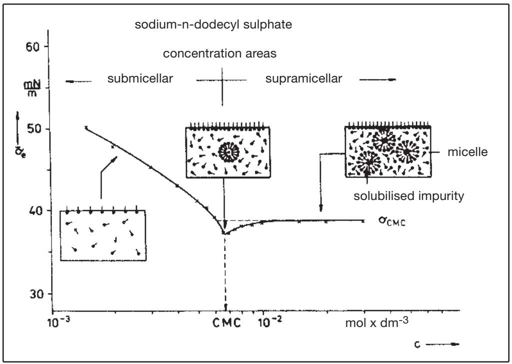


Fig. 8: (Equilibrium) surface tension/concentration isotherms of the aqueous solutions of an impure sodium dodecyl sulphate (SDDS). The concentration conditions of the SDDS and the surface active impurities in the various concentration areas: a) submicellar concentrations; b) CMC and c) supramicellar concentrations are schematically illustrated.

if no minimum occurs in its balance surface tension(σ_e) concentration(c)-isotherms (Fig. 8). The occurrence of the minimum can be explained in thermodynamic terms by the fact that the main component is no longer absorbed when the CMC is exceeded, but a new phase, the micellar phase, is introduced instead. In the first instance this does not apply to contamination, since, as a residue of the hydrophobic original product, this generally does not form micelles itself. When the CMC is exceeded, the contamination is initially further absorbed at the solution surface, which can cause the surface tension to be further reduced. Not until an adequately large number of micelles is present in the solution, are contamination molecules increasingly locked into the hydrophobe interior of the micelles. This process is known as solubilisation.

These micelles are reversible aggregates which decompose again into surfactant monomers when the solution is diluted. The example of an anionic micelle in water shows (Fig. 9) that the outer layer consists of the hydrophile, polar group, which is therefore surrounded by water. The micelle core is formed by the hydrophobe hydrocarbon chains which are in an unordered fluid state. The positive inverse ions of the anionic surfactant partially surround the micelle with a diffuse layer. The structure of a micelle of non-ionogenic surfactants is identical with the exception of the diffuse layer.

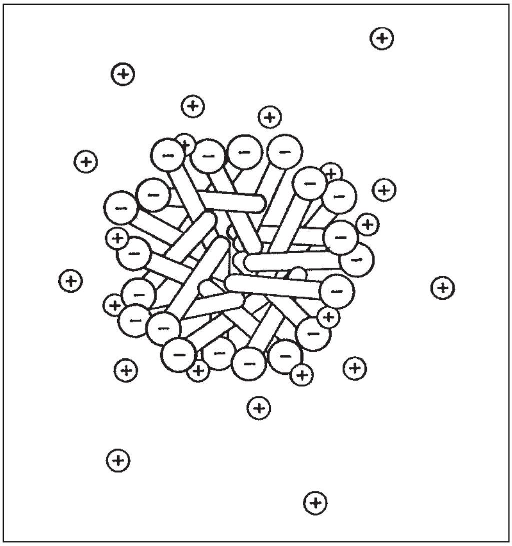


Fig. 9: The formation of a micelle by an anionic surfactant in water.

The number of surfactant monomers dissolved in a micelle, i.e. its aggregation number as well as its size, are determined by the length of the hydrophobe hydrocarbon element of the surfactant; it is therefore limited in the upward direction. If the concentration is increased, the number of micelles increases accordingly. The micellar system is in a state of thermodynamic balance so that permanent exchange takes place between the micelles and individual dissolved surfactant monomers. Depending on the surfactant concentration, a series of physical properties of the solutions provide information on the critical micelles formation concentration. The example of sodium dodecylsulfate demonstrates that a turning point occurs at the same concentration for all of the listed properties so that the critical micelle formation concentration must be located (Fig. 10).

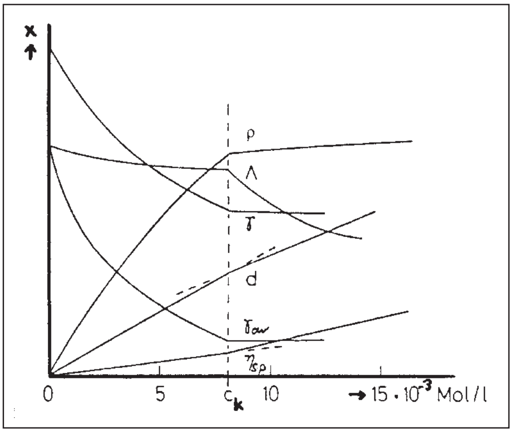


Fig. 10: Various properties (x) of aqueous solutions of sodium-n-dodecyl sulphate in relation to concentration. ρ = *osmotic pressure;* Λ = *equivalent conductance;* γ = *surface tension;* γ_{ow} = *interface tension with respect to n-heptane; d = density;* η_{sp} = *specific viscosity. The ordinate scale is arbitrary.*

In the first instance the length of the hydrophobe chain has an impact on the value of the critical micelle formation concentration. With increasing hydrocarbon chain length, the value of the micelle formation concentration is reduced. Branching of the chain causes the value to increase. The addition of electrolyte causes the critical micelle formation concentration of ionogenic surfactants to be reduced significantly. The influence of this is slighter in the case of non-ionogenic surfactants. Mixed solutions of ionogenic and non-ionogenic surfactants result in particularly low critical micelle formation concentration values. The influence of temperature on the critical micelle formation concentration is relatively slight. At a temperature increase of 50°C above room temperature it increases by approx. 30%.

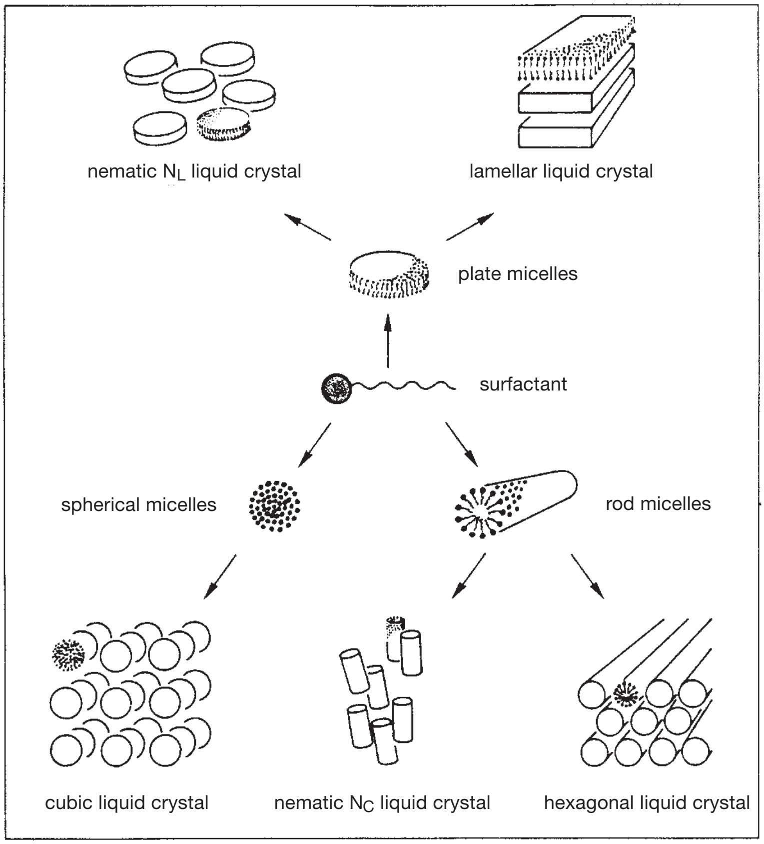


Fig. 11: Aggregation of surfactants into micelles and lyotropic liquid crystals (Henkel).

The forms of micelles depend on concentration (Fig. 11). At the critical micelle formation concentration, ball or spherical micelles form in the first instance. The cylindrical micelle form is predominant at higher surfactant concentrations. If this concentration increases still further, the surfactants accumulate to form large surfaced lamellae. A surfactant solution has the highest degree of washing and dispersion effects in the laminar state. If the surfactant concentration is further increased, the aggregates become larger or their number increases; in most cases both at a high concentration. Due to the interaction between the aggregates so-called mesophases are formed above a certain concentration. In these the individual aggregates can still be recognised as such. They arrange themselves in geometrical fashion in such a way that repulsion between individual parts is minimal, i.e. a variety of structures is formed depending on the structure of the aggregates. Thus, cubic phases result from ball or spherical micelles, hexagonal micelles develop from cylindrical ones and lamellar phases develop from wafer shapes. The aggregates in the mesophases are seen as liquid crystals due to their crystalline arrangement.

One of the most important properties of micellar solutions is their capacity to dissolve non-soluble or only slightly soluble substances by inclusion of these in the hydrophobe cores of the micelles. This process of dissolving into micelle cores is known as solubilisation. Dissolving by means of solubilisation should be differentiated from dissolving by means of hydrotropic substances. In the case of hydrotropium dissolving a substance, which is only slightly soluble or non-soluble in water, takes place by means of concentrated solutions of a not necessarily surfactant like body, solubilisation representing dissolving by means of a diluted solution of a micelle-forming surfactant. Also, solutions which originated through solubilisation should be differentiated from emulsions. Surfactant solutions with and without solubilised material have the same phase characteristics; they are thermodynamically stable, as opposed to emulsions. The tight tolerance value for adsorption of the solubilised substances represents a further difference to emulsions. The quantities of material which can be solubilised depend on the type of surfactant as well as on the type of material to be solubilised. Branching generally opposes solubilisation in the hydrophobe range of the surfactant molecule. Solubilisation of dirt particles represents an important factor in the washing process.

The purpose of surfactant application in the textile finishing industry can either be its own effect, as is the case in the use of washing and cleaning agents or their auxiliary effect during finishing with other materials, when they facilitate or help to improve the application of a finishing agent as a net, disperser, emulsifying, equalising agents, etc., developing a protective effect and rendering some processes possible due to their specific properties. The first range of application is determined by the hydrophile group. Thus cationic surfactants are mainly used as softeners, whereas anionic or non-ionogenic surfactants are used as net, dispersing, emulsifying or equalising agents, etc. The hydrophobe group also determines its own range of application. Surfactants with a long non-branching hydrocarbon chain have, for example, an intensive washing and cleaning effect. Whereby, on the other hand, the hydrophobe element is short-chained and branched, the surfactants are particularly good as network agents or emulsifiers.

Surfactant stability to hard water Definition of the level of resistance exhibited by surfactants in the presence of hard water. Hardness caused both by calcium and magnesium is taken into account, with a ratio of 17 : 3. Detection characteristics: breakdown of the bond between surfactant and alkaline earth ion, or change in colloidal state caused by ionic forces, salt effects, etc.

Surfactant toxicity If surfactants are ingested orally, they are not particularly toxic to mammals. The Tab. shows the acute toxicity levels of both surfactants and soaps most commonly used in industry. A range of substances having different chain lengths are listed under each heading; testing was carried out under varying test conditions, using different test organisms of the same generic type. For this reason, there is a wide spread of results. However there is a stronger toxic effect on aquatic organisms, which are subject to physical contact rather than oral ingestion, as is the case with mammals. They have extremely thin, delicate membranes inside the gill, which are damaged by surfactants in high concentrations. In the worst cases recorded, even concentrations of a few mg per litre have been observed to cause acute toxicity. Sodium dodecyl sulphate even has anti-shark properties. In the case of LAS, the level of aquatic toxicity increases proportionally to the length of the side chain, i.e. fat solubility. Similarly, biodegradability becomes better, and so a compromise in chain length must be found in order to develop surfactants that are particularly environmentally friendly. Therefore surfactants with low toxicity and high stability could be developed to counteract oil spills caused by tanker accidents at sea. However, ecologists are extremely sceptical as to whether the advantages of using surfactants (rapid oil dispersion) would actually outweigh the disadvantages (additional water pollution). With non-ionogenic alkylphenol ethoxylates (APEO, Tab.), biodegradation begins on the ethoxyl side, so that nonylphenol is formed as an intermediate product, which takes significantly longer to biodegrade. This product has a higher level of toxicity for aquatic organisms. For this reason, APEO is not used in detergents and cleaning agents in Germany.

Suri (alpaca) fibre Fine animal hair originating from a species of South American camel. From a quality point of view, it is the best type of → Alpaca fibre, having an even colour shade and even linear density (approx. 25 µm, about 90–110 scales per mm).

Surikome printing Ancient Japanese technique, a multi-coloured version of → Kasuri dyeing.

Surplus liquor application → Liquor application in

Substance	mammals LD_{50} mg/kg	fish LC_{50} mg/l	bacteria LC_{50} mg/l	algae LC_{50} mg/l	daphnia LC_{50} mg/l
LAS	650 – 2500	3 – 60	40	10 – 300	5 – 15
Alcohol ether sulphates	1800 – 10000	2 – 20	> 1000	60	1 – 50
Secondary alkane (C_{13}-C_{17}) sulphonates	1000 – 3000	3 – 24	60 – 700	4 – 120	2 – 5
Sodium fatty alcohol (C_8-C_{20}) sulphate	1300 – 20000	3 – 20	–	60	5 – 70
a-olefin sulphonates C_{14}-C_{18}	1300 – 3600	2 – 20	–	10 – 100	5 – 50
Sodium-a-methyl ester sulphonates C_{12}-C_{18}	> 2000 – > 5000	1 – 2	> 220	3	20 – 40
Sodium stearate (soap)	7000 – 20000	20 – 150	700	10 – 50	300
Alcohol ethoxylates	1600 – 25000	1 – 50	60 – > 1000	1 – 30	1 – 5
Fatty alcohol-EO/PO additive compounds	2300 – > 5000	1 – 6	> 1000	–	2 – 6
Dialkyl (C_{16}-C_{18}) dimethyl ammonium chloride	5000 – 20000	1 – 6	50 – > 2500	1 – 75	0,1 – 1
Imidazolinium salt	3300 – > 10000	1 – 16	27 – 50	3 – 17	2 – 3
Nonyl phenol ethoxylates	1400 – 3800	5 – 11	32 – 64	20 – 50	4 – 50
Nonyl phenol	600 – 2500	0,1 – 1	> 10	1	0,2

Tab.: Acute toxicity of surfactants.

a greater quantity than can normally be achieved on a padder. The surplus is the amount of surface water that can be held as an intermediate volume (e.g. in a pile), where the water could be removed by squeezing. Various surplus liquor processes have been developed and implemented in fabric pre-treatment. The Menzel Optimax machine, for example, operates with a "split" padder, to strip off the surplus liquor up to the surplus application value (110%). The Babcock Super-Sat system impregnates up to the surplus liquor application value in the nip of the deflecting rollers. The Küsters Flexnip machine uses a type of aquaplaning effect for surplus liquor application.

Suspending power Property exhibited by certain substances of holding solid particles in → Suspension.

Suspending property → Soil suspending property.

Suspension Dispersion is a generic term for all dual phase mixes. Dispersion from a solid phase (e.g. "dispersion" dye) and a liquid phase (e.g. dye liquor) is known as suspension.

Suspension centrifuge → Centrifuges.

Suspension drying,

I. (screen printing). Before fabric that has been printed using the flat-screen technique can be processed further, the print paste must be completely dry to avoid smudging. For this purpose suspension dryers are used, which are mobile or static systems. If there is good air circulation, the fabric will dry rapidly enough, or the air can be heated to speed up the drying process. Another option is to dry out the humidity in the ambient air by using a silica gel filter, which produces good results.

II. → Drying systems.

Suspension drying in screen printing Obsolete drier used in screen printing, on which the fabric was hung in loops from drying rods. Air was circulated slowly from top to bottom.

Suspoemulsion A mixture of anionic and non-ionogenic emulsifiers or anionic dispersants, with specific stabilizers and de-foamers. With a suspoemulsion, it is possible to combine biocides with varying physical and chemical properties, because it has a mixed structure.

SVCC Schweizerischer Verein der Chemiker-Coloristen (Swiss Association of Chemical Colourists). Specialist publication: "Textilveredlung" (Textile Finishing). → Technical and professional organizations.

SVD Schweizerische Vereinigung für Dokumentation, or ASD Association Suisse de Documentation (Swiss Documentation Association). Publisher of → SKT.

Svenska Färgeritekniska Riksförbundet (SFR). Swedish Association of Textile Engineers and Technicians. → Technical and professional organizations.

SVF Schweizerische Vereinigung von Färbereifachleuten (Swiss Association of Dyeing Specialists). Official publication: "Textilveredlung" (Textile Finishing). → Technical and professional organizations.

SVMT Schweizerischer Verband für Materialprüfungen der Technik (Swiss Association of Technical Material Testing). → Technical and professional organizations.

SVT Schweizerische Vereinigung von Textilfachleuten (Swiss Association of Textile Specialists), Zurich. Formed by the merging of VST (Vereinigung Schweizerischer Textilfachleute) and VeT (Verein ehemaliger Textilfachschüler). Publication: "Mittex". → Technical and professional organizations.

SWA Soil Water Air. Refers to → Ecological problems in textile dyeing, printing and finishing. There is an SWA group in Basle, Switzerland (Basler Chemie). It is mainly Swiss textile finishing professional organizations that are involved in SWA group textile finishing.

Sweat (perspiration). Consists of 98% water; $^3/_4$ organic salt residue (sodium chloride, phosphates, sulphates, potassium, calcium, magnesium); the rest is made up of organic compounds (urea, uric acid, neutral fats, volatile fatty acids, cholesterol, lactic, citric and amino acids, etc.). The sodium chloride content is usually in excess of 0.5%. Usually acidic to begin with (pH 4.5–6), however it moves into the alkaline range after a few hours (particularly if the diet consists mainly of vegetables). The composition of sweat is dependent on lifestyle, time of year, diet and general health. Human sweat glands produce between 0.2 and 2 l of sweat per day (→ Clothing physiology). The penetrating odour of sweat is caused by the growth of different types of bacteria that cause the protein compounds in sweat to be broken down. Biodegradable components in finishes and the fact that sweat is becoming increasingly alkaline provide ideal conditions for the bacteria to develop. Types of germs that have been detected in sweat include yeast, aerobic germs (sarcina), bacillaries, staphylococci and even pathogenic bacteria (which can cause disease).

Sweated wool → Skin wool treated using the sweating process (sweating: controlled rotting process, the oldest biological method of dewooling). → Mazamet wool.

Swelling Limited solubility (solution = infinite swelling). A fibre swells if it has the capacity to store substances in liquid or vapour form on a temporary basis. This increases the volume of the fibre, which is frequently associated with shortening of the fibre (transverse swelling). In some cases the fibre can also become longer as a result of swelling (longitudinal swelling). After the liquid is extracted or discharged, the fibre will return to its original volume. The temperature of the liquid (e.g. water or solvent), the size of the particles and the pH (acid or alkali) also have an influence on the fibre's absorbency and swelling capacity. Natural fibres have a better swelling capacity or hygroscopic properties (absorbency) than synthetic fibres, because natural fibres have larger cavities, whereas the swelling potential of synthetic fibres is dependent on the chemical substance and the method of manufacture (ratio of crystalline zones). Each swelling process is a preparatory stage towards becoming a solution. The lower the packing density, the more amorphous areas there are, and the more cavities they contain, the easier it is to dissolve a fibrous material. If the liquid or solvent penetrates through the amorphous areas and between the crystalline zones, temporary (reversible) swelling occurs. Permanent swelling occurs when the solvent penetrates the crystalline zones, which can cause damage. Widening of the pores caused by the swelling agent is dependent on two factors:

1. the type of swelling agent.
2. the morphological fibre structure.

I. Cellulose fibre swelling: viscose exhibits a high swelling capacity in water. The water penetrates into the fibre pores, which is not caused by capillary effects alone. The absorption of water is a consequence of molecular solvation forces originating from the free, unbonded hydroxyl groups in the glucose. Swelling in water takes place, therefore, primarily in the amorphous areas of the fibre, which is why it is known as intermicellary swelling. The volume increases in parallel with water swelling. This can be seen from the increase in diameter of the fibre, but not so clearly when the fibre is in solution (Fig. 1). This anisotropy is closely linked with the degree orientation of the crystallite towards the fibre axis.

Fig. 1: Model showing a fibre which has been swollen in water (according to Hermanns).

The water penetration causes the paralleled molecule chains, which are not very strong, to be forced apart. This forcing apart can cause chain shifts even in the structured areas, because the boundaries between the amorphous and crystalline regions are fluid. Water penetration is not possible because of the high level of hydrogen linkage bond crosslinking. As the fine structure of the fibril threads after deswelling (drying) is not significantly altered, water swelling can also be termed reversible. After each swelling process followed by drying, there is a slight decrease in water absorbency. For this reason, free hydroxyl groups must have already undergone saturation, a slight rearrangement of the hydrogen linkage bonds, after the deswelling process. The extent of swelling for cellulose in an alkaline solution is greater than in pure water. In contrast to water, swelling in an alkaline solution occurs, to a certain extent, in the crystalline areas, as well as in the amorphous areas. This intramicellary swelling is irreversible when the alkali concentration is above a certain level, and it can ultimately result in deterioration of the fibre structure.

Influence of the absorbed quantity of sodium hydroxide on structural changes in cellulose (→ Mercerization):

– 0–9%	unchanged cellulose,
– 9–12%	unchanged cellulose and soda cellulose I,
– 12–20%	soda cellulose I,
– 20–45%	soda cellulose II.

The extent of cellulose swelling in an alkaline medium depends on the quantity of water absorbed, which in turn is dependent on the alkali concentration in the solution.

The first theory on cellulose swelling can be credited to Neale. He categorizes cellulose as a weak monobasic acid (pH 13.7). It reacts with alkalis, forming salts:

$$\text{cell–OH} + Na^+ + OH^- \rightarrow \text{Cell–O}^- + Na^+ + H_2O$$

The salt dissociates into the counterions (Na^+, K^+), which are fairly mobile, and into the cellulose anions. It is not possible for the counterions to revert to a liquid state because of the membrane potentials that occur. They remain in the swelling water contained within the amorphous and crystalline areas, where they resist any further penetration of alkali. The level of resistance increases in proportion to the alkali concentration in the liquid phase, which means that the difference in ion concentration is increased in both phases. The osmotic swelling pressure also increases as the alkaline concentration increases, until the alkaline concentration reaches the maximum cellulose bonding level. If the alkaline concentration continues to increase, the amount of free alkali in the fibre will also increase, so that an assimilation of ion concentration in both phases occurs.

However the theory described does not explain the varying swelling behaviour of cellulose in different metal hydroxide solutions (KOH, NH_3OH). Chédin and Marsaudin discovered that swelling is triggered when the hydrate water of the solute metal hydroxide is substituted with hydroxyl groups, as shown by the following:

$$\begin{gathered}\text{cell–(OH)}_3 + Na^+ + OH^- \cdot n\,H_2O \\ \rightarrow \text{cell–(OH)}_3 + Na^+ + OH^- \cdot (n-3)\,H_2O + 3\,H_2O\end{gathered}$$

If hydrated ion pairs are adsorbed by the cellulose, three water molecules are detached from the hydrate water and replaced by three alcoholic cellulose end-groups. The water molecules that are now free have a greater volume than the hydrate water of the Na ion, and therefore cause the fibre to swell. The hydration tendency of the metal ions decreases in the following sequence:

H → Li → Na → K → Rb → Cs → NH_4

The swelling tendency of regenerated cellulose fibres is lower in electrolytic solutions than in pure water. This is because some of the ions (salt) penetrating the fibre together with the water are adsorbed by the fibre, which reduces the water bonding properties of the freely accessible hydroxyl groups. As the ions of different elements are adsorbed at different rates by the hydroxyl groups in the cellulose, the water bonding properties and therefore the swelling potential of cellulose varies in different electrolytic solutions. Ions with a larger ionic radius are bonded less strongly than ions with a smaller radius. On this basis, the swelling of cellulose in electrolytic solutions containing the following cations increases in the sequence:

Cs → Rb → NH_4 → K → Na → Li

Energy is released during water swelling, as well as during swelling in alkaline solutions. The heat of reaction, i.e. the freed energy, varies in quantity. For water swelling, the amount of heat is 15 J/g cellulose, and for alkaline swelling (NaOH 7.4%) it is 28 J/g cellulose.

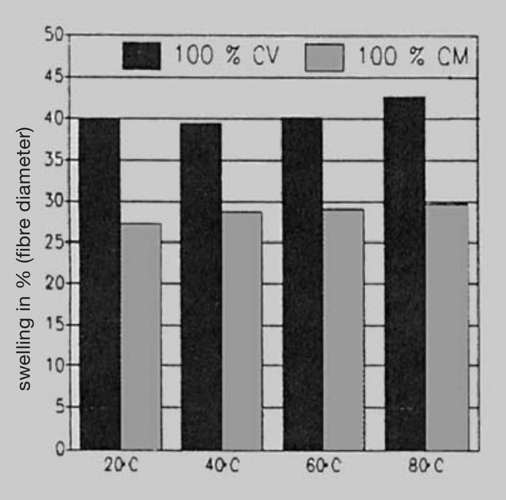


Fig. 2: The influence of temperature on the swelling of viscose and modal fibres (1.3 dtex, pH 7).

Any external energy source in the form of an increase in temperature would in theory have a negative effect on the swelling process, since exothermic reactions are taking place, which produce their own activation energy. With viscose fibres however, the water swelling increases slightly as the temperature of treatment is raised (Fig. 2).

On the other hand, the properties of equilibrium swelling are exactly the opposite in a concentrated caustic soda solution (250 g/l), in other words the extent of swelling decreases as the temperature rises (Fig. 3). The concentration of alkali during viscose fibre dyeing with reactive dyes does not reach these levels.

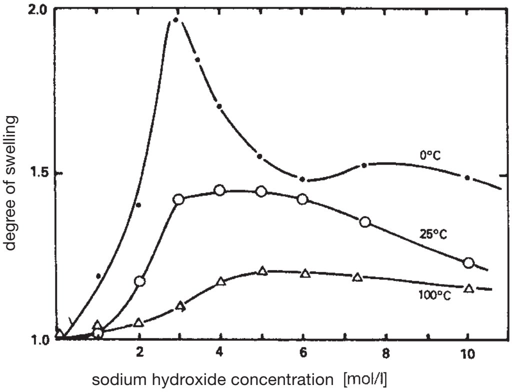


Fig. 3: The equilibrium swelling of cotton in solutions of sodium hydroxide.

However, the water swelling results stated above contradict the opinion of dye and fibre manufacturers, who are of the opinion that cellulose swelling is at its highest when the temperature is low. Experiments have been carried out to test through flow in vat dyeing of viscose filament yarn packages at varying temperatures and pH levels, which confirm this controversial point of view.

The construction or twist of the yarn also influences the extent of swelling. If the yarn only has a slight twist, it will swell to a much greater extent than a ply yarn. To compensate for this effect, packages of yarn such as viscose filament (ply-yarn) are wound very loosely, so that the yarn, which has a high swelling capacity, has enough space to swell. This prevents a situation where the pressure on the inner yarn layers caused by the change in volume after swelling results in an uneven flow of the dye throughout the entire yarn package.

II. Swelling as an indicator of a chemical reaction: a chemical reaction is not directly visible. However it can be followed indirectly. There are various different possibilities: the temperature curve, the change in pH or redox potential, the formation of a precipitate or a gas, a change in colour, or another indicator that does not display the reaction itself, but merely constitutes a signal. A change in shape resulting from a chemical effect is also no more than an indicator of the reaction itself. There are two types of reaction that can cause a change in shape, corrosion and swelling. Both of these processes play an important role in microscopy: One in metallography, and the other in fibre microscopy. A swelling object becomes larger in volume if it absorbs a liquid swelling agent. In other words a xerogel becomes a gel if it reacts with a swelling agent. A xerogel is a very dry gel. Many pre-prepared foodstuffs are xerogels, which are converted to gels, usually hydrogels, during cooking. Rice and all dried pulses are xerogels, and bread is a hydrogel, which becomes a xerogel as a result of ageing. Textile fibres also consist of xerogels which, if the substance is cellulose or keratin, can only be dyed and finished in the form of a swollen hydrogel. There is a linkage, even though narrow, between the properties of the fibre in the dyeing bath and the swelling reaction under the microscope, provided that the dye liquor and the swelling agent are chemically similar.

Swelling can be isotropic or anisotropic in character. Amorphous bodies, such as gelatine, glue, gum arabic, agar agar, pectin, cellulose ether, swell isotropically. An increase in volume occurs all round without a preferred direction of expansion. However, when fibres are exposed to a swelling agent, they behave anisotropically, virtually shrinking as they swell primarily in width. Both types of swelling are shown diagrammatically in Figs. 4 and 5.

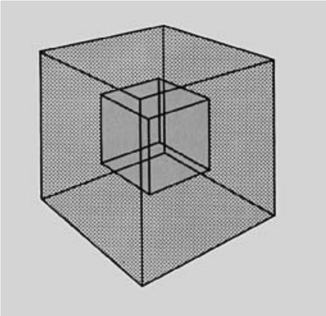


Fig. 4: Isotropic swelling.

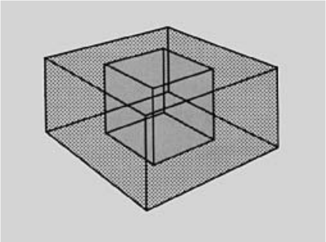


Fig. 5: Anisotropic swelling.

An object only swells anisotropically if its macromolecules are ordered in some way; in other words anisotropy is an indicator of order. This can be demonstrated by means of a simple model. The model consists of straight sticks, the system of order being that the sticks, which are equidistant from and parallel to each other, form a bundle. It is also assumed that the sticks exhibit mutual attraction. The bundle has a certain level of stability. The swelling agent, represented here as particles in free motion, is located outside the bundle, and is attempting to penetrate the lengthways cavities between the sticks from the narrow side. For its entry to be successful, the particles of the swelling agent must interact with the sticks. This neutralises the forces that act between the sticks, the swelling agent can fill up the cavities, and as the process continues the bundle expands in width. The bundle of sticks behaves as an object that swells anisotropically (Fig. 6).

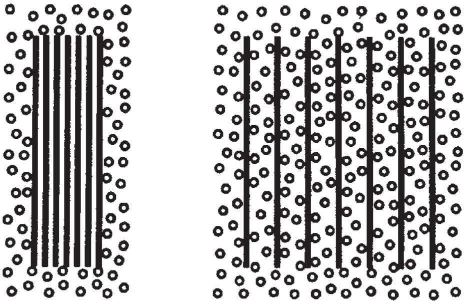


Fig. 6: Proposed model of swelling. The elements of the model are rods; these enter into an interaction with the swelling agent which results in a lateral swelling of the bundle of rods.

The bundle can be stabilized by means of linkages, which cause widthways expansion to be limited or impossible. It would be thought that the crosslinkages could be forced apart if the appropriate action was taken, which would be reflected in the swelling behaviour. It would be assumed that the stick model would ultimately be partially or totally destroyed. The further decomposition progresses, the more the substance dissolves instead of swelling. Variations in the stick model that represent these different possibilities are shown in Figs. 7–9 (according to Bigler).

Cuprammonium, the so-called Swiss reagent, has been used for almost 100 years as a solvent for cellulose. As soon as cellulose comes into contact with a solution of copper (II) hydroxide in concentrated ammoniac ($Cu(NH_3)_4(OH)_2$), it dissolves rapidly, forming a complex up to the highest mole weight ever recorded. The hydroxyl groups in positions 2 and 3 of the cellulose react with complexed copper ions. The intramo-

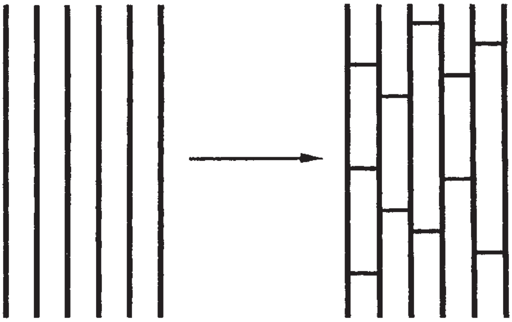


Fig. 7: Stabilization through cross-linking.

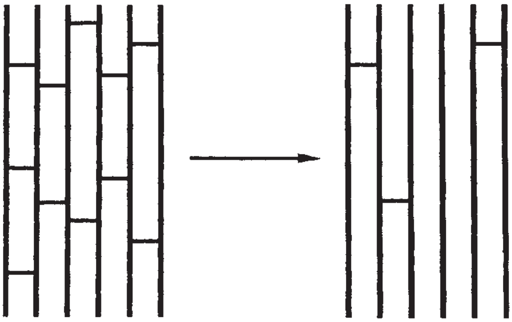


Fig. 8: Breakdown of the crosslinkages.

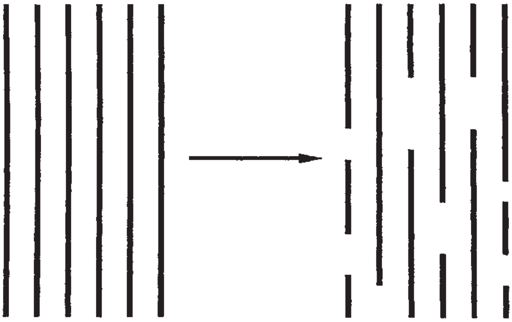


Fig. 9: Break-up of the model.

lecular hydrogen linkages are dissolved, which means that the cellulose loses its stiff quality. Conclusions can be drawn from the dissolving behaviour of dyed and undyed cellulose in cuprammonium, regarding the fibre/dye bond. In addition, these properties can be regarded as an indicator of the cuticle condition in the cotton fibre. The insolubility of cuprammonium, when bifunctional reactive dyes are used, is caused by two reactive dye groups reacting with the cellulose to form a crosslinking bond. However there is no adequate explanation of why, only the crosslinking is the reason for insolubility in cellulose dyed with bifunctional dyes, because cellulose dyed with a dichlorotriazine dye and set on one side only (recognizable because of the large quantity of unreacted chlorine) is just as insoluble in cuproammonium as cellulose that has been treated with fully reacted DCT dye. Complex Cu ions from the cuprammonium can be sterically prevented from affecting the fibre by means of bonding the dye to the fibre, which is the reason for insolubility. For this reason, it would be easy to reach the wrong conclusion that crosslinking is the cause. Yet it makes no difference whether crosslinking occurs or not. Therefore fibres dyed with a concentrated bifunctional vinylsulphone dye with good setting properties (C) swell less strongly than fibres dyed with a monofunctional vinylsulphone dye with lower setting properties (E), or a heterobifunctional reactive vinylsulphone/DCT dye (D) (Tab.).

Fibres dyed with Remazol Black B swell very little in cuprammonium. The fibres treated with Cibacron

	solution	swelling	begins to swell or dissolve	after 15 minutes
A	+	+	after 2 seconds	entirely dissolved
B	+		immediately	entirely dissolved
C	-	+	after 90 seconds	slight swelling
D	-	+	after 30 seconds	moderate swelling
E	-	+	after 30 seconds	moderate swelling

Tab.: Test on the swelling behaviour of samples A to E. A = raw goods; B = blank dyeing; C = Remazol Black B (Hoechst) (200 g/l; fixation ratio 92%); D = Cibacron Marine C-G (Ciba Geigy) (50 g/l; fixation ratio 91%); E = Remazol Black GK (Hoechst) (200 g/l; fixation ratio 40%).

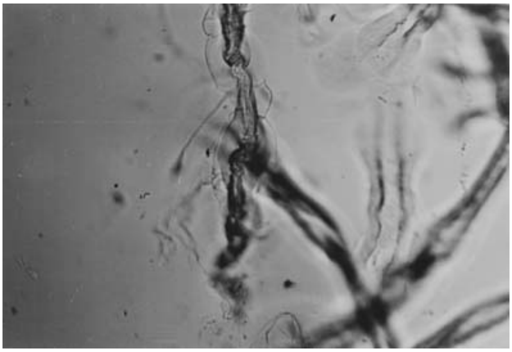


Fig. 10: Solubility in cuprammonium as endless swelling. Raw goods after 60 s: the fibres dissolve particularly rapidly at their cut ends.

Fig. 11: Solubility in cuprammonium as endless swelling. Blank dyed sample after 10 s: the dissolving process here is also connected to a swelling process, as shown in the photograph.

Fig. 12: Cibacron Marine C-G (Ciba Geigy) after 15 min. The fibres are entirely swollen but no dissolving has taken place.

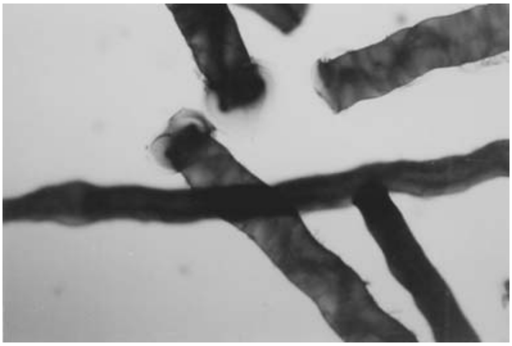


Fig. 13: Remazol Black B (Hoechst) 200 g/l after 90 s. The fibres are only beginning to swell slowly. The fraying at the cut ends (mushrooming) is clear to see.

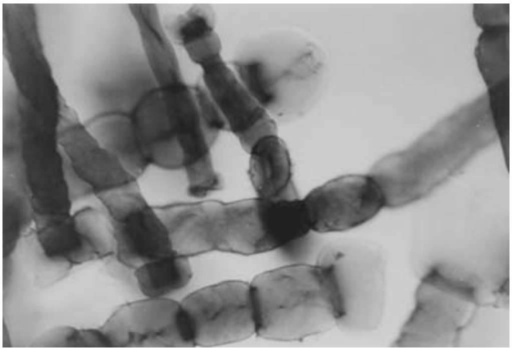


Fig. 14: Remazol Black GK (Hoechst) after 15 min. The ligatures show more clearly why the fibre diameter has increased.

Marine C-G or Remazol Black GK swell faster, and when the swelling process has finished they have a wider sectional expansion. In contrast to untreated fibres and the control sample fibres, the dyed fibres do not dissolve in the cuprammonium reagent (Figs. 10–14).

Swelling agent in dyeing → Carrier.

Swelling agent in printing The absorbency of print pastes is frequently limited in regenerated cellulose fibres, and for this reason swelling agents are added to the print paste, or a → Carrier is used, as is the case for polyester dyeing. For acetate filaments the following swelling agents are used: triacetin or triurea and salicylic acid. For synthetic fibres, using a swelling agent as a print paste additive presents problems, because fibre swelling and therefore dye uptake is uneven as a result of the uneven application of print paste. Swelling agents can also be used as setting accelerators. Setting accelerators, e.g. alkylphenol-based, can be useful for setting processes using superheated steam, hot air or contact heat on hot cylinders.

Swelling anisotropy The fibre swells significantly more strongly in diameter as opposed to length.

Swelling as a precondition for finishing Cellulose fibre swelling is of primary importance for the finishing of these fibres. Cellulose is a substance that does not melt. Because of this, chemical reactions are only possible via the swelling solution, which can be used to penetrate inside the fibre to the cellulose molecule. In this way it is possible to involve the substances in the swelling solution in the reaction. Failing to take this fact into account can lead to an unsatisfactory result from dyeing and resin finishing processes. It is essential to have an overall picture of the complex histological and morphological structure, in particular of cotton fibre. Cellulose fibres can absorb water either by direct contact with the water or from environmental air humidity. The water penetrates as far as the intermicellary cavities. The path travelled by the water inside the fibre to reach these cavities, taking into account the relative size of the molecules, is narrow and extremely long. The diameter of the most important structural molecules is approx: cellulose molecule as the smallest unit: 0.5 nm; cellulose fibrils: 10–20 nm; fibril bundle: 0.1–0.2 µm.

As the cellulose absorbs the water, it heats up significantly enough to be measurable, which signifies an exothermic reaction. An equilibrium with the atmospheric humidity is reached, depending on the humidity level. The difference between the humidity in contact with 100% saturated humidity, which occurs in close proximity to the body because of sweat secretion, and normal air humidity of about 65%, results in precipitation, whereby the moisture from the human skin is transported outwards. This is particularly important for wearing comfort in clothing.

During the dyeing process, the dyes are intercalated in the fibre by means of the swelling solution. Reactive dyes are chemically bonded to the cellulose molecule. It takes a certain amount of time for the swelling solution to transport the dye, however it is still relatively fast if the fibre can be treated with solutions containing all the substances necessary for the reaction. If the fibre is already swollen, exchange can only take place according to the laws of osmosis, which requires much more time and makes continuous processes difficult.

If crosslinking takes place while the fibre is wet, the treated fibre will be wet crease resistant. If moisture levels are controlled, dry crease resistance can be achieved. The optimum combination of a good dry and wet creasing angle can be achieved with a water content of 6–8%. The moisture limits are very close together, because if the moisture level is in excess of 8%, it causes the dry creasing angle to drop sharply. By this means the necessary parameters for a good wash-and-wear finish can be controlled. It is not enough just to regard the chemical process as the important factor, it is also essential to take physical conditions into account, particularly the swelling of the cellulose and the consequences resulting from it. For instance, wet crease resistance is not only a result of chemical crosslinking of the amorphous cellulose regions, but also of physical processes.

The speed of the swelling reaction can either be determined by the diffusion speed of one or several components crosslinking into the substrate, or by the speed at which the intermolecular and interfibrillar cellulose forces are released. In the first situation, the swelling is controlled by diffusion, and in the second the diffusion is limited by the swelling process.

The swelling kinetics can be analysed by measuring the increase in weight of the cellulose fibres during crosslinking, as increase in volume (= swelling) is proportional to increase in weight. The relative swelling f_Q of the fibre can therefore be calculated using the following formula:

$$f_Q = \frac{G_t - G_0}{G_\infty - G_0}$$

f_Q = relative fibre swelling
G_t = weight of fibre at time t
G_0 = weight of fibre before reaction
G_∞ = weight of fibre at time $t \to \infty$.

In series 1 and 2 (Figs. 1–2), the swelling speed increases in line with the water content in the crosslinking solutions. It increases particularly in experiments with between 30 and 50% water. The S-shape of the relative swelling curves shows that the swelling process is not, or not solely, defined by the diffusion speed of the crosslinking components, but is probably dependent on the speed at which the interfibrillary interactions are broken. If the swelling process was diffusion-controlled, the relative swelling speed up to $f_Q \leq 0.4$ would have to show a linear dependency of $t^{1/2}$, which can be almost reached if the level of water is very high. In crosslinking solutions without hydrochlo-

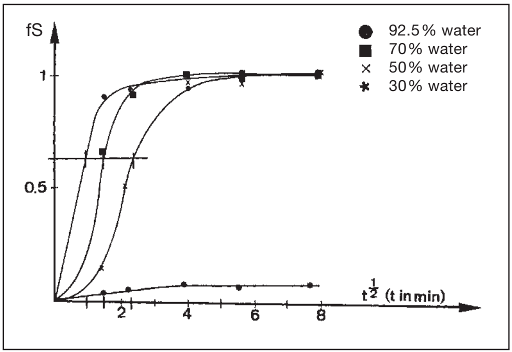


Fig. 1: The relative swelling rate of a viscose fibre, series 1 (7.5% formaldehyde, 92.5; 70; 50; 30% water, remainder acetic acid) (according to Annen).

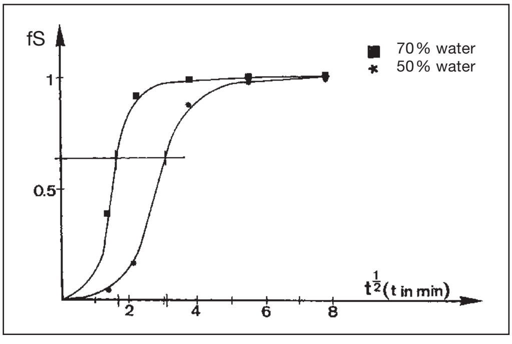


Fig. 2: The relative swelling rate of a viscose fibre, series 2 (14% hydrogen chloride, 7.5% formaldehyde, 70% or 50% water, remainder acetic acid) (according to Annen).

series	H_2O %				
	92.5	70	50	30	18
1	1.2	2.0	6.0	$3 \cdot 10^3$	–
2	–	3.2	10.2	$> 10^3$	$> 10^3$

Tab.: Relaxation time in swelling t_q (in minutes).

ric acid (series 1), the swelling speed is higher than for equivalent experiments with hydrochloric acid (series 2). In series 2 it is not possible to determine the equilibrium value of the experiments with 18 and 30% water, because the fibres hydrolyse before they reach the swelling parameter.

By definition the relaxation period during swelling is the time required for the fibre to swell to 1 – 1/e of the final swelling value (Tab.). The swelling curves are cut at $t^{1}/2 = \tau_Q{}^{1}/2$ and run parallel with the $t^{1}/2$ axis in the diagram $f_Q = \Psi(t^{1}/2)$ where $f_Q = 1 - 1/e$ (Figs. 1–2).

The swelling properties of human hair form important criteria both for the evaluation of diffusion processes, as well as monitoring reversible and irreversible structural changes. In Fig. 3 the chronological sequence of swelling during a sulphite permanent wave process is shown. The influence of temperature on the swelling is clearly visible. There is a surprising result – there is an increase in swelling while the hair is being rinsed after reduction, which is caused by osmosis. This leads to irreversible hair damage.

Swelling capacity Swelling capacity or swelling potential means the capacity of textile fibres to absorb water or other substances such as solvents, in liquid or vapour form, and to store it temporarily. To measure absorption and swelling capacity, the moisture uptake or water uptake and water retention capacity are measured. The moisture uptake is calculated as a percentage of dry weight (under normal atmospheric conditions). Moisture levels can be measured by determining the dry weight by drying out the fibre, or by means of electrical or physical processes.

Swelling fixation (swell thermosetting), term for thermosetting using hot water, saturated steam or aqueous solutions at 20–110°C with swelling agents.

Swelling-induced fabric relaxation The cotton fibre within a yarn or fabric is primarily subject to longitudinal tension during the manufacturing and finishing processes. Wet treatment causes the cotton fibres to swell to a greater or lesser degree, and causes the threads or the run of fabric to stretch lengthways. In this way, the tensile energy becomes more intense in the swollen fibres, and distortion is initially prevented in the subsequent drying or deswelling processes. According to this principle, high levels of latent tension can build up during wet treatment of cotton fabrics under tension. If the deformed fabric is then subjected to a tension-free wet process, the water triggers anisotropic swelling behaviour, which means that the cotton fibre undergoes an extreme expansion in cross-section as opposed to an increase in length. The take-up and twist of the yarns in the fabric is increased, and as the fibre

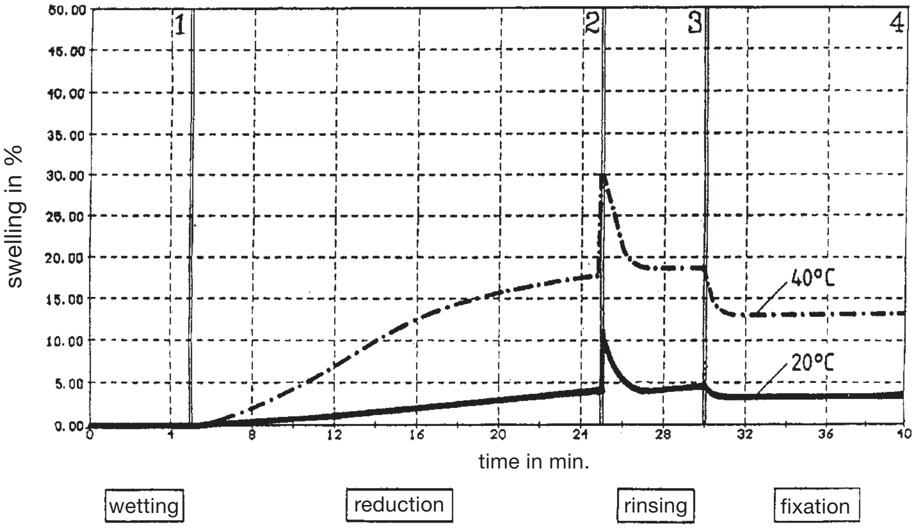


Fig. 3: The swelling curves in a sulphite permanent wave at two different application temperatures.

swelling progresses, freedom of movement of the fibres and yarn becomes restricted. During tension-free water treatment, the hydrogen linkages can be suspended and the deformation reversed. A deeper level of swelling, and suspension of interactions or new formations during deswelling, can only be achieved by using an alkali treatment. This method of stabilization is permanent, in contrast to subsequent water treatment.

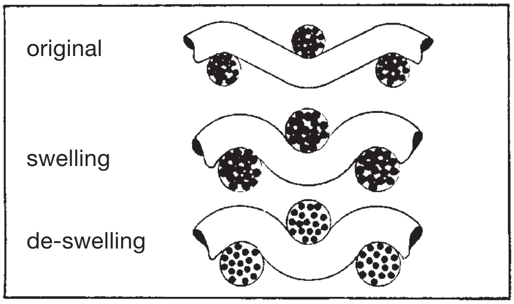


Fig. 1: Diagram of the shrinkage mechanism.

Woven fabric consists of two thread systems that cross over each other. During swelling the take-up and twist, or ondulation, of a thread system needs to increase in order to adjust to the growth of the yarn cross-section of the other thread bundle. It is not possible for the yarn to stretch for reasons of energy, as the fibre only has a small zone of elasticity. As a result, the number of warp and weft threads increases (Fig. 1).

Mercerization means causticizing at an alkali concentration of 28–32° Bé under tension. If the fabric or yarn is tensioned during the swelling process, the lustre is also increased. This lustre occurs as a result of the fibre being pulled smooth, and because of the change to the cross-section. The kidney-shaped cross-section of the cotton fibre becomes almost round as a result of mercerization. This causes increased light reflection in the fibre, which manifests itself as an increase in lustre. In addition to this, mercerization also significantly increases swelling capacity and tear strength, although improved tear strength results in worsening of elasticity.

As an alternative to treatment with a caustic soda solution, pronounced swelling in cotton can be achieved using liquid ammoniac. The Sanforized Company (Cluett Peabody Company) uses a process that consists of an ammoniac treatment machine with a subsequent sanfor system. The use of ammoniac results in further effects and economic advantages, as well as similar positive changes to the properties of the material. The speed and extent of the swelling and shrinkage processes are dependent on

- the particle size of the swelling agent,
- the viscosity of the swelling liquid
- the pretreatment of the cotton fibre and the fabric.

Liquid ammoniac (NH_3) has a lower viscosity and surface tension than cold caustic soda solution. The capacity of caustic soda solution, which is relatively viscous, to wet grey fabric without any added auxiliaries is poor. The NH_3 molecules are small in comparison to the relatively large ion hydrates of caustic soda which react with the fibre, and they can reach the fibre structure much more rapidly.

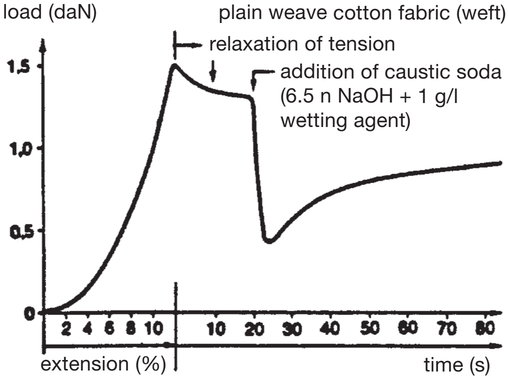


Fig. 2: The inversion effect during mercerization at constant fabric length.

If caustic soda solution is added to a cotton fabric that is subject to a specific tension, the initial result is relaxation caused by tension release. It is only after a few seconds that the swelling forces start to occur (Fig. 2). If water is added to the cotton fabric during the relaxation phase (Fig. 3), it can be observed that water alone has the capacity to accelerate the tension relaxation to a great extent. It can be assumed that the water, which diffuses into the fibre structure more rapidly than Na^+ and OH^-, initially triggers relaxation by opening the H linkages, so that the caustic soda solution (NaOH), which diffuses subsequently, reaches the crystalline zones in the fibre and starts the contraction process.

The treatment of cotton both in liquid ammoniac (NH_3) and caustic soda solution produces pronounced swelling effects. These are caused by the splitting of hydrogen linkages between the OH groups of the cellulose molecules within and between the fibre crystallites and the formation of cellulose swelling agent adducts. This causes a change in the external fibre shape and a greater or lesser degree of fibre shrinkage. This is a consequence of the significant increase in fibril width due to the formation of adducts with the swelling agent and the relaxation of chain molecules which are highly orientated. Liquid ammoniac has a less pronounced

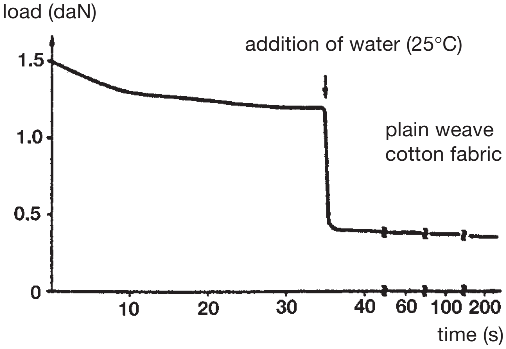


Fig. 3: Accelerated relaxation of tension by the addition of water.

swelling effect than caustic soda solution at room temperature; an increase in temperature causes the level of swelling to decrease. Cotton shrinks much more in caustic soda solution than in liquid ammoniac, however, the shrinkage forces that develop in ammoniac are non-uniformly higher. If the temperature in the caustic soda solution is raised, the shrinkage forces are reduced. A temperature dependency can also be detected using liquid ammoniac. At temperatures below 33°C the shrinkage forces are significantly greater. The reversal of shrinkage force when the caustic solution temperature is raised is relative to the degree of swelling, which reduces. The fact that the ammoniac system produces more pronounced shrinkage forces is caused by the more extreme relaxation processes.

X-ray analysis shows that the basic reactive units in intracrystalline swelling are not individual cellulose chain molecules, but layers of polymer chains. The NH_3 molecules or the hydrated ions in the caustic soda solution only penetrate between the layers of the crystal lattice that remain intact by splitting the hydrogen linkages. The result is the formation of defined cellulose/swelling agent complexes. The water molecules in the solvate shells of the NaOH ions are replaced by OH groups from the cellulose, and the NH_3 molecules are bonded to the cellulose OH groups via hydrogen linkages. If natural cellulose is treated with NH_3 at temperatures in excess of 30°C, the NH_3 cellulose I complex is formed, and at temperatures below 30°C the NH_3 cellulose II complex is formed. Extreme intercrystalline swelling also occurs. If the yarn or fabric is constructed in such a way as to constrain the swelling, the ammoniac swelling value can be drastically reduced. With 20% caustic soda solution between 15°C and 80°C, cellulose forms the NaOH cellulose I complex, and at temperatures in excess of 80°C the cellulose II/III complex is formed.

The low swelling level of cotton in liquid ammoniac is caused by the less pronounced expansion of the crystal lattice because of the relatively small NH_3 molecules. The degree of swelling decreases as the temperature rises. Firstly this effect can be explained by a reduced absorption of caustic soda solution and water, and secondly if the temperature is higher the cellulose II/III complex can occur with a lower level of water accumulation. The NH_3 molecules are more efficient at holding the crystallite layer system together with H linkages than the hydrated NaOH ions. This explains the low level of plasticity, the greater development of shrinkage forces, and the lower expansion capacity of the NH_3 cellulose complex.

Removal of the swelling agent causes the cellulose swelling agent adducts to be destroyed. The fine structure of the fibre is reformed. After the caustic soda solution is washed out at a low temperature in a tension-free state, cellulose II is usually formed. If the washing temperature is high, and tension is applied, the fibre reverts to cellulose I. If ammoniac is removed by vaporization, the cellulose III lattice is usually formed. Cellulose III is not stable in the presence of water; if ammoniac residue is removed in a short steaming process, cellulose III reverts to cellulose I. NaOH mercerization results in a higher level of shorter and narrower crystallites. NH_3 treatment also reduces the size of the crystallites, however the conversion of cellulose III into cellulose I leads to crystallite enlargement. X-rays have shown that after caustic soda or ammoniac treatment, the fibre area where there is little ordered structure has increased by a factor of 2 or 3. Primarily with the ammoniac process, and particularly in the case of cellulose I, there is a large increase in small pores in the fibre, which can be seen from the fact that the fibre is inaccessible for larger dye molecules.

From a morphological point of view, swelling treatments result in

- thickening of cell walls,
- reduction in lumen size,
- an almost round fibre cross-section
- elimination of fibre convolution.

However all these changes are not pronounced in fabric/yarn treated with ammoniac.

Strength is increased as a result of mercerization processes; this is linked with the higher orientation of the crystallites within the macrofibrils. The mercerization process means that dimensional stability is increased, in some cases even without losing fabric length and width. The basic principle that causes alkali treatment to be effective is the reduction of textile tension by splitting and reforming H linkages in the cotton fibre, as a result of which the fibre adopts a low-energy state to suit its shape. Ammoniac treatment can be used for efficient stabilization of particularly thick and heavy fabrics. However after the liquor has been washed out and the fabric has been dried by means of deswelling, the textile adopts new tensions. In this situation it is more effective to remove the ammoniac by drying and steaming, since it occurs in a deswollen state (according to Bredereck).

Swelling kinetics and thermodynamics
Swelling and dissolving are mixing process. Solution is referred to if unlimited mixing of the liquid and the polymers is possible, swelling if there are limitations to mixing. Mixing only occurs voluntarily if the change to the free enthalpy ΔG is negative. In sealed systems with constant pressure, the following applies for ΔG:

$$\Delta G = \Delta H - T\Delta S$$

Therefore whether or not mixing takes place depends on the size and mathematical sign of the mixing heat ΔH and the mixing entropy ΔS. Entropy is dependent on how freely the molecules move. In solid polymers the long chain molecules are extremely strongly fixed. If the polymer is mixed with a liquid, the molecules start to move freely; they can change position in relation to each other, and the individual molecule can bend, twist or curl up. If polymers are mixed with liquids, entropy will generally increase. A rise in temperature increases the value of the negative term $-T\Delta S$, and for this reason has exactly the same effect as a positive entropy change regarding swelling or solution. If ΔG is negative, either ΔH must be negative, i.e. heat is released during the dissolving process, or if it is positive, it must have a value lower than that of $T\Delta S$. If non-polar polymers such as rubber or polyethylene are mixed with liquids, physical bonds such as van der Waals and London forces between polymer molecules and between liquid molecules are broken and replaced with similar bonds between the molecules of the polymer and the liquid. To break these bonds heat is absorbed; while bonds are forming, heat is given off. Depending on which of these processes is dominant, the fibre swelling process is either exothermic or endothermic. If ΔH is positive, the following equation applies to the mixing enthalpy of non-polar polymers:

$$\Delta H = V_M \cdot \vartheta_L \cdot \vartheta_P(\delta_L - \delta_P)^2$$

V_M = volume of mixture;
ϑ_L, ϑ_P = fractional volume of solvent or polymer;
δ_L, δ_P = solubility parameters of solvent or polymer.

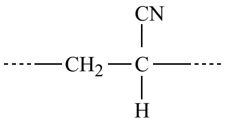
The solubility parameter is a measurement of the intermolecular forces of attraction, which must be overcome during the dissolving process as well as during vaporization; it can be calculated by use of the following equation:

$$\delta = \left(\frac{L - RT}{V^*}\right)^{1/2}$$

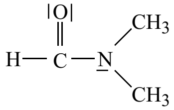
L = molar heat of vaporization;
V* = mean mole volume at temperature T;
R = general gas constant.

If the positive value of ΔH is low, $\delta_L - \delta_P$ is also small, and δ_L and δ_P must be similar in value. If $\delta_L = \delta_P$, the mixture is defined by the entropy term alone. Another way of expressing this: like substances dissolve in each other. Until now, the observations have applied strictly to non-polar polymers. For polymers that contain polarized groups, strong bonds exist between the molecules, which can be explained by hydrogen linkages or dipolar interactive effects. Much higher levels of energy are necessary to split bonds of this type than are required to split the forces between non-polar polymer molecules. For this reason, liquids that are strongly polar themselves are used as solvents, which give off heat while they interact with the polymers. This process is known as solvation, which according to Brønstedt can be described as an acid/alkali interaction: If the polymer contains acidic groups it will be solvated by alkaline liquids and vice versa. Obviously no proton transition occurs in this situation; the process can be more accurately described as electrostatic interactions between polarized molecules.

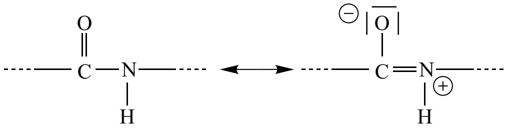
Polyacryl nitrile, for example, contains acidic hydrogen atoms caused by the inductive effect of CN groups, and it dissolves in alkaline liquids such as dimethyl formamide, where the C=O group behaves like a proton acceptor.



$$\cdots - CH_2 - CH(CN) - \cdots$$



There are polymers that contain both acidic and alkaline groups. According to Pauling, the carbon amide groups in polyamides are structured as follows:

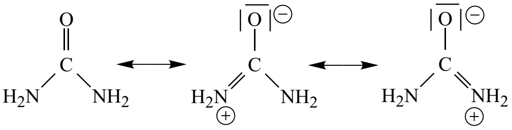


(approx. 40% double bonding properties)

The electron pair at N is not free. For this reason it no longer exhibits any alkaline properties. On the contrary, the C=O group has alkaline properties, and the

N–H group has acidic properties. However the proton acceptor property of the C=O group is much stronger than the proton donator property of the N–H group. For this reason, acidic liquids, such as formic acid and phenols are primarily used as solvents.

The interchenary forces of attraction in polyamides can be better described as dipolar interactions than H linkages. The interaction of urea with polypeptides and proteins is also caused by dipolar forces, as urea exhibits its polar elements in its mesomeric limit form.



The free motion of the molecules is limited by the solvation process, which lowers the ΔS value. In addition, the polymer becomes less polar as the acidic and alkaline groups neutralize. The solvated polymer now behaves almost like a non-polar polymer, and only mixes with the liquid if the solubility parameters of the liquid are not too different from those of the solvated polymer. Analysis of the glass transition temperature and swelling properties are among the most important physical/chemical methods that characterize the crosslinking potential of polymers. Crosslinking of polymers raises their glass transition temperature. This displacement is insignificant for low levels of crosslinking, such as is used in cotton finishing. It is only at higher levels of crosslinking that this displacement becomes more significant. Furthermore the displacement of the glass transition temperature with an increasing level of crosslinking is not independent of the chemical composition of the polymer concerned, so that this method is not universally applicable. If a non-crosslinked polymer is soluble in a liquid, once it is crosslinked it will only swell in that solvent. Swelling measurements provide three types of information about crosslinked polymers:

- quantity of polymer that is not incorporated as a covalent part of the polymer network, and can therefore be extracted as a sol fraction,
- molecular weight of sol fraction,
- swelling level of insoluble gel fraction.

Under normal circumstances the swelling ratio is as follows:

$$\frac{\text{volume of swollen gels}}{\text{volume of non-swollen gels}} = q$$

The sol fraction is denoted thus:

$$\frac{\text{weight of extracted polymers}}{\text{initial weight}} = s$$

The analysis of sol gel is used on cellulose crosslinked with formaldehyde; the apparent crosslinking density, measured using the gel fraction in cuen. The formaldehyde content of the sample increases, with the variation depending on the type of crosslinking process. Since the swelling of cotton with solute reagents is so important, there are many known methods of analysing the swelling. In most cases the increase in fibre weight is measured. The actual swelling parameter in a thermodynamic sense, i.e. the volume effect that is additional to the superficial adsorption effect, is only defined in methods where the change in volume is measured directly (if there is uptake of a substance into a solid body, it is known as adsorption, if the volume effect outweighs the superficial effect). There are only a few reagents that, independently of their chemical nature, have particular physical qualities that enable them to react anyway with the cellulose hydroxyl groups in the morphological structure of a cotton fibre without the presence of additional swelling agents. Dimethyl sulphate, for instance, is very effective at methylating cotton cellulose in the presence of sodium hydroxide, because the reagent is liquid, and once it has caused swelling in the insoluble cotton substrate, it can diffuse away to the hydroxyl groups of the cellulose. In the same way, formaldehyde in gas form in the presence of gaseous hydrochloric acid is capable of crosslinking cotton fibres very evenly, because the diffusion of the reagent and catalyst in a gaseous state at a specified level of fibre moisture occurs rapidly and penetrates right into the morphological fibre structure.

In both cases, the volume effects that accompany diffusion and adsorption of the reagent cause more hydroxyl groups in the cellulose to become accessible for reaction than the number of hydroxyl groups on the surface of the solid body, e.g. on the capillary walls. But even in the case of the gas phase crosslinking described, the presence of an agent that influences the hydrogen linkage system in the cotton, such as water vapour, is necessary to enable a reaction to take place.

In a similar way most chemical reagents need a solvent as a partner for the reaction with cellulose, which prepares the solid substrate, i.e. which causes swelling to allow diffusion of the reagent into the hydroxyl groups. To achieve this, the solvent itself must diffuse into the pores of the fibre, split the hydrogen linkages of the cellulose, and build new linkages to the substrate. It is only then that further high-volume solvent molecules can penetrate into the solid and break further hydrogen linkages. Known solvents have varying levels of suitability for this process, as a result of various factors. The surface tension of different solvents has a strong influence on their interactive potential with fibres. Water has by far the highest surface tension (0.073 N/m), and is retained more strongly by hydrophilic fibre surfaces than for instance acetic acid (0.027 N/m). For this reason, when methods such as centrifuge swelling are used for comparing the swelling capacity of cellulose in different solvents because of the varying adhesion potential of liquids to the fibre surface, apparent effects that have nothing to do with swelling are measured.

Obviously the diffusion processes that are essential for fibre swelling are dependent on the size of the molecule. Two simultaneous processes are occurring at different speeds while a solvent is acting on cotton fibres, for example:

a) Rapid diffusion in interfibrillary cavities in the accessible areas of the micro-fibrils and elementary fibrils, which seems to be independent of the molecular size of the solvent.

b) Further rapid penetration into the elementary fibrils is only possible with cotton if there are sufficient small molecules, such as water or methanol. Classification according to molecule size is only practical if the molecules have similar capacity to split hydrogen linkages. The capacity of solvents to split hydrogen linkages varies greatly. This means that the degree to which cotton is accessible for methylation is dependent on the swelling effect of the solvent used. If the fibre is treated with diazomethane in ether, only the surface of elementary fibril systems, which on average appears to consist of four elementary fibrils, is methylated. In contrast, if 2-molar caustic soda solution and dimethyl sulphate are used as a methylation agent, a much more extensive methylation of the surface of individual elementary fibrils is possible. This is because the aqueous alkaline solvent is able to separate the elementary fibrils from each other, which are bonded by means of strong hydrogen linkages. This is not the case if ether is used. In the situation described, the ether could only penetrate the morphological structure of the fibre to a certain extent because it was saturated with a small amount of water. On this principle, the extent of interaction of an organic solvent with the hydroxyl groups and acetal oxygens present in the cellulose can be increased by adding substances with a higher capacity for splitting hydrogen linkages.

Because of cotton's complex physical, morphological and supermolecular structure, non-ambiguous measurement of swelling is almost impossible. Length measurements of the swelling fibres have to be classified as unsatisfactory, because cotton fibres exhibit swelling anisotropy, i.e. they swell much more in the direction transverse to the fibre axis than longitudinally. For this reason, care has to be taken to measure the fibre expansion in width or cross-section. However, as the cotton fibres are non-uniform, it is very difficult to record the results. Warwicker's work showed that in order to analyse the transverse swelling it was necessary to take 200 individual measurements at the widest point of the fibre for each swelling. In addition to this, measurements of the change in width are not necessarily representative of the overall swelling process, because the fibre mass does not only extend externally, it can also extend into the lumen of the fibres. This effect can only be detected under a microscope, by means of complicated measurement of the increase in cross-sectional area of the fibre. However the methods that analyse an increase in fibre volume are suitable for relative measurement; absolute measurement of fibre swelling does not appear to be possible using current processes, because the morphological structure of the cotton fibre is irregular. In literature on this subject there appears to be some confusion whether the diffusion of various different types of swelling agent into the fibre fibrils causes changes to the x-ray structure or not. The varying statistics result mainly from the swelling conditions, which are sometimes very different from each other. The x-ray structure of cotton fibres was analysed in the presence of swelling agents of varying strengths and after their removal. A comparison was made with the increase in volume of the fibre. It became apparent that even with swelling at a maximum, there was a residual flexing effect. According to Warwicker, although swelling of the elementary fibrils is possible, using

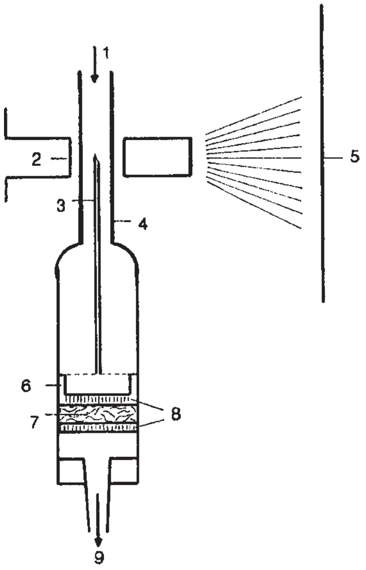


Fig. 1: Swelling volume measuring device for pressed cotton fibres (according to H. K. Rouette and Kalyana Raman).
1 = addition of swelling agent; 2 = projector; 3 = pointer; 4 = glass vessel; 5 = screen; 6 = piston; 7 = cotton fibres; 8 = porous plates; 9 = drain for swelling agent.

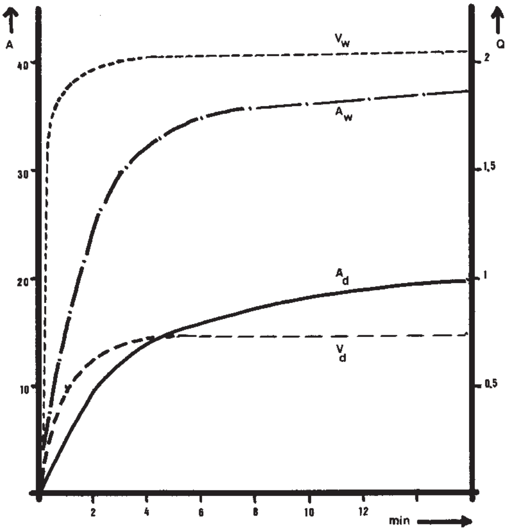


Fig. 2: Comparison of the swelling kinetics of cotton in crosslinking liquor following the detwisting rate method (A) and the swelling volume method (Q).
1 = swelling vloume in the form W solution; 2 = detwisting rate in the form W solution; 3 = detwisting rate in the form D solution; 4 = swelling volume in the form D solution.
Form D process and form W process: crosslinking of cotton.

caustic soda solution for instance; it is not possible to completely separate all cellulose molecules, because the van der Waals forces within laminar cellulose chain units are too great. Warwicker's work showed that recording the x-ray structure is a suitable method of describing a swelling process in an aqueous swelling medium in a state of equilibrium swelling.

The yarn untwist count is a measurement of swelling and to a lesser extent for tension relaxation of cotton fibres in an appropriate swelling agent (Fig. 2). It is not possible to distinguish these two phenomena clearly. Cotton yarns in liquids that cause particularly slow swelling (dimethyl formamide) do not untwist completely within the prescribed test period of 3 min, i.e. they do not reach the level of equilibrium. For this reason it is recommended that the number of twists until it becomes completely motionless are taken into account for an absolute analysis, i.e. the overall kinetics of swelling should be observed. Although the untwisting rate of yarn is indirectly caused by an increase in volume from the swelling, a more direct method must be used for an exact measurement of the increase in volume (Fig. 1). One method of measuring the swelling of polymers allows the swelling speed in solvents to be analysed. The increase in volume of a sample that is both in contact with the swelling agent and with mercury has the effect of displacing the mercury. This transitory displacement is measured using a calibrated capillary. With the help of this device made by Vavruch, it was established that the swelling curves of sephadex gels in water form an S shape. The overall swelling process can be divided into three phases:

1. Induction period.
2. The diffusion of the solvent molecules into the gel becomes the phase that determines the speed.
3. The restriction of this diffusion becomes the dominant factor.

In the middle part of the swelling/time curve, the process can be described using a kinetic equation of a reaction of the first order.

The swelling kinetics of modal fibres in water (Fig. 3) dependent on temperature is scarcely different from that of cotton (Fig. 4) or viscose (Fig. 5): Although swelling is an exothermic process, after 20 min at a higher temperature, a higher level of swelling in water is always achieved than at room temperature. Presumably this effect can be linked with the fact that the actual heat effect caused by swelling is superimposed by the decomposition of the water clusters, which means that the water can penetrate more efficiently into the fibre. This is because the swelling substance consists of smaller, more mobile molecules that can penetrate further into the fibre.

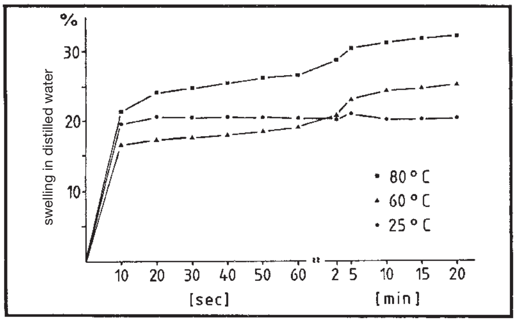


Fig. 3: The swelling of modal fibre in water at various temperatures (by DITF).

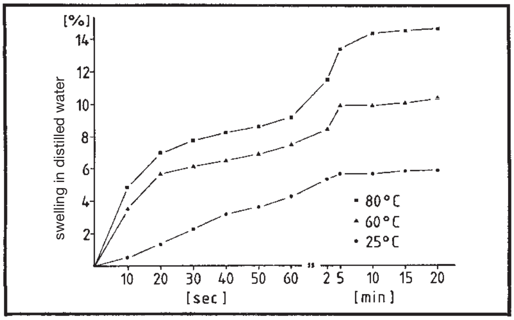


Fig. 4: The swelling of cotton fibre in water at various temperatures (by DITF).

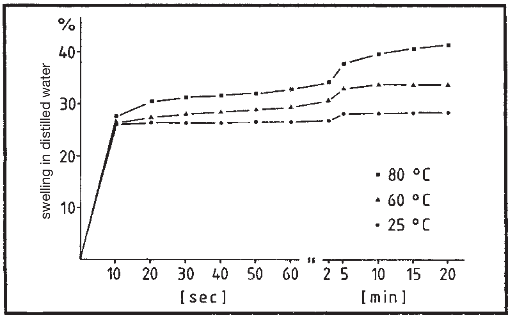
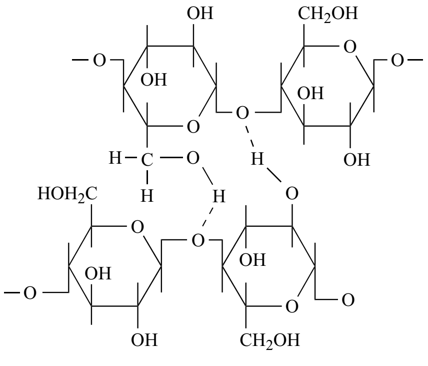


Fig. 5: The swelling of viscose fibre in water at various temperatures (by DITF).

A swelling process can be divided up into a dynamic initial phase that is driven by kinetics, as well as a dynamic equilibrium phase that is based on thermodynamics. The state of the polymer chains in the crystalline zones, which are facing each other a minimal distance apart, is determined by van der Waals forces and hydrogen linkage bonds. The hydrogen linkages, where the H atom of a polarized molecule forms a linkage to the adjacent electro-negative atom, can be categorized as electrostatic interactive effects. If a proton belongs to two atom structures of maximum size, energy can be gained.

Between the two immediately parallel polymer chains, an electro-positive H atom links with two oxygen atoms with a high level of electro-negativity; oscillation takes place between the two oxygen atoms. The separation energy is between 20 and 40 kJ/mol. Segments of two cellulose molecule chains with formation of hydrogen linkages:



The van der Waals or London interactive effects are intermolecular forces that are important for crystallite formation. This bond results from the fact that even completely apolar molecules are subject to a temporarily altered dipolar moment as a result of electron motion. Although the separation energy of each bond is only 20 kJ/mol, the high number of these bonds causes adsorption forces to be generated. There are intermicellary cavities between the fibrils. As the cellulose molecules in these regions are amorphous (unstructured), there are hardly any polymer chains that are a minimal distance apart. For this reason only a few partial valency bonds can form. The numerous functional alcoholic groups and the amorphous structure of the intermicellary regions cause cotton to have a high affinity to water. This is apparent from the fact that it is highly hydrophilic and has a high level of water retention. Cotton has the capacity to absorb up to 11% humidity from the air, and to bond physically up to 45% of its dry weight in water. In water a swelling of the fibre occurs. As the fibre has an anisotropic structure, there is a high transverse swelling of approx. 28% as opposed to longitudinal swelling of approx. 1%. The water can penetrate the crystallite structure of the cotton fibre and split up the physical interactions in the intermicellary regions. The fibrils can slide past each other, i.e. the water penetrates the areas where there is less structure and forces the fibrils apart. On drying, the hydrogen linkage bonds reform and the van der Waals forces become effective again. This new orientation depends on the angle of the fibre axis in relation to the direction of strain. In other words, if a cotton fabric is turned while it is in a wet or swollen state, the H linkages will form in the deformed state. If the fabric has sufficient opportunity to relax, the newly formed physical interactive forces stabilize the relaxed dimension during deswelling.

Cellulose has the capacity to take up water via the H linkage links. Since no shift of the valency electrons occurs, the process is known as type 2 hydration. Because of the hydrogen linkage bonds, a relatively solid solvate shell forms around the cellulose molecule, i.e. the water dipoles can be deposited on the polymer. In thermodynamics the progress of a reaction is defined by the interaction of activation energy, enthalpy and entropy. If a solvated, inorganic molecule changes in water, it is not only the entropy change of the molecule that should be taken into consideration, but also the change to the solvation water. If a macromolecule only bonds with a little water, the water entropy increases. If cellulose dries, energy must be extracted from the surroundings in order to split the state fixed by means of hydrogen linkages. Enthalpy, the driving force of the reaction, can be termed endergonic. According to the Gibbs-Helmhotz equation, the free energy acquires a positive value.

$$\Delta G = \Delta H - T \cdot \Delta S$$

$$\Delta G > 0$$

ΔG = free enthalpy, driving force of reaction;
ΔH = size of energetic state, degree of reaction heat or enthalpy at constant pressure in kJ/mol;
ΔS = entropy change, controls the state of order of a system;
$T \cdot \Delta S$ = energy used to create order.

The water accumulation can be described as follows:

$$(C_6H_{10}O_5)_n + (H_2O)_n \rightleftharpoons (C_6H_{10}O_5)_n \cdot (H_2O)_n$$

The increase in volume causes the entropy of the system or the cellulose to become greater.

$$S = K \cdot 1n\ (M)$$

K = Boltzmann constant;
M = possible number of states.

The system aims to reach a state of maximum stability, the driving force of the reaction decreases; this is known as exergonic.

$$\Delta G = \Delta H - T \cdot \Delta S$$
$$\Delta G < 0$$

When water accumulates on cellulose, energy is released. This energy appears in the form of reaction heat or enthalpy. The preceding sign is negative, and the reaction can be termed exothermic.

$$\Delta H = \Delta G + T \cdot \Delta S$$

The crystalline structure of cotton fibre is fixed by means of H linkage bonds while the fibre is at air humidity level. The solvate shell around the cellulose molecule is also formed as a result of this bond. However, to enable swelling and water accumulation, the hydrogen linkage bonds of the micellary formation need to be split. Energy must be available, even if only a small amount, to break these partial valency bonds. If the cotton is in an aqueous medium, there is more energy available because of reaction heat to split the H linkage bonds in the micellary structure.

Swelling liquid (absorption liquid), bonded liquid that is generated in the amorphous regions and on the surface of the crystalline areas of fibres as a result of accumulation or addition of liquid molecules. If polar liquids accumulate, partial valency bonding occurs.

Swelling of rubber-covered rollers Rollers that have an elastomer coating are subject to dynamic and/or chemical stress during operation. Since the main component, rubber, is organic in nature, it means that the ageing process (as with all organic materials) begins shortly after manufacture. These ageing processes vary greatly depending on the type of elastomer, and in most cases it is so slow that it is not possible to detect by short-term observation. In addition these processes are extremely dependent on the compound structure and development factors. Chemical stress can be caused by interaction with the active medium (or a component of that medium) and components in the rubber mix. These are the physical processes of swelling, or vice versa of extraction (see Fig.), which occur primarily in the organic phase (with the exception of water). However they can also be based on chemical reactions, and in the worst case scenario they can be caused by a combination of the two.

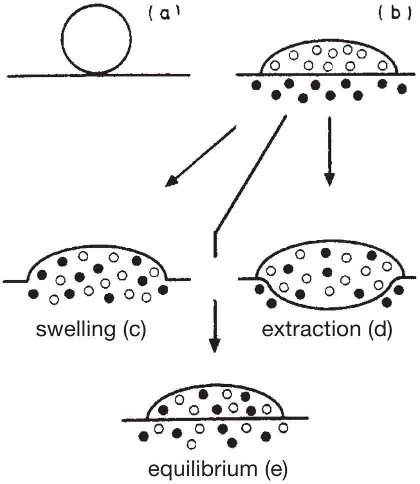


Fig.: Diagram of the swelling of rubber-covered rollers.
a) no wetting = no interaction; b) wetting = the possibility of interaction; c) swelling = penetration into the rubber; d) extraction = leaching out from the rubber; e) equilibrium = penetration and leaching.

The German standard DIN 7716 contains a summary of general guidelines for the cleaning and maintenance of rubber products, in particular where the expected storage time is in excess of 6 months. The basic ideas can be applied fully to rollers, but the guidelines do not include storage requirements specific to rollers.

Rubber-coated rollers used as elements of a machine are subject to continuous operating stress. For this reason it is advisable to monitor their condition and functioning capacity constantly by means of (preventative) maintenance.

Swelling of textiles, measurement of In order to characterize the changes in the properties of cellulose caused by caustic soda solution, several methods can be used. These methods frequently only simulate secondary states of cellulose, i.e. the swelling state in the absence of the swelling medium, after the caustic soda solution has been washed out.

There are different types of swelling measurement:

I. Woven fabric swelling: The fabric sample is placed between two glass plates, weighted with 2 kg and pressed for 3 min. The thickness of the sample D_0 is measured. Then the sample is placed in the measuring gauge between the carrier and the stamp, which transfers the change in thickness of the sample caused by the effects of swelling directly and continuously onto an iron core of two inductive coils. The inductivity of the coils changes direction when the iron core moves. The current generated is transferred to a recorder, where the signal can be amplified as required. Any change in the current is directly proportional to the change in sample thickness ΔD. The swelling at a specific time t can be calculated as follows:

$$Q_t = \frac{\Delta D}{D_0} \cdot 100$$

Advantage: Rapid, simple, time-related recording of the swelling sequence and of the smallest and most rapid swelling process.

II. Microscopic measurement of the fibre width is carried out on relatively long fibres. This is an awkward method, and it is not possible to record the time-related sequence. At least 200 measurements must be taken for statistical reasons.

III. Laminar thickness swelling measurement, carried out on punched cellulose sheets: visually inaccurate, time-related tracking not possible.

IV. Compressed cellulose platelets; swelling is measured using a vertical microscope.

V. The change in volume of a compressed cotton fibre layer is transferred to a stamp that is linked to an indicator.

VI. Yarn detwist test, where the yarn untwisting rate in the swelling medium is measured. Unsuitable for low levels of swelling.

Swelling of wool in formic acid Formic acid swelling has been proposed as a method for analysing the level of crosslinking in wool. This process is a gravimetric analysis of the quantity of formic acid absorbed by the wool fibre. This method can be used for instance in order to assess the extent to which the wool is crosslinked by bifunctional reactive dyes. Overall three materials were tested. 4 parallel wool samples, of 0.3 g each, were weighed exactly in a 100 ml glass beaker containing 40 ml formic acid (98%, density 1.22) and left for exactly 15 min. After 12 min the samples were stirred once using a glass rod. After the 15 minute period had expired, the swollen wool was removed using the glass rod, allowed to drip-dry and transferred to a centrifuge tube. This centrifuge was previously packed with 2 g of cotton wool, which half filled the tube. There is a paper filter on the cotton wool, to ensure that the wool and the cotton wool are kept separate. Finally hydro-extraction was carried out in the centrifuge at approx. 8000 rev/min. After the centrifuge process, the wool soaked in formic acid was transferred to a weighing bottle and weighed. Finally the dry weight of the wool was established by drying overnight at 105°C in a drying oven. The swelling capacity of the wool in formic acid is given as a volume fraction of the wool.

$$V = \frac{W_W/d_W}{(W - W_W)/d_A + W_W/d_W}$$

W_W = initial dry weight of wool;
W = damp wool after centrifuge treatment;
d_W = density of wool (1.3);
d_A = density of formic acid (1.22).

As can be concluded from the results (see Fig.), the swelling capacity of wool dyed with reactive dye with a high crosslinking effect (C) is between the values for untreated wool (A) and the values for (B), which was dyed with a low crosslinking dye. For this reason, formic acid swelling is not suitable for analysing the level of swelling in wool after reactive dyeing using α-bromacrylamide dyes (according to Werkes).

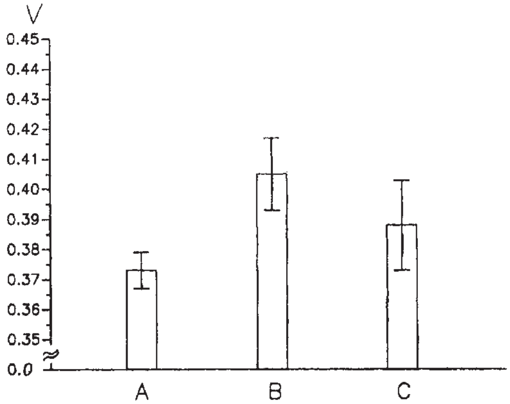


Fig.: The swelling in formic acid of dyed and undyed wool, with indication of the confidence range for a statistical certainty of 95%.
A = untreated fabric, HBL 41%; B = fabric dyed with 10% by weight Lanasol Red B (Ciba Geigy), HBL 17%; C = fabric dyed with 10% by weight Lanasol Red G (Ciba Geigy), HBL 9%.

Swelling-resistant finish The high swelling capacity of synthetic fibres made from regenerated cellulose is the cause of reduced mechanical properties while the fibre is wet. Water-repellent finishes can only delay swelling but not prevent it. Since more utility properties than just reduced swelling capacity are expected of regenerated cellulose products, swelling-resistant processes are no longer particularly significant. Reduced swelling can be achieved at the same time as good crease recovery properties using crease-resist finishes (→ Resin finishing). All other types of process are today only of historical interest, such as → Formaldehyde finishes. Not only regenerated cellulose fibres show a reduction in swelling, for instance if dried several times, it can also apply to natural fibres, and it can be assumed that this effect derives from a change to the fibre structure.

Swelling test for cotton (soda swelling process), microscopic test for chemically damaged cotton. Treatment of cut fibres between object carrier and cover glass with caustic soda solution (density = 1.26). Results: circular, sector-type protuberances = healthy cotton. Some degree of protuberances that have disappeared, with broadened ends = start of damage (permitted damage threshold). Nothing but swollen cylinders = extreme damage (e.g. resulting from too much bleaching). This sampling method for swelling is a certain test for any cotton damage, which is more reliable than other possible methods such as Fehling's solution, methylene blue count, silver test.

Swelling test for wool Microscopic test for (un)damaged wool. Treatment between cover glass and object carrier with ammoniac caustic potash solution (20 g pure potassium hydroxide in 50 ml pure ammoniac, density 0.857, dissolved during cooling). Results: After 1–2 min slowly growing "ulcers" appear over the entire length of the fibre = acid-damaged wool; if this phenomenon only appears after 8–10 min = healthy wool (→ Sodium hydroxide process).

Swelling time of polyester fibres in hydrothermic treatments One of the most important process-related parameters in textile finishing processes is the amount of time the fabric spends in the medium used for treatment. For reasons of economy, this duration should be as short as possible, and for technical reasons related to quality assurance in production, it needs to be relatively long. Because of this discrepancy it is essential to be sure, after each time the fabric is treated, that the treatment has been successful from a technical point of view. For heat-setting processes involving synthetic fibres, success can be gauged by tension relaxation and subsequent crystallization, which can be monitored afterwards with pretreated polyester fibres.

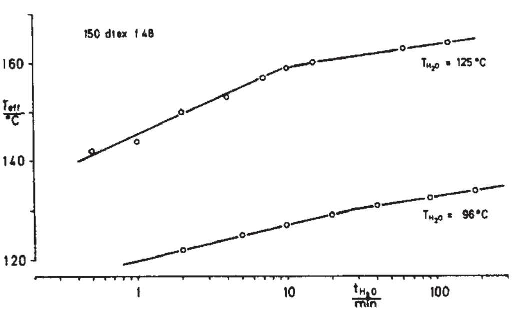


Fig. 1: The effective temperature of hydrothermic treatments of polyester multifilament yarn (according to Berndt).

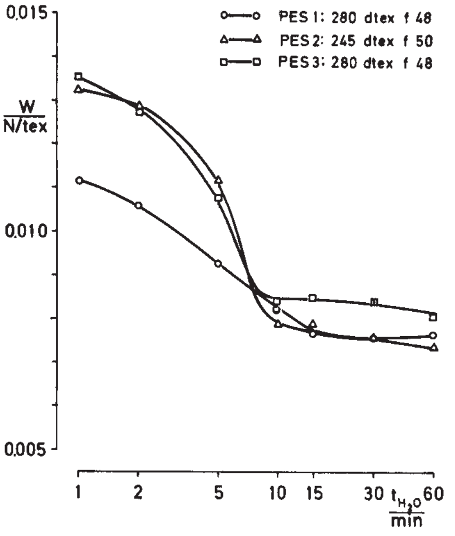


Fig. 2: The working capacity between 5% and 10% extension of various polyester filament yarns which have been pretreated with free shrinkage in water at 98 °C (according to Berndt).

With hydrothermic treatment the softening effect of the water is superimposed on the purely thermal effect. To achieve this softening effect, as well as reducing friction between the fibres, the water has to diffuse into the fibres. If the "hydrofixation" of the polyester fibres is tested using differential thermoanalysis dependent on the duration of treatment in the medium, which is water at a constant temperature, the result is the relationship shown in Fig. 1. Regarding the effective temperature, two linear logarithmic periods of time are observed, which reflect the increase in crystallization speed. From this result it can be concluded that in the first period the speed of crystallization can be established from the diffusion of the water into the fibres, because if the fibre structure remains identical the diffusion speed increases in line with the temperature. In the second time period however, the crystallization speed is independent of the treatment temperature, as is the case with setting in hot air. If the slopes of the curves in the first period are extrapolated to an effective temperature value that is equal to the treatment temperature, then in both cases, the result will be approx. 2 s treatment time, which should be equal to the time taken for the fibres to heat up in the treatment medium (water). The deviation points in the curves in Fig. 1 represent the times at which water absorption into the fibres reached equilibrium point. For the fibres in this test, this occurred after 10 min at 125°C, and after approx. 30 min at 96°C. The structural changes to the fibre shown at the effective temperature with hydrothermic treatment was monitored using a classic textile testing method, the stress-strain behaviour test.

In Fig. 2 the working properties of polyester filament yarns, that were pretreated hydrothermically at 98°C at different times with free shrinking are shown. In this case there are also two characteristic curve sections, from which the first section shows short dwell times that can be explained by the increasing absorption rate of the fibres. On this principle the deviation point in these curves shows the point in time at which the fibre swelling has finished. However this point is certainly not defined only by the single filament titre - even though the cross-section is round, no correlation has been found between the swelling time and the titre; it is dependent on structure.

It has been established that alteration to the structure, and therefore also the shrinkage of hydrothermically treated polyester fibres has to be divided into three phases:

1. The heating up phase, which only lasts a few seconds, and during which a change to the material occurs, as in hot air.
2. The diffusion phase, which lasts for several minutes, depending on the temperature of the treatment medium, titre and structure of the fibre.
3. The dwell phase, in which the fibres have swollen to saturation and subsequent crystallization eases off exponentially to the treatment time.

The first two phases are particularly important in textile finishing. In the first phase the shrinkage is created, depending on the treatment temperature, and in the second, after-shrinking occurs depending on the rise in effective system temperature. After the swelling process has finished, this temperature is about 35 K above the temperature of treatment. Stabilization of the fibre structure also occurs as a result of subsequent crystallization, which is basically completed during balanced swelling (Heidemann, Berndt and Stein).

Swelling, water of (swell water), water taken up by the fibre adsorptively by means of actual → Swelling, which can only be eliminated by the effect of heat (drying). There are two different types:

I. Water that is bonded chemically by means of hydrogen linkages (the most difficult type to remove, usually only present in small quantities. Exception: wool).

II. Water that has accumulated in the amorphous regions of the fibre, which determines the actual swelling of the fibre.

Swell process nonwovens → Nonwovens made from fibre fleece; bonded by the effects of a swelling agent (e.g. cotton felt).

Swimming roller (S roller), roller construction where the roller floats on a hydraulic cushion. In many textile finishing processes, squeezing is required. As well as separating liquor off, this process is also used to transport the fabric. The intention is to remove substances from the fabric or to add something. Both actions need to take place as smoothly as possible. In textile washing machines it is frequently the case that the fabric run is squeezed unevenly, usually with better results at the edges. In addition to this, the concentration of liquor to the right and left of the fabric run is often not evenly concentrated around the fabric itself. The consequence of this is a higher exchange of substances at the edges of the fabric. In order to keep the deviation within acceptable limits, squeezing units with rollers should be installed at certain points of the finishing process to ensure that any deflection is corrected. Wrapped or angled rollers can be used for correcting deviation. Deviation correction using S rollers (Küsters) was developed in 1956 as a follow-up to the built-in squeezing element with stabilizing rollers (Fig. 1). This squeezing element made it possible, even in the early 50‘s, to adjust a nip evenly or deliberately unevenly. As a result of specific disadvantages, such as pressure elements external to the roller and above the fabric run, the S roller system used today was devel-

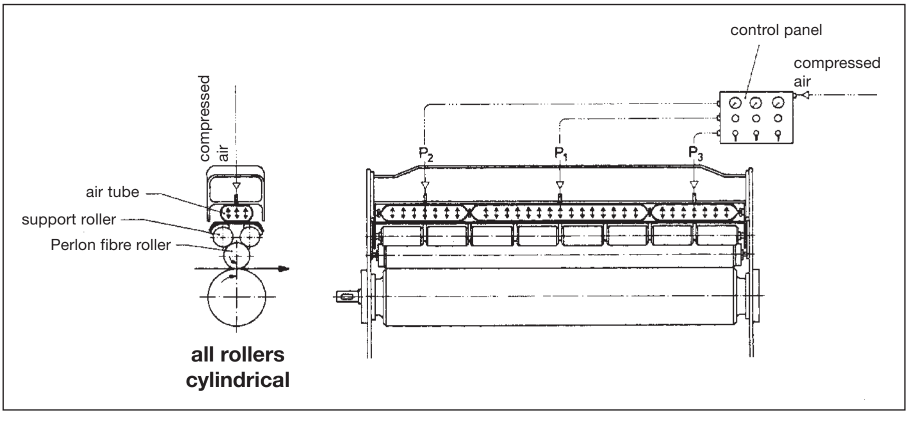


Fig. 1: Diagram showing the principle of the squeezer installation component of the year 1956 (Küsters).

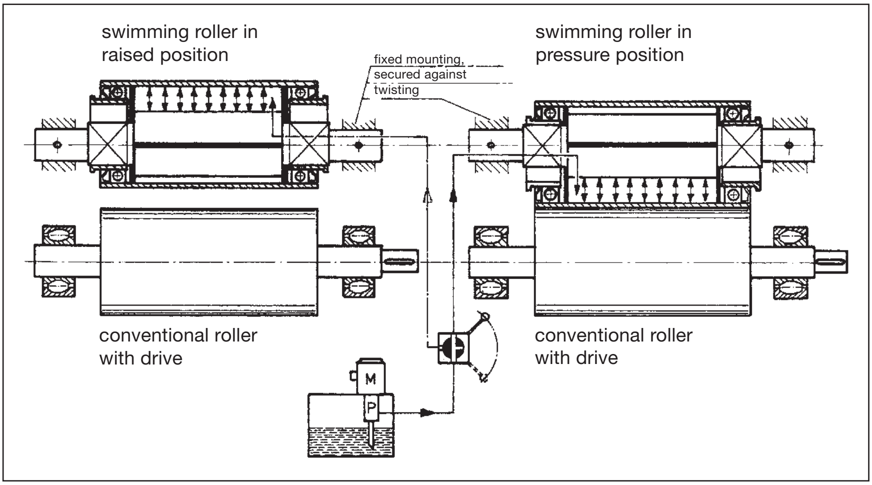


Fig. 2: Diagram showing the principle of a swimming roller as in the old system from the 1950s (Küsters).

oped, where the pressure elements are contained within the roller. The first rollers of this type only had a hydraulic pressure chamber (without individually adjustable bearing pressure). Although these rollers were along the lines of a conventional cylindrical roller, the flexing potential was limited (Fig. 2). Despite the elastic roller coatings, the system put the fabric seams under stress. Instead of a fixed pivot bearing, pneumatic pressure cylinders were used and the lifting gear inside the roller was rigid. It was only with this configuration that the way was clear for a pressure roller as shown in Fig. 3.

The operation of the hydraulic chamber and the bearing pressure can deflect every S roller positively or negatively, or allow the flexible line of a conventional roller to be followed whilst applying even pressure. The extent of linear pressure deviation depends on the construction of the conventional roller. For many processes it is sufficient to operate using only one S roller in the padder or drying system. This applies to drying (water extraction), application of substances that are invisible or not easily visible, treatment of pile articles or printed fabric, and low-temperature dyeing by rolling (side balancing in batch) (Fig. 4). The situation is different in processes with a rapid reaction, such as before a hot flue or steamer, and during drying. Here the most important factor, as before, is that articles are smooth and identical on both sides. To ensure that this is so, the rollers must have an identical diameter, hardness, quality and roller arrangement. These requirements apply to a dye padder with two S rollers arranged horizontally (Fig. 5). The two rollers are carefully

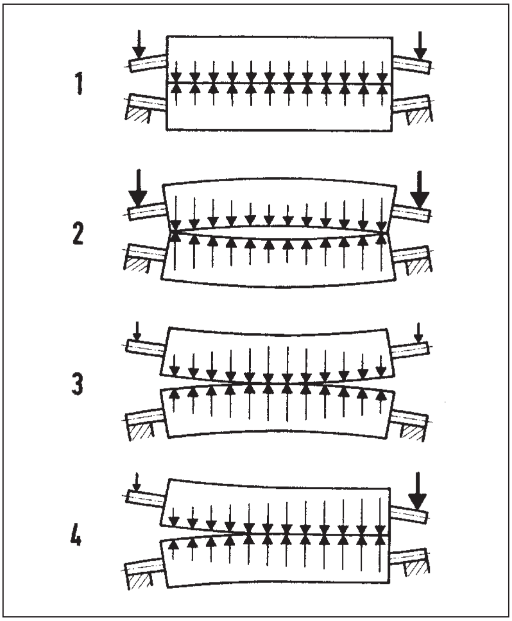


Fig. 3: Possible settings for the nip between the paired rollers of a swimming roller, once it had become feasible to replace the fixed pivot bearing with pneumatic pressure cylinders (Küsters).

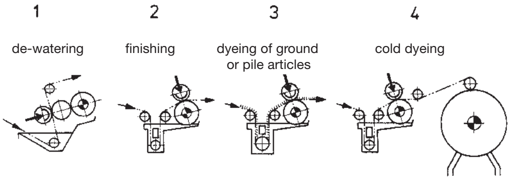


Fig. 4: Diagram showing the application of swimming rollers to various wet processes (Küsters).

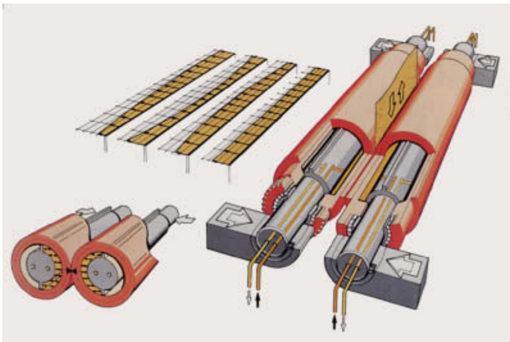


Fig. 5: Diagram showing the application of swimming rollers mounted horizontally (Küsters).

joined together. This is because of the bending behaviour of the two S rollers against each other. When interaction takes place between a conventional roller and an adjustable roller, the conventional roller deflects under pressure. In order to keep deflection at a low level, this roller must have a specific diameter. The adjustable roller should be a little inflexible, so that it can follow the bending line of the conventional roller.

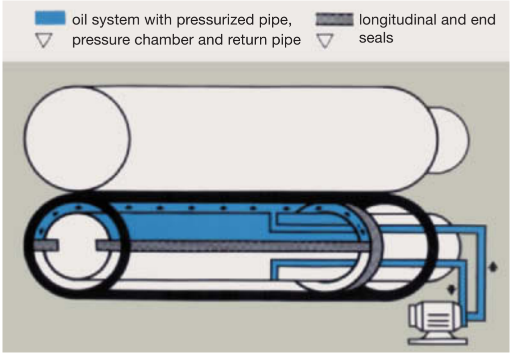


Fig. 6: Finishing padder with a swimming roller mounted vertically below the conventional squeeze roller (Küsters).

The conventional roller deflects when the linear pressure is even, and must deflect even more if a higher level of squeezing is required in the centre of the roller. On this principle, pairing a rigid roller with a highly flexible roller will create the ideal joint. However, a joint formed between two adjustable S rollers is different. In this situation the controlled deflection of the two rollers combine. If the squeezing effect in finishing processes needs to be particularly even, a floating roller with a conventional roller, arranged vertically, is the ideal combination (Fig. 6) (according to Itgenhorst).

Swivel batcher Swivelling → Batching device for screen printing with axle drive and two operating points, which can be varied and used alternately by swivelling. Ensures that the batch is changed quickly and that the fabric runs evenly.

Synchronization (Gk.: synchronos = at the same time), making two processes or machines operate simultaneously; for instance the assimilation of fabric running speeds of a serial combination of machines in a continuous production line, by modulating the electricity supply (voltage or frequency) of each motor, e.g. by means of a → Compensator roll device. This type of synchronization to reduce voltages can also be installed in an individual roller vat between every deflecting roller (Fig. 2).

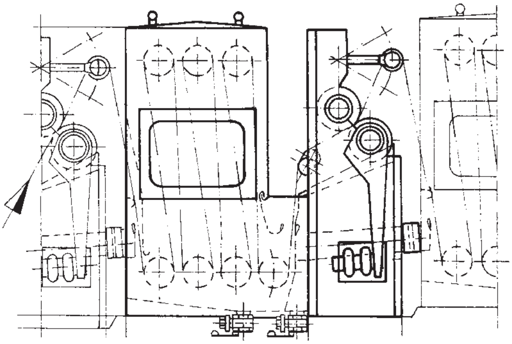


Fig. 1: Synchronization achieved between two roller vats using compensator rollers which supply information to the drive motors.

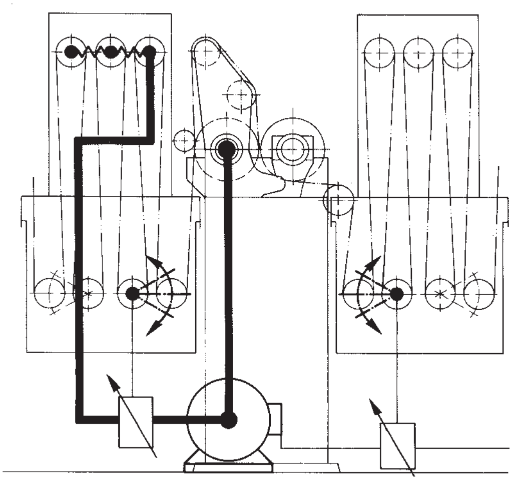


Fig. 2: Synchronization of the movement of goods from one loop to the next in a Babcock roller vat.

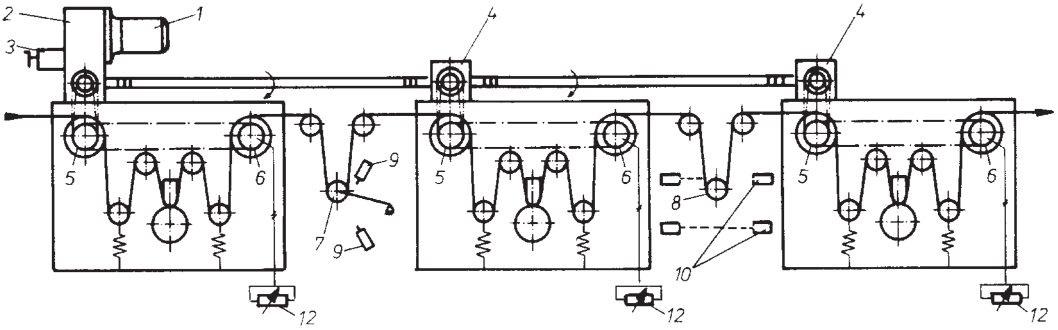


Fig. 1: Two-position control. 1 = three-phase AC motor; 2 = steplessly adjustable transmission; 3 = manual adjustment; 4 = angular transmission; 5 = electromagnetic clutch; 6 = electromagnetic friction clutch; 7 = compensator roller; 8 = dancer roller; 9 = terminal position switch; 10 = photoelectric barrier; 11 = actual value sensor; 12 = potentiometer.

Synchronization control The finishing of textile fabrics (wovens, knitgoods, nonwoven fleece, etc.) can be carried out profitably using finishing lines, in which the necessary machinery for the different finishing processes are set up in series in the appropriate order for the production phases (continuous lines). The devices for transporting the fabric have to be synchronized with each other in all machines, in such a way that the fabric speed is identical at every point in the line, and there is no area in or between machines where the fabric tension reaches unacceptable levels. The usual type of solution for these functions consists of two and three-point control devices (Figs. 1 + 3).

The problem of synchronization control occurs in all technical areas in which materials being processed in plants with several drive systems for transporting the fabric are processed in continuous production. Various different options have been developed over the course of time to solve this problem. The most commonly used method for this purpose is to use direct current drives. The direct current motor is a component of the automatic control system closed loop. The number of revolutions can be adjusted using the excitation flow or armature voltage as a variable. Because of similar control possibilities, the control loop can be set up for almost any timing, depending on the design of the controller. The reliability of the control loop is almost limitless, and has an outstanding quality of control. The oldest type of synchronization control is driven from a single point by means of a drive shaft. Bevel gears are used for fine adjustment between different sections of the plant. The bevel gears are controlled by compensator rolls or dancer rolls.

Direct current drives are not sensitive to load variation if the armature voltage is used as a control variable. Furthermore, additional gears are superfluous because direct current machines have such a wide speed range. Significant disadvantages of direct current control (Fig. 2) are the high costs. The complicated structure of direct current machinery means that the cost of acquisition is significantly higher than for comparable three-phase machines. First the alternating current network needs to be converted to a direct current network (Ward-Leonard system or thyristor control). Direct cur-

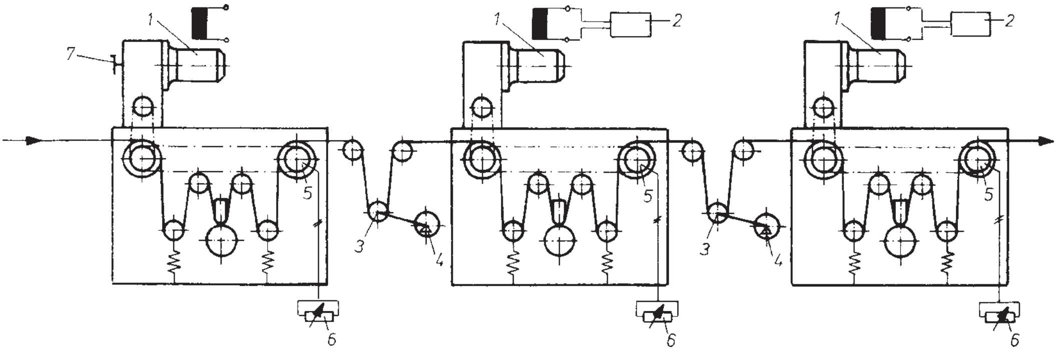


Fig. 2: Continuous control with a DC motor as fabric drive. 1 = DC motor; 2 = controller; 3 = compensator roller; 4 = actual value sensor; 5 = electromagnetic friction clutch; 6 = potentiometer; 7 = manual adjustment.

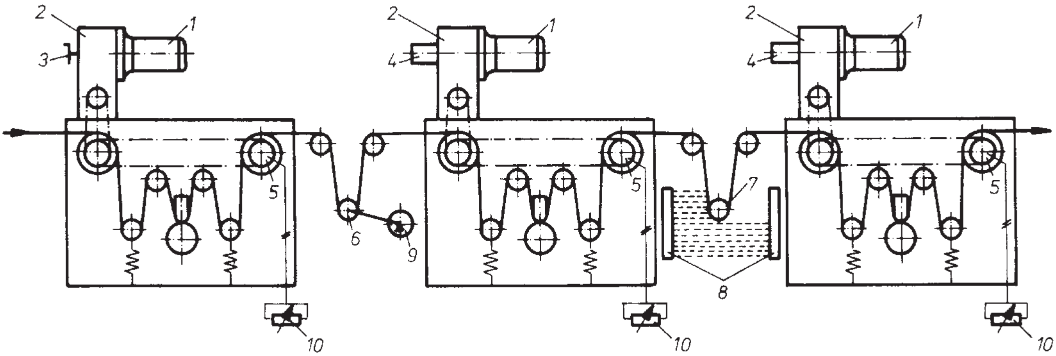


Fig. 3: Three-position control. 1 = AC motor; 2 = steplessly adjustable transmission; 3 = hand wheel for ground fabric speed adjustment; 4 = servomotor; 5 = electromagnetic friction clutch; 6 = compensator roller; 7 = dancer roller; 8 = analogue measurement light curtain; 9 = actual value sensor; 10 = potentiometer.

rent machines have various working parts (e.g. collector and brushes) that require more maintenance. In addition to this, direct current machines take up more space than three-phase equipment with the same power rating because of their construction.

Because of the high costs of direct current equipment, lower priced drive units have been developed. The two jobs done by the direct current machine, transforming electrical energy into mechanical energy and enabling the revolutions to be adjusted, became separated during the course of this development. A three-phase motor replaced the direct current motor for transmitting energy. Speed adjustment is carried out by means of an infinitely variable gearbox, in connection with an appropriate adjustment device. During the course of time, various different processes were developed on the basis of this principle. The differences between these processes are essentially only the construction of the infinitely variable gears and the type of set point sensor. Due to the inertia of the gear components and the final set speed of the servo motor, greater time constants occur than with direct current control. For this reason, the blocks consisting of three-phase motor and gears as a single unit are popularly replaced with frequency-controlled three-phase motors. An appropriate impulse from the compensator roll increases or reduces the frequency of the three-phase current supply in a frequency transformer. The correct type of motor reacts with a correspondingly higher or lower speed.

Syndets → Synthetic detergents, prepared for sale in the form of "ready-to-use detergents" for specific uses. Word origin based on abbreviated English form of synthetic detergents. There are different types of synthetic detergent:→ Mild washing agents, Special washing agents and Heavy duty detergent. Build up of:→ Surfactant: a) combined with each other or with → Soap; b) with → Builders, in liquid, paste or solid form. Available in solid form (usually for household use) as powder, scales, flakes, hollow balls or pieces. Use: primarily in the household and in commercial laundries, also for textile auxiliaries, dry cleaning detergents, etc.

Syndiotactic molecules Macromolecules in which the light hitting one structural element rotates in one direction, which always follows another structural element that rotates polarized light in the other direction, so that both structural types alternate systematically throughout the whole molecule. This type of molecule occurs in modified synthetic fibres, for instance → Isotactic polymers.

Syneresis (Gk.), contraction; term applying to self-drying in foaming; → Foam performance evaluation.

Synergistic (Gk.), concurrent influence causing increased interaction, i.e. more than the additive effect of a combination at a specific ratio, e.g. in the case of well-proportioned mixtures of surface-active substances. → Synergistic effect.

Synergistic effect Effect that causes a combination of two surfactants for example (or other substances) to achieve a specific effect even at a low concentration within certain interactively defined concentration limits in a solution. The concentration is lower than the mix-ratio concentration that corresponds with the linear dependency for this effect. Any substances involved in this effect can also be compounds/mixes.

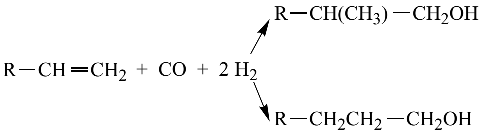
Synthesis (Gk.), adding individual components together. Chemical compounds structured from elements or low-molecular to high-molecular compounds. The simplest example is the well-known synthesis of water from hydrogen and oxygen gas: $2\,H + {}^{1}/_{2}O_2 \rightarrow H_2O$. In technical chemistry, synthesis is taken to mean a controlled reaction sequence that results in a planned amount of a chemical compound.

Synthesis alcohols Synthesis alcohols are important as a basis for textile auxiliaries. The following important examples must be mentioned:

1. Synol alcohols (synthesis alcohol): these are pro-

duced as a result of carbon dioxide and hydrogen in the presence of a catalyst at 175–200°C and 18–25 bar pressure, according to the principle: 17 CO + 20 $H_2 \rightarrow C_6H_{13}OH$ (+ C_6H_{14} + 6 H_2O + 5 CO_2). The result is over 50 % normal, non-branched alcohols (mostly ethanol) with $C_{2–20}$, as well as hydrocarbons, esters, fatty acids and aldehydes. The formations that are of importance for textile auxiliaries, $C_{10–20}$, constitute approx. one-third.

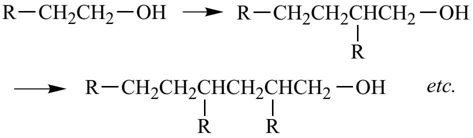
2. Oxo alcohols: These form when carbon monoxide and hydrogen accumulate simultaneously on → Olefins, in the presence of a catalyst at 50–200°C and 20–300 bar pressure as follows:



$$R{-}CH{=}CH_2 + CO + 2\,H_2 \rightarrow R{-}CH(CH_3){-}CH_2OH$$
$$R{-}CH{=}CH_2 + CO + 2\,H_2 \rightarrow R{-}CH_2CH_2{-}CH_2OH$$

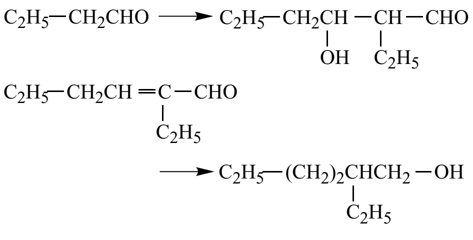
The result consists of approx. 80% alcohols, as well as higher condensation products and carboxylic acids. Fatty alcohols, fatty alcohol sulphates, acrylic acid (acrylic ester/amides), etc. can be manufactured using this method.

3. There are many other known types of synthesis, such as the large-scale Wacker condensation of alcohol molecules at high temperature, based on the following principle:



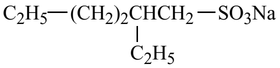
$$R{-}CH_2CH_2{-}OH \longrightarrow R{-}CH_2CH_2\underset{\substack{|\\ R}}{C}HCH_2{-}OH \longrightarrow R{-}CH_2CH_2\underset{\substack{|\\ R}}{C}HCH_2\underset{\substack{|\\ R}}{C}HCH_2{-}OH \quad etc.$$

This synthesis results in alcohols with branched chains and a higher number of molecules with $C_{8–12}$ (ethylhexanol, butyloctanol) as a wetting agent. Another important type of synthesis is based on higher aldehydes derived from ethyne and their condensation. This synthesis can also lead to ethylhexanol as follows:



$$C_2H_5{-}CH_2CHO \longrightarrow C_2H_5{-}CH_2\underset{\substack{|\\ OH}}{CH}{-}\underset{\substack{|\\ C_2H_5}}{CH}{-}CHO$$
$$C_2H_5{-}CH_2CH{=}\underset{\substack{|\\ C_2H_5}}{C}{-}CHO$$
$$\longrightarrow C_2H_5{-}(CH_2)_2\underset{\substack{|\\ C_2H_5}}{C}HCH_2{-}OH$$

The sulphate of ethylhexanol is a basis for high-quality wetting agents:



$$C_2H_5{-}(CH_2)_2\underset{\substack{|\\ C_2H_5}}{C}HCH_2{-}SO_3Na$$

Synthetic colloids Different types of → Colloid consisting of plastics or synthetic resins, which can be used in finishing technology as a stiffening agent for sizes, proofing, print thickeners, etc.

Synthetic detergents Non-manufactured → Wash-active substances resulting from a technical process (they also contain the by-products formed during manufacture).

Synthetic dyes,

I. This term can be used to mean man-made dyes (also covers the old-fashioned aniline and tar dyes). They are manufactured using chemical synthesis. They should not be regarded as the opposite of natural dyes, because they are both structured according to the same rules of dye chemistry.

II. As opposed to → Natural dyes, which are obtained from plants or animals, synthetic → Dyestuff is manufactured on the basis of a chemical reaction involving basic material that was originally obtained from mineral oil (formerly coal). Typical natural dyes such as indigo are manufactured in large quantities in the same way as synthetic dyes.

Synthetic fatty acids and natural fats → Fatty acids, synthesis of.

Synthetic fibres (synthetics) → Fibres spun using various different processes from high-molecule, chain-structured substances manufactured synthetically, composed of low-molecule modules of the following main synthetic fibre groups:

I. Polymer fibres, e.g. polyacrylonitrile, polyethylene, polyvinyl chloride.

II. Polycondensation fibres, e.g. polyester, polyamide.

III. Addition polymer fibres, e.g. polyurethane.

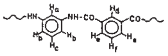
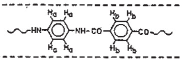
Since it is possible to select the raw material for the fibre, and also to produce fibres and yarns with greatly varying properties using different processes, synthetic fibres suitable for almost every textile purpose can be manufactured. As it is also possible to mix synthetic fibres with each other or with other fibres of chemical origin or natural fibres, or to combine individual textile parts made from different types of fibre, the development of synthetic fibres is likely to be ongoing. In the long term the textile industry will be forced to prepare itself for a continuing increase in the production of synthetic fibres because worldwide fibre requirements are rising rapidly. For the finishing sector this means that new problems and new finishing processes are always appearing, for example in dyeing, easy-care and resin finishing.

The main synthetic fibres are →: Polyester fibres; Polyamide fibres; Polyacrylonitrile fibres. A variety of fashionable effects can be achieved with modification, which opens up new opportunities for people in the textile finishing trade. Synthetic fibres are in competition with natural fibres on the textile market. As it is no longer a problem to make synthetic fibres similar in price and quality to natural fibres, the decision to use a synthetic fibre, which is financially of interest, is usually decided on the basis of specific properties. Frequently a particular market or fashion is made accessible by the use of fibre mixes (such as wool/polyester or cotton/polyester), or by means of modification, for example textured, profiled or dual-component fibres.

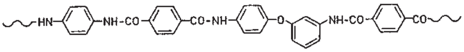
Synthetic fibres for technical applications Synthetic fibres have expanded enormously in type in the second half of the twentieth century. The classic first generation fibres at the beginning of the 1950s were essentially only polyester, polyamide and polyacrylonitrile. However from the end of the 1960s specialist modified fibre types with a complex chemical and physical structure (second generation fibres) with specific property profiles followed. Fibres with even greater homogeneous properties, in which various different polymers are combined (dual-component fibres and polyblends), form a further stage of this development. Since then, a variety of fibres, with more than 5000 brand names based on the three classic fibre polymers, as well as polyurethane and polypropylene, have become available.

Synthetic fibres with new chemical and physical structures were developed and manufactured particularly in the 1970s and 80s. This was initiated by requirements that are usually less important in the field of traditional textile applications (clothing, domestic and household textiles): a high level of strength, a high E modulus, a high level of thermal stability, low flammability and good chemical resistance. Because of these property profiles, these “non-conventional” fibres are particularly suitable for technical applications, a field that is constantly on the increase.

This includes the following fibre polymers:

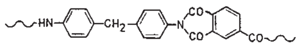
name	structural formula
PMI	
PPTA	

poly-(p-phenylene-co-3.4’-diphenylether-terephthalamide) (PEA)



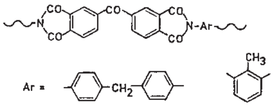
highly crystalline, chains straight

poly-4.4’-diphenylmethane trimellitic imidamide (PAI)



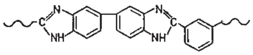
non-crystalline

poly-(4.4’-diphenylmethane-co-2.6-toluylene-benzophenone-tetracarboxylic acid) (PI)



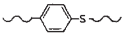
non-crystalline

poly-2.2’-m-phenylene-5.5’-bisbenzin imidazol (PBI)



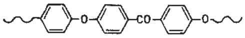
non-crystalline

poly-p-phenylene sulphide (PPS)



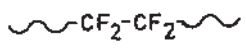
partially crystalline, chains folded

poly-ether-ether ketone (PEEK)



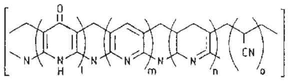
partially crystalline, chains folded

polytetrafluoroethylene (PTFE)



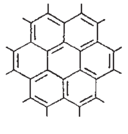
crystalline, chains folded or straight

oxidized polyacrylic fibre (OPF)

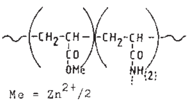


non-crystalline

polymer carbon (polycarbon) (carbon fibre)

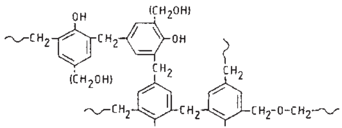


poly (acrylate-co-acrylamide) (P-AAcMe/AAm)



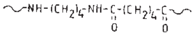
non-crystalline

phenole formaldehyde fibre (P/F)



non-crystalline

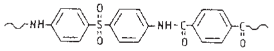
poly (tetramethylene adipamide) (PA 4, 6)



$\sim NH-(CH_2)_4-NH-\underset{\underset{O}{\|}}{C}-(CH_2)_4-\underset{\underset{O}{\|}}{C}\sim$

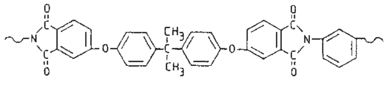
partially crystalline

poly (4.4'-diaminodiphenylsulphone terephthalamide) (PA pDPSO, T)



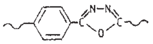
partially crystalline

poly (m-phenylene-2.2-bis [4-(3.4-dicarboxy-phenoxy)]-phenylpropaneimide) (PEI)



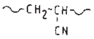
non-crystalline

poly(p-phenylene-oxadiazole) (POD)



partially crystalline

polyacrylonitrile (PAC, PAN)



$\sim CH_2-\underset{\underset{CN}{|}}{CH}\sim$

partially crystalline

The polymers demonstrated belong to various different classes with regard to chemical structure and fine structure. Some are linear polymers with aliphatic, aromatic or heteroaromatic structure elements. The melting and/or glass transition temperatures, which in most cases are high, are reached by means of intensive intermolecular interactions and/or chain rigidity for these fibre polymers. The other type consists of covalent crosslinked polymers, of which there are various different types (Fig. 1):

- one-dimensional crosslinked polymers (conductor polymers), in an ideal situation in the form of oxidized polyacrylonitrile fibres,
- two-dimensional crosslinked polymers (surface polymers), which occur in carbon fibres,
- polymers that are crosslinked in all spatial dimensions (three-dimensional), which can be realized in phenol-formaldehyde polymers and poly(acrylate-co-acrylamide).

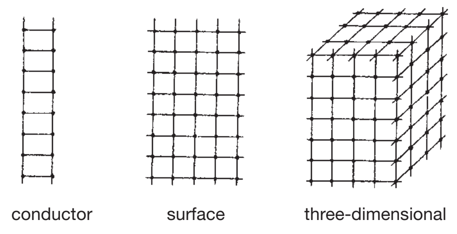


Fig. 1: Types of crosslinking of fibrous polymers (according to Roßbach).

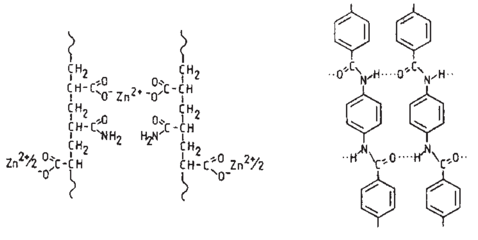


Fig. 2: Structural stabilization due to ionic and secondary valency bonding of special synthetic fibres (according to Roßbach).

As well as covalent bonds, ionic bonds (salt linkages) and partial valency bonds (e.g. hydrogen linkages) can function as crosslinking points (Fig. 2). Typical examples in the field of specialist fibres, where this type of non-covalent crosslinking points are particularly important, are fibres based on poly(acryl-co-acrylamide) (with Zn linkages) and poly-p-phenylenterephthalamide (with three-dimensional regular formation of hydrogen linkages) (according to Roßbach).

Synthetic filaments Dated term for → Elementary filament made from synthetic fibres, →: Filament; Capillaries; Fibrils, single end threads; but also for → Filament yarn.

Synthetic filament yarn → Filament yarn made from synthetic fibres.

Synthetic finishing agents → Synthetic colloids.

Synthetic leather (synthetic suede), term for →: Imitation suede; Artificial leather banned on the grounds that the term is anti-competitive.

Synthetic monofilament Monofilament made of synthetic fibre with Ø > 0.1 mm.

Synthetic resin exchanger Synthetic → Organoliths.

Synthetic resins (for textile finishing) Group of → Plastics with resin quality, insoluble in water, not infrequently also insoluble in organic solvents, which improve the efficiency of textiles significantly. Classification is analogous to plastics, so that synthetic resins can also be found classified under polymerization, polycondensation and polyaddition products. According to the German Federal Immission Protection Regulation (Bundes-Immissionsschutzverordnung – BImSchV), synthetic resins are substances and preparations that can react primarily with themselves in coating and impregnation, or steeping, such as

- melamine resins,
- urea/formaldehyde resins,
- phenol resins,
- polyester resins.

Monomers that are not able to react with themselves are not categorized as synthetic resins. Use: auxiliaries in all aspects of textile finishing, for resin finishing, wet crease-resistant, hydrophobic, slip-resistant and anti-snagging finishes. Permanent handle, stiffening, weighting, backcoating finishes; hat stiffening; permanent embossing, Schreiner, chintz effects; sizing; coating; laminating; permanent impregnation; nonwoven fleece impregnation; flocking adhesive; binding agents for pigment printing, etc.

Synthetic rubber Synthetic rubber is superior to natural rubber (→ Caoutchouc) in certain qualities (higher gas permeability, more resistant to oils and chemicals), while natural rubber is distinguished by its superior adhesive properties to fabric and metals (→ Latex). However chloroprene and silicone rubber also have good adhesive properties. Typical examples are butadiene polymers, chloroprene polymers or mixed polymers (→ Polyblends), e.g. made from ethylene-propylene-diene, isobutene-isoprene, butadiene-acrylonitrile, butadiene-styrene or sulphochlorinated polyethylene.

→: Butadiene-acrylonitrile-rubber; Styrene-butadiene rubber; Epichlorohydrine rubber; Isoprene; Polyester elastomers; Polyurethane rubber; Silicone rubber.

Synthetics This applies to

I. → Synthetic fibres.

II. → Synthetic detergents.

Synthetic suede → Synthetic velours.

Synthetic thickener Weakly crosslinked copolymers of oleofinic monomers containing carboxyl groups with a high molecular weight, which act as polyanionic bodies in the range of pH 7–10 as thickeners with similar rheological properties to an → Emulsion thickener. A particular high rate of swelling takes place in this pH range, and therefore the capacity to form a hydrate shell (Fig. 1) (increase in volume of approx. 100 times). Partial loss of solvate shell (Fig. 2) in line with increasing shear stress (→ Rheology), causing reduction in viscosity (steeply dropping viscosity curve with protracted → Flow limit). Synthetic thickeners are extremely sensitive to electrolytes and are subject to the salting-out effect. They are also sensitive to bruising.

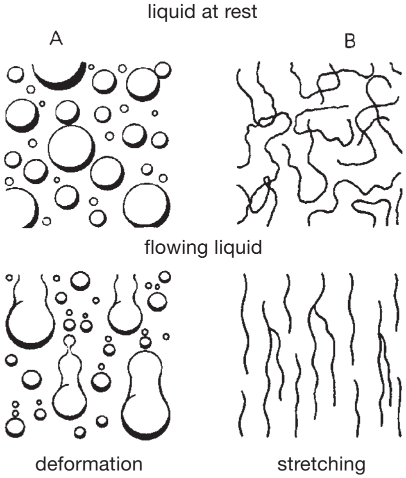


Fig. 2: The deformation of benzin droplets.
A = in benzin emulsion and stretching of thickeners; B = in synthetic thickeners at high shear stress.

Synthetic velours A term covering the following: synthetic leather knit (synthetic leather), imitation suede, imitation leather, microfibre whirled pile, synthetic leather, synthetic suede, suede imitation. "Leath-

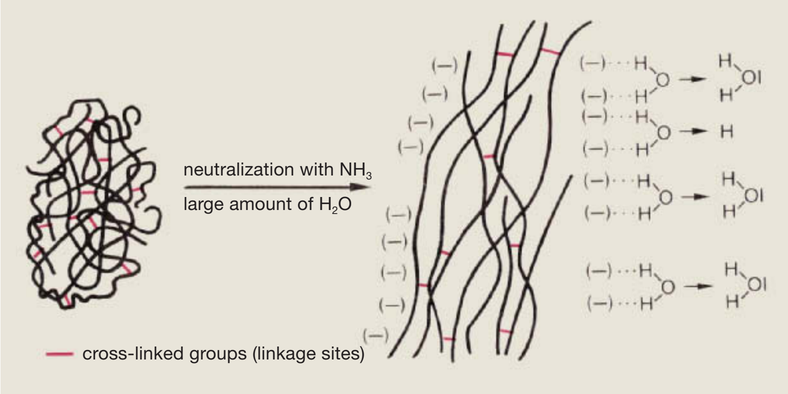


Fig. 1: Molecule packets of synthetic thickener.

er imitations and synthetic leather" is the only generic term considered by the association Verband Deutscher Lederindustrie und Kunstleder to be freely applicable. Synthetic velour is available in different strengths and with different surfaces (velours, nubuk, nappa-type). It can be dyed, printed, perforated, embossed, embroidered, pleated, etc. Other properties are for instance wool-type velour surface (extended knops) or velvet-type nubuk characteristics, extending to microfibre cross-section varieties, other handle and lustre trends, as well as even higher abrasion resistance. Manufacturing principle of synthetic velours: → Imitation suede.

Synthetic washing agents → Syndets, i.e. washing agents manufactured from synthetic detergents.

Synthetic waste water Used to analyse biodegradability in line with the Detergent and Cleaning Agent Law. Manufacture of 24 l (amount for one day) of a solution, containing the following components per litre of drinking water: 160 mg peptone, 110 mg meat extract, 30 mg urea, 7 mg sodium chloride, 4 mg calcium chloride ($2\,H_2O$), 2 mg magnesium sulphate ($7\,H_2O$); analysis of biodegradability at 20 ± 2°C using → MBAS.

Synthetic waxes (artificial wax, man-made wax), used as additives in sizing, finishing, waterproofing, etc. There are different types depending on their origin:

I. Solid → Polyethylene glycols: products of this type are soft or hard waxes, which almost always have water-soluble properties.

II. Montan wax or paraffin oxidation products (→ Fatty acids, synthesis of) in the form of esterized (and natural) fatty acids and alcohols, with or without further additives, also as soft and hard waxes with widely varying melting points (approx. 70–100°C), dark and light in colour, varying solubility, can usually be saponified and emulsified (e.g. in boiling water without alkali water-in-oil or oil-in-water emulsion).

They are used in a non-saponified or emulsified form for sizing, specialist preparations, finishes, hydrophobization. Type I and II products give textiles a soft handle, but frequently insufficient bulking elasticity.

Syrup formation Practical term for the secretion of droplets that occurs near boiling point or when the dyeing process is complete, e.g. of many non-ionogenic levelling agents in dyeing with 1 : 2 metal complex dyes. The dye liquor appears to be clear as water on extraction, when the fabric is unpacked from the machine and during cooling, the addition compound of dye/levelling agent begins to flow out. If this flowing "syrup" begins to dry, it can lead to non-fast, uneven dyeing.

Systems (Gk.: combination), from a cybernetic point of view, systems are structures consisting of elements and components linked by relationships. They can be homogeneous or heterogeneous, static or dynamic, open or closed.

In contrast to linear thought of a monocausal type, a feedback system thinks in complex causalities. A control loop is a system that consists of a sensor, a microprocessor (target/performance comparison) and an actuator linked together. A system has a transparent structure (atomic system, planetary system), of which it is not necessary to recognize all the elements, but their effects must be calculable. The biological structures of a chaotic system (e.g. chaotic layers) on the other hand is not transparent, and require a large amount of computer power to control them.

In 1987 Lehn described the systems of supramolecular chemistry (Fig. 1). Polymer systems interact with one another. Enzymes, for example, function according to the "key-lock" principle. Proteins are generated as the final product of amino acid monomers during biosynthesis. These receptors with a specific detection capacity for their substrate, form an "active pocket" of supramolecules by enclosing functional groups of the substrate, which are formed either for detection, transformation or translocation.

Systems can be classified according to the aggre-

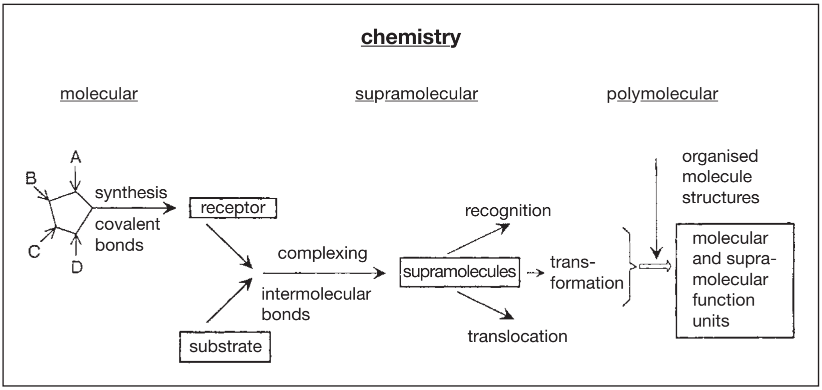


Fig. 1: Schematic explanation of the connection between molecular and supramolecular chemistry (according to J.-M. Lehn).

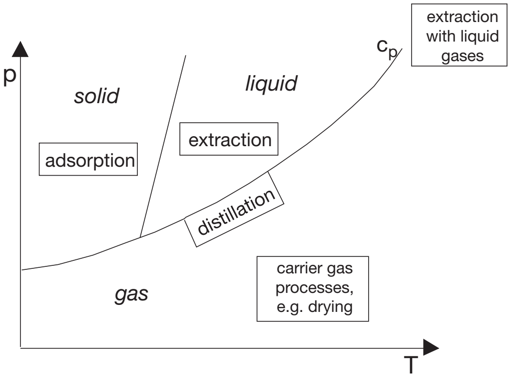


Fig. 2: System of aggregate conditions (according to Schollmeyer).

gate state in which the system's processes occur (Fig. 2). The three aggregate states are calculated by defining the ordinate system pressure and the absolute system temperature on the abscissa. Depending on the process parameters in textile finishing, typical processes occur within this system, such as

- adsorption,
- extraction,
- distillation,
- drying.

The use of supercritical states in this system is new (extraction with liquid gas).

Systems of units The SI unitary system (→ SI System of Units, SI = Système Internationale d'Unités) has been applicable in Germany since 1970 for business and official use, according to the law governing units of measurement. This law has been introduced internationally throughout the industrialised regions of the world for the purposes of standardization.

System washing agents Usually household detergents, containing dirt-dissolving agents and optical brighteners, the detergency power of which takes effect at different temperatures in one operating cycle.

SZ New term for referring to the Swiss Patent.

T

T Abbrev. for temperature.

t,

I. Abbrev. for time.

II. Abbrev. for weight unit, ton.

TA,

I. → Triacetate fibres, → Textile fibre symbols, according to the → EDP key system, → CTA.

II. Ger. abbrev. for "Technische Anleitung" (Technical Instructions); →: TI-waste; TI-noise; TI-air.

Ta Element symbol for tantal (73).

Table adhesives These are designed to glue fabrics on to flat screen printing tables. Temporary adhesives behave neutrally towards the print application, fabrics of every type and the various dyes. The fabrics can be bonded together on a backing fabric or previously on a bonding machine independent of the table. →: Flat screen printing; Table printing.

Table printing → Flat screen printing. High-quality, multi-coloured prints, e.g. in small runs on silk (e.g. scarves), are printed on tables with a moving film printing carriage (Fig. 1).

The carriage takes its direction from the repeat rails which run along the edge of the table (Fig. 2). The flat templates are printed through one after the other; initially one pattern is printed over another without intermediate drying. When all the individual colours have been applied, (Fig. 3) the fabric is stripped from the rubber conveyor (Fig. 4) and passed on to the vertical drier (Fig. 6) whilst the conveyor passes through a

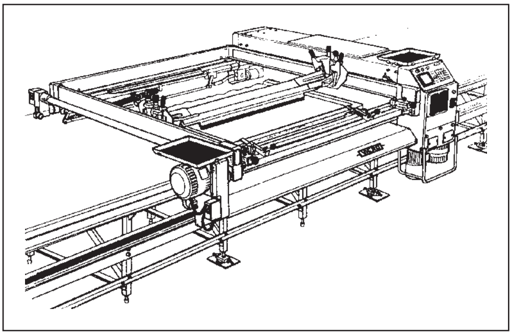


Fig. 1: Viero table printing carriage.

Fig. 2: Table printing room with electrically heated tables and typical repeat edges (by Sigma).

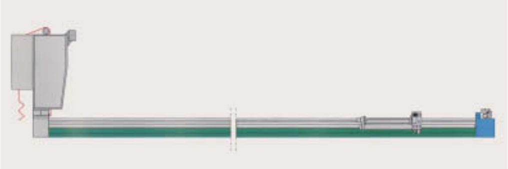


Fig. 3: Side view of a modern table printing device with glueing device, conveyor belt for transportation of the printed fabrics and drying chamber.

Fig. 4: Feeder and glueing device for fabrics to be printed (Viero).

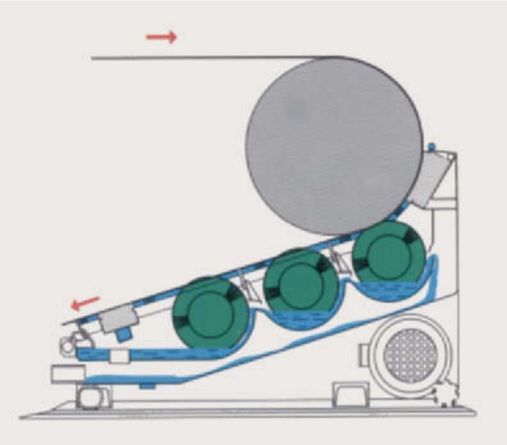


Fig. 5: Rubber blanket washing range at the end of the table.

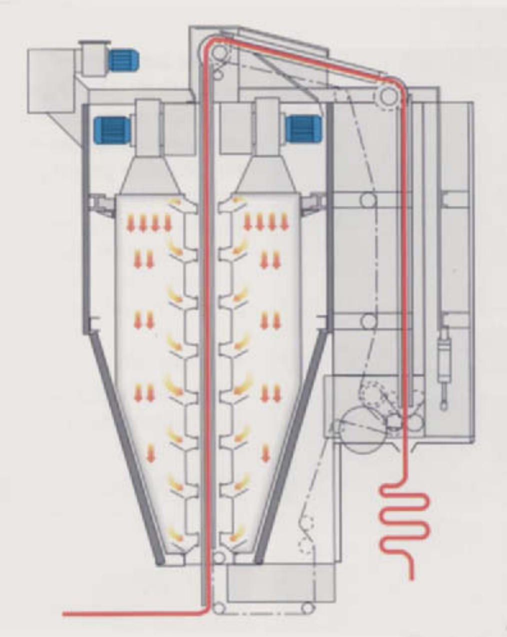


Fig. 6: Vertical drying device for printed goods (Viero).

washing process (Fig. 5) after the printing line and possibly under the print table.

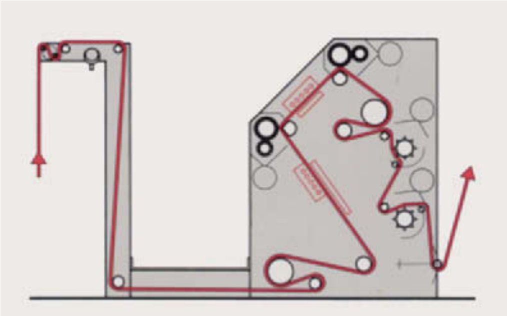


Fig. 1: Menschner table raising machine.

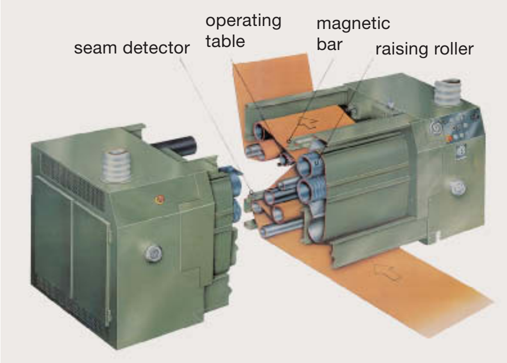


Fig. 2: Sucker-Müller PRN table raising machine.

Table raising machine Used for polyester fabrics, velours, velvet and imitation furs. Depending on the fibre material, the pile is rendered thermoplastic (Fig. 1) using infra-red heaters before passing over the table. The temperature, i.e. the intensity of radiation, can be regulated. The material passes over the table (Fig. 2) so that the raising roller runs against the direction of pile of the fabrics.

Table raising/polishing/shearing machine Raises, polishes and shears in a single run. Both sides of the material can also be processed in a single run without the use of a turning device (back-to-back). An electrically-heated polishing cylinder with beaters ensures lustre. The shearing table can be replaced by a roller for heavily-coated or reverse-side-coated articles for example.

Tablet test → Pill test.

Table washing device in flat screen printing Appliance for cleaning the printing table surface after printing. An electrically-driven brush roller scrubs the table surface whilst water flows into it from spray pipes. The liquid is wiped from the table surface by a double doctor blade in contact angle of approx. 30°.

Tabriz carpets Thin Persian knotted carpets with short, smooth woollen tufting. Precise, richly decorated, fine patterns in light colour on background colours of sand, red, matt blue and natural white. Also produced as medallion and hunting carpets. 220 000–250 000 Persian knots per square metre.

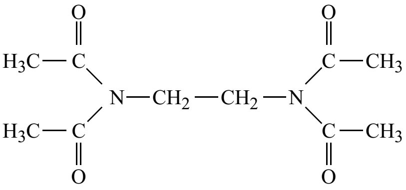
Tachometer Revolution (speed) counter for measuring revolutions of machine shafts, rollers, drums etc. Produced as tachometer for measuring number of revolutions per minute and as an automatic counter for any other period of time. Available in various versions for manual use (checks), fixed installation (works checking of pieces or meter count), the latter also provided with electrical contacts, and registration unit etc.(→ Oscilloscope).

Tackiness index Measure of speed of action of a paper printing paste. This is determined by means of an inkometer or → Tackoscope and depends largely on the amount of binder contained. The tackiness index is a relative figure which is influenced by the experimental set-up.

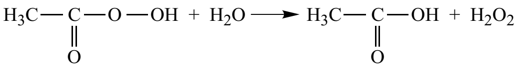
Tackoscope Serves to measure relative → Speed.

Tacticity → Isotactic polymers; syndiotactic molecules.

TAED Short form for the chemical compound N,N,N,N,-tetraacetylethendiamine ($C_{10}H_{16}N_2O_4$) with the structure formula



Manufactured on an industrial scale by converting ethendiamine with anhydride acetic acid; degree of purity over 99%. Colour and aroma free rhombic crystals. Melting point 156–157°C. Easily dissolved in ethanol and a little ice vinegar, less easily dissolved in benzene, difficult to dissolve in petroleum ether. TAED is an important bleaching activator for detergents with bleaching systems on the basis of inorganic oxygen carriers. TAED activation of perborat bleaches has proved particularly useful in practice. This process is accelerated in relation to the temperature by the presence of TAED. At moderate temperature perborat and TAED react with each other in the washing bath to form intermediary → peracetic acid by residual acyl which has separated from the TAED combining with H_2O_2. As peri acetic acid is an unstable compound, the following disintegration reaction occurs almost immediately:



$$H_3C-\underset{\underset{O}{\|}}{C}-O-OH + H_2O \longrightarrow H_3C-\underset{\underset{O}{\|}}{C}-OH + H_2O_2$$

Thus in the lower temperature range TAED produces a significant bleaching effect in the washing bath which at 60°C corresponds virtually in terms of performance to the bleaching effect achieved by perborat at boiling point. The TAED-Perborat bleaching system kills off microbe germs at 40°C and therefore produces hygienic washing results. As far as textiles and dyeing processes in the bath are concerned, this system is no more aggressive than perborat bleaches on their own. Accelerated bleaching at low temperatures is a realistic consideration for practice as it saves energy and time and eliminates the necessity to raise the temperature to boiling point each time. After a short washing time at 60°C the system virtually eliminates stains.

Taffet → Taffeta.

Taffeta (taffet). Smooth, usually shiny fabric (made of silk or acetate) in plain weave and single colour, in different colours (glacé taffeta) in changeant, etc. Light taffeta is known as → Muslin. Used for blouses, dresses, linings, etc.

Taffeta weave Plain weave in silk ware. → Weave.

Tagal Interlaced fabric for hats, bags, arts and crafts, fabricated from → Manila fibre.

Tailing Gradual transition from dark to light shades of the same colour tone in textile printing and dyeing. In the course of this transition one or both edges (listing, side-to-side shading) or the end (ending) of a batch demonstrate lighter or darker colouring as compared with the centre of the fabric. This is usually not desirable but is sometimes consciously exploited in printing and dyeing to achieve fashionable special effects. The causes can originate during a number of stages of the fabrication process:

I. During the fabric manufacturing process:
- differing tensile stresses on the warp beam;
- uneven sizing application, uneven drying or overdrying;
- thick selvedges;
- differing warp and weft thread densities.

II. During pretreatment:
- saizing residue on the fabric;
- uneven mercerization, can be monitored by means of staining, microscopic tests or swelling value determination;
- differing degrees of whiteness caused by oxidative damage to the fabric;
- alkali and acid content, can be determined by means of titration;
- singeing damage;
- distortion of the fabric.

III. During dying:
- squeezing differences caused by differing pressure in the centre and at the edges of the squeezing rollers;
- changed degrees of hardness of the roller coverings or their deformation (wear);
- uneven liquor level in the pad bath, immersion period (prevention of runback);
- uneven padder liquor temperature;

- uneven distribution of padder liquor over the width of the chassis.

IV. During drying and dye setting:

- migration processes (fabric appearance, dye penetration, changes in colour shade, dual-sidedness) caused by uneven drying conditions;
- uneven setting in thermosol plants over the width (particularly frequent in the case of very high temperatures);
- uneven heat transfer over the width caused by a) influx of cold air as a result of defective or open doors; b) improper adjustment of valves; c) blocked sieves in the air circulation and venting systems;
- uneven steamer conditions;
- air pockets;
- indequate supply of fresh water in the water lock;
- too long exposure to air between padder and steamer or steamer and rinsing tank.

V. During final finishing:

- unevenly applied finishing liquor;
- differing condensation conditions.

It is important to recognize unwanted tailing and ending as quickly as possible. Using dye measurement devices on running strips, it is possible to detect tailing and ending at an early stage, making immediate correction possible for continuous dyeings. The → Formatted piece method is important for rotary film printing. Other possibilities are measuring and regulating application dampness, measuring and regulating a pre-drying shaft and monitoring temperatures in dry heat aggregates. (→ Sewing test in listing).

Tailing and listing In textile printing and dyeing the gradual transition of a colour shade from dark to light in textile printing and dyeing → Tailing.

Tailing in continuous dyeing Modern padding mangles work with the least dye liquor quantities in the trough, liquor circulation and dosage equipment when reactive dyes and alkali are used. Partial hydrolysis of the reactive dye may take place in the trough, and if there is not sufficient mixing, it will take time to establish an equilibrium between dye supply at the fabric surface, rate of hydrolysis and dye absorption at the beginning of the continuous dyeing process. The colour intensity may be greater at the start than, for example, after 500–700 m (equivalent to 10–15 min dyeing time) (Fig.).

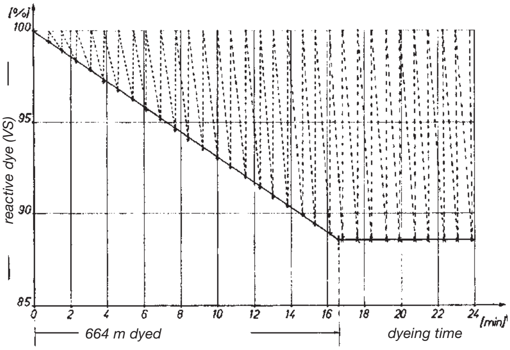


Fig.: Colour intensity variations up to a state of equilibrium in the padder.
VS = vinylsuphone dye.

The steep sides of the peaks occur as a result of additional dosing and represent extreme dye strength differences. These should not become obvious until after the 10th add-on dose when the max. dye strength differences exceed 5%. Dye strength differences below 5% can be recorded easily with the aid of transmission measurement, whereas visual assessment by a person has its limitations. Thus tailing would become visible after approx. 300 m corresponding to a dyeing time of approx. 8 min. The chemical processes in the dye trough must be included in the equation. From the chemical point of view, a hydrolysis balance establishes itself during the dyeing process. Whilst this balance is establishing itself, there is a corresponding tailing on the fabric. After the hydrolysis balance has established itself the dye strength remains constant during the remaining dyeing process. Whilst the hydrolysis balance is forming, the liquor in the trough increasingly accumulates reactive dye hydrolysate. The formation of hydrolysate is an alkali-consuming reaction which has little effect on the overall alkali concentration of the pad liquor. On the other hand the additional dosing liquors always have the same dye concentration corresponding to 100%. At the boundary between the residual liquor and the additive liquor the hydrolisate formation changes increasingly in the direction of the add-on liquor. This explains why 100% dye strength or a dyestuff with 100% reaction capacity cannot be achieved. The line of the curve would therefore have to run close to the actual curve until hydrolysis equilibrium has established itself. The new line of the curve would result in different liquor take-up by the fabric during passage through the trough resulting in tailing of the dyed fabric and the resulting changed liquor total in terms of time and the associated dye concentration difference (according to Dienst).

Tailor's canvas →: Buckram; Linen interlining.

Tailor's chalk This is used for marking measurement and pattern details on fabrics. It usually consists of finely pulverised clay or in the form of small plates cut with sharp edges (coloured ones with the addition of mineral dyes), also made of soapstone and talcum.

TAK dyeing Serves to produce multi-colour effects on carpets. Background colour is first applied to a strip of carpet up to 5 m wide by first dipping/squeezing. Then up to four further batches of dye are floated over the width of the carpet strip using special equipment. To fix the dye, the carpet strip is subjected to steaming and then rinsing processes. This process produces a blotchy effect which has a similar appearance to → Space dyeing. The dye solution is distributed over the carpet strip in snake-like patterns by means of special mobile spreader. Multi-colour effects are achieved by means of multi-colour processes. – Manuf.: Küsters.

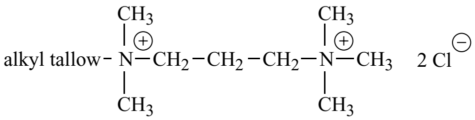
Talc → Talcum.

Talcum (light white, magnesium silicate, talc), $3\,MgO \cdot 4\,SiO_2 \cdot H_2O$. Density 2.7–2.8. Flaky or crystalline substance, shiny appearance like mother of pearl, (non) transparent, colourless or light white in colour, soft and greasy to touch, not soluble in water. It is characterised by its property of rapidly absorbing moisture. Utilized as Detachier powder (sometimes with the addition of dyeing agents), to prevent the formation of rims, to remove grease stains (scatter and iron over); to dehumidify wet-treated (glacé) leather gloves; to powder rubber items or plastic-covered textiles (to prevent sticking); to whiten white felt hats; as a filler for finishing agents, etc.

Tall oil Bi-product of cellulose production in accordance with the sulphate process. Raw tall oil consists of predominantly 45–70% fatty acids and 20–50% resin acids (usually abietine acid), strongly coloured, with an unpleasant smell. Refined tall oil contains mainly only resin acids. Tall oil is one of the cheapest capillary-active substances. Soaps made of tall oil have unusual emulsifying, moistening and cleansing properties but this has to be balanced against the unpleasant smell. Used in sulphurising, estering, condensation, oxyethylising products, also for moistening, smoothing and textile aids.

Tallow (suet). Fat originating from abdominal cavity of cattle, goats, sheep, mutton. Yellowish white in colour, hard and brittle; mild smell and taste. Melting point 37–41°C (mutton tallow). Dissolvable in ether, petroleum, turpentine, alcohol 1 : 5 (heated). Used to manufacture soap for smoothing, dressing etc.; has a slight dulling effect on colours. Composed of fatty acids with traces of glycerine, 32–50% fatty acid, 14–31% stearic acid, 3% myristine acid (beef tallow), 3% linoleic acid (beef tallow).

Tallow-alkyl compounds Dialkyl tallow- (→ Imidazolinium compounds) and Diquarter compounds such as for example N-alkyl tallow-pentmethyl-propendiamindichloride represent interesting avivage raw materials.



$$\text{alkyl tallow}-\overset{CH_3}{\underset{CH_3}{\overset{\oplus}{N}}}-CH_2-CH_2-CH_2-\overset{CH_3}{\underset{CH_3}{\overset{\oplus}{N}}}-CH_3 \quad 2\,Cl^{\ominus}$$

N-alkyl tallow-pentmethyl-propendiamindichloride

Tallow fat alcohols → Fatty alcohols with 14, 16 and 18 C atoms.

Tallow fat amines → Fatty amines with 14, 16 and 18 C atoms.

Tallow soap → Sodium stearate. Derived from congealed fish-oils. Utilized inter alia as a substitute for → Marseilles soap, in particular for soap soda rollers. When subjected to high temperatures, it is known to result in a tacky substance (turbidity point, deterioration point 65–70°C). 0.25% solution of pure tallow soap has a pH value of 9.2; degree of hydrolisation at 90°C = 13%. It is suitable for washing temperatures of 40–60°C.

Tallow sulphonate Tallow product with usually low degree of sulphonization; its natural fat properties are retained to a large extent. It is usually soluble in water. Anion active. Utilized as an avivier agent, as finishing and smoothing additives and as grease basis for matt finishing of foulard.

Tamarind pectin Fine, white powder derived from cold-processed tamarind seeds and kernels (with husks removed) (India, Sri Lanka, Burma). The powder is odourless, differs significantly from other fruit pectin and is 99.87% soluble in alcohol. Does not result in a blue coloration with iron but produces a deep blue or bluish black coloration using tamarind kernel flour which contains particles of husk, cream-coloured, or frequently even brown or reddish brown and possessing a typical odour. Use: as a sizing material due to its viscosity, gelling and film formation capacities. It has a better sizing capacity than maize starch; also as a finishing agent (recommended as very successful on cotton); in screen printing (2% paste does not drip, producing a rubber-like paste with sodium tetra borate).

Tambour,

I. Smooth, hollow roller (printing cylinder; presser roller), sometimes bombarded with rubberised wool or woollen felt fabric in Rouleaux print. Driven by means of pressure rollers.

II. The central, large cylinder on raising machines and in spinning machinery (carding, combing machines).

Tandem rolls Term used to describe two heated steel rollers in roller coating.

Tandem units Two identical elements are utilized twice in succession in a machine. Examples are the tandem rotary milling machine, a milling machine with dual rotary milling units which the fabric passes through one after the other on each rotation, or the coating machine with two coating heads (see Fig.).

Tangential washing machine → Horizontal washing machines used for washing linens.

Tangling → Air entangled yarns.

Tanner Dirt contaminated scum formed when scouring woollen goods in the scouring or milling machine.

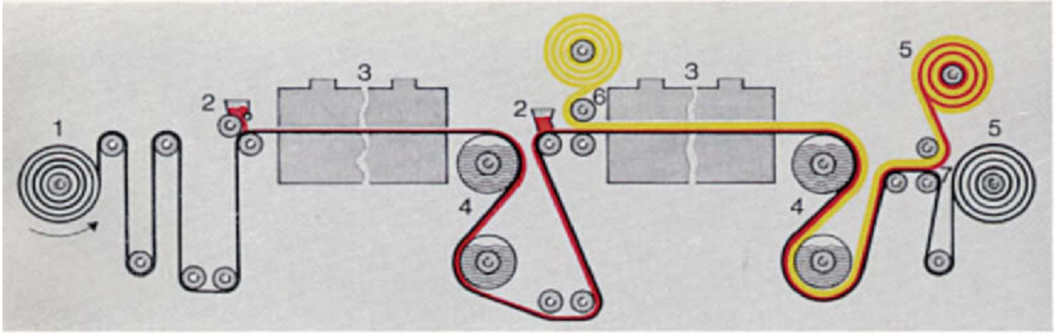


Fig.: Tandem units with two paint heads (by Bayer).
1 = unrolling; 2 = coating heads; 3 = drying tunnels; 4 = cooling cylinders; 5 = take up; 6 = laminating roll; 7 = separation;

Tannic acid → Tannin.

Tannic acid solution 5 g tannin in a water bath dissolved in 100 ml water. For finishing analysis during which glue, protein, starch, slime produce precipitants (glue precipitate dissolves partially in diluted hydrochloric acid).

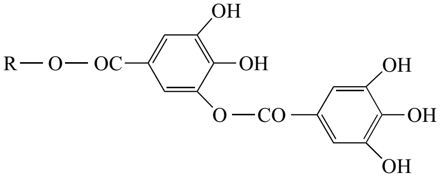
Tannic acid/tartrate emitic aftertreatment of polyamide Dyeing carried out with acid and metal complex dye substances has improved wet-fastness characteristics (water, sweat and washing fastness). Work process: Rinse after dyeing and treat with 2% tannin and 1% acetic acid (80%) for 15 minutes at 70°C. After the tannic acid has been absorbed, add to the same bath 1% cracked wine lees (potassium antimony(III)-oxide of tartrate) solution and continue treatment at same temperature for 15 minutes and rinse.

Tannic acid/tartar emitic mordant Dyeing stain with sufficient uptake and fixing of cationic dyeing substances on cellulose fibres, particularly for medium to dark colourations. Used before dyeing with cationic dyestuffs in the dyeing of cellulose, wool and silk.

Tannic mordant → Tannic acid/tartar emitic mordant.

Tannic mordant substitutes have the advantage, compared with → Tannin, of single bath staining and dyeing without metal salt follow-up treatment. Usually sulphured phenols or → Thiophenols. They serve as Reserving materials for wool and cotton and to improve fastness of polyamide dyeing.

Tannin (gall tannic acid, tannic acid). A natural tanning substance with differing composition depending on its origin (polygalloyl-glucose). Acts like mild acid on the basis of many phenolic OH groups. Density 1.35. Light powder, white to light yellow or brown; crystal needles (needle tannin); foamy mass (foam tannin, almost chemically pure); brittle, glassy flakes (flake tannin); all of these having the typical smell and acetic taste. It is a colloid, soluble in one part water (acid reaction) or two parts of alcohol as well as in glycerine and related substances. It has a strong tanning effect; 0.5% solution precipitates glue and gelatine; in combination with metal salts (iron, copper, mercury, lead) it forms insoluble or barely soluble tannins and in combination with cationic dyeing substances it forms insoluble colour varnishes. The staining properties are derived from the presence of residual gall acids:



High-quality tannin contains 65–76% tannic acid (best quality 75–80%), "water tannin" 26–60%; "alcohol tannin" (expensive) is cleansed with alcohol. Used for staining (superseded by → Thiophenols) for cationic dyestuffs (particularly water tannin); for colour varnish fabrication (colour fastness increase as an after treatment); decrease in the affinity of wool against certain colour substances.

Tanning Process for refining animal skins or pelts to make leather. It is carried out using → Tanning agents and works on the principle of starting with tannage from weaker solution and finishing with concentrated tannage solutions:

I. Using plant-based substances (bark or red tannage): usually in concentrated water-based solutions using vigorous mechanical movement, within a few days. Calf leather is tanned using willow bark, re-fatted with birch tar resin and then dyed with aluminium potassium sulphate and sandalwood.

II. Using mineral-based substances (mineral tanning): a) chrome tanning often with ready-to-use chrome products or with chrome alum or sodium dichromate. Chrome leather is pale bluish green. b)

White tanning (for white leather): Weak tanning action, leather shrinks slightly in hot water, can be swelled with dilute acetic acid. Soak in water-based solution of aluminium potassium sulphate and sodium chloride.

III. Using fats (fat or chamois tanning): by kneading with fish oil which oxidises during subsequent air-storage and can no longer be washed out. Excess residues are pressed out, or the skin is washed in sodium carbonate. Finished chamois leather is light cream in colour, supple and washable.

IV. Using synthetic products on the lines of I.

V. Combination I + IIa, I + IV, etc. Further treatments for improving and softening are known as dressing.

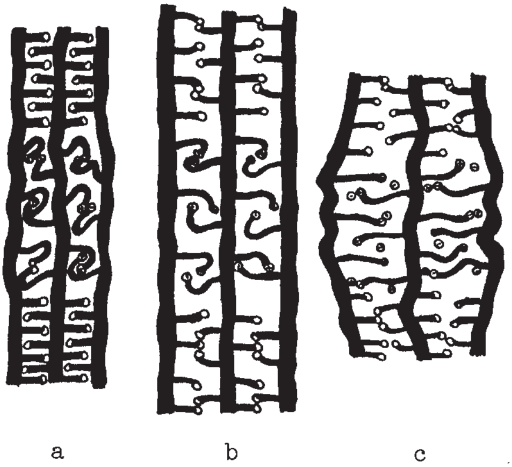
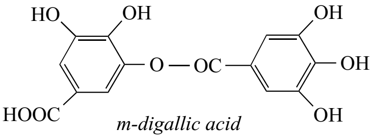


Fig. 1: Collagen swelling behaviour.
a = fibrils dry; b = fibrils swollen in neutral water;
c = fibrils swollen in acidic water.

Tanning is the most important and indispensable treatment for converting raw skins into leather. The collagen fibres normally have a high swelling capacity (Fig. 1). They swell quickly in water or acidic and alkaline solutions due to penetration of hydrogen and hydroxyl ions into the unstructured areas. The collagen molecule itself also swells. Such methods prevent the skin fibres, which consist of collagen chains, swelling due to water absorption or shrinking due to water loss. The collagen thus achieves hydrothermal stability. Hydrothermal stability is defined by the property of not shrinking when heated in a water-based medium until a certain characteristic temperature is reached. This temperature is the so-called "shrinking temperature". It is a measure of the forces which the structural order withstands, a phenomenon of denaturing and depends on the type and age of the collagen. In the case of untreated collagen the shrinking temperature is within the range of 40–60°C. Untanned collagen is therefore unstable in hot water and as such is unsuitable for use or for direct processing. The skin has to be tanned to stabilise the collagen. During the tanning process various chemical compounds (tanning agents) react with those protein groups capable of reaction. The incorporation of cross linkages gives the collagen a greater degree of strength which it does not naturally possess. The shrinking temperature is increased as the tanning process progresses thus improving the stability of the collagen when exposed to heat, enzymes and chemical influences. Swelling of the collagen in water, acid or alkaline is also reduced.

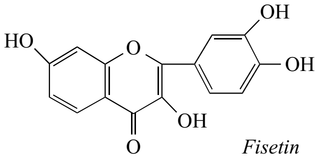
The tanning agents are divided into 4 types according to their various mechanisms: The crosslinking with vegetable-based tannages is carried out using the hydrogen bonding between the phenol hydroxyl groups in the tanning substance and the amide groups in the collagen. Two types of vegetable-based tannages are used.

1. Hydrolysable tanning agents: In the tanning agent molecule the benzene rings form large complexes with the aid of oxygen atoms. These include depside-, gallotannins and ellagi-tanning. They are esters of phenol carboxylic acid.



m-digallic acid

2. Condensed tanning agents: Multi-hydroxy phenols are joined together with the aid of carbon atoms as an ether bond to form a higher-molecule polyphenol.



Fisetin

The two types of vegetable-based tanning agents are used to process lower shoe sole leather, plain leather, drive belt leather, as well as some upper shoe and fine leather. Tanning with mineral tanning agents is carried out using complexing agents. Previously aluminium salt was used for tanning and this resulted in so-called "white tanning". Iron and zirconate tanning agents were also used. When chrome salts were introduced in tanning, the other mineral-based substances were no longer of interest with the exception of aluminium and zirconium. In chrome tanning the chrome salts react with the collagen carboxylic groups. The complex bonds are strong. Chrome salts are found in nature in chromite. The chrome is 2-, 3- or 6-valent in its compounds; only the compound with the 3-valent chrome can react with the skin fibres. Chrome compounds in an alkaline state are used in the tanning process. The more –OH groups are present in the chrome complex, the greater is the tanning action (Fig. 2).

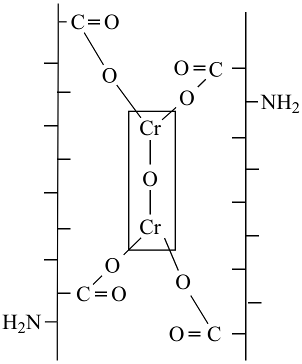


Fig. 2: Chrome tanning mechanism, crosslinking by principal valency bonding via COOH groups.

When tanning with synthetic tanning agents, no crosslinking occurs but secondary valency bonding by means of electrovalent salt linkages in the sulphonate acid groups with the NH_2 groups of the collagen (Fig. 3).

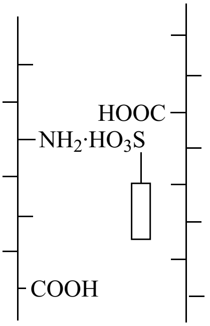


Fig. 3: Mechanism of tanning via salt bridges.

These tanning agents include polyphosphoric acids, complex poly-acids and lignin sulphonate acids. In aldehyde-based tanning agents, e.g. aldehydes, quinones, the tanning action is based on principal valency crosslinking. The tanning substance reacts with the free amino groups (NH_2) of the collagen (Fig. 4).

Polyfunctional compounds which are able to react simultaneously with several reactive centres of the collagen thereby causing crosslinking are generally known as tanning agents. Thus formaldehyde, di- and polyaldehyde and quinone form covalent bridges between two ε-amino groups of the lysine and hydroxylysine.

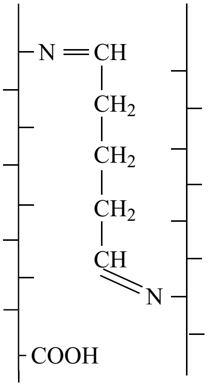


Fig. 4: Mechanism of tanning with bifunctional aldehydes.

Tanning agents (tannic acids), substances with a tanning effect, soluble in water and as colloids; have an unpleasant taste; prevent rotting; precipitate glue and protein solutions and convert animal skins into leather; with lead salts they mostly result in insoluble precipitates. The presence of numerous phenolic-OH groups in the molecule is characteristic. Differentiation is made between:

I. Hydrolysable tanning agents (ester-like properties), usually derived from gallic acid (e.g. tannin).

II. Condensed tanning agents (with carbon bonds) from natural sources are, for example, catechu, oak bark and of similar synthetic origin, for example condensation of formaldehyde and phenol and naphthalene sulphonic acid. In a sense, sulphite cellulose lye can also be regarded as a tanning agent.

Tannin stains Removal: a) Warm glycerine; b) 20% solution of tartaric acid (warm/hot); c) isopropanol (hot).

Tape fibres Spliced, slit or split fibres. Fabricated of sheet materials, → Tape yarns or flat threads, cut lengthwise or through lengthwise split fibrils, and cut into staple fibre lengths.

Tapestry carpet Chain pattern, machine woven tufted carpet in loops (Brussels tapestry) or velour form (tapestry velour). Patterns are produced using chain dyeing technique.

Tapestry carpets, tapestries → Flat carpet with representations of hunting scenes, historical events; modern non-naturalistic motifs are usually also used as wall hangings.(e.g. → Gobelin).

Tape yarns → Extruded tape cut from foils or tape strips. After cutting, they are hot stretched monoaxially and thermoset. A new process is based upon mono- or bi-axially hot stretching, thermofixing and then lengthwise slitting.

Tape yarns, stretched Stretched → Tape yarns in degrees of fineness ranging from 300–3000 tex.

Tarpaulin Jute double linen for sacking, linings, etc. Coatings can be applied for certain purposes.

Tarpaulin coating Lorry and container tarpaulin covers are woven of strong polyester yarns in Panama or Plain weave (→ Transport tarpaulins). The tarpaulin fabrics are coated to a weight of 600–800 g/m^2 with polyvinyl chloride which is coatable after plasticising and can be subsequently gelled.

A tarpaulin fabric coating system (see Fig.) consists of the following main system groups:

1. Preconditioning unit: This unit is necessary to reduce residual humidity as much as possible in order to prevent bubble formation and water inclusion in double-sided coating.
2. First coating unit: This is designed for single-sided coating of closed fabrics and for double-sided coating of fabrics with open weave.
3. Second coating unit: For production speeds of over 25 m/min it is advisable to use a double vertical drier. This unit also includes an embossing calender which can be equipped with two steel embossing rollers for various finishes on each side of the coated substrate, e.g. high-gloss finish on one side and matt finish in order to prevent clinging on the other. In this case one of the rollers is a “swimming roller” in order to prevent sagging.

Tarpaulin, heavy canvas Sailcloth made of hemp and/or linen and jute, with waterproof impregnation or multiple tar coating, for tarpaulins, tents and the like.

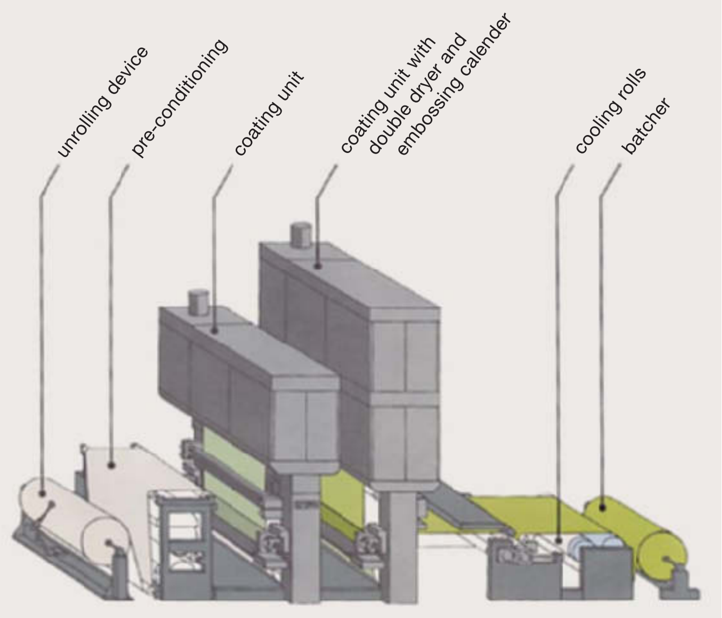


Fig.: Tarpaulin coating unit (Stork).

Tar stains (tar). Usually brownish black, sticky when warm, sharp edges, becoming harder, more brittle, and therefore easier to remove the longer the stains are left. Removal: a) benzene; b) benzene/carbon tetrachloride (or tri-, tetrachloroethene) 1 : 1, possibly with glycerine (= dye protection) in equal parts; c) carbon disulphide or acteone; d) chloroform (ether)/carbon tetrachloride; e) benzene/carbon tetrachloride 1 : 5 with diethyl ether/ethanol. If this does not produce satisfactory results, soak with concentrated grease-solvent soap (possibly overnight). Rework yellow stains: a) 3% ammoniac; b) (silk) 20% sodium tetraborate solution, possible reductive post-bleach; c) particularly for brown residues: Mixture of 75% oleic acid and 25% carbon disulphide, rinse with pure solvent.

Tartan Scottish tartan pattern, Scottish cloth.

Tartan fabrics (plaid fabric). Does not denote origin but is a generic term for all boldly-checked fabrics with predominantly green, red and blue colour shades. Woollen tartan fabrics can be fabricated from carded yarn or worsted filaments; important is the strong patterning. There are distinct summer and winter weights. The most frequent weave is the 1 : 4 twill, in same-sided twill as well as Plain weave. Worsted tartan fabrics are usually sheared; those made of carded yarn have a clear surface to lightly milled, occasionally also finished with long combed finish, causing the colours to flow delicately into one another. Used for dresses, skirts and coats.

Tartaric acid (dioxy succinic acid), $C_4O_6H_6$ molecular weight 150; density 1.759. Salts = tartrates. Large, colourless crystals, stable when exposed to air, odourless, nonpoisonous. Soluble in water with acid reaction, soluble in alcohol and ether. Water-based tartaric acid solution is dextrorotatory. Tartaric acid is a strongly dissociated acid (1% solution pH 2.1; 10% solution pH 1.6). Has a harmful effect on fibres when they are subjected to solution steam; reducing agent. Softening of textiles and silk scroop fabrication (silk, viscose); preservation agents (finishing agents for protein-based substances); spotting agents (lightening, freshening, etc.).

Tartrates Salts of → Tartaric acid.

Tasar → Tussah silk.

Tassel Tuft of threads or

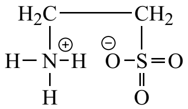
looped threads, bound together at one end. These are counted amongst → Trimmings.

Tatami mats Smooth floor covering, frequently used in Japan, made of Tatami straw. This is derived from Tatami grass, a type of rush cultivated in Japan, China and Taiwan.

tato Abbrev. of the German Tagestonne day-ton(s), tons/day.

Tatty-Look Fashion direction which values a worn appearance of clothing. Worn effects can be achieved by irregular contact drying, emerising or dripping of chemicals, etc. onto the fabric.

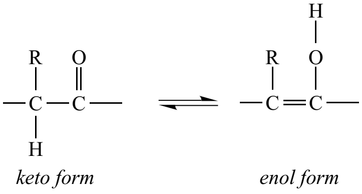
Taurine (amino ethane sulfo acid).



Molecular weight 125, melting point over 240°C, white crystals. It is easily soluble in water (neutral) and alkali, not in alcohol or ether. Originally derived from → Gall extract. Reacts like ester with cellulose hydroxyl groups (acid dye substance affinity). By-product of dye substance synthesis. It is used for detergent synthesizing and for animalisation of cellulose.

Taurocholic acid → Gall extract.

Tautomerism Organic compounds, in which two isomeric-structure forms merge partially, like keto- and enol forms (→ Ketones) when in dyeing vats, known as tautomerising. keto-enol-tautomerism causes a shift in the chemical combination:



As opposed to mesomeric (→ Mesomeric resonance), in which electrons change their position in the isomers, in tautomerism an atom (hydrogen) is displaced.

Tb Element symbol for terbium (65).

TC,

I. “Total Carbon“ = total carbon content (term used in biological effluent cleansing. (→ TOC).

II. Abbreviation for “Toxic Concentration”, i.e. in the case of gases, the concentration at which any → Toxic effect on humans is demonstrable.

Tc Element symbol for technetium (43).

T-Carbate Substituted dithiocarbamate, which at pH 5 in acetic, tartaric solution is a suitable reagent for quantitative precipitation of metal traces (including cobalt, copper, nickel, platinum, precious metals, lead, manganese, iron, zinc, vanadium, chrome, molybdenum), whereas titanium, aluminium and earth alkali do not precipitate. It is used for spectral analysis of heavy metal traces in incinerated cellulose materials.

TCF process (textiles continuously formed). Direct technique for fabrication of spun fleeces and spot-bonded nonwovens fabricated of viscose. Spun threads contain the components hydrozyl methyl cellulose xanthate (HMCX), cellulose and caustic cellulose in concentrated ringed layers. The thermoplastic component is HMCX, which has a sticking effect during hot calendering of the spun fleece and is transformed into cellulose during the process. A bonding agent is not required.

Td Abbreviation for tighter denier, obsolete → Linear density of fibres and yarns

Te Element symbol for tellurium (52).

Tearing Tester Elmendorf Used to establish initial tearing and further tearing values (= Elmendorf values) of particularly highly refined cotton fabrics by applying a strain with pendulum stroke testers.

Tear strength The force necessary to tear or tear through a strip of fabric in the direction of its length. Measurable with special clips on the tensile strength tester, where values can be read directly from a scale.

Teasel cards Dry teasel plant heads for rod teasel machine and roller card raising machines. → Raising machines.

Technical and professional organizations The following list contains the most important technical organisations and institutes in German-speaking countries. Further information and addresses are obtainable from the Gesamtverband der deutschen Textilindustrie e.V. (Gesamttextil) (Umbrella Association of German Textile Industry).

I. German textile reseach institutes:

- Bundesanstalt für Materialforschung und -prüfung (BAM) (Federal Institute of Material Research and Testing), Fachgruppe Textilien und Leder (Specialist Department for Textiles and Leather), Unter den Eichen 87, Berlin.
- Deutsche Institute für Textil- und Faserforschung (German Institutes for Textile and Fibre Research) Stuttgart/Denkendorf, Körschtalstr. 26, Denkendorf:
  - Institut für Chemiefasern (Institute for Chemical Fibres) (Chf),
  - Institut für Textilchemie (Institute for Textile Chemistry) (Tch),
  - Institut für Textil- und Verfahrenstechnik (Institute for Textile and Textile Processing Technology) (ITV).
- Deutsches Institut für Normung e.V. (German Institute for Standards) (DIN) (Normenausschuß Textil und Textilmaschinen) (Standards Committee Textiles and Textile Machines), Burggrafenstr. 4–10, Berlin.

- Deutsches Teppichforschungsinstitut e.V. (German Carpet Research Institute) (TFI), Germanusstraße 5, Aachen.
- Deutsches Textilforschungszentrum Nord-West e.V. (German Textile Research Centre) (DTNW), Frankenring 2, Krefeld.
- Deutsches Wollforschungsinstitut an der TH Aachen e.V. (German Wool Research Institute at the Technical University, Aachen) (DWI), Veltmanplatz 8, Aachen.
- Faserinstitut Bremen e.V. (FIBRE) (Fibre Institute Bremen) (Cotton Exchange), Wachtstraße 17–24, Bremen.
- Forschungsinstitut für Reinigungstechnologie e.V. (Research Institute for Cleaning Technology) (wfk, Wäschereiforschung Krefeld) (Laundry Research Krefeld), Adlerstraße 42, Krefeld.
- Hohensteiner Institute (Hohenstein Institutes), Schloß Hohenstein, Bönnigheim:
  - Bekleidungsphysiologisches Institut Hohenstein e.V. (Clothing Physiological Institute) (BPI),
  - Forschungsinstitut Hohenstein (Research Institute) (FI),
  - Forschungsstelle Textilreinigung e.V. (Research Centre for Textile Cleaning) (FTR) (based in Krefeld).
- Institut für Nähtechnik e. V., Jülicher Str. 336, Aachen.
- Institut für Makromolekulare Chemie und Textilchemie (Institute for Macromolecular Chemistry and Textile Chemistry) (IMTC), Mommsenstraße 13, Dresden.
- Institut für Textilmaschinen TU Chemnitz (Institute for Textile Machinery at the Technical University of Chemnitz (ITM), Reichenhainer Straße 70, Chemnitz.
- Institut für Textiltechnik der RWTH Aachen (Institute for Textile Technology of the RWTH Aachen (ITA), Eilfschornsteinstraße 18, Aachen.
- Institut für Textil- und Bekleidungstechnik TU Dresden (Institute for Textile and Clothing Technology at the Technical University Dresden (ITB), Mommsenstraße 13, Dresden.
- Sächsisches Textilforschungsinstitut e.V. (Textile Research Institute of the State of Saxony) (STI):
  - Forschungsinstitut für Textiltechnologie Chemnitz GmbH (Research Institute for Textile Technology Chemnitz Ltd.) (FIFT), Annaberger Straße 240, Cheminitz;
  - Institut für technische Textilien GmbH (Institute for Technical Textiles Ltd.) (ITT), Hohe Straße 6, Dresden.
- Textilforschung Bielefeld e.V. (Textile Research Bielefeld) (TF), Am Bahnhof 6, Bielefeld.
- Textilforschungsinstitut Thüringen-Vogtland e.V. (Textile Research Institute) (TITV):
  - Textilservice GmbH Greiz (TS), Zeulenrodaer Straße 42, Greiz;
  - Textilforschung Plauen GmbH (Textile Research) (TFP), Morgenbergstraße 41, Plauen.

II. European associations:

- Aachener Textilzentrum e. V., Veltmannplatz 8, Aachen.
- Bundesverband der deutschen Bekleidungsindustrie (Federal Association of German Clothing Industries) (BDI), Mevissenstraß, Cologne.
- Gesamtverband der deutschen Textilindustrie (Gesamttextil) e.V. (Umbrella Association of German Textile Industries), Schaumainkai 91, Frankfurt am Main.
- Gesamtverband der deutschen Textilveredlungsindustrie (Umbrella Assocation of German Textile Finishing Industry) (TVI-Association) Schaumainkai 91, Frankfurt/Main.
- Schweizer Verein der Chemiker und Coloristen (Swiss Association of Chemists and Colourists) (SVCC), Postfach 262, Zürich.
- Schweizer Verein der Färber (Swiss Association of Dyers) (SVF), Gossauerstraße 129, Herisau.
- VDI Gesellschaft Textil und Bekleidung (Association of German Industry Textile and Clothing) (VDI-TXB), Graf-Recke Straße 48, Düsseldorf 1.
- Verein Deutscher Textilveredlungsfachleute (VDTF), Weinbrennerstr. 4, Schwetzingen.

III. Institutes and associations:

- Ahmadabad Textile Industry's Research Association (AITRA), P.O. Polytechnic, Ahmadabad 380 015, India.
- American Associations:
  - American Association for Textile Technology (AATT), POB 99, Gastonia, NC 28 053, U.S.A.
  - American Association of Textile Chemists and Colorists, (AATCC), POB 12 215, Research Triangle Park, NC 27 709-2215, U.S.A., promotes the Wet Textile Industry. It has worked for 70 years with dyers, finishers, educators, students, chemists, mill superintendents, laboratory technicians, management executives and others who are involved with the application of chemistry textiles.
  - American Fiber Manufacturers Association (AFMA), is a domestic trade organization representing U.S. producers of more than 90 percent of the domestic production of manufactured fibers, filaments and yarns.
  - American Polyolefin Association (APA) is a U.S. based organization dedicated exclusively to promoting polyoloefin textile and ancillary products. APA and ist member companies open and broaden opportunities for polyolefin use in apparel, automotive, home furnishings, industrial, technical and related markets.
  - AMTEX, the American Textile Partnership (between the Department of Energy, the DOE laboratories, other federal agencies and universities.
  - Cotton Incorporated, with headquarters in New York City and eight other offices the world. Cotton Incorporated is a research and promotion company funded by U.S. cotton producers and importers of cotton goods into the United States.
  - Dallas Textile Club, nearly 200 active and honorary members representing the textile industry and related

  fields. Promoting cooperation to enhance the professional, social and personal development of each participating member.
  - National Textile Center is a group of four universities: Aubrun University, Clemson University, Georgia Institut of Technology, North Carolina State University, located in the heart the U.S. textile industries manufacturing base. Sharing human resources, equipment and facilities, mission goals are accomplished through innovative research and collaborative partnerships.
  - Textile Institute, U.S.A. The mission of the Textile Institute is to promote professionalism in all areas associated with the textile industries worldwide. Industrial and commercial operations from fibre production to the use of product by individual and corporate consumers.
- Associatión Española de Quimicos y Coloristas Textiles (AEQCT), c/o Joaquin Vidal Artes, Paseo General Mola 35, Barcelona 9, Spain.
- Association Internationale des Laboratoires Textiles Lainiers, 19 Rue du Luxembourg, B-1040 Bruxelles.
- Association Interprofessionelle pour la Formation Permanente dans le Commerce Textile, 69 Rue de Richelieu, 75 001 Paris, France.
- Associazione Italiana di Chimica Tessile e Coloristica (AICTC), Viale Sarca 223, 20 126 Milano, Italy.
- Associazione Italiana di Cinematografia Scientifica, Via Alfonso Borelli 50, 00161 Roma, Italy.
- Associazione per lo Sviluppo di Studi e Ricerche nell'Industria Tessile Laniera Oreste Rivett, Piazza Lamamorra 5, 13 051 Biella, Italy.
- Australian Wool Corporation, Wool House, 369 Royal Parade, Parkville, Vic 3052, Australia.
- Bombay Textile Research Association (BTRA), LB Shastri Marg, Ghatkopar, Bombay, India.
- Canadian Apparel Manufactures Institute, 141 Laurier W, Ste 804, Ottawa Ont. K1P 5J3, Canada.
- Centre de Perfectionnement des Industries Textiles Rhône-Alpes (CEPITRA), 55 Montée de Choulans, 69 323 Lyon Cédex 1, France.
- Centre International d'Etude des Textiles Anciens (CIETA), 34 Rue de la Charité, 69 002 Lyon, France.
- Compagnie Française pour le Développement des Fibres Textiles (CFDT), BP 1699, Couala, Cameroon.
- Costume Society of America (CSA), 55 Edgewater Dr, POB. 73, Earleville, MD 21919-0073, U.S.A.
- Educational Foundation for the Fashion Industries (EFFI), 227 W 27 ST, New York, NY 10 001, U.S.A.
- European Association for Textile Polyolefins (EATP)/Association Europénne des Polyoléfines Textiles, 4 Av. E. van Nieuwenhuyse, B-1160 Bruxelles.
- Federation of Asian Professional Textile Associations, objectives are to develop fraternity among members of the professional textile associations of the Asian region, upgrade technologicla status, organize conferences and programs for improving interaction between Asian countries. Approx. 10 member associations are representing thousands of textile and clothing professionals.
- Institute of Textile Science, c/o Dominion Textile Inc, POB 6250, Montréal, Qué. H3C 3L1, Canada.
- Institute of Textile Technology (ITT), POB 391, Charlottesville, VA 22 902, U.S.A.
- Instituto Nacional de Tecnologia Industrial (INTI)/National Institute of Industrial Technology, Av Leandro N. Alem 1067, 1001 Buenos Aires, Argentinia.
- Internationale Föderation der Vereine der Textilchemiker und Coloristen (IFVTCC)/International Federation of Associations of Textile Chemists and Colourists, Hollenweg 8 a, CH-4153 Reinach.
- International Textile and Apparel Association (ITAA), POB 1360, Monument, CO 80 132, U.S.A.
- International Wool Secretariat (IWS), Wool House, 6–7 Carlton Gardens, London SW1Y 5AE, UK
- Irish Textiles Federation Confederation House, Kildare St, Dublin 2, Ireland
- Malaysian Textile Association membership from all sectors of the textile and apparel manufacturing, covering the fibre, spinning, weaving, knitting, garment-making, industrial textile/accessories
- National Council for Textile Education (NCTE), POB 391, Charlottesville, VA 22 902, U.S.A.
- Norsk Tekstil Teknisk Forbund (NTTF), Lars Hillesgt 34, 5000 Bergen, Norway.
- Shanghai Textile Ingineering Society, 197 North Wulumuqi Rd, Shanghai, China.
- South India Textile Research Association, POB 3205 Coimbatore 641 014, India.
- Tecnotessile/Centro di Ricerche, Via Valentini 14, 50047 Prato, Italy.
- Textile Academy, Ying Jia Fen, Beijing CA: 9444, China
- Textile Institutes (TI):
  - TI China Liason Office, 18 Guang Wie Road, Guangzhou 5 100 030, China.
  - TI Czech Republic National Office, Na Ostrove 1165, 562 23 Usti nad Orlici, Czech Republic.
  - TI India National Office, 308 Raheja Centre, Avanashi Road, Coimbatore 641 018, India.
  - TI International Headquarters, 10 Blackfriars Street, Manchester M3 5DR, United Kingdom.
  - TI Poland National Office, Institute of Natural Fibers, Wojska Polskiego Str 716, 60 630 Pozna, Poland.
  - TI Turkey National Office, Byksehir Kltr Merkezi, 8 Medidiyeky, Istanbul, Turkey.
  - TI USA National Office, 2207 Concord Pike, Wilmington, DE 19 803, U.S.A.
- Textile Research Council (TRC), 2 First Av, Sherwood Rise, Nottingham NG7 6JL, United Kingdom.
- Textile Society of Australia, 594 Saint Kilda Rd., Melbourne, Vic 3004, Australia.
- Textilpari Müszaki és Tudományos Egyesület (TMTE)/

Hungarian Society of Textile Technology and Science, Fo utca 68, 1027 Budapest, Hungary.

- Trade Associations:
  - American Apparel Manufacturers Association (AAMA).
  - American Association of Textile Chemists and Colorists (AATC).
  - American Fiber Manufacturers Association (AFMA).
  - American Society of Mechanical Engineers (ASME) – Textile Ingineering Div., represents U.S. producers of manufactured fibres, filaments and yarns
  - American Textile Machinery Association (ATMA), working on improve conditions within the textile machinery industry of the U.S.
  - American Textile Manufacturers Institute (ATMI), is the national trade association for the U.S. textile industry.
  - Ayrshire Textile Group, helping strengthing the textile industry's profile and competitiveness in the UK and worldwide.
  - Carolina Hosiery Association (CHA), representing hosiery manufacturers and suppliers in the Carolinas.
  - China Garment Enterprise Association, social economic organization of the China garment industry.
  - Consortium on Competitiveness for the Apparel, Carpet and Textile Industries (CCACTI).
  - Embroidery Trade Association (ETA), developing solutions to the challenges of running an embroidery company.
  - Garment Contractors Association of Southern California Inc. (GCA).
  - German Apparel Association, an independent forum for European fashion and textile business.
  - Honduras Apparel Manufacturers Association.
  - International Apparel Federation (IAF), the representative organization for apparel manufacturers worldwide.
  - International Swimwear and Activewear market (ISAM).
  - Korea Textile Communication, providing up-to-date accurate and reliable information about the Korean Textile Industry.
  - Japan Cotton Promotions Institute, promoting cotton fabrics and fashions in Japan.
  - Malaysian Textile Manufacturers Association (MTMA), important and indespensible guiding forces in the Malaysian Textile Industry.
  - Nottingham Derbyshire Clothing and Textiles Association.
  - San Francisco Fashion Industries (SFFI), representing the Northern California Apparel Industry Trade Association.
  - Silk and Rayon Printers and Dyers Association of America, providing members with ideas and innovations in textile processing.
  - The Scottish Textile Association, promoting Scottish manufacturers and textile services throughout the world
  - Southeastern Apparel Manufacturers and Suppliers Association (SEAMS)
  - Taiwan Textile Federation (TTF)
  - Textiles from France
- Union of Textiles, Clothing and Leather, Rakovski 198, 1000 Sofia, Bulgaria
- Wuhsi Academy of Textile Engineering, Iiande Rd, Wushi 214004, China

IV. German universities with international education curricula in textile and garment technology and management:

- Institut für Textiltechnik, RWTH Aachen, Eilfschornsteinstraße 18, 52062 Aachen, Telefon 02 41 80 56 21, http://www.ita.rwth-aachen.de/~vth index.html; European Master of Science
- Technische Universität Dresden, Institut für Textil- und Bekleidungstechnik, 01062 Dresden, Telefon 03 51/ 4 65 83 70, http://www.tu-dresden.de; Master of Science in Textile and Clothing Engineering
- Fachhochschule Niederrhein, Textil- und Bekleidungstechnik, Webstuhlstraße 31, 41065 Mönchengladbach, Telefon 0 21 61/18 67 02, http://www.fh-niederrhein.de; Bachelor of Science in Textile and Garment Management and Master of Science in Textile and Garment Management (in English language only)
- Fachhochschule Reutlingen, Hochschule für Technik und Wirtschaft, Alteburgstraße 150, 72762 Reutlingen, Telefon 0 71 21/27 12 55, http://www.fh-reutlingen.de; Executive Master of Science in Global Textile Marketing
- Fachhochschule Albstadt-Sigmaringen, Jakobstraße 6, 72458 Albstadt-Ebingen, Telefon 0 74 31/57 92 13, http://www.fh-albsig.de; Master in Textile and Clothing Technology (TCT).

Technical grease solvents → Fat-solubilising soaps.

Technical guideline concentration A technical guideline concentration for hazardous substances and their concentrations (in the form of gas, vapour or suspended matter) in the air taken as a reference value for the introduction of appropriate protective measures at the workplace and the monitoring of exposure levels. It applies particularly to carcinogenic substances which have been removed from the MAK (maximum workplace concentration) list and included in the TRK (technical guideline concentration) list. Technical guideline concentrations are only allocated to hazardous substances for which no MAK limit, based on industrial toxicology, can be specified at present (→ Carcinogenic substances). The observance of technical guideline concentrations is intended to reduce health risks at the workplace, although these cannot be entirely excluded. No technical guideline concentrations have been adopted in the USA where the → TLV (threshold limit value) applies as far as possible in industrial practice, even for carcinogenic substances.

Technical organizations → Technical and professional organizations.

Technical textiles Frequently used term for textiles used for technical purposes, for preventive or auxiliary functions in consumer and utility goods as well as in the production of goods and services (→ Industrial textiles). These are textiles, whose fibre substance and form, texture or weaving technique, impregnation, coating, rubberising or composite construction render them independent technical products, are used in technical products, or demonstrate technical or special industrial properties. They may completely lose their textile character in the following phases of manufacture and use.

Technical textiles can be systematically categorized as follows:

1. construction textiles
1.1 geotextiles for underwater and underground construction
1.2 textiles for civil engineering (Figs. 1–2) (reinforcing, roofs and tents)
1.3 agro textiles (Fig. 3)
1.4 floor coverings
1.5 screening and sound insulation
2. medicinal textiles
2.1 hygiene articles and cosmetic articles
2.2 hospital linens
2.3 surgical articles and dressings
3. industrial articles
3.1 composite fabrics as alternative materials (Fig. 4)
3.2 rope articles, hose piping, cables

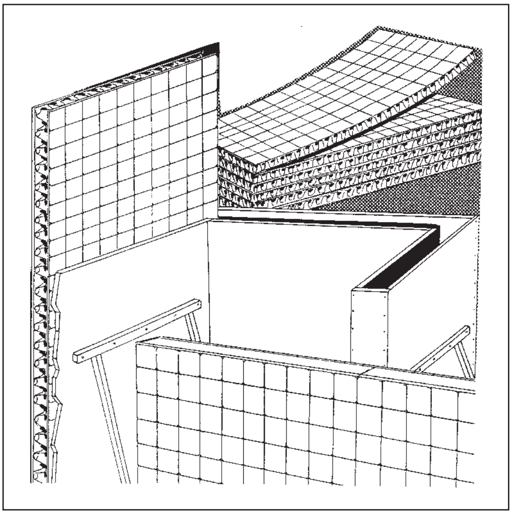


Fig. 1: Light partition walls for trade fair construction, can be rapidly installed and dismantled because of their honeycomb textile structure and easy to both store and transport (by TexTec).

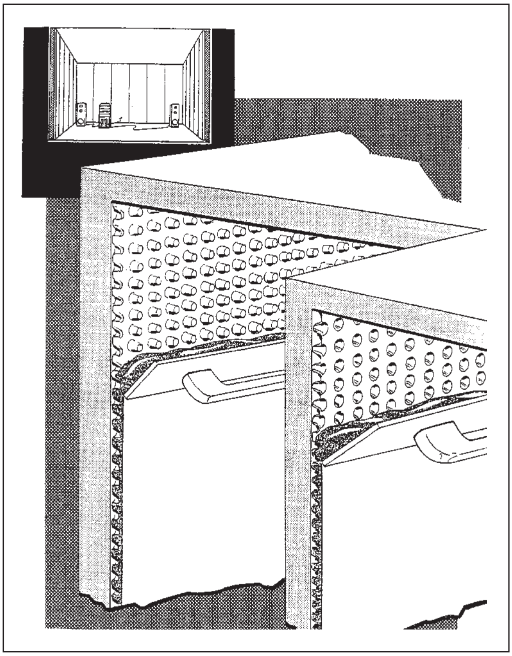


Fig. 2: Sound insulation walls made from composite material (by TexTec).

3.3 nets, belts, webbing, fastenings
3.4 filter fabrics and sieves
3.5 polishing textiles (sanding, cleaning cloths)
3.6 roller coverings
3.7 packaging material
3.8 dyestuff carriers
3.9 circuit boards
4. mobile textiles
4.1 automobile interior design (Figs. 5–7)
4.2 transportation tarpaulins (Fig. 8)
4.3 aviation and space travel
4.4 tyres, V-belts and drive belts
4.5 transport belts, conveyor belts
4.6 seals, brake linings
5. protective textiles
5.1 defence textiles
5.2 technical goods
5.3 heat, cold, fire, chemical protection
5.4 weather protection and sport clothing
5.5 cleaning textiles
5.6 safety clothing.

Technical textiles frequently demonstrate three-dimensional properties, as is demonstrated by the structure of a drainage pipe (Fig. 9) or by the differentiated construction of a tyre (Fig. 10). This type of textile construction has to be reinforced in order to fulfil the profile requirement. Reinforcement is often carried out mechanically, e.g. by means of stapling (Fig. 11) or by

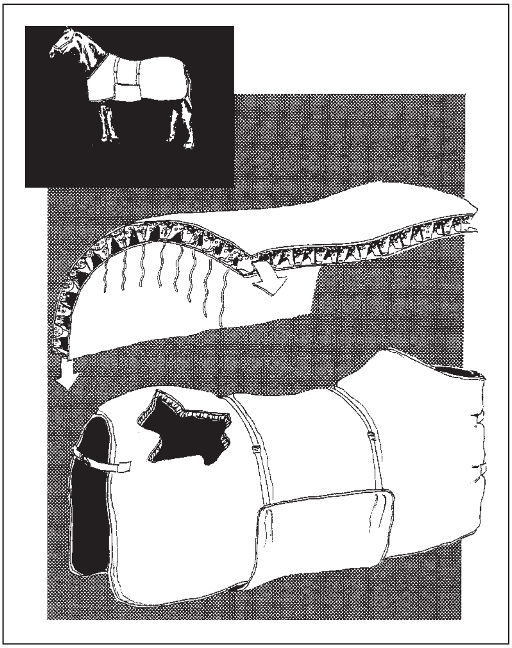


Fig. 3: Three-dimensionally fixed textile structure serving as a layer of insulation in water vapour permeable horse blankets (by TexTec).

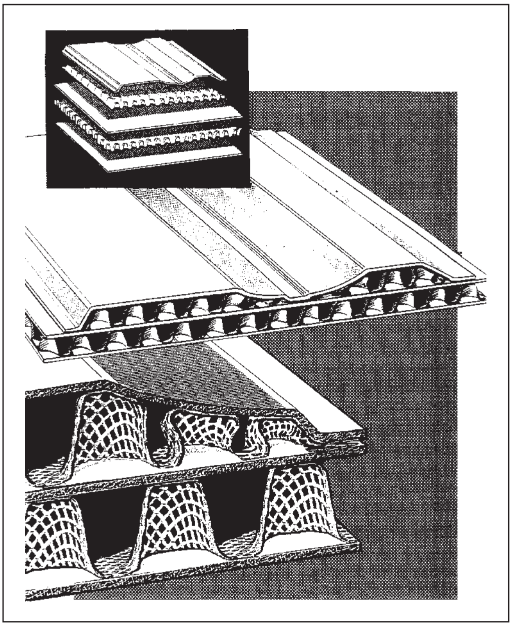


Fig. 4: Moulded textile nets, set three-dimensionally as prepreg and used as a construction material in the insulation industry (by TexTec).

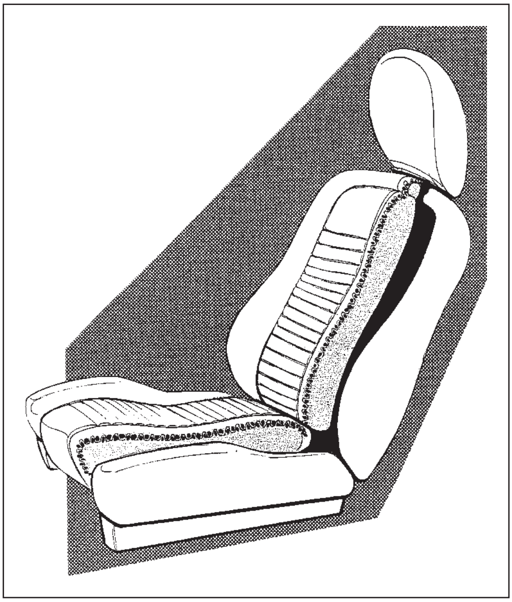


Fig. 5: Cross-section through a car seat (by TexTec).

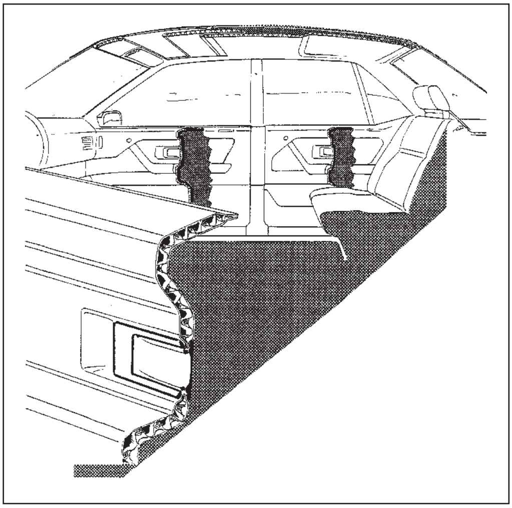


Fig. 6: Bonded fabric as internal car trim (by TexTec).

sewing multi-axial, non-shrink composite fabrics made of various textile materials (Fig. 12). Reinforcement is often achieved by means of textile refinement methods.

Most technical textiles are subjected to the textile refinement stage (TRS) during the fabrication process. Exceptions are for example tyre cord, cigarette filters, dyke reinforcement mats, ships' tackle, brake and clutch linings and similar items. Some technical textiles are not subjected to the complete, classical refine-

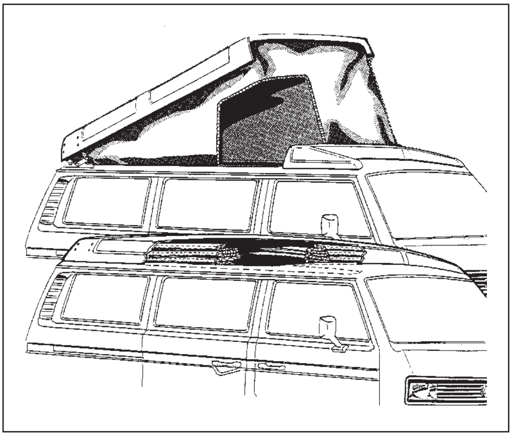


Fig. 7: Rising roof (open and closed) with extensible fabric sheathing, coated for improved insulation (by TexTec).

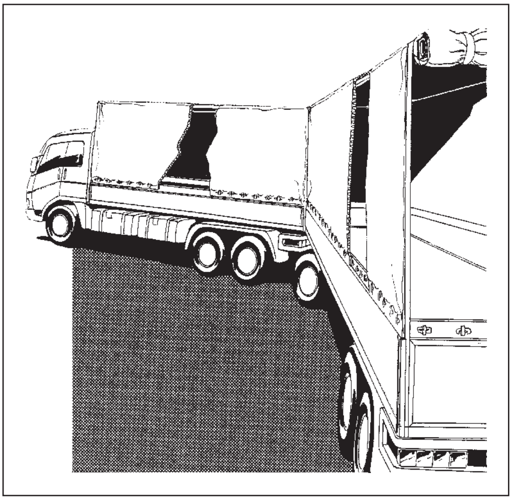


Fig. 8: Transport tarpaulins, used to insulate lorry cargo space against the weather (by TexTec).

Fig. 9: Pipe structure (Drainage) (Multiple Fabric Co. Ltd.).

ment process, i.e. pretreatment, dyeing or printing and finishing but are subjected to specific refinement processes, e.g. coating, glueing, cationisation, softening, roughening, etc.

Calculations made by the German Textile Processing Industry (TVI) Association come to the conclusion that the German textile processing industry treated approximately 126 000 tons of technical textiles in the form of fluff, yarn or made-up fabric in 1992, i.e. almost 19% of the total production of the textile processing industry in that year. This quantity can be broken down into the industry's main sectors (Fig. 13). Textiles for technical purposes sometimes play very differing roles in the individual refinement fields.

The proportion of fluff represents 41% and is thus the highest. Fabric refinement represents 15% and fabric printing only 4% (Fig. 14). The fluff as raw material is subjected to numerous refinement stages before being processed as technical textiles in the subsequent production path. These include materials for car seat coverings, fitted carpeting for car interiors and boots,

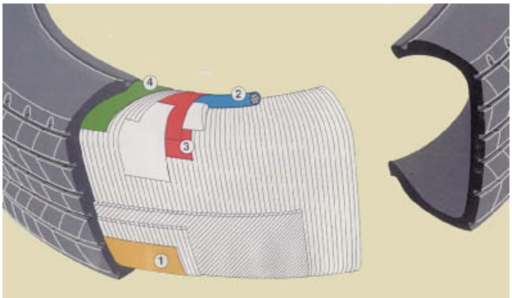


Fig. 10: Tyre structure (by Milliken).
1 = shoulder protection; 2 = closing ring; 3 = flipper;
4 = side protection.

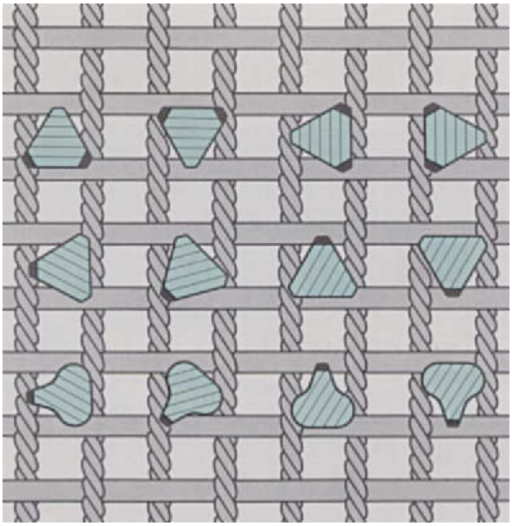


Fig. 11: Needling of a fabric (Groz-Beckert).

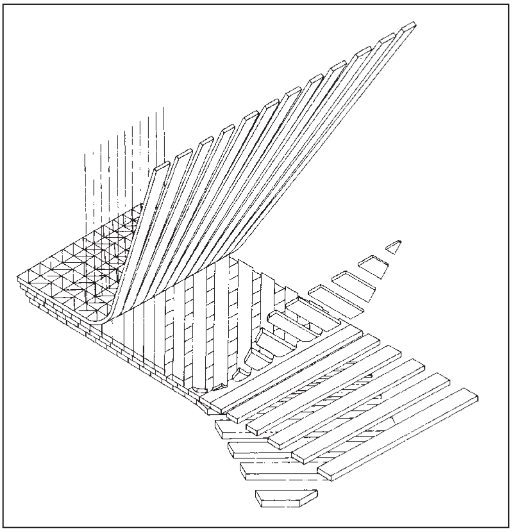


Fig. 12: Multiaxial textile construction.

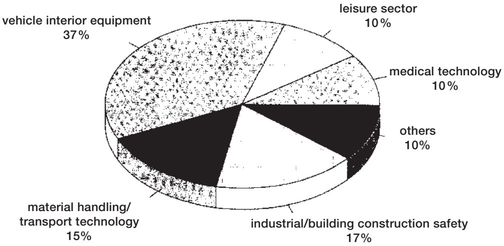
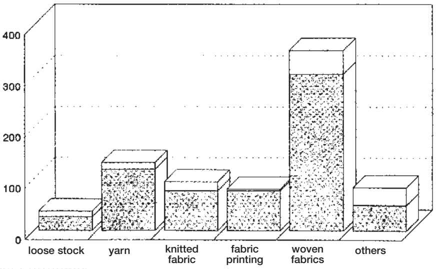


Fig. 13: Breakdown into portions of the total technical textiles tonnage in textile finishing for 1992, split into fields of application (estimate).



	loose stock	yarn	knitted fabric	fabric printing	woven fabrics	others
technical textiles tonnes ☐	10.86	13.11	17.72	3.1	45.99	34.61
sector total tonnes	26.49	119.16	77.03	77.64	306.6	49.45

Fig. 14: Breakdown into portions of technical textiles in the textile finishing categories for 1992.

belts, cotton-wool, fleeces and felts for various uses, e.g. as insulation material. Fluff industrial textiles are usually dyed and then processed into made-up fabrics. During the finishing process they are again subjected to textile refinement. The main materials to be bleached are cotton wool for medicinal and cosmetic use.

The most important substrates are polyester, polyacryl nitrile and polyamides. Fluff refinement has been considerably reduced in the fitted carpet area of the automobile sector due to the increase of spin jet dyeing of chemical fibres. Textiles for technical purposes represent 11% of yarn refinement activities. More than half of this quantity is destined for the automobile sector. Here dyed products are predominant and polyester, followed by polyamides, are the most used raw materials. As in the case of fluff, in the field of yarn refinement

Fig. 15: Foam fine-coating of a blackout curtain.

Fig. 16: Heavy-coating a transport tarpaulin with polyvinylchloride.

spin jet dyed articles have managed to attract parts of the market in the automobile sector. In the fabric refinement area technical textiles represent a considerable proportion at 15%. This is also true for the range of articles. The refinement sector is well represented in vehicle construction (fabrics for seat covers, roof linings and fitted carpeting for cars, air-bags, convertible roof covers, etc.), in the industry sector (base fabrics for conveyor belts, sanding and polishing discs, tarpaulins, computer adhesive tapes, filter materials, container construction), in medical technology (dressings, bandages and plaster materials, blood filters etc.), in safety technology (fabrics for certain types of protective clothing, life-rafts), in environmental protection, in the building sector (fabrics for façade cladding and roof construction, stall mats, tennis flooring, etc.) and others (e.g. fabrics for Velcro-fastenings), black-out curtains, parachutes, hot-air balloons, surfboard sails, ironing board covers). These fabrics are frequently coated (Figs. 15–18).

Dyed products represent a considerable proportion of the total, particularly in the case of fitted carpets for cars, but also for other industrial uses; car seat coverings have usually been dyed during the stages prior to fabric refinement and are only subjected to a finishing process as a fabric. Bleached products are predominant in the medical sector; an example of bleached products is gauze. In general the proportion of dyed products used as technical textiles is increasing. The most important types of raw material are polyester, viscose and cotton.

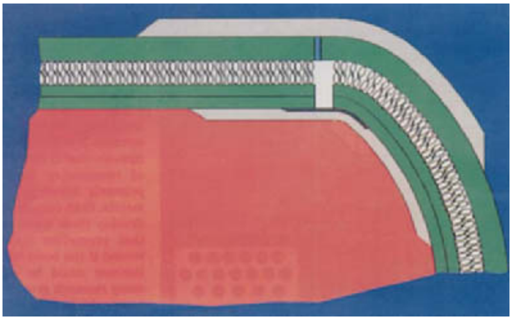


Fig. 17: Setting a 3D structure using double-sided coating (green) to form a tank-cell (red) (coating polymer: phenol-formaldehyde resin).

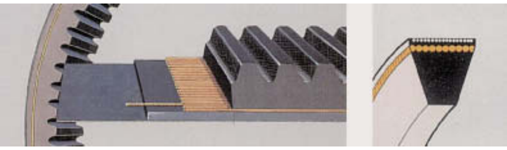


Fig. 18: Setting a 3D structure by coating it with rubber which is vulcanized into hard rubber.

The highest proportion of technical textiles refinement is represented by the refinement of mesh materials. Automobile construction with seat coverings and panelling elements plays a predominant role here. Due to economic trends in this user group the significance of technical mesh materials has increased over the last few years. This was intensified by the trend away from woven materials to mesh materials. However, there is also a range of other technical mesh materials, often special fabrics such as linings for loudspeakers, velvet for glasses cases, shoe linings etc. Dyestuff and equipment more or less balance one another. The most important raw material by far, is polyester.

The strengths of printed fabric lie in fashion articles for clothing, house and home textiles. The market segment for technical use is small at 4%. Car seat covers, tents, flags and sausage skins should be mentioned here.

Belt refinement covers a wide range of technical articles, e.g. safety belts, belts for lifting goods and window blind belts. Concealed and coated mesh materials, which are listed under other materials (these articles have often previously been subjected to another refinement stage), have numerous uses. The further refinement of these techniques has led to new applications in addition to established uses such as vehicle and container construction, safety technology and other markets. Technical textiles have a considerable significance in textile refinement. This market segment is very little affected by variations of fashion or structural changes as are clothing and house and home textiles. It is, however, very much dependent on the economy as a whole.

Technical textile sampling (taking of samples) is to be carried out in accordance with DIN 53 803. It must be representative for populations and be done in accordance with the statistical law of chance occurrence (random testing). → Statistical analysis.

Technique follow-up assessment Attempts to ensure socially and environmentally friendly choice of techniques. Technique follow-up evaluations and assessments are not at present subject to any generally valid definition. Guideline 3780 (Technique Assessment: Terms and Basic Concepts) produced by the German engineering association, Verein deutscher Ingenieure (VDI), has provided a current viable definition. According to this guideline, technique assessment consists (including technique sequence evaluation) of:

- analysis of the status of a technique and its development potential,
- evaluation of technical and non-technical consequences,
- assessment of the consequences on the basis of aims and values,
- definition of appropriate measures in terms of action and redesign.

Even on the basis of this definition, classification of projects in terms of technique follow-up assessment presents considerable difficulties, as plans and projects generally only investigate partial aspects of an overall technique follow-up assessment.

Technological progress Technological progress is expansion of technical knowledge by means of → Research and development. Technical research consists in the use of new technologies in industry, and brings about a macroeconomic increase in productivity which should include quality improvement.

Technology cards Specially developed clocking-on card (for thyristor technology) containing programmable tasks for machines and systems according to the type of process.

Tecum fibre → Palm fibres (Brazil), white and solid, similar to flax, sometimes coarser, high moisture absorbency without feeling damp, used particularly for upholstery material.

Tedeco mercerizing process Technique developed by the Norwegian Textile Institute and the Institute for Industrial Research in Oslo for treating fabrics in liquid ammonia. The technique is derived from the → Prograde process. The fabric is passed through liquid ammonia at –33/35°C causing an immediate reaction to occur. Reaction time is 10 seconds maximum. The fabric is then stretched and fed over heated drums where the ammonia evaporates and is recycled, except for a residue of 3%. The remaining 3% can be removed by steaming. The resulting ammonia steam mixture is incinerated.

TEFO Swedish documentation authority. → Technical and professional organizations.

TEGEWA German association of textile and leather aids and staining and washing raw material industry (Verband der Textilhilfsmittel-, Lederhilfsmittel-, Gerbstoff- und Waschrohstoff-Industrie e.V.). → Technical and professional organizations.

Telescope effect Microscopically detectable stretch marks in the form of local bottle-neck-shaped tapering (restriction effect) of zones most subjected to stretching when processing cold-stretchable high polymers (polyamide, polyester).

Telescopic dyeing spindle is used when dyeing cross bobbins or muffs which are compressed axially before dyeing. This process offers a time-saving factor compared with traditional methods. It consists of a perforated tube with appropriate base thread for screwing into material carrier. The charging spindle consisting of longitudinal struts can be screwed into the perforated tube in a telescopic manner (pressure spring fastening, as required, in extended position). A closing cap with several stable tenons is used for automatic locking. – Manuf. Tigges.

Telescopic dye vat loader → Telescopic packing cylinder.

Telescopic packing cylinder Infinitely adjustable telescopic central tube which can be lowered, using a crane, to 40% of the overall height of the packing cylinder before being re-lifted (after dyeing/bleaching). Compared with the conventional type design with its dome-like upper end (= unused packing volume), the telescopic packing cylinder encompasses 20–30% more material. A sprung ring acts as a seal between the interior of the apparatus and the packing cylinder lid (completely flat, adjustable). Economical solution for processing small quantities (including regulatable liquor condition) of fluff, coils, muffs, rope yarn, spinning cable. – Manuf.: Jasper.

Telescopic sleeves Telescopic sleeves which expand and retract into each other and can be easily compressed. They are often used instead of perforated sleeves for dye spools in order to achieve a better dye penetration.

Telomer → Telomerization.

Telomerization (Gk.) So-called specific → Polymerization uses compounds (so-called “telomer”) resulting in end groups, which are determined in advance, and renders possible a controllable, stage-by-stage increase of polymerization by adduction 1 : 1, 1 : 2, 1 : 3, 1 : x up to several thousand. Telomerization results in a wide range of synthetic waxes, plasticising agents, lubrication oils, textile aids, plastics, synthetic fibres, etc.

Temperature (Fr.: température = degree of temperature). There is only one temperature used to indicate the physical state of heat of a body or of the air. According to international agreement, this temperature is indicated by the name → Kelvin and the symbol K, the “degree” symbol being left out. According to this system, temperature is defined as a basic dimension of the SI system using Kelvin as its basic unit. The basic unit of 1 Kelvin is one 273rd part of the → Triple point of water, i.e. of the temperature scale which begins with 0 K (0 K = absolute zero point, 273 K = freezing point, 373 K = boiling point). Temperature units of other basic scales are determined arbitrarily. The so-called empirical temperature is based on the expansion of a fluid volume and the displacement effected thereby of a fluid filament. The conventional units are degrees Celsius (°C) [not valid in the SI-system; degrees Fahrenheit (°F), degrees Rankine (°R), obsolete; degrees Reaumur (°R)]. 1 degree Fahrenheit is equivalent to 1 degree Rankine, and likewise 1 degree Celsius to 1 Kelvin. When the temperature is quoted in degrees Celsius, this refers to the Celsius temperature scale where the freezing point of water (zero point) is ±0°C and the boiling point is +100°C. Kelvin units are equivalent to degrees Celsius with Celsius units being used here in a specialised sense. Temperature differences (temperature ranges) thereby have identical numerical values, no matter whether read in K or °C, for 1°C is equivalent to one K as a temperature differential anywhere on the temperature scale. In this sense, therefore, 1°C = 1 K since, throughout the temperature scale a temperature range of, for example, 15°C is identical to the temperature range of 15 K. What should be remembered is that the "Kelvin" is to be understood as a dimension and not as a scale, whereas Celsius remains a scale:

373.15 K = 100°C
273.15 K = 0°C
0 K = –273.15°C

Temperature characteristics of textile fibres are shown in (°C) in the Table.

	A	B	C	D
wool	110	80	130*	300
cotton	100	75	*	160
polyester	140	120	235	255
m-aramide	250	200	300	400

*Tab.: Temperature characteristics of textile fibres (ºC). A = hot air temperatures after 2500 h, causing a 50% reduction in the tear strength of the fibres; B = hot air temperatures after 10 000 h, causing a 50% reduction in the tear strength of the fibres; C = softening or decomposition temperature; D = melting or carbonisation temperature. * = according to moisture content.*

Temperature control of dyeing machines In practice, temperature regulation circuits are often planned according to the form of the programme or information carrier, i.e. circular plates, plug board, punched tape, plastic partition cards, cut cards, magnetic cards, computers. The Fig. depicts variations in such control systems for a temperature time-control on dyeing apparatus.

Temperature indicator colours Temperature-indicating salts (of e.g. copper, cobalt, nickel, chrome, molybdenum, uranium) which change their colour at certain temperatures and retain it after subsequent temperature reduction. Several colour transformations per salt are possible. Temperature indicator colours are used as a paint coating or as pencils for temperature measurement, which are used according to colour transformation range to monitor dangerous levels of heat on, for example, pipelines, radiators, electrical appliances and movable machine parts such as drums, brakes, couplings.

Temperature measurement Totally accurate temperature measurement is difficult. Usually only a mean temperature is measurable between the product, the wall temperature and the energy carrying medium (water, air, heat bearing oil). The exact temperature is not measured accurately even when it is taken in contact with the material to be measured. The temperature sensor is in a permanent state of temperature exchange with its environment and the following points should therefore be noted:

– Heat exchange between the material to be examined and the temperature sensor must be encouraged;
– Loss or addition of heat from or to the temperature sensor must be prevented as far as possible.

It is obvious that a measurement or sensor installation location should generally be chosen which has the highest constant speed of measurement and is as near as possible to the heat consumer. Depending on the system or machine, measurement locations should be as follows:

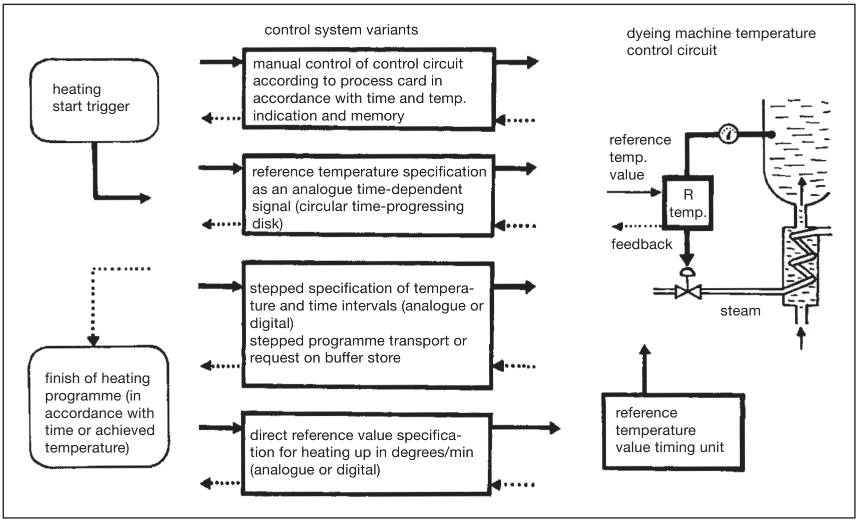


Fig.: Control system variants on dyeing machines for controlling steam supply (Rüttiger).

- For systems heated by means of fluids: at the heating agent influx or outflux;
- For systems with steam heating: pressure measurement at the heating agent influx, temperature measurement at heating agent outflux;
- On the product itself in machines or systems without circulation;
- At the product discharge point in machines or systems with circulation;
- At the mixed product discharge point.

Resistance thermometers are used as sensors in technology (Fig. 1). They can be manufactured with a high degree of accuracy but have the principal disadvantage compared with platinum sensors that they age, i.e. their values change slightly after a few years. For technical use (e.g. temperature regulation), constant voltage is applied to the resistance thermometer and the current is then measured. The process is generally too time-consuming for temperature measurement.

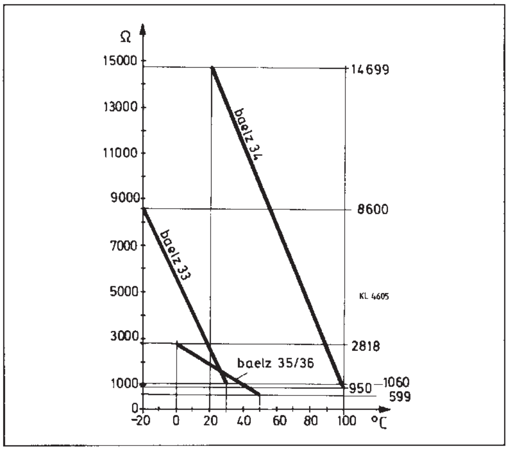


Fig. 1: Resistance thermometer resistance values (Baelz).

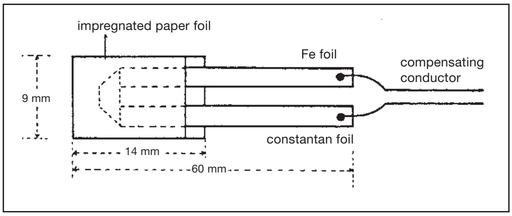


Fig. 2: Surface thermoelement diagram.

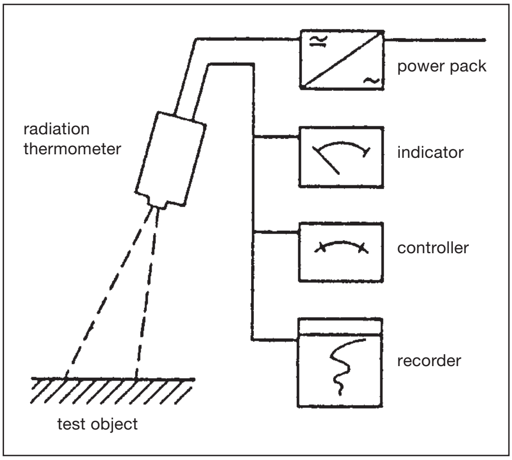


Fig. 3: Infra-red radiation thermometer, diagram (Heimann).

Thermoelements (Fig. 2) are used particularly for high temperatures. The measureing element is a thermometer consisting of two strips made of different metals or metal alloys soldered or welded to each other at one end of the measurement point. If the measurement point is subject to a temperature different from that at the free end of the thermocouple, a voltage or thermo electric voltage results at these free ends. The value of the thermo electric voltage depends on the temperature differential between the temperature at the measurement point and that at the free end, as well as on the material combination of the thermocouple. Thermo elements are less strictly linear than resistance thermometers, so that the measurement converter requires more time to achieve a comparable level of accuracy than the platinum measurement circuit.

If the correct materials are not used, measurement errors occur at clamping points and on the cable. Radiation thermometers function without contact (Fig. 3).

Normally temperature measurement with contact thermometers takes place on calenders, for example, when using radiation sensors. In the case of all heated and rotating cylinders, the most important component in order to achieve good, reproducible accuracy is the choice of the measuring device. In addition to radiation sensors, which are expensive, the following measuring methods can be used (Fig. 4):

- For slowly rotating cylinders: a thermo element sensor which glides directly along the roller surface;
- For fast rotating cylinders: a thermo element which is kept at a distance of 0.5 mm from the rollers;
- A normal resistance thermometer is adequate for use in heating with hot water or heat carrier oil;
- For steam heating: measurement with a resistance thermometer in a loop in the condensate outlet gives reliable results.

Dip sensors for measuring the temperature of baths are usually resistance thermometers.

Temperature sensor TDS 95 (Fig. 5) is used for non-

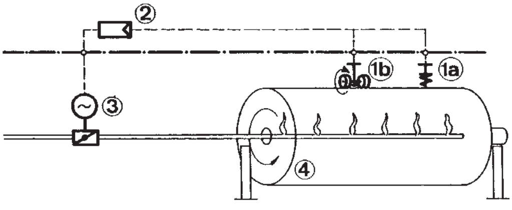


Fig. 4: Thermoelements acting as sensors in a gas heating closed loop control (according to Baelz).
1a = sliding thermocouple sensor; 1b = thermocouple sensor kept 0.5 mm away by revolving castors; 2 = control unit wih deviation indicator and actual indicator; 3 = motor-driven actuator for motor propulsion on control shutter;
4 = cylinder.

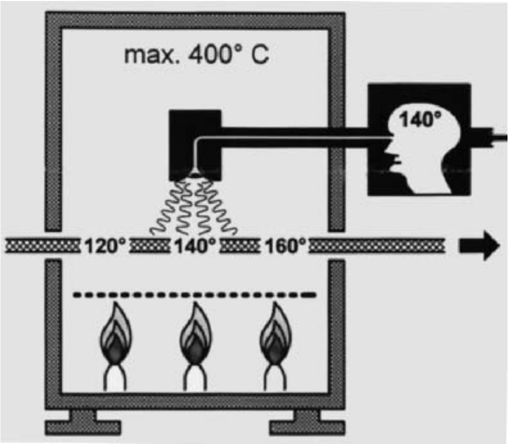


Fig. 5: Temperature sensor TDS 95 (according to Pleva).

contact measurement of the surface temperature of materials. The special design of the TDS sensor allows it to be used inside a heat-treatment machine (e.g. drier) up to temperatures of 400°C. The robust, rugged design of the sensor is a first requirement for use in production machines. The measuring principle is based on exchange of thermal radiation between the material to be measured and the sensitive surface of the TDS 95. It is located behind a radiation-permeable window in the TDS 95. Rapid changes in temperature are detected. The temperature sensor is calibrated for materials characterized by approx. the same properties as a black body (emission factor $\varepsilon \approx 0.9$). Such materials include textiles, paper and plastics for instance (according to Pleva).

Temporary hardness → Water hardness salts.

Tenacity → Viscosity.

Tendering dye Characteristic of certain vat dyes of damaging cellulose by catalysis during the dyeing process (→ Vat dyes and fibre damage). Damage only occurs if dyeing is carried out on open apparatus under strong light or if the dye oxidizes frequently due to lack of sodium dithionite making it necessary to reduce it again.

Tensile elasticity The most important type of → Elasticity which is measured after pre-tensioning under gradually increasing load (stress-strain behaviour). Evaluation of the figures to attain, for example:

1. Elastic elongation: Retraction of the test specimen when the load is removed as % of the initial length.
2. Degree of elasticity: Ratio of elastic elongation to overall elongation, as %.
3. Modulus of elasticity (E-modulus): Ratio of tensile stress to the elongation unit. Measure of the resistance of a fabric to changes in form.

Tensile force (tensile load). The force in the direction of traction acting on the test sample at any one time during a simple → Tensile strength test: the maximum measured tensile force on rupture of the test sample is known as the maximum tensile force; in relation to fineness = tensile strength; in relation to the initial cross-section = tensile stress.

Tensile strength (strength, rupture strength, limit strength, tear strength). Resistance of a material to tensile load; the tensile strength is the → Tensile force (maximum tensile force) in relation to fineness. In the SI system of units the tensile strength corresponds to the measured tensile load in newtons divided by fibre fineness in tex. If the centi-newton is chosen instead of the newton, the results are the same (with a 2% margin of error) as for the old measure of breaking length:

$$1\,\frac{\mathrm{cN}}{\mathrm{tex}} \approx 1\,\frac{\mathrm{p}}{\mathrm{tex}} = 1\ \mathrm{Rkm}$$

Tensile strength loss Measurement for loss of → Tensile strength in textile goods as a result of treatment expressed in %. Tensile strength loss can be caused by mechanical or chemical factors, e.g. as an evaluation of the impact of the washing process on fabrics (→ Laundry quality control) the tensile strength loss should not exceed 30% after 50 washing processes.

Tensile strength test (elongation test). The simple tensile strength test is used to establish the relationship between tensile force and length modification of a sample until it ruptures. Forces are only measured in one direction (fibre axis). The material to be tested is stretched between two clips in a tensile strength-testing unit at a defined pre-tensioning load, the stretching length being the distance between the two clips. One clip moves at a defined speed while the other remains fixed (deformation speed) until the sample tears (maximum tensile force). The resulting tensile force elongation curve is characteristic for a certain fibre material and for the particular yarn construction (→ Stress-strain behaviour).

Variations in yarn twist result in varying tensile strengths. This is because with increasing yarn twist the individual fibres are pressed more closely to each other causing friction between the fibre surfaces to increase. The friction exceeds the cohesion of the individual fibres relatively frequently and, as a result, the fabric is not forcefully reduced to its component parts but the individual fibres are destroyed at a certain point when the yarn ruptures, leaving the overall fabric intact directly next to the point of rupture.

Tensile strength testing During the course of textile manufacture, e.g. during yarn and fabric manufacture and during use, textile fibres are frequently exposed to stress at high stretching speed. Sudden and short term stress only occur for example during the weaving process (weft insertion, shed formation, beating up), during sewing and embroidery or when cutting tow. High acceleration at the deflection points also has to be taken into consideration during winding of the yarns. On modern high performance weaving apparatus, accelerations of up to 12 000 m/s^2 and during sewing at 6000 stitches/min. as much as 60 000 m/s^2 occur during weft insertion. The forces occurring during such short-lived stress often approach the limits of maximum tensile force.

The connections between tensile stress and subsequent relaxation, either under retardation (modification of the length at constant tension) or relaxation conditions (modification of the tension at constant length) are usually considered for low deformation speeds: the experiment of tensile strength testing of textile materials is generally carried out in accordance with DIN 53 835. This testing procedure with the deformation speed e = 0.83% does not, however, provide details of the characteristics of the materials during fabrication processes in which deformation speeds of up to 200%/s such as during weft insertion and up to 8000%/s such as during sewing occur. Experiments are therefore required in which the material is stressed under relatively high deformation speeds (according to Bossmann, Beier and Schollmeyer).

Tensile stress In a → Tensile strength test the quotient from the → Tensile force and the initial cross-section.

Tension control A textile finishing machine should keep the tensile stress on the fabric constant.

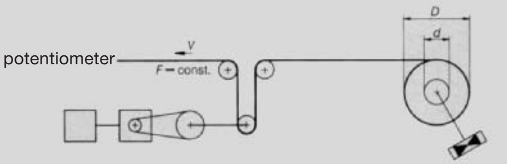


Fig.: Tension control (Siemens).

It is advisable to use a magnetic-particle brake as well as control equipment with a compensator potentiometer. The control equipment gives the brake the information on whether or not to brake according to actual/target comparison of the position of the compensator roll. The tensioning roller pair (not shown in the Fig.) always transports at the same speed.

Tensioning rollers When processing textile webs, it may be necessary to keep the web tension constant within the working or processing length (Fig. 1). For slow-running machines with low web tensions it is adequate to install a magnetic-particle brake on the second pair of tensioning rollers.

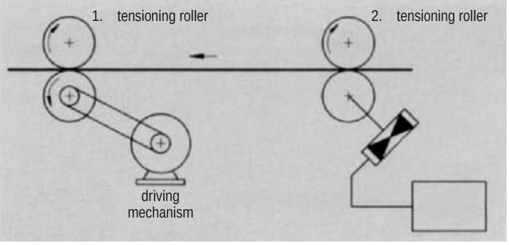


Fig. 1: Two pairs of tensioning rollers, with those at the rear being controlled by a magnetic-particle brake.

The necessary torque is adjusted in a potentiometer on the control equipment. The brake works with a constant slip. With this arrangement the total energy loss is converted into heat. If processing of the material takes place with fluctuating tension, a vertically-moving dancing roller should be installed in front of the second pair of tensioning rollers (Fig. 2).

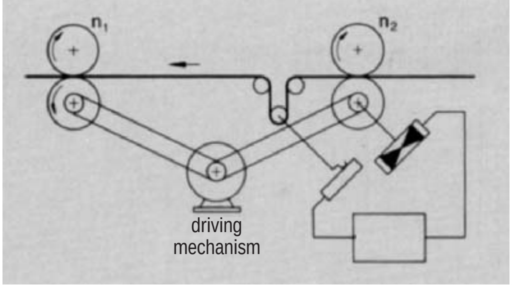


Fig. 2: Controlling the cloth tension between pairs of tensioning rollers by means of a dancing roller.

Coupled with the dancing roller, electrical supply to the magnetic-particle coupling is adjusted by means of potentiometer or inductive switching.

Tensions in fabrics These are metastable states expressed in the form of folds, waves, bulges and bands as well as in the form of slackness. If a fabric with tension from spinning (from differences in twist and number) and especially from weaving (from width controllers, warp beam let off) is able to relax whilst energy is released, weft and warp shift in relation to each other (deformation). A prerequisite for the successful relaxation of fabric tension is therefore the introduction of energy to overcome the fibre-to-fibre frictional forces as well as the ability of the fibres to slide as a result of the effect of water. In woollen fabric, the tensions are fixed by a range of hydrogen bonds. Soaking in water as a speed-determining function is a pre-condition to enable water to reach those groups of hydrogen bonds under tension in the wool fibre stem to bring about relaxation at the exact location where the tensions are. The hydrogen bonds split, the polymer chains slide over each other until a tension-free state is achieved, and hydrogen bonds are recreated in the relaxed state when water is removed during drying. In this sense, the degree of relaxation of a woollen fabric during washing of an individual article is important in terms of design factors.

Tenter frame for dry fabric Tensioning frame in the form of → Expanding device for fabrics and → Straightening machine.

Tent fabric The thermal regulation processes of a tent are similar to those of the skin which are influenced by clothing materials. The climatic zone between skin and textile is a micro-climate in the case of the clothing model which is larger in the case of the tent. This reduces the problems of condensation formation. The larger climatic zone allows a greater humidity absorption capacity and a suitable ventilation construction promotes evaporation.

The temperature difference between the interior and the exterior of the tent is normally less extreme, so that humidity on the tent fabric does not cool down so rapidly and does not condense if the textile has an adequate buffer effect. Differing temperatures during day and night do, however, cause a humid atmosphere in the tent in which the humidity which has formed cannot escape as air exchange is not sufficient. A humid climate of this nature promotes the formation of mould, so that the use of materials which allow humidity to pass through is beneficial, not only for comfort but also for tent stability.

During the day the temperature within the tent adapts to the temperature on the outside. At night the external temperature cools down much faster, however, resulting in a difference of temperature. During the cooling down process, the water absorption capacity of the interior climate decreases, and humidity condenses. This condensation is still present in the morning and only evaporates in the course of the day. This effect is increased with the effect of transpiration in the case of tents inhabited at night. Tent fabrics which allow humidity to pass through are designed to provide a remedy, by transporting humidity through the substrate to the outside with low ventilation before it condenses. In this way, inside temperatures can be maintained for a longer period than with strong ventilation otherwise needed to dispose of humidity.

Under certain climatic conditions the advantages of tent materials which allow humidity to pass through are limited. There must be a sufficient humidity pressure difference between the inside and the outside climate which means that their use in humid tropical climates is not beneficial. Under these conditions, condensation formation in the tent is also comparatively negligible as the outside temperatures do not cool down significantly, and therefore there is no marked temperature variation. Their use can also be beneficial under extreme conditions; humidity transportation mechanisms through the substrate are imaginable, for example, where temperatures fall strongly at night, as in the desert. Permeability of the fabric would also have a beneficial effect in extremely cold climates where the tent was being inhabited.

A breathable tent fabric should be structured in such a way that a hydrophilic layer on the inside absorbs humidity quickly. It can then be diffused in the material and transported to the outside. On the other hand it must also have adequate waterproofing with a hydrophobic outer layer to preclude the risk of becoming saturated. As one-sided coating is generally used, the interior side consists of a textile carrier which must be stable against hydrolysis, mildew, moulds, micro-organisms, etc. as well as having the necessary strength. Polyester fabrics are often used, the properties of which can be modified by specific fabric pre-treatment. Coating properties depend on the product used and can be improved if necessary by using additives. In addition to the properties already mentioned, the outer layer must have features such as light stability, light fastness, pigmentation capacity, soiling-resistance, etc. The requirement profile for the entire system also includes sewability, add-on specifications and requirements for handle, drape and optical properties.

Teratogen (Gk.). Substances which are harmful to the health causing deformation (→ Poisons). In addition to teratogen potential effective pharmaceuticals, this includes, for example, radiation protection substances, certain dyestuffs, solvents, insecticides, etc.

Terephthalic acid $C_6H_4(COOH)_2$. This p-dicarbonic acid is an important raw material for synthesis of polyester fibres. Production, for example through oxidation of p-xylol (petroleum and crude oil fraction) or through toluol (coal tar distillate). The name terephthalic acid is derived from turpentine (Latin: telbinthina, originally for terephthalic acid fabrication) and phthalic acid.

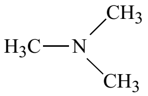
Terephthalic acid dimethylester → Dimethylterephthalate.

Terminal Outside, located at the end. Term used for example for the location of typical groups in the elongated (chain) molecules of textile auxiliaries. Term denoting the opposite: → Internal.

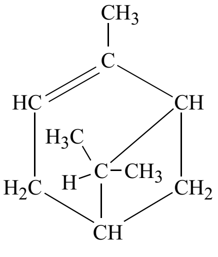
Termoman Test doll which was originally developed by the US airforce (→ Copper man), which withstands intensive heat and registers textile burning characteristics as well as effects on the human being. The termoman is 1.85 m tall and is equipped with 122 sensors distributed over the entire body registering each temperature increase. With the doll it is possible to ascertain how long it takes before a person feels pain and on which parts of the body second and third degree burns occur with time.

Terms of delivery (committee for) → RAL.

Ternary Triple, consisting of three substances; e.g. a product fabricated from three different elements (ammonium chloride: NH_4Cl) or triple substitution by alcyl groups, e.g. trimethylamine:

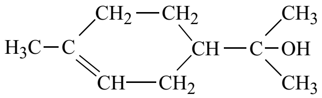


Terpenes Terpene hydrocarbons (terpenes), a group of cycloaliphatic and hydro-aromatic hydrocarbons with the general formula $(C_5H_8)_n$, which form important solvents of the type →: Turpentine oils; Pine oil; Hydrated terpene and depanols, and are derived primarily from α-pines $C_{10}H_{16}$.



Used in components for solvent soaps or emulsions for boiling cotton, for linseed oil sizing agents, antifoam agents, for dissolving rubber, polyacryl acid esters and artificial resins (for print thickeners), for stain removing purposes, etc.

Terpineol (α-terpineol). $C_{10}H_{17}OH$.



Component part of → Pine oil. Density 0.92. Boiling point 219°C. Thick oil, colourless or yellowish, lilac-like smell. Not soluble in water. Easily soluble in alcohol, ether, benzol, chloroform, etc. Possesses hydrotropic properties. Dissolves → Linoxyn, among other substances. Used as component of textile auxiliaries containing solvents (linseed oil de-sizing); foam prevention agents (printing pastes), etc.; lightening agents for microscopy.

Terpolyamides Melting adhesive for bonding textiles and for melting lining materials. Consists of polyamides with various chemical structures. Terpolyamides for textile bonding must be colourless and have melting temperatures of approx. 100°C, so that they can be utilized in presses with LP steam (118–120°C). They have to withstand the effect of soapsuds at 60°C and chemical cleaning with tri- and tetrachloroethene.

Terpolymer → Polymerization products with three basic structural element types.

Terry cloth identification,

I. Frotté:

- woven on standard weaving machine,
- looped fabric surface,
- effect may be produced by using frotté,
- loops cannot be pulled out.

II. Terry fabric:

- woven on terry weaving machine,
- loops formed by the pile warp,
- loop thread can be pulled out in the warp direction.

Terry fabric Looped fabric made of cotton or cotton viscose mixture; fabricated on terry fabric weaving frames (Dobby or Jacquard loom) with a so-called pile wire and 2 warp systems. A tightly-tensioned base warp forms the base fabric together with the weft. The loosely-tensioned pile warp is pulled by the pile wire after only every 3rd or 4th end (depending on the desired loop length). Milled terry: a particularly soft and fluffy structure is achieved using a roller process. Warp terry: the loops are formed with the aid of a pile bar and bound into the base fabric using a locating rail before removing the pile bar. Terrry velours: dense terry fabrics with loops which have been cut open or sheared on one side giving them a velvet-like appearance. Used for hand and bath towels, dressing gowns and the like.

Tertiary alcohols → Alcohols.

Tertiary salts Neutral salts of three basic acids in which three H-atoms are replaced by metal, e.g. tri sodium phosphate Na_3PO_4 derived from phosphoric acid H_3PO_4. →: Primary salts; Secondary salts.

Test batch → Batch.

Test fabrics for soiling tests Artificially soiled fabrics of cotton, polyester/cotton, wool, synthetics; soil consisting of tetrachloroethene or hydrocarbon solvents.

Testing and evaluation costs Costs of routine tests and control of → Quality (→: Quality costs; Quality assurance). Similar problems occur as in the case of → Defect prevention costs. Checks are integrated into the production method more and more frequently or allocated to fabrication departments.

Testing costs → Testing and evaluation costs.

Testing for chromium → Chrom test for dyeings.

Test specimen (test sample, test unit), → Sample unit for testing purposes. → Fastness test specimen.

Tetra (Gk. = four),

I. Prefix meaning "four times, quadruple".

II. Abbrev. for → Carbon tetrachloride.

Tetracene $C_{18}H_{12}$ → Cyclic hydrocarbons.

Tetrachloroethylene (perchloroethylene, per) C_2Cl_4. Colourless fluid, clear as water, neutral, evaporates rapidly, characteristic smell, anaesthetizing, nonflammable. Stabilized, non-decomposed tetrachloroethylene corrodes metals at temperatures up to 140°C even if water is not present. Distillation takes place inter alia by injecting steam up to 0.5 bar (thereby lowering the boiling point to approx. 100°C). Dissolves all fats and oils including resin, pitch, asphalt, tar, wax, paraffin and perfume stains (particularly well, compared with other similar solvents). Tetrachloroethene is of great significance in chemical cleaning processes.

	Water	Tetrachloroethylene
Density [g/ml]	1.00	1.62
Boiling point [°C]	100	121
Surface tension [mN/m]	72.7	32.3
Dielectric constant (DIN 58 483)	80	2.4
Specific heat [kJ/kg K]	4.2	0.9
Heat of vaporisation [kJ/kg]	2257	210

Tab.: Comparison of textile washing agent water (washing) and tetrachloroethylene (dry cleaning).

Advantages of tetrachloroethylene compared with water for cleaning outer clothing:

- textile compatibility: no fibre swelling, no shrinkage, causes no deterioration of shape.
- high density: stable for use in highly-mechanized processes, good dirt removal properties.
- low surface tension: rapid moistening, rapid dirt penetration.
- grease dissolving: cleaning without temperature increase.
- rapid evaporation: rapid, energy-saving drying.
- low evaporation heat: bath regeneration by means of distillation, waste concentration in residue, well-directed disposal.

As far as the care of outer clothing is concerned, → Dry-cleaning has advantages with regard to maintaining the value of the textiles and to cleaning performance, lower time requirement, lower energy requirement and lower material consumption, since the solvent used is always recovered and the residue is disposed of efficiently. The use of tetrachloroethylene does, however, involve certain risks. Its environmental behaviour is determined to a large extent by the following typical characteristics:

- decomposition as a result of hydrolysis and/or ultraviolet radiation;
- release of chlorine radicals;
- formation of salt acids in the hydrosphere;
- its half-life in the atmosphere is 2–4 weeks;
- tetrachloroethylene is highly mobile; it is distributed over long distances by air currents;
- almost all greasy surfaces (e.g. tree foliage and needles) form depositories for tetrachloroethylene where it accumulates;
- forms layers under ground water;
- penetration of walls and brickwork;
- reacts to highly poisonous phosgene (carbonyl chloride) in an open flame.

General toxicology: acute toxicity is low, i.e. relatively high one-off doses have to be consumed before symptoms of poisoning occur, such as slowing down of central nervous system, damage to liver and kidney and finally lung oedema. The fatal one-off dose for a human is approx. 0.5–5 g/kg body weight. The substance has a moderately irritating effect on eyes, nose and respiratory system. It has a drying effect on the skin and can cause skin ailments. Tetrachloroethylene is easily assimilated via skin and the digestive system. When it is breathed into the lungs, it is mostly exhaled again without being assimilated. Records of observation of people exposed to the substance over a long period of time at their workplace show frequent toxicological damage to the liver resulting from a past high dosage range. As is also known from the workplace as well as from investigations carried out on volunteers, concentrations of around 100 ppm can cause a series of central nervous system vegetative phenomena, such as inability to think, dizziness, tiredness, sickness, etc.

Standard mutagenic tests provide no evidence of a mutagen effect of tetrachloroethylene; there are no indications of toxicological effects on reproduction. Tetrachloroethylene has been tested in a number of long-term trials for a possible carcinogenic potential. Inhalation studies on rats and mice submitted by the National Cancer Institute in 1986 are of particular significance. According to these studies liver carcinomes were observed in male and female mice and mononuclear leukaems in male and female rats as well as a somewhat increased frequency of kidney tumours in the male rats. The carcinogenic effect is attributed to certain metabolic by-products (Fig. 1).

Since the metabolic assimilation of tetrachloroethylene in humans is frequently less than in the case of

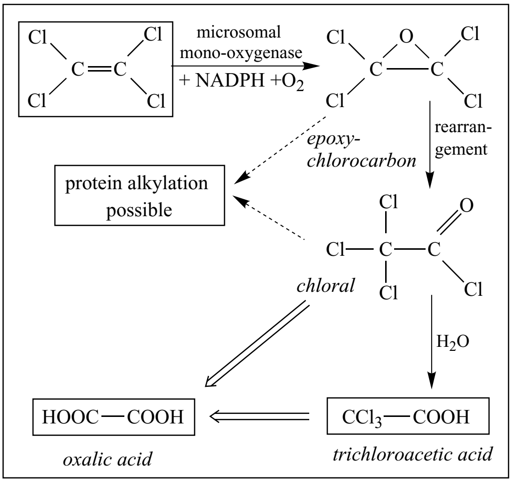


Fig. 1: Metabolism of tetrachloroethylene. Urine metabolites detected are trichloroacetic acid and (in the rat) oxalic acid. MFO = microsomal mono-oxygenase ("mixed functional oxidase").

rats and mice, the results observed in the animal tests cannot be assumed to be applicable to humans. Epidemological studies have not to date provided any scientific proof of a carcinogenic effect on humans. The theoretically attributable possibility of tumour origination does, however, remain. The substance is therefore categorized by the World Health Organisation's (WHO) International Agency for Research on Cancer as well as by the TLV Commission, as one strongly suspected of carcinogenic effect.

Tetrachloroethylene contamination of the consumer can take place

- when visiting a chemical cleaning facility,
- from chemically-cleaned clothing,
- by living adjacent to a chemical cleaning facility,
- by contamination of foodstuffs which have been stored in the immediate vicinity of a chemical cleaning facility.

When visiting a well-managed chemical cleaning facility (for generally only a few minutes) no impairment of health is to be expected. This also applies to chemically cleaned materials supplied by well-managed cleaning facilities. However, there have been a number of incidents in conjunction with textiles cleaned in coin-operated cleaning facilities. This invariably involved voluminous textiles such as cushions and soft toys and/or the drum was overloaded and the aeration times were not observed, or material, which was unsuitable for cleaning in this type of coin-operated chemical unit, was not adequately freed of solvent in the aeration period. The revised German legislation (2nd BImSchV – Bundes-Immissionsschutzverordnung – German Federal Immission Protection Regulation) prescribes that self-operated machines may only be used in the presence of trained personnel.

Incorrect use of chemical cleaning facilities is known to have caused instances of high indoor contamination in appartments in the same building as the facility, as well as to contamination of food which was sold in the cleaning facility itself or in its immediate vicinity. Particularly during the years 1986–1988, tetrachloroethylene values were found in living areas (flats, consulting rooms, offices), some of which approached the range of the TLV scale. Article 1 of the relevant German Federal Immission Protection Law (BImSchG – Bundes-Immissionsschutzgesetz) provides the possibility of intervention.

A biological workplace tolerance value (BAT-value) of 1 mg/l tetrachloroethylene is applied to workplaces. This BAT-value in the blood of exposed employees is defined according to the TLV list in such a way that the corresponding blood test may not be taken until at least 15 hours after the end of the last tetrachloroethylene exposure in the workplace. Only then can the measurement be seen as a reliable warning of the threat of damage to the central nervous system due to increased contamination of the body during the period of exposure. The value is not usually exceeded when the TLV value is constantly observed, but can be reached or exceeded in individual cases. In the case of permanent tetrachloroethylene contamination, e.g. when living in the vicinity of a chemical cleaning facility, these exactly defined framework conditions cannot be complied with; the analysis value gathered cannot be evaluated as the environmental reference points are missing. Evidence of tetrachloroethylene in the blood indicates that contamination has taken place. However, only an investigation of the air in the room can provide exact information on the extent of the exposure.

Foodstuffs which are stored or sold within the emission range of chemical cleaning facilities can be significantly contaminated by tetrachloroethylene. High content values were established in tests on foodstuffs from apartments situated above chemical cleaning facilities as well as in tests on foodstuffs from the grocery trade. Foodstuffs with a high fat content always proved to have the highest contamination levels. The tetrachloroethylene content of foodstuffs is influenced by factors such as

- ventilation in the foodstuff outlet and in the cleaning facility,
- duration of storage of the foodstuffs within the emission range
- type of packaging.

Basic contamination is generally under 10 µg/kg. In accordance with a regulation which came into effect on 10.10.1990, foodstuffs exceeding a content of 0.1 mg/kg can no longer be sold. This regulation of solvent upper limits also specifies that foodstuffs whose tetrachloroethylene, trichloroethene and trichloromethane content exceeds 0.2 mg/kg together are no longer saleable. The second regulation passed in October 1990 on the implementation of the relevant German Federal Immission Protection Law (BImSchG – Bundes-Immissionsschutzgesetz) contains rules requiring the recommended orientation value of 0.1 mg/m^3 in living areas in the vicinity of chemical cleaning facilities can be met within a transition period of 2 years.

In addition to tetrachloroethylene,1,1,1-trichloroethane, 1,1,2,2-tetrachloro-1,2-difluoroethane (R112), 1,1,2-trichloro-1,2,2-trifluoroethane (R113) and trichlorofluoromethane (R 11) have been used in chemical cleaning facilities. Due to their physical and chemical characteristics, these can also diffuse into adjacent rooms and accumulate in foodstuffs containing fat. Because of their damaging effect on the ozone layer, their use was prohibited by the revised second German Federal Immission Protection Regulation (BImSchV – Bundes-Immissionsschutzverordnung) which came into effect on 1.1.1993.

The use of tetrachloroethylene is therefore problematic. As a result the legislature has put into place effective application guidelines. Thus a chemical cleaning facility may only be operated when staff are present who have proven specialist knowledge and have passed the appropriate examination. In addition, guidelines have been prescribed for the installation of chemical cleaning facilities which are intended to ensure that tetrachloroethylene can no longer escape from the facility. The core points of the guidelines are:

- no open use of tetrachloroethylene;
- max. 2 g/m^3 drum volume at the end of the drying period depending on the type of cleaning apparatus;
- max. 0.1 mg/m^3 enclosed air in the vicinity of chemical cleaning facilities;
- diffusion barriers on the facility walls to prevent tetrachloroethylene from escaping into the vicinity;
- regulated ventilation and air-release to outside of facility.

The detail is as follows:

- Article 4, para. 1: the max. mass concentration of tetrachloroethylene in the drying air at the exit from the drum area with rotating drum and closed loading door and a temperature 35°C must not exceed 2 g/m^3 (Fig. 2). An air exchange rate of at least 2 m^3 up to a maximum of 5 m^3/kg load weight and hour in the measurement phase.
- Article 4, para. 1, sentence 2: It must be ensured that the loading door remains locked until levels are below the above-mentioned mass concentration. This must be guaranteed by a permanent measurement monitoring system.
- Article 4, para. 2: With open machines the exhaust fumes must be conducted to an extraction unit.

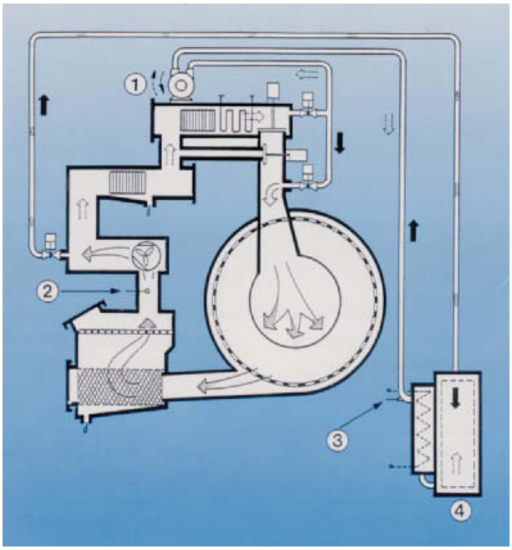
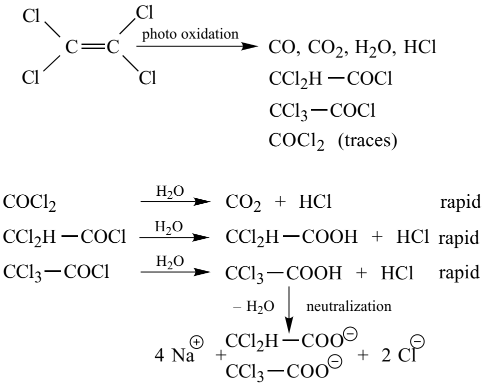


Fig. 2: MULTIMATIC multisolver air exchange system in dry-cleaning machines.
1 = air-exchange fan; 2 = ppm measuring position/drum exit; 3 = ppm measuring position/activated carbon exit; 4 = multisolver (adsorption/regeneration).

- Article 4, para. 3: Only filters which can be re-cycled may be used in chemical cleaning machines for cleaning the liquid solvent.
- Article 12, para. 2: The operator of the facility (textile cleaner) is obliged to inspect the machine to determine whether it meets the legal requirements for a facility as defined in Article 26 German Federal Immission Protection Law (BImSchG – Bundes-Immissionsschutzgesetz) between 3 months and 6 months after commissioning of the facility.
- Article 12, para. 3: The operator of the facility (textile cleaner) is obliged to determine conformity with the appropriate requirements in accordance with the second German Federal Immission Protection Regulation (BImSchV – Bundes-Immissionsschutzverordnung) once in each calendar year after notification of opening of a facility in accordance with Article 26 of the BImSchG.
- Article 13, para. 1: Filling of the system with solvent or aids may only be carried out using a closed device.
- Article 13, para. 1: The removal of used solvent may only be carried out using a closed device.
- Article 13, para. 2: Residues containing volatile halogenous hydrocarbons may only be removed from systems using a closed device.
- Article 12, para. 7: No re-occurring measurements are necessary if proof of conformity with the requirements is provided by means of continuous

monitoring using a measurement recording system. (according to Hasenclever and Rosskamp).

Tetrachloroethylene in the atmosphere It seems that the substance is subject to decomposition by photo-oxidation in the atmosphere:



In addition to CO, CO_2, H_2O and HCl, relatively stable chloro-organic decomposition products (di- and trichloroacetylchlorides) and traces of → Phosgene are formed which hydrolyze very rapidly. Chloro-acetic acids are neutralised by alkaline components in the lower atmospheric layers and their anions eliminate themselves, for example by means of biological decomposition in sea water (oxidation).

Tetrachloroethylene recovery for distillation residues Economy dictates the distilling out of distillation residues, i.e. extracting and recovering tetrachloroethylene residues quantitatively to the greatest possible extent. This becomes more difficult towards the end of the distillation process, as the residue in the distillation receptacle loses solvents and becomes increasingly thick. Three methods are used in practice:

I. direct steam distillation;

II. addition of water without direct steam;

III. addition of water and direct steam.

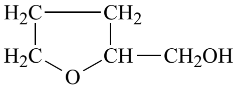
Process III is known to be the most economical method, particularly in the case of residues of heterogeneous composition, since 10 min of distillation by this method cuts down by half the tetrachloroethylene losses which otherwise occur with processes I and II.

Tetrachloroethylene retention in hydrophobic fibres Whilst small quantities of tetrachloroethylene remain in treated textiles during → Dry-cleaning (working method under/around 50°C, i.e. below the glass transformation point of approx. 60°C), finishing processes in the tetrachloroethylene boiling point range (120°C) lead to very stubborn tetrachloroethylene residues under drying conditions. The glass transformation point possibly plays a role and is quoted for the polyester/tetrachloroethylene system at up to <40°C. In hydrophobic polyester yarn, tetrachloroethylene absorbtion of max. 9.8% by weight is reached at a treatment temperature of 0–120°C in 1 h. Outlet tests (polyester, texture and mesh goods) contained approx. 4.5–5% by weight before drying. By drying in dry heat at 22°C and 50°C the remaining tetrachloroethylene content remained almost unchanged even after 1 hour at approx. 4 % by weight. Not until over 80°C is there a noticeable increase of the desorption speed and a sharp decrease of the residue values to approx. 2% by weight. At 120°C the residue contained falls to less than 1% after only 10 minutes. A further change in the drying conditions has demonstrated that, with wet steam as the drying medium, tetrachloroethylene can be eliminated completely. It is important not to use too dry steam, which works as an inhibiting medium on the tetrachloroethylene. The hydrophobic wool fibre in the scale layer binds up to 3% by weight tetrachloroethylene.

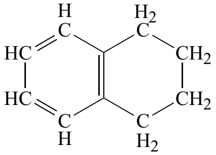
Tetrachloroethylene water pollution Tetrachloroethylene (like all → Chlorinated hydrocarbons) is not biochemically decomposable or is biochemically difficult to decompose and is a substance which is harmful to water. Evidence and quantitative determination takes place either by gas chromatography (more expensive in terms of apparatus but higher specific separation sharpness) or spectro photometrically (interference from other chloride hydrocarbons). The presence of the slightest concentration of unimaginably small quantities can be detected by means of measurement methods which have become more sensitive. German, and in particular European legislation in respect of ground water quality, utilizes extremely low concentrations as guideline values for max. permitted pollution of potential drinking water. Suspected ground contamination with tetrachloroethylene therefore results in costly removal and decontamination of affected ground. In addition to the call for chlorine-free chemical processes, it is the expensive consequences of water contamination which above all point towards eventual discontinuation of chemical cleaning with tetrachloroethylene, while the argument concerning its carcinogenic potential has less weight because of its slight probability.

Tetrafluoroethylene fibre → Polytetrafluoroethylene fibres.

Tetrahydrofurfuryl alcohol (THFA). Hydration product of → Furfural. Density 1.064, boiling point 177°C. Pleasant smelling liquid, clear, slightly tinted, mixable with water. Good solvent for nitrate cellulose, chloro caoutchouc, styrol resin, vinyl acetate, schellac, waxes, resins, etc., as well as for all widely-used dyestuffs; also has a cleaning and degreasing effect.

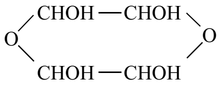


Tetrahydronaphthalene (tetralin). $C_{10}H_{12}$. Molecular weight 136. Density 0.976. Boiling point 200–209°C. Colourless liquid with characteristic smell. Insoluble in water. Easily soluble in turpentine oil, petroleum, benzole, chloro-hydrocarbons, ether, amyl alcohol. Good solvent for grease, oil, wax, pitch, asphalt, lacquer, varnish, linoxin, rubber. Tetrahydronaphthaline, particularly in fine emulsified form, forms temporary peroxides which have a mild bleaching effect before they decompose. This is used for kier boiling of cotton. Used as a component of grease dissolving soaps, stain removing agents, etc.



Tetrahydropyrimidone resins Reactant types which, as with for example → Dimethylol-propyleneurea, have a low nitrogen content and are similar in structure to dimethyloltriazine.

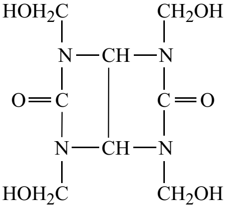
Tetrahydroxydioxane Hydrated form of → Glyoxal in aqueous solution, which contracts when dried in the presence of acid to glyoxal.



Tetralin → Tetrahydronaphthalene.

Tetramer Consists of four → Monomer.

Tetramethylol acetylenediurea Tetramethylol glykoluril, suitable for use as → Resin finishing agents for dry, damp, and, in particular, for wet moistening processes, does not impair light fastness but is not chlorine-fast.



Tetramethylol-2,4-diamino-6-3,3,3-trisbromo-1-propyl-1,3,5-triazine (TM-DABT). Phosphor-free flame-retarding agent for cotton with washing permanence. Application of dimethylformamide/water mixture without additional auxiliary aids, binding agents or catalysts. Condensation at 140°C. Optimum flame-retarding effects at 11–13%. On polyester/cotton 50 : 50 application takes place together with colloidal antimonic trioxide.

Tetraoxymethene (tetroxane, tetraoxane). Tetrameric, cyclic formaldehyde which is used in high finishing as a moistening agent (→ Polyoxymethyenes). Application of tetra- and/or pentaoxymethene in the form of solvents or dispersions and moistening in the presence of acid catalysts at temperatures of at least 100°C.

Tetrapod test Utilisation test for textile floor coverings. Walking with rubber heels is simulated using a specific four-footed (tetrapod) device in a rotating drum which is lined with the floor covering to be tested. This English test specifically measures the change in appearance of floor coverings, particularly in bedroom and living areas. Marks are awarded on a scale of 1–5. The tetrapod test is known to have good simulation properties in terms of colour changes, surface characteristics, patterns, design errors (fibre hardness, pilling), etc.

Tetrapropylene benzene sulphonate (TBS). $NaSO_3C_6H_4C_{12}H_{25}$, → Alkyl benzenes sulphonate with branched alkyl chain. Washing raw material which is biologically difficult to decompose. In Germany, alkyl benzine sulphonates with straight alkyl chain is substituted.

Tetroses → Sugar.

Tex system Used to define the length-related mass (→ Linear density of fibres and yarns) of textile fibres, bi-products, yarns, threads and related products. 1 tex is the degree of fineness at which a fibre or yarn of 1 km length weighs 1 g: 1 tex = 1 g/km. Multiples and fractions thereof are kilotex (ktex), decitex (dtex), centitex (ctex), millitex (mtex). The fineness of fibres is usually quoted in dtex, yarns and threads in tex, and cables, tapes, etc. in ktex.

Textile (Lat.: textilis = woven, knitted). In the widest sense fabric made of spinnable fibre (materials). Textile processes include spinning, weaving, knitting and all processes derived from or based on these processes. The semi-finished products and products resulting from these processes are known as → Textile product or → Textiles.

Textile auxiliaries (assistants, agents processing aids), considered as belonging to → Textile chemicals. Textile auxiliaries on the one hand make it possible to or have a positive effect on the execution of a textile process, and on the other hand have a positive effect on quality, efficiency by helping to reduce or eliminate faults and damages. Textile auxiliaries are thus found in all types of textile processes from fibre production, oprocessing, finishing and make-up of finished goods to subsequent textile care in washing, dry cleaning and soil removal.

The term “textile auxiliaries” is a historically-based generic concept for chemical products which are used in the manufacture of textile fibres, yarns and fabrics and in the finishing of textiles. The term includes products which remain on the textile end-product as well as auxiliaries which are applied to the material temporarily and facilitate or improve certain stages of the finishing process and are no longer contained in the end product.

Products included under the generic term “textile auxiliaries” include:

I. Auxiliaries and finishing agents for fibres and yarns:
- additives for spinning solution,
- additives for spinning lubricants,
- additives for spinning baths,
- preparation agents (frequently used as a generic term),
- spinning lubricants,
- spool oils (coning, winding and twisting oils),
- yarn humectants and stabilising agents.

II. Pretreatment agents:
- fibre protection agents for pretreatment,
- boiling auxiliaries,
- bleaching auxiliaries,
- mercerizing and causticizing auxiliaries,
- carbonizing auxiliaries,
- size and size additives,
- desizing agents,
- hydrophilic auxiliaries.

III. Textile auxiliaries for dyeing and printing:
- dye solvent and hydrotropic agents,
- dispersing agents and protective colloids,
- dyehouse wetting and de-aerarting agents,
- levelling agents,
- dye accelerators (carriers),
- anti-crease agents,
- dye protective agents, boiling protective agents,
- padding assisitants (anti-migration agents, anti-frosting auxiliaries, products for increasing liquor take-up),
- fixation accelerators for continuous dyeing and printing,
- after treatments for improving fastness,
- binders for pigment dyeing and printing,
- print thickening agents,
- emulsifying agents for solvent printing,
- print thickener removal agents,
- print shop and fabric edge gums,
- oxidizing agents,
- reducing agents,
- etching and etching assisiting auxiliaries,
- reserving agents,
- staining agents,
- brightening and clearing agents,
- fibre protection agents for dyeing,
- pH-regulators, acid and alkaline release agents.

IV. Finishing agents:
- optical brighteners (white toners),
- agents for improving crease and shrinking properties,
- additives for low crease and shrinkage finishing,
- catalysts for low crease and shrinkage finishing,
- handle modifying agents (weighting, filling, stiffening and softening agents),
- anti-static agents,
- repellent agents (hydrophobic agents, oleophobic agents, agents for soil-repellent finishing),
- agents to assist soil release,
- milling auxiliaries,
- antifelting agents,
- lubricants,
- lustre finishing agents,
- matt finishing agents,
- anti-slip, -ladder and -snag agents,
- flame-retardant agents,
- anti-microbial agents (finishing and storage preservative agents),
- rot proofing agents,
- agents and additives for fibre and yarn binding,
- coating agents and relevant additives,
- concealing agents and corresponding additives.

V. Auxiliaries which can be used for applications throughout the textile industry:
- wetting agents,
- defoaming (foam inhibiting agents),
- scouring, dispersing and emulsifying agents,
- stain removing agents,
- complexing agents,
- stabilizers (except bleach and preparation stabilizers).

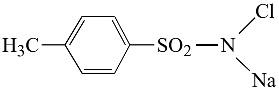
Textile auxiliaries association → TEGEWA.

Textile auxiliaries – ionic activity Also known as ionic charge. When textile auxiliary electrolytes dissociate in aqueous solution, the ionic charged residue (alphatic hydrocarbon) carries either a negative charge (cationic) or positive charge (anionic). In both cases the character is determined by the solubilising (hydrophilic) group attached to the water insoluble (hydrophobic) fatty residue, the former being correspondingly ionically active and strongly solvated thus bringing about dispersion in water. Usually such a group is adequate to overcome the hydrophobic properties of a hydrocarbon of 10–20 C atoms.

Textile auxiliaries with fibre and dye affinity (wool) The wool fibre reacts electro-positively in an acid dye bath, therefore it is a cation. Acid stable anionic products have the effect of producing a fibre affinity. They are rapidly absorbed by wool (weight increase 5–10%) and thereby force slower dye anions to exhaust more slowly. However, if the levelling product is cationic, it quickly accumulates on the electro-negative dye particles. Its reaction demonstrates a dye affinity.

This takes place in a similar fashion with non-ionic products during neutral dyeing. Enlarged dye/auxiliary agglomerations occur (molecular weight increased up to 1000-fold and more) which reduce the rate of exhaustion. The addition of anion-active products naturally has the effect of cancelling deceleration.

Textile auxiliaries with oxidative action E.g. the important toluene sulpho chloramide:



Organic chlorinated products of this type are hardness and alkali stable, by exposure to higher temperatures slowly release their chlor-containing part to allow a controllable oxidative bleaching action. Application: starch decomposition products for sizes and finishes, desizing and alkali boiling, alkali boil additives with bleaching effects, pre-bleaching, coloureds bleaching, oxidation, development of fast dyeings, chlorination of wool. More important are chlor-isocyanate compounds, e.g. for bleaching effects in household detergents, disinfectants for textile laundries and anti-felting finishing of wool. Valuable in combination with fatty alcohol derivatives, with active oxygen content and stabilisers; give slow, temperature controlled release of effect. Application: Desizing and pre-scouring, pre-bleach, combination bleach (single bath de-chlorinating after wash), oxidative development of fast dyeings (aftersoaping), etc. Based on the majority of inorganic oxygen donating products (sodium perborate, sodium percarbonate) are a wide range of starch decomposition agents as combinations with fat, waxes, glues, for sizes and finishes. Sodium perborate is the most important bleaching agent for laundries.

Textile auxiliaries with soaplike properties Various emulsifiers, e.g. saponified castor-oil anhydration products for fats and oils for lubrication and softening, etc. or saponified castor-oil polymerization products in the form of low-stability hydrocarbon emulsifiers. Fatty acid amides derived from disubstituted ethenamines forming a foam even in very acid liquors, as excellent emulsifiers, etc. In the wider sense, also foaming and washing textile aids of more or less synthetic character, e.g. →: Fatty alcohol sulphates; Fatty acid condensation products and → WAS.

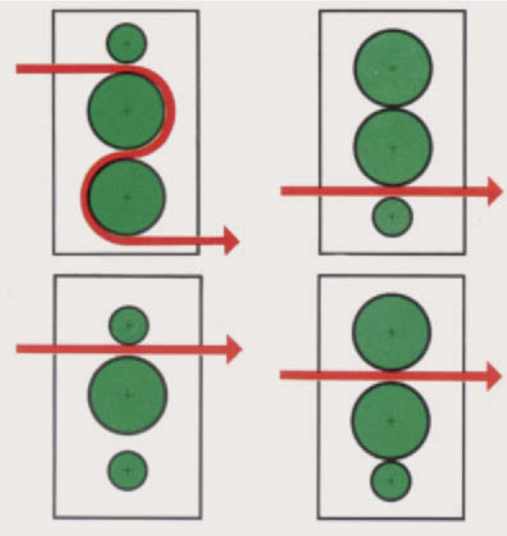


Fig. 1: Various take-in possibilities in textile calenders.

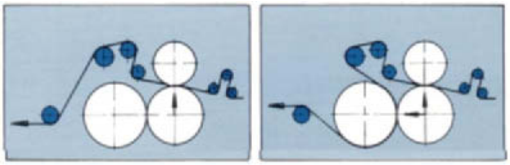


Fig. 2: Kleinewefers KTM L-Calender.

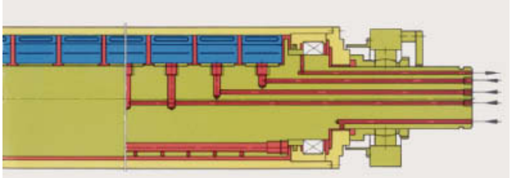


Fig. 3: Multi-zone, thermo hydrein roller (Kleinewefers KTM).

Textile calenders Arrangements of smooth rollers which rotate on each other in such a way that fabrics are compressed under the influence of heat once or several times (Fig. 1). L-shaped arrangement of the rollers has proved advantageous in order not to overload the rollers under the huge pressures (Fig. 2). In order to compensate for the natural unevenness in pressure over the width of the material the roller is divided into multi-zone pressure stamp-pads which are operated with oil (Figs. 3–6). Unusual systems are used to achieve special effects (Fig. 7). Thus, for example, the combination of two calenders with special properties on certain home textiles is necessary (in bed linen, particularly for lining and damask qualities). “Nipco-Star” is the Pre-calender for stabilizing the material so that it does not stretch. The subsequent chasing calender is a roller device which transports the fabric through the calender in spiral form. The material lies in 7 layers in the roller nip. With the chasing calender the material is lead to the calender from the interior over a bar. The material travels outward in a spiral form so that with the last

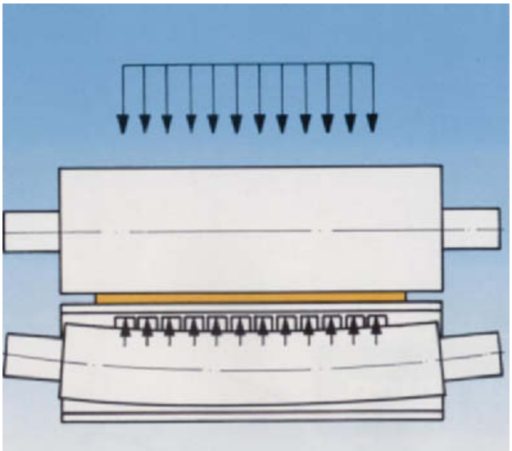


Fig. 4: Attaining the ideal slot load flow through use of a thermo hydrein roller with a compression zone (Kleinewefers KTM).

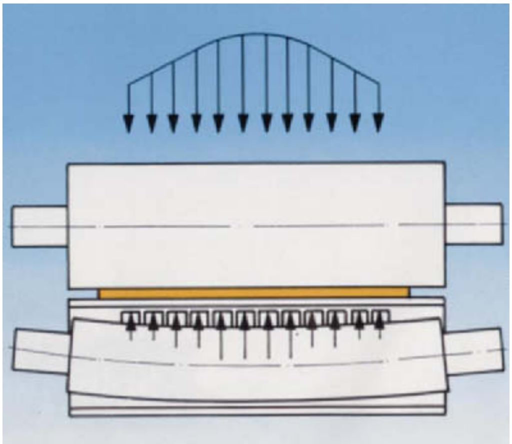


Fig. 5: Any slot load arrangements can be set when using multi-zone print settings over the width of the roller (Kleinewefers KTM).

Fig. 6: Subdivision of the contact surface of a Kleinewefers KTM calender roller.

outer strip the material leaves the roller nip before being rolled up. The material density is increased when it passes through the chasing calender. Density and at the same time air permeability are the aims which are achieved in the chasing calender. The yarns remain round and voluminous due to the multi-layer threading system in the machine and the roller nip. → Calender.

Textile care This encompasses the maintenance of efficiency of textiles including amongst other things → Textile cleaning.

Textile care labelling → Care labelling for textiles.

Textile chemicals All chemicals (including → Textile auxiliaries), which are used in → Textile finishing and should be biodegradable. Depending on the type of application, the following are differentiated:

I. Textile chemicals which only come into contact with the fibre temporarily, such as during wetting, scouring, mercerising, carbonising, bleaching, dyeing, printing, etc. Such products should offer optimum effect, not have any negative impact on the textile material (wool sensitivity to OH^-, cellulose to H^+, etc.), be easily removable from the material (particularly important in the case of lubricants) and not form any difficult to remove residues (e.g. line soaps).

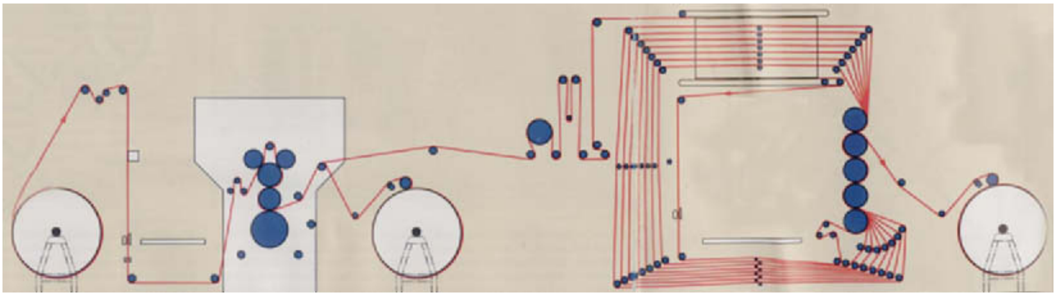


Fig. 7: Nipco-Star and Nipco-Chasing calenders combination (Kleinewefers KTM).

II. Textile chemicals which remain on the material including all types of finishing. In addition to optimum effect and non-impairment of the fibre material, products in this group also need to demonstrate certain fastnesses, as is for example possible when proofing against creasing and moths, and to a certain extent also in the case of dressings which must withstand washing and chemical cleaning using synthetics and in the case of crease resist finishing.

Textile chemicals, concentration determination Physical and chemical determination and quality control methods (mainly for electrolytes and ionic compounds):

I. → Potentiometric measurements: at the forefront is pH-measurement using a glass electrode. Sodium-sensitive measurement chains are used often in combination with pH-electrodes (for sodium salts and mixtures of these with acids, such as used in dyehouse processes). Antimony oxide alloy electrodes are used for surfactant control. Electrodes of the second type are used to determine, for example, chlorides (→ pCl) or sulphides and hydrogen sulphide (silver/silver sulphide-electrode), for example in the exhaust air of a viscose spinning plant by absorption into a solution and potentiometric determination.

II. → Redoxpotential measurement: determination of concentration changes in oxidation-reduction systems, for example in bleach baths.

III. → Conductometric measurement: suitable for use with acid, alkali and salts. Also suitable for monitoring rinsing water.

IV. Amperometric measurements are seldom used.

V. → Photometric measurements: Particularly for low concentrations and traces of substances. Also suitable for non-electrolyte. Operation monitoring methods for non-electrolyte or non-ionic compounds are still in their early stages.

Textile cleaning Generic term for chemical cleaning and washing treatments.

Textile dyehouse (dyeing company). Industrially-operated → Dyehouse for loose material, tow, cops, warps, hanks, piece goods, garments, etc. Either for own requirements (vertical operation) or on commission to other companies (spinner, knitter, weaver, trader).

Textile dyeing A general term for textile coloration which includes all dyeing processes, methods, etc. The dyeing of textiles is a finishing process in which, depending on the type of fibre, suitable dyes and machines appropriate for the form of textile material are used. The dyeing process can normally be sub-divided into the following stages:

1. pretreatment.
2. preparation of the material (work scheduling) and dye solutions (colour kitchen).
3. dyeing operation in the dyeing machine.
4. washing-off and rinsing + aftertreatment if necessary.
5. drying.

In dyeing by the exhaust process, a dye exhausts from a dilute solution (dye liquor) and concentrates on the fibre. Such a process cannot proceed on its own; certain forces must be involved which bring about the exhaustion of dye on to the fibre. In general, a distinction has to be made between continuous and batchwise (discontinuous) dyeing processes. The former includes the pad dyeing process in which the addition of dyes and chemicals is calculated in g/l whereas in the latter (i.e. exhaust process), the addition of dyes and chemicals is calculated in % on the weight of material. In order to carry out a dyeing, a dye liquor is required which, apart from water and the necessary dyes, also contains chemicals and auxiliaries. The quantity of dye liquor required is determined by the quantity of material to be dyed. The ratio of these two values is called the liquor ratio, e.g. 20 : 1, which means that 20 l of liquor is needed in order to dye 1 kg of material. For a batchwise dyeing machine, the loading and unloading times involve machine downtime and are referred to as “set-up” times.

Dye molecules contain a component which is responsible for the sensation of colour (the chromophore), certain substituents (auxochromes) and sometimes reactive groups. Dyestuffs are characterized by the following properties:

- chemical structure
- dyeing behaviour
- general colour fastness properties
- commercial form
- dissolving requirements
- principle of dyeing
- suitability for specific fibres.

Nowadays, dyes are mainly synthetic organic compounds which are capable of colouring textile fibres by suitable methods of application. Natural organic and inorganic colorants also exist which are no longer of much commercial importance. The synthetic organic dyes are classified in accordance with their chemical structure or according to their dyeing properties. Both soluble and insoluble dyes are used in practice. Direct and acid dyes are examples of dyes which are soluble in water. Disperse dyes, on the other hand, are almost insoluble in water and, because of their better solubility in polyester fibres, they dissolve preferentially in that fibre during the dyeing process. Before dyeing with vat dyes, they must first be made water-soluble by a process known as vatting (chemical reduction) in which form they have an affinity for cellulosic fibres; at the end of the dyeing process, the vatted dye is converted back again to the insoluble form on the fibre by re-oxidation to give a very fast dyeing.

The quality of a dyeing on a textile substrate is evaluated by its colour fastness in addition to its levelness and by how closely the colour matches that of the standard sample. As far as the colour fastness is concerned, a distinction is made between the colour fastness to processing treatments and the colour fastness of the dyed textile in use (serviceability fastness). Colour fastness to processing includes, e.g. the colour fastness to milling, carbonizing and cross-dyeing, etc., as well as the wet fastness. Examples of serviceability fastness include the colour fastness to light, washing, perspiration, rubbing, water, etc. Colour fastness is assessed by comparison against standard fastness scales. The standard blue scale, which covers 1–8 steps (where 1 = the worst and 8 = the best fastness), is used for the assessment of light fastness. For all other colour fastness assessments the standard grey scales are used (one to assess colour change and another to assess the degree of staining on to adjacent textile material). Both these grey scales cover 1–5 steps (where 5 is the best).

An understanding of dyeing terminology and its implications is essential for the textile dyer. The following characteristics of each dye are usually given in the respective dye maker's pattern cards:

- build-up properties
- rate of exhaustion
- migration properties
- behaviour on different types of fibre or the covering of irregularities
- combinability
- suitability for aftertreatments
- ability to reserve other fibres
- ecological aspects.

Textile dyes → Dyestuffs for commercial reasons are not identified according to their structure, rather by their comparison to established dyestuffs types.

Up to October 1990 the Colour Index lists, for example, 439 red acid dyestuffs, 369 blue disperse dyestuffs and 179 yellow reactive dyestuffs. Some of the generic names recorded in the index no longer show products, as the dyes are technically out-of-date or only of secondary importance. These figures are, however, intended to give an idea of the variety of dyes that can be used to dye textiles and which can be categorized analytically (see Tab.) (according to Sewekow).

Textile eczema Contact eczema caused by textiles and finishing chemicals, localised on parts of the body where there is particularly close contact between the skin and clothing. The distribution of textile eczema outbreaks is therefore characteristic and can be diagnosed clinically. → Skin diseases.

Textile fibre materials → Fibres.

Textile fibres → Fibres.

Textile fibre symbols These are used to simplify correspondence and texts for the sometimes complicated terms denoting chemical fibres. They are intended to be an internationally understandable communication aid between trade, production, research and teaching. In addition to the two most commonly used systems the → EDP Code and the DIN symbols, there has existed since April 1989 a recommendation from BISFA. The DIN symbols have a scientific classification basis and have been more extensively applied in favour of other systems during decades of use. They are used by technicians in the fibre and chemical industries. An international directive on abbreviations resulted in the issuing of DIN 60 001 in October 1988, revised in the modification of August 1991. The result was an adjustment to a unified method of spelling in capitals according to international nomenclature [e.g. CO for cotton instead of the German Bw for Baumwolle = cotton] and similarly for the synthetic fibres with the BISFA system. The EDP Code of → Gesamttextil was designed for data transfer systems. It works according to phonetic values and is consequently limited to using 2 letters. It is used by textile salesmen and is included in the European

dye class	yellow	orange	red	violet	blue	green	brown	black	total
acid	127	81	183	45	146	50	204	86	922
cationic	57	23	47	25	77	4	11	3	247
direct	72	33	79	24	113	27	52	55	455
disperse	104	68	168	44	160	3	12	11	570
chrome	18	10	18	9	18	11	19	21	124
pigment	111	41	146	22	38	26	18	18	420
reactive	105	71	149	23	147	11	30	14	550
sulphur	17	6	13	2	28	32	51	15	164
vat	16	16	21	13	41	19	30	31	192
									3 644

Tab.: Number of C.I. generic names covered by commercial products (October 1990 status).

Textile Labelling Regulations as an appendix but not an integral part. To resolve the problems of the use of 2 separate systems by sales and technical users in Western Europe, BISFA issued a binding unitary system for its members in April 1989. This system follows the scheme of ISO 1043 and is incorporated in DIN 7728 and has been used for many years in the Plastics Industry. In addition to these 3 systems, there is also the Eastern European TGL system from the former GDR. This lexicon has not used abbreviation symbols in the text to avoid this confusion.

Textile finished goods In accordance with DIN 60 000 these are "products utilising textile fibre materials, semi-finished or finished products by tailoring, designing and/or other work processes which are passed on to the processor, the trade or the end consumer in a state suitable for sale".

Textile finishing This facilitates production of attractive ready-to-sell textiles intended to fulfill requirements for specific use. This includes all processes which help to maintain the value or increase the value of the textile material.

Textile finishing encompasses:

- dyeing,
- printing,
- resin finishing,
- finishing,
- dressing,
- coating.

Related areas: technical preparation for spinning and weaving, spin dyeing and spin matting of fibres, incorporation of ultra-violet stabilisers, heat stabilisers, antioxidants as well as garment dyeing, dry cleaning and spotting agents.

Generic terms corresponding to the German "Textilveredlung" (textile finishing) do not exist in all languages; other languages tend to differentiate in accordance with the above list.

Textile finishing is used at all textile processing stages to impart the necessary processing and utilisation properties to textile products. The requirement profile for improving the properties of the textile raw material depends on the area in which the finished product will be used. The work processes associated with textile finishing increase the quality in that they result in saleable and attractive products in the technical textile range or with fashion appeal in the form of articles of clothing or home textiles. Textile finishing therefore makes textile raw material usable by creating properties with a useful effect. But they are also effective in facilitating all the aspects of textiles which express an aesthetic appeal by dyeing, forming and other effects. Durability of the desired finishing results in the subsequent processing stages or during consumption of the product (use and care) is demonstrated by fastness of finishing effects. In the case of representation properties, optical and detail values are tested and placed in correlation to subjective assessments, whereas, when finished products are used for technical purposes, objective values of fibre substance testing as a material represent a criterion of the quality of the finishing process. As the utilisation properties of technical textiles are subject to constantly increasing demands and fashion requirements are exposed to constant modifications of marketability, the textile finishing industry has to be very adaptable and must react dynamically to new textile products or take the initiative with regard to textile design itself. The legislature also makes considerable demands on textile finishing from the point of view of environmental protection measures.

Textile finishing machinery Textile finishing makes use of the basic technological principles of physics and chemistry, in particular physical chemistry. The design of finishing machinery takes into consideration the often complex properties of the fibres used. As a textile product in varying presentations the fibre can only be subjected to a sensible physical and/or chemical change if the necessary energy forms and finishing products are transported into the fibre in a suitable medium in the textile finishing machine. Diffusion and convection processes in the heterogenous system are typical processes in the medium. If the finishing

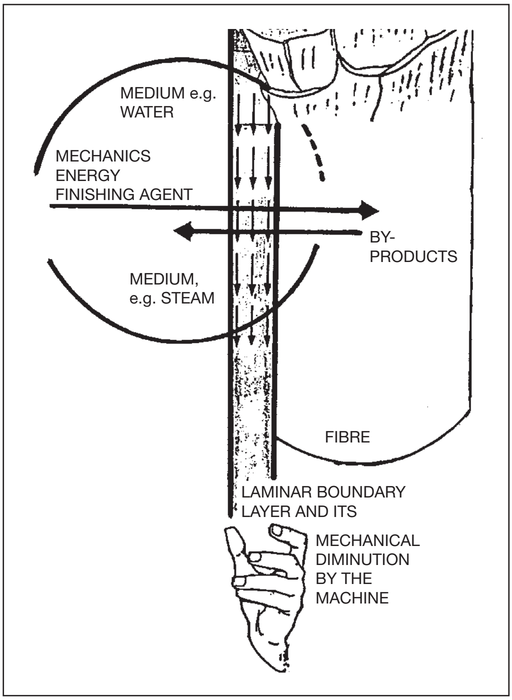


Fig.: Fibre/medium interaction in the textile finishing machine.

process is no longer diffusion-controlled by suitable permeation processes in the liquor exchange zone, the time spent in the rest zone is composed of the processes which make the procedure reaction-controlled. Typical parameters which are frequently dealt with empirically are time, temperature, pressure and humidity which often interact with each other in complex fashion (Fig.). Liquor exhange zone and rest zone are frequently not clearly separated in the machine.

The limitations of the textile finishing machine are to be found where the properties of natural or synthetic fibres and of the products manufactured from them are overstretched. Textile finishing always attempts to improve or to eliminate typical negative (undesired) fibre properties. In addition, textile finishing initiates completely new and positive (desired) fibre properties (e.g. Easy care finishing). Finishing effects are, however, usually only achievable by tolerating undesired side effects. If these side effects exceed subjectively determined and objectively measurable tolerances, the term “damage” is used (e.g. excessively high fibre strength losses) or the overall result is seen as a reason for complaint (e.g. colour deviation). The costs of machine time to achieve uniform finishing effects are usually considerable. The investment necessary to achieve certain effects or to reduce undesired side effects to tolerable levels is expressed in the costs. The finishing costs only make up a small proportion of approx. 10% of the final finished product when it is placed on the market. The costs of energy and environmental protection are, however, assuming increasing proportions in the cost structure for textile finishing.

Together with wage costs, the requirements for air protection and effluent cleaning as well as those of the workplace make textile finishing a capital-intensive industry. For this reason, textile finishing in the last instance requires a high standard of ecological conscience, since it uses large quantities of chemical products which are not always wholly absorbed by the fibre and therefore, under certain conditions, have a potential impact on clothing physiology or the environment around the plant location but are frequently transported away as surplus by-products, possibly in the finishing medium, before being prepared for recycling or disposal. Environmental protection measures are, therefore, a prime consideration when designing textile finishing machinery.

Textile finishing processes Development factors which impact heavily on textile finishing are the requirements of the consumer (e.g. ease of care), those of the legislature (e.g. environmental friendliness, safety), those dictated by scarce resouces (water, energy) and new fibres or fibre mixtures. A more economic design of apparatus which facilitates batch processing would appear to be more important than further investment in the development of continuous processes. This is particularly true of the dyehouse in which overflow apparatus is offered. The significance of continuous finishing lines will increase with the growing printing industry. This will be accentuated as more progress is made towards continuous wet processing of fabrics such as knitted fabrics which have previously not been accessible to such processes.

The following developments of process technology are conceivable in textile finishing:

- monitoring and control of work processes across all areas by process computer (process data registration);
- shortening of work processes (e.g. dyeing);
- reduction of reaction temperatures;
- recovery of auxiliaries and energy;
- high-temperature steaming;
- increase of passage or turnaround speeds (e.g. continuous systems to 300–500 m/min);
- reduction of liquor ratios during dyeing to 1 : 3;
- more formaldehyde-free finishing;
- uniform, substrate-independent dyes and auxiliaries which have no adverse effect on the environment;
- dyes and auxiliaries with a one hundred percent fixing effect;
- products which dye and finish simultaneously;
- use of electrical power as a finishing agent;
- complete recovery of products which are not one hundred percent fixed;
- self-destructing and self-disposing finishing agents.

Textile floor coverings Generic term used in the carpet trade for fitted carpet, carpeting, runners, rugs, bed surrounds, bath mats in a wide range of fibre materials (natural and synthetic). The most important requirements: low electrostatic build-up, measurement accuracy/form stability, good sound-proofing capacity, high resistance to wear (durability), good repeat capacity, adequate light, rubbing and shampoo fastness. The most important finishing processes: anti-static, anti-soil, anti-microbial finishing, flame-retardant finishing, metal fibre incorporation, fibre types with “anti-static building”, anti-static aftertreatment, 3-effect anti-soil-anti-static hygiene-active finishing.

Textile foam Especially fine-pored and soft → Foam which is characterised by tear and tensile strength as well as greater extensibility. After laminating they are extensively used for upholstery covers.

Textile glass According to DIN 61 850, generic term for → Glass fibres and products made of glass fibre.

Textile institutions → Technical and professional organizations.

Textile iodine solution Used to detect starch based sizes and for testing for true starch sizes. Presence of starch results in blue colour. Details: → Iodine potassium iodide solution.

Textile labelling Details of the raw material composition of textile products.

I. Between processing stages as a rationalisation measure.

II. For the consumer as a protective measure when purchasing textiles in accordance with → Textile labelling regulations

Textile labelling regulations (Ger.: TKG – Textilkennzeichnungsgesetz). Based on a consumer protection control over trade and industry requiring the labelling of all items sold with regard to the composition of the textile raw material. It specifies the labelling according to the percentage composition of the principal fibres present and any other required or specified detail. The proportion of the main fibres must always be listed. The remaining fibres have to be listed in the order of the quantities used without quoting the percentage, if none of the fibres makes up 85% of the total weight. If two types of fibre in a mixture make up less than 10% of the mixture, they can be listed together under "other fibres". If a single fibre makes up at least 85% of the total weight, the remaining fibres do not have to be named. The consumer should always find clear and unambiguous details of raw material content on every textile item, including clothing, suits, linens, carpets and furniture coverings. The lining material of a piece of clothing must be listed separately. → Care labelling of textiles.

Textile leather → Artificial leather.

Textile lubricants Oily liquid, paste or solid products which are applied to textile materials to be processed by carding in cotton and wool spinning plants in order to bring the fibre to the necessary state before carding or spinning. Lubricants help in the opening and blending of fibres and impart smoothness and suppleness to the fibre structure, and on the other hand they provide better cohesion of the fibre during spinning and elongation due to their cohesive qualities. Textile lubricants can also have wetting, scour-active or milling promoting properties depending on the purpose of their use. Textile lubricant groups:

I. Fatty acids and emulsifying mixtures: olein can be washed out easily but requires alkaline milling and scouring processes. Emulsified oleins facilitate preparation of lubrication emulsion and, with an appropriate choice of emulsifier, can make washing out easier if the quantity of sodium carbonate used is less than that necessary for total saponification. Triglycerides (olive oil), which are only used for worsteds, require a special washing technique with specific washing agents as they cannot be saponified with sodium carbonate.

II. Composite lubricants (compounded mineral oils) are mixtures of mineral oil with (usually more) olein.

III. Mineral oils have good spin-technical properties but require a washing procedure which is thoroughly controlled and carried out using specific washing agents.

IV. Emulsion lubricants are so-called self-emulsifiers on mineral oil basis with emulsifier.

V. Scouring and milling lubricants (spin washing agents) are compound products made of olein, mineral oil with emulsifiers and wash-active additives which promote the milling process (olein activators). Certain aliphatic alkyl phosphates, amino compounds, further anion-active and in particular non-ionogenic scouring agents have a similar effect.

VI. Various lubricants such as neutral silicon dioxide dispersions which, although they can be washed out, impart greater yarn strength (particularly of smooth fibres) by increasing fibre to fibre friction.

Textile magnifier → Piece glass.

Textile markers,

I. Textile markers in the form of paste in tubes for marking raw materials with 4 different writing heads (for different types of material), resistant to all finishing stages.

II. (markers, fabric markers, signal markers) are used for → Marking of grey fabrics in wet and/or dry processing (fabrics, number strips, garment bags, laundry). Suited to each process type (finishing, dry cleaning, laundering) with appropriate fastness and yet capable of being easily removed (e.g. with soap). Colours usually white, yellow, red and black. Textile marker types: Liquid as inks, semi-liquid in tubes or pens, solid as pencils.

Textile meter Kretschmer commented on the importance of permeability in textiles with textile finish-

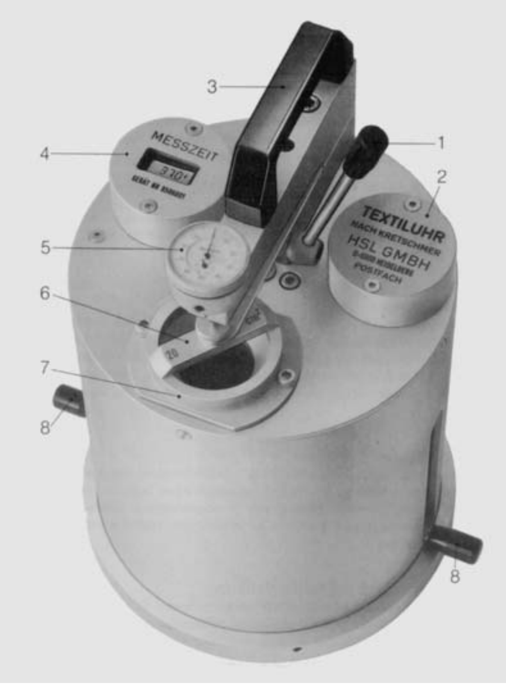


Fig.: Textile meter (Kretschmer) called "Textiluhr".

ing liquors. The textile meter measures the air permeability of dry fabrics. During the permeability measurement a weighted bellows is lowered thereby sucking air with defined differential pressure through the sample (Fig.). Before the measurement the bellows is (magnetically) fixed in the upper position. The sample is clamped into place between the sample pressure ring (6) and the support (7) with the aid of the operating lever (1). The measurement process is started by swinging the operating lever forward. The timed measurement is automatically switched on and off by the lowered bellows. The measurement process is completed by reading the measurement time indicator (4) and the thickness measurement indicator (5). The bellows is repeatedly led back to and fixed in the upper position by the two lifting jacks (8). The measurement time indication is automatically erased by the fixing process. The textile is ready for measurement again. With its rechargeable battery in (2), the textile meter can be used anywhere. The convenient handle (3), the low weight of 4.5 kg, the diameter of 20 cm and the overall height of 32 cm make the meter easy to use in laboratory and factory.

Cross wound packages can also be installed and their air permeability measured, if the other side of the tube is sealed.

Textile microtomy → Microtome.

Textile parasites Small insects, particularly small nocturnal lepidoptera such as moths as well as beetles from the Middle East such as fur and carpet beetles, which either feed on substances containing keratin (wool, animal hairs, feathers used in bed linen, down, fur) or live on the organic substances of cellulosic fibres such as silverfish and the golden spider beetle. Finishing agents to prevent carpet parasites are mainly used for preventing moth attack (via poisons which obstruct digestion); contact poisons are prohibited in the Federal Republic of Germany. Rooms and bookcases infested by parasites are sometimes treated using respiratory poisons (gas releasing substances such as camphor, naphthalene, paradichlorbenzene, moth balls) however, this kind of treatment can prove problematic even when using commercial parasite control agents and it is vital that instructions for use of these agents should be strictly observed; → Mothproofing. Destruction by insect infestation can be proven microscopically by identification of typical arc-shaped traces thereby enabling this type of damage to be differentiated from damage caused by small rodents. → Microbial damage to textiles.

Textile perfumes → Fragrant finishes.

Textile printing → Printing.

Textile product According to the textile designation law, goods or articles consisting of at least 80% weight → Textile raw materials.

Textile raw materials consist of fibres and hair which can be spun or processed to create textile fabrics. These also include fibres made of rubber, glass, metal, paper and asbestos. → Fibres.

Textile Research Institute American textile research institute; → Technical and professional organizations.

Textile scanner Typical → Scanners have larger formats of 112 x 100 or 112 x 247 cm. Different to colour scanners (for smaller formats), used for paper printing in that the recording of individual colours can be differentiated, digitalized and processed onto magnetic discs, making it possible to work on patterns on a desktop with an electronic pencil (digitizer). Images can be transferred directly onto film in “instant mode”. The following linked stages (with programmable options) can be carried out:

- colour separation into, for example, 15 colours with brightness control;
- recording onto a magnetic disc prior to further processing;
- alternatively in “instant mode” onto film with colour bleed-in and mixed colour separation, scanning (for three and four colour printing);
- zoom control (10–400%);
- automatic film alignmemnt (straightening of the gradation curve in film densities of the recording);
- colour area determination (information on the area of separate colour usage).

Textile serviceability This concerns human ideas regarding clothing and home textiles in areas such as ease of care, construction, raw materials, finishing, component parts, fabrication technology, special properties (→ Service life of textiles).

Textiles These are understood to include half- and fully-finished fabrics made from spinnable → Fibres. They are therefore structures which consist of textile fibres in their smallest components and are further processed by means of textile processes (spinning, weaving, knitting, etc.). Textiles are frequently influenced more by their structure than by the type of fibre.

At the outset of human history the first materials used as clothing textiles were leaves, furs and skins. These materials are two-dimensionally structured and have the disadvantage of limited availability and difficult handling. The textile industry and fibre technology, which originated several thousand years later, were based on the discovery that two-dimensional systems (textiles) can be fabricated from simple one-dimensional elements (fibres). Adequate quantities of fibre materials were available. These consisted exclusively of natural fibres, either from animals (wool, hair, silk) or from plants (cotton, flax, hemp, etc.) which differed in their chemical composition as well as in terms of their mechanical properties. These were spun into yarns and textiles and woven or knitted. All the handicraft stages, such as isolation of fibres from their natural sources, cleaning, spinning and production of the fabrics were based on empirical development without exact knowledge of the chemical composition of the raw materials. The technical revolution of textile production began at the outset of civilisation and continued into the 20th century in the form of technical innovations such as the steam engine which formed the basis of industry. Chemistry established itself in the textile industry at the end of the 19th century with processes such as mercerising of cotton or moth-prevention treatment of wool. If the discovery and introduction of spinning machines is recorded as the first technical revolution in the fabrication of textiles, then this innovation represents the transition from manufacture by hand to factory or industrial mass production of textiles (1750–1830). The discovery of worsted made of fine wool fibre (approx. 1870) represented the second technical revolution, since this made possible the manufacture of highly-fashionable articles in addition to simple woollen goods. From this point onwards, textile developments in mass consumption were strongly influenced by fashion. The third technical revolution (approx. 1960) can be seen as the introduction of Sulzer weaving machines. From then on, textile fabrication went through an enormous rationalisation process and developed from a wage-intensive to a capital-intensive industry. The fibre industry was dependent on the development of the textile industry. Since exclusively natural fibres were used as textile raw materials until the middle of the 19th century, scarcity of resources dictated the search for other raw materials.

This phase of research into fibres and textiles began with a chance discovery by Christian Friedrich Schoenbein, chemistry professor in Basle, in 1846. He noticed that cotton could be converted into a plastic substance by means of a mixture of potassium nitrate (“saltpetre”) and sulphuric acid. This was pressed into fine filaments by Hilaire de Chardonnet in 1884. At this time efforts were concentrated on the manufacture of regenerated fibres. Organic chemistry, which was already well-developed, succeeded in separating more and more natural products such as cellulose, proteins, or chitin by denaturing, thereby making them accessible to fibre production. New processes had to be found for each separated material in order to convert it into fibre form. When such a process had been found, it was possible to return to the time-proven technologies for production of textiles such as spinning, weaving and knitted goods fabrication. The range of products which could be fabricated from these new fibres ranged from fashionable clothing to transportation belts for the industry. These materials were not, however, “real” synthetic fibres, since they were based on natural materials.

In the nineteen twenties polymer research gradually began to develop with the work of Staudinger. The path to synthetic fibres with direct polymerisation of monomers had been found. This development was the beginning of the era of synthetic fibre technology and fibre research with its rapidly growing possibilities of producing new textile goods. The following criteria were evaluation standards for synthetic fibres:

- good spinnability from melt or solution,
- resistance to the usual organic solvents,
- high melting point,
- high tensile strength,
- good stretchability.

The first commercially successful polymer category were polyamides which came onto the market under the name nylon (PA 6.6). They were developed simultaneously by W.H. Carothers (DuPont) and P. Schlack (I.G. Farben). These were soon followed by polyester, polyacrylonitrile, polyvinyl and a little later polyolefine and polyurethane.

The existence of many fibres of differing chemical compostion accelerated the search for their molecular structure. Of particular interest was the dependence of the mechanical properties on the structure. By the sixties so much well-founded knowledge about the relationships between the structure and the characteristic properties had been accumulated that a start could be made with the “tailoring” of fibres. First the desired properties were formulated, then the suitable polymer was synthesised by Pfropf- or copolymerisation or by spinning two components. Systematic use of this concept of “macromolecular engineering” resulted in a range of special fibres whose properties (high elasticity, high strength, heat resistance, water repellency) were not comparable with those of natural or regenerated fibres. These “high chem”- fibres also initiated the development of modern high-speed spinning, weaving and knitting machines. The era of → Technical textiles began. New possibilities for use beyond classical textiles are represented by the increase of duro- and thermoplasts in the automotive, aviation and space travel industries. Other applications exist in medicine and the development of better optical fibres for data transmission.

Textile standards The responsible authority is the Specialist Standards Committee of the Textile and Textile Machinery Industry in the DNA (Deutscher Normenausschuß – German Standards Committee). Area of activity: establishment of standards for the entire textile industry, textile machinery constructors and the clothing industry which are issued by the DNA as DIN-standards. In the area of textile testing methods they work closely with the specialist standard committee for “Materials Testing”. → Industrial standards.

Textile testing Textile testing covers three main areas:

1. Product development: assessment of composition, structure, and characteristics (behaviour under various wear conditions) of behaviour during

- processing,
- use,
- recycling/disposal.

2. Production control, i.e.
- quality control,
- meeting specified values and tolerances (production-related).

3. Product declaration: quality definition, i.e.
- setting up of requirement profile (application-related),
- determination of the quality features and assessment of the product.

Test, evaluate and respond are the main activities of the material tester. Tab. 1 shows the close relationship of these three activities. The task of the material tester shows which decision will have to be made on the basis of the tests. The requirement catalogue and the quality profile must therefore initially be derived from the expectations of a product. The appropriate evaluation criterion must then be established which indicates which characteristic or properties must be tested.

test	→ assess	→ decide	
properties	← standard	expectations	
react	↑	↓	
↓	quality profile	← set of requirements	
observation of data			
material behaviour (spec. features or general)	observe product in the overall system		
in a set situation (consider test conditions)	user-product relationship in: – technical – economical – sociological – ecological		} context

Tab. 1: Link-up of the material checker's basic activities.

Material testing is permanently exposed to the tensions between analysis and synthesis. Measurement techniques should record significant individual characteristics. The situation in which measurement takes place is usually determined on the basis of test conditions in order to ensure reproduceability. The specific data recorded must subsequently be integrated into the overall system during the evaluation and decision-making process. The necessity for an integral system of evaluation with different frames of reference is becoming increasingly greater, particularly in the area of quality evaluation with growing awareness of the close relationship of technology, economy, society and the environment.

The Fig. demonstrates that technology, the market and the environment place demands on consumer goods during their entire life cycle. The suitability demanded in the individual stages must be tested again and again. In other words material testing accompanies a product from its conception to its disposal.

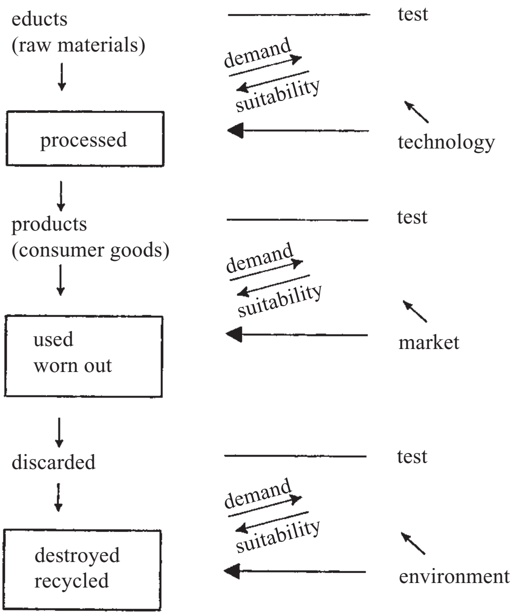


Fig.: Consumer goods requirements.

The quality characteristics of textile materials are often subject to considerable fluctuations since textiles are not an ideal standardised body. These fluctuations of the quality characteristics during fabrication or production can always be attributed to five basic factors. These are

1. material,
2. machine,
3. method,
4. human,
5. environment.

These factors determine the quality fluctuations either individually or in varying combinations. Not every fluctuation constitutes a defect, however, but only those which no longer fulfil the minimum requirements of the customer for the product. It is the responsibility of → Quality assurance to investigate to what extent the causes of such defects should be eliminated. To this end it is important to recognize whether or not the defects in question are of an accidental or systematic nature.

Accidental defects are unavoidable during all processes and are the result of various influences during fabrication compounded in different ways, therefore occurring completely unpredictably and possibly disappearing again after a certain time. The actual cause of an accidental defect is therefore difficult or impossible to determine. On the other hand systematic defects occur when certain factors have a disturbing influence on the production process. The causes of these factors can be eliminated if a thorough investigation is carried out. The causes of accidental and systematic defects can also be attributed to the above-listed five basic factors.

1. Material: a) accidental: e.g. fluctuations in the fabric or fibre material, fluctuations in size composition, etc.; b) systematic: e.g. false or improper pretreatment, use of an unsuitable material, etc.
2. Machine: a) accidental: e.g. fluctuations of energy, humidity, speed, etc.; b) systematic: e.g. damaged machine parts, worn machine parts, use of unsuitable machines, etc.
3. Method: a) accidental: e.g. varying speeds, not sufficiently precise observance of regulations, etc. b) systematic: e.g. choice of unsuitable process, false interpretation of regulations, missing or unclear regulations, wrong adjustment of machinery, etc.
4. Human: a) accidental: e.g. fluctuations in performance capacity, fluctuations in attitude to work, etc.; b) systematic: e.g. individual way of working, lack of training, etc.
5. Environment: a) accidental: unavoidable climatic fluctuations, etc.: b) systematic: e.g. avoidable climatic fluctuations, inadequate lighting, etc.

Textile testing is intended to determine a specific property, if necessary to derive other parameters from it and to relate this to the properties of the product during the following processing stage and during use. This task can only be carried out if largely objective, scientifically-based testing processes are used which are repeatable under identical uniform conditions thereby guaranteeing clear results. This is why the norming of testing processes is of national and international importance.

The quality characteristics of interest for textile finishing and the associated testing processes are listed below (*no compulsory norms exist).

I. Incoming check of raw materials:

– Weft thread count (raw) Stitch density (rows)	DIN 53 853, 53 883
– Warp threads count (raw) Stitch density (stitch wale)	DIN 53 853, 53 883
– Width of raw materials	DIN 53 851, 53 881
– Length of raw materials	DIN 53 851, 53 881
– Weight of raw materials (piece weight)	DIN 53 854, 53 884
– Yarn contraction	DIN 53 852
– Strength and elongation	DIN 53 857, 53 858, 53 861
– Pile height	*
– Chemical properties	IWTO 2-66, 3-66, 4-66, 11-66, 15-66
– Solubility of sizing and preparation	*
– Shrinking test (raw)	DIN 53 892, 53 894
– Visible yarn and weave defects	*

II. Preparation of raw materials

III. Dry pretreatment

IV. Wet pretreatment:

– Liquor condition (concentration, pH, quantity, temperature)	DIN 19 260
– Squeezing effect	*
– Liquor absorption, residual humidity	DIN 53 923, 53 800
– Residual content of sizing and preparation	DIN 54 285 IWTO 10-66
– Modification and damage	*
– Degree of desired properties (e.g. wettability)	IWTO 2-66, 3-66, 4-66, 11-66, 15-66
– Drying	*

V. Dyeing:

– Raw material weight	DIN 53 854, 53 884
– Raw material humidity	DIN 53 800
– Dyestuff weight (recipe)	*
– Time-dependent changes in liquor condition	*
– Dye (sampling)	DIN 6169
– Number of additions	*
– Drying	*
– Uniformity of dyestuffs	*
– Colour fastness	DIN 54 000–54 065
– Modification and damage	*

VI. Printing:

– Dye weight (recipe)	*
– Dyestuff (sampling)	*
– Defects	*

VII. Print aftertreatment:

– Temperature	*
– Time	*
– Steam pressure	*
– Liquor condition	*
– Drying	*
– Modification and damage	*

VIII. Wet finishing:

1. Milling	*
– Milling width	DIN 53 851, 53 881
– Milling length	DIN 53 851, 53 881
– Milling weight	DIN 53 854, 53 884
– Milling liquor (quantity, pH, concentration, temperature)	*
2. Scouring	*
3. Wet decatizing, boiling and corresponding processes	*
– Temperature, time, pressure	*
– Concentration, pH	DIN 19 260
– Fabric width	DIN 53 851, 53 881
4. Impregnation and finishing	*
5. Carbonization	*
– Acid concentration of bath	*

– Duration of acidifying	*
– Acid content of wool before oven	DIN 54 280, IWTO 3-66
– Water content of wool before oven	*
– Temperature in chambers	*
– Liquor condition of neutralization bath	*
– pH of aqueous extract from carbonized wool	DIN 54 276, IWTO 3-66
– Acid content of carbonized wool	DIN 54 280, IWTO 3-66
– Alkali solubility of carbonized wool	DIN 54 281, IWTO 4-66
– Purity	e.g. payment system
6. Raising and combing	*
– Raised effect/combed effect	*
– Air permeability	DIN 53 887
– Shearing height	*
– Number of passages	*
IX. Dry finish	
1. Mechanical shrinking	*
– Temperature, humidity, duration	*
– Width of fabric	DIN 53 851
– Residual shrinkage	DIN 53 894
2. Shearing	*
– Shearing height	*
– Pilling test	*
3. Drying	*
– pH	DIN 54 275, IWTO 2-66
– Temperature, humidity	*
– Residual moisture content	DIN 53 800
– Weft distortion	*
4. Setting, condensation	*
– Temperature	*
– Moisture content of goods	DIN 53 800
– Air humidity	*
– Degree of desired properties	IWTO 2-66, 3-66, 4-66, 11-66, 15-66
– Modification and damage	*
5. Pressing, decatizing	*
– Incoming goods moisture content	DIN 53 800
– Temperature, pressure, duration	*
– Thickness of goods	DIN 53 885
X. Final inspection:	
– Finished width and length	DIN 53 851, 53 881
– Finished weight	DIN 53 854, 53 884
– Colour (sampling)	DIN 6169
– Handle, effects	*
– Strength, elongation	DIN 53 857–53 859, 61 200
– Weft thread count	DIN 53 853
– Residual shrinkage	DIN 53 892, 53 894
– Colour fastness	DIN 54 000–54 065
– Bending strength	*
– Bursting strength	DIN 53 861
– Abrasion testing	DIN 53 863
– Crease recovery angle	DIN 53 890, 53 891
– Other required properties	*
– Defects	*

Material testing provides different types of statement. These are:

– attributive	(nominal)	without values
	(ordinal)	with values
– metric		by measurement
– graphic		function, frequencies, integration.

Evaluation of such information is generally carried out with the aid of mathematical statistics, i.e. the distribution of features resulting from sampling can be analysed by the usual characteristics such as average, standard deviation and manner of distribution, whilst the conclusions from sampling are investigated in terms of their more general relevance or a hypothesis is tested with the aid of test and estimation methods with regard to the probability of its occurrence. As well as considering what constitutes reasonable risk, exact testing and monitoring plans can be set up in this way as the basis of all types of statistical quality control.

Classification of defects, which is important for quality control, can also be made on the basis of the quality profile into the following categories:

- supercritical defects (e.g. risk to life and health),
- critical defects (unusable),
- main defects (greatly impaired usefulness),
- additional defects (slightly impaired usefulness).

The furnishing of a testing laboratory with testing apparatus and calculators is complex. When the testing equipment is suitably standardised then Industry Standards can be applied to using comaptible computerised systems. For reasons such as testing frequency and economy not every → Laboratory will use computer-integrated systems. In many cases tests still have to be carried out using traditional methods, i.e. measured values are simply read from testing equipment. To control the work of the laboratory these individual values must be recorded appropriately and evaluated by a suitable system. The use of mobile data units (MDU) allows the measured value to be input at the place of measurement. The measurement values are stored in the MDU and passed on to the computer after measurement is completed. This can take place via a direct coupling by means of a plug in connector or via the telephone by means of an acoustic muff.

The use of mobile data technology makes it possible to apply computer technology to conventional quality assurance methods such as the use of control chart techniques. The purpose of control charts is to establish nat-

	process control	goods labelling	performance testing
reference point	production	product	application
requested	standard values tolerances	composition properties	– behaviour under wear and tear – use – destruction
testing methods	simple rapid	analysis standard method	– situation simulation – model and parameters
accuracy	tolerances adapted	often very high	risk adapted
sampling	frequent, considerable ↓ production control	once, typical ↓ – customer information – comparability – safety	once ↓ forecast on use and life-span

Tab. 2: Material testing tasks.

ural or accidental occurrences of a process and using this as a basis to establish limits above which systematic deviations are indicated. Using control charts the process can be monitored in such a way that fabrication can be interrupted immediately at the appropriate time. Software systems allow all measurement data occurring in the laboratory and during the fabrication process to be recorded, statistically evaluated and the appropriate test reports printed out. The measurement values are then archived on hard disk or diskette and are therefore available as long-term statistics.

As quality documentation can be said to be the passport of a product it is important that the data documented for a quality product is clear and generally intelligible. There is further scope for the introduction of norming in this area. Both norming and textile testing need to pay attention to the definition of quality-relevant properties. The testing processes and conditions can then be developed from these definitions. It must be the aim of normed testing processes to differentiate the products on the market in a logical manner and to carry out testing under conditions which do not only allow good reproduceability of the results but also demonstrate a clear relationship to practice.

The material tester is expected to make statements on the suitability, nature or general quality of a product (Tab. 2). On the other hand he should also compare and evaluate products, raw materials and semi-finished products as well as establishing defects and contamination and clarifying their causes. Defect investigation always plays an important part in material testing. In many cases it could be defined as a rare occurrence in terms of probability which originates as the result of the coincidence of a number of unfavourable factors. Clarification of the cause of damage involves studying the interaction of these negative factors and possibly reproducing the damage by simulating the case.

Product comparison is an important component of quality assessment. The results of such tests naturally have considerable economic consequences. This is why all product comparisons require careful planning. It is therefore not surprising that there is extensive literature on this matter although it is not possible to establish exact regulations of a prescriptive nature. In fact only the principles on which such comparative tests should be carried out can be set out. Comparative tests should enable the consumer to make a reasonable choice from the products available on the market. First of all it is important that a study of the market ensures that a representative selection is made. The quality features to be tested should be based on the end-purpose but should also take into account factors such as safety, operating costs, environmental damage and use of energy. As a price comparison is usually included, packaging, customer information and service should feature as well (according to Fink and Dressler).

Textile wallcoverings Wall coverings and textile wallpapers of polyamide, polyproylene, polyacrylnitrile, wool and glass fibres. Main requirements: simple application, good form stability, ease of care, good light and wear fastness, good sound-proofing properties.

Textile wallpapers Composite wallpaper produced by laminating paper and textiles as threads, woven- or raschel knitted fabrics. Polymer dispersions are usually used as adhesives, seldom from solvents, more often from polymer powder by dot coating.

Textile waste recycling → Recycling.

Textile wastes According to the waste catalogue specified by waste removal legislation, this includes specific natural and man-made fibre waste materials (textile industry), material/fabric remnants (textile clothing industry), used clothing/rags (used materials trade), cleaning wool/cleaning cloths (used commercially), filtration cloths (filtration processes, exhaust air cleaning), polishing wool/felt (polishing), sludge from textile dyeing plants, textile finishing, wool washing facilities and laundry sludge.

Textile waste water In many cases the pollutants which occur during textile finishing are eliminated in biological waste water treatment works. The following list shows the core substances contained in textile waste water including important categories:

I. Relatively easily biodegradable:

- natural fibres and accompanying substances,
- sizes on the basis of starch (quantity problem),
- scour and rinsing agents with predominantly linear alkyl chains,
- acetic and formic acids,
- neutral salts in not too high a concentration.

II. Biologically difficult to eliminate:

- scour and rinsing agents with aromatic rings, long alkylene oxide chains or branched alkyl chains,
- synthetic polymers (some dressing agents, as well as sizes on the the basis of polyvinyl alcohol and polyacrylate),
- fibre preparations on a mineral oil basis, silicons,
- complexing agents, emulsifiers and softeners,
- some dyes and optical brightening agents.

III. Toxic to the biological treatment stage:

- mineral acids and alkaline lyes,
- active chlorine, chlorine dioxide,
- inorganic (sulphite-like) reducing agents,
- chlorinated organic solvents, e.g. as carriers,
- phenols and diphenyl derivatives in high concentrations,
- formaldehyde (toxic in first phase, then biodegradable),
- various other organic compounds or solvents,
- heavy metal compounds such as chrome-VI, mercury.

This list demonstrates that category allocation and therefore a targeted approach to waste water problems is only possible if, in addition to the brand designation of the products, the safety data sheets contain adequate details of composition and ecological properties. Without this information, vital preventive → Water protection measures are not feasible (choice of the right products, economical use, optimization of finishing processes) and waste water cleaning will have no chance of success. (according to Schefer).

Textile whiteness scale (textile whiteness standard, cotton whiteness standard), derived from the → Ciba-Geigy white standard. Division into 18 sections (each comprising 10 units) on a scale from 70 to 240. The lowest section of 70 is applied to max. bleached, non-brightened cotton and the highest level of 240 to intense white effects achieved with optical brighteners. → Whiteness scale.

Textometer Device for measuring moisture content of textiles which determines the residual moisture using the principle of conductivity. There are various versions of the device: easily transportable battery unit, universal device for monitoring processes as well as a version with electronic regulation for monitoring and automatic control of sizing machines, fabric driers and the like.

Texture Natural arrangement (structure) of crystallites in fibres, etc. Orientation phenomena exist in higher structural units (→ Micelles) and in → Macromolecules, such as occur in crystalline substances after plastic distortion and re-crystallisation. In contrast, there are also non-orientated regions when the crystalline micelles in the molecular structure do not show orientation effects. (Fig.). Relaxed, orientated polymers crystallize easier than polymers under stress.

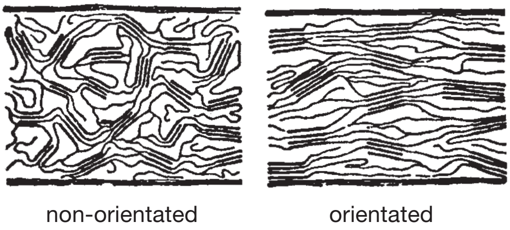


Fig.: Non-orientated and orientated network of cristalline and amorphous zones in polymers.

Where symmetry exists around an axis, this is known as → Fibre texture. Growth textures are the result of natural organization processes during growth which are familiar in the case of a number of natural fibres. Texture determination is carried out by means of X-ray interferences which directly reflect texture by intensity distribution. → Structural models for man-made fibres.

Textured fabric Fashionable fabrics for underwear, clothing and outerwear with raised or depressed waffle-like pattern effects (lace-like tied warp and weft threads).

Textured yarns (texture yarns, structured yarns). Generic term for yarns of mainly synthetic fibre filaments whose external structure is modified during or after yarn manufacture by means of mechnical, physical or chemical methods in order to create additional properties such as: increase in volume, more or less increased elastic twist, increased moisture regain, greater air content and therefore greater insulating capacity, gloss reduction, improved texture, avoid pilling. Chemical fibre filaments are usually used as fibre material (in addition to acetate, tri-acetate, cupro, viscose, mainly polyamide 6/6.6, polyester, polyacrylonitrile, modacryl). Special yarns made of natural fibre (e.g. → Slack mercerization of cotton) are less significant.

The extensive range of textured yarns makes it necessary to divide them simply into the following textured yarn types in accordance with their main properties of appearance and manufacture:

I. Stretch-yarns: highly elastic, stretchable to approx. 5-fold length, usually made of thermoplast threads with relatively low bulk (→ Helenca principle), preferable not doubled but in Z or S form. Produced mainly by means of real or false twist process, Klingen process. (→: Core spun yarns; Elastomeric fibres).

II. Crimped yarns: in addition to strong mechanical or chemically-created crimp, these are characterised by moderate elasticity and moderate to strong volume. Production particularly according to stuffer-box process, gear-wheel crimping process. (Bi-component yarn; in the case of bi-component thread material bulking is also by means of subsequent hot-air treatment in tumbler or in specialised dry-cleaning machine).

III. Bulked yarns: are characterised by high volume and therefore good covering power, combined with relatively low additional elasticity. Produced mainly by air jet technique.

IV. Types on the borderline of basic types I.-III, for example highly-elastic volume-yarns, elasticity-regulated (so-called modified) stretch yarns, high-volume crimped yarns and the like (e.g. →: Torque; Non-torque yarns).

BISFA definition of textured yarns:

- Dual-component yarn: textured yarn containing filaments which consist of two components (dual-component fibres).
- False twist bulked yarn: texture yarns treated with false twist process producing high crimp elasticity or crimp contraction.
- False twist yarn (set yarn): yarn treated with false twist process where a heat fixing process is carried out in a state of intermediate tension between complete relaxation and complete uncrimping.
- Yarns with variously shrinking filaments: textured yarn made of two groups of filaments with differing shrinking properties.
- Knit/de-knit yarn which is de-knitted after knitting.
- Torque-yarn: yarn with a strong looping tendency.

Texturing This term isused to include all process stages downstream of the actual texturing process. In the filament yarn sector these include:

- Intermingling: normally accomplished by air-jet techniques,
- Assembling: combination of multiple yarns with zero twist,
- Coning (winding): transferring the yarn onto a suitable carrier.

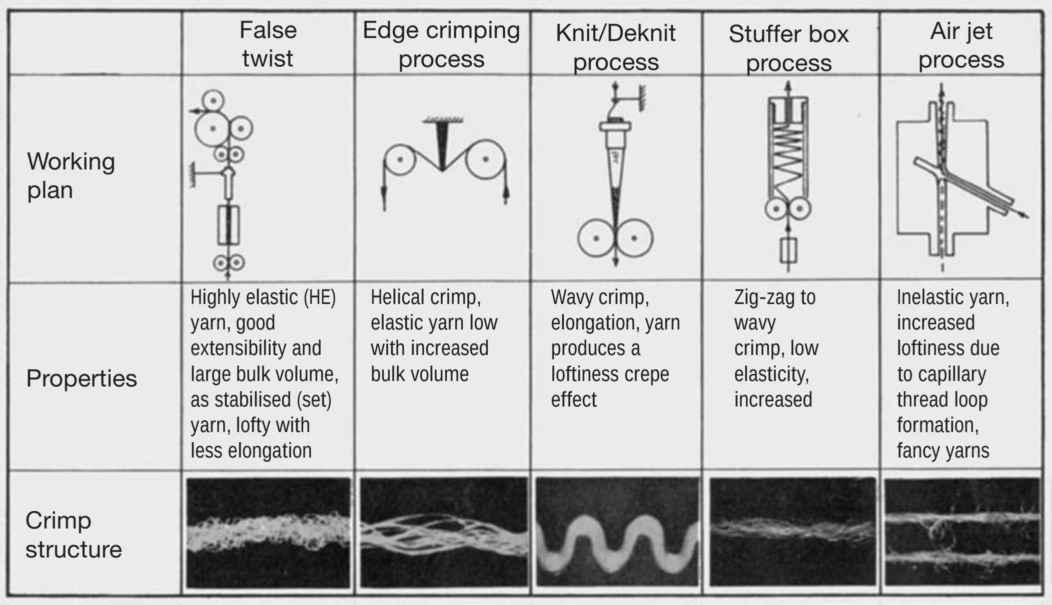
Texturizing The treatment of smooth filament yarns by permanently modifying the orientation of the molecular structure giving it more textile character. The changes to texturized yarns are: improved softness, volume and covering power, increased thermal insulation effects and an end-use required increase in elasticity. Thermoplastic filament yarns are particularly suitable for texturizing, i.e. yarns which are deformable under the influence of heat. These are mainly polyamide and polyester yarns. The most important texturizing processes are (Fig. 1):

- Twist-texturizing (including false twist): A filament yarn which has been twisted under the influence of heat is straightened again.
- Air jet texturizing: Yarn is crimped in a turbulent current of air (gas or steam).
- Knit/de-knit texturizing: Yarn is knitted, subjected to heat treatment and then de-knitted.
- Stuffer box-texturizing: Yarn is crimped by means of compression.
- Asymmetrical heat-texturizing: Contraction of the filaments on one side only is induced by asymmetrical heat treatment.
- Edge-texturizing: Yarn is pulled over an edge at an acute angle.
- Gear wheel-texturizing: Yarn is crimped between two sprockets.

Processes have been developed for the most commonly used twist-texturizing with which the texturizing procedure is combined with stretching.

Thermoplastic filament yarns are usually smooth when they have been spun and less well adapted to requirements than natural fibre yarns. The textile qualities of such yarns are improved significantly by texturizing procedures. Texturizing often increases the volume of the filament yarn by modifying the geometrical form of the filaments resulting in a certain elasticity in some cases which represents an advantage for the yarn. In the lower decitex range up to 300 dtex (frequently clothing fabrics, underwear and curtains) the false twist texturizing process is the predominant texturizing technique. This is mainly due to the economical nature of the technique but also to the elastic properties of the resulting yarn.

The false twist texturizing process (Fig. 2) is based on twisting the filament to a high-twist density and fixing this twist into the molecular structure of the filaments by heating and subsequent cooling in this twisted form. The yarn is then completely straightened. As the filaments and therefore their molecules have had a migrated spiral-form configuration, back-winding the filaments does not re-align the molecules. The filaments



	False twist	Edge crimping process	Knit/Deknit process	Stuffer box process	Air jet process
Working plan					
Properties	Highly elastic (HE) yarn, good extensibility and large bulk volume, as stabilised (set) yarn, lofty with less elongation	Helical crimp, elastic yarn low with increased bulk volume	Wavy crimp, elongation, yarn produces a loftiness crepe effect	Zig-zag to wavy crimp, low elasticity, increased	Inelastic yarn, increased loftiness due to capillary thread loop formation, fancy yarns
Crimp structure					

Fig. 1: Comparison of the most current texturizing processes.

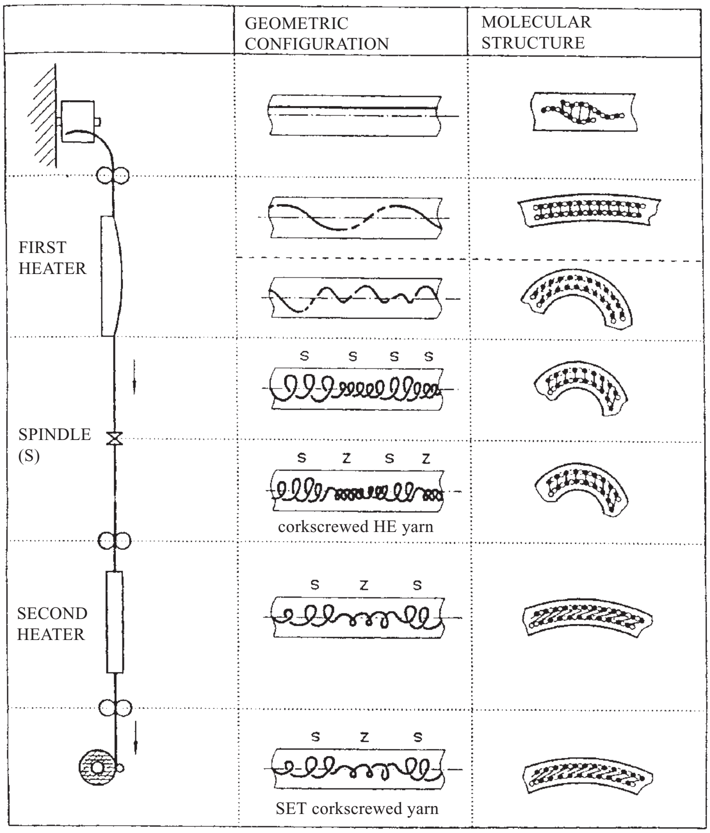


Fig. 2: Schematic illustration of the false twist texturizing process with the geometric and molecular structure of an individually texturized filament in different processing stages (according to Akzo).

have a tendency to move to the minimal energy level, i.e. to a spiral-form configuration. If they are not forced to open completely, the yarn assumes a voluminous structure. The volume of the yarns depends on the tension at which they are treated. This limited elasticity of the yarns coincides with the elastic properties and represents an advantage for certain applications such as for tights and elastic fabrics.

During its long period of development the false twist texturizing process underwent a spectacular transformation from a long multi-stage process to magnetic false twist texturizing at moderate speed and on to friction false twist texturizing at high speed. Most friction false twist texturizing processes now use a POY Feed pack (polyester, polyamide and polypropylene), stretch and texturize simultaneously at speeds of 800 m/min and, in some applications, at speeds of up to 1200 /min. The actual texturizing operation is completed after passing the false twist spindle. At this stage of processing the texturized yarn is voluminous and elastic. The process is, therefore, often known as HE (High Elasticity) or HB (High Bulk). As the molecules are aligned in a migrated, spiral-form structure, the outer filaments create a torque. This torque in the molecules creates a looping effect in the yarn which becomes visible when both ends of the yarn (or of a single filament) are fixed and the tension is reduced by placing the two ends together. The yarn or the filament will then assume its minimal energy level by creating a loop.

The looping effect of HE yarn is also considerable. This looping effect (Fig. 3) sometimes results in problems in the subsequent processing stages of textile production. Particularly in the case of applications for which high elasticity and volume are not important, volume and elasticity and therefore the looping tendency of the yarn are reduced by a subsequent setting operation. The HE yarn is fed with over-feed through a second heater in order to reduce elasticity and to increase the size of the diameter of the spirals which were fed into the first heater. This results in reduction of the volume, the elasticity and the looping tendency of the texturized yarn.

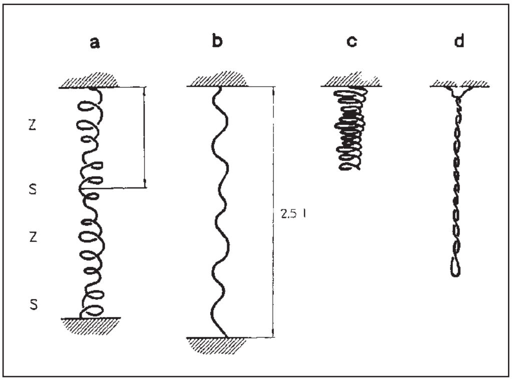


Fig. 3: Model of a single texturized filament (a), stretched filament and formation of internal torque (b), texturized filament free on one side: theoretically balanced out, minimal energy level (c), curled-up texturized filament: balanced out and with minimal energy level (d).

The individual filament of a texturized yarn can be regarded as a fine spring with variable diameters along its length. The yarn is produced in such a way that both ends are fixed. As a filament is a flexible element, the torsion is compensated by reversal of the spiral direction. When such as filament is pulled apart it assumes the form shown in Fig. 3b. Strong torsion also occurs in the filament. If an end of this filament is free it rotates and contracts until all the torsion has been compensated. If both ends are placed together without letting one end rotate freely, the torsion is compensated by a loop.

Texturizing oils In order to ensure a sufficiently low friction coefficient when processing textured yarns on knitting machines, texturizing oils are applied to the threads either on the texturizing machine before spinning or during unwinding on the precision-wound package machine. Thread speed and thread tension fluctuations caused by different upper and lower yarn package diameters on the precision-wound package machine result in correspondingly differering texturizing oil absorption by the thread on the lick-roller which can lead to uneven distribution of texturizing oil within the yarn package body (local differences up to approx. 1 : 3). This variation in texturizing oil distribution within the yarn package is already present after winding has been completed and therefore cannot have originated as a result of texturizing oil migration. As no noteworthy changes in texturizing oil distribution are to be found after long storage periods, it can be concluded that migration does not take place at all but that local accumulation of texturizing oil in packages is caused by corresponding thread speeds and tension conditions. On the other hand cylindrical direct winders and texturizing machines, in which only periodical thread speed and tension differences occur, show even texturizing oil distribution.

TGL Technical standards, quality regulations and delivery conditions (Technische Normen, Gütevorschriften and Lieferbedingungen) of the former German Democratic Republic.

Th Element symbol for thorium (90).

Thermachrome process (thermacrome process). Transfer print process for transfering paper prints in up to 4 colours onto synthetic fibre textile piece goods. The paper is printed with thermoplastic pigment print pastes which are transferred onto the textile material on passing a heated calender. This process is limited to the printing of labels and emblems.

Thermal (Gk.: thermos). Concerning heat.

Thermal analysis Thermal analysis uses sensors to monitor changes in polymers during thermal treatment. Differential Scanning Calorimetry (DSC) is one of the processes used in thermal analysis. With this process conversion temperatures and heats can be determined in a relatively simple way. The principle of the DSC process is that two pieces of test material are heated together. A temperature regulator ensures that both pieces of test material always have the same temperature (iso-thermal trial management). When the test material reaches a conversion point either more or less heat must be added to it than to its counterpart depending on the type of conversion. This is registered by a recorder which records ΔQ as a function of time (see Fig.). Thus an exothermic peak appears in the case of crystallisation processes and an endothermic peak in the case of melting processes. Glass conversions require a modification of c_p; this is shown in the thermogram as a displacement of the base line. (The base line corresponds ΔQ = 0. It should ideally be horizontal.) As the heat capacity also changes during the melting and crystallization process, a displacement of the base line also occurs here.

Determination of the thermo-dynamic dimensions of polymers encompasses:

1. Glass point: As the temperature is recorded as a function of heating rate, it follows from the equation:

$$\frac{dQ}{dt} = c_p \frac{dT}{dt}$$

that displacement of the base line in the thermogram corresponds to Δc_p; therefore Δc_p can be determined simply from the thermogram.

2. Melting of the crystals: as polymers do not have a sharply-defined melting point the melting range is quoted in their case. The melting enthalpy can be determined in accordance with the following equation:

$$\Delta H_u = \frac{K \cdot R \cdot A}{m \cdot S}$$

ΔH_u = conversion enthalpy
K = equipment constant
R = sensitivity
A = peak surface
m = contents
S = paper speed

Another thermal analysis process is Differential Thermal Analysis (DTA) which functions adiabatic (ΔQ = 0). This process records against temperature the temperature differential which occurs upon conversion between the two pieces of test material. The evaluation process is rather more complicated than in the case of the DSC method.

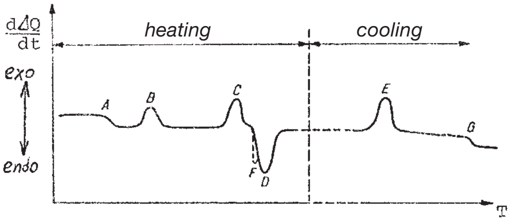


Fig.: Thermal effects of physical transformation of high polymers (in diagram form).
A = glass transformation; B = cold crystallization; C = premelt crystallization; D = melting; E = crystallization; F = disorientation of crystalline zones; G = glass transformation upon cooling.

Thermal balance → Heat balance.

Thermal conductivity coefficient → Heat conductivity.

Thermal conductivity coefficient of textile fibres Whereas heat conductivity in liquids and gases is a diffusion phenomenon, in the case of solid substances it is based on interaction with neighbouring oscillating molecules and the forces involved (→ Absorption). Thermal conductivity varies enormously according to the type of substance, metals having the highest, and gases the lowest, as only relatively few molecules are available for energy transporation within the unit of space. This is why textile materials which have a high air content are characterised by low thermal conductivity. The technical thermal conductivity (λ) indicates the quantity of heat which flows through two opposite surfaces of a cube of 1m edge length per hour when the temperature difference between both surfaces is 1°C (→ Heat retention).

Thermal conductivity in W/m · °C:

glass	1.000
polyethylene	0.337
polypropylene	0.221–0.302
polyamide	0.209–0.290
m-Aramid	0.128
viscose (filament)	0.071
viscose (spun fibre)	0.063
asbestos	0.058
cotton	0.058
triacetate	0.058
acetate	0.050
polyester	0.046–0.081
wool, silk	0.046
air	0.025

Thermal disinfection Disinfection by means of direct heat ; 5 min at 30°C in the pre-wash phase, 10–20 min at 85–90°C followed by clear-wash cycle. → Disinfection washing of textile.

Thermal imaging camera,

I. The measurement procedure of the thermal imaging camera is based on the principle of heat radiation detection. The infrared radiation given off by bodies and media is detected with an HgCdTe-photo-semiconductor and the digitalized infrared images are recorded with a video recorder or represented in colour or grey shades on a monitor. Thermal imaging cameras are used anywhere where heat radiation can indicate a defect or inadequate processing. A thermal imaging camera can, therefore, just as well ascertain a burst pipe in a wall or a badly-insulated window as it can a heat leak in a stenter frame, permitting heating costs to be reduced in each case.

II. The measurement system of the thermal imaging camera is based on the infrared radiation of an object being recorded by means of an infrared optical system and suitable semi-conductor sensors (mercury-cadmium-tellerium) in the context of time and position. By comparison with an internal reference source in the camera absolute temperature measurements are possible allowing direct analysis of dynamic and static thermal patterns. As the camera records a representation of the temperature distribution of the entire surface, this process is also known as thermography. The representation is made in false colours, i.e. a certain colour is attributed to each temperature which can be observed on a monitor in an image-like representation. With the aid of infrared optical system selector the resolution capacity of the system can be varied from microscopic applications to the recording of entire landscapes. For technical measurement with the thermal imaging camera the measurement data is transferred to comprehensive infrared image processing computer software (CATS Computer Aided Thermography Software). In addition to false colour representation, dynamic point measurements and temperature profile representations are also possible.

This feature makes a thermal imaging camera with a computer-aided evaluation unit very well suited to registering the entire thermal pattern of a length of textile in the exit area and to recording temperature profiles or cooling down properties at designated points.

Conclusions can be drawn from such analyses regarding the influence of the cooling down conditions on the properties of the textile (Schollmeyer).

Thermal post-combustion (TPC) Combustion of substances contained in exhaust air takes place in accordance with the following reaction:

$$C_n \cdot H_m \cdot O_x + \left(n + \frac{m}{4} - \frac{x}{2}\right) \cdot O_2 = n\,CO_2 + \frac{m}{2} H_2O$$

If air is the source of oxygen, nitrogen oxides $(NO)_x$ result from the nitrogen in the air. As the concentration of the harmful substances in the exhaust air is far below ignition point, automatic combustion of the harmful substances in the exhaust air is not possible. In order to ensure that the above-shown reaction occurs, it is necessary to increase the temperature level of the exhaust air (usually between 700°C and 800°C) and to keep it at this temperature level until the reaction is complete.

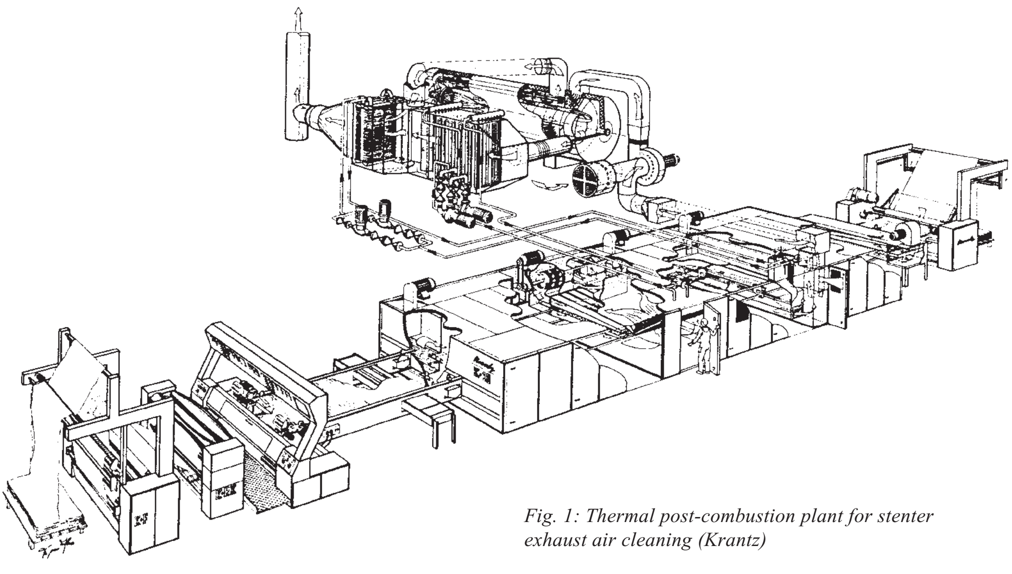


Fig. 1: Thermal post-combustion plant for stenter exhaust air cleaning (Krantz)

Additional fuel is, therefore, necessary to achieve higher temperatures (Fig. 1).

The production of CO_2 is problematic in terms of global warming. There are limitations to possible energy recovery when using heat exchangers. For example it is practically impossible to construct heat exchangers with a thermal efficiency of more than 70%. If, for example, a flow of exhaust air is to be combusted in a TPC at 750°C, pre-heating of the exhaust air to more than 550°C is not achievable using a recuperative heat exchanger. In order to maintain the desired 750°C it is, therefore, necessary to add energy to the process in the combustion chamber until the exhaust air flow is increased from 550°C to 750°C. The cleaned exhaust air then leaves the TPC at a temperature of approx. 230°C higher than the input temperature.

The reaction temperature of TPC can be reduced with special catalysts. Pure oxygen can be used instead of air in order to eliminate $(NO)_x$ production and to achieve higher combustion temperatures.

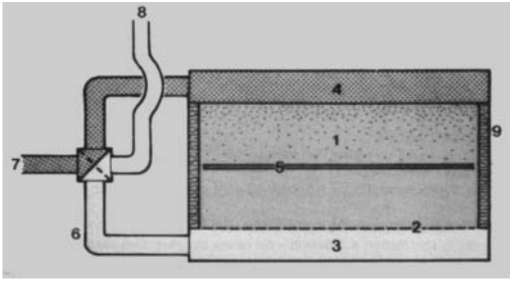


Fig. 2: Principle of the Combu-Changer (Kraftanlagen Heidelberg AG).

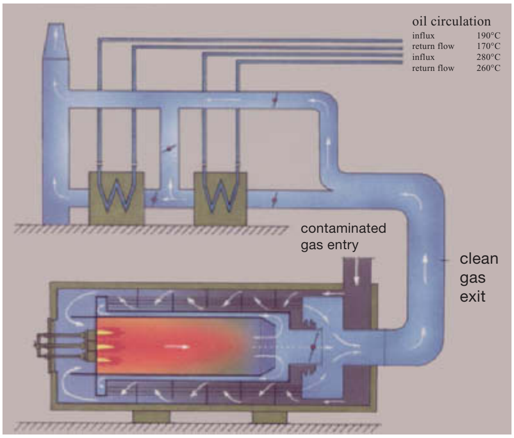


Fig. 3: Recovery of heat energy from the waste gases cleansed by post-combustion.

The Combu-Changer principle (Fig. 2) uses a different method of eliminating $(NO)_x$ production. The Combu-Changer consists of a layer of shingle which is heated electrically in the centre. When it is put into operation the shingle bed is heated electrically over a period of several days without admitting air. The exhaust air to be cleaned is then conducted to the shingle bed from one side. The exhaust air is heated to approx. 1000°C as it passes the shingle bed. This temperature is far above the reaction temperature of the harmful substances which is between 700–750°C. The advantage of this process is that there is no open flame so that nitrogen oxides and carbon monoxides practically do not occur. The volume of the shingle bed is chosen so that the temperature difference between the shingle bed and the air is never greater than 20°C. The exhaust air is heated in the first layer of shingle as it passes through and reaches the necessary temperature for converting hydrocarbons into CO_2 and H_2O in the centre of the shingle bed. Then the cleaned exhaust releases its heat to the second layer of shingle which it now passes through before being conducted to the outside. In order to prevent displacement of the temperature profile and therefore reduction of the max. shingle bed temperature the flow direction of the air through the shingle bed is changed every 90 seconds. When the combustion reaction takes place exothermically, the electrical heating energy can be switched off after a certain time since the process is running of its own accord. Pollution of the exhaust with 0.7–0.8 g/m^3 is adequate to compensate for the consumed temperature difference of 20°C depending on the heat value of the harmful substances. When using TPC it is always advisable to recover the surplus heat from the cleaned exhaust (Fig. 3).

Thermal resistance Capacity of textiles to retain the heat of a covered body.

Thermal shock Heat treatment at 200°C:

I. Thermo-stabilization of synthetic fibres within 1 second.

II. Rapid fixing of dyes (particularly of reactive dyes) during printing and continuous dyeing within 20–60 seconds.

Thermal stability →: Thermal stability of dyes; Thermal stability of fibres.

Thermal stability of dyes Thermal stability when subjected to contact heat (ironing, fixing, drying), hot air (fixing, drying) and steam (steaming, decatizing, pleating).

Thermal stability of fibres The impact of dry heat can bring about changes to fibre properties, the extent of which depends on the specific thermal stability of the fibre (heat stability) as well as the duration and temperature of treatment. As not only recognizable changes in chem. and technological properties, such as yellowing and greying, can be effected, it is advisable to check for other non-visible signs of temperature impact. This applies particularly to synthetic fibres (→: Softening range; Melting point).

Thermal value Specific thermal value based on the relationship between mass, volume, molar thermal value and the fabric quantity. Particularly important when comparing energy source data. Indication in Joule/unit (J/kg, J/m^3, J/mol).

Thermal value of fuels Thermal value indications are generally made as “lower thermal value” H_u. The “upper thermal value” (combustion value H_o) is of lesser practical value as the condensation heat of the steam produced on combustion of fuels containing hydrogen is included which is practically not useable. When calculating the thermal value of different fuels it is important to take care that they are based on either thermal or combustion value (Tab.).

	thermal value H_u	combustion value H_o
solid fuels [kJ/kg]:		
– hard coal (Ruhr)	35 000–35 400	36 000–36 250
– anthracite (Ruhr)	35 275	36 000
– coking duff	33 100	33 225
– coalite	32 700	33 300
– brown coal	26 000–26 800	27 450–28 300
– brown coal briquettes (Rhineland)	25 775	26 800
– wood (firewood)	18 850	20 100
liquid fuels [kJ/kg]:		
– benzene	43 500	46 925
– paraffin	43 350	46 500
– heating fuel oil EL	42 750	45 675
– heating fuel oil S	40 650–41 000	43 150–43 575
gaseous fuels (liquid gases) [kJ/m^3]:		
– n-butane	123 725	133 650
– propane	93 000	100 775
– propane	46 400	50 275
– n-butane	45 775	49 450
– natural gas (NAM)	31 850	35 200

Tab.: Thermal value and combustion value of various fuels.

In the case of liquid fuels it is advisable to note whether quotations indicate the thermal value in J/kg or J/l (approx. 10% lower thermal value).

Thermo-balance The so-called thermogravimetric method is used mainly for determining water and moisture on the basis of the weight loss of a specimen which has been dried using heat. The specimen to be investigated is placed on the thermo-balance and dried using infrared heat. Penetration of the material by heat radiation causes the moisture to evaporate rapidly and this process can be monitored with the aid of the balance. When the evaporation process is complete, the moisture content of the specimen can be established. Specimens can, of course, be examined for substances other than water content. Other substances which evaporate easily can be determined gravimetrically. Using high steam pressure it is possible, for example, for material to be examined for substances adhering to it which have been left after finishing processes.

Thermobonding Increasingly stringent demands on the quality of non-woven products and the requirement for more and more rapid production speeds make optimum production lines a necessity. Fleece strengthening using calenders, known as thermobonding for the sake of brevity, is one of the processes principally applied for economic production of quality fleeces. This process is becoming more and more widespread. It is based on the two physical elements of temperature and pressure. It is important that both elements can be adjusted in optimum fashion as this ensures the best possible quality of the final product which can be characterised by

- strength in lengthwise and transverse directions,
- elasticity in lengthwise and transverse directions,
- handle
- appearance.

Pressure and temperature cannot be chosen at random. Also too low a pressure cannot be compensated by high temperature or vice versa. Optimum pressure and temperature depend on the fibre material used, production speed, diameter of the rollers (Fig. 1) and also on the engraving. It is only possible to ascertain the optimum combination of pressure and temperature by means of intensive experimentation and on the basis of extensive experience. Heat transfer from the thermo-oil to the roller improves at higher oil speed. This achieves efficient heat transfer. It is also important for the oil flow to be distributed absolutely evenly over the width of the roller in order to reach the same temperature. This requirement is met by so-called peripheral-bore rollers which are equipped with several oil boreholes around the circumference of the roller. The oil makes it possible

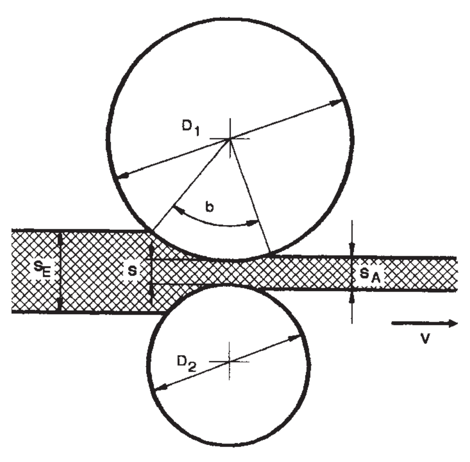


Fig. 1: Contact with heavy nonwovens.
s = roller press slot; s_E = thickness of nonwoven upon entry; s_A = thermobonding thickness.

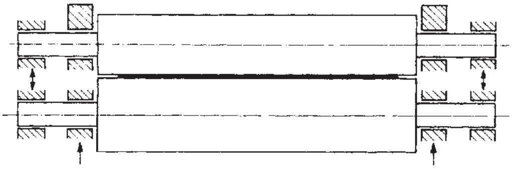


Fig. 2: Flex compensation through roll bending.

to achieve an even temperature which can be adjusted rapidly. It is important to install a bending compensation system (Fig. 2) in which no temperature differences occur by means of heat losses, for example to an appropriate support roller which cannot be heated to such a high temperature. Each roller is bent as far as possible by the pressure in the gap. If this effect is not compensated, a lower gap pressure results in the centre of the roller than at the outside edges. Several principles are used in technology to compensate for this effect:

- roller lapping,
- axis distortion,
- hollow roller charged with interior pressure,
- roll bending,
- hydraulic elements inside a hollow roller.

The lapping of a roller is certainly the simplest and most effective procedure but is only suitable for a certain line pressure. In the case of axis distortion, the roller axis is crossed by means of lateral displacement of the main bearings resulting in an increase in the size of the gap at the extremities. In the case of the hollow roller with interior pressure, partial compensation of the bending line occurs. Bending of a roller due to constant gap pressure and compensation with a hollow roller cannot be expressed by the identical function. This means that compensation can only be achieved to a limited extent. The so-called W or M profile occurs as a result of overlaying of the two curves. In the case of roll bending, (Fig. 2) bending compensation is achieved by means of an overlayed bending moment positioned from the outside. Compensation is, therefore, purely mechanical.

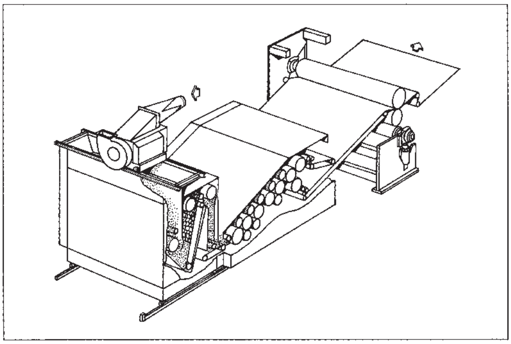


Fig. 3: Diagram showing the course of the thermobonding nonwoven device by the Hergeth-Hollingsworth system.

Efficient thermobonding systems include fibre mixing, fine opening, card (preferably random fleece card), thermobonding calenders and a winding device. Fig. 3 shows the Hergeth-Hollingsworth system with a processing width of 3.5 m and a max. production speed of 150 m/min for fleece layers of approx. 20 g/m^2. The process makes extreme demands on fibre preparation.

Thermochrome pencils A range of different pencils for temperature measurement in the range of 65–670°C. Each one has a specific temperature-dependent colour-turning point whose colour pattern is recorded on the pencil. When applied, for example, to steam conduits, calender rollers and irons, a coating is formed which can be removed quickly by wiping it off. Colour transformation within approx. 1–2 seconds corresponds to the testing temperature whilst delayed colour transformation indicates a lower temperature.

Thermochromism Often significant, reversible change of colour shade brought about by an increase of temperature which, in the case of certain dyes, is of adequate duration to represent a problem, for example during drying, thermo-fixing, steaming and ironing. In the narrower sense thermochromism is the result of the occurrence of long-wave chromatic bands in the visible spectral range. The cause is assumed to be a temperature-dependent → Trans-cis-isomerism of dyes, facilitated by an increasingly polar molecule structure. It is present in the azo-naphthol types due to a temperature-dependent displacement of azo-hydrazone tautomerism. Thermochromism is taken into account, for example, when testing ironing fastness in accordance with DIN 54 022, when a colour shade is assessed after heat application and after a certain recovery phase.

Thermocolour markers (temperature measuring pencil). Usually metal salts of complicated structure whose colour change at certain temperatures is based on oxidation or separation of water, carbonic acid and ammonia. Temperature measuring dyestuffs are also used as measures of heat radiation.

Thermocouple, thermoelement Principle of a bimetallic strip which, by heating its connecting solder or welding points, creates a measurable thermocurrent, the voltage of which increases with increasing temperature. With a copper and constantan thermoelement (which is used for temperature measurement and regulation up to temperatures of 350°C), a temperature change of, for example, 20°C corresponds to a voltage change of a millivolt. Used for example in → Pyrometer or → Total radiation pyrometer.

For determining the temperature on or in a textile test piece, miniature jacket thermoelements are used with the thermopair combination nickel-chrome, nickel-aluminium (NiCr-NiA1). The diameters of the jacket

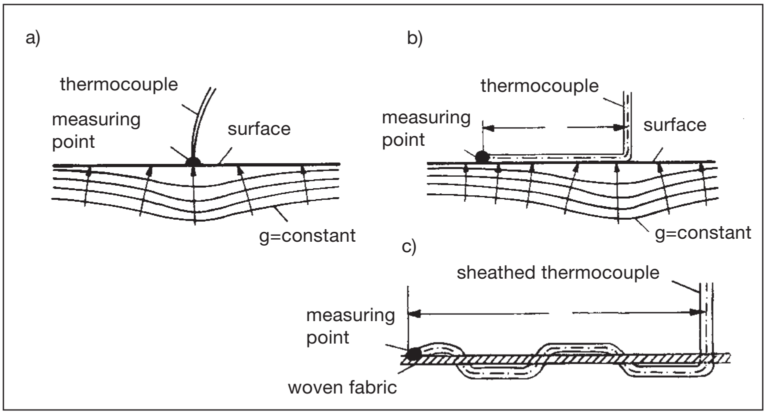


Fig.: Mounting a thermocouple (thermo-element) on textile fabrics (DTNW).

thermoelements are 0.25 mm, 0.5 mm and 1.0 mm (according to DIN specifications). The connection between measurement test price and temperature sensor has to be adapted to suit the measurement in question. In order to ensure optimum heat transfer between the test piece and the temperature sensor (this applies in particular to bodies with a high specific surface), the sensor is pressed onto the test piece so as to promote heat conductivity. The Fig. shows the impact of the supporting length of the thermoelement on the temperature field. This impact lessens with decreasing diameter of the thermoelement and increasing supporting surface.

Due to bending tensions the tip of the thermoelement, i.e. the actual measuring point, is pressed firmly onto the fabric and, in the case of thicker fabrics, penetrates the yarn composition. The thermoelements are connected to a measurement converter with zero point and measurement range adjustment. This measurement converter provides an analogue output signal of 0–1 V which is directly proportional to the temperature. The measurement signal is registered on a multi-channel recorder together with the measurement signal of the radiation pyrometer (partially in accordance with Schollmeyer et al.).

Thermocracking Dyestuff constitution based phenomenon caused by certain reactive dyes by which the wet-fastness values of a dyed or printed material are significantly impaired after thermal treatment. Thermocracking is caused by splitting the ether or ester binding of the dye to the cellulose fibre and is most in evidence in ester-bound dyes.

Thermodynamics Thermodynamics is an important principle of natural science as it describes the equilibrium of a system. Thermodynamic concepts therefore occupy an important place in ecology as well. A knowledge of thermodynamics is particularly necessary in order to answer the question of whether and in which direction a system can develop and what its stable final condition will be (see Fig.).

Whether it is a gas (ideal or real), liquid or solid, a thermodynamic system can be described by means of condition equations and condition functions which depend only on the initial and final condition. Condition functions (thermodynamic potentials) include inner energy U, enthalpy H, free energy F, free enthalpy G and entropy S. The system can be regarded macroscopically. This involves describing the named system by means of macroscopically-measurable system characteristics and their connections. This is known as phenomenological thermodynamics, which is the oldest branch of thermodynamics. The system can also be regarded microscopically. This involves attributing the macroscopic system characteristics to the interaction of the system components (atoms, molecules). The statistical methods of classical and quantum mechanics are used to describe phenomena. Thus, for example, the kinetic gas theory explains the origin of gas pressure and makes possible a deeper understanding of the concept of temperature. Or, with the aid of statistics, thermodynamic potentials can be derived from which all condition dimensions and material properties (e.g. specific heat capacity) result.

A thermodynamic system can be in a state of interaction with its environment. If no exchange of energy and mass takes place across the system boundaries, the system is closed. If only energy ΔW (e.g. mechanical, magnetic, electrical energy) is exchanged, this is known as an adiabatic system. With closed systems an exchange of energy ΔW and heat ΔQ takes place and with open systems an exchange of mass takes place as well.

The primary basic law of thermodynamics, that of energy conservation, states: energy can neither be created nor destroyed. In an isolated system, in which neither energy nor material exchange with the environment takes place, the overall energy content is constant. The energy occurs in various forms which can be transformed into each other. Energy forms are, for instance,

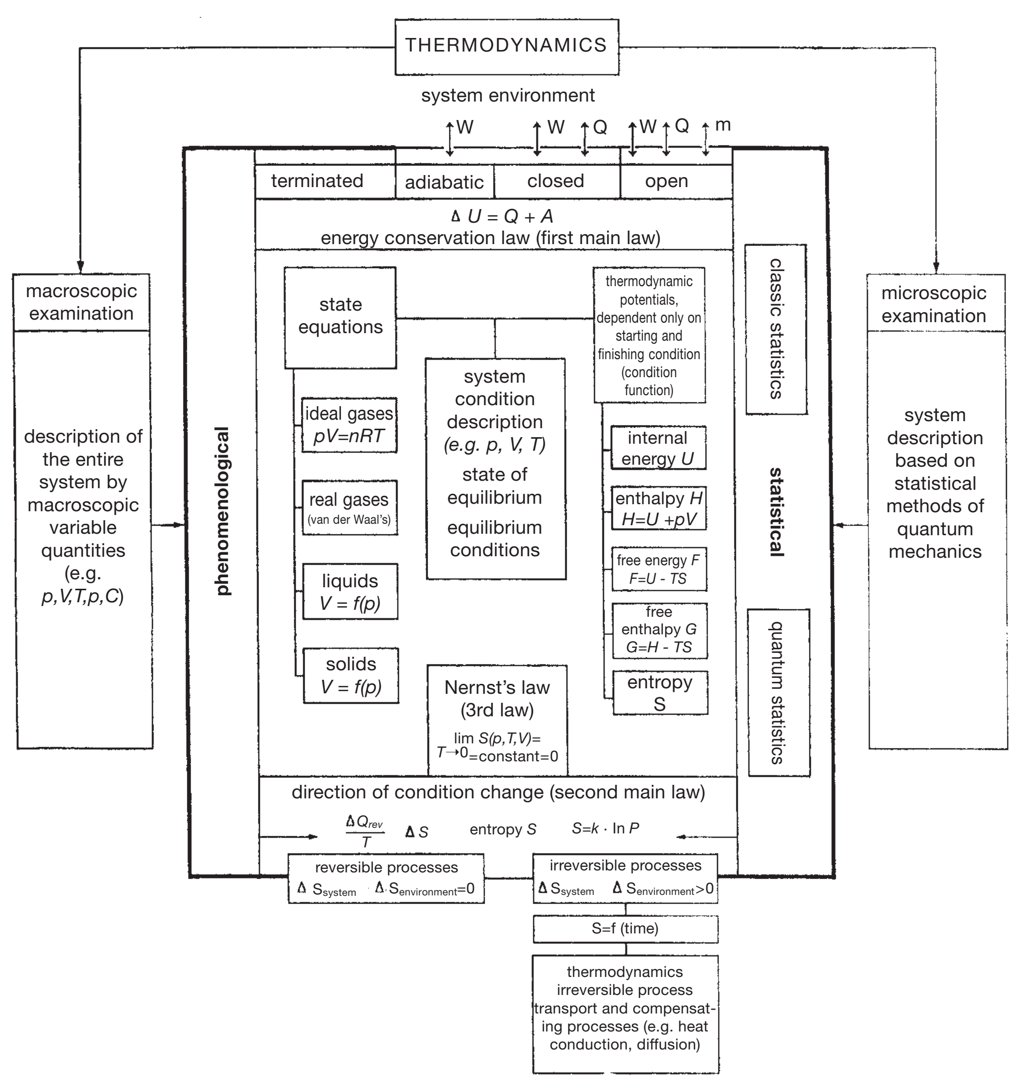


Fig.: Thermodynamics.

mechanical energy (kinetic and potential), electrical energy, light, chemically-stored energy, work or heat. According to the primary basic principle (and the mass conservation principle) the world's resources can never run out. If enough energy was expended, all substances could be recovered from waste materials. There are, however, limitations to energy transformations in physical or chemical processes.

The second basic law of thermodynamics describes the direction in which a certain energy transformation takes place of its own accord. With each energy transformation part of the energy is transformed into a (theoretically and practically) no longer usable energy form. What changes during energy transformation, therefore, is the further usability of the energy. As opposed to the substance cycles in an ecological system, there can be no energy cycles, as according to the second basic law energy recycling is impossible. With the concept of entropy, the second basic law states how the direction of condition changes. The entropy change is zero in the case of reversible processes; in the case of irreversible processes it is positive, i.e. the heat is not completely transformable into other energy forms. Among the irreversible processes of thermodynamics, transportation and compensation processes are of particular practical significance. Entropy S can also be interpreted microscopically as a probability function (logarithm of condition probability ln P multiplied by the Boltzmann-constant k). Condition changes will take place in the direction of max. probability (max. entropy). The third basic law (Nernst) shows that entropy becomes constant when the temperature approaches the absolute zero point. This constant is equated to zero. It also follows from the third basic law that the absolute zero point (T = 0) cannot be reached. As a result of the influence of technology and civilisation, ecological systems can be so far removed from a state of balance that they react to small interferences in an unpredictable way. The further a system is removed from a state of balance, the more rapidly the processes take place and the more entropy is created per time unit (according to Hering, Martin and Stohrer as well as Kummert and Stumm).

Thermofixation and thermosol process (TT-process). One-stage continuous process for dyeing fabrics made of polyester/cotton mixture using disperse and reactive dyes in which the reactive dyes are only bound to the cellulose in the presence of polar substances which facilitate their diffusion into the fibre interior. It is preferable to use dicyandiamide rather than urea for this process as it permits fixing of the reactive dye without alkali. If urea is used the process takes place as follows: Pad with dye, urea, alkali (sodium hydrocarbonate) and with further additives depending on the dye, → Thermosol fixation and Washing off.

Thermofixation of disperse dyes on polyester Mechanism of solid solution of the dye in the substrate in which hydrotropic substances in the print paste actively promote the endothermal process. At the high fixation temperature they also form a fluid paste which dissolves the dye particles and facilitates transportation to the surface.

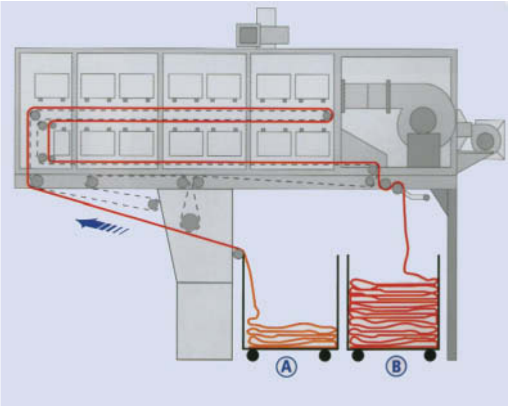


Fig.: Heat setting/thermofixing.

The above advantage offers the possibility of a normal drying and a heat setting or thermofixing of dyestuff if needed. The above is carried out independently from the next printing cycle. As shown in the Fig. during the a.m. process the cloth from A goes through the drier and is collected at B (Viero).

Thermoflush Procedure for shortening the rinsing process for reactive dyeing by means of intermediate steaming several times, thereby reducing water consumption.

Thermofusion Procedure whereby dry fleeces are completely bonded just by means of heating and subsequent cooling, e.g. → Spot-bonded nonwovens. The bonding of nonwovens of bi-components and other fibres or fibres mixtures is carried out using thermofusion systems, in every case using only hot air without steam or binders.

Thermograph (temperature recorder). A recording thermometer which functions on the principle of the bimetal thermometer. The movements of the bimetal strip are transferred to a recording lever which records temperature flucutations on a registration drum. The thermograph is used for uninterrupted recording of the temperature in drying systems and air-conditioned rooms.

Thermogravimetric analysis (TGA). Procedure for investigating flameproof textiles. The weight reduction of a test piece is determined at increasing temperature (until decomposition).

Thermohydrograph Device for uninterrupted recording of temperature and air humidity.

Thermolabels Self-adhesive thermopapers, coated with plastic, printed for 37.8–260°C and for five temperature ranges in 8 different arrangements (reaction speed: 2–5 seconds).

Thermomechanical analysis (TMA). In many finishing operations fibres are subjected to one or more thermal treatments. During these treatments, not only the finishing chemicals are fixed but massive structural changes can take place in the fibres as well as changes in the mechanical properties of the fibres. TMA attempts to simulate these processes. Fibres are measured for strength and elasticity in a controlled heating chamber (Fig. 1). This type of simulation is important to ascertain the influence of fabric tension on their heat setting effect (Fig. 2) (according to Berndt).

Thermometer Thermometers are divided into:

I. Glass thermometers with liquid filling: a) mercury column surrounded by a vacuum (measuring up to 100°C), also available as rod and angle thermometers (for drying rooms, boilers, heating system pipes) and as tele-thermometers (for calenders, drying systems, washing machines); b) as listed under a) but, instead of vacuum, high-melting glass with nitrogen, hydrogen or carbon dioxide under pressure (prevents mercury evaporation, measuring up to 750°C; c) particularly for

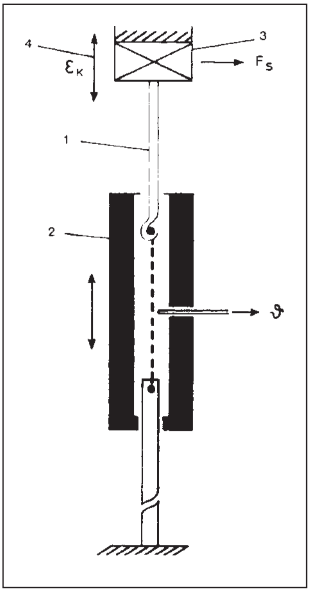


Fig. 1: Thermomechanical analysis diagram of a unit for shrinkage force measurement (Berndt).
1 = clamping unit with measuring sensor; 2 = heater unit with thermocouple for recording room temperature; 3 = force transducer for recording shrinkage force F_s; 4 = possibility of applying specific shrinkage methods ε_k.

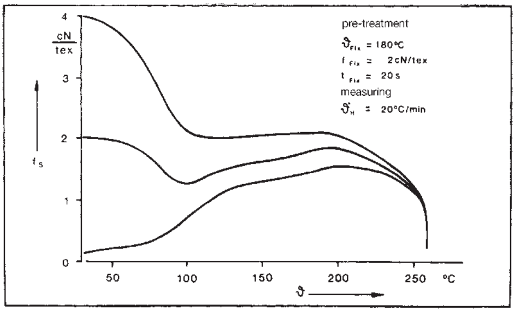


Fig. 2: Thermomechanical analysis of PES filament yarn shrinkage force measurement. Effect of pre-tensioning at the start of measurement on shrinkage force behaviour (Berndt). f_s *= count-related shrinkage force;* J *= measuring temperature;* J_H *= rate of heating;* J_{Fix} *= setting temperature;* f_{Fix} *= count-related setting tension;* t_{Fix} *= setting duration.*

wide measuring ranges by means of other fluids such as, for example, toluol (–90°C to +100°C), ethanol (–110°C up to +40°C) and pentane (–200°C up to +20°C).

II. Spring thermometers: a) indicator thermometer with metal spring as temperature meter and face (also available as tele-thermometer); b) tensions thermometer with liquid filling and tubular conduit in the heat sensor, indicating and registering with tele-conduit or contact device (controls relay and signals), frequently used in, for example, dyehouse, boiler plants.

III. On thermo-electrical principle: a) thermo-elements; pyrometers; b) so-called surface thermometers (for drying cylinders and other heated rollers, also available as tele-thermometers).

IV. Resistance thermometers: Measurement of electrical resistance of a platinum wire located in the submerge tube (increasing resistance with increasing temperature), direct temperature indication up to 1000°C, both registering and tele-transmission, also for light mains connection.

V. Electronic surface thermometers: Heat-sensitive sensor with germanium semi-conductor, the resistance value of which changes almost instantaneously with temperature, impacting on the anode flow of an electron tube and visible on the indication instrument within 2–3 seconds of operating the switch. Various portable models with measuring ranges of –10°C to +210°C, battery-operated.

Thermometer papers Paper strips or rolls with heat-sensitive covering (also self-adhesive) in series of varying heat degree gradations (37.8–254°C). At a certain temperature each strip changes its colour from white to black instantaneously and constantly at a quoted reaction speed of ±1% of the standard value.

Thermomigration Desorption in the form of migration of dyes, particularly of disperse dyes on polyester under the influence of dry heat and in the presence of surfactants.

For thermal post-treatments, e.g. for drying, post-fixing and finishing of dyed polyester fibres, disperse dyes can migrate to the fibre surface and accumulate on it. Thermomigrated disperse dyes are no longer fixed and can, therefore, drastically reduce the fastness of previously perfect dyes. The change in fastness depends not only on the quantity of thermomigrated dyes but also on their affinity for white accompanying fabric under fastness-testing conditions. If standard accompanying fabrics are treated with dye additives under test conditions, it will be found that even small amounts of additive result in staining, rating 2–3 on the grey scale. If these dye quanitites are related to dyeings in 1/1 standard type depth, it becomes evident that a non-fixed proportion of 1% of the total dye applied can reduce wet fastness by 2 scale points. These results are of particular significance for selection of dye. It is not sufficient to select dyes which have low migration properties during thermal treatment on the basis of a one-off test and which are not absorbed or only slightly absorbed by white accompanying fabric during fastness testing.

As small quanities of non-fixed or low-fastness dyes can reduce fastness by several scale points, it is necessary to ensure that the selected dyes are regularly (on delivery-to-delivery basis) free of less fast auxiliary components or shading dyes.

Disperse dyes for polyester fibres generally demonstrate low solubility in water which only increases within limits at higher temperatures. Absorption rate, affinity to the fibre and diffusion rate are also important. A measure of the affinity of a dye is the distribution co-efficient between fibre and dye-bath

$$\text{Distribution coefficient (K)} = \frac{\text{Dye concentration in the fibre } (C_F)}{\text{Dye concentration in the dye-bath } (C_B)}$$

The disperse dye dispersed in water is in equilibrium with the part that is dissolved in water and this again is in equilibrium with the part which is absorbed by the fibre surface, which in turn is in equilibrium with the part which is dissolved in the fibre and has dispersed in the fibre interior.

Generally the following procedure can be assumed for levelling:

a) diffusion of the dye at the fibre surface;
b) desorption at the fibre surface;
c) solution of the dye particles in water and migration to the surface layer fibre/water;
d) renewed adsorption at the fibre surface;
e) diffusion into the fibre interior.

The slowest step is stage b), i.e. the desorption rate could be a measure of migration. The levlling capacity regularly decreases independently of the dye constitution with increasing distribution coefficient (C_F/C_B). Dyes level most readily with a distribution coefficient of less than 700. However, these dyes are not adequate in terms of exhaustion rate and sublimation fastness. Dyes with a higher distribution coefficient must be applied at increased temperature or in the presence of carriers. Dye dispersion in the dyebath is in equilibrium with a saturated solution of the dye. At a dyeing temperature of 120–130°C, the dispersed dye can disperse more intensively into the aqueous phase. If this dye is not totally exhausted during the dyeing process, the solution can tend to crystallize when cooling down. The dye crystals can settle on the fibre with low rub fastness results. A significant increase in particle size (risk of recrystallization) can occur with many disperse dyes due to an excess levelling agent in the dyebath. It would, therefore, appear to be more advisable to dye at 130°C in the presence of carriers or other auxiliaries which can diffuse into the polyester fibres.

The disperse dye is present in the polyester fibre in “solution” (mono-molecular) form. If the polyester fibre is offered a competitor in terms of solubility capacity for disperse dyes, then the disperse dye follows the Henry’s distribution law and migrates to where there is higher solubility. It is well-known that the mobility of disperse dyes within the polyester fibre improves as the temperature increases.

The causes of thermo-migration can be summarised by the following points:

- heat treatment: drying and themofixing,
- preparation treatment: softeners, anti-static agents,
- finishing: finishing agents,
- coning: spool oils,
- residues of preparation treatment, dyeing auxiliaries.

The following reactions can easily occur under the influence of thermal treatment during migration of disperse dyes from dyed polyester substrate to a finishing agent. However, the extent to which these reactions occur depends on the chemical constitution of the dye, the type of finishing agent as well as treatment time and temperature. Depending on time and/or temperature, these reactions impact on desorption of the dye from dyed substrate to finishing agent:

1. Current distribution of dye between surface active substances and surface layer of the substrate: The first stage of migration consists of migration of the dye from the surface layer of the dyed substrate into the finishing agent. This movement is dependent on the area through which dye migration takes place, the diffusion coefficient of the dye in finishing and modification of chemical potential, which is the driving force for migration of the dye at any one time.

2. Diffusion of the dye from fibre interior to the surface: in order to replace the dye which migrates from the suface layer of the substrate into the finishing agent during reaction, migration of dye from the interior of the substrate to the surface layer takes place. This dye migration is dependent on the diffusion area within the fibre, the diffusion coefficient inside the fibre and the local gradient of chemical potential. As this local concentration gap of the dye in the substrate is a consequence of extraction of dye molecules by the finishing agent, the extent of the concentration gradient is proportional to current dye migration which takes place during the first step. During this phase the compact inner structure of the substrate constitutes greater diffusion resistance for the dye compared with the resistance of dye molecules during diffusion into the finishing agent. Under these conditions, migration within the fibre is the rate-determining step which determines the further extent of thermomigration as a result.

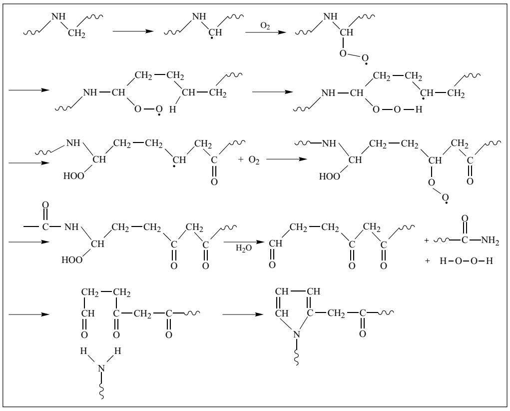
3. Diffusion of the finishing agent into the fibre: depending on the nature of the finishing agent and the time and temperature of the thermal treatment, the finishing agent can in some cases penetrate the substrate. In this case the dye content of the finishing agent decreases at the fibre surface for two reasons; firstly because the dye-containing finishing agent disperses into the substrate and secondly because the quantity of finishing agent available for extraction of the dye from the substrate is now reduced as a result of diffusion of the finishing agent into the substrate. During this phase distribution of the dye between the substrate and the finishing agent at the surface is determined by which of

the two reactions is predominant, diffusion of the finishing agent into the substrate or extraction of the dye from the substrate by the finishing agent.

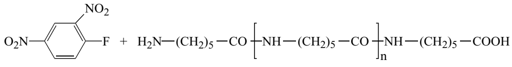
4. Formation of a phase substrate/dye/finishing agent: as a result of diffusion of the finishing agent into the fibre substance, a change in the morphology and fine structure of the fibre takes place. This can lead to an increase of the free volume in the fibre. Under these conditions the dye molecules in the fibre have greater mobility enabling them to diffuse from the fibre into the finishing agent at the fibre surface.

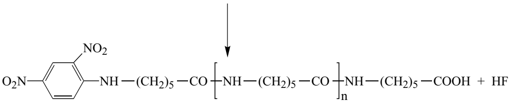
The extent to which some or all of the above mentioned reactions take place depends on the chemical constitution of the dye, the type of finishing agent and the conditions of thermal treatment (according to von der Eltz and Sheth).

Thermo-oxidative degradation of polyamide The most significant damage to aliphatic polyamides in terms of practical application is based on their heat sensitivity, particularly in the presence of oxygen. During the course of technical manufacture, processing and finishing, heat has an impact on the polymer. Macroscopically the impact of heat causes impairment of the mechanical-technological properties, a significant yellowing and a changed absorption capacity for dyes. At present assumptions can only be made as to the nature of the chemical processes which cause these changes. One of these assumptions, which explains a number of chemical changes to polymer, is illustrated below.

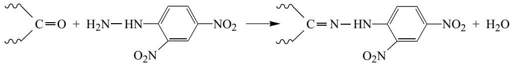


Where this mechanism is valid, a reduction of amino end groups and formation of carbonyl and pyrrol groups should be provable in thermo-oxidized polyamide. A photometric determination method for the amino groups is available which is based on conversion with 1-fluoride-2.4 dinitrobenzene:

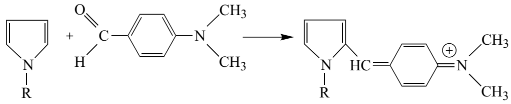




The carbonyl groups can be determined in similar chemical fashion using 2.4-dinitrophenyldydrazine:



Pyrrols can be determined photometrically after conversion with p-dimethylaminobenzaldehyde to a methine dye.



Thermo-physiological comfort Objectively thermo-physiological comfort is a state in which humans are not subjected to heat stress in terms of significant deviation from normal values for body temperature and in terms of other physiological parameters such as circulation or pulse frequency. Subjectively this includes the absence of unpleasant feelings resulting from temperature or humidity in the micro-climate between skin and clothing or from the presence of perspiration. The body has several involuntary means of maintaining or regaining thermo-physiological balance, e.g. shivering or perspiring in order to create or dispense with heat.

Fibre material, fabric structure and the cut of clothing can also have an impact on thermo-physiological comfort, since they influence the extent to which heat and humidity are transported away from the body. The heat insulation provided by textiles such as clothing or bed linen can support the body by altering the involuntary control range or inducing lower or higher environment temperatures. However, the limits which textiles place on heat disposal via perspiration (evaporation) can impair the control range to an undesirable extent thus limiting the body's capacity to adapt easily to changes induced by temperature or activity. → Clothing physiology.

Thermoplastic composites Filament-reinforced → Composites with duroplastic matrix are not only used in the aerospace industry but also compete with metals in all other sectors of industry. The cycle times during component manufacture are, however, too long for medium and large production series. Shorter cycle times can be realized with thermoplastic composites.

Thermoplastic composites

Composites with thermoplastic matrix can be divided into three sections (Fig. 1):

- glass-matting-reinforced thermoplastics (GMT) of long-fibre-reinforced polypropylene offer acceptable mechanical properties at a low price and are used in the automobile industry.
- endless-fibre-reinforced high-temperature resistant (HT) matrices, such as polyester for example, are used under the name “Advanced Composites”. They are mainly used in the aerospace industry.
- composites made of technical plastics allow mechanical properties to be achieved which utilise the strength potential of the fibres used. Good fibre/matrix adhesion is a prerequisite for this. PA12 is a technical plastic which is suitable as a matrix for these composites.

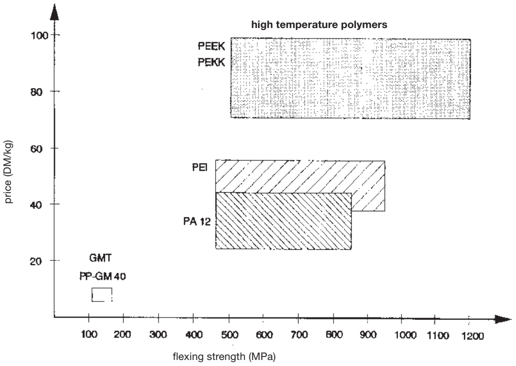


Fig. 1: Thermoplastic composites (glass fibre reinforced).

The fabrication of laminates or components with duroplastic or thermoplastic matrices requires different processes. In the case of duroplastic matrices, the properties and the quality of the finished component is influenced by monitoring the crosslinking reaction of the matrix. The crosslinking reaction is monitored throughout the entire fabrication process including storage and transportation right through to final hardening in the autoclave. In the case of composites with thermoplastic matrices, monitoring of the chemical process is not the decisive factor but the rheological properties of the matrix. Depending on the polymer, thermoplastics have a viscosity between 500 and 5000 Pa · s at their processing temperature, whereas duroplasts have less than 100 Pa · s. Due to the high viscosity of thermoplastic matrices, the impregnation process is particularly significant. Impregnation can be carried out in accordance with various processes:

- melting impregnation,
- solution impregnation,
- film laying process (film stacking),
- powder impregnation,
- hybrid yarn and hybrid weaving technique.

Not all processes can be used with each polymer. The melting viscosity of the polymer influences the selection of the optimum impregnation method. Thermoplastic polymers with a viscosity of less than 1000 Pa · s are suitable for most impregnation processes. Polymers with higher viscosity are dissolved in a solvent and the reinforcement fibres and/or a fabric are impregnated with the solution. Not all polymers can be dissolved simply, however. Disposal of the solvent after impregnation can pose an additional problem.

Film laying techniques and powder impregnation have proved particularly economical for the fabrication of thermoplastic composites. Both processes can be applied using PA12 as matrix. Due to the availability of PA12-powder, powder impregnation with this polymer is of particular interest. There are three processes for powder impregnation. In one process thermoplastic powder is enclosed with the reinforcement fibres by a foil of the same polymer or of a polymer with a low melting point. The resulting product can be used for component fabrication using the winding process or for manufacturing fabrics. Another process uses polymer powder in an aqueous solution for impregnating the fibre. The water is removed from the Prepregs during laminate manufacture. In the third process polymer powder is scattered onto the reinforcement fibres and then heated to a temperature above the melting temperature of the polymer.

The scatter process can also be replaced by a spinning disc which controls the spraying of the fibres. Not every polymer is suitable for powder coating. Polymers which occur as powder with the appropriate grain size during the manufacturing process are the most economical for the impregnation process as they eliminate the necessity for additional grinding. Otherwise the matrix costs can increase by more than 50% and the process can become uneconomical. Variations of the third process for fabric impregnation use PA12. Glass, carbon and aramid fabrics are covered with PA12-powder on both sides. Impregnation of the fabric then takes place under infrared radiation, heating the polymer to 200°C

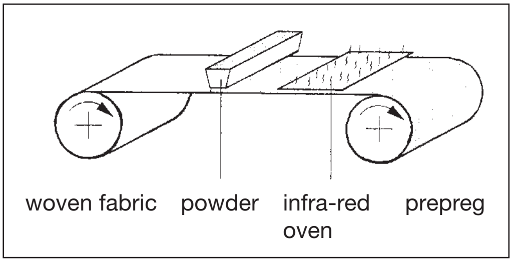


Fig. 2: The powder impregnation process.

(Fig. 2). The low melting viscosity of PA12 facilitates good penetration of the fibre bundles and good impregnation of the fabric. However, this does not yet constitute total coverage of all the fibres. When manufacturing laminates or components with more than two Prepreg layers, further consolidation in a stationary press or a double band press is necessary at approx. 250°C.

Thermoplastic composites of PA12-Prepregs are pressed at temperatures of 250°C and low pressures of 5–10 bar to form laminates and/or components. This can take place in heated or cold presses with preceding infrared treatment. These techniques were first used for the fabrication of sports equipment. Shoe soles with PA12-composite are layed up in cats before overspraying. The suitability of thermoplastic composites in conjunction with PA12 is currently under investigation in the automobile industry. Its good processing properties, low water absorption and its high energy absorption are of particular significance for the automobile industry. Composite bands with uni-directional glass or aramid fibre and PA12 as matrix are used for reinforcing pressure containers (Baron).

Thermoplastic fibres Fibres which demonstrate a → Softening range and are therefore thermoplastic. This property is also utilized during → Heat setting, → Thermoplastics.

Thermoplastic resins Glass-like, hard solids that are thermoplastic are used in textile finishing for improving texture, draping properties, stiffness, durability, scrub-fastness and dimensional stability. → Thermoplastics.

Thermoplastics (plastomers). Substances which are transformed reversibly into a plastic and therefore formable state when heated to a certain temperature (specific softening temperature). This does not involve any chemical change and the substance returns to its original hard or elastic state when it cools down. Thermoplastics can change from one state to the other as frequently as required.

Thermoplast print blanket adhesives Adhesives which are effective from a certain temperature and which are used in film printing where they are heated to the necessary temperature by means of heated rollers. Thermoplast adhesives, vulcanized in rubberized continuous printing blankets, allow the preheated fabric to be printed without glueing and washing using the preheated printing sheet to position the pattern for printing.

The temperature is adjusted and regulated by means of a thermostat. The fabric is transported over a convex plate allowing it to be bonded smoothly to the blanket (Fig.). Conventional types of glue can be applied to the thermoplast layer. After passing through the printing zone, the fabric can easily be pulled away from the printing cloth, even when cold. It is possible to print 200 000 to 1 million metres but it may be necessary to replace the thermoplast earlier depending on the printing process.

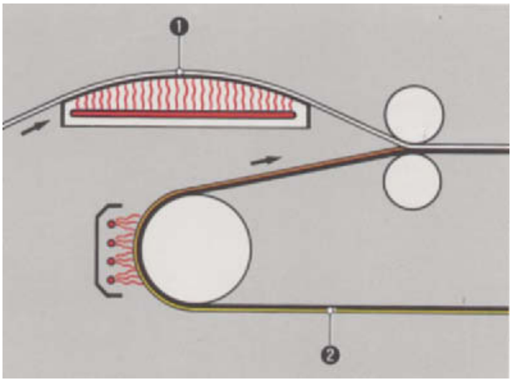


Fig.: Attaching the printing background to the rubber blanket containing the thermoplast backing cloth adhesives (Stork).
1 = fabric; 2 = thermoplast.

Thermosetting process → Heat setting.

Thermosol dyeing processes Important continuous process for dyeing polyester and polyester/cellulose fibre mixtures with disperse dyes, which is used mainly for fabrics and knitted materials. First dye, thickening agent or migration inhibitor and possibly a hydrotropic agent (urea, thiourea) and an acidifier are padded. Then initial pre-drying is achieved by means of an infrared heater (prevention of dye migration) before drying completely by means of jet drier, tension frame or cylinder drier (Fig. 1). Diffusion of the dye from the surface to the fibre interior takes place during subsequent → Thermosol fixation in the vapour phase. The thermosol fixation process is also suitable for triacetate fibres. It is only suitable for polyacrylnitrile fibre when certain cationic dyes are used.

During thermosol fixation, disperse dyes are set on polyester fibre at a temperature of 200–225°C which is applied for 30–60 seconds. The setting speed, the degree of setting and the penetration of dye into the fibre depend above all on the following factors (Fig. 2):

- chem. constitution and finish of the dyes,
- dye combination,
- concentration of the dyes and fibre surface,
- type of polyester fibre,
- ratio of polyester/cellulose fibre,
- fabric structure,
- auxiliary additives in the pad bath,
- temperature of the fabric and thermosol fixation time.

The fibre material is specified before dyeing; dyes, auxiliaries, thermosol fixation temperature and time can be selected. The temperature of the fabric and the ther-

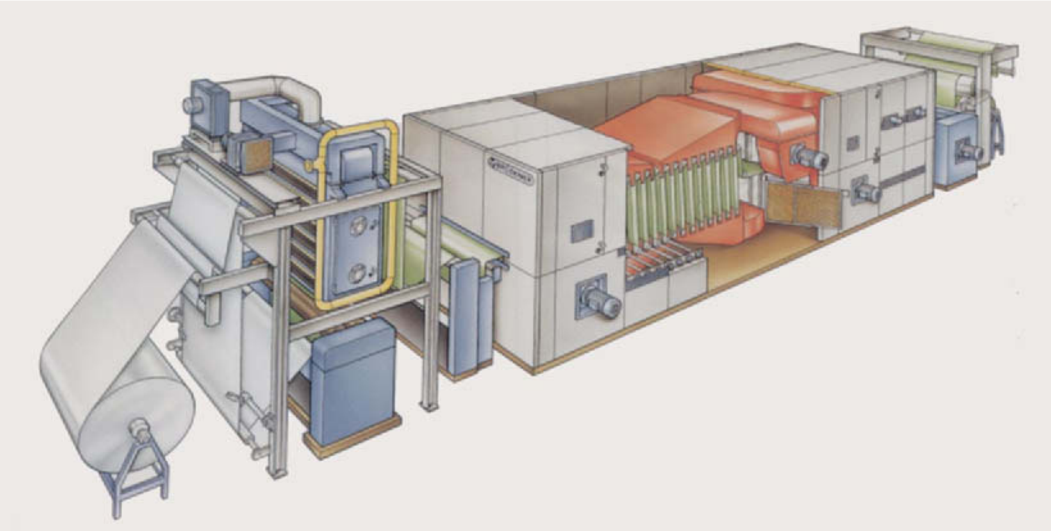


Fig. 1: Thermosol dyeing plant (Brückner).

mosol fixation time are not necessarily dictated by the temperature of the heat medium and the time spent in or on this medium. They are dependent on the heating speed which in its turn depends on the fabric structure, residual moisture and type of heat transfer. Fluctuations in the temperature of the fabric and the thermosol fixation time cannot be completely eliminated at reasonable expense under operating conditions. Therefore, disperse dyes are preselected which result in level dyeings over a temperature range which is as wide as possible. Temperature dependency of dye fixation is documented by so-called thermosol curves on which either the degree of fixing or the dye strength are recorded against the temperature. The degree of fixing indicates the quantity of fixed dye in relation to the padded dye quantity. The relative dye strength corresponds to the visual or colour measurement determined dye strength in relation to the max. achieved dye strength. Both dimensions are usually quoted as a percentage.

Migration during intermediate drying continues to cause problems in practice. The migration of dyes is not only the cause of two-sidedness and listing; strongly migrating dyes also lead to a non-uniform appearance, double colour effects (dichroism) and colour

process described by total functions	THERMOSOL DYEING of P E S FABRICS					
process stage described by part functions or total functions	dye padding	drying	thermosolling	washing	finish padding	drying and heat setting
processing elements described by elementary functions	immersion squeezing	heating	heating cooling	immersion squeezing spraying	immersion squeezing	heating cooling
basic processes described by basic functions	wetting mixing open-width feeding transporting deflection through-flow compression	evaporation migration diffusion open-width feeding transporting	dwelling diffusion sublimation evaporation open-width feeding transporting deflection	wetting through-flow dilution shrinkage stuffing open-width feeding transporting compression	wetting mixing open-width feeding transporting deflection compression	evaporation dwelling diffusion stentering overfeeding relaxing shrinkage storage transporting deflection

Fig. 2: Thermosol dyeing process classification (according to Schollmeyer).

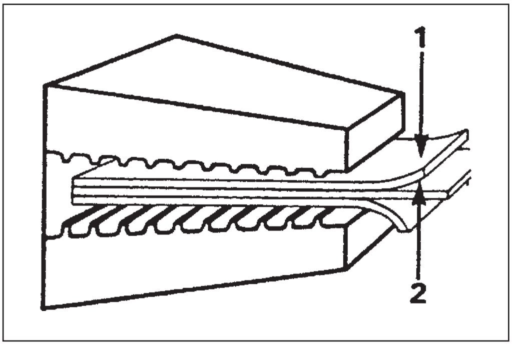


Fig. 3: Migration during intermediate drying – effect of the dispergator system on the migration code using the example of Foron marine blue S-2GL (Sandoz).
Fabric: PES/CO 65/35 merc.; padding liquor: 32 g/l Foron marine blue S-2GL, 20 g/l Sanapol AM liquid (Sandoz); dry/thermosol: 2 m, 150 ºC/min, 215ºC reductive cleaned, PES skeleton. 1 = fabric upper surface; 2 = fabric lower surface

deviations in the sewing sample. Thermosol dyeing on a polyester mix fabric can have a worse appearance than an exhaust dyeing due to inadequate dye penetration. Optimum machining prerequisites, drying conditions, the migration inhibitors used and also disperse dyes with a minimum tendency to migrate can have a positive impact on the appearance of a thermosol-dyed product. The migration capacity of a thermosol dye mixture can be simulated in a laboratory test (Fig. 3) (Richter and Somm).

Thermosol fixation Treatment during the → Thermosol dyeing processes which causes diffusion of dye into the fibre interior by means of hot air, superheated steam, contact or radiation heat. Of these, hot air fixation is the most significant. It is important that the material should be subjected to a constant temperature over its entire width during the thermosol fixation process since temperature fluctuations lead to colour differences. The specific optimum temperature and the duration of the process depends on the dye. In the case of temperatures which are too high there is a danger that the the dye already present in the fibre will re-sublime. If temperature stability is not ensured, dyes which are not very responsive to temperature differences must be selected. To achieve maximum dye utilisation the material should contain a certain amount of humidity. This should not, however, be too high as this could lead to dye agglomeration (flecks). Thermosol fixation during the thermosol dyeing process results in form stabilisation (thermosetting) as well as in dye fixation.

Thermosol pad-steam process Two-stage dyeing process for continuous dyeing of polyester/cotton mix fabrics with reactive and disperse dyes:

1. Padding with both dye groups (without alkali), drying, → Thermosol fixation.
2. Cold padding with alkali and steaming (fixation of reactive dyes).

Thermosol plants Combined plants designed for → Thermosol fixation which meet the following basic requirements: temperature accuracy and constancy over the entire material width and high production capacity, for which efficient measuring and recording units are a prerequisite. Dye uniformity in thermosol plants depends to a large extent on air circulation (Fig.) in the hot flues.

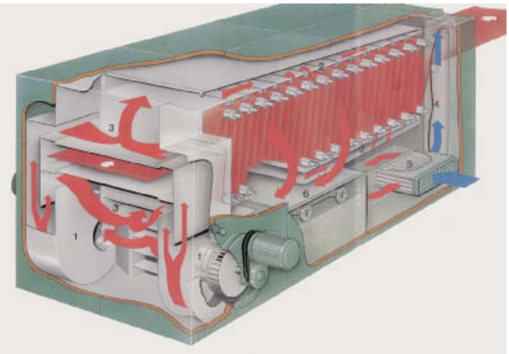


Fig.: Monforts Thermex system for thermosol fixation or hot air fixation of dyes.
1 = fans; 2 = distributor boxes; 3 = hot air; 4 = exhaust air; 5 = heat exchanger; 6 = sieve.

Thermosol single-bath processes These include:

I. Thermosol cold batch process,
II. Thermofix-thermosol process with urea,
III. Thermofix-thermosol process without urea,
IV. Thermosol-pad-steam process,
V. Thermofix-thermosol-pad-steam process,
VI. Thermosol-alkali-shock process,
VII. Thermofix-thermosol-alkali-shock process (one-shot process).

Thermosol stiffening Fabric stiffness and stiff texture brought about by → Thermosol fixation particularly of knitted fabrics in textured yarns which can be removed by subsequent wet treatments or on the mechanical breaking machine.

Thermosol two-bath processes These are divided into

I. Thermosol-exhaust process.
II. Thermosol-cold batch process.
III. Thermosol-thermofixation process.
IV. Thermosol pad-steam process without intermediate drying.
V. Thermosol pad-steam process with intermediate drying.

Thermostats For maintaining certain working temperatures at a constant level by means of the instal-

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lation of contact thermometers. Heat sensors with, for example, a highly heat-sensitive fluid or, made of bimetal strips and used as impulse transmitters, transmit each contraction or expansion directly to an electrically operated steam inlet valve by making or breaking platinum contacts and opening the steam valve via a mercury relay after the set temperature has been reached. Various design principles (usually using compressed air, oil, or water). Varied use, for working liquor and processing machines of all types, drying aggregates, heating and cooling systems, boiler operation, hot water storage (contact switching of engines, ventilators, etc.), air temperature regulation, etc.

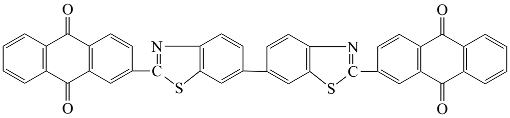
Thermoweave process Yarn or filament fibre used for producing carpet yarns by the bonding process are rolled and deep-frozen. This roll is sliced and the slices are bonded onto an underlay material.

Therm-Set process → Permanent-press process for cotton and polyester/cotton. The textiles are impregnated and dried with DHDMEU and a weak resin finishing catalyst (glycolic acid) before crosslinking and after-curing with a 1% magnesium chloride hexahydrate catalyst solution to fix pleats and creases in a pressing process.

Thiazine dyes A group of cationic, acid, mordant and sulphur dyes which are derived from phenthiazine (→ Heterocyclic compounds).

Thiazole → Heterocyclic compounds.

Thiazole dyes Dyes named after their principal structure (one or more thiazole, 5 atom rings) in various dye classes including cationic, direct, acid, sulphur and vat dyestuffs.



Thickener boiler Have lost their relevance as cold water soluble → Thickeners are more widely used. The most common thickener boilers are the double-wall boiler and the Votator with which the thickening boiling process can be carried out continuously and with pressure at over 100°C.

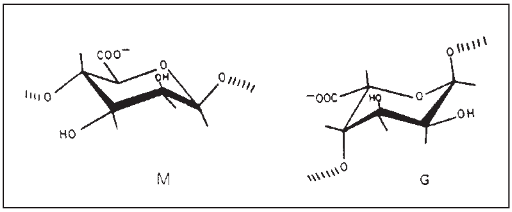


Fig. 1: Components of the alginates manuronate (left) and guluronate (right).

Thickener gel theory Thickening is made with polymer having a structural viscosity swollen to form a gel. As Flory demonstrated in his seminal work on crosslinking between 1941 and 1944, gelling occurs in a system when two crosslinking components per molecule used (monomer or polymer) are present. Below a critical total (α_c) only linear and branching molecules of finite size are present. Above (α_c) the system consists of an infinitely extending network encompassing the entire solution and a large number of finite branching clusters. When the topology formed during the reaction remains stable, homogenous, permanent, i.e. chemically-linked gels are referred to. In the case of reversible gels, however, the linkages are redissolved and can be reformed. Thus polymer chains can, for example, be linked to each other by means of hydrogen bonds, electrostatic interaction or dipole forces but also by “hydrophobic” interaction. These secondary valency bonds can be split temporarily by supplying energy (heat, mechanics). Alginates are composed of different (1–4) connected sequences of α-L-Guluronate and ß-D-Manuronate (Fig. 1), both homopolymer blocks and alternating sequences of monomer units.

Gelling occurs when monovalent ions (in particular Ca^{2+}) are exchanged. Gelling takes places with blocks of at least 20 guluronic acid units. However, blocks of manuronates play only a small part in the gelling process. The alternating sequences show no tendency towards association and therefore act as a solvent within the network. Rees proposed what he called the “egg box” model as the mechanism of Ca^{2+}-induced gelling of alginates (Fig. 2). Biaxial association of the guluronate results in a heavily-folded chain formation which contains “holes” the diameter of which corresponds to the ion radius of Ca^{2+}. O-atoms are located at a suitable

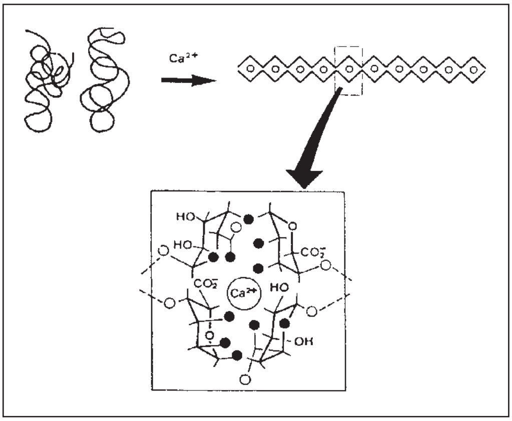


Fig. 2: The “eggbox”-model of non-reversible alginate gelation.

Previous Page

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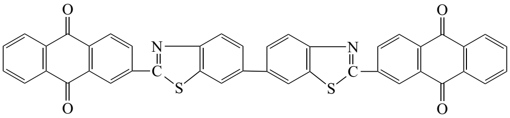

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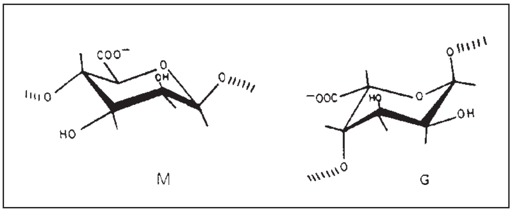

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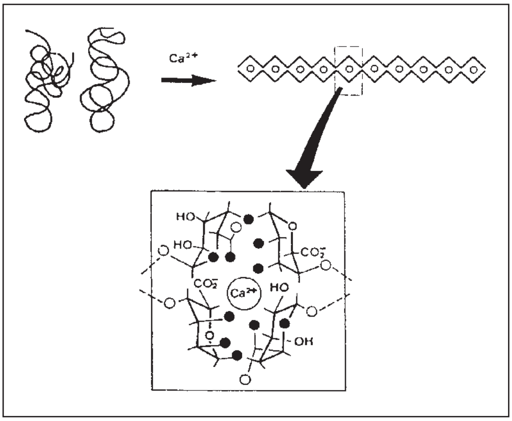

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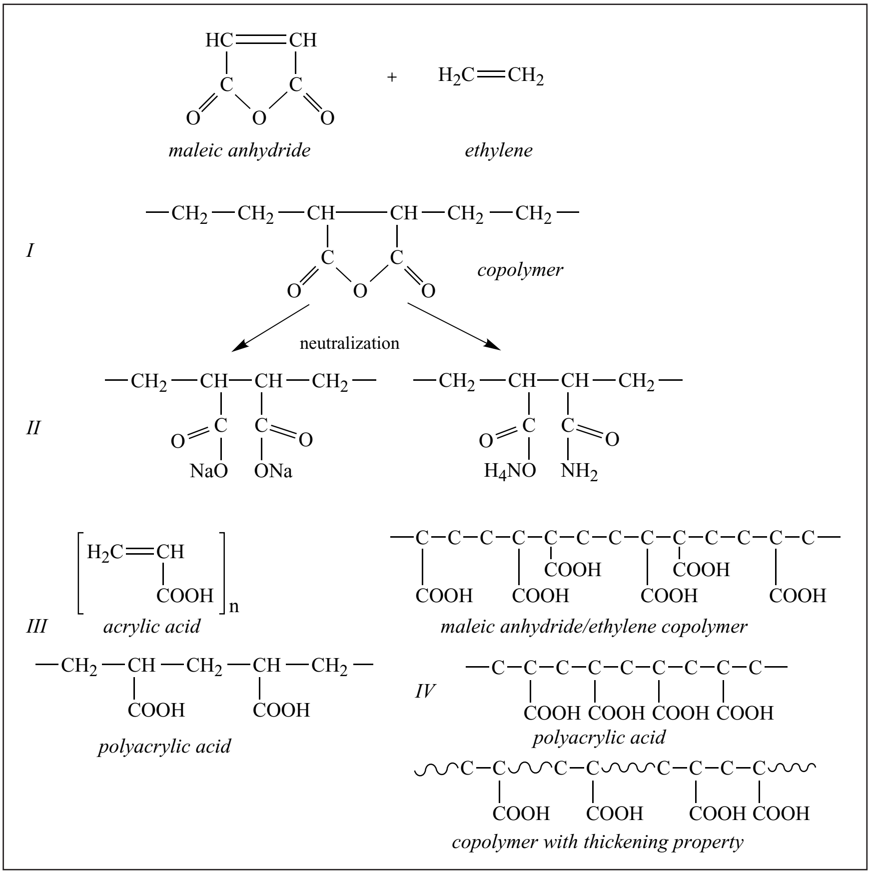


Fig. 3: Increase in the copolymer properties and fitness as a thickening agent due to the correct hydrophile carboxyl groups and hydrophobe components ratio (Zickzack).

location within these holes so that a deposit of Ca^{2+} in these holes stabilises the folded formation by means of complexing. Two polymer chains are linked to each other in parallel fashion by means of such – Ca^{2+}-chelate bridges. At higher Ca^{2+}-concentrations, several such double strings can form an association. The Ca-bridges between them are, however, considerably weaker and can be suppressed by high concentrations of single-value ions.

The manuronate blocks and the alternating sequences are not responsible for the formation of chelates and therefore prevent complete crystallisation of the alginates. Thickeners do, however, demonstrate similarity with liquid-crystallite surfactant solutions. The polymer chains have two different structural elements. Sequences which are capable of association and others which are unable to form an association. When they cool down those sequences capable of association form the linking points between the chains. The interspersed units prevent complete crystallisation of the polymers.

Association of the chains differs in strength depending on the degree of substitution and the thermodynamic conditions of the solution (ion strength, solvent activity). Gelling occurs when each polymer chain in the agent is associated with two others. Reversible gelling can be seen as a special case of polymer association (up to crystallisation). Quasi copolymer structure is a prerequisite. Thus, for example, copolymers of ethane and maleic acid anhydride represent synthetic thickeners; hydrophilic, carboxylic groups in the form of lateral chains (after neutralisation as carboxylate groups) alternate with hydrophobic areas (Fig. 3).

Such thickeners are structurally viscous in their flow characteristics and have a flow limit. Below this flow limit the viscosity is infinitely great and above it extremely low, causing printing pastes to flow through the screen mesh during the printing process. After the printing process, i.e. when the shear force is no longer present, the paste immediately adopts its original viscosity and remains still on the textile in exemplary fashion. This rheological property is demonstrated by benzine (white spirits) emulsions for example, which were the basis of pigment printing's success in the fif-

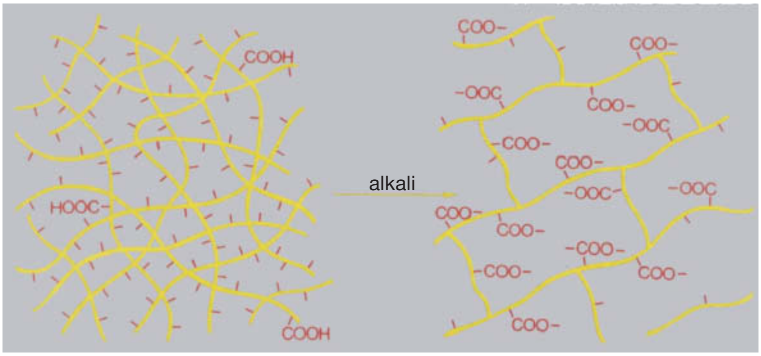


Fig. 4: Transition of polyacrylic acid copolymer in a colloidal solution into highly uniform, swollen, disperged polyacrylate gel, but with reversible gelation through the action of external energy (structural viscosity) (by Bayer).

ties. The use of benzine is, however, accompanied by a series of problems: flammability, odour, air and waste water contamination as well as the high price. For this reason benzine emulsions were replaced by synthetic thickeners as these have almost the same rheological properties as emulsion thickeners.

The substances in synthetic thickeners are "packets" of long molecule chains. The "packets" are achieved by weak crosslinking of macro-molecules which are produced by polymerisation and copolymerisation of suitable oleofinic monomers (e.g. acrylic acid, maleic acid anhydride). They are polyanionic bodies which only become effective as thickeners in the dissociated state. As the acids only dissociate very slightly even in water, they are transferred to the corresponding ammonium salt. The initially tangled packet of polyacid is now capable of expanding. It surrounds itself with a solvent shell. The bonding energy of the hydrosphere on the "balloons" is so slight that even slight stirring disturbs the structure of the system reversibly. The molecules align themselves parallel to the shear direction at an increasing speed difference (elongation and orientation) which renders the flow limit considerably more pronounced. This alignment of the molecules allows them to glide past each other more easily, which is expressed in decreased inner friction and viscosity (viscosity loss). After shearing and completion of the printing process the elongated molecules spontaneously take on their original tangled state as a result of the Brownian movement. Deformed drops become round again. The original resting viscosity has been assumed again (Fig. 4).

Synthetic thickeners act as a catalyst in pigment printing pastes and replace the otherwise necessary acidifier in benzine emulsions. In similar fashion to the acidifier (ammonium salts of low volatile inorganic acids), the ammonia evaporates on drying after the printing process, rendering the system acid via the polymer-bound carboxylic groups. The hydrophobic areas result, for example, from the monomers styrene, butadiene and acrylic acid ester in the copolymer. Copolymers of acrylic and maleic acid anhydride are statistically dissolved colloidally in the form of tangles in the water and gelling occurs, i.e. swelling and dispersion, if alkali is added (Fig. 4).

The quasi liquid-crystallite structure in the reversibly swollen gel can be imagined like a fringed micelle (Fig. 5) (with the crosslinking points in the gel similar to the crystallites shown by Hermann in 1930). As only like blocks can "crystallise", the length and distribution of the hydrophilic and hydrophobic blocks determine the thickness and length growth of the liquid crystals. The polymer chains can run through several "crystalline" areas causing a net-like structure to occur. A factor which influences gelling is the amount and the nature of the free dilution enthalpy relative to the free melting enthalpy of the crystallites.

For the thermodynamic interaction between network and solvent in the gel Flory derived a relationship in the form of osmotic pressure in a grid model. In addition to the interactions between polymer/polymer, polymer/solvent and solvent/solvent, which are also present in solutions, a contribution from the entropy-

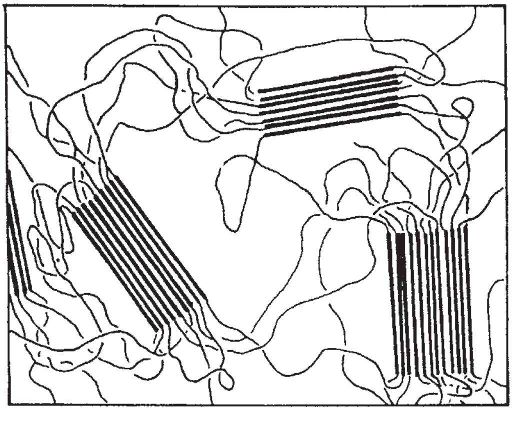


Fig. 5: Model of the fringed micelle network points in swollen gel.

name	Individual constituents	Solubility and viscosity behaviour in water	Gel formation
starch	glucose	swelling from approx. 60°C, viscosity behaviour variable, dependent on the amylose/ amylopectin ratio	gel formation at RT, destruction of gel structure in storage due to retrogradation
guar	mannose, galactose 2:1	soluble at RT, 1% solution: 3–4 Pa · s, electrolyte and pH resistant	no gel formation (only after the admixture of borate)
carob seed grain ether	mannose, galactose 4:1	soluble at 80 – 90°C 1% solution: 0.05–0.3 Pa · s electrolyte and pH resistant	no gel formation (only after the admixture of borate)
agar	galactose 3.6, anhydrogalactose approx. 1:1	soluble at 80–90°C, 1% solution: 0.005-0.01 Pa x s, electrolyte resistant	gel formation reversible, melting point: 80°C, gel temp. 30°C
gum arabic	arabinose, rhamnose, galactose, glucuronic acid 3.5:1.1 : 2.9:1.6	soluble at RT, 1% solution: 0.002–0.005 Pa · s, 20% solution: 0.03 Pa · s, electrolyte and pH dependent (max. pH 6-7)	no gel formation
gum tragacanth	arabinose, xylose, rhamnose, fucose, glucose, galactose, galacturonic acid	partially soluble at RT, 1% solution: 0.5–2 Pa · s: electrolyte and pH resistant	virtually gel-like consistency
carragheen (kappa, iota)	galactose 3.6, anhydrogalactose approx. 1:1 esterified with H_2SO_4	soluble at 50–60°C, 1% solution: 0.05–0.3 Pa · s, sensitive to electrolyte and pH	weak gel formation reinforced by K^+ ions + carob seed grain ether, reversible
lambda	galactose esterified with H_2SO_4		no gel formation
pectin	galacturonic acid (main constituent) galactose, arabinose, rhamnose (secondary constituent)	sodium salt, methylester soluble at RT, 1% solution: 0.005–0.1 Pa · s, sensitive to electrolyte and pH	highly esterified: gel formation with sugar + acids, irreversible, low esterification: gel formation with calcium salts, reversible
algin	mannuronic acid, guluronic acid 1:(0.5–1.9)	sodium salt, soluble at RT, 1% solution: 0.1–1.5 Pa · s sensitive to electrolyte and pH	gel formation with calcium salts, reversible
xanthane	glucose, mannose, glucuronic acid 2.8: 3.2 esterified with pyruvic acid + acetic acid	soluble at RT, 1% solution: 1.2 Pa · s, low dependency on electrolyte and temperature	no gel formation on its own, good gel formation with carob seed grain ether, reversible

Tab. 1: Survey of the properties of the most important polysaccharide-containing thickeners: natural products (according to Scherz).

elastic force of the network also has to be taken into consideration. It is a question of a swelling balance which can be displaced at any time by external influences such as, for example, mechanical squeegee force. Gelling is, therefore, reversible. The idea of quasi-crystallites is vivid if one remembers that the melting point as a thermodynamic property is characterised by the complete disappearance of the crystalline phase, i.e. the most stable crystal. The gelling point on the other hand is a purely topological property. The topology is not only determined by the long and large crystals but also by the large number of small associates whose melting point is lower and which only make a slight contribution to the melting point. The capacity to gel differs in the most frequently used thickeners, as shown in Tables 1 + 2.

This can be explained as follows: for pigment printing such high-solid thickeners are not commonly used as in direct printing. High-solid thickeners form “quasi-liquid crystals” depending on the concentration of dry substance in the thickener or exclusively tangle structure (Fig. 6). These super-structures depend to a large extent on the degree of polymerisation of the thickeners. The following therefore applies:

a) The concentration of possible bonding points is proportional to the polymer concentration.
b) The concentration of crosslinking points is proportional to the concentration of polymer molecules at the gelling point.
c) The binary association balance (free chains/crystallite) between crosslinking point and free bonding point is described by a van’t-Hoff’s Isochore.

Under these conditions the following parameters result for the link between polymer concentration c_p and “melting temperature” of the gel, $T_m{}^g$,

$$\ln (c_p) = \frac{\Delta H_m}{RT_m} + \text{const.}$$

ΔH_m being the dissociation energy of the crosslinking point. The connection between melting point of crystallite and gelling point is

$$\frac{1}{T_m{}^g - 1/T_m{}^k} = R \ln \frac{x}{\Delta H_u - 2\,\sigma_{ec}}$$

The end surface energy σ_{ec} is always smaller than the melting enthalpy ΔH_u. This means that the melting point $T_m{}^g$ of the gel with a fringed micelle gel is always below the melting point of the crystallite $T_m{}^k$. The gelling point is described by the probability of the presence of two branching points per polymer chain and according to Flory is dictated by

$$p_c = \frac{1}{f-1}$$

f = M(f–2) +2 is the functionality of the polymers with a degree of polymerisation of M. On the other hand the probability p_b exists of bonding between two monomer units according to statistical thermodynamics.

$$p_b = \frac{(1-\zeta)^{\frac{-E}{kT}}}{\zeta^{\frac{-W}{kT}} + (1-\zeta)^{\frac{-E}{kT}}}$$

E = bonding energy between monomer units;
ζ = weighting factor taking into account the semitropical difference between directed bonding to uncontrolled van-der-Waals interaction.

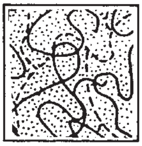
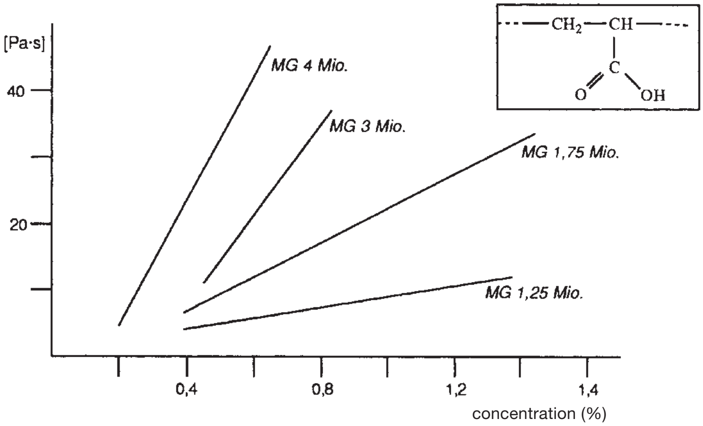
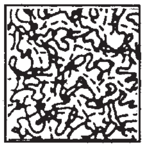
network dissolution structure	characteristic	rheological characterisation	printing result
	polymer concentration > $C_{crit.}$, no uncombined liquor, low thickener concentrations, “wide network dissolution,” high molecular weights	viscosity: high, shear sensitivity: high, covers a wide area of the speed gradient, viscosity at rest: immeasurable, elasticity: very high	colour application: high, contours: poor, reason: water extracted from the polymer network by the woven fabric capillary system
			
	polymer concentration > $C_{crit.}$, no uncombined liquor, higher thickener concentrations, “dense network dissolution”, low molecular weights	viscosity: average to high, shear sensitivity: marked, elasticity: high	colour application: good, contours: good

Fig. 6: Dependency of thickening property on polymer structure in the case of polyacrylic acid (according to Schulz).

If solvent is still present in the gelling system, bonding probability p_b has to be multiplied by probability a, a being the bonding probability that two adjacent grid places are occupied by a monomer segment. Thus a reduces the effective functionality of the polymers. Existing interaction between solvent/solvent and solvent/polymer is taken into account by factor a. By means of this interaction a is linked to the temperature. Thus the following condition results for the gelling point of a polymer/solvent mixture

$$p_b = a\, p_b(T)$$

i.e. there is a temperature $T_{max,}$ above which there can be no more gelling, no matter what the polymer concentration is, as a is always = 1. Low-solid thickeners also form super-structures in swollen gels but at considerably lower concentrations (Fig. 7) than high-solid thickeners. Low-solid thickeners are used as opposed to high-solid ones for emulsion thickeners. If they have a polyacrylic acid base, the structural viscosity proves to be very electrolyte-sensitive. In Fig. 8 the viscosity sinks considerably in the presence of a disperse dye with anionic dispersing agents, whereas the use of non-ionic dispersing agents has little influence on the course of the viscosity curve of the thickener.

Low-solid polyacrylic acid derivatives have become important in the area of thickeners for pigment printing for the following reasons: these ionised polyvalent chain polymers have polar or polarised groups incorporated in their molecule causing adhesion to the fibre and to the binder film by means of secondary valency forces. In addition to the adhesive effect, the thickening effect of this polyelectrolyte is significant in that it passes a maximum at a certain electrolyte concentration and can also have a thixotropic flow property. These products also have good emulsification properties. The acid groups in the molecule render the addition of an acidifier for condensation of the binder film superfluous. The concept of low-solid thickening originates from the time when pigment printing was applied using benzine as one phase and water as another in an emulsion. As heavy benzine and water evaporate when dried after printing, an emulsion is practically solid-free = free of

name	individual constituents	solubility and viscosity behaviour in water	gel formation
pregelatinised starch	glucose	swelling at RT, otherwise behaviour like natural starch	gel formation
thermally modified starch	glucose	soluble at RT, reduction in viscosity, increase in solution transparency	weak to no gel formation
acid modified starch 60°C	glucose	soluble from 60°C, reduced viscosity , in heat, low retrogradation,improved solution transparency	improved gelling ability
starch monophosphate	glucose esterified with H_3PO_4	soluble at RT, cold-swelling, clear solution, no retrogradation, good freezing and dew stability	no gel formation
di-starch phosphate	glucose with H_3PO_4 bridges	reduced swelling capacity, markedly improved viscosity stability at high temp., no retrogradation, good freezing and dew stability	gel formation reduced
starch acetate	glucose esterified with acetic acid	soluble at RT, clear solution, no retrogradation, little sensitivity to pH and electrolyte	no gel formation
methyl cellulose	glucose, methyl glucose	soluble at RT, falling out in the heat, 1% solution, ca.. 0.15 Pa · s	no gel formation at RT, reversible gel formation in heat
carboxymethyl cellulose	glucose, carboxy methyl glucose	soluble at RT, 1% solution: 0.05-1.2 Pa · s, sensitive to electrolyte and pH	gel formation with trivalent ions (e.g. Al)
propene glycol alginate	mannuronic acid, guluronic acid esterified with 1.2-propene glycol	soluble at RT, improved acid stability	gel formation with calcium: dependent on degree of esterification

Tab. 2: Survey of the properties of the most important polysaccharide-containing thickeners: modified products (Scherz).

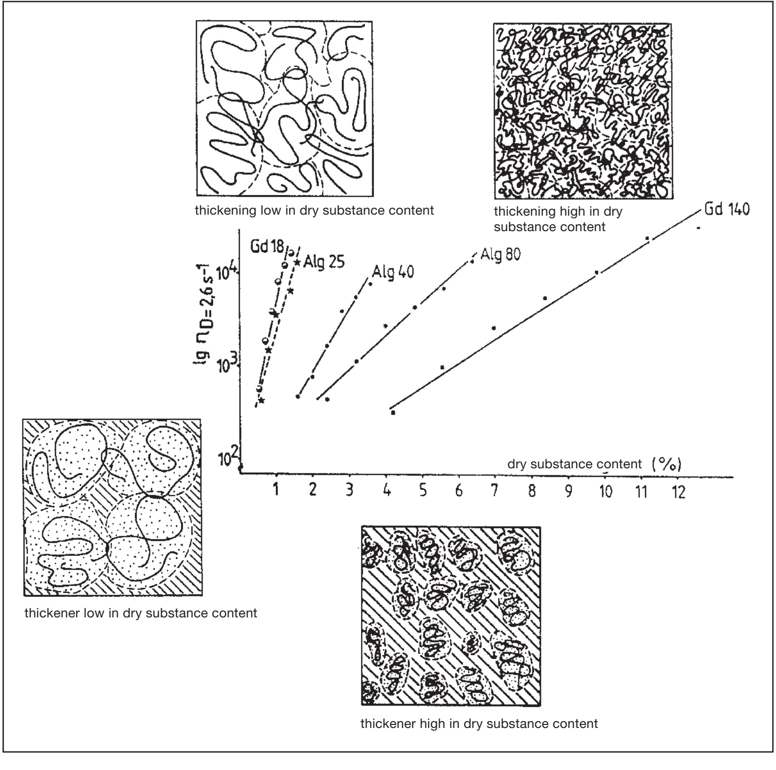


Fig. 7: Dependency of thickening agent structure in swollen gels on concentration (according to Schulz).

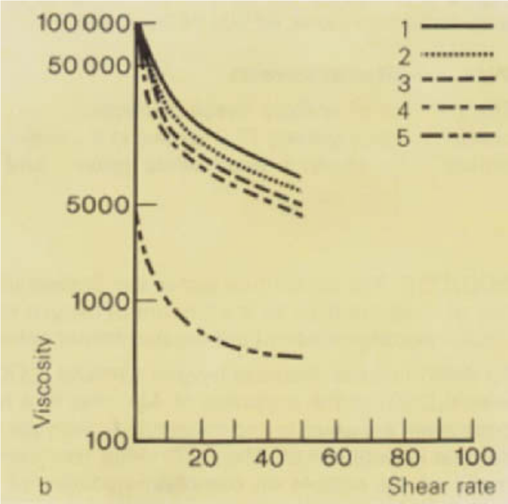


Fig. 8: Effect of a disperse dye with non-ionic dipersing agent (N-GLS) and anionic disperging agent (GLS) on the structural viscosity of polyacrylic acid thickener (by Bayer). 1 = acraconz + water; 2 = 8 g/kg Resolin Navy Blue N-GLS; 3 = 80 g/kg Resolin Navy Blue N-GLS; 4 = 8 g/kg Resolin Navy Blue GLS; 80 g/kg Resolin Navy Blue GLS.

dry substances, unless mixtures (wrongly known as “semi-emulsions”) to which small quantities of suitable, known thickeners (e.g. alginates, tragacanth, starch ethers) are added to a pure emulsion. This lack of solids in an emulsion provides a considerable improvement of handle as well as reducing effluent. There are also technical advantages from the printing point of view: as a result of the low surface tension, emulsion thickeners penetrate the fabric surface rapidly; a good push through is achieved and only small quantities of substance adhere to the screen. Emulsion thickeners are also not very sensitive to flushing of prints.

With the W/O system the emulsion frequently collapses as soon as it comes into contact with the fabric. The smaller the water droplets emulsified, the more this phenomenon can be counteracted. Pigment printing first utilised the advantage of solid-free, soft-handle thickener with the W/O system. As the greater inner phase consists of water, the solution and diffusion processes are often more productive. For environmental reasons the use of benzine is unfavourable as long as the emulsion is not used for low-benzine pigment printing by adding suitable wetting agents or hydrotropic compounds. With the type of emulsion used for benzine-free pigment printing one has to differentiate between an external, coherent phase, the dispersion medium (= dispersing agent) and the inner dispersion (= dispersed) phase. The degree of dispersion shows whether coarse dispersion, fine and colloidal-dispersions or high and molecular-dispersed ranges are present. Differentiation is also made between mono- and polydisperse systems depending on whether the particles are of identical or different size. By means of suitable emulsifiers, liquids which are actually not miscible are brought together to form a system which is as stable as possible using the necessary energy and the resulting significant increase of the inner phase (which in the thermodynamic sense does not exist in a stable state). With earlier benzine-based emulsions water and heavy benzine were used (boiling point 150–200°C, aromatic portion as low as possible, low Kauri-butanol values) and special emulsifiers with a hydrophilic/lipophilic-balanced polar structure. With HLB-values (hydrophilic/lipophilic balance) which are recorded in a norm system of 1–40, those emulsifiers which lead to water-in-oil emulsions (W/O) lie within the range of 3–6, i.e. in which the external phase is the oil (e.g. the heavy benzine) and the dispersed phase is the water. With emulsifiers with HLB-values of generally between 8 and 18, the system oil-in-water occurs (O/W) in which the phases are the other way round; the lower quantity of water is to be found in the external phase. Due to surface tension the liquid particles are normally present in the dispersed phase in symmetrically-ordered fashion in the form of small globules. Where a monodisperse system is densely packed with globules, the inner phase amounts to 74%. Due to the high volume proportion of the inner phase, emulsion pastes have a stiff consistency and high structural viscosity. Because of their globule structure emulsions also demonstrate a structure-viscous flow curve with a flow limit and typical plastic characteristics. The emulsifier builds an “interfacial film” around the globule-like particles of the dispersed phase. It can have monomolecular or multiple-molecular thickness and these molecules themselves are submerged into “their” adjacent liquids with their hydrophilic or lipophilic polar ends in brush or globule structure. The lateral surfaces of these rod-shaped emulsifier molecules can also either be interspersed with gaps or lie closely to one another causing an open or closed interfacial film to be formed (according to Wigger, ter Meer and Schlösser).

Thickener powder dissolving unit Dry, pourable thickener powder that is cold-soluble often has a tendency to form lumps when being mixed. Each powder particle therefore has to be wet-out immediately with water. With intensive stirring (Fig. 1) the preparation time (including swelling time) can be reduced considerably. In normal scattering processes preparation takes 60–90 min. with 6–12 h swelling time. A system (Fig. 2) for preparing thickener in the printing dye works produces thickener stock solutions.

Thickeners Usually water-soluble, swellable substances with colloidal character which are used in their thickened state as thickeners for printing with aqueous solutions of dyes, pigments and the like are

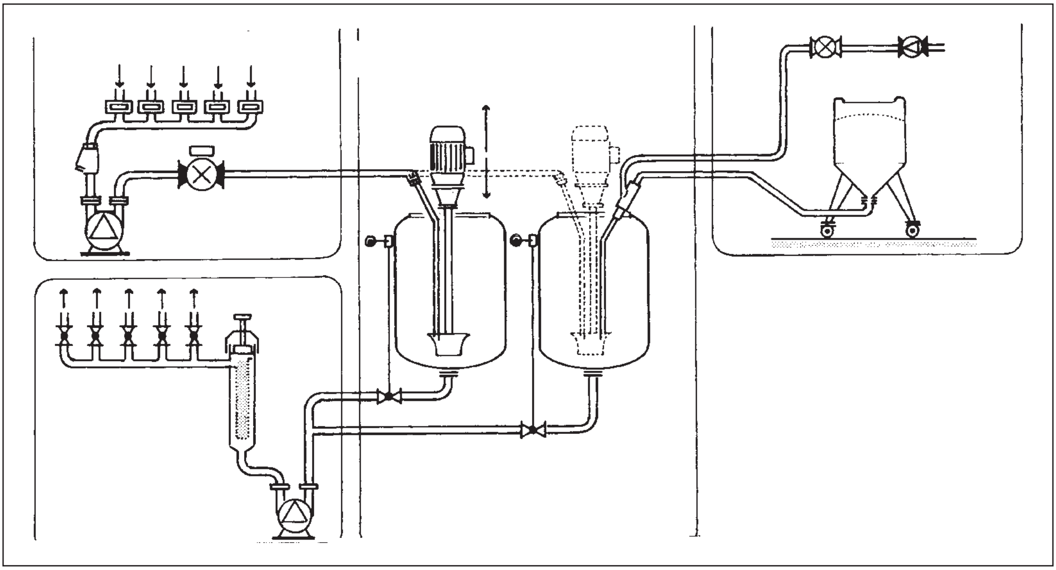


Fig. 1: Diagram of an installation for the preparation of thickeners in the colour kitchen.

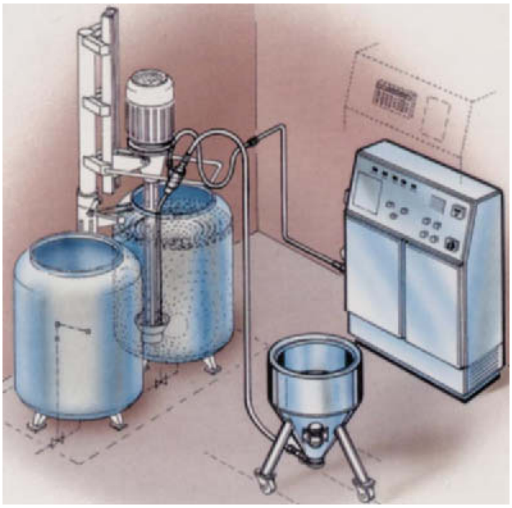
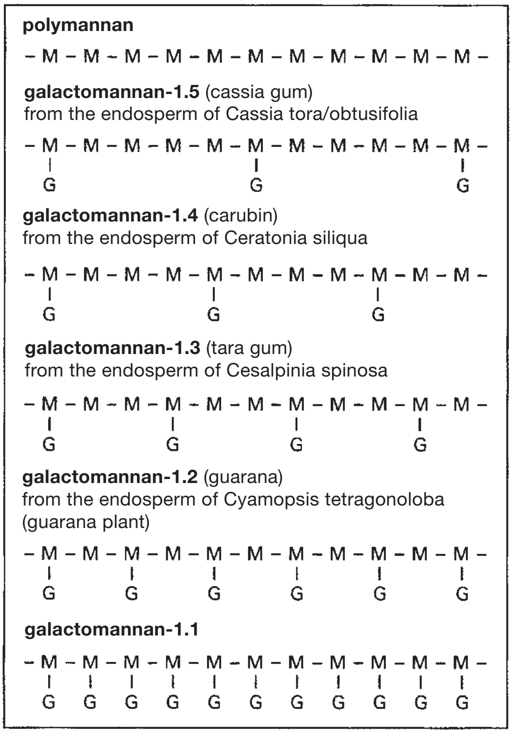


Fig. 2: Van-Wyk plant for the preparation of thickening paste.

used to prevent running (flowing) of the printed pattern on textile material (→ Print paste application).

I. Natural thickeners: a) plant-based products: → Starch, particularly wheat starch, swelling starches, roasted maize starch, types of gum (→ Vegetable gums) such as gum arabic, industrial and synthetic gum; → Locust bean flour, Tragacanth, extracts of lichens, mosses, types of seaweed, such as →: Alginates; Agar-agar, carragheen. b) Animal products →: Albumen;



polymannan

```
– M – M – M – M – M – M – M – M – M – M – M –
```

galactomannan-1.5 (cassia gum)
from the endosperm of Cassia tora/obtusifolia

```
– M – M – M – M – M – M – M – M – M – M – M –
  |                   |                   |
  G                   G                   G
```

galactomannan-1.4 (carubin)
from the endosperm of Ceratonia siliqua

```
– M – M – M – M – M – M – M – M – M – M – M –
  |               |               |
  G               G               G
```

galactomannan-1.3 (tara gum)
from the endosperm of Cesalpinia spinosa

```
– M – M – M – M – M – M – M – M – M – M – M –
  |           |           |           |
  G           G           G           G
```

galactomannan-1.2 (guarana)
from the endosperm of Cyamopsis tetragonoloba
(guarana plant)

```
– M – M – M – M – M – M – M – M – M – M – M –
  |       |       |       |       |       |
  G       G       G       G       G       G
```

galactomannan-1.1

```
– M – M – M – M – M – M – M – M – M – M – M –
  |   |   |   |   |   |   |   |   |   |   |
  G   G   G   G   G   G   G   G   G   G   G
```

Tab. 1: Structure of galactomannan molecule chains.
M = mannose; G = galactose.

Gelatine; Casein; Glue. c) Mineral products (earth) →: China clay; Kaolin; Colloidal solution.

II. Artificial thickeners: (modified natural products): →: Cellulose derivatives; Starch ethers; Starch esters; Ethoxylated or monoacetic converted meal.

III. Synthetic thickeners (synthetics and synthetic resins): particularly polymerisates on the basis of polyvinyl alcohol, polyacrylate, also chlorinated rubber.

IV. Special thickeners for pigment printing etc: → Emulsion thickener on hydrocarbon basis.

Individual thickeners and their properties:

1. Galactomannans: Galactomannans are polysaccharides which are predominantly constructed of the individual sugars mannose and galactose (Tab. 1). The mannose components form a chain of several hundred (1,4)-ß-D-mannopyranosyl-units which carry bonded α-D-galactopyranosyl units at varying distances (1,6) depending on the origin of the plant. Such galactomannans are mainly found in the endosperm of seeds from plants of the leguminosae species. These leguminous substances are in many cases able to supply themselves with nitrogen from the air via tuber bacteria. The galactomannan is incorporated plastically in the cells of the endosperm and can be released and produced by cell-destroying selective grinding.

Carubin, which is made of locust bean flour, had already been marketed in the twenties, and this was followed by guar (Tab. 2), fabricated from the guar seed, in 1953. It had been developed in the U.S.A. during the Second World War when the most important areas cultivating the locust bean tree around the Mediterranean were involved in the events of the war preventing access to locust bean sources.

Modification processes give locust bean meal a particular solubility in cold water, flexible thickening films, electrolyte-stability as well as better compatibility with dyes and chemicals.

Alkaline degradation and ethoxylation have the following effect:

- optimum cold-water solubility in a wide pH range (carboxymethylated products can be difficult to dissolve in the acid range),
- low salt content,
- optimum heavy metal salt stability.

Chemical treatments naturally also have an impact on environmental properties and the degradability of such thickeners (Tab. 3).

2. Starches:

a) Thermal decomposition of maize starch: this causes dextrin to be produced which is known as roasted starch or British gum. These are low-viscosity products which are used as colour-intensifying components. A further development is roasted swelling starch which is soluble in cold water.

b) Carboxymethylisation of maize starch: this process results in starch ethers which are all soluble in cold water. Starch ethers are predominantly used as colour-intensifying components in thickener combinations.

3. Celluloses: methyl-, carboxymethyl-, hydroxyethyl- and hydroxypropyl celluloses are used to a small extent in the printing industry. Depending on the degree of substitution the possibilities for use are varied including hot steam treatment and as an alginate substitute in reactive printing.

4. Alginates: fabricated predominantly from brown algae by precipitation and separation of the alginic acid with subsequent solution in caustic soda liquor or ammonia resulting in sodium and ammonium alginates.

5. Natural types of gum: all of these types must be subjected to a lengthy process of cleaning, hydrolysing and bleaching due to the high purity specification in textile printing. This method results in medium-to-low-viscosity thickeners with faster solution and good chemical stability.

a) Crystal rubber: a crystal-like gum-resin from cherry and almond trees from the Shiraz region of Iran. For this reason this is known as “Shiraz gum”.

b) Gum arabic: a dried, crystal-like plant juice from acacia arabica, also known as Senegal or Kordofan gum. This is no longer widely used in printing.

c) Tragacanth gum: a gum-related, dried plant juice of the astralagus type which is traded in plate or shell form. The colour is greyish white to reddish and usually indicates the degree of contamination. Tragacanth gum was a widely-used thickener in printing until the mid fifties.

6. Combination thickeners: in order to utilise the various properties of the different thickeners, two or three products are often used in combination. Whereas printers previously purchased the individual components separately, thickener manufacturers are increasingly asked to supply ready-mixed combinations. This is the most significant reason for the large number of printing thickeners to be found on the market. The reasons for using such combination products are numerous and range from increased colour yield and improved washing out capacity to cost reduction.

Important criteria when testing and assessing printing thickeners are:

- initial behaviour in water,
- viscosity and swelling rate,
- residues,
- push-through capability,
- pH,
- sieving capability,
- storage stability,

In addition to these criteria, print strike-offs are carried out on the textiles to be printed and assessed from the point of view of the following:

- colour yield,
- contour effects,

Basic galactomannan	Chemical change	Preferred field of application
Guarana Galactomannan 1.2	Unchanged	Carpet printing/dyeing Acid and metal complex dyes
	Depolymerised	Carpet printing/dyeing Acid and metal complex dyes Cotton/viscose Vat, substantive, fast salt dyes Polyester Disperse dyes Polyamide Acid and metal complex dyes Polyacrylic Cationic dyes
	Hydroxyethylated $-CH_2-CH_2-OH$	Carpet printing/dyeing Acid and metal complex dyes Cotton Africa print with fast salt Cotton/viscose Vat dyes Polyester Disperse dyes Polyamide Acid and metal complex dyes Polyacrylic Cationic dyes
	Hydroxypropylated $-CH_2-CHCH_3-OH$ Additionally depolymerised	Carpet printing/dyeing Acid and metal complex dyes Sizing
	Carboxymethylated $-CH_2-COO^-Na^+$	Carpet printing/dyeing Acid and metal complex dyes Cotton Vat/reactive dyes (conditional)
Carubin Galactomannan 1.4	Hydroxyethylated $-CH_2-CH_2-OH$	Carpet printing/dyeing Acid and metal complex dyes Cotton Africa print with fast salt Polyester Disperse dyes Polyamide Acid and metal complex dyes Polyacrylic Cationic dyes Wool/silk Acid and metal complex dyes
	Carboxylated $-CH_2-COO^-Na^+$	Cotton/viscose Vat dyes Wool/silk Acid dyes
Cassia Galactomannan 1.5	Hydroxypropylated $-CH_2-CHCH_3OH$ Additionally depolymerised	Sizing
	Carboxylated $-CH_2-COO^-Na^+$ Additionally depolymerised	Carpet printing/dyeing Acid and metal complex dyes Cotton/viscose Vat dyes Wool Acid dyes

Tab. 2: Galactomannans and their derivatives for textile printing.

product	BOD [mg O_2/mg substance]	COD [mg O_2/mg substance]	decomposition [%]	OECD-Test 302 B Zahn-Wellens test of potential decomposition [%]
raw material	0,89	0,62	70	100 (3 days)
decomposed raw material	0,88	0,56	64	100 (9 days)
ethoxylated raw material	0,91	0,22	24	92 (23 days)

Tab. 3: Effect of guar degradability by chemical treatment.

	regenerated-cellulose	Polyamide	Polyacrylonitrile	Polyester
meal	+++	+++	+++	+
starch	+++	–	+	+++
alginate	+++	–	+	+++
natural rubber	+++	–	–	–
CMC	+	–	+++	++

Tab. 4: Fields of application of different thickening agents. +++ of importance; + of little importance; – of no importance.

- evenness of distribution,
- penetration,
- ease of washing out,
- handling properties.

One look at the range of textile materials made of natural and synthetic fibres and the variety of products available (from yarn to carpet and the finest taffeta fabric) makes it clear that it is not possible to print with only one type of thickener. Even if it is understandable for cost and environmental reasons that the printer aims to work with a thickener which is as low in solids and has as high a viscosity as possible, it is important to differentiate as the requirements for individual articles are different.

When selecting the print thickener the most important factors are:

- chemical compatibility with the dyes and chemicals to be used,
- the necessary high solids content (a high-viscosity locust bean flour is, for example, generally adequate for printing carpets whereas a polyamide umbrella silk definitely requires a low-viscosity thickener),
- machine facilities (dissolving systems and printing machinery),
- capacity of the thickener to be washed out and its ecological properties,
- costs of thickener taking into consideration the required quantity to be used.

Tab. 4 shows which natural substances are mainly used with different synthetic fibres.

Thickeners for pigment printing Emulsion thickeners are useful for pigment printing. The viscosity of emulsions plays a decisive role not only as far as subjective quality assessment is concerned. In addition thickeners must be dosed, applied and dispersed easily. In order to be able to adjust the required viscosities of emulsions, structurally different high-molecular or low-molecular additives are used according to their phase properties in aqueous medium usually in combination with surfactants, co-surfactants and electrolytes.

Most surfactant formulations are based on alkyl ether sulphates or alkyl sulphates mixed with betaines or amphoteric co-surfactants, the viscosity being adjusted by the addition of salt and/or fatty acid alkanol amides. When formulating emulsion thickeners surfactants are used which place particular demands on the effectiveness of a thickener. An additional factor is the possible formation of nitrosamine (NDELA) due to the unavoidable presence of free diethanolamine in the alkanol amides. It is therefore recommended to refrain from the use of secondary amines. At-

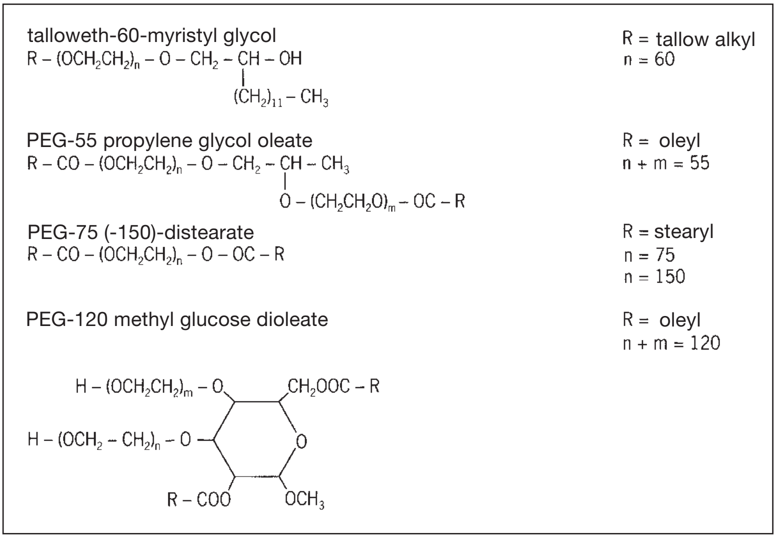


Fig. 1: Selected nitrogen-free thickeners (Henkel).

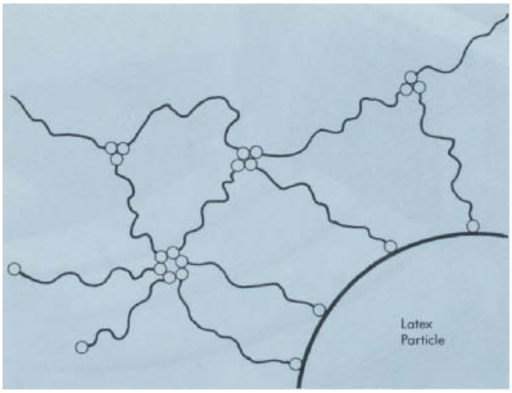


Fig. 2: Associative thickeners (Röhm).

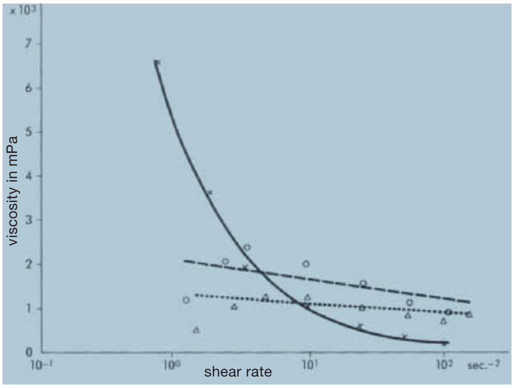


Fig. 3: Viscosity curves of alkyd resin lacquers and dispersion lacquers.
— x dispersion based on hydroxyethyl cellulose as the thickener; – – – O dispersion lacquer based on associative thickeners; - - - Δ alkyd resin lacquer.

tempts were made recently to develop new nitrogen-free additives to adjust viscosity (Fig. 1).

The viscosity-increasing effect of polymer thickeners in dilute aqueous surfactant solutions is due particularly to the construction of a three-dimensional hydratized network in the water phase into which the surfactant micelles are incorporated. Viscosity-promoting synergetic interaction between surfactant and polymers is an additional factor. In a similar fashion this mechanism is also relevant for synthetic co-polymers and chemically-modified natural polymers which can be used as thickeners. Associated thickeners on a polyacryl basis are alkali-soluble acryl polymers containing hydrophobic groups and behave in a similar fashion to a polymer emulsifier, i.e. the hydrophobic groups of the thickener molecules form an association creating a network and causing a viscosity increase. The dispersion and pigment particles are incorporated into the network formed by the thickener resulting in a stable dye paste with virtually Newton-like flow properties. The interaction between dispersion and the thickener also plays a significant role (Fig. 2). Appropriate structural viscosity naturally depends on the formulation of the thickener (Fig. 3).

Thickeners for printing reactive dyes Reactive dyes could not previously be used with locust bean meal thickeners on a galactomannan basis for printing as the dye reaction with highly-reactive galactomannan-OH-groups results in a stiff fabric handle. For this reason alginates are used exclusively which do not yield undesired reactions as they are polyuron acids. However, a guar-based thickener is fabricated by chemical modification of the galactomannan-OH-groups which can be used with reactive dyes without any effect on handle.

Thickness of textile fabrics DIN 53 855 Sheets 1 and 2 defines the following concepts (for textile with raw thickness of > 0.05 g/cm^3 ; with the exception of floor coverings):

I. Thickness a: Distance between upper and lower side of a textile fabric, measured as the distance of two plane parallel measuring plates of a certain size between which the textile fabric is located under a certain measured pressure. At a raw thickness of > 0.1 g/cn3 the size of the surface to be measured and the pressure on the textile fabric is defined.

II. Norm thickness a_x: thickness at a defined measured pressure and test area. It also serves as a reference dimension when calculating the raw density, the relative compressibility and dimensions derived from this.

III. Absolute compressibility Za_x: difference of norm thickness and thickness at 10 times greater measured pressure.

IV. Relative compressibility ZR_x: relationship of ZA_x to norm thickness or thickness as %.

Thin layer chromatography (TLC). A method for the separation of extremely small quantities of individual substances in mixtures by adsorption and partition chromatography. The procedure involves the use of glass slides which are coated with a thin, well-anchored sorbent layer (e.g. silica gels, aluminium oxide) so that development can proceed on a rising solvent front. Advantages in comparison with paper chromatography are:

- less time-consuming,
- as a rule, purely inorganic sorbent layers are employed,
- sharper separation effect and lower detection limit,
- extremely small quantity of test substance required,
- very simple procedure.

TLC utilizes the different distribution ratios of substances in the mobile (liquid) phase on the one hand, and in the stationary liquid phase adhering to a polar solid substrate on the other. Because of its simplicity, it is often used for preliminary checks on the purity of samples or to supplement other test methods. Procedure: a commercially prepared, coated glass or plastic plate is placed in a suitable eluent mixture in a closed container saturated with mobile solvent vapour. The eluent ascends by capillary forces and the substances applied on the start line at the bottom are eluted along with it. The different distribution coefficients of the substances lead to different migration rates which, in turn, result in separation. Mixtures of methanol, acetic ester, chloroform, distilled water, glacial acetic acid, heptane, etc. are used as eluents. When choosing the eluent, it is essential that the solubility of the substances being separated is taken into consideration. If the substances are too readily soluble, no separation takes place as they migrate along with the mobile solvent front. Too low a solubility, on the other hand, leads to the components not migrating from the point of application or the formation of blurred, indistinct peaks.

Thin shade Term used particularly when sampling dark colours to describe missing → Bloom or character.

Thio Gk.: thios = sulphur.

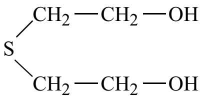
Thiocarbamide → Thiourea.

Thio compounds (Gk.: thios = sulphur). They are derived from oxygen compounds whose oxygen was substituted by usually divalent sulphur. Examples are sulphurous acid ($H_2S_2O_3$) and sodium thiosulphate ($Na_2S_2O_3$). Other thio compounds are, for example, thioethers (alkyl sulphides) of the type $H_5C_2–S–C_2H_5$ and thiophenols of the type (C_6H_5)SH.

Thiocyanates SCN-type compounds, e.g. thiocyanic acid HSCN and its salts, thiocyanates, such as → Potassium thiocyanate and KSCN. Thiocyanates are usually colourless and easily soluble; only lead thiocyanate is difficult to dissolve; copper, mercury and silver thiocyanates are not soluble. With iron(III)-chloride solution ($FeCl_3$), soluble thiocyanates result in a typical blood-red colour (iron detection).

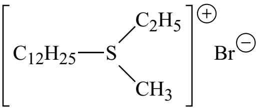
Thiocyanate/tin discharges A very aggressive discharge system → Tin salt discharges which are carried out under stringent conditions.

Thiodiethylene glycol (thiodiglycol).



Substance with a molecular weight of 122 and b.p. at 282°C which is used as a dye solvent and fixation accelerator for vat printing. Contact with hot hydrochloric acid results in the formation of mustard gas: $S(CH_2–CH_2–Cl)_2$.

Thioethers (alkyl sulphides, type: $R–S–R_1$) alkyl-substituted → Mercaptans and/or dialkyl derivatives of hydrogen sulphide such as dimethyl sulphide ($CH_3–S–CH_3$) or methylethyl sulphide ($CH_3–S–C_2H_5$). They are used as the basis of textile auxiliaries. Thus, for example, the thioether, dodecylmethylethyl sulphide, results in the corresponding cationic sulphonium compound.



Oxethylated thioethers on the other hand serve as the basis of non-ionic wetting agents and detergents ($C_{12}–H_{25}–S–(C_2H_4–O)_n–C_2H_4–OH$). Thioethers are usually water-soluble, in their pure form not unpleasant smelling liquids, which turn into sulphoxides ($R_2–SO$) and sulphones ($R_2–SO_2$) as a result of strong oxidation.

Thioglycolate number Test for evidence of damage to wool (particularly in the case of acid damage) in which the solubility of wool in alkaline thioglycolate solution is determined and quoted as a percentage. Untreated wool has a thioglycolate number of 15.9; after treatment with sodium carbonate: 0.00–6.8; with H_2O_2: 18.7–25.8, with H_2SO_4: 27.0–89.5. Determination of the thioglycolate number (based particularly on peptide splitting) is a valuable supplementation of alkali solubility determination (specifically on initiating cystine splitting).

Thioglycolates Salt of → Thioglycolic acid.

Thioglycolic acid (mercaptoacetic acid), $HS–CH_2–COOH$; unpleasant smelling, oily, colourless 80–85% liquid with a density of 1.325 and a boiling point of 104°C. It is miscible with water and boils easily (particularly in the presence of copper, iron and manganese). Thioglycolic acid is used, for example, for establishing the thiglycolate number; dehairing skins in tanning facilities, alkali stabilization of wool, removing rust and boiler scale, removing heavy metal contamination from water, providing evidence of iron and molybdenum by means of colourimetric determination, as an additive for artificial resins and synthetic rubber. The ammonium salt of thioglycolic acid, ammonium thioglycolate, is a strong reducing agent which is used widely for surface finish and permanent crease and pleat fixation in woollen articles as well as in the production of cold permanent wave effects. Basically the sulphur bonds of wool keratine are split reductively: $R–CH_2–S–S–CH_2–R \rightarrow R–CH_2–SH + HS–CH_2–R$. The wool fibre can therefore assume a new form which remains stable after washing and cleaning after the reducing effect has ceased.

Thioglycol test,

I. With Ferric(III)-chloride: a few drops of 5% solution in aqueous test extract (can also be carried out specifically on wool), adjust to alkaline using ammonia, red violet colour is a positive result.

II. With sodium nitroprusside: a few drops of 1% solution in aqueous test extract, adjust alkaline using dilute ammonia, red violet colour provides positive result.

-thiol Term used for organic compounds with the group R–SH of the type → Mercaptans which result, for example, during sulphitolysis of wool cysteine.

Thiol-catalysed disulphide exchange Self-cross linking reaction in wool during certain fixation processes (see Fig.). Both reducing agents (e.g. overheated steam) and bases produce wool-bound cystine ions out of cystine (in the case of reducing agents) or out of cysteine (in the case of the bases) which cause disulphide exchange during the further course of orientation (stretching). → Wool chemistry.

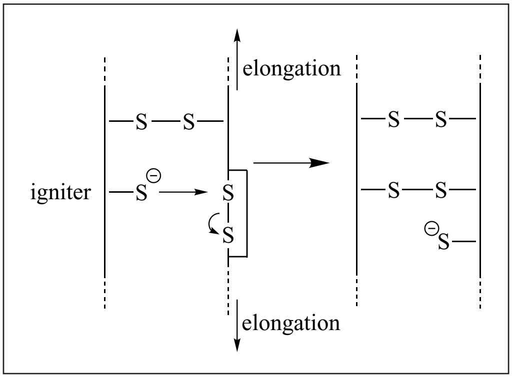


Fig.: Result of thiol-catalysed disulphide exchange in wool: additional crosslinking = stabilization.

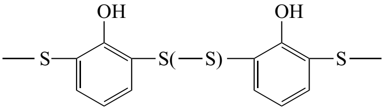
Thiols → Mercaptans.

Thionaphthene → Heterocyclic compounds.

Thionyl chloride An acid chloride of sulphorous acid: $SOC1_2$; colourless liquid which produces smoke when exposed to air, smells suffocating and is strongly light-refracting. It splits in water to HC1 and SO_2. Density 1.638; b.p. 78°C. Thionyl chloride is categorized as a “particularly dangerous substance” of high inhalation toxicity with less than 4 ppm/h. This value can only be seen as an average as the exact limit of inhalation duration cannot be determined. Thionyl chloride is used among other things for providing evidence of polyvinyl alcohol sizes; pass steam through of an aqueous fibre extract, after cooling add thionyl chloride until yellow coloration indicates total solution has taken place: change of colour to black-brown, then black precipitation as positive evidence for formation of characteristically coloured polyenes.

Thiophene → Heterocyclic compounds.

Thiophenols Phenol sulphur products which are used as reserving agents and tannin substitutes. Fat-free, aromatic products.



Thioplasts Rubber-elastic polycondensation products (elastomers) of dihalogen compounds with sodium polysulphide (Na_2S_4). The reaction products are precipitated as a coherent mass but contain many foul-smelling by-products which limit their technical usefulness. Like natural rubber, thioplasts are supplemented by filling materials, rolled and vulcanized. They decompose in acid and alkaline solutions but are characterized by high oil and petrol resistance. They can be hardened by means of oxidising agents which bring about a linking of the sulphur atoms. Equipment items made of thioplasts are used predominantly where high solvent resistance is required, for example in chem. apparatus construction, for boilers and pipe linings, cable coverings, fuel pipes and insulation materials. Thioplasts are used to a lesser extent as binding agents and protective coatings.

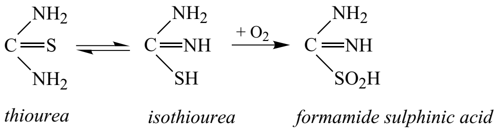
Thiosulphates Salts of thiosulphuric acid ($H_2S_2O_3$) which, with the exception of the salts of silver, barium and lead, are soluble in water.

Thio sulphuric acid → Sulphur oxyacids.

Thiourea (sulphonate urea, sulphonate carbamide, thio carbamide). $H_2N–CS–NH_2$; molecular weight 76, density 1.40. White rhombic prisms which are soluble in water (neutral reaction) and in hot alcohol. Thiourea salts are formed in conjunction with strong acids. Additional compounds result with heavy metal salts and many organic componds. Other chem. characteristics correspond approx. to those of → Urea. There is a close relationship to → Ammonium thiocyanate: $NH_4–SCN$.

Thiourea is used as a softening agent to increase the durability of heavy silk; for preventing over-oxidation when developing vat leuco ester dyes; as a vulcanization accelerator; as a padding auxiliary. Thiourea is used less and less frequently for printing polyamide with acid and substantive dyes. As a stable reducing agent in stripping and discharge effects on dyeings formamide sulphinic acid is used from the oxidation of isothiourea.

Condensation products with formaldehyde (→ Aminoplasts) are used for crease-free, swelling-resistant and low-shrinkage finishing. The development of cati-



onic thiourea derivatives is worth mentioning in this context.

Thixotropy Property of certain liquids to change their viscosity reversibly under mechanical strain and to convert from a thick gel-like consistency into a thin liquid solution state. Thixotropy is present in non-Newton liquids (→ Rheological behaviour of solutions). In thixotropic liquids viscosity decreases with increasing duration and intensity of mechanical strain under isothermal conditions in the form of a hysteresis. As opposed to structure-viscous and diluent flow characteristics, the viscosity does not increase when the strain is reduced but continues to decrease due to the increasing duration of strain. The viscosity does not reach its original value again until the liquid has recovered for a period after complete discontinuation of the strain. The reverse characteristics, sol-gel-sol conversion is know as → Rheopexy.

Thousand-point roller (kiss roller). Has fine point engraving and is used for → Kiss roll padding on the printing machine, i.e. for transferring a fine liquid film that may contain additional chemicals and dyestuffs. It is used for pre-moisturizing less absorbent fabrics, for dyeing one side of a fabric and for ludigol treatment, etc.

THPC Abbreviation for tetrakis-hydroxymethyl-phosphonium-chloride which is used for washing- and dry-cleaning-resistant → Flame-retardant finishing of cotton. Originally this finishing process was carried out using a nitrogen methylol compound, such as trimethylolmelamin, under dry crosslinking conditions. Nowadays the finishing process is usually carried out using THPC urea or substituted melamine products and subsequent gas- or aqueous NH_3 treatment. The advantages of this method are less significant losses of tear and friction resistance, although an impairment of texture has to be taken into account. Analytical determination of THPC is carried out by iodometric methods.

THPOH Abbreviation for tetrakis-hydroxymethyl-phosphonium-hydroxide which is used for flame-retardant finishing. THPOH is volatile at higher temperatures and the flame-retardant effect can therefore be partially reduced during machine stops in the finishing process.

THPOH-NH$_3$-Finish Permanent → Flame-retardant finishing for cotton and rayon staple fibre with → THPOH or → THP salts, such as, for example, → THPC.

THPS Abbrev. for tetrakis ammonium-hydroxymethylphosphonium sulphate which is used for → Flame-retardant finishes of cellulose and cellulose/polyester mixtures with a minimum proportion of 65% cellulose. The application process involves impregnation, which is carried out first, followed by drying, condensation and after-washing. The finish withstands 50 household washes. When used after the condensation process with the addition of finishing agents it results in a crisp, stiff handle.

THP salts Term used for tetrakis-hydroxymethyl-phosphonium compounds such as, for example, →: THPC; THPOH; THPS which are commercially available under different names.

THPX Abbreviation for → THP salts.

Thread According to DIN 60 900 thread is the term used to describe textile structures in linear form such as roving, simple yarns, ply-yarn, laces, etc., where the form and not the type of product is denoted.

Thread-by-thread (Fr.: fil à fil), fabric in plain weave 1/1 or twill 2/2 which is characterized by a special pattern achieved by alternate weaving of light and dark yarns in warp and weft directions. Fil-à-fil fabrics created in this manner are also known as → “Pepper and salt articles”, black and white and grey-white in point patterns. Thread-by-thread fabrics are used for manufacturing outer clothing.

Thread count Number of threads in warp or weft direction of a screen gauze per cm (= fabric-no.) or per inch (mesh number).

Thread lubrication → Yarn lubrication.

Thread-up Fabric path or thread-up in a → Steamer.

Three-bath process Term used in dry cleaning (solvent application). Cleaning, rinsing and finishing using 3 different liquors.

Threeply carpet (Scottish carpet). → Reversible carpet made of three interwoven fabric layers.

Three-quarter cloths Shorn soft and semi-dull brushed fabric (woollen cloth), belonging to the class of so-called fine cloths, in linen weave, not too heavy, i.e. below 400 g/m^2.

Three-roller yarn Generally cotton or viscose spun yarns (as opposed to two-roller yarns) from so-called three-roller spinning which works on the principle of the stretching process (3-cylinders as pre-spinning machine, also known as flyer, for stretching, twisting and parallel alignment of tow).

Three-stage carpet printing process When printing carpets it is normal to use 10–20 times the quantity of printing paste per surface unit which is used for printing textiles with a smooth surface. This is because particularly high-pile material absorbs dye in 3 dimensions whereas, in the the case of normal textiles, it is sufficient to dye the surface. The three-stage carpet printing process avoids these large quantities of printing paste (which a carpet printing machine has difficulty in processing technically) by applying only 30–50% of the total printing paste quantity necessary during the first stage which penetrates to approx. half the pile height (good print definition). Short heat treatment follows during the second stage (infrared, hot air or steam) to fix the dye in the pile tufts (preventing greying effect). During the third stage with the aid of a DD-unit a thin, chemical-free thickening solution is applied to achieve deeper penetration of the dye into the pile. The process achieves considerable savings in thickener and other chemicals as well as in effluent cleansing.

Three-stage drip-in dyeing process This is used for reactive dyes in exhaust dyeing processes. Especially recommended for jet dyeing machines. Constant temperature of 60°C. Addition of dye in two stages and of trisodium phosphate in three stages.

Threonine (monaminomonooxycarbonic acid). An amino acid contained in wool (6.76%) and silk (1.50%), → Amino acids.

Threshold effect Delayed precipitation of low solubility compounds that is shown by polyphosphates and also by complex phosphates in similar fashion. Polyphosphate ions are included in the network of low solubility precipitates that show interference in crystal growth. Phosphonic acids have the advantage over other complexing agents of high stability in cold and hot alkaline and also oxidizing liquors. Examples of the wide choice of phosphonic acids are listed in Fig. 1.

The property of preventing or delaying precipitation is known in technology as Stein-inhibition. This property is based on the "threshold effect". It indicates the effectiveness of a chemical compound in a substance or a physical process at under stoichiometric concentrations. This effect can be attributed to intermediate area phenomena which have an impact on crystal growth.

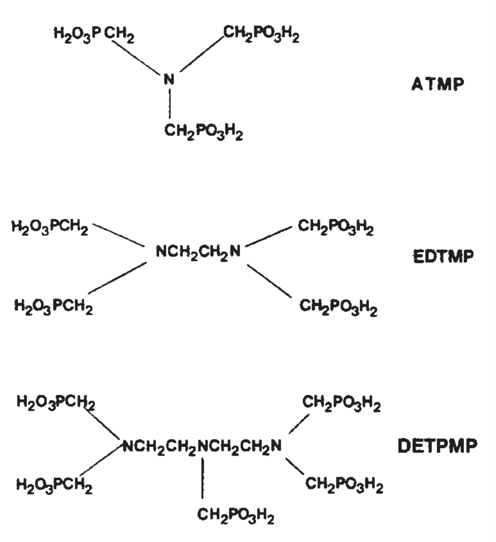


Fig. 1: Significant phosphonic acids.
ATMP = aminotrimethylenephosphonic acid;
EDTMP = ethylenediaminetetramethylenephosphonic acid;
DETPMP = diethylenetriaminepentamethylenephosphonic acid.

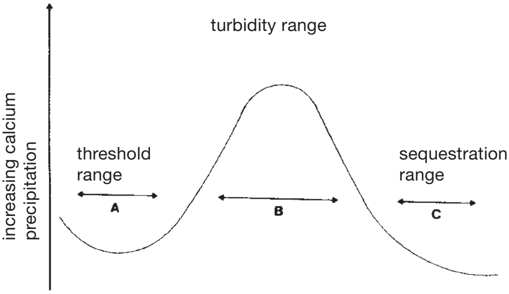


Fig. 2: Qualitative representation of the activity of threshold active substances.

The "threshold effect" was discovered at the end of the thirties with solutions of 1–10 ppm sodium hexametaphosphate, when it was established that precipitation of $CaCO_3$ from over-saturated solutions was delayed or inhibited (Fig. 2). In the sixties it was found that phosphonic acids also bring about a threshold effect. However, these have the decisive advantage over polyphosphates that they are hydrolytically stable and also have an effect over a wide pH range.

Threshold Limit Value (TLV). This value was created by the ACGIH (Am. Conference of Governmental Industrial Hygienists) → TLV values (used as an average concentration).

Threshold limit values for waste water The threshold limit values listed in Tables 1–4 (mg/l) are taken from the following regulations and drafts (in accordance with → DTNW, Krefeld):

A. 38. Administration Regulation of Waste Waters (Abwasser VwV – Abwasserverwaltungsvorschrift), Ministerial Publication No. 83, 6. December 1984.
B. Annex 38 Administration Regulation of Waste Waters (Abwasser VwV), Draft official representative, 26. July 1990.

	A	B	C	D	E	F
nitrite (NO_2)				20		10
ammonium	5	10	10	200	200	80/200[a]
fluoride$_{tot}$				60		60
sulphide$_{tot}$		1	1	2	2	
CN$_{free}$				0.5		
CN$_{tot}$				20		20
P		2	2			15
chlorine	0.3	0.3		0.5		
sulphate				600	800	600
sulphite	1	1				

a) < 5000 PE or > 5000 PE; tot = total; PE = population equivalence

Tab. 1: Anions (mg/l).

	A	B	C	D	E	F
AOX	–	0.5/3[b]	0.5[c]	1.0	–	
SHHC		0.1/1	–/1	1_{tot}	5	
phenols[d]				20	100	100
HC	10	15/50	15/100		20	20

b) segregated stream threshold limit value c) exceptions: chlorinating wool treatment; hypochlorite bleach d) water-vapour volatile
AOX = adsorbed organic halogen compounds: SHHC = simmering halogen hydrocarbons; HC = hydrocarbons

Tab. 2: Halogenated and non-halogenated hydrocarbons (mg/l).

	A	B[e]	C[e]	D	E	F
Al		3				
Ag				1		
As				0.1	1	
Cd				0.1	0.5	
Cr (VI)		0.1/0.5	–/0.5	0.5	0.5	
Cr_{tot}	2	0.5/2	0.5/2	2	3.0	
Cu	1	0.5/2	0.5/2	1	2,0	
Fe		3			–	
Hg				0.05	–	
Ni		0.5/2	0.5/2	1	3.0	
Pb		0.5		2	2	
Se				0.1		
Sn		2/10	2/10		5.0	
Zn	3	2/10	2/10	3	5.0	

e) second value: segregated stream threshold limit value; tot = total

Tab. 3: Metals (mg/l).

	A	B	C	D	E	F
BOD_5	40/30[f]	25	25			
COD	280/200[f]	160	160			
filtrable solid pollutants	40		40			
settlable solid pollutants (ml/l in 0.5 h)	0.3			1		1
pH				6.5–10	6–9.5	6.5–10
temperature (°C)				35	35	35
G_F[g]	4/3[f]	2	2			

f) composite sample: 2/24 h; g) dilution factor for fish toxicity;

Tab. 4: Other criteria (mg/l).

C. Annex 38 Administration Regulation of Waste Waters, Textile Industry Draft, 21. February 1990.

D. Draft of the statutes of the town of Krefeld dated October 1989.

E. Waste water drainage statute of the town of Krefeld dated 22. December 1983.

F. Waste water regulation manual; draft dated October 1990.

Throttle valve Device for regulating flows of substances and media.

Throughflow drying → Water extraction throughflow method.

Throughput time includes production times as well as set-up and shut-down times. The “handling” and intermediate storage of fabric takes up a relatively high proportion of the throughput time. The repeated “reversal” of the fabric in particular, and the final unrolling of fabric from batch rolls, etc. necessitates repeated operations between all process steps which is time-consuming and also ties up capital in the stages of adding value. Moreover, transport operations are involved in plaiting down (“reversal”) of fabric and winding on to batch rolls. The throughput time is determined by the speed of the fabric through machines, resp. the treatment times and intermediate → Storage times between the individual processes. Intermediate storage times occupy a large proportion of the total throughput time. They can be reduced by appropriate work planning and order scheduling. Dependent factors may include:

- multiplicity of processes involved,
- non-standard batch sizes,
- different speeds of the various production machines,
- different machine efficiencies,
- transport problems (shortage of yarn carriers, fabric wagons, A-frames, etc.),
- several passages through one machine,
- changes to the order of batches in process,
- requests made at short notice by the sales department for changes to the production program,
- different aftertreatment requirements,
- sample batches and quality standards,
- unexpected major repairs,
- excessively long administrative procedures between receipt of order and the issuing of finishing instructions as well as in dispatching finished goods from the warehouse,
- failure to prepare the required dyes/chemicals in good time,
- inadequate or no daily planning of machine utilization,
- inadequate daily monitoring of work in progress with regard to meeting the required deadlines or maintaining production efficiencies.

Thrust reversal When tensioning frames come to a temporary halt measures have to be taken to prevent the stationary fabric from suffering hot air damage. Thrust reversal temporarily changes the direction of air flow whilst simultaneously reducing burner performance causing the jets to suck in air upon standstill (see Fig.).

Thumb test Subjective manual test for assessing the resistance to tear and elongation properties of textiles. The textile is stretched over the top of both thumbs until it tears. This represents a subjective assessment of quality and is difficult to reproduce.

Thyristor Used for feeding direct current multimotor drives which are used among other things for powering continuous finishing machinery.

Ti Element symbol for titanium (22).

TI-air The Technical Instructions for the mainte-

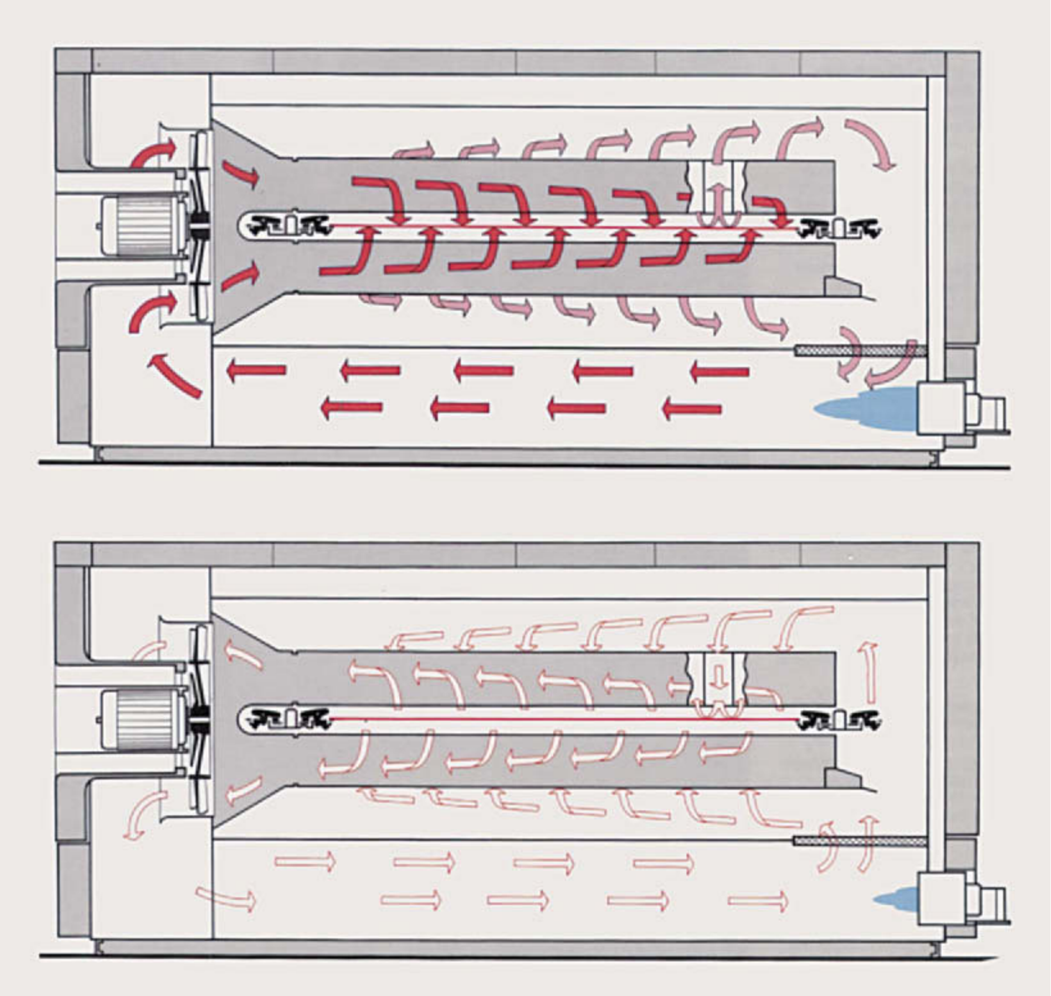


Fig.: Thrust reversal process in a Babcock stenter.

nance of clean air are general administrative regulations for the maintenance of clean air. Of significance for the textile finishing industry are the more stringent limits for volatile organic substances. The hourly rates have been reduced in Category I from 0.2 to 0.1 kg/h, in Category II from 3 to 2 kg/h and in Category III from 6 to 3 kg/h (Tab. 1). If these rates are exceeded, then the maximum concentrations for the corresponding category are applicable. The aim of the TI-air, is among other things, to protect the environs of a facility that emits toxic or offensive substances.

class	old		new		example
	mg/m^3	kg/h	mg/m^3	kg/h	
I	20	0.2	20	0.1	formaldehyde
II	150	3.0	100	2.0	tetrachloroethane, acetic acid
III	300	6.0	150	3.0	alcyl alcohols, paraffin hydrocarbons

Tab. 1: Classes of TI-air (as of 1993).

New regulations are coming into force concerning substances with an offensive odour. If neighbours feel that they are being unreasonably imposed upon by the presence of substances with an offensive odour, the facility is obliged to introduce measures to reduce emission.

The range of application of the TI-air.

– checking of applications from facilities requiring authorization (para. 6 BImSchG – Bundes-Immis-

sionsschutzgesetz – German Federal Immission Protection Law),
- checking of partial authorizations (paras. 8, 9 BImSchG),
- additional regulations (para. 17 BImSchG),
- regulations regarding the monitoring of the extent of air polluting emissions (para. 26 BImSchG).

In addition to the explanation of the range of application, the TI-air can be divided into two principal sections. The first of these is the section on “General Regulations” for keeping air clean and the second section on limitation and monitoring of emissions. As well as listing technical terms used and units used for measuring emissions, the General Regulations explain the range of odours and the processes of applying for authorization for a facility. The emission values for inorganic air content substances are also determined and listed in terms of concentrations and rates. Also listed are the measuring techniques used by the German engineering organization (Verein deutscher Ingenieure = VDI) needed to determine inorganic air impurities. In the second section, limits and methods of ascertaining emissions are defined. This section also contains the limits and categories for organic substances and for equipment for printing fibre material in strips or sheets as well as equipment for reticulated fibre soaking.

The annexe to the regulations concerning facilities requiring authorization contains a final list of those facilities that have to be licensed in accordance with standard or simplified procedures.

In the textile finishing industry the following facilities require a licence:
- rotary printing presses including appropriate drying units if they process more than 25 and less than 250 kg/h of organic solvents.
- dyeing equipment using dyeing accelerators including tension frames but excluding equipment operated under high pressure.
- equipment for bleaching thread or fabric using alkali, chlorine or chlorine compounds.
- equipment for coating or impregnating materials manufactured in strip form including appropriate drying units using from 25 to a max. of 250 kg/h of organic solvents.
- equipment for coating, impregnating or soaking materials with artificial resins in strip form, including drying aggregates (this includes tension frames).

Even if a facility does not fall under the licensing requirement, the plant is obliged to operate its equipment in such a way that neighbouring premises and the general public are protected from noxious and offensive air pollutants. The operator is obliged to take measures to prevent noxious air pollution from occurring. The TI-air uses the term offensive (offensive odour) as well as the term noxious. Both terms have implications for the emissions caused by textile finishing processes. Colour fixation and finishing/permanent finishing processes are particularly problematic. A proportion of the fibre preparations evaporates when untreated wool is dried. In particular, bobbin and spin oils are oxidized when subjected to high treatment temperatures to yield odour intensive aldehydes, the smell of which often gives cause for complaint. Depending on the finishing or per-

class	mass flow	mass concentration
I	0.5 g/h or more	0.1 mg/m^3
II	5 g/h or more	1 mg/m^3
III	25 g/h or more	5 mg/m^3

Tab. 2: TI-air: Threshold limit values for carcinogenic substances.

class	mass flow	mass concentration
I	1 g/h or more	0.2 g/m^3
II	5 g/h or more	1 mg/m^3
III	25 g/h or more	5 mg/m^3

Tab. 3: TI-air: Threshold limit values for inorganic substances in the form of dust.

class	mass flow	mass concentration
I	10 g/h or more	1 mg/m^3
II	50 g/h or more	5 mg/m^3
III	0.3 kg/h or more	30 mg/m^3
IV	5 kg/h or more	0.5 g/m^3

Tab. 4: TI-air: Threshold limit values for vapourous and gaseous organic substances.

class	mass flow	mass concentration
I	0.1 kg/h or more	20 mg/m^3
II	2 kg/h or more	0.1 g/m^3
III	3 kg/h or more	0.15 g/m^3

Tab. 5: TI-air: Threshold limit values for organic substances (e.g. steam distilled).

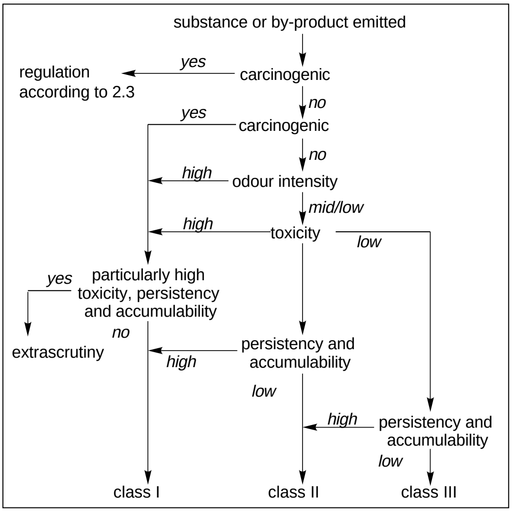


Fig: Assessment chart for the classification of substances according to TI-air (Umweltbundesamt – German Federal Environment Agency)

manent finishing process the resultant emission contains various substances of which formaldehyde can exceed the limit of 20 mg/m^3. Analysis of the emission is costly because of the difficulty of taking samples. It is therefore advisable to estimate the emission by means of an initial material analysis as a first step. The following measures for keeping emissions clean are the most important: selection of low emission techniques/products, optimisation of conditions of treatment and combustion emission from the boiler-house. Adsorbents and emission washers have a limited range of use (according to Richter and Schollmeyer et al.).

Limits for mass flow and mass concentration are determined in individual sections of the TI-air and the substances and groups of substances are divided into categories (Tabs. 2–5).

The order of magnitude of the permitted mass concentrations of noxious substances in accordance with TI-air can be illustrated by means of a practical example: An emission of 20 mg/m^3 means that at an emission volume of 12 000 m^3/h, 240 g of noxious substance may be transported in one hour. This means that on a strip of material of a width of 1.50 m treated at a speed of 50 m per minute only 50 mg = 0.05 g of noxious substances may be released per square metre. Irrespective of the mass concentration of the noxious substances (i.e. also in the case of less than 20 mg/m^3) the environment can be affected in an offensive way in the case of odour intensive properties. In this instance the TI-air specifies that “odour intensive emissions are generally to be fed into emission cleaning facilities or that equivalent measures are to be taken” (see Fig.). →: Emission problems; Environmental protection legislation.

Tibetan cashmere is derived from the Tibetan goat which lives in Tibet and is closely related to the cashmere goat. Tibetan cashmere is somewhat rougher and a little more glossy in appearance. Production, properties and utilization are similar to cashmere. → Animal hair fibres.

Tibet wool (Tybet). Term used for unmilled fabrics sorted as → Rags and used to produce → Reclaimed wool of quality category II.

TIC Abbreviation for “Total Inorganic Carbon”; value used in → Biological waste water treatment, quoted in mg/l waste water or in mg carbon/g substance.

Ticking Densely woven, generally striped patterned linen, cotton or half linen fabrics in twill weave. → Drill fabrics.

Tie (tying). This is carried out for patterning of:

– warp or weft threads (→: Ikat; Kasuri dyeing),
– fabrics (→: Bandhana; Plangi; Shibori technique).

Tying is carried out by binding with threads which prevents penetration of the dyes on subsequent dyeing. Machine tying of yarns has also been carried out for some time using wires which give reproducible patterning.

Tie-dyed batik →: Bandhana; Plangi; Shibori technique.

Tie-Dye-Pack Special folding technique which can be combined with → Tieing techniques and is used, for example, for dyeing with reactive dyes.

Tieing techniques Fabrics (and in many cases finished items of clothing, particularly T-shirts) are tied in a certain way along the lines of tie-dyed batik or tie-dyed technique prior to dyeing resulting in interesting patterns. Dependent on the type of → Tie, effects known as the “Mukeka Mutono Special“, the “Grill” or the “Tortoise” are given.

Tie molecule The physical structure of semi-crystalline polymers, of which polyethene terephthalate is one, can be described by means of a two-phase model of alternating crystalline and amorphous regions. The crystallites are rigid blocks upon first approach. The molecular arrangement in the amorphous regions is, therefore, of decisive significance for the mechanical properties of the yarn. The molecule folding at the edges of the crystallites and the length distribution of the connecting molecules (“tie-molecules”, Fig.) can be recorded by infrared-spectroscopy. If a yarn is stretched, molecule “a” in the elongated location can adapt by widening of the valency angle or chain bridge. Molecule “b” can bridge the enlarged distance between the crystallites by rotation from the gauche into the trans-conformation. Molecule “c” is so long that it can contain a considerable portion of the original tangling even in the lengthened form.

Infrared-spectroscopy can be used to determine the

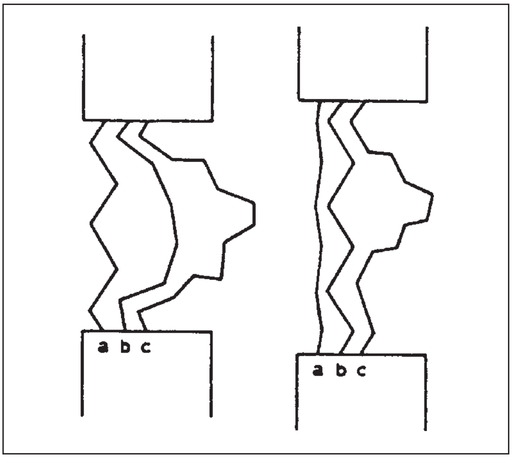


Fig.: Polyester tie molecule transitions in the amorphous ranges on elongation of the fibres (left = unstretched; right = stretched).

trans-gauche transitions, sections of folded molecules and molecular tensions were recorded quantitatively on the tie-molecules. With increasing winding-up speed of spun yarns, the crystalline character and the number of folds increases whilst the proportion of gauche conformations decreases. The increasing orientation of the amorphous molecules can also be recognised, as these untangle and adopt the trans-conformation. The best orientated amorphous trans-segments are incorporated in the growing crystallites (according to Zahn).

Tier drier Driers through which textiles are moved in several tiers (Figs. 1 and 2).

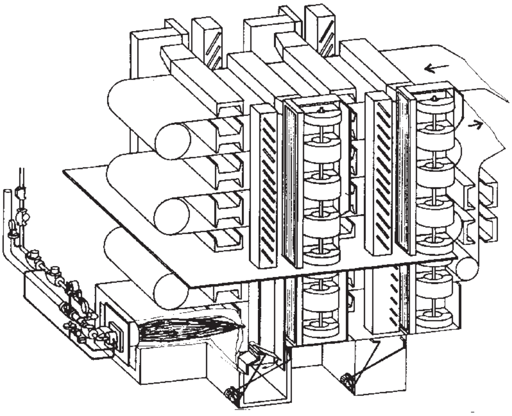


Fig. 1: Krantz's old style drying stenter in tiers (without housing).

Tie-up thread (tie-up yarn, tie-up) →: Hank; Skeins; Reel.

Tightness factor (TF) → Cover factor (CF).

Tight pick → Shiners.

Tight threads Warp or weft threads caused by too great a tension (usually due to the state of humidity during weaving so that these threads in the fabric shrink during drying) which can result in unevenness in fabrics which has to be eliminated by stitching or at least improved.

Tiles → Carpet tiles.

Tillandsia fibre,

I. (American moss, tree hair, Louisiana moss). This is produced from the jointed and branching stem of the

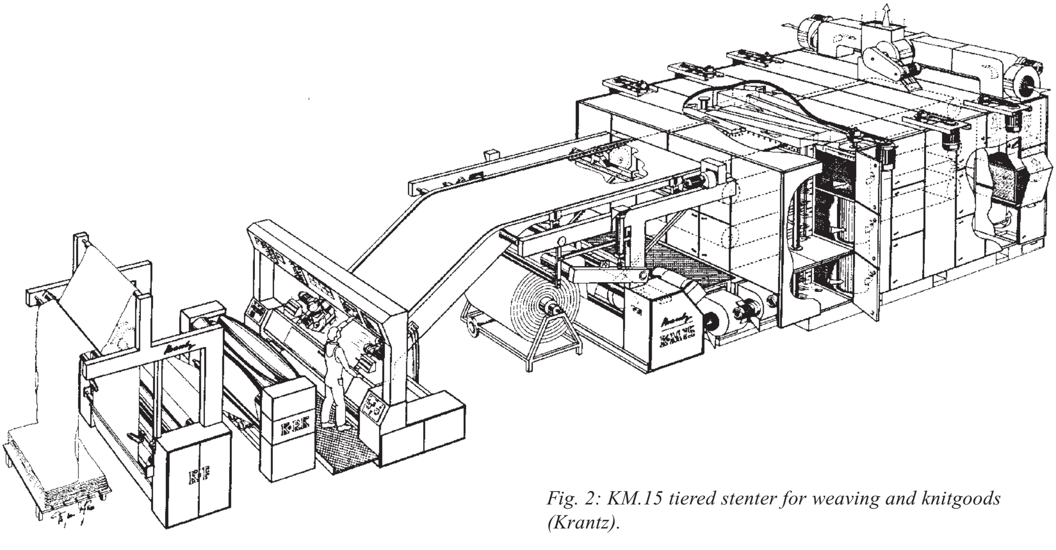


Fig. 2: KM.15 tiered stenter for weaving and knitgoods (Krantz).

rootless tendril creeper (tree parasite) whose three metre long stem hangs from branches in beard-like fashion. The unpeeled raw fibre is grey-greenish white; the peeled pure fibre is brownish black and is often dyed black artificially. The fibre bundles are separated using boiling sodium carbonate solution. Tillandsia fibre is characterised by great durability and strength and is often used as a substitute for horse hair and as upholstery material.

II. → Kenaf.

Time (concepts) of time used in the course of processing →: Operating time; Processing time; Working life; Idle machine time; Throughput time; Transportation time; Storage time; Machine time; Down time; Productive time; Forming time; Handling time factor. Work study terms →: Order processing time; Completion time; Basic time; Setting-up time; Allowance; Standard times; Unit time.

Time of half-dyeing Time in minutes which is required for 50% of the amount of a certain dye contained in the liquor to be absorbed by the fibre. Unsuitable as a basis for selection of combination dyes for cationic dyes on polyacrylnitrile. → Compatibility value is better suited.

Time step levelling test This is used to compare the effectiveness of different levelling agents for dyeing wool (Fig.). Recipe: 1% Supranol fast blue G (Bayer), 10% sodium sulphate anhyd., 3% acetic acid 60%, liquor-to-goods-ratio 1:50 in relation to the total weight of dyed wool. Method: fabric samples of equal size are placed in the dyebath when it reaches boiling temperature (0 min) and at 2, 4, 8, 16, 32 and 64 min. When testing without levelling agent the greater proportion of the dye is absorbed almost completely after a short period and there is no levelling between the fabric sample first treated and the one which was added later. When dyeing with levelling agents all test samples are dyed to almost the same intensity due to the levelling and suppressing capacities of the levelling agent.

Tin (Sn), atomic weight 118.8. Silver white → Metals, glossy, crystalline, very soft and elastic, rollable (leaf-tin, tin foil). Resistant to air and water. Melting point 228/232°C, can be pulverized at 200°C. Soluble in hydrochloric, sulphuric and nitric acids and alkalis. Compounds bivalent and trivalent, the latter being more stable. SnII compounds are strongly reducing. Tin(II)-hydroxide is important as a stain, tin-acetate as a discharge, tin-chloride as a tin salt stain. The latter is easily soluble. When the corresonding solutions are diluted with water strong hydrolysis takes place (decomposition). Alkalis, alkali carbonates and ammonia cause precipitation that is soluble in the alkali surplus. Sn(IV)-compounds have a low-oxidizing effect. Important: with alkalis, alkali carbonates and ammonia, tin-chloride (for staining and weighting) results in easily-soluble tin(IV)-hydrate as meta stannic acid, $Sn(OH)_4$ (salts: stannates). This is used for staining and weighting silk.

Tinge Term used in sample dyeing for “a trace more” dye.

Tin(IV) hydrate $Sn(OH)_4$ or $SnO(OH)_2$. Used as a mordant in alizarin printing inks.

Tin(II) hydroxide $Sn(OH)_2$, molecular weight 152. Used as a mordant in alizarin printing.

TI-noise The Technical Instructions for noise prevention apply to all facilities requiring authorization to operate in accordance with paragraph 4 of the German Federal Immission Protection Law (BImSchG – Bundes-Immissionsschutzgesetz), even if they are only authorized by means of the simplified procedure in accordance with paragraph 19 of the same legislation. The concept of “facility” is to be understood in a wide sense. A facility is understood to mean the overall complex of technical equipment necessary for operation of the plant including auxiliary appliances that have been

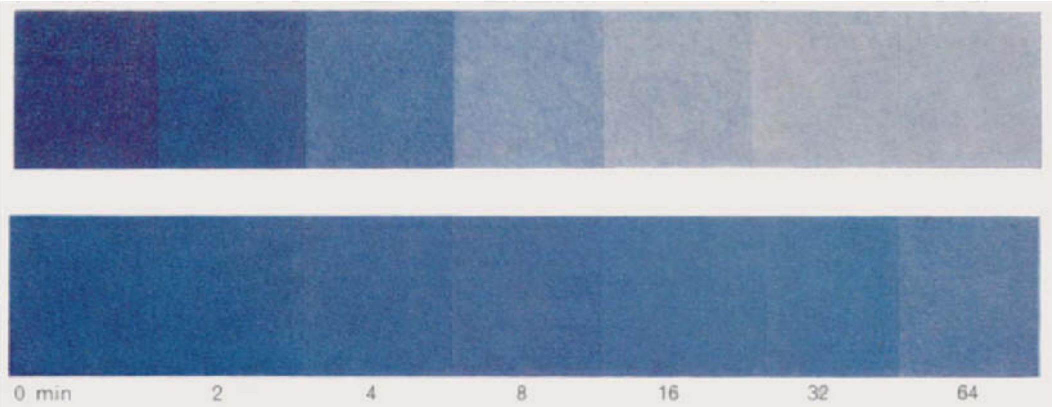


Fig.: Time step levelling test; top without and bottom with levelling agent.

set up and are operated in close geographical proximity, for technical, procedural or other reasons. Ownership conditions are not to be regarded as definitive on their own. Applications for authorization should prove that noise prevention measures in accordance with state-of-the-art noise abatement technology have been put in place and that it can be expected with a high degree of certainty that noise pollution guidelines will not be exceeded throughout the entire area influenced by the facility, including the area outside the boundaries of the facility premises excluding any noise originating from other sources.

Measures which can be considered to ensure that the noise abatement guidelines are observed include positioning the noise sources at an appropriate distance from the areas under protection by extending the facility premises or by a commitment guaranteeing that adjacent premises will not be used in a manner necessitating noise prevention measures.

Paragraph 5, item 2 of the German Federal Immission Protection Law (BImSchG – Bundes-Immissionsschutzgesetz) obliges the operator of facilities, requiring authorization to take preventative action against detrimental environmental impact of noise in particular by taking measures to limit noises which meet current standards. The legislation makes it unlawful not to implement state-of-the-art measures in accordance with current standards. →: Noise protection; Environmental protection regulations.

Tin-phosphate-silicate weighting Mineral silk weighting: → Weighting of silk.

Tin salt discharges → Reductive discharges with tin(II)-chloride. No longer generally used on cellulose fibres. Was used frequently prior to introduction of sulphoxylates. On acetate and triacetate → Acetate fibres in discharge printing.

Tin salt reaction is used for testing alkali-damaged wool. Method: hot treat sample for approx. 30 min in acetic tin salt solution (10% acetic acid + 5–10% stannic (II)-chloride) resulting in a light to dark brown colour depending on degree of damage. Reaction consists of slight sulphur discharge; formation of brown stannic sulphate.

Tin salts, organic E.g. → Tributyltin oxide. These have an important function as a → Preservative.

Tinsel → Paillette.

Tinsel-print Pigmentation process with tinsel pigments.

Tinsel threads Metal threads made of base metals; → Metallized yarns.

Tin sulpholeate (ammonium sulphoricinoleate, stannisulpholeate), used as a stain for alizarin colours and for softening of pink and red colour shades.

Tin(II) thiocyanate $Sn(CNS)_2$. Used as an additive in alizarin printing pastes.

Tinting dyes for bleached goods (blueing dyes). Blue, red and violet dyes for application during → Tinting of bleached goods. In small quantities tinting dyes achieve a significant increase of the white appearance both with optically-brightened material and with optically-brightened ground white. Dyes used for this purpose are as brilliant as possible in order to reduce the absorption range for as narrow a band as possible. On the other hand dull tinting dyes, such as mixtures of a brilliant dye with grey, reduce the brightness unnecessarily. Use: a) to increase degree of whiteness whilst to a large extent retaining the optical brightening shade; b) for modifying the optical brightening tint, usually whilst likewise increasing the degree of whiteness.

Tinting of bleached goods (blueing). Application of blue-violet tinting dyes to prevent yellow cast (blue defect) of a ground white to further increase the degree of whiteness. This makes reflectance in the green-yellow spectral range relatively lower then in the blue and red range, i.e. yellow-green light is absorbed more and no longer reflected thus reducing brightness, but darker as well, since compensation of yellow by blue violet produces neutral light grey (subtractive dye mixture). This is perceived visually but not as such due to the fact that a blue-violet shift is registered by the eye as an increase in the degree of whiteness. However, the proportion of grey produced is also increased with a more pronounced yellow cast before the shade converts from yellow to blue and the grey portion becomes obvious all the sooner. This is why poor ground white cannot be changed into attractive white by means of tinting but only into light grey. Stronger tinting leads to over-compensated yellow cast as blue cast. The rule of experience as far as tinting is concerned is that light can only be taken away by tinting, as opposed to fluorescent brightening where the blueing effect is not based on taking away yellow-green light but on adding blue light (additive radiation mixture), i.e. increase of brightness, → Fluorescent brightening agents. These parameters are still valid as they explain why further white effect increase is possible by means of tinting after optimum bleaching and its optical brightening effect. It is, however, only possible when brighteners and tinting dyes are harmonized as well as possible.

Tin weighting → Weighting.

Tip effects Tip effects on pile fabrics; vivid patterned woven fabrics or furs are produced by surface coloration of the extreme tips of the pile. → Emboss printing.

Tippy dyeing The tips of woollen fibres are exposed to light, weather and environmental influences during their growth. For this reason tips and root-ends dye differently (→ Skittery dyeing wool). The extent of the colour difference between tips and root-ends depends not only on the wool but also on the category of dye and the process used. The addition of cationic or non-ionic levelling agents only partially compensates for the colour difference. More hydrophobic dyes or hydrophobia-increasing auxiliaries result in more even dyeing whilst the easily-soluble, more highly sulphonated and more hydrophilic dyes colour the tips more intensively.

Tirtey Reasonably-priced and generally durable fabrics which consist in the warp of fine-threaded strong cotton or rayon staple fibre yarns but of carded yarn (often reclaimed wool with the addition of cellulosics) in the weft. Finished with either Melton or brushed effects.

Titanium White metal, at. wt. 48, melting point approx. 2250°C. Contact with air causes it to convert to titanium dioxide. Trivalent compounds are violet in solution and have a strong reducing effect whereas quadrovalent compounds are colourless. The most important compounds are: → Titanium dioxide (TiO_2) as a matting agent, titanium acid ($TiO_2 \cdot H_2O$) as a reagent to hydrogen peroxide, titanyl sulphate $TiOSO_4$ which dissolves easily in cold water and hydrolyses easily when heated.

Titanium dioxide Titanium(IV) oxide, TiO_2; molecular weight 70, density 3.8 (–4.2). The white powder is not soluble in water or dilute acids. It is used as a white pigment with a high covering capacity in paint coatings and as a matting agent for fibres and frosted glass. It is usually supplemented by calcium or barium sulphate. Thus, for example, Kronos-titanium dioxide contains 1–5% barium sulphate. Fixation takes place with fatty alcohol sulphonates (sulphonated oils, suet, wax) possibly with the addition of protective colloids (proteins, cellulose). It has a negative impact on certain substantive dyes in that it reduces the light fastness by 4–5 categories. Titanium dioxide is the most important pigment for synthetic fibre delustring but it is also used for printing damast; it absorbs ultra-violet rays.

Titanium potassium fluoride → Titanium potassium hexafluoride.

Titanium potassium hexafluoride K_2TiF_6. Molecular weight 240.09. White crystals, soluble in hot water. Used in IWS-flame-retardant finishing.

Titration is used for quantitative content determination of a solution to be tested by means of a normal solution of known content which flows into it (using a burette or a pipette), → Normal solutions. The end of the reaction (neutralisation, oxidation, reduction, precipitation) is shown by the colour change of an added indicator. The content calculation is made from the relationship between the utilized quantity of solution to be tested and the consumed normal solution.

Titration is a method which can be carried out rapidly, which supplies precise values in terms of weight analysis.

Titrimetry is subdivided as follows:

I. Alkaline and acid measurement: determination of alkalis and acids with normal acids or alkalis.

II. Oxidimetry: determination of reduction or oxidation with normal permanganate solution.

III. Iodometry: determination of reduction or oxidation with normal iodine and sodium thiosulphate solution.

IV. Precipitation analysis: reaction evaluation by means of mutual precipitate formation.

V. Complexometry.

VI. Electrometrical processes: a) Conductometry: recognition of the end point by determination of conductivity; b) Potentiometry: recognition by measurement of potential.

Titration curves of proteins The electrostatic interaction between protein and hydrogen ions and hydroxyl ions can be measured because the lateral chains, which project from the main chains, have varying pK depending on sequence. When the consumed acid or alkali quantities are calculated against the particular pH of the solution, in which the soluble or insoluble protein is located, the titration curve (Fig. 1) is attained. As shown in Fig. 2, acid reacts with wool below pH 4.7(cationic and acid dyes) and alkali above pH 4.7.

Wool does not provide such a steep titration curve as, for example, insulin and the definition of the isoionic point is problematic. In the wide range between pH 4 and pH 8 neither acid nor alkali are bound and the loading charge remains zero (isoelectric zone). This is a result of the insolubility of wool and the formation of an electrical double layer on the fibre surface. This makes it difficult for the hydrogen ions to penetrate. The addition of salt reduces the electrical double layer so that the wool behaves like a soluble protein and the curves for the acid and alkali absorption meet at the isoionic point.

Salts destroy the electrical double layer which builds up on the fibres. Peters and Speakman give an

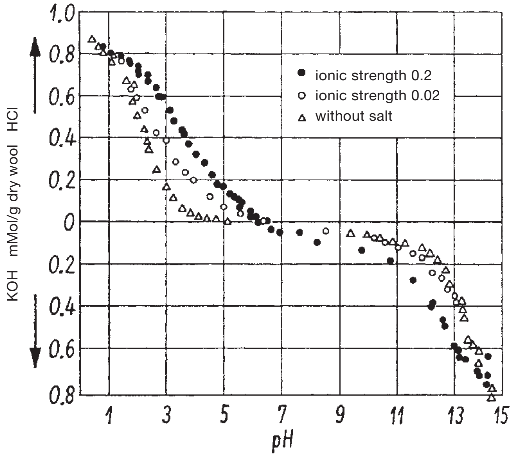


Fig. 1: Wool titration curves (according to Steinhardt and Harris).

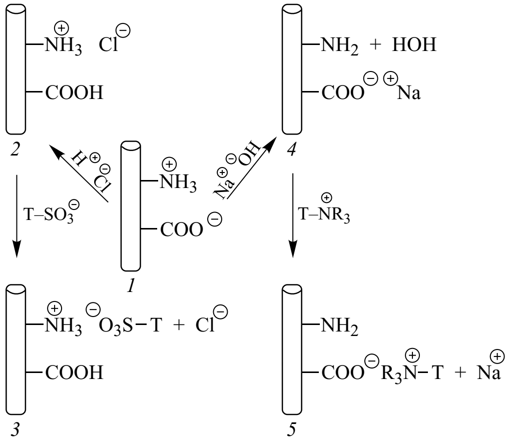


Fig. 2: Reaction of wool (1) with acid during the formation of the wool cation (2) or with alkali during the formation of the wool anion (4); (3) = acid dyed wool; (5) = alkaline wool transformed with cationic substances.

internal pH-curve for titration which corresponds to a soluble protein nitration and define an inner pH. On the basis of the Donnansch membrane balances the salt effect explains why the internal pH comes into line with the external pH when the salt concentration increases.

Titre,

I. Term denoting fineness of fibres and yarns. The valid SI-fineness is tex which indicates weight in grams per 1000 metres length, → Tex system. The older term of Denier (den) indicated the mass in grams in relation to 9000 metres length (1 tex = 9 den).

II. Decimal titre in gram per kilometre as gen. fineness term for fibres and yarns: Titre = thread mass/thread length.

III. In dimensional analysis the content of effective reagent in a solution used for titration (expressed in gram equivalent/l).

Titre of soap solution (turbidity point, cloud point). Any temperature at which coarsely dispersed, non-detergent particles occur in a colloidal soap solution. The turbidity point is a measure of the temperature-dependent application range of a soap and corresponds to the melting point of the fatty acid used in its manufacture. That is why soaps made of unsaturated oleic acid are used for low-temperature washing and cleaning processes (e.g. raw wool scouring), but not for wash-at-boil processes, where soaps made of palmitic and stearic acid (tallow and hard soap, soap flakes) are more useful. Soaps made with liquid fats are used at temperatures of approx. 40°C, soaps made with semi-solid fats at temperatures up to 60°C and soaps made with solid fats at 80–90°C and even higher temperatures.

Titre variations Variations in the → Titre of fibres:

I. As an intentional effect (→ TS).

II. Accidentally such as, for example, great titre variations in polyester threads of strongly striped tie fabric. The cause of these titre variations, which cannot be compensated in terms of colour, is partially blocked spinning nozzles.

Titrimetry → Titration.

TITUS (TITUS Textile Information). Abbreviation for “Textile Information Treatment Users Service”; international documentation system which is operated on the basis of international community work by the TITUS organisation and is based on the “Thesaurus of Textile Terms” developed by the MIT (Massachusetts Institute of Technology) in 1966 (Ger. further development: Internationale Thesaurus Textiler Begriffe, Düsseldorf; Verein Deutscher Ingenieure). Since 1971 the TITUS organization has been working with a linguistic analysis and translation system with the aid of data processing, which for the first time enables scientific texts to be translated automatically into German, English, French and Spanish using abstracts (short versions) of textile-specific publications. The foundation of the “Association of Textile Documentation and Information” (Verein textiler Dokumentation und Information e.V.) has created a widely based maintenance association which links the TITUS organization with associations of the user organisations as well as with information providers and information conveyors.

Documentation and information make an important contribution to technology transfer. In 1980 the → VDTI (Verein Deutscher Textilindustrien) was founded by the Textile Industry, the Textile Machinery Association (Fachgemeinschaft Textilmaschinen) in the → VDMA (Verband deutscher Maschinenbau- und Anlagenbau e.V.) as well as textile research institutes and specialist textile publishers. Its brief is to inform the textile industry and associated areas, i.e. the chemical fibre industry, textile machinery construction, the clothing industry as well as the laundry and chemical cleaning industry, about global literature of relevance to textiles and to document the publications.

To this end the VTDI promotes the development of a data bank which is accessible by remote data processing, as well as the production of printed services and the procurement and delivery of original literature. The association, which is promoted by its members, transferred the documentation activities to the Fachinformationszentrum Technik e.V. (“FIZ Technik”) (Specialist Technology Information Centre) in 1989. At the same time it declared its readiness to support “FIZ Technik” financially and to participate in the management of “FIZ Technik” to promote its interests. This measure represented an important step towards rationalising data base production and to making the data bank design more user-friendly.

The extended possibilities of "FIZ Technik" were used in 1990 to develop the TOGA data bank. This is based on the TITUS data bank system but has a greater range of expression for the abstracts at its disposal due to its free choice of words as well as improved search facilities.. The inclusion of additional sources makes a contribution towards a more complete information supply for the textile industry. Approx. 140 international trade magazines are evaluated as well as all leading specialist conferences. Interesting Ger. and European registered patents and exchange of papers with the Fr. co-operation partner and with other data bank providers supplement internal literature evaluations.

The rapidly increasing operation times of the TOGA-data bank have confirmed that the right measures were introduced. As well as the data bank offered by "FIZ-Technik" a further 70 data banks are provided for technology, economics, purchasing guides, standards and materials. Specific software known as "Sherlock" makes it possible for the uninitiated to carry out research in all of the "FIZ-Technik" data banks without prior knowledge.

The monthly magazine "FIZ-Technik Information Service for the Textile Industry, Textile Machinery Construction and the Clothing Industry" gives an overview of textile publications world-wide which have recently been included in the data bank. Many companies use the possibility of gaining a rapid overview of important publications in the field of fibres, spinning, yarn treatment, manufacture of textile fabrics, composite materials, finishing, confection, textile care, examination of polymers, textile testing, plant organisation or environmental protection before ordering the particular original literature required.

Retrospective research and selective permanent information (profiles) are interesting information services offered by "FIZ-Technik".

The range of services also includes the following:

- magnetic tape service,
- information on products and manufacturers,
- thesaurus (as search aid for research),
- list of evaluated magazines quoting publisher,
- advice, user training, provision of original literature.

As well as "FIZ-Technik", the Textile Research Institutes are also active as information distribution points, as requested by the Textile Industry Research Curatorium. The employees of "FIZ-Technik e.V." are available for information regarding the most suitable information service and for all specialist questions. "FIZ-Technik" also provides photocopies of original literature from around the world.

TIUC Abbreviation for "Textile Information Users Council Inc.", a loose association of textile companies for promotion of information and documentation, founded in 1961; → Technical and professional organizations.

TI-waste In order to minimize increasing quantities of waste, Technical Instructions (TI) were issued regarding the temporary disposal, treatment, combustion and permanent disposal of waste materials in need of particular monitoring, in the form of administrative regulations to underpin waste legislation (→ Environmental protection regulations). The state of the art in the context of these Technical Instructions is the development status of advanced techniques, facilities or operations, which as far as possible, guarantee the practical suitability of measures for environmentally friendly → Waste disposal. When determining what is the state of the art, preference is given to comparable, suitable techniques, facilities or operations which have been tried and tested and found to be successful in operation. All waste materials in need of particular monitoring are listed in a waste material catalogue and each item provided with a waste material code. The person responsible must keep a disposal or utilization record in the form of a declaration of responsibility (accompanying document) confirming disposal of the waste materials by a licensed waste disposal specialist. The TI-waste covers the following subject areas:

1. range of application;
2. general regulations;
3. registration of waste disposal centres;
4. allocation of waste materials to disposal procedures and facilities;
5. requirements for the organization and staffing of waste disposal centres as well as for information and documentation.

Tjanting Ladle-like container made of thin copper sheet with fine draining tubes which is used for applying wax resists particulary in the manufacture of → Batik.

Tjap print Japanese stamp batik which is carried out using so-called tjaps, stamps made of copper strips (block fastened). The process is more rapid than the free-hand method using the → Tjanting.

Tl Element symbol for thallium (81).

TLC Thin layer chromatography.

TLV Abbreviation for → Threshold Limit Value.

TLV values Maximum threshold limit values in the workplace are the highest permissible concentrations of substances such as gas, steam or other airborne substances which, on the the basis of current knowledge, do not impair the health of employees in the case of repeated long-term exposure and likewise do not place undue strain on them (→ BAT value). The dimension of the value for workplace concentration is calculated as required by means of specific testing processes for the specific contaminants in question. These testing processes are either of a purely chem., physical-chem.

or purely physical nature. Semi-quantitative measurements with gas testing tubes are adequate for monitoring TLV values which only have information character. Exact establishment of the TLV values requires a quantitative process generally on the basis of a defined quantity of air which is channelled through an adsorption or collection device. Preparation of the sample material collected in this way is mainly carried out on the basis of microanalytical processes. In the interests of simplicity and clarity, values should always be quoted in mg/m^3. The TLV values of a gas or steam can also be quoted in vol.%. If, for example, 100 ml of carbon monoxide are distributed evenly in 1 l of air, this corresponds to a final value of 100 ppm carbon monoxide (equivalent to 0.01 vol.%). The final concentration is the amount of substance or contaminant which is present after mixing, solution or distribution in the vehicle or medium. The air content of the contaminant in question can be calculated in mg/m^3 according to the following formula by conversion, in which the relative molecule mass M_r and the molvolume V have to be taken into account in relation to 25°C and 101.3 kPa:

$$\text{TLV (mg/m}^3\text{)} = \frac{V_1 \cdot M \cdot T_0}{V_0 \cdot T_1}$$

V_1 = volume of the reference in TLV (ppm),
M = molecular weight in g ($M = \text{Mol}^{-1} \cdot \text{g}$),
T_0 = temperature of 273 K,
V_0 = molvolume of a gas by 273 K,
T_1 = temperature in K.
As TLV values are basic values, the following fixed figures are used in the formula:
V_0 = 22.41 l,
T_1 = 293 K,
T_0 = 273 K.

TLV values are used to promote health protection as the basis for assessing the extent of the risk presented by existing concentrations (but not the short-term effect of higher concentrations). They are not constants from which the occurrence or non-occurrence of effects over longer or shorter periods of exposure can be calculated. TLV values are also not suitable for comparative evaluation of the risk of different substances. Simultaneous or consecutive impacts of different substances can increase or reduce the health implications considerably. The commission responsible, the so-called MAK Werte Kommission (German TLV value commission), is not yet able to establish TLV values for mixtures. This does not in any way imply that there is not a risk. Cold applications of solvent mixtures are a typical example. These are non-flammable in the state in which they are supplied, but can become flammable during use when one or more component parts evaporate. This can present uncertainties not only in terms of a risk to health but also in terms of risk of fire and explosion.

Tm Element symbol for thulium (69).

TMU Abbrev. for Time Measurement Unit, time unit of the → MTM. Conversion into other time units:

1 TMU = 0.00001 h = 0.0006 min = 0.036 s;

1 h = 100 000 TMU; 1 min = 1667 TMU; 1 s = 27.8 TMU.

TMU units are widely used for movement analyses, for workplace and goods flow studies in which the smallest amount of time corresponds to the most efficient method.

TNC Abbrev. for Swedish “Teksnika Nomenclaturcentralen Publikationer”, publication of the technical nomenclature centre.

TNO Abbrev. for Dutch “Toegepast Natuurwetenschappelijk Onderzoek” (applied scientific research) used by the Dutch research organization; → Technical and professional organizations.

TOC Abbrev. for Total Organic Carbon. The TOC value, which is quoted in mg carbon/l waste water or mg carbon/g substance, only takes into account the carbon proportion of the particular organic compound so that different organic compounds have different TOC-values. The TOC-decomposition test is a process for testing organic substances for complete biological decomposition and measures the actual mineralisation of the substance to be tested. →: Summation parameters; Waste water evaluation.

TOD Abbrev. for Total Oxygen Demand = total content of oxydisable substance (inorganic and organic substance, including nitrogen and sulphur) which is quoted in mg oxygen/l waste water or in mg oxygen/g substance.

Toile Plain weave underwear and clothing made of silk or synthetic fibres; single-colour with colour effects, printed or also embroidered.

Tolerance limits With a → Poison, the concentration in mg/m^3 which leads to incapacitation after 1 min. As max. workplace concentration → TLV values.

Toluene (methyl benzene), $C_6H_5CH_3$. Density 0.8716; Fl.p. –95 °C; b.p. 110.8°C. Clear and colourless liquid with aromatic smell; highly light-refracting and inflammable (bright-burning and sooty flame). Toluene is virtually insoluble in water; it is miscible with alcohol, ether, benzene, etc. Other properties and use are similar to those of → Benzene and → Benzine.

Toluene diisocyanates → Tolylene diisocyanates.

Tolylene diisocyanates (TDI, methylphenyl diisocyanate, toluene diisocyanate), $C_7H_6(NCO)_2$. Density 1.22 at 25 °C; mol. wt. 174.16. Tolylene diisocyanates represent technical isomer mixtures of 2.4 and 2.6 tolylene diisocyanates. Properties: clear to yellowish, flammable and relatively volatile liquid with pungent smell. The vapours are heavier than air and form an explosive mixture with air when subjected to intense heat.

Toluene diisocyanates have a highly irritant effect on skin, eyes, the respiratory system and can cause asthma and allergies. It is possible to suffer damage to health as a result of smelling the substance. It is therefore imperative to heed the many safety regulations for its use. Tolylene diisocyanates have a steam pressure of 1.33 Pa at 20°C. Their TLV value is 0.01 ppm or 0.07 mg/m^3. Tolylene diisocyanates are used as crosslinkers for polyurethane manufacture and for polyurethane coating.

Tommy dodd Term for machinery for finishing reverse side of fabrics. Consists of a trough filled with finishing liquid and a roller which is half lowered into the liquid. The fabric is processed face side up. A doctor blade wipes off the excess finish from the reverse side of the fabric. Another doctor blade cleans the roller before the incoming fabric comes into contact with it.

Tom-Tom-Dollys → Dollys.

Tone-in-tone dyeing,

I. "Same shade" dyeing in the sense of a single colour shade (→ Self shade) with mixed-fibre articles and yarn mixtures; both components of the mixture demonstrate the same colour shade.

II. "Colour shift". An example is the → Multicolour process in which only one type of fibre is used but of which a section has assumed greater capacity to absorb or to resist dye as a result of appropriate pretreatment. The dyeing process results in different colour shade intensities with the same colour shade.

III. → Dyeing of ombré or shaded effects.

Toning Previously-practised method of after-shading (→ Shading) on fast dyes, usually vat and sulphur dyes, (due to the lack of suitable products in these groups) with small quantities of brighter dyes from other categories (usually cationic dyes). This has the effect or reducing overall fastness to a greater or lesser extent. Dyes with 1 : 2-metal complex dyes are used predominantly for toning using acid dyes.

Tonne Weight measurement unit; 1 tonne (t) = 1000 kg.

Top After-dyeing of fibres in mixtures, particularly to light dyed fibres in single-bath or two-bath systems. Used predominantly for reserve and for creating two- or multi-colour effects.

Top bottom air quantity regulation Depending on the type of goods (e.g. woven or knitted; elastic textile) the dry textile material is subjected to more top or bottom air (see Fig.).

Top cloth Generic term for all materials which determine the external appearance of an item of clothing.

Top fusing Term used to describe the direct bonding of lining fabrics for collars and sleeves.

Topper,

I. Automated machine for trouser waist-band steam pressing machine after dry cleaning. It replaces the time-consuming and technically expensive process of manual steaming or pressing of trouser waist-bands.

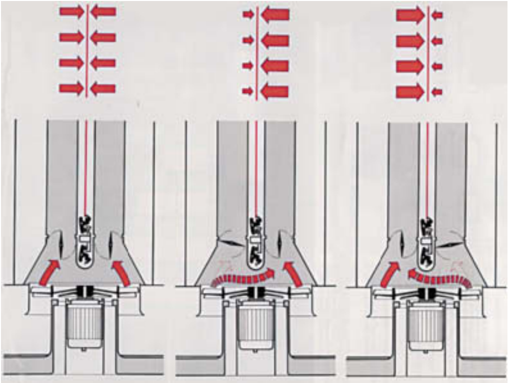


Fig.: Controlling the air quantity above and below the fabric in the stenter (Babcock) through appropriate air damper setting.

II. Garment manufacturing term: a) leisure jacket with the face edge and under seam at right angles; b) short, elegant gentleman's summer coat, fashionably wide and with lightly padded chest.

Topping dyes Dyes for topping which as far as possible do not dye the foreign fibre or only slightly. They should be simple to apply.

Top scouring Second washing process for woollen tops before spinning to remove residual grease (de-oiling), dye pigments, dust, etc. on the back-washer. To avoid subsequent fibre disruption and yellowing in drying processes, it is carried out with sodium carbonate or ammonia with calcium stable synthetic products (→ Raw wool scouring).

Tops printing → Vigoureux printing.

Top, to Production of an "after shade" in a dye solution by addition of other, usually brighter dyes (→ Toning).

Torque (Lat.: torquere = to twist), English: torque = torsional power.

Torque yarn Yarns which are fabricated discontinuously by means of high twist, fixation and un-twisting ("conventional" or "classical" process) or continuously (false twist process). Simple yarns with twisting tendency (Up-twisting of suitable high twist yarns with S- and Z-twist gives compensating possibilities).

Torr Physical pressure unit which is no longer permitted with which 1 Torr corresponds to the pressure of 1 mm mercury column on a 1 cm^2 surface. The current SI-unit for pressure is → Pascal (1 Pa = 0.0075 Torr).

Torsion (twisting, drilling, turning, → Twisting of spun yarns). Special form of shear used particularly for long shapes (rod, wire) which are fastened at one end whilst a turning moment is applied to the other end displacing the cross-sections.

Torsional elasticity Non permanent plastic deformation of a shape occurs up to a specific applied force known as the torsion modulus. Up to this limiting value it remains elastic, i.e. when the force is no longer present it returns to its original state. The torsion modulus is quoted in kg/mm^2. With fibres and yarns it is for example usually 35–200 and it facilitates assessment of the suppleness or stiffness of fibres.

Torsional strength (twisting strength). Resistance of a shape or body to a force which tries to twist it. When a force above the torsion modulus is applied, plastic changes take place in a body or shape which remain permanently after the force has been removed. The twist factor at break is used to measure plastic processes during torsion. This increases according to the fineness of a fibre or the break twist angle (as opposed to brittleness angle) which is practically independent of fibre fineness and is therefore a criterion of fibre brittleness.

Total colour management Special software for recording, monitoring and evaluating (see Fig.) for example

- dye strength,
- substrate routine,
- correlation,
- transferability from laboratory to production,
- specification and corrections calculation for continuous and exhaust dyeing,
- batch production,
- storage contents and recipe recording,
- machine programmes,
- management programmes,
- colour kitchen software.

With the aid of this software, colorimetry and a high-performance computer an exact statement is made prior to initiation of actual production on the feasibility of substrate-specific customer requirements in terms of optimum pricing and colour uniformity. Networking with operationally-relevant systems and equipment is made possible by means of the "real-time multi-user hardware" computer configuration.

Total hardness → Water hardness salts.

Total nitrogen determination (according to Kjeldahl). Determination according to DIN 38 409, Section 11. An effluent sample is mixed with concentrated sulphuric acid and a selenium reaction mixture and brought to the boil. The nitrogen contained in the sample is converted quantitatively to ammonium nitrogen and distilled using steam distillation in a strongly alkaline medium into a sulphuric acid receiver. The consumption of acid is determined by means of titration with base to which the nitrogen content of the sample is proportional.

Total production time is quoted in min/1000 m; dependent on degree of textile finishing utilisation and batch size.

Total radiation pyrometer Temperature measurement unit, e.g. for steam boiler firing. Principle: concentration of heat radiation by means of a lens on blackened platinum sheet and measurement thereof by means of a thermoelement.

Touch and close tapes Textile tapes are used in many articles including many specifically technical articles. The most widely-known fastenings are zips and touch and close tapes. The latter are products with many applications for clothing, shoes, medicinal and military textiles, hobby and sport articles, automobile and aeronautical industry. There are two different types of touch and close fastening, the adhesive fleece fastening and the mushroom tape fastening. Both products are woven with the aid of special techniques. The specific after treatment results in the touch and close tape.

The male and female fastening (Fig. 1) consists of two tapes, one with numerous hooks, the other with numerous small loops. When they are pressed together the hooks are compessed into the fluffy looped surface where they bind, resulting in a fastening which can be reopened simply by pulling it apart. When the tapes are pulled apart, the hooks stand up

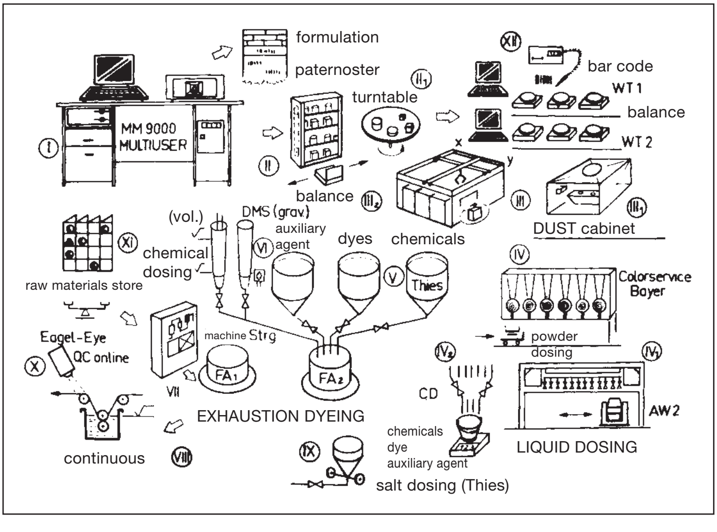


Fig.: Total colour management-automation in the textile mill.

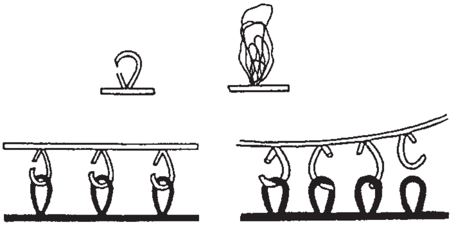


Fig. 1: Male fastening (schematic) (according to Mageba).

releasing the loops. This special opening technique allows the fastening to be used many times.

The mushroom fastening (Fig. 2) likewise consists of 2 tapes, one of which has numerous mushroom-shaped protrusions and the other numerous small loops which, when compressed, attach themselves around the mushrooms-shaped protrusions. These are torn, however, when the tapes are pulled apart. As a result this type of fastening can only be used a limited number of times.

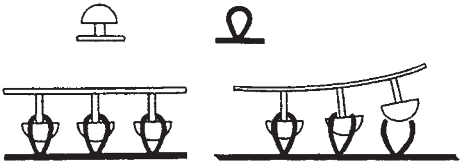


Fig. 2: Mushroom fastening (schematic) (according to Mageba).

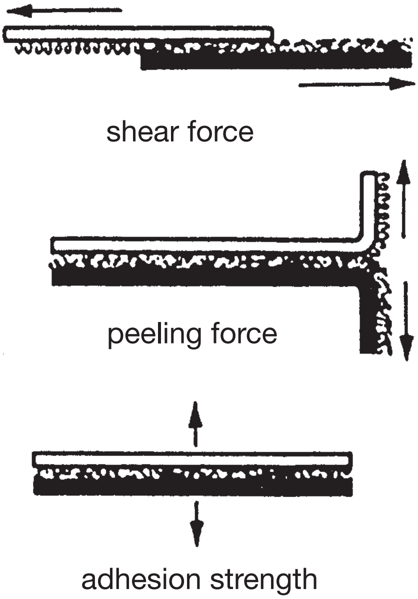


Fig. 3: Active forces on touch and close tapes.

On opening and closing, touch and close tapes are subjected to different forces (Fig. 3). Differentiation is made as follows:

a) Shear force: the force which is necessary in order to pull the 2 tapes apart in length direction. The difference in effect during closing and opening of the two types means that the force on the mushroom tape is highest (hook tape: 5-10 N/cm^2; mushroom tape : > 10 N/cm^2).
b) Peeling force: the force necessary to pull the tapes apart ("peeling off") (hook tape: 1–1.5 N/cm^2; mushroom tape 0.5–1 N/cm^2).
c) Adhesion strength: the force which is necessary when pulling the tapes apart in a vertical direction (hook tape: 5 N/cm^2; mushroom tape: 6 N/cm^2).

The forces vary from fastener to fastener and are dependent on the raw materials used. The values quoted are the mean values of various polyamide fasteners (according to Mageba).

Touch-up roller →: MA process; Applicator roller.

Tournay carpet Named after the Belgian town, a wire insertion pile velour carpet with numerous and varied coloured warp pile giving sharply defined jacquard patterning; also seen as → Face-to-face Tournay carpet in a double velvet technique.

Tow,

I. → Tow yarn fabricated of short fibres as opposed to → Line (yarn).

II. → Combed top.

III. spin, fibre tow: manufactured form of chemical fibres which are combined taken off the spinning jets as a bundle of parallel aligned, single endless fibres; virtually no twist → Multifilament with counts of > 3 ktex. Further processing is by means of cutting and breaking (converting) or by stretch-break or texturising.

IV. marine rope.

Tow dyeing process Dyeing facilities (perforated-drum or perforated conveyor system) for continuous processing for the dyeing of spinning tow (Fig.).

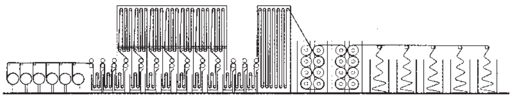


Fig.: Tow dyeing process by Sucker-Müller.

Tow yarn Yarn spun from tow.

Toxic,

I. Having a poisonous effect.

II. Caused by or resulting from → Poison. TLV values are used for reference.

Toxicology The science of poisons (toxins) and their effect on the organism. This area of pharmacology is divided into chem. medical and forensic toxicology. Toxicology investigates the harmful effects of chem. substances on living creatures with the aim of recognizing the risks and averting damage to the health of humans and animals. Toxicological research fields include both experimental as well as epidemological studies in which particularly qualitative-analytical and quantitative-biological aspects are differentiated. A large volume of data for toxicological characterization has to be investigated to establish the harmlessness of a substance. The toxicological data investigated make it possible to classify the effect of the substance according to the degree of potential damage and to make an appropriate toxicological evaluation in the sense of weighing up the benefits and risks.

Classification of the effect of substances:

- physiological effects (tendency to deviate from the mean);
- faults which can be compensated (deviation from physiological area);
- reversible damage to organs and organ systems (clinically-manifest symptoms of poisoning);
- irreversible damage to organs and organ systems;

Toxicological evaluation:

- differentiation between indicator, disruptive and damaging effects (classification of substance effect);
- setting up of recommendations for the substitution of harmful substances (substitution research);
- determining means of counteracting the damage of a substance taking into account not only the effect of the finished product but also the damage which can occur during manufacture or on destruction.
- setting up a framework outlining human ability to withstand exposure (sum of all possible effects in relation to the range of individual sensitivity).

The basis of evaluation of the risk to health, and therefore the assessment of the toxicological profile of a substance, can generally only be provided by results from tests on animals during the first phase of investigation. New substances must therefore initially be tested for acute toxicity by means of appropriate investigation in order to have a concept of the effects on important bodily functions after administering a single dose. It is not necessary to use a large number of animals for this purpose. It is sufficent to determine the toxicity ranges in the sense of an “approximate LD_{50}” (lethal dose resulting in the death of at least 50% of the tested animals). Such investigations are generally carried out after oral use of the test substance. In the case of substances which can be inhaled whilst conforming with the specified application, acute inhalation toxicity should also be tested (→ Poison).

Investigations to establish sub-acute toxicity are of particular significance as they make it possible to obtain information about the toxicity of a substance over a prolonged continuous period including that of smaller quantities. It will also be necessary to clarify whether and what type of damage occurs and which organ systems are affected. The cutane resorption rate of a substance is significant, i.e. determination of the substance quantity which penetrates the main barrier and is therefore distributed and can develop its effect. In the interest of minimizing animal tests whilst at the same time retaining the necessary guarantee of harmlessness to health the following possibilities are available:

- There is no cutane resorption of a substance. In this case it is possible under certain circumstances to do without testing for sub-acute and sub-chronic toxicity.
- The cutane resorption rate of a substance is known. In this case under certain circumstances sub-acute toxicity testing can be carried out using only one dose.
- The “no observed effect level” of a substance is known from a sub-acute toxicity test. If this value is greater than the substance quantity, which taking into account the safety factor can do no more than penetrate the skin from the point of view of calclulation (worst case calculation), it is possible to do without determination of cutane resorption.

Tests of chronic toxicity in any case encompass continuous administering of the test substance over a period of more than six months and provide information on organ behaviour after prolonged continuous administration of quantity substances which should exceed the exposure level of normal use. If in an individual case investigations to establish the carcinogenic nature (→ Carcinogens) of the test substance are necessary, these will generally be carried out over the lifetime of the corresponding species. Such investigations can at the same time provide information on possible toxicity of the test substance when used over a longer period of time and therefore also on older animals and the changing state of the metabolism which come with more advanced age, although the primary aim of such tests is to gather evidence of possible tumour-producing effects.

In the same context it is absolutely imperative to carry out investigations of mutagenity and of embryo toxicity on suitable models. In these particular areas methods are available which do not involve tests on animals. Even if toxicological charcterization and evaluation of the test substance on the basis of evaluation of the results of these investigations is mainly possible in terms of systematic toxicity in the sense of assessing a health risk, evaluation must be carried out with the aim of a decision regarding “harmlessness to health” together with a benefit/risk analysis which also encompasses evaluation of other “benefits”.

Further research into and particularly validation of in-vitro methods as alternatives to animal tests should be given priority. But not until in-vitro methods meet the current standard of excluding toxicological risks in terms of comparison and validity of conclusions reached can the extent of methods used to date be reduced or replaced (according to Lüpke).

Toxic substances (Gk.: toxicon = poison), poisonous (toxic) substances which are attributed to five different hazard groups according to the degree of toxicity and are usually regulated normatively. Employees in the workplace have to be protected from their damaging effect particularly in the case of toxic gases, vapours and particles. → TLV values.

Toxins Organic poisons (usually proteins or lipopolysaccharides), particularly from pathogenic → Bacteria.

TP Abbrev. for → Triple point.

Tracers → X-ray fluorescence.

Trachea Respiratory organs of insects at which → Respiratory poison is aimed.

Tracheids Fibre cells which form the main body of coniferous trees but are also found in deciduous trees (→ Woody fibre); generally several mm long, having alumen to a greater or lesser degree and with pointed ends. Spring tracheids have thin walls and their main function is as sap conductors. Late tracheids have narrow lumens, have thick walls and have the function of reinforcement elements.

Trademark Legally protected word and/or symbol denoting goods which have been fabricated in the same way by a certain company and can be differentiated from similar goods, such as, for example, the Indathren trademark. Trademark designation by the letter ® represents the so-called "Registered Trade Mark". (→ Quality symbols).

Tragacanth (gum tragacanth), → Vegetable gums produced from the southern Astragalus species which has various forms, is up to 20 cm long and yellow-red-brown in colour (also bleached white); normally found in powder form. Tragacanth consists of 50–70% → Bassorin. Good quality tragacanth is transparent. The following types are differentiated:

I. Smyrna tragacanth: high quality tragacanth available in tape or sheet form, 2–5 cm long, parallel striped surface.

II. Morea tragacanth (Greek): variety of external forms (some of which have similarity with the best Smyrna types, also all types of irregular forms).

III Syrian tragacanth: much lower quality than Smyrna tragacanth (various forms, sizes and colours).

Commercially available raw tragacanth is a mixture of 40–50% white or sheet and/or tape form, 15–25% brown, 10–25% worm form tragacanth and 10–15% other usual tragacanth types. Waste tragacanth is an irregular mixture of grains of all possible sorts and colours which is not necessarily of inferior quality. Tragacanth imitations exist to a greater or lesser degree. Tragacanth is not easily soluble but is usually soluble with the addition of ammonia. Tragacanth solutions are light in colour or slightly coloured and have a slimy and sticky consistency. It can be washed out of textiles easily. Tragacanth is used as a finishing agent (for example for cellulose goods, ribbons, silks and lace) and as a thickener in printing.

Train oils Fats and oils, light-yellowish brown in colour, penetrating fish odour. Produced from the fatty tissue of large acquatic animals (whales, sharks, dolphins, seals, etc.). Contained in → Olein, stearic acid and various → Glycerides. Used especially in the leather industry. Solid fats with virtually no odour can be obtained by means of catalytic hydration. These are represented in important textile auxiliaries.

Tram Slightly-twisted silk thread (fabricated from Grège threads) for weft yarns (weft silk).

Tramlines,

I. Localized faults in fabrics, in the warp direction (dent stripes).

II. Missed sections in direct printing due to uneven repeat.

Trans-cis-isomerism (→ cis-trans isomerism). Light causes transformation of the lower-energy trans-form of the brightening molecule into the higher-energy cis-form, which absorbs shorter-wave ultra-violet light than the trans form and is no longer fluorescent in the visible range (Fig. 1). The change takes place all the more easily, the more inadequately the fluorescent whitening agent is fixed on the substrate. Fluorescent

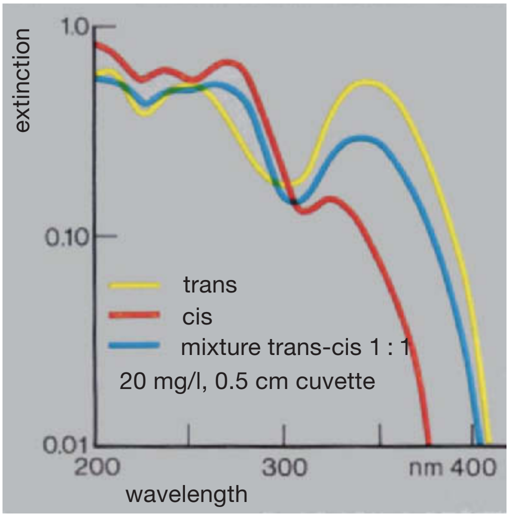


Fig. 1: Reflectance curves of aqueous fluorescent whitening agent solutions of the trans-form, cis-form and a mixture of cis-form and trans-form. The trans-form absorbs at approximately 300 nm, the cis-form at approximately 280 nm. The reflectance of the mixture diminishes, shown by the decrease in fluorescent whiteness (by Bayer).

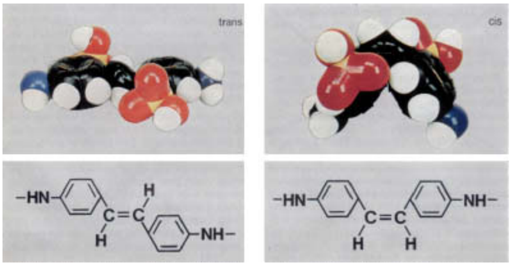


Fig. 2: Trans-form and cis-form of optical brightener molecules (by Bayer).

whitening agents are commercially available in the trans configuration. The conditions under which transformation into the cis-form can take place and the significance of trans-cis-isomerism in practice can be explained. A non-brightened filter paper is submerged in a 0.2% water-based solution of an optical brightener. Subsequent testing in ultra-violet light results in clear fluorescence. After rinsing in a basin with luke-warm water the sample is again subjected to ultra-violet light. The fluorescence is just as strong and the fluorescent whitening agent has not been rinsed out. A 3–4 mm shallow layer of the same solution is irradiated with ultra-violet light in a developing tray. A filter paper which is then dipped into the solution is already considerably less fluorescent than the one soaked in non-irradiated solution. After rinsing (as in part 1 of the test) fluorescence can scarcely be seen in ultra-violet light. The brightening molecules were transformed by the radiation from the trans-form into the cis-form which has only low substantivity to cellulose and can easily be rinsed out.

If a diluted fluorescent whitening agent is exposed to daylight, it penetrates the solution and in time converts the trans-form into the less effective cis-form. The light cannot penetrate deep into concentrated solutions; the transformation takes place more slowly. It is therefore imperative that diluted brightening solutions should be protected from light and particularly laboratory stock solutions should always be stored in brown bottles. Trans-cis-isomerism is reversible but only with ultra-violet light. For test purposes, treat a shallow layer of 0.1% water-based solution with ultra-violet light for approx. 3. min., submerge a filter paper in it and dry it without washing it out. If the paper is now subjected to ultra-violet light for a longer period, it gradually becomes fluorescent again. The effect is clearly visible if part of the paper is covered during the ultra-violet radiation treatment allowing the original state to remain for the purpose of comparison. Tests should not be carried out in strong light in order to eliminate light sources which might interfere with the process. The molecule models in Fig. 2 show why the substantivity of a brightener decreases on transition from the trans-form into the cis-form. The trans-form is almost even and can therefore be taken up easily by the fibre or binding agents such as starch, casein, polyvinyl alcohol, etc. The oblique cis-form has significantly less contact surface with the substrate and therefore poor affinity. Also the conjugated system is disrupted by steric hindrance of the ortho substituted H-atoms of the cores. They are forced into a crooked position, the resonance of the molecule is reduced and the more energetic cis-form is no longer fluorescent.

Transfer coating,

I. Process for coating or laminating fabrics (see Fig. 1) in which adhesives and coating compounds are not applied directly to the fabric width but are first applied onto a specially prepared paper (release paper) or endless metal band, onto which they are dried and subsequently combined with the fabric. This circumvents the problem of unwanted push-through of coating compounds.

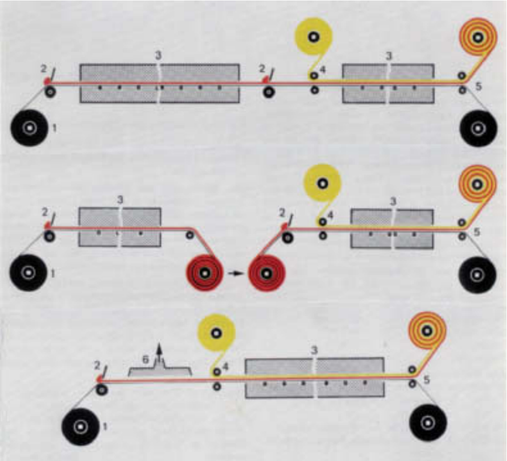


Fig. 1: Transfer coating (by Bayer).
Top: Tandem-machine (continuous); middle: discontinuous process; bottom: continuous process with a coat.
1 = carrier sheet; 2 = coating application (red); 3 = drying; 4 = substrate (yellow); 5 = separation.

II. Transfer coating works on the basis of the same application principle as direct coating. Instead of the final carrier material, an intermediate or auxiliary carrier is coated first (usually a paper siliconized on the coating side which is known as the transfer or release paper). The sequence of layers applied is reversed (see Fig. 2): what will eventually form the outside layer is applied first. A subsequent coating station can be used to apply a blowing agent or compact middle layer. The last coating station will apply an adhesive or laminating

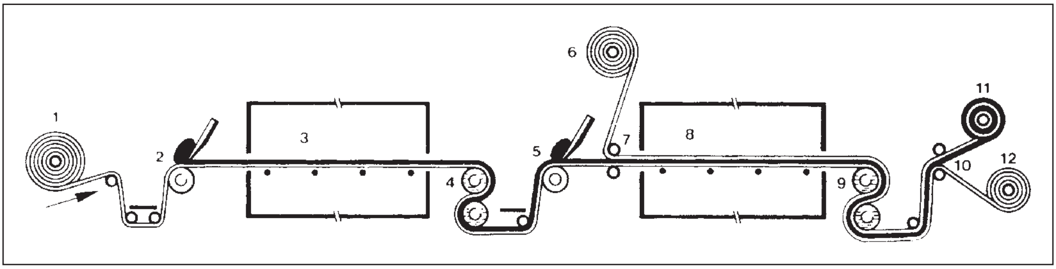


Fig. 2: Transfer coating installation (by Bayer).
1 = paper take-off; 2 = coating unit (cover coat); 3 + 8 = drying tunnel; 4 = cooling cylinder; 5 = coating unit (tie coat); 6 = textile carrier; 7 = laminating unit; 9 = cooling cylinder; 10 = separation device; 11 = batching of the coated goods; 12 = paper batching.

coating. Between the last coating station and the following heating zone the carrier fabric is introduced onto the coating that may be still liquid or paste-like form and is lightly pressed onto the coating by a roller running with the fabric direction.

The composite material then passes through the drying or gelling channel before being stripped from the paper. Paper and goods are rolled up separately. The paper can be used several times.

This type of coating is usually used when the coating compound would penetrate too far or go straight through due to its low viscosity when using the direct process or where the carrier is too elastic or not sufficiently resistant to tear to carry the weight of the coating. The process is also used increasingly where direct process coating would actually be possible.

Transfer dyeing unit Based on the Palmer system of dyeing disruptive foreign fibres in woollen articles and woollen articles as well as articles made of cellulose/synthetic fibre mixtures. This consists of predyeing the main portion of the fibre in the usual way and colouring synthetic fibres by means of the transfer dyeing unit. A re-colourable polyester “reservoir” fabric is used instead of the usual paper to transfer the dye.

Transfer paper control This is used for monitoring printed transfer paper, for cutting the edges and rerolling onto smaller roller diameters. It accommodates up to 200 cm wide transfer paper rollers. Monitoring field 200 x 80 cm. Max. roller diameter 30 cm. Operating console with foot-operated switch for switching on and off, pre-selectable speed and electrical meter counter.

Transfer paper printing/gravure screen size For printing paper for → Transfer printing with water-based printing pastes on a vertical roller printing machine a 60 mesh screen is used. Eight colours can be printed onto the paper using the Portalrouleaux printing machine (Fig.) prior to drying in an overhead drier. Disperse dyes are normally used.

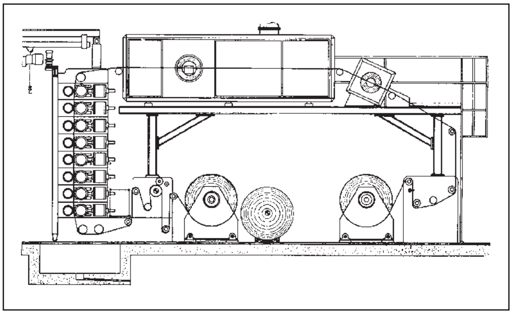


Fig.: Diagram showing the paper run with direct printing of transfer paper printing on the Saueressig roller printing machine.

Transfer printing Indirect → Transfer printing processes. Printing does not take place directly onto the fabric but onto paper (Fig.). In a second process the design is then transferred from the paper to the fabric. During the transfer printing process a paper printed with special disperse dyes is brought into contact with fabrics, knitted fabrics or nonwovens made of synthetic fibres (particularly polyester, triacetate, possibly polyacrylnitrile and polyamide) at a temperature of 190–215°C for 18–30 s. This causes the greater part of the printed dyes to sublime from the paper and be adsorbed onto the fibre material causing it to take on the pattern.

The printing processes applied are gravure printing, offset printing and rotary film printing. As mainly paper is printed, typical paper printing machines were used at first, initially almost exclusively rotary gravure printing machines such as are used for paper; later flexoprint machines were also used as well as offset machines.

The printing pastes generally only contain thickeners and disperse dyes. Alginates, locust bean flour derivatives, guar gum derivatives, cellulose derivatives and high-viscosity synthetic thickeners can be used as

Transfer printing – advantages/disadvantages

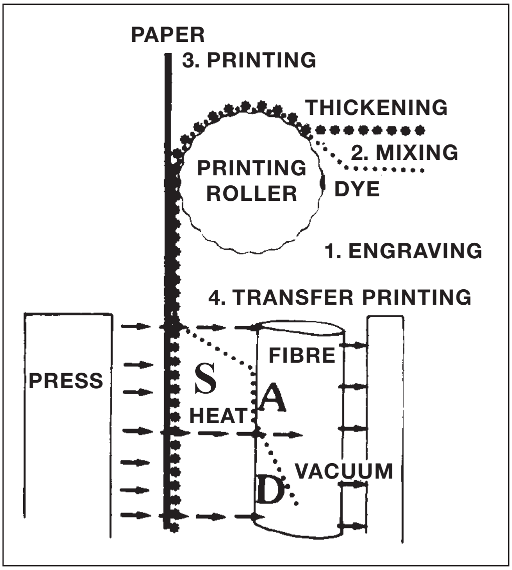


Fig.: Vacuum transfer printing (schematic). Process stages 1–3 take place in paper printing; the transfer stage 4 on the fabric printer.
S = sublimation in air; A = adsorption on the fibre; D = diffusion in the fibre.

thickening agents. In transfer printing the thickener stays on the paper which is burned to dispose of it.

Transfer printing – advantages/disadvantages,

I. Advantages:

- particular simplicity of process sequence compared with classical textile printing (Fig.),
- low investment capital and personnel costs,
- no waste water,
- low space requirement,
- steaming, washing and drying (heat setting after-treatment) not necessary,
- important advantages in the case of short metre lengths in terms of setting-up and idle machine times; dye losses no longer occur,
- risk of producing seconds quality is low; no high-quality materials are involved,
- quicker reaction to changes in fashion, little storage of raw fabric, shorter delivery times,
- fewer reproduction problems,
- problem free printing of bonded fabrics, geometrical and horizontal designs are easier to print,
- full use of gravure printing technique (effective shading of full to zero shade),
- highly-qualified personnel not necessary in laboratory, printworks, steaming facility, washing-off, etc.,
- flexibility during machine changes,
- simple order planning.

II. Disadvantages:

- difficulties in procurement of sample material (price) in the case of exclusive designs,
- not all fibre materials can be printed,
- limited fastnesses in the case of certain fibres, above all with dark shades,
- lack of colour brilliance in the case of polyacrylnitrile and mixtures of synthetic fibres with cellulose and wool,
- storage of large quantities of paper over prolonged period of time is a risk in terms of undiscovered faults,
- articles which require sublimation-fast dyes cannot be used,
- less print-through and associated danger of “grinning”,
- structured articles become flat, deterioration of handle in the case of certain qualities,
- lower production speeds due to existing transfer calenders,
- increased demands on colour technicians; necessity to re-think.

III. Parameters for strong position of transfer printing:

- trend towards increased use of synthetic fibres,
- responsibility for creativity is devolved to the paper supplier,
- non-skilled personnel can be used for transfer printing,
- risks of producing seconds quality in the case of difficult articles such as georgette, voile, satin, polyester/wool mixtures are drastically reduced.

This development has not yet been completed. Further development impulses can be expected due to:

- scarcer and more expensive resources,
- conventional printing in commission finishing plants becoming more expensive,
- increasing ecological sensitivity in society,
- expanding exportation of fashionable transfer paper from Europe into so-called development countries.

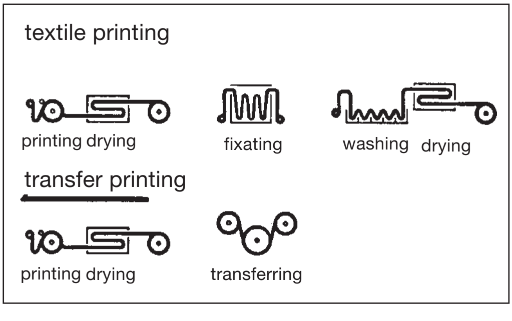


Fig.: Transfer printing/textile printing comparisons; schematic comparison of operating cycles.

Transfer printing calenders For standard fabric widths with a roller diameter on the electrically heated cylinder of approx. 800 mm, for production speeds of approx. 10 m/min (Fig.).

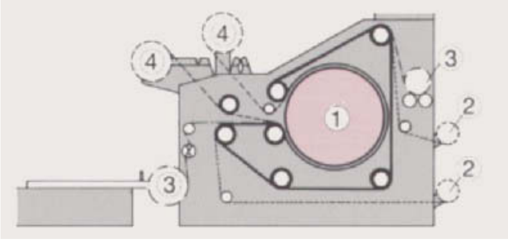


Fig.: Transfer printing calenders (Stork).
1 = heating; 2 = backing paper; 3 = substrate; 4 = transfer printing paper.

Transfer printing dyes Non-sublimation-fast → Disperse dyes which (when printed on an intermediate carrier) are transferred to the textile substrate during transfer printing at high temperatures (Fig.).

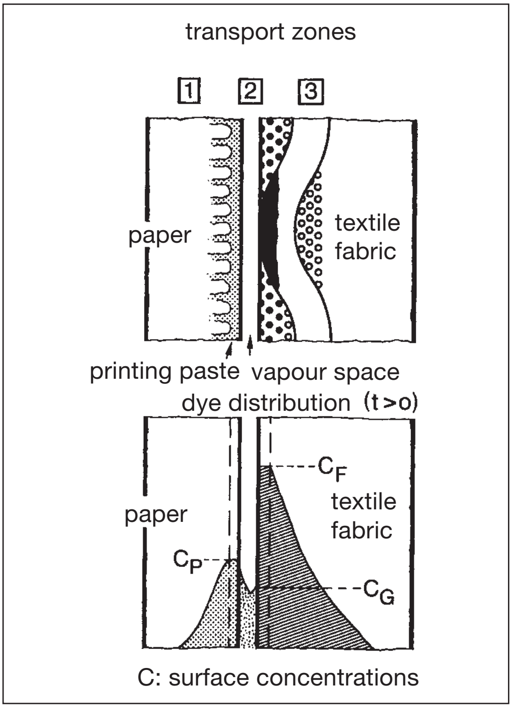


Fig. Schematic illustration of transport zones and dye concentration profiles in transfer printing (according to Hoffmann).

Transfer printing of floorcoverings Advantages compared with conventional → Carpet printing:

- simple process requiring temperature, contact time and vacuum only;
- dry process can be used even on rubber-coated material; no steaming, drying, no harm to the environment, economical in terms of energy;
- low investment costs compared with high costs for screens in conventional carpet printing;
- no aftertreatment except brushing;
- flexible process in terms of size of print commissions.

Transfer printing of polyamide Polyamides are not always suitable for transfer printing due to the varied manufacturing processes used. Careful selection of dyes does, however, allow good transfer printing results to be achieved, particularly on polyamide 6.6.

Transfer printing of wool In order to apply transfer printing techniques to wool the fabric has to be pre-impregnated and post-steamed for approx. 30 min after printing. Certain dyes have to be used which are not commercially available. Further advice for the process: a) Transfer printing with sublimable disperse dyes is possible after pretreatment of the goods with textile auxiliaries. This also applies to polyester/wool. b) Wool is pre-treated with a mixture of chromium salts, urea, lactic acid and surfactant. Then thermal transfer printing techniques are used to apply sublimable polyazo dyes which are capable of forming a metal complex due to hydroxyl groups in the ortho position. This is followed by steaming. Washing out is not necessary. For printing on polyester/wool specific dyes are added to standard transfer dyes.

Transfer printing on cotton and polyester/cotton In order to achieve good results with selected disperse dyes using transfer printing techniques on cotton and polyester/cotton it is necessary to modify the dye. The affinity of the disperse dye to cellulose must be increased. The following are used:

1. Glycols, e.g. polyethene and polypropylene glycols with a particular molecular weight, together with special agents, in particular DHDMEU.
2. Selected melamine/formaldehyde compounds.
3. Certain polymer dispersions, e.g. acrylate.
4. Formation of polymers on the fibre, e.g. polyester (from an acid chloride and a bisphenol) or polyamide (from an acid chloride and a diamine).
5. Partial acetylation which results in the best washing fastnesses.

Cotton and polyester/cotton textiles which are pretreated in this way are then transferred under standard conditions (e.g. 20–30 s at 200–225°C) and using standard transfer techniques. Transfer and crosslinking of the N-Methylol compound can be carried out in a single stage.

A reactive transfer printing technique for cotton makes use of vinyl sulphonate dyes which are printed onto paper. During transfer the entire print paste is transferred onto the cotton fabric without the reactive dye having previously reacted to the paper. After the dye reaction with the cotton it is necessary to rinse in order remove the surplus of print paste. The transfer printing machine of Küsters uses three "swimming roller" pairs (Fig.).

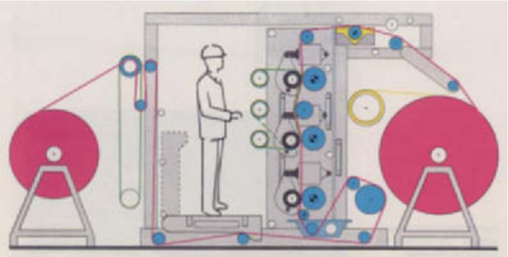


Fig.: Transfer printing machine for the Dansk "Cotton-Art" transfer printing process (Küsters).

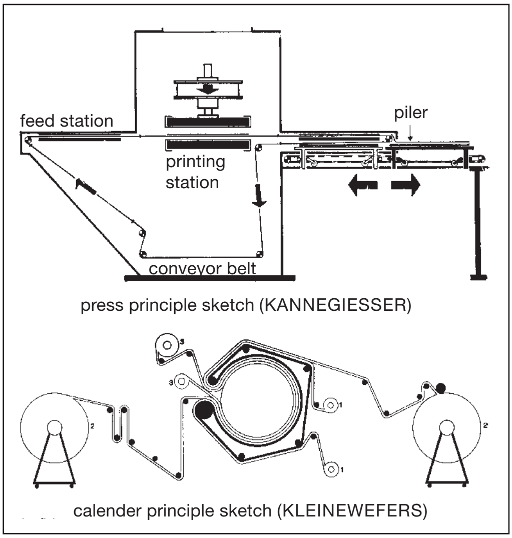


Fig.: Comparison of batch type (top) and continuous transfer printing (bottom) in the transfer printing process.
1 = protective paper; 2 = fabric; 3 = printing paper.

Transfer printing papers are available in two categories: omnibus and exclusive quality. The former quality is supplied at a reduced price to all interested parties without any type of limitation, usually with a minimum quantity of 500 m. The second quality can be reserved for certain companies for the duration of a year or longer at a corresponding surcharge with no minimum quantity being specified. Manufacture is by means of gravure printing, offset printing, screen printing .

Requirements:

1. Printability depends on surface smoothness of transfer printing paper (achievable by means of calenders or coating and/or choice of raw material and paper manufacture).
2. Handling during transfer process requires a certain suppleness which is promoted by low humidity content (4-6%). Even thickness and absence of folds are important.
3. The process of transferring the printing dyes onto the textile substrate must take place uniformly and effectively. The structure of the transfer printing paper has a great impact on this.

Transfer printing processes Indirect transfer of colour designs onto textile material, i.e. via previously executed printing onto rubber cloth (offset printing) or paper rolls (Fig.), in the latter case transfer by means of hot calender rollers. → Transfer printing.

Paper transfer printing is the basis of the Italian Colombo- and Star printing processes and the American Dynascope process works in a similar fashion (Sark process). In the Star process slightly smoothed paper is pre-coated with gelatine to prevent the printing paste from being absorbed. The paper is then printed with the addition of a easily melting resin (direct, reactive, acid, vat or disperse dye) continuously (4-dye copper roller rotary press) or discontinuously (with copper plates, 4-dye pattern, i.e. 4 prints). Transfer takes place onto the suitably prepared fabric on a heavy calender between steel and cotton roller, steel roller approx. 160°C, print at 1600 mm width 70 t, speed 6–10 m/min. The unprinted paper side runs counter to the steel roller and the paper sheets are manually placed directly in front of the calender gap onto the fabric roll. The melting print paste and the already well-mixed screen print on the paper cause the dyes to flow together on a screen-free surface where they are adsorbed by the fabric. This process makes it possible to transfer finely-structured designs onto relatively coarse fabrics and even onto velvet (85% dye transfer = good result). The process is completed by standard steaming and washing, etc.

Transfer printing resist effects Printing over or under a board with a print paste in which a blocking agent ensures that the dyes on the board are not transferred. There are two possibilities: a) blocking agent in the form of reactant resins, e.g. hexamethoxy methyl melamin and acid catalysts; b) blocking by means of metal salts with complex-forming capability. All salts of multi-valent ions such as iron, chrome, cadmium, aluminium can adopt this function. Copper is the most suitable in the form of acetate in a copper/amine complex.

Transfer system in dry-cleaning Dry-cleaning system on the principle of the → Cold unit. The transfer system in dry-cleaning may only be used in the Federal Republic of Germany if the operating company has been granted an individual exemption approval upon application in accordance with § 3, Para. 3 of the German Accident Prevention Regulations that control the assessment and definition of hazard (VBG 110). This also requires the approval of the supervisory trade authority.

Transfer zones In → Transfer printing dyes have to be selected which transfer as evenly as possible. These can be referred to as optimum transfer zones (Fig.); at temperatures which are too low, dyes which sublime too rapidly are frequently the origin of blurred printing edges (so-called bleed-out).

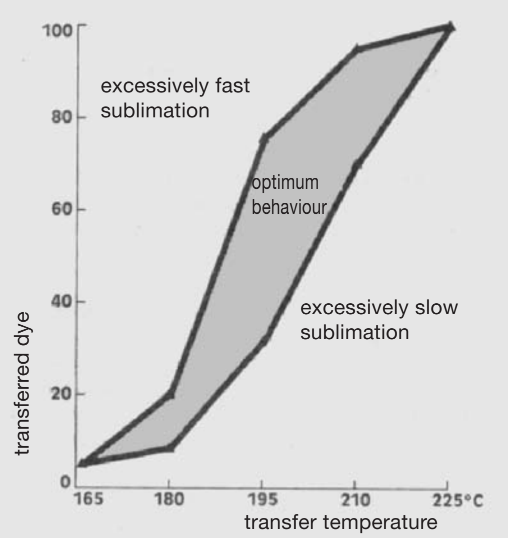


Fig.: Effect of temperature on dye transition in transfer printing.

The sublimation properties do not depend entirely on the dye molecule but also on the physical form of the dye (commercial form) and the dye concentration used. It should be noted that paper only absorbs approx. $^1/_5$ of the print paste quantity as compared with direct printing onto textiles and the dye quantities used in paper print pastes are much higher than in textile printing. The special commercial dye form with high dye content and low electrolyte content has to be adapted to these circumstances. Use of large dye quantities in liquid form (also simple colour kitchen work) is preferable.

trans form (opposite form) → cis form.

Transformation temperature (→ Accomodation point), temperature at which the fluctuations of the molecule cease in the non-crystalline ranges of a polymer i.e. are frozen. Example: Heating of thermoplastic fibres above the glass point brings about a partial splitting of the hydrogen bonds which solidify again into new bonds when they cool down stabilizing the new state. This temperature varies with different fibres: e.g. polyamide 6: 65°C, polyamide 6.6: 82°C, polyacrylnitrile: 75°C, polyester: 87–90°C. The freezing temperature is not identical with the → Softening range.

Transformers are used for converting electrical voltage of alternating or three-phase current, e.g. with air or oil cooling, as protection transformers for low voltage mains networks (of 110–300 volt to 24 volt), as regulator transformers for step changing on machines, apparatus, etc.

Transmission (transmitting). Term denoting the proportion of radiation which is neither (completely) absorbed nor reflected by the irradiated goods but is allowed to pass through to a greater or lesser extent. Transmission represents an important function in the case of infrared or ultra-violet absorption as not only the atoms at the irradiated surface participate in the energy exchange but also the adjacent atoms located in the lower layers. The less energy each atom layer converts into collision energy and passes this on as irradiation energy, the greater the penetration depth. On transmision, each atom functions as a secondary radiator passing on the primarily absorbed energy collision free directly to adjacent atoms as potential energy.

Transmission belts, drive belts are used as → Transmission for driving machines of all types and for connecting movable machine parts the speed of which is adjustable at will by selecting appropriate drive belt discs. Depending on the type of use, belts are made of leather (split and chrome leather), rubber or textile material. The latter are made of impregnated camel hair, cotton, silk (for rapid shift), viscose, synthetic fibres, possibly as an insert in rubber with sprung steel insert, etc. In addition to standard drive belts also tensioning roller leather belts (perforated), semi-, cross- and cone discs (→ V-Belts), angle belts, etc. →: Belt drives; Motive power engineering.

Transmission measurements on dye liquors According to the Lambert-Beer's Law, extinction and concentration of a dye in diluted solutions are directly proportional. White light of varying wave lengths passes through the measurement sample; as this happens a substance-specific light weakening of certain wave lengths occurs (Fig. 1). In this wave length range the light intensity of the incident light Φ_0 sinks to the light intensity of the transmitted light Φ_{trans} the ratio of which is the degree of transmission (Fig. 2).

$$\tau = \frac{\Phi_{trans}}{\Phi_0}$$

The light absorption corresponds to extinction (E) which is related to transmission in the following manner:

Transmission measurements on dye liquors

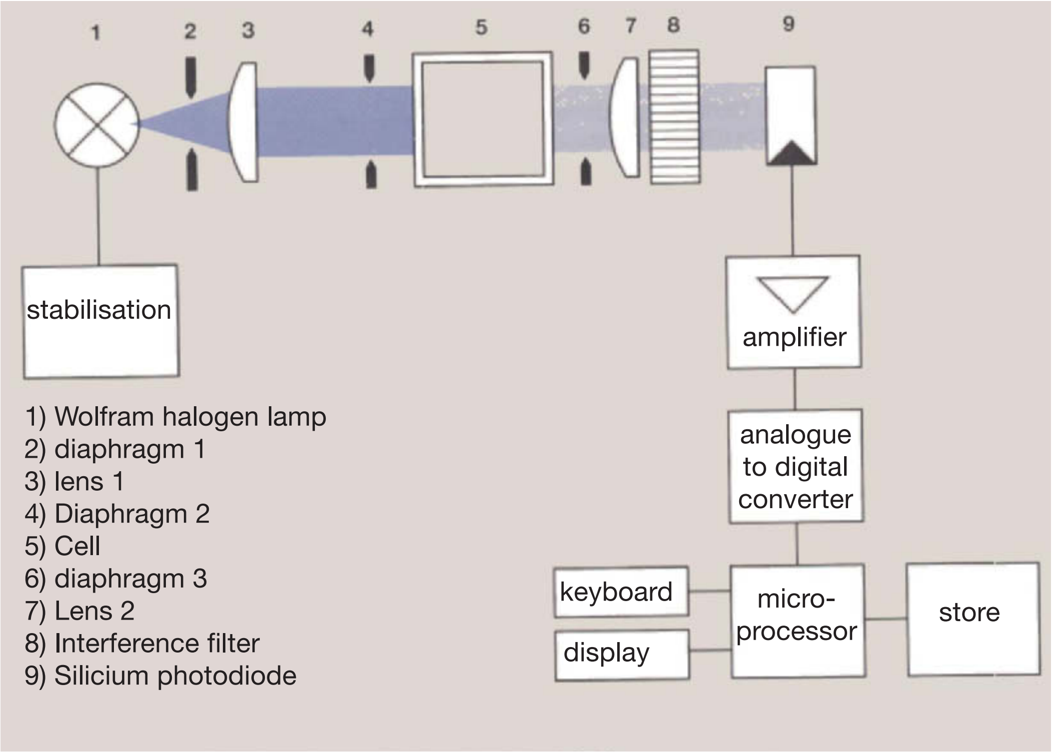


Fig. 1: Construction and measuring principle of a transmission measurement photometer (Merck).

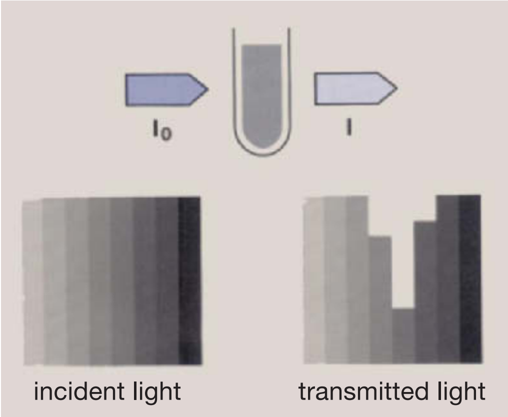


Fig. 2: Transmission measurement principle.

$$E = \log \frac{1}{\tau} = \log \frac{\Phi_0}{\Phi_{trans}} = \varepsilon \cdot c \cdot d$$

(Lambert-Beer's Law)

→ Extinction E increases with the concentration c of the disolved substance in the measurement solution and the depth of the cuvette. The extinction coefficient e is a substance-specific constant and depends on the wave length used, i.e. on the chosen interference filter. The following simple ratio results with constant layer depth of the cuvette:

$$C = \varepsilon \cdot F$$

F = factor

A blind sample is always measured first. This is followed by conversion of the mg/l-indication of the photometer into mg/kg of goods.

The existence of associates, agglomerates and coloured dye components which are inactive in terms of dyeing does not limit the validity of the proportional relationship between extinction and concentration within the degree of accuracy necessary for the dye liquor measurement. The decisive factor is that the relative number and size of associates and agglomerates, i.e. the particle size distribution of dispersions, must not be dependent on concentration. As long as this prerequisite is fulfilled, transmission measurements have proved to be an exact method of determining concentration including dye dispersions.

In order to facilitate comparative statements over a period of time, the consistency of supplies in terms of particle size distribution and relative content of coloured but colour-inactive dye elements should be indicated. If this important prerequisite is fulfilled, the ratio of measured extinction ranges and colour-active liquor components can be reproduced. As long as the dyeing properties of the substrate and the process sequence can be reproduced, liquors with corresponding extinction ranges can be expected to result in comparable colours.

The solvent for transmission measurement should be chosen so as to ensure that the dyes in the relevant concentration range are either totally soluble or are so difficult to dissolve that the dyes are available virtually completely as a dispersion and the dissolved molecule element is negligible.

As textile dyes are usually standardized for colour effectiveness which can be reproduced, coloured elements which are inactive in terms of dyeing, such as for example sythesis by-products or hydrolized reactive dyes, give the impression of having too high an effective dye concentration during transmission measurement. Errors of this nature are likely to occur when dyed by-products fluctuate markedly from batch to batch and a dye preparation is based on calibration measurements resulting from batches with deviating colour-active dye content.

Systematic optimization of dye synthesis, which is of economic interest, has resulted in the content of synthesis by-products in commercially available dyes becoming relatively small and reproducible. Within these parameters transmission measurement is also used by dye manufacturers for quality control and standardization of dyes in terms of intensity and shade. The Inter-Society Color Council and well-known dye manufacturers have publicised guidelines for the use of transmission measurement in quality control. The system for dye liquor measurement consists of a spectral photometer, a dilutor and a personal computer with a printer (according to Locker and Firmann).

Transmission profiles Longer wave absorption max. of sulphonated ultra-violet absorbers at 330–340 nm can be used for investigating their distribution in fibre cross-sections. With the aid of a rapid computer-controlled scanning table and the APA-MOS-programme (Zeiss) fibre cross-sections can be analysed with comb-like action and the transmission intensities in the absorption max. analyzed. The width of step in each direction is specified in advance. It depends on the degree of fineness of the fibre material investigated. A width of step of 1–2 µm in each direction has for example proved suitable for fine merino wool.

In this way transmission profiles can be achieved for woollen samples which have been pre-treated with ultra-violet absorbers. The profiles allow a statement to be made regarding the migration of the ultra-violet absorber into the wool fibre under the existing conditions. There are a variety of techniques for evaluating the resulting transmission profiles of a wool fibre cross-section. For transmission profiles of fibre cross-sections the minimum (T_{min}), max. (T_{max}) and fibre interior (T_M) as well as the differential ($T_M - T_{min}$) transmission values can be used to recognize the extent of ring dyeing. Low t-values are characteristic for wool with high ultra-violet absorbers concentrations.

In addition to this evaluation process, the area containing the ultra-violet absorber or dye can be placed in relation to the entire area. From this the degree of dye penetration can be calculated (Fig. 1).

$$A = \pi (R^2 - r^2)$$

$$\text{degree of dye penetration} = \frac{\pi (R^2 - r^2)}{\pi (R^2)} \cdot 100$$

r = total fibre radius (µm)
R = "ring-dyed" fibre radius (µm) which contains dye

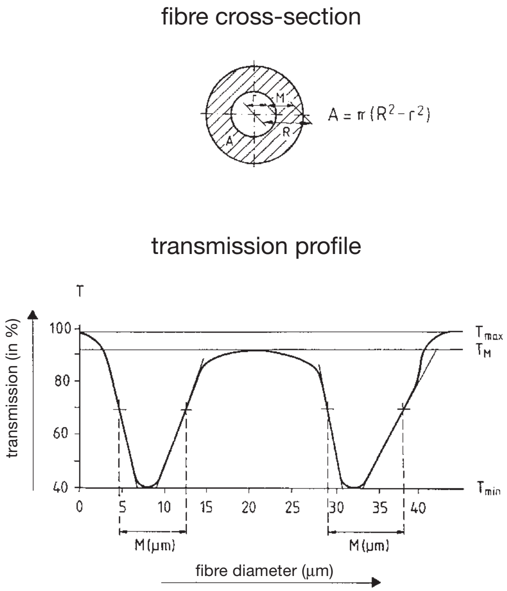


Fig. 1: Diagram of a ring-dyed wool fibre cross-section and an average transmission profile of a wool fibre cross-section (DWi).
A = the area containing dye; M = migration of the dye into the fibre.

Emission ranges (Fig. 2) and intensities can be measured on white-tinted woollen fibres making comparison of fluorescence intensities during various treat-

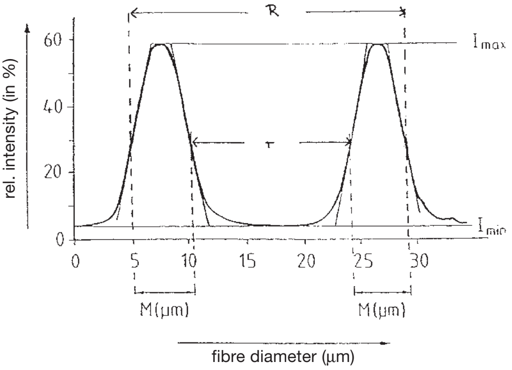


Fig. 2: Diagammatic average emission profile of optically brightened wool. The relative fluorescence intensity interrelates to a fluorescence standard (DWi). R = fibre radius (µm); r = radius of the fibre zone showing no fluoresence intensity; I_{max} = max. fluorescence intensity; I_{min} = min. fluorescence intensity; M (µm) = migration into the fibre (µm).

ments possible. The fluorescence intensities attained with the aid of photometric microscopy represent relative measurement values (according to Schäfer and Höcker).

Transmissions Devices for transmitting energy, e.g. between electrically-driven gears and apparatus, machinery, etc., such as for example → Transmission belts, drive belts.

Transparency The measure of light transmitted by a transparent medium. It is a function of the wavelength of light and decreases exponentially as the wavelength of the incident light increases. The transmission ratio is the ratio of the transmitted luminous flux to that incident upon a transparent medium. It is the reciprocal of opacity.

Transparent and opal finishes,

I. (→: Glass batiste; Organdy finish), used to create more or less transparent and stiff elastic effects on fine cotton fabrics (batiste). Principle: treatment in concentrated sulphuric acid, mercerization must also be carried out before and/or after acid treatment; possibly without tension. Organdy (glass batiste): glass-like transparency and boil-resistant stiffness effect. Opal: milky-white somewhat lower transparency. Imago: embroidery-like pattern created prior to acid bath treatment by printing a resist. Resisted areas appear matt white on a base which shows through.

II. Fabrics made of polyester fibres are subjected to a “de-weighting process” in which the fibres are peeled off from the surface by means of saponification. The process aims to achieve weight reductions of 10–20%. Reduction of the fibre titre achieves a casual appearance. The fibre itself takes on a slightly irregular surface structure and has a very similar appearance to silk fibre. As manufacture of light, transparent fabrics requires sophisticated spinning and weaving techniques, burn out processes are also occasionally used by means of which the cellulose component is removed from polyester/cellulose fibre mixtures. The treatment stages mentioned, which depend on the type of article, only represent a basis for fashion-conscious finishing which should be flowingly soft, lively and, whenever possible, hydrophilic.

Amino-modified polysiloxanes, transparent micro emulsions, represent an important group for achieving the specific handle characteristics of these materials. They differ from conventional polysiloxanes and softeners due to the low particle size of their active substance.

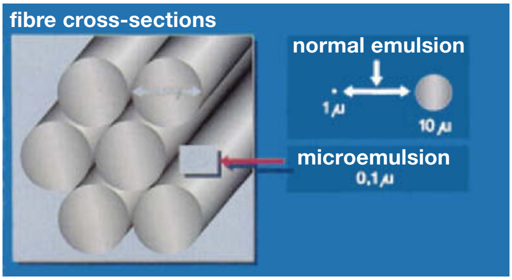


Fig.: Particle size in emulsions (Sandoz).

The Fig. is a schematic representation of the size ratios of particles of an emulsion and microemulsion as compared with a fibre bundle. They show that products based on microemulsions penetrate the fibre bundle far more easily and are distributed more homogeneously over the fibre surface than conventional emulsion softeners whose particles are mainly deposited on the fibre exterior. This explains why it is possible to achieve previously unknown soft handle effects with these products working on the basis of an action principle which could be described as “inner softness”.

Unfortunately the most effective of softeners create a decidedly hydrophobic surface and reduce the absorbency of the fibre material. This can on the one hand impair wearing comfort due to lack of perspiration absorption and on the other hand increase soiling properties in terms of greasy soiling agents such as skin grease and oily soot as well as increasing soil redeposition from washing liquors which again impairs the care characteristics. These disadvantages can be eliminated by using hydrophilic softeners without any major sacrifices in terms of soft handle characteristics.

Transparent films Thin materials made of cellulose-based fabric (cellophane) or synthetic high polymers (polyamides, polyester, polystyrol, polyolefins, polyvinyl alcohol, etc.). Ranging from very thin to cardboard thickness, transparent, non-transparent, glossy, matt, colourless, coloured, printed. Used particularly for film packaging.

Transparent prints Cotton fabrics can be made transparent (parchmented) by printing with suitable chemicals. → Transparent and opal finishes.

Transportation time Proportion of → Handling time factor or goods transportation time outside/within a company or organization which is necessary to process goods. This is totally unproductive time from a microeconomical point of view.

Transport equipment This includes for example conveyor belts, spiral conveyors, cable systems, garment lifts, chain drives, pneumatic systems, lifts, cranes, etc. → Transport systems.

Transport systems Transport automation takes up, sorts and transports individual parts produced by machines to the next production location. An example is the Pally (Innovatex) which is used as a transport system in spinning. The Pally drives up to a machine, which has indicated that a certain number of packages is ready to be picked up, and positions itself. The Pally takes on two packages simultaneously without touching the yarn systems and deposits them on a pallet with perforated or embossed intermediate shelving. After filling a shelf, the Pally removes an intermediate storage shelf from the pile and places this on the paletted package level. The completed pallet can be deposited by the mobile unit using the lifting and moving forks either directly behind the machine (e.g. on roller tracks) or alternatively the pallet is positioned at the end of the group of machinery at a transfer point for further transportation within the company or organization (Fig.).

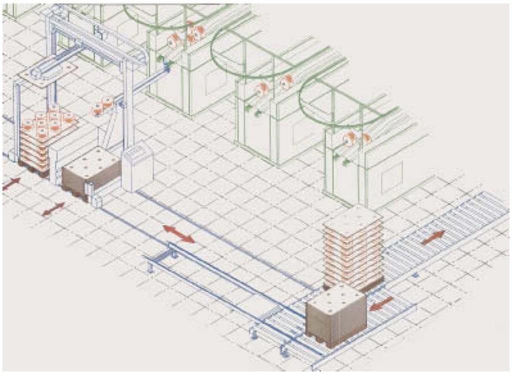


Fig.: Automatic paletting of cross-wound bobbins and transport system for the palettes (by Innovatex).

Transport tarpaulins Fabrics for covering lorries and containers, coated with polyvinyl chloride (PVC) on semi-calenders or blade coating with stenter processing. The base fabrics of polyester fibre are generally plain or panama weave in weight category 600–800 g/m^2. The coated surface is lacquered with solvent based polymers. The PVC paste is prepared with pigments, softeners and possibly filler materials and give the transport tarpaulin typical coloration (also signal effect). → Tarpaulin coating.

Transverse brittleness angle → Torsional strength.

Transverse cutting machines automatically separate the fabric web at a pre-specified meterage, deposit the finished fabric roll and provide a new wooden or cardboard roller for the next fabric roll without interrupting the process.

Transverse tricot (traverse tricot). → Tricot with wide transverse weave ribs, particularly elastic and stretchable. Opposite:→ Warp rib tricot.

Trash Contamination of cotton including dust. Mechanical operating systems, such as, for example, the Shirley analyser, Shirley trash separator and the Uster-MDTA dust and trash tester are used to measure contamination of cotton from bales, card lap or tow. Cotton contamination particles are separated from the fibres by means of dissolving and cutting devices before being weighed. The percentage value of contaminated content can be calculated from the weighed contamination quantity expressed as a proportion of the overall sample quantity. The contamination particles are divided into three size categories which generally include particles of 0.05 mm^2 to 3.00 mm^2 surface content:

category A (small)	from >0.05 mm^2 to 0.30 mm^2
category B (medium)	from >0.30 mm^2 to 0.70 mm^2
category C (large)	from >0.70 mm^2 to 3.00 mm^2.

Traverse mechanism Fabrics with thick edges form bulges in wound form which can cause the fabric to stretch; the edges mark the elastic rollers in the calender. The traverse mechanism displaces the fabric web laterally by a variable dimension; the edges are no longer aligned on top of one another.

Traverse winding Winding of threads with slight traverse movement resulting in the individual thread layers not being located exactly above one another. The thread conductor traverses in addition to its stroke when forming the spool; this strengthens the spool edges and a better spool form results. This thread conductor stroke displacement serves to build the spool structure and is created by the traversing gear. Traverse winding improves the thread location on the beam during building of warp beams; the individual layers do not cut in. (Additional) cardboard layers can also be inserted to prevent individual layers from cutting in. → Traverse mechanism.

Tread comfort value This is intended to give an indication of the degree of tread comfort when walking on textile floor coverings. It is determined by the deformation energy on compression in accordance with DIN

54 327. Increasing pressure in 6 specified pressure stages (p_1 to p_6) is used to determine different deformation energies. The ratio of these deformation energies to correspondingly specified reduced deformation energies provides indicators (B_i) which are used to determine the tread comfort value. Tread comfort values B_W, B_A and B_{SP} are differentiated for different use areas (living (w), working (a) and sports (sp) areas).

Tread sound insulation (carpets) This concerns the actual tread body sound; the denser the carpet the better the tread sound insulation. The underlay plays an important role (felt, foam backing, etc.). The degree of tread sound transmission is expressed by normal sound level and is measured in a room under a ceiling construction when a standard hammer device impacts on this. A simple dimension for the quality of tread sound insulation is the ISO-recommended tread sound insulation index I_i in decibels (dB). For the purpose of comparison with the German norm, additional indication is made on the sound prevention scale (TSM) in dB. The higher the degree of tread sound insulation, the smaller the decibel number of the insulation index I_i or the greater the TSM-value. A further dimension is the tread sound insulation improvement $V1_i$ of the uncovered floor through the tested carpeting = difference of the index values without and with carpeting.

Tread surface Walking surface or uppermost layer of carpeting.

Tree beard Colloquial term for → Tillandsia fibre.

Tretrad (walk wheel) This device consists of a rotating 4-part wheel with “feet” and is used to determine wear on textile floor coverings. It is also known as a Lisson unit on the basis of the Lisson tretrad system. It is used for measuring weight loss in g/m^2 due to abrasion. The device enables abrasion-sensitive fibre materials to be determined and assesses their suitability for use on stairs. It is suitable for use on pile carpets as well as needle felts and needle punched floor coverings.

TREX English textile machinery association; → Technical and professional organizations.

TRI Textile Research Institute; → Technical and professional organizations.

Tri (from the Greek: tris = three),

I. Prefix meaning “three times, triple”, e.g. trioxide (containing 3 oxygen atoms).

II. Short form for → Trichloroethane.

Triacetate According to DIN 60 001 this is a generic term for → Triacetate fibres with at least 92 wt.% acetylated –OH groups in accordance with American proposal.

Triacetate fibres (cellulose triacetate, primary cellulose acetate), belonging to the group of regenerated cellulose fibres on the basis of → Cellulose acetate; at least 92% of cellulose hydroxyl groups are acetylated. Although related to so-called normal → Acetate fibres, there are significant differences in terms of various important details. Manufacture: known for a long time; but initally difficult to spin due to predominant insolubility in technically easily accessible solvents (e.g. production costs too high using chloroform); the use of the cheaper dichloromethane made manufacture economically viable; dry and wet spinning processes possible. Thermosetting process is used to improve properties which results in modification of the crystalline structure. Large-scale production since the middle fifties. Properties for textile use (quoting acetate for comparison in brackets): density 1.30 (1.33); humidity absorption: normal 4.9–4.5 % (6.0–6.5%), thermoset 2.5–3.0%; water retention capacity: normal 16–17% (25–28%), thermoset approx. 10%; tear strength: 10–13 cN/tex; elongation at break: 18–30%; crease resistant, low electrical conductivity. Resistant to micro-organisms. Light, ultra-violet and weather resistance similar to acetate fibres. Good temperature stability: melting point 300°C (225°C); easily pleatable: pleating temperature 165–175ºC (mixed fabrics to 185°C); boil-resistant (HT-process possible), easy-care. Thermosetting necessary (surface shrink unset 16%, set approx. 3–4% after 2 h machine wash at 60°C), always measured after dyeing at the following setting temperature:

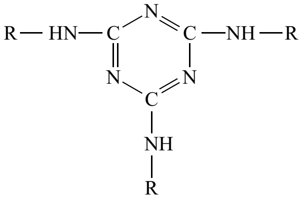
\>180°C = improved washing, gas and abrasion fastness.
\>200°C = increased ironing point, improved dimensional stability and crease-resistance.
\>210/220°C = modification of crystalline structure, improved thermal stability.

Usually dry heat setting. Ironing temperature: normally max. 180°C, thermoset 240°C. Chemical stability as compared with acetate fibres: acids such as acetate (strong acids are corrosive), more resistant to alkalis (mercerisation in cotton mixture is safe; to pH 9.5 and 95°C “no noticeable saponification”; concentrated alkalis saponify, particularly at higher temperature), more resistant to oxidation bleaching agents, i.e. difficult to bleach (suitability of chlorite, per acetic acid, hypochlorite). Soluble in various organic solvents (→ Acetate/triacetate – solubility in organic solvents). Used in pure form and in mixtures for ladies’ clothing (dresses, blouses), children’s clothing, fleece fabrics, technical fibres (mixtures with polyamide, polyacryl nitrile, polyester, wool).

Triacetate fibres/damage Testing by determining the → Viscosity index of a diluted solution of triacetate in m-cresol.

Triacetate fibres in dyeing → Dyeing of triacetate fibres.

Trialkylmelamines Category of → Defoamers effective against all types of anionic and cationic surfactants at concentrations of 0.1–1% in terms of washing agents; completely independent of water and type of complexing agent.



Triangular spindles Spindles used during dyeing of yarn packages to accommodate the spools and attached to the base plate of the dye package carrier.

Triarylmethane dyes → Triphenylmethane dyes.

Triaxial fabric These consist of 2 warp and 1 weft thread systems crossed at an angle of 60°. This arrangement results in excellent strength values at reduced weight. Compared with conventional fabrics (biaxial fabrics) of the same weight, triaxial fabrics have a tear strength which is four times higher. Elasticity and strength should be approx. the same in all directions. Used particularly in technical fabrics, they offer great potential for the clothing sector and curtains in conjunction with appropriate material and fabric construction.

Triazones → Dimethylol-triazone.

Tribasic Term for acids with 3 effective acid hydrogen atoms which are ionisable and metal-replaceable; e.g. phosphoric acid H_3PO_4, trisodium phosphate Na_3PO_4.

Tribology Term used to denote the theory of surfaces which impact on each other in terms of relative movement and of associated problems. Term for the theory of friction which also includes the surface properties of fibres and their behaviour towards solids, liquids and gases.

Tributyl phosphate (TBP), phosphoric acid tributylester), $(C_4H_9O)_3PO$; density 0.977; boiling point 289°C (decomposition). Light-coloured solution, virtually odour-free, easily soluble in alcohol, soluble in water. Used also for → Antifoams; not easily biologically degradable.

Tributyltin oxide $(H_9C_4)_3$-Sn-O-Sn-$(C_4H_9)_3$; organo-metallic compound with bactericide and fungicidal effect. Water-soluble liquid. Boiling point 180°C. Wood protection agent; used for odour control with textiles and the like.

Tricarballylic acid $(CH_2–COOH)_2–CH–COOH$. Produced by the reduction of → Citric acid which contains one additional oxygen atom. Sulphonated tricarballylic acid esters make highly effective wetting agents (→ Sulphonated polycarboxylic acid esters).

Trichloroacetic acid (TCA), $CC1_3–COOH$; molecular weight 163.4; density 1.62. White dissolving crystals with a slightly acid smell, soluble in water, carcinogenic. Results from oxidative decomposition of tetrachloroethane (under ultra-violet rays and ozone).

Trichloroethane (1.1.1-trichloroethane, methyl chloroform), $CH_3–CC1_3$; molecular weight 133.42; density 1.31-1.35; boiling point 74°C) (azeotropic mixture with water at boiling point 65°C with 95.7 wt.% trichloroethane). Colourless liquid; volatile; evaporation index 2.6. Not easily flammable. Good solvent for lubricating greases, mineral oils, resins, waxes, tar, vinylidene chloride. Corrosive in pure form (therefore for chemical cleaning with up to 6% stabiliser); hydrolysing in the presence of water. Used as cold cleaning agent for metal surfaces, solvent for chemical cleaning, raw material for adhesives, putty, dyes, aerosols, spotting agents. → Chlorinated hydrocarbons. Prohibited for use as a chemical cleaning agent in the Federal Republic of Germany.

Trichloroethylene (tri, ethylene trichloride), $HC1C=CC1_2$. Colourless liquid, clear as water, nonflammable, evaporates easily, smell similar to chloroform, strong anaesthetizing effect, prolonged presence on the skin causes “burn blisters”. Does not corrode standard construction metals (except light metals) at temperatures under boiling point. Not easily soluble in water; hygroscopic; miscible with almost all organic solvents. Dissolves light and heavy greases, oils, resins, rubber, waxes, tar, oil-based dyes (if not too resinated, otherwise + alcohol + benzene soap), bitumens. Dissolving tendency for certain acetate, naphthol and vat dyes; also for polyvinyl chloride fibres (becoming hard and brittle), certain plastic parts (buttons, zips, buckles and the like) as well as plasticised finishes. Particularly dangerous, carcinogenic substance the use of which is prohibited in Germany. → Chlorinated hydrocarbons.

Trichlorofluoromethane → Chlorofluorocarbons.

Trichloroisocyanuric acid → Chloroisocyanuric acids.

Trichloropyrimidine The basis of certain commercially available reactive dyes. → Reactive dyeing.

Trichlorotrifluoroethane (R113), $CF_2C1–CFC1_2$, boiling point 47.6°C; density 1.58. Refrigerant used in chemical cleaning for cleaning leather, furs and delicate items of clothing in special cleaning machinery. Its use is prohibited in Germany. → Chlorofluorocarbons.

Trichromat Perception of colour by the normal-sighted. → Colour vision.

Trichromatic Three-coloured (→ Chromatic), the normal perception of colour (→ Trichromat). Deviations: → Defective colour vision.

Trichromatic colorimeters → Colour measurement.

Trichromatic colour coordinates → Colorimetric measures. In this context the following concepts are identical: trichromatic system X,Y,Z = trichromatic components = norm colour values X, Y, Z. Trichromatic coordinates or coefficients = norm colour value proportions x, y, z.

Trichromatic colour values Identical with the so-called trichromatic → Colorimetric measures, also known as tristimulus values or tristimuli.

Trichromatic dyeing Dyeing with triple combination of yellow (or orange), red and blue (basic colours). Widely used in the dyeing of wool and synthetic fibres, not generally used for dyeing cellulose fibre. → Colour triangle.

Trichromatic printing (three colour printing). Use of printing rollers with appropriately graded engraving depth or templates with corresponding grid with which multi-colour pattern is achieved by means of multiple fall-ons. A 4th roller or template is often used for black or grey.

Trichromatic RGB system → RGB colour measurement system.

Tricot,

I. Elastic fabric with fine, narrow ribs in warp direction, transverse or diagonal direction (warp rib, transverse, diagonal tricot). For suit and coat materials (e.g. uniforms) and sports clothing (e.g. riding trousers).

II. Single-surface weft-knitted fabrics with right and wrong sides. Used mainly for underclothes and T-shirts.

Tricotine Diagonal-weave, worsted fabrics with tricot-like appearance used for ladies' dresses and suits (with smooth finish).

Tricot weave,

I. Created in fabrics by tying reverse warp threads (warp rib tricot) or reverse weft threads (transverse tricot) as well a special weave (diagonal tricot).

II. A form of ground structure used in warp knitting in which the threads are transferred from one needle to its neighbour and returned.

Tricresyl phosphate (TCP, → Alkyl phosphates), $(C_6H_4–CH_3)_3PO_4$. A tricresyl phosphoric acid ester. Oily liquid, colourless, neutral, odourless; density 1.172; molecular weight 368. Almost insoluble in water; soluble in alcohol, ether, chloroform, benzene, glacial acetic acid, lipoids. Ortho-tricresyl phosphate is an extremely powerful nerve poison whereas meta- and para-tricresyl phosphates are harmless. Used predominantly as plasticiser for artificial leathers, synthetic resins, waxed cloth, etc. Also used as a preservation agent for sizes and finishes.

Triethanolamine $N(CH_2–CH_2–OH)_3$; density 1.119–1.124; boiling point 270–279°C. Reaction product of ethane oxide on ammonia. Thick oil similar in consistency to glycerine, slightly fishy odour, sticky, hygroscopic, absorbs carbonic acid from the air, very alkaline. Miscible with water, alcohol, glycerine. Slightly soluble in acetone, chloroform, virtually insoluble in ether, benzene. Triethanol compounds with oleic acid (triethanol-soaps) are soluble in water and are neutral, fibre-friendly, highly effective emulsion agents (for dirt, oils, waxes, chlorinated hydrocarbons, etc.) Used as emulsifiers, pasting agents for vat dyes, solvents for acid dyes. Also used as additives in lubricating oils. Component part of wetting, cleaning, softening, sizing and finishing products.

Triethanolamine ester salts Cationic surfactants in which 1, 2 or 3 hydroxyl groups of → Triethanolamine can be esterified.

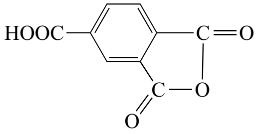
Triethylamine $(C_2H_5)_3N$, colourless liquid with odour similar to ammonia. Density 0.73; boiling point 89.4°C. By-product of manufacture of quarternary compounds. Used amongst other things as a stabiliser for chlorinated hydrocarbons.

Triethylsulphateamine, disodium salt Used as a resin finishing agent for alkaline wet crosslinking and for two-step processes.

Trifluorochloroethylene $F_2C=CFCl$, colourless gas which is polymerized to form → Polytrifluorochloroethylene.

Trifluorotrichloroethane → Chlorofluorocarbons.

Trimellitic anhydride (TMA). $C_9H_4O_5$, a hemimellitic acid. Colourless crystals. Use: for synthetic resins, adhesives, textile auxiliaries, surfactants, polyvinylchloride softeners.



Trimer Oligomers of three monomers.

Trimers as a problem source of polyester oligomers Most polyester fibres contain approx. 1.5% → Oligomers, of which 1.1–1.2% are cyclic trimers. The surface content of the polyester is from 0.1-0.3%, of which 97% are trimers. According to experience, difficulties start to arise when the surface concentration of oligomers reaches 0.3%. Trimers such as those of low water solubility, with a tendency to crystallise rapidly and which are resistant to alkalis, are mobile in the non-crystalline areas of the polyester fibre and migrate (depending on the fibre structure and temperature and duration of dyeing) to the surface of the fibre and into the dyebath where they form saturated solutions and rapidly crystallise on crystal nucleii which have been on the fibre from the outset. As well as this, crystal nucleii form on rough, sharp-edged components of the dyeing machine, in preference where the temperature periodically fluctuates or is lower than at other sites in the machine. Oligomeric deposits inside the dyeing machine increase from one dye batch to the next when only polyester fibres are dyed, and if the machines are seldom cleaned, using reductive-alkaline media. Using the shortest possible dyeing times can somewhat reduce the release of trimers and growth of large crystals (= well adjusted dye formulation without shading times and optimum temperature/time programs). Carrier additives tend to produce thicker deposits. Even carriers, the active components of which dissolve trimers, are not a reliable solution to the problem as they are extensively absorbed by polyester fibres at dyeing temperatures and the small amounts which remain in the aqueous emulsion in the dyebath are normally not sufficient to dissolve the trimer deposits completely. Neither can other auxiliaries (dispersants or emulsifiers) reliably keep the trimer crystals in a dispersion which is fine enough to be drained later with the liquor. More trimer crystals are removed by draining the liquor at high temperatures (125–135°C) than by draining the liquor after it has cooled down (particularly in the case of wound (yarn) package and flocks). The removal of deposits from dyeing machines after dyeing using saponification catalysts seems promising. One trimer-specific development clearly promotes the saponification of trimers in alkaline cleaning liquors, keeps the surfaces of dyeing machines free from trimer deposits and leads to improved polyester-flock and combed-top spinning behaviour.

Trimethoxymethylmelamine → Methoxymethylmelamines.

Trimethylglycocoll Same as trimethylglycine → Betain.

Trimmings,

I. Smooth, (so-called double-braided) → Braids made from cotton, viscose or mixed yarns (8–10 braids/cm). Examples of use: bordering furnishings, covers and curtains.

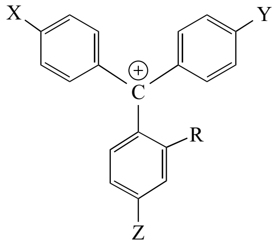
II. Used for hems, borders or decoration of textile products. Restricted use, for example, as fringes, tassels →: Braids; Gimp and → Tuft and the like.

Trioxane $(CH_2O)_3$, particularly stable cyclic oligomer of → Formaldehyde. Freely soluble in water, alcohol and ether. Among other things, used as a stabilizing agent for trichloroethylene. Heating trioxane and acids in the absence of water produces pure, dry formaldehyde in its gaseous state. (→ Polyoxymethylenes).

Triphenylmethane $(C_6H_5)_3$–CH, → Cyclic hydrocarbons made up of three benzene nuclei linked to a single carbon atom. Parent substance of → Triphenylmethane dyes.

Triphenylmethane dyes (triarylmethane dyes). Dyes derived from → Triphenylmethane, the water-solubility and dyeing properties of which are determined by the amino-, sulfo-, and carboxylic groups attached to the molecule.

Among these are cationic dyes, acid dyes, a few chrome or mordant dyes, substantive dyes and fat-soluble dyes. Some xanthene dyes are triphenylmethane dyes. (→ Carbenium ions).



e.g.

malachite green type: $X = Y = NR_1R_2$, $Z = H$

crystal violet type: $X = Y = Z = NR_1R_2$

phenolphthalein type: $X = Y = OH$

Triphenyltin chloride $(C_6H_5)_3SnCl$; molecular weight 385.45; colourless substance, relatively non-poisonous, almost water insoluble; soluble in alcohol, ether and acetone; unstable in hot solution. Used in the form of an emulsion as, for example, moth repellents during dyeing and bleaching (with sodium dithionite and sodium peroxide). Triphenyltin chloride is absorbed rapidly by wool with good fastness properties.

Triple point → Reference temperature of the three phases (solid, liquid and vapour) in a one-component system, such as water, in which case it is the ice point (±0°C) and the steam point (+100°C).

Triple point of water This is the fixed point on the international temperature scale, where ice, water and water vapour are in equilibrium, i.e. exist simultaneously and reversibly. This temperature is 273.16 K (Kelvin) = ±0°C (Celsius).

Triple pressure zone calander When building the calander, an effort is made to align the rollers in different positions in relation to each other in order to achieve a uniform distribution of pressure over the width of the goods and to apply particularly high pressures (Fig. 1). A Nipco roller with three pressure zones

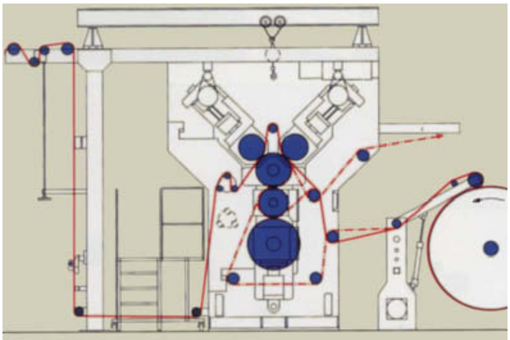


Fig. 1: Typical triple pressure zone calander with Nipco roller in the centre of the pressure zone (Kleinewefers KTM).

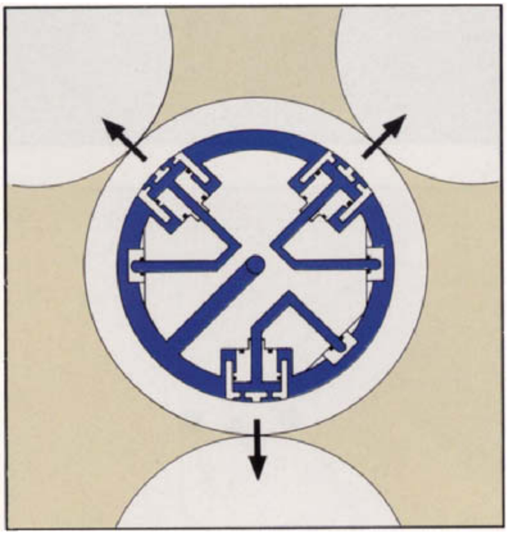


Fig. 2: Triple zone pressure diagram with Nipco roller (Kleinewefers KTM).

in a triangular arrangement can be particularly effective in equalizing the pressures applied by the three counter rotating rollers using hydraulic rams (Fig. 2).

Triple weft carpets Woven carpets in which each row of knots is bound to three wefts.

Triple(zone)filter photometer → Colour measuring instruments.

Triple zone method → Colour measurement using a triple-zone filter photometer.

Tripolyphosphates → Phosphate, condensed.

Tris- (from Gk. tris = three), prefix for organic compounds made up of three identical ("complex") substituents, for example → Tris(1-aziridinyl) phosphine oxide.

Tris(1-aziridinyl) phosphine oxide $(CH_2–CH_2–N)_3P=O$; Aziridinyl compound for permanent flame-retardant finishing using, for example, → THPC.

Tris(2,3-dibrompropyl) phosphate Since the mutagenic and carcinogenic properties of this substance have been established, products based on tris(2,3-dibrompropyl) phosphate are practically no longer commercially available as flame retardants.

Trisilicate So-called "neutral" → Water glass ($SiO_2 : Na_2O = 3.3$) as opposed to alkaline water glass ($SiO_2 : Na_2O = 2.0$).

Trisodium phosphate (TSP) (tertiary or tri-basic sodium phosphate), Na_3PO_4; density 2.536; calc. as dust-fine powder; cryst. as white powder, flakes or needles; non-hygroscopic; freely soluble in water. Aqueous solution strongly alkaline (1% solution pH 11.3) due to the formation of sodium hydroxide: $Na_3PO_4 + H_2O \rightarrow Na_2HPO_4 + NaOH$. The solution alkalinity lies between that of sodium carbonate and that of sodium hydroxide at comparable concentrations. Hardness elements are rapidly precipitated as insoluble salts, and fats and oils are emulsified. Use: water softener for boiler feed water for complete or residual softening, also used as a descaler; alkali factor for oxygen bleaching; washing and degreasing agent; builder for detergents and cleaning agents.

Trisodium phosphate water softening process Water-hardness elements are precipitated out by adding → Trisodium phosphate (TSP). Softening achieved down to 0.1°d. Mainly used as an additional method to the → Lime-soda water softening process. For security reasons, trisodium phosphate is often added to completely softened boiler feed water and distilled water for high-pressure boilers (corrosion).

Tristimulus values Standard colour values (x, y, z) are numbers which fully characterize the colour stimulus specification (→ Colorimetric measures). When a bundle of parallel white light rays meets a triangular prism, it is split up into its components and can be separated precisely into colour lines (Fig.).

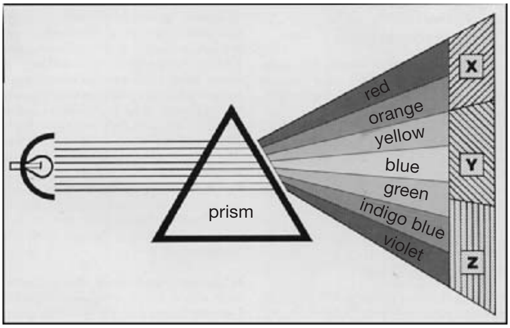


Fig.: Prismatic splitting of white light.

Tritik (Plangi-Tritik, crimped batik). → Plangi technique, in which yarn, threads or bast is drawn into the fabric in rufflets corresponding to the pattern and then gathered before dyeing, in order to produce resists during the dyeing process.

Trivinyl According to the → EDP key system for fibres made from three different vinyl monomers (acrylonitrile, chlorinated vinyl monomers and a third vinyl monomer).

Tropical Light worsted yarn goods in linen or Panama weave, plain or patterned (yarn or colour-effect patterns); up to 300 g/running m; with napless finish. Used for men and boys' outerwear and women's outerwear summer clothing. → Fresco.

Trough doctor (screen printing) Used to apply the coating of lacquer during → Screen making.

Trough roller Ball-bearing-mounted roller in a trough for unwinding rolls of fabric at the feed end of fixing machines, steam calenders, folding machines and inspection machines, etc.

Trough type fabric store A device for storing goods by folding in zigzag fashion in cross pleats on a trough-shaped base. → J box.

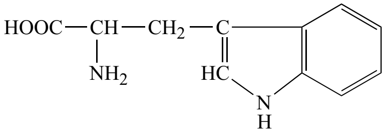
Trubenizing (trubenizing process), for the purpose of chemical stiffening of men's laundry (without using finishing products). Method for stiff collars: a lining which has been soaked with cellulose acetate and swollen with solvent (acetone) is inserted between the outer fabrics beforehand and then bonded to them using a hot iron. This type of collar is soft when wet, washes well and always achieves its original stiffness again (without the use of a finish) after ironing.

True solutions These are solutions in the strictest sense. Their component particles exist in monomolecular form in contrast to → Colloidal solution.

Trypsin An → Enzyme (→ Proteinases) produced by the pancreas which breaks down proteins. Unlike pepsin, the hydrolytic decomposition of protein leads to free amino acids which means that even → Polypeptides are attacked (behaviour similar to that of papain). It is most effective in the weakly alkaline range pH 8–8.7. Amorphous trypsin only attacks proteins in the presence of a protein-type activator which is not required in the case of crystalline trypsin. Trypsinogen is a crystalline trypsin precursor. Pure trypsin is a yellow to grey powder which dissolves in water to give a turbid solution. Crystalline bovine trypsin has a molecular weight of 34 000.

Tryptases → Proteinases of the trypsin type.

Tryptophan A cyclic → Amino acids (2-amino-3(-indolyl)propionic acid).



TS,
I. Titre fluctuation, → TS-type
II. Turk. Standardlari = Turk. Standard.

Tsatlee silk Chinese Grège yarn from live cocoons, products from the cottage industry, non-uniform.

T screens Rotary screens for printing → Transfer printing papers. They have a particularly smooth surface and 80 mesh size to compensate for the sensitivity of transfer printing to any unevenness in the screen due to low absorption capacity of paper. – Manuf.: Stork.

TSE Turkish Standards Association; → Technical and professional organizations.

T-Shirt Formerly a short-sleeved vest; today, this is a term used for a multitude of different fashionable casual shirts, with or without sleeves (short or long sleeved), coloured, printed, and decorated with motifs, etc.; made from knitwear.

TT (dyeing) process → Thermofixation and thermosol process.

TTZ (cloud point index) → Cloud point index.

Tub dyeing machine To shorten the liquor ratio in yarn dyeing, the dyeing volume (otherwise a dyeing boiler) is sectionalised into a number of tubes. A dye column is dyed separately in each tube (Fig.). Associated with this method of dyeing is an adapted finishing method which, under certain circumstances, is carried out by robots.

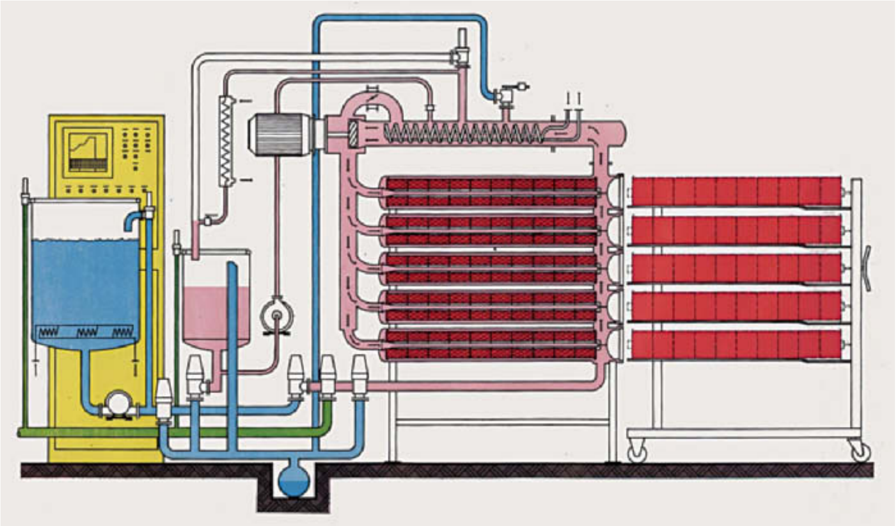


Fig.: Reduced liquor-to-goods-ratios through yarn dyeing in pipes by OBEM ("API/O").

Tubeless cross-wound yarn package Wound packages without a batch centre (dyeing tubes). Promotes better penetration of dye.

Tubular fabric dye padder Padder for the continuous dyeing of tubular cotton wear with reactive dyes according to the CPB method. After impregnation of the tube which is width guided through, it is blown up like a balloon by air-injection nozzles and then squeezed out. A warping device is used to lay the edges of the tube marked by the squeezing process. Special place for depositing goods: → Tubular fabric dyeing range.

Tubular fabric dyeing,

I. Term from piece dyeing which is used for fabric or knitwear with the edges sewn together to form a tube and dyed on the winch as an effective way of countering selvedge curling.

II. Dyeing of tubular knitwear.

Tubular fabric dyeing range The essential purpose is to prevent creases. The main application is reactive dyeing according to the cold-pad batch dyeing method, coupling naphthol dye by padding up fast colour salts, continuous dyeing with vat dye followed by the steamer. Mainly tubular cotton wear is impregnated in the padder economy trough, blown up like a balloon after the squeeze nip and the balloon squeezed for the optimum distribution of liquor (liquor pick-up 130–140%). Then the edges creased by the squeezing unit are laid using a turning device and plaited down in small dwell packages. For thermo-dwelling using heated panel cars; enclosed in plastic film to prevent partial drying. Fabric speed: 25–35 m/min.

Tubular fabric mercerization → Mercerizing tubular knitwear.

Tubular fabric mercerizing machine Tubular knitwear which has not been cut open should be mercerized without fixing the fold creases. For this reason, the impregnated hose is blown during stabilisation in the following steps (Fig. 1) : A = roller-vat type impregnation zone using the squeezing unit; B = mercerization cartridge with controllable lateral and longitudinal tension and end squeezing unit; and C = wash, neutralizing and rinsing step.

The machine in Fig. 3 is ideal for the mercerizing of all types of knitted fabrics such as single jersey, inter-

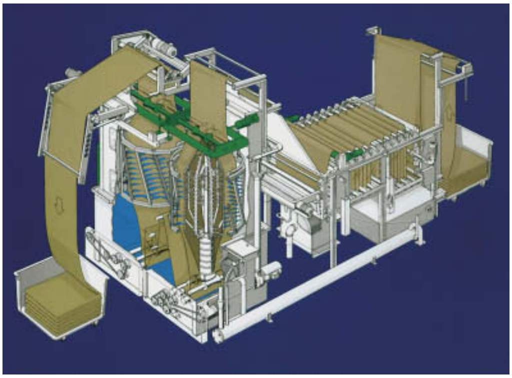


Fig. 2: Tubular mercerizing for knitwear: technical drawing of the Dornier Ecomerc mercerizing range.

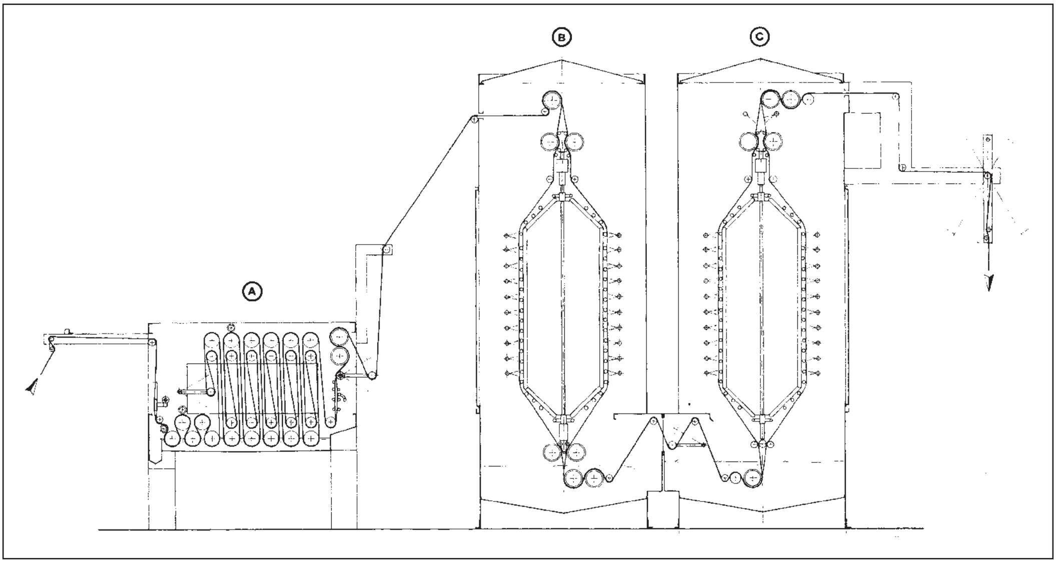


Fig. 1: Tubular fabric mercerizing machine according to Sperotto Rimar with the processes A = impregnation; B = stabilization; C = rinsing.

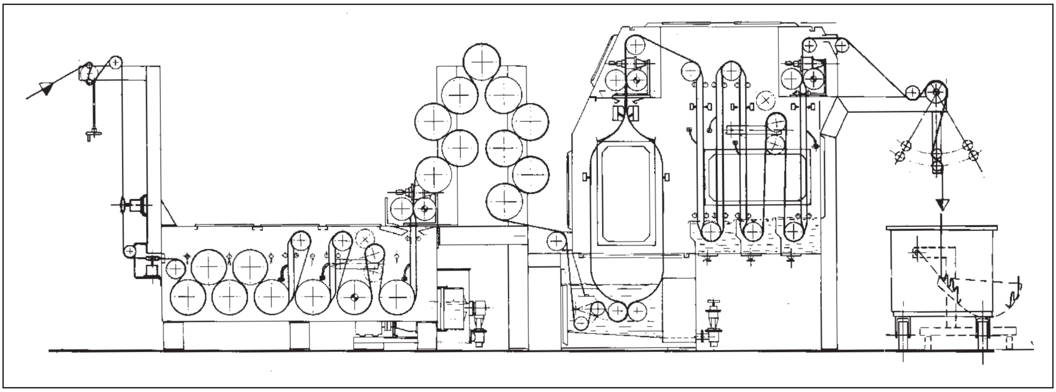


Fig. 3: Tubular mercerizing for knitwear (MCS).

lock, fine rib and pique in cotton or its blends. Not only high-grade fabrics of fine, combed cotton twist but also medium grades in short-staple cotton yarn undergo an appreciable boost to their quality as a result of this process. Aside from outerwear and sportswear, the main applications for fabrics treated in this way include the more upmarket underwear. The Dornier system (Fig. 2) featuring its patented power-adjustable circular expanders in the stabilizing, washing and neutralising sections ensures the cost-efficient mercerizing of tubular knit fabrics for all such garments.

Tubular fabric singeing Tubular knitwear can be passed through a circular burner so as to cause uniform singeing of the goods (Fig.).

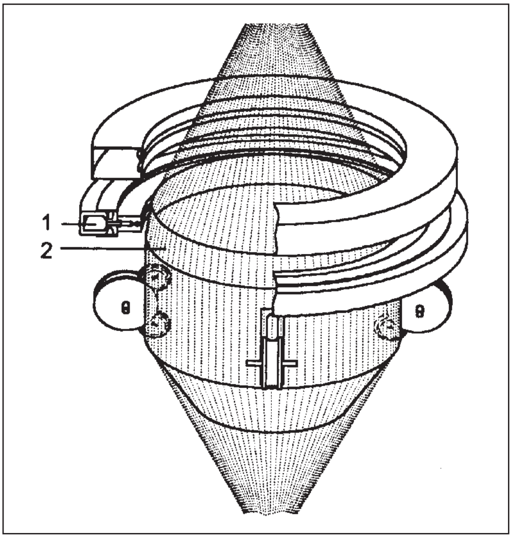


Fig.: Osthoff tubular fabric singeing.
1 = circular burner; 2 = circular tube opening.

Tubular fabric slitting machines (tube openers). They are used to slit open tubular knitted goods to expose the surface of the fabric to the finishing process. The slitting process can be achieved using burners (welding) or cutters. A cut thread or → Separating course is provided for this purpose and is picked up by electronically controlled units (Fig.). The tube slitting machine detects the separating course using a photo-electronic device and opens the tubular wear automatically. The tubular wear runs over a fabric guide cage,

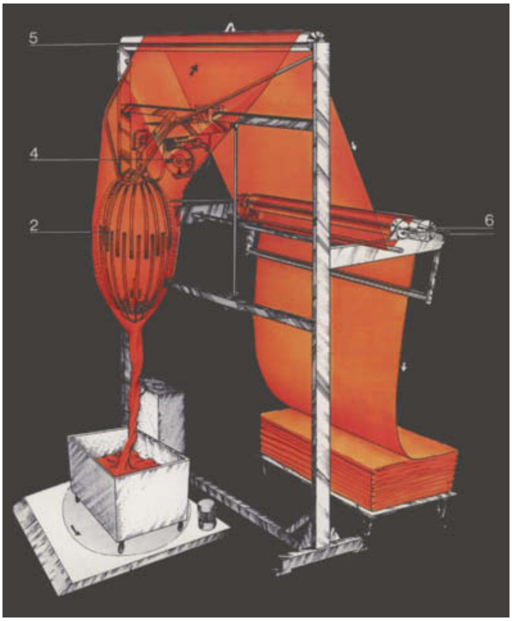


Fig.: Sperotto Rimar tubular fabric cutting machine.
2 = fabric guidance frame; 4 = cutting device; 5 = powered draw-off roller; 6 = powered run-off roller.

which is manually adjusted to the size of the tube, and on to the photoelectronic detector. Amplified signals turn the guide cage via a d.c. drive motor so that the separating course runs exactly under the circular knife of the slitting machine. Also used for slitting tubular goods is the → Calender crease (instead of separating course).

Tubular fabric turning machine Device for turning tubular knitwear using aerodynamics. The tubular wear is pushed on to the turning tube (length 3 000 mm, ∅ 180 mm). The end of the piece is drawn into the tube opening aerodynamically and this turns it at the same time. Fabric speed is 600 m/min (loading) and 300 m/min. (unloading) (see Fig.). – Manuf.: Sperotto Rimar.

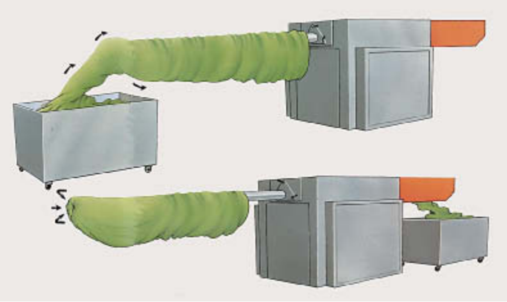


Fig.: Tubular fabric turning machine from Sperotto Rimar.

Tubular felt (felt sleeves). Industrial wool felt in the form of continuous woven or nonwoven pressed felt for covering rollers (lapping), for sizing and finishing machines, calenders, for transferring printing in roller printing, etc. also used as an underlay for machine foundations and seals, etc.

Tubular gauze Tubular fabric made from screen gauze used on nickel screens in rotary-screen printing.

Tubular knitgoods A tubular knitted fabric, generally knitted in tubular form to be cut open subsequently.

Tub washing machine,

I. American design of domestic washing machine with vertical wash tub and wash agitator (cyclically oscillating wash paddle or rotating agitator). There are significant differences in washing technology because of this (as opposed to Europe where most are → Drum washing machine): by connecting to a domestic hot water supply, washing temperatures are usually below 60°C (instead of perborate, chlorine bleach solution is used as required), shorter washing times (approx. 15 min.) relatively higher proportion of wash liquor to laundry (liquor ratio approx. 1 : 20), less detergent (approx. 1–2 g/l) for generally lower water hardness (on average 7° d = approx. 130 ppm) and only one rinse cycle, approx. $^{1}/_{4}$ water consumption for the same amount of laundry.

II. Used for washing printing pastes or dyes from batch containers (Figs. 1 + 2). The effluent must be fed to a controlled disposal unit.

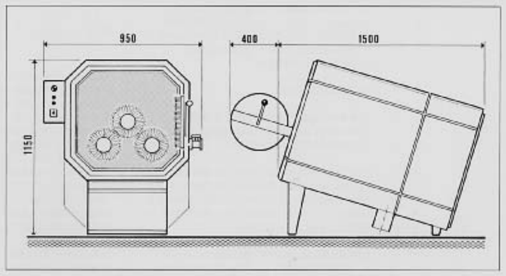


Fig. 1: Diagrammic representation of a tub washing machine (van Wyk).

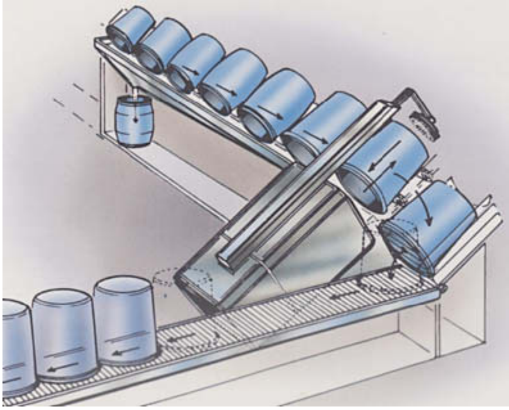


Fig. 2: Tub washing machine (van Wyk) functional principle.

Tuft A bundle of fibres, yarns, etc.

Tufted carpets → Carpets with sewn-in pile loops, using the tuft anchorage process (tufting, → Tufted textiles), in which pile yarn in the form of loops are inserted into a finished woven fabric with the aid of needles (sewing machine principle) (Fig. 1) and then fixed with adhesive on the back.

There are two types of tufted carpets, loop pile type with closed or upright loops and velours (Fig. 2) with cut, open pile loops (cut pile). In contrast to the manufacture of pile loop or wire loom carpets with → Pile loops woven into the fabric, "sewn-in" pile loops in tufted carpets have practically no firm hold in the fabric. They are therefore glued on the reverse side (→

Backcoating of carpets) in order to fix the pile loops and increase the stability and comfort underfoot.

Tufting can either be carried out with dyed pile fibres, or the carpet piece dyed prior to backcoating. When developing designs for tufted carpets or multicoloured carpet yarns, it is essential to obtain computer-generated patterns, in order to check whether the specifications and the degree of patterning are adhered to. In the case of cross-over techniques, in which needle bars can be moved in different ways, the effects of the different movements can be represented by the use of a computer program. In the case of the usual tufting techniques, computer simulation of multicoloured yarns can be used to check whether the colour spaces are long enough and whether negative effects such as barring or patterning arise. Relatively simple computer programs can be developed for the cross-over techniques, but large-scale simulations are necessary for standard tufting techniques. These require the programming of a comprehensive carpet yarn process model.

Depending on the tufting process, carpet widths of e.g. 4.50 m can be produced mechanically (simultaneously with 1000–1200 pile loops) and approx. 2–3 linear m per minute (10–20 times faster production speeds possible in comparison with woven carpets). Manufactured increasingly with natural tufts (i.e. undyed), otherwise in single shades, marl, melanges or mottled. The backing fabric is mainly polypropylene, although jute is sometimes used; all carpet fibres used for the pile material can be tufted. The main ones used, however, include polyamide, polyacrylonitrile, polyester, as well as wool and cellulose.

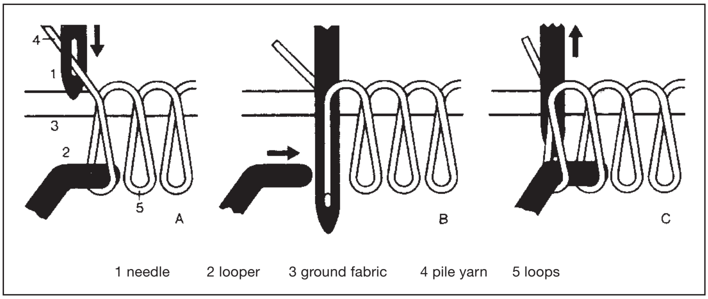


Fig. 1: Manufacture of a tufted carpet.

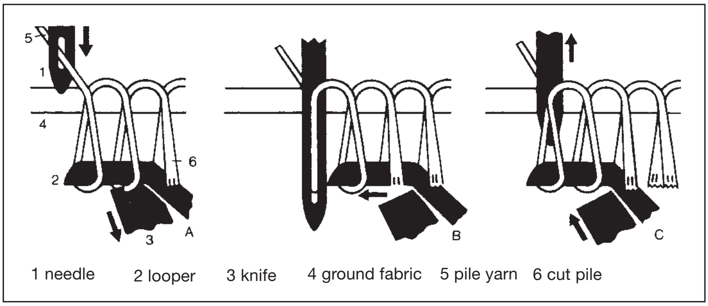


Fig. 2: Pile cutting in a tufted carpet.

The grey goods are submitted to a carpet finishing plant in rolls, which are sewn together as they enter the plant. Intensive cleaning removes lint and threads. The carpets can then be dyed and the dye fixed in the fibres in a saturated steam atmosphere. Non-fixed dye is washed out in a washing unit; then the carpet is dried to a residual moisture content of 50% by extraction. Like continuous dyeing, there is no final drying stage. In place of dye, the carpet can also be impregnated with an anti-static finishing agent. The fixing also takes place in a saturated steam atmosphere. In this process, too, a final residual moisture content of less than 50% is ensured by extraction. A further auxiliary agent can then be sprayed on. For the straight backcoating process it is possible to stop all process stages after cleaning, so that, as in classic coating methods, the carpet is offered

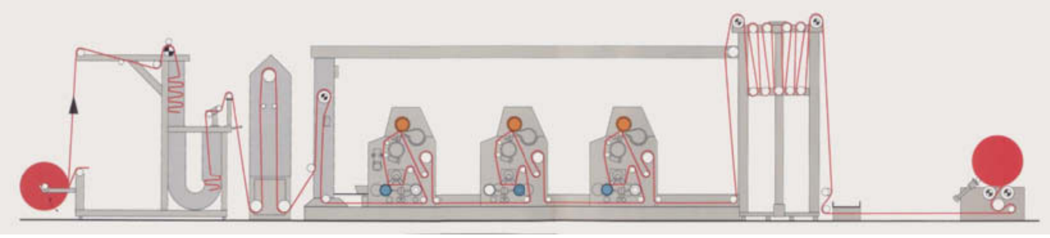


Fig. 3: Tufting shearing range (Menschner).

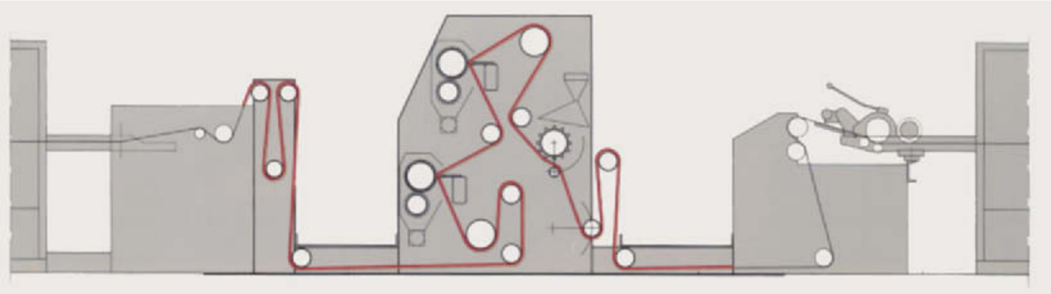


Fig. 4: Tufting pile raising (Menschner).

for latex coating when dry. In all other cases a residual dampness of 50% or less must be achieved before latex coating.

After latex coating, which is necessary for binding the fibres to the backing material, the carpet is dried with hot air. Now, either the foam is applied and gelled in the infrared zone or the adhesive and secondary backing applied. The necessary drying or vulcanization is also carried out with hot air. Specific patterns can be achieved by shearing (Fig. 3) and/or pile raising (Fig. 4).

Tufted textiles In accordance with DIN 60 000, these are fabrics which are made by inserting yarns, into a usually textile backing, using one or more needles, forming loops (pile loops). The loops may be cut and/or fixed to the backing using an adhesive or by heat sealing.

Tufting The manufacture of → Tufted textiles, in particular → Tufted carpets, using the tufting technique.

Tulle A net-like fabric of honeycomb 6 or 4 sided (→ Bobbinet) cells with diagonal weft, used for dresses, blouses and (usually embroidered: florentine tulle) for net curtains.

Tumble drier A drying machine with a rotating, perforated drum, in which the material is spun loosely, without tension, and discontinuously (Fig. 1) or continuously (Fig. 2). The first tumble drier (Passat) came onto the market in 1967. The load weight of a tumble drier is between 6–3000 kg, and they are used both as drum or transfer driers (semi-/fully automatic), for surface finishing (e.g. for imitation lambskin, goatskin or Persian lambskin effects, imitation leather grain, for the preparation of cut-plush fabrics, for the shrinkage of looped plushes and terry cloth goods, the tumbling of tufted garments, the crinkling of yarn hanks, the relaxation of knitted goods, etc.) and for drying cut-plush fabrics, tights, socks, fully-fashioned articles, knitted articles, terry goods, bath mats, etc. (→ Continuous tumbler).

These are processes for establishing quality profiles for drying, relating to handle improvement, voluminosity, relaxation and dimensional stability. The fact that the goods being dried in the rotating drum fall loosely and unimpeded and therefore are not forcibly guided results in a relatively high energy consumption. In contrast, a → Recirculating tumble drier results in almost >70% energy savings. Advantages: reduced drying time (approx. 15–20 min) with maximum material protection. Heating by electricity, steam or gas.

With the Henrikson tubular goods tumble drier, a knitted tube for T-shirts is sewn together as an endless

Fig. 1: Obermaier discontinuous tumble drier.

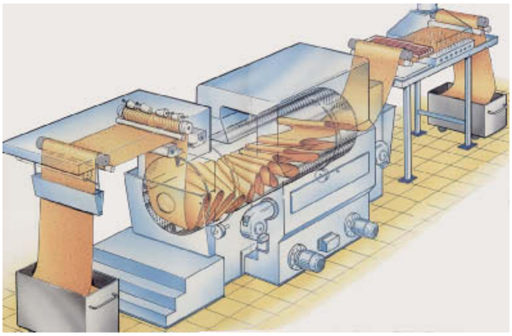


Fig. 2: Obermaier MTM-O continuous tumble drier.

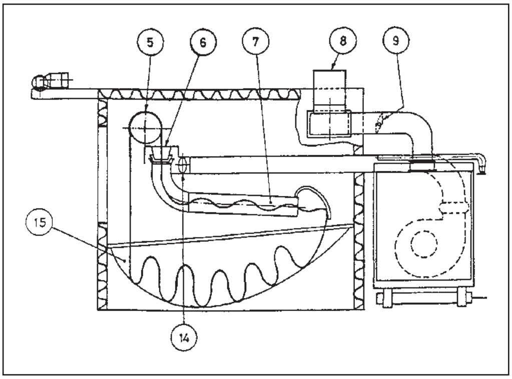


Fig. 3: Henrikson tubular knitgoods tumble drier.
5 = winch; 6 = fabric infeed; 7 = air-heat exchange zone with impact plate; 9 = throttle flap for fresh air access to the fan; 8 = heat exchanger; 14 = control for air access into the Venturi tube; 15 = dwell trough.

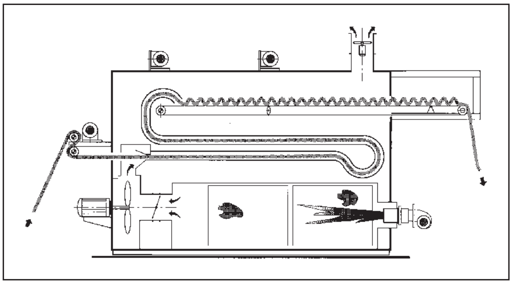


Fig. 4: Thies Tumbler T310 for open width fabrics (woven or knitted).

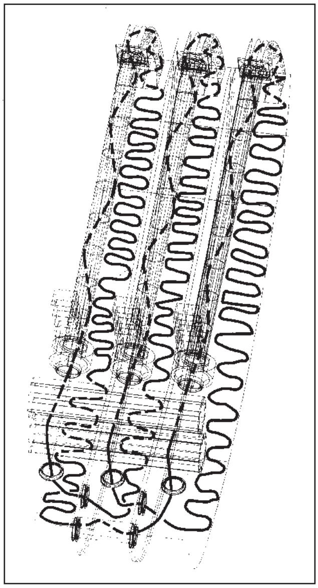


Fig. 5: Rope tumbler.

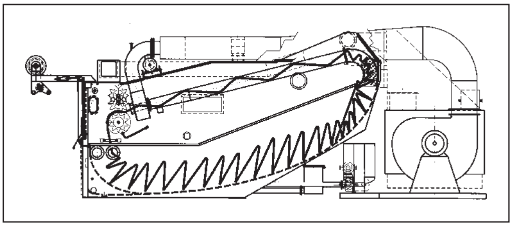


Fig. 6: Flainox Multifinish.

fabric and dried with hot air by the jet principle (Fig. 3).

A tumbler is especially suitable for bulk fabrics such as Nicki, terry towelling and certain qualities of plush, velvet and corduroy. Even the handle of most of the wovens e.g. trouser cloth made from PES/Cel can substantially be improved.

The fabric is treated in open width (Fig. 4) by an air flow whilst running through rectangular wave-shaped channels. These wave-shaped channels perform an intensive motion of the fabric, as well as very fast heating-up and drying by the positive air circulation. The construction of the driving and fabric transport systems are designed in such a way that no longitudinal tensions are effected. Due to the high fluff building whilst tumbling pile cloth, large filter sieves are installed which are easily accessible for cleaning. The advantages of a tumbler are tensionless fabric transport, high mechanical effects and possible steam atmosphere during drying, improved quality, better handle, volume, good pile and residual shrinkage values (Fig. 5–6).

Tumble-dry Drying with hot air in a tumbler, the usual term for the drying method used when testing the fabric smoothness of resin-finished textiles after household washing (→ Wash-and-Wear Standards).

Tumbler drier → Tumble drier.

Tumbler finishes Aftertreatment agents for washable textiles, for the application of active substances (finishing, anti-static, fragrance) during the drying process in the tumble drier or drum drier. Form of application: as foam spray (carrier: cloth/item being washed), spray (carrier: drum walls), pad impregnated with active substance (fixed by adhesive to tumble drier paddles) and → Sheets. Because of the specific difficulties encountered with tumbler application (consistency of viscosity, ease of prefabrication, storage stability), in comparison to fabric softeners, tumbler finishing agents have had to be re-formulated wholly or partially having regard to suitability for specific emulsifying systems. Examples include distearyl, di-coconut alkyl, tallow alkyl, imidazoline compounds, polyamines (partially quaternized to a greater or lesser extent). Proven significant emulsifiers in combination include polyoxethene, oxethylized fatty alcohols, alkyl-phenol polyoxythene and oxethylized fatty amines.

Tumbler shrinkage Unwanted shrinkage which can arise when items of clothing made from heavy cotton fabrics are dried excessively in a tumble drier after washing.

Tungsten (W), atomic weight 184. A grey heavy metal. Melting point 2700–2940°C. Possesses extraordinary hardness and resistance. Application: when smelted with sodium = richly-coloured tungsten bronzes, components of tungsten steel (→ Stainless steel), filament of tungsten lamps, (durability, low power consumption).

Tunnel shrinking machine → Shrink-finishing tunnel.

Tunnel steamer → Arch steamer.

Tunnel test → Steiner Tunnel Test.

Turbidity measuring instrument → Turbidity meter.

Turbidity meter (nephelometer, Tyndall meter). A unit for the determination of the concentration of cloudy solutions from the intensity of laterally diffracted Tyndall light (→ Tyndall effect) and also for the measurement of the light which penetrates cloudy solutions. It is used for the determination of fine dispersed precipitations, for the detection of colloidal changes of state, for the investigation of the growth of micro-organisms, etc. Thus the photoelectric universal colorimeter is, itself, useful for measuring cloudiness which can barely be detected with the eye. Measurements by different observers with different units can be compared using a second measurement with cloudiness standard meters, opaque glass rods, which are used in the nephelometer container with distilled water. Suspension particle size or cloudiness can also be determined using the sedimentation process, in accordance with the time taken to clarify as they sink to the bottom of the container. However, a better way of determining particle size is to use a photoelectric sedimentometer. Particle size detection can also be used for synthetic resins for finishes. The intensity of the light diffused from the suspension or solution is measured in the range from 40–150°. In addition, turbidity meters are also used in → Fluorimetry.

Turbodynamic principle A process in the wet treatment of textiles, in which the bath is set in intensive motion (turbulence), in order to achieve uniform results in a short time.

Turbo mixer A unit in which mixing takes place at high rotational speeds (up to 6000 rpm) by a mixing head with rotating blades, similar to a turbine, around which a guide ring is fitted in order to control the centrifugal forces. This construction creates strong suction on the surface of the fluid, which draws the substances to be mixed from the sides, continually propelling them to the centre of the vessel, thus whilst maintaining a level liquid surface and without splashing, a thorough mixing and compounding of even viscous elements can be achieved.

Turbo spray washer for rotary screens Intensifies rotary screen washing in the vertical screen washing cabin, particularly for the purpose of removing printing pastes of high viscosity and tackiness. Connected to the central washing water supply within the screen. There are polyamide fibres on the rotating element which are spun onto the insides of the screen by centrifugal force, thus mechanically intensifying the cleaning effect of the sprayed water.

Turbostapler yarns High-bulk yarns (strongly textured yarns). Manufactured on a turbostapler. A tow made up of high-shrinkage fibres of varying lengths is passed through electrically heated plates then stretched, thus gaining high residual shrinkage. Around 60% of the slivers entering the turbostapler are then relaxed in the turbosetter by a controlled vacuum vapour process at 1.7 bar and 115°C. The vapour process has a marked effect on the subsequent ease of dyeing, as a difference in temperature of only 2.5°C can result in a completely different dyeing shade to the finished fabric. The non steamed (high shrinkage) and steamed (low shrinkage) slivers are combined for the subsequent spinning processes.

Turbulent flow Water flowing in a river bed displays various types of flow: in the middle the water flows freely. At the banks, some of the water is held back by the embankments (→ Laminar flow). The transition zone displays increasing eddy formation, or turbulence, towards the middle of the river. Using this principle in the wet finishing of textiles, the fibre bulk is comparable to the bank (→ Flow mechanism in dyeing). The finishing chemicals diffused by the laminar layers in the fibre bulk must be dispensed by turbulent flow.

A textile finishing operation can be compared to stirring: the finishing chemicals in the liquor concentrated in one place on the outside of the fibre should be homogenized, i.e. introduced to the fibre in such a way that they can be adsorbed into the fibre surface and removed from the mix. “Stirring” is a mixture of liquids which are soluble one in the other (areas of the liquor with high concentrations in comparison with areas of the liquor which have given up their finishing chemicals by adsorption into the fibre surface). Stirring has the objective of a specific degree of homogeneity. Minimum effort in this process means a short mixing time Θ and a low agitator rotation speed n. The mixing time by stirring is calculated with the aid of the mixing time characteristic, in which the dimensionless reference quantity “n · Θ” (“mixing time”) is plotted using the Reynolds number.

$$\left(\frac{n \cdot d^2 \cdot \rho}{\eta}\right)$$

In the turbulence zone the mixing coefficient “n · Θ” is constant. In the laminar area near the sides of the mixing vessel (in the textile finishing process, close to the fibre, and in the interstices of the fibre bulk inaccessible to the “mixing process”), a constant reduction in the mixing coefficient can be seen. If the Reynolds numbers in laminar flow are small and increasing, then the mixing coefficient falls with an increase of Reynolds number. With Re > 10^4 in the turbulent zone the mixing coefficient “n · Θ” is practically constant, i.e. concentration balances happen quickly. Close to a surface the concentration reduces in the absence of flow (mixing), so that the non-homogeneous substance A (Fig.) can only diffuse there with difficulty.

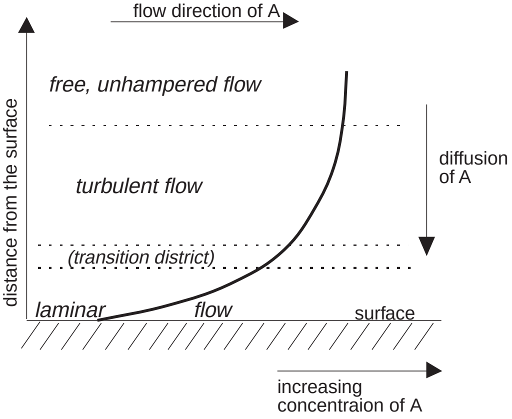
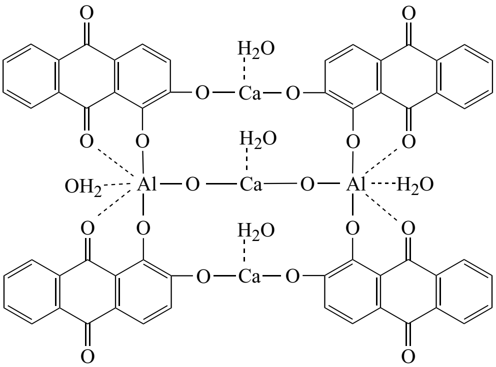


Fig.: Model presentation of turbulent flow in the fibre mass.

Turka fibre → Kendyr fibre.

Turkey red (adrianople red). Among the oldest organic dyes, and according to tradition was used back in the 17th century as a mordant dye. The dye was formerly obtained from the natural alizarin in the madder root. At the beginning of the 18th century Turkey red was used as a classic old red dye, also in Germany, especially in Wuppertal. By 1868 the natural alizarin was replaced by the purer and cheaper synthetic alizarin. The working methods it involved were difficult and led to an alizarin-calcium dye lake with a complicated structure:



Turkey red is now merely of historical interest, having been replaced by naphthol dyes.

Turkey red oil (red oils, T’ red oils). Consist of → Sulphonated surfactants and similar products. Used as wetting, dye penetration and levelling agents.

Turkish carpets → Oriental carpets from Anatolia and Asia Minor. Original with traditional patterns of flowers stylised to a greater or lesser extent (tulips, daffodils, hyacinths). Introduced to Europe from 15th century and used in particular as wall hangings and table covers.

Turpentine oils Distillation product of the balsams of various types of pine (Balsam turpentine oil) and of resinous wood waste (wood turpentine oil including → Pine oil) which belong to the group of → Terpenes. Density 0.86–0.89; boiling point 152–200°C. Colourless to slightly yellowish liquid, smell like colophony (American) or juniper berry (French), sharp and abrasive taste, easily stirred, rapidly volatile, becomes resinous when exposed to air (store in well-sealed container); highly inflammable; vapours explosive; mixable with alcohol, ether, chloroform; not harmful to fibres or dyestuffs. Imitations: petroleum, pine-wood oil, resin spirit, etc. Used in stain removing agents (for asphalt, resin, varnish oil, pitch, car lubrication, stains etc; but creates clean areas with sharply-defined edges, removable with petrol); used cleaning cloths, left lying about, can self-ignite.

Turpentine resins Natural resins of fir trees, some of the main representatives of which are → Colophony and, for example, → Dammar resin and Mastic.

Turpentine substitute Mixture of colourless hydrocarbons which are generally covered by the term white spirit or lacquer benzine. Mostly with high-boiling point with flame point over 21°C. Occasional addition of etheric oil in order to conceal the smell of petrol or petroleum. Used in solvents and stain removing materials as a substitute for turpentine oil (with its advantages, without its disadvantages).

Tussah silk (tasar, tusser, tussor). → Wild silks obtained from the caterpillars of the Indian (Antheraea mylitta), Chinese (Antheraea peruyi) or Japanese (Antheraea yamamai) tussah silk worms found in the wild and rarely cultivated. Due to the high tannin content of the caterpillars' food (oak leaves), tussah silk always has a light-to dark brown colour. → Silk.

Tutorette process A mechanical shrinking process for cotton/polyester blend fabrics, licensed by Bancroft Far East Inc. in Japan and using the Everest Shrinking Machine (Manuf.: Hunt & Moscrop). Tutorette textured seersucker is a finished crêpe. The regular pattern of the textured surface is achieved by a flatbed embossing calender. An artificial resin finish is used to fix the embossing.

TV → Trivinyl, → EDP Code abbreviation.

TVI German abbreviation for the textile finishing industry.

Tweed Originally the term for hand-woven fabrics of hand-spun yarns with a small colour pattern effect (→ Homespun). More generally applied to ground weave or twill carded yarn cloths, hand-woven in character, which have a mottled, hairy surface (→ Harris tweed) with knops, or which are patterned by varying the colours in the warp and weft (→ Donegal) or some other small-scale pattern.

Twill A general term for a variety of fabrics with diagonal stripes in twill weave (→ Weave). General term for all twill weave fabrics, recognised by the distinctive diagonal ridge pattern.

The term can loosely be applied to all twill weave fabrics (→ Serge). In the wool sector twill is used above all to denote those fabrics which have a coarser or more pronounced twill rib. Usually the woollens are based on the 6-thread even-sided twill. The term twill is only used for worsted yarn, not carded yarn cloths. The term is similarly used in the cotton and silk sectors.

Twill carpet → Flat carpet, woven from coarse yarns in twill weave (Dutch carpets, Parisian, Sayette runners).

Twill ridge The diagonal ridge in twill weave fabrics.

Twill weave One of the 3 basic weave types (→ Weave); the smallest repeat is 3 threads. Different types include one-sided and even-sided, narrow and broad, single-line and combined twill, warp and weft twill.

Twilo yarn A twist-free yarn, ribbon-like in appearance (viscose staple fibre, HWM-, polynosic fibres) of good uniformity from wet-drawn fibre bundles, bonded with hot-water soluble adhesive or polyvinyl alcohol binding fibres (5–11% by weight). The fabric possesses substantial covering property. Once the binding agent is washed out the yarn strength in the fabric decreases. Twilo yarns possess good strength, covering property, softness, sheen properties.

Twin-pole system Rope dyeing plant in which the ropes are treated whilst hung on 2 poles. The hank length can be changed, during treatment, by raising the lower pole.

Twinset In the clothing industry, a term for a fashionable combination of ladies' pullover and cardigan.

Twin star dyeing machine A star dyeing machine, in which piece goods are fixed into 2 stars and thus rotated through the treatment liquor.

Twin-tail chemistry A wide range of variations can be achieved with finishing effects obtained from fluorine chemistry. For example, by means of chemical reactions or compounding by the introduction of additional components. With these variations, effects such as a soft handle and special adaptations to suit different substrates and finished articles can be achieved. Tailor-made solutions to problems are possible. A very specific term, "twin-tail chemistry" refers to spatially close perfluoralkyl chains (see Fig.). The resistance properties, particularly in the case of cotton and blends, are therefore good.

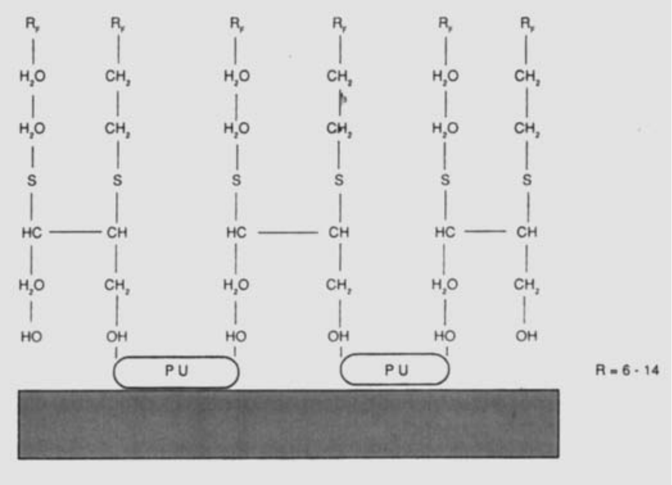


Fig.: Twin-tail chemistry.

Twist,

I. A yarn of cotton, linen, viscose, also cotton/viscose blends with even twist. Different types include water (tight twist), medio (medium) and mule (loose) twist. Reference should also be made to darning twists. These are usually multi-ply (usually 6-ply) cotton twists, which in contrast to the twists in the wool industry are only loosely twisted, have almost no turns and are used for darning household items. They are particularly thick and soft.

II. In the wool industry, twist usually denotes worsted or carded yarn cloths, which consist wholly or predominantly of mouliné yarns in the warp and weft and are usually produced in simple weaves (linen, panama, twill weave). A particular feature of these fabrics is their lively colouring (flecked) and also the fact that they are usually stiffer in feel, due to the higher turn count of mouliné twists. The finish is usually unnapped or in the case of carded yarns, clear. Of the two yarn types, the worsted yarns are superior.

Twist factor at break According to Krais, → Torsional strength.

Twisting (doubling). Starting from single yarn, the production of twist yarn involves 2 stages:

1. bringing the yarns together (on the doubling machine) = plying;
2. twisting the yarns (on the twisting machine) = twisting.

→ Plying is an essential process for the production of 3-fold and multiple-fold yarns with the two-for-one or Topham box twisting machine. For two-fold yarns, two different processing techniques have established themselves in two-for-one twisting (Fig. 1):

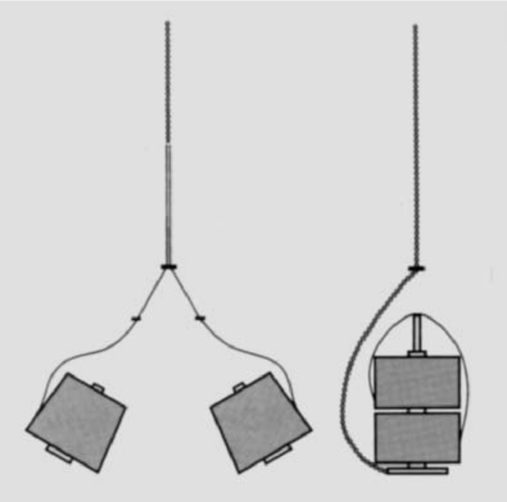


Fig. 1: Twisting with doubling packages (left) and twisting with direct feed packages (right).

- the traditional method with doubling yarn supply packages
- the so-called direct feed with two packages of single yarns positioned one on top of the other.

A perfect twist yarn is characterized by the individual component yarns being twisted together symmetrically. By contrast, a covered yarn is made by feeding one yarn component under a controlled degree of tension (without twisting) through the axis (or axes) of one or more revolving spindle carrying the other wrapping (covering) yarn component (Fig. 2). In this latter case, the quality-enhancing effect is lost since one yarn can slip against the other. Yarn wrapping can take place if a high tension is applied to one yarn and a low tension to the other during the twisting process. There is no possibility for the taut yarn to become deformed in twisting, so that the loose yarn wraps itself around the taut yarn.

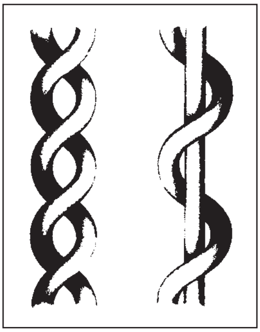


Fig. 2: Two-fold twist yarn (left) and covered yarn (right).

The folded yarn supply packages on two-for-one twisting machines are drawn off through a twisting flyer (campanello) so that the combined yarn components do not separate. The flyer rotates at the same speed as the yarns rotate during their take-off overhead. The rotational speed as the yarn delivery point moves down the package is not the same as that during its upward movement (Fig. 3).

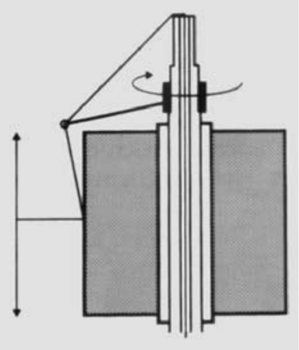


Fig. 3: Upwards and downwards movement of the yarn delivery point on two-for-one twisting machines.

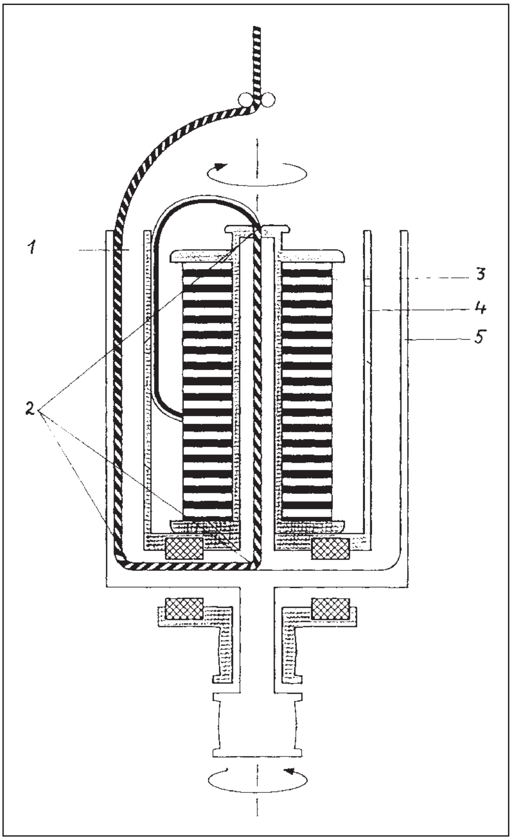


Fig. 4: Cross-section of a two-for-one twisting machine (“Tritec” Twister of Saurer).
1 = open yarn guide; 2 = optimized deflection points;
3 = yarn supply package; 4 = inner yarn guide device;
5 = outer yarn guide device.

The functional principle of two-for-one twisting machines is illustrated in Fig. 4. They consist of two rotating systems mounted on bearings. The outer system with the spindle centre shaft and the inner system which serves as a carrier for the yarn supply package rotate at the same speed in opposite directions. Both systems are fitted with a cylindrical yarn guide. The yarn is thrown off the supply package by the rotation of the inner system and forms a self-regulating spiral-shaped accumulation in the guiding device. Subsequently, the yarn is led through the hollow spindle in which two turns of twist are inserted due to the opposing movements of the fixed point (i.e. insertion of two turns of twist for each revolution of the twisting element). A further accumulation of yarn is formed on the outer guide device and receives a third turn before it is drawn off by the delivery system.

Another method of inserting twist is the cabling process which, from a textile technology standpoint, represents a special kind of covering process. The essential feature of this process lies in the fact that the individual components (inner and outer yarns) are only subjected to a false twist operation. After the cabling process, both yarns have no twist in themselves although they are wrapped around each other. For this reason, the process is particularly suitable for the production of two-fold, symmetrical, tyre-cord constructions. With this technique, the laborious preliminary twisting and twisting at the head, as required for conventional twisting processes, are dispensed with. As a result, only a single operation with a spindle is required in order to produce a perfect tyre cord with zero turns in the individual yarns. This only applies, however, to cases where the supply yarns contain no turns and a two-fold tyre cord is being produced. The production of

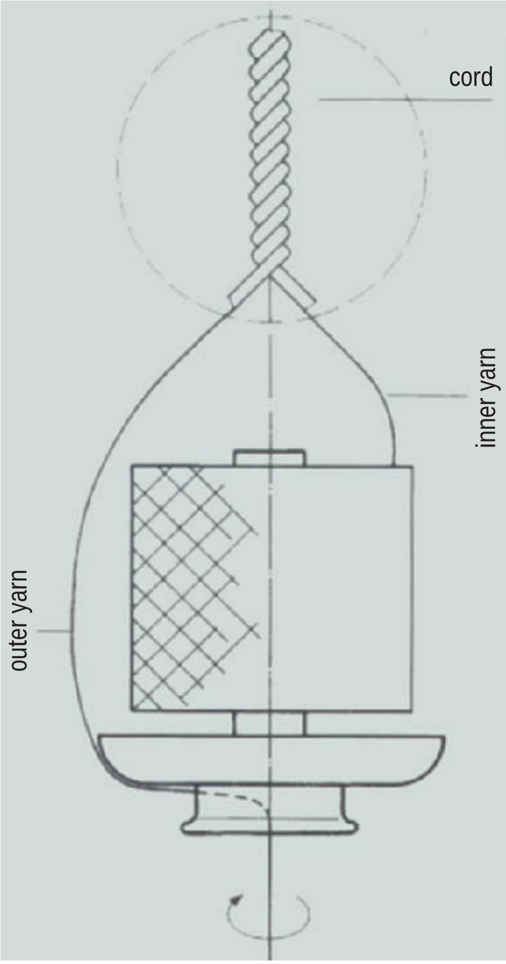


Fig. 5: Principle of cabling (Saurer Alma).

multiple-fold yarns is not possible with the cabling process.

From its constructional features, a cabling machine resembles a two-for-one twisting machine (Fig. 5). In terms of the spindle construction, in particular, they are virtually identical. The inner yarn comes from the yarn supply package which is located on the stationary head of the spindle and is led directly in an axial direction upwards to the point at which it is joined by the outer yarn. The outer yarn comes from the creel and is led into the bottom of the rotating part of the cabling spindle, emerges again from the accumulator disc forming a balloon of yarn and wraps round the inner yarn above the package can.

Twist of spun yarns The twist of spun yarns denotes the amount of twist applied to a yarn (twist) to fix the bundle. The direction is denoted by S- (right-hand) and Z-twist (left). The number of turns (degree of rotation) relating to 1 m yarn length (T/m) depends on the fineness, raw material and ultimate application of the yarn to be spun and the spinning process. The relationship between twist, raw material and fineness is expressed by the formula T/m = α_m R(Nm).

Twist-texturing A texturing method in accord-

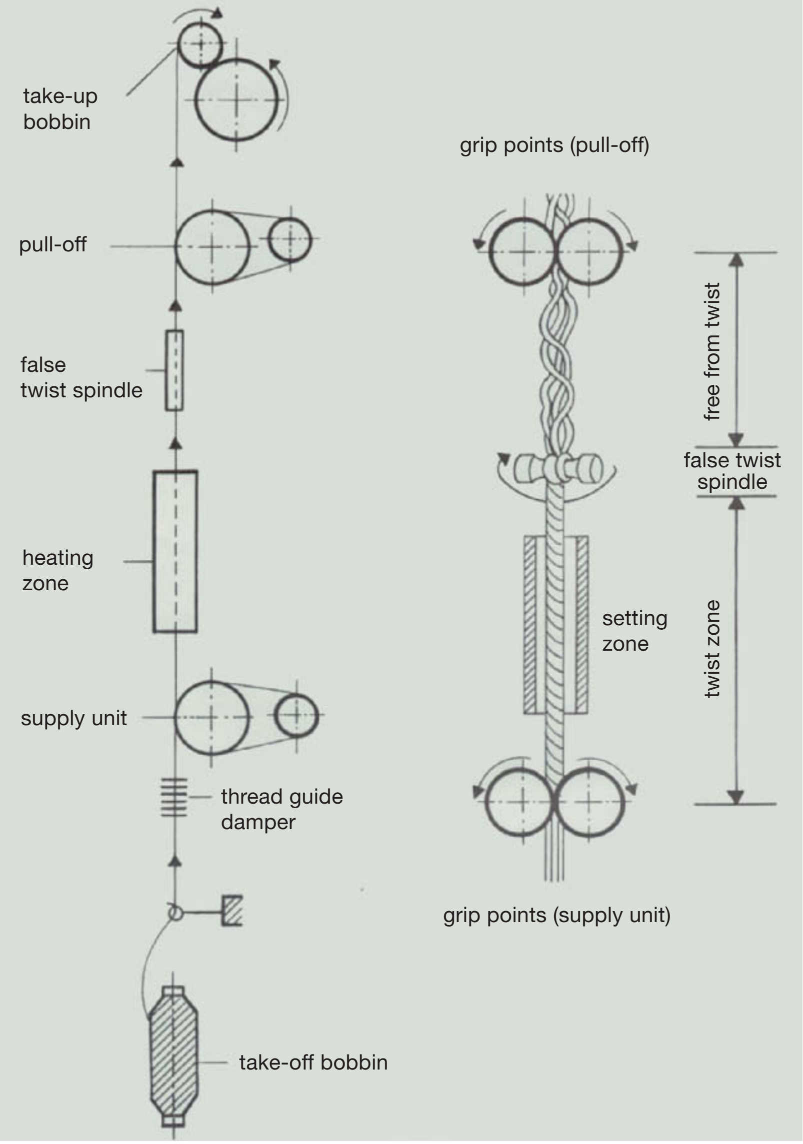


Fig. 1: Twist-texturing (false twist).

ance with the mechanical/thermal principles; the two different processes are torsion crimping and friction texturing. The following phases are followed as a continuous process during manufacture:

- high-twisting,
- heating and cooling to fix the twist,
- downtwisting (doubling).

The process is essentially based on the twist principle, although it is not only two (or more) yarns being twisted together, but a multifilament being twisted around its own axis. The high-twisted fibres are thermofixed and the twist again applied (Fig. 1). This gives rise to high bulk yarns.

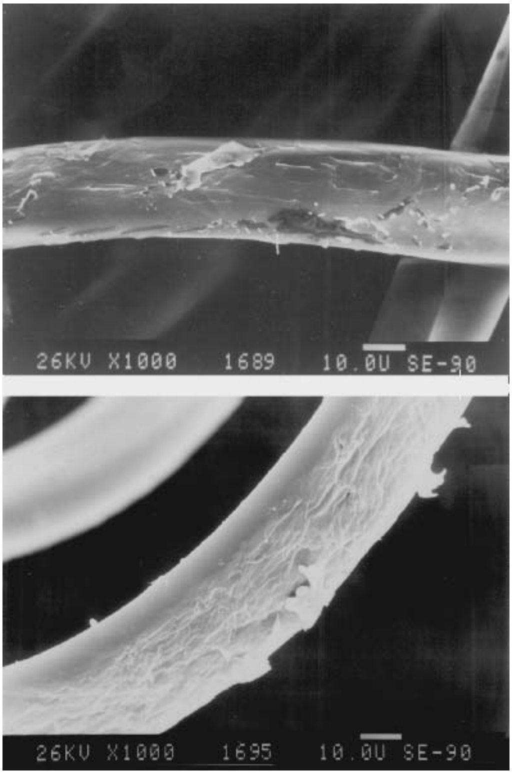


Fig. 2: SEM photographs of twist-textured polyester filament surfaces (by Cerasiv).
Top: slight fibre damage: bottom: heavily damaged fibre surface.

During the process the material is subject to high mechanical forces. The resultant friction means the filament surfaces may be roughened (Fig. 2), and fibres may be abraded. Yarns damaged in this way are more matt when dyed, whilst undamaged yarns have a clearer, brighter dyed appearance. This effect can be minimized by selecting appropriate materials for the friction disks.

Two-bath pad-batch process for reactive dyes A semi-continuous principle: goods are padded with neutral dye solution, dried, padded with alkali and salt, batched up and given several hours' dwell time.

Two-bath pad-steam process Another term for the → Pad-steam process. A continuous dyeing process, in which the goods are padded in the 1st bath with dye, in the 2nd with the chemicals necessary for fixing, and then briefly (max. 60 s) fixed in steam. Examples: for vat dyes, caustic soda and sodium hydrosulphite, for reactive dyes a saline alkali or sodium silicate solution.

Two-bath process Working with two baths in series. For example, in the case of polyester/wool blends, the polyester content is dyed first in one bath, with overdyeing of the wool in a fresh bath. Opposite: → Single-bath process.

Two-component mixing jets Liquor application technology to date consists of the three processes occurring in series:

1. application of the treatment liquor to the goods;
2. metering of the liquor (removal of excess);
3. application of energy to the liquor and goods to achieve the prerequisites for the interaction between substrate and chemicals (reactions).

In the case of application technology using two-component mixing jets, these three processes do not take place in series, but the application, the metering and the energy supply occur simultaneously. This is achieved using steam/liquor mixing jets. The liquor is applied to the goods through the jet in the desired quantity in atomized and heated form. The aerosol is already activated when it makes contact with the textile goods.

Two-component mixing jets have the following properties:

- The liquor flow is independent of the steam flow, i.e. the flow of the treatment liquor may be varied according to the speed of travel of the goods and the desired liquor application, depending on the fabric weight.

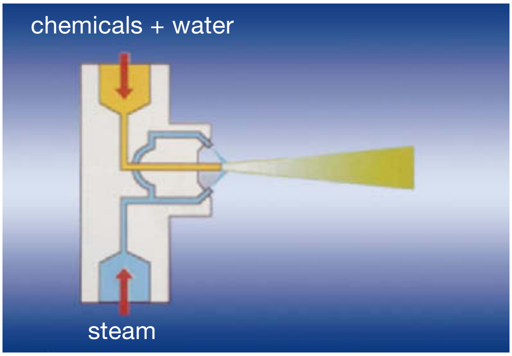


Fig. 1: Two-component mixing jet with external mixing (by Kleinewefers KTM).

Fig. 2: Two-component flat spray mixing jet (by Kleinewefers KTM).

- In the control zone of the jet an even distribution of the volumetric flow and droplet distribution can be achieved across the spray range.
- The jet is operated under 3–4 bar steam pressure and can thus be used by the majority of textile finishers without additional generation of steam.

The jets are supplied with external mixing, as shown in Fig. 1. “External mixing” means that the inter mixing of steam and liquor takes place outside the jet unit. As can be seen from Fig. 2, a flat spray is thus formed.

Two-component system for polyurethane coating Consists of the two components polyol with low molecular weight and isocyanate. Post-curing is necessary after coating.

Two-phase flash-age process In this variation of the → Two-phase printing process, goods printed with alkali free reactive dyes are fixed in a flash ageing plant which consists of a pad, preferably a Mini-Fluid, and a flash ageing steamer.

Fixing involves application from the pad of either an alkaline saline liquor of varying composition or sodium silicate or a combination of sodium silicate and caustic soda (Fig.).

Two-phase laminating process For the laminating of synthetic → Secondary backing for tufted carpets, enabling sufficient adhesive strength to be achieved without blistering across a full carpet width of 4–5 m. The range of the adhesive properties is similar to that of jute backings. The tuft anchorage is unaffected, being principally determined by the quality and manufacture of the base/primary coat. Method: application of primary coat (latex compound with 300–500% chalk filling), lightly dried (application quantity 600–900 g/m^2), application with doctor blade of 400–500 g/m^2 of a less filled, foamed laminating compound (using a foam mixing unit with foam weights of 600–700 g/l) and finally the application of the second backing, which is pressed into the laminate compound thus forming a sandwich.

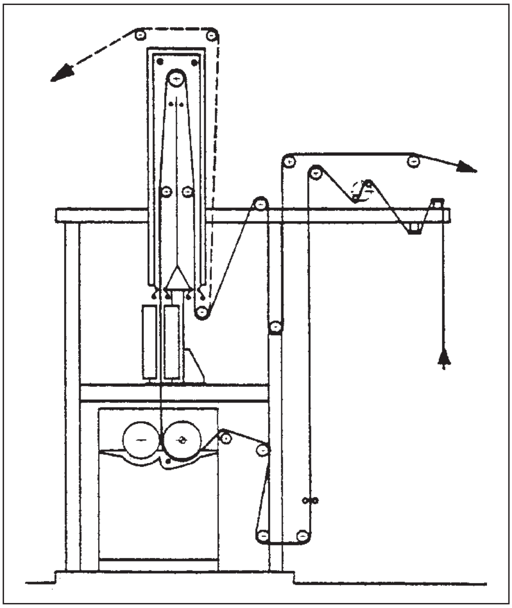


Fig.: Flash ager (Hoechst System) for two-phase printing.

Two-phase mercerizing process A process whereby in the 1st phase cotton is impregnated with 24–25% caustic soda and in the 2nd phase with dilute alkaline solution of approx. 11%.

Two-phase printing process A special printing process in which the chemicals necessary for dyeing and fixing are applied to the goods separately, and the dye is fixed by steaming. The preferred method for vat dyes (→: Colloresine process; Flash ageing) and reactive dyes. Principle: print on the printing dye paste, dry, pad with fixing chemicals (for vat dyes: alkali + electrolyte), then steam, usually without interim drying (100–140°C, 20 s up to 8 min) and wash (Fig. 1). Particular advantages include: unlimited fastness of the dye pastes and prints on printed materials, extremely quick fixing of dyestuffs, low energy consumption for fixing. Disadvantage: high chemical consumption.

The main distinction from the single-phase process with vinyl sulphone dyes is that in the single-phase process the urea and the alkali are already added to the printing paste, whereas in the two-phase process the printing paste dye simply contains thickener and pigment, and the alkali required for the dye/fibre reaction is applied in a second stage. The different processes shown in Fig. 2 can be used for the fixing of reactive prints in the single- and two-phase processes.

In the single-phase process, saturated-steam fixation predominates, whilst in the two-phase method the more widely-used flash ageing process is preferred to the cold pad-batch method, which is limited to cotton

Two-phase printing process

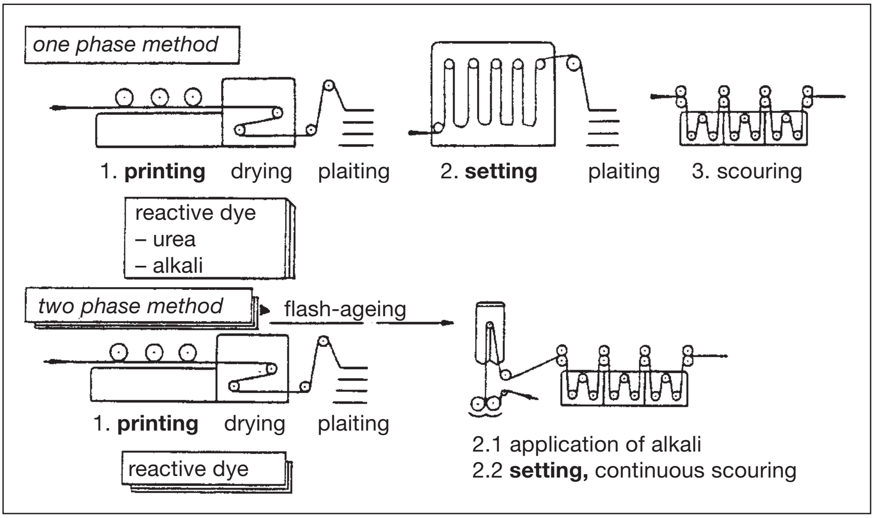
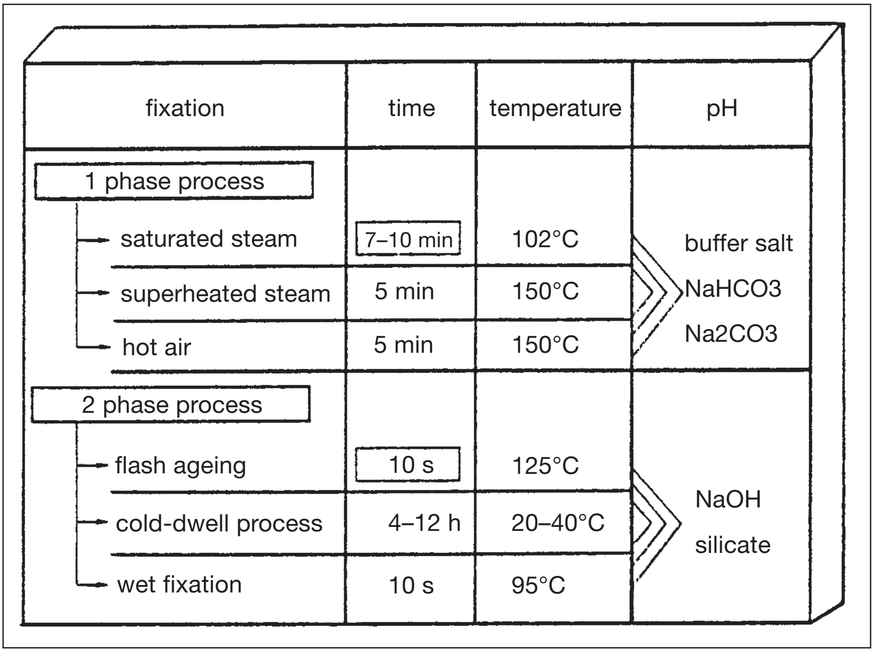


Fig. 1: Process sequence of one phase and two phase reactive dye printing methods (by Hoechst).



fixation	time	temperature	pH
1 phase process			
saturated steam	7–10 min	102°C	buffer salt NaHCO3 Na2CO3
superheated steam	5 min	150°C	
hot air	5 min	150°C	
2 phase process			
flash ageing	10 s	125°C	NaOH silicate
cold-dwell process	4–12 h	20–40°C	
wet fixation	10 s	95°C	

Fig. 2: Fixation for reactive dyes in textile printing (by Hoechst).

(viscose to a limited extent). The cold pad-batch method (Fig. 3) provides an opportunity for fixing dyes with very little energy consumption. The cold pad-batch method also involves the application of reactive dyes without the use of alkalis or urea; the alkali is applied in a second phase and the print fixed by dwelling (4–12 hours, depending on alkalinity of the fixing liquor) at room temperature. The versatility of the vinyl sulphone system makes it possible to build up a largely interchangeable palette for printing and dyeing. This provides considerable dye stocking and storage advantages.

The two-phase method results in substantial savings when formulating the printing paste, both manually and automatically, as neither alkali nor urea need to be added. The life of the paste for the two-phase process is practically unlimited due to the absence of alkali. With the single-phase process the life of the printing pastes can lead to problems. This is particularly apparent if

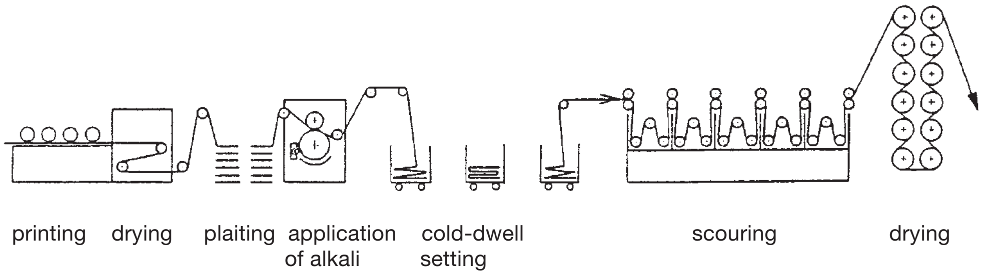


Fig. 3: Cold pad-batch technique with alkali face-padding (by Goller).

alkali quantity and alkali type are not carefully adjusted to suit the reactive dye (anchor) used (Fig. 4) and the quantity by weight of the dye. In addition the effect of temperature should not be underestimated. This is particularly the case with light and medium shades consisting of blends of different dyes. Here, it is not just the depth of colour which varies, but as a result of the variation in alkali stability of the individual dyes, the shade of the printing paste can alter significantly if left standing for a long period. Additional costs, losses and reproducibility problems also arise in relation to the reuse of surplus dye paste. Figs. 5 + 6 show this clearly in relation to light to medium shade depths for monochlortriazinyl dyes.

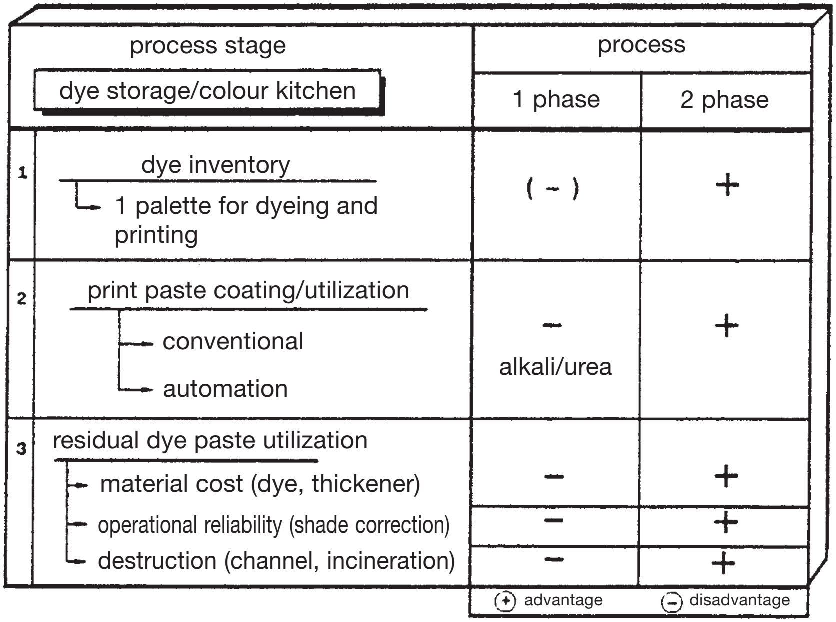
Whilst in the single-phase process the presence of urea gives rise to a substantial thermal pre-setting, the resultant print is not noticeably affected due to the absence of alkali and urea (Fig. 7).

Moreover, the use of urea has two major disadvantages which should not be underestimated:

1. High drying temperatures mean the risk of sublimation of the urea and its products by decomposition in the drying lofts. The cleaning is time and labour intensive.
2. Urea contributes to an increase in the nitrogen levels of waste water and represents a potentially serious ecological problem.

Saturated steam usage (single-phase process), as required for the fixing of reactive dyes, is rare (Fig. 8).

The transferability of print pattern coupons or test



	process stage	process	
	dye storage/colour kitchen	1 phase	2 phase
1	dye inventory 1 palette for dyeing and printing	(–)	+
2	print paste coating/utilization conventional automation	– alkali/urea	+
3	residual dye paste utilization		
	material cost (dye, thickener)	–	+
	operational reliability (shade correction)	–	+
	destruction (channel, incineration)	–	+

⊕ advantage ⊖ disadvantage

Fig. 4: Process comparison between 1 and 2 phase reactive printing (by Hoechst).

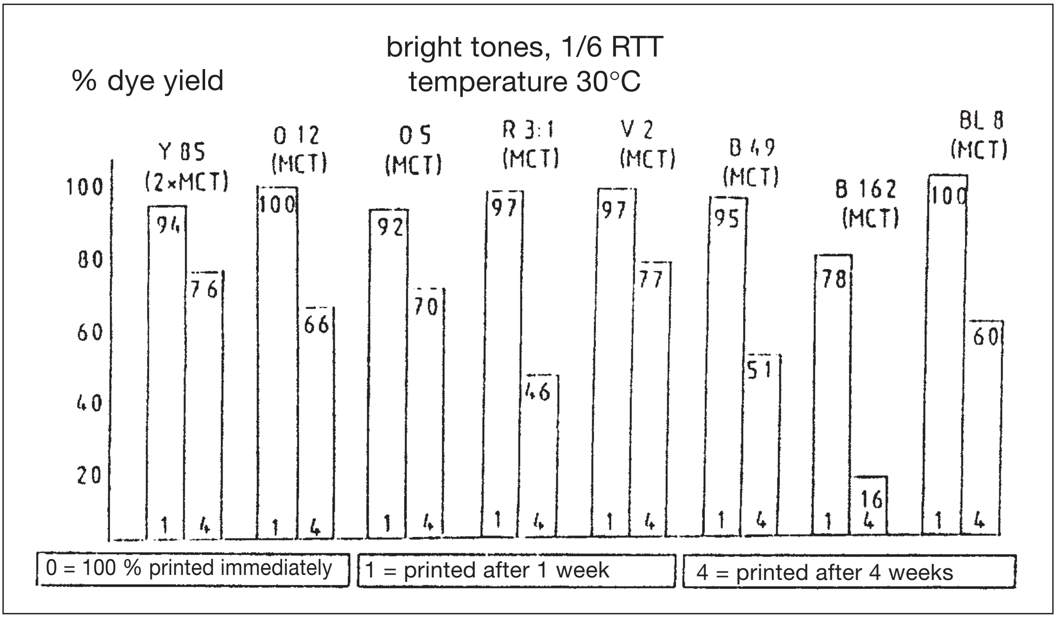
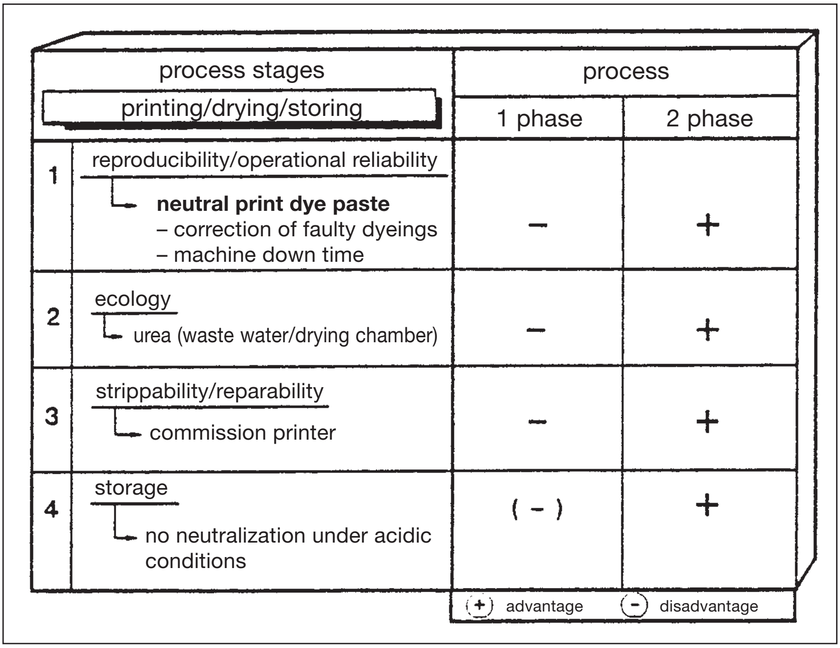


Fig. 5: Reactive 1-phase printing print-paste durability; alkali; sodium hydrogen carbonate ($NaHCO_3$). MCT = monochlorotriazine dyes (by Hoechst).



	process stages printing/drying/storing	process	
		1 phase	2 phase
1	reproducibility/operational reliability **neutral print dye paste** – correction of faulty dyeings – machine down time	–	+
2	ecology urea (waste water/drying chamber)	–	+
3	strippability/reparability commission printer	–	+
4	storage no neutralization under acidic conditions	(–)	+

(+) advantage (–) disadvantage

Fig. 6: Printing process stage comparison between 1 and 2 phase reactive printing (printing, drying, storing) by Hoechst.

residues in the production plant usually varies according to the drying conditions, other pattern steaming moisture content conditions and absence of pattern (Fig. 9).

In the two-phase method the absence of alkali and urea has a similarly positive effect on the production plant. In addition the patterns are completed substantially quicker using the two-phase method, leading to

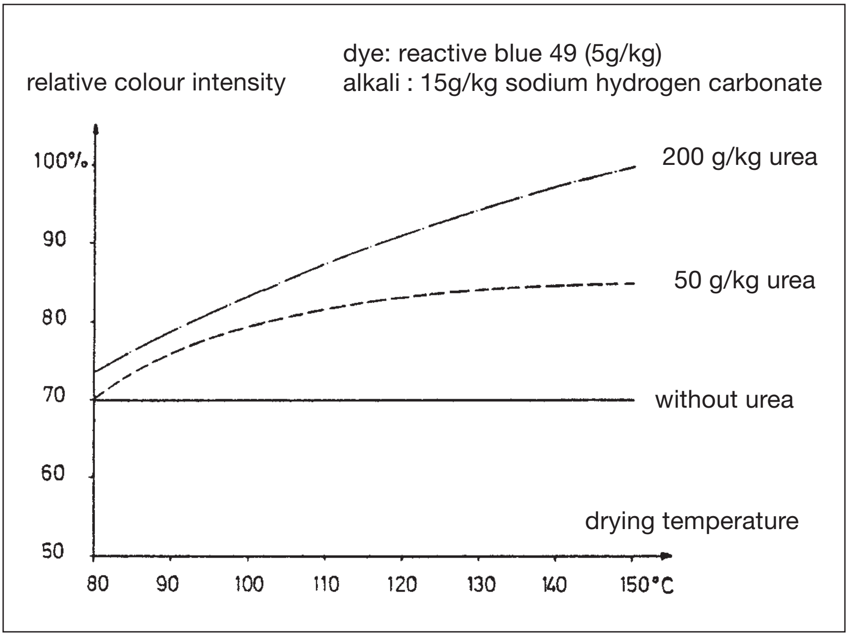
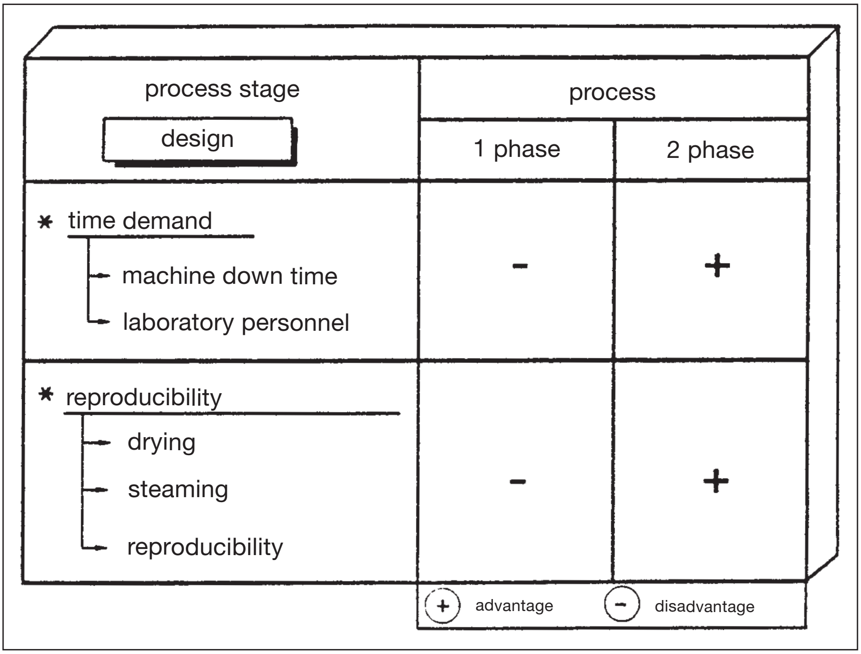


Fig. 7: Dependence of dye yield on urea concentration and drying temperature (by Hoechst).

	process stage setting	process	
		1 phase steaming	2 phase steaming
1	time demand	=	=
2	constancy of temperature	(−)	+
3	steam humidity	(−)	+
4	levelness	(−)	+
5	flexibility	+	−
6	cost	(−) discontinuous	+ continuous

⊕ advantage ⊖ disadvantage

Fig. 8: Print setting process comparison between 1 and 2 phase reactive printing (by Hoechst).



process stage design	process	
	1 phase	2 phase
* time demand machine down time laboratory personnel	-	+
* reproducibility drying steaming reproducibility	-	+

(+) advantage (-) disadvantage

Fig. 9: Process comparison between 1 and 2 phase reactive printing during the design process stage in textile printing (by Hoechst).

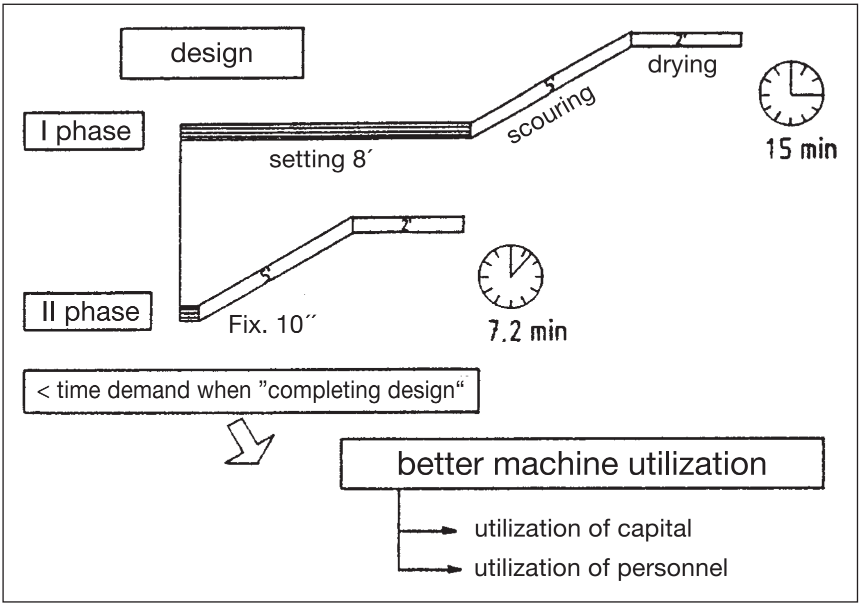


Fig. 10: 2 phase printing design (by Hoechst).

fewer machine stoppages (Fig. 10). The use of a special pattern steamer enables the pattern to be applied quickly, reliably and inexpensively.

Two-phase vat discharge prints The discharge dyeing of direct and reactive dyed backgrounds using vat dyes is only possible using the classic vat printing method with sodium formaldehyde sulphoxylate, which requires long fixing times; with two-phase vat discharge printing the advantages of the → Two-phase printing process can also be of benefit to discharge printing. The goods to be printed are padded with reactive dye of the alkali free vinyl sulphone type, dried, and then overprinted with vat-dye paste, which, apart from the dye, only contains formaldehyde sulphoxylate. The alkali necessary for both dye types is padded on and the discharge print completed using the → Two-phase flash ageing process. The desired rapid decomposition of the formaldehyde sulphoxylate is achieved by a heavy metal complex catalyst, e.g. cobalt dimethylglyoxim, which is added to the printing dye paste.

Two-phase wet fixation process (Hoechst system), for reactive dyes (→ Wet fixation process, Caustic shock process). Fixing in the two-phase wet fixation process is carried out in the wet fixation trough, a simple, inexpensive device, available in various sizes. It contains extendable roller casings, consisting of a feed roller at the upper end, then a pair of nip rollers, and at the bottom end a diversion roller, with a variable feed unit in between. The fixation liquor, consisting of a strong alkaline saline solution or, as has proved preferable, 600 ml sodium silicate 38–40°Bé and 200 ml 33% caustic soda, heated indirectly to 95–105°C. Fixation of the goods under these conditions takes approx. 10 s. Used liquor is transferred to a high-level container for subsequent addition. Manuf.: Goller.

Two-sided effect In the case of textiles made from blended fibres, provided two-tone or → Multicolour effects are not required, all fibres are dyed by means of tone-in-tone dyeing. Otherwise the goods would have an uneven appearance. In the case of certain fabric types, each side of the fabric has a different shade.

Two-sided effects by vertical migration A coloristic variant, which uses the generally undesirable effect of → Vertical migration to achieve a design. This is a continuous dyeing process, which is particularly suited to polyester and/or cellulose fibre fabrics. Two fabrics are padded double with slightly increased liquor pickup (Fig. 1).

Then they are dried at between 160 and 200°C; the best methods are stenter or cylinder drier. The effect of steaming on the outside and the dye migration in the flow of liquid gives the outside a deeper colour than the inside. The result is a light/dark effect. An interesting variation is the two-tone effect. This is achieved by dyeing again in a similar manner; usually in a contrasting colour. The lengths of fabric are turned first. The deeper dyed sides now lie together, the lighter sides turned outwards. When drying, the migration process once again takes place. The dye applied during the second phase again migrates to the outside, and the insides with the deeper colour from the first phase retain their shade (Fig. 2).

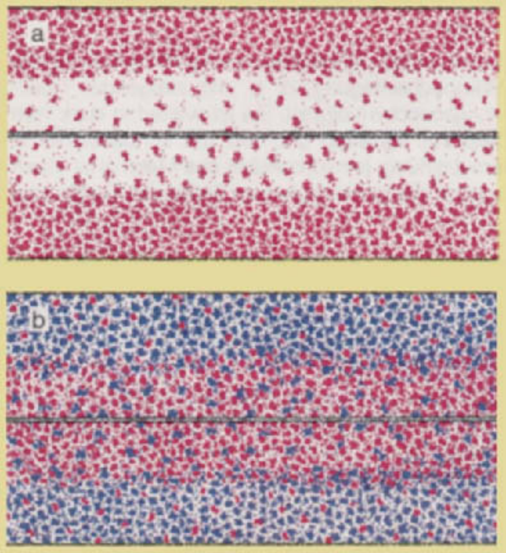


Fig. 2: Dye distribution through migration when dyeing double-laid fabric lengths.

The extent of migration increases with heat transfer, i.e. increased drying speed. It is also strongly dependent on the substrate and is more clearly seen the more hydrophobic the material. The technological characteristics of the fabric are also significant. In general migration increases more sharply, the heavier and thicker

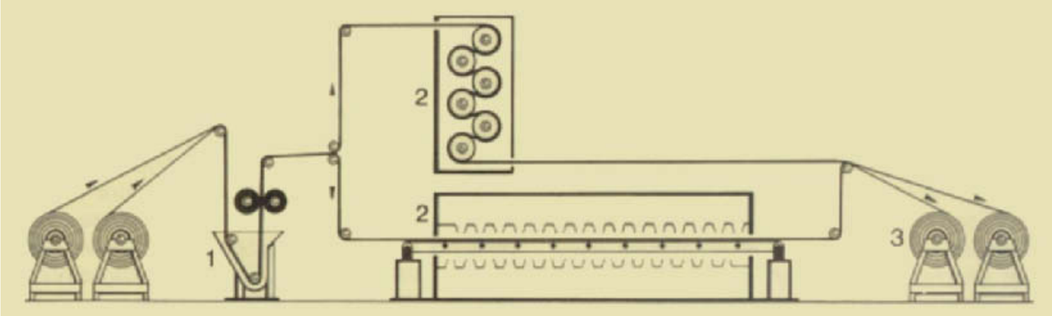


Fig. 1: Diagram of the process: padding (1), drying (2), batching (3).

the fabric and the higher the dynamic water content in the capillaries. A further criterion for migration is the dye itself. Wherever possible, dyes should be used which have low affinity and high microdispersion. Finally, higher quantities of surfactants, i.e. the usual wetting and dispersion agents, can significantly increase the tendency of a dye to migrate (according to Bayer).

Two-tone effects E.g. on fabrics (woven, knitted goods) which fashion requires should contain two colours (for more colours → Multicolour effects), distributed evenly or randomly; e.g. jaspé, melange, vigoureux, changeant (two different-coloured yarns in warp and weft), thread-by-thread (double twill), mouliné twist.

Tying up The division of hanks by means of tie threads, which are usually of a different colour and enable the immediate recognition of e.g., individual and overall titre and degree of twist.

Tyndall effect Named after an Irish physicist; the phenomenon known as the "milky band" of a ray of sunlight (or beam of a headlamp) falling into a dark space or through fog. In these cases dust particles or water droplets in the air cause a lateral deflection of the original direction of light, i.e. light scatter due to diffraction. In accordance with the same principle, in an ultramicroscope a strong beam of light directed through a drop of colloidal solution against a dark background generates individual punctiform diffraction patterns of colloid particles, the number and size of which can be determined. Thus at an angle of 90° to the beam of light, turbidity measurements can also be taken. Turbidity meters and colorimeters can also be used to examine fluorescent solutions (→: Turbidity meters; Fluorimetry), in particular in weak concentrations.

Tyndall meter Used as a → Turbidity meter.

Type of colour Colours of the same type are those in the shade series (e.g. → Grey series) which each represent a point on the same level of the colour triangle (→ Chromaticity diagram). Such a colour group is defined by shade and density and can be distinguished by its brightness. The colour type is defined by the chromaticity coordinates x, y. The colour type of a colour/dyeing is made up of shade and density.

Typha fibres Strong, woolly fibres belonging to the → Bast fibres group, obtained from the leaves of the reed mace. Only of localised significance. Spun alone, or (usually) with flax (tow), jute, recovered wool, etc. Used as a replacement for jute and hemp, or for coarse woven fabrics.

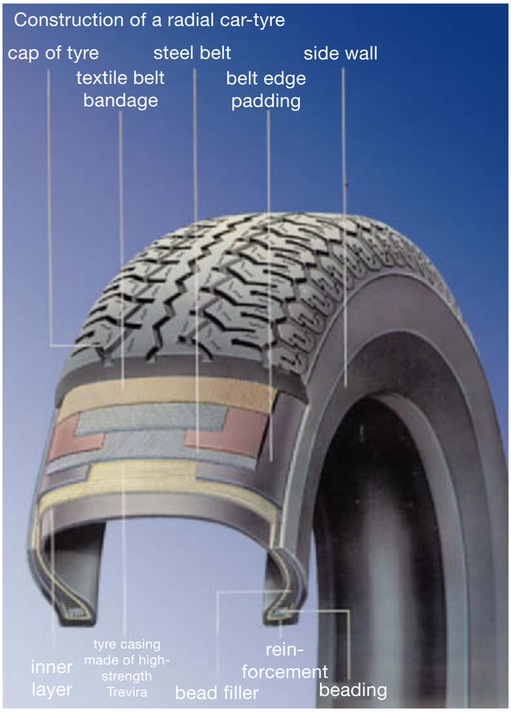
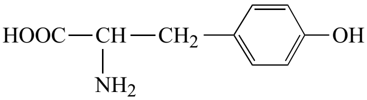


Fig.: Construction of a car tyre from tyre cord layers, made composite through vulcanization of layered rubber (Hoechst).

Tyre cord A special insert material forming the carcass of motor vehicle tyres, etc. Consists of a continuous filament tyre yarn (Fig.). Contains a latex preparation to increase the adhesion to rubber, because the tyre cord polymer and the rubber polymer would otherwise be incompatible and repel one another, which could lead to increased risk while in motion.

Tyrosine A cyclic → Amino acids, contained in wool at 5.8% and in silk at 10.6%. In wool tyrosine is found in wool keratin and in the spindle cells, but not in the scale layer. This forms the basis of the Pauly Diazo Reaction, an important tendering detection test.



U

U Symbol for the chemical element uranium (92).

Ubiquitous Distributed or present everywhere (e.g. in traces: dioxin, formaldehyde, silicone).

UBS Abbrev. for → Urea-Bisulphite solubility.

UCMTF French Union of Textile Machines; → Technical and professional organizations.

Ulbricht sphere photometer → Ball reflectometer.

Ulster,

I. A heavy, fulled, rough woollen winter coat material of coarse yarn (often pure virgin wool, but also an admixture of shoddy and rayon) with a Melton finish, usually with a woven-in lining, named after an Irish province. The weave of the outer fabric is usually twill and herringbone; that of the inner fabric is 4-ply evenly spanned twill.

II. A large winter coat with a broad collar and largish lapels made from heavy, soft material; a classic Ulster is double-breasted, modern sport and short Ulsters are single-breasted.

Ultimate shearing strain (shearing stress) → Rheology.

Ultra- (Lat.), beyond, on the other side of, in excess of.

Ultracentrifuge Used in colloidal chemistry to determine molecular weight and sedimentation rate of particles suspended in either liquids or gases. It can attain a centrifugal force of 260 000 to 1 million g (motor driven at approximately 30 000 rpm).

Ultrafiltration A membrane extraction process (→ Permeation) using membranes or cellulose film to separate colloidally dispersed dissolved substances from molecularly dispersed substances. Pore diameter from 1–1000 nm. Ultrafiltration suitable for cleaning waste water from the dyeing and textile industry. An ultrafiltration plant was specifically developed for the important application of size recovery (Fig. 1). For example, rinsing water containing polyvinyl alcohol is continuously cycled through a circulation tank until a predetermined concentration is reached, e.g. 7% polyvinyl alcohol (→ Reverse osmosis). Ultrafiltration is usually carried out in tubular systems (Fig. 2).

Ultrafiltration in size recycling. Ultrafiltration is an extraction process whereby a solid is separated from a solution by means of semi-permeable membranes. The size is almost entirely washed out and the recovered bath is concentrated at a membrane with microscopic

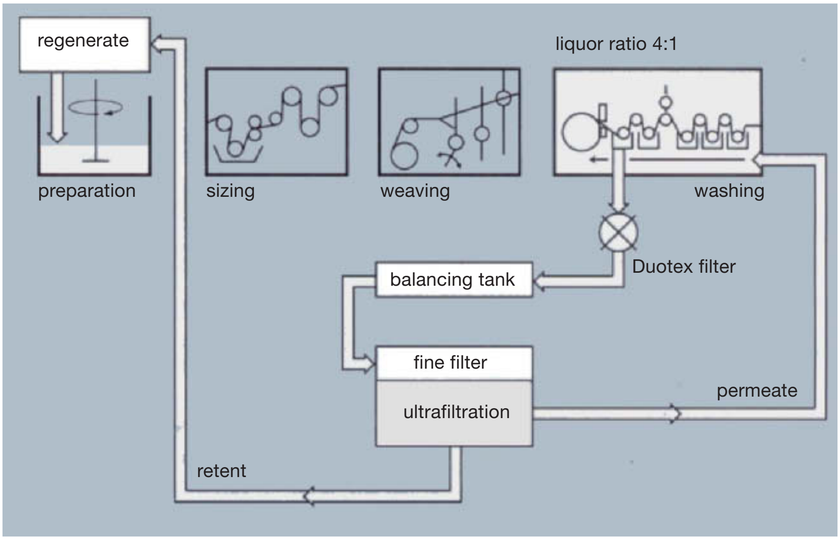


Fig. 1: Through ultrafiltration the sizing-desizing becomes a closed, effluent-free system (Hoechst).

Ultrafiltration

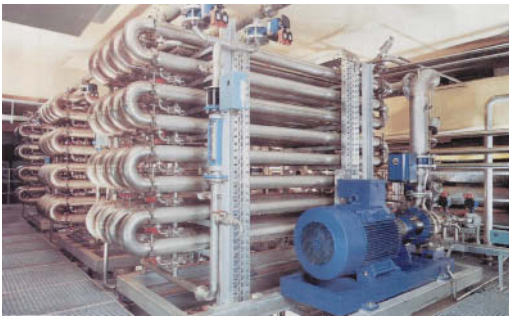


Fig. 2: Typical pipe system of an ultrafiltration plant (by GTV).

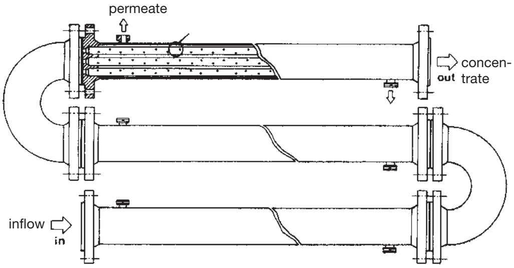


Fig. 3: Schematic illustration of a pipe membrane in an ultrafiltration plant module with effluent inlet, permeate outlet and concentrate outlet.

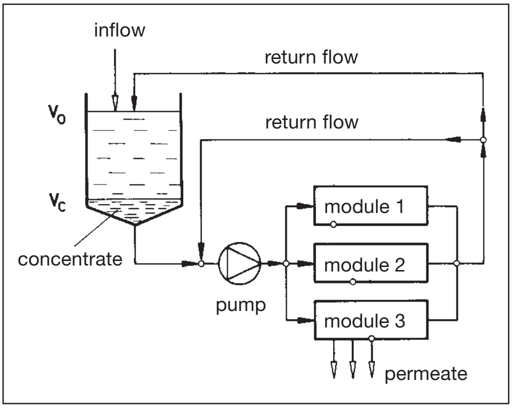


Fig. 4: Batch process ultrafiltration.

pores. The pores of the membrane are so small that the macromolecules of the size are held back while the water can pass through. To achieve this, the liquid to be filtered must be subjected to high pressure.

The concentrate remains within the pipe while the permeate drains out of the pipe (Fig. 3). Short chain molecules are separated out with the water, so there is a constant loss of material known as the permeate loss. This permeate loss gives rise to a particular aspect of the size recovery process: since only short chain molecules are lost from the size, this explains why recovered size is at least as effective in sizing as is the original size. In order to regenerate the ultrafilter, batch processing may be desirable (Fig. 4).

The principle requirement is that the size is soluble in water without thereby changing its characteristics. As a result products are unsuitable if, as starch, they

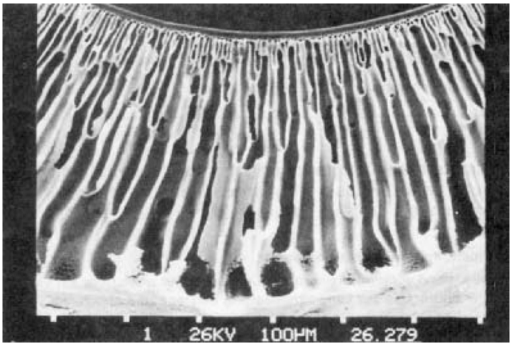


Fig. 5: Section through an asymmetrically structured ultrafiltration membrane.

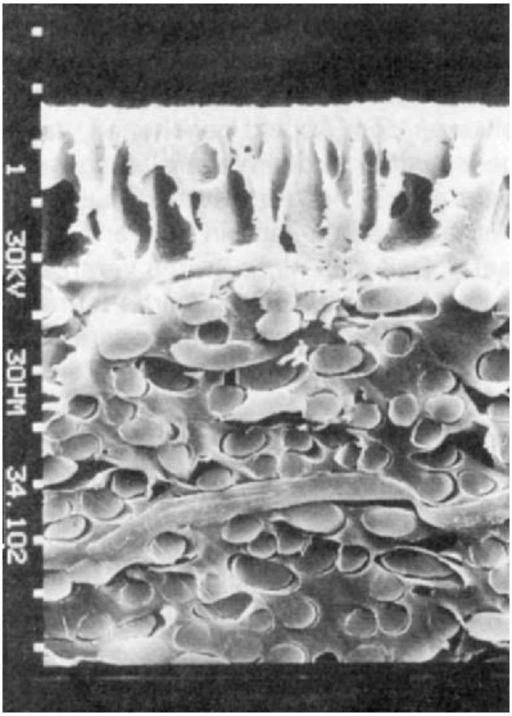


Fig. 6: Membrane, applied to a nonwoven base.

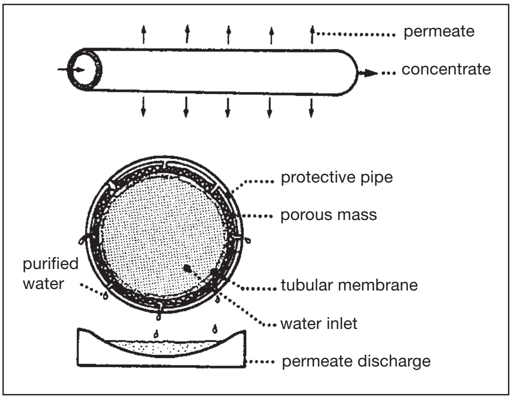


Fig. 7: Tubular ultrafiltration membrane.

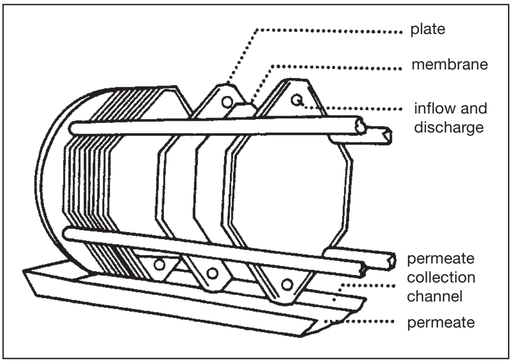


Fig. 8: Ultrafiltration plate module.

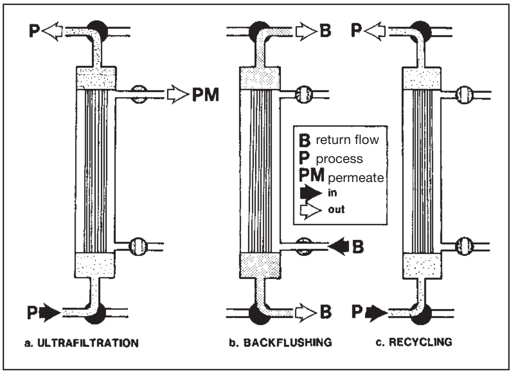


Fig. 10: Hollow fibre module with three ultrafiltration operations.

must be broken down enzymatically, or if they can only be dissolved with the aid of chemical additives. Each class of size substances include some that are water soluble: modified starch/CMC/PVA/PAC. In addition to water solubility a further characteristic is required: stability. Recovered size must not break down chemically while being stored prior to re-use.

Ultrafiltration facilities make use of microporously layered membranes attached to fibrous substrates (Figs. 5 + 6) which are used in a variety of modules:

- tubular module (Fig. 7),
- plate module (Fig. 8),
- spiral module (Fig. 9),
- hollow fibre module (Fig. 10).

Ultramarine (-blue, blue powder, washing-blue). Mineral dye obtained by heating together kaolin, sodium carbonate, sulphur and charcoal. A fine brilliant blue powder (of variable composition), also blue-green, violet and red. Insoluble in all solvents. Fast in the presence of light, air and soap, it is bleached by acid (giving off hydrogen sulphide), which reaction can be used to prove the presence of or to destroy ultramarine

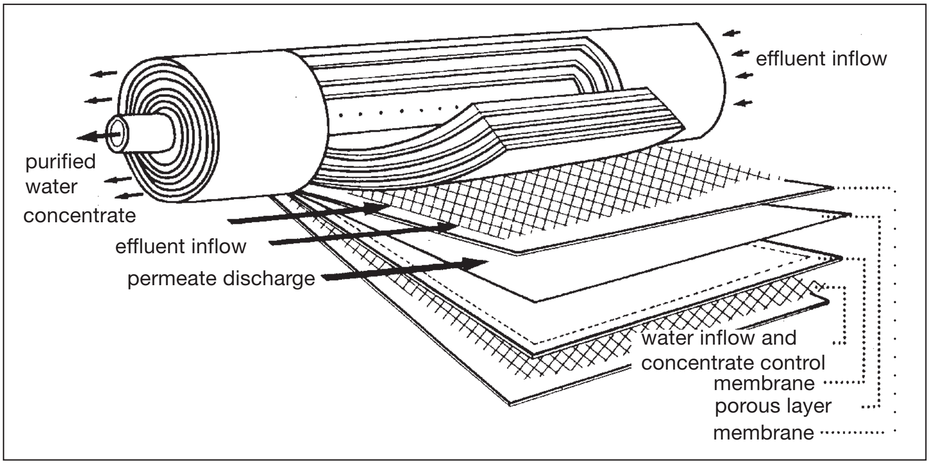


Fig. 9: Spiral ultrafiltration membrane.

marking dyes. However, acid resistant ultramarine does exist. In common with zinc oxide, ultramarine is highly reflective to infrared (therefore use in camouflage colours). Usage: component of white conditioner in printing; frequently used in the blueing of bleached goods, underwear, feathers, etc.; dyeing of plastic, rubber, wax cloth, leather, paper; as marking dyes, etc.

Ultra-rapid accelerator → Vulcanization accelerator.

Ultrasonic cutting Thermo-mechanical contact process. In this case, textiles and other planar objects are not melted by applying ultrasonic sound energy, but instead the oscillations activate a chisel-shaped tool. The principle is similar to that of a pneumatic chisel, but uses oscillations in the region of 20–40 kHz. Cutting is generally done by means of pliers, whereby the material is introduced between one jaw and an opposing jaw suitable for the particular purpose. The ultrasound frequency is modulated such that an acoustic resonance is created between the two jaws. The material is modulated by the sonotrode, causing its fibres to vibrate at the resonant frequency. Heat is created by friction and melting begins. The ultrasonic oscillations are dampened by the thermoplastic fibres, which therefore limits the melting process to a narrow zone.

Ultrasonic cutting has several notable advantages compared with thermal cutting:

- Virtually all materials can be cut, e.g. glass fibre, natural fibres, synthetic fibres, aramid fibres, metal fibres. This depends merely upon the generator power, the working parameters and the form of the cutting tool (sonotrode).
- However, a welded edge is produced only in the case of thermoplastic material containing up to 35% other materials (as in thermal cutting). Firm welded edges of good appearance are produced with either narrow or wide melting zones.
- No noticeable heat is generated and the cutting tool remains completely cold. The maximum irradiated temperature does not exceed 50°C, therefore both combustion of the product or the risk of burns to the worker are out of the question. As a result, thick and voluminous material may be cut in this way.

Since the clothing industry is beginning to recognise a market demand for single or low-number cuts, ultrasonic cutting presents an alternative to rapid water jet cutting. In contrast to previously available cutting techniques, this technique offers increased performance over mechanical means. The maximum blade cutting speed is indeed 60 m/min, but because of mechanical friction between blade and material a somewhat lesser speed is possible than that for water jet cutting. Compared with conventional cutters, ultrasonic cutters are approximately twice as fast for the same quantity of material.

Ultrasonic energy application → Laminating.

Ultrasonic flowmeter The ultrasonic measuring process can be described as follows. Sound propagates through a fluid at rest at a velocity which is dependent upon the elasticity and the kinetic properties of the fluid. If the fluid is flowing, the propagation velocity of the sound decreases or increases in proportion to the velocity of flow, depending upon whether the sound is transmitted with the flow direction or against it.

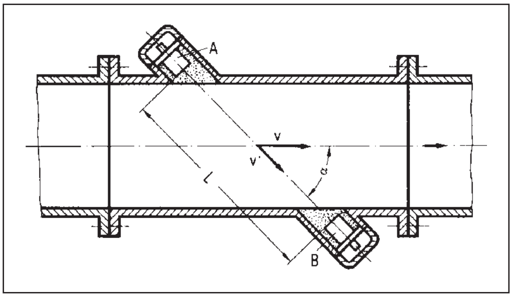


Fig.: Operational diagram of an ultrasonic flowmeter. A = transmitter and receiver; B= transmitter and receiver; L = distance between transmitter A (B) and receiver B (A); n = average flow rate of the measuring material in the measuring tube. n' = n · cos a (velocity component of the average flow rate, in terms of the transmitter/receiver direction).

The Fig. shows the way in which this works. Pulses of ultrasound are sent alternately from transmitter A to receiver B and then from transmitter B to receiver A. The time taken for each transmission is measured, represented as a frequency, and the two frequencies are subtracted one from the other. The difference in frequency is proportional to the flow.

Ultrasonics Higher than audible sound with a frequency above approximately 16 kHz up to approximately 10^6 kHz.

infrasound	up to 16 Hz
audible sound	16–16 000 Hz
ultrasound	above 16 000 Hz.

Ultrasonics is a specialist area of more general acoustics, which studies the behaviour of mechanical oscillations in solid, liquid and gaseous media (→ Sound). In reference to the characteristics of the human ear, high frequency and no longer audible oscillations are termed ultrasound or hypersound.

There are many ways to generate ultrasound. The best known ultrasonic transmitters are whistles and sirens of various forms, as well as piezoelectric and magnetostrictive generators. As a rule ultrasonic generators driven by compressed air are used as these most easily allow the required acoustic pressure level to be reached. Typical values range from 140–165 dB. Whistles and sirens, because of their mechanics, permit an optimal coupling of the generated ultrasound with the

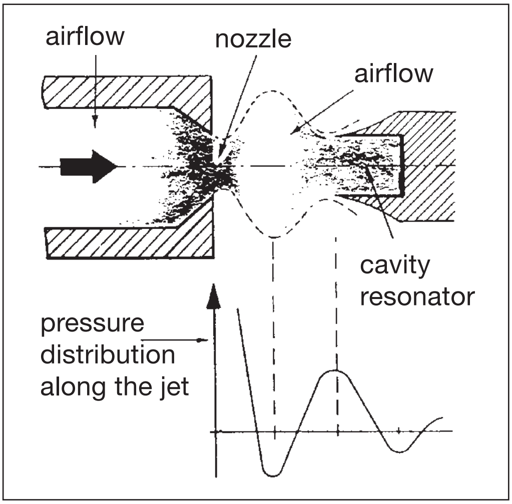


Fig.: Schematic illustration of a Hartmann generator.

surrounding air mass. Magnetostrictive and piezoelectric ultrasound emitters create only low amplitude oscillations inside the generator itself and coupling with gases is poor.

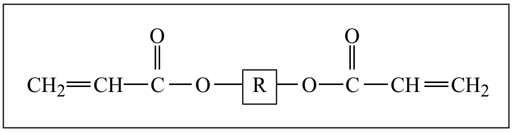
Generation:

I. Mechanical: Ultrasonic oscillations may be generated in gases and liquids by means of whistles, whereby gas or liquid streaming over a blade gives rise to separating vortices, which then excite resonant spaces or resonant bodies into oscillation. Well-known examples are the Galton whistle and its further development, the Hartmann generator (Fig.). The Siemens ultrasonic whistle (for exciting liquids) produces a relatively high ultrasonic output. Ultrasonic sirens (for exciting air) produce ultrasound by blowing a jet of compressed air through a rotating aperture.

II. Electrical: emission of frequencies by tubular transmitters, translation of an alternating electrical voltage into ultrasound (mechanical oscillations). This requires transformers operating on the following principle:

a) Magnetostriction, i.e. alternate lengthening and shortening of a laminated nickel rod according to the rhythm of a magnetic field generated by electrical oscillations (in a surrounding coil).
b) Electrostriction, i.e. alternate compression and extension of an oscillating quartz crystal (piezoquartz; → Dielectric) according to the rhythm of an alternating voltage known as piezoelectricity. The frequency created may be as high as is desired (only 50–200 kHz for a quartz rod, but 200–30 000 kHz for a quartz disk).

Ultra-violet curing of polymers Polymer systems capable of being cured by irradiation need not have a complex structure and may comprise only a single chemical substance. For reactive components such as acrylates, the energy level of accelerated electrons is high enough to begin radical polymerization. However, if UV light is used as a source or irradiation a photoinitiator is usually required in order to generate sufficient radicals to start the polymerization reaction. For practical reasons polymer systems to be cured by irradiation usually comprise more than one component. Each major component normally contains reactive groups (usually acrylate or vinyl groups). The main components can be ordered into two sets: pre-polymers and diluents. The pre-polymers (Fig. 1) are oligomers such as polyurethane, polyester and polyether, possessing acrylate groups at the ends of their chains. In contrast, reactive diluents are simpler molecular components such as the monomers in Fig. 2. Typical examples are glycol acrylate, N-vinyl-pyrrolidon and styrol. These compounds are used in order to manipulate viscosity, improve characteristics in solution and optimize coatings to be applied. Additives may also be incorporated in a mix in order to improve specific characteristics such as colour. If an additive contains a reactive group it may take part in the reaction and become an incorporated component of the polymer network. If it does not, the additive will be enclosed within the polymer network.



$$CH_2{=}CH{-}\overset{\overset{O}{\|}}{C}{-}O{-}\boxed{R}{-}O{-}\overset{\overset{O}{\|}}{C}{-}CH{=}CH_2$$

Fig. 1: Pre-polymers with 2 reactive groups.

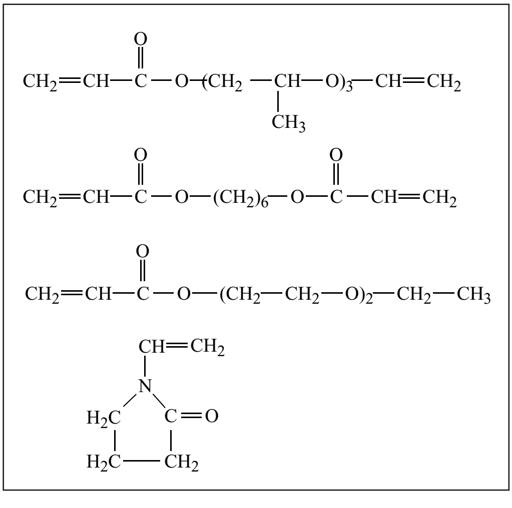


Fig. 2: Examples of typical monomers as reactive diluents.

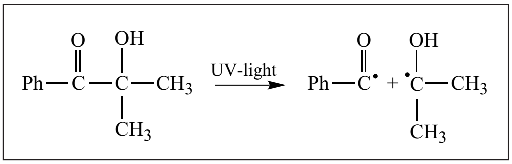


Fig. 3: Generation of radicals through photo-degradation.

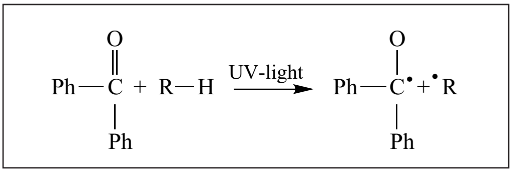


Fig. 4: Generation of radicals through dehydrogenation.

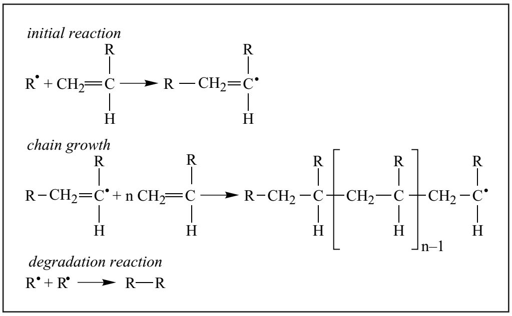


Fig. 5: Radical polymerization (initial reaction, chain growth, degradation reaction); R = alkyl, acyl.

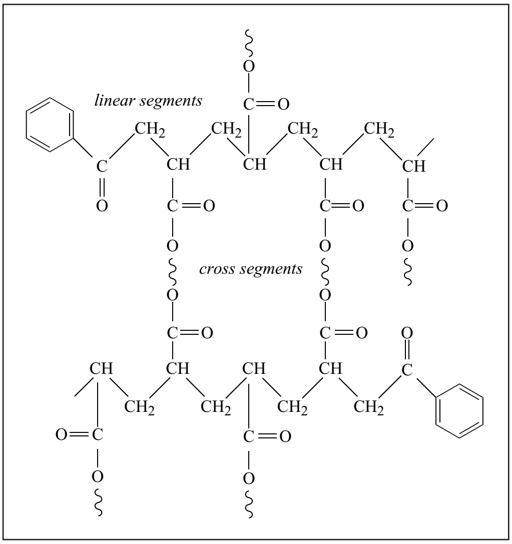


Fig. 6: Crosslinked polymer.

In the case of UV-cured coatings, photo-initiators are used to provide the energy required in order to generate radicals which then initiate the polymerization reaction (Fig. 3). If the concentration of photo-initiators is too low the excitation will not be sufficient to produce a fully polymerized product. If the concentration is too high, the greater proportion of the UV-light is absorbed by photo-initiators in the outer layer of the film and the layer below receives insufficient light to achieve complete curing. In order to ensure that the desired degree of curing is achieved throughout the thickness of a coating an optimal concentration of initiator is essential.

In recent years a great number of photo-initiators have been developed which generate radicals either through photo-degradation or dehydrogenation (Fig. 4). Examples of photo-initiators which release radicals under irradiation by UV-light (Norrish type, Fig. 3) are benzol derivatives, acetophenon derivatives, hydroxyalkylphenons and acylphosphinoxides. The second main group of photo-initiators generates radicals by dehydrogenation, as shown in Fig. 4; this category includes aromatic ketones such as benzophenone and thioxanthrone. The hydrogen donator is generally a tertiary amine such as methyldiethanolamine.

The basic form of radical polymerization by which an irradiation-cured coating is built up is shown in Fig. 5. Long side chains are built from pre-polymers while monomers give rise to short side chains. Since a pre-polymer or a monomer generally contains more than one reactive group, irradiation often results in a crosslinked polymer (Fig. 6) (according to Luiken).

Ultraviolet fluorescence of textiles Fibres emit → Fluorescence in the ultraviolet region, e.g.:

faintly yellowish, whitish	(USA) cotton
pale yellowish	cotton, mercerised and bleached
straw yellow	viscose, unbleached
sulphur yellow with blue shadow	viscose, bleached
intense yellow	polyester
yellowish green	polyacrylonitrile
blue-green	polyvinylchloride
bluish violet, brightly luminous	acetate
reddish white, milky	cuprous
bluish white	wool, unbleached; silk, scoured; casein
pale bluish, whitish	wool, bleached.

→ Luminescence analysis.

Ultraviolet lamp (quartz lamp, quartz-mercury lamp, mercury lamp). Artificial source for the generation of ultraviolet radiation. For lamps used in analysis the visible component of light from such sources is removed using a special filter, e.g. for use in → Luminescence analysis.

Ultraviolet radiation (UV radiation). Includes light of a wavelength from approximately 140 nm to 360 nm. Ultraviolet radiation is present in sunlight but is nevertheless invisible to the human eye since it lies beyond the violet portion of the visible spectrum. → UV Excimer radiator.

Umbrella fabrics A thick, light fabric (often printed) made from yarn-dyed polyamide threads and made water repellant.

UMIST English textile research organisation in Manchester; → Technical and professional organizations.

UNARI Burmese standardization association; → Technical and professional organizations.

Unbalanced mass Unevenly distributed mass within a rapidly rotating machine, e.g. because of unevenly distributed wet articles in a centrifuge or tumble drier. The frame of the machine (its base) must be so constructed as to accommodate the effect of the unbalanced mass.

Unbleached linen (Écru linen, raw linen). Naturally coloured, unbleached → Linen.

Unboiled silk → Écru.

UNCO Una Norma Colombiana, Colombian standard.

Uncollapsed cake Rewound cake in crossed layers of yarn, mechanically stronger with improved dyeing characteristics (package and pin up system).

Undecane (Lat.: undecim = 11) Containing 11, e.g. → Undecanoic acid is an amino acid which contains 11 carbon atoms.

Undecanoic acid (11-amino-undecanoic acid) $NH_2\text{–}(CH_2)_{10}\text{–}COOH$ has an important role in the manufacture of polyamide 11. The starting point for the process is castor oil. The production is outlined in principle as follows (the basis is ricinic acid):

$$CH_3(CH_2)_5CHOH\text{—}\ CH_2CH{=}CH(CH_2)_7COOH$$

$$\xrightarrow{\text{overheat}} CH_2CH(CH_2)_8COOH \qquad \textit{undecylenic acid}$$

$$\xrightarrow{+\,NH_3} NH_2(CH_2)_{10}COOH \qquad \textit{11-amino-undecanoic acid}$$

$$\xrightarrow[-\,H_2O]{\text{polycond.}} [NH(CH_2)_{10}CO]_n \qquad \textit{polyamide11}$$

Under exposure of photosensitive screens In order to manufacture a printing screen, the photosensitive screen, which lies either on or around the stencil gauze, is illuminated at those points which are not coloured black on the transparency sheet which covers it. The rays of incident light penetrate both the photosensitive screen and the gauze threads. Because of a difference in refractive index, or due to reflection at the surface of the thread, the gauze threads cause a degree of scattering of the light, which in turn leads to under exposure of those parts of the photosensitive screen which are exposed by the transparency. Remedy: dyeing the gauze threads yellow leads to absorption of the photochemically active violet and UV radiation. Under exposure can also result from light falling at an angle upon the transparency and the photosensitive screen.

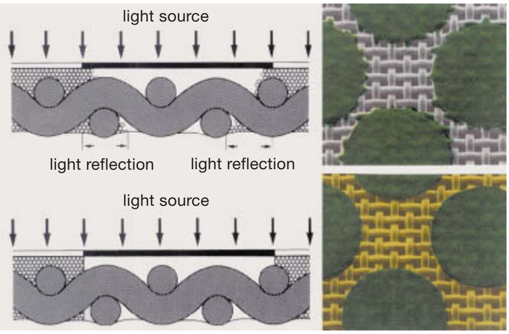


Fig.: Result of under exposure with white gauze (above) and avoidance thereof using coloured screen gauze (below) (Swiss Silk Bolting Cloth Factories, Thal and Zürich).

Undercoat hairs (down hairs, wool hairs). Shorter and finer hairs forming the inner layer of an animal's coat, usually unmarked, soft/elastic, curled with good felting quality.

Underfloor/elevated machine siting Term used for the positioning of a machine above a production floor (elevated) or below the floor level in e.g. a pit (underfloor) (see Fig.). Underfloor positioning can be of advantage with respect to tooling/equipping if a machine incorporates a product feed or output at high level.

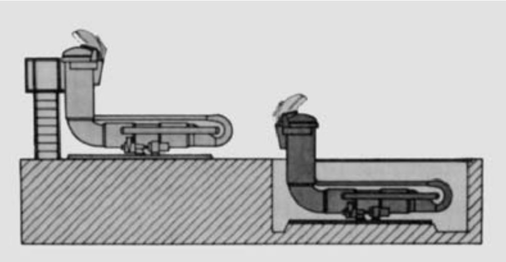


Fig.: Diagrammatic comparison of the siting of an elevated (left) and underfloor machine (right), Alphorn model (Scholl).

Underground biological digestion Process for → Waste water treatment. In this process waste water is

Underground biological digestion

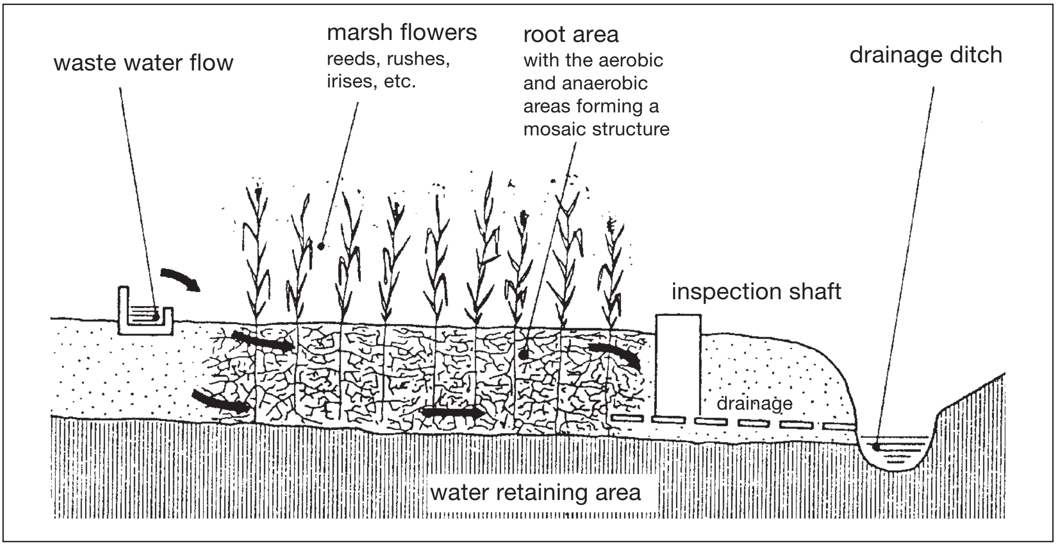


Fig. 1: Section through the ground in underground biological digestion.

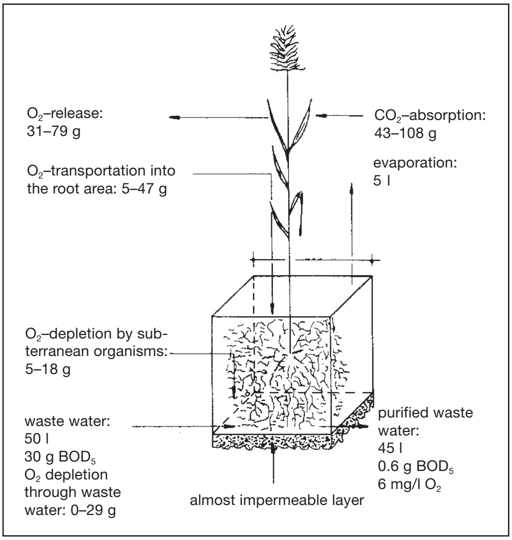


Fig. 2: Structure of the drainage system in underground biological digestion.

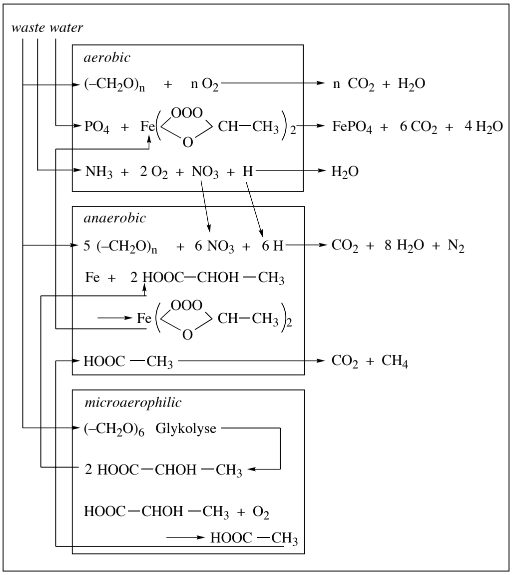


Fig. 3: Combination of aerobic and anaerobic fermentation in underground biological digestion.

allowed to flow horizontally underground, above an impervious layer, through a flow zone which has been dimensioned precisely to match the nature of the waste water and of the soil, and then into an open drain (Fig. 1). The sediment is planted with reeds (Fig. 2) which, in addition to other important physiological benefits for effluent treatment, deliver oxygen from the air to the roots within the saturated sediment. This gives rise to an aerobic-anaerobic mosaic matrix (Fig. 3) which permits waste water recovery other than the usual purely oxidizing or reducing purification processes.

One of the basic requirements of conventional oxidation-based waste water technology is to deliver the waste water to the treatment works in the freshest possible state, i.e. as quickly as possible. If water is delivered in a partially stagnant state, this can lead to smells and to corrosion problems in the enclosed space above the flowing water. Even normal waste water smells are considered unpleasant by many people. Waste water containing sulphur gives rise to largely unacceptable smells and undermines the sense of well-being. It is therefore an important aspect of underground biological digestion that such facilities are constructed decentrally, i.e. well away from residential areas (according to Kickuth).

Underwear Clothes worn directly against the skin and covered by other textiles. Underwear is intended to absorb the moisture emanating from the skin through perspiration and release this to the outer air. If the rate of absorption is greater than that of evaporation, the textile remains wet against the skin and this leads to an unpleasant sensation (→ Clothing physiology).

Functional knitted goods work in such a way that sweat is removed from the body as quickly as possible as it occurs, this being due to the special construction of the textile. Such a textile may be, for example, a two-layered knitted item with an inner layer composed of hydrophobic synthetic fibre and an outer layer of cotton or modal fibre. Most fine-fibrillar synthetic fibres (polypropylene, polyester or polyamide) transport moisture rapidly through the capillary spaces between the fibres and release it to the absorbent outer layer without themselves taking up moisture (the same principle applies if absorbent textiles are worn over simple synthetic fibre underwear).

Such a clothing system only functions if the absorbency of the construction is optimal. Layers of hydrophobic synthetic fibre usually loose their absorbency after dyeing, and this can only be restored with the application of an appropriate hydrophilic agent. This consideration should be included in the design in all cases.

UNE Spanish standards association; → Technical and professional organizations.

UNESCO United Nations Educational Scientific and Cultural Organization (headquarters in Paris) whose "International Organization of Standardization" (→ ISO) is, among other things, responsible for the standardization of colour fastness in dyes.

Uneven dyeing for fashion effects,

I. Interesting fashion effects are achieved by dyeing ready-made goods with the use of stones (stone dyeing). For this purpose selected direct, reactive or acid dyes are used. This method of finishing is characterized by not being energy intensive while remaining simple, and is suitable for the treatment of goods made from acetate fibres or from an acetate/synthetic mix.

II. An irregular dye pattern can, for example, be achieved by spraying dye solution onto a moving band of fabric by steam, while at the same time applying suction to the fabric (→ Space dyeing).

III. Due to a variety of processes, textiles may be treated with special liquid crystals, or else with thermochromatic pigments made from particles of a specific size suspended within a binding agent. Textiles finished in this way react with a change of colour to changes in temperature.

IV. Hoechst AG has patented a process for uneven colouring (a batik process for use on textiles made from synthetic fibre). A reserving agent is applied to the fabric. Once dry, the material is mechanically "broken" and subsequently heat set.

V. Sandoz has developed a technology for uneven dyeing or etching. The continuous finishing process involves spraying stones or porous material from above with one or several dyestuffs, while these stones or this porous material also come in direct contact with one side of a moving textile band.

VI. Equally widely used is a process which makes use of enhanced dye uptake at various locations along a textile band. After dyeing, pronounced two-colour or multicolour effects are achieved.

VII. Technologies are widely established which make use of stones in the processing of finished goods in order to achieve a worn and washed-out effect. The stone wash process has the effect of mechanically removing the dye from the surface of the textile, e.g. in the case of → Denim, so that a subsequent "lightening" can under certain circumstances be attained by treating with hypochlorite. Stone wash technology depends in principle on chemically washing with stones impregnated with potassium permanganate. This technology can be used on knitted goods to produce an interesting fashion effect, since the surface of the fibres is simultaneously roughened to a degree, lending the goods a slightly satin or peach-skin appearance. A series of different technological processes have been developed for this method of finishing, whereby the textile is fretted using either stones or pumice or treated in a bubbling stream of sand. → Enzymes are also used for this purpose.

VIII. A washed-out appearance may also be achieved by spraying the textile with a bleach bath or by chemically washing it in a dilute NaOH or KOH solution.

UNI Italian standards association; → Technical and professional organizations.

Uniflow principle in drying The internal airflow system within a drier can essentially be either a uniflow or a counter-flow system: in uniflow, the driest portion of hot air flows in the same direction as the goods (Fig. 1). The uniflow principle entails central airflow, central automatically regulated exhaust, and a heat transfer medium (air) which moves in the same sense as the fabric band or goods line, and may be employed for the following reasons (Fig. 2):

1. During drying the upstream zones can operate with circulating air at a higher temperature, which increases the evaporation effect. Downstream zones operate with circulating air at lower temperatures.

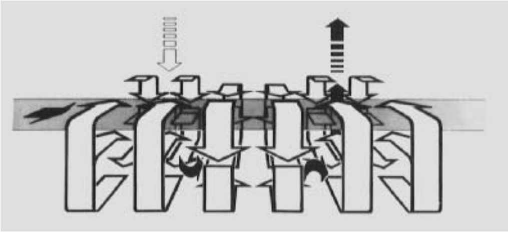


Fig. 1: Uniflow air control (Babcock).

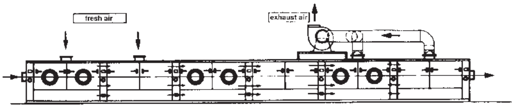


Fig. 2: Fresh air and exhaust air control with the Econ-Air system (Babcock).

Since air is only extracted downstream, the lower temperature means reduced heat loss.

2. During drying the goods attain a higher temperature downstream. This increases the diffusion rate of water on the surface and improves drying efficiency, as shown in both theoretical investigation and practical tests.
3. During curing any softener fumes which may be given off are drawn out of the drier in the direction along which the temperature of the goods increases, thus avoiding condensation on the goods.
4. During combined drying and curing, softener fumes do not penetrate into colder drying zones and form droplets there.
5. During combined drying and curing, the humidity of the circulating air in the downstream zones is higher, thus reducing the risk of yellowing.

Uniformity The most important determining factor when assessing goods according to → Quality, e.g. in terms of pattern, finish, weight, length, thickness, section, strength, stretch, etc. Calculated as: % U (uniformity) = 100 – deviation in % (→ Deviation).

Unipolymerisate Product of → Polymerization resulting from basic building blocks of only one type.

Unisyn concept Universal desizing technique for water soluble synthetic size. The desizing in practice of water soluble sizes is usually dependent on the product used. Water soluble sizes of all types can be washed out cost effectively on a continuous wash production line using the Unisyn technique (BASF) with the application of:
1 g/l wetting agent,
2 g/l dispersing agent,
3 g/l sodium hydroxide.
The particular value of the process lies in the fact that all generally used water soluble sizes can be dealt with in this way (according to Rüttiger).

UNIT Instituto Uruguayo de Normas Tecnicas, Uruguay Institute for Technical Standards; → Technical and professional organizations.

Unitary (Lat.: una = together, combined), refers in chemistry to a molecular structure comprising atoms of only one kind, e.g. O_2. →: Binary; Ternary.

Unit of force Within the → SI System of Units force is no longer a fundamental dimension, but instead the SI unit of force, the Newton (N), is derived from three fundamental dimensions (length, mass, time). 1 N corresponds to the force required in order to impart to a body of mass 1 kg an acceleration of 1 metre per second: i.e. $1\ N = 1\ m\ kg/s^2$. The unit used earlier, the kilopond (kp), is no longer accepted.

$1\ N \approx 100\ p$
$1\ kp \approx 10\ N = 1\ daN$
$1\ p \approx 0.01\ N = 1\ cN$

Unit processes Single processes which recur regularly within larger processes. A unit process must be self-contained and obeys only one law. A unit process cannot be realised in itself. Unit operations, unit procedures or discrete operations are clearly defined in chemical process engineering as physical unit processes which lead to a change of state. They are divided into mechanical, electrical, magnetic and thermal unit processes. Mechanical and electromagnetic unit operations essentially take place without heat transfer or the transportation of molecular material. In the case of thermal unit operations, on the other hand, forces which instigate flux place the central role in the change of state. In this way, for example, both a concentration gradient and a temperature gradient can give rise to diffusion (simple diffusion and thermal diffusion). In this sense relaxation processes are also counted as thermal unit operations, since locational changes of the polymer segments within a fibre are necessary in order to increase or reduce tension.

Within a general technical system inverse pairs of unit functions may be formulated as follows:

flow	inverse of	isolate
fuse	“	split
group	“	disperse
combine	“	divide
rectify	“	oscillate
conserve direction	“	change direction
store	“	discharge
mix	“	separate
enlarge	“	reduce
transform (change)	“	untransform (change back)

Chemical processes by which substances change are described as unit processes. These processes fall within reaction technology. They are divided according to whether they are thermal, electrochemical, photochemical, mechanological, biochemical reactions and so on.

Unit processes within textile manufacturing are, for example:

a) mechanical: passing, compressing, brushing, abrading, stretching, storing, crushing;
b) thermal: diffusion, calendering, mixing, wetting, swelling, relaxing, shrinking, diluting, vaporizing, dwelling;
c) chemical: addition, hydrolysing, condensing, oxidizing, reducing, crosslinking.

The unit processes are formally described in terms of unit functions within textile manufacture. They are characterized by the fact that the input and output conditions of the respective system have not yet been finally determined.

Units → SI System of Units.

Units of measurement → SI System of Units.

Unit time (time per unit). Processing time required for a single unit (single item of a commodity) =

$$\frac{\text{completion time}}{\text{number of units}}$$

→ Completion time is a mutiplication of unit time by the number of units. → Basic time and → Allowance.

Universal loop steamer → Steamer, in which knitted goods are transported through the steam chamber suspended in long loops and thus are not under tension (Fig.). An externally heated standard universal loop steamer, accepting goods with a width of 2.6 m and accommodating a length of 200 m, requires approximately 1700 kg steam/hour to supply heat from the external source to its steam chamber when operating with superheated steam (180°C) in order to fix dyes after printing. In contrast an internally heated universal loop steamer (Artos) of the same size and capacity requires only approximately 560 kg/h when operating with superheated steam. For technical reasons hot air operation of externally heated steamers is either impossible or very difficult to achieve. Internally heated universal loop steamers, on the other hand, permit hot air operation provided they are equipped with a fresh air intake system. Hot air operation allows an almost complete avoidance of the costs incurred for steam.

Unlevel dyeings Faults occurring in the dyeing of textiles of all varieties. The dyestuff is not level (→ Levelling properties) but instead is spread unevenly over the textile material. Unlevel dyeing may be caused by, among others, any of the following factors: omitted or inadequate pre-treatment, packing too tightly in apparatus, a too weak or a too strong dye bath circulation, inappropriate or faulty dyeing conditions, inappropriate choice of dye.

For example, during the heating up phase while dyeing either polyester yarn or beam dyeing polyester piece goods, the glass transition temperature is exceeded. When this occurs, the substrate begins to draw the dissolved dyestuff from the adjacent liquid. If it were the case that the dyestuff was instantly replenished through a process of diffusion or dissolving from dispersed particles, then the concentration of dissolved dyestuff would remain equal at every point above the substrate surface and would match the solubility of the dyestuff. The sorption rate would be everywhere the same and the resultant dyeing would be exactly level. This limiting sorption rate is determined solely by the diffusion process taking place within the substrate.

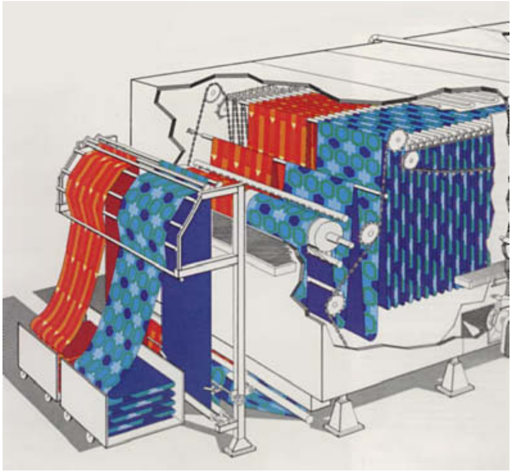


Fig.: Universal loop steamer (Babcock).

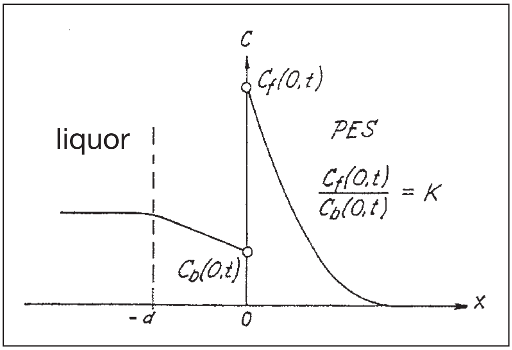


Fig.: Liquor-substrate concentration profile on the suface.

However, since the replenishing of dissolved dyestuff takes place only at a limited rate, the boundary layer above the substrate becomes depleted (see Fig.).

This depletion causes on the one hand a reduction in the sorption rate and on the other a simultaneous increase in the delivery of dissolved dyestuff to the boundary layer. The concentration of dissolved dyestuff C_b (0, t) at the boundary between dye bath and substrate (x = 0) adjusts itself constantly such that sorption rate and replenishment rate remain in balance.

If the depletion of this boundary layer is slight a level dyeing may be expected. In such a case the replenishing of dissolved dyestuff is not significantly influenced by local current effects. If, however, the depletion is greater, replenishment becomes strongly dependent upon the thickness of the laminar boundary layer, in other words upon local currents. This results in the sorption rate being no longer independent of location and unlevel dyeing begins to develop.

Unlevel dyeing is a consequence of a depletion of dissolved dyestuff in the boundary layer. The ratio between the limiting sorption rate and the replenishment rate of dyestuff (UK) is a measure of this depletion and thus offers a criterion for levelness.

$$UK = f\left(\frac{C_f}{C_s}\right)$$

The dimensionless levelness criterion UK has a different value at every moment during the heating up phase because both the quantity of dyestuff absorbed C_f and the dyestuff's solubility C_s are temperature dependent. The greater the value of UK at any particular moment during the dyeing process, the more level the sorption of dyestuff by the substrate at that moment (according to Gerber).

UN number So-called classification number for "hazardous substances" the transport of which involves particular dangers (→ Hazardous substances act). An international cataloguing and classifying system of types of hazard which is largely uniformly implemented. Its basis is the recommendations of an expert commission of UNO. Transport of chemicals in the Federal Republic of Germany requires a special permit (brown-bordered form) and accompanying papers (safety information sheet).

Unrolling of liquid droplets The separation of a flattened and spread-out oil droplet from the surface of a textile material (e.g. when washing with surfactants). As the unrolling process proceeds (see Fig.) the thin film of oil first flows together to form a hemisphere and then develops into a sphere which separates from the surface. This process can be measured optically by observing the angle of contact between oil droplet and surface.

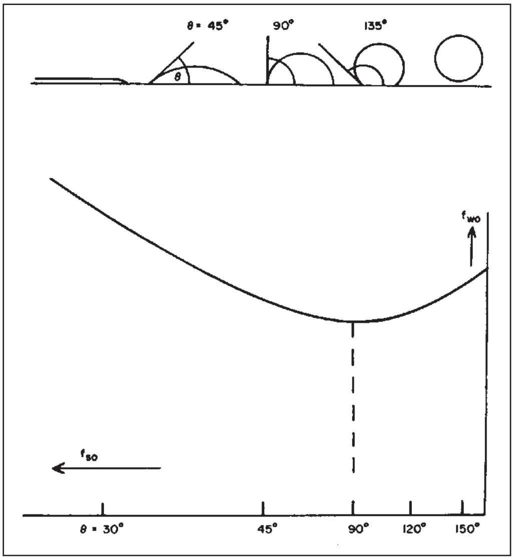


Fig.: Separation of an oil droplet from a solid foundation (e.g. textile substrate), as nearly the opposite of wetting, shown as size f_{wo} of the boundary layer liquid/liquid (ordinate) in relation to the surface area f_{so} (abscissa).

Unsaturated organic compounds Compounds in which not all available carbon atom bonds (depending upon → Valency) are saturated with hydrogen atoms (or oxygen atoms, etc.) and are therefore still free and capable of addition; e.g. acetylene C_2H_2 → H–C=C–H.

Unsaturated steam → Superheated steam (→ Steam).

UNSCC United Nations Standards Coordinating Committee; → Technical and professional organizations.

Unused colour paste recycling using colour measurement Unused colour pastes are segregated according to variety and approximate dye colour differences in minimum quantities of approx. 50 kg.

Printing paste preparation:

1. colour strike-offs made on the substrate to produce calibration values for the computer.
2. store strike-off data in the computer.
3. measure the pattern.
4. using a computer, calculate the recipe that is required to adjust the old dye paste to match the required sample.
5. recipe selection criteria: number of dyes, quantity of dye, price, type of dye etc.
6. prepare old dye paste as per the recipe, control strike-off, re-use.

Upholstery crêpe A woven crêpe made from cotton, usually printed.

Upholstery fabric finishing is aimed towards the quality standard (Fig. 1). The fact that the conventional types have no clearly distinctive crystal structure, but that the fibre structure is always in a range between

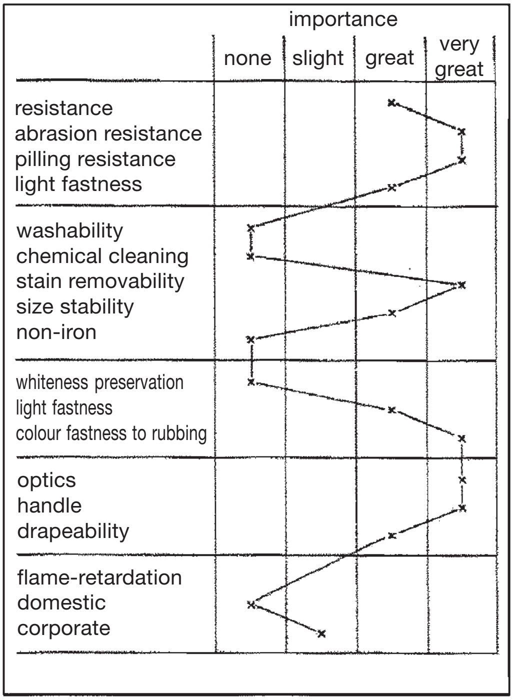


Fig. 1: Requirements profile of upholstery fabrics.

amorphous and crystalline, which is the reason for the good deformability of the material, is what has made the use of polyacrylonitrile fibres in furniture velours preferred and appealing from the start. The pile loops can be placed in any desired position depending on result; crimping (crinkling) of yarns, whirled, crushed and embossed designs can be achieved relatively easily. As the glass temperature of polyacrylonitrile fibres is generally between 70–80°C, the temperatures necessary for deformation can be reached easily in textile finishing. Plasticizability occurs much earlier in damp heat or in hot water than in dry treatment with heat. The temperatures essentially depend on the continuous amount of material, exposure time, shade of colour and on the desired degree of deformation. Darkly coloured fibres take up temperature more quickly than light dyeings. Wool crimped velours formerly in fashion in the 50 s were redeveloped from polyacrylonitrile fibre yarns. Crimping (crinkling) occurs in both materials in the knit-deknit method. The position of the pile loops has a critical effect on the appearance and handle of upholstery velours. Design effects are already possible due to so-called layer weaves, which result in the familiar shaded velours.

Planographic printing, roller printing, rotary printing and heat transfer printing are suitable for printing of polyacrylonitrile upholstery velours. There are two main types of polyacrylonitrile fibres as regards dyeability: firstly the types dyeable using cationic dyes and secondly those, which are dyed using acid dyes. The polyacrylonitrile fibres predominantly used are those which can be dyed cationically. The combination of both types facilitates piece dyeings using dyeing and design effects similar to those of yarn dyeings, with which the piece dyeings combine simplification of layout, production and stocking of spare parts.

In velour manufacture polyacrylonitrile yarns are to an increasing extent combined with yarns made from other raw materials, e.g. with cotton, polyester, or viscose, amongst others. Not only in yarn-dyed items are attractive effects produced by this, but also in piece dyeings, for which not only raw white yarns but also super dye fast dyed yarns are used for special effects.

Whirled designs are produced by means of rotating or traversing brushes (Figs. 2–7) with or without a screen and with subsequent design setting. “Setting” is also normal for polyacrylonitrile fibres, but it does not mean the same as in crystallites, e.g. polyester. For polyacrylonitrile fibres this means the production of a permanent structural change, which is not reversible, e.g. the triggering of a shrinkage or residual shrinkage. The drawing of pile fibres by heat and mechanically for

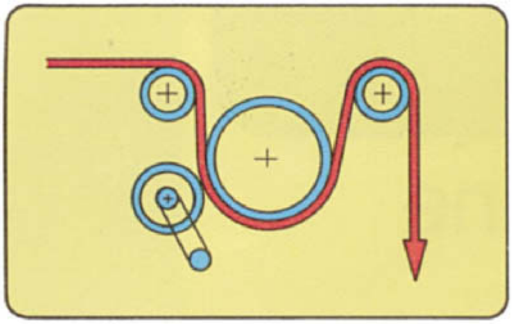


Fig. 2: Embossing upholstery velour fabrics.

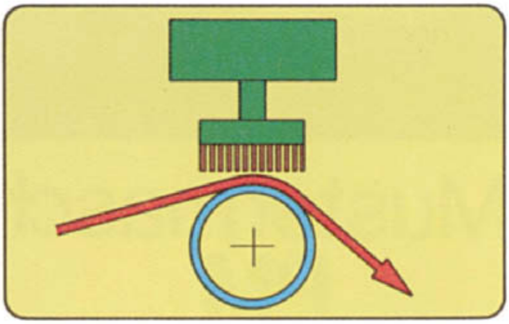


Fig. 3: Whirled pile finishing of upholstery velour fabrics with round brushes.

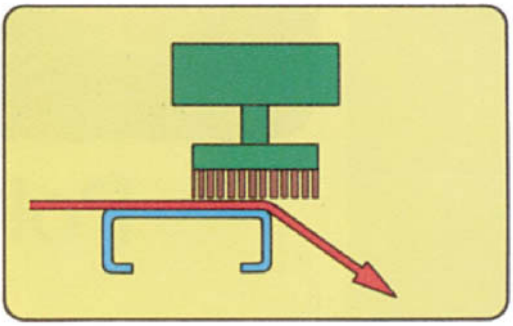


Fig. 4: Flat-table whirled pile finishing of upholstery velour fabrics with round brushes.

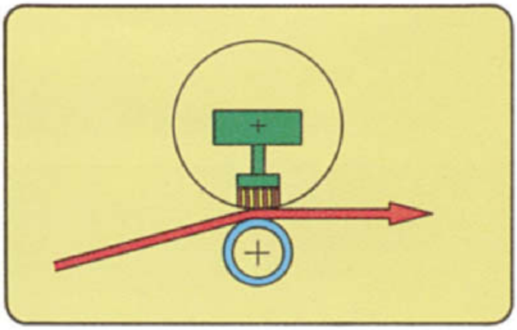


Fig. 5: Screen drum whirled pile finishing of upholstery velour fabrics with round brushes.

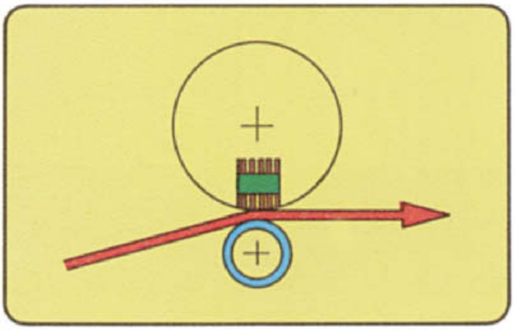


Fig. 6: Screen drum cross-brushing of upholstery velour fabrics with a brush bath.

the purpose of partial or complete uncrimping also results in a certain determination of this state, as the fibre crimping in velours may still be returned into a very small part again. The piece good is actually deformed in a tumbler by heat recovery, above the glass temperature to produce crush-effect designs. Embossed designs in wool and viscose fur fabrics already existed before the production of polyacrylonitrile fibres, but they have

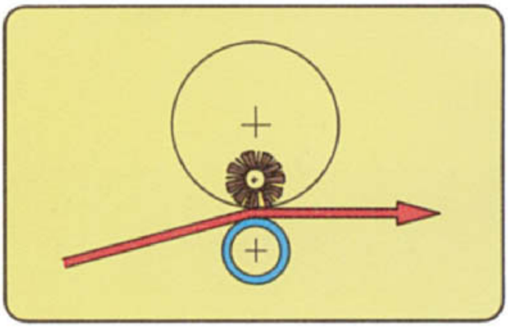


Fig. 7: Screen drum long-brushing of upholstery velour fabrics with a brush roller.

only been made more seriously available on the polyacrylonitrile velour market in recent years since it became possible to keep the surface temperature of embossing rollers almost constant within narrow limits. All types of polyacrylonitrile velours can be supplied with embossed designs and new, versatile designing possibilities are added. This does not only concern the copying of woven designs, but also fantasy designs.

The upholstery market demands especially highly inflammable fabrics. This objective cannot, however, be achieved by using highly inflammable fibres in the pile, otherwise modacrylics could possibly help, but these lack versatility in supply and usability. The back design and/or behaviour of the entire material plays an equally important role, which is why velour manufacturers are either forced to process highly inflammable fibres into the rear yarns or to finish the velours with suitable chemicals or to combine both options (according to Hoppenz).

Upholstery fabrics As woven, warp-knitted, raschel-knitted fabrics and stitch-bonded fabrics in wool, polyamide, polyacrylonitrile, cellulose and blends. Collective term for covering, hank stretching and padding fabrics of different type and composition, e.g. upholstery brocade, cord, damask, gobelin, moquette, plush, rib fabrics, etc.; partly also as → Furnishing fabrics and hemmed for couch and table cloths. Exceptionally complex market. Anti-soiling finishes, no pilling, high light fastness, good colour fastness to rubbing (wet and dry) are demanded.

Upholstery velour fabrics – development of lustre in use A typical property and characteristic of all velour qualities which manifests itself during use are variations in the lay of the pile which are visible to a greater or lesser extent and which are associated with differences in light reflection. The development of lustre in use, therefore, is not an indication of defective quality nor does it signify any deterioration in the serviceability of the article.

UPN Urad pro Normalizaci a Mereni, Prag;

Polish Office of Standardization and Metrology; → Technical and professional organizations.

Upper knife Part of the cutting gear on → Shearing machine.

Upright pile finish Plush fabrics with pile made from cotton fibres are impregnated with synthetic resin, brushed, dried and set. The pile stands up again after being pressed down.

Upright pile velvet Raised fabric with velvety appearance. The napped fibres stand vertical (opposite → Nap velours). → Pile lifter.

Uranium (U), atomic weight 238.07. Element of pitchblende. Is of importance as the basis of atomic nuclear energy.

Urea (carbamide, urea), $CO(NH_2)_2$. Molecular weight 60.12; density 1.335; melting point 133°C. Long crystals, colourless and odourless; easily soluble in water or alcohol, neutral solution. Properties: dye dispersing and releasing force; methylol compounds (→ DMU) of the urea are important resin finishing agents, self crosslinking resins. Use: addition in wool vat dyes (printing); manufacture of slip resistant, crease-resistant and shrink-proof finishings, delustrings, special processes, etc. Urea causes better accessibility of cellulosic fibres to reactive dyes and accelerates their diffusion into the fibre core (= improved full penetration dyeing). Predominantly less substantive reactive dyes and polyamide dyes are suitable for this machine-intensive continuous process due to shorter diffusion and setting times. Work with urea is accompanied by a less pleasant appearance though, as it decomposes at temperatures > 133°C:

$$H_2N–CO\boxed{–NH_2 + H–}NH–CO–NH_2$$

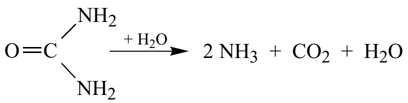
$$\longrightarrow NH_2–CO–NH–CONH_2(I) + NH_3\uparrow$$

$$OC(NH_2)_2 \longrightarrow NH_3(II)\uparrow + NCOH$$

$$3\ NCOH \longrightarrow (NCOH)_3(III)$$

Urea decomposition products form smoke in the setting machine, which can have a disturbing effect. → Dicyandiamide is therefore used as a urea substitute in the → ATE process.

Urease Urea-breaking enzyme, belonging to →: Hydrolases; Amidases. Gradual degradation into ammonia and carbonic acid results with water absorption:



$$O{=}C(NH_2)_2 \xrightarrow{+H_2O} 2\ NH_3 + CO_2 + H_2O$$

in which partially decaying ammonium (hydrogen) carbonate forms again. Urease was of great importance in wool finishing with urine (wool washing, indigo vat). Manufacture in purely crystalline state from the jack and soya bean since 1926. 1 g of urease splits almost 60 g of urea in 1 min at 20°C. Urease is inactivated by low quantities of heavy metal ions (Cu) (immobilisation of active groups through complex formation), which can be reversed again by adding cyanides or hydrogen sulphide.

Urea-Bisulphite solubility (UBS, Ger.: HBL), UBS reaction, was developed in order to determine the alkali damage to wool without costly mechanical tests and, for example, to differentiate from acid damage. The UBS is changed depending on the treatment of the wool (steaming, alkaline influences, heating, etc. reduce the UBS, however acidic and oxidative influences increase it). Especially important for comparison between untreated and treated wool (degree of damage). Implementation:

1. Determination of the dry weight m_1.
2. Place second wool sample in a 65°C solution, which contains 50 g of urea and 3 g of sodium pyrosulphite ($Na_2S_2O_5$) in 100 ml and has been adjusted to pH 7 using NaOH. Therein treat for 1 hour, filter and determine dry weight m_2 of the residue.
3. Calculation of the dry weight m_1 for 2 from 1 in g.

$$\text{UBS in \%} = \frac{m_1 - m_2}{m_1} \cdot 100 \quad \text{for acid free wool}$$

$$\text{UBS} = (\text{UBS} - S) \cdot \frac{100}{100 - S} \quad \text{for wool containing acid}$$

S = acid content in % of the dry weight.

The UBS is based on the reductive breaking of cystine bridges using hydrogen sulphite ions. 1 mole cysteine and 1 mole cysteine-S-sulphonates (bunte salt) are thereby formed from 1 mole cystine.

$$>CH–CH_2–S–S–CH_2–CH< + HSO_3^-$$

$$\longrightarrow >CH–CH_2–SH + >CH–CH_2–S–SO_3^-$$

The new crosslinkages formed from the cystine in alkali effect on wool are not broken by a sulphitolysis. Treatment of wool in alkaline baths may result in a considerable acceptance of the UBS, which is normally 40–50%. The extent of the reduction in solubility is thereby in direct correlation with the newly formed crosslinkages and provides an indication of the degree of alkali damage.

Urea-formaldehyde compounds Condensation products made of urea and formaldehyde (→ Dimethylol urea), partly also etherised with methanol (→

Dimethoxymethylurea); → Self crosslinking resins. Used as finishing agents amongst other things.

Urea-formaldehyde Resins → Urea-formaldehyde compounds.

Urea-free printing (→ Urea in textile printing). Dye manufacturers try to replace urea as a hydrotropic agent with low molecular surfactants. Since the spray technique using rotor damping may in the meantime be described as technically dated, the use of this device has proved to be more successful than a print steamer on a semi-technical scale in order to fix reactive prints on viscose without using the waste water problematic urea. In normal setting yields of 60% effectively fixed dye (referring to the dye used, the K/S value is = 100%) the best colour yields are achieved at approx. 30 % rotor damping before entering the steamer: The reactive group of the dye has a certain influence on the print result in so far that MCT dyes with 0 % moisture without urea hardly react (K/S value = 30%), against which spraying with water in the absence of urea achieves an improvement in colour intensity.

Vinylsulphone dye produces a K/S value of 126% under these conditions, while the dichlorotriazine dye is 110%. Speculation should not be made about the reasons for successful urea-free reactive print on viscose. It is however valuable for printing practice that there is a possibility of satisfying extensive environmental requirements.

Urea in textile printing There are official measures to discharge nitrates from drinking water. These are produced in excess due to the ground water being overloaded with nitrogen compounds via the natural nitrogen circulation and their equilibrium transfer. That is why the elimination of urea from printing recipes or at least the reduction of its concentration in the waste water from after-print washings is striven for. But for reasons of print technology and colloidal chemicals, the elimination of urea from the recipes is not easy. Dried prints are usually steamed after a certain intermediate storage period with a low moisture content. Special viscose fibres collaborate so much in deswelling during drying, that re-swelling during steaming is aggravated as a pre-condition for the inner diffusion of the dyes. Because swelling is an exothermal process, fibres as well as the dried out thickener should be swollen before steaming at room temperature if possible. The transmission of dyes from the print paste onto the fibre requires humidity for diffusion in most dye classes. Part of the water quantity required is obtained from steam condensation on the “solid fabric” when the dry fabric enters the steamer. The condensate quantity is determined by the specific heat of the printed fabric and by the temperature difference between the fabric entering the steamer and the boiling point of water under the prevailing steam conditions. The specific heat of cellulosic fibres and natural thickeners is approx. 1.26 kJ/kg · °C (0.3 kcal/kg · °C), that of the printing auxiliary at 0.42 kJ/kg · °C (0.1 kcal/kg · °C). Moisture on the fabric has a specific heat 4.2 kJ/kg · °C (1 kcal/kg · °C). So the presence of water influences the condensation of steam considerably more than the printed textiles. On the other hand, the steam composition in the steamer possibly varies considerably. Dry steam occurs if there is insufficient steam supply, and saturated steam conditions cannot always be evenly adjusted in the steamer, which is why a constant high temperature of 102°C is demanded by “good” steamers.

A careful selection of reactive dyes from the point of view of “compatibility” is beneficial in preventing yield differences (and therfore the shade variations from batch to batch) as a result of temperature/humidity fluctuations in the steamer. Circulation steamers with moisture injection also increase the reproducibility of the printing result, in particular in reactive dye printing on cellulosic fibres, and with the printing performance. Above all the addition of urea to the reactive stock colour pastes (besides the quantity of alkali) reduces the demands on the steam quality as regards the fixation of different reactive dyes. This is because urea with the condensed steam forms a “melt” on the fabric, which only releases the water again at temperatures above 115°C. But the use of urea should not only be optimised for ecological reasons mentioned at the start, but also from the point of view of the ability to store the dried fabric. The composition of the reactive stock colour pastes as regards quantities of alkali and urea is usually a compromise, which is determined by the reactivity of the dyes and by their sensitivity to hydrolysis compared with moisture (absorbed by the urea in dried printing).

Thickeners can only bring their flow properties to bear when they are swollen with water. But even during the steam process the polymer thickeners, which were deswollen by drying, have to swell quickly again, i.e. the dried thickener film (micelles, networks) have to be expanded and separated if the diffusion of dyes and chemicals from the print paste film is to be eased into the fibre. To what extent the solute cases of a thickener are constructed and decomposed, amongst other things, essentially depends on the chemicals, which promote the thickener being absorbed in water. Urea promotes water absorption during steaming in varying ways depending on polymer thickener for example. The hydration spheres of the urea molecules taken up onto the polymers are the amino groups directed outwards. The hydrophily of the polymers is therefore increased by the amino groups; but the take up can also promote the swellability of the polymers without increasing hydration if the cohesion of the macromolecules is reduced. In addition, urea functions in the dried on print paste (also in the preparation of the print paste) as a hydrotropic agent. As a water-soluble compound itself, urea increases the water solubility of the dyes broken down in the dried print paste, depending on the quantity used. In order to overcome the intermolecular forces (due to the short liquor-to-goods-ratio during printing and steaming) of less soluble dyes, a third, solution-conveying component is required, which introduces dissolving properties together with water. The surface tension of the water should firstly be reduced in the course of this before hydrogen bond interactions can come into force in the ternary system.

The hydrophilic amino groups of urea reduce the surface tension of the water and so cause the structure of the water in direct proximity to the solid dye to be dissolved, which promotes the dissolving process. The carbonyl group on the other urea dipole end has (in contrast to the amino groups with their hydrogen donor properties) an affinity for electrons: both carbenium C atoms and semipolar absorbed oxygen appear as a mesomeric restricted form, which is why energy exchange is possible with other organic reaction partners (the chemically diverse dyes). Under these circumstances, the question arises as to whether urea can be dispensed with in the formulation of dyes, in the fixation of prints in the steamer and also in the printing area (when the screens have a tendency to addition). On the one hand, it is difficult to define where the hydrotropic character of a compound stops and, for example, its surfactant character begins. On the other hand small surfactant molecules also have typical dissolving properties in water and have already been tested as alternatives in order to replace urea.

Urea peroxide → Carbamide peroxide.

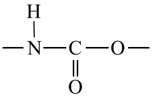
Urea reagent is used to identify urea (derivatives) in textile materials finished with relative synthetic resins. Is based on red dyeing of hydrolytically released urea through furfural in the presence of acetone. Reaction is regarded as specific (possible fault in dyed goods by acetone soluble dye). Sensitivity 0.5 mg (2g/l of urea can certainly still be identified). Urea reagent production (always fresh, will only keep for 2-3 hours, colour yellowy gold initially, then changes to brown) made from 20 ml acetone, 20 ml water, 10 ml concentrated hydrochloric acid and 1 ml furfural. Mode of operation: heat to boiling approx. 10 cm^2 testing section in the reagent glass with 5-6 ml of freshly produced urea reagent, leave to stand, orange to red dyeing after a few minutes. Melamine resins do not give this reaction.

Ureides Organic acid derivatives, related to → Acid amides, whereby instead of the NH_2 group the urea radical $-NH–CO–NH_2$ is joined in the carboxyl group (–COOH). Example: acetic acid ($CH_3–COOH$) → Acetic acid ureide or acetyl urea ($CH_3–CO–NH–CO–NH_2$).

Urena fibres → Bast fibres (e.g. aramina fibre, congo jute) from many tropical countries (Brazil, Madagascar), similar to → Rosella as a jute substitute.

Urethane elastomer → Polyurethane elastomer fibres.

Urethane group Basically weaker compared with the → Carbamide group (–NHCO), affinity only to disperse and selected acid dyes (below pH 2).



$$-\overset{\overset{\displaystyle H}{|}}{N}-\underset{\underset{\displaystyle O}{\|}}{C}-O-$$

Urethane rubber → Polyurethane rubber.

Urethanes (carbamates, ester amides). CO(OR)(NH_2), the compounds of carbonic acid intended here can be interpreted as esters of → Carbamic acid. Due to their chemical relationship to urea they are called urethanes (of → Urea), whose structural principle is represented in → Polyurethanes.

Urone (urone ethers), as an N,N'-Bis (methoxymethyl) compound used as a reactive resin; → Dimethoxymethyluron.

Useable area Useable layer in fitted carpets, in accordance with DIN 61 151: the surface of fitted carpets needed in use.

Used Equipment Worldwide Guide Trilingual directory for used equipment from more than 1000 dealers. Trade publications from the International Institute for Used Machinery.

Useful life of working The time required for using the production resources in the → Processing sequence. In the case of their use one talks of machine time (main machine time, secondary machine time), in contrast to idle machine time (processing sequence dependent, decommissioning, fault-dependent, work-dependent).

U-shaped curved tubes Material carriers for hank yarns for dyeing in liquor, especially using sulphur, vat dyes and similar.

U.S.P. (A.P.). U.S. patent, American patent.

USPO United States Patent Office; → Technical and professional organizations.

USS United States Standard.

U.T.I.T.B. Belgian Union of Textile Engineers and Textile Plant Managers; → Technical and professional organizations.

UV Absorber Substances, which absorb → Ultraviolet radiation and protect such fibres, dyeings and/or skin. Term, which in the broadest sense also includes → Fluorescent brightening agents. In the narrower sense, however, UV absorbers are understood to mean those organic compounds (with carbonyl and hydroxyl groups), which protect from and/or make inactive harmful, especially UV, contents of solar radiation (important for example in polyurethane fibres). This does not happen via emission (light radiation), but via light absorption and is usually expressed in the appearance of complementary yellow shades of colour. The light protection effect can be controlled by preserving the tear strength, for example, and/or the degree of polymerisation. According to the present level of experience, UV absorbers can be washed off more or less quickly (loss of light protection effect).

UV calibration device Supplementary device for measuring fluorescing white samples with spectrophotometers and triple zone devices with sample lighting similar to daylight. Is used for the regular compensation of lamp alteration and resultant reduction of radiant energy in the UV range. It is a prerequisite that when using new lamps a UV excess is available first. Until now only possibility for measuring fluorescent brightening with good long-term reproducibility and/or elimination of differences in the white rating using various measuring instruments.

UV Excimer radiator UV rays belong to the spectrum of electromagnetic waves. They belong to the short-wave part of visible light and extend to the other side up to the ionising rays (X-ray radiation, γ radiation). Usually a range of 100–400 nm is given, which is further subdivided into UV-A, UV-B and UV-C for practical considerations. The conventional division of the UV spectrum in the FRG is (Fig. 1):

UV-A:	315–400 nm
UV-B:	280–315 nm
UV-C:	200–280 nm
VUV:	100–200 nm

Industrial processes use UV radiation for
- drying paints,
- harmful pollutant degradation,
- photochemistry,
- medical treatment,
- depositing of thin metal, insulator and semiconductor layers.

Only a few powerful UV radiators had been used for these processes until now. These include electrically powerful arc discharges in xenon and mercury/inert gas mixtures. It is common to both that they have a broad emission spectrum. Besides the desired UV radiation, UV radiation of other wavelengths, visible light and IR radiation is also emitted. In contrast, selectively intensive UV radiation can be produced at a certain wavelength using excimer UV radiators. The excimer formation known from UV lasers is thereby used in certain gas mixtures to produce incoherent UV radiation.

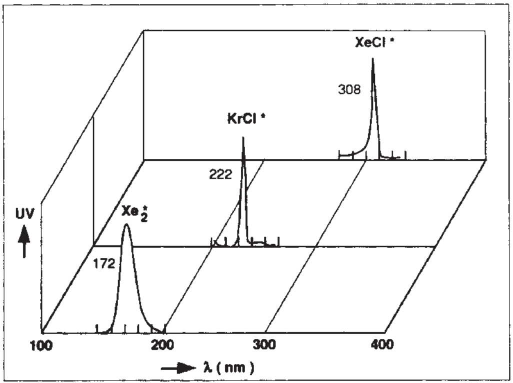


Fig. 2: Emissions spectra of some excimer radiators (according to Heraeus).

Fig. 2 shows the narrow-band emission spectra of a xenon excimer radiator (λ = 172 nm), a krypton chloride radiator (λ = 222 nm) and a xenon chloride radiator (λ = 308 nm). A large number of excimers is well known so that a suitable gas mixture can be selected virtually for every desired wavelength range. Com-

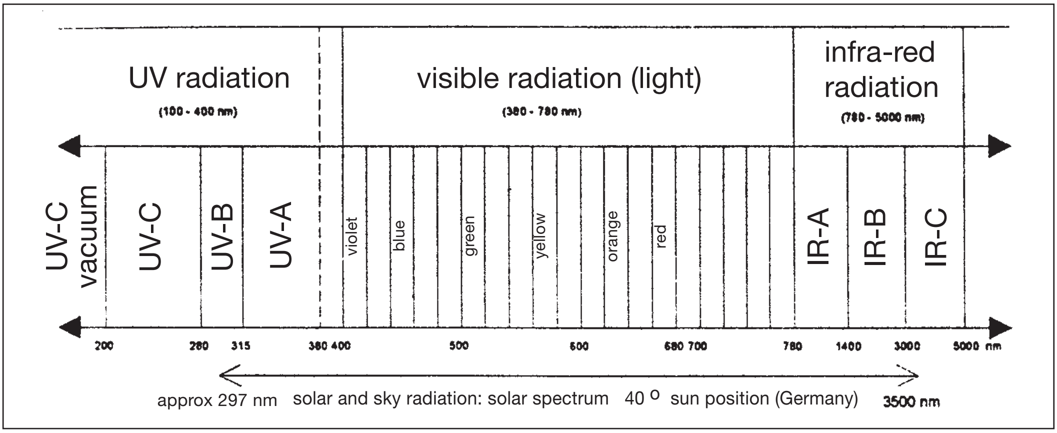


Fig. 1: Electromagnetic optical radiation wave spectrum.

pared with other UV sources, extremely high radiation doses can also be achieved in the VUV using the excimer radiators. The advantages of excimer radiators are:

- monochromatic, not coherent,
- wider range of achievable wavelengths,
- simple structure,
- variable geometry,
- high degree of efficiency in the deep UV, no heat influence from the radiated material,
- immediate start, re-ignitable, pulsable,
- no electrodes in the discharge area,
- ozone-free model possible.

A simple model of excimer radiators consists of two coaxial, cylindrical quartz tubes, which are gas tight connected. The excimer gas is in the gap between the tubes; the electrodes are located outside the discharge area (Figs. 3 and 4).

Besides the cylindrical discharge geometry, low UV sources and special geometries can also be achieved for photochemical reactors. The flexible geometric arrangement of excimer radiators can be extensively adapted to the object to be radiated in many cases.

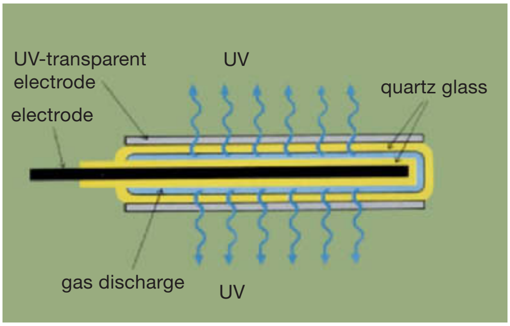


Fig. 3: Excimer radiator structure (according to Heraeus).

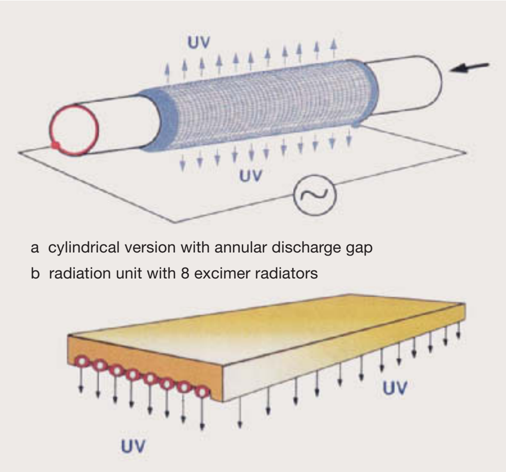


Fig. 4: Schematic structure of the new excimer radiator (according to Heraeus).

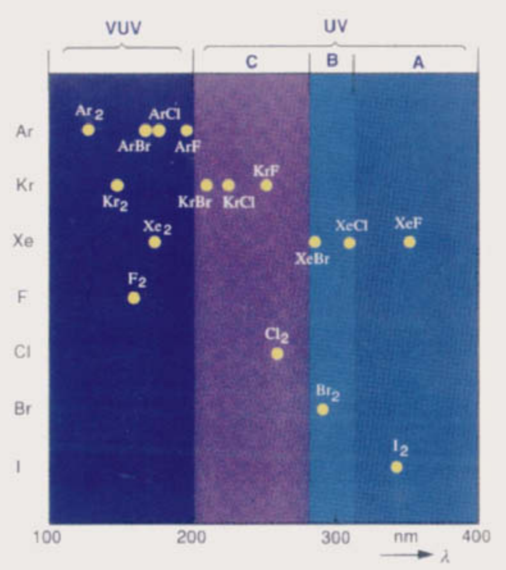


Fig. 5: Emissions wavelengths of various excimers (according to Heraeus).

A number of gases are available, which can be activated to form excimers in this way (Fig. 5).

The excimer formation is carried out in a so-called “still” and/or dielectrically obstructed discharge. The discharge area is hermetically sealed by a dielectric (quartz glass); the electrodes are outside the discharge area. Still discharges are carried on using alternating voltage. The current flows in many micro discharges, short airflows each of only a few nano seconds duration. The excimer formation takes place exclusively during these discharges. Free electrons are present, due to the short current pulses, in order to stimulate the atoms of the molecules of the gas emitted during charging. During this surge process (Fig. 6 a) an atom or molecule assumes almost the entire energy of an electron in fractions of a nano second and is thereby transferred into an excited state (Fig. 6 b). The electron, which flows after the surge with a much reduced speed, must be accelerated in the dielectric field again in order to be able to excite another atom. The excited atom may however then collide with the numerous neutral atoms present and so form an excimer (Fig. 6 c):

$$e + Xe + Xe \rightarrow e + Xe + Xe^* \rightarrow Xe_2^* + e$$

The excimer molecule is not very stable. It decays within a few nano seconds and delivers the excitation energy in the form of a UV proton (Fig. 6 d):

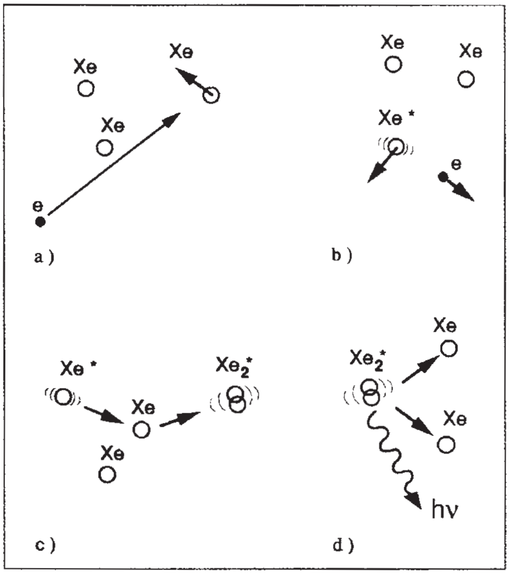


Fig. 6: Diagram of the excitation process of excimer formation and UV production.
Xe = xenon in its normal state; Xe = excited xenon atom; Xe_2^* = xenon excimer; e = electron; hv = UV photon.*

$$Xe_2^* \rightarrow 2\,Xe + \text{UV photon (172 nm)}$$

(according to Heraeus).

UV fluorescent dyes → Fluorescent dyes in combination with UV irradiation. Application → UV marking pen.

UV-induced oxidation of waste water Oxidation is a process for waste water treatment. It is used for decontaminating hazardous substances such as cyanide and nitrite and for decomposing organic substances, which are recorded by the summation parameters COD or BOD. Oxidizing agents can be used for all these reactions, whereby they frequently contribute to the formation of substances harmful to the environment or contain such substances. Hydrogen peroxide, oxygen and ozone are considered by preference, as they make no contribution to the salt accumulation in the water. Oxygen only reacts in an activated and/or atomic state in the desired manner.

Oxidation occurs when electrons are extracted from the substance being oxidized. It should not be characterised by the uptake of oxygen. How easily or how difficultly a substance can be oxidized and how strongly an oxidizing agent works (standard potential) is decisive for oxidation. The more positive this is, the stronger is its oxidizing effect. All substances, whose standard potentials are more negative than one of those given in the Tab., can be oxidized by the respective oxidizing agent. This illustration shows that hydroxyl radicals still exceed the high oxidation affinity of ozone. A hydroxyl radical has the positive standard potential of all oxidizing agents both in the acidic range (+ 2.8 V) and in the alkaline range (+ 2.0 V).

Radicals are changeable compounds or atoms, which are only produced by expending energy. After interrupting the energy supply they immediately turn into stable inert or non-reacting compounds, by releasing energy. But as radicals they are capable of reacting severely with other partners. If they have an oxygen balance such as the OH radical, this occurs via oxidation of other substances.

OH radicals are produced by electrolysis through discharge of OH ions on the anode, by the effect of UV radiation on ozone in the presence of moisture and by the irradiation of solutions containing hydrogen peroxide with UV light. Of these three possibilities the last mentioned should be preferred, as the oxidation of substances using OH radicals takes place in a homogeneous medium. The technical reaction difficulties do not thereby occur as they are present in the heterogeneous reactions (reaction on the solid/liquid interface as in anodic oxidation or on the gaseous/liquid interface, as in ozone reaction).

The activating influence of the energy from electromagnetic radiation on different kinds of substance is well known. Its effect thereby extends from the stimulation to rotation and oscillation in the molecular range by IR radiation via the stimulation of electrons in the molecular and atomic range due to radiation of the vis-

oxidizing agent	redox reaction*	E° in V*
oxygen (atomic)	$H_2O \rightleftharpoons O + 2\,H^+ + 2e$	+ 1,229
chromate	$2\,Cr^{+++} + 7\,H_2O \rightleftharpoons Cr_2O_7^{--} + 14\,H^+ + 6e$	+ 1,33
hypochlorite	$oce^- + H_2O \rightleftharpoons HOCl + H^+ + 2e$	+ 1,495
permanganate	$Mn^{++} + 4\,H_2O \rightleftharpoons MnO_4^- + 8\,H^+ + 5e$	+ 1,51
hydrogen peroxide	$2\,H_2O \rightleftharpoons H_2O_2 + 2\,H^+ + 2e$	+ 1,776
ozone	$O_2 + H_2O \rightleftharpoons O_3 + 2\,H^+ + 2e$	+ 2,07
hydroxyl radical	$H_2O \rightleftharpoons {}^{\bullet}OH + H^+ + e$	+ 2,8

Tab.: Comparison of the oxidation potential of some oxidizing agents.
** in an acid medium; the standard potentials E^0 are smaller in alkaline media.*

ible and ultraviolet light, to the ionizing effect of electromagnetic radiation of even shorter wavelengths. If radiation of a particular frequency meets with a response in the molecular and atomic range, it is expressed in the fact that the radiation is absorbed. The absorbing substrate is thereby in an excited, high energy state, in which it reacts with another substance more easily and/or the radiated energy is sufficient to convert the substrate itself (photochemical reaction).

Hydrogen peroxide absorbs electromagnetic radiation in the short-wave UV range, the so-called UV-C range (200–280 nm). So a photochemical reaction occurs, which divides the hydrogen peroxide molecule into two OH radicals.

$$H_2O_2 \longrightarrow 2\,\dot{O}H$$

Due to their high oxidation potential, these radicals are capable of oxidizing substances, which cannot be oxidized using other oxidizing agents. They are also in a position to react with themselves in reverse of the equation and using hydrogen peroxide by forming O_2H radicals (hydrogen peroxide radicals). Oxidizing agents are always formed again with the exception of the reaction of OH with O_2H radicals, which by breaking chains results in water and oxygen.

Depending on the wavelength and/or the frequency (ν) of the light, a very specific amount of radiation energy is required to convert a molecule (quantization of the light). The unit of this light energy is called Einstein (E).

$$E = h \cdot \nu$$

h = Planck's actuating constant ($6.63 \cdot 19^{-33}$ *Js).*

In order to convert 1 mole of a substance using photochemical reaction, $6.02 \cdot 10^{23}$ E is required provided that each photon scores a hit on a molecule. This can be considered as a chemical reaction partner due to the quantization of the light. But as not every photon hits, the quantum yield is smaller than 1, and is smaller, the smaller the concentration of hydrogen peroxide is to be converted. So this is referred to as the quantum yield φ. This is the ratio of photons, which result in a photochemical reaction (hit), to the photons irradiated into the solution, which could trigger a photochemical reaction. The material turnover is larger, the higher the radiation output of the light source and the larger its UV-C yield to the OH radical formation.

The reaction finished products in the oxidation of organic compounds are carbonic acid, water, nitrate, sulphate and chloride. The oxidation consists of the photochemical reaction and the kinetic reaction. The reaction curves show, as long as there is still sufficient oxidizing agent (hydrogen peroxide) due to the radiation of constant light energy at the start a straight characteristic of a zero order reaction,

$$\frac{dc}{dt} = k_0$$

dc/dt describes the material turnover; k_0 is the velocity constant of a zero order reaction. The following oxidation reaction runs as long as the concentration of the substance to be oxidized is still relatively large and spontaneously so that the straightness of the reaction curve does not change at the start. If the concentration of the oxidizing agent is small at the end, the quantum yield is also low and the reaction is dependent on the concentration of OH radicals formed. The oxidation is at the same time also dependent on their concentration due to weakening concentration of the substance to be oxidized. The entire reaction then turns into a higher order pseudo-reaction as it is dependent on the concentrations of two reactions.

$$\frac{dc}{dt} = k_n \cdot c^n$$

k_n is the velocity constant of an nth order reaction; c the concentration of the substance to be oxidized. An odd number between two and three can be expected for n.

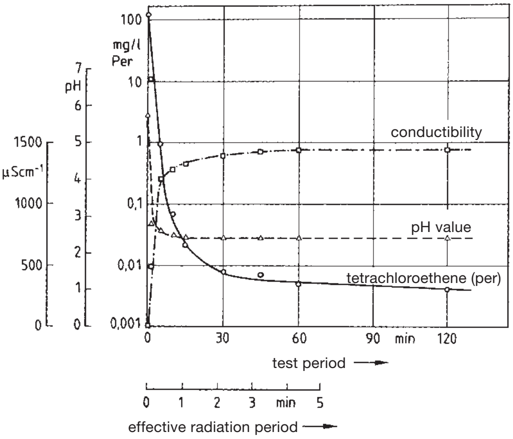


Fig. 1: Oxidative destruction of tetrachloroethene with hydrogen peroxide under the effect of UV radiation (according to Götzelmann and Hartinger).

A corresponding process for waste water treatment (Fig. 2) is suitable for the degradation of tetrachloroethylene in water (Fig. 1) (in accordance with Götzelmann and Hartinger).

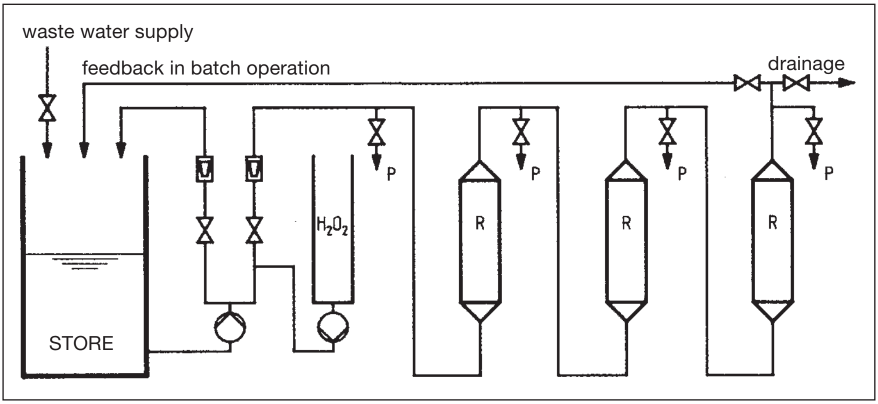


Fig. 2: Diagram of a waste water treatment plant (Goemalux) with three reactors for batch or continuous operation in series connection.

UV Lamp → Ultraviolet lamp.

UV marking pen Is used for the invisible labelling of material faults and pre-programmable material positions (combination using UV irradiation), also for valuable fabrics (carpets, fleeces, furs, etc.) for invisible sighting using recognition features. Constructed on a wax basis and in the form of → Retouching pencils. The fabric spot to be marked must be ironed so that UV dye penetrates into the fabric. Chiefly used for wool and wool blend fabrics, as cotton and synthetics do not absorb any wax.

UV radiation → Ultraviolet radiation.

UV sun protection of the skin UV light results in cell damage and creates inflammations on human skin. The most obvious consequence of the inflammation is the formation of an erythema (sunburn). Depending on the wavelength of the UV light, an erythema develops in accordance with widely varying absorbed radiation doses. The reciprocal value of these critical doses is called erythema effectiveness (EW(λ)). The harmful dose for each wavelength is the product of EW(λ), the sunlight output (P(λ)) for this wavelength and the time. The entire harmful dose is the total of these products.

Sun protection agents (sun cream or garments) absorb a part of the UV radiation and so reduce the amount of light hitting the epidermis and with that the harmful dose resulting in sunburn. The sun protection factor (SF) is defined as a quotient of the harmful dose without and harmful dose with sun protection. It can be calculated from EW(λ), P(λ) and from the wavelength-dependent transmission of the sun protection agent. The transmission of fabrics in the UV range can be strongly reduced by applying UV absorbers, i.e. the SF is increased (in accordance with Reinert).

UV transmission of textiles The transparency of cotton, silk, polyacrylonitrile and polyamide fibres is very high for UV radiation so that dressed skin is damaged by intensive sun irradiation. With UV absorbers, these fibres and/or the products manufactured from them can be given a high sun protection factor.

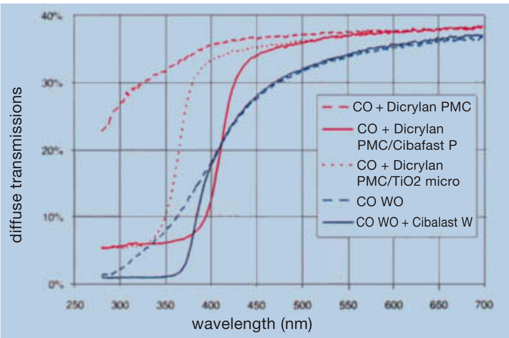


Fig.: Transmission spectra (diffuse light) of CO fabrics and CO/WO fabrics (intimately blended 50 : 50), with and without UVA. The CO contains the UVA in finishing (according to Reinert).

The Fig. shows the transmission spectra of cotton and cotton/wool fabrics. Small transmission values in the UV range correspond to a good screening from UV radiation or, expressed differently, a good sun protection effect.

UV/VIS Concerns → Spectroscopy in the ultraviolet/visual (= visible) range. Range of electromagnetic spectrum 200–800 nm.

V

V,

I. (Chem.). The symbol for vanadium.

II. (Phys.). The symbol for volt; the SI unit of potential difference, electrical potential and electromotive force (emf).

Vacuole (Lat.: vacuus = empty), a cell cavity found especially in plant and algal cells, including vegetable fibres, which takes up a large part of the cellular volume; fibre cavities, intermicellar regions, → Crystallites.

Vacuum (Lat.: vacuus = empty), virtually air-free space, negative pressure. Although, literally, a vacuum is defined as a space totally devoid of any matter, which does not exist on earth, the term is used loosely for an enclosed space within which the pressure of a gas or air lies below that of air at the normal atmospheric air pressure of 1 bar. For practical purposes, a vacuum is produced by means of → Vacuum pumps (single stage up to 95–99% vacuum). In textile finishing a vacuum is applied, e.g. in the printing of carpets on screen printing machines, to suck print paste through the carpet pile and achieve better penetration. In dyeing (→ Vacuum dyeing), attempts have been made to improve dye penetration on textile fabrics which are difficult to penetrate by saturating the material with dye liquor with the aid of a suction slot (see Fig.). In dry cleaning plants a vacuum is applied, e.g. in the still, as well as the machine system, when working with chlorinated fluorocarbons, (the use of these solvents is banned in the Federal Republic of Germany).

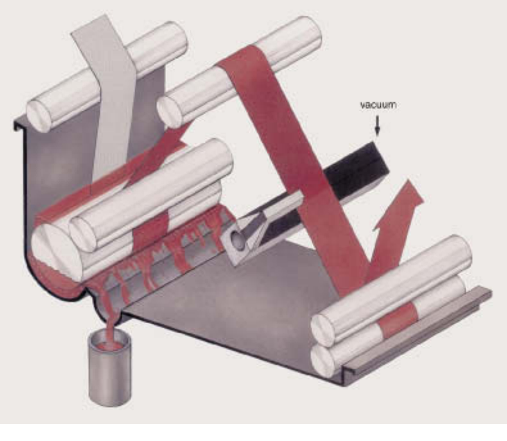


Fig.: Vacuum application in continuous dyeing by Evac-Küsters.

Vacuum breaker A ventilating valve for steam-heated equipment (e.g. feed water tanks) to protect the tank/unit against the build-up of excessive vacuum pressures. A vacuum is formed, e.g. in the feed water de-aerator by the choice of superheated steam to raise the water temperature and introduction of cold water at the same time, due to condensation of superheated steam which is still present. To prevent the build-up of excessive vacuum pressures, therefore, a flow of air into the de-aerator must be ensured by a suitable device as soon as a negative pressure develops in order to equalize the pressure.

Vacuum drier This type of drier is based on the principle of a → Suction-drum drier and has been designed particularly for drying yarn on packages or in the form of hanks at temperatures of only 40–70°C. The 3-phase vacuum drier (Fig.) works intermittently by alternating cycles of heating up under pressure and evacuation to allow vaporization at a lower boiling point. When boiler I is under vacuum, boiler II is heating up. Heating air is circulated by a fan (3), then passed through the heat exchanger (4) and into boiler II where the relative humidity of the air increases as heat energy is transferred to the wet textile material. During the second phase, the moist air is recirculated without cooling down to the heat exchanger (4) where it is heated again to penetrate the textile material. Thus, air with a relatively high moisture content is used to warm up the yarn, and this is also maintained towards the end of the drying process by steam injection. Air flow is automatically controlled by built-in multiple valves in the bottom of the boilers. When the heating phase is complete, boiler II is connected to vacuum. The change-over flap (1) closes, and the vacuum flap (8) opens. Vacuum pressure produced by vacuum pump (10) lowers the boiling point to 40°C and the moisture in the yarn is evaporated by heat energy contained in the yarn which is then condensed in the vacuum condenser (9). The cooling unit (5) cools the air during the first drying phase and also eliminates any rise in temperature from the heat of compression in the fan.

Vacuum dyeing

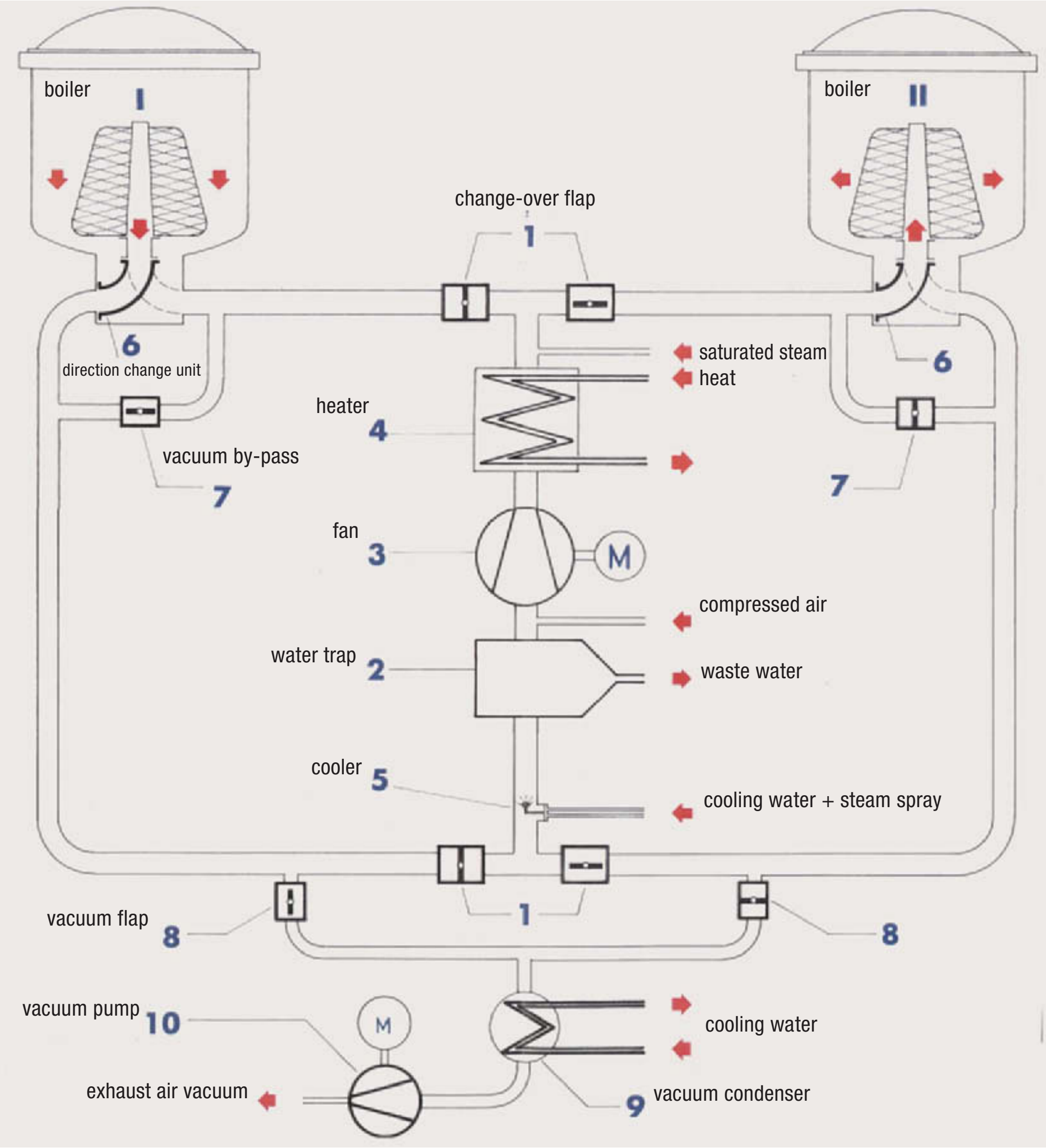


Fig.: Vacuum drier (MTM Obermaier).

Advantages of vacuum drying include: gentle drying conditions with no thermal damage to the fibre; no overdrying; uniform residual moisture content throughout the dried yarn; no migration of aftertreatment chemicals and softeners; no yellowing of the yarn; energy savings of up to 60% are possible when compared to conventional driers. Manuf.: MTM Obermaier.

Vacuum dyeing Fibres from which all the air has been removed in a vacuum wet out more rapidly and penetration of dye liquor into the material is more complete. Enclosed circulating liquor dyeing machines are suitable for this technology in exhaust dyeing. The technique is of particular interest for vat dyeing in view of the absence of air. Machines specially designed for pad dyeing applications are illustrated in Figs. 1 + 2.

After passing over a suction extraction cap via a draw roller to remove air, the fabric is run directly into the processing liquor. The vacuum unit consists of a suction cap, adjustable control system, vacuum pump

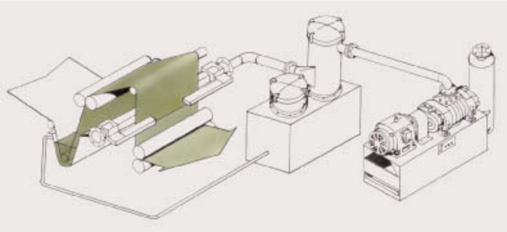


Fig. 1: Evac-Küsters vacuum impregnation plant.

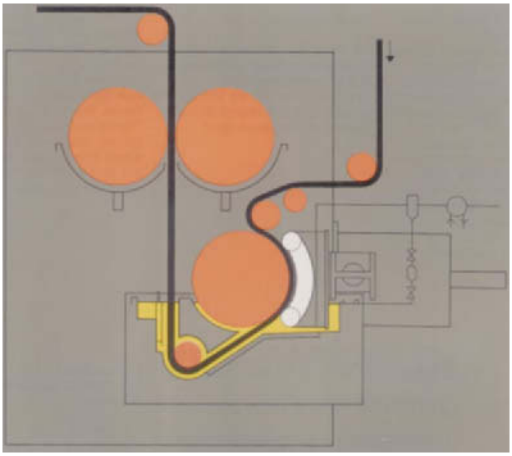


Fig. 2: Kleinewefers KTM Vacupad.

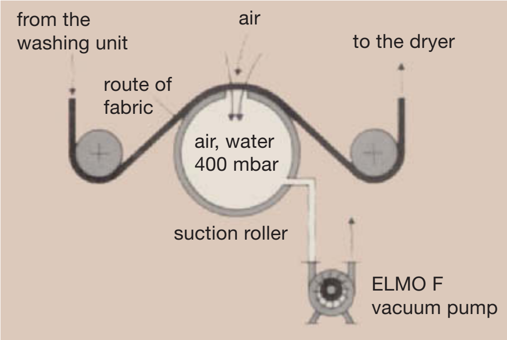


Fig. 1: Suction slit for vacuum extraction (ELMO).

Fig. 2: Tube-Tex-Jet-Extractor (vacuum extraction) for knitgoods.

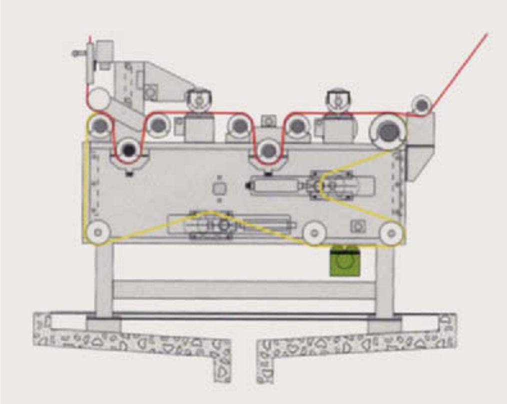


Fig. 3: Evac Ultraknit in diagram form.

and a draw roller. In the suction cap zone, air is removed from the fabric by a vacuum of 3325 Pa. The cap is sealed against the rotating draw roller. Control of vacuum pressure during the process is not necessary. Sealing of the suction cap and the liquid vacuum pump ensure a constant vacuum of 3325 Pa is maintained even during continuous operation. The driven draw roller is ground cylindrically. As with the suction cap, its dimensions are such that no deformation occurs under load. For fabric entry, the vacuum cap allows the fabric to leave the draw roller approx. 170 mm horizontally. The resultant impregnated fabric is squeezed off in the nip of a 2-bowl padder with deformation-resistant bowls. Up to 30% higher liquor pick-up is possible with vacuum impregnation.

Vacuum extraction of piece goods Surface water adhering to woven fabrics is easily removed through suction extraction by exploiting the principle of gas kinetics with the aid of a vacuum. In this process, the wet fabric passes over a suction slit (Fig. 1).

For knitgoods, on the other hand, finer suction slots are required such as those employed in the Tube-Tex-Jet-Extractor. In this system, superheated steam is passed through the wet fabric from above which then becomes saturated with water and is extracted underneath the fabric by means of a vacuum (Fig. 2).

In the Ultraknit machine of Evac-Küsters, wet fabric is transported through the unit on a conveyor so that vacuum extraction with high-performance suction slits is also possible (Figs. 3 + 4).

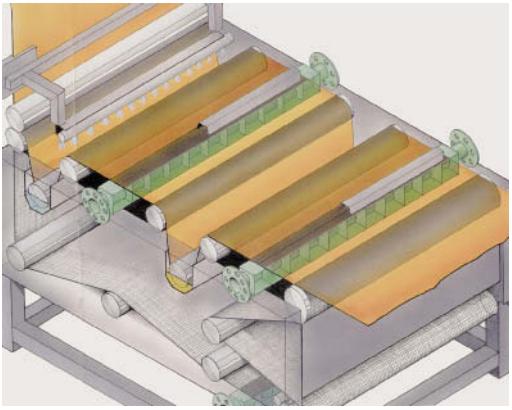


Fig. 4: Evac Ultraknit range.

Vacuum extractor for yarn packages A device for extracting water from yarn packages with a branch circuit to a vacuum station and an interrupter valve. The rapid intermission frequency developed by the latter produces shock-like suction pulses which entrain the bound water. Residual moisture content after extraction is approx. 100%.

Vacuum impregnation An impregnation technology for applications on the padder which removes the air present in the fibre's intercapillary spaces by means of a vacuum (3325 Pa) immediately before entry into the liquor (Fig. 1). After leaving the liquor, the fabric enters the air again. The penetration of liquor is more rapid and complete due to the extraction of air before immersion. Application of the vacuum principle offers savings in liquor consumption compared to conventional padders as well as reduced drying costs. The removal of air can also be achieved with steam. Besides its application in fabric pretreatment and mercerization, the technique is also used mainly for the application of dye liquors to circular-knit cotton fabrics, where savings of up to 20% dye are possible as well as more uniform dyeings (Fig. 2).

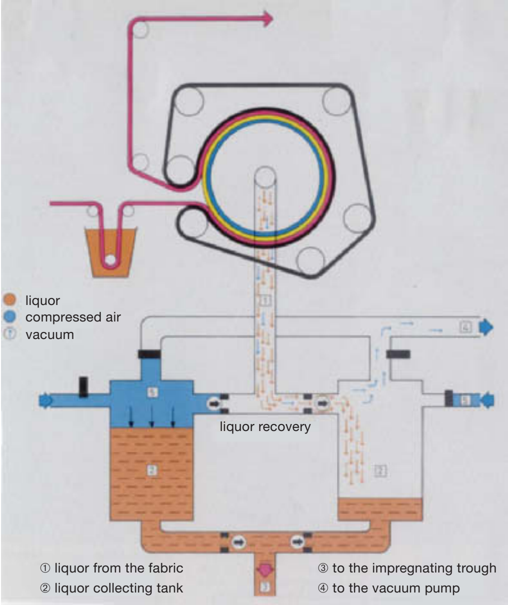


Fig. 1: Monforts Matex-Vac impregnation machine.

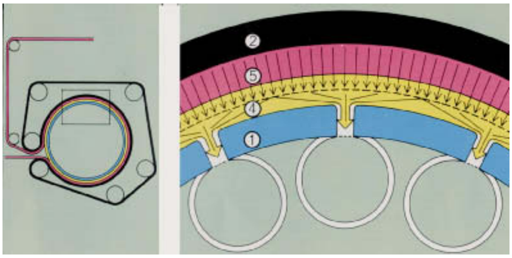


Fig. 2: Vacuum application and capillary active dehydration (Monforts).
1 = cylinders for vacuum; 2 = cover band; 4 = fabric; 5 = viscose nonwoven.

In the Farmer Norton vacuum impregnation unit the fabric is transported between an endless polyester film belt and a coarse mesh rotary screen. The vacuum and liquor tube assembly are mounted inside the screen as shown in Fig. 3. As the screen rotates it carries the fabric progressively under a high vacuum slot (A), then a slot filled with liquor to be applied (B) and finally a second vacuum slot (C). The endless belt prevents loss of vacuum and the screen prevents the fabric being

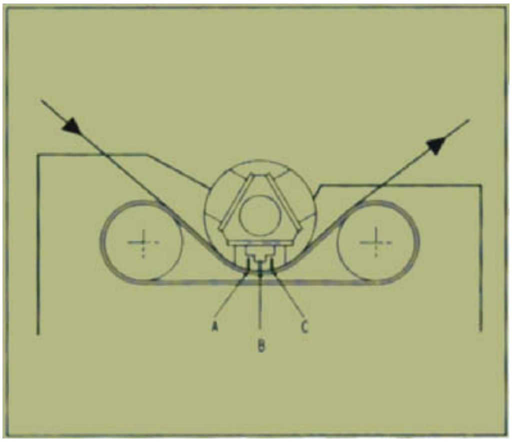


Fig. 3: Vacuum impregnation (according to Farmer Norton).

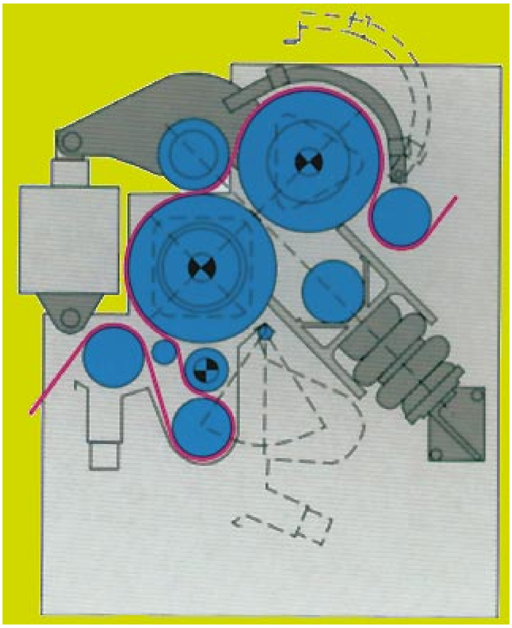


Fig. 4: Evac-nip.

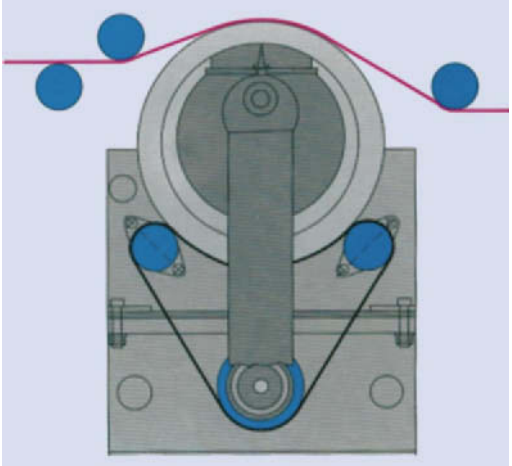


Fig. 5: Evac-roll for knitted good.

drawn into the vacuum slot. Consequently, the fabric is not subjected to any tension or drag. The flexibility of VAS-200 is achieved by independantly adjusting the level of vacuum applied to slot (A) and (C). In this way it is possible to adjust the amount of liquor first applied and then extracted from the fabric. This control allows the liquor pick-up to be adjusted from 35%–200%, as is nearly also the case in Küsters Evac-nip (Fig. 4) and Evac-roll (Fig. 5) for knitwear.

Vacuum mercerization → Vacuum treatment during mercerization.

Vacuum metallizing → High-vacuum metallizing.

Vacuum pumps → Vacuum technology pumps.

Vacuum sieving machine A → Print paste sieving machine which operates on the vacuum principle.

Vacuum strainers High-speed → Print paste sieving machine for sieving print pastes and thickeners with a sieving cycle of 1–3 min. These strainers are equipped with a liquid ring vacuum pump to ensure a long trouble-free life. Their function is to remove small particles of dust and other foreign matter from print pastes in order to prevent streaking or blocking of printing screens.

Vacuum suction device An open-width suction unit (Fig. 1) designed to reduce the liquor content of a textile fabric before drying, and before or after the application of chemical liquors (wet-on-wet treatment) for the removal of unbound water. Savings in drying energy are achieved. Vacuum suction units can also be retrofitted to existing machines. The use of an underliquor vacuum suction unit allows, e.g., the desizing of tightly woven airbag fabrics (Fig. 2).

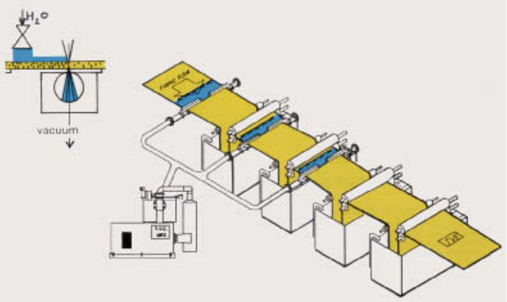


Fig. 1: Liquor spray vacuum suction process for rinsing the textile fabric after every roller vat treatment (TVE).

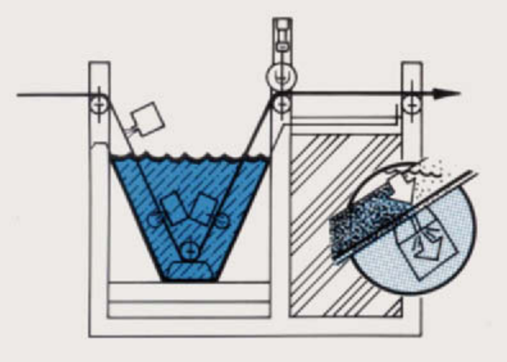


Fig. 2: Under-water suction with vacuum for intensive throughflow of especially thick fabrics (TVE).

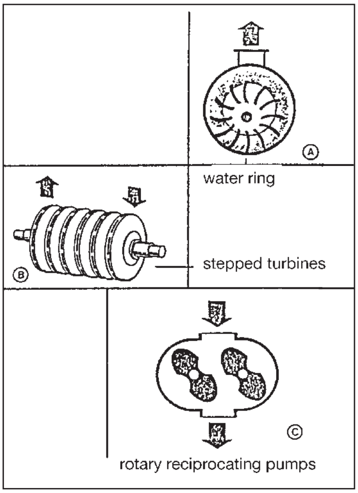


Fig. 1: Vacuum technology pumps.

Vacuum technology pumps The choice of pump system to produce a vacuum is determined by the field of application (Fig. 1). The following types of pump are used:

- water ring pumps,
- stage turbine pumps,
- rotary positive displacement pumps.

For the dewatering of carpets, water ring pumps appear to be the most popular choice.

Pumps are designed to displace gas against a pressure. In a typical vacuum pump an electric motor drives a paddle-wheel on a shaft which transports air regulated by a cam plate (Fig. 2). The intake valve is installed on the suction side of the system being evacuated. → Pumps.

Fig. 2: Exploded view of a vacuum pump (Siemens Elmo F) a) side casing; b) cam plate; c) impeller; d) floating ring seal; e) pump housing; f) motor.

Vacuum transfer printing machine The objective of this type of transfer printing machine is to achieve higher production speeds and improved print quality. It is essential that the air-permeable stainless steel conveyor, textile fabric and transfer paper are transported together before entry into the vacuum zone in order that the fabric passage can be checked and corrected if necessary without any intervention in the vacuum zone (Fig.).

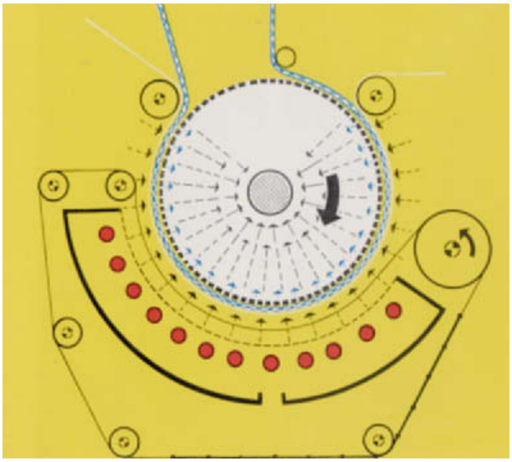


Fig.: Kannegießer Vacumat for continuous transfer printing.

Vacuum treatment during mercerization A method which requires the installation of a vacuum unit at the entry of a mercerizing machine in order to express air from a textile fabric before immersion in the mercerizing liquor. With an overhead caustic impregnation compartment this process offers some savings in floor space. Immediately before impregnation, entrained air is evacuated from the textile material which allows cold NaOH liquor to be forced into the still unswollen interior of the fibres by external overpressure during immersion. The vacuum cap is an essential machine element here.

Vacuum yarn steamer With automatic dosing of chemical additions. This type of steamer can be preprogrammed from 50–150°C in increments of 1°C with steaming times of 2–120 min (punched card controller). → Yarn steaming.

Vagabondo effect In addition to the “stone wash” treatment of denim articles to obtain various effects (e.g. “snow wash”, “moon wash”, “gold wash”, etc.) as well as sand-blasting to produce a fine, velvety handle, another process designed to give denim articles a modish character has established itself. This process, which is used to produce a so-called “vagabondo effect” on cotton goods, involves four stages:

1. Cationization of the cotton.
2. Dyeing with water-soluble sulphur dyes or selected reactive dyes. A pronounced ring-dyed effect is obtained due to the cationization treatment.
3. Enzyme treatment with cellulases to achieve an irregular and lighter colour.

4. Final finish to obtain the desired handle and other utility effects.

The enzyme treatment should be carried out in a drum washing machine (analogous to the “no stone” technique) in order to obtain an optimum “washed out” and “used look” effect.

Vagrant currents (stray currents). Stray electrical ground currents which are not infrequently responsible for severe electrolytic → Corrosion of underground water pipelines.

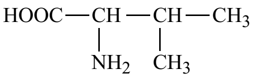
Val A derivation from equivalent weight which, expressed in grams, corresponds to 1 val of a particular substance. Thus, 1 val of a substance dissolved in 1 l of water = $^1/_1$ normal solution. $^1/_{1000}$ val = 1 millival (abbrev. 1 mval).
Terminology:

	val		mval
1 l	$^1/_1$ normal solution	= 1	= 1000
1 ml	$^1/_1$ normal solution	= $^1/_{1000}$	= 1
1 ml	$^1/_2$ normal solution	= $^1/_{2000}$	= 0.5
1 ml	$^1/_{10}$ normal solution	= $^1/_{10\,000}$	= 0.1, etc.

Consequently, 1 ml each of a $^1/_1$, $^1/_2$ and $^1/_{10}$, etc. normal solution corresponds respectively to 1, $^1/_2$ and $^1/_{10}$, etc. mval.

Valency The combining power of an → Atom or radical, equal to the number of hydrogen atoms that the atom could combine with or displace in a chemical compound (hydrogen has a valency of 1). →: Atomic bond; Chemical bond; Saturated organic compounds and Unsaturated organic compounds. Example: in one molecule of water H_2O, two atoms of hydrogen H combine with one atom of oxygen O: i.e. H–O–H. Therefore, H is monovalent and O is bivalent. Some elements can also have different valencies, e.g. copper (Cu) is usually bivalent and seldom monovalent. Similarly, iron (Fe) is trivalent in iron (III) chloride, $FeCl_3$, and bivalent in iron (II) chloride, $FeCl_2$. By analogy, groups of atoms (→ Radicals) also have their own valencies. A knowledge of valency therefore simplifies the understanding of chemical formulae and the representation of reactions in chemical equations. A distinction is often made between positive (metals) and negative valency (non-metals).

Valine → Amino acids (α-aminoisovaleric acid). A monoamino-monocarboxylic acid present in wool (4.72%) and silk (3.20%).



$$HOOC-\underset{\displaystyle NH_2}{\underset{|}{CH}}-\underset{\displaystyle CH_3}{\underset{|}{CH}}-CH_3$$

Valves Shut-off devices to control the flow of liquids, superheated steam and gases under high pressure through pipes. Operated by means of a hand wheel and a threaded spindle (the valve is always opened slowly otherwise a risk of bursting exists).

I. Globe valves (two-way valves) with drip catcher, valve cone, annular ring and valve seating.

II. Piston valves (plunger valves) with cylindrical piston and two gasket rings (upper and lower, liquid enters through louvres).

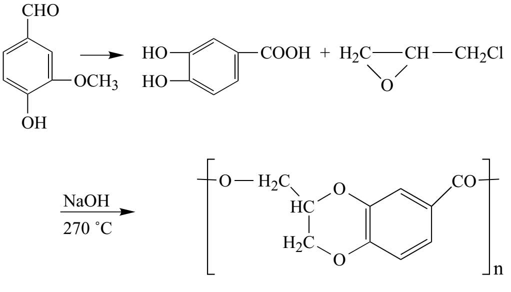
Valves are designed in various shapes and sizes according to the particular application, e.g. a) as shut-off, relief and overflow, bottom or dump, and dispensing valves (for mobile and highly viscous media as well as steam); b) electrically or thermally-controlled valves (for heating units, air compressors, cooling water pipes); c) piston slide valves (for steam); d) plastic valves (for acids, bases, salt solutions, various solvents, hydrogen peroxide: suitable for working temperatures up to 130°C); e) diaphragm valves (e.g. with exchangeable thick-walled rubber linings; positive operation; suitable for water, acids, corrosive liquids); f) pressure reducing valves (→ Reducing valves); g) self-closing and non-return valves (close automatically under back-pressure); h) acid valves (hard lead, iron-silicon, chromium-silicon); i) float valves (closed by a float-ball in an elbow joint); k) safety valves designed to operate with different safety loads or springs; used to prevent unacceptable increases of pressure in steam boilers, pressure pipes, water-heating systems, etc. and lastly as shuttle valves, forced safety release (on boiler shut-downs); l) glandless valves; m) feeler valves (with instantaneous shut-off for the humidification of textiles), etc.

Vanadium (V). A silvery-white ductile metallic element, atomic weight 50.95. Used as a hardening component in alloy steels and in the manufacture of vanadium compounds, e.g. → Vanadium dichloride.

Vanadium dichloride (vanadous chloride). VCl_2, molecular weight 122. Derivation: from ammonium metavanadate. Used as a catalyst in the dyeing and printing of aniline black (in solution 1:1000).

Van der Waals forces Weak attraction forces between molecules or crystals named after the Dutch physicist and Nobel Prize winner, J. D. van der Waals (1837–1923). They vary inversely as the sixth power of the interatomic distance and are due to momentary dipoles caused by fluctuations in the electronic configuration of the molecules. These forces are somewhat weaker than hydrogen bonds and far weaker than interatomic bonds. They are the forces responsible for the non-conformity of gases to the ideal gas laws and for the lattice energy of molecular crystals. The term is also used sometimes to include → Hydrogen bonds. Van der Waals forces are usually divided into two main groups, known respectively as polarization (or electrostatic) and dispersion forces. The former represent interactions between the electrons and atomic nuclei of different molecules lying in close proximity to one another. They involve incompletely compensated electrostatic attraction forces, i.e. intermolecular active residual valencies which are left over after saturation of principal valencies as so-called → Secondary valency forces, the function of which may be attributed to cross-cohesion between macromolecules. The reason why substances condense to form liquids or solidify to form solids at sufficiently low temperatures has also been attributed to the action of van der Waals forces. Likewise, the boiling point of a substance can be regarded as a measure of the strength of molecular excitation necessary to overcome van der Waals forces. These forces increase to some extent with increasing molecular weight. It therefore follows that heavy molecules are more strongly attracted than lighter ones. However, van der Waals forces only play a significant role if the molecules are quite close to one another. They only act over a very short distance and have a relatively strong action over a distance of approx. 0.5 nm. From monatomic molecules, (e.g. rare gases) it is known that on doubling the distance from 0.5 nm to 1 nm, the effect is to reduce the attraction force by less than one hundredth. Van der Waals forces are also involved in dye/fibre bonding and are particularly important in the case of substances with a detergent action where they appear to function as solution-promoting forces alongside → Ionic bonds. In terms of energy, however, their strength is only one tenth that of interionic bond forces. Despite this, they are responsible for colloidal properties and the formation of micellar colloids in particular.

Vanillin (poly) ester fibre A polyester fibre produced from vanillin (3-methoxy-4-hydroxybenzaldehyde) derived, among other things, from wood lignin (1 kg wood gives 0.5 kg lignin), then converted to protocatechuic acid and subsequently to a condensable oxy acid with epichlorohydrin. Filaments are spun from the polycondensate:



Vantean process A finishing process to produce a high lustre on wool fibres. It involves a preliminary impregnation (mordanting) with a nickel catalyst which, after an intermediate wash, remains in the endocuticle. Subsequent chlorination is accelerated to such an extent that the exocuticle peels off resulting in a smooth fibre surface.

Vapour phase process → Gas phase crosslinking.

Vapour pressure (evaporation). A vapour pressure exists wherever molecules leave their associated state in a liquid since they possess sufficient kinetic energy (at the surface of liquids, i.e. the boundary interface for the process of evaporation). The energy necessary to evaporate 1 mole of a liquid is known as the molar heat of evaporation.

The most important vapour in nature and technology is water vapour or steam. The vapour itself is not visible but rather the finely distributed water droplets held in suspension due to their charge. Steam in a two-phase system in which steam and condensate are in a state of equilibrium at the same temperature and pressure is described as saturated steam. Steam fulfils several functions in textile processing: it transfers heat and moisture to a textile substrate through condensation. In many cases, the steam also dissipates the heat of reaction and condensation as well and maintains moisture in the textile which is absolutely essential for fixation processes. Moreover, undesired decomposition products released during fixation processes, as well as spin finishes, etc. are transported away by the exhaust steam.

The process of vaporization or evaporation involves a combination of heat transfer and mass transfer between a moist surface and the air flowing over it. For heat transfer the following formula applies:

$$Q = \alpha \cdot F \cdot (t_{Wo} - t_L) \text{ [J/h]} \approx \text{evaporative capacity N}$$

Q = quantity of heat transferred [J/h],
α = heat transmission coefficient,
F = surface area for heat transfer [m^2],
t_{Wo} = temperature of water at the boundary layer [°C],
t_L = temperature of the air [°C].

Apart from physical characteristics, the heat transmission coefficient α is dependent above all on the flow conditions. By applying similarity considerations, useful formulae are obtained via dimensionless variables which allow α to be calculated for a respective application.

A similarly derived equation has been introduced for the determination of mass transfer:

$$W = \delta \cdot F \cdot (x_s - x) \text{ [kg/h]}$$

W = quantity of water evaporated [kg/h],
δ = rate of evaporation [kg/m^{2}h],
x_s = saturation content corresponding to the temperature of the water surface t_{Wo} [kg/kg],
x = moisture content of the air [kg/kg],
F = surface area for heat transfer [m^2].

Dalton’s law of evaporation states that the quantity evaporated is proportional to the vapour difference between a wet surface and the air.

Just as a temperature difference is the driving force for heat transfer, mass transfer involves differences in moisture content. Without external expenditure of energy, heat is always transferred in the direction from higher to lower temperature regions. The 2nd main law of thermodynamics states correspondingly that heat cannot be transferred from a colder body to a hotter one of its own accord. In a similar manner, the mass transfer of water vapour takes place from regions of higher to those of lower concentrations. Mathematical formulae to determine the rate of evaporation δ lead via similarity considerations, as in the case of the heat transmission coefficient α, to dimensionless constants where flow conditions are again of decisive importance.

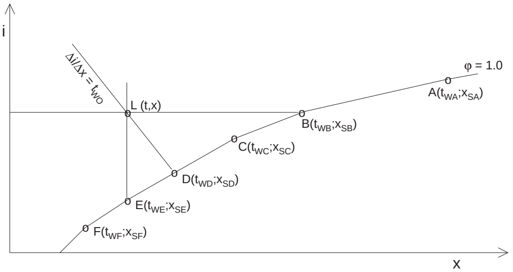


Fig.: I-x diagram to explain the relation between heat transfer and mass transfer during the volatilization process.

The i-x diagram (Fig.) is particularly helpful as a visual aid for understanding the combined effects of heat and mass transfer in the evaporation process. In the schematic diagram, L represents a specific state (t, x) which should not change by transfer from the air flowing over the evaporation surface. The saturation state x_s immediately on the surface of the water is found on the saturation line $\varphi = 1.0$ and should be able to change by the influence of the water supply from A to F. As long as the temperature of the boundary layer t_{Wo} lies above the temperature of the air t_L, heat is transferred from the water to the air (state A). After cooling down to B, the temperature of the water surface and the air temperature have become the same ($t_{Wo} - t_L = 0$) and, correspondingly, no more heat is transferred ($Q_B = 0$). Below B, the direction of heat flow is reversed: from now on the air is warmer than the water and gives up heat at the boundary layer. At C, D, E and F the temperature difference gradually increases and more and more heat is released from the air.

If care is taken to ensure that the evaporation vessel is sufficiently well insulated so that no heat can transfer from the surroundings, then the water supply at state A will cool down through the release of heat into the air. It could now be assumed that after reaching state B, the cooling process is ended and that heating up would occur below this point through heat supplied from the air. However, the water still continues to cool even below B due to the superimposition of mass transfer on the heat transmission.

The driving force for the mass transfer ($x_s - x$) is greatest at state A and decreases through B, C and D until at state E it is zero ($x_{sE} - x = 0$, $W_E = 0$). E is the dew point of air corresponding to state L; no further mass transfer takes place after cooling the water supply to the dew point. With a further decrease in the water temperature, ($x_s - x$) is negative; i.e. no more water evaporates but moisture thaws out of the air (point F).

If both transfer flows are considered in context, then an intensive release of heat is to be expected from the water (at state A) which not only gives up heat to the colder air but which, the same time, has supplied the entire heat of evaporation for the evaporation process. When no heat flows from the surroundings, i.e. when the process proceeds adiabatically, the water will cool down to a great extent. Even at B the release of heat has not ended since the water supply still has to carry the entire heat of evaporation. Below B, the air begins to give up heat to the surface of the water and the heat contribution of the water to the evaporation process can decrease correspondingly. At the same time ($x_s - x$) has become smaller (state C). A boundary state has now established itself at which the heat supply from the air can just compensate for the heat of evaporation necessary for the decreasing mass transfer. An “adiabatic steady state condition” is then said to exist (indicated by D).

An adiabatic equilibrium is only reached when no heat transfer takes place with the surroundings. If heat flows into the water supply then inertia occurs above D (with heat extraction, below D). In a state of adiabatic equilibrium, the air exchanges heat for water vapour. Its total enthalpy, which is related to liquid water at 0°C, is increased as a result so long as $t_{WD} > 0°C$. State D is found in the i-x diagram at the point where the mist isotherms $\Delta i/\Delta x = t_{WD}$ are drawn through L. Since the lowest temperature is obviously reached at D at which point the water can be cooled down by air under the given conditions, it is described as the dew point temperature. The dew point lies appreciably below the air temperature.

The evaporation enthalpy (also known as heat of evaporation) corresponds to the amount of energy which must be supplied to a material, e.g. water, with a mass of 1 kg to convert it from the liquid to the gaseous state at the boiling point and vice versa.

$$r = h'' - h' = u'' + p\,(v'' - v')$$

r = evaporation enthalpy,
h = enthalpy,
u = internal energy of a system,
’ = state variable for water,
” = state variable for water vapour,
p = pressure,
v = volume.

The enthalpy of evaporation therefore consists of an internal energy component Δu to overcome molecular forces and an external component of volume work $p \cdot \Delta v$. The external component is needed for expansion of the water volume to the water vapour volume.

If the evaporation entropy is calculated from the enthalpy of evaporation at the boiling point for various substances

$$\Delta S_{\text{evap.}} = \int_{n=0}^{1} \frac{\Delta H_{\text{evap.}}}{T} dn = \frac{\Delta H_{\text{evap.}}}{T}$$

values are obtained which are dispersed around a mean of 88 J/K/mol. This statement is known as the Pictet-Trouton rule. Considerable deviations from this rule are often found, however, which can be attributed to molecular chemistry.

All substances with evaporation entropies greater than 88 J/K/mol exhibit associations through hydrogen bonds in the liquid state, e.g. H_2O. Associated H_2O molecules possess less freedom of motion which results in a lower entropy of H_2O and consequently a greater entropy of evaporation.

Compounds with an entropy of evaporation ($S_{\text{evap.}}$) smaller than 88 J/K/mol are not only associated in the liquid but also in the vapour phase. Association through hydrogen bonding, e.g. in organic acids, results in dimeric molecular complexes which are also present in the vapour phase. The smaller $S_{\text{evap.}}$ value is because the single molecular weight and not the molecular weight of the molecular complex has been used to calculate the entropy of evaporation. Consequently, the entropy of evaporation is only half as big.

Liquids which obey the Pictet-Trouton rule are independent of specific molecular structures, and deviations can be attributed to a change in the kinetic energy of the evaporating molecules (according to Häussler).

Variable temperature dyeing processes Dyeing methods on the basis of drawing out at different dyeing-bath temperatures. Varying degrees of drawing effectiveness are demonstrated at individual temperatures, temperature ranges or stages, i.e. the substantivity, degree of fixation and drawing speed react differently in different temperature ranges. There are temperature stage-dyeing processes using increasing and decreasing temperatures. → Vat dyeing.

Variable-tension rolls A system of rolls to adjust fabric tension by changing the wrap angle of the fabric around guide rollers or guide rods. When variable tension rolls are installed at the entry to a continuous processing plant, they are also sometimes described as the fabric feed system (consisting of 2 tubes only).

Variance In → Statistical analysis, variance is a measure of the dispersion of the distribution of a random variable. The square root of the variance is called the → Standard deviation (s), and is the most widely used measure of variability.

Variance comparison The difference between target and actual values (regulating variables) in closed control loops. This difference is called the standard tolerance. It is a measure of the quality of regulation and is used by a controller (automated control unit) as an input quantity. → Automatic control systems.

Varnish (oil-based varnish). A varnish consists of → Drying oils (usually linseed oil with turpentine and resins if desired). Its rate of drying is increased by the addition of a drying agent. Varnish produces an elastic hard smooth coat (oil film). When applied as a thin coating, varnish hardens by oxidation within 11–24 h.

Varnish stains These stains are tacky when fresh; hard and brittle with blurred edges when old. Removal: it is advisable to loosen the varnish film mechanically first before treating the material in a suitable solvent, e.g. a) chloroform-carbon disulphide (or ethyl ether) 1 : 1; b) turpentine followed by gasoline (benzine); c) concentrated benzine soaps/ethanol/trichloroethylene; d) benzene/acetone 1 : 1; → Grease stains.

Vascular bundle A discrete strand of cells in the stems of some plants for the transportation of sap. → Flax stem structure.

Vase carpets → Oriental carpets with coloured representations of flower vases surrounded by palmettes and stylised floral motifs.

VA steels → Stainless steel.

Vat,

I. An alkaline sodium dithionite bath either without dye (blank vat) or with → Vat dyes (dye vat). In the latter case, the vat dye is present as the soluble → Leuco compound of the water-insoluble parent vat dye and is able to exhaust on the fibre in this form (→ Vat acids).

II. The term “vat” was originally used to describe a wooden tub used for the fermentation of indigo.

Vat acids The leuco compound of a vat or sulphur dye which, in this (water-soluble) form, possesses affinity for the fibre. A vat acid is a very weak acid. Principle: all vat dyes contain the characteristic >C=O group (keto group). In an alkaline sodium dithionite vat, the addition of hydrogen (= reduction, hydrogenation) takes place first of all to form the >C–OH group which corresponds to the leuco form as the vat acid. However, due to the presence of caustic soda in the vat, H and Na are exchanged and the sodium salt of the vat acid >C–ONa is formed which represents the actual state of vatting.

Vat dye fine dispersions The development of the → Pigment dyeing process with vat dyes and its continuous variants was made possible mainly by the preparation of special fine and ultrafine dispersed vat dye pigments having a particle size of approx. 0.2–6 µm which are suitable for this type of application. These dispersions guarantee accelerated fixation in textile printing and better penetration and levelness in (pad) dyeing (especially on thick materials). Particularly recommended for continuous processes.

Vat dyeing In general, dyeings produced on textiles with vat dyes have the highest colour fastness although one and the same dye cannot always satisfy every colour fastness requirement at the same time. Consequently, dye manufacturers have classified their dyes into 3 groups, i.e. for washable goods (e.g. uniforms), interior furnishings and all-weather articles. Indigo, which can be regarded as the first vat dye, has now lost much of its former importance in cotton dyeing. It is still used for special articles such as "blue jeans" which are only considered to be "fast" if they have been dyed with indigo or when a range of different fashion effects is desired. Chemically, vat dyes are classified into two main groups:

– indigoid vat dyes: derivatives of indigo and thioindigo which give leuco compounds of relatively low affinity.
– anthraquinonoid vat dyes: based on anthraquinone, the leuco compounds of which are taken up rapidly and completely by the fibre.

In terms of overall colour fastness, the anthraquinonoid vat dyes are superior to indigoid vat dyes. With the exception of indigo, therefore, the latter class of vat dye is only used for textile printing in the main. A peculiarity of vat dyes used to be the various physical commercial forms available in the market. Nowadays, the dye maker generally limits his production to a single commercial form suitable for all applications in view of the trend in dyehouses to move towards liquid forms. The unsurpassed wet fastness of vat dyeings is due to the complete insolubility of these dyes in water. In order to apply vat dyes to the fibre, therefore, they must first be converted into their water-soluble leuco salts which then behave in a similar manner to substantive dyes. As a rule, the reduction (vatting) stage is carried out with sodium dithionite in alkaline solution and the dyes are converted back to their insoluble state on the fibre after dyeing by oxidation in air or with substances capable of liberating oxygen.

1. Vatting: sodium dithionite reduces vat dyes very rapidly at 50–60°C. With certain dyes there is already a risk of over-reduction at temperatures above 70–80°C. Sodium dithionite solutions decompose in the presence of oxygen which is why reduced dye liquors (vats) have to be protected from exposure to the atmosphere. 1 l of air alone consumes approx. 3 g sodium dithionite. In HT dyeing, more stable reducing agents are used, but more is necessary to maintain the state of the vat; sodium dithionite is still used to reduce the dyes, however. The vatting time is dependent on the dye constitution and the particle size (commercial form). In order to achieve satisfactory dyeings, the concentration of sodium dithionite in the dyebath must be checked at appropriate intervals during the dyeing process. For anthraquinonoid types, the pH of the vat is approx. pH 13, and for indigoid and thioindigoid dyes a pH of approx. 10 is used. If the pH falls below these values there is a risk of the vat acids separating out. Apart from sodium dithionite, sodium borohydride (sodium tetrahydroborate) and thiourea dioxide can also be considered as reducing agents for vat dyeing in theory. Whilst the first of these has achieved no success in practice, neither alone nor as an additional stabilizing element, thiourea dioxide has gained some importance in Europe, since it inhibits the biodegradability of organic substances in waste waters to a far less extent than sodium dithionite. It also has a high reducing power and is more stable.

2. Oxidation: after dyeing, the leuco dye present on the fibre is reconverted to the insoluble pigment form by oxidation. Depending on the particular dye, this is carried out in the rinse bath (direct rinsing dyes) or by a special treatment (non-direct rinsing dyes). The latter category applies above all to the so-called cold-dyeing types of low affinity. With these dyes, it is recommended to remove the vat as completely as possible mechanically by squeezing-off, suction extraction or centrifuging in order to avoid non-uniform migration of dye in the rinse bath. The rate of oxidation is dye-dependent. Oxidation already begins to take place when the dyed material is exposed to the air. It occurs most rapidly at pH 10–11. To achieve the most favourable pH value, carbonic acid can be fed into the first rinse bath (a method which has found favour in the USA) or, alternatively, the vat can be neutralized with sodium bicarbonate after dyeing has been completed; a process which is recommended for cold-dyeing types with low affinity. For those dyes which oxidize rapidly, oxidation is completed in the rinse bath. For others, oxidation takes place in an additional bath with hydrogen peroxide after rinsing. In principle, sodium perborate, percarbonate or persulphate, as well as sodium bromate, can also be used. For ecological reasons, however, the use of potassium dichromate should be avoided. In some dyehouses, acetic or formic acid is added to the bath for neutralization after oxidation is complete. Under no circumstances should neutralization be carried out before oxidation since otherwise the difficult to oxidize or no longer oxidizable vat acid is formed.

So-called shock oxidation by the addition of sodium hypochlorite to the first rinse bath, which must however be restricted to vat dyes with adequate colour fastness to chlorine, is also used in practice. To achieve complete development of the shade and optimum colour fastness, dyed materials must be given a soaping treatment at the boil after oxidation. The duration of this treatment varies and a few minutes is sufficient for many dyes; a minority, however, require up to 0.5 h. The soaping treatment removes the excess dye loosely adhering to the fibre and also brings about a rearrangement of the dye molecules from the amorphous to the crystalline state or an aggregation to larger particles. A vat dyeing which has not been soaped, or which has been soaped insufficiently, will therefore not exhibit its correct shade and will not have maximum light fastness. On the other hand, a soaping treatment which is too intensive can impair colour fastness to rubbing. For economic reasons, many dyers now carry out the soaping process with suitable products in the spent oxidation bath at pH 6–6.5 thereby saving a separate bath. Oxidation with organic oxidizing agents is also possible, e.g. sodium m-nitrobenzenesulphonate.

I. Exhaust processes: the exhaust process with its many variants is of chief importance for yarn dyeing (package dyeing) and the dyeing of knitgoods. It is less important for woven fabrics where applications on the padder are preferred. In the exhaust process, the dye is either vatted in a concentrated bath (stock vat) or directly in the dyebath. The latter method is the most frequently used in practice. Only shading additions are still vatted in the stock vat as a rule. In some cases, vat dyes in most dye makers' ranges are quite different in their constitution and therefore have different properties as well. For example, different temperatures and quantities of caustic soda and sodium dithionite may be necessary for vatting. If the recommended vatting conditions are not observed, partial destruction of the dye and defective dyeings are likely to occur.

Variations in the properties of vat dyes have led dye makers to classify them into 3 groups. The allocation of individual dyes to these groups is not easy; some dyes may be dyed equally well by two different methods. For reasons of colour fastness, the so-called cold-dyeing types are no longer of any commercial importance and nowadays the warm and hot dyeing types are no longer treated differently from a processing point of view. In order to shorten the dyeing times and still achieve level results, dyers have switched more and more to higher temperatures. Since the vatted dye exhausts very rapidly (90% of the end state is reached after approx. 10 min), special measures have to be taken to obtain level dyeings. Diffusion and migration behaviour differs from dye to dye (in general, the difference is relatively small but increases with rising temperatures). In order to retard the rate of exhaustion, auxiliaries have been developed whose main effect is based on aggregation of the dye molecule (products with dye affinity). Aggregates formed in this way exhaust more slowly on to the fibre and break down again during the course of dyeing.

Control of the dyeing temperature and state of the vat, i.e. the alkali and sodium dithionite content, is necessary. At the end of dyeing, the dyebath must still contain sufficient reducing agent. Appropriate instruments are available for monitoring the redox potential of dyebaths. The consumption of reducing agent in a dyebath depends on the type dyeing machine, the textile material (entrained air) and the temperature. Enclosed machines are therefore particularly important for vat dyeing. The use of nitrogen as a protective gas in winch dyeing machines, for example, has already been recommended. Recently, BASF have begun to supply already vatted indigo solutions under nitrogen as a protective gas in special containers. Additions of ammonia above the bath can likewise provide protection against atmospheric oxygen. Further variants of the exhaust process include:

a) Dyeing with decreasing temperatures (rapid dyeing process). The bath contains the vatted dye. Dyeing begins at 80°C and is maintained at this temperature for 30 min in the case of pastel shades and 10 min for medium to dark shades. This is followed by a 20 min cooling down phase to 50°C. After a further 20 min, exhaustion is complete.

b) Incremental temperature process: the bath is presharpened at a temperature no higher than 15°C, i.e. alkali and sodium dithionite are added followed by the stock vat. With a temperature rise of 1°C/min, the dye exhausts slowly on to the fibre. This process is only suitable for warm and hot dyeing dyes.

c) High temperature process: dyeing is carried out according to the normal recipe and, during the course of dyeing, the temperature is increased to 115–120°C to improve levelling and increase the rate of diffusion. Only selected vat dyes can be dyed under these conditions. However, many dyes can be stabilized by additions of sodium dithionite, glucose, formaldehyde and formaldehyde-liberating products, e.g. methenamine (hexamethylenetetramine). Besides sodium dithionite, which is unstable at high temperatures, different types of reducing agent can be used to maintain the vatted condition of the dye. The HT process has found particular favour for the dyeing of unscoured cotton yarn in pastel shades.

d) Pre-pigmentation process: the unvatted dye has no affinity for cotton. By using finely dispersed commercial brands, it is therefore easy to achieve a uniform distribution of the dye in yarn packages (cross-wound packages). The finely dispersed dye is taken up by the material from a warm bath with additions of sodium sulphate (Abbot-Cox process) or special auxiliaries. The dyeing is then developed in the same or a fresh bath with caustic soda and sodium dithionite at the recommended temperature. This process can be easily controlled with modern control systems. According to one variant, special additions are dispensed with and the pre-pigmentation bath is heated to 90°C followed by addition of caustic soda and sodium dithionite after a certain time, and the temperature is then allowed to fall to 50–60°C. With some dyes, pre-pigmentation with dye and alkali together can lead to undesirable coarsening of the dye particles and filtering out problems. Only selected dyes are suitable for this process variant. At low temperatures, on the other hand, the dye, alkali and sodium dithionite can be applied together. The bath is then heated slowly to 60–80°C, during which time the dye is gradually vatted and taken up by the fibre. This process is described as the semi-pigmentation process. In principle, it is possible to increase the temperature to 110–115°C in the pre-pigmentation process (as in the HT process) so long as appropriate additions are made. Levelling agents recommended for the normal exhaust process can also be used to advantage in this process (Fig. 1). For all pre-pigmentation processes, finely dispersed commercial brands must be used without exception. These processes are not suitable for dyeing woven fabrics on beam dyeing machines.

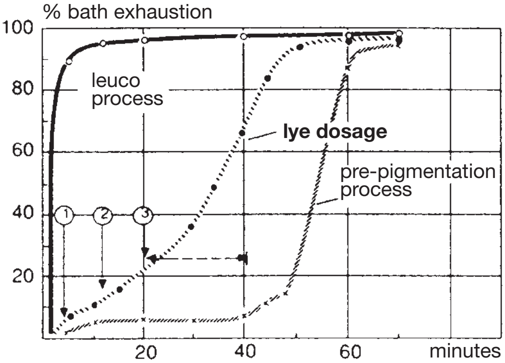


Fig. 1: Absorption behaviour of Indanthrene Brilliant Violet 3 B in different processes on cross-wound yarn packages; (VP = pre-pigmentation process).
4% dyestuff, 2 g/l of Dekol SN (BASF), 25 ml/l of caustic soda (38°Be), 10 g/l of sodium dithionite, Obermaier laboratory dyeing machine, liquor ratio 10 : 1, cotton yarn, cross-wound yarn packages inside to outside.
Lye dosage: 1 = dye, auxiliary agent, sodium dithionite, 3 g/l of sodium carbonate calc.; 2 = sodium dithionite; 3 = in a 4 minute cycle: 1, 1, 1, 2, 5, 15 ml/l of caustic soda (38°Be), 20 min at 30°C, in 25 min up to 60°C, 35 min at 60°C.

II. Padding processes: continuous dyeing processes are very important in piece dyeing. They guarantee high rates of production, good penetration and solid dyeings. A distinction is made between 2 process methods, i.e. padding with vatted or unvatted dye. The latter method has found the widest application in practice.

a) Processes with vatted dye: the high affinity of the leuco dye and the instability of the vat are the main reasons why this process has not achieved any success in practice. At one time, it was believed that the ”Standfast” or ”molten metal” process in which a textile fabric was impregnated with a vatted dye in a small pad trough had a promising future. Dye fixation was achieved by subsequent passage through a bath containing a molten metal alloy. The process only proved successful for loosely woven fabrics produced from loosely twisted yarns. A further development in this area was the “rapid dyeing” or “flash dyeing” process which had also been promoted in England: in this case, the dyebath is prepared cold with all additions and, shortly before running in the very small pad trough of a padder, it is heated to 90°C by an inlet-controlled water heater. The fabric, preheated to 90–95°C, runs through the bath within 0.6–2 s. In this case also the penetration of densely woven fabric qualities is problematic. Another process used in former times is the so-called vat-acid process. This involves vatting the dye and converting the leuco compound thus formed into the vat acid by addition of an acid. After application on the pad, development was carried out in a warm blank vat with caustic soda and sodium dithionite.

b) Processes with unvatted dye: these methods of application only became possible after finely dispersed commercial brands with a satisfactory mean particle size distribution had been developed. The dye dispersion, which has no affinity for the fibre, is applied on the padder and, after a possible intermediate drying, it is vatted in a second stage. By far the most important methods are the pad-jig and pad-steam processes. Pad troughs with liquor circulation, i.e. continuous liquor circulation from and to the stock tank are not recommended for padding with unvatted dyes where the action of pumping can cause the dyes to agglomerate. Opinions are divided concerning the absolute necessity of an intermediate drying stage before vatting. As experience has shown, however, the constancy of shade within a batch is more reliable when an intermediate drying stage is given. It is, of course, true that intermediate drying involves higher costs and a risk of dye migration when driers are used with non-uniform heating. Modern driers are, however, designed with air circulation systems to ensure uniform drying. Cylinder driers in which the fabric is dried on both sides are also used but at least 3 independently-controlled groups of cylinders must be available. Typical temperature settings for the different groups of cylinders are:

1st group:	70°C
2nd group:	80°C
3rd group:	120°C
4th group:	150°C

There is a risk of clip marks when drying is carried out on stenters. The tendency of a dye to migrate is dependent on the particular fabric (fibre type, fabric construction), fabric pretreatment, the dye and its particle size as well as any necessary additives. Thickening agents are not sufficiently effective in preventing migration. Products which become insoluble at high temperatures and cause the dye particles to aggregate are more effective for this purpose. In pad-jig dyeing, the discontinuous vatting of pigment-padded fabric in the full bath of a jigger can, under certain circumstances, cause end-to-end variations in shade since some of the dye is transferred to the blank vat from the fabric. This defect can be avoided by making suitable additions of pad liquor to the bath at the beginning and end of the 1st passage. The correct quantity of pad liquor to use demands appropriate experience on the part of the dyer. Continuous vatting in a full bath, e.g. in a so-called "Williams unit" consisting of a roller vat with minimum liquor content, gives rise to shade variations within the batch, which is why this process is hardly ever used nowadays. The pad-steam process (Fig. 2), on the other hand, is capable of producing uniform dyeings over the entire length of a batch by continuous vatting and involves impregnation of pigment-padded goods in a blank vat (caustic soda and sodium dithionite) followed by subsequent steaming (30–60 s). A continuous plant of this type is expensive and only intended for high production. Smaller pad-steam plants capable of dyeing small production lots economically are also now available. The individual stages are carried out in the following order:

1. pigment padding.
2. drying.
3. cooling.
4. padding with blank vat.
5. short steaming.
6. open-width washing machine for oxidation and aftersoaping.

The extreme sensitivity of sodium dithionite to atmospheric oxygen requires a continuous excess of the product in the bath and continuous monitoring by automatic titration is recommended. The blank vat is usually applied from a padder immediately in front of the steamer. However, some pad-steam dyeing ranges also have a small trough (booster) installed inside the steamer itself.

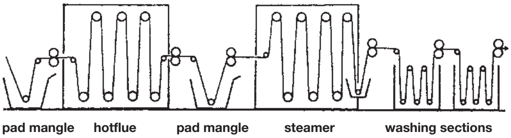


Fig. 2: Diagram of a pad-steam line.

Vat dyeing faults Some typical defects which occur in vat dyeing and their most likely causes are listed below:

- Unlevel dyeings: dyebath heated up too quickly; salt addition too high at the beginning of dyeing as well as inadequate oxidation.
- Poor penetration: dyebath heated up too quickly (= dye is only deposited on the surface of the fibres).
- Dull shade: dyeing temperature too high with too much sodium dithionite at the same time (= over-reduction).
- Formation of stains: unsatisfactory vatting of the dye; inadequate rinsing of vatted batches before oxidation (= localized concentrations of dye liquor); inadequate movement of dye liquor or textile material.
- Poor rub fastness: unsatisfactory vatting; incorrect after-soaping; too much dye on the substrate. This defect must not be confused with inadequate wet rub fastness which can be attributed to abrasion of the external layers of cellulose.
- Incorrect shade: aftersoaping treatment too short or carried out with too little energy.
- Poor light fastness: inappropriate dye selection, especially the use of unsuitable dye combinations (→ Catalytic fading).
- Fibre damage: → Vat dyes and fibre damage.

Vat dyeings, oxidation of An important stage in the development of correct shades in vat dyeing. After dyeing, the leuco vat dye which is present in its water-soluble reduced form (enol form) must be reconverted into its insoluble keto form again. In exceptional cases this can be achieved by aerial oxidation (e.g. by hanging in air); as a rule, however, the oxidation stage is carried out in baths containing suitable oxidizing agents. The rate of oxidation is dependent above all on the constitution of the dye as well as on the type and concentration of oxidizing agent used and the temperature and pH of the oxidation bath. The most favourable pH for oxidation is from 10–11. The excess alkali after dyeing must therefore be reduced as closely as possible to this value. The oxidation procedure varies according to the type of dye: e.g. vat dyes with leuco compounds of high substantivity (IN/CI dyeing types) can be rinsed directly after dyeing by the exhaust process. In order to save rinsing water, however, the material is often squeezed-off or suction extracted beforehand. For dyes with less substantive leuco compounds (IW/CII and especially IK/CIII dyeing types), the material must be squeezed-off or suction extracted first, otherwise considerable losses in yield and unlevel dyeings will result. The most favourable pH is achieved by an addition of sodium bicarbonate to the rinse bath. Under no circumstances should excess alkali be neutralized with acid otherwise the vat acids may be formed which can no longer be oxidized. The concentration of oxidizing agent and the conditions of oxidation (temperature and time) should be kept to the minimum required in order to prevent damage to the fibre.

Vat-dye instability A loss of colour caused by the decomposition of printed vat dyes due to storage of printed goods at high temperatures and high humidities before steaming. Other possible causes include steaming with air present in the steamer or poor steam circulation, and premature oxidation of a vatted dye by exposure to air. Loss of colour in discharge prints is due to the loss of reducing agent through atmospheric oxidation when printed goods have been stored too long before the reducing agent can be activated during the steaming process.

Vat dye printing Besides reactive dyes, vat dyes represent the fastest dye class for the printing of cellulosic fibres. They are used for printing articles which have to meet the highest standards of colour fastness. Vat dyes are supplied either in solid form (powder or granules) or as liquid brands.

The reduction process necessary for the fixation of vat dyes on the fibre can be carried out in two ways:

1. Potash process (“all-in” process): in this case the print paste contains both a reducing agent (e.g. sodium formaldehyde sulphoxylate) and an alkali (potassium carbonate = potash). In some cases, potassium carbonate may also be substituted with sodium carbonate. Starch-tragacanth was for many years the standard thickener for vat dyes. However, since this thickener is difficult to remove in the print afterwash, more readily soluble thickeners are also used nowadays such as starch-ethers, locust bean gums, alginates, etc. The fabric must be dried immediately after printing since otherwise the reducing agent would decompose on exposure to atmospheric oxygen during storage in the wet state and the dye would no longer be capable of vatting in subsequent steaming. A steaming time of approx. 12 min is usual. Care has to be taken to ensure that the steamer is completely air-free, otherwise the reducing agent would be consumed prematurely. During steaming, the shade of a vat dye changes to its so-called vatted colour, e.g. a blue may change to yellow or a green to red (usually the complementary colour is formed). After steaming, the printed fabric is finally oxidized and soaped. Oxidation can already be achieved with atmospheric oxygen but, in order to speed up the oxidation process in practice, hydrogen peroxide is usually added to the first wash bath. A final hot soaping treatment is absolutely essential in order to wash out loosely adhering, unfixed dye pigments from the surface of the fibres and thus achieve optimum colour fastness. Both direct prints as well as discharge prints can be produced by this process.

2. Two-phase process: this method is only possible for prints on white (i.e. undyed) fabric and offers optimum process reliability. The water-insoluble vat dyes are printed first as pigments. Thickeners capable of undergoing coagulation are used to prepare the print pastes, e.g. locust bean gums and their modifications. In this case, the printed fabric can be stored indefinitely before development which is a considerable advantage compared to the “all-in” method described above. The prints are finally developed by impregnation in a bath containing reducing agent/sodium carbonate or sodium dithionite/caustic soda followed immediately by steaming. This bath also contains sodium tetraborate which coagulates the thickener and prevents the vat pigments from bleeding out of the thickener film, thus ensuring sharp printed outlines. Excess liquor is squeezed off through a nip and the printed goods are steamed immediately to reduce the vat dyes to their soluble leuco compounds, in which form they can penetrate the fibre. Finally, the printed goods are oxidized, soaped and washed off as in 1 above.

Vat dyes These are water-insoluble dyes containing at least one keto group >C=O. Most are quinone derivatives (quinone group $O{=}C(C_4H_4)C{=}O$) which undergo molecular rearrangement in alkaline solution with a reducing agent, e.g. sodium dithionite (vat) to hydroquinone-like compounds $HO–C_6H_4–OH$ (vat acids) and their sodium salts ($NaO–C_6H_4–ONa$). In this form (i.e. so-called leuco compounds) vat dyes are water-soluble and have an affinity for textile fibres (cellulose, wool, silk). Vat dyes can be applied by exhaust and pad dyeing methods as well as by textile printing. Nowadays, vat dyes are available in a variety of commercial forms: e.g. the usual fine or microdisperse powders as well as paste or liquid forms. After they have been taken up by the fibre, vat dyes are converted back to the insoluble quinone form again by re-oxidation. The well-known, outstanding, high wet fastness properties of vat dyes are due to their insolubility in water. A final aftersoaping treatment is necessary for correct development of the shades and achievement of optimum colour fastness. Vat dyes are classified according to their constitution into anthraquinonoid and indigoid types; the latter are of relatively little importance nowadays.

Uses: for dyeing and printing textiles where the highest colour fastness requirements are demanded, especially colour fastness to light, weathering, washing at the boil, as well as for coloured articles required to withstand bleaching. The application of vat dyes to cotton, regenerated cellulose and linen is of greatest importance in practice. Their application to wool, silk, polyester and polyester blends, as well as the printing of acrylics and polyamide is relatively unimportant. Vat dyes are also used in the mass coloration of man-made fibres.

Vat dyes and fibre damage A few vat dyes (in the yellow, orange, brown and red sectors) can act as catalysts under certain conditions during oxidation processes, which results in the partial degradation of cellulose. A distinction can be made here between dyes which cause tendering during bleaching, dyeing and exposure to light. An individual dye does not have the same effect in all 3 categories. Dyes with a tendering effect in bleaching are only active in the bleaching of coloured wovens if sodium hypochlorite is used at a $pH < 7.5$

only or when the bleached material is exposed to direct sunlight. Dyes with a tendering effect in dyeing are only active if the dyed material is exposed to sunlight in open machines and the dyeing oxidizes due to repeated shortages of sodium dithionite and has to be reduced again. There is no remedy for dyes which cause tendering on exposure to light. Such dyes should be avoided and only those dyes specifically recommended by reputable dye makers as suitable for curtains and all-weather articles should be used.

Vat dyes in direct printing,

I. All-in method: the print paste contains vat dye, potassium carbonate (or sodium carbonate), reducing agent (usually sodium formaldehyde sulphoxylate) and thickener. After printing, the fabric is thoroughly dried and steamed (in air-free saturated steam at 101–104°C). During steaming the dye is reduced and converted to the soluble leuco compound, in which form it is taken up by the fibre. During oxidation in the subsequent washing-off stage the vat dye is restored to its original insoluble form again. This is followed by an aftersoaping treatment.

II. Two-phase methods:

a) → Colloresine process.
b) → Flash ageing.

In both the above two processes, the vat dye is printed without chemicals and the dye is only fixed after subsequent padding in a solution containing alkali and reducing agent followed by a steaming treatment. These two processes differ in the composition of the pad liquor, steaming time and temperature.

Vat dyes in discharge printing,

I. As dyeings: local destruction of the vat dyes was formerly achieved with oxidative discharges and nowadays exclusively with strongly alkaline reductive discharges.

II. As coloured discharges: vat dyes are the preferred choice of dye class for the production of coloured discharges on grounds dyed with direct or reactive dyes and naphthols.

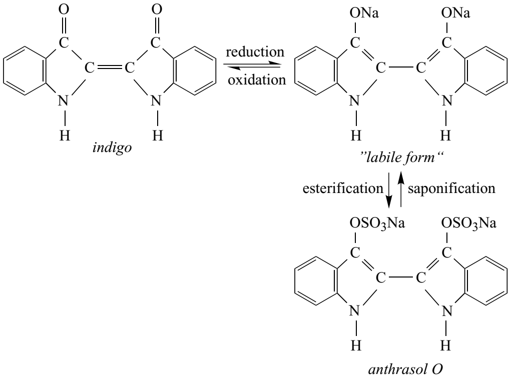
Vat dyes in resist printing This technique is no longer practised to any significant extent. Vat dyeings can be resisted by preprinting the fabric with substances having a mechanical and/or chemical resisting action: e.g. by preprinting with oxidizing agents, heavy metal salts with an oxidizing action, or metal salts with an alkali-binding action, either alone or in combination.

Vat-Flashage-discharge process→ Two-phase vat discharge prints.

Vat leuco ester dyes (solubilized vat dyes). The leuco compounds of → Vat and → Sulphur dyes are unstable unless special measures are taken. Dyeing with vat dyes is often accompanied by levelling problems since water-insoluble pigments are involved, which have to be made water-soluble by the addition of appropriate chemicals in order to dye the substrate. Vat leuco ester dyes, on the other hand, are already water-soluble products which produce very level dyeings. In most cases, these dyes have only slight substantivity and are used for dyeing and printing cotton as well as other cellulosic fibres. These products are not dyes in themselves and have to be developed on the fibre after dyeing to form the vat dye. In principle, they are vat dyes which have been esterified by chemical reaction and thus rendered soluble.

The dyeing procedure is generally as follows: a dyebath or pad liquor is prepared with the required vat leuco ester dye and a calculated quantity of sodium nitrite. Textile material is then dyed or padded with the solution, squeezed off and run into a second bath containing sulphuric acid, taking care to protect the goods from direct sunlight. The vat leuco ester dye on the fibre is then saponified to the leuco vat dye and the sodium nitrite, which is converted to nitrous acid by the sulphuric acid, oxidizes the leuco compound to the original vat dye. The textile material is then neutralized, soaped and finished as usual. Dyeings produced in this way are no different from vat dyeings produced by the conventional route.

Single-bath process: in this method, textile material is dyed with a vat leuco ester dye, sodium nitrite and sodium sulphate. When the correct shade has been achieved the vat dye is finally developed on the fibre by portionwise additions of sulphuric acid. For continuous dyeing, the individual baths can be arranged in succession.



Printing methods:

a) Nitrite process: the most popular method, which involves printing the vat leuco ester dye together with the oxidizing agent. The print paste contains: dye, solvent, sodium nitrite (oxidizing agent), water and thickener. After steaming (5–10 min), the printed fabric is passed through a hot developing bath (60–80°C) containing approx. 20 g/l sulphuric acid which then oxidizes the dye. Safety precautions are necessary, since the nitrous gases liberated during acid development are injurious to health.

b) Steaming process: in this method a different oxidizing agent is applied in the print paste. Since oxidation takes place in an acidic medium an appropriate acid-liberating salt must also be present. The print paste recipe for the steaming process is as follows: dye, solvent, water, ammonium thiocyanate (acid-liberating salt), sodium chlorate (oxidizing agent) and ammonium vanadate (oxygen carrier). A steaming time of 5–10 min is sufficient to develop the dye. Printed fabric still awaiting development after printing is sensitive to acidic vapours and direct light and must be carefully covered to protect the dyes before development. This sensitivity has been exploited in the so-called Photonprint process in which a textile fabric is padded with the aqueous dye solution and exposed to direct light (sunlight or carbon arc) after passing through a negative film which develops the colour. Dye in the unexposed and therefore undeveloped areas of the print is removed on washing off the fabric.

Vat leuco ester dyes in direct printing,

I. Processes involving wet development:

a) Nitrite process: the thickened dye solution is printed together with sodium nitrite, dried, and given a short steaming treatment if necessary. The dye is finally developed by passing the printed fabric through a hot bath containing sulphuric acid and sodium sulphate. Transparent prints can be produced in a developing bath with a higher concentration of sulphuric acid.

b) Dichromate process: the thickened dye solution is printed, dried and given a short steaming treatment if necessary. The dye is finally developed by passing the printed fabric through a hot bath containing sulphuric acid and sodium dichromate.

c) Iron nitrate process: the thickened dye solution is printed, dried and developed by passing the printed fabric through a hot bath containing sulphuric acid and iron nitrate followed by a treatment with oxalic acid during the final wash off.

II. Processes involving steam development:

a) Ammonium thiocyanate process: the thickened dye solution is printed together with ammonium thiocyanate, sodium chlorate and ammonium vanadate, dried, steamed and washed off.

b) Chromate process: the thickened dye solution is printed together with a neutral solution of sodium chromate, dried, steamed in acid steam and washed off. As an alternative to steaming, wet fixation with sulphuric acid is also possible.

c) Diethyl tartrate process: as process a) but replacing ammonium thiocyanate with ammonium chlorate together with diethyl tartrate. The colours are fixed by a short steaming treatment or by hanging in air.

Vat leuco ester dyes in discharge printing,

I. As dyeings: → Vat dyes in discharge printing.

II. As illuminating colours: this process is seldom used and can be considered as an alternative whenever difficulties are encountered in discharge printing with conventional vat dyes. The process involves printing a thickened solution of the vat leuco ester dye together with a reducing agent (with or without alkali depending on the dyeing) followed by drying, steaming and a passage through a hot bath containing sodium nitrite/sulphuric acid (the quantity of nitrite is increased and a longer dwell time is given since some undecomposed reducing agent is usually still present). The fabric is finally rinsed and afterwashed.

Vat printing → Vat dye printing.

Vatting The process of converting → Vat dyes from the water-insoluble (pigment) into the water-soluble substantive form (→ Leuco compounds) by reduction, usually with sodium dithionite and caustic soda.

Vatting condition When a → Vat has the correct composition it is described as a ”satisfactory vat”. If the quantities of sodium dithionite or caustic soda (or both) are deficient, partial oxidation occurs and some of the dye may begin to separate out under certain circumstances and the vat appears dull, i.e. the vat is said to be “unsatisfactory”. Even if the dye does not separate out, an “unsatisfactory” vat results in unlevel dyeings.

Vatting test An unreliable test for hydro-, oxy- and photocelluloses. Cellulose which has been chemically damaged has reducing properties which are sufficient to convert Indanthren Yellow G (flavanthrene) in alkaline dispersion into its blue leuco compound. Procedure: treat the sample in an alkaline bath with the dye. Formation of a blue colour indicates chemical damage.

Vat yellow paper → Indanthren yellow paper.

V-belts (Vee belts) → Transmission belts, drive belts with a tapered cross-section which run in the corresponding vee-tapered grooves of pulleys. V-belts are usually made of a rubber composition reinforced with V-belt cord. To transfer higher forces, several identical V-belts are used parallel to one another. Advantages: minimum possible distance between shafts, less wear, non-slip characteristics.

VCRS Abbreviation for the Swiss Federation of Dry Cleaners (Verband Chemischer Reinigungsanstalten der Schweiz); → Technical and professional organizations.

VdCh Abbreviation for the former (1887–1945) German Association of Chemists (→ Verein Deutscher Chemiker); → Technical and professional organizations.

VDF Abbreviation for the Society of German Dyers (Verein Deutscher Färber); → Technical and professional organizations. Today → VDTF.

VDI Abbreviation for the Society of German Engineers (Verein Deutscher Ingenieure). A German professional organization. Publication: VDI Nachrichten; → Technical and professional organizations.

VDMA Abbrev, for the German Machinery and Plant Manufacturers Association (→ Verband Deutscher Maschinen- und Anlagenbau e.V.); → Technical and professional organizations.

VDTF since 2000 union of VDF and VTCC.

Vector dye media for multicolour printing The usual colour solids conceived as colour ellipsoids can also be represented more simply as colour polyhedrons resp. as polyhedral colour lattices with defined colour edges and corners as colour vectors, e.g. in the form of four, five, six and seven vector colour solids. The seven vector colour solid has, e.g., 448 different coloured edges and 128 coloured corners. It is used for calculating mixing ratios of the yellow, magenta and cyan primary colours employed in typography.

VEGAT Abbrev. for the Federation of Swiss Yarn and Tricot Finishers (Verband Schweizerischer Garn- u. Tricotveredler); → Technical and professional organizations.

Vegetable (Lat.), of plant origin (when used as an adjective) as in vegetable fibres (e.g. cellulosic fibres) or vegetable impurities in wool.

Vegetable colloids These products are used as stiffening agents for textile sizes and finishes, e.g. →: Starch; Mucilages; Vegetable gums.

Vegetable dyes → Natural dyes.

Vegetable fibres →: Natural cellulosic fibres; Cellulosic fibres, regenerated; Natural fibres; Fibres.

Vegetable gums (natural gums). Carbohydrate high polymers insoluble in alcohol and other organic solvents which are obtained as dried exudations from various African and Asian trees and shrubs mainly of the acacia type in tropical areas. They are amorphous substances with very complex polysaccharide constitutions and are generally soluble or dispersible in water to give solutions with adhesive characteristics. They are coagulated by aluminium and chromium salts and are often used as thickeners in textile printing (especially in discharge and resist printing; unsuitable for mordant dyes) as well as for thickening pad liquors in dyeing. Also used in sizing (for this application it is recommended to use vegetable gums together with soluble starch). Formerly, they were also used in textile finishes to achieve a full handle. The diverse range of product names on the market is easier to understand from the following classification based on their main components of →: Arabin acid; Bassorin or Cerasin:

I. Gums containing predominantly arabin: →: Feronia rubber; Arabic gum; Cape gum, Mahagoni and Senegal gums.

II. Gums containing arabin + approx. 35% cerasin: → Rosaceae gum.

III. Soluble varieties of II marketed as so-called → Industrial rubber.

IV. Gums with a high bassorin and low arabin content: Bassora gum, Chagual gum and Gum Tragacanth.

Vegetable hair fibres Single cell seed hairs (→: Cotton; Akund) or fruit wall fibres (→ Kapok) of various plants the original purpose of which is to disseminate or protect the seeds. →: Natural cellulosic fibres; Fibres.

Vegetable horsehair → Crin d'Afrique.

Vegetable impurities The main impurities in the fleece, e.g. wool grease, dung and sand are removed in raw wool scouring. Burrs, seeds, leaves, bits of straw and wood, which become entangled in the fleece during the time when the sheep are at pasture, remain so obstinately attached to the wool that they seriously impair the appearance of wool fabrics. This particularly applies to piece dyed goods since the burrs are undyed by wool dyes. These various impurities of vegetable origin are generally described as vegetable matter.

The nature and frequency of occurrence of such vegetable matter in raw wool is dependent on animal husbandry and the country of origin of the sheep as well as on climatic conditions, e.g. the predominance of dry or wet weather and the associated growth of plant life. If manual removal is not practicable only chemical separation, i.e. a carbonizing treatment, is suitable for removing the vegetable matter from wool piece goods. In the case of worsted materials, however, a large proportion of the vegetable matter is removed during combing.

The carbonizing process involves an acid treatment followed by heating. When the material is dry, the carbonized and degraded cellulosic components "dust out" and are separated from the wool by mechanical means. The process of carbonizing is based on the different behaviour of animal and vegetable fibres in the presence of strong acids. Unlike wool protein, the vegetable matter is degraded hydrolytically by mineral acids. This vegetable matter contains in addition to 60–70% cellulose, 30–40% lignin which is not degraded by the carbonizing process. The next most important factor determining the wool price after fibre diameter and yield is the content of vegetable matter. This is because the vegetable impurities have to be removed during the course of wool processing, which incurs fibre loss as well as extra process time and an increased number of process stages.

The carbonizing process is mainly applied to loose wool in carded wool spinning. The non-uniform distribution of vegetable matter in loose wool requires a high acid content so that some fibre damage is unavoidable, which again leads to reduced yields, reduced fibre strength and problems in the subsequent processing of textile fabrics. These problems can be avoided to some extent by carbonizing in the piece, which is hardly ever applied to worsted fabrics any more but may be carried out on carded wool fabrics.

The content of vegetable impurities in Australian wool has been remarkably constant for a long time. As

application	type of error	vegetable impurity contamination level	basic vegetable impurities content	percentage of the shear [%]
worsted yarn	FNF B + S errors C + L errors D errors	none light medium heavy	< 1.0 1.1–3.0 3.1–7.0 ≥ 7.1	49.1 25.5 10.4 1.7
carded yarn	Y, carbonizing + waste during carding and combing	light to heavy	< 1.0 up to ≥ 7.1	13.2

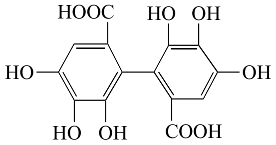
Tab. 1: Distribution of vegetable impurities in Australian wool for the 1988–89 season.

a result, the outcome of one season could also be taken as an example for a longer period of time with confidence. Tab. 1 shows that approx. 49% of the clip has a basic vegetable matter content of less than 1% and approx. one quarter of the clip has a vegetable impurity content of 1–3% which, with an improvement in the elimination rate, could be reclassified into the high-quality end-consumer category.

In worsted yarn manufacture, vegetable impurities are specifically separated during the carding and combing stages. Nevertheless, losses are incurred in all processing stages and particularly during spinning. A typical example for the elimination of vegetable matter is given in Tab. 2; the performance has been measured in order to estimate the level of impurities in wools with the given types and content of vegetable matter in the card sliver and tops. The values reproduced in the table show that wools containing burrs with a maximum vegetable matter content of 1% and a length of more than 10 mm correspond to normal commercial standards. Wool containing seed and vegetable matter residues with a basic content of 1% is acceptable but if this increases to 5% then the wool can no longer be used for high quality end uses.

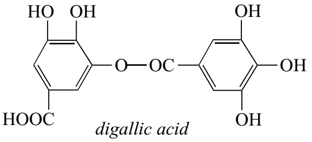
Vegetable silk → Akund.

Vegetable tanning A considerable number of plants and bark woods offer technically economic yields of tanning agents on extraction. Most of these vegetable tanning agents are extracts from horse chestnut trees, wattle, quebracho bark, oak woods, mimosa bark, oak barks, valonia acorns, myrobalan fruits and other plants rich in tanning agents. These vegetable tanning agents are complex compounds of high molecular weight with numerous phenolic hydroxyl groups. In chemical terms, vegetable tanning agents may be classified into two main groups, i.e. the pyrogallol and the pyrocatechol tanning agents. Hydrolyzable pyrogallol tanning agents are readily decomposed by ferments with the formation of ellagic acid (a valuable tanning agent).

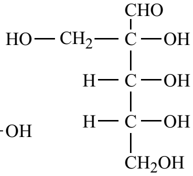


ellagic acid

They also form gallotannins and depsides, esters of phenolic carboxylic acids and hamamelose.

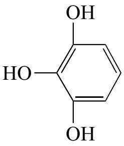


digallic acid



hamamelose

On heating to 180–200°C, the hydrolyzable tanning agents yield pyrogallol.



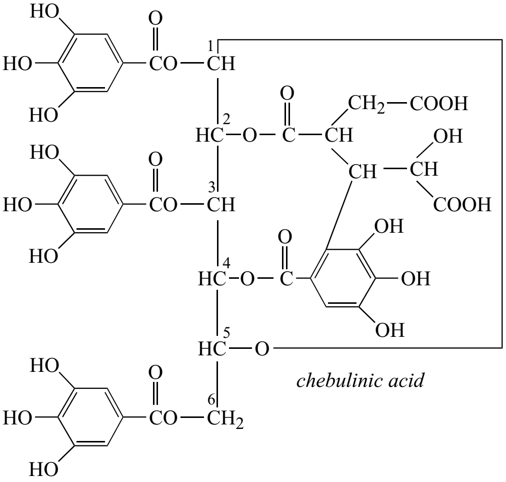
pyrogallol

The benzene nuclei in the tanning agent molecule, which are linked together by oxygen atoms to form large complexes, are another characteristic of such compounds.

type of vegetable impurity	basic vegetable impurity content [%]	secretion during carding [%]	occurrence of vegetable impurities in the card sliver (number of particles per kg > 10 mm)	secretion during combing [%]	occurrence of vegetable impurities in the combed top	usual commercial standards
					number of particles per kg > 10 mm)	
burrs burrs	1 5	95 95	833 4165	99.6 99.6	3 15	10 10
seeds/shives seeds/shives	1 5	85 85	2500 12500	99.6 99.6	10 50	20 20

Tab. 2: Secretion of vegetable impurities in carding and combing.

Pyrocatechols are more resistant to fermentative exposure and have a pH of 4.5–5 in solution. They form phlobaphenes in solution which again form pyrocatechol on heating to 180–200°C.



In the condensed pyrocatechol tanning agents, a large number of polyvalent phenols (pyrocatechol, pyrogallol) is fused together through carbon atoms, chain ether compounds or heterocyclic structures from furane, pyrane, or other types, to form high molecular weight polyphenols (Fig. 1).

Tanning with vegetable extracts involves the formation of crosslinks between the polypeptide chains (–CO–NH) through hydrogen bonding with the phenolic OH groups of the tanning agent (Fig. 2).

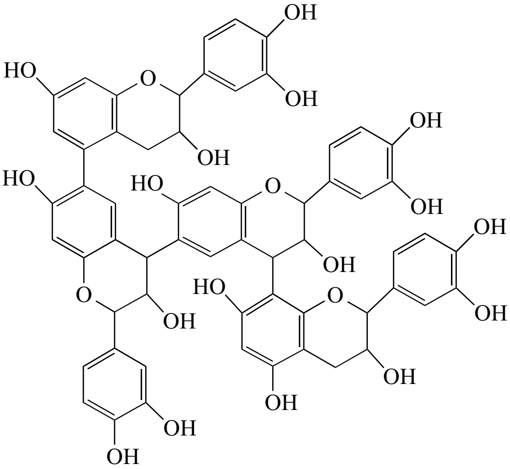


Fig. 1: Tetraflavonoid tanning agent from rhus lancea.

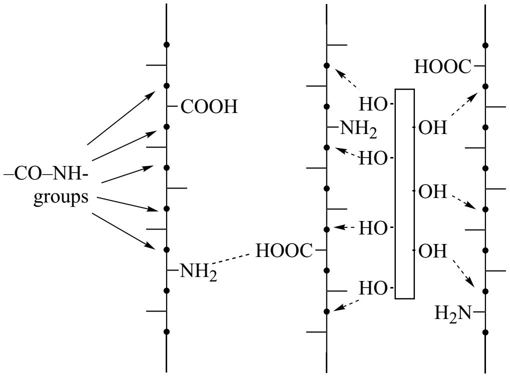


Fig. 2: Diagram showing crosslinking of the collagen chain by vegetable tanning agents.

Ionization and the formation of electrical charges on the skin and tanning agent is necessary so that the electropositively charged free amino groups in the skin cause the electronegatively charged particles of the tanning agent to be discharged thereby resulting in a mutual precipitation.

Vegetable tannage gives leather the characteristic colour of the corresponding tanning agent and a low shrinkage temperature at the same time. Vegetable tanning agents tend to be used as aftertanning agents. Starting products for the production of aromatic syntans include aromatic polynuclear hydrocarbons such as naphthalene and diphenyl, as well as mono and polynuclear phenols such as phenol, cresol and diphenyl ethers as simple aromatic ethers (Fig. 3). The production of synthanes with active tanning properties proceeds through sulphonation of the starting products to condensation with formaldehyde, urea or dimethylol urea.

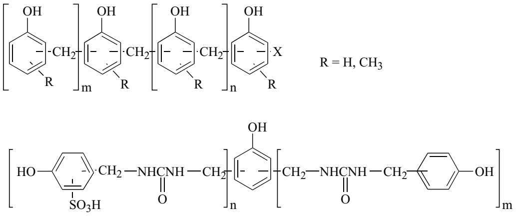


Fig. 3: Structural principle of synthanes.

The water-soluble sulphonated products are linked by bridging groups (–CH_2–) or (–O–CH_2–O–) and become tanning active substances by an additional adjustment of the concentration, pH and acid value.

Vegetable waxes are used as components in textile finishes and sizes, e.g. →: Japan wax; Carnauba wax.

Veining Long incompletely drawn nodules in spun filaments, e.g. in finished polyamide fabrics caused by soiled polyamide starting materials in spinning. These nodules dye much darker than normal filaments.

Velour, warp A French word derived from the Latin vellosus = “hairy”. Velour is a general term for → Warp velvet (→ Velvet). The pile is formed by an additional warp thread system, i.e. two warp thread systems are used, the ground warp and the pile warp, and one weft thread system. Velour is produced as wire and double velvet. Wire velvet can be produced as cut velvet (velour-coupé) with cutting wires, as curled velvet with an uncut pile (velour-frisé) as well as mixed velvet (with alternating cut and uncut pile). Patterned warp velvets are also produced. Numerous modifications exist, e.g. with transverse stripes (velour-chiffon), transparent (velour-transparent), so-called mirror velvet (velour-moiré), or additionally patterned with a swivel embroidery stay. Metal or Lurex threads are frequently used as embroidery threads (velour-broché), etc.

Veloutine,

I. A French dress fabric with a napped finish produced with a thick wool warp that forms cords and a soft merino weft.

II. A lightweight weft-pile fabric with a pronounced twill effect mainly used for linings.

III. A fine cord fabric produced from a silk warp and a wool weft.

Velvet,

I. A pile fabric with a dense short pile. A distinction is made in the case of woven velvet between plain and twill weave velvets (ground weave). The anchored pile loops can have a V-shaped or a W-shaped form. In the nature of things, the W-form is more firmly anchored. A distinction is also made between warp velvet (→ Velours) and weft velvet. Both types of velvet require different finishing treatments. Woven velvet is already cut from the loom, whereas weft velvet is cut only after a pre-preparation in velvet cutting. A large number of special machines are required for finishing weft velvet. Continuous production lines are used for efficient resin finishing. A typical production line consists of a padder with double immersion and an immediate brush roller, a pre-drier with a downstream drum drier, and a beating and raising machine.

Warp-knitting also offers the possibility to produce good velvet qualities which are of particular interest as far as production costs are concerned. An automated warp-knitting machine can produce between 8 and 50 m of grey fabric per hour depending on the article and the speed of the machine. Velvets produced on automated warp-knitting machines are of chief importance as furnishing fabrics, outerwear velvets, trimmings and case linings. The finishing of warp-knitted velvets differs considerably from weft, warp, raschel and other velvets. Unlike the latter, warp-knit velvets are dyed or aftertreated in the still unopened state. The velvet pile is only produced after the drying process by cutting the floating threads on a raising machine followed by subsequent shearing. This has the advantage that the pile cannot be broken or distorted during wet processing. The problem of “shadings” cannot arise under these circumstances. Moreover, loss of pile need not be feared since the pile yarns are firmly anchored in the loop structure of the knitted fabric. Loss of pile can occur, however, if the pile yarns are subjected to abrasion on the back side of the fabric. With outerwear velvets, this sometimes occurs during wear unfortunately. The problem is also not unknown even in the case of woven velvets.

II. A so-called weft velvet with a dense short pile (the term “velvet” is also used for cotton warp-plush). The weft pile yarns are inserted into the stable warp in such a way that they float on the face side of the fabric. These weft pile yarns are then cut in the stretched material and the resulting pile is opened and aligned by brushing.

Velvet carpet (velvet tapestry), a → Plush carpet very similar to a → Tournay carpet but produced by printing.

Velvet/corduroy cutting machines Special cutting machines in which the cutting arm with its extremely low mass inertia follows every lateral or vertical movement of the fabric without backlash. An angle adjustment with a scale on the cutting head enables a reproducible inclination of the knife to be obtained in the cutting channel. With the machine shown in the Fig. particular attention has been given to parallel guidance of the velvet tips to the weft channels. During operation, the main element is guided automatically and requires no further monitoring by the machine operator.

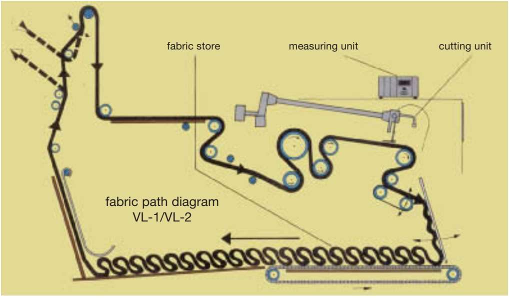


Fig.: Sucker-Müller velvet cutting machine fabric path diagram.

Velveteen A cut weft-pile fabric, usually of cotton or cotton blend, in which the cut fibres form the surface of the fabric to resemble true velvet. The effect is produced by cutting the weft floats after weaving. The finished fabric may be dyed or printed and has a smooth surface covered with short cut pile not exceeding 3 mm in length. Uses: bedspreads, children's wear, draperies, menswear, womenswear, upholstery, trimmings.

Velvet pile carpets A collective term for carpets produced by various methods of manufacture with a cut plush-like pile. → Cut-pile carpets.

I. A cut-pile carpet made in the same manner as tapestry carpets, but substituting cutting wires for looping wires.

II. A non-jacquard carpet with the same construction as a Wilton carpet.

Vented hood All open machines where steam or exhaust gases are produced should be fitted with vented hoods (see Fig.) in order to collect and vent these vapours outside the workplace.

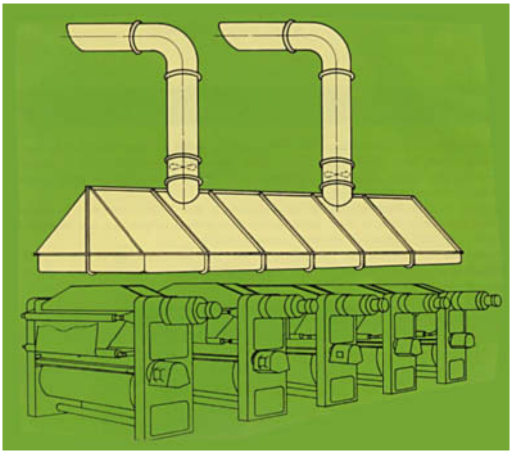


Fig.: Vented hood by Windel.

Ventilation systems → Extractor fans and → Radial fans are used for air extraction and ventilation, to control fresh air input, etc. (for high pressure; → Compressors). Ample air volume requirements/person are as follows: approx. 60 m^3/h for factories and 100 m^3/h for unhealthy working conditions; correspondingly more (+ 25 m^3/h) where gas flames are present. In cases of moderate evolution of harmful vapours or dusts, a complete change of air is recommended 4–6 times/h). The size of extractor fans and radial fans is determined by the quantity of air to be moved and the required air pressure. The latter is mainly dependent on the necessary length of the air ducting. Where suction extraction is carried out from different locations at the same time, the sum of the suction openings must correspond to the cross-section of the main ventilation duct (adjustable shutters are recommended on individual openings).

Ventilation systems in driers Through-flow, jet-flow and parallel- flow ventilation. →: Drying systems; Drying technology.

Venturi (venturi principle, tube, jet). A short tube with a) a narrow throat in the middle to give a constricted cross-section and b) a final section which gradually widens out (so-called diffusor). Fluid or gas passing through the tube speeds up as it enters the throat and the pressure drops, i.e. with the development of a so-called Venturi gradient. The pressure differential is used to measure and control the rate of flow of material passing though the tube (gas, compressed air or liquid). The pressure rises again in the diffusor (b).

Verband Deutscher Maschinen- und Anlagenbau e.V. (VDMA), Frankfurt. German Machinery and Plant Manufacturers'Association. → Technical and professional organizations.

Verdigris Green basic copper (II) carbonate formed on the surface of copper exposed to moist air (patina).

Verdigris stains These are typically blue-green in colour and are often only present on the surface of a textile material. Removal: 1. Ammonia 10–15% (and a fatty alcohol sulphate) warm, followed by hydrogen peroxide 3%. 2. Fatty alcohol sulphate/formic acid 15% warm to hot. Repeat if necessary. 3. Potassium bifluoride 10%.

Verein der Textilchemiker und Coloristen (VTCC, Union of Textile Chemists and Colourists). German professional organization for practitioners and scientists. It continues the tradition of the earlier IVCC with cooperative research, practical and scientific lectures, discussions and summarising reports as well as through furthering the exchange of ideas with like-minded foreign organizations. Cooperative member of the → IFVTCC. Business address: Heidelberg. Official publication: Melliand Textilberichte (textile reports). → Technical and professional organizations. → VDTF.

Verein Deutscher Chemiker (VDCh, Union of German Chemists). Defunct general professional organization (1887–1945) whose traditions have been continued since 1946 by the Gesellschaft Deutscher Chemiker (Society of German Chemists) → GDCh. → Technical and professional organizations.

Verein Deutscher Textilveredlungsfachleute (VDTF). Since 2000 union of → VDF and → VTCC.

Verein Österreichischer Textilchemiker und Coloristen (VOeTC). Austrian Association of Textile Chemists and Colorists. An Austrian organization, which is a cooperative member of the → IFVTCC, → Technical and professional organizations.

Verein Textildokumentation und -information e.V. (VTDI, Association for Textile Documentation and Information). Founded in Frankfurt towards the end of 1980 as a new body in the FRG to house the Textile Documentation and Information System →

TITUS, it commenced operation on 01.01.1981. The founding members are, in addition to the VDI which can no longer itself house the system, the Gesamttextil (Gesamtverband der Textilindustrie in der Bundesrepublik Deutschland e.V.) and the Fachgemeinschaft Textilmaschinen im VDMA (both associations for firms using the system), as well as textile research institutes (producers of information) and specialist publishers (disseminators of information). The hope is that this cooperative undertaking, which is unique in the FRG, will be able to support companies in taking up the results of research and development more rapidly into actual industrial practice.

Vertical company A fully-integrated manufacturing company, e.g. a textile company that undertakes all the processing stages from the fibre to finished product including spinning, weaving or knitting, finishing and, in many cases, garment manufacture as well.

Vertical drier A sieve-drum drier of vertical design based on the through-flow principle which offers the highest heat transmission coefficient and maximum drying performance in the smallest space. Heat recovery is determined by the machine construction. The specific heat losses in this type of drier are low due to its compact design and effective heat insulation (without thermal bridges).

Vertical finisher Whilst a commission finisher must have a wide range of flexible machinery at his disposal in order to be in a position to carry out all the necessary finishing processes and satisfy a variety of customer requirements, a vertical finisher (owner-operator or integrated finisher) tailors the development of his merchandise to whatever machinery and process technology is available to him. The vertical finisher therefore has an advantage (see Tab.) over the commission finisher who receives his goods horizontally (i.e. at the same level as the company placing the order) → Organizational structures in textile finishing.

Commission finisher	*Vertical finisher*
Finishing process tuning singeing, desizing, bleaching, mercerising rope treatment, open-width treatment, relaxing, stabilising, dyeing, printing, finishing	Tuning, grey fabric, fibre, yarn spinning process, setting of the weave size
On the grey fabric type of yarn, type of weave, weave setting, type of size, grey soiling, shrinkage behaviour	On the finishing process Bleaching Loose stock Yarn Piece Dyeing Loose stock Yarn Piece Dyeing process } fastnesses Shade depth Chemical finish chemical Final finish mechanical
On the finished fabric Width, weight, degree of whiteness, dyeing, accuracy of shade, fastnesses, residual shrinkage, reproducibility	On the finished fabric (width, length, shrinkage, appearance, accuracy of shade, fastnesses)

Tab.: Differences in commissioner and vertical finisher product development.

Vertical flammability test → Flammability test.

Vertical migration (selective migration). The variable rate of migration of a dye combination through the cross-section of a textile fabric. This behaviour is exploited intentionally for the production of → Two-sided effects by vertical migration between the face and back sides of a textile material to give either a different colour on each side (two-colour effect) or different depths of the same shade (dark/light effect). → Migration.

Vertical open-width washing machine A machine with a series of open-width compartments (see Fig.) for washing off or impregnating fabrics with chemical liquors (e.g. in pretreatment). → Roller vat.

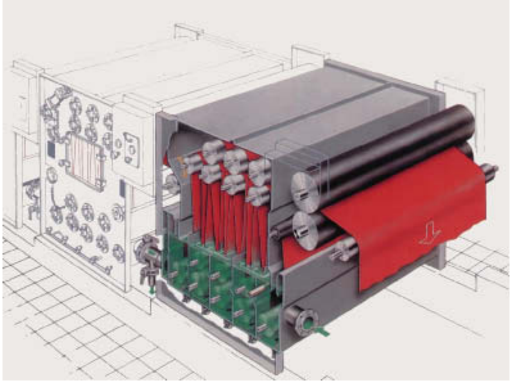


Fig.: Vertical open-width washing machine (Kleinewefers KTM).

Vertical padder A → Padder with a vertical arrangement of squeeze rolls.

Vertical roller printing machine A roller printing machine formerly produced by Saueressig (Germany) with a vertical arrangement and an individual pressure roll for each engraved printing roller or rotary screen. The colour boxes, doctor blades and furnisher rollers are all mounted on a hinged sub-frame which can be swung to one side (like a gate) thereby offering the advantage of easier and quicker servicing compared to conventional roller printing machines. Specially constructed pressure rolls adapt themselves automatically to any bending distortion of the engraved printing

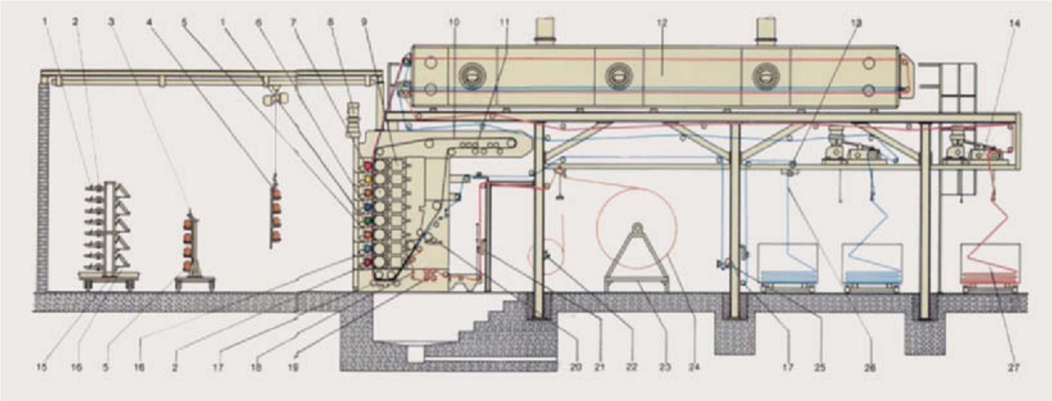


Fig.: Saueressig vertical roller printing machine (portal roller printing). 1–10 = printing zone; 11–20 = periphery; 21–27 = passage of fabric.

rollers. Print paste is fed to the printing heads automatically (see Fig.).

Vertical space-dyeing printing unit A development for → Space-dyeing (Micro-Space) with vertical fabric transport from bottom to top and up to 6 pairs of printing rollers (print stations) as modular units. Splashing of print pastes at high speeds is prevented with this system and the practical application of lint doctors is possible.

Vertical star dyeing machine An upright star dyeing machine where vertical movement of the loaded star frame in the dye liquor is actuated by a cam.

Vertical sueding machine (sanding, emerizing). A surface finishing machine for the → Sanding and → Emerizing of knitted and woven fabrics. The fabric runs tangentially against the sanding resp. emerizing rollers.

VI,

I. → Viscose fibres, → Standard abbrev. for textile fibres according to the → EDP Code; → CV.

II. Abbreviation for → Viscosity index.

Vi → Vicuna, → Textile fibre symbols, according to DIN 60 001 until 1988, from 1991 → WG.

Vibraire process A continuous felting process for yarns and slivers co-developed by the Fibre Research Institute TNO Delft and the IWS England. The yarn is passed, together with the felting liquor, through a tube which is subjected to intense vibrations (also known as the Periloc process).

Vibrating open-width washing machine An open-width washing machine consisting of a series of roller vats (countercurrent principle) which uses vibrating elements between the ascending and descending fabric web (see Fig.) to achieve a more intense washing and rinsing effect.

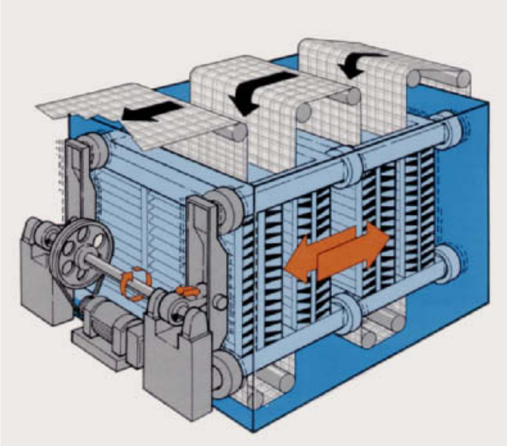


Fig.: Vibrating open-width washing machine (MAT).

Vibrating steamer A steaming device for the relaxation of elastic materials which utilizes the combined action of a short steam shock and intense vibration. The treatment makes it easier to handle such materials in cutting and garment making.

Vibrator units Special vibrating elements designed to achieve more rapid movement of processing liquors and/or a textile fabric in order to intensify the washing effect in, e.g. open-width washing machines (see Fig.).

Vibratory felting machine A machine for the production of plate felted (technical felts) from wool.

Vichy,

I. A cotton dress fabric generally made with two different coloured yarns.

II. A gingham fabric with a stiff finish frequently made in large checks and plaids in Spain, Chile and Bolivia.

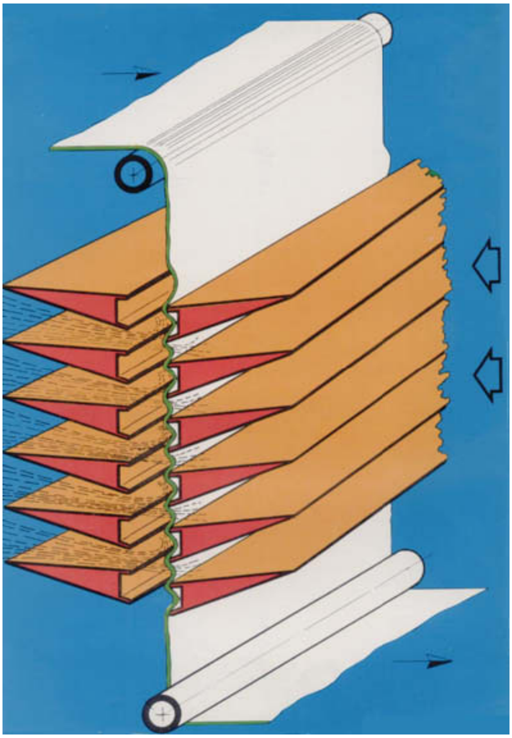


Fig.: Vibrator device on a continuous washing machine (MAT).

III. A fine gingham produced in Serbia.

IV. An inexpensive gingham and yarn-dyed cotton plaid produced in Turkey usually with a stiff starchy finish.

Victoria Blue 4R (CI 42 563). Victoria Blue 4R colourings are used to distinguish between different man-made fibres, particularly regenerated cellulose fibres, and for improving the visibility of fibre structures under the microscope when no dark-field illumination is available.

Victoria Blue B test (Sieber test). Cationic blue dye for examining raw and bleached vegetable fibres. The reduced fibre sample is boiled in 3% solution for 0.5–1 min. This is then thoroughly rinsed with distilled water repeatedly and dried. Raw cotton turns deep dark blue and bleached cotton turns pale blue.

Vicuna South-American fine → Animal hair fibres from the vicuna, related to the llama and the guanaco (Peru and Bolivia). Only the undercoat hair is processed – deep yellow to reddish brown, soft, silky-glossy, curly and fine (10–20 µm, around 84 scales/mm).

Vienna chalk Finely milled pure dolomite which consists of calcium magnesium carbonate $CaCO_3 \cdot MgCO_3$, density 2.8–2.95. Source: Dolomites, German Mittelgebirge and similar places. Examples of use: in working up chlorinated hydrocarbons (neutralization); where there is no free acid, Vienna chalk causes alkaline corrosion of non-ferrous metals and → Blue water phase on copper (also decomposes relatively solid N compounds).

Vigoureux printing (tops printing). Diagonal or transverse striped printing of combed wool tops (using relief rollers). The twisted and drawn (Fig. 1), essentially homogenous blends produce mixtures of different-

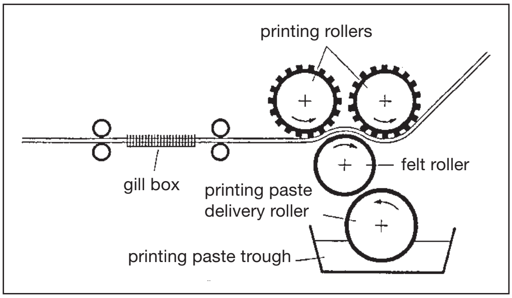


Fig. 1: Diagram of classic vigoureux printing on wool tops.

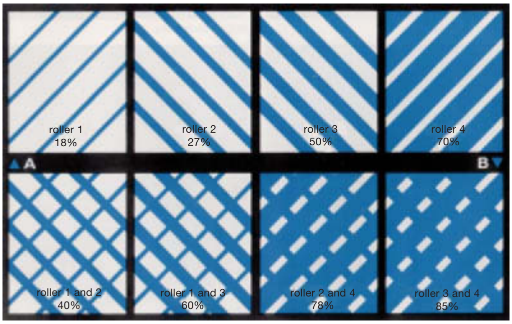


Fig. 2: Vigoureux printing rollers print formats with strips of varying width (A) and twin roller print possibilities (B). The percentages indicate the printed area of the combed top (according to Bayer).

Fig. 3: Typical vigoureux patterning on combed tops (Fleissner).

coloured fibre. In most cases, black is used for printing which gives grey colour-blend effects depending on the depth of colour in the mixture and cover in non-printed areas. Printing with metal-complex and chrome dyes is preferred on combed top wool but is also carried out on polyester with dispersion dyes and polyacrylonitrile with cationic dyes. Zebra-striped patterns (Figs. 2–3) are produced which blur after drawing and spinning.

Vigoureux yarn Mottled yarn which is made by printing stripes in a single colour on combed top in → Vigoureux printing and then doubled and stretched several times.

Vinal American generic name for polyvinyl alcohol fibres (→ Vinylon) containing at least 50% vinyl alcohol, i.e. more than 85% by weight vinyl groups. According to DIN 60 001: a minimum of 85% by weight vinyl alcohol or vinyl acetate.

Vinyl Abbrev. for → Polyvinyl chloride.

Vinyl acetate (acetic acid vinyl acetate). Colourless liquid with characteristic smell, $CH_3COOCH{=}CH_2$; melting point –93°C; boiling point 72°C; glass transition temperature 29°C. Industrial manufacture is carried out by the addition of acetic acid to acetylene:

$$\underset{\textit{acetylene}}{HC{\equiv}CH} + \underset{\textit{acetic acid}}{CH_3COOH} \xrightarrow{Hg^{2+}} \underset{\textit{vinyl acetate}}{CH_3COOHC{=}CH_2}$$

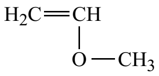
In the presence of heat, light and peroxides, vinyl acetate easily polymerises to → Polyvinyl acetate. Acetates exist which are based on pure vinyl acetate polymers (homopolymers) or on superficially softened polyvinyl acetate dispersions, i.e. dispersions containing softeners. Vinyl acetate polymers freely dissolve in organic solvents. Vinyl acetate copolymers are used in various adhesives, binders, coating agents and film formers, etc.

Vinylal According to DIN 60 001, generic name for fibres based on → Polyvinyl acetate, i.e. acetylated, making the polyvinyl alcohol fibres insoluble in water (→ Vinal).

Vinylbenzene → Styrene.

Vinyl cyanide → Acrylonitrile.

Vinyl ether Colourless liquid (manufactured by reacting acetylene with alcohols at high temperature and pressure) such as vinyl methyl ether. Resistant to alkalis. Hydrolyses completely on heating with dilute acids. Reacts with the hydroxyl groups on cellulose. Starting material for → Polyvinyl ethers.



$$H_2C{=}CH{-}O{-}CH_3$$

Vinyl group $H_2C{=}CH{-}$. Component of vinyl derivatives and polyvinyl derivatives.

Vinylidene chloride $CH_2{=}CCl_2$, identical to asymmetrical → Dichloroethylene.

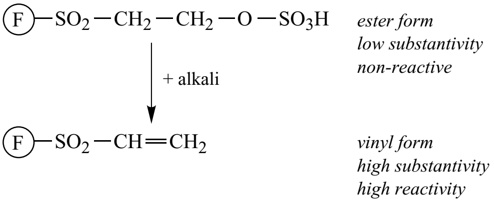
Vinylidene fibre → Polyvinylidene chloride fibres.

Vinylidene group $CH_2{=}CR_2$, → Polyvinylidene group.

Vinylon Since 1948, generic name for polyvinyl alcohol fibres made in Japan (→ Vinal).

Vinyl resins →: Polyvinyl alcohol; Polyvinyl acetate; Polyvinyl chloride.

Vinylsulphone dyes As a Sulphatoethylsulphone dye, the commercial form contains a protected reactive group. In this ester form, they only have moderate substantivity. The actual reactive dye, vinyl sulphone, is not released until the required alkali is added for dyeing to take place. In this form, the dye is now reactive showing high substantivity.



Although automated, progressive alkali dosing offers advantages in the case of all reactive dyes, due to the chemical structure of vinyl sulphone dyes, they are particularly suitable for this method. One application variant consists of initially adding a relatively weak alkali, such as sodium carbonate, to start the process and not adding the stronger alkali until a high level of fixing has already been achieved. The quantities of alkali added and the periods between the additions should be maintained exactly to ensure a high level of reproducibility. Obviously, methods such as these are labour intensive and, therefore, oppose the trend towards increasing efficiency and quality.

Collaboration between Adcon AB in Sweden and Hoechst AG in Germany has resulted in the develop-

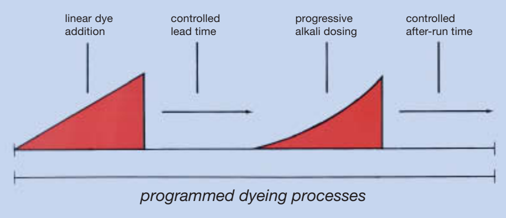


Fig.: Dosing programme in dyeing with vinylsulphone dyes (Remazol Automet, Hoechst).

ment of dosing equipment and a method which can be used to control and optimise the fixing behaviour and eliminate the disadvantages of conventional dyeing methods. The principle used in this method relies on the automated, progressive addition of alkali at the dyeing temperature. It is a constant-temperature dyeing process which operates at 40°C, 60°C or 80°C. The process operates the same way at all three temperatures (Fig.).

In principle, all alkalis usually used in reactive dyeing can be used. Out of economic considerations and because of handling, caustic soda solution is used in preference. In the case of pale shades only, it is buffered by small amounts of sodium carbonate or replaced with the latter. Corresponding recommendations for alkalis are available in the form of alkali diagrams when dyeing at 40°C, 60°C and 80°C, both in the case of mercerised cotton or viscose and in the case of non-mercerised cotton.

Vinylsulphone group $–SO_2–CH=CH_2$. Reactive group which reacts with the OH groups of cellulose: $–SO_2–CH_2–CH_2–O–Cell$ in the presence of alkali. Important compound with masked vinylsulphone group, for example:

$$–SO_2–CH_2–CH_2–O–SO_3H \rightarrow –SO_2–CH=CH_2.$$

Bifunctional compounds used as high-grade finishing aids are known as: → Divinylsulphone compounds; → Vinylsulphone dyes.

Vinyon American generic name for polyvinyl chloride fibre with at least 85% by weight vinyl chloride.

Virgin wool,

I. Commercial name derived from the method of recovery of wool which has been shorn from live sheep and has not yet been spun or filtered or been subjected to a recovery process which damages the fibres. In contrast to this is → Skin wool (fellmongered wool), →: Pelts; Fallen wool; Recovered wool or → Reclaimed wool. The quality symbol for virgin wool is the → Woolmark. Virgin-wool blend tolerances: for visible decorative effect, 5% (in the case of woolmarked products) or 7% (according to the textile labelling regulations), for unavoidable extraneous fly fibres 0.3%.

II. (South Africa), expression analogous to pure wool.

Viscoelastic behaviour → Rheological behaviour of solutions.

Viscoelasticity Property of a substance which, when subjected to shear, compressive and tensile stresses, shows both viscous and elastic properties (→ Viscosity, → Rheology). Plays a decisive role in textile printing. As the polymer molecules are subjected to increased stress, the viscosity of the swollen thickener spontaneously drops and increases again as the stresses are relaxed.

Viscometers Instruments for measuring → Viscosity.

I. Capillary viscometer. This type of viscometer is filled with the fluid which is to be measured, as shown in Fig. 1. When the small bulb on the left hand side is filled with the liquid, the fluid level should be approximately in the middle of the bulb on the right. The time taken (t) for the fluid level to fall from the upper mark S_1 to the lower mark S_2 is then measured. The bulb on the right must be large enough for the increase in the level of the fluid inside it to be negligible when the level in the other side falls. In order to calculate the viscosity from the equation below, it is necessary to know the pressure ΔP due to gravitational force.

$$V = \frac{\pi \cdot r^4 \cdot \Delta P}{8\,\eta\,l} \cdot t$$

This is obtained from the density of the fluid ρ, the acceleration due to gravity g and difference in height h of the two levels of fluid. $\Delta P = \rho g h$. Using this relationship, the equation for viscosity becomes:

$$\eta = \frac{\pi g r^4 h}{8 l V}\,\rho\,t.$$

The parameters, acceleration due to gravity and parameters associated with the specified set-up measurements are represented in the experimental constant:

$$C = \frac{\pi g r^4 h}{8 l V}$$

to give:

$$\eta = C\,\rho\,t.$$

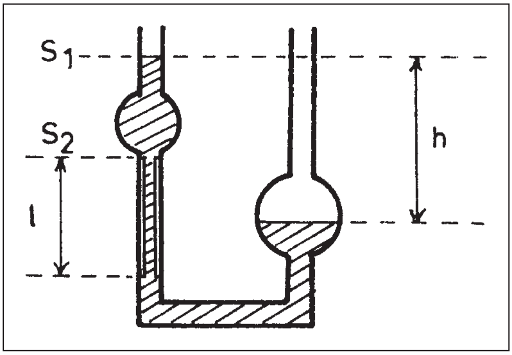


Fig. 1: Diagram showing how a capillary viscometer works.

The experimental constant for the viscometer is obtained by calibrating it with water at 20°C ($\eta = 1.0002$ mPa s), the flow time being determined several times over. An Ostwald viscometer essentially consists of a U-tube, one arm of which is in the form of a capillary. Bulbs are situated above and below the capillary. The volume of the top bulb is bound by two marks. Disadvantage: not suitable for determining intrinsic or non-Newtonian viscosity (→ Rheological behaviour of solutions). Instruments: Ostwald, Ubbelohde and Bingham, etc. Measurement range 10^{-3} to 10^{11} Pa s. Sucker viscometers are suitable for monitoring liquor viscosities where the viscosity varies with differential pressure.

II. Flow cup: the time taken for a given quantity of fluid to flow through a tube at test temperature is measured and compared with the behaviour of a standard fluid (water). Disadvantage: the fluid level and, therefore, the magnitude of the shear stress continually changes throughout the measurement. Conversion of the measurement units into Pa s is only possible for Newtonian fluids. Measurement range 10^{-} to 10^{11} Pa s. Known instruments are the Engler, Ford and DIN flow cup instruments.

III. Falling-ball viscometer: the viscosity is determined by measuring the time taken for a ball to fall in a tube filled with the test fluid. The results obtained are precise and reproducible. Data in Pa s is only possible for Newtonian fluids (while taking density into account). The shear stress cannot be measured. This method is not suitable for measuring non-Newtonian viscosity. Instruments: Höpler viscometer, etc. Measurement range 10^{-5} to 10^{11} Pa s.

IV. Rotary viscometer (Fig. 2): various shaped impellers rotate in the fluid. Measurement range 10^{-4} to 10^{11} Pa s. It is easy to understand how this measurement system is derived from the Newtonian parallel plate model by imagining the level parallel plates bent as inner and outer cylinders. A substance found in the circular gap can be subjected to a defined shear force as in the Newtonian model.

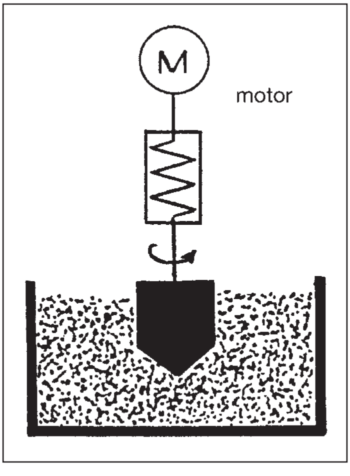


Fig. 2: Rotary viscometer without defined slot.

There are two different ways of realizing this geometry in viscometers:

1. A defined shear force is imposed on the inner or outer cylinder (using a defined torque) while the other cylinder is at rest. A certain shear rate or characteristic speed is measured which is defined by the resistance of the sheared substance due to its viscosity.

2. The shear rate is applied (inner or outer cylinder rotates with defined speed) and the shear force determined by the viscosity of the substance acting on the walls of the inner cylinder is measured. Most viscometers operate using the second measurement principle. This can be classified into two types as follows (Fig. 3):

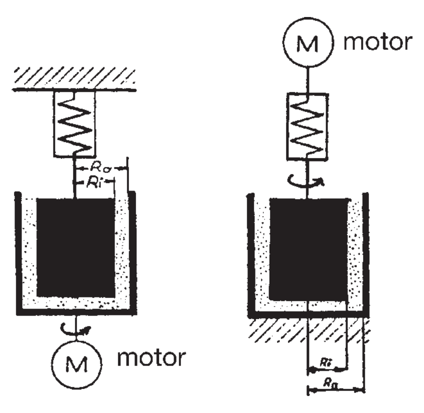


Fig. 3: Rotary viscometer with defined slot: Couette system (left) and Searle system (right).

a) The Searle system: In this case, the inner cylinder rotates at a constant or variable speed while the outer cylinder is at rest. The rotating cylinder causes the substance to flow and the resistance exerted by the substance being sheared is proportional to the viscosity-dependent torque or effective shear stress. The measuring element for this torque is a distorted steel spring located between the drive motor and the axle of the inner cylinder. The spring distortion is a direct measure of the viscosity of the test substance.

b) The Couette system: In contrast to the Searle system, the outer cylinder is rotated causing the fluid to flow while the effective shear stress is transmitted to the inner cylinder, which would rotate with the outer cylinder if it were not prevented from doing so. The torque on the inner cylinder is measured by determining the counter force required to prevent it from rotating.

The Searle system is the method which is most frequently adopted in the manufacture of viscometers. The reason for this is the ease with which the temperature of the test substance can be controlled and the many different ways in which it can be used. Thus, viscosity ranges from low to extremely high can be measured. However, there is one restriction: the measurement of very low viscosities leads to non-laminar flows (< 3 mPa s), so no sensible values can be expected.

V. Vibration viscometer: relies on the determination of the damping effect of the fluid on the vibration of the vibrator. It is suitable for testing viscoelastic behaviour (→ Rheological behaviour of solutions). Measurement range 10^{-8} to 10^5 Pa s.

VI. Compression or extension viscometer: viscous media are compressed or stretched between two plates. Deformation is measured relative to time. This method is suitable for determining the viscoelastic properties of high polymers. The measurement range is from 10^3 to 10^8 Pa s.

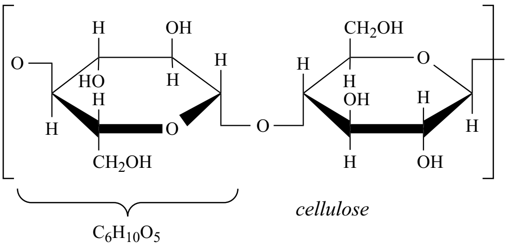
Viscometer, torsion type (visco printogram). Used to determine the → Viscosity of printing thickeners; → Viscosity of printing pastes.

Viscose,

I. Spinning paste, thick, viscous, made from alkali cellulose and carbon disulphide dissolved in caustic soda solution. Starting material for → Viscose fibres.

II. Short for → Viscose fibres.

Viscose fibre properties in comparison to other cellulosic fibres Cellulose fibres are classified into native cellulose fibres (cotton) and regenerated-cellulose fibres (viscose and modal). The chemical structure of both types of fibre is identical:



cellulose

Chemical reactions with the cellulose fibre take place on the cellulose molecule. For example, a reactive dye reacts with the functional groups on the molecule, which in the case of cellulose, are OH groups. In preference, a dye will react with primary groups (the –CH_2OH groups on the outside of the molecule). Only 1% of the OH groups on the cellulose react in reactive dyeing, but this is sufficient for deep dyeings. The differences between cotton, viscose and modal are due to their different physical structures, i.e. the fine structure of the different types of fibre. The fine structure of the fibre is determined by the combination of monomers and chain molecules, the way they are bundled into crystalline and amorphous zones and the fibrils which usually lie parallel to the fibre axis.

Each fibre is characterised by highly ordered crystalline zones, non-crystalline, i.e. amorphous zones and non-crystalline, semi-amorphous zones of chain molecules.

The amorphous zone in cotton is identified by its reversible swellability in water. In contrast to its reversible swelling property in water, in caustic soda, the whole fibre structure swells irreversibly as the crystal lattice is converted from cellulose I to cellulose II.

The crystal lattice of viscose fibre is cellulose II. The non-crystalline chains are significantly disoriented as the fibres are spun from solution and crystallise out of solution. At the same time, when a viscose fibre is dried and then made to swell again in water, the cellulose molecules in the non-crystalline zones take on a rather randomised structure which hardly changes. In contrast to the regenerated cellulose, the number of hydroxyl groups in the non-crystalline zone of cotton make themselves noticeable by the effect that moist cotton fibres with the cellulose I lattice are more solid than dry fibres.

In the case of cotton, this phenomenon is explained by the randomised molecular chains in the non-crystalline zones becoming ordered, albeit reversibly, as the water molecules penetrate into the structure. When the quantity of water reaches a critical level, the hydrogen bonds are broken and internal stresses in molecular chains are removed. This behaviour of cotton differs from that of regenerated cellulose as native cellulose crystallises out from the liquid crystal state. The amount of water bound to cotton is again subdivided (unlike viscose) into 19.8% "non-freezable" and 2.2% "freezable" water.

The regenerated modal fibres of the high-wet modulus types (HWM) represent a special case in comparison to conventional viscose. During the development of modal fibres, the most important criteria was to achieve reduced swelling and a reduced tendency to shrink. Investigations have shown that the disadvantages of conventional viscose mentioned are due to a wet modulus which is too low. The modulus describes the amount a fibre stretches under a given load (the relationship between bad and extension) – the smaller the extension for a given load, the higher the modulus and the greater dimensional stability of the textiles manufactured from these fibres. Such fibres may only be called modal fibres if the amount they stretch under a load of 22 cN/tex in the wet state does not exceed 15% which, according to the definition, is the same as having a high wet modulus.

Another characteristic difference is the essentially higher average degree of polymerisation (DP) of modal spinning solution in comparison to that of viscose.

While a drop in the DP to 280 must be accepted when producing standard viscose fibres, the values achieved for high wet modulus types exceed 500. Coagulation of the spinning solution takes place in the precipitating bath with significantly reduced sulphuric acid and sodium sulphate concentrations and is relatively slow. This means that high drawing is possible which causes the cellulose molecules to be highly oriented.

The following differences may be summarised for the different types of fibre, cotton, viscose and modal:

Conventional viscose fibres have lower strengths and higher stretching properties than cotton. The DP of viscose is lower, as is the degree of orientation, which is 30–40% lower than that of cotton (50–60%).

Compared with cotton, modal fibre does have a weaker tensile strength/extension ratio in the wet state. Its other properties, however, such as water retention values, which range from around 60–70%, are very similar to those of cotton. In comparison with cotton, modal and viscose fibres have the following advantages which are mainly the result of their being regenerated fibres: uniform quality, large capacity for variation with regard to staple length and titre, high purity and therefore better spinnability and a soft silky handle.

The advantages of modal fibres over viscose fibres are found in their essentially high strengths in the conditioned and wet state, higher wet modulus, lower water retention values, reduced swelling properties and higher resistance to alkalis.

Due to the variation in the additions in the spinning solution and spinning bath, a DP of 180–280 is achieved for standard viscose fibres (cotton type) and 250–380 for modal fibres (high wet modulus type), although the DP of both the starting cellulose (800–1200) and the spinning solution (300–700) is the same for both types of fibre.

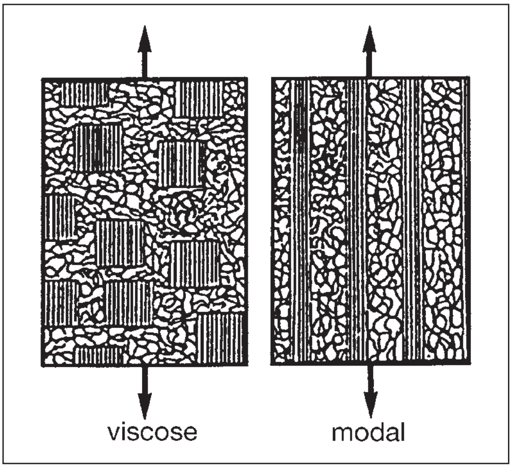


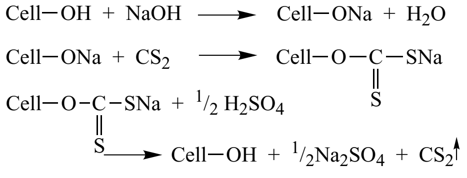
Fig.: Difference in the sub-microscopic structure of crystalline and amorphous areas of viscose and modal fibres.

The differences between viscose fibres and cotton can be explained by their different crystal-lattice structures. This results in a weaker load/extension ratio for viscose fibres, both in the conditioned as well as the wet state. Other characteristics typical of viscose fibres are pronounced swellability, high moisture absorption, lower shape retention as well as the need for improvement in breaking strength and abrasion resistance.

The regeneration process has been so well mastered that it is possible to alter the morphology, degree of orientation and orientation of the fibre at will. Based on this knowledge, cellulose fibre groups can be developed which are very similar to those of cotton. Representatives of these modal fibres are the polynosic and high wet modulus types. Polynosic fibres have good shape retention, increased linear strength and are easier to mercerise in comparison to standard viscose fibres. The high wet modulus types have around 50–70% higher lateral strength; thus, under certain conditions they are also easier to mercerise, are less resistant to bending and do not fibrilate. At 60–70%, their water-retention value is of the same order as that of cotton. The properties listed predetermine these fibres for use in mixed processing with natural and man-made fibres.

The difference in the structure of regenerated fibres from that of cotton (Fig.) results in their having different properties. Thus, conventional viscose fibres have lower strengths, higher water-retention, a greater susceptibility to creasing and a higher stretching ability than cotton.

Viscose fibres Regenerated fibres made from the renewable raw material "cellulose" can only be wet-spun as filaments in precipitation baths with the aid of special solvents for the base polymer. The compounds shown in Fig. 1 are used for the classical solvent-precipitation bath system.



$$\text{Cell}-\text{OH} + \text{NaOH} \longrightarrow \text{Cell}-\text{ONa} + H_2O$$

$$\text{Cell}-\text{ONa} + CS_2 \longrightarrow \text{Cell}-O-\underset{\substack{\| \\ S}}{C}-\text{SNa}$$

$$\text{Cell}-O-\underset{\substack{\| \\ S}}{C}-\text{SNa} + {}^{1}/_{2}\,H_2SO_4 \longrightarrow \text{Cell}-\text{OH} + {}^{1}/_{2}Na_2SO_4 + CS_2\uparrow$$

Cellulose is immersed in approx. 18% caustic soda solution where the alkali cellulose is formed, a greatly swollen but non-solubilised material. The alkali cellulose is brought into contact with gaseous or liquid carbon disulphide to form the cellulose xanthate, an unstable compound which dissolves in caustic soda solution. It is spun into an aqueous solution containing salt and acid. The salt promotes coagulation and the acid neu-

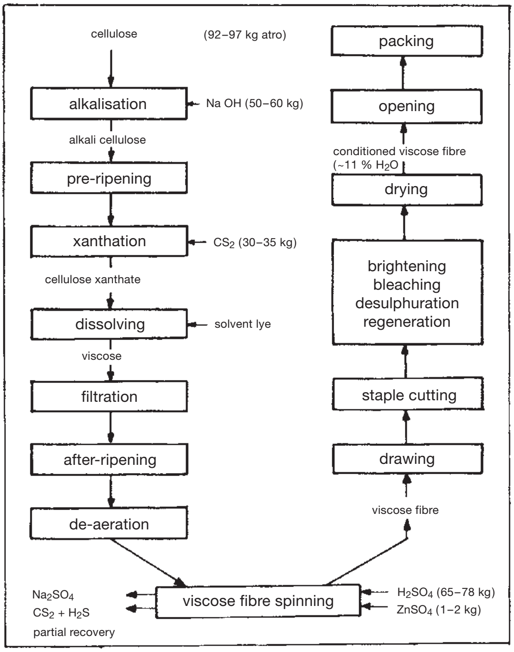


Fig. 1: Diagram of viscose staple fibre production (consumption in kg/100 kg of conditioned fibre).

tralises the alkali and decomposes the xanthate. This process regenerates the cellulose in the form of continuous fibres which are known as viscose fibres.

While the cellulose is regenerated, sodium sulphate and carbon disulphide are formed, the latter being released in the form of a gas. Some of this carbon disulphide is condensed and recovered. The carbon disulphide which is not condensed is washed out and the components with an unpleasant smell are removed.

During the stage when the xanthate is formed, a side reaction takes place during which the carbon disulphide partly reacts with the sodium hydroxide in the alkali cellulose. This produces sodium trithiocarbonate via various intermediate steps.

$$3\,CS_2 + 6\,NaOH \rightarrow Na_2CO_3 + 2\,Na_2CS_3 + 3\,H_2O$$

The characteristic orange colour of viscose is explained by the presence of the sodium trithiocarbonate.

It cannot be overlooked that the production of regenerated cellulose fibres is associated with significant shortcomings, i.e. the poor ecology of the most commonly used viscose processes due to the emission of CS_2 and H_2S. This problem has been known for some time, so a considerable amount of work is being undertaken to

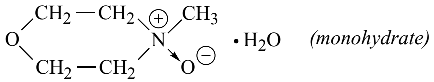
a) increase the safety of the viscose process at higher productivity by improving the industrial technology (for this, there are examples which are effective for production)
b) look for alternative solvents for cellulose and develop new processes.

A series of new aqueous and non-aqueous solvents has been discovered for cellulose (Tab. 1).

The “Newcell” process uses N-methylmorpholine oxide (NMMO) as a solvent for cellulose.

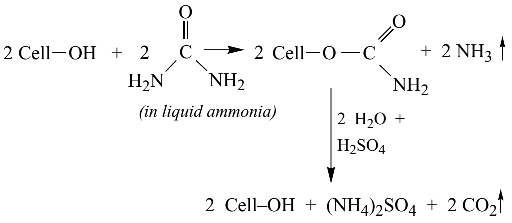
Amine/dimethyl sulphoxide	NH_3/NH_4SCN
N-methyl morpholine-N-oxide	Phosphoric acid
$(HCHO)_x$/dimethyl sulphoxide	$ZnCl_2$/water
N_2O_4/dimethyl formamide	LiOH/water
LiCl/dimethyl acetamide	
LiCl/urea derivatives	

Tab. 1: Unconventional solvents for cellulose (left), with precipitating bath (right).



A stabiliser is added to reduce the interactions of the redox system which is produced (cellulose is reducing and, at high temperatures, N-methylmorpholine oxide is oxidizing).

The “Celca” process is based on the dissolution mechanism and precipitation reaction:



CS_2-free processes for the production of regenerated cellulose fibre are

- the process for producing tencel fibres which was developed by Courtaulds;
- the Akzo process for spinning newcell fibres;
- the Lenzing process for spinning lyocell fibres.

These fibres have completely round cross sections, smooth surfaces and modified cohesion properties, high wet modulus, high dry strength as well as a pronounced tendency to fibrilate.

Viscose fibres

Cellulose triacetate dissolves in trifluoroacetic acid (or in the cheaper and less toxic alternative, concentrated nitric acid). The 30–50% solution is anisotropic, i.e. liquid crystals are formed in the solution, which after a sharp increase in the viscosity, at the critical point, leads to a subsequent decrease in viscosity. When spinning these types of high-concentration but low-viscosity liquid-crystal solutions using "air gap" technology, triacetate fibres can be spun which then yield regenerated cellulose fibres after saponification.

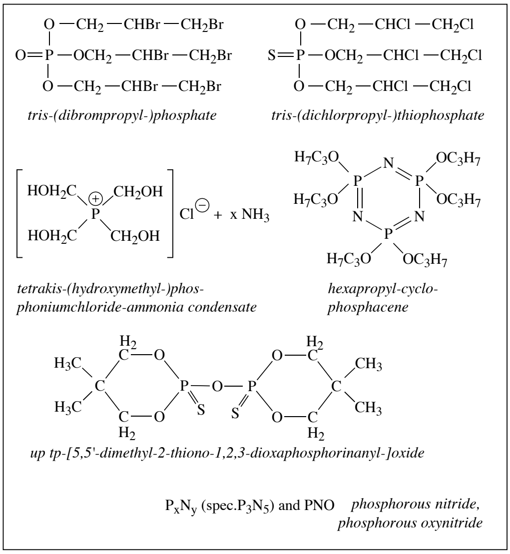


Fig. 2: Examples of core spun agents for flame retardation of viscose fibres.

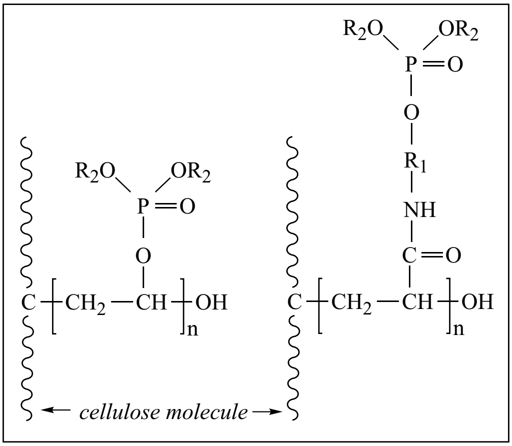


Fig. 3: Examples of achieving flame retardation of cellulose fibres through graft modification.

Flame-resistant viscose fibres can be produced in the cellulose xanthate by adding phosphorous compounds (as well as graft polymers) to the melt (Figs. 2–3).

Cellulose exists in different crystalline configurations of which the most important are cellulose I and cellulose II.

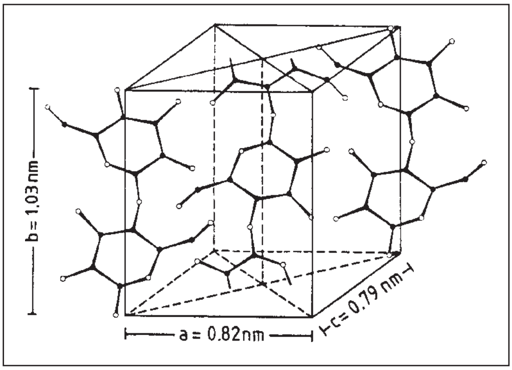


Fig. 4: Layers in cellulose I linked by hydrogen bonds in the elementary (unit) cell (radioscopic) according to Fengel.

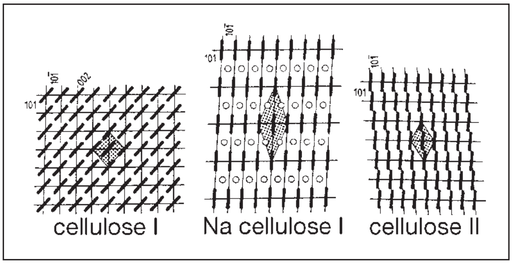


Fig. 5: Transition of cellulose I into cellulose II.

While the natural product is characterised by cellulose I, cellulose II appears in regenerated cellulose products. In comparison to cellulose I, cellulose II is thermodynamically more stable. An intramolecular hydrogen bond exists on both sides of the oxygen atom in cellulose I (Fig. 4) linking the two neighbouring anhydroglycose units. Apart from this, there are also intermolecular hydrogen bonds. In the arrangement of cellulose II (Fig. 5) there is only one hydrogen bond parallel to the oxygen atom link. Thus, the number of intramolecular bonds found in cellulose II is only half that found in cellulose I. As the intramolecular hydrogen bonds contribute to the rigidity of the polymer chain and their number is only half that of cellulose I, their contribution to the rigidity of cellulose II is lower. Thus, the theoretical modulus (a measure of stiffness) of cellulose II is lower than that of cellulose I. With their cellulose II configuration, viscose fibres have a lower modulus than that of natural cellulose fibres such as cotton, jute, hemp, flax and ramie, etc.

It is generally accepted that the polymer chains in cellulose I run parallel to each other and that in cellulose II they have a stable anti-parallel arrangement. In cellulose II, the chains are arranged in parallel in a particular plane in the crystal lattice. On the next plane, however, they are oriented in the opposite direction, i.e. they run non-parallel to the first plane. This gives rise to the problem that this material swells significantly when cellulose I is immersed in a caustic solution, although it continues to remain in the solid state. Nevertheless, it appears as if the cellulose structure transforms itself into the crystal lattice of cellulose II on regeneration. This means that all the lattice planes in the solid state have switched round by 180°, which is difficult to explain.

The shape and arrangement of the molecules are also decisive, apart from the length of the chains which is determined by the DP. In the case of viscose, the macromolecules are oriented axially during production due to stretching. At the same time, the chains are in a position to form sub-microscopic crystallites. High-strength fibres result from a high level of orientation, an ordered zone involving a bundle of 40–60 macromolecules. X-ray analyses have shown that 40% of the fibre substance in the case of viscose fibres and 70% in the case of cotton is found in crystalline zones which alternate between amorphous segments. The molecular chains are partly folded (Fig. 6) and form a so-called fringed fibrila structure.

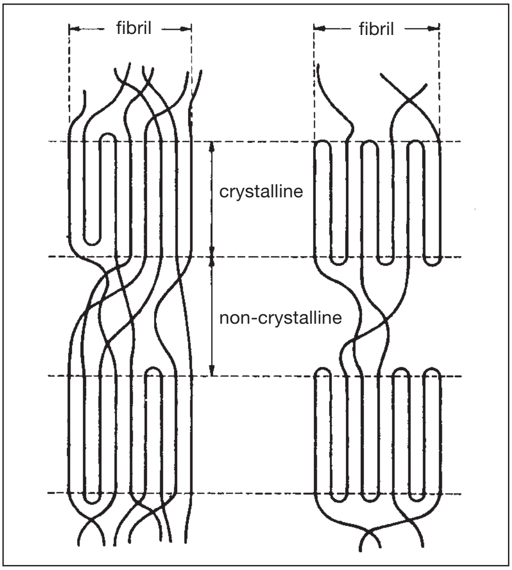


Fig. 6: Structural model of a drawn fibre (with chain overfolding).

The extension and swelling of viscose fibres depends on the number, size and distribution of crystalline and amorphous zones. The finishing processes only affect the amorphous part of the fibre material in which water penetrates as the hydrogen bonds split up. But even in the amorphous zones, not all OH groups are available to react because, for example, some of the dye molecules are too large and are so sterically inhibited that reaction is impossible. Apart from axial orientation, lateral arrangement is also important for the fine structure of the fibre. As the viscose enters the precipitation bath, a tiny skin is first formed by coagulation and this acts as a membrane. Thus, the viscose fibres receive a denser outer layer, the so-called “sheath”. Inside the fibre, the conditions for forming crystallites are less favourable as fewer crystallisation centres are available there. In the so-called “core”, an irregular network of larger crystallites develops which are separated by large amorphous zones. The sheath, on the other hand, has a homogeneous structure composed of many small crystallites. The structural differences between the core and the sheath are made easily visible under a microscope by staining.

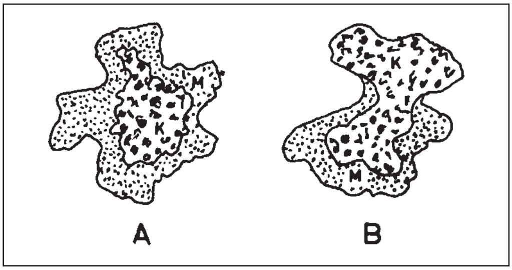


Fig. 7: Cross-section structure of a normal viscose fibre (A = sheath core structure) and a highly crimped viscose fibre (B = “two-component structure”).

The crimp is an extremely important property of the spun fibre. It is necessary for good workability and optimum spinnability, giving strength, volume and uniformity to the yarn and a good appearance, surface coverage and handle and pleasant wear behaviour to the fabrics and knitwear produced from it. The usual types of regenerated-cellulose-based spun fibre have long been know in crimped forms, even if hardly crimp-resistant. New techniques have been developed which are based on special coagulation, regeneration and drawing conditions. These produce viscose fibres which have a “live” crimp which can be regenerated. The special spinning method causes the primarily formed outer sheath of freshly spun fibre to break out in small areas during the fibre formation and drawing process, and the fibre core, while it is still plastic, can reach the fibre surface through the fibre capillaries. This produces a kind of "two-component structure", in which the stretching and swelling properties caused by the different fine structures of the core and sheath zones provide a basis for latent crimping as well as crimp recovery. Fig. 7 is a schematic illustration of this "two-component structure".

Moisture absorption and swelling behaviour of viscose fibres: viscose is very hygroscopic, i.e. it rapidly absorbs moisture from the surrounding air and reacts more sensitively to fluctuations in climatic conditions than man-made fibres. This behaviour is of great importance during further processing. Under standard atmospheric conditions (20°C and 65% relative humidity), the following moisture absorptions are observed for viscose and cotton:

- viscose 13–14%,
- cotton 7–8%.

The dependence of moisture absorption on the relative humidity is shown in Fig. 8.

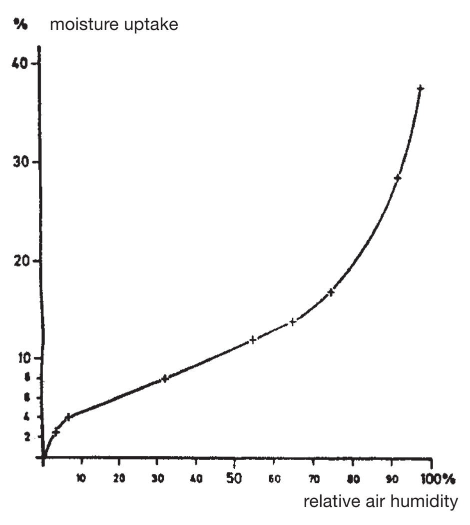


Fig. 8: Moisture uptake of viscose relative to relative air humidity.

As the drawing properties are strongly dependent on the moisture content, the fibre can easily be over-drawn during processing as the climatic conditions fluctuate and this may become noticeable in the form of contraction variations in the goods (bagginess and bands in the finish).

The degree of swelling during moisture absorption is one of the most important properties of viscose. The percentage of water retained by the fibre serves as a measure of its swelling capability. The following are found for viscose and cotton:

- viscose 80–115%,
- cotton 45–50%.

Although the ability of the fibre to swell is not lost during drying, the water-retention value decreases with each drying. How this changes with intermediate drying after each finishing stage and can be seen in Tab. 2.

The disadvantage is that swelling in the case of viscose is always associated with loss in strength as the effect of the hydrogen bonds between the chains is removed by their bonding with water. The relative wet strengths for viscose and cotton are as follows:

- viscose 42–50%,
- cotton 100–113%.

The consequences of this are felt during treatment in the wet state in particular. The decrease in strength is also associated with an increase in stretch. Tab. 2 also shows that the filament number is important for strength in relation to fineness. Yarn with fine filaments has a higher relative wet strength because the finer filaments have a higher proportion of crystalline sheath structures. The yarn therefore does not swell so much.

count (dtex)	84 f 24	84 f 30
individual filament count (dtex)	3,5	2,8
strength (cN/tex)		
dry	18,4	16,7
wet	7,7	8,0
relative wet strength (%)	42	48
stretch (%)		
dry	12,5	18,0
wet	23,5	26,0
water retention capacity (%)		
sized and dried	88,8	83,2
washed and dried	82,3	78,7
bleached and dried	79,5	–
dyed and dried	75,8	74,7

Tab. 2: Strength and water retention capacity of viscose filament yarns (Enka).

As the limited degree of swelling in water is reversible, none of the changes in the fibre properties remain. The behaviour of cellulose in alkali solutions, on the other hand, has more impact. Alkalis produce significantly more swelling than water, as intermicellar swelling turns into intramicellar swelling. Accessibility to the hydroxyl groups and, therefore, the reactivity of the cellulose is increased significantly by alkaline treatment. It is important to find the right measure and not exceed the target.

Cellulose can be dissolved by converting it into sodium cellulose using caustic soda solution. The highest possible alkalinity for the compound is achieved with:

1 Mol caustic soda to 1 Mol glucose.

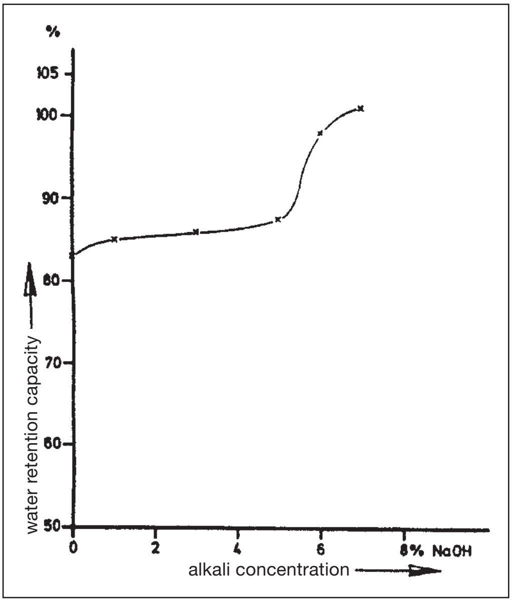


Fig. 9: Change in the water retention capacity of viscose due to caustic soda treatment.

Solubility in caustic soda solution is dependent on both the concentration and temperature and reaches a distinct maximum at a concentration of 10%. Regenerated celluloses dissolve in 10% caustic soda at –5°C. Providing the NaOH concentration remains below 5%, the amount of viscose fibres dissolved is negligible. At room temperature, they are resistant to alkali solutions up to 1%, almost without any change to the water-retention value. When viscose is treated with 4–6% caustic soda solution, there is a clear increase in the dye affinity and corresponding differences in colour. This is made use of when causticizing with caustic soda solution between 6 and 8°Bé. The change in the water-retention value, particularly the sharp rise at 5%, is shown in Fig. 9.

Caustic treatments at concentrations above 5% NaOH significantly loosen up the crystalline fibre structure.

The swelling effect is different for different alkali-ion solutions and depends on the atomic volume of the alkali ion. This increases in the following order:

$$K^+ < Na^+$$

This explains why a caustic potash solution is less dangerous to viscose than a caustic soda solution at the same concentration.

A typical finishing process for viscose fibre fabrics would have the following sequence:

- singe,
- desizing with enzymes using the CPB method,
- after washing, intermediate drying,
- caustic treatment (8°Bé Na0H),
- wet-in-wet-pad-steam-peroxide-bleach,
- intermediate drying,
- CPB reactive dyeing,
- acidulating on the padder with intermediate drying,
- resin finishing (padding-drying-condensation),
- sanforizing.

This finishing procedure produces crease values such as those shown in Fig. 10 for coarse- and fine-titre viscose fibre fabrics in comparison to cotton (according to Shaumann, Krässig, Vollbrecht, Berger und Morgenstern).

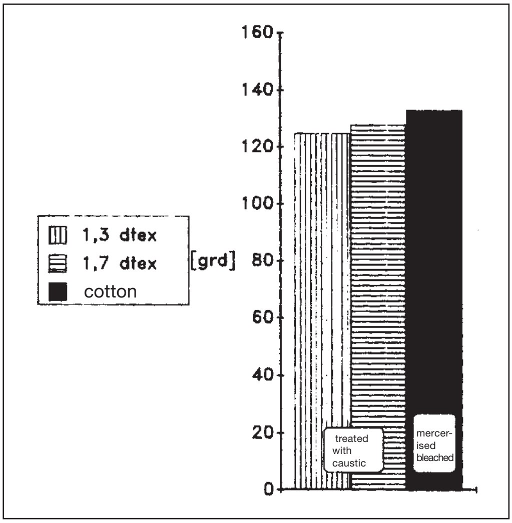


Fig. 10: Effect of count and pre-treatment on crease recovery angle (mean value K/S after 30 min) of viscose in comparison to cotton.

Viscose fibres, finishing Following the general trend, viscose articles are manufactured from very fine yarns. Yarns up to Nm 60–80 as well as those of Nm 100/2 are used. The weight of these goods, which are predominantly printed with large-area patterns, range from 80 to 120 g/m^2. In order to achieve high elasticity, finishing is carried out using urea-formaldehyde resins (resin finishing agents). The disadvantage of these finishes is the extremely high proportion of free formaldehyde which leads to high levels of odour pollution. For this reason, viscose articles are also finished using low-formaldehyde DMDHEU crosslinkers. However, in order to achieve a formaldehyde level as low as that for cotton, note must be taken of the following points:

- viscose has a higher proportion of amorphous zones in which there will be alkali residing from pre-treatments and dyeing processes carried out beforehand.

This disrupts the catalytic effect and prevents complete crosslinking.

- The alkali can be neutralized by adding 1 ml/l acetic acid (80%) to the finishing liquor.
- Increasing the amount of catalyst by 30–50% and intensifying the condensation conditions also have a positive effect on the formaldehyde content. At the same time, the negative effect on the strength is essentially lower for viscose than it is for cotton.

An elastic finish is achieved by combining the DMDHEU crosslinker with a polyurethane product, while a silicone elastomer can be added to increase it further. Due to the surface structure of the viscose and the general trend towards a softer finish, the risk of impaired non-slip properties for this article group increases. For this reason, it is advisable to add an anti-slip product. Whether it is crêpe, staple goods or smooth articles with high-twist yarns, it is really the causticization which produces the desired effects, i.e. the handle, the brilliance of the colours and the fall of the fabric.

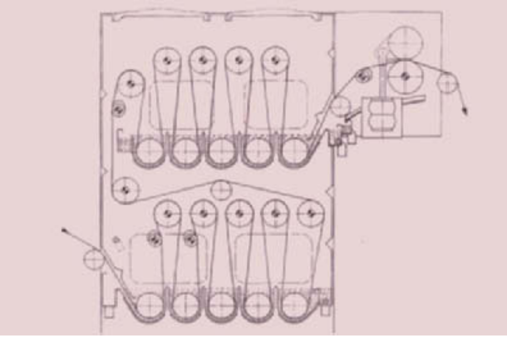


Fig.: Wet-caustic causticizing machine for viscose fabrics (Wet-Tex).

Theoretically, causticization is simple to carry out: the substrate is soaked with caustic solution for a certain period of time (caustic soda solution at 5–8°Bé and temperature approx. 15–25°C). The caustic solution is then washed out of the textile. Not only is the material intensively wetted with the caustic solution at the desired concentration during the treatment, the absence of tension must be maintained throughout the entire process. In practical terms, various procedures are usually adopted:

a) Batch treatment in wide form: it is only possible to causticize on the jigger if shrinking of the goods is to be avoided. Jigger-treatment is, therefore, not appropriate for most viscose articles which are tension-sensitive.

b) Semi-continuous method: the semi-continuous method using an impregnation device and batching station offers a good ratio between the textile mass and amount of caustic soda solution used. The tension required for the goods in the pad roll or pad batch methods for secure reeling prevents the goods from shrinking. Thus, the desired improvements with regard to fabric breakdowns are not achieved.

c) Continuous method: good results are achieved with the long-loop method. The system is limited by the maximum possible fabric speed. The fabric, wetted with a caustic solution, must be soaked in the treatment bath using a special device. The liquor stream must only flow at a certain velocity, otherwise the turbulence in the dwell bath make the smooth conveyance of the long loops into the dwell bath more difficult.

Often, the conventional open-width washing machines used for the occasional causticization of viscose cannot operate at the minimum fabric tension. As the warp shrinks, the length of the weft threads change at the same time. The rapid change in the width of the fabric produces a number of small “waves” in the direction of the fabric run and these can join to form rope creases which cannot be repaired. The fabric tension in relation to this problem can be better controlled in a short-loop roller vat (Fig.) (according to Fornelli and Meyer).

Viscose fibres, reactive dyeing One of the main factors which affect reactive dyeing of viscose filaments in the exhaustion process is the substrate or its properties. On the one hand, the high swelling capability of viscose, particularly in alkaline dyes, must be taken into account and on the other hand, it is the dye pickup which has to be considered. When dosing with solid salt, it is possible to compensate for the high affinity of the material by slowly increasing the substantivity of the dye.

The relationship between pH and fixing temperature and the possibility of dosing with alkali can be used to

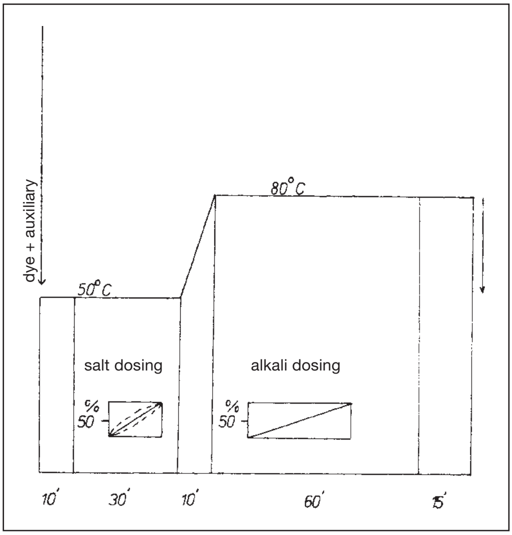


Fig. 1: Dyeing method 1 for viscose dyeing.

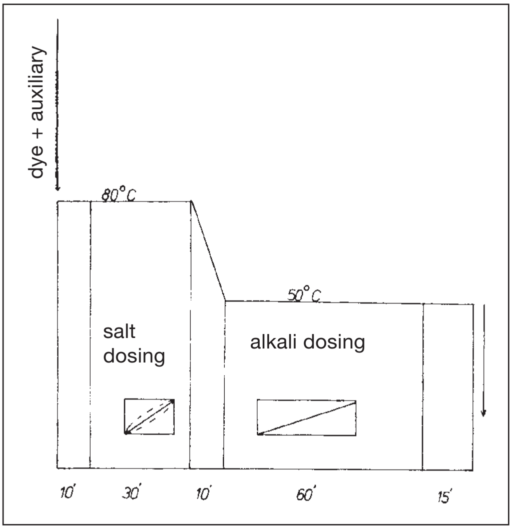


Fig. 2: Dyeing method II for viscose dyeing.

reduce the swelling properties. Based on this principle, five dyeing methods are available which are suitable for dyeing viscose filaments (Figs. 1–5).

Method I corresponds to the conventional migration process, except that the salt (for increasing the substantivity) and alkali are dosed. In spite of the slow increase in substantivity, it is possible that the flow through the wound packages will be disrupted due to the swelling of the viscose filaments, particularly in water at lower temperatures. Consequently, dosing salt delays the absorption of the dye but the requirement that the dye be distributed uniformly before fixing begins is probably not fulfilled because the flow of liquor through the packages is impaired.

In the case of method II, the salt is dosed at a higher temperature. Swelling is limited at higher temperatures and the diffusion and migration of the dye improved. The probability of uniform dye distribution during the substantive phase is greater than it is for method I.

Cooling and fixing in the cold bath could have a negative effect on the final levelling. The substantivity of the dye increases as the temperature of the total quantity of electrolyte in the dyebath decreases. The dye fills up as the equilibrium shifts in the direction of the fibre. By adding alkali to the cold bath, three factors effect each other and cause increased swelling of the material and, therefore, impair the flow of the liquor through the packages:

- an increased tendency to swell due to the low temperature,
- an increased tendency to swell in alkaline solutions,
- lower fixing temperatures require stronger alkaline conditions to achieve the final fixing value. Swelling increases with increasing amounts of alkali.

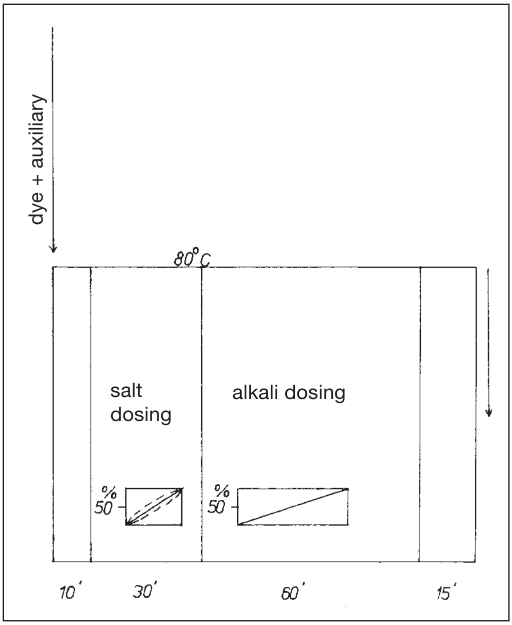


Fig. 3: Dyeing method III for viscose dyeing.

Judging by the dyeing profiles, the isotherm method III is the most suitable for achieving level dyeing, taking into account the lowest degree of swelling for the material and associated even flow through the packages. Based on uniform temperatures, non-uniform filling of the dye (as assumed in the case of method II due to cooling of the bath) is not to be expected. The fixing conditions are milder in line with the higher bath temperature, and this has a positive effect on the swelling state.

In the case of dyeing method IV, high temperatures

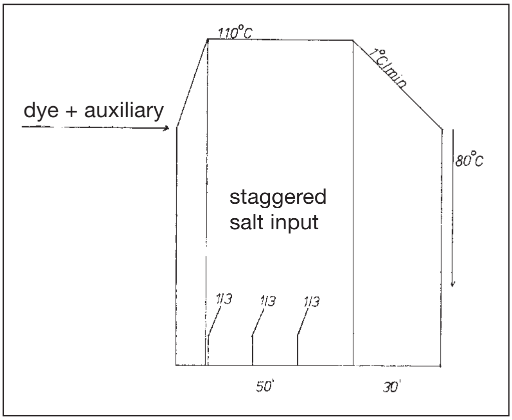


Fig. 4: Dyeing method IV for dyeing viscose filaments with substantive dyes.

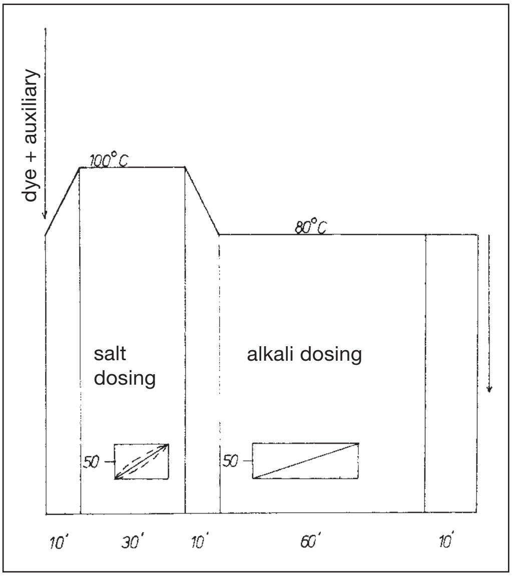


Fig. 5: Dyeing method V for dyeing viscose filament packages with reactive dyes.

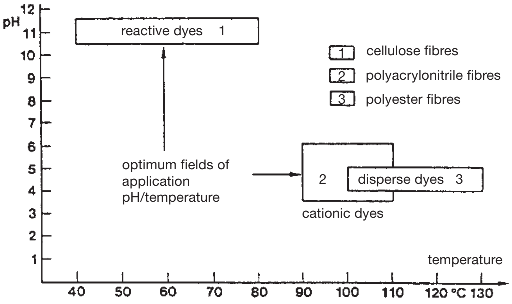


Fig. 6: Problem with the exhaustion dyeing of synthetic fibre/cellulose blends with the use of reactive dyes (Bayer).

are selected mainly to ensure better flow of liquor through the dye packages due to the reduced tendency to swell at high temperatures. When using reactive dyes, particularly in the case of the high-reactive type, these high temperatures cannot be achieved as dye fixing and increased hydrolysis takes place within this temperature range even in the absence of alkali (pH around neutral).

The dyeing profile of method V is suitable for reactive dyeing. At the selected temperatures, the reactive dyes have a high diffusion rate, whereas the substantivity only increases slowly after the bath has cooled in a defined manner and salt has been added. The dye is also fixed at high temperatures. Thus, it is possible to work with milder alkalis or with smaller amounts of alkali. The main factors (temperature and pH) which affect the swelling of the material are chosen to favour reduced swelling and, therefore, uniform flow of liquor through the packages.

A problem peculiar to the dyeing of viscose-polyacrylonitrile blends arises from the conflicting absorption and fixing conditions for the classes of dye used for the cellulosic or man-made fibre (Fig. 6).

A single-bath procedure using reactive and cationic dyes cannot be achieved because of the risk of agglomeration which exists between the two classes of dye.

cationic dye$^+$ + reactive dye → dye-dye

A two-bath procedure must, therefore, be used, making sure that the polyacrylonitrile in the blend is always dyed beforehand, exactly to the shade, as it is almost impossible to dye it with cationic dye afterwards.

Viscose high tenacity fibres (rayon cord, supercord, all-skin fibres and modal fibres), developed with the aim of increasing strength, dry modulus, fatigue resistance and dimensional stability, etc. This aim was realized to a limited extent using older spinning meth-

	breaking strength		elongation at break		water retention capacity
	dry cN/tex	relative wet strength %	dry %	wet %	%
standard viscose					
F	13,5-27	42- 65	15-30	20-35	90-120
S	13 -18	55- 65	11-31	12-38	90-125
high tenacity viscose					
F	40,5-49,5	55- 70	6-21	6-30	62- 70
S	24 -34	65- 75	14-21	16-20	60- 75
extra high tenacity viscose					
F	45 -58	75- 80	11-17	20-30	60- 70
CO in comparison	27 -40	100-130	9-15	7-11	45

Tab.: Properties of different viscose fibre materials. S = staple fibres; F = filament fibres.

ods (such as the Lilienfeld and Lanusa principle and stretch spinning similar to cupro). By modifying viscose (→ Modified fibres) the production of high-strength viscose fibres with thickened → Covering layer and super-strong viscose fibres in all-skin structure with high-strength and high elongation (Tab.).

Use: as a filament for industrial fabrics, tyre cord, fabric linings, conveyor belts and drive belts. As a staple fibre: alone or in a mixture for rainwear, uniform fabrics, work clothing and protective clothing.

Viscose high wet tenacity fibres → Modal fibres.

Viscose modified fibres → Modified fibres.

Viscosity (Lat.: viscum), thickness, internal friction, internal resistance of a fluid against the relative movement of two neighbouring layers, i.e. the resistance a substance offers to flow.

A distinction is made between:

1. Dynamic viscosity η (→ Rheology; Rheological behaviour of solutions):

$$\eta = \frac{\text{shear stress } \tau}{\text{velocity or shear gradient D}} \quad [\text{Pa s} = \text{Ns/m}^2 = \text{kg/m s}]$$

2. Kinematic viscosity ν:

$$\nu = \frac{\text{dynamic viscosity } \eta}{\text{density}} \quad [\text{m}^2/\text{s}]$$

Both parameters “shear stress” and “velocity gradient” are defined using the parallel plate model (Fig. 1). In this model, two flat plates are arranged in parallel at a distance y to each other, the lower plate being stationary and upper plate being in motion. Both plates have an area A and the viscous substance is divided into laminae between the plates. If a force F now acts on the upper plate (in the direction shown), then this plate moves with a constant speed in the direction of the force and the substance begins to flow. The quotient of force F and the boundary area A of the substance underneath is called the shear stress τ.

$$\tau = \frac{\text{F(force)}}{\text{A(area)}} \quad [\text{N/m}^2 = \text{Pa}]$$

The shear force is responsible for the flow velocity of the substance which also depends on the internal resistance of the substance acting against the flow (viscosity).

Between the two plates, there is a velocity gradient where the substance has a velocity v_{max} at the upper plate and velocity 0 at the lower plate.

In the model presented, the fluid is divided up into laminae so the model is examined in terms of laminar flow. Laminar flow means a continuous stack of thin laminae of fluid in relative motion parallel to each other. The velocity gradient is established from the differences in velocity of two neighbouring laminae of substance divided by the distance between them and is defined by the following differential quotient:

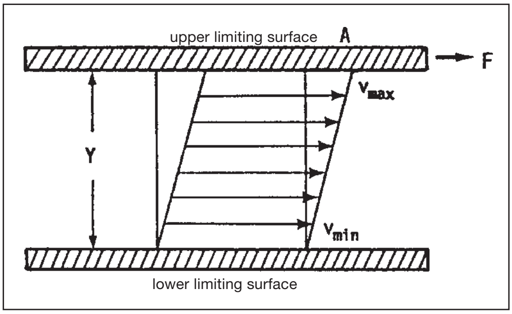


Fig. 1: Parallel plate model.

$$D = \frac{dv}{dy} = [\text{cm/s/cm} = \text{s}^{-1}]$$

The equation for dynamic viscosity is found by applying Newton’s law of viscosity:

$$\eta = \frac{\tau}{D} \quad [\text{N/m}^2 \cdot \text{s} = \text{Pa} \cdot \text{s}]$$

The unit of viscosity is the Pascal second (Pa s). The older unit, Poise, is still frequently used and is related to the new unit as follows: 1 Pa s = 10 Poise. There are two different types of flow or viscosity depending on whether the fluid is Newtonian or non-Newtonian. The first case covers all substances which behave according to Newton’s law of viscosity, as follows:

$$\tau = \eta \cdot D; \eta = \text{const.}$$

In this case, the dynamic viscosity is a constant for the substance which can be seen from the flow or viscosity curves. The relationship between shear stress and the velocity gradient D is shown graphically by the flow curve (Fig. 2), where τ is the ordinate and D is the abscissa. A corresponding relationship to the flow curves is found in the viscosity curves where the viscosity η is plotted against the velocity gradient (Fig. 3).

The flow curves of Newtonian substances appear as a straight line passing through the origin with a gradient α. The viscosity curve appears as a straight line parallel to the abscissa.

From Figs. 2 and 3, it can be seen that curves for non-Newtonian substances have a fundamentally dif-

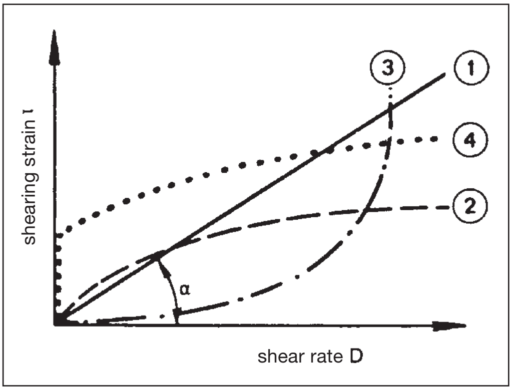


Fig. 2: Flow curves.
1 = Newtonian liquid; non-Newtonian fluid; 2 = structural viscous liquid; 3 = dilatant fluid; 4 = intrinsically viscous fluid with a flow limit = plastic fluid.

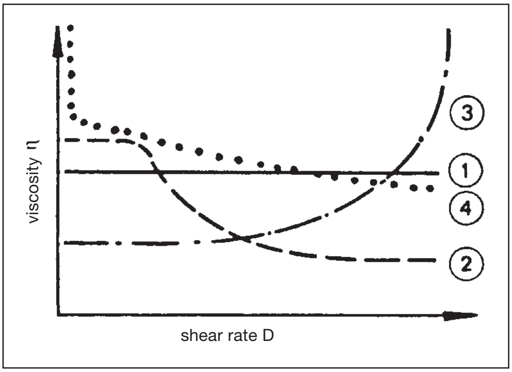


Fig. 3: Viscosity curves.
1 = Newtonian liquid; non-Newtonian fluid; 2 = structural viscous liquid; 3 = dilatant fluid; 4 = intrinsically viscous fluid with a flow limit = plastic fluid.

ferent shape. In this case, the viscosity does not have a substance-dependent constant but a dependent variable. In the following, the different flow characteristics will be described in more detail. In regard to viscosity as a function of velocity gradient, there are two different kinds of flow: dilatant and structurally viscous flow. If the viscosity increases with increasing velocity gradient, this is described as dilatant flow. If the viscosity decreases with increasing velocity gradient, this is structural viscosity or pseudo-plastic flow.

When the viscosity is dependent on the velocity gradient producing a yield limit τ_0, this is described as plastic flow. Substances showing this type of behaviour, apart from a yield limit, also show structurally viscous behaviour in most cases.

Viscosities which are dependent on D and time t:

a) If the viscosity increases with shear time, this is rheopexy flow.
b) If the viscosity decreases with shear time, this is thixotropic flow.

Most thickeners are non-Newtonian fluids and show more or less pronounced structurally viscous behaviour (Fig. 4); a few have a yield limit and are, therefore, plastic. The rheological behaviour of foam is also structurally viscous flow.

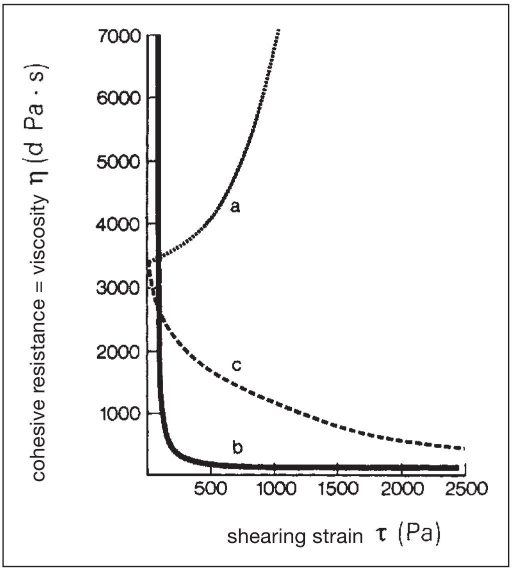
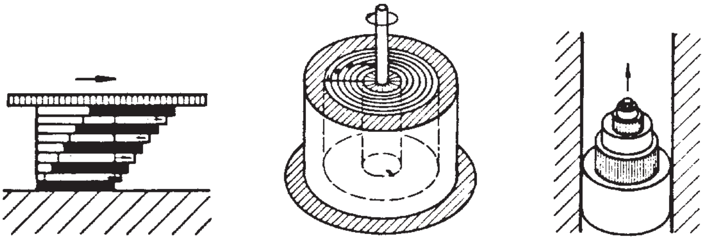


Fig. 4: Intrinsic viscosity of thickeners b and c; a is not to be used for printing thickeners.

For absolute viscosity measurement, values obtained must be based on the measurement of the fundamental physical parameters force, length and time. It must be possible to calculate the test substances mathematically, i.e. their flow measurement system must correspond to one of the four types of flow profiles shown in Fig. 5.

Another essential prerequisite is that it must be possible to calculate the shear force and velocity gradient exactly. In addition to this, the following boundary conditions must be fulfilled:

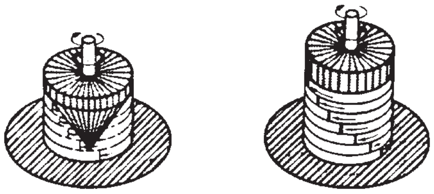
– Laminar flow: the shear must only generate laminar flow.
– Stationary flow state: in Newton’s viscosity equation, the shear stress applied is proportional to the velocity gradient. At the same time, the shear stress is only in a position to achieve constant velocity flow. Thus, the energy required to accelerate or retard flow velocity cannot be recorded.
– Wall adhesion: the effective shear stress must be



a) Flowing between two parallel flat plates

b) Flowing in the annular gap between two coaxial cylinders

c) Flowing through capillaries, sheet dies, tubes or pipes



d) Flowing in the annular gap between a cone and a flat plate or flowing in the gap between two plane-parallel round plates

Fig. 5: Different flow profiles.

transferable. If there is no adhesion between the layer of fluid and the two walls, i.e. moving and stationary, then it is not possible to produce a meaningful viscosity measurement.

- Homogeneity: when measuring mixtures, there must be no sedimentation of either component, otherwise the measurement will be distorted by the changes in the composition of the mixture.
- No chemical or physical changes: in order to characterize a sample using viscosity measurement, these effects must be excluded. On the other hand, if it is necessary to record the changes in viscosity caused by chemical or physical reactions, then this can be achieved by using a special experimental arrangement where the viscosity parameters (type of substance, temperature of substance, pressure, velocity gradient and shear time) must be kept constant.
- No elasticity: for substances which show viscoelastic flow behaviour, the measurements can no longer be regarded as due to viscosity if there is a large increase in the elastic component.

Viscosity index η is boundary value of the relationship between the specific viscosity η_{sp} and the concentration C, if the latter tends to zero:

$$[\eta] = \lim_{C \to 0} \frac{\eta_{sp}}{C}$$

The specific viscosity of a dilute solution of the fibrous material in a solvent is determined using a capillary viscometer. The viscosity index is a characteristic of the quality of the material and, through this, a measure of the reduction in the molecular weight, i.e. the reduction of viscosity index. The viscosity η_0 of a solvent is raised to the value η by the dissolution of a given amount of polymer. The quotient of η and η_0 is called the relative viscosity:

$$\eta_{rel} = \frac{\eta}{\eta_0}$$

Furthermore, the increase in relative viscosity, i.e. the difference between the η and η_0 in relation to η_0, is called the specific viscosity:

$$\eta_{sp} = \frac{\eta - \eta_0}{\eta_0}$$

As proportional factors, both η_{rel} and η_{sp} are dimensionless. For their determination, therefore, it is sufficient to measure only one parameter which is proportional to the viscosity η or η_0.

A measure for viscosity is obtained by running the diluted polymer solution through a capillary and measuring the time for it to stop at time t. A corresponding value is obtained for the pure solvent at time t_0. According to the Hagen-Poiseuille law, the viscosity is proportional to the flow time. The flow times can, therefore, be substituted by viscosities:

$$\eta_{sp} = \frac{t - t_0}{t_0}$$

The viscosity of fluids is strongly dependent on the temperature and the measurements must, therefore, be carried out at a defined temperature under temperature-controlled conditions. Einstein showed that, for a solution or dispersion of spherical particles, the specific viscosity η_{sp} is directly proportional to concentration c and inversely proportional to the particle density ρ:

$$\eta_{sp} = 2.5 \frac{c}{\rho} \quad \text{or} \quad \frac{\eta_{sp}}{c} = \frac{2.5}{\rho}$$

η_{sp}/c is called the reduced viscosity. A macromolecule in solution, however, is not a sphere but forms a statistical coil in solution. ρ is, therefore, not the density of pure polymers but of the coil, the solution contained within the coil not being taken into account. Strictly speaking, the corresponding relationship only applies to infinite dilution where the dissolved particles no longer have any effect. As η_{sp} determinations can only be sensibly made for finite dilutions, measurements are carried out at several concentrations and the reduced viscosity η_{sp}/c is plotted against c and extrapolated to concentration c = 0 (see Fig.). Where the line cuts the ordinate is designated the intrinsic or limiting viscosity or the viscosity index or even the Staudinger index and is given the symbol [η]. The coil density is not a constant for the substance but depends on the molecular weight M. Finally, from this relationship comes the Kuhn-Mark-Houwink-equation:

$$[\eta] = K \cdot M^a$$

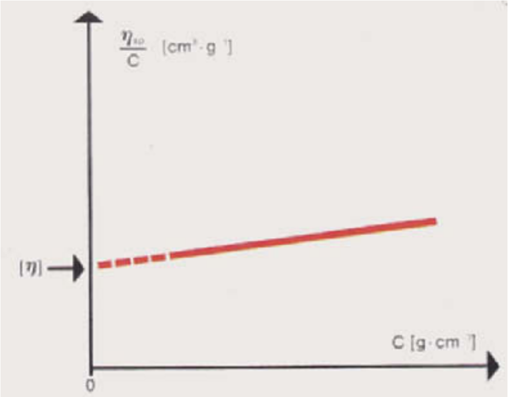


Fig.: The viscosity index [η] is obtained through extrapolation of η_{sp}/c against c = 0.

In this, K and a are constants when polymers, solvents and temperature are known. The value of a lies between 0.5 and 1 but is frequently in the vicinity of 0.8.

Viscosity of print pastes The rheological behaviour of print pastes plays a part in textile printing which is not insignificant. Apart from tensile loads, shear forces in particular act on the pastes (→ Rheology in printing and coating). However, so far, measurement techniques have not asserted themselves in printing practice. In most cases, assessment is subjective – tack-tests judged by the flow of paste from a rod. However, viscosity measurement has been introduced into printing practice indirectly as thickener manufacturers use the flow properties to characterize thickeners and then use this information in formulation recommendations.

Investigations into the relationships between the rheological properties of a printing paste and its printing behaviour show the limits of viscosity measurement. As a single parameter, viscosity measurement cannot offer an adequate prognosis on the printing result. However, if the rheological behaviour is used in relation to other parameters, then the characteristic behaviour of each printing paste can be established and the printing process controlled.

In the case of foam printing, viscosity measurement is a fixed component of certain printing systems because the reproducibility of foam production is directly related to the starting material (the liquor feed is calibrated to a particular viscosity value of the starting paste).

Viscous Thick, turbid.

Visual display terminal (VDT). Combined input/output unit with visualization in alphanumeric or graphical format using dot or line matrix.

Visualising masks for colour monitors Graphics and text displays guide the user during the entry of set-

Fig.: Visualising mask for colour monitor.

up data, show current machine data, give information concerning the production process and present error correction messages (see Fig.).

Vitamin (Lat.: vita = life and amin), a material which is essential for life and controls organic functions in the body. Vegetable or synthetic origin. Very effective at low concentration. Of interest in textile chemical processes, such as desizing, degumming, carbonizing or scouring; effective vitamins, are, among other things, component of → Enzymes, including those in the group of → Co-enzymes.

Vitriol salts → Sulphates of bi-valent metals containing waters of crystallization such as copper (blue vitriol → Copper(II) sulphate), iron (→ Copperas vat), cobalt, nickel and zinc.

VOeTC Verein östereichischer Textilchemiker und Coloristen (Austrian Association of Textile Chemists and Colourists). → Technical and professional organizations.

Voile,

I. Material (grenadine and veiling): light translucent, thin and loosely woven cotton fabric (and wool) made from hard-twist in linen weave, the hard-twisted, fibreless yarns giving the fabric a granular feel and slip resistant properties. The following distinctions are made:

- full voile: warp and weft ply yarn,
- semi voile: warp ply yarn and weft simple yarn,
- imitation voile: warp and weft simple yarn (Indian mull),
- silk voile: warp and weft natural silk.

In addition to these, there is marquisette voile, etamine voile, brocaded voile and ondulé voile. Voiles are used in curtain making, decoration and cloths.

II. Yarn: fine, hard-twist (gas-singed) cotton or worsted ply yarn.

Volatilization,

I. Change of state from liquid to vapour/gas (opposite → Condensation). Arising from molecular movement, based on the fact that molecules of high velocity escape from the surface of the liquid, the liquid being depleted by its fastest moving molecules.

II. The progressive change from a liquid to a gaseous state without heat input. Example: evaporation of volatile organic solvents such as benzene.

Voltage ranges According to the VDEW (Vereinigung deutsche Elektrizitätswerke e.V.) [Association of German Electricity Generating Stations]:

– low voltage	< 1 kV
– medium voltage	1–6 kV
– high voltage	60–150 kV
– extra-high voltage	> 150 kV

Voltammetry In voltammetry, the shape of the current/voltage curve is dependent on the type of voltage excitation (E vs. t), of the mass transfer to the electrode and on the degree of reversibility of the electrochemical reaction producing the signal.

Apart from the Ohmic resistances in a solution at rest for a given chemically stable species "Ox" (oxidized form) or "Red" (reduced form), the diffusion of the substances participating in the reaction is of prime importance for the transport of the electroactive substance to the electrodes. "Convective diffusion" applies when the solution or the electrodes are not at rest. A step-shaped current/voltage curve is observed under stationary conditions. As the signal increases, the kinetics of the electron transfer is the determining factor. Mass transfer dominates when each of the electroactive molecules or ions is converted as it reaches the electrode. This means that a limiting current is reached which is independent of any further increases in voltage.

$E_{1/2}$, the half-wave potential, is the potential at which half the value of the limiting current is reached (Fig.). The $E_{1/2}$ is used to describe the process and, in any given medium, is characteristic of the electroactive substance in question, i.e. it is qualitative. Limiting currents i_{gr} are used to determine the concentration of the electroactive substance in question, i.e. they are quantitative. If the reduction potentials are far enough apart from each other, voltammetric measurements can be taken of several substances together at the same time.

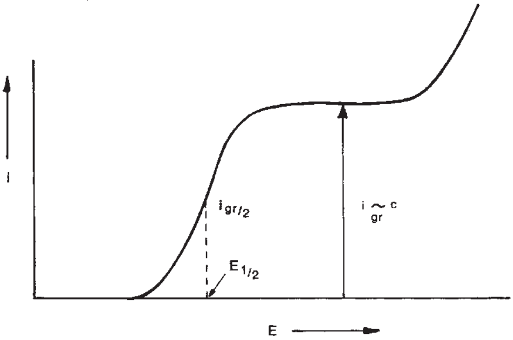


Fig.: Current potential curve in the case of stationary measuring methods.
E potential vs. reference electrode, $E_{1/2}$ half stage potential, i_{gr} marginal current.

For a simple electrochemical conversion, the magnitude of the Faraday current that can be achieved depends on the following parameters:

- the concentration of the electroactive substance,
- the number of electrons participating in the reaction per molecule or per mol.
- the transport mechanism of the substance (for example, the diffusion coefficients)
- the electrode surface.

The magnitude of the current arising from the electrochemical conversion is calculated from Faraday's and Fick's laws of diffusion; it also may be necessary to take into account the convection of the solution. For all methods listed below, a clear relationship is obtained between the measured current signal for the solution concentration being determined and the parameters of the measurement technique.

Voltammetry = the measurement of current in relation to voltage:

- current signal caused by electrochemical conversion of a substance (reduction/oxidation) at the electrodes,
- current (usually) proportional to the solution concentration of an electroactive species,
- voltage (in relation to reference value) corresponds to the energy in the electrochemical reaction (voltage x faraday constant = energy per mol), can be used for selective substance determinations.

Several types of current can be observed in voltammetry:

- faraday current i_{far}, arising from the electrochemical substance,
- kinetic currents i_{kin}, for example, affected by the rate of preceding equilibrium reactions of an outgoing inactive species A (A → Ox)
- currents arising from the adsorption of products of electron transfer and capacitance currents which arise from the molecular structure of the phase boundary electron conductor/ion conductor.

(according to Knittel et al.).

Volumetric analysis → Titration.

Volumetric weight of textiles The volumetric weight of yarns cannot be accounted for by the density of the type of fibre in question alone as it is generally significantly less. This is because the pore volumes and air content can fluctuate strongly depending on how the materials have been processed. The volumetric weight of textile fabrics is calculated as follows:

$$\frac{\textbf{weight (g/m}^2\textbf{)}}{\textbf{1 000} \cdot \textbf{thickness of fabric (mm)}}$$

VSCTU Swiss specialist textile cleaning organization (Schweiz. → Technical and professional organizations.

VSM,

I. Swiss standards organization. → Technical and professional organizations.

II. Swiss textile machine organization. → Technical and professional organizations.

VST Association of Swiss Textile Specialists (Vereinigung Schweizer Textilfachleute). United with VeT to form → SVT. → Technical and professional organizations.

VSTV Association of the Swiss Textile Finishing Industry, Zurich (Verband Schweizerischer Textilveredlungsindustrie); → Technical and professional organizations.

VTCC → Verein der Textilchemiker und Coloristen. Today → VDTF.

VTDI → Verein Textildokumentation und -information e.V. (Association of Textile Documentation and Information).

Vulcanization accelerator A distinction is made between ultra-rapid accelerators (thiocarbamates, thiuramide sulphide and xanthogenic acid derivatives), semi-ultra-rapid accelerators (aldehydamine derivatives, derivatives of 2-mercaptothiazols and thiur ammonium sulphides), medium-strength accelerators (di- and triphenylguanidine) and weak accelerators (thiouria derivatives, 1.6-diaminohexane and formamide).

Vulcanized fibre Cellulose-plastic (plasticized using zinc chloride solution; paper webs "welded" by roller pressure) in the form of slabs, rods and tubes. Horn-like, tough, hard to leather-like soft and pliable. Absorbs little water (also water-proof impregnated). Resistant to oils and hydrocarbons, etc. Low flammability. Can be machined in any way to make gearwheels, sealing washers and suitcases (and the like).

Vulcanize, to Rubber or plastic coatings are produced by vulcanizing polymers with sulphur, which contain double bonds (such as natural rubber).

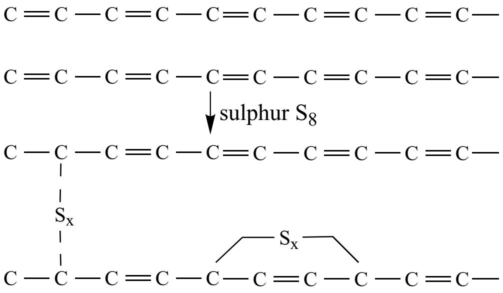
Natural rubber has a molar mass of 200 000–400 000 (Tab.), which corresponds to a structure containing 3000–5000 isoprene units of a basic monomer with a molecular weight of 68. In the case of "synthetic natural rubber", polyisoprene, it is possible to produce molecules containing 1–1.5 million units (even as many as 2.5 million units). The molecular weight and the molecular weight distribution, in particular, essentially determine the processing behaviour of the rubber.

Goodyear discovered the reaction of natural rubber with sulphur under heat in 1839. He called the reaction vulcanization after the Etruscan-Roman God of fire Vulcanus. As sulphur exists in the form of an eight-

rubber	abbreviation	molar mass
natural rubber	NR	200 000 to 400 000
styrene-butadiene rubber	SBR	250 000 to 800 000
polybutadiene rubber	BR	250 000 to 350 000
polyisoprene rubber	IR	1 000 000 to 2 500 000
ethylene-propylene rubber	EPDM	200 000 to 300 000

Tab.: Molar mass of rubbers.

membered ring, this must be broken open during vulcanization so that it can then form links with the fragments via the double bonds of the rubber molecule.



Sulphur is incorporated as the link S_x in all molecule lengths from S_1–S_8. The type of link formed depends on the vulcanization temperature, the duration of vucanization and, above all, the vulcanization activators. The length of the sulphur links determines or affects the properties of the vulcanized product. Thus, during the ageing process, it can be assumed that bonds break, the chain length changes and free sulphur links bond again to other carbon atoms.

The most important vulcanizing agent for sulphur crosslinking is elemental sulphur of 99.5% purity. This exists in colloidal form in the vulcanization pastes. As sulphur exists in the form of an S_8 ring, it is slow to react and requires approx. 270 J/mol to open the ring. Vulcanization does not start, therefore, until a high temperature has been reached or a vulcanization accelerator has been added. These are in the form of mercaptans, dithiocarbamates, disulphides and metal oxides (such as ZnO). The S_8 ring is opened by ionic or free-radical reaction or opened thermally at high temperatures. With latexes, ionic or free-radical reactions are used for opening, depending on the vulcanization accelerator.

Ring opening by ionic reaction: $^{+}$S:S:S:S:S:S:S:S:$^{-}$

Ring opening by free-radical reaction: .S:S:S:S:S:S:S:S·

Bases, such as amines, open the ring in the ionic form and dithiocarbamates open the ring in the radical form. The activated sulphur then reacts with methane groups or the double bonds to produce intra- and intermolecular bonds.

When crosslinking using metal oxides and synthetic resins, intermolecular bonding of the macromolecules is carried out via monomers with reactive groups, which have been incorporated in the polymer for this purpose. Crosslinking converts the polymer from its plastic rubber state into its elastic rubber state.

A schematic representation of the behaviour of long-chain filamentary molecules during plastic deformation under heat and elastic deformation after vulcanization is shown in Fig.

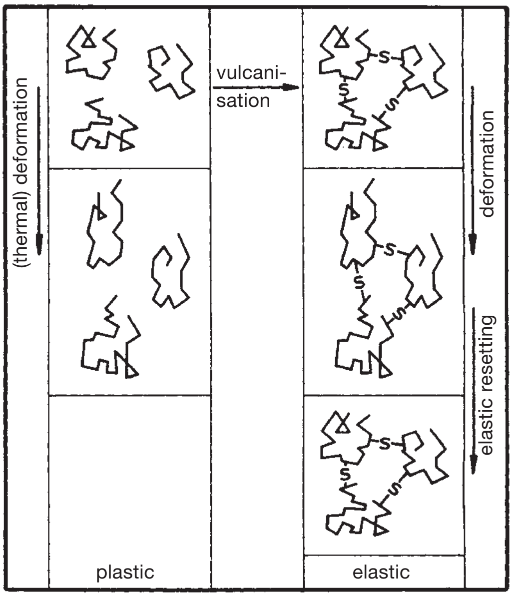


Fig.: Diagram showing plastic deformation with heat, vulcanization and elastic deformation (stretching).

The term “crosslinking” is often used instead of vulcanization. Originally, there was a difference between the two terms. Vulcanization stood for all molecular bondings using sulphur or sulphur-donating compounds. Crosslinking stood for other bonding mechanisms without sulphur (such as radiation energy or peroxide), which are no longer commonly used.

The production of natural rubber, originally from wild plants discovered in Middle and South America (Brazil), in particular, was stabilised to a certain extent, after Wickham 1876, on a detour via England, laid out plantations in Eastern Asia. Nevertheless, rubber still remained a speculative commodity with frequent peaks in price. As Staudinger clarified the chemistry of high polymers in chemical research at around the turn of the century, rubber was soon to be synthesized. The name Staudinger, especially, is associated with the development in structural analysis, as are the names Faraday and Williams with the search for basic building blocks. In regard to the synthesis of rubber, these names are joined early on by names such as F. Hofmann (methyl rubber, 1906–1909) and Harries (butadiene with alkali, 1910). Technical solutions were developed at Bayer’s dye works in Germany (Zahlenbuna = sodium butadiene, 1926) and by Carothers at DuPont in the USA (chlorobutadiene, chloroprene and neoprene) and finally, there are the solution polymers according to Ziegler/Natta (polybutadiene, polyisoprene, ethylene propylene rubber, around 1960) (according to Zeppenick).

VY → Vinylal, symbol according to the → EDP key system.

W

W,

I. Abbreviation for → Watt.

II. Element symbol for tungsten (74).

WA → Angora, → Textile fibre symbols in accordance with DIN standard 60 001 T4/08.91.

Wadding Cotton wool type raised frieze interlining and stuffing material (providing filling and warmth) for dresses, ladie's and gentlemen's suits. Wide-meshed woven or knit fabric consisting of loosely processed wool (black in colour), wool mixes, cotton, viscose; also in the form of textile composite fabric with strengthened thread interlining and quilted (quilt wadding).

Wadding component Component of → Padding, stuffing, specifically for the perfection of form stability in the chest/shoulder area. It is used as an integral wadding component for strengthening wadding in the shoulder and armpit areas.

WAK (Ger. abbrev. for "waschaktive Komponente" = wash-active components), rarely used term referring to synthetic detergents. WAK consists of a percentage of sulphonates (alternatively a percentage of sulphonated ester or phosphonated ester); also a percentage of → Fatty acids as in soaps. For example, 100% wash-active substances if liquid triethanolamine is used, contain 64% WAK, in the case of potassium salt, 88% WAK, with common sodium salt, 93% WAK, and 94% WAK with ammonium salt in the case of dodecylsulphonate. Non-ionogenic detergents do not form this type of salt, which is why there is, apparently, no great difference between wash-active substances and WAK.

Walk test,

I. Method of testing wear resistance, such as soiling properties and pile firmness in textile floor coverings. The sample is spread out in an area where people frequently walk, usually together with a comparable carpet that has known properties. Soil pick-up, wear, colour change, etc. are monitored over several months.

II. Test to establish the electrostatic properties of textile floor coverings (DIN 54 345, Section 2).

Wall hangings Wallpaper or carpets for decorating and/or providing acoustic insulation on walls. Wall hangings can be divided up into smooth and those having a textured surface. Nonwoven wall hangings are usually pinned with lustred fibres. In general wallpaper is hung wet, i.e. affixed to the wall with a water-based paste. This is taken into account when nonwovens are used for wallpaper, by laminating it with special wallpaper paper. If the wallpaper has been sintered with thermoplast powder, transfer printing and laminating can be carried out in a single process.

Smooth nonwoven fabric that has been slightly prepinned, for instance 100% polyester fibre with a weight of 80 to 100g per m^2, is coloured by means of transfer printing with transfer paper. If it is necessary to cut out the separate paper sintering phase to enable online production, a powder dispersal system is installed before the transfer calender, which disperses the thermoplast powder as required on the reverse side of the nonwoven or wallpaper.

This method is used not only to colour nonwovens made of polyester fibre, but also nonwovens based on cellulose fibre, although they have to be chemically bonded first, using polyurethane dispersions, for instance. This is because this binder takes up transfer dye with a high yield, in the reverse process.

Wall-to-wall carpeting A term for carpets that are laid from wall to wall (fitted carpets). → Contract carpet.

Ward-Leonard control In continuous production lines, electrically driven machines which operate in series are synchronized using the Ward-Leonard control via compensator roll potentiometers (see Fig.).

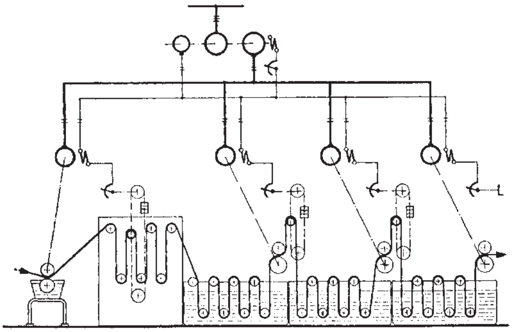


Fig.: Leonhard multi-motor drive with compensator roller control for an open-width washing machine.

Wardrobe Clothing, in particular outerwear, dresses, general outer garments, in French it also applies to underwear.

Warm-dyeing vat dyes Vat dyes that act in a heated environment on the basis of the → IW dyeing method.

Warming up time The time required by measuring devices from switch-on until calibration stability is achieved.

Warning devices → Alarm and indicating equipment.

Warning limits Variation limits marked on → Control charts, which may only be exceeded under certain conditions. → Control limits.

Warp,

I. In weaving: all the parallel threads running in a longitudinal direction of a woven fabric. The yarn used for this is known as warp yarn. Woven warps consisting of spun fibre yarns are usually yarns with a higher twist, which have also been (warp) sized prior to weaving, so that they will withstand the stress to which they are subjected during the weaving process. Ply warps are not usually sized.

II. In warp-knitting: the yarns that are wound onto the warp beam and serve to form stitches.

Warp beam (warp-wound bobbin). Roller-shaped device that holds the warp yarn ready for weaving. Perforated warp beams are used for bleaching or dyeing the warp (or the fabric) on → Beam dyeing machines.

Warp beam centrifuge Centrifuge for beam dyeing machines or card lap beams, usually upright rather than horizontal.

Warp dyeing process This process is used for the manufacture of warp patterned carpets. Pile yarns are wound in parallel onto drums with dye liquor application systems, they are dyed in stripes, and finally the dye is set using steam.

Warp ends → Warp.

Warper-Sizer-System The warp yarn runs from the warping reel frame straight into the sizing machine with no sectional warping process. This means that each thread in the multi-thread warp is sized individually. This system is particularly suitable for warp preparation of untwisted synthetic fibres (e.g. fine titre of polyamide and polyester threads).

Warping Whereas warp threads with the required sett are wound individually onto the sectional drum or a sectional warp beam in → Sectional warping, there is also a type of warping where the warp yarn is wound onto warping beams to the intended weaving width but with a reduced sett. More and more beams of this type are being consolidated into a standard warping beam. This technique is primarily suitable for long warps of a single colour. Multi-coloured yarns are usually warped sectionally.

Warp-knit → Warp-knitted fabrics.

Warp knit nonwoven pile fabric Nonwoven knitted fabric consisting of a basic material with additional nonwoven fibre. The nonwoven fibre is bonded into the basic material by forming it into pile loops.

Warp-knit stitch-bonded nonwovens (stitch-bonded nonwovens). Nonwoven knits consisting of fibre fleece, bonded by means of a row of sliding needles with tongues that are pushed into and pulled out of the fabric, causing loops of fibre (stitches) to be formed.

Warp-knitted fabrics Textile fabric manufactured from one or more thread systems by forming stitches. Warp-knitted fabrics, unlike → Weft-knitted fabrics or knitgoods (single-thread knits), are formed into stitches from several adjacent threads (warp) at the same time. The process of forming stitches is less time-consuming than in weft-knit manufacture, and it is not possible to chafe the fabric. → Knitted fabrics.

Warp patterned carpets Multi-coloured machine-woven carpets in which the pile yarns are dyed using the → Warp dyeing process.

Warp printed carpet A true warp printed carpet is a wire carpet. The pattern is created before weaving, using the → Warp printing technique on the pile warp yarns. This type of warp printed carpet (tapestry or velvet-type carpets) typically exhibits settled patterning. In contrast to this, multi-coloured printed carpets have a certain degree of pattern bleed after weaving.

Warp printing (Chiné printing). Printing the warp thread system of woven fabric with thin print pastes (complete print penetration), drying, and then, in most cases, weaving immediately (to avoid extreme pattern displacement). Dye setting and washing processes are carried out once the fabric has been woven. Small pattern displacements are inevitable, and they produce the characteristic blurred and slightly jagged appearance. This technique is used in particular for articles where complete print penetration is required (e.g. curtains). Two-phase print processes are frequently used for warp printing.

Warp printing process Variant of → Space dyeing.

Warp rib tricot → Tricot with ribs running in the direction of the warp (lengthways). The opposite of this is → Transverse tricot.

Warp size naphthol preparing Dyeing process using naphthol dye from sizing, for cotton and polyester/cellulose warps. Preparation takes place on the sizing system.

Warp sizing Sizing of the warp in wovens in preparation for the weaving process. The evenness is particularly useful in practice for reasons relating to technology and economy. For this reason the aim is to reduce unevenness in the sizing along the warp. Control systems are available that reduce the variation in warp size application, for example in the slow/fast transition phase. The advantage of a control system to keep

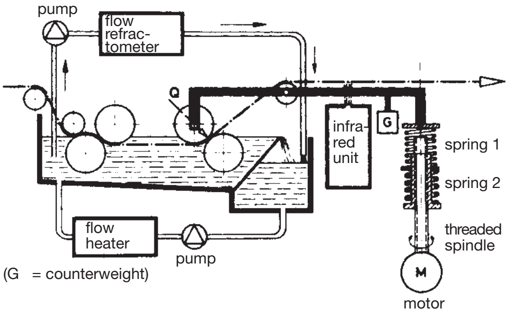


Fig.: Warp size application with bath control (refractometer) and liquor application control (infra-red etc.) (Sucker-Müller).

the degree of sizing constant (see Fig.) is that the effects of all influential parameters are summarized and sizing variations are regulated by varying the squeezing pressure. Use of a closed loop control circuit has the added advantage that the degree of sizing is returned to the target parameter after a control deviation. A computer continuously evaluates the signals measured with an IR device (to analyse H_2O) and a throughput refractometer, with which it calculates the target warp sizing parameter.

Warp sizing and dyeing Process for dyeing cotton warp during sizing. Only used for a few types of fabric, such as denim, blue jeans.

Warp smoothness A special type of warp wax for coating the warp in weaving. It enables the warp to "run" better, minimizes yarn breakage and loom outtime, as well as improved weaving performance. From a practical point of view it is only suitable for fabrics that are washed directly without singeing, or for multicoloured fabrics. Non-existent or poor saponification properties usually mean uneven dyeing. This type of damage can be tested easily by ultra-violet (low luminance).

Warp velvet (wire velvet, velours). Smooth or patterned → Velvet, in which the pile layer consists of an additional warp system (pile warp). Wires with a lancet-type blade on one side are inserted into the velvet on a specially designed loom after the pile warp threads have been lifted. When the wires have been pulled out (still on the loom), the loops formed are cut open. In warp velvet, these loops are held by the weft, as opposed to → Weft velvet where the tufts of fibre are held by the warp. The depth of pile is determined by the thickness of the wire. Plush and velours carpets are also manufactured using this technique.

WAS (abbrev. for wash-active substance). A pure, organically effective component of → Synthetic detergents or → Soap (→ Surfactants). The WAS content is stated in %, e.g. 30% pure alkylarylsulphonate or alkylsulphonate or fatty alcohol sulphonate, etc. Although WAS content plays an important part in the effectiveness of → Washing agents, it would be wrong to assess the quality of the detergent on this basis alone, or even to try to calculate it. There are significant differences even between WAS products of the same raw materials group. There are also WAS mixes in which the individual components have the effect of mutually increasing wash-active properties (synergetic), or of reducing them. Finally there are further components (→ Builders) that contribute to greater effectiveness. Objective washing or cleaning experiments are important for carrying out objective quality tests, by means of → Soiling tests.

Washable goods Washable textiles, divided into the following categories: → Coloured articles wash; Delicate articles; Laundry for 100°C wash. →: Wash and Wear; Machine-washable wool. → Care labelling of textiles provides information regarding washability.

Wash-active component → WAK.

Wash-active substance (active material, active substance) → WAS.

Wash and Wear (W & W), textile property, usual term for easy-care textiles. The garment is so smooth after washing that it can be worn again with virtually no ironing. → Wash and Wear Finishing.

Wash and Wear Finishing Cotton, viscose, linen and mixes containing these materials with synthetic fibres are fibre types that are important on a worldwide scale. All attempts to achieve comparable finishing effects using mechanical finishing processes alone, targeted action on the fibre or specific use of the article, have not resulted in the same quality as chemical modification using appropriate finishing products. Resin finishing agents, catalysts and additives, applied using low-cost process techniques combined with mechanical finishing phases still ensure the best wash and wear finish (→ Resin finishing). Obviously ecological changes have taken place during the past 10 years, particularly in industrialized countries, which have meant that it was necessary to re-think and re-organize the approach to wash and wear finishing, among other things. Consumer requirements with regard to textiles are more demanding and more quality-orientated and the emphasis is on function and variety. Fashion trends mean that alterations to articles have to be carried out at short notice more and more frequently. Increasing operating costs mean that high requirements apply to existing production capacity, and mean that rational process techniques are necessary. It is becoming more and more complicated, detailed and specific to take into account ecology and toxicology and the constraints associated with them.

1. Formaldehyde crosslinkers: in today's state of wash and wear finishing, N-methylol compounds are still used. These compounds are the most significant product group of → Resin finishing agents (Fig. 1).

Wash and Wear Finishing

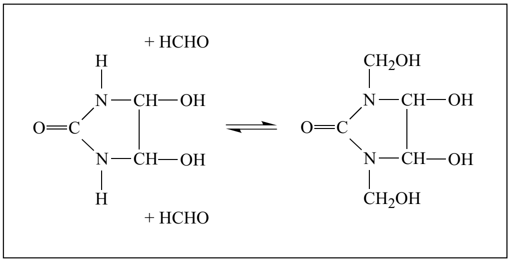


Fig. 1: *Methylolation/glyoxal urea.*

At least 95% of all processed crosslinkers used for wash and wear finishing (at least 100 000 t worldwide) contain formaldehyde in bonded form. Using the functional N-methylol group, reactant crosslinkers cause the known modification of cellulose (Fig. 2), thereby producing the required wash and wear effects. →: Low-formaldehyde resin finishing; Formaldehyde-free finishes.

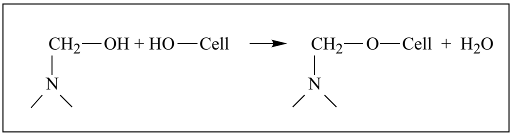


Fig. 2: Part of the crosslinking reaction.

As well as the intended crosslinking reaction with cellulose, there is a range of possible auxiliary reactions in the finishing liquor and on the fibre, which cause formaldehyde to be released (Figs. 3 and 4). This released formaldehyde presents problems of a toxicological and ecological nature.

The risks associated with formaldehyde, which are detrimental to health, have resulted in legally defined limitations in many countries, applying to finishing products, the workplace, exhaust and formaldehyde levels on textiles.

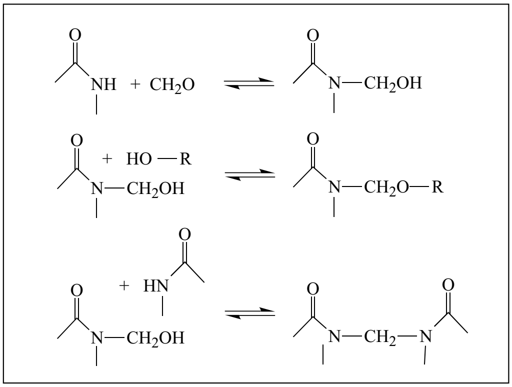


Fig. 3: Free and bonded formaldehyde in crosslinked cotton articles or in the finishing liquor.

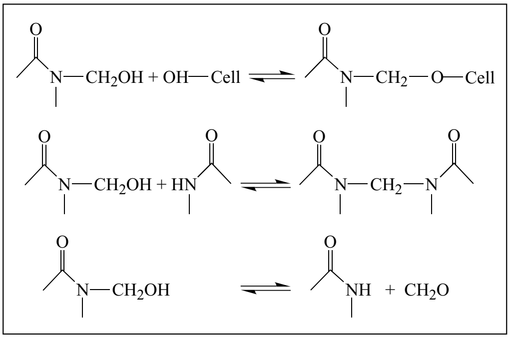


Fig. 4: Cellulose crosslinking reactions and formaldehyde self-crosslinking and splitting.

In many countries, the maximum concentration applying to the working environment (threshold limiting value TLV) for formaldehyde is subject to law. In Germany for example, the TLV for formaldehyde is 0.5 ppm, a low TLV value, that, in practice, can cause problems. Other industrialized countries are aiming to halve the current TLV value, which is usually 1 ppm. Japan was the first country several years ago to legislate set limits for formaldehyde on textiles. In Germany, textiles with a free formaldehyde content higher than 0.15% have been subject to identification regulations since 1988. As well as legal limitations (which by now exist in several countries), there is a range of involuntary regulations specific to each company relating to formaldehyde on textiles. It is not just well known retail and storage operations that set limits for their articles; the textile finishing industry itself is striving towards taking responsibility for low-formaldehyde finishing. The formaldehyde problem in textile finishing is no longer just restricted to the working environment and the textiles themselves, but in many countries these regulations also apply particularly to the exhaust from drying and condensation systems. Complex measurement and monitoring becomes necessary.

2. Low-formaldehyde crosslinkers: the necessity for low-formaldehyde crosslinkers in the textile finishing industry is constantly on the increase, and always involves higher requirements relating to free formaldehyde. Methylolglyoxal ureas (Fig. 5) are the most commonly used crosslinkers for low-formaldehyde finishing. The most frequently encountered are methylolglyoxal ureas modified with methanol, and increasingly with diethylene glycol.

3. Formaldehyde-free crosslinkers: the chemical industry, by developing low-formaldehyde crosslinkers,

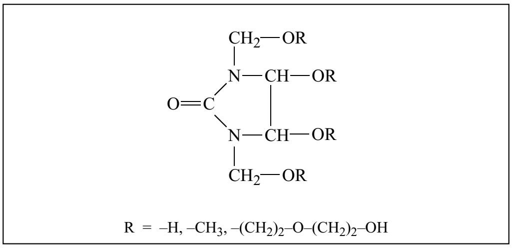


Fig. 5: Modification of the N-methylol group.

and the textile industry with purpose-orientated technologies for production, have made a significant contribution towards dealing with the formaldehyde problem. The problem could only be solved completely if formaldehyde-free crosslinkers were available that provided a comparable finishing quality at the same cost, and were also harmless from the point of view of ecology and toxicity. However, unfortunately that has not been the case so far. Formaldehyde-free crosslinkers such as chlorohydrines, vinylsulphones and acrylamides, which were used for a variety of applications in the 1960s, also constitute a toxicological risk. All these would do is to shift the current problem to a different category of hazardous substances.

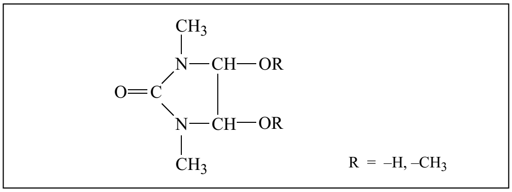


Fig. 6: Dimethylglyoxal ureas.

The formaldehyde-free crosslinkers that are currently available to the textile finishing industry in the form of commercial and trial products are almost exclusively reaction products of glyoxal. The conversion products of glyoxal and dimethylene urea (Fig. 6) are the most widely used in practice, and which can sometimes be etherized with methanol. Furthermore the conversion product of glyoxal, ethylene urea and methanol is described. Conversion products of glyoxalic acid are also under discussion.

It has also been suggested many times that glyoxal itself could be used for formaldehyde-free crosslinking of cellulose (Fig. 7). At the moment it is really only practical to use glyoxal conversion products as formaldehyde-free crosslinkers. Wash and wear effects can be achieved that are near in quality to standard reactant crosslinkers. The level of whiteness is not usually quite as good as it is when standard crosslinkers are used. The disadvantage is the high cost of finishing, which is three or four times as expensive. There are no particular points relating to application for dimethylglyoxal urea-based crosslinkers. Pad-drying takes place on the padder, and crosslinking occurs in the presence of catalysts at, for example, 150°C within 2–4 min. A specific post-wash process is not necessary.

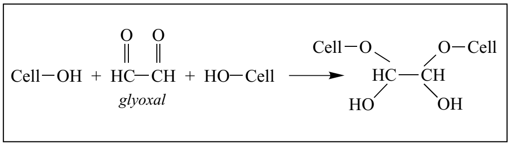


Fig. 7: Crosslinking with glyoxal.

4. Additives: the attempts to create alternative products to crosslinkers for wash and wear finishes resulted in selected polymer dispersions based on polyacrylate, polysiloxane and/or polyisocyanate (Fig. 8). However they did not constitute a comprehensive solution for a high-quality wash and wear effect in all cellulose fibres with regard to formaldehyde release and minimal fibre damage. Polymer dispersions have no effect on shrinkage stability. Crease resistance is only significantly better with polyester/cotton; however wash and wear fastness is not achieved.

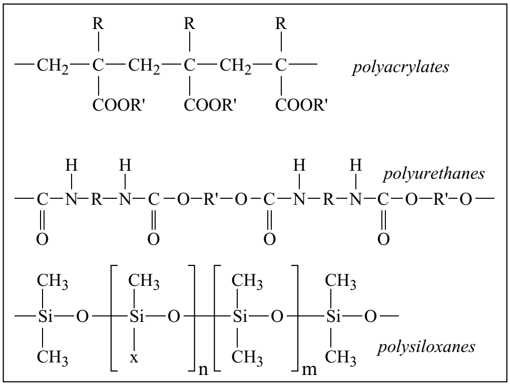


Fig. 8: Various polymer dispersions as additives.

However, in the form of so-called additives in combination with crosslinkers, the polymer dispersions described are becoming more important. A significant optimization of the effect can be seen even on cotton. The creasing properties are improved without further detrimental effect to the fabric strength.

5. Creating the handle: the current handle favoured throughout Europe is still extremely soft. High quantities of softeners, up to 60–90 g/l, are used on wovens

and in particular on knitgoods. Silicon softeners are becoming increasingly popular. Amino-polysiloxane micro-emulsions are especially sought after because they create a cotton-type, particularly soft handle, they have good washing stability, and they have a positive influence on sewability (according to Seidel).

Wash and Wear Standards Photographic and three-dimensional standards for the assessment of wash and wear properties. AATCC 124-1973: Smoothness of textiles. AATCC 88B-1973: Appearance of garment seams. AATCC 88C-1973: Appearance of ironed creases on garments, in each case after domestic washing. Samples for testing of specified sizes are washed under defined conditions, dried (drip dried, spin dried, tumble dried) and allocated the grades relating to the comparative standard (1–5). 1 is the lowest grade possible, and 5 is the highest (Monsanto crease photographs).

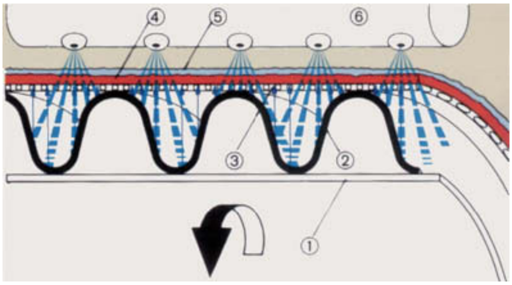
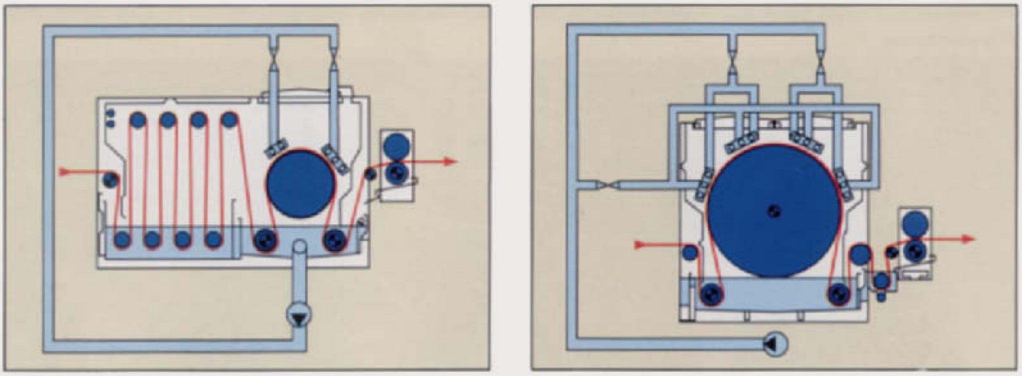


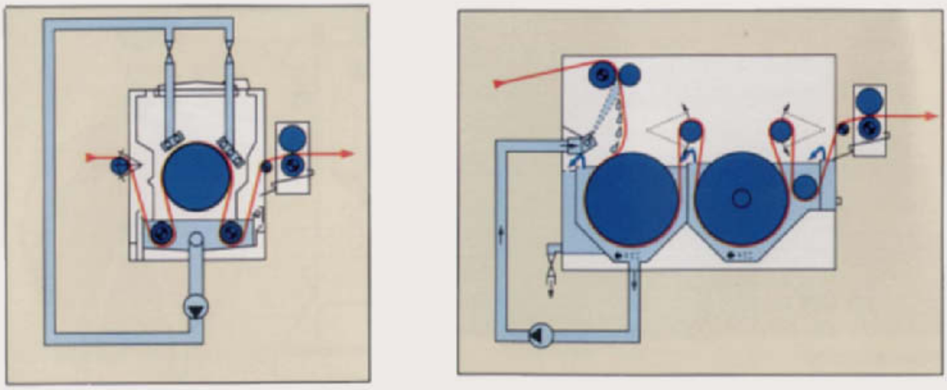
Fig. 2: Active wash principle with ribbed drum (Kleinewefers KTM)).
1 = closed drum body; 2 = groove profile; 3 = perforated belt; 4 = fabric; 5 = outer liquor film; 6 = spray pipe.

Wash compartment A specific washing principle, which is independent of other wash compartments, is applied in the wash compartment of an open-width washing range. The layout of the washing elements in the wash compartment is dependent on the fabric to be treated in it (Fig. 1). If a drum washer is used, it may be necessary to construct high-volume wash compartments, because for instance a ribbed drum (Fig. 2) has a very large diameter. If water savings are to be achieved in a single wash compartment, the collection of the wash water draining off the fabric is relocated external-



woven fabric TVG 15 wash compartment

wash compartment EA



washing and impregnating compartment W50

washing and relaxing compartment DK80

Fig. 1: Open-width washing machine types each in a wash compartment (Kleinewefers KTM).

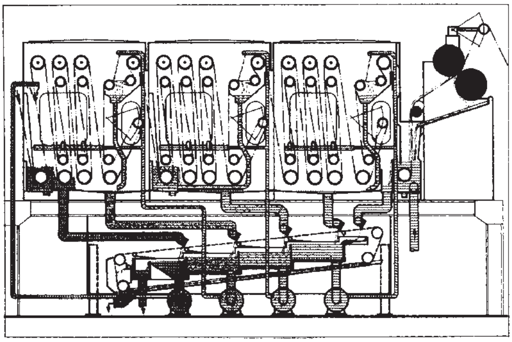


Fig. 3: Three wash compartments in the Babcock Econ-Tex washing line.

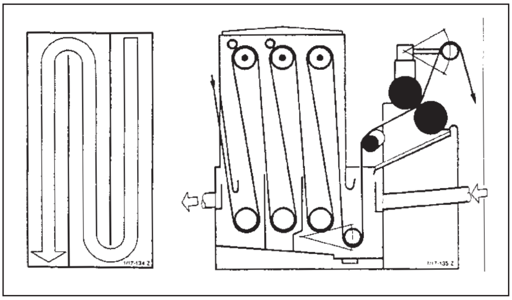


Fig. 4: Dividing plates in the Convi-Tex wash compartment (Babcock). Left: plan view; right: side view.

ly (Fig. 3), and only the necessary water for running the pump is retained within the wash compartment.

Dividing plates (Fig. 4) in the wash compartment also guide liquor flow opposite to the fabric direction, alternately from the right to the left side of the wash compartment and then left to right, i.e. at right angles to the fabric direction. This transverse flow directs the entire liquor specifically at the fabric, thereby preventing part of the liquor flowing past unused. At the same time it has the effect of ensuring that the fabric is evenly rinsed across its entire width.

In Fig. 4, feeder rollers can also be seen in addition to the upper rollers. The purpose of these is to hold back the liquor carried on the surface of the fabric. In conjunction with the dividing plates this has the effect of an additional separation of the liquor within the compartment. There is also a spray line with flat beam jets between compartments, which is charged with fresh water, to ensure liquor separation. The final component of a wash compartment is a squeezing system, which also ensures liquor separation.

Wash creases in fabrics containing polyester texturized yarns After washing this type of fabric, washing creases can be observed again and again. These creases run transversely or longitudinally depending on the type of washing machine, and are still visible when the finished fabric is tensioned at higher temperatures. Microscopic inspection shows that these crease markings are primarily caused by distorted crimping. In order to avoid wash creases of this type, the fabric should be opened out and crease-free when it is introduced to the wash liquor. The structural alterations must have finished taking place before the creases are removed and mechanical processing starts. The time taken to process crease-free fabric depends both on the temperature of washing and the initial material/construction.

Washfast finish → Permanent finishing.

Washfastness testers Mechanical instruments for measuring washfastness. Consist of a water bath, in which sealed stainless steel or glass containers rotate on a horizontal axis. The containers hold the sample with the prescribed test solution, and possibly a set number of steel balls. Usually also suitable for testing other types of fastness (e.g. peroxide washing, hypochlorite washing, milling fastness, dry cleaning fastness, etc.).

Washfastness testing Test to establish the resistance to all types of industrial and domestic washing. The specimen is treated together with control fabric samples in a suitable mechanical washing device. After the test is completed, the specimen is rinsed twice in cold distilled water, squeezed, rinsed for 10 min in flowing water, the specimen is opened on 3 sides, dried at max. 60°C and then assessed (using grey scales to check the colour change and level of bleeding).

Washing Process in which heavy or slight soiling is removed and transferred to the water in the form of a solution or dispersion. Washing has the effect of cleaning surfaces. The resulting effect is several physical/chemical processes (→ Washing process).

Washing and cleaning constitute a complex process, during which soiling is removed by means of physical separation, with or without substance conversion, from a substrate.

Industrial washing processes can be categorized as solution washing, dispersion washing and reaction washing.

1. With solution washing, the substances to be removed from the fibre are soluble in the washing liquor. Examples of this type of solution washing are the removal of salts, bleaching chemicals and synthetic sizes by means of washing.

2. In the case of dispersion washing, the substances to be removed from the fibre are not soluble in the washing liquor, i.e. disperse systems are created during the washing process. This means the more or less fine distribution of one or several substances in the dispersion agent (washing liquor). If the system is solid/liquid, it is known as a suspension, if it is liquid/liquid it is

called an emulsion. Examples of this type of washing process are the removal of pigments, fat, wax, oils and print thickeners by washing.

3. Reaction washing renders it necessary to distinguish between washing processes with and without degradation. In reaction washing with degradation, the substances to be removed from the fibre are not soluble or dispersible in the washing liquor. It is only after a chemical or biological conversion that soluble or dispersible substances are created. A typical reaction washing process with degradation involves the removal of starch sizes. Reaction washing processes without degradation are for instance, where an excess of alkali or acid is removed not by means of thinning, but by neutralization, and the excess is removed subsequently by means of solution washing.

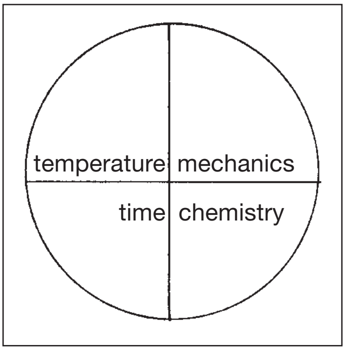


Fig. 1: The Sinner Circle for representing washing performance.

The → Washing process is essentially dependent on four factors, which can be represented as sectors of a circle (Fig. 1). All washing processes are based on these four factors, with only the influence of the individual factors varying from process to process. The Sinnerscher wash circle is frequently extended by water as a solvent. The liquor ratio is one significant parameter in the washing process. It influences the concentration gradient of the soil from the fibre to the washing liquor, and regulates the strength of the mechanical forces. The washing process can be divided up into four steps: The first step is the wetting of both the substrate and the soiled surface with the washing liquor by reducing surface tension. During soil detachment, the second stage, differentiation is made between pigment soiling and oil-based soiling. In the case of pigment soiling, soil release is based on increasing the equal negative electric charges of the soil and fibre in the wash liquor, and on raising the propogation pressure in the adsorbed layers between the soil and the fibre, which is manifested as nip pressure. In the case of oil-based soiling, the reduction of interfacial pressure by means of surfactant adsorption followed by a rolling process and rewetting of the fibre are particularly important. Further stages of the washing process are using surfactants to keep the soil particles in suspension in the wash liquor, and removal of the soil by the free-flowing wash liquor.

The → Surface tension is a parameter relating to the state which identifies the energy properties of the surface to distinguish them from internal properties. In the case of water/air, this value is $\sigma = 72.8 \cdot 10^{-3}$ N/m. This figure corresponds to the work that must be done in order to bring molecules from inside the water to the surface against cohesion pressure. On the same principle, the → Surface tension (interface tension) between two phases can be defined. Interface tension of this type occurs for example between a gaseous and a liquid phase (air/water) or a liquid and liquid phase (oil/water) or a solid and liquid phase (pigment/water or fibre/water). Fig. 2 depicts the surface tension. The electrical forces of attraction between the molecules of a liquid (in this case water) generate an interface tension, which helps to prevent foaming of the liquid. Molecules deep inside the liquid are attracted equally strongly in all directions by the adjacent molecules as a result of van der Waals forces. For this reason molecules at the surface are subject to a unilateral force from the inside. Because of this, energy is necessary for a molecule to reach the interface surface against this force. Interface tension is a measurement of the endeavour of a liquid to keep its surface as small as possible.

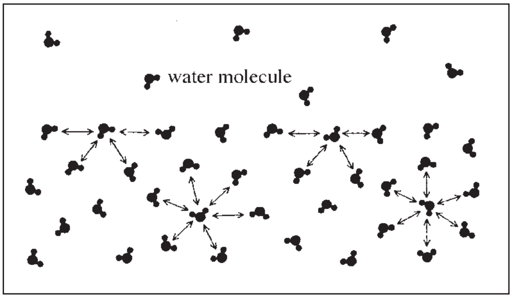


Fig. 2: Electrical forces of attraction between the molecules of a liquid.

→ Wetting means the lowering of surface tension between a liquid and a solid body, where the phase limit solid/gaseous is suppressed by the solid/liquid system, by reduction of the free surface energy.

As shown in Fig. 3, the → Wetting angle is a measurement of wetting. If this angle is greater than 0° but less than 90°, wetting is spontaneous. If the angle lies between 90° and 180°, then wetting is involuntary. As the surface and interfacial tension can be varied significantly through the use of surfactants, it is easy to see that

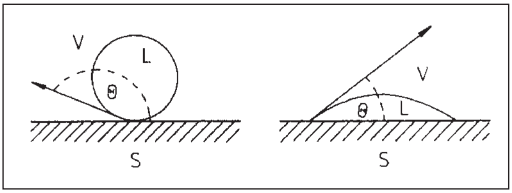


Fig. 3: Wetting illustration.
V = gaseous phase; L = liquid phase; S = solid phase;
θ = wetting angle.

surfactants are important for wetting problems, such as the wetting of textiles during the washing process.

The → Washing mechanics, as one of the four factors in the Sinnerscher wash circle, is based on the current generated as a result of textile or wash liquor motion. It can be assumed that the particles of dirt are picked up by the current generated in the wash liquor, and shaken out of their stationary position. This is dependent on the particles being large enough and standing out from the stationary layer of liquid adhering to the substrate (adhesion layer).

As shown in Fig. 4, the current generated during the washing process causes not only free-flowing wash liquor, but also flow boundary layers. The adhesive layer is created as a result of the fibre's forces of adhesion, so that there is a strong interactive effect between the water molecules and the fibre. The second layer is the diffusion boundary layer. In this layer the flow is slowed by interactive effects between the water and the fibre. The flow boundary layers are dependent on the type of textile. These layers become important during the washing process, as they cause an extreme reduction in the capacity to wash out soiling. Although the soil has already become detached from the fibre, it is still in the flow boundary layers in the case of smaller particles, and can therefore not be carried away. From this it can be concluded that the phase of the washing process that determines the speed is the slow diffusion of the soil particles out of the diffusion boundary layer; in other words it is diffusion-controlled. This means that stronger washing mechanics (flow) lower the diffusion boundary layer and result in a faster washing process.

Washing activity Specific properties relating to the removal of → Soil (with significant involvement of surface or interfacial activity) of wash-active substances (→ WAS).

Washing activity of surfactants This is mainly in relation to the → Surface activity and the characteristic molecular structure of → Surfactants. Because of their binary character, they can convert hydrophobic substances that are not soluble in water into hydrophilic water-soluble substances by means of surface adsorption. The first requirement for a good washing effect (→ Washing) is adsorption of the surfactants by the soil as well as the substrate, resulting in a reduction of the → Surface tension and changes in the interfacial potential values. It is essential that adsorption takes place to ensure that wetting occurs during soil detachment. In the case of liquid soiling, oil (for instance) is forced from the surface, and the substrate is rewetted. The washing liquor comes out of the fibre surface in the context of wetting at the same time as the oil-based soiling. Surfactant adsorption causes the oil to form droplets. In this process the increase in cleavage pressure is caused by the hydrate shell of the surfactants in the limit area. The consequence is further surfactant adsorption at the interface between the washing liquor/oil, which leads to complete detachment of the oil-based soil, which is then carried away. This process of removing oil-based soil is known as unrolling of liquid droplets. Detach-

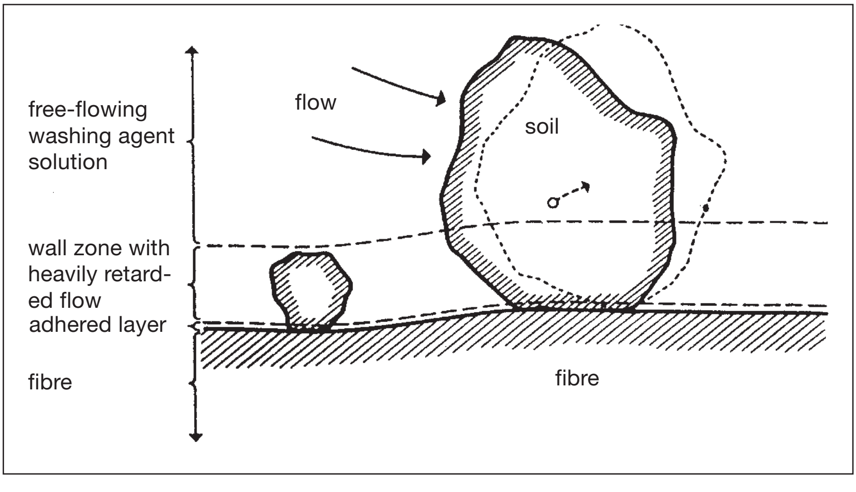


Fig. 4: Diagram of the dispersion of soil particles through wash liquor flow dependent on the particle size.

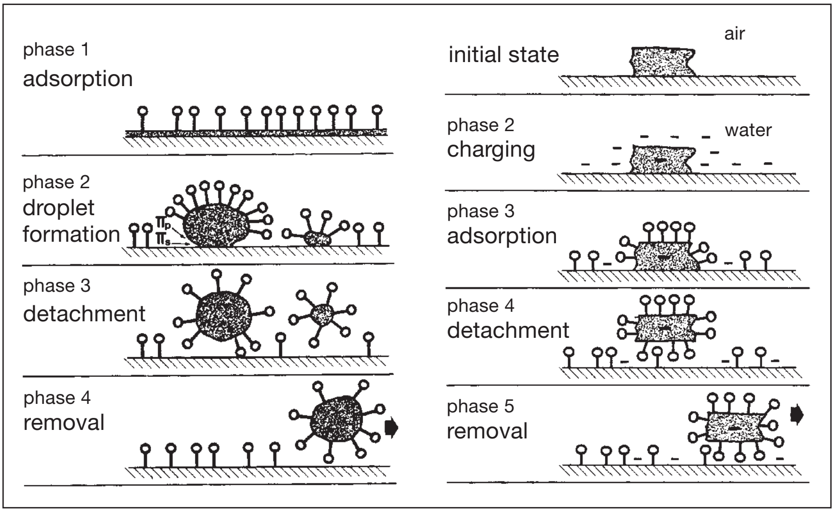


Fig. 1: Diagram showing the effect of surfactants on the detachment of oily soilings (left) and of pigment soil.

ment of pigment-based soiling using surfactants is dependent firstly on an increase in the negative solid body charge (→ Zeta potential), which can be achieved using anionic surfactants. As both the textile fibre as well as the attached soil pigments have a higher negative charge as a result of surfactant adsorption, a higher level of repulsion occurs. This makes soil removal easier, and the washing effect increases. In addition there is pronounced spread pressure in the adsorbed layer, and the soil particles are infiltrated by adsorbing surfactants and the bonding energy between the substrate and the soil particles is reduced. This causes the pigment soiling to be detached and carried away. Soil detachment of pigments and oil-based soil using surfactants is shown in Fig. 1.

Another function of surfactants in the washing process is the soil suspending property or dispersion of detached soil in the washing liquor. The dispersion process with anionic surfactants can be partially explained by the fact that their adsorption by soil pigments or oil droplets, because of the negative charge that has formed, results in increased repulsion between the different particles. This prevents agglomeration or coalescence, and therefore also prevents re-absorption onto the clean fibre surface. The dispersion or solvation effect of non-ionogenic products is so strong that particles surrounded by a shell do not conglomerate even if there is a negligible electric charge. The washing effect of non-ionogenic surfactants can be explained by the fact that they have a larger hydrate shell than anionic surfactants.

When cation-active surfactants are used in washing, the soil particles are charged positively; the negative charge of the fibre under normal conditions is reduced without going to the extreme of converting to a positive charge, because the charge of fibres is difficult to change by this method. Under these circumstances it is difficult to detach the soil, which means that it is not practical to use cation-active surfactants for washing.

The way in which surfactant effects can be blocked by soil has been sufficiently researched with regard to hardness salts such as calcium, magnesium and even iron compounds, which are present in natural soiling. For instance it has been discovered that soap is converted to lime soap if calcium ions are present that bond with the carboxyl group in the soap. The soap loses its properties of interfacial activity and precipitates. A second type of washing activity blocking where surfactants are used can be explained by the fact that surfactants form aggregates (micelles) above a certain concentration, which are responsible for the soil suspending properties. The soil suspending properties are limited. The soil particles that are already detached form “micelle germs” in the washing liquor with which surfactants are bonded. For this reason they are then no longer available for detaching soil components from the textile. The more the soil suspending properties are utilized, the more a wash liquor is “saturated”, and consequently the cleaning effect is worse. Extinction measurements, with water-soluble dyes instead of soil, can be used to show that once the dye concentration exceeds a certain level, the consequence is saturation of the micellary solution.

The electrokinetic phenomena that occur when textile fibres come into contact with water and aqueous solutions at the phase boundary show that a charge distribution must be present. The positive charge can be allocated to one phase, and the negative charge to the other. Helmholtz provided an initial theory to explain this principle, the theory of the electrical dual layer. According to his theory, there is a drop in electrokinetic tension at the phase interface between solid and liquid, between the dispersed particles and the dispersing agent. The concept of the electrical dual layer at the interface between fibre and solution proves that a monomolecular layer of counter-ions, the so-called star layer, is adsorbed at the fibre surface, which (in pure water) always exhibits a negative charge. The diffuse Gouy-Chapman layer is adjacent to this, which contains the necessary counter-ions for complete compensation at the fibre surface as well as co-ions; the internal solution connected to this layer is known as the bulk phase. The interface between the star layer and the Gouy-Chapman layer is known as the external Helmholtz layer, and the potential that occurs there is called star potential (Fig. 2).

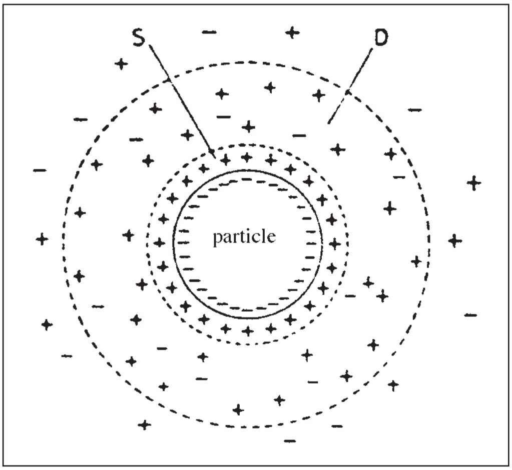


Fig. 2: Construction of the electrochemical dual layer.
S = Star layer of securely adsorbed ions with so-called surface potential or equilibrium potential (towards the particle) and so-called star potential (towards D).
D = diffuse layer (Gouy-Chapman dual layer).

For a dual layer to be formed, the surface must carry a charge. The source of the charge can be traced back to functional polar groups, molecular dissociation, ion adsorption because of ions dissolving out, and friction-generated electricity. Micelles also have a dual layer. Conductivity tests show that without a particular bond being present between the surfactant ion and counter-ion, about 80% of the counter-ions are bonded to the micellary surface, while the remaining counter-ions are distributed in the aqueous phase in free motion. This means that the micellary surface of ionic micelles is charged in comparison with the aqueous phase; the charge density can be calculated from the aggregation index and the level of dissociation.

Zeta potential (ξ potential) is a term applied to the galvanising tension in the diffuse part of the electrical dual layer at the interface between two phases that can not be mixed (e.g. between fibre with adsorbed soil particles and the wash liquor). Zeta potential is defined as the potential drop along the Gouy-Chapman layer, in other words from the external Helmholtz surface to the bulk phase. There are various methods available for measuring the zeta potential. Of these, the method that has proved to be the best for characterizing solid substances is the current potential method. The zeta potential (ZP) can be calculated from the current potential measured using the Helmholtz-Smoluchowsky formula:

$$ZP = \frac{4\pi\eta}{D} \cdot \frac{E}{p} \cdot \lambda \ [V]$$

η = viscosity of liquid phase
p = pressure difference
D = dielectrical constant
E = current potential
λ = conductivity of liquid phase

The strength of the electrical dual layer and therefore the level of the zeta potential is dependent on polarity, as well as the tendency of the interface to form hydrogen linkages with water. Furthermore the zeta potential decreases as the electrolyte concentration increases (Fig. 3).

The pH-dependent negative zeta potential is increased by the adsorption of anionic surfactants; cati-

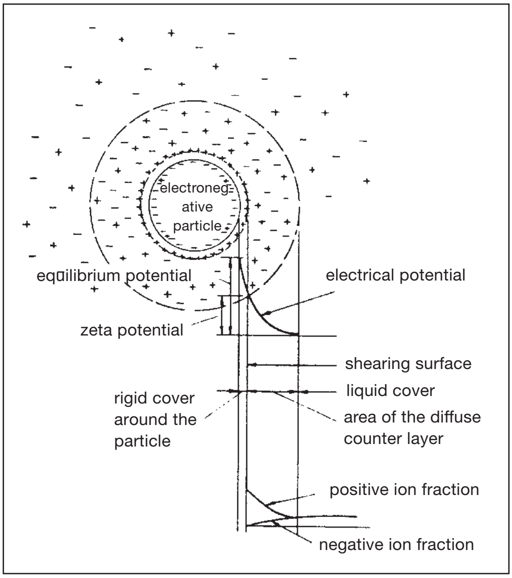


Fig. 3: Zeta potential diagram.

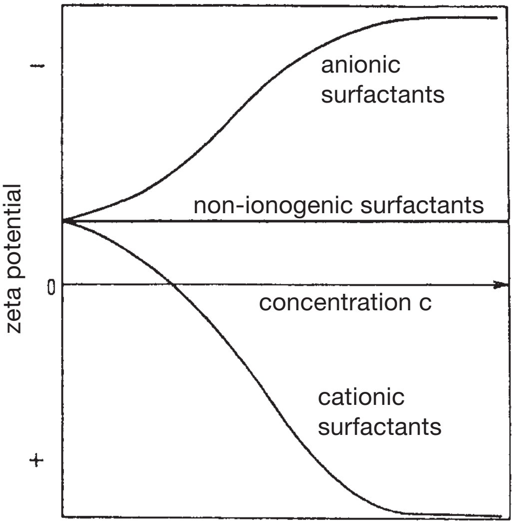


Fig. 4: Diagram showing the change in the zeta potential of textile fibres and pigment soil after surfactant addition.

onic surfactants compensate for it, while non-ionogenic surfactants do not influence it (Fig. 4).

The effectiveness of anionic surfactants in the washing process has several reasons, including the increase in the negative zeta potential of the fibres and soil particles, and the repulsion between the two that results from it. Experiments on fibres soiled with soot and mineral oil depending on zeta potential have shown that only surfactant concentrations up to the critical micelle formation concentration (cmc) of the surfactant in question result in an increased wash effect. This means that the micelle forms of the surfactants therefore have no influence on the zeta potential.

The equation gives the instantaneous contamination concentration c_s in the wash liquor.

$$c_S = c_\infty - (c_\infty - c_0) \exp \left[- \beta 0 \left(\frac{1}{V_c} + \frac{1}{V_S}\right) t\right]$$

c_∞ = equilibrium concentration after an infinite dwell period of the fabric in the liquor,
c_0 = initial liquor concentration,
β = substance exchange factor,
0 = substance exchange surface,
V_c = liquor volume carried within the textile,
V_s = liquor volume in the machine,
t = dwell time in the liquor.

The → Detergency efficiency is defined by the ratio of the residual and initial charge of the textile being washed, and therefore the time-dependent changes in concentration of the impurities to be washed out that are in the liquor c_s. c_∞ depends on the ratio of the initial charge of the fabric to the liquor volume. c_0 is given. The exchange factor β is usually unknown, and is defined by the machine construction and settings, as well as the textile, the impurities themselves and the washing liquor. The exchange surface 0 and the volume V_c are factors that are known, and depend on the textile and machine settings. In the same way, V_s is a known factor dependent on machine construction and settings. The detergency efficiency that can be achieved during a wash process is therefore essentially dependent on the unknown substance exchange factor, which can be estimated. In a single washing bath, the detergency efficiency decreases with the progression of time, i.e. with the quantity of textile being washed. On the other hand, washing machines that are set up in series with counterflow between the textile and washing liquor reach equilibrium after a certain length of time, so that the residual charge remains constant. The point in time at which equilibrium is reached is in turn dependent on the exchange factor and machine settings. Because of this it is important to be aware of these factors in order to enable process control resulting in cost-effective production with a consistent finishing result.

Washing aftertreatment auxiliaries These have the task of returning laundry to its original state after washing, which is one of the decisive factors for consumers when purchasing. → Fabric softener; Fabric softeners can be used for this purpose. → Soft handle treatment.

Washing agent additives The increasing differentiation in textiles, and as a result, washing programs, but also for instance the efforts to produce alternatives that save on packaging and that space, and are also environmentally friendly, have resulted in a range of detergents that is constantly increasing. In line with this, the performance features vary throughout the market.

For universal detergents suitable for all temperatures, textiles and types of soiling, the washing power is the factor of primary importance. Universal powder detergents that contain bleach exhibit optimum performance at 60–95°C, have powerful fat/pigment soil removing properties, are efficient at removing bleachable soiling, and are particularly suitable for washing the cotton and cotton-mix fabrics that dominate the market. There is a definite tendency to omit the pre-wash cycle when using powder-type universal detergents. With liquid universal detergents this trend has already been taken into account. They exhibit optimum performance in the low temperature range at 30–60°C, particularly with all types of soiling containing fat. As yet there are no liquid detergents on the market worldwide that contain integral bleach-active substances. Even without a bleaching agent, liquid detergents remove bleachable stains at low temperatures to a standard comparable with universal powder detergents. However in the higher temperature range (60–95°C), detergent chem-

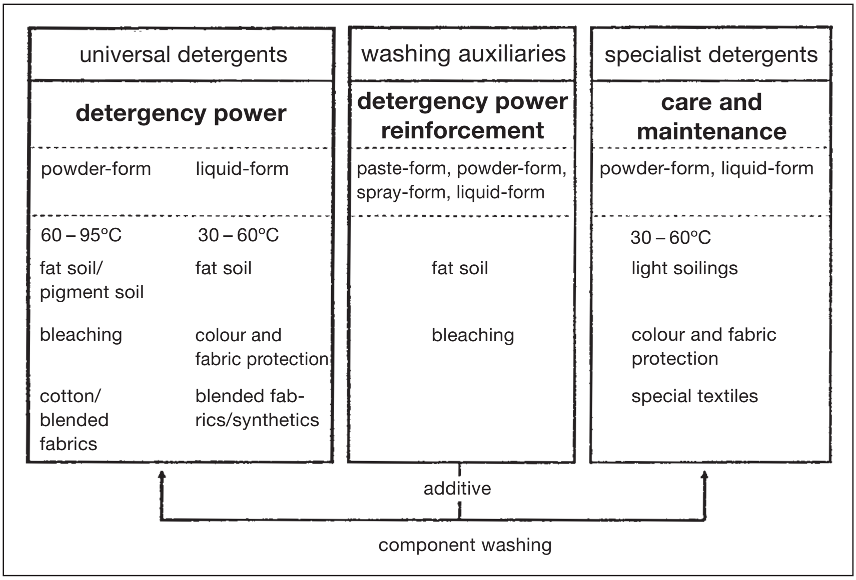


Fig. 1: Main use and benefits of classical detergent types (according to Puchta).

ists have the difficult task of achieving the same effect as universal powder detergents by incorporating suitable bleaching agents. On the other hand, the missing bleaching agent has the advantage that liquid products are more gentle on colour and fibre. The differentiation in performance (Fig. 1) between the two universal detergent categories demonstrates why the liquid versions are considered more as complementary rather than alternative products to powder options.

With specialist detergents, care and mildness of textile treatment are the primary factors. Use of detergent for specialized textiles, such as coloureds and delicate fabrics, for wool, curtains, etc. implies not only low washing temperatures (30–65°C), but also specially adapted formulae. Specialist detergents are, for the most part, free of bleaching agents and optical brighteners, for instance. Sometimes it is necessary to have specific pH levels, or in some cases the addition of softeners causes the laundry to have a soft handle. Washing auxiliaries are available for specific requirements of washing performance. These auxiliaries can be used specifically depending on the type or level of soiling, to attack fatty soiling (fat boosters), bleachable stains (bleach boosters), or both types of soiling (universal boosters) as additives to a universal or specialist detergent. Bleach boosters (scouring salts) in particular have recently taken on greater significance, because from an environmental point of view they are only used in combination with bleach-free specialist detergents and liquid universal detergents only in situations where a specific bleach-

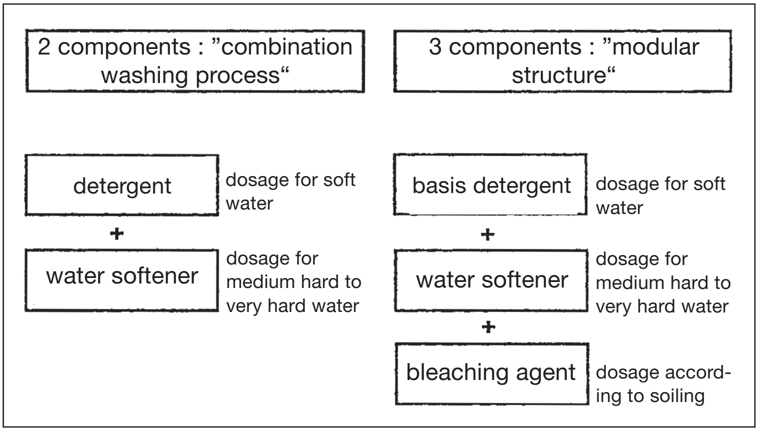


Fig. 2: Component washing systems (powder).

ing performance is required. This means that component washing is possible using traditional types of detergent. Under the general term “component washing systems”, independently of the combination of classic detergent types, new types of washing systems are increasingly being launched onto the market (Fig. 2).

In the combination washing process a detergent dosed for soft water is combined with an additional water softener for medium to very hard water. The modular system incorporates a separate bleaching agent as well as a bleach-free basis detergent in concentrate form and a water softener. This process is intended to make it possible to minimize on chemical additives in domestic washing, using only chemicals for a specific purpose. The future of this type of washing system will certainly be influenced by the development of compact detergents, which were introduced at about the same time. Compact detergents also feature minimal and highly efficient use of chemical additives.

Compact detergents, also known as detergent superconcentrates (Fig. 3), can be identified by their high weight per litre, which saves on packaging and space, and by a concentration of washing performance due to elimination of bulking substances and the use of more efficient raw materials. Perborate monohydrate for instance, which is usually used in compact detergents, is about 50% more effective than perborate tetrahydrate, which is usually used in conventional powder detergents.

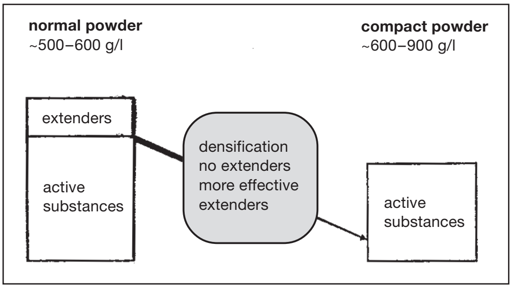


Fig. 3: Principle of a compact detergent (“superconcentrate”).

One reason why it is possible to use relatively small measures of phosphate-free compact detergent is because of the high level of reliability in the performance of the phosphate-free softening system. With products containing phosphate, especially reduced phosphate, a precise balance of softener concentrate with respect to water hardening salts (calcium, magnesium) is necessary to prevent phosphate precipitation, which means that a higher quantity of detergent is necessary if the water is harder. Opposed to this, phosphate-free detergents containing zeolites can be administered in relatively low doses even in hard water, without causing increased deposits on textiles and washing machines, which would be relevant in practice. This discovery is confirmed by the example of a phosphate-free branded detergent currently on the market. In the case of phosphate-free detergents, and even more so with the compact varieties, the quantities recommended for each wash are decreasing. At the same time the graded dosage of phosphate-free detergents, dependent on the level of hardness, is becoming increasingly less important. On the other hand, detergent quantities are differentiated more according to the level of soiling, because in the same way as products containing phosphate, the degree to which soiling is removed is significantly dependent on the amount of detergent used. This action is a good idea from an ecological point of view, and falls in line with the requirements of the Detergent and Cleaning Agent Law (Ger.: Waschmittelgesetz) relating to minimal use of detergent (§ 1).

compact detergents (phosphate free)	↔	modular-system (phosphate free)
● low dosage		● low dosage
● adaptable for the best possible results from every wash		● selective dosage depending on soiling
● easy to use (only 1 washing component)		● independent combination of the individual components

Fig. 4: Comparison of compact detergents and modular system.

Phosphate-free compact detergents and modular systems make it possible to use the smallest quantity of detergent. Compared with modular systems, compact detergent (Fig. 4) represents the universal type because of its complete composition, and it guarantees highly reliable performance because of the optimally balanced effect of all components in each wash cycle. It is easy to use and does not pose problems for the consumer. With modular systems, a specific measure of detergent can be used depending on the soiling, or individual detergent components can be combined. As is the case with component washing using traditional detergent types, these detergents are aimed particularly at consumers who have knowledge of washing technology.

An example of a basic formula of a modern phosphate-free universal powder detergent (Fig. 5) shows that the percentage of individual ingredients can vary extremely. With some ingredients this can be partially explained by the differentiation between conventional

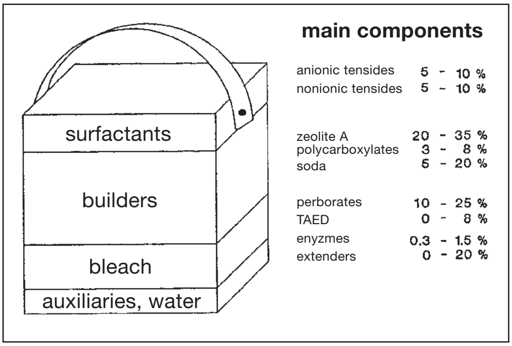


Fig. 5: Contents of phosphate-free powder universal detergents.

and compact powder types. Compact detergents are noted for their lack of bulking substances and a correspondingly relative proportion of active substances. But there are also examples of conventional powders that contain practically no bulking substances.

Certain washing agent additives can be found in the waste water from domestic washing machines, as shown in Tab. 1.

The evaluation criteria for the ecological behaviour of detergent and cleaning agent additives originally concentrated mainly on primary biodegradability in the case of surfactants. The German Detergent and Cleaning Agent Law as well as EC guidelines including the relevant legislation were restricted until now to the requirement for a minimum degradability of 80 or 90% for anionic and non-ionogenic surfactants. To limit the liming effects of detergent phosphates, the quantity of phosphate used was controlled by means of the directive concerning maximum phosphate levels.

The debate on the environmental impact of detergents and cleaning agents clearly shows that an increasing range of criteria has an extreme eco-political significance. The possibility should not be ruled out that a requirement for legislation on this matter will be recognized in the foreseeable future. The following general criteria or aspects are being considered and debated:

- aquatic toxicity for fish, daphnia (water fleas) and water plants,
- total decomposition of organic detergent additives,
- formation of toxic metabolites,
- complex forming properties and remobilization properties for metals,
- enrichment processes in the soil in agricultural sludge recycling,
- bio-accumulation (enrichment in the food chain),
- fertilizing effects in lakes, ponds, etc.,
- unwanted supply of salts in the form of Na^+, SO_4^{2-}, SiO_4^{3-}, BO_3^{3-} ions in surface water.

There is a current trend, not governed by the law, towards surfactants that biodegrade completely. Completely biodegradable means that the surfactant decomposes rapidly under any environmental conditions (in the presence and absence of oxygen), without any residual molecule fragments that do not biodegrade easily. A second general trend is the increasing importance of → Surfactants on the basis of raw materials that can be regenerated (Fig. 6).

contents of heavy-duty washing agent	percentage %	Waste water concentration (mg/l)
Surfactants:		
anionic surfactants	10	14
non-ionic surfactants	5	7
special soaps (behenates)	3	4.2
Builders:		
Tripolyphosphate	20	28
Na-Al silicate	24	33.6
Bleaching agents:		
Na-perborate	20	28
Bleach activators:		
TAED	2	2.8
Other contents:		
CMC	2	2.8
Na-sulphate	10	14
Na-silicate	3.6	5.0
enzymes	0.4	0.56
optical brightening agents	0.2	0.28
perfume oil	0.2	0.28

The calculation is based on a specific washing agent consumption of 28 g and a waste water output of 200 l (both per person per day). This corresponds to a total content of ≈ 140 mg/l of washing agent additives.

Tab. 1: Specific waste water concentrations of washing agent additives.

Despite this general trend, the most important surfactant from a quantity point of view will for many years continue to be an anionic surfactant based on mineral oil, known as LAS (linear alkylbenzol sulphonate). It is expected that fatty alcohol sulphate (FAS) will increasingly take the place of LAS as a detergent additive. The raw materials of FAS can be regenerated, and it is fully biodegradable. In the case of non-ionogenic surfactants a trend towards low-ethoxylated alcohols can be observed, which improve the removal of fat-based soiling during washing, particularly at low

Washing agent additives

overall	trends	→ towards surfactants based on regenerating raw materials → towards completely biodegradable surfactants
anionic surfactants	LAS FAS	quantitively still the most important surfactant increasing significance, partly replacing LAS
nonionic surfactants	AE EPG	trend towards low EO; increase in FAE increase

Fig. 6: Trends in surfactants for household detergents.

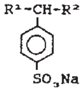
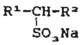
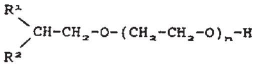
temperatures. In this instance too the use of raw materials that can be regenerated, i.e. fatty alcohol ethoxylates (Tab. 2), will increase. Alkyl polyglucosides constitute a particularly interesting category of surfactants, which are obtained by condensing fatty alcohols with glucose, e.g. from starch. These surfactants are not only completely biodegradable, they are also gentle on the skin, and also have a performance that is comparable to standard surfactants. Alkyl polyglucosides are used in universal liquid detergents, in particular for liquid dishwasher detergents.

The development of detergent builders (Fig. 7) is generally identified by the increasing spread of phosphate-free detergents in Europe. As a consequence, zeolite use and requirements will increase, while phosphates will continue to become less significant. This development can be seen by the intensive development of zeolite capacity on a worldwide basis, for example in countries such as Spain or Great Britain.

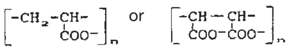
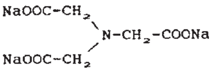
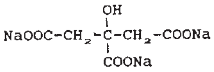
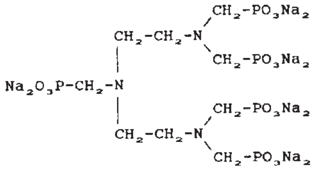
overall	trends	→ towards trans-European phosphate-free builder systems → towards even more environmentally friendly combinations
main builders	zeolite A tripolyphosphate	increase decrease
co-builders	polycarboxylate NTA citrate tartrate succinate	search for substitutes which are more easily degradable limited application slight increase limited application

Fig. 7: Trends in builder substances for household detergent.

As well as the main building ingredients, zeolites, phosphate-free detergents also require so-called co-builders, so that the full performance of the

compound name	chemical structure	ecological properties primary decomposition * MBAS/BiAS (19d) %	 total decomposition ** DOC (19d) %	 fish toxicity LD_{50} mg/l
soaps	$R-CH_2-COONa$	–	85–99***	20–150
alkylbenzene sulphonates		94–98	75–92	3–10
alkane sulphonates	 $R^1-\underset{SO_3Na}{CH}-R^2$	95–99	85–98	3–24
alkyl sulphates (fatty alcohol sulphates)	$R-CH_2-O-SO_3Na$	95–100	90–99	3–20
fatty alcohol ethoxylates	$R-CH_2-O-(CH_2-CH_2-O)_n-H$	90–99	80–98	1.7–30
oxo alcohol ethoxylates		80–99	75–95	0.25–40

Tab. 2: Chemical structure and ecological properties of surface active compounds (surfactants) in the form of detergent components.
** OECD Screening Test, MBAS-, BiAS decomposition; ** OECD 302B; *** demonstration of soap fatty acid decomposition through gas chromatographic analysis.*

compound name	chemical structure	ecological properties primary decomposition MBAS/BiAS (19d) %	total decomposition DOC (19d) %	fish toxicity LD_{50} mg/l
soda	Na_2CO_3	–	–	200–740
sodium disilicate	$Na_2O \cdot 2SiO_2$	–	–	>1000 (LD_0)
zeolite	$Na_2O \cdot Al_2O_3 \cdot 2SiO_2 \cdot 4,5H_2O$	–	–	>16 000
polycarboxylates	 $[-CH_2-CH(COO^-)-]_n$ or $[-CH(COO^-)-CH(COO^-)-]_n$	–	<15	>200 (LD_0)
nitrilotriacetate (NTA)		–	90–98	475
citrate	 $NaOOC-CH_2-C(OH)(COONa)-CH_2-COONa$	– –	95–100	440–760
sodium sulphate	Na_2SO_4.	–	–	7–14 g/l
phosphonates e.g. DTPMP		–	<10	758

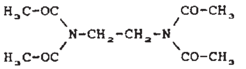
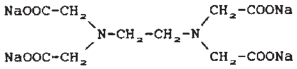
Tab. 3: Chemical structure and ecological properties of washing alkalis and softeners as detergent components.

tripolyphosphate can be achieved. The co-builders most commonly used in Europe (Tab. 3) are sodium carbonate and polycarboxylate, a co-polymer based on maleic and acrylic acid. Although this polymer is eliminated to about 90% by adsorption in purification plants, and as yet no ecological disadvantages have been discovered, the insufficient biodegradability is always under debate. For this reason, priority is given to a search for substitutes with better biodegradability. Examples of substances with good biodegradability are citrate, which has been known for a long time, and tartrate succinate. These raw materials apparently have limited use in Europe and overseas. NTA (nitrilotriacetic acid) could represent an alternative co-builder. However this substance, which has been known for a long time, gained a bad reputation in the past because of its alleged poor degradability, and it was feared that it had heavy metal remobilization properties. For this reason, the textile industry subjected itself to restrictions regarding NTA use in Germany, for example. NTA is not used in any household detergents in Germany. Extensive experiments and an extended monitoring program have proven that the misgivings expressed in the past were unfounded. NTA biodegrades very efficiently under environmental conditions. However it is still questionable whether these positive findings will be sufficient to restore the reputation of NTA. Crystalline sodium layered silicates are a new development in builder products. The substance “SKS-6”, which bonds hardness ions, falls into this category. Because this compound is so unstable above a wash temperature of 60°C however, its use is presumably limited to specialist applications or perhaps as co-builders in combination with zeolite A.

Bleaching components (Fig. 8) are also undergoing significant changes as a result of the ongoing tendency towards low washing temperatures and compact detergents. Because of this, the proportion of perborate monohydrate instead of perborate tetrahydrate will increase in parallel with the development of compact detergent.

Perborate is added to full detergents in a ratio of 10–25%, which makes it one of the most important detergent additives as regards quantity (Tab. 4). It exerts an intensive bleaching effect because the peroxide releases active oxygen. Since the perborate has a boron con-

Washing agent additives

compound name	chemical structure	ecological properties		
		primary decomposition MBAS/BiAS (19d) %	total decomposition DOC (19d) %	fish toxicity LD_{50} mg/l
sodium perborate	$NaBO_2 \cdot H_2O_2 \cdot 3H_2O$	–	–	623
tetraacetylethylenediamine (TAED)	 $(H_3C{-}OC)_2N{-}CH_2{-}CH_2{-}N(CO{-}CH_3)_2$	–	>98	>1600
magnesium silicate	$MgO \cdot SiO_2$	–	–	>1000 (LD_0)
ethylenediamine-tetraacetate (EDTA)	 $(NaOOC{-}CH_2)_2N{-}CH_2{-}CH_2{-}N(CH_2{-}COONa)_2$	–	<5	2040

Tab. 4: Chemical structure and ecological properties of bleaching agents and bleaching systems as detergent components.

bleaching agents	perborate monohydrate	increase
	perborate tetrahydrate	decrease
	percarbonate	increase
	per acids	negligible
activators/ stabilizers	TAED	increase
	EDTA	negligible (e.g. not used in Germany)
	phosphonates	decrease
	ISDA	used since 1995

Fig. 8: Trends in bleaching agent components for detergents.

tent of approx. 7%, a specific boron level in waste water of 250–300 mg can be calculated per inhabitant per year. At a specific waste water level of 200 l per head, the result is a mean waste water concentration of 1.25–1.5 mg of boron per litre, but in practice the value measured in the purification plant flow is 0.9–1 mg/l.

The discharge values indicate that in principle boron compounds can not be eliminated by means of conventional waste water purification processes, i.e. neither physical/chemical processes nor biological processes result in complete removal of boron. This means that boron is discharged unaltered into water in the form of boric acid or borate ions. If the waste water is diluted at a ratio of 1 : 10 in the drainage, in theory the maximum water concentration to be expected is 0.12–0.15 mg/l. However boron has a low acute toxicity towards water organisms (Tab. 5).

Perborate has been used in European detergents for over 80 years. Since an alternative to perborate that is comparable in detergent stability and ease of use has not yet been found, perborate is likely to remain the most significant bleaching component for the next few years. Percarbonate on the other hand became a bleaching component in washing auxiliaries (scouring salts), and as part of a modular system. Organic per acids, such as diperoxydodecandic acid (DPDDA) or phthaloylaminoperoxycapronic acid (PAP) exhibit good bleaching effects at low temperatures. Bleach activation is essential at low temperatures. For this reason the use of bleach activators will increase. TAED (N,N,N,N,-tetraacetylethendiamine), with a current annual capacity of approx. 60 000 t, clearly dominates the European activator market. There are competitors, such as pentaacetyl glucose (PAG), diacetyldioxohexahydrotriazine (DADHT), and nonanoyloxybenzene sulphate (NOBS), but they are not used in Europe, or only play a very minor role.

The use of bleach stabilizing components, i.e. heavy metal bonding substances such as EDTA (ethylene diamine triacetic acid) and phosphonates, is regressive. EDTA, which is not easily biodegradable and has heavy metal remobilizing properties, is no longer used in domestic detergents in Germany, for example. It

compound	type of fish	acute toxicity
naborate	minnow	3000 – 3300 mg/l = 396 – 435 mg boron/l
boric acid	rainbow trout	2000 mg/l = 350 mg boron/l
boric acid	gambusia	3600 – 5600 mg/l = 630 – 980 mg boron/l
boric acid	rainbow trout	339 mg boron/l
perborate	rainbow trout and guppy	750 – 1000 mg/l = 52 – 71 mg boron/l
boric acid	rainbow trout and guppy	5000 mg/l = 874 mg boron/l
borax	rainbow trout and guppy	2500 mg/l = 538 mg boron/l

Tab. 5: Acute toxicity of boron compounds for fish.

enzymes	proteases	1st generation → 2nd and 3rd generation
	amylases	limited application (principally in liquid products)
	lipases	negligible speciality use
	cellulases	negligible speciality use
others	foam inhibitors	soap → silicon oils/paraffins
	cellulose derivatives	decrease
	optical brightening agents	no significant changes
	extenders (sodium sulphate)	decrease

Fig. 9: Trends in auxiliaries for household detergent.

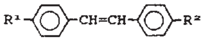
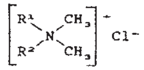
seems that an alternative has recently been found with better biodegradability for some applications. This alternative is isoserin diacetic acid (ISDA).

Other detergent ingredients that are now considered almost indispensable are enzymes (Fig. 9). Proteases constitute the most important category of enzymes by a long way. Their important contribution is to remove soiling with protein content. It can now be observed that after decades of 1st generation protease use, most powder detergents have now switched to 2nd generation proteases, i.e. more effective proteases, in particular in a highly alkaline environment. There are also so-called 3rd generation proteases with further improved stability on the market, which in future will be used in detergents. The use of amylases, which act against starch-based soiling, will remain restricted. Currently amylases can be seen mainly in liquid products in combination with proteases. New specialist enzymes, such as lipases which act against fatty soiling, or cellulases, which clean and maintain cotton fibres, are already used globally in some detergents. Since their spectrum of effectiveness is limited, particularly compared with the other components of detergent, such as surfactants, these new enzymes are likely to be used only on a limited basis in detergents. After all, these enzyme developments can contribute towards the removal of soiling, particularly at low temperatures, and therefore restrict the use of surfactants even though they are not rendered superfluous.

Where foam inhibitors are concerned, a further decline in the use of soap is to be expected, and it will be replaced by foam inhibitors containing silicon oil or paraffin. The greying inhibition function of cellulose derivatives has now been mainly superseded by other detergent components, such as polycarboxylates, and therefore a further reduction in cellulose derivatives is expected. No immediate change of any significance is expected in optical brighteners (Tab. 6), in other words their use will continue to be restricted just to the category of universal detergents. Bulking agents, primarily sodium sulphate, will be practically eliminated as compact detergents come to the fore (according to Upadek and Krings, as well as Brüschweiler, Felber, Schwuger and Huber).

Washing agent dosing Because of the chemical industry's self-imposed commitment to ecology and the economic pressure to conserve raw materials and energy, it is essential to rethink optimization of detergent formulae and recommended dosage constantly, as well as domestic laundering care methods.

During the 1980s, the general population became much more aware of environmental issues. Many households in Germany claim to be environmentally orientated. Detergents and environmental tolerance are subjects constantly under debate. Much has happened in the past few years in the way of improvement. This is illustrated by the fact that phosphates in detergent have

compound name	chemical structure	ecological properties		
		primary decomposition MBAS/BiAS (19d) %	total decomposition DOC (19d) %	fish toxicity LD_{50} mg/l
carboxymethyl-cellulose		–	–	>250 (LD_0)
stilbenes, e.g.		–	can be eliminated	10–100 (LD_0)
cationic surfactants		–	80–98	1–6
bentonites	$H_2O\ 4SiO_2\ Al_2O_3\ nH_2O$	–	–	–
glycols	$HO-(CH_2-CH_2-O)_n-H$	–	85–98	
alcohol	R-OH	–	decomposes easily	

Tab. 6: Chemical structure and ecological properties of detergent components: other possible additives.

been completely replaced by raw materials that are compatible with the environment, in particular sodium aluminium silicate of the type zeolite A, or the introduction of compact detergent systems. Both legal requirements and the requirements of consumer organizations and environmental associations continue to aim for an overall reduction in detergent use, even though detergent dosage has fallen within the past 20 years to one-fifth of the original quantities (Fig. 1).

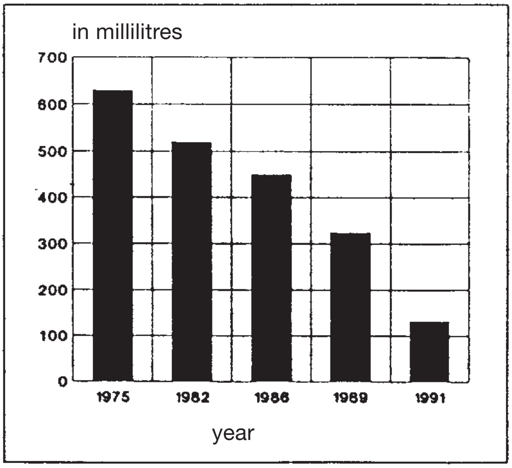


Fig. 1: Reduction of washing agent dosing, demonstrated from the Persil example: over 16 years the Persil dosage fell from more than 600 ml to less than 100 ml per wash (recommended dosage for water hardness range 3).

Environmental protection and washing performance are equally important to the detergent manufacturer. The environment should be subject to as little burden as possible. At the same time, detergent dosing should be orientated towards achieving the required cleaning performance and the necessary care of laundry and washing equipment. The consequences of under-dosing are frequently not only insufficiently cleaned laundry and reduced hygiene, but also damage to the textile being washed and to the washing machine. The correct solution in order to conserve the environment is to use the lowest dosage, which fulfils both these conditions.

For this reason, a constant objective of detergent development is establishing the specific minimum dose for the current detergent formula. In order to establish the required dosages, application-orientated tests are usually carried out on domestic laundry. The textile being washed is treated with a variety of different naturally occurring soil types, such as fats (skin grease, make-up), protein (milk, egg, blood), pigment soil (dust, mud), or bleachable stains (coffee, tea, fruit and vegetable juice, red wine). Various different quantities of detergent are used. The amount of soiling is assessed before and after washing, by means of visual examination or objective methods such as optical measuring processes. The smallest quantity of detergent that still results in an acceptable wash effect is used to define the minimum dosage.

The main additives in the detergents used for domestic washing are surfactants. The most commonly used universal detergents contain surfactants in standard form or as a compact powder, or also as a liquid formulation. Surfactants improve the wetting properties of water; they reduce its surface tension. Pure water has very high surface tension, and is poor at wetting the laundry or other hydrophobic surfaces. If surfactants are added, the surface tension of the solution becomes lower and the laundry is penetrated by the liquid. For this reason, if a hydrophobic surface is available to a surfactant solution, e.g. a textile fibre surface with fat and particle soiling, the surfactant molecules will be deposited on it. During this process they affix themselves with their hydrophobic residue into the fat. The hydrophilic head remains in the water. As further surfactant molecules are deposited, all the fats gradually become detached from the surface in the form of small particles surrounded by surfactants. Depending on the melting temperature of the fats, these particles can be liquid or solid. The detachment process is assisted by the washing machine mechanics (rotary movement of the washing drum), the heat supply (washing temperature) and the duration of the wash cycle. The fat particles are only stable in water because they are protected by the surrounding surfactant shell. The case of pigment soil particles is similar to fat-based soiling; surfactant particles are also deposited on their surface. They even penetrate into the tiny cleavages between the particles and the fibre surface. This causes the entire soil particle to be completely surrounded by surfactant molecules, so that it can then be rinsed off with the water.

There are other additives in detergent that support surfactants. There are substances known as builders that soften the water – which constitutes an essential condition for a good wash result. Further additives raise the alkaline level in the washing liquor, which makes soil detachment easier. Detergent enzymes also make soil detachment easier, by hydrolyzing protein or fat-type soiling into small fragments. For example protease ensures easy removal of protein; lipase assists the washability of fatty soiling. In order to remove soiling as fully as possible, the washing liquor must contain enough surfactants, i.e. sufficient reserves of detergency power. At the beginning of the washing process, all surfactants dissolve rapidly in the washing water. Gradually a proportion of these deposit on the surface of the textile fibres. The other surfactants lift soil from the fibre and hold it in a stable situation in the washing liquor. With both of these surfactant groups, the original total quantity is “lost” since it no longer contributes to further cleaning: the detergency power reserve decreases.

The properties of “hard water”, which can be damaging, are well known. Only about one-fifth of drinking water is “soft”, i.e. only has a low level of water hardness. Water hardness is caused by small amounts of calcium and magnesium salts, which are present in all drinking water. When the water is heated, the salts precipitate as carbonates in the form of insoluble lime. Lime deposits would also occur in washing machines and on laundry if modern detergents did not contain a sufficient proportion of softeners, which fix the hardness in the water. Where phosphates were a necessary additive in detergents for the complex fixing of water hardness, nowadays in phosphate-free detergents, the problematic calcium and magnesium salts are removed from the washing liquor by zeolite A, which is insoluble in water.

Lime also has an unfavourable effect on the washing effect of a detergent. Since some of the calcium and magnesium salts can form insoluble compounds with some surfactants, wash-active substances are removed from the detergent. The wetting properties and wash performance are reduced.

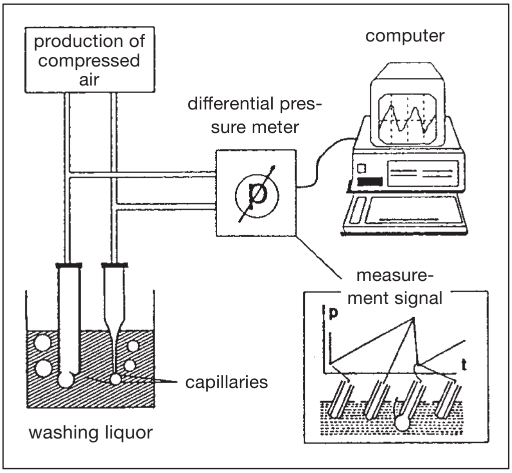


Fig. 2: Construction of an online tensiometer: compressed air flows through two capillaries of different widths into the washing liquor. The pressure difference between the capillaries is recorded electronically (by Henkel).

An online tensiometer can be used during washing for direct analysis of the ratio between the quantity of surfactants still available or “free”, and the amount deposited on fabric and soil, i.e. “used”. The online tensiometer is a sensor to detect surfactants, and functions on the principle of the maximum bubble pressure method (Fig. 2). Small quantities of air are pumped through two thin capillary tubes, which are immersed at the same depth in the washing liquor. Air bubbles form constantly on both capillaries. The pressure required to form bubbles varies because of the different diameter. The higher pressure is measured in the narrower capillary. The pressure difference between the two capillaries now only depends on the surface tension of the liquor. This parameter is in turn directly linked with the surfactant concentration in the washing liquor.

Pure water has a high surface tension. The more surfactants there are in the water, the more the surface tension drops. The level of surface tension can be used to determine the surfactant amount. The only surfactants measured are those that are still free in the solution and can therefore still exhibit surface-active properties. In other words these are the surfactants which are in the form of individual molecules or micelles. An exception to this is the surfactants that are already attached to the fibre surface or soil particles. For this reason an online tensiometer records the quantity of surfactants in the washing liquor and the wash reserve, which is particularly important in practice, by measuring the dynamic surface. This method is particularly easy if the differential pressure measured is compared directly with the prescribed dosing of the detergent. This produces a calibration curve (Fig. 3), which can be used to work out an unknown concentration of detergent in a washing liquor if all other influential parameters are kept constant.

An online tensiometer measurement taken from the washing liquor discharged from a simulated wash cy-

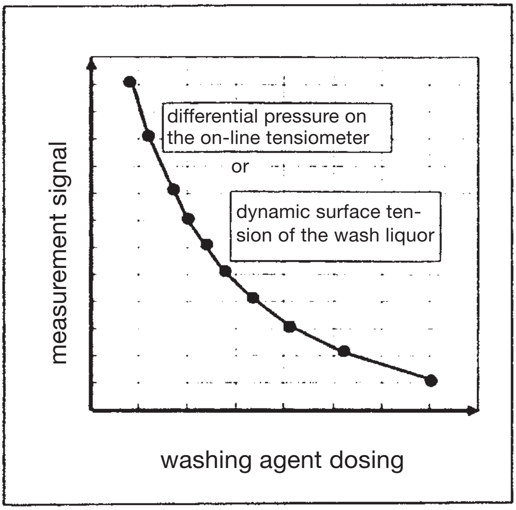


Fig. 3: The online tensiometer as a surfactant sensor: connection between the washing agent dosing and the measuring signal of the online-tensiometer or the dynamic surface tension of the wash liquor (by Henkel).

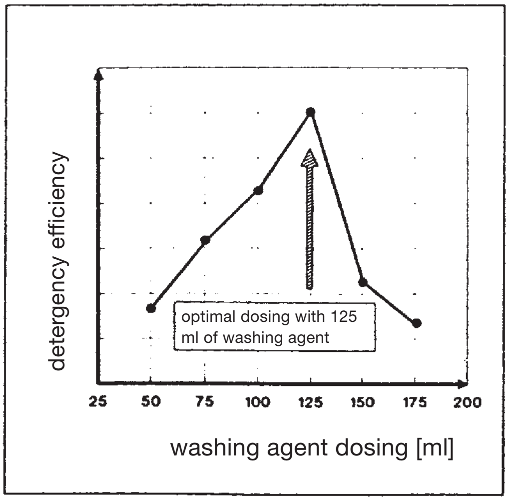


Fig. 4: Maximum detergency efficiency at optimal dosing: if the optimal dosing is maintained, there is a maximum of washing agent action. The overdosing avoided guarantees the minimum of environmental pollution (by Henkel).

cle, shows that the quantity of wash-active surfactants and therefore the detergency power in the washing liquor as a result of increasing amounts of laundry and soil in the wash liquor, is actually reduced. The online tensiometer can be attached directly to the washing machine. In practical tests for example 3.5 kg of normally soiled domestic laundry is washed at 60°C in the main wash cycle without a pre-wash. If there is a constant water flow of 20 l per wash cycle, there are varying initial concentrations of detergent in the washing liquor depending on the dosing. Dosing varies in another area. At the end of the wash cycle, the actual surfactant concentration (and therefore indirectly the concentration in the detergent) can be measured with the online tensiometer. If the detergency efficiency is calculated from the values measured, the optimum dosing can be seen in graphic format. The detergency efficiency reaches its maximum at the exact point at which the detergency power reserve and the quantity of "used" surfactants are at optimum compatibility (Fig. 4) (according to Krings, Smulders and Müller-Kirschbaum).

Washing agent enzymes Detergent enzymes have a high resistance to alkali and thermostability at approx. 60–65°C. Towards the end of the 1960s, the technical production of detergent proteases underwent rapid expansion. In 1968 the first heavy duty detergent with microbial → Proteases was manufactured by Henkel. In 1969, about 80% of detergents in West Germany had enzyme additives; in 1975 this figure stabilized. The most popular detergent enzymes in 60°C detergents are microbial proteases, bacillopeptidases and → Amylases (→ Enzymes).

Washing agents Washing agents or Detergents remove fat and soiling substances from textiles. In the context of textile finishing, detergents are specially adapted to suit each finishing process, e.g. for raw wool scouring, washing after dyeing and printing, etc. Laundry and domestic detergents are specifically included under the category of detergents. Domestic detergents can be classified depending on their use into the following categories: →: Heavy duty detergent; Mild washing agents; Special washing agents. Depending on the method of manufacture, detergents can be classified as mix and spray (cold and hot sprayed) products. Depending on consistency there is a distinction between detergents in powder form and liquid products.

	[%]
anionic surfactants (LAS)	5–10
niosurfactants (alcohol ethoxylates)	1– 5
foam regulators (soaps, silicon oils)	3– 5
builders (zeolite, polycarboxylates, NTA)	30–40
bleaching agent (sodium perborate)	20–30
extenders (sodium sulfate)	0–10
bleach activators (TAED)	1.5– 4
stabilizers for perborate (EDTA, Mg-silicate)	0.2– 2
enzymes (proteases)	0.3– 1
greying inhibitors (CMC)	0.5– 1
optical brightening agents (stilbene and pyrazoline derivates)	0.1–0.3
aromatics	0.2

Tab.: Universal washing agents.

→ Surfactants (WAS) form the product basis, as well as preparations made from surfactants using → Washing auxiliaries or builders, boosters, as well as other additives or bulking agents (Tab.). → Washing agent additives.

Washing and hydroextraction machine Multipurpose machine used as a washing machine, hydroextraction machine, and agitator (loosener). The drum construction is usually divided in a Y shape for side or front loading, also available in the form of a → Front loading washing machine (loading/unloading can be manual or mechanical). Operates on the multi-bath principle. The revolutions for washing/agitating is 20–30 rev/min, for the final spin it is 500–1000 rev/min. Load time is 40–50 min. Residual moisture 50–60%. Capacity 9–800 kg.

Washing auxiliaries (→ Builders), improve the effectiveness of detergents. In the textile industry these are usually colloids, such as cellulose derivatives, and also water correction agents, organic solvents, etc.

Washing blue → Ultramarine.

Washing carriage in screen printing After printing, the printing blanket is washed with rotating brushes and water. During this process, washing carriages run on tracks that are also intended for the → Printing carriage. It can be powered manually or electrically.

Washing detergent analysis → Surfactant analysis.

Washing detergents Products manufactured from →: Surfactants; Phosphates; Perborates or alternative products and other complementary components as specified by the → Detergent and Cleaning Agent Law. They act in conjunction with water to produce a cleaning effect, or are intended for cleaning (according to an additional suggestion: or products that can be used as additives and auxiliaries in washing and cleaning processes), which can finish up in environmental waters after use. The definition also includes particular textile and leather auxiliaries and industrial cleaners.

Washing in hard water,

1. Dependent on the presence of soap, the formation of insoluble, wash-inactive calcium and magnesium soaps (→ Water hardness salts).
2. If sodium carbonate is added (before soap and during heating), only partial softening occurs.
3. High-molecule → Polyphosphates in a quantity appropriate to the hardness enable the detergent to be utilized fully; can not be used in boiling baths.
4. → Lime soap dispersant only prevents flaky lime soap secretion by forming colloid dispersing particles (clouding of washing liquor) with no detergency power.
5. Although synthetic ionogenic detergents are usually resistant to lime, they have a lower detergency power in hard water at 10–30°d (fatty alcohol sulphates, fatty acid condensation products), or they frequently require 3 to 4 times the quantity of the product than would be necessary in the case of water at 0°d to achieve the same washing effect.
6. Synthetic non-ionogenic products have better detergency power than ionogenic products.

Depending on water hardness (particularly in the presence of heat, where inactivation additives are only effective under certain conditions), there are always excesses of detergent. The value of the detergent should always be weighed against the cost of → Water softening.

Washing lubricants → Textile lubricants.

Washing machines There are two different types of washing machine:

I. Washing machines for laundry care (domestic washing machines, laundry washing machines).

II. Industrial washing machines for pretreatment or after-washing, e.g. after-print washing of textiles.

In the case of pretreatment washing machines, discontinuous systems (Fig. 1) are available for small batches, and continuous systems (Fig. 2).

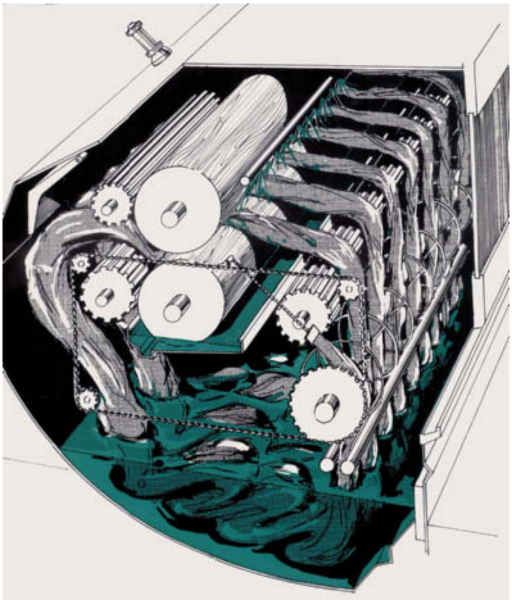


Fig. 1: Discontinuous rope washing machine (Hemmer) for the pretreatment of woollen fabrics.

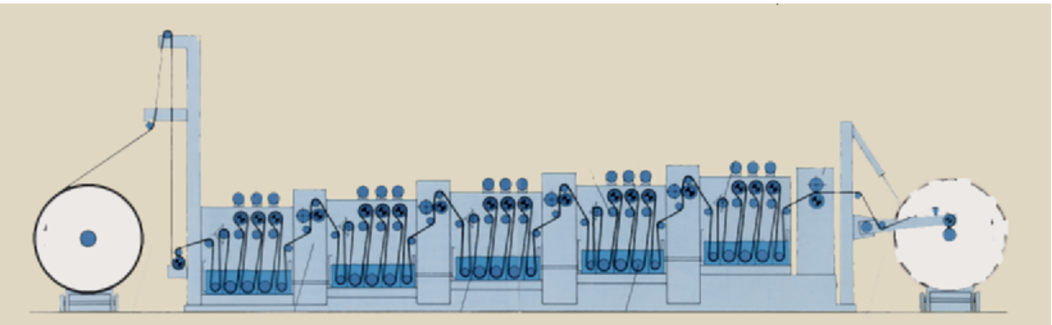


Fig. 2: Continuous open-width washing range for the pretreatment of fabrics (Kleinewefers KTM).

Washing machines

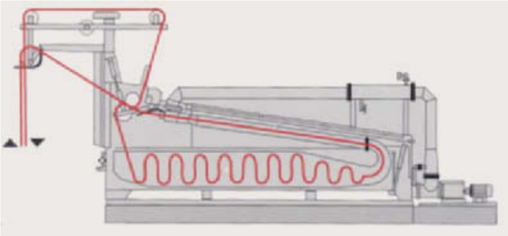


Fig. 3: Continuous rope washing machine (Küsters).

Depending on the type of fabric/thread, washing can be carried out in rope form (Fig. 3) or open-width. Open-width washing machines can be sub-divided into roller vat types (Fig. 4) and drum washing machines (Fig. 5).

Machines designed for continuous open-width washing usually consist of individual washing systems, which are considered as modules of a plant, each having washing functions. The sequence of these systems within a machine is variable. The individual systems in a plant can be distinguished, sometimes significantly, in their management of textiles and washing liquor. The washing liquor in the individual washing systems is either changed in charges, or is transferred from one system to another against the direction of the textile. Combinations between so-called standing baths and constant liquor change occur within a plant. A counter-flow between the liquor and yarn can be implemented while the yarn is still in the system, particularly when multiple liquor separation is carried out.

Yarn guiding can be fixed or non-fixed. When it is non-fixed, there are two different types – plaiting down without folds, or with folds or loops. Plaiting down without folds is done rarely because of the length of the bath or dwell period that would be required if plaiting with folds is not indicated because of the danger of fold marking. Plaiting down in folds can be done horizontally in a trough, on a belt, roller bed, chain or sieve. Alter-

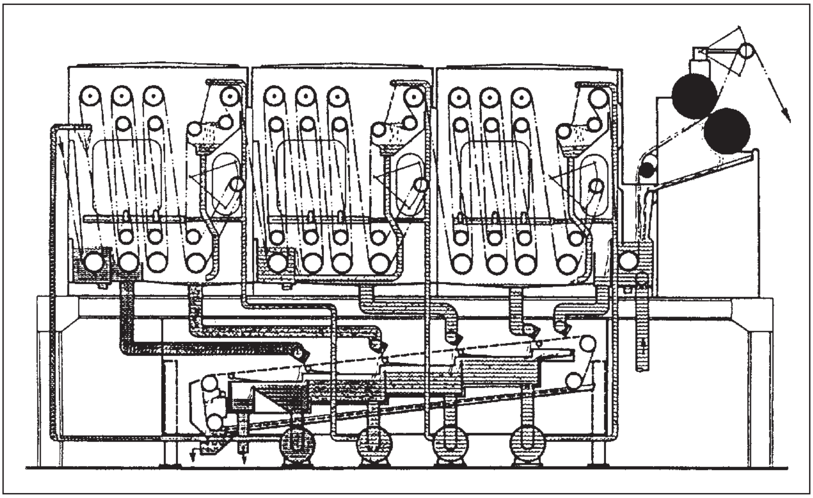


Fig. 4: Econtex roller vat (Babcock).

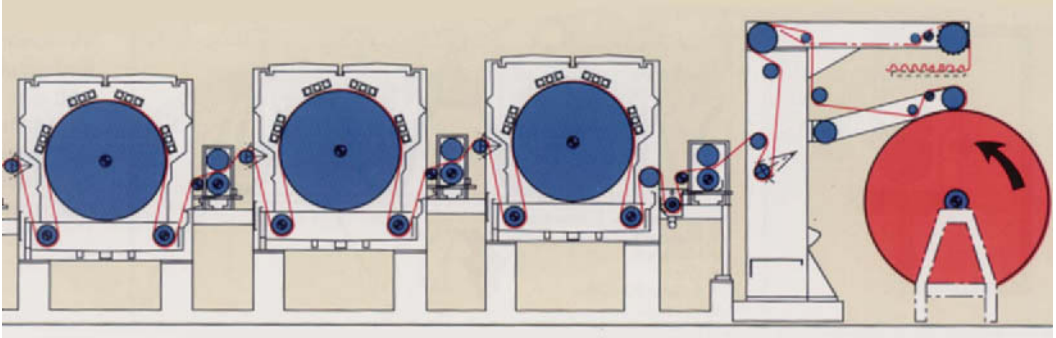


Fig. 5: Trikoflex-2000 drum washing range (Kleinewefers KTM).

natively it can be done vertically in a J-box or trough. During this process, the fold marking is more intensive the higher the pressure on the fold and the more intensive the structural change is during the dwell period in the liquor. The pressure on the fold is at its lowest with hanging loops and at its highest in the J-box. Fabric transport occurs either independently as a result of gravity, or it is forced by the liquor impulses, as well as milling elements or the motion of the plaiting elements. The mechanics acting on the yarn are designed to aid relaxation and soil detachment.

Rotating sieve drums constitute a transition between non-fixed textile guiding to fixed methods. The rotating sieve drums are in a flooded state, and they use pulsation or constant suction so that the liquor flows through the textile.

The simplest example of fixed textile guiding is the roller vat washing machine. Its washing effect is firstly improved by liquor separation using individual compartments as well as squeezing units and strippers. Secondly the liquor exchange is intensified with the aid of overflow weirs or gutters, spray tubes, beating and vibration elements, as well as air blowing, double yarn thread-up and associated liquor turbulence. Under optimum conditions with regard to machine construction and condition, the textile tension is affected by friction with the liquid rather than with roller bearings. Other guiding elements can be used instead of rollers, such as winches and corrugated rollers.

To achieve maximum liquor separation, the objective is to keep the liquor as short as possible, for example by employing several squeezing units in series with spray tubes or overflows between. The squeezing units can be arranged around a central cylinder or above one another in a tower, to avoid a long free yarn path. A high level of liquor separation and textile throughflow can be achieved in non-flooded systems with horizontal guidance and counter-flow. In special cases the detergency efficiency can be improved by increasing liquor exchange with the textile by using suction and pressure jets. In addition, continuous washing can be carried out under pressure at temperatures in excess of 100°C. In order to do this, it is essential that the washing system is purpose-designed and sealed.

Washing machines for disinfection laundry Functionally standard drum washing machines that operate discontinuously, which are used for a disinfection washing process. However they have a built-in separator for the clean/dirty section (side for clean laundry/side for soiled laundry) and accordingly there are separate openings for loading and unloading, which each have to be locked on both sides so that it is impossible to open both at the same time. This type of machine is specifically required by the Federal Health Office in Germany.

Washing mechanics One of the four factors of Sinner's wash cycle (→ Washing). It refers to the flow ratio caused by the movement of washing liquor or textile. In the case of a → Laminar flow, all parts of the flowing medium move parallel to the sides of the tube, so that the speed is highest at the middle point, and towards the sides it drops off to zero. This is because the layer adjacent to the side adheres as a result of surface forces. However if a specific critical speed is exceeded, or if the tube cross-section is larger, swirling effects occur, and at Re > 2300, the laminar flow becomes a → Turbulent flow or swirling flow. The limit layer theory applied to laminar flow, permits simplification of the differential equation of the flow and diffusion field to such a degree that in this case it can be solved exactly. For laminar and parallel flow to and over a plate, the flow velocity can be broken down into components Wx and Wy on a vertical axis, which are constant with respect to time. The mass flow of the substance passing over can be calculated in the same way. The differential equation of the concentration boundary layer is derived from the second → Fick's law of diffusion. Furthermore the continuity equation is valid for the speed component.

If the differential equation is simplified so that the friction and inertia forces of flow are only effective in the direction x, and transport of the substance in this direction only occurs by means of free convection, the solution for localized substance transport is:

$$\mathrm{Sh} = 0.664 \cdot \mathrm{Re}_x^{0.5} \cdot \mathrm{Sc}^{0.33}$$

In this situation,

$$\mathrm{Re}_x = \frac{w_\infty \cdot x}{\nu}$$

represents the Reynolds number Re formed with the unobstructed approaching flow velocity W_∞ and x (distance). The concentration and velocity profiles are of the same type. If D (diffusion coefficient) and υ (viscosity) have the same numerical value (i.e. Sc = 1), then both profiles are congruous. The most important characteristic of these profile curves is the disappearing curve at the side, at which substance transport occurs only by means of diffusion. Since the profiles decline asymptotically to the values of the unobstructed flow, the thickness of the boundary layer can be defined as the distance from the side up to which an unobstructed flow velocity or solution concentration of up to 99% is reached.

The flow velocity and the run distance (= flow path over the surface) influence the thickness of the boundary layer (δ) and the substance transport number (β) the opposite way around, i.e. $\beta \sim {}^{1}/\delta$.

Reynolds recognized that there is an analogy between impulse exchange and substance transport in turbulent flows where the flow velocity and concentration fields are congruous (Reynolds analogy). Prandl and Taylor expanded further on this analogy to the higher values of the Schmidt number. These theories are based on the assumption that the turbulent boundary layer near to the side becomes a laminar sub-layer because the velocity drops on a linear basis towards zero.

The Reynolds analogy is used to calculate the resistance correction value for an even surface in a turbulent flow where $c_W = 0.074\ Re_x^{-0.2}$.

The resulting substance transport value in a turbulent flow is $\beta \sim w_\infty^{0.8}$. According to this, the influence of speed on the substance transport is significantly greater in turbulent flow than in laminar flow. It is often the case in turbulent flow that the resistance correction value is independent of the Reynolds number, and therefore according to the analogy, substance transport is not dependent on viscosity.

Five different flow types are possible:

1. liquor approach flow in the direction of textile travel (parallel flow).
2. liquor approach flow in the opposite direction to textile travel (counter flow).
3. Liquor approach flow vertical to the direction of textile travel (stagnation point flow or impact flow).
4. liquor approach flow transverse to textile surface and direction of textile travel (transverse flow).
5. liquor approach flow through textile (throughflow).

None of these flow types occur exclusively in an open-width washing machine. For this reason it is difficult to make quantitative statements and calculations in the context of substance transport and flow mechanics.

In order to discuss the link between substance transport and flow mechanics, a further distinction must be made between forced convective and free convective substance transport. In the case of forced convection, the substance transport is characterized by the substance transport parameter β and the diffusion coefficient D, and the flow process is distinguished by the velocity of the fluid and its kinematic viscosity. A further factor is “l”, which is needed to identify the geometric size ratios.

According to the Buckingham theories, these five influential factors are used to produce three dimensionless indices. From this the substance transport for forced convection can be calculated (Sherwood number)

$$Sh = f\,(Re_x, Sc)$$

Free convection is caused by gravity as a result of varying densities that occur in the layers near to the side between non-saturated and saturated solutions (washing liquors). As opposed to forced convection, the velocity of the flowing fluid must be replaced by the gravity coefficient S. In this way, the Grashof number Gr is calculated instead of the Reynolds number. In this way, the following equation can be applied to substance transport in forced convection:

$$Sh = f(Gr, Sc)$$

Calculation formulae derived from traditional flow theory can be used to calculate substance and heat exchange for the five flow forms in simple individual cases. These formulae produce a solution in the case of laminar flow.

Washing off The removal of scrooping agents, preparations, sizes, chemicals, textile auxiliaries, non-set dyes and finishing agents. Washing off has a high level of influence on water use, and therefore also on costs and the problem of waste water. With discontinuous washing off, the textile stays in a machine and the washing and rinsing liquors are added or exchanged. Keeping the liquor ratio as short as possible lowers water consumption. With continuous washing off, the textile runs through several individual machines or sections, and the rinsing liquor is directed in counter-flow, i.e. there is a fresh water supply at the point at which the textile leaves the machine. Turbulence is used to ensure that the liquid lamella between the textile and the liquor is constantly broken up (increasing kinetic energy). The number of washing baths should be kept as low as possible (see Fig.).

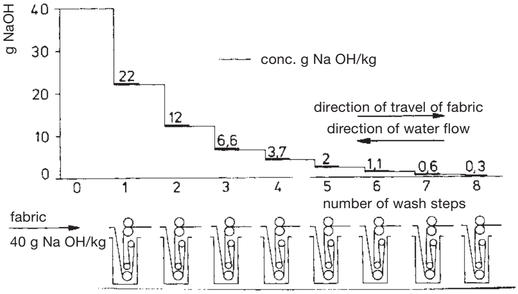


Fig.: Washing off 40 g caustic soda liquor/kg fabric with 4 l water/kg fabric.

Washing of printed goods Printed articles usually need to be washed after setting (with the exception of pigment and transfer prints). Washing serves to remove thickeners, chemicals and non-set dye, in order to achieve optimum fastness. Each washing process is dependent on the substrate and the type of dye that has been applied. Depending on the arrangement of each particular plant, the process can be carried out either continuously or discontinuously. → After-print washing.

Washing of woollen goods,

I. Raw wool: removal of lanolin, sweat, soil, e.g. Leviathan (Belgian process) using soft water and soap (calculated according to the wool; poss. 10–20% substitution with lime-resistant synthetic detergents, which makes clear rinsing in the final baths easier), ammonia or soap + sodium carbonate, poss. + fat solvent soap (in the case of pitch tips). Final rinsing in soft water. The impurities that are washed out precipitate to form a solid sludge. → Raw wool scouring.

II. Wool yarn: removal of spinning oil and size (→ Desizing). Sodium carbonate or higher alkaline levels should be excluded if possible with yarns that felt easily. Carded yarn is washed using soap or synthetic detergent + sodium carbonate calc. or ammonia. Worsted yarn with up to 1% fat content is usually washed with synthetic detergents, poss. + ammonia, and rinsed thoroughly.

III. Hairy yarn: mainly any melted-on mineral oil that requires removal. In certain circumstances difficulties can arise, in that the use of a highly effective synthetic detergent is urgently recommended. Technique (→ Salt wash is also possible), depending on soiling and fat content, using detergent (poss. + sodium carbonate calc. or ammonia). Subsequent rinsing is carried out, twice warm and once cold, until the water is clear. Lustre and handle can be influenced by subsequent acid treatment in a bath containing formic acid or acetic acid.

IV. Piece goods:

a) Worsted yarn, light ladies' goods, wool union goods, etc. usually using hank or open-width washing machines. Usually only a light wash is carried out, with soap + ammonia (poss. sodium carbonate if olein has been used as a lubricant, then with slight alkali excess with a significant alkaline reaction), after "kick-off" there is a further wash with synthetic detergent + ammonia (for the purpose of clearer fabric appearance). Light textiles are washed only with synthetic detergent (to avoid felting). In general the final rinse is lukewarm, then cold. Washing and milling are frequently combined (favourable effect on handle and lustre), particularly for cloth with "grease milling".

b) Carded yarns: mainly the removal of fat used in spinning (fatty acid or olein), so-called "wool scour", using sodium carbonate solution. A significant alkaline reaction should be expected, poss. + synthetic detergent, followed by lukewarm and cold rinsing. Generally speaking, the addition of water correction agents in a final rinse is recommended for soft water and rinsing with hard water. If hard water is being used for washing, less synthetic detergent + sodium carbonate is used, and after the first wool scour has started, further synthetic detergent is added (complete removal of soap). If melted or broken-down mineral oil is present, further fat solvent additives are required. →: Acidic washing; Solvent scour process for wool.

Criteria: the following points should be borne in mind when wash batches are being put together:

a) The machine should not be overloaded, otherwise soil removal becomes more difficult, roller pressure becomes lower, soil drains off less easily, felting hazard, risk of crease formation.
b) Batches of pure wool, wool union or worsted and carded yarn should not be mixed.
c) Batches of wool, yarn and piece-dyed articles should not be mixed because of varying dye pigment soiling and varying levels of tension.
d) Individual articles should only be processed using the same washing period. Loosely woven articles should not be washed together with heavy weaves, since the latter require a longer period of treatment and the former would become too narrow and felting would be extreme if this washing time was used.
e) In general the weight and thickness of articles should be carefully monitored. A thinner article running between thicker textiles is not subjected to enough roller treatment. If necessary, thick articles can be processed on one side of the machine and thinner ones on the other side.
f) Batches of the same colour shade should be washed at the same time, because light, dark or different coloured articles can bleed and cause colour changes.
g) Care should be taken that the level of soiling is the same (this is frequently a decisive factor in selecting the correct detergent type).
h) If possible, articles should be of the same length (± 2 m).
i) It is practical to exercise the same quality arrangements for all articles.

Washing pH In practice, the most efficient detergency power of soap (→ Electrokinetic interfacial potential) is achieved when the pH is 10.7 = 3 g/l of soap with a fatty acid content of approx. 30%. Many detergents contain significantly less fatty acid (up to 5%). The following washing alkalis in g/l result in pH 10.7: 1–1.5 g sodium metasilicate or 2–3 g sodium carbonate calc. or 5–8 g sodium carbonate cryst. or 20 ml ammonia.

Washing powder Specific term for → Washing agents in powder form.

Washing process Washing is a chemical-physical process, during which the combination of a multi-phase system consisting of fibre, oil-based soiling, solid soiling, washing liquor and air re-groups to form a new multi-phase system (Fig. 1).

As long as there is no total shielding of one phase, a system like this features contact between three phases. In addition, the washing liquid should not be regarded as a homogeneous phase, since detergent in the concentration used in practice does not form pure solutions. Instead it forms a system of micelles that has unequal

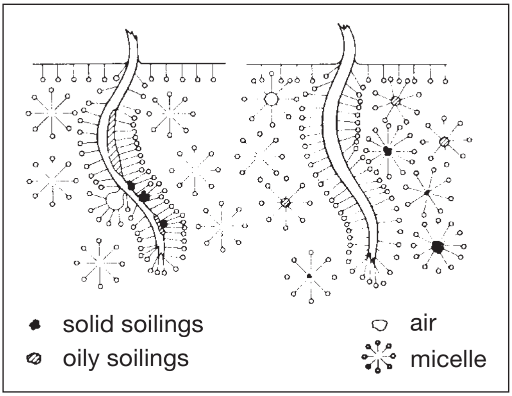


Fig. 1: Phase change in the wash process.

concentrations, which should, at least, be regarded as a two-phase system. The washing process itself is a dynamic process, at the end of which the fibre is soil-free, possibly surrounded by a shell of detergent adsorption layers, and a liquid multi-component phase with mutual equilibrium (thermodynamic). Furthermore the formation of an unstable system at the end of the washing process is possible, which exhibits a change in enthalpy as a result of energy absorption. At the end of washing, there is a much larger proportion of interfaces. Since each interface has a higher energy charge compared with its internal volume, the formation of the liquid phase after washing is linked with energy absorption. In a three-phase system, either forces of attraction or forces of dispersion predominate; under certain conditions an equilibrium of both forces must be present.

The principle of the washing process is based on the removal of substance deposits from a solid body, for which primarily an aqueous medium or washing liquor is used. It is essential that the substance deposits have the potential to be transported in the washing liquor, or can be made capable of being transported in a detachment process beforehand. Furthermore, the transportable deposit must be taken over by the washing liquor and removed from this, or thinned to such an extent that the purpose of washing has been fulfilled. The conditions stated apply to all types of treatment, whether it is the removal of dye hydrolysates from dyed textiles, the removal of print thickeners after printing, or the removal of soil.

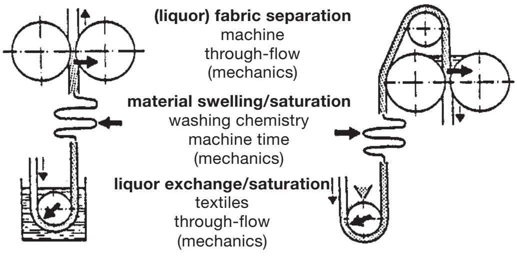


Fig. 2: Separate steps in the washing process (according to Kretschmer).

Fig. 2 shows the three aspects of the washing process, using an open-width washing machine as an example. The three aspects are:

– liquor exchange and charging,
– swelling and dissolving,
– separation of the substance.

Liquor exchange ensures that the concentration on the fibre surface is reduced, and that detached substances are transported away from the fibre surface. A high liquor flow velocity in textile loading is important for reducing the concentration at the fibre surface, because the thickness of the flow boundary layer is dependent on this, and therefore the length of the time-related diffusion path. In contrast to this, the liquor flow velocity is practically insignificant for removing transportable deposits, since the substance transporting properties of the liquor is ten times more powerful than the released substance flow at the fibre surface.

Swelling and dissolving constitute a time-orientated process. This process is accelerated by temperature, which also causes improved diffusion in the flow boundary layer and shortening of the diffusion path in the flow boundary layer. The time-orientated swelling and dissolving process is a decisive factor for the definition of the length of the washing machine, and its fixed costs have a significant influence on the cost of washing. Diffusion occurs according to the following formula:

$$C_t = C_0 \cdot e^{-\frac{\gamma}{V_0} t}$$

C_t = concentration as a function of time (g/kg),
C_0 = initial concentration (g/kg),
γ = substance transmission coefficient (m/s),
V_0 = volume of liquor involved in the washing process per textile area (m^3/m^2),
t = time (s).

The (liquor) substance separation has a central significance for washing treatment. It occurs in open-width washing machines in the squeezing unit with paired rollers. For each thinning process, the proportion of liquor that is subject to liquor separation must not be thinned further. The effect of the nip between the squeezing rollers is not simply limited to liquor separation. In addition, the high speed at which the liquor flows out of the roller nip causes an effective reduction in the flow boundary layer on the fibre surface, and therefore an increase in intensity of substance transport, which is after all the objective of any washing process.

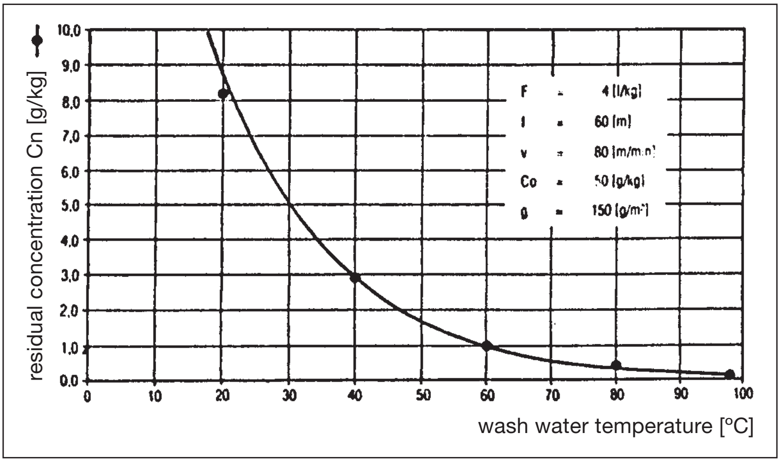


Fig. 3: The effect of water temperature on residual concentration when rinsing away caustic soda liquor (according to Paulsen).

The washing off result is dependent on several factors:

- temperature,
- textile weight and structure,
- quantity of washing water,
- duration of wash, number of textile circuits and textile speed.

As the temperature increases, the viscosity of the water changes. In the temperature range 20–100°C it drops by about a factor of 4. The lower viscosity of water means that textile wetting and throughflow are more efficient. Furthermore the textile expands at a higher temperature, which improves the washing off process. Fig. 3 shows the influence of the water temperature, using the washing off of a caustic soda solution as an example. It can be seen that compared with the result at 20°C, the residual concentration at a liquor temperature of 60°C is reduced by a factor of 8 and at a liquor temperature of 98°C, it is reduced by a factor of approx. 40. The temperature has a direct influence on the substance transmission coefficient γ, and therefore on the washing off process.

The substance transmission coefficient γ can be defined as follows:

$$\gamma = \frac{D}{h} = \frac{k_B \cdot T}{6 \cdot \pi \cdot \eta \cdot r \cdot f}$$

γ = substance transmission coefficient (m/s),
D = diffusion coefficient (m^2/s),
h = diffusion path (m),
k_B = Boltzmann constant (J/K),
T = temperature (K),
η = dynamic viscosity (Pa s),
r = radius of diffusing molecule (m),
f = correction factor.

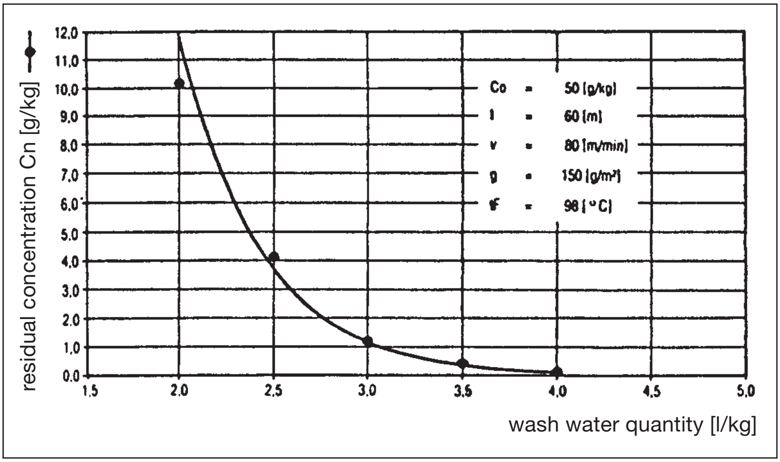


Fig. 4: The effect of wash water quantity on residual concentration (according to Paulsen).

Washing process

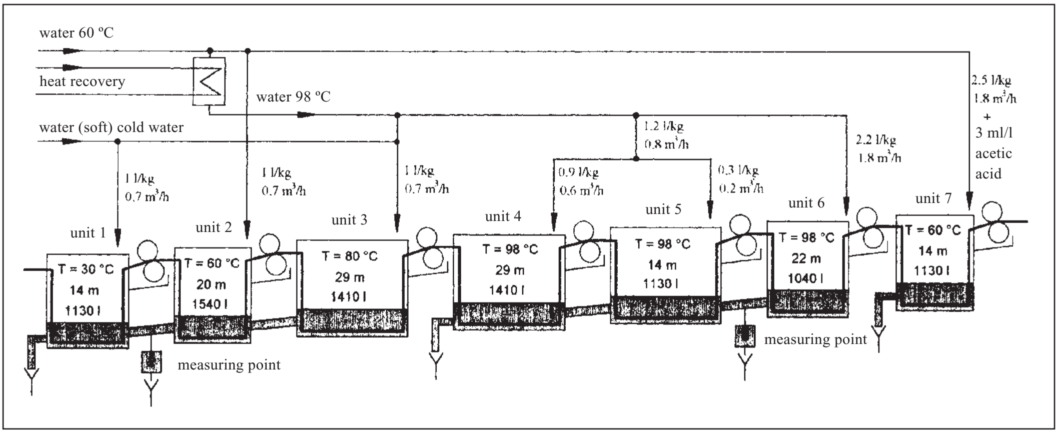


Fig. 5: Open-width washing unit for dyeing and printing aftertreatment.
Example: 100 % cotton article; fabric weight 720 kg (225 g/m); fabric speed 50 m/min; water consumption 6.4 m³ (8.9 l/kg).

Since the thickness of the textile increases in line with the weight (and therefore also the diffusion path), the throughflow properties of the textile decrease, causing a reduction in washing effect. The accessibility of a textile is dependent on its structure. In a thread with a heavy twist or a densely woven fabric, the liquor flow will reach the fibre surface less efficiently than in the case of an open weave or loose twist.

The quantity of fresh water used has a strong influence on the quality of the washing process, since it has a direct effect on diffusion. Fig. 4 shows that the quantity of fresh water increases sharply in proportion to the depth of the residual concentration of the substance to be washed off (in this case caustic soda solution). In order to save water, the permitted residual concentration must be scrutinized carefully.

Washing duration, number of textile circuits and textile speed are directly linked with each other, and are incorporated directly into the diffusion equation. At a high textile speed, the washing time is reduced, and therefore the dwell time. However, since diffusion is a time-dependent process, the textile speed must not be excessive, thereby shortening the washing time, in order to guarantee an optimum washing result.

Fig. 5 shows a conventional open-width washing machine, in which the individual washing compartments in the textile direction are set up in the form of basic elements that increase like a flight of steps. This means that the water is directed against the textile by means of a natural slope. Open-width washing machines of this type are usually arranged to comply with the prescribed initial and final concentration of the substance being washed off. Additional information regarding textile properties and machine constants is then used to define the machine properties (e.g. number of washing compartments) and operating parameters (e.g. textile speed). After one water change, two-thirds of the substance being washed off has been removed. The remaining interval until complete equilibrium is reached can be calculated as follows:

$$R = 100 \cdot e^{-n}$$

After one water change the interval to complete equilibrium (complete removal of substance being washed out) is only 36.8% (Fig. 6).

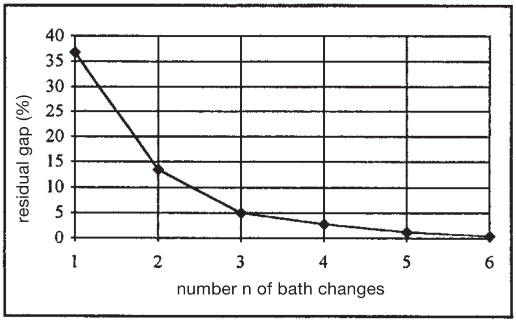


Fig. 6: Percentage residual gap of complete levelling.

The calculation of transient response in a washing compartment can be derived from the following example: two containers of water at different temperatures are mixed in one container. The new temperature can be calculated using the following formula:

$$T_3 = \frac{m_1 \cdot T_1 + m_2 \cdot T_2}{m_1 + m_2}$$

m_1 = water content of 1st container,
m_2 = water content of 2nd container,
T_1 = temperature of 1st container,
T_2 = temperature of 2nd container,
T_3 = combined temperature of T_1 and T_2.

In the same way, this formula can be used to calculate the transient response in a water trough containing dye (Fig. 7) with a permanent water supply, if the parameter concentration c is inserted for the temperature. The time response is recorded by inserting mass flow (kg/s) and time (s). The current trough contents at a given time can be calculated from the mass balance for a washing trough.

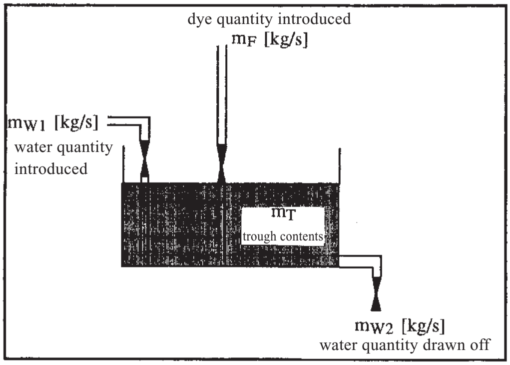


Fig. 7: Water trough mass flows.

A specific quantity of dye (defined concentration) and a specific quantity of fresh water are continuously supplied to a water trough of a defined size. The sum of the quantity of dye and fresh water is taken out of the trough again. The new concentration each time in the trough can then be calculated as follows:

$$c_{T2} = \frac{(m_{W1} + m_F \cdot c_F - m_{W2} \cdot c_{T2-1}) \cdot dt + c_{T2-1} \cdot m_{T-1}}{(m_{W2} + m_{F1} - m_{W2}) \cdot dt + m_T}$$

m_{W1} = water supply quantity (kg/s),
m_{W2} = quantity of water taken out (kg/s),
m_F = dye supply quantity (kg/s),
c_F = concentration of dye infeed (–),
m_T = trough contents (kg),
c_{T1} = old concentration in trough (–),
c_{T2} = new concentration in trough (–).

Washing process temperature Kretschmer divides the washing process into three sub-categories:

- In the substance detachment zone, the substances adjacent to the fibre are dispersed or dissolved so that they can be transported by the washing liquor.
- In the substance transmission zone, the substance flow occurs mainly by diffusion, since the convective flow is not effective in the boundary layer near to the substrate.
- In the substance removal zone, the convective flow causes intensive substance transport.

In the substance detachment zone, the transport of substances occurs mainly as a result of diffusion and only slightly by means of convection where the flow is parallel to the textile. The diffusion coefficient can only be influenced by temperature, while Kretschmer advocates the use of washing auxiliaries to cause acceleration. The liquor flow in the transition zone is responsible for substance transport, because the liquor flow can reduce the thickness of the diffusion boundary layer and therefore shorten the length of the molecular substance transport path (thin diffusion layer), or increase it (thick diffusion layer). An increase in temperature can have the effect of reducing the thickness of the diffusion layer by reducing the viscosity of the liquor.

In the substance removal zone, Kretschmer does not envisage any great problems. In this zone, the only point to watch is that a sufficient concentration equilibrium should be maintained in the washing liquor transverse to the fabric run. →: Washing; Washing mechanics.

In a washing process, washing in the final compartment of a washing machine frequently takes place using cold water to avoid interim storage problems before drying, such as edge drying, migration, etc. This meth-

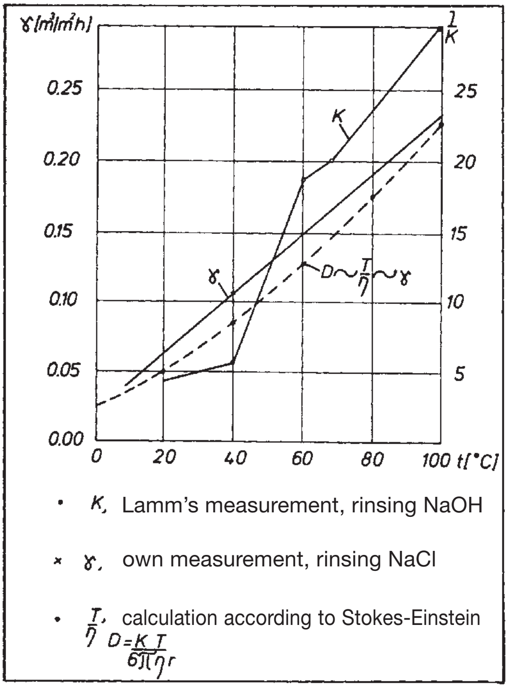


Fig.: Effect of temperature on washing (Tischbein).

od of process management has three significant disadvantages:

The washing effect in the final compartment is relatively poor. In order to wash as effectively as possible, it is essential to aim for a high substance exchange number γ(m/h) and a high concentration difference according to Fick's first law.

Fick's 1st law:

$$g = \gamma \cdot (C_{textile} - C_{liquor})[kg/m^2h]$$

The substance exchange number γ can essentially only be influenced by temperature. An increase in temperature from 20°C to 100°C has the effect of increasing the value of the substance exchange number by a factor of 4 (see Fig.). The concentration difference between the textile ($C_{textile}$) and the washing liquor (C_{liquor}), which also improves the washing effect, is usually low in the final compartment of a washing machine because the concentration in the textile has already become low and the counterflowing washing water still has a concentration of $C_{liquor} = 0$. For this reason, a high washing liquor temperature is particularly important in the final compartment. The investment in this washing compartment is only properly utilized if a good washing effect at a high temperature is achieved.

Washing shrinkage A change in physical state is understood to be the change in physical structure of a fibre as a result of swelling, crystallization and increasing/decreasing tension, causing properties to be altered during and after washing. A change in fabric thickness caused by contraction, volume development or material flattening is usually linked with shrinkage or stretch in a transverse or longitudinal direction.

A textile fabric shrinks during washing if the tension caused during fibre, yarn or fabric manufacture can be partially or totally reversed. Tension applied as a result of purely mechanical processes during secondary spinning, twisting, weaving and knitting, also known as "cold deformation", can be reversed even at temperatures at which the first molecular motion processes within the fibre are triggered. This temperature range (glass, freezing or thawing phase) is dependent on the steric arrangement of the macromolecules and the bonding forces between the molecules, and varies from fibre to fibre.

In the presence of solvents that diffuse into the fibre, preferably water in the case of hydrophilic fibres and organic solvents for hyrdophobic synthetic fibres, this tendency towards motion is increased further. A liquid medium acts as a kind of "molecular lubricant", causing the "thaw temperature" to drop, the frozen tension to be released, and to be converted into a shrinkage path. This proportion of shrinkage is known as substance shrinkage. It can be triggered in a range of fibre types even in cold water. For this reason, cold deformation usually occurs fully in the washing phase.

On the other hand, tensions that are generated during thermic or hydrothermic processes (primary spinning, texturizing, steaming and sizing), which are blocked by a physical network of crystallites, are only triggered by temperatures that are equivalent to the "effective temperatures" of the preceding thermic processes. In the same way, the temperature required to release the blocked tension, which, depending on the fibre type and arrangement, can be reduced to a greater or lesser degree by the effect of the washing liquor, analogous to the reduction in melting temperature of fibre in water.

Substance shrinkage increases in all fibres as the washing temperature rises, however it is inhibited by external tension acting on the fabric during the washing process. Substance shrinkage can also be less effective if the yarn has a higher number of bonding points in the fabric, i.e. when there is increased fibre-on-fibre friction. In this situation, the friction coefficient can be reduced by mechanical means and/or by adding a lubricant. A shrinkage process is mainly completed within a short time if there is minimal tensile stress and tension caused by friction; longer periods result in a level of shrinkage that is only minimally higher. The shrinkage speed also increases as the temperature of treatment rises.

Any natural or manufactured crimp present in the textile is also associated with latent internal tension, known as flexion tension, to a greater or lesser degree. This type of tension is triggered in the same way as substance shrinkage tension, and the crimping effect is made more extreme by tension-free washing treatment. Shrinkage associated with crimping is called crimp shrinkage. However crimp shrinkage can only become effective if relaxation shrinkage is triggered, i.e. if the crimping that has been pulled out during a mechanical process is reversed. As the washing temperature is increased, the bulking effect increases, which is linked with the shrinkage. If mechanics are used during the washing process, it is not only possible to encourage relaxation shrinkage by suspending the friction within a fabric, the crimp shrinkage is also continued inasmuch as the crimps are pushed into each other by hooking together. This causes the material to become denser in the same way as felting in wool, which is associated with further increasing shrinkage but worsening elastic properties. Pronounced crimps and loosely woven fabric provide ideal conditions for the hooking principle.

Crimp development is inhibited by substance shrinkage, which can occur in varying degrees and usually acts along the fibre at the same time. The released shrinkage tension chooses the path of least resistance, i.e. the shrinkage occurs in the non-fixed crimps, causing the crimp to flatten out. In that situation, extra volume can not even be developed as a result of intensive mechanical processing. The crimp volume therefore represents the difference between overall shrinkage and substance shrinkage.

With crimp development, time is an extremely secondary parameter in comparison with temperature and mechanics. For knitgoods made from texturized polyester, the shrinkage after 10 s of mechanical washing is greater than after 1000 s without mechanical washing.

Crimp development can be ruined if the textile tension is too high within the washing phase. Although tension-free treatment is quite possible in the weft direction, quite a significant distortion can occur in a warp direction, for instance when pulling the wet fabric out of the hot washing liquor. Because of the material buoyancy in the relatively high liquor, there is a favourable fabric tension ratio in Mezzera-type open-width washing machines; however the washing effect is minimal. On the other hand suction drum washing machines have a good washing effect; however tension is exerted on the material as a result of high liquor circulation.

Excessive stretching can be avoided in the washing phase if the material is pre-stabilized in the first phase of the washing process with a low level of tension, and not below the prescribed wash temperature. Care should however be taken that the textile run remains crease-free. This method of treatment permits the application of higher processing tension levels after 5 s. As a result, less crimp is pulled out than would have been the case if higher process tension had been applied at the point of immersion in the liquor. The tendency towards deformation during the washing process decreases as the stabilization temperature rises. This effect also causes sized fabric to have an insufficient crimp volume after desizing at an increased development temperature, if the yarn crimp was pulled out during sizing and this state was then set by the size film. For this reason, desizing is frequently carried out in a cold state of structural development in a hot washing liquor, i.e. the process is discontinuous.

This phenomenon also plays an important role in crease marking during washing, even if it is only localized on the crease fold. A fabric made from polyester crimp yarn, exposed to a boiling water treatment spread out and at low tension for only a few seconds, results in a finished fabric that is crease-free with no dye markings after a subsequent fold operation in the same washing solution.

If specialist yarns are used in fabrics, crimping or specific patterned reliefs can be created, which do not appear until washing. These yarns are known as “producer texturized yarns”, and they have the advantage that smooth yarns are easier to make up into fabric than crimped yarns. These include:

a) High bulk yarns, made of mixed fibre yarns that are smooth in their raw state of a non-crimped nature and/or synthetic spun fibres with varying shrinking properties;
b) Mixed filament yarns that are folded or twisted from synthetic filament yarns with deviating shrinkage;
c) Yarns made from dual component fibres, where two polymer components with varying shrinkage are combined by spinning into a single filament.

Fabrics made from these yarns, where the required crimp volume is compensated for by a lower raw material density, should be washed as recommended by the yarn manufacturer. Usually this involves consecutive stages where the temperature is gradually increased, so that the blocked tension in the yarn is not suddenly released, causing the fabric quality to be barky.

The high bulk yarns or mixed filament yarns contained within fully-shrunk fabrics can be differentiated from texturized yarns by the fact that the component with more extreme shrinkage tendencies is flush with the yarn twist, whereas the components which shrink less or not at all are pressed into small loops at the edge of the yarn. As is the case with texturized yarns, area shrinkage is the objective, combined with an increase in thickness. This causes an increase in specific volume, which exerts a favourable influence on the physiological properties of the clothing material.

Shrinkage and volume development are not only dependent on the fibre structure of the textile used, but also they depend on the construction of the yarn and the fabric made from it. In fabrics made from flat filament yarn or spun fibre yarn, usually only surface shrinkage takes place during washing, which is dependent on the level of substance shrinkage in the fibre type used, and is limited by the fibres’ freedom of movement within the yarn, or the yarn within the fabric. For this reason, substance shrinkage can be less effective in fabrics made with ply yarn and with short thread floats. The fabric actually tends to become more compact and stiff because the torsion tension in the yarn or twist increases, as do the forces of friction between the bonding points of the yarn in the fabric. If this blocked tension is not balanced out during the washing phase using mechanical means and lubricants, then additional released tension will accumulate during the drying and setting phase. It is only during washing care that the blocked tension is successively released by the constant cleaning, washing and tumble-drying mechanics, leading to what is known as “progressive shrinkage”.

The bowed nature of the yarn within the fabric, and therefore the fabric thickness, is only marginally increased as a result of surface shrinkage in fabrics made with smooth yarns. An increased ply twist in crimped yarn has a negative effect on crimp development.

In knitgoods, as the stitch size decreases, whether deliberately for practical reasons or because of thread shrinkage, the flexing tension levels are increased, and therefore also the energy content of each stitch. Because of this, stitches that gradually become smaller are increasingly difficult to distort and always attempt to revert to the ideal round shape if there is an opportunity to balance out the tension. For this reason, fabric often becomes shortened in one direction during the washing process, at the same time widening in the other direction.

Shrinkage and volume development should only be encouraged in the washing phase to the extent permitted by the prescribed final width. On this principle, shrinkage should not take place in excess of the final width, because this will mean that width tensioning will be necessary during setting or final finishing, which is again associated with flattening of the fabric and increased residual shrinkage. However if too little shrinkage is released in the washing phase, it is not then possible to compensate for the lost shrinkage in the drying and setting phases.

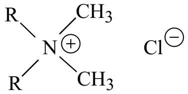
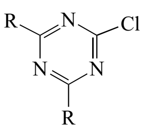
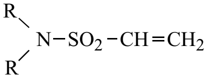
Excessive shrinkage in the washing phase can be avoided by lowering the temperature or increasing tension, i.e. by means of dimension-controlled washing, or stabilization of the required dimension by steaming or hot air treatment prior to washing.

Usually 60–70% of overall shrinkage is triggered in the washing phase.

Finally, when washing fabrics made from polyamide and wool, a change in physical state should be taken into account, even if it is reversible. This change in state is known as “hygral expansion”, which means stretching during water treatment that reverts completely to its normal state after drying. This effect can cause run creases if the fabric is not stretched out mechanically before feeding onto the rollers (according to Berndt and Heidemann).

Washing wool fabric → Washing of woollen goods.

Wash-liquor softener application Articles that are potentially suitable for wash-liquor softener application need to be inert to the substances present in → Washing agents. The objective of preparatory treatment and application testing is to produce substances with fibre affinity for temporary wash-liquor softening effects and fibre-active bonds for semi-permanent and permanent scrooping effects according to the following principle of categories:

constitution	*type*
	with fibre affinity
	reactive
	reactive

Wash-off factor (C_0/C_n), this refers to the fact that the chemical/soil concentration C_0 is taken into account at the point of fabric infeed, and the residual concentration C_n at the point of fabric exit. C_n is reduced by the concentration of substances to be washed off the fabric in the machine to the value.

$$C_n = \frac{\text{initial concentration}}{\text{wash-off factor}}$$

Wash-out jeans Denim garments that change in appearance after a domestic wash cycle. One variant of the pigment dyeing process is the wash-out finish. This consists of pigment dyes to shade depth that are manufactured using reduced quantities of binders. Fabrics are only subjected to a washing process (mill-wash, stonewash) when they have been partially made up into a garment, but usually this is not done until the garment is fully made up. The formulae for these articles, in particular washing methods, vary from firm to firm, and are usually trade secrets.

Wash (process) The process of → Washing (rinsing).

Wash/rub test Test for pigment dyes and prints, by rubbing with the washing solution to check the adhesive properties of the binder.

Wash test →: Washfastness testing; Wash testing; Wash tests for dye identification.

Wash testing Artificially soiled test fabrics are used to assess the cleaning effect of detergents and washing processes. These soiling models are widely used, for example for the following: by detergent manufacturers for the development and improvement of detergent formulation, by the manufacturers of detergent base materials for carrying out assessment of different surfactant types, detergent components, complexing agents, enzymes etc, and by washing machine manufacturers to test wash programs. The test materials are suitable for developing water-saving detergent products or wash programs that use energy economically. Soiled and non-soiled test fabrics are also used as control samples in laundries, for carrying out consumer testing and in institutes for comparative quality testing.

The washing result depends on a variety of influential factors determined by detergent, water, washing machine, soiling level of the washload, and textile type. The factors that influence the wash result are itemized in the Tab.

When testing detergents and washing processes for their cleaning effect on textiles, it is practical to limit

1. Detergents

washing agent dosing

surface-active compounds
anionic surfactants
non-ionic surfactants
soap
cationic compounds

inorganic constituents
washing alkalis (sodium carbonate, silicates)
phosphates (sodium tripolyphosphate)
ion exchangers (sodium aluminosilicate)
bleaching agents (sodium perborate)
stabilizers (magnesium silicate)

organic constituents
complexing agents (NTA, citrate, etc.)
polymeric polycarboxylic acid
fluorescent brightening agents
solvents (alcohols)
enzymes (proteases)
bleach activators (tetraacetyl ethylene diamine, etc.)
greying inhibitors (carboxymethylcellulose, hydroxyethyl cellulose, etc.)

2. Water
water quantity
water hardness, Ca^{2+} Mg^{2+} ratio
purity, heavy metal content

3. Washing machine
washing temperature (initial temperature, heating-up rate, maximum)
washing time
washing mechanics (rotation speed of the washing drum, drum run time and drum useful life, drum diameter, wash load, liquor quantity, dimensions and weight of the textiles, fabric-on-fabric friction, foam formation);
pre-wash, main wash, rinses

4. Laundry soilings
degree of soiling
various laundry soilings

5. Textiles
fibrous materials
natural fibres (cotton, wool, etc.)
man-made fibres (polyester, polyamide, etc.)
synthetic fibres (viscose, acetate, etc.)
fabric type (woven fabrics, knitwear, etc.)
finishing, dyeing
garment manufacturing (dimensions, weight, etc.)

Tab.: Factors affecting the washing result.

the tests on usual washing conditions and areas of use, and to incorporate standard detergent, washing processes and textiles into the experiments. If the appropriate experiments are set up, it is possible to obtain results that provide useful information. In this way, detergents belonging to different product categories, such as phosphate-free or perborate-free washing powder, powders containing these substances, and liquid detergent, can be differentiated clearly in their effects, using washing machines with different washing programmes, pre-wash/main wash, economy wash, load levels, etc. Specific test conditions must be used for more subtle differentiation, which is necessary for developments within a product group or a washing program, and to optimise detergent and washing processes.

As well as the primary wash effect, i.e. the removal of soiling and staining after a single wash, it is also important to take into account the secondary washing results after several washes during technical washing tests. The secondary effects include greying (re-depositing of soiling), calcium deposits (loss of tensile strength, chemical damage), for which a non-soiled test fabric is available as a control sample.

For residual soiling, soil removal (ΔS) occurs proportionally to the logarithm of the washing time (t), using the formula

$$\Delta S = a \cdot \log t + b$$

In this formula the factor a is dependent on the type of pigment soiling, the effective chemical/physical factors and the washing mechanics, and b is primarily dependent on the washing temperature. At different washing temperatures the remission parameters for increased washing times, are virtually parallel (Fig. 1). The effective factors (chemicals, temperature, time, washing mechanics) are mutually interchangeable to a large extent, to ensure that the same washing result is achieved.

Washing experiments using artificially soiled fabrics should be carried out as comparative tests using

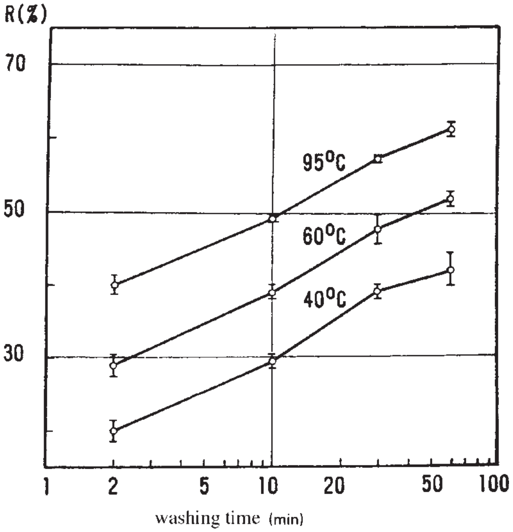


Fig. 1: Washing effects (remission parameters) on carbon black/oil soiling (EMPA, Art. 101). Washing at constant washing temperatures of 40, 60 and 95°C in a drum washing machine.

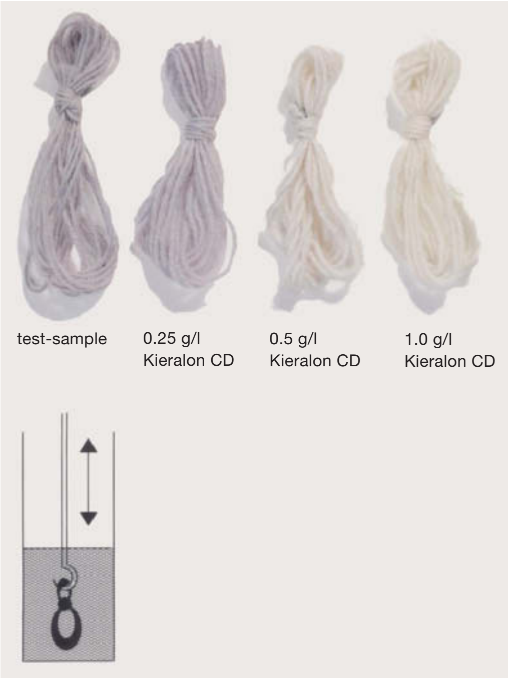


Fig. 2: Take a wool length impregnated with dyed oil, wash for 15 min at 45ºC, then rinse and assess (BASF).

fabrics in the same soiling batch, with standard detergent and standard washing processes under precisely specified conditions. A wool hank impregnated with dyed oil (Fig. 2) could for instance be used to test the fat washing effectiveness of a surfactant (Brüschweiler).

Wash tests for dye identification The purpose of this is to provide information complementary to the → Dye class identification on fibres.

I. + II. On fibres of plant or animal origin: interweave the test material with white wool and white cotton. Immerse in a cold solution of 5 g/l soap + 3 g/l sodium carbonate. Slowly bring to the boil (observe the colouring of white wool, white cotton, test material, washing liquor). Rinse and dry after 1 h.

1. Dyed wool: at first intensive (not or only slightly with cotton), almost complete decolorization during boiling, test sample usually completely decolorized: Cationic dyes. Counter-sample: a) when dabbed with acetic acid, the test material and wool revert to a weaker form of the original colour shade; b) in chlorine solution 1°Bé: decolorization; c) tannin test.
2. Dyed cotton: At first intensive, also wash liquor, wool also not later, after 1 h almost the same colour depth as the test material: Direct dyes. Counter-sample: new test material + conc. sulphuric acid: usually shade change (usually shade reversion during rinsing). Or: wool/cotton dyes: in this case the wool is often more decolorized (magnifying glass) (additionally: → Ammonia test (for dyeings).
3. Dyed wool and cotton: frequently decolorized at the start, after 1 h test material is usually completely decolorized. Acid dyes (additional ammonia test). Delayed and weakened appearance: metal complex dye, dye with milling fastness, etc. Particularly delayed appearance: metal complex dyes (additionally: →: Copper detection in fabric dyeing; Chrome test for dyeings), chroming dye (sometimes also reduced washfastness, then confusion with simple acid dyes: chrome test. New sample + conc. sulphuric acid: usually colour change, reverts during rinsing.
4. Undyed wool and cotton/low soiling level: fast dyes (additionally →: Paraffin test for dyeings on cellulose and protein fibres; Chlorine test for dyeings on cellulosic fibres; Hydrochloric acid test); black staining: mineral dyes (chrome/paraffin test).
5. Reactive dyes: non-reactively bonded dye bleeds. With repeated wash sample, usually no bleeding or only slight bleeding of white samples.

III. On acetate fibres (according to): 5 g/l soap, 80°C, 15 min treatment time.

1. Cationic dyes: intensive colour bleeding, woven-in acetate takes up dye. → Benzene test positive.
2. Dispersion dyes: considerable bleeding, white sample takes up dye. Benzene test positive.
3. Diazotizable dyes: slight bleeding, white sample at worst slightly soiled. Benzene test negative. Paraffin test slightly positive.
4. Naphthols: no bleeding or only slight bleeding, white sample not colorized. Paraffin test extremely positive.
5. Pigment dyes: microscopic test on fibre cross-section. Even distribution: Spinning bath dyeing; only on fibre surface: binder setting.

IV. On polyamide fibres: 5 g/l soap + 4 g/l sodium carbonate calc., boil for 20 min.

1. Cationic dyes: extreme bleeding. Benzene test positive.
2. Acid and dispersion dyes: extreme bleeding. Benzene test negative (acid dye) or positive (dispersion dye). Paraffin test definitely positive (dispersion dyes).
3. Substantive dyes: extreme bleeding. Benzene test negative.
4. Metal complex dyes, vat dyes, development dyes: no bleeding or only slight bleeding. Additionally see I + II. 4.

Waste → Textile wastes from manufacturing and processing, which are usually re-processed after appropriate treatment.

Waste disposal Considering that disposal is becoming more difficult, the textile finishing industry must aim to re-use or re-process residual substances by optimizing processes and formulae. Even then residual substances that cannot be recycled will be generated, and for these disposal methods must be developed that generate a low volume of waste. It should after all be permissible to burn certain residual substances in order to make use of recyclable heat energy that the substances contain, or to purify water in a treatment plant for substances in waste water that have low toxicity and have a good level of biodegradability.

Compared with the overall annual waste volume of a medium-sized textile finisher, the proportion of liquid/paste waste originating from sludges, residual paste and residual preparation liquors in textile finishing is currently still categorized as "of little significance". However these residual substances will become more significant in future as a result of the regulations contained in Appendix 38 of the German Administration Regulation of Waste Waters (Abwasser-Verwaltungsvorschrift). This also applies to residual finishing liquors. Waste disposal considerations are already practised within limitations for reasons of economy. This includes organizational measures such as consolidation of batches, tightening up on the number of formulae and the type and quantity of auxiliary used. In the past, great efforts were made to keep the contents of the padder trough as low as possible by installing displacers and introducing alternative processes such as nip padding, foam application or spraying techniques. However there is one thing in common to all techniques and processes and even the best organization: there will be residual substances consisting of aqueous dispersions and finishing chemicals with a greater or lesser concentration level. The quantity of residual substances can be reduced even more using automatic finish equipment so that there are no superfluous preparations left over. However the quantity of finishing chemicals required for the immersion line means that there will be a residue, in the same way as liquor used for spraying and foaming, which by definition will remain in the system.

If the residual finishing liquor can not be re-used or re-processed, then in future differentiated disposal must be implemented. Possible reasons for this are because of progressive crosslinker reactions leading to a negative effect on quality, because bleeding dye in the finishing liquor makes recycling impossible, or because using certain formulae for fashion garments means that preserving the substances is impractical for time reasons. Textile off-cuts from leader cloths that are no longer usable, edge off-cuts and ends are hardly ever re-processed. They are "used". They can possibly be used as cleaning cloths, which (when smeared with oil) must be disposed of separately, as they are considered to be "waste requiring particular monitoring". When exhaust air is cleaned, the substances removed from the exhaust either precipitate directly as a condensate, or when the droplet separator is cleaned. This is also considered to be "waste requiring particular monitoring", consisting of oils, fats, paraffin carbohydrates and cracked products from thermal processes. The same applies to the condensate from flame backcoating. There are extra problems associated with unavoidable clippings that are composites from different textiles and foam, for instance, which excludes them from being recycled.

It is frequently the case that there are insufficient internal strategies for residual substance collection, which at least would enable all the residual textiles to be put into a recycling process. Sometimes the good will that is present founders because of the requirement to separate textiles according to their raw material type. It is not possible to put together a complete summary of the most important waste products generated during textile finishing, but it is becoming apparent how specific the subject of residual substances is becoming. From a volume point of view, one large group of waste is the empty finishing agent containers, which can not always be completely cleaned of the residual substances adhering to them. This means that they also become "waste requiring particular monitoring". Many companies now have internal regulations to deal with the complex subject of empty packaging, so that internal sorting can be carried out.

Much of the waste generated in companies requires monitoring, so that there must be accompanying documentation when it is disposed of. Some high-volume waste occurring in plants does not fulfil the classification criteria for depositing above ground; the active

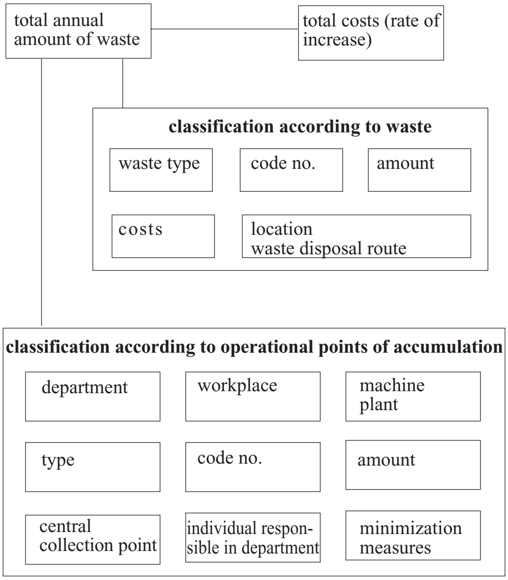


Fig.: Waste register for waste disposal.

substances they contain need to be sorted. As it would seem uneconomical to store these substances in a container initially for subsequent sorting, the residual substances generated in plants are collected separately at source, which is more practical. To do this, an exact quantitative analysis of residual substances generated internally is necessary, which should also contain allocation of disposal costs to individual parts of the company, plants or even processes. This network of residual substance ratios should finally be applied to the waste register diagram (see Fig.) for all areas of the finishing company. In this way it will be possible to enforce a remarkable reduction in the volume of domestic-type commercial waste in the future, because more than 90% of the residual substance mix consists of plastic film, textile off-cuts, packaging and waste paper. However the conditions required for economical recycling of these residual substances still need to be established (according to Marzinkowski).

Waste disposal considerations The principle of environmental protection in an industrial environment is based on the sequence: avoidance, reduction, recycling (see Fig.). The first principle is avoidance or minimization, then re-processing, and only the residual substances that can be reduced no further are disposed of. This hierarchy should be adhered to during planning, among other reasons because the optimization suggestions in the first two points (with the exception of the automatic finish boiler) can be implemented relatively fast and without great expense. A disposal process of any type will always incur costs for setting up the necessary infrastructure, operating costs and in some circumstances extra personnel. Appendix 38 of the German Administration Regulation of Waste Waters (Abwasser-Verwaltungsvorschrift) is effective (regarding waste water from textiles); a detailed system of regulations will also be enforced governing indirect discharges by the textile industry, which will make it essential to take internal avoidance and reduction action, applying in particular to textile finishers. In this context, textile finishers have not only to pay attention to the emissions from their production, but also of the contents of the waste water from the preliminary textile stages. The most important strategies are to avoid waste by means of re-using or re-processing residual liquor, to use auxiliaries sparingly, and to substitute potentially harmful auxiliaries and dyes. Further emphasis in future will be placed on water recycling strategies. The concentrated residues that still remain from treatment solutions constitute an increasing waste problem if it is not possible to introduce low-waste disposal techniques.

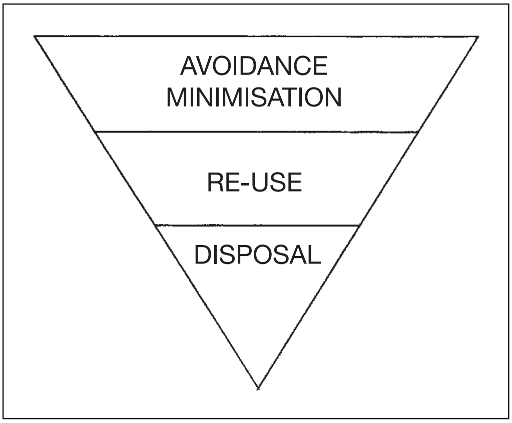


Fig.: The optimal residual matter pyramid.

Waste disposal site Supervised, ordered depositing of waste substances. Domestic and industrial waste as well as sludge from purification plants is normally taken to waste disposal sites if incineration or storage of special waste at specialist waste sites is not necessary. The law governing preservation and recovery of natural resources gives environmentally active authorities the opportunity to monitor the dumping of hazardous waste. At the same time, the authorities can issue specifications for the filling of above-ground waste disposal sites. These specifications are precisely defined, and set standards for the compatibility of covering materials and waste. In this context, advice relating to design and operation to ensure that these sites are properly secured and sealed is important. The basic objective is to store the waste as economically as possible and in a controlled way, solid waste being deposited at waste disposal sites and liquid substances in pools. Lining with sealant as well as synthetic fibres in the form of woven material, nonwoven fleece or even a superimposed yarn layer is an important aspect of waste site construction at landfill sites and above ground dumps. The use of technical textiles has opened up new opportunities with anticipated success in the construction of waste disposal sites, as a way of setting up specific barriers to prevent uncontrolled leakage.

Barriers are constructions that are intended to provide a secure boundary to an area. The area should be for the purpose of storing solid or liquid materials, either permanently or temporarily. Barriers have two main purposes: they must hold the mechanical pressure of the stored deposits, and they must also prevent potential hazardous substances from escaping underground or reaching the water table. The types of barrier commonly used are dams made of earth or from concrete, wood, cast iron segments or sheet pile walls. They are constructed according to criteria stemming from mechanical strength analysis. However these barriers have limited suitability when it comes to holding back potentially hazardous substances. The penetrability coefficient of concrete, for instance, is $10^{-9} < k < 10^{-7}$ m/s, and the value for compressed clay with a Proctor optimum water content is $10^{-10} < k < 10^{-8}$ m/s. For this reason geo-membranes are used to reduce the seepage and to control the volume of seeping liquid so that the leakage rate is as close as possible to zero. In some cases the seepage is collected between two geo-membranes and stored in containers for subsequent treatment. Penetrability coefficients have been measured for geo-membranes with a range of $10^{-14} < k < 10^{-12}$ m/s.

In dams made of earth, geo-membrane linings are often installed in conjunction with geo-textiles to protect them from puncture. If geo-membranes are spread out on rough ground and subjected to the pressure of the rising water table, geo-textiles can be used for specific purposes relating to improving adhesion to the ground, drainage, filtration and the separation of fine and coarse materials.

The last phase of the waste disposal strategy (→ Waste management) is depositing it in long-term or permanent storage. A waste disposal site is a bioreactor in which biological, physical and chemical processes occur, mostly in an uncontrolled manner. It is not likely that these processes will be able to be controlled in the immediate future. The critical factors are environmental compatibility and long-term characteristics of the deposited waste. Many textiles do not contain any hazardous substances, in particular substances that are hazardous to water. For this reason they can be deposited at domestic waste sites. Waste from lining fleece for example is only partially biodegradable. In order for → Biodegradation to be possible, substances must have the following properties: they must be hydrophilic and as amorphous as possible (not crystalline), have a low molecular weight, linear polymer structure, as well as having as great a surface area as possible, and they must not be crosslinked. These criteria are only fulfilled by some of the raw materials used.

1. Viscose fibres and some surfactants, for instance, have a good level of biodegradability.
2. Polyamide fibres, polyamide fusible fibres, ethylene vinylacetate binders and other wetting agents, thickeners and softeners are partially biodegradable (even though it is a difficult process). This group constitutes the highest proportion of the overall quantity.
3. Polyester fibres, polyester fusible fibres, polyethylene fusible fibres, pigments, crosslinked polyacrylate binders and silicons are not biodegradable.

Waste management The concept of waste is described in law as follows: waste according to the AbfG (Abfallbeseitigungsgesetz – German Waste Disposal Law) is constituted by “movable items of which the owner wishes to rid himself, or which should be disposed of properly in order to preserve general welfare, particularly in order to spare the environment”. According to paragraph 1 of this law, recycling of substances is of equal status to converting them into energy. Potential waste should be inspected at source to establish whether or not it could be avoided in the future. Organizational and technical action can be taken in this context (Fig. 1). Residual waste with the potential to be re-used undergoes a recycling process. Waste disposal can take place in the form of thermal treatment (waste incineration) or as a physical-chemical treatment process (waste disposal site with or without biodegradation). Special waste, which can not be disposed of in this way because of its hazard, is disposed of at special waste sites or treated by means of special waste incineration (Fig. 2).

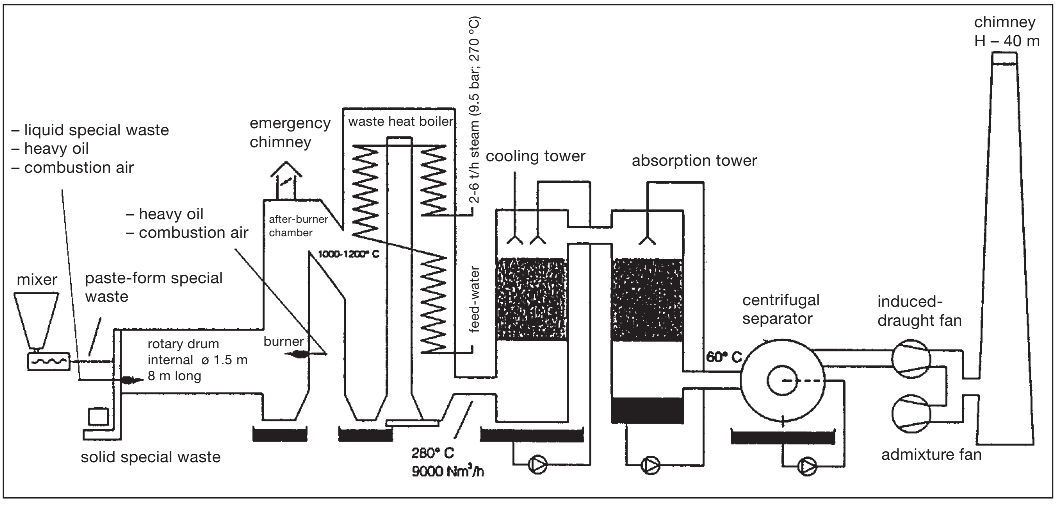


Fig. 2: Special waste incineration plant.

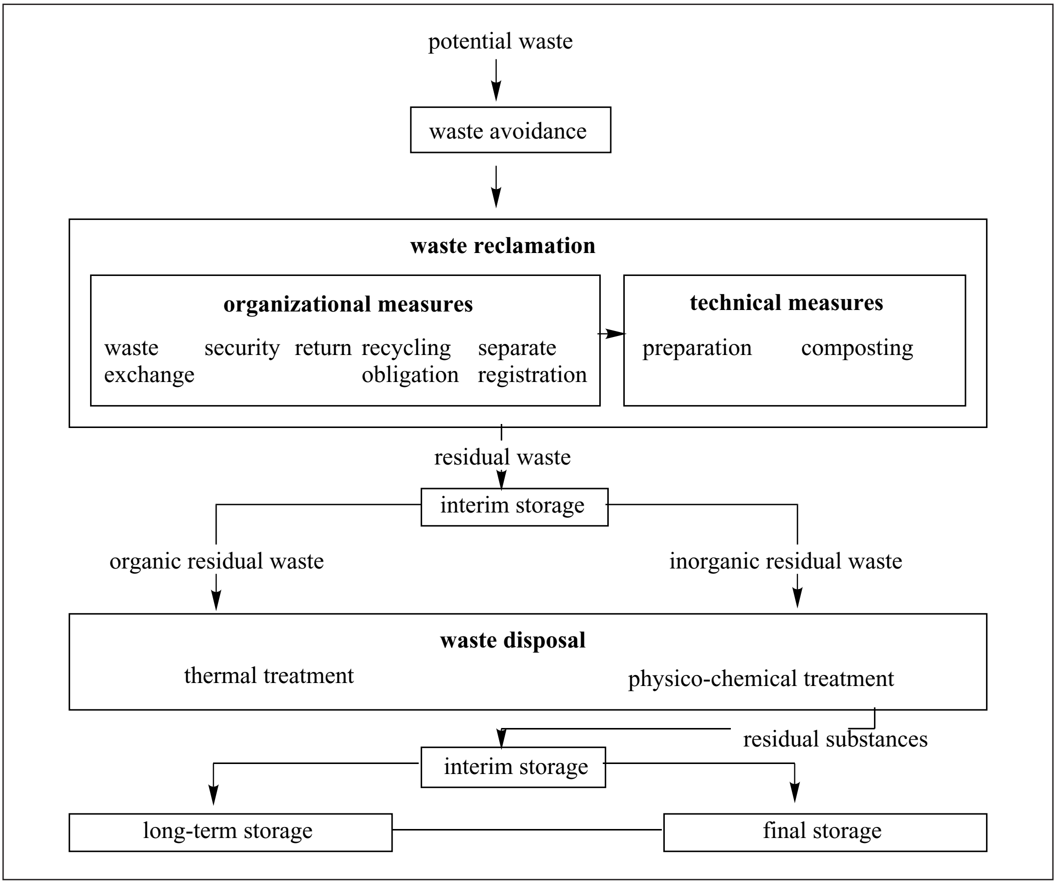


Fig. 1: Waste reclamation flow chart in terms of waste management.

Waste water Strictly speaking, water that is soiled by domestic, commercial and industrial use, as well as drain precipitation water from built-up land (roofs, roads), contains impurities in solute, colloid and solid forms. The characteristics depend on origin, e.g. communal sewage waters have a like composition in comparison with the great differences between commercial and industrial waste water. Most of the waste water generated by the textile finishing industry (see Fig.) contains primarily organic substances (fibre particles, dyes, fats, surfactants, phosphates, textile auxiliaries, proteins, carbohydrates, etc.) as well as inorganic salts, acids, alkalis, chlorine, etc. A permit is required for releasing waste water into open water, and is subject to certain conditions according to the terms of the German Water Resources Law (WHG – Wasserhaushaltsgesetz). Experience has shown that even where toxins are actually being specifically withheld, the cumulative effect of waste water pollution should be considered so great, that in time a negative effect on the ecological equilibrium must be expected. In particular non-toxic organic substances that consume the oxygen dissolved in the water to enable them to biodegrade should be kept away from the drainage system. Nowadays it is no longer sufficient to carry out corrective treatment at the end of waste water production, because a new concept for the textile finishing industry is required that incorporates an environmentally friendly preventive ideology (→ Ecological problems in textile dyeing, printing and finishing).

It is essential to monitor industrial systems that produce waste water. It is self-evident that problem factors such as unclear pipework management, leak points, etc. must be identified and alleviated. The systems relevant to waste water in question that are found in textile finishing plants, for instance as polluters, are shown in the Fig. In this situation there is a practicable possibility to reduce the quantity of waste water by reducing water consumption. It is possible to minimize the quantity of fresh water using automatic fill level control and over-

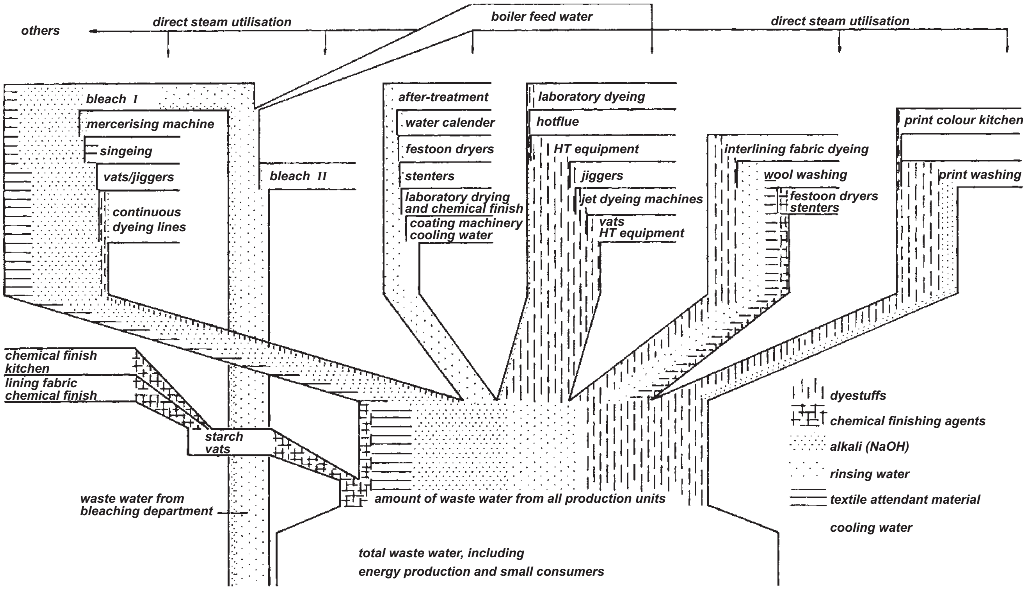


Fig.: Important textile plant waste water initiators.

flow barriers, counterflow washing arrangements, coolant circuits, condensate backfeed systems, padder displacers. A remarkable amount of water and chemicals can be saved using partial process circuits, e.g. by feeding polluted water back to different sections of mercerizing machines.

Waste water analysis →: Summation parameters; Waste water evaluation.

Waste water automatic analysis Used for continuous monitoring of water or waste water. The concentration of sulphate, nitrate, phosphate, ammonia, chlorine, iron, etc. can be continuously monitored.

Waste water balance This can be construed as the material balance in the complex of waste water, for example sub-divided as follows:

- Raw water supply (R value): quantitative definition for energy centre, quantitative definition for manufacture;
- Waste water all-in pollution (A value): Quantitative definition, qualitative investigation;
- Waste water purification plant complying with German Water Resources Law (Wasserhaushaltsgesetz) (W value) in drainage.

Since the initial and final values must balance, as soon as the values of R and A are known, the following target for value W, which can be specified, is set as close as possible to the R value. Processes that involve partial treatment before the waste water flows into communal sewage plants cause the most problems as a strategy directive, because communal plants are never in a position to cope with an uncontrolled inflow. Many synthetic fibre substances are non-biodegradable, or only to a certain extent, which means that they are not eliminated in biological treatment plants. Biological plants have a biodegradation rate of approx. 90–93% because of the BOD. Dyes (up to approx. 10% of waste water) and other non-biodegradable substances pass through this type of plant unchanged. Flocculation and precipitation means that a proportion of up to 40% of non-biodegradable substances can be eliminated. However that is by no means enough, because waste water should be almost colourless. This means that an extra chemical-physical phase is necessary to remove dyes, metallic ions and other non-biodegradable substances before it can be diverted to the biological plant.

Waste water dye removal Dyes are not very biodegradable, they colour the waste water even in extremely small amounts and therefore have a visually disturbing effect. For this reason the incidence of dye baths in waste water should be limited as far as possible.

The following processes are available for the removal of dye:

I. Chemical precipitation using flocculating additives such as iron or aluminium salts, possibly in combination with calcium oxide. An adsorption effect takes place, which means that pseudo-dissolved dyes are not affected by the precipitation agents. In most cases they have to be destroyed by a reduction agent such as caustic iron (II) chloride solutions or sodium hydrogensulphide. Azo dyes can be split using reduction agents.

II. Filtration can often be a suitable process for decolorisation.

III. Biological purification can lead to decolorization if there are no toxins present in the waste water.

IV. A combination of chemical precipitation and biological purification leads to a satisfactory result in many cases.

Waste water evaluation The crucial notification for waste water contributions will contain control values for the damage parameters A, COD and G_F that should be mean values and maximum values that should under no circumstances be exceeded. Any hazards in water taken from open water can be considered existing pollution and deducted. For all textile finishers who do not cause pollution directly, harmfulness units can be grouped together per m^3. Companies that are liable for these levies have to carry the costs of measuring the levels of harmfulness themselves. The following formula has been suggested for calculating the pollution index using the analysis data (possibly with regional variations).

For soiled water and water from mines, the following formula can be used (as an example) to establish the level of pollution at peak pollution times:

$$B = \frac{Q}{0.15}\left[0.40 + 0.25\,\frac{A - 0.3}{6.0 - 0.3} + 0.35\left(0.5\,\frac{BOD - 20}{250 - 20} + 0.5\,\frac{COD - 80}{500 - 80}\right)\right]$$

B = pollution count per head of population,
Q = quantity of water supplied in m^3/day (not including precipitation water),
A = sediment in ml/l (excluding carbon),
BOD = biochemical oxygen demand BOD_5 in mg/l for the deducted sample,
COD = chemical oxygen demand in mg/l for the deducted sample.

I. Definition of the water quantity Q: the water quantity can usually be established from the level of water consumption if no private water supply is present. Alternatively, flow measuring devices can be used to establish the quantity of waste water from the cross-section of the outfall. Representative sampling is a particularly awkward problem if the analyses are expected to give a precise conclusion, because the sample must represent the mean value of the waste water properties. This can certainly not be guaranteed if random samples are taken only occasionally. It is essential to take water samples continuously using the appropriate devices over a long period of time, particularly during operation, which will automatically generate a good mean value. Authority testing should only take place at the outfall and not at the machines.

The harmfulness of the pollutant waste water is recorded in the form of pollution indices, which take into account the following:

a) sediment (A),
b) the chemical oxygen demand (COD),
c) the level of toxicity (G_F).

II. Sediment (A): sediment consists of solid substances that settle on the bottom within 2 h. The harmfulness is not only clouding and the formation of sludge, but also the negative effect on the oxygen content. It is also possible to analyse the harmfulness of the sediment by its weight instead of volume if the annual volume in cubic metres is more than five times as large as the annual weight in tons of the dry substance. This is almost always the case in the textile finishing industry, where the factor is usually in excess of 20. This calculation is carried out on application. Settling mineral substances are rated lower than organic sediment. After the weight of the dry substance has been established, the proportion of organic sediment can be established by further analysis of the glow reduction. Evaluation:

a) sediment where the organic proportion is at least 10% 1 pollution index per m^3 annual quantity or in tons as an annual quantity,
b) sediment where the organic proportion is less than 10% 0.1 pollution index per m^3 annual quantity or in tons as an annual quantity.

This method can be used to analyse sediment with a concentration higher than 0.05 ml/l. Analysis should be carried out as soon as possible after the sample has been taken, using the entire range of samples. One litre of the sample is shaken well and placed in an Imhoff sediment glass. This is shaken several times jerkily. The volume of sediment is read after 2 h. Any undissolved substances that have not formed sediment can be gravimetrically analysed when the liquid is siphoned off by filtration. Flaky or fibre-type solids prevent straightforward precipitation.

III. Substances that can oxidize (COD): substances that can oxidize can be found in waste water that has been subjected to the action of oxidizing agents. They are measured using the chemical oxygen demand (COD) after the sediment has been removed. Analysis is carried out using the dichromate process, with silver sulphate as a catalyst. Evaluation: DIN 38 409 (12/1980) or process H41. Oxidizable substances in chemical oxygen demand 2.2 pollution index 100 kg annual quantity (COD). Ag_2SO_4 is used as a catalyst. $HgSO_4$ bonds the chlorine ions (because mercury is so toxic, the use of $HgSO_4$ should be avoided. Instead Cl_2 should be fully oxidized and this should be taken into account during calculations).

IV. Toxicity towards fish: aquatic organisms exhibit varying reactions to substances in water. The law defines a test fish, which is debatable because of possible adaptations, and also it is designed for analysing the effects of toxicity by using waste water thinned to varying levels. There is no provision for neutralization of the water.

Toxicity (G_F): the effect of toxicity in waste water on fish is analysed by testing the effects on the test fish, a golden orfe. The thinned waste water that no longer has a toxic effect is measured. Further regulations relating to the way the test is carried out, such as test time, can be found in the legal administration directives contained in the AbwAG (Abwasserabgabengesetz – German Waste Water Discharge Regulation), which relates to waste water levies. Analysis of toxicity towards bacteria has not been included. Evaluation: DIN 38 412 (12/1980). Toxicity towards fish (G_F) 0.3 · G_F · pollution index 1000 m^3 annual waste water quantity. G_F is the thinning factor at which waste water no longer has a toxic effect in the fish test. Where $G_F = 2$, zero is used.

V. Biochemical oxygen demand (in 5 days) BOD_5 and biodegradability: the measurement of the biochemical oxygen demand during aerobic, microbial oxidation in principle covers all water-soluble organic substances, and evaluation can be done in the same way as the natural biodegradability and self-cleaning of water; DIN 38 409, (5/ 1987). The higher the level of organic impurities, the more nutrients are present for the bacteria, causing the oxygen demand to increase. It is assumed that the oxygen consumption is caused only by the metabolic activity of the bacteria. However it can be the case that waste water contains toxic substances, for instance, which destroy the bacteria and therefore cause a falsely low BOD reading. The substances themselves have by no means degraded, and have a high oxygen demand. The BOD value measured however leads to an incorrect conclusion. The 5 day BOD value was introduced to provide comparative values as a basis, on the assumption that a certain level of environmental adaptation would have taken place within 5 days. A further disadvantage is the fact that only the oxygen consumption that is needed by the bacteria to biodegrade is measured, and the chemical reactions are not taken into account. As well as the biological oxygen demand, biodegradation test processes allow precise conclusions to be drawn regarding chemical processes.

VI. Analysis of oxygen consumption: the analysis of BOD_5 only provides values after a period of 5 days. For this reason, BOD_5 is as little suited to regulating a biological purification plant in a way that is appropriate to the quantity of pollution, as the analysis of COD or TOC, because these values only describe the pollution load relatively precisely if external conditions remain constant. It would appear to be more practical to use the measurement of consumption as a gauge for the quantity of pollution. The advantage of this process is that the measured values are ready within 10 min, and the instruments used to measure this are of a relatively convenient size and can be installed directly in the sludge activation chamber or the return sludge line. Construction and function: with the valve closed, the medium is transported to the pipe reactor from the container that is immersed in the medium to be measured. After a few circuits, the valve is opened. The medium circulates through the reactor, and consumption measurement begins.

Waste water harmfulness The level of harmfulness expressed as a → Pollution index (effluent) according to the waste water levy law.

Waste water heat exchanger It is necessary to make a basic differentiation between cold and hot waste water when planning heat recovery plants in the textile finishing industry. This thermal separation should be fully automated at approx. 60–70°C, because otherwise it has been found in practice that if all waste water is mixed, the max. mixed temperature is approx. 45°C. However, despite the high heat content of this mixed waste water, heat recovery would be inefficient because of the high quantity, since the fresh water could only be heated up to about 40°C. Older equipment can also be used to separate hot and cold liquors without great expense by installing thermostats and control valves in the run-off system of the dye machinery. However, individual checks must be carried out to establish which liquor temperatures can still be used in the heat exchanger, and which liquors are drained off directly.

For this application, the following are the best heat exchangers in practice, and have different types of construction as follows:

1. Plate heat exchanger (Figs. 1 + 2).

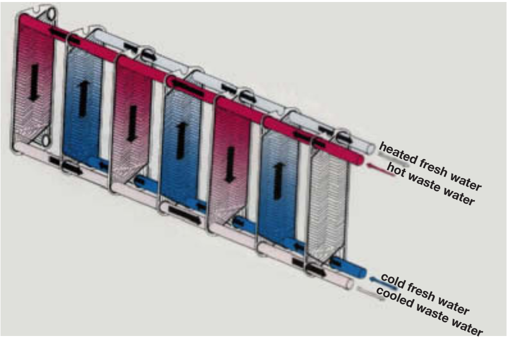


Fig. 1: Plate heat exchanger (W. Schmidt KG).

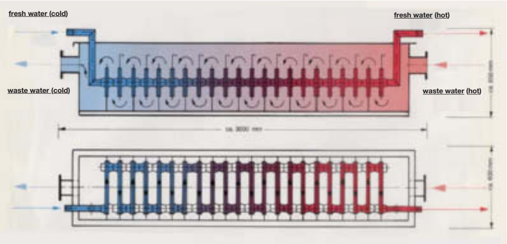


Fig. 2: Menzel waste water heat exchanger (6000 l/h capacity).

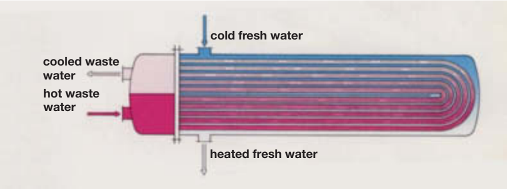


Fig. 3: Shell and tube exchanger (bundle heat exchanger).

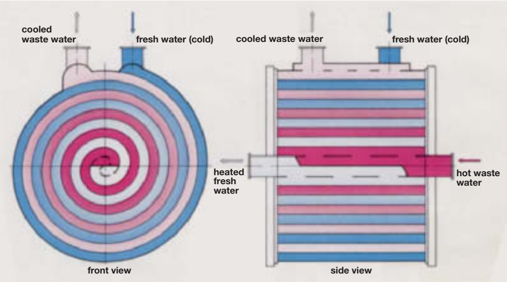


Fig. 4: Spiral heat exchanger.

2. Tubular heat exchanger as
   a) double-tube heat exchanger,
   b) tube bundle heat exchanger (Fig. 3).
3. Spiral heat exchanger (Fig. 4).

Waste water load Amount of impurities. Pollution in flowing water containing substances that consume oxygen (→: Waste water; Waste water pollution; Summation parameters). Calculated as a quotient of the limiting value per head of population and low water drainage.

Waste water measuring probe → pH/redox probe.

Waste water neutralization Alkaline waste water (e.g. from cotton or wool pretreatment) can be neutralized using acid, or acidic waste water (e.g. from wool dyeing) with alkali. Acidic and alkaline waste water from textile finishing processes can neutralize each other in a neutralization bath if none of the individual water requires specific treatment.

Waste water oil separation and adsorption This process is for cleaning waste water containing oil and fat, such as washing water emulsions, fat removal baths, etc., where the oil content is approx. 0.5–1.0% and surfactants are present to ensure stability. Oil emulsions can be broken up within a few minutes by adding separating agents, and the oil released is separated by silicic acid. The flakes of separating agent with adsorbed oil are filtered out of the purified waste water. The filtered oil cake is incinerated at a suitable incineration plant. Silicic acid, which is ecologically neutral, remains as ash. Low investment costs.

Waste water partial stream pollution A partial stream of waste water is considered to be concentrated waste water from the starting liquor. Some limit parameters are expected in Appendix 38 (textile manufacture and finishing) of the German Framework Administration Regulation of Waste Waters (Rahmen AbwVwV – Rahmen-Abwasser-Verwaltungsvorschrift) in line with paragraph 7a of the Water Resources Law (WHG – Wasserhaushaltsgesetz), which apply to a selection of auxiliaries and dyes.

1. Colour: the spectral adsorption coefficient is stipulated as follows:
   - 436 nm (yellow range) $7\ m^{-1}$
   - 525 nm (red range) $5\ m^{-1}$
   - 620 nm (blue range) $3\ m^{-1}$

   Colour is only included for aesthetic reasons. Also the limiting values (almost) correspond to clear water.
2. AOX: The source of AOX is hypochlorite bleach, and also (in unfavourable situations) chlorite bleach. Further sources are reactive dyes containing halogens with different reactivity in the reactive group in certain circumstances, as well as dyes that contain halogens in the form of auxochromic groups. This means that the AOX value can be controlled by increasing the dye yield and by means of process technology. A further source is the chlorination of wool for antifelt finishing and print pretreatment.
3. Sulphide: can be extremely toxic to bacteria in certain situations. The limiting value forces the textile industry to rethink the use of sulphur dyes, i.e. a transition to low-sulphur dyes and reduction agents, e.g. pre-reduced dyes and glucose as a reduction agent.
4. Heavy metals: these originate from metal complex dyes and afterchroming of wool, aftercoppering of substantive dyes in the case of cellulose and the cotton itself. Zinc salts are catalysts in resin finishing, however it is possible to replace them with NH_4 and Mg salts. Tin salts are used as reduction agents in textile printing, and they can also be substituted.
5. Surfactants: the recommendations relating to relieving the strain on waste water should be taken seriously, this also applies to products containing surfactants that are not included in paragraph 2 section 1 of the German Detergent and Cleaning Agent Law (WRMG – Wasch- und Reinigungsmittelgesetz). These must fulfil the legal requirements defined on the basis of paragraph 3 of the Detergent and Cleaning Agent Law from the point of view of biodegradability. Texturizing auxiliaries are exempt from this. The set requirements regarding biodegradability also have to be fulfilled by a large number of textile finishing auxiliaries. Furthermore, the following is required:
   - treatment of screen and print blanket washing water, as well as the washing water from print machinery cleaning, to be re-used as washing water.

- separation of dyeing and washing liquors with a high concentration of dye for special treatment.
- washing of barrels and packaging only when concentrates have been removed.

The following short-term strategy for the textile finishing industry can be derived from Appendix 38:

- checking individual formulae using the avoidance principle. It would be helpful if dye manufacturers would provide information regarding heavy metal and AOX content;
- checking process methods in the plant; multi-use of process water, e.g. rinsing water (dependent on temperature and dwell time);
- consistent introduction of measurement techniques;
- construction of a waste water installation system that fulfils the requirements of the partial streams;
- installation of sampling systems to check that the limiting values are adhered to;
- installation of a collection and neutralization basin;
- installation of a sampling system at the point of transfer to the communal purification works (Venturi shaft);
- checking economical and ecological compliance.

It is essential that the mid-term and long-term targets of the textile industry are subject to scientific processing with respect to their ecological responsibility. In the medium term, the following theories among others are particularly important:

- in future, the functional mechanism of textile auxiliaries must be highly efficient and biodegradable in a process;
- development of specific purification methods for partial stream cleaning; if this can not be regulated, aerobic or anaerobic disposal should be the objective;
- circulation of process water;
- measurement/control techniques should be suited to the individual components;
- all biotechnological opportunities should be used to full advantage.

(according to Schollmeyer).

Waste water permanganate consumption The → Chemical oxygen demand (COD) of a sample of waste water, expressed as a weight of potassium permanganate (in mg), which contains reducing components and oxidizes under certain reaction conditions in 1 l of waste water. According to the normal values that apply in Germany, mechanically purified domestic waste water should have a potassium permanganate consumption of less than 200 mg/l, and for biologically purified waste water the value should be below 100 mg/l. These values are exceeded by far in waste water from the textile industry, at 300–30 000 mg/l (where the normal value for surface water is 10–30 mg/l).

Waste water pipes The best type of pipes for aggressive waste water are formed pieces internally enamelled with no internal bushings: having the hardness of glass, mirror-like, with high resistance to acid, alkali and other aggressive substances; extremely resistant to temperature. Sealing sleeves made from ethylene propylene terpolymer rubber or nitrile rubber are used as connectors.

Waste water pollutant load Calculation of → Waste water pollution x waste water quantity/unit time. Conventional value is the → Population equivalence.

Waste water pollutants are aggressive, toxic and inorganic and organic compounds as well as their ions which impede biodegradation (→ Waste water pollution). Given as a concentration in mg/l. Permitted waste water threshold limit values for discharging waste water pollutant are aimed at the required protection of the sewerage system, biological → Waste water treatment and the outfall channel.

Waste water pollution,

I. Contaminants accumulating in waste water. Stemming from textile finishing substance burdens in the waste water: dyes (absorbable, non-absorbable), acids, alkalis and neutral electrolytes, oxidants (chrome compounds, bleach liquors, nitrites, nitrates, etc.), reducing agents (sulphur compounds), plastic emulsions/dispersions, finishing agents (e.g. fermentable starch products), metal salts, especially salts from heavy metals (toxic substances) such as copper, chrome(III), chrome(VI), mercury, lead, zinc, zirconium and such ions. Textile auxiliaries/wetting agents, surface-active substances, thickeners, lubricants/oils, sequestering agents and phosphates, tannin-like products amongst others → Waste water pollutants.

The waste water pollution of a finishing business (Tab.) approximately consists of the following: 46% sizing, 39% preparation, 15% dyeing and finishing.

	Pollution g of COD/kg	Waste water accumulation l of water/kg
Coloured CO fabric	100–150	100–180
Printed fabric	180–250	140–200
Knitted fabric (coloured)	80–100	80–140
Yarn dyeing	70–100	100–140
Coloured PA fabric	60–100	60–100
Carpet dyeing		
– exhaust process	25– 60	50– 80
– continuous process	35– 60	50– 80
Carpet printing	35– 60	60– 90

Tab.: Special characteristic numbers of some textile chemical finishing processes (calculated to 1 kg of textile product). CO = cotton; PA = polyamide.

II. Results from domestic, technical and agricultural water consumption as well as polluted rainwater. The degree of pollution is measured in settleable solids (ml/l), ignition loss, as oxygen consumption in the oxidation of contaminants in chemical or biochemical methods and as organic carbon content. →: Oxygen demand; Waste water pollutants; Waste water pollutant load; Population equivalence.

Waste water pollution from dyehouse effluents Each phase of the dyeing process contributes to waste water pollution to a greater or lesser extent depending on composition (see Tab.).

	COD value (mg O_2/l)	g of COD/kg of fabric
Dye liquor before dyeing	982	19,6
Dye liquor after dyeing	995	19,9
1st rinsing bath	233	4,6
2nd rinsing bath	74	1,5
3rd rinsing bath	55	1,1
Total pollution according to individual liquor measurements	(1357 : 4) = 339	27,1

Tab.: Waste water pollution from wool dyeing with acid dyes (20 : 1 liquor ratio), relative to the liquor and to the fabric.

The pollution values can be calculated using the following formula:

$$\frac{\text{COD value}}{1000} \cdot \text{liquor ratio} = \text{g COD/kg fabric}$$

These values correspond with the figures in the last column of the Tab. The second-last column, the so-called mixed waste water value results from the COD values of the liquor mixture. The arithmetic mean of the mixed waste water value provides good insight into how efficient the addition of the COD values of the individual liquors is with respect to the overall value. As a complement to this, the waste water pollution of acidic wool dyeing used as an example in the Fig. is shown as a function of conductivity, COD value and extinction.

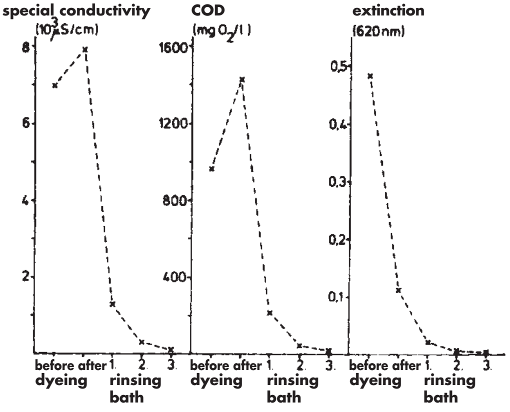


Fig.: Fall in typical waste water values with rinsing time.

It is apparent that the conductivity (measured with a conductivity gauge) and the COD value in the dye liquor increase after dyeing (in comparison with the dye liquor before dyeing), which is linked with the acetic acid feeding liquor. On the other hand the extinction, which is dependent on dye uptake, decreases. Then all three values drop successively during subsequent rinsing. Regarding the level of pollution, the dye bath before and after dyeing and the first rinse are considered to be heavily polluted, and the second and third rinsing baths as slightly polluted.

Waste water pollution sources,

I. Direct pollution sources are those which drain directly into the outfall channel of a works sewerage system and works waste water treatment plant. Minimum requirement in accordance with § 7a of the German Water Resources Law (WHG – Wasserhaushaltsgesetz).

II. Indirect pollution sources are those which drain into a public sewerage system to a municipal waste water treatment plant and from there indirectly into a body of water.

Waste water, potassium dichromate consumption → Chemical oxygen demand.

Waste water pretreatment Hydrocarbons and colloidally dissolved dyes as well as some auxiliaries can be flocculated by the addition of electrolytes, e.g. iron or aluminium salts. The pH should also be controlled to complete the precipitation and a suitable flocking auxiliary added. The costs of such a pretreatment are, relative to the water volume, often considerably higher than those of biological cleaning. So, such a pretreatment is only appropriate if it is essential for the protection of the subsequent waste water treatment plant. Main source of hydrocarbons in textile waste water is grey fabric; this mainly concerns auxiliary substances from preceding processing stages, e.g. spinning preparations, sizing waxes, etc. The following product groups are considered in finishing:

- scrooping agents,
- synthetic thickeners,
- dust extraction agents (powder dyes),
- benzine (in printing).

Waste water in textile finishing mainly contains aliphatic hydrocarbons (liquid or wax-like paraffins); textile waste water contains ecologically and toxicologically questionable aromatic hydrocarbons to a lesser extent, as, e.g. in motor spirit for automobiles. Hydrocarbons disrupt the operation of local authority waste water treatment plants only in higher concentrations; a lower recommended parameter is therefore being discussed in the new version of the ATV/Work sheet A115 (ATV – Abwassertechnische Vereinigung – German technical association for waste water). Hydrocarbons are present in emulsified form in textile waste water; simple mechanical removal is therefore not possible. A precipitation/flocculation process is required to break the emulsion; not only is the mineral oil concentration reduced, but the COD value and the AOX concentration are also considerably lowered at the same time. Some businesses already have the appropriate plants today. It can be expected that more firms will be subjected to pressure from the authorities to segregate highly polluted flows from physical/chemical treatment systems before discharging into the public sewerage system. However, a segregated stream treatment is particularly problematic especially in textile finishing, as the possible segregated streams neither occur continuously nor (due to the frequent lack of strict assignment of machine and process) always at the same site.

Waste water quantity As m^3/day in the hazard formula (→ Waste water evaluation).

Waste water regulations In 1976 § 7a, amongst others, was introduced into the German Water Resources Law as the 4th law on the amendment of the → Water Resources Law, with which demands on the introduction of waste water into public bodies of water (Tab. 1) should be controlled (→ Water protection). The objective read: "In order to protect the bodies of water from contaminants, only waste water introduction consistent with § 7a, paragraph 1, clause 1 of the German Water Resources Law (WHG – Wasserhaushaltsgesetz) may continue to be permitted, if quantity and hazards of the waste water are kept as low as possible when using methods in accordance with technological regulations." The Federal Government established so-called minimum requirements for different types of waste water in the form of General Administrative Regulations (VwV – Verwaltungsvorschriften) for the execution of the law. These VwV were prepared by committees from the State Working Group for Water (LAWA – Länderarbeitsgemeinschaft Wasser) with more or less strong involvement of representatives from industry and associations. The VwV for the textile manufacturing industry was issued in 1984 (38th Abw.VwV – Abwasserverwaltungsvorschriften – Waste Water Administrative Regulations) and amended in 1994.

In § 7a, WHG, "dangerous substances" are described as follows: "substances or substance groups, which due to the concern that toxicity, durability, accumulation ability or a carcinogenic, fruit-damaging or genetic altering effect can be considered as dangerous". This long-winded, unclear definition is open to many possible interpretations.

The 38th Abw.VwV (Abwasser-Verwaltungsvorschrift – German Administrative Regulation of Waste Waters) applies, as all other Administrative Regulations in accordance with § 7a WHG, only to direct pollution sources, of which there are very few left in the

		1984	1990	comment
filtrateable solid pollutants	mg/l	40	-	d
settlable solid pollutants	mg/l	0.3	-	d
COD	mg/l	280	160	a
BOD_5	mg/l	40	25	a
fish toxicity	(conc. factor)	4	2	b
zinc	mg/l	3	2	b
copper	mg/l	1	0.5	b
total chromium	mg/l	2	-	
chromium-VI	mg/l	-	0.5	b
NH_4–N	mg/l	5	10	a
active chlorine	mg/l	0.3	0.3	b
sulphide	mg/l	0.1	1	b
sulphite	mg/l	1	1	b
hydrocarbons	mg/l	10	15	b
total phosphorus	mg/l		2	a
iron	mg/l		3	a
aluminium	mg/l		3	a
AOX	mg/l		0.5	b
volatile halogenated hydrocarbons	mg/l		0.1	b
nickel	mg/l		0.5	b
lead	mg/l		0.5	b
tin	mg/l		2	b
dye				
spectr.abs.coeff.	m^{-1}		3, 5, 7	b c

Tab. 1: Minimum requirements for textil manufacturing and textile finishing waste water according to § 7a of the German Water Resources Law – Wasserhaushaltsgesetz (by DTNW).
a = requirements according to common engineering standards; b = state of the art requirements; c = applies to the yellow, red or blue zone; d = from the sample.

textile industry in the old states of the Federal Republic of Germany. This is more so, however, in the new states of the Federal Republic of Germany. It can be assumed that some municipal waste water treatment plants are subject to these VwV provided that a textile firm provides most of the pollutant load in the local authority in question. It is stated in the 38th VwV: this VwV "is valid for waste water which is introduced into bodies of water whose pollutant load essentially comes from the processing and treating of textile fibres and yarns and textile finishing." The question as to how the word "essentially" should be applied could not be explained until now. It would be justified if at least 50% of the pollutant load, but at any rate 75% of the average pollutant load from the municipal waste water treatment plants, came from one or several textile firms. There are such examples in several places in Germany without the authorities having applied the 38th VwV until now.

Meanwhile the Federal Government ordered the LAWA committees to revise the requirements. Some of the new minimum requirements for other branches of industry have meanwhile been issued and this is as a rider to the amended General VwV, which henceforth applies to all waste water treatment plants, from which waste water is introduced into bodies of water and is with additional minimum requirements, depending on the type of, or the industrial undertakings, from which the waste water mostly comes. The appropriate rider for the textile industry exists as appendix 38 in the draft of 25 May 1990. The minimum requirements are referred to in the middle column of Tab. 1. A whole series of parameters was recently incorporated, which increases requirements for most parameters already listed. The trend in pollution control legislation can be recognised from these measures. Waste water experts comment on the existing minimum requirements in the draft, to the effect that some of the requirements mentioned are scientifically unjustified, many measures cannot be achieved in accordance with technological regulations or state-of-the-art, and many lack relevant parameters.

Besides the requirements of laws pertaining to water and waterways, the water protection regulations contain detailed provisions on dealing with water threatening substances. The neighbouring countries of Germany do not have a similarly dense network of overlapping laws, regulations, guidelines or statutes in accordance with the provisions of the state of the art. While in Germany, demands on the discharge of waste water are partly stipulated in an industry-specific way (in accordance with the regulation of origin), in other European countries they usually apply to all areas. From there it is only comprehensible that, for example, Spain has meanwhile introduced a wealth of individual monitoring parameters, which are comparable with German ideas with regard to their results. Belgium has laid down partly specific and sectoral standards for industrial waste water. Nevertheless as a result of separate information, up to 30% of textile waste water is directly discharged into the outfall channel without considerable treatment. In France it is up to 45% of all textile waste water. The Netherlands, however, consistently pursue the way of load limits also frequently demanded in Germany.

Sometimes only vague advice exists on the issue of self-checking, which indicates that the extension of municipal or supra regional state monitoring organisations is not yet intended or was not yet concluded. It can certainly be confirmed that state controls are being revoked and there is an increasing desire to introduce self-checking. It is quite different in the federal constitution of Germany. The competing legislation (embedded in clauses 72 and so on of the Basic Law) is taken literally in the German states and results in vying competition. The German regional water laws authorise the regulatory body to decree self-checking regulations, which were introduced into the old states of the Federal Republic of Germany, sometimes in a very different form. These generally apply to public waste water plants and other waste water plants with a low limit of, for example, 8 m^3 per day or less than 60 inhabitants. Self-checking and/or self-monitoring is committed to the following measures:

- installation of control and measuring devices,
- keeping an operating diary,
- seal-tight tests for waste water channels and pipes,
- storage of resetting samples,
- reporting of stoppages,
- preparation of an annual report.

Extent and frequency of the checks are dependent on the type of waste water plant and the daily waste water accumulation, in which distinctions are made between plant and production-related checks. The following checks should be carried out first and foremost by textile finishing companies:

- general type (independent of waste water accumulation),
- general parameters
- certain substances regularly occurring in textile waste water.

Bavaria has "practically revised" the EKVO (Emmissionskonzentrationsverordnung – Emmission Concentration Regulation) of Baden-Württemberg in the Waste Water self-monitoring Regulation (AbwEV – Abwassereigenüberwachungsverordnung), reduced the low limit and production-related self-checks, which should be used for the formation of a waste water register, but not incorporated. The municipalities are in principle responsible for waste water treatment. It is their task to build waste water treatment plants of sufficient dimensions and to operate properly. These requirements (as "generally accepted technological regula-

Size classification of waste water treatment plants	Chemical oxygen demand (COD) [mg/l]	Biochemical oxygen demand in 5 days (BOD_5) [mg/l]	Ammonium nitrate (NH_4-N) [mg/l]	Total phosphorus (P_{tot}) [mg]
Class 1 less than 60 kg/d BOD_5 (raw) Qualified sample or 2 h mixed sample	150	40	-	-
Class 2 60 kg/d or more BOD_5 (raw) Qualified sample or 2 h mixed sample	130	340	10 (>300 kg/d BOD)	2 (>3000 kg/d BOD)

Tab. 2: Waste water threshold limit values (local variation in COD down to 20).

tions") are fulfilled if the empirical values of the cleaned waste water correspond to the values mentioned in Tab. 2. If they are exceeded a punishable offence exists in principle as regards § 7a WHG (and/or the similar regulation in the state law).

The discharger must pay a tax in accordance with the German Waste Water Discharges Regulation (Abwasserabgabengesetz) for discharging the waste water in bodies of water. The law intends that an evaluated quantity of harmful pollutant is calculated on the basis of data in the content of COD, settleable solid pollutants in waste water, certain heavy metals, AOX and fish toxicity, which is summarily deposited each year at an outfall channel. This is described as a damage unit. A waste water tax is calculated for each damage unit by multiplying the damage unit by DM 40.00 per damage unit. Roughly calculated one damage unit corresponds to approx. the cleaned waste water of 10 inhabitants. For a small town with approx. 10 000 inhabitants with 100 000 damage units in the raw sewage and (90% cleaning performance of the waste water treatment plant assumed) 10 000 damage units occur in the waste pipe. A waste water tax of DM 400 000/year results. If the cleaning performance fulfils all the specified conditions and corresponds with the normal standard of the purification technology, i.e. the generally recognised technological regulations, only 50% of the calculated tax, i.e. DM 200 000, should in fact be paid. If, however, faults occur and these are recognised by the supervisory authority, the reduction does not apply. In particularly efficient waste water treatment plants, which clean in accordance with the state-of-the-art, the attainable reduction is even 80%, i.e. in the case of a fault the tax to be paid can in fact be increased fivefold. This not inconsiderable reduction is less a concession but more a motivation to encourage the waste water treatment plant users to operate their plant carefully, to discover possible causes of faults amongst the indirect polluters and to cause a change in their behaviour.

The regulations on minimum requirements for waste water treatment plants and the size of the waste water tax firstly only concern the direct discharge of waste water, i.e. those institutions, which discharge their waste water directly into a body of water after successful cleaning, e.g. the municipalities. Laundries are normally not direct polluters, as they mostly discharge their waste water into municipal waste water collection systems. The waste water tax must always be paid as well as the costs of the waste water treatment by the associated indirect polluters. That is why indirect polluters always pay a waste water charge, which covers the costs of the waste water tax, the channel operating system, the operation of the waste water treatment plant and the waste water monitoring. The type of charge is different depending on the region. There are often fixed prices per m^3 of waste water with no consideration for the content of the pollutant. But a lot of local authorities have introduced so-called waste water coefficients, which assess how high the pollution of the waste water actually is, using analysis data. They then calculate a charge corresponding to the pollution. But also compulsory waste water threshold limit values, which should not be exceeded, exist for indirect polluters independent of this charge issue. The effective regulation of these threshold limit values (Tab. 2) lies with the local authorities, who draw up so-called local waste water statutes. The criteria recommended by the German Technical Association for Waste Water (ATV – Abwassertechnische Vereinigung) in worksheet A 115 are normally assumed in these (in accordance with Gode, Reetz and Schulze-Rettmer).

Waste water situation textile finishing Investigations have revealed that from 1000 kg of cotton fabric, substances reach the waste water, which, determined as COD (→ Chemical oxygen demand), have values of 130–150 kg. This COD component consists of:

51% sizing agents,
25% fibre degradation products,
11% chemicals
13% resultant products of dyeing and finishing.

This is the reason that a search for methods for reducing waste water loads, mainly in sizing and desizing, was suggested. For instance the following picture results as regards fabric; values for COD are compiled in accordance with water treatment at 100°C (1 hour) (10 g of textile material was used each time; liquor-to-goods-ratio 1 : 10) [mg O_2/l]:

– cotton fabric, sized (starch)	7350
– cotton fabric, desized	2740
– cotton fabric, peroxide-bleached	2140
– cotton jersey knit good	1780
– polyester fabric, carrier-free dyeable	760
– polyester fabric, cotton type	1130

The waste water situation is characterised by:

- quantitative waste water accumulation,
- a series of the most varied materials, alkalis, acids, in part high salt quantities, diverse finishing agents, low-molecular paraffin hydrocarbons, surface-active substances, polymers, natural and synthetic oxidizing agents, reducing agents, etc. Decomposition products of the fibres: hemicelluloses, pectins, waxes, oligomers, dyes and optical brightening agents,
- pH and temperature fluctuations,
- potential toxic effects,
- discolorations, odour, cloudiness, foam,
- sludge and its production during extensive elimination of waste water materials.

Waste water technology embraces all technologies of → Waste water treatment.

Waste water treatment Reserves of dirt, poison or re-usable substances, which are contained in waste water, as well as separate waste water and separate sludge treatment.

Waste water treatment methods are classified as follows:

I. Physical (mechanical): a) sedimentation, b) filtration, c) distillation, d) sorption, e) freezing out.

II. Chemical: a) neutralization, b) ion exchange, c) oxidation, d) reduction, e) catalysis.

III. Biological: a) aerobic treatment, b) anaerobic treatment, c) activated sludge process, d) fungus treatment.

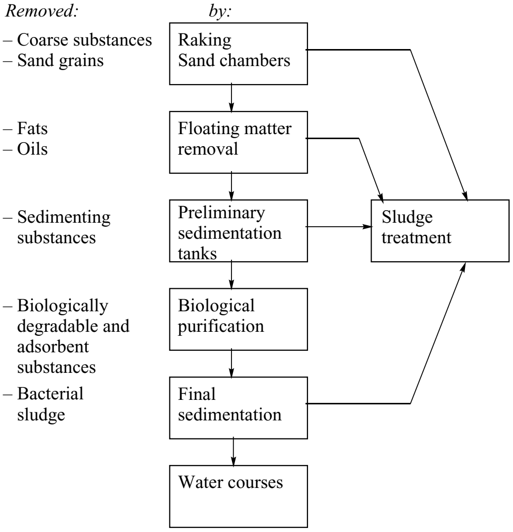


Fig. 1: Diagram of a communal waste water treatment plant.

IV. Physical/chemical: a) flocculation and precipitation (coagulation), b) ventilation, c) activated carbon filtration, d) foam fractionation, e) solvent extraction, f) combustion, g) osmosis, h) electrolysis.

Depending on the type of treatment carried out, a distinction is made between treated or so-called clarified waste water, which is either re-used or introduced into an outfall channel. The sludges are re-used, stored, re-structured or burnt. Most municipal waste water treatment plants have a mechanical and a biological cleaning stage; the technique is sophisticated and is also used successfully in large industrial plants. Such a plant is constructed schematically as follows (Fig. 1):

a) arithmetic processing unit: for coarse substances;
b) sand trap: for grains of sand (protection of pumps, seals);
c) floating material separator: for oils and fats;
d) sedimentation tank: for settleable solid pollutants in waste water;
e) sludge activation tank or percolation filters: for biologically degradable and adsorbable substances;
f) secondary settling tank: for bacterial sludge.

Fig. 2 shows in detail which waste water loads are reduced, degraded or eliminated (sorption in sludge) by certain waste water treatment methods.

The following processes run in the actual biological stage (sludge activation tank or percolation filters):

Bacteria degrades organic substances by the consumption of atmospheric oxygen, in which firstly CO_2 and water and secondly new bacterial mass develops. Filter candles, injectors or aeration tanks, for example, are used for ventilation. At the same time the bacterial sludge is in a position to extract substances from the

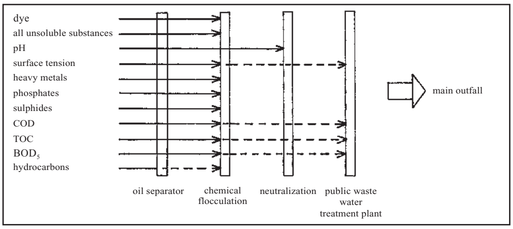


Fig. 2: Treatment of waste water of a textile finishing manufacturer by oil separator, chemical flocculation with iron hydroxide and calcium hydrate, neutralization and biological oxidation.

waste water through adsorption; this includes most textile dyes, for example.

Water and sludge are separated in secondary settling tanks; the cleaned water drains through an overflow channel. The sludge is extracted on the floor of the basin. The larger part of the sludge flows back into the sludge activation tank as return flow sludge in order to inject the newly added waste water. The excess sludge, approximately 10–50% of the removed organic substances, must be disposed of and/or further treated. It is firstly thickened, whereby the dry content of approx. 0.1–1% is increased to approx. 5%. In municipal plants, a decaying process is possibly connected, i.e. an anaerobic biological sludge treatment, in which part of the organic mass is converted into methane and carbon dioxide. As a result of the decaying the sludge is at the same time transported in a perfectly hygienic state; after draining the humus-rich material can be used to improve soil in agriculture (in accordance with relevant regulations). Sludges from industrial waste water treatment plants are normally burnt after conditioning or sent to a disposal site.

In catchment areas of inland lakes phosphate reduction is required after the mechanical/biological waste water treatment in order to avoid an uncontrolled algae growth. The necessary chemicals, e.g. iron or aluminium salts, can be added at various process stages (Fig. 3).

- pre-precipitation in sedimentation tank,
- simultaneous precipitation in the sludge activation tank,
- post precipitation in a separate 3rd stage.

In the first two processes, costs arise only for the chemicals; an additional third stage, however, requires high investment costs, though it also results in an even better phosphate elimination. In the pre- and/or simultaneous precipitation the danger exists moreover that not enough (dissolved) phosphate is available in the sludge activation tank for biodegradation; but if a third stage is to be avoided, metering the precipitate in the outlet of the sludge activation tank is also considered. The mechanical/biological waste water treatment outlined, (possibly supplemented by a precipitation stage) is also the most convenient process, economically and ecologically, for waste water from textile finishing; this applies particularly to mixed water from municipalities and the textile finishing industry.

I. Mechanical (physical) waste water treatment: is based on physical properties and includes the separation of coarse disperse solid substances from the liquid phase and their stabilization. Is used as pre-treatment for easing the subsequent waste water treatment processes, especially the biological stage.

1. Coarse substance precipitation with rakes, screens and filters.
2. Gravitational precipitation via:
   - flotation plants,
   - oil and fat separators,
   - sand traps,
   - settling basins: rectangular basins, round basins, two-storey settling basins (Emscher tank), slat-type settling basins and vertical throughflow settling basins.
3. Balancing reservoirs are plants, which cause a mixture of different qualities and concentrations of

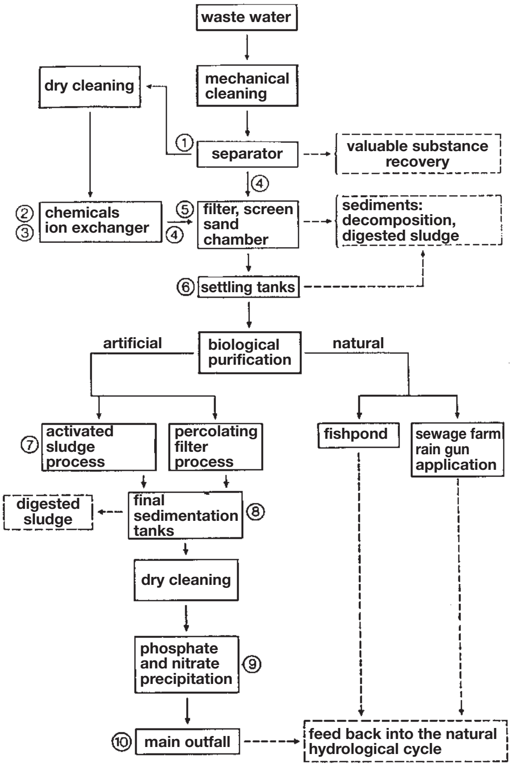


Fig. 3: Model of a 3-stage waste water treatment plant, including artificial or natural biological decomposition with valuable substance recovery (top, right). The figures describe the waste water treatment sequence in a public waste water treatment plant.

waste water to drain by mechanical processes. Ponds or specially built basins are used as balancing reservoirs. Balancing reservoirs are designed and built with horizontal, vertical or tangential charging machines.

II. Chemical waste water treatment: comprises the retention or the conversion of the settleable, suspended and dissolved matter through the use of chemicals. The processes are based on purely chemical or physical/chemical reactions and are used to achieve the following effects:

- neutralization of acid or alkali drains,
- separation of solid matter, which cannot be removed by simple mechanical waste water treatment,
- elimination of colloidal, usually organic matter and some dissolved inorganic matter,
- removal of the residual amounts of fats and oils,
- improvement in the waste water treatment effect of flotation and filter plants,
- reduction in radioactivity of contaminated waste water,
- through use of chlorine and chlorine oxygen compounds, achievable effects such as: disinfecting, controlling algae growth, maintaining water freshness, decontamination, odour prevention, decolorizing, oxidation and controlling fly larvae in percolation filters.

1. Neutralization: is required before the introduction of acid or alkali waste water into an urban sewerage system. The following groups of neutralization processes are common nowadays:
    - use of the buffer properties of the outfall channel,
    - mixing of acids with alkali waste water,
    - addition of chemicals, which react as alkalis, such as NaOH, $Ca(OH)_2$, etc.,
    - filtration through neutralization of filter material, such as with $CaCO_3$, etc.

   During the neutralization process, a pH shift occurs, which often results in flocculation of colloidal constituents of the waste water. An after treatment in a settling plant is necessary in such cases.
2. Flocculation and precipitation: the substances, which are present in the water in colloidal form, are transformed into larger agglomerates through addition of appropriate auxiliaries. The flakes thereby are in a state and a size, which make them capable of forming a sediment, capable of flotation or filterable, through which extensive mechanical separation of the suspended matter from the water is possible. The generic term flocculation and precipitation is understood to mean both coagulation and flocculation. Both inorganic and organic substances as well as in combination are used as flocculation agents. The most important inorganic ones are aluminium salts, iron salts and calcium hydrates; the organic ones are polymers with a long chain length, manufactured from natural substances (algae, starch) or by a synthetic process.
3. Adsorption of dissolved materials in the water on the surface of, e.g., activated carbon particles and thus their elimination from the treated water flow. Another possibility for adsorption is sand filtration, in which the suspended particles are adsorbed on the particle surface. Activated carbon is the most important technical adsorbent, which can be so varied in its porous structure through appropriate control of the manufacturing process, so that an optimum adsorption of certain substances is facilitated.
4. Extraction using solvents: the capability of some substances (solvents) to dissolve in certain liquids is used in this connection but not in the waste water. The liquids can consequently be separated and recovered from the dissolved substances which are to be removed from the waste water. Butyl acetate, isopropyl ether and other similar products are used as solvents, for example. The extraction processes may be varied dependent upon how the solvents came into contact with the waste water, for example, with single or repeated contact, counter-current, etc.
5. Membrane separation (ultrafiltration, reverse osmosis): dissolved substances can be removed from aqueous solutions and electrolytes through membranes. In contrast to conventional filtration (treated waste water and adsorbed substances on dry sludge), hyper and ultrafiltration of the volumetric flow is separated into two segregated streams, one enriched with dissolved substances and one depleted of dissolved substances. Hyperfiltration and ultrafiltration are differentiated by their operating pressure and also by the membranes used as well as by the systems to be processed.
6. Distillation: as the mineral and organic matter are not easily vaporized, distillation is based on the change of state of the waste water through evaporation of the liquid and then condensation. High energy costs and greater technical expenditure are disadvantageous.
7. Oxidation: is used in waste water, which contains hydrogen sulphide, mercaptans amongst other sulphide compounds. The most commonly used oxidizing agents are atmospheric oxygen and chlorine. Atmospheric oxygen is used for the oxidation of organic substances with low reducing property. The following are thereby distinguished:
    - pressure oxidation with oxygen (at 110°C; $3.5 \cdot 10^5$ Pa),
    - wet combustion (225–347°C, $150 \cdot 10^5$ Pa).
8. Reduction: for waste water, which contains easily reducible, harmful constituents. Chrome acid can be reduced, for example, using sulphuric acids, their

salts or using bivalent iron salts in waste water containing chlorine by means of activated carbon.

9. Ion exchange process: certain ions in this process are absorbed from an electrolyte solution and an equivalent quantity of other ions are exchanged with the solution. Similar to adsorption, ion exchange also results in the reversible bond of material in waste water with an auxiliary, with whose regeneration a phase low in foreign matter, but concentrated, precipitates the material. Most ion exchangers are polymers, on the framework of which certain substances are absorbed. Besides the synthetic resin exchangers, there are also inorganic-based exchangers (zeolites). The following are used in waste water treatment:
   - cationic exchangers, resins with sulphonic acid and carboxylic acid groups. They bond copper ions, for example, and release sodium or hydrogen ions.
   - anionic exchangers, resins with amino groups, for example, bond sulphates or cyanites in exchange for chloride or hydroxyl ions. (→ Ion exchanger).
10. Other physical/chemical treatment processes:
   - flash steam,
   - ventilation,
   - fumigation with carbonic acid or flue gases,
   - evaporation,
   - freezing processes,
   - crystallization,
   - electrolysis,
   - dialysis.

III. Biological waste water treatment: is carried out mechanically on treated waste water by fixed or moving lattices of oxygen containing micro-organisms.

1. Soil and/or dynamic filters: levelled off soil (easily permeable, not too fine a sand) with at times waste water back up and breaks in atmospheric oxygen absorption. 300–750 m^3 daily output per hectare. The water table should be a maximum 2 m below the surface; sealing required; poss. after spraying.
2. Drip process: percolation filters are cylinder or polyhedron-shaped vessels with filling of sand-free, weatherproof, broken stones, mineral pieces, lava tuff, burnt pieces or plastic filling. The waste water is distributed across the surface by sprays, rotary sprinklers, channels, etc. and drips dependent on load, under gravity, in 20–60 minutes via a 2–3 m high percolation filter. A type of film develops on the broken filling, which is formed by the mineralising micro-organisms from the matter in the waste water. The films and/or the micro-organisms living in it, also referred to as “biological grass”, adsorb and mineralise the matter contained in the waste water. A distinction is made between low-polluted (containing sludge) and high-polluted (flushing-) percolation filters. Waste water pollution of a percolation filter is understood to mean the quantity of waste water, which is distributed on a m^3 filter material in a certain unit of time (expressed in m^3 waste water/m^3 filter material · day = $m^3/(m^3 \cdot d)$). In the low-polluted case, dead bacterial films are mineralised and then repelled; in the high-polluted case, immediately rinsed out; in both cases a post waste water treatment is required. The percolation filter rating is not in accordance with the quantity of water, but in accordance with the quantity of soil. A volumetric pollution of 200 g $BOD_5/m^3 \cdot d$ and/or 5 E/m^3 for low-polluted and 600 g $BOD_5/m^3 \cdot d$ and/or 15 E/m^3 for high-polluted percolation filters is expected; the latter require a surface coating of at least 0.8 m^3 water per m^2 surface for the maintenance of the rinsing force (E = population equivalence, d = days).
3. Stimulation processes: waste water treatment with stimulated flocks (activated sludge), which are produced by biochemical oxidation of organic contaminants. Besides oxygen, a nutrient ratio of $C : N : P = 5 : 1 : 0.15$ is required. Activation plant usually has a higher degree of treatment than percolation filters, but produce more sludge containing a lot more water; a good settling plant should be connected. Mixing of the activated sludge with waste water as well as oxygen input are carried out in the sludge activation tank: compressed air basins, Haworth channels, oxidation trenches, basins with rotary scoops, Dessener basins and mixer basins with added air. Activated sludge is precipitated in the after waste water as return sludge and is mixed as return sludge with pre-treated waste water in the sludge activation tank. Excess sludge produced is usually removed from the pre-treatment together with sludge. Volumetric pollution of 500 g $BOD_5/m^3 \cdot d$ and/or 12 E/m^3 (low-polluted activation) up to 1000 g $BOD_5/m^3 \cdot d$ and/or 25 E/m^3 (full treatment) are necessary to rate activated sludge. Higher levels of pollution only result in a partial treatment. In addition, there are other important pollution parameters such as ventilation periods and sludge load, i.e. the ratio of daily BOD_5 volumetric load to the sludge quantity operating in the sludge activation tank. Oxygen supply at full treatment in compressed air basins should be 1.2–2 Nm^3 air/E · d and in basins with surface ventilators 1.2–2.0 O_2/g BOD_5. An O_2 content of 1–3 mg/l must be guaranteed from the air supply in all parts of the ventilation basin.

Other waste water treatment processes: →: Activated sludge process; Electro-m-process; Ion-exchange processes; Katox-system; Methanation in the biogas process; Reverse osmosis process.

Waste water treatment by plant biology Biodegradation of municipal waste water can be achieved with the aid of marsh plants (rushes, reed, irises, etc.). A promising alternative to the conventional waste water treatment technique presents itself for areas difficult to develop infrastructurally. With low maintenance costs, little care needed, the long residence times, the high biodegradation rates and the almost complete avoidance of problematic residual matter (sludge), this process presents an alternative solution. In this method, the waste water is transported into special plant beds, which are sealed against the subsoil, similar to a foil basin. Optimisation of the sediments is required, on whose composition the efficiency of energy use of degradation is crucial. The physical, chemical and biological processes take place in the ground including the metabolic activity of micro-organisms. The plants are first and foremost responsible for the reliable performance (hydraulics) of sediments and for the absorption of degradation products. The natural degradation mechanisms can be used to extract phosphorous or nitrogen compounds, for example, via the structure of organic materials (plants and micro-organisms) and the immobilisation on the substrate of the sediments of the waste water chain. The large area required, the feed of the plants to be harvested (due to possible contamination with heavy metals), the reduced degradation performance in the cold season (→ Waste water treatment plants) as well as possible odour nuisance are all problematic.

Waste water treatment plants degrade waste water materials biologically, adsorb or filter harmful pollutants in the waste water or allow untreated waste water to run through into the outfall channel (body of water). The drawing off of textile waste water to a central waste water treatment plant using a biological stage and common treatment with domestic waste water is the norm. Insufficient effluent values with regard to TOC, DOC and surface tension usually ensue from washing and rinsing agents, complexing agents amongst other textile chemicals difficult to degrade.

In the field of biodegradability (besides the actual degradation, the term "biological elimination potential" also includes adsorption processes) a satisfactory uniformity in the test methodology is still lacking. Nevertheless a fundamental discovery is almost generally accepted: the "real" elimination, which includes the substance in question along with its possible conversion and partial degradation products is, for example, ascertained with the aid of DOC evaluations in the water phase of activated sludge, and is important. On the other hand, only one so-called primary degradation is recorded with the traditional "detergent criteria" MBAS (methyl blue active substance) and BIAS (bismuth-active substance), namely that first degradation stage, which is normally shown in detergents by the disappearance of disruptive foam formation.

The waste water supplied to the waste water treatment plant has a certain pollution from organic/chemical matter. The Tab. gives an overview and obligatory approximate figures. The terms TOC (Total Organic Carbon) and DOC (Dissolved Organic Carbon) are observed by name. TOC is a measure of the total contents of organic/chemical compounds in the sediment; but not filtered waste water. DOC on the other hand, is for the contents of purely dissolved organic/chemical compounds (membrane filtrate) (→ Summation parameters).

cumulative parameters		I	II
BOD_5	mg O_2/l	200–400	50– 500
COD	mg O_2/l	300–600	200–2000
TOC	mg C/l	100–200	70– 700
DOC	mg C/l	50–150	50– 500
MBAS	mg MBAS/l	2– 10	2– 20
BIAS	mg BIAS/l	0.2– 3	0.2– 10
OSP	mN/m	38– 50	35– 55

Tab.: Cumulative parameters for the analytical evaluation of effluents and effluent content substances (OSP = surface tension).

The current state-of-the-art increasingly determines the demands put on waste water treatment plants. Particular waste water structures force related problems to be solved, which also require external measures from time to time, besides classical treatment processes. This can and should return to basic product manufacture. A significant objective of future waste water treatment will consist of avoiding and/or substituting retardants of toxic and biodegradation processes. The short-term degradability and the consideration of possible intermediate degradation products should be increasingly considered in the choice of chemicals and

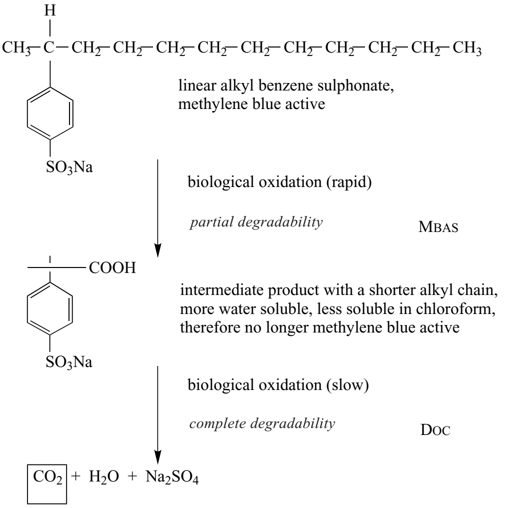


Fig. 1: Diagram of partial and complete degradability.

production processes. Pretreatment measures should be efficiently co-ordinated with waste water treatment plants and should be operated in a co-ordinated way. Total treatment with several treatment stages mounted side by side is state-of-the-art, but results in above average increases in costs. Economically tenable solutions should be sought in combination with textile finishing processes. A large proportion of textile waste water mixed with domestic waste water results in some moves for joint treatment. The biocoenosis operating in an aquatic medium can be adapted to particular waste water structures within certain limits. Extreme values (temperature, pH, etc.) which are too high result in restraints, with losses in performance up to the prevention of the aeration activity.

The essential features of textile waste water compared with domestic waste water are shown in the varied parameters in the following list:

temperature
pH
P and COD load
heavy metal portions
hydraulics
chloride
AOX
dye
surfactants
phosphonates
nutrient ratio
sulphate

While the unbranched alkyl chain is degraded quickly from the chain end by micro-organisms, the aromatic ring reacts in a resistant way. An organic/chemical intermediate product remains in the water despite an “outwardly” good degradation reaction. The MBAS method indicates “complete” degradation, the DOC determination in the same test medium compares with incomplete degradability in reality (Fig. 1). Both cases are quantitatively represented by Fig. 2 (top and bottom curve). The middle curve also indicates the DOC elimination, but with the distinction that activated sludge was used with its known high elimination performance, instead of the very diluted bacterial suspension.

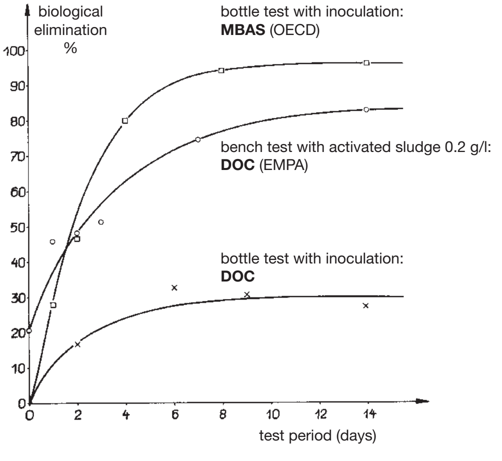


Fig. 2: Biological elimination in accordance with three different test methods.

The choice of the biological test medium, which either, as in the OECD “selection test”, may consist of an inorganic nutrient solution, inoculated against bacteria (bottle test), or activated sludge following the event in the waste water treatment, is unclear. Finally the activated sludge method can be carried out as a flow test or, with similar results, simplified, as a level test (→ Waste water evaluation).

The textile expert, who is responsible for the performance of the operational waste water on the biological waste water treatment plant, will generally fall back on the flow or level test with activated sludge in order to come as close as possible to the ratios in practice (in accordance with Schefer).

Waste water treatment plants are always multi-stage (Fig. 3). The associated waste water treatment process stages in a waste water treatment plant consist of:

a) mechanical operating stage,
b) biological operating stage,
c) chemical operating stage.

Fig. 3: Large-scale waste water treatment plant.

In the interests of an optimised total performance each treatment stage has a special industrial task to perform. Possible waste water treatment process stages should be briefly explained. As a comprehensive examination of all waste water treatment processes would be too costly, the processes, which are most often used, should be examined more closely.

I. Various functions can be led to the surge tank within waste water treatment, which may have a supporting effect on the waste water treatment process and may consequently increase the efficiency of the entire waste water treatment plant. Firstly, the surge tank performs a mixing and buffer function, secondly, a reduction of the contaminant load may already take place in the surge tank. Textile finishing waste water accumulates in varied ways in quantity and concentration conditioned by the production rhythm. At first, concentrated dye liquors accumulate, for example, during the draining off of a dyeing machine; on the other hand, in the following rinsing processes waste water has a decreasing concentration. Moreover this waste water accumulates spasmodically, only on completion of a process. So firstly the function of the surge tank is to absorb the waste water surges and secondly to mix the high and low concentrated waste water, so there is a dual function with regard to quantity and concentration. Such a comparison may be of great importance for an associated biological waste water treatment stage. A constant waste water residence time is guaranteed within this by a constant stable inflow to the biological stage. A contraction of the residence time through a spasmodic, strong hydraulic loading, along with a falling degradation performance in the biological stage, is avoided by connecting a surge tank in series. This also applies with regard to the concentration of the waste water. By comparison, an almost constant supply of nutrients is safeguarded to the biological stage. No shortage and/or excess supply of nutrients occurs due to fluctuations in concentration; this also secures a stable degradation of the waste water materials. The surge tank has a supporting role in the process stability of a biological waste water treatment stage connected in series. There is a definite possibility of the reduction in the contaminant load already in the surge tank. As the most varied chemicals are used in textile finishing, a compensation of chemical reaction properties already takes place in the surge tank, for example, electrolytes neutralize acids, and reducing agents and oxidizing agents are mutually eliminated. If the parameters of temperature and pH are considered in addition and kept in the physiological range, it is possible to settle bacteria in the surge tank. These bacteria can then produce a certain degradation in the contaminant load during the storage of waste water. As most processes in biological waste water treatment run under aerobic conditions (in the presence of oxygen), a sufficient supply of oxygen should be guaranteed in the surge tank.

With heavy bacterial activity, the surge tank should therefore be ventilated, or otherwise a high oxygen depletion causes the occurrence of anaerobic conditions and unpleasant odours. With bacterial activity, activated sludge accumulates due to aggregation of micro-organisms, which should inevitably be removed from the surge tank in order to avoid a complete silting up. An extraction or ploughing device should therefore be included in the design when building such mixed reservoir. The use of a surge tank to reduce contaminants can also be carried out by innoculation with special bacteria for the elimination of certain waste water materials. In addition, the creation of aerobic and anaerobic zones is possible using a selective ventilation of the surge tank (e.g. only the upper part of the tank is ventilated). Besides oxidative, i.e. aerobic degradation processes, the metabolism of such waste water materials, which are degraded via a reductive step (i.e. under anaerobic conditions), is also already facilitated in the surge tank. If the entire waste water flow from a textile finishing is not treated, but only their segregated streams, the mixture drops in the surge tank.

II. In mechanical waste water treatment, the dissolved matter, which can be removed mechanically, should be so removed from the waste water. Firstly, the coarse solids are removed from the running waste water by fixed or movable equipment, such as rakes, screens, gravel filters and similar. Secondly, the difference between the specific weights of the material to be removed and that of the water is used for precipitation and removal via settling and flotation processes. This is the case in sand traps, which are used for the removal of dense mineral material (e.g. sand, stone), in precipitation plants for the removal of floating material (oil, fat, benzine, etc.) and in sedimentation tanks for the removal of suspended sediment. The method of mechanical waste water treatment used depends on the waste water composition and the demands on the complete waste water treatment system.

III. The chemical processes for waste water treatment are essentially understood to mean methods, which are based on chemical or physical/chemical reactions. They are thereby in conflict with, or supplemented by, biological treatment processes, in which the purification effects are, to a large extent, conditioned by bacterial, enzymatically catalysed metabolic reactions. Moreover inorganic matter is only slightly (≈ 5%) eliminated in the biological system, while chemical processes facilitate a removal up into the trace range. Such processes are stable and insensitive to poisons and fluctuations in concentration and quantity as far as the system is concerned. Biological waste water treatment processes have limitations and are therefore sometimes ruled out for the treatment of industrial waste water on the basis of its complex waste composition as well as a high rate of pollution, which is not biologically ascertainable. Great importance will be given to the chemical waste water treatment processes in the future for safeguarding the aquatic part of the ecosystem for the same reason. These processes are often used in conjunction with other waste water treatment processes. In chemical waste water treatment processes, distinctions are made in principal between reactions with and without material conversion.

a) The following basic operations include the undissolved matter:
   - sedimentation,
   - filtration,

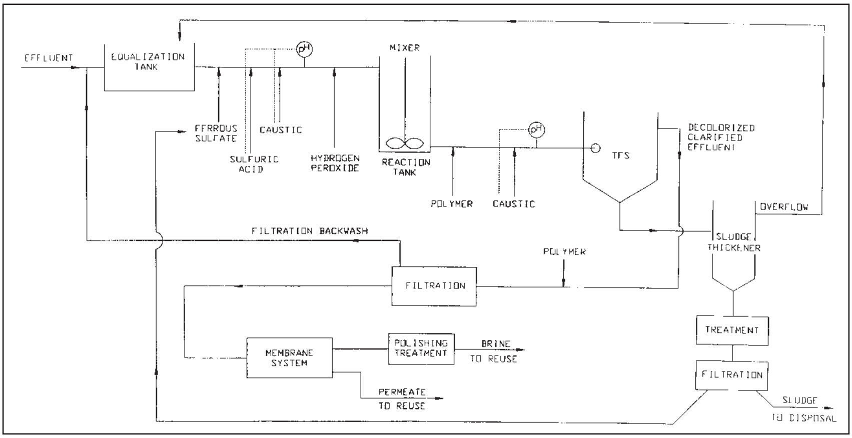


Fig. 4: Textile Dyeing Effluent Reuse-Flow System (Gaston County) (TFS = Tangential Flow Separator).

- flocculation and precipitation,
- adsorption,
- flotation.

b) The following basic operations, which are essentially based on physical/chemical reactions, are used to include the dissolved matter without material conversion:
  - adsorption,
  - extraction,
  - membrane filtration,
  - distillation.

c) Basic operations to include the dissolved matter including chemical reactions with material conversion are:
  - neutralization,
  - precipitation,
  - oxidation,
  - reduction,
  - ion exchange.

Through the specific combination of the above-mentioned basic operations it is possible to construct waste water treatment processes (Fig. 4), which actually make any approach to a problem soluble. The different basic operations are described in the reactions below. The operations with material conversion are described first.

- Neutralization: Acid waste water is adjusted to around the neutral point with basic reaction agents and alkaline waste water, with acids to a given pH range (i.e. in waste water technology between pH 6.5–9). This pH range is required for the introduction into sewerage systems, waste water treatment plants and bodies of water.

  Example: $HCl + NaOH \rightarrow NaCl + H_2O$

- Precipitation: not easily water-soluble material, which is precipitated as sludge and detached. It is produced by chemical conversion during precipitation.

  Example: $Fe_2(SO_4)_3 + 3\ Ca(OH)_2 \rightarrow 2\ Fe(OH)_3 + 3\ CaSO_4$

- Oxidation: certain waste water materials can be removed by chemicals acting as oxidants (chlorine, permanganate, ozone and similar). An example is the reaction of cyanides with chlorine.

$$\begin{aligned} NaCN + HOCl &\rightarrow NaOH + CNCl \\ CNCl + H_2O &\rightarrow HCNO + HCl \\ 2\ HCNO + 3\ Cl_2 + 2\ H_2O &\rightarrow 2\ CO_2 + N_2 + 6\ HCl \\ HCl + NaOH &\rightarrow NaCl + H_2O \end{aligned}$$

- Reduction: the conversion of 6 valency to 3 valency chrome is called an example of reduction, because only in the 3 valency form does chrome form a product insoluble in water.

$$2\ CrO_3 + 3\ SO_2 \rightarrow Cr_2(SO_4)_3$$

  The Cr(III) ion formed from alkaline additions can then be precipitated as a hydroxide.

- Adsorption: these operations with no material conversion, but with phase change cannot be formulated so simply, as they are based on complex thermodynamic or electrochemical processes, whose complete sequence consists of several increments. Essentially concerns adsorption effects and/or diffusion through boundary layers. The adsorption can be represented schematically as follows:

$$[\text{water + contaminants}] + \text{chemicals} \rightarrow \text{water} + [\text{chemicals + contaminants}]$$

  The contaminants do not experience any chemical change; they are merely adsorbed onto the surface due to their charge and the adsorptive force of the chemical. The contaminants may be dissolved or undissolved in water; they may be solid, liquid or gaseous. The adsorbent, e.g. activated carbon, is in solid form and has an extremely large surface area.

- Chemical flocculation and precipitation: a special case of the industrial structuring of adsorption is chemical flocculation and precipitation, whereby the adsorbent is formed from a chemical reaction with material conversion in the water. The reaction occurs in two stages:

1. Formation of the adsorbent:

$$FeCl_3 + 3\ NaOH \rightarrow \underset{\text{adsorbent}}{Fe(OH)_3} + NaCl$$

2. Adsorption process:

$$[\text{water} + \text{dye}] + Fe(OH)_3 \rightarrow \text{water} + [\text{dye} + Fe(OH)_3]$$

The reaction product in this example is an adduct of iron(III) hydroxide flocks and dye.

- Flotation: in chemical flocculation and precipitation the adducts of flocculation agent and contaminant have a larger specific weight than water and are separated by sedimentation. In flotation, the adducts are specifically lighter than water, due to a deposit of micro-fine air bubbles, float and can be removed from the surface.
- Extraction: without altering the chemical composition, the specific material from the aqueous phase changes into a non-aqueous liquid phase, in which it has a greater solvent power.

Other processes: oxidation processes are mentioned as further processes of chemical waste water treatment, which are initiated by chemicals with an oxidizing effect, and/or cannot be regarded as biological oxidation processes. With pressure oxidation and wet combustion the organic waste water materials are oxidized into carbon dioxide and water with atmospheric oxygen, at high temperatures (150–250°C) and pressures between 20–150 bar. By this method “wet” combustion of oxidized substances is achieved. Oxidation using ozone has still not become very widespread in waste water treatment because of the technical complexity and associated costs. It is simply mentioned here, as it is used repeatedly in the textile industry in a process developed by the Scholl Company. The “Scholl process” represents a combined oxidation/flocculation and precipitation process, in which waste water materials are oxidized by air enriched with ozone (in which an extensive decoloration is usually achieved) and are then subject to flocculation and precipitation. Oxidation by chlorine is frequently used in waste water containing cyanide from plating works. Besides the cyanide oxidation, ammonium is also removed. With the aid of oxidation through chlorination, disinfection, destruction of dye and odourous material, decontamination and maintaining waste water freshness are striven for on the other hand. Reduction processes are seldom used in chemical waste water treatment. They are possible if waste water contains easily reducible harmful constituents, as may be the case in waste water from plating works, if it contains a lot of chrome. Chrome reduction is necessary, in which sulphuric acids and their salts such as iron(II) ions, among others, are possible reducing agents.

IV. The biological treatment of waste water is the norm in waste water treatment. The microbial degradation of organic substances, widespread in nature, is used as the basis for the biological and/or biochemical treatment technique. This process of natural self-treatment of surface waters is imitated in biological treatment processes, in which the process is essentially accelerated by increasing the concentration of bacteria, etc. and by oxygen supply in the form of air. The microbial degradation of organic substances is chiefly carried out under aerobic conditions and may thus be regarded as an oxidation, and thereby, elimination of waste water materials via atmospheric oxygen, with the exchange of micro-organisms. Two groups can be distinguished in micro-organisms:

a) primitive forms, the prokaryotes (cells without a nucleus) such as bacteria and blue-green algae;
b) higher developed forms, the eukaryotes (cells with a nucleus) such as fungi, algae and protozoa.

Prokaryotes have the advantage that they are insensitive with regard to external effects such as high temperatures and that they have a conspicuously high rate of growth. Organic waste water materials are partly mineralised into carbon dioxide, water and inorganic salts (chiefly nitrate, sulphate and phosphate) and partly enlisted for the construction of new cell substance and as an energy provider. Adsorption of the organic substance on the cell mass is intrinsic to the actual oxidation process. The oxidation process can be described approximately by the following reaction equation:

$$\begin{aligned}&\text{organic substance} + n\ O_2\\ &\rightarrow CO_2 + H_2O + NH_4^+ (\rightarrow NO^-{}_3) + SO2^{-}_{4}\\ &+ \text{new cell mass} + \text{energy}\end{aligned}$$

The aerobic biodegradation of waste water materials is carried out in two stages. The degradation of carbon compounds is performed first and only in the second stage does the nitrification of nitrogen compounds take place. The metabolism of micro-organisms represents combined degradation (dissimilation) and construction (assimilation) processes. The oxygen consumption of micro-organisms, which directly refers to the physiological recycling of the nutrients introduced to the cell from outside, is described as substrate breathing. If there are not enough organic substances for further cell construction, the bacteria consume their own, likewise organic cell substance on demand of oxygen. The resulting oxygen consumption is described as endogenous breathing. The metabolic processes are branched and multiple combined systems of separate biochemical reactions. The transition of the waste water materials is carried out in many smaller steps, in each of which the surmounting of an energy threshold is required in order to transfer the reacting substance into a reaction-ready state. In addition, enzymes are formed from the micro-organisms for intracellular and extracellular reactions, which catalyse the processes. This enzyme-catalysed reaction can be described as follows: Organic substances contained in the waste water enter into a complex with the enzyme, whereby it is transferred into a reaction-ready state. This facilitates the decomposition of the substrate. The enzyme is not consumed as a typical catalyst in the reaction. Favourable living conditions exist for micro-organisms if the necessary nutritional salts (nitrogen and phosphorous) are present. If they are missing, as is frequent in industrial waste water, they must be compensated for. There should be a minimum ratio

BOD : N : P = 100 : 5 : 1 in waste water
BOD : N : P = 90 : 5 : 1 in sludge.

The demand for trace elements is so small that it can usually be covered by the waste water itself. Moreover the biological waste water treatment is tied to a particular BOD_5 : COD ratio. The following should apply:

for domestic waste water ≈ 0.5
for commercial waste water < 0.5

Small values of this ratio indicate that organic matter is contained in the waste water, which is accessible for the micro-organisms only with difficulty or not at all. The number of chemical compounds which can be converted by micro-organisms is large, provided that the natural bases of life remain. The following are prerequisites:

a) sufficient quantity of oxygen;
b) sufficient quantity of food;
c) favourable living conditions, for example, moisture, settlement areas, as well as temperature and pH in the physiological range (pH ≈ 5–9);
d) no bacterial poisons.

It is noted for d) that adaption phenomena in bacteria, even in extreme waste water compositions, can result in adequate treatment performance. For example, cyanide in a concentration of 1 mg/l normally has a highly toxic effect; biological plants with adapted micro-organisms can, however, definitely tolerate cyanide in a concentration of 50 mg/l.

Anaerobic bacterial work, i.e. work without access to air, is applied in waste water treatment only in special cases, e.g. in denitrification. The anaerobic conversion of organic waste water materials has great status in the decoloration of waste water because most dyes used in textile finishing can be classified as persistent under the conditions of aerobic biological treatment. The breaking and thereby decolorizing of most dyes is carried out via a reductive step, in which the chromophore group is split. The degradation products resulting from this step can therefore be extensively oxidatively degraded in the subsequent reactions. The decolorizing performance of aerobic biological processes can therefore be seen primarily in the adsorption of dye molecules on the biomass. The actual process of decolorizing is carried out in later sludge decaying, which takes place under anaerobic conditions. The technology of biological waste water treatment processes has meanwhile achieved a high level. These processes are chiefly used in the treatment of municipal waste water, however endeavours are made to use biological processes exclusively for the treatment of industrial waste water. Two possibilities essentially exist for biological treatment:

1. Natural processes, which are generally based on agricultural waste water exploitation and use of waste water ponds.
2. Technical processes such as activated sludge biologies or, more correctly, activation processes and carrier-fixed biologies.

The biological treatment is carried out with “activated sludge” in waste water activation plants. The activated sludge mainly consists of flock-forming micro-organisms, which are concentrated in an enormous number in a small space. Their surface area is 2000–10 000 m^2/m^3 ventilation space. Artificial ventilation ensures that the bacteria have adequate oxygen at their disposal and the flocks are kept in balance. The bacteria would die if the sludge was deposited on the floor of the basin. An oxygen content of 2–3 mg O_2/l is regarded as optimum. The biological treatment of waste water is carried out in two stages. To obtain energy a part of the organic contaminants is oxidized first and new cell matter is formed at the same time. In a second phase the bacteria are gathered together into easily settleable flocks. The flakes of the activated sludge consist of a slimy element, in which bacteria and protozoa live. Carbon, nitrogen and phosphorous are built in approximately in the ratio 5 : 1 : 0.5. The oxygen demand of an activation plant follows the BOD_5 degradation and the ventilated quantity of sludge. If there is so much air that the degradation ability of the activated sludge can be fully developed, the oxygen consumption is dependent on the sludge pollution. Sludge pollution is understood to mean the quantitative ratio of contaminants in the waste water to the bacteria in the activated sludge. With lower sludge pollution endogenous breathing predominates; with higher sludge pollution the substrate breathing prevails so that so much new cell matter is produced that a part of it has to be removed from the system as superfluous sludge. The reproduction of the bacteria can be accelerated by an oversupply of food, but the bacteria would not withstand the reproduction of the food supply, and a partial treatment of the waste water would be the result. Activation plants normally consist of preliminary sedimentation tanks, ventilation or sludge activation tanks and a secondary settling tank.

Preliminary sedimentation tanks are usually settleable basins, in which the solid contaminants are settled in a one to two-hour period. In the subsequent sludge activation tank the water is mixed by air with the activated flocks or the “activated sludge”, which is pumped back as return sludge to a secondary settling tank. The dwell time is approximately 8 hours in this stage. In the secondary settling tank, the sludge added to the waste water is precipitated again by settling, removed and either drawn off as surplus sludge or re-used as return sludge. Despite intensive construction of mechanical/biological waste water treatment plants, the pollution of rivers and lakes with various contaminants is still increasing. Plant nutrients such as phosphorous and nitrogen, non-easily degradable organic matter, suspended matter, toxic substances amongst other water-harming substances can often only be reduced effectively with more extensive treatment stages. The increasing water pollution from already treated waste water reveals three areas:

a) Eutrophication of the body of water: eutrophication phenomena can only be avoided and/or kept under control by reducing the supply of nutrients. For waste water treatment this means the targeted elimination of algae nutrients, phosphorous and nitrogen.
b) Oxygen economy of the body of water: the oxygen-feeding load of already mechanically/biologically treated waste water can chiefly be put down to suspended matter in the waste water treatment plant run. The oxygen economy of bodies of water can be clearly eased by extensive retention of residual suspensions. Such material can be included via the BOD_5.
c) Accumulation of refractory organic substances: refractory organic substances are not accessible to any biological processes. Biological processes do not alter their concentration in the body of water so that there is a continuous accumulation. Refractory matter can be summarily included via the chemical oxygen demand (COD) and the carbon content (TOC).

Water H_2O. Molecular weight 18. Clear, colourless, odourless, tasteless, chemically neutral (pH 7); freezing point 0°C, boiling point 100°C (both at 1 bar pressure). Greatest density of 1 at + 4°C. Density above and below this temperature is lower (e.g. ice = 0.9168). Liquid/solid transition means volume increase by $^1/_{11}$ in closed vessels (tubes, containers, and fissures in buildings), therefore pressure effect (burst pipe) from freezing. The viscosity at 0°C is approx. 8 times greater than at 100°C. Mean specific heat between 0°C and 100°C = 1 (temperature increase of 1°C = 4.1868 joules), from ice at 0°C = 2.093 joules, from water vapour at 100°C (and constant pressure) = 1.934 Joules. Heat of fusion and/or solidification at 0°C for 1 kg (ice-water or vice versa) = 334.944 joules. Heat of vaporisation per kg (water at 100°C, steam at 100°C) = 22 483.1 joules. Steam pressure (equilibrium pressure of water/water vapour) at 100°C = 1 bar (saturated steam), greatly increasing with increasing temperature. Steam with higher (than normal) pressure is supersaturated, with lower pressure, unsaturated. The electric dipole character of the water molecule (→ Dipoles) is technically important; it partly decays (dissociates) into its electrically charged molecular constituents (ions) and is (theoretically): $H_2O \rightarrow H^+ + OH^-$ (but practically: $2\ H_2O \rightarrow H_3O^+ + OH^-$) because the unstable hydrogen ions are combined with a neutral water molecule in the formation of H_3O ions. The molecules of water exist in the main as multimolecules $(H_2O)_n$ stored together (cluster, → Iceberg structure of water).

Water absorption of porous substrates A typical curve for the weight increase of a macroporous film through water deposits is shown in Fig. 1. Such a functional correlation can be described by the following equation:

$$c_t = c_\infty \cdot \left(1 - e^{(-k_a \cdot t)}\right)$$

whereby the weight at any moment is described by c_t and the weight after the time $t \rightarrow \infty$ by c_∞. The speed constant of water absorption is k_a. The dimension c_∞ corresponds to the max. water absorption of the macroporous film. The following expression is obtained by converting the equation:

$$-\ln\left(1 - \frac{c_t}{c_\infty}\right) = k_a \cdot t$$

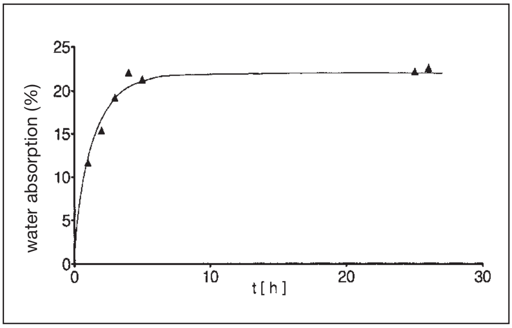


Fig. 1: Water absorption of a polyurethane film (PU 555), out of which starch (1%) was released, as a function of time (according to Schollmeyer).

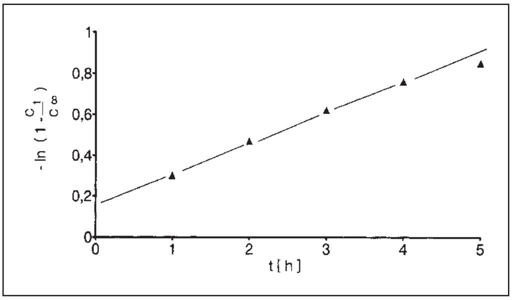


Fig. 2: Application of $-\ln(1-c_t/c_\infty)$ against time t to determine the speed constant k_a of the water absorption of a polyurethane film (PU 555), out of which starch (1%) was released, as a function of time (according to Schollmeyer).

A straight line, whose gradient is k_a, is obtained by applying $-\ln(1-c_t/c_\infty)$ compared with the time t. In Fig. 2, the experimental data shown in Fig. 1 is applied in accordance with the equation.

Independent of the size of the pores, which is determined by the molecular size of the various substrates dissolved out, it is observed that the speed of water absorption is smaller with increasing substrate concentration in the film (in accordance with Schollmeyer).

Water and oil repellents Finishing agent for →: Waterproofing; Oil-repellent and/or → Soil-resistant finishing.

Water as finishing medium Water is one of the essential production resources in textile finishing. This is already apparent in the descriptions used for one task or another:

- material to do work as steam,
- coolant for the dissipation of the heat of condensation of steam or for temperature control of machines,
- heat carrier in liquid or gaseous form for energy control and for heating in the industrial sector,
- reaction medium and solvent in liquid form.

In addition, it is used for treatment activities, in the sanitation area as washing and drinking water and as water for fire extinguishers. The properties of water in the form of liquid and vapour as well as the properties of water as regards pressure and temperature should be observed to safeguard a faultless plant operation. The variation of state occurring in the course of a finishing process, the change in the aggregate state during steaming and condensing, the interactions with the design materials as well as the contact with the fabric during open circulation thereby play a special role. Appropriate demands for the quality of the water used and the steam produced are necessary in the operational practice in view of the operating parameters, the design layout of the plant and the use of materials. The expenditure required for processing as well as the limited quantities available, demand an economical use of water, which can above all be achieved by extensive circulation control.

A considerable portion of the relatively low known reserves of freshwater is used industrially in modern social systems (Fig. 1). While the large part of the coolant quantities required for energy generation, up to the higher temperatures, hardly pollute the environment, other industrial waters are more or less mixed with materials, which must be removed before the water is put back into natural circulation.

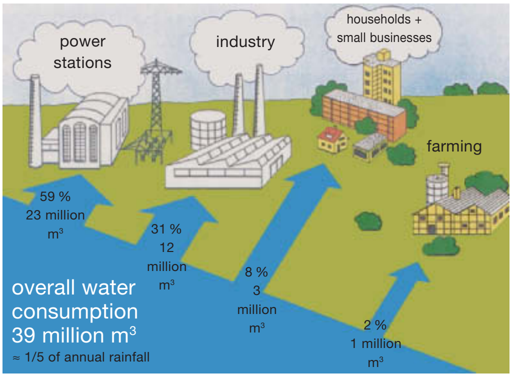


Fig. 1: Water demand in the former West Germany (1989) (according to Röhm).

There is practically no known industrial process, which is not dependent directly or indirectly on water. Besides the costs of obtaining water, the question is therefore also put for each industrial operation in accordance with the costs for → Waste water treatment, as leakage of untreated waste water must be ruled out. Many industrial operations therefore make a special effort to control the water in circulation. But this circulation control, on the other hand, again has the disadvantage that the residual quantities of waste water are thereby extremely highly polluted and the treatment processes necessary are especially complex and expensive. Endeavours are therefore made to start waste water treatment at the root cause, in industry (Fig. 2). The mixing of different types of sewage from different industrial undertakings immensely aggravates the waste water treatment. Waste water treatment is therefore chiefly carried out as follows:

1. Pretreatment at the cause, i.e. separation of undissolved, suspended solid matter of inorganic or organic type.
2. Chemical/physical treatment for the separation of dissolved inorganic or emulsified organic materials.
3. Treatment of dissolved organic contaminants using aerobic and anaerobic biological processes.

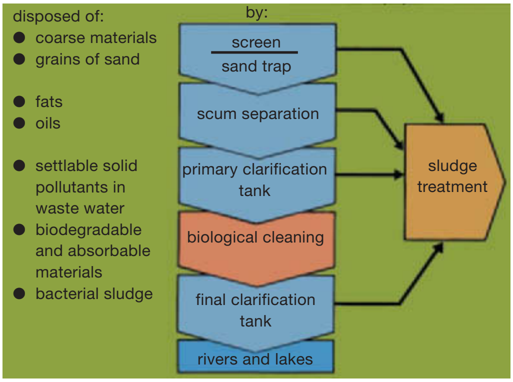


Fig. 2: The technique of waste water treatment (according to Röhm).

4. In future, public waste water treatment plants will be retrofitted by a so-called third stage (N elimination).

Viewed thermodynamically, water has a certain heat content per mole (enthalpy H). The change in heat energy as a result of a chemical reaction of the water can be expressed as the difference between the heat content of the reaction educts and the heat content of the reaction products.

$$H_2O\ (g) \xrightarrow{1000\ K} H_2\ (g) + {}^1/_2\ O_2\ (g)$$

$$\Delta \bar{H}_{reaction} = (\bar{H}_{H_2O\ (g)}) - (\bar{H}_{H_2\ (g)} + {}^1/_2\ \bar{H}_{O_2\ (g)})$$

$$\Delta \bar{H} = 272\ \text{kJ/mole water vapour}$$

The representation of heat transfer in reactions by ΔH is described as catalytic combustion, which is positive for endothermic (heat absorbing) reactions and negative for exothermic (heat producing) reactions. The signs of the heat transfer are altered by reversing the reaction direction:

$$H_2\ (g) + {}^1/_2\ O_2\ (g) \xrightarrow{1000\ K} H_2O\ (g)$$

$$\Delta \bar{H} = -272\ \text{kJ/mole}$$

Whether a reaction is endothermic or exothermic depends on several factors. Sodium chloride is dissolved in water endothermically, caustic soda liquor exothermically, however. On the one hand energy will be expended in this dissolving process in order to separate the ions oppositely charged in the crystal from each other (lattice energy, ΔH_{git}). Energy is released however if the ions separated from each other are taken up around polar water molecules (Fig. 3) (hydration energy, ΔH_{hyd}). The molar solution heats are not sufficient to account for the relative solubilities of different compounds in water; endothermic solution processes would be impossible if the heat transfer was the sole driving force for the reactions. Just as each chemical reaction is linked to an enthalpy change ΔH, an entropy change ΔS also occurs with it. The entropy change can be simply established for some processes: If water evaporates at constant pressure, the heat, which is supplied to the system in order to achieve this conversion, corresponds to the heat of vaporization ΔH_d. As this process runs endothermically, ΔH_d is positive. The change in entropy for this process can be described by the relation

$$\frac{\Delta H_d}{T} = \Delta S$$

ΔS is positive in this process, as the probability of a highly random gas phase is greater than the probability of the more strongly ordered liquid phase. As the temperature is directly linked with the molecular weights, the entropy change ΔS in the system with the same enthalpy change ΔH, should be larger, the lower the temperature at which the heat effect occurs. The entropy S of a system is larger, the higher its temperature. At low temperatures the disorder of the systems is small and a phase transition such as evaporation causes a large entropy change. At high temperatures the systems, however, have such a great disorder due to the thermal movement of the molecules that a phase transition means a much lower change in the disorder or entropy.

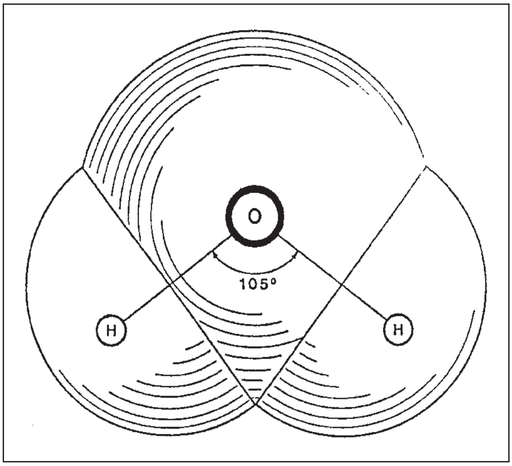


Fig. 3: Water molecules possess a dipole due to their angled arrangement.

Gas molecules move more quickly and have more energy (and enthalpy) than molecules in a liquid. The same heat energy is released if water vapour condenses:

$$H_2O(g) \rightarrow H_2O(l) \qquad (\Delta H = -42\ \text{kJ/mole})$$

The formation of H bridges in water is considered as a predominantly co-operative phenomenon, which is why in most cases, if an H bridge develops, others are immediately formed due to resonance effects and vice versa. If an H bridge breaks in the cluster, it decays immediately. The life of the cluster is very short, 10^{-10} to 10^{-11} s. The image (Fig. 4) of a high frequency, structural flicker (flickering clusters) is consequently produced.

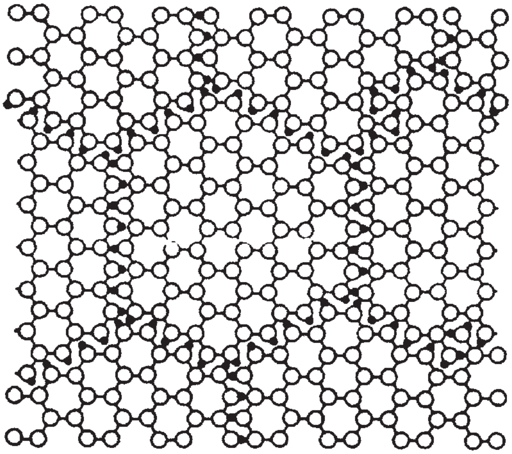


Fig. 4: Cluster structure of water in liquid form at 0ºC.

Tab.: Number of water molecules of average cluster size in H_2O (very idealized).

T [°C]	cluster size
0	700
100	50
200	10
240	8
310	4
370	1–2

An idealised structural image of the water, which probably corresponds well to reality, is shown in Fig. 4. The oxygen atoms are represented by open circles, the bridge-combined protons by lines and the free, unbonded protons by filled circles. Assuming that the free OH groups are located on the surfaces of the cluster, the temperature dependency of the cluster size was estimated (see Tab.). Formation and decay of hydrogen bridges in the water represent an equilibrium reaction. The position of the association equilibrium is described by the change in the free enthalpy ΔG_{ass}. Signs and sizes of ΔG_{ass} are essential for the value of the association constant K_{ass} and decide whether the association equilibrium is on the part of the association (negative ΔG_{ass}, $K_{ass} > 1$) or the monomers (positive ΔG_{ass}, $K_{ass} < 1$). In most hydrogen bridge equilibria K_{ass} is < 100, but possibly even smaller than 1, so that ΔG_{ass} adopts small negative or positive values. When the temperature is increased, the association constant K_{ass} decreases in accordance with the principle of Le Chatelier, as a consequence of the increasing kinetic energy of the molecules, which results in the gradual break up of the association. For an isothermal process the size ΔG_{ass} is combined with the association enthalpy ΔH_{ass} and the entropy change ΔS_{ass} by the thermodynamic basic logic function:

$$\Delta G_{ass} = \Delta H_{ass} - T\Delta S_{ass}$$

H bridge formation is an exothermal reaction, i.e. ΔH_{ass} is always negative. The position of the association equilibrium is however not only determined by the H bridge enthalpy, but also by the association entropy. The equilibrium is on the part of the associates (negative ΔG_{ass}) if $T\Delta S_{ass}$ is < ΔH_{ass}. As the atomic state of the system increases in the formation of H bridge complexes, ΔS_{ass} assumes negative values in accordance with the second law of thermodynamics. While the energy content of the water shows the actual states of the particles for individual temperatures and explains the macroscopic type of state, the representation in the p/T graph (also referred to as phase, state or vapour pressure graph) facilitates ease of measurement of accessible state variables, pressure and temperature. The lines of the graph (Fig. 5) indicate the conditions under which two phases are in equilibrium next to each other at any one time. The following appear as characteristic:

- triple point, for which all three aggregate states are next to each other at the same time; the values are p = $0.61 \cdot 10^{-3}$ MPa and = 0.01°C

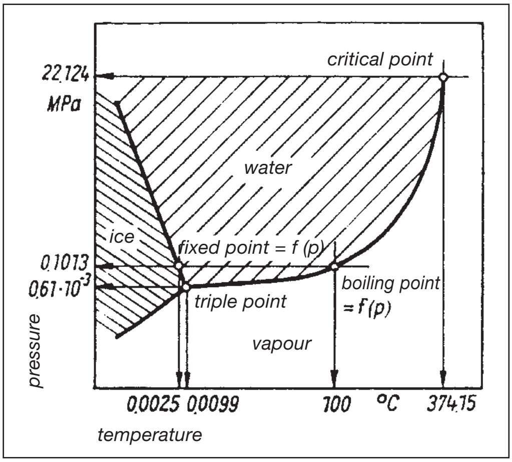


Fig. 5: p/T diagram of water.

- critical point, whereby a (gas) phase still exists above the accompanying critical temperature (ϑ = 374.15°C) independent of pressure. The critical pressure is p = 22.124 MPa.

Phase transitions are always equilibrium processes. Heats of vaporization, heats of fusion and heats of sublimation (ΔH_d, ΔH_{sch} and ΔH_{sub}) always have positive values. Condensation and solidification occur if heat is extracted from the output phase. Melting, vapour pressure and sublimation occur if heat is supplied to the output phase. Because water stores a high amount of energy with vapour pressure, water vapour is a common energy carrier; the molar heat of vaporization ΔH_d is 40 700 J/mole. The statement of ΔH_d = 40 700 J/mole refers to the evaporation process of one mole of H_2O (l):

$$H_2O\ (l) \rightleftharpoons H_2O\ (g)$$

A quantity of heat ΔH = –40 700 J is released again during the condensation of a mole of H_2O (g).

$$H_2O\ (g) \rightleftharpoons H_2O\ (l)$$

Analogous to the definition of the heat content, each material has a certain entropy S and the change in entropy of a reaction is equal to the entropy of the products minus the entropy of the reaction partner. For example, the molar change in standard entropy for the dissociation of water vapour is given by the following relation:

$$H_2O\ (g) \xrightarrow[1.013\ \text{bar}]{25\ ^\circ C} H_2\ (g) + {}^1/_2\ O_2\ (g)$$

$$\Delta \overline{S}^\circ = (\overline{S}^\circ_{H_2\,(g)} + {}^1/_2\,\overline{S}^\circ_{O_2\,(g)} - \overline{S}^\circ_{H_2O\,(g)})$$

Absolute order will rule at the absolute zero point (0 K) in an imagined ideal crystal, and the entropy of such a system is equal to zero. Processes, which comprise an increase in the entropy (ΔS > 0), are favoured or are more probable than processes, in which the entropy decreases (ΔS < 0). The entropy will increase in the following reaction:

$$H_2O\ (g) \rightleftharpoons H_2\ (g) + {}^1/_2\ O_2\ (g)$$

ΔS > 0, as more product molecules of the reaction partners are available in this process.

The efforts to achieve a max. heat emission and the efforts to attain a max. increase in entropy are both driving forces in the chemical reaction, also in the cycle of phase transitions in the water (Fig. 6). A combination of change in enthalpy and change in entropy must determine the course of the phase transition in the water (Fig. 7), which can be used for the prediction of the position of the equilibrium of a chemical system: the change in the so-called free enthalpy or even Gibb's free energy.

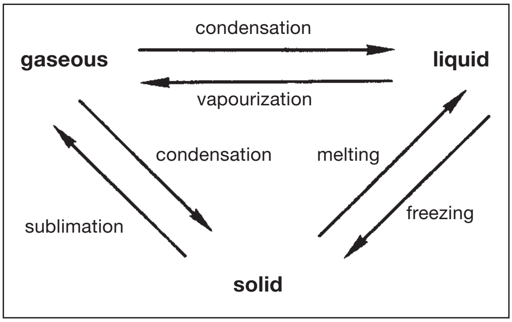


Fig. 6: The cycle of the phase transitions.

$$\Delta G = \Delta H - T\Delta S$$

At constant temperature the change in free energy ΔG is equal to the change in enthalpy minus the change in entropy, multiplied by the absolute temperature TΔS. It can be understood that a reaction is spontaneous when the free energy decreases altogether, whereby it plays an independent role with enthalpy and entropy at any one time. Spontaneity is only achieved by the interaction of H and S. Ice has an entropy of 41 J/K/mole, liquid water of 63 J/K/mole and water vapour of 188 J/K/mole. The energy is consumed in the transition from liquid to gaseous water (ΔH > 0). This endothermic process is nevertheless carried out voluntarily at temperatures above 100°C. The increase in entropy clearly outweighs the loss in enthalpy. With increasing temperature (in K) the importance of the difference in entropy is growing. Both laws of thermodynamics concerning enthalpy and entropy were summarised by Clausius around 1865 as follows: "The energy in the world (cosmos) is constant; the entropy in the world strives (in the long term) for a maximum".

The solubility of a substance in water depends on the change in the free enthalpy of the system, which is connected with the solution process. Polar substances are either constructed from ions or have a polarised electron pair bonding. If the solution of a sodium chloride crystal in water is considered as an example: the water dipoles are taken up with their charge centres by the crystal surface by oppositely charged ions. The ions are hereby released from the grid lattice. The dielectric constant of the water is approx. 80, i.e., the Coulomb attraction force in water is still only $^1/_{80}$ of the Coulomb force in the ionic crystal. The water molecules enclose

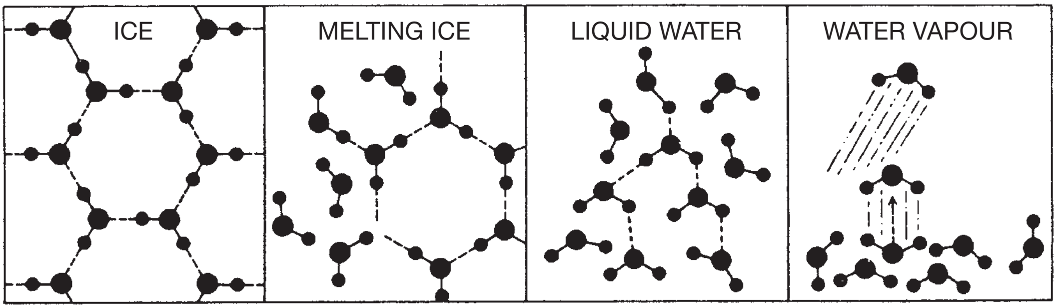


Fig. 7: The disorder increases from ice to liquid water to water vapour: more water vapour bridge-type bonds are dissolved and water molecules start moving past each other freely.

the released ions (hydrate envelope, general solute case): the ion is hydrated (general: solvated). The process is connected with a change in energy. In the case of water, it is called hydration energy and/or enthalpy and general solvation energy and/or enthalpy (sometimes also hydration and solvation enthalpy). It corresponds to ΔH in Gibb's equation. The solvation enthalpy depends on the charge concentration of the ions, i.e., it is directly proportional to the ionic charge and inversely proportional to the ionic radius. It decreases with growing radius for equally highly charged ions. Small, highly charged cations and anions are therefore strongly solvated, e.g.

$Na^+ \rightarrow [Na(H_2O)_6]^+$
$\Delta H = -418.6$ kJ/mole; radius 97 pm
$Al^{3+} \rightarrow [Al(H_2O)_6]^{3+}$
$\Delta H = -4605.4$ kJ/mole; radius 51 pm

Ions are always surrounded by a hydrate envelope in water (aquo complexes). The solvation enthalpy is dependent on the polarity of the solvent and it is inversely proportional to the temperature.

Only a part of the water, which is found in solid polymers, corresponds to liquid water. Thermoanalytical methods, nuclear magnetic resonance and other processes all show that water, which is found in polymers, essentially forms three states, namely so-called non-solidifying, bonded, but solidifying and finally free water. The water molecule layers, which are found on internal or external surfaces of polymers, are no longer entirely free, but "linked" via hydrogen bridges and polar forces of the polymer. For this reason this water can partly no longer enter the ice-like, "frozen" state when cooled below 0°C. A series of investigations has revealed that the mobility of chemical compounds is severely slowed down in this bonded water.

In Fig. 8 the state of the water in polyacrylonitrile fibres was determined calorimetrically (DSC method). The curves described with f_{wf}, f_{wb} and f_{wi} represent the proportions of the three types of water in polymers mentioned above. The results on the vertical broken lines of both graphs are important for the water content under dyeing conditions. It is thus recognised that only approx. 60–66% of the water is released onto both fibres. Only in this proportion is diffusion carried out by dye molecules and ions just as quickly as in aqueous free solution. For this reason, the results of the diffu-

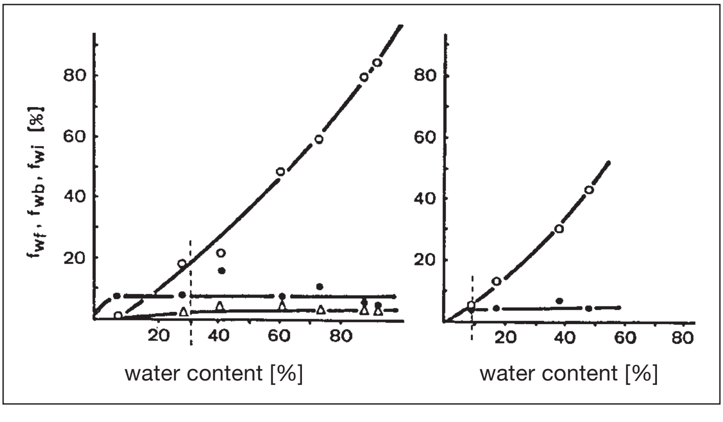


Fig. 8: Proportions of free (O), bonded (·) and "intermediate" (Δ) water in polyacrylonitrile fibres (a) = Dunova; b) Dralon X-100, Bayer) (according to Zollinger).

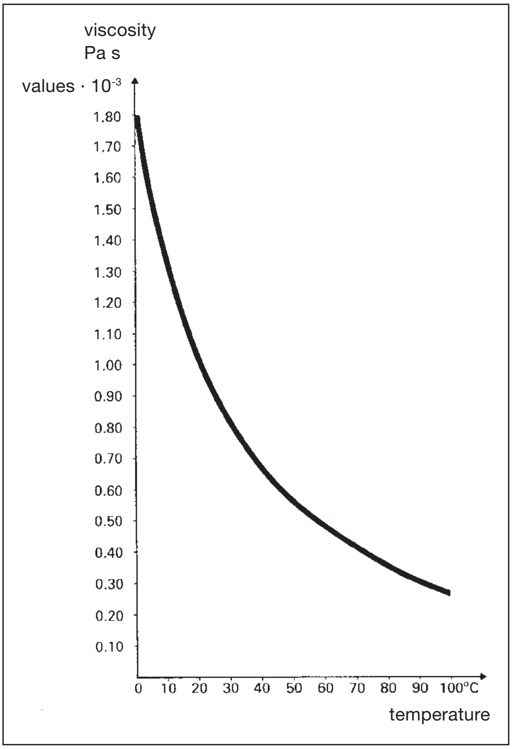


Fig. 9: The effect of temperature on the viscosity of water.

sion of dyes by cellulose membranes also result in calculated diffusion coefficients, which are still somewhat smaller than the diffusion coefficients of these dyes in free water: Cellulose membranes also contain bonded and not solidifying water on the pore walls, in which the diffusion of dye molecules is certainly much slower than in free water (according to Zollinger).

Surface tension and viscosity (Fig. 9) of water decrease with increasing temperature, whereby material to be washed is better moistened and passed through. High operating temperature is given as a reason for this. This also applies to water extraction required by fabrics on the padder. With pure H_2O as the so-called potential electrolyte no ions exist in the solid state. They are firstly formed in the liquid, but also in the gaseous state in interaction with other molecules. This is called a self-dissociation. The following separate steps, which in reality run simultaneously and overlap, are given formally as shown in Figs. 10 + 11.

Ionic formation:

$$H_2O \rightleftharpoons H^{\oplus} + OH^{\ominus}$$

The resulting H^+ corresponds to an atomic nucleus (proton) and is not constant in the presence of other H_2O particles. It consequently forms hydronium ions

$$H^{\oplus} + H_2O \rightleftharpoons H_3O^{\oplus}$$

The H atoms arranged symmetrically around the O atom enable (with other H_2O molecules) the complexes $H_5O_2^+$ and $H_9O_4^+$ to form: the latter is especially stable and further hydrated (Fig. 10).

Very pure water conducts electric current one bil-

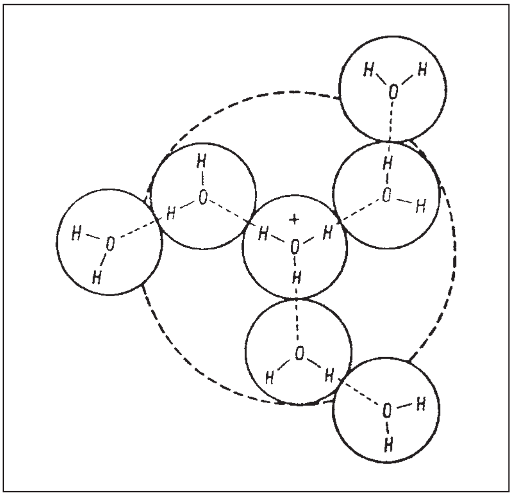


Fig. 10: Hydration of the proton in aqueous solution.

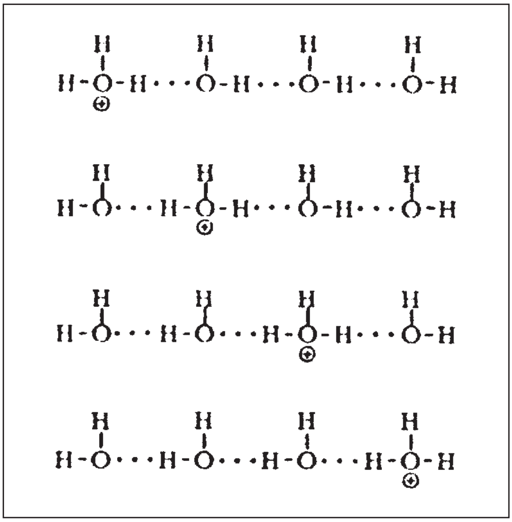


Fig. 11: Migration of a positive charge via hydrogen bonds.

lion times less than strong electrolytes. If its conductivity is measured and correspondingly analysed, it is revealed that approximately every hundred millionth molecule is split into ions. As the concentration of unsplit water molecules is constant due to this very low dissociation, the law of mass action demands that the product of the concentrations of cations and anions is a constant. This is 10^{-14} at room temperature and in water, where both concentrations are equal to each other; the concentration of hydrogen ions is the square root of this, that is 10^{-7} mole/l, a ten millionth of a gram of ions in 1000 g of water. Decimal powers are not readily written out in full, but high-ranking number, i.e. the number of zeros is sufficient. This number is 7 in pure water. Water has a pH of 7. The more acidic an acid solution is, the smaller this number is; it is 0 in normal hydrochloric acid (1 mole/l).

It is found that the ion mobility is much greater than would be expected on the basis of molecular size in the H^+ ion (and/or H_3O^+ ion) and in the OH^- ion. It is therefore assumed that in these cases the ion itself does not migrate at all, but that only the positive and/or negative charge is further transported via hydrogen bridges on the way (Fig. 11).

Water balance Represents the water balance of a finishing business in the most graphic way possible. Besides integrated water support from wells or outfall channels, water from the public supply system may be used. 100% of this fresh water goes (see Fig.)

– for fixed objects,

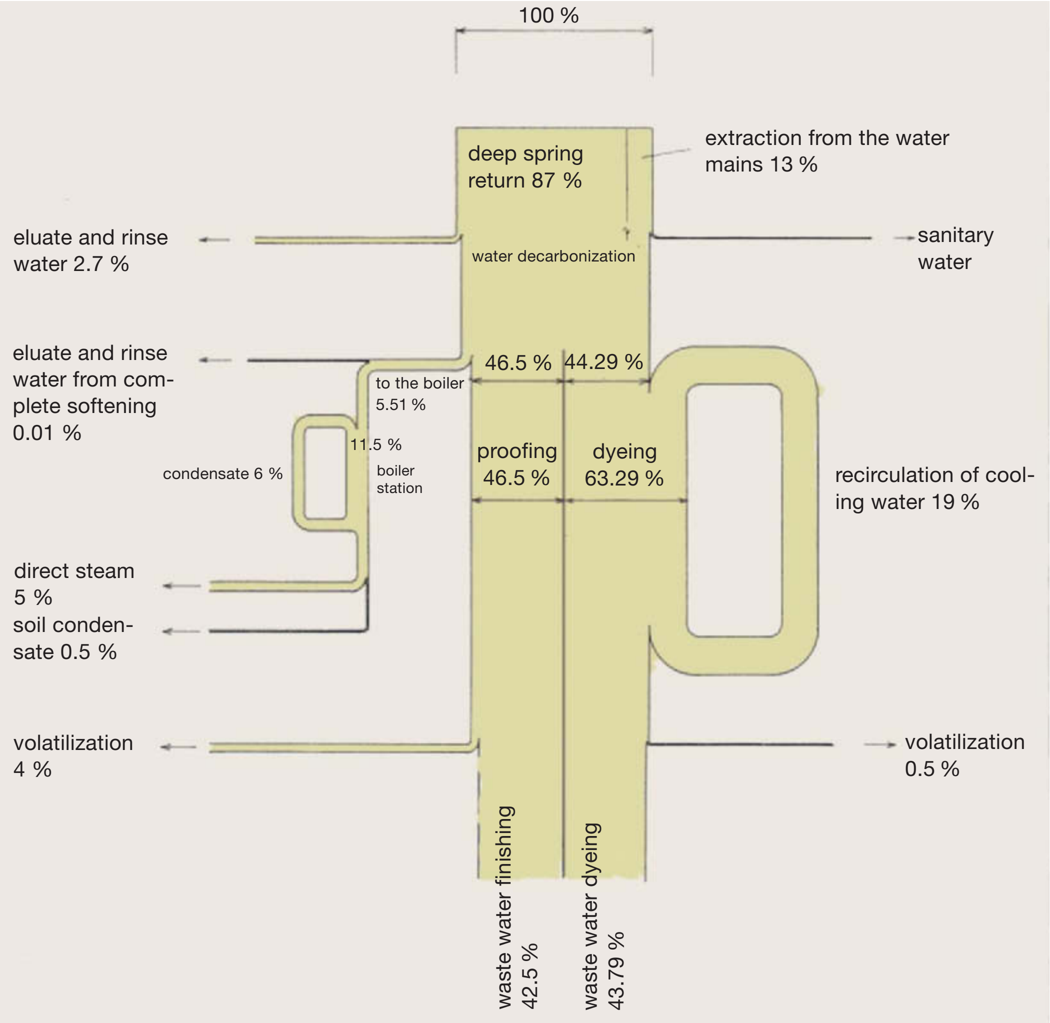


Fig.: Water balance.

- to the boiler house and thus as steam into circulation with return as condensate,
- as evaporation,
- into wet finishing,
- into the dyehouse and printing,
- as cooling water in respective circulation systems,
- as waste water.

Waterborne bacteria →: Iron bacteria; Nitrobacteria.

Water calender → Water mangle.

Water clarification →: Waste water treatment; Waste water treatment plants.

Water consumption averages in textile processing Reduction of the (considerable) water consumption, especially in the cotton sector, but also in wool, is at the forefront of the short liquor technique. The detail of obligatory water demand parameters for the different finishing steps becomes difficult because they are dependent on the technique selected, the age of the mechanical equipment and on the operating staff. A specific water consumption of 120 l/kg of fabric on average was given in the water/waste water survey of 1988. The minimum and maximum values were 18 and/or 375 l/kg of fabric. Waste water quantities are given for different process stages and substrates in the Tab.

It would be wrong to prescribe an estimated reduction of the water consumption, as a reduction of the liquor-to-goods-ratio is not always possible especially for rinsing and soaping depending on article and plant, without having to accept a reduction in quality.

1. piece-dyed woolen fabrics		
pretreating/dyeing/softening		100 – 250
2. piece-dyed cotton fabrics		
desizing/scouring/bleaching		30 – 120
dyeing/softening		50 – 120
	total	80 – 240
3. piece-dyed cotton knit fabric		
pretreating/dyeing		70 – 180
4. printed cotton fabric		65 – 280
5. manufacture of a blanket from flock dyed polyacrylonitrile		
dyeing/softening		30 – 80
washing		10 – 70
	total	40 – 150
6. fabrics and stitch-bonded fabrics made of cotton, viscose fibres and blends thereof with synthetic fibres		
singeing		0.5 – 1
washing		3 – 7
desizing		4 – 8
mercerizing		6 – 12
alkaline treatment		5 – 8
continuous bleaching		3 – 15
continuous dyeing		1 – 25
discontinuous dyeing		55 – 90
printing		3 – 16
aftertreating printed goods		12 – 50
finishing		1
7. carded yarn woollen fabrics and blended with man-made fabrics		
– overcoating		
dyeing incl. washing		172 – 212
– suit and costume fabrics		
continuous washing		5 – 20
dyeing incl. washing		65 – 120
8. worsted yarn fabrics		
– suit, costume fabric and dress fabric 55 polyester/45 wool		
washing		9 – 14
dyeing		75 – 95
finishing		1

These examples produce a standard value of 100 l water/kg of fabric.

Tab.: Values (l of water/kg of fabrics) for optimized water consumption in textile finishing.

Water crimp → Crimp, types of.

Water decarbonization Removal of temporary hardness (→ Water hardness salts) using appropriate → Water softening process, e.g. so-called lime decarbonization via precipitation process or so-called hydrogen decarbonization with ion exchangers, which contain carboxyl groups and work accordording to the principle of desalination. Also as more economical pre-softening, to which a neutral exchanger is connected in series for total softening. Achieved by alkaline decomposition using saturated lime water or milk of lime. Decarbonization plant operates in accordance with the principle (see Fig.): a) process water supply into open reservoir and ventilation/oxidation ; b) sampling of ventilated water; c) filtration via gravel filter; d) treatment in the rapid reactor; e) renewed filtration in further gravel filter.

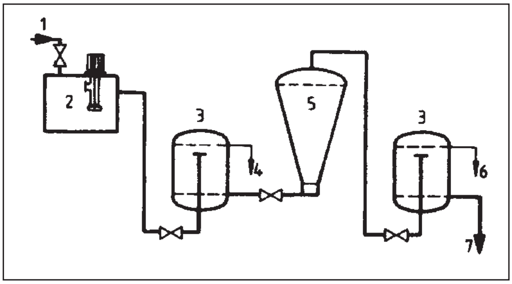


Fig.: Modified water decarbonization unit for yarn dyeing. 1 = water supply; 2 = ventilation/oxidation (FeMn); 3 = gravel filter; 4 = sludge (FeMn); 5 = rapid reactor; 6 = carbonated sludge; 7 = treated process water.

Water degasification Release of dissolved gases: air, oxygen, carbonic acid, etc.

I. Mechanical: watering, vacuum.

II. Thermal (especially for atmospheric oxygen): heating above 100°C (high pressure enclosed vessels or low pressure at 40–60°C). Residual oxygen content approx. 0.5 mg/l, practically no free carbonic acid.

Water demanganizing Manganese content rarely exceeds 1–2 mg/l, but often becomes unpleasantly noticeable in quantities of 0.1 mg/l in mains water. Manganese makes dark brown stains, which are difficult to remove.

I. Iron-contaminated water should have the iron removed and, if necessary, be deoxidised before the demanganizing. In water with a lot of organic matter demanganizing is only possible using aluminium sulphate precipitation.

II. Special manganese filter: with preprepared (potassium permanganate) filter sand or special filters (manganese ore) and/or base exchange filters (manganese permutit, filter regeneration using potassium permanganate). Principle: oxidation of the bivalent to the polyvalent form via oxygen dissipating manganese dioxide hydrate (precipitated on sand layer) and filtering of the insoluble hydroxide.

III. Biological: (carbonic acid up to 30 mg/l harmless). Vertical double gravel filter with iron and manganese retaining algae, water flow under pressure, great activity. Principle: adsorptive deposit and/or bonding of the manganese salts.

Water deoxidation Removal of carbonic acid from water using different processes depending on water hardness, carbonic acid content, iron quantity.

I. Mechanical: a) for hard to medium-hard water (6–8°d): ventilation; b) for hard water with little carbonic acid: trickling flow; c) for hard and soft water with high carbonic acid content: spraying, ventilation, vacuum degassing.

II. Chemical: a) marble filter process for water with degree of hardness below 6°d and above 2°d, unsuitable for water containing iron and manganese; b) magnesite process, for water with degrees of hardness up to 15°d; c) dolomite filter compounds, especially for drinking water; d) calcium hydrate process for hard and soft water containing iron.

Water desalination process → Ion exchanger.

Water discharge legislation Approximately 15% of the process water used during textile manufacture is lost to evaporation, spillage or incorporation with the product. By far the greater portion is discharged by processors into the public sewage system, which means that it is subject to the discharge legislation of the various states on the one hand, and on the other to the waste water bye-laws of the local authorities.

Under the 5th amending statute to the German → Water Resources Law (WHG – Wasserhaushaltsgesetz) and its associated "Appendix 38" concerning the framework AbwVwV (Abwasserverwaltungsvorschrift – Waste Water Administrative Regulation), which is presently under review, measures may in future be required to address waste water treatment according to the "state of the art" with respect to each → Segregated stream. This applies, however, only to those batch discharges which contain hazardous substances. The definition of the term "hazardous substance" is disputed but is crucial to the necessity of treating batch discharges. It thus demands a final resolution in order to avoid unnecessary dispute between textile manufacturers and authorities once the revised Appendix 38 comes into force. → Waste water evaluation.

In recent years the imposition of a major polluter premium by local authorities has led to a drastic rise in costs and thus financial burdening of textile manufacturers. In many cases this cost increase can be traced back to a lack of cooperation between indirect discharger and local sewage works. Any business will of necessity make projections which compare the water supply and waste water costs which fall due if the existing facilities are retained against the capital and operating costs of in-house effluent treatment. If the company is presented with ready-made conclusions by the authorities, it is inevitable that it will do its utmost to reduce its liability to costs. The result is that the discharge ratios at the relevant sewage works will fluctuate, which in turn invalidates the dimensioning parameters applied at the sewage works.

It is also possible that major polluter premiums are not in keeping with the actual cost of dealing with waste water from textile plants. Since such water is usually depleted in both nitrogen and phosphorus, combining its treatment with waste water from other sources may actually result in cost savings. For example, an "excess BOD" (biological oxygen demand) of industry-sourced water may contribute to a reduction in denitrification volume and a saving on aeration costs.

It is fundamental that the biological treatment of textile waste water is to be preferred over all other methods of treatment. Only if such exclusively biological treatment fails to meet the mandatory maximum pollutant levels should additional chemical and physical procedures be considered. This, however, requires that the indirect discharger accepts as self-evident the need to carry out certain preliminary procedures:

- A balancing of both the quantities and the concentration levels of waste water through the use of mixing and holding basins (for weekly adjustment). This has advantages when it comes to accommodating possible errors or faults. Balancing makes allowance for a lower maximum biological treatment capacity.
- Neutralization of pH to between 8.5 and 9 (preferably using flue gases). A lower pH is not to be recommended due to the danger of releasing hydrogen sulphide.
- Recycling weak leaching (alkali) solution following mercerization by means of evaporation.

It is yet to be seen whether waste water from textile plants may be transferred separately to the sewage works using company pipelines. Given the poor state of most public sewers, this may be the preferred option from the point of view of local authorities. If this were done, it would also be possible to site mixing and holding basins at the sewage works in cases where there is insufficient room on the company's own site.

I. Iron-contaminated water should have the iron removed and, if necessary, be deoxidised before the demanganizing. In water with a lot of organic matter demanganizing is only possible using aluminium sulphate precipitation.

II. Special manganese filter: with preprepared (potassium permanganate) filter sand or special filters (manganese ore) and/or base exchange filters (manganese permutit, filter regeneration using potassium permanganate). Principle: oxidation of the bivalent to the polyvalent form via oxygen dissipating manganese dioxide hydrate (precipitated on sand layer) and filtering of the insoluble hydroxide.

III. Biological: (carbonic acid up to 30 mg/l harmless). Vertical double gravel filter with iron and manganese retaining algae, water flow under pressure, great activity. Principle: adsorptive deposit and/or bonding of the manganese salts.

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Water economy in discontinuous (rinse) process

Water economy in discontinuous (rinse) process Technically feasible and technologically responsible, rinsing processes should be carried out with a liquor-to-goods-ratio as short as possible in order to save water. Decisions on the optimum rinsing process can only be taken in each individual case in view of technical and technological conditions and staff and water costs. When considering the expenditure of time and energy, preference should be given to the continuous rinsing process in the short liquor-to-goods-ratio, despite an increased water demand compared with the discontinuous rinsing process. It is advisable to monitor the rinsing process (and water consumption). Considerable reduction in fresh water demand can be brought about by a single discontinuous draining (or even better for example by suction) of the treatment bath. If it has to be rinsed with a long liquor-to-goods-ratio for any reasons, the last mentioned process should be considered because of high water consumption by the continuous rinsing process as well as in view of the increasing number of rinsing operations in the discontinuous rinsing process with increasing liquor-to-goods-ratio. Considerable savings of water and time can be achieved by reducing the liquor backlog (e.g. via suction) after draining.

Water-endangering substances The German water conservancy law → Water Resources Law (WHG – Wasserhaushaltsgesetz) contains special regulations in §§ 19 g–1 relating to the handling of water polluting substances (see Fig.). These federal regulations are further supplemented by regulations of the German states for installations handling water polluting substances (VAwS), which refer back to a standard ordinance of the LAWA (Länderarbeitsgemeinschaft Wasser = state working group on water). Despite this standard LAWA ordinance, regulations in the various federal states differ, especially since the water legislation is linked to building legislation, which also differs in the

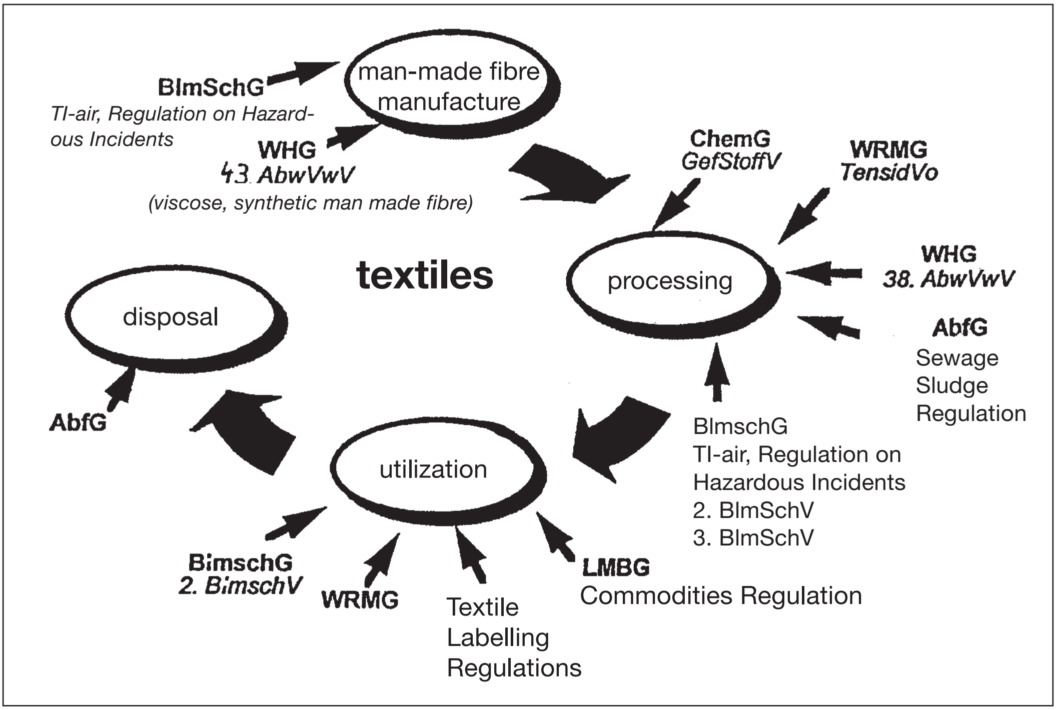


Fig.: Points during the manufacture and utilization of textiles at which water-endangering substances might appear, along with regulations valid in the Federal Republic of Germany for the handling of water-endangering substances.
BImSchG = Bundes-Immissionsschutzgesetz – Federal Immission Protection Law; Störfallverordnung – Regulation on Hazardous Incidents; WHG = Wasserhaushaltsgesetz – Water Resources Law; AbwVwV = Abwasser-Verwaltungsvorschrift – Administration Regulation of Waste Waters; ChemG = Chemikaliengesetz – Chemicals Law; GefStoffV = Gefahrstoffverordnung – Directive for use of Dangerous Substances; WRMG = Wasch- und Reinigungsmittelgesetz – Detergent and Cleaning Agent Law; TensidVo = Tensidverordnung – Surfactant Regulation; AbfG = Abfallbeseitigungsgesetz – Waste Disposal Law; KlärschlammVO = Klärschlammverordnung – Sewage Sludge Regulation; BImSchV = Bundes-Immissionsschutzverordnung – Federal Immission Protection Regulation; LMBG = Foodstuffs and Commodities Law; Bedarfsgegenständeverordnung – Commodities Regulation; Textilkennzeichnungsgesetz – Textile Labelling Regulations.

various German states. §§ 19 g–1 applies to installations for storage, bottling/packing and transhipment, installations for production, treatment and use, as well as pipeline systems which do not extend beyond the limits of an industrial plant. §§ 19 g–1 stipulates that installations for the storage, bottling/packaging, production and handling of water polluting substances, as well as installations using water polluting substances in the commercial business sector and in the area of public undertakings must be so designed that the quality of a water course does not suffer any detrimental change. The same stipulation applies to pipeline systems within the confines of an industrial plant.

For the purposes of §§ 10 g–1, water polluting substances include all solid, liquid and gaseous substances capable of bringing about a detrimental change in the physical, chemical and/or biological properties of water.

Various substances and preparations have been grouped into the following 4 water hazard classes (Wassergefährdungsklassen – WGK) according to their properties:

WGK 0 = substances which, in general, are not water polluting,
WGK 1 = slightly water polluting substances,
WGK 2 = water polluting substances,
WGK 3 = highly water polluting substances.

These classes are based on a classification system introduced by the “Commission for the Evaluation of Water Polluting Substances” which is subject to the Federal Ministry for the Environment, Nature Preservation and Safe Operation of Nuclear Power Plants.

Every installation handling water polluting substances is obliged to submit a suitability declaration (§ 19 h). From this suitability declaration, the authorities are able to certify that installations, or parts of installations, as well as technical safety devices, satisfy the requirements of § 19 g, Clause 1 or 2 of the WHG in an individual case. For installations, parts of installations and safety devices of standard manufacture, this suitability declaration can be substituted by a building permit pertaining to water legislation. Despite this stipulation, there are a number of exceptions here. Suitability declarations are not necessary for installations, parts of installations and technical safety devices of a simple or conventional type. Where installations, parts of installations or safety devices are subject to an industrial building permit or a test of conformity under building legislation, the suitability declaration is likewise dispensed with. As a rule, this applies to installations, parts of installations and safety devices of standard manufacture.

The following are excluded from the obligation to submit a suitability declaration:

– Installations for production, treatment and use where the substances are involved in a process.
– Temporary storage of transport containers.
– Short-term availability or storage of water polluting substances in connection with transport if the containers or packages satisfy the regulations and requirements for transport on public highways.
– Storage in laboratories where small quantities are dispensed by hand.

In § 19 i, Clause 2, of the WHG it is stipulated that the operator has an obligation to monitor the soundness of the installation against leakage and the functional integrity of safety devices. Installations, or parts of installations, where water protection is involved, must only be installed, erected, repaired, maintained and cleaned by specially monitored specialist firms. This applies to the operator’s industrial plant (§ 19 l, Clause 1) as well as to other companies sub-contracted by him (§ 19 i, Clause 1). The operator must allow the proper state of the installation to be checked by official experts, or recognized experts for these purposes, especially before an installation is commissioned, as well as after a significant modification and before an installation is recommissioned after it has been shutdown for a period longer than one year, or to comply with special instructions, or for special reasons and after notification of an inspection has been given. This also applies when the installation is shutdown.

According to the requirements of water legislation in the German states, the operator is subject to additional obligations, such as

– a duty to notify the authorities of any installation, erection and significant modifications for which specific information is required;
– a duty to notify the relevant authorities immediately when any leakage of water polluting substances occurs if there is any risk of these substances entering the sewer system or seeping underground (according to Schäfer).

Water equilibrium Term in dry cleaning for the final state of water distribution between treatment liquor and textile.

Water extraction,

I. (pre-drying), aims at the removal of water from fibre and fabric pores for the relief of high drying costs. Approx. 40–100% water still remains after water extraction. Mechanical water extraction is considerably more economical than thermal drying, which requires approx. 400 times as much energy. Distinctions are made between water extraction processes shown in the Fig 1.

Water extraction can be carried out

– mechanically,
– gas kinetically,
– capillary active,
– thermally by drying.

The advantages and disadvantages of separate processes are shown in the Tab.

The following methods are common:

Water extraction

	mechanical		gas kinetic	capillary active
	discontinuous	continuous	continuous	continuous
equipment and machinery employed	centrifuge	pad mangle with different variants (polyamide fibre rollers, swimming rollers, additional negative pressure etc) continuous centrifuge (staple fibre yarns)	suction pipe, suction roller, Mach nozzle, jet squeezer, venturi nozzle	squeeze-suction method capillary-vacuum process water extraction by continuous nonwoven fabrics
water extraction effect	residual noisture levels near original swelling water value	residual moisture levels approx. 20-30 % higher than centrifuge values	residual moisture figures somewhat lower than by pad mangling on average	reduction of residual moisture values to centrifuge figures sometimes possible in the case of synthetics
quantities affecting the water extraction effect	– type of fibre – speed	– type of fibre – fabric weight – type of construction – machine speed – line pressure in the nip – liquor temperature (recovery feasible under certain circumstances if it can be effected via heat recovery)	– type of fibre – machine speed (e.g. Mach nozzle: at 20 m/min, the residual moisture content of a woven polyester fabric is 25 %, and 45 % at 100 m/min) – fabric air permeability – energy density of the gas flow and installed power	– type of fibre – machine speed – number of passages
advantages	also suitable for sensitive and highly textured fabric	– ease of handling – perfected process – easy roller cleaning	– effect is independent of parameters such as water surface tension, fabric temperature etc – suction machines also suitable for extensible fabric – 2 water extraction operations possible at the same time by roller-jet-squeezer (wet on wet process)	– capillary vacuum system: very good with synthetics; also suitable for warp and weft knitted fabric; easy to extract water from rope and tubular fabric; suitable for structured and pile fabric; water extraction effect very little dependent on speed; – improved liquor penetration – QS technique: also suitable for natural fibres
disadvantages	discontinuous	– relative to the centrifuge, higher residual moisture levels with open fabrics like net curtains etc) – high pressure on the fabric – danger of creasing	– high energy consumption in the case of the suction principle – Mach nozzle unsuitable for extensible fabrics – dye liquor hardly uniformly removed	– unsuitable for extensible fabrics with the exception of the capillary vacuum system and water extraction by continuous nonwoven fabrics – usable only for final processes with the use of nonwoven fabrics (water extraction from heat set and washed fabric) – seam impression in the case of thin fabrics

Tab.: Comparison of water extraction processes.

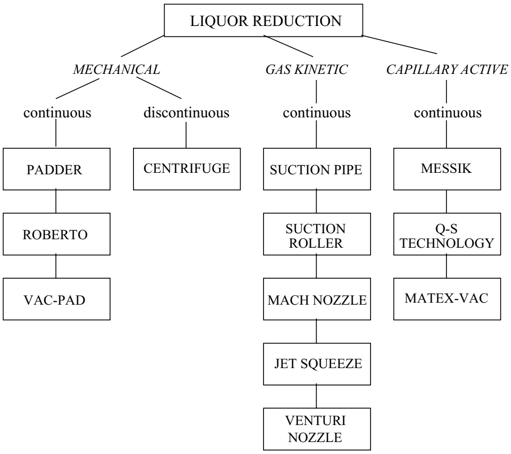


Fig. 1: Water extraction process classification (without thermal water extraction).

1. Squeezing or pressing between squeeze rollers under pressure, usually in the open-width state of the fabric, on so-called wet or water calenders, chiefly for heavy fabrics.

The most efficient removal of water from fabric at the end of open-width washing ranges can be achieved by means of water mangles with swimming rolls (Fig. 2).

2. Centrifuge hydro-extraction: most used process for every type of making up of finished textiles. Performed in centrifuges at approx. 750–1200 rpm. Yarn packages on material carriers in accordance with the hydro-extractor slip-on process are directly centrifuged, also with simultaneous hot air blast (water extraction at 40–50%); in dyeing machines with a vacuum system it is often only sucked and then centrifuged.

3. Suction by vacuum pump: performed for fabrics on so-called suction extractors in the crease-free open-width state by the passage through a tube with suction slots and vacuum connection. Especially suitable for sensitive fabrics.

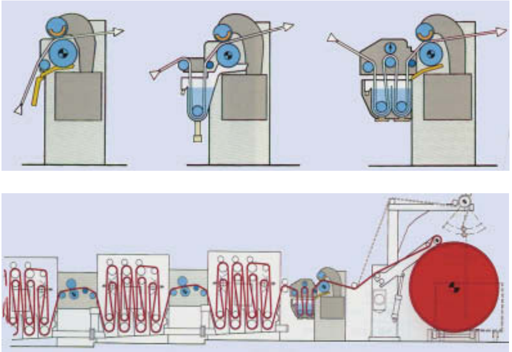


Fig. 2: Water mangle (Küsters).

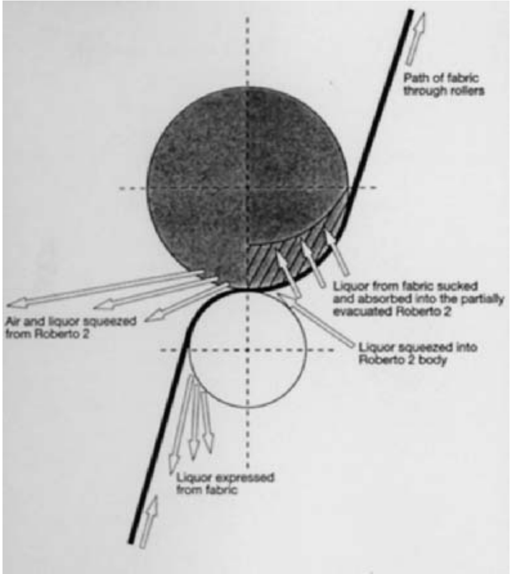


Fig. 3: Hydroextraction by porous roller.

4. During hydroextraction by porous roller excess liquor is removed by the steel and squeezed out by the Roberto as it is compressed (Fig. 3). Then with the fabric still in the nip, the Roberto regains its shape, drawing air through the fabric into the filling of the Roberto and creating a sucking action which removes more liquid from the fabric. Compared to the established Roberto, tests with Roberto 2 show expression increased by an average 12% running against a stainless steel roll. For a tubular knitted or thick pile fabric where two Robertos are recommended, the average increase is 18%. These figures are improvements over a roller which already outperforms conventional rollers by as much as 60%.

II. (f_1), remaining water weight in relation to textile dry weight:

$$f_1 = \frac{g_{ges} - g_{atro}}{g_{atro}} \cdot 100\ \%$$

g_{ges} = water content before drying
g_{atro} = absolute drying.

Water extraction by compressed air (compressed air squeezing system). Device for non-contact water extraction of width fed fabric webs. A compressed air water extraction machine (in contrast to the vacuum suction machine) with perforated passage (moveable top element, e.g. as plate and bottom slot device). Air under high pressure, in which water adhering to the textile web is pressed and blown off, and flows through the operating slot.

Water extraction machines for piece goods Mainly continuously operating systems for mechanical water extraction (→ Squeeze off). Division:

I. Discontinuous: → Centrifuges.

II. Continuous: squeezing units, such as → Water calender; →: Suction roller for textile webs; Water extraction throughflow method.

Attainable residual moisture from water extraction machines is between 30 and 100% depending on fibre and machine type.

Water extraction throughflow method The mechanical energy of a gas (mass) flow is used to release free water from the textile bond.

Water fastness Resistance of dyeings and prints to the effects of water.

1. Light strain (DIN 54 005-73): test sample with adjacent fabrics well moistened (surplus water poured away), 1 hour weighted with 4.5 kg tested at 20°C, separated and dried at 60°C and assessed using grey scales.

2. Heavy strain (DIN 54 006-73): as 1., but tested for 4 hours at 37°C and/or 16 hours at 20 °C. AATCC test: 18 hours. Assessment using grey scales. The perspirometer from AATCC (Atlas Electric) or the hydro test equipment (Schröder) is used as the tester.

Both standards are essentially adapted to ISO 105, issue 1982.

Water filter for turbidity contamination,

I. Slow filter: open (covered) reservoirs, filter material (from bottom to top) gravel, shingle (quartz) sand, filter use (according to process water) a few days to several months. Disadvantages: large space required. Principle: logging of mainly most finely grained suspended sediments. Effect: a) mechanical; b) adsorptive through jelly-like filter skin (being produced during filtering); c) biodegradation (by bacteria settled in the filter skin). Result: clear treated water.

II. High speed filter: for the preparation of boiler feed water. Filter material of rounded quartz sand. Result: deoxidation, iron elimination and fine filtration.

III. High performance filter: with special sludge suction.

IV. Microfilter: material of porous kieselguhr or porcelain, fireclay hollow cylinder, etc.

→ Filter for waste water treatment.

Water fire extinguisher → Fire extinguishers holding 6–12 litres of water (to which salts have been added to lower its freezing point) and containing a riser pipe, a cartridge filled with either dilute sulphuric acid or compressed liquid carbon dioxide, a heavy duty button and a nozzle through which the extinguishing fluid is expelled. Activation of the heavy duty button causes the cartridge to be broken, whereupon the carbon dioxide (released directly or else generated due to the reaction of sulphuric acid with sodium carbonate) forces the water through the riser pipe and the nozzle as a jet, several metres long, which may be directed at the seat of the fire.

Water flow meter Measuring instrument for water flow velocity and flow quantity.

Water glass (→ Sodium silicate), is produced by melting quartz sand (SiO_2) and sodium carbonate, whereby approximately the following ratio exists in the product which is of interest to the textile industry: 8% sodium oxide and 27% silicon dioxide. The exact structure of water glass cannot only be given by 37–40°Bé, but it is well-known that the structures SiO_3^{2-}, a chain structure, and $Si_4O_{11}^{6-}$, a band structure, represent the main constituents. O–Na groups are produced, corresponding to the ratio of alkaline carbonate addition, from a part of OH groups by melting with alkaline carbonates. The free OH groups are capable of bonding further caustic soda liquor. This characteristic results in an excellent buffer power compared with sodium hydroxide. In addition, a salt formation with alkaline earth metals such as calcium and magnesium as well as with heavy metals such as iron, copper and manganese is possible in these OH groups. The polysilicic acid

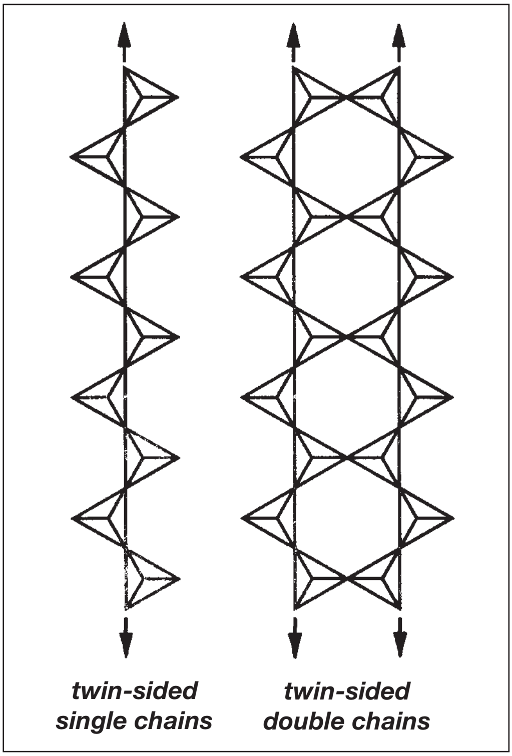


Fig. 1: Polysilicic acid molecules.

molecules (Fig. 1) and their sodium salts are responsible for these positive properties of water glass. Unfortunately these structures are not very stable. Already higher quantities of CO_2, which are brought into impregnating baths by the air, high quantities of alkaline earth salts, chiefly Ca^{2+}, which are input using mechanically harvested grey fabric, as well as heat and pressure result in a dehydration (water release) and in the formation of silicic acid gel and insoluble metal hydroxides as well as insoluble alkaline earth silicates. The heat sensitivity of colloidal silicates can be very easily proven by observations in practice. If, for example, reactive dyeings, whose dye recipe contains 60 ml/l of silicate, are washed off immediately by boiling in the first bath, the machine shows severe silicate encrustations in a short time. If however 20–40°C is selected as the washing temperature in the first bath, the plant does not show any encrustations even after a longer period of production.

If bleach preparation liquors are prepared with water of 8°d and a) 12.5 ml/l of water glass, b) 5.0 g/l of sodium hydroxide, c) 40.0 ml/l of hydrogen peroxide 35 percent by weight, once in the sequence described (beaker A) and secondly in the sequence b, a, c (beaker B), glass A shows an unchanged appearance over weeks; glass B contains a precipitate after only a few hours.

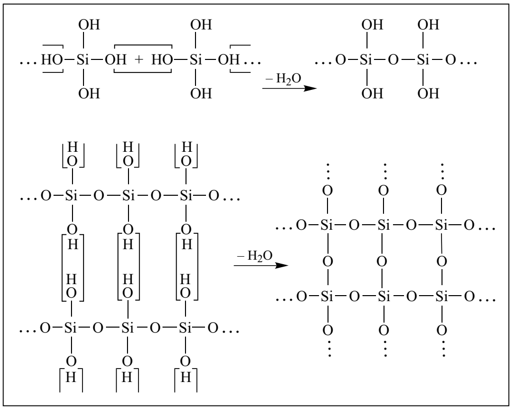


Fig. 2: Dehydration of water glass (according to Ney).

This dehydration (Fig. 2) is responsible for the dreaded deposits on steamers. Rock hard coatings are formed, which are difficult to remove. The phenomenon described may however also be formed in laying the fabric web on excessively heated machine parts. This is shown by a hard fabric handle, as polysilicic acids are difficult to rinse out. The process water plays a crucial role in stabilizing when using water glass. If the water hardness is higher so that it can be bonded as magnesium silicate by the silicate and can be kept in solution by alkali, not easily dissoluble calcium silicates are formed, which break down and are deposited on the fabric. These are also detrimental to the handle and possibly to the fabric appearance of a later dyeing.

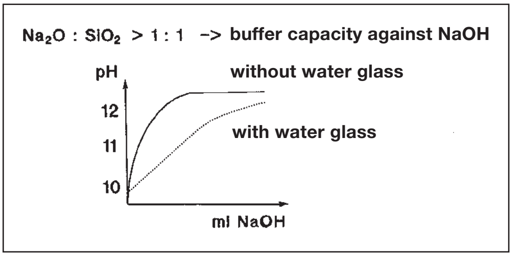


Fig. 3: Buffer capacity of water glass against caustic soda liquor.

Besides its stabilizing properties, water glass has the advantage of reducing and/or preventing the effect of catalytes. Catalytes are understood to mean, above all, in the hydrogen peroxide bleaches, salts from heavy metals and/or heavy metal ions. They have the capacity to decompose the bleach liquor so rapidly that it turns into a spontaneous, uncontrolled discharge of atomic oxygen and acid and causes local fibre damage. During the manufacture and/or processing of textiles, iron compounds can get onto the fabrics so that the risk of catalyte damage from iron is especially large. Iron salts can be eliminated by so-called complexing agents (e.g. ethylenediaminetetra-acetic acid), but most of these auxiliaries are not effective in the strongly alkaline medium of the bleach bath. On the other hand, these complexes are also not stable so that stabilizers, which are constructed on this basis, are far less effective than water glass. In this, the iron is not bonded in a complex way, but “absorbed” like a porous sponge and virtually mechanically removed from the bleach liquor and made ineffective.

Water glass has yet another important function in bleaching. It buffers away the alkali and thereby creates an alkali reserve in the bleach bath (Fig. 3) without concentrating the activation of the peroxide. In this way 2.5 g/l sodium hydroxide is buffered away by 10 ml/l water glass; up to a fourfold quantity of water glass

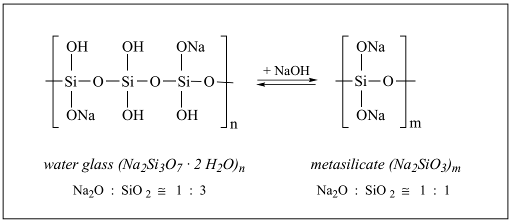


Fig. 4: The buffer effect of water glass.

(in ml/l) can be used compared with sodium hydroxide (in g/l). If this ratio is exceeded to the disadvantage of the water glass, the alkali can no longer be adequately buffered away by the water glass (Fig. 4); the free alkali increases the activation and reduces the stabilization (in accordance with Ney as well as Wurster).

Water glass variant Alternative to → Cold pad batch dyeing (CPB), which necessitates a special aftertreatment on the open-width washing range (see Fig.), so that water glass is properly washed out from the reactive dyeing.

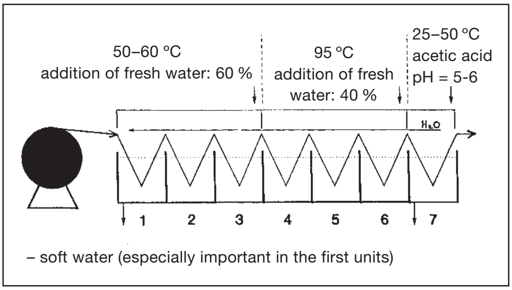


Fig.: Water glass variant (Hoechst) in the CPB process with carefully directed afterwashing of the batch on an open-width washing range (4th + 5th unit: addition of 1 g/l Ladiquest 1097).

Water hammer is produced in steam and condensate return piping by rapidly moving/retarded water drops or by combination of steam and hot condensate with colder condensate. Remedy: Lay old piping with sufficient gradient at the water extraction point; prevent water pockets in piping; drain water from all low points; slowly put evaporation plants into service; all water drainage systems should function well; steam piping and heat exchangers should be empty when out of service; thermostats and pressure regulators should be correctly sized; sufficiently large bore condensate piping; steam or hot condensate of higher pressure should not come into contact with considerably cooler condensate.

Water hardening salts The degree of water hardness means the quantity of calcium and magnesium ions (hardness salts) in the water. They can cause undesired linking of textile auxiliaries and dyes and may therefore result in difficulties in textile finishing. Problems with hardness salts also occur in the household, for example lime soap, lime deposits on the heating elements of washing machines. In Germany, the total hardness of calcium and magnesium compounds in the water refers to the oxides of both alkaline earth metals, although these oxides themselves are not present in the water. 1°d (degree of German hardness) means that 10 mg of calcium oxide is present in 1 l of water. All hardness salts are converted into these reference variables by applying stoichiometry. The hardness can be determined in °d directly with the aid of colour indicators. Free, aggressive carbonic acid (carbon dioxide), released in water, attacks many compounds, in which temperature and time play an essential role. In most cases the bonded carbonic acid predominates in the form of hydrogen carbonates of calcium and/or magnesium. In boiling and/or heating the hydrogen carbonates are decomposed and the insoluble carbonates (boiler scale), which break down and are deposited on machine parts, are produced. Due to this decomposition reaction, the calcium and/or magnesium hydrogen carbonates are described as temporary hardness salts. In contrast to this, the dissolved chlorides and sulphates of calcium and magnesium are permanent hardness salts.

One talks of calcium accumulation if fibrous materials (above all cotton) or textile auxiliaries (e.g. sea salt or rock salt in direct dye dyeings) add additional water hardness to the hardness of the process water. Sequestrene (e.g. EDTA) or polyphosphates can be used together for the binding of water hardness in the dye liquor. Polyphosphates are not completely harmless ecologically and sequestering agents not only bind calcium ions during dyeing with copper complex dyes, but also extract the copper ions from the dye. Thus there is the need for an auxiliary that is completely harmless ecologically, shows no or only a slight complex formation compared with polyvalent cations and prevents the crystal deposits caused by calcium hardness on the dye material. → Water hardness salts.

Water hardness → Water hardness salts.

Water hardness agent remove Removal of the → Water hardening salts by deactivating agents (→ Complexing agent).

Water hardness, degree of → Water hardness units.

Water hardness determination → Complexometry offers a suitable method for total, calcium and magnesium hardness, which works simply, rapidly and accurately (0.05°d). → Water hardness salts.

Water hardness, determination of → Water hardness determination.

Water hardness, microdetermination See → Complexometry with complexing agents (complexometric titration).

Water hardness salts Water-dissolved calcium and magnesium salts (total hardness) cause the "hardness" in water. The hydrogen carbonates break down when boiled by releasing the carbonic acid holding them in solution (temporary, carbonic acid or carbonate hardness). The remainder is resistant to boiling (permanent, mineral acid or permanent hardness). Magnesium salts produce magnesium hardness; calcium salts, calcium or lime hardness. The units of hardness are different depending on the country and are usually given in mVal = millival (→ Water hardness units).

I. Soluble carbonates (of magnesium and calcium) cause (→ Water hardening salts):

1. During boiling, bleaching, soaping, washing, etc. sticky/dirty lime soap precipitates (vessels and fabric), soap and auxiliary losses, stains, yellowing, rancid smell, wetting difficulties, unequal result, worsened handle and promote fibre brittleness.

2. During dyeing: precipitation and sudden change in shade of dyes sensitive to hardness, poor wetting, unevenness, cloudy dyeing, bronzing, stains, reduced colour fastness to rubbing, dye losses, etc.

3. In steam boiler operation: boiler scale formation (chiefly carbonate and sulphate of lime, 1 mm boiler scale layer approx. 15% increased fuel consumption), deposits in pipework (blockages), overheating at the boiler end, corrosion, burning through, tube fractures, explosions, malfunctions, costly repairs and/or boiler cleaning, reduced performance, shortened life of the boiler; increased energy consumption.

II. Soluble non-carbonates:

1. Soluble chlorides, often up to 30 mg/l and more, contaminate water up to 1000 mg/l and more. More than 100 mg/l have an effect in soft (low in carbonate) water metal corrosion (especially with increased temperature and pressure), high chloride content causes ferrous corrosion (sea water) and zinc damage. High calcium carbonate content promotes formation of protective layers inside tubes in water containing chlorides. Reactions occur with mortar/concrete, cracks, loosening of foundations, etc., serious damage only above approx. 200 mg/l.

2. Free chlorine, usually not more than 1 mg/l, may possibly, especially in the dyehouse, cause unwanted failures, possibly also mains damage is caused by "soft" water, low in minerals.

3. Soluble nitrates/nitrites: in finishing: traces have a disruptive effect. High nitrate content has a corroding effect on metal (encouraging rust, sea water) especially in the presence of "aggressive carbonic acid" in the zinc-containing mains system (reduction to nitrites), with low temporary hardness possibly already 50 mg/l damaging to the mains system. Nitrites are especially detrimental in lead pipes, generally increased corrosion in steam boilers (burn-out, explosion hazard).

4. Soluble sulphates (sulphides): a) count in textile finishing, where work is carried out at a higher temperature, to the most damaging hardness salts, as they represent the "remaining residual hardness" (sulphate, calcium sulphate hardness); b) high sulphate content has a rust promoting and zinc corroding effect on the mains water system; c) in steam boiler operation high sulphate content is the most dangerous boiler scale forming agent, which results in the dreaded hydrated calcium sulphate scale. Deposit in solid micro-crystalline form on heat transfer surfaces, not easy to remove, low heat conductivity. Last process is accelerated by decreasing sulphate solubility with increasing temperature; d) lime building materials: not only does free sulphuric acid have a rapid corrosion effect, also neutral water with more than 300 mg/l of bonded acids as well as especially dangerous water low in sulphate (of loam, marl, clays with fluctuating water table) during evaporation and concentrated accumulation. Besides hydrated calcium sulphate, sulphates of magnesium also corrode (seriously damaging due to additionally unfavourable magnesium influence), sodium (potassium). Formation of voluminous calcium sulphaluminate, concrete destruction, pulp transformation (so-called → Gypsum expansion). In addition excretion of gypsum crystals, cracking in foundations, breaks, etc. Sulphides (as well as, if necessary hydrogen sulphide, often in small quantities in ground water containing iron) have a similar effect of metal and mortar corrosion.

5. Soluble silicates, almost in every natural water, rarely more than 10 mg/l, with sufficient magnesium content, the most feared stone-like silicate boiler scale results, lowest thermal conductivity coefficient.

III. Soluble metal salts:

1. Iron, (usually iron II-) hydrogen carbonate sulphate (-hydroxide), frequently 1–3 mg/l. Removal is encouraged with more than approx. 0.2 mg/l, in the air, water often opalescent to cloudy, yellow formation of small flocks, with rapid higher temporary hardness, retarded in especially soft or humus-rich water. Ensuing results: a) water pipes: inner deposits, light silting up, encouraged occurrence of iron-storing algae, blockages and corrosion. In the presence of small quantities of free carbonic acid in water, oxygen/air-free and/or lacking in air, further iron contamination (iron pipes) takes place especially at line ends . There is also corrosion-dissolved iron in water containing sulphate, sulphite, hydrogen sulphide, chloride and nitrite. b) In finishing: in bleaching and washing more than approx. 0.05–0.1 mg/l already has a disturbing effect, no pure white, yellow/dirty brown bonded discoloration, rust stains, catalytic fibre damage, musty smell, etc., with more than approx. 1 mg/l, tendency to stain removal in processes using soaps and metal-sensitive auxiliaries, dyes (sudden change in shade), dull, cloudy dyeing, etc.

2. Manganese, more frequent, an accompanying complex in water containing iron, quantities usually smaller, but often up to approx. 0.3 mg/l; removal (similar to iron) is promoted by manganese-storing algae, pipe blockages are often more serious than with iron. In finishing extensive excess lengths sometimes occurring; brownish black discoloration, more visible in bleaching, strong rubber poison in rubberising.

3. Lead, usually as an easily soluble hydrogen carbonate as well as not easily soluble carbonate and hydroxide. Not in water containing carbonic acid/air-free

water. Less in flow lines, easy to remove by pipe cleaning. Occurrence in corrosion-dissolved form only in atmospheric oxygen, especially also soft water containing air/carbonic acid free/low in carbonate, in soft water (low in carbonate), containing air and chloride also containing air and nitrate in the presence of nitrites, humus acid, etc. chiefly in newly laid lead pipes, especially also using lead alloys (soldered joints). Results: lead soaps, etc.

4. Zinc, corrosion dissolved in respective tubes and containers with water, which contains “aggressive carbonic acid” (with or without atmospheric oxygen), as well as other acids, alkali carbonates, liquors, high content of chlorides or sulphates, even soft water corrodes. Zinc is released from brass pipes under the above conditions. Zinc is initially corroded in galvanised iron pipes.

5. Tin, corrosion dissolved only in strong acid or strong alkaline water (scarcely in water containing carbonic acid/oxygen), however in tinned iron pipes (electrolytically conditioned, are more likely to rust than untinned iron), in lead pipes containing tin (frequently) only lead is dissolved. The feared tin decay (tin pest) occurs especially in tin pipes laid in the ground (average annual temperature + 18°C): big increase in volume, decomposition to grey powder. Then pumped water may possibly contain a lot of tin. Presence of small tin particles.

Water hardness scales, conversion factors → Water hardness units.

Water hardness units → Hardness ranges of water, for determination of the resistance of surfactants to hard water, in accordance with DIN and ISO standards, always used for water with balanced calcium hardness. With the introduction of the international system of units the parameter “German degree of water hardness” (°d) can no longer be retained as the unit of water hardness because it does not correspond to international standards. The necessity to convert into statutory SI units follows. It thereby offers manageable figures for conversion, which are as easy to use as the old °d. In principle two possibilities are given at the same time for details of chemical concentration: details of the mass (in this case in mg) per unit of volume and/or details in mole per unit of volume (e.g. mmol; mole). The graduations quoted in the Tab. approximately apply.

Water-impermeable finishes (→: Water repellent finishing; Solvent impregnation). These are some of the most important textile finishes and offer real value to the consumer, i.e. improved quality, especially if the effects are resistant to washing and dry cleaning.

I. Waterproof and water repellent effects:

1. → Water repellent finishes with no influence on air permeability, suitable for e.g. rainwear such as poplin, gabardine and loden coats, anoraks, sportswear, uniforms, loden fabrics, suitings, dress fabrics, costumes, etc.

2. → Waterproof, finishes resistant to water pressure: the air permeability is greatly reduced or non-existent, especially in the case of finishes produced with coatings. These finishes are used for heavy fabrics such as tarpaulins, tenting, etc. The degree of waterproofing is dependent on the fabric construction, i.e. suitable fabrics must be tightly woven for optimum effects.

3. Combination effects: these finishes are often combined with oil repellent, non-iron and crease-resist finishes (for outerwear and similar fabrics) or in rotproof finishes (tarpaulins, tents, etc.).

II. Basis for good water repellent effects: a woven fabric with a uniform structure and fine capillaries; low-swelling fibres; production of a closed, elastic, hydrophobic film on the textile material; the hydrophobic substance must be firmly bonded to the textile substrate and have a high wetting angle. Fabric construction must be adapted to the field of application. Unless the woven structure is sufficiently tight, the fabric will allow water to pass through it in spite of the water repellent finish. A water repellent finish should have as little effect as possible on the handle and appearance of the treated material (e.g. no dulling of the fabric lustre, hazing or chalking). Water repellent effects resistant to washing and dry cleaning can only be obtained with products capable of combining chemically with the fibre.

III. Fabric requirements: woven and knitted fabrics must be given a thorough pretreatment preferably with products having no affinity for the fibre; only non-ionic textile auxiliaries should be used. The absence of wet-

assessment	old unit of measurement °d	new unit of measurement total alkaline earth (hardness) mmol/m³	mmol/l
very soft	0 . . . 4	0 . . . 716	0 . . . 0.7
soft	4 . . . 8	716 . . . 1432	0.7 . . . 1.4
medium hard	8 . . . 12	1432 . . . 2148	1.4 . . . 2.1
quite hard	12 . . . 18	2148 . . . 3222	2.1 . . . 3.2
hard	18 . . . 30	3222 . . . 5370	3.2 . . . 5.3
very hard	>30	>5370	>5.3

Tab.: Classification of water according to hardness (total hardness) regarding of the old and new units of measurement.

ting agents, acids, alkalis and salts is necessary for good water repellent effects. Detergents with a wetting action must not be used in dry cleaning.

IV. Technology: 3 processes are used in dry cleaning establishments:

1. Spray application: minimum concentrations, therefore economical.

2. Application by infusion: the goods are sprinkled with 1–1.2 times their own weight of impregnating solution in the machine which is allowed to run for approx. 5 min, followed by a short centrifuging.

3. Dipping process (standing bath, intracellular process): the goods are treated in a full bath followed by centrifuging. The bath is not exhausted in this process and can be used again up to 10 times after appropriate replenishment.

In all these processes, the treatment should be followed by a slow stepwise drying. The maximum temperature depends on the particular product used.

In textile finishing plants, exhaust methods and continuous application on the padder are possible. Exhaust methods are of secondary importance here. The concentration of impregnating agent in all these processes is dependent on the type of fibre. Synthetic fibres require particularly high quantities in view of the fact that they can only absorb a small amount of liquor.

4. Exhaust methods: the treatment is carried out at a long liquor ratio on winches or jiggers depending on the fabric quality. The impregnating agent is only partially taken up by the fibre and the degree of liquor exhaustion is variable and difficult to monitor. After the fabric has been treated, it is suction extracted or centrifuged without rinsing then dried. Emulsions of single-bath impregnating agents specially manufactured for this type of application are used.

5. Padding processes: a single or two-bath application is possible depending on the particular impregnating agent. For the two-bath method, an intermediate drying may be given if necessary. The impregnating agents are emulsions of water-insoluble hydrophobic substances. These emulsions must be stable during impregnation. Even the smallest separated particles are noticeable as translucent dark stains during drying. Emulsion breakdown is not only due to the influence of chemicals washed out of the material but can also be caused by high mechanical shear stresses (e.g. during squeezing-off between the padder bowls or liquor circulation by pumping).

6. Solvent impregnation.

V. Examples of water repellent impregnations (the examples below are given roughly in order of increasing resistance to washing and dry cleaning):

1. Aluminium salts (aluminium acetate, diformate, triformate). When used alone, these compounds only produce slightly water repellent effects.

2. Aluminium soaps + wax or paraffin: in two-bath methods the fabric is first padded with a soap solution into which wax or paraffin has been emulsified to increase the water repellency effect. It is then passed directly, or after intermediate drying, through a solution of an aluminium salt. This process is repeated if necessary. The procedure is, however, laborious and involved.

3. Single-bath impregnation: suitable products for this type of application contain an aluminium salt, a protective colloid and paraffin in the form of an emulsion. These products are also suitable for application by exhaust methods although such methods are uneconomic.

The water repellent effects obtained in examples 1–3 are not resistant to washing and dry cleaning.

4. Zirconium salt/paraffin wax emulsions: more resistant effects are obtained by substitution of the aluminium salt with a zirconium salt. Padding and exhaust methods are used.

In examples 1–4, no chemical bond is formed between the impregnating agent and the fibre. This not the case with the following examples:

5. Isocyanate basis: esterification with cellulose takes place with isocyanates at high temperatures (above 130°C) to form cellulose urethanes (Cell–O–CO–NH–R) whilst a substituted alkyl urea is formed on wool (Wo–NH–CO–NH–R). Cellulose esterification is also achieved with fatty acid chlorides; solvent application plants are necessary for this method.

6. Stearyl-pyridine derivatives: curing at 150°C. Breakdown of pyridine and formation of the cellulose ether or, in the case of wool, the amine (unpleasant smell).

7. Fatty acid substituted ethylene urea derivatives: fatty acid modified melamine resins. Some of these derivatives can already be cured at relatively low temperatures. Besides a reduced propensity to soiling and good water repellency effects (not as pronounced as paraffin emulsions), these products confer a marked resistance to washing and dry cleaning and are highly effective softeners at the same time.

8. Chromium complex/fatty acid derivatives (chromium stearate): these products give excellent water repellent effects resistant to washing and dry cleaning. Their main disadvantage is, however, the greenish self-colour.

9. Fatty acid modified synthetic resins: apart from the derivatives mentioned in 7 above, other aminoplasts can also be used. After drying, they require an additional curing stage.

10. Silicone derivatives (organopolysiloxanes): these products are also applied in emulsion form and some are applied in combination with heat-curable resins. Organic metal compounds and zinc or zirconium salts are used as catalysts. Such silicone derivatives form crosslinkages with the fibre at high temperatures. They are suitable for all types of fibres. Excellent water repellent finishes (with good soil repellency and usual-

ly a soft handle). Some silicones have excellent resistance to dry cleaning (organic solvents, although this varies in the presence of dry cleaning detergents) and household laundering.

11. Perfluorocarbon derivatives (perfluorinated compounds): oil-repellent effects, above all, are obtained with these products (→ Oil repellent finishing). In order to intensify the water repellent effect, they are mainly combined with the products in examples 7 and 9, where they also function as extenders at the same time. The impregnating agents mentioned in 10 and 11 confer a positive charge on textile fibres which has the effect of attracting oil-based soils since the latter are usually negatively charged.

Water impermeability test The impermeability of a textile fabric to water (i.e. the effectiveness of a waterproof finish) can be determined by the water pressure (hydrostatic head) test described in German Standard DIN 53 886. To carry out the test, a test specimen is mounted in a test apparatus and the underside of the specimen is subjected to increasing pressure from a column of water. The water impermeability of the test specimen may be determined in units of water pressure in mbar or as the height of the water column (mm) and is also known as the "Schopper value" (see Fig.). This value is read off the water column as soon as the first three drops of water have penetrated through different parts of the fabric surface.

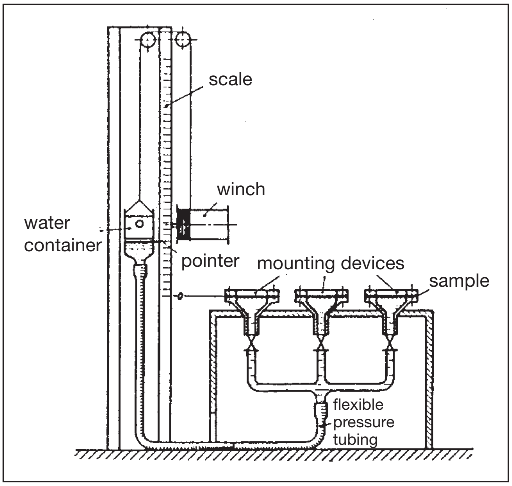


Fig.: Water pressure test as laid down in DIN 53 886.

The rate of increase of water pressure is approx. 10 mbar/min which corresponds to approx. 10 cm water column per minute. → Water repellency of textile fabrics (Bundesmann method).

Water impermeability testing →: Water repellency; Bundesmann; Basin; Burette; Empirical; Permeability bag; Spray; Immersion; Water pressure and Water tap tests.

Water-in-oil emulsions (W/O emulsions) →: Emulsion; Emulsion thickener.

Water jet cutting In garment manufacture, patterns are cut mechanically with knives or saws, or thermally with laser beams. Multiple layers of textile fabric or leather can also be cut into single layers by high power jets of water provided the momentary discharge of water is dissipated with the aid of a suitable backing material (Figs. 1 + 2).

Fig. 1: Typical water jet cutter nozzle.

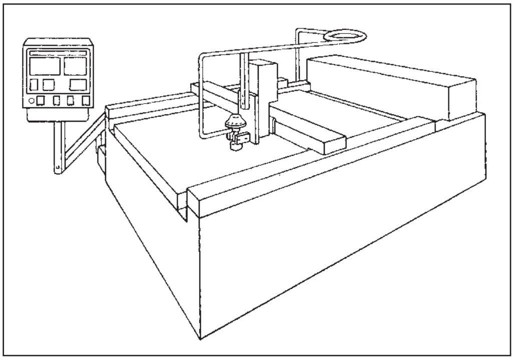


Fig. 2: Water jet cutting machine for garment manufacturing.

Water jet vacuum pump A simple suction pump capable of producing a moderate degree of vacuum, in which air is drawn through the branch of a T-tube by the action of a fast jet of water passing through the straight section. The pump has no moving mechanical parts.

A controllable water jet pump consists essentially of the elements shown in the Fig. Due to the difference in pressure P_{01}/P_{03} between the propulsion flow and the suction flow, the propulsion flow has a higher speed than the suction flow at the exit of the jet and carries it along by the mechanism of turbulent apparent friction into the collector jet. The speeds v_T and v_S of the propulsion and suction flows differ up to the end of the mixing tube. The pressures are equal, however. The Bernoulli equation holds good here

$$P' = P_{03} - h_S \qquad \left(h_S = \frac{\rho \cdot v_S^2}{2}\right)$$

where h_S is the dynamic pressure of the suction flow.

Both flows become mixed together in the mixing tube by the transfer of energy and impulse. Since the impulse decrease of the propulsion flow is smaller than the impulse increase of the suction flow, the pressure in the mixing tube rises. Both flows are so well mixed together at the end of the mixing tube that the speed at that point is almost uniformly distributed throughout the cross-section. The speed decreases in the diffusor and the pressure rises to P_{04} at the end of the diffusor (according to Baelz).

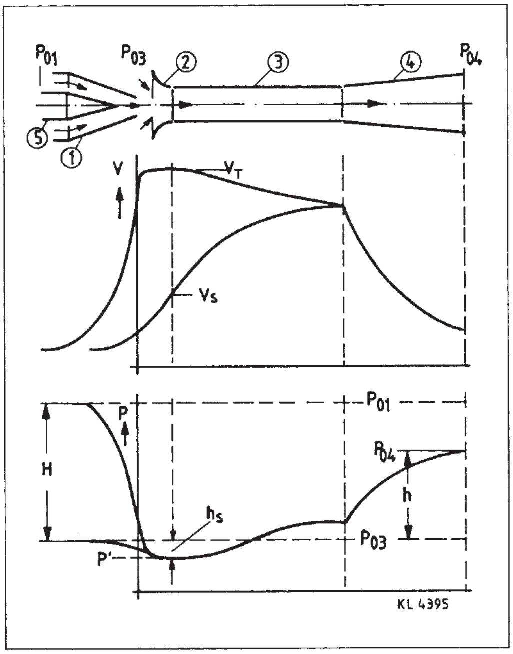


Fig.: Jet vacuum pump in diagram form showing speed and pressure flows.
1 = feeding nozzle; 2 = reception aperture; 3 = mixing tube; 4 = diffusor; 5 = controlling taper.

Water lock The installation of a water seal prior to the delivery of fabric from a steamer ensures an air-free passage of the latter through the steamer, e.g. by immersing the lower exit rollers inside the steam chamber in the liquor contained in the 1st aftertreatment bath (see Fig.).

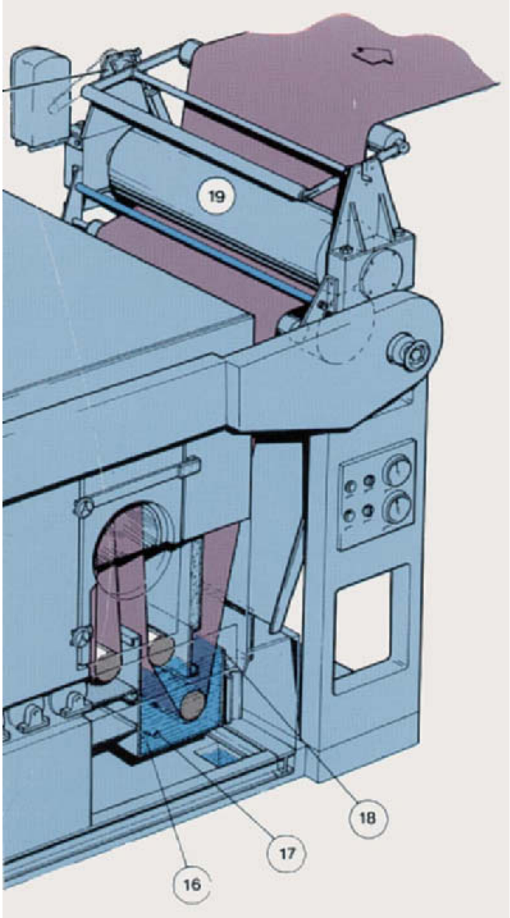


Fig.: Water lock on the run-out of a fabric steamer.
16 = water lock; 17 = fresh water distributor pipe;
18 = water lock overflow; 19 = run-out squeezer.

Water mangle, water calender A mangle with two squeeze rolls for the dewatering (pre-drying) and simultaneous smoothing of textile fabrics. A water mangle is often used before drying piece goods in rope form after pretreatment.

Watermarks,

I. Differences in light reflection from a textile fabric caused by the action of otherwise harmless water sprays or water drops. The effect is due to a temporary swelling which occurs particularly with regenerated cellulosic fibres sensitive to wetting. In most cases, these water marks can be successfully removed with a mixture of alcohol/glycerol 3 : 1 (dabbed on the affected area with a prewetted cloth followed by smoothing and drying. Crêpe fabrics should be covered with a cloth after dabbing on the above solution and dry ironed).

II. Moiré effects caused by the pressure of one layer of fabric on another.

III. Undesired marks due to the presence of wet spots on a textile fabric prior to continuous dyeing (or beam dyeing) which reduce dye uptake in localized areas.

IV. Variations in the pile orientation of pile fabrics causing differences in light reflection.

Water meter A programmable meter which has the function of a summation counter to predetermine and control the total consumption of water in wet processing treatments. Quantities of water for individual process stages can be preselected by means of a rotary switch and are automatically measured as the program runs. Different quantities of water can be preselected.

Water of crystallization (water of hydration). Water which is chemically combined in many crystalline substances. This water may be held in the crystal in various ways. Thus, the water molecules may simply occupy lattice positions in the crystal, or they may form bonds with the anions or the cations present. Hydrates are examples of compounds containing water of crystallization and include such well-known salts as, e.g. sodium carbonate crystals ($Na_2CO_3 \cdot 10\,H_2O$) and sodium sulphate ($Na_2SO_4 \cdot 10\,H_2O$) as the decahydrates which lose their water of crystallization on heating at fairly high temperatures (calcination). Numerous salts exist with different amounts of water of crystallization, i.e. hydrates with a low and a high water of crystallization content such as copper (II) sulphate in the form of, e.g. the monohydrate $CuSO_4 \cdot H_2O$, the trihydrate $CuSO_4 \cdot 3\,H_2O$ and the (normal) pentahydrate $CuSO_4 \cdot 5\,H_2O$. The pentahydrate is converted to the monohydrate at 100°C and only becomes anhydrous (as a white powder) above 250°C. Loss of water of crystallization is accompanied by a breakdown of the characteristic crystalline form.

Water parameters recommended for steam generation Boiler feed water for steam generating purposes must be of a particular quality as far as its chemical make-up is concerned (Tab.).

Water pistols A water pistol is used in textile cleaning operations for the localized dosing of liquid cleaning agents by hand. Such a water pistol may be attached to a flexible hose of any length and the main water supply tap does not have to be opened and closed before and after each application. The water spray (Fig.) stops automatically on releasing the trigger.

Water pockets If batch rolls containing wet fabric in the open-width state are inadvertently kept standing during, e.g. a prolonged machine stoppage in wet

		low-salt		saline
elec. conductivity at 25 °C	μS/cm	10–30	> 30–100	> 100–1500
general requirements	–	clear, no sediments		
pH value at 25 °C	–	9–10 1)	9–10.5 1)	9–10.5 1)
oxygen (O_2)	mg/l	< 0.1 2)	< 0.05 2)	< 0.02 2) 3)
alkaline earths (Ca + Mg)	mmol/l	< 0.02	<0.02	< 0.02
phosphate (PO_4)	mg/l	< 5 4)	< 10 4)	< 15
when using oxygen binders:				
hydrazine (N_2H_4) 5)	mg/l	0.3–3	0.3–3	0.3–3
sodium sulphite (Na_2SO_3)	mg/l	–	–	< 10

Tab.: Water chemical standard values recommended for the recirculation water of directly or indirectly heated systems.
1) If the provisions of the drinking water ordinance/ drinking water preparation ordinance are to be observed, it is essential not to exceed the pH of 9.5 and the PO_4 ion concentration of 7 mg/l. 2) In continuous operation significantly lower values normally appear. 3) If appropriate inorganic corrosion inhibitors are used, the oxygen concentration in the recirculation water can be up to 0.1 mg/l. 4) For hot water generators with smoke tube heating surfaces, e.g. flue smoke tube boilers, the half maximum value of 2.5 or 5 mg/l of PO_4 ions is to be observed as the lower phosphate concentration. 5) Only for heating systems without direct drinking-water heating.

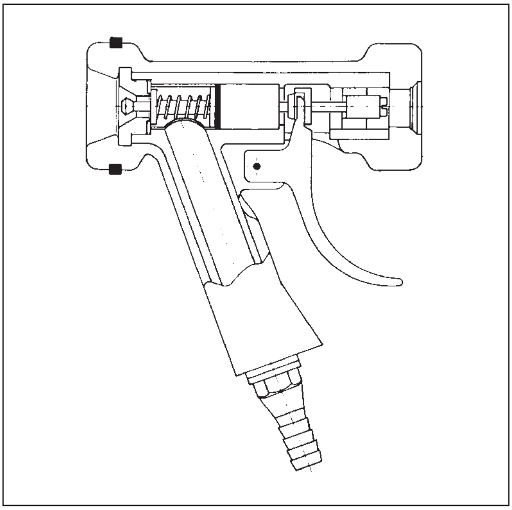


Fig.: Water pistols (van Wyk).

processing, unavoidable concentrations of liquor build up in the lower parts of the batch roll (in the form of a water pocket) due to gravity. The consequences are unbalanced running and unwinding problems.

Water power Water power is little used in the textile industry. Conversion systems designed to exploit the energy contained in falling or flowing water (dams, rivers, etc.) include: a) a simple turbine wheel (rotating about a perpendicular axis, which diverts the water in one direction by means of a fixed wheel with guide vanes); b) a Francis spiral turbine (rotates on a horizontal axis and requires no fixed guide wheel); c) a Pelton wheel (an impulse water turbine in which specially shaped buckets attached to the periphery of a wheel are struck by a jet of water, the nozzle being either deflected or valve-controlled by a governor); d) "overshot" water wheels are now obsolete (low efficiency).

Water pressure resistant → Waterproof.

Water pressure test (hydrostatic head test). A method for testing water-repellent and waterproof finishes on textile fabrics (→ Burette test). The time taken for the first drops of water to penetrate through the material or the quantity of water which has passed through the material per unit time is measured. For the Schopper water pressure test, the following practical guidelines are useful: a textile material resistant to a water column pressure up to 20 cm is regarded as "showerproof", up to 50 cm as "rainproof" and resistant up to 1 h at 50 cm without any penetration of water as "waterproof".

Waterproof A term commonly applied to textile fabrics fully resistant to penetration by water (resistant to water pressure) and "completely impermeable" to air (i.e. the pores of the fabric are closed). Examples include oiled silk with an appropriate finish, ground sheets, tenting, tarpaulins, etc. This term must not be confused with the term → Water repellent.

Waterproofing The production of a → Water repellent finish (analogous to a waterproof or water pressure resistant finish) on a textile fabric. → Waterproof and water repellent finishes.

Water protection Embraces all measures necessary for the protection of surface and ground waters against harmful pollution. The German Water Resources Law (WHG – Wasserhaushaltsgesetz) was amended in 1986 (→ Waste water regulations) with a view towards introducing more stringent requirements for the protection of water as well as to safeguard future drinking water supplies. As a consequence of this amendment, direct polluters (as well as some indirect polluters) are now faced with much stricter demands in terms of the minimum requirements to be met for waste water discharges. If the receiving body, into which waste water is directly discharged, is also used for the abstraction of drinking water, a waste water management plan is prepared which can place even higher requirements on the direct polluters concerned.

The WHG was promulgated in 1957 to protect all surface waters and ground waters on a statutory basis for the first time. The WHG provides, so to speak, the rough outline for the codification of water legislation. First of all, the WHG contains an introductory clause setting out the scope of its application (§ 1). This is followed by general clauses relating to water courses (§ 1a–22: legal consents; old legislation; old utilization; compensation procedures; effluent disposal plans and effluent treatment plants; ground water preservation areas; pipelines; installations for the storage, bottling/packing and transhipment of water polluting substances; compensation; monitoring requirements; the designation of authorized persons with responsibility for water protection; and absolute liability). This is followed by special regulations for surface waters (§§ 23–32; licence-free usage; pollution control; upkeep and consolidation; flood areas), as well as special regulations for coastal waters (§§ 32a, 32b), special regulations for ground water (§§ 33–35), regulations for water management planning and the water account (§§ 36–37) and finally administrative fines and concluding clauses. (§§ 41–44).

According to § 2 of the WHG, the utilization of a water course requires an approval from the relevant authority (§ 7) or consent (§ 8). According to § 3 of the WHG, utilization includes abstraction from surface water courses as well as the discharge or introduction of substances into surface water courses. According to § 7a of the WHG, a permit for the discharge of effluent may only be granted if the quantity and pollution of the effluent are kept as low as possible. In order to give the requirements relating to the discharge of effluent a concrete form, the federal government has issued, with the agreement of the federal parliament, general administrative directives for specific industrial sectors setting out the minimum requirements for the discharge of effluent (e.g. the 38th general administrative regulation for the textile industry) (§ 7a WHG). Licencing as well as monitoring of the required discharge limits is undertaken by the authority responsible for the respective user. The licence is granted by the higher water authority (government president) for discharge quantities greater than 200 m^3/2 h, and by the lower water authority for discharge quantities les than 200 m^3/2 h. These minimum requirements are monitored by the national department for water management and waste disposal in the corresponding administrative district or the responsible department of the environment. In addition, § 21a WHG requires that users of water courses discharging more than 750 m^3 of waste water per day must appoint at least one authorized person (company employee) with responsibility for the protection of water courses. According to § 21b WHG, this person is under an obligation to monitor compliance with the directives, conditions and regulations in the interests of water protection, especially by the routine control of waste water treatment plants in terms of their functional integrity, proper operation as well as maintenance, by measuring the quantites and properties of the waste water discharged and by recording the results of such measurements and controls. This kind of self-monitoring is often carried out several times a year by an authorized body. If required by the Water Resources Law, plans for the management of water courses are drawn up by the German states (§ 1a) which take into account the various requirements for their utilization (management plans) (§ 36b). Such management plans are drawn up especially for those surface water courses to be used as water supplies. The uses to which a particular water course may be put, the characteristics which the water course must exhibit during its passage (e.g. water quality classes) and the measures necessary to realize the required objectives are laid down in the management plan. These management plans can also be declared mandatory for other authorities by state law.

The WHG is subject to continual amendment. The 5th Amendment, which is particularly concerned with improved water protection and therefore places greater emphasis on the interests of water ecology and stricter observance of water saving measures, came into force on 1.1.1987. Not all the changes introduced in the amendments to the WHG will be mentioned here. Only those changes which place much stricter requirements on the operation of effluent treatment plants and which particularly affect the discharge of effluent will be discussed in greater detail. The most important amendment in this regard is the change made to § 7a WHG. The communiqué of 16.10.1976 on § 7a lays down that effluents that contain polluting substances must be avoided according to the best technology available or must be treated properly before they are discharged into a water course (direct discharge) or into a public sewer (indirect discharge). The administrative regulations on minimum requirements likewise correspond to generally recognized standards of technology. The corresponding branch-specific administrative regulations are limited, as a rule, to just a few parameters which take account of the practical properties that have been protected. In the 5th Amendment of 25.6.1986 the WHG imposed considerably more stringent requirements with regard to the provisions of § 7a for limiting emissions. As before, the requirement for minimization exists, i.e. by keeping the pollutant load as low as possible. In addition, however, the regulation now makes a distinction between hazardous and other substances. The discharge of effluent containing hazardous substances is subject to increased requirements for their reduction in conformity with the general state-of-the-art as reflected in the administrative regulations. Effluent which only contains "other substances" is, by contrast, only subject (as before) to requirements for reduction directly in accordance with generally recognized standards of technology. In the new draft of § 7a, such noxious substances are defined as follows: "substances or substance groups which, because of concern as to their toxicity, persistence, bioaccumulation, or

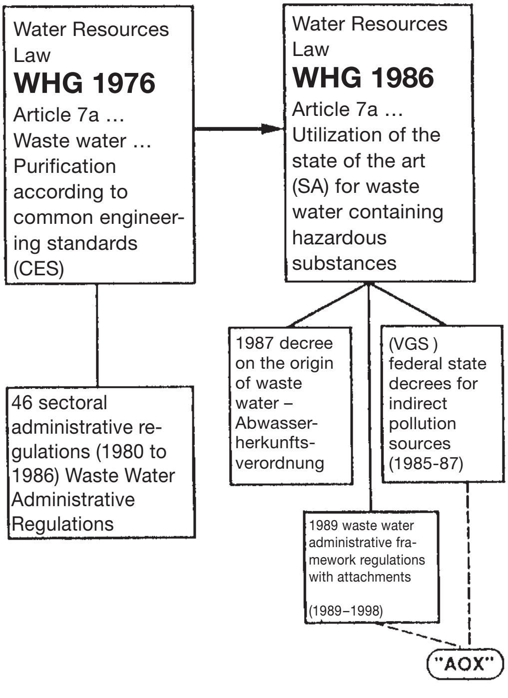


Fig.: Administrative regulations of the German Water Resources Law – Wasserhaushaltsgesetz (WHG).

which have a carcinogenic, fruit-damaging or genetically-mutational effect, are to be rated as hazardous". According to § 7a, the federal government has specified the sources of origin for effluents containing noxious substances in the Ordinance on Waste Water Origins of 3.7.1987 (which includes textile manufacturing and finishing). For branches of industry mentioned in the Ordinance on Waste Water Origins those requirements which, in the opinion of the federal government, can be met by current state-of-the-art procedures have been specified in concrete form within the General Administrative Ordinance on Minimum Requirements for the Framework Administration Regulation of Waste Waters (Rahmen-Abwasser VwV; see Fig.) and are contained in approx. 50 industry-specific annexes. "State-of-the-art" differs from best available technology with regard to the possibilities for reducing the presence of noxious substances with a sufficient degree of certainty by employing advanced, if not yet tried processes, installations or operating methods without involving excessive expenditure. A new development here is that limits for noxious substances have now been fixed not only for direct polluters but also for indirect polluters as well (and even for certain segregated effluent streams so that no dilution within a plant is possible). Individual states are allowed to modify the WHG, provided the result is not less stringent than federal law. It should be noted that state regulations differ slightly but all set specific threshold limits for concentrations and pollutant loads of noxious substances in effluents.

The legally binding 38th former General Administrative Regulation as well as the future 38th Annex to the Framework Administration Regulation of Waste Waters, which currently exists in draft form, apply to effluents discharged into water courses where the pollutant load originates essentially from the treatment or processing of yarns and fabrics and textile finishing. The requirements of the former 38th General Administrative Regulation have now been compared in tabular form with the new definitive requirements which will probably have to be met in future under the new General Administrative Ordinance (see Tab.).

A comparison of the minimum requirements for the discharge of effluent reveals that considerably more stringent limits have been laid down for almost all the parameters. In the requirements according to generally recognized standards of technology, which are only important for direct polluters, the limits for COD and BOD_5 have been virtually halved. In addition to the unchanged limit for ammonium nitrogen, a new limit for total phosphate and a specific denitrification has now been specified. The requirements according to state-of-the-art procedures (applicable to direct and, above all, indirect polluters), are now much more stringent compared to the Administrative Regulation of 1984 as far as the threshold limits for heavy metals are concerned. In addition to these, further limits have been introduced for other parameters (Sn, As, Hg, Cd, AOX, volatile halocarbons) and the colour of effluent is also subject to specified limits. When the future General Ordinance on Waste Water comes into force, the textile finishing industry will have to satisfy considerably higher requirements on the discharge of effluent and these will only be met by pollutant-specific effluent cleaning treatments or pretreatments.

Parameters		38th gen. Administrative Regulation 1984	Draft of 38th Appendix	Requirements acc. to
Filtrateable solid pollutants	(mg/l)	40	?	CES
Settlable solid pollutants	``	0.3	?	``
COD	``	280	160	``
BOD_5	``	40	25	``
NH_4-N	``	5	5-10	``
Total phosphate	``	-	2	``
NO_3-N	``	-	concerted denitrification requirements	
HC	``	10	15	SA
VHHC	``	-	0.1	``
AOX	``	-	0.5	``
Cu	``	1	0.5	``
Cr (total)	``	2	0.5	``
CrVI	``	-	0.1	``
Ni	``	-	0.5	``
Pb	``	-	0.5	``
Zn	``	3	2	``
Sn	``	-	2	``
As, Hg, Cd	``	-	pract.0	``
Sulphide	``	0.1	?	?
Sulphite	``	1	?	?
Active Cl	``	0.3	?	?
Fish toxidity	``	4	2	``
Colouration				
yellow 436 nm		-	3.5 m^{-1}	
red 525 nm		-	2.0 m^{-1}	
blue 620 nm		-	2.0 m^{-1}	

Tab.: Consequences of amendment of the German waste water legislation for textile industry.

Water quality,

I. 1. Temperature: ground and surface waters in particular, as well as piped water to some extent, often exhibit considerable variations in temperature.

2. Chemical reaction: soft waters can be acidic in reaction to approx. pH 5 and hard waters may have an alkaline reaction up to approx. pH 8.

a. Numerous problems in textile wet processing are obviously dependent on other properties related to water composition.

b. All waters can have a corrosive action under certain circumstances: 1) an acidic reaction is mainly due to the presence of humus or other organic and inorganic acids such as carbonic acid (in air-free water), sulphuric acid (especially in swamp water), silicic acid and acidic surface corrosion. Results: formation of soft lime soaps on mortar and concrete foundations, strength losses, hazardous destruction, etc.; 2) a neutral reaction can also lead to the corrosion of metals and mortar building materials, especially in the case of chemically pure water. The presence of atmospheric oxygen causes typical pitting corrosion and is particularly dangerous in half-filled pipes and boilers; 3) an alkaline reaction can also cause metal corrosion under certain circumstances (high ammonia content).

3. Suspended solids (suspended matter):

a. Organic substances (humus products) of a more or less acidic character, various colloids with reducing properties provide favourable conditions for 1) dark-coloured precipitations in dyeing (from soaps, auxiliaries, mordants, dyes), stain-like deposits, dull cloudy dyeings; 2) troublesome precipitations in steam boilers and wall incrustations causing hot spots (accumulations of heat), etc.

b. Oils and greases (from condensate contamination with lubricants). These cause 1) spot-like stains in dyeing and defective dyeings; 2) corrosion of boiler plant and concrete foundations in normal operation due to breakdown into free fatty acids, even small quantities are dangerous (5–10 mg/l), including unsaponifiable mineral oils. There is a tendency to form thin heat-insulating protective layers on the inner walls of boilers (heat conductivity approx. 100 times less than steel); these deposits make boiler scale more impervious to water which results in local overheating, bulging, burst tubes, operational safety risks, etc.

4. Dissolved substances upset the equilibrium of H and OH ions in water and influence the mutual solubility of other dissolved or soluble substances. Consequences: the neutrality of the water usually changes in an acidic or alkaline direction, diverse chemical interactions take place depending on concentration and temperature. Dissolved components sometimes participate energetically and uncontrollably in numerous finishing processes as electrolytes. Dissolved substances also represent a corrosion factor as far as most metal installations and cement-concrete structures are concerned.

a. Water containing air with a high oxygen content can, under certain circumstances, interfere with reductive processes in textile dyeing and finishing due to the sensitivity of the latter to oxidation. Water containing air with a high proportion of chlorides, nitrates or free carbonic acid has lead-dissolving properties. In general, soft water (low in carbonates) with only 4 mg/l of oxygen has a detrimental effect on metal pipes up to approx. 7°d. On the other hand, water with a higher carbonate hardness and 9 mg/l oxygen usually has no detrimental effect. Water containing air is responsible for the much feared pitting corrosion in steam boilers and this has to be prevented by the deaeration of boiler feed water and/or the addition of oxygen scavengers.

b. Water containing free carbonic acid in different states: 1) totally bound carbonic acid (e.g. neutral carbonates such as calcium carbonate $CaCO_3$); 2) partially-bound carbonic acid (e.g. acid carbonates such as calcium bicarbonate $Ca(HCO_3)_2$); 3) free carbonic acid (i.e. not bound to a base, with up to 99% as the gas CO_2). Free carbonic acid serves to maintain the carbonate/water equilibrium. When water is heated, half of the carbonic acid which is present in readily soluble bicarbonates escapes as gas whilst the less soluble carbonates are partially precipitated. The free carbonic acid content rises with increasing temperature.

II. Water for textile dyeing and finishing must have a certain degree of purity if it is to be used as process water. The term ”water quality” is also used in an ecological sense. Even treated waste water which can be recycled for textile dyeing and finishing processes must meet certain water quality requirements if its constituents are not to interfere in various processes.

Element species analysis involves an analysis of the physical and chemical states of elements. The results of this analysis (Fig. 1) allow inferences to be drawn, e.g. on possible sedimentation processes or toxic effects towards aquatic organisms. Copper ions, for example, are considerably more toxic to algae as free metal ions than when they are bound in the form of stable organic copper complexes.

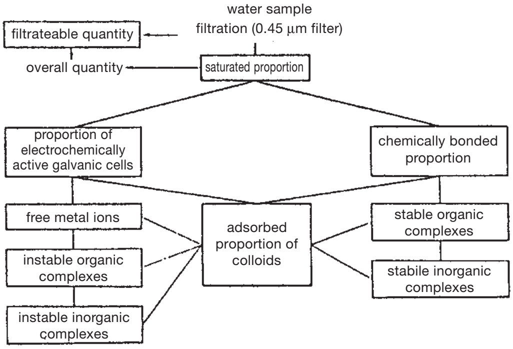


Fig. 1: Diagram enabling galvanic cell species analysis in water.

Water treatment (Fig. 2) or waste water treatment (Fig. 3) is necessary to improve the quality of water. A certain water quality is recommended for recycled waste water for use in dyeing and finishing processes after a cleaning treatment (Tab. 1).

The optimum condition of fresh process water for textile dyeing and finishing is reproduced in Tab. 2. Organic substances are found in surface waters particularly and may be present in a suspended or colloidally dissolved form after heavy rainfall as well as in fast flowing rivers.

The processes frequently used for the treatment of drinking water, e.g. the removal of iron and manganese by aeration, sand filtration or the removal of carbonic

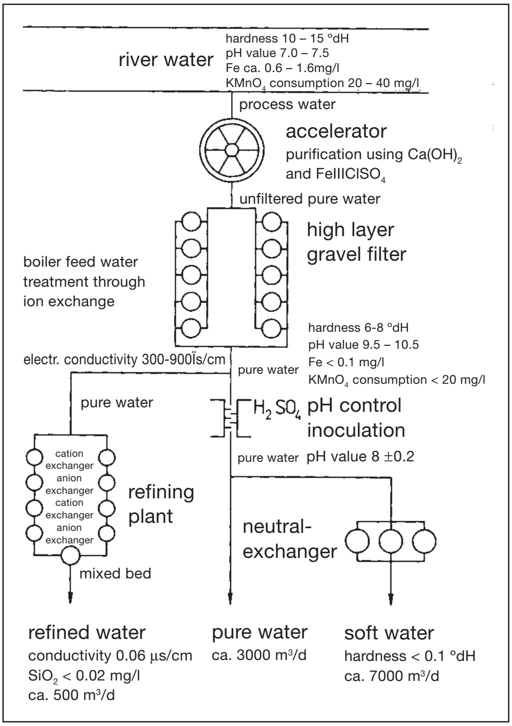


Fig. 2: Diagram of the water treatment process.
°dH = German units of hardness.

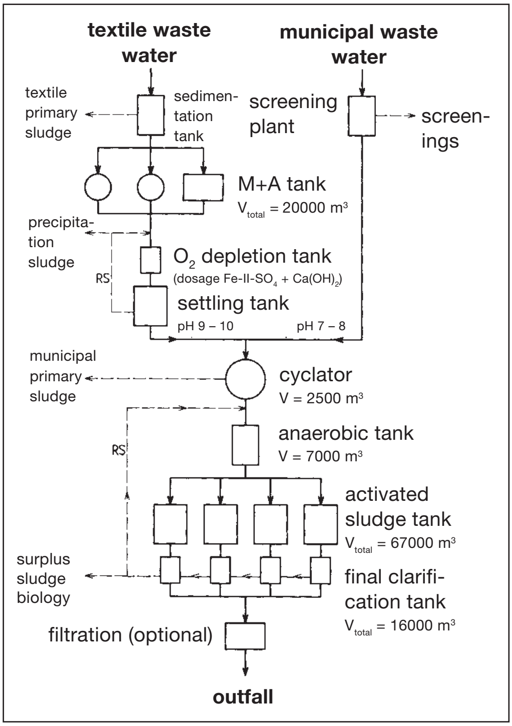


Fig. 3: Diagram of the waste water treatment process.

colouration	colourless
pH	6.5–7.5
fixed solids	ca. 250 mg/l
evaporation residue	ca. 500 mg/l
Cu^{2+}	0.005 mg/l
Cr^{3+}	0.1 mg/l
Fe^{2+}/Fe^{3+}	0.1 mg/l
Mn^{2+}	0.05 mg/l
Al^{3+}	0.2 mg/l
Cl^{-}	ca. 150 mg/l
SO_4^{2-}	ca. 200 mg/l
NO^{2-}	–
total hardness	up to 5 °d
temporary hardness	up to 2 °d
magnesium hardness	up to 2 °d
COD	< 50 mg/l
settlable solid pollutants	none

Tab. 1: Required water quality of reusable, treated waste water.

appearance		clear
odour		none
water hardness	dyeing	0 – 3 °d
	peroxide bleaching	0 – 8 °d
	chlorite bleaching	0 – 20 °d
iron content		max. 0.1 mg/l
copper content		max. 0.005 mg/l
manganese content		max. 0.02 mg/l
permanganate consumption (organic material)		max. 20 mg/l
pH		neutral

Tab. 2: Process water quality of fresh water.

acid by atomizing the water are usually insufficient for the treatment of surface water.

A well-proven process combination for the treatment of river water is the sludge contact process with subsequent sand filtration and the removal of residual hardness by neutral ion exchange.

In the so-called "accelerator" (Fig. 2) a number of processes take place alongside each other. On the one hand, carbonate hardness is precipitated out by the addition of calcium hydroxide according to the formula

$$Ca\,(HCO_3)_2 + Ca\,(OH)_2 \rightarrow 2\,CaCO_3 + 2\,H_2O$$

and partial softening also takes place. On the other hand, suspended organic matter is eliminated by the simultaneous addition of iron (III) chloride sulphate as a flocculant. By adjusting the pH to approx. 10, iron and manganese are precipitated out in the form of their hydroxides. Because of the large reactor volume (approx. 1000 m^3 for a maximum throughput of 800 m^3/h), the plant (Fig. 2) is relatively insensitive to changes in feed quantities and quality. After subsequent sand filtration, the iron content usually lies below the required 0.1 mg/l. Permanganate consumption is also reduced by about 30%. Since the water has an alkaline reaction due to the addition of lime, it is necessary to correct the pH by adding sulphuric acid.

Water treated in this way is optically clear and free of iron and colloidal impurities. This water can be used for cooling purposes and similar dyeing and finishing processes where residual hardness will not give rise to problems. For dyeing, however, the water must be fully softened in an additional ion-exchange treatment stage to obtain a residual hardness of < 0.1°d. As a rule, the water is sufficiently free of organic substances after sand filtration to feed into a full deionization plant. Feed water required for the operation of steam boilers represents approx. 5% of the total water consumption in textile dyeing and finishing.

Even before any process water is used for textile dyeing and finishing, considerable quantities of effluent and residues will already have accumulated during the treatment described above. The quantity of concentrated carbonate sludge from the carbonate hardness removal stage can indeed be just as high as the total quantity of industrial wastes accumulated in a textile plant. Moreover, a significant amount of polluted waste water results from the high salt load due to regeneration of the water softening or full deionization plant. Compared to the quantity of salt removed from the raw water, at least double this quantity accumulates in the effluent due to the salt load from regeneration.

From a waste water standpoint therefore, efforts directed towards the minimization of waste water and wastes should not only be concerned with the use of process water within the dyeing and finishing plant itself but should already begin at the raw water treatment stage. Examples here include the recycling of rinsing water from the sand filters into the accelerator as well as minimizing the consumption of regeneration agent by counter-current and coupled regeneration.

Water quality classification The condition of water is described by objective, measurable data based on chemical, physical and biological parameters, e.g. concentrations of substances, temperature, flow rate, biomass productivity, etc. The biocoenosis is always the result of the physical and chemical environmental conditions. The latter represent the origin of biological activity. The biocoenosis, for its part, can induce secondary changes in the physical and chemical environmental conditions; reactions and interactions always have a role to play here of course. In contrast to the condition of water as determined by objective measurable parameters, information concerning water quality involves subjective considerations. An effective condition of water is thus compared against a predetermined reference condition. Such reference conditions are based on the requirements placed on water courses for specific utilization objectives such as drinking water supplies, exploitation of certain types of fish or aesthetic considerations (bathing quality). The qualities of water courses are therefore dimensionless parameters (comparative values) compared to a reference condition at the same time. For this reason, water classifications are arbitrary gradations in accordance with a freely selected gradient of water qualities. Such classifications are not practically useful or capable of objective interpretation. Even the so-called water "quality" classes are hardly applicable as far as the totality of properties of a particular water course are concerned. Nevertheless, indicator organisms present in a water course can provide information on its saprobic state.

The determination of a so-called "saprobial index" is based on the observation that organisms whose development in water can take up to one year and longer, are constantly exposed to changes in their aquatic environment and can therefore provide an indication of the

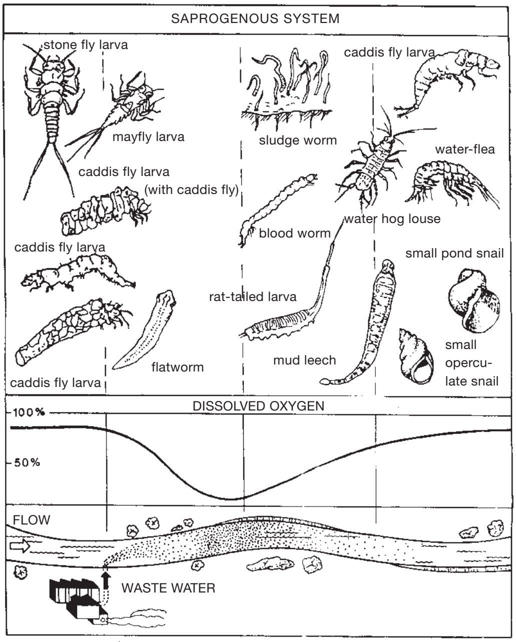


Fig.: Saprogenous system of a body of water before and after waste water discharge into an outfall.

integral condition of the water from only one sampling. The saprobial index describes a typical composition of microorganism species for a particular water course, especially e.g. animal and plant communities living on the bottom of rivers with a specific species diversity and biocoenosis composition. Depending on the degree of pollution, the number of living organisms which can be counted in a specific volume of water is reduced, thus providing a measure of the water quality in terms of its saprobial index (see Fig.).

The German → Water Resources Law describes water pollution from a different standpoint in terms of so-called water hazard classes:

Class 1: water containing unproblematic substances.

Class 2: water containing hazardous substances.

Class 3: water containing particularly hazardous substances (as well as all non-classified substances).

Water recycling Cooling water is unpolluted after use and can be re-used for production purposes. Machines which use cooling water must therefore be provided with the necessary peripheral equipment for recycling (Fig. 1).

Process liquors which have become depleted of essential components during dyeing (Fig. 2) or bleaching (Fig. 3) due to their affinity for the fibre can be replenished again after intermediate storage, e.g. during the rinsing stage, for re-use as starting liquors.

Water repellency test,

I. A severe test method for textiles with a hydrophobic (water repellent) finish. Procedure: a specimen of the textile fabric is lightly stretched over a wooden frame inclined at an angle of approx. 15° (attached to a glass plate with a rubber band if necessary) and placed 50 cm below the outlet of a dropping bottle. Water drops (previously adjusted to a rate of 100 drops/s) are allowed to fall on the same area of the textile specimen until a perceptible wetting occurs (as indicated by a darker colour in the wetted area). Good water repellent impregnations should be able to resist at least 20 of

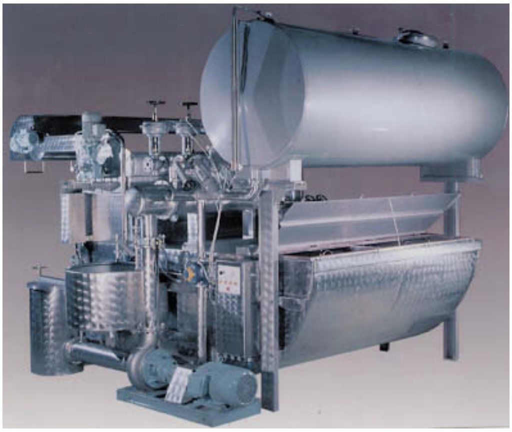


Fig. 2: Recovery (F.A.M.I.T. Ecoflow system) of exhausted polyamide carpet dye liquor in a high container, from which it is re-used as a new feed liquor.

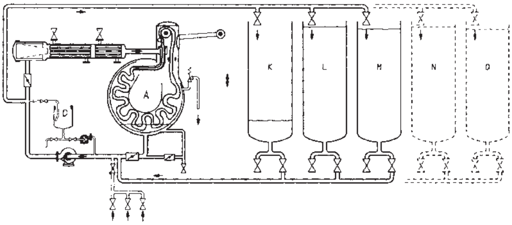


Fig. 3: Scholl Bleachstar: re-use of recycled bleach liquors.

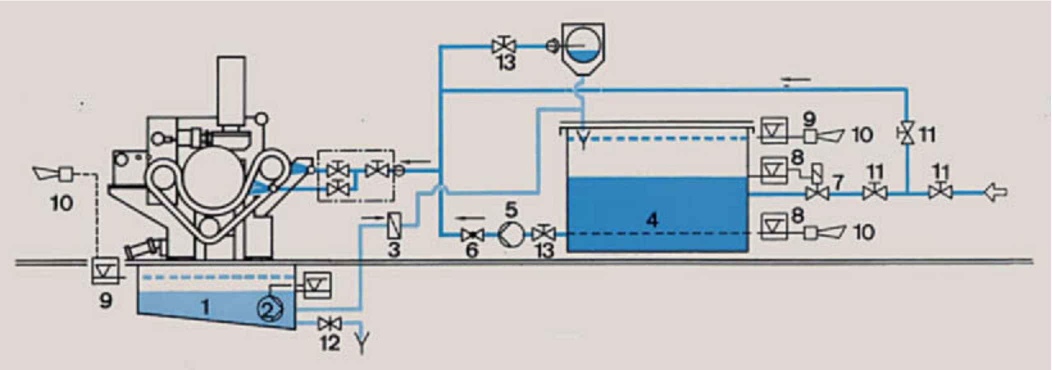


Fig. 1: Cold water recycling reduces water consumption, therby reducing production costs and it is also environmentally friendly (Monforts shrinker).
1 = holding tank; 2 = submerged pump with float switch; 3 = dirt catch pan; 4 = collecting tank; 5 = pump; 6 = non-return valve; 7 = magnetic or submerged valve; 8 + 9 = float switches; 10 = hooters; 11 + 13 = check valves; 12 = shut-off slide.

these drops without any wetting. Alternative: → Spray test.

II. This test method is used for the evaluation of water repellent and waterproof finishes. The test is based on the principle of subjecting a textile test specimen to the action of simulated rain with simultaneous rubbing on the underside of the fabric. The water repellency of the fabric is assessed by measuring the water absorption (%) and the quantity of water which has passed through it (simulated rain values). →: Pfersee-testing instrument; Hydrophobic finishes, evaluation of; Spray test.

Water-repellency testing The Bundesmann rain simulation tester is used to test the water repellency of textile fabrics. A provisional standardization of this test method was already in existence at the beginning of the 1950's and eventually led to the issue of German standard DIN 53 888 in 1965. This standard specifies the procedure for testing water repellent properties for evaluating the effectiveness of finishes intended to improve the water repellency of textile fabrics (Fig. 1). Already at the time of this standardization in Germany, an international standardization of this procedure was also under discussion in the International Standards Organization (ISO).

In order to simulate the action of rain drops, the Bundesmann tester uses a system of 300 identical jets with a drop surface of 4 mm in each case mounted above the centre of the test specimen surface at a height of 1500 mm. The size of the drops falling from the jets is constant and their volume is approx. 0.07 ml. The speed of the drops, and therefore the prescribed quantity of 100 ± 5 ml/min of simulated rain for an exposed surface area of 100 cm^2 is accurately adjusted by means of a pressure reducing valve (coupled to a manometer) built into the water supply line. A cleaning filter with exchangeable inserts is also built into the water supply line to retain mechanical impurities. A swivelling catchment tray mounted immediately underneath the water jets allows the flow of simulated rain to be interrupted immediately at the end of the specified exposure time.

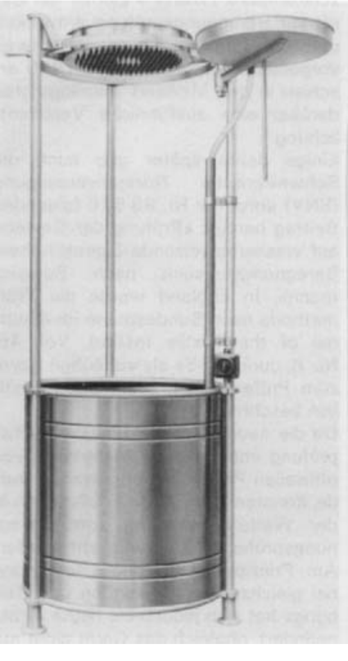


Fig. 1: Water-repellency tester, water-repellency device (according to Bundesmann).

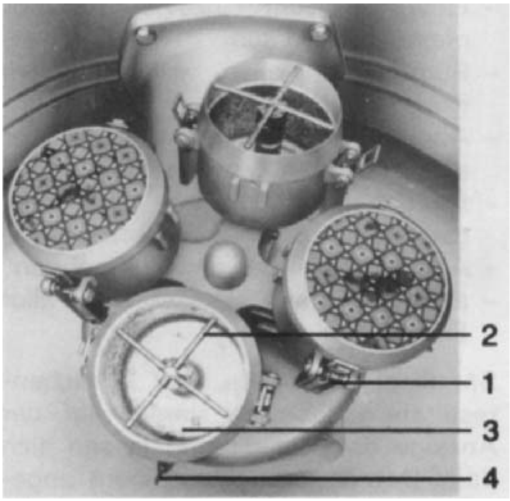


Fig. 2: BP2 water-repellency tester, gauge (according to Bundesmann). 1 = bevelled tension device; 2 = rotating cross-member; 3 = collecting cup; 4 = outlet tap.

During the discussions in ISO on the acceptability of the Bundesmann method, Great Britain proposed its own simulated rain test. However, it was not only the opinion of the German side that the Bundesmann method, which had been introduced a few decades ago, should be retained as the standard test method since specifications such as those for, e.g. uniform fabrics, were based on this well-proven method in many branches of the economy. After further deliberations and an international evaluation of the Bundesmann simulated rain test, ISO Sub-Committee 14 decided at a meeting in 1975 that this procedure should continue to be recommended in view of the fact that a large number of such testers were already in use worldwide and it represented the most reliable and comprehensive test method available. In order to obtain additional information on the suitability and limitations of the method, the Standards Committee NMP 514 ("Test Procedures for the Effect of Water on Textiles") decided in 1982 to carry out a comprehensive interlaboratory trial with the additional participation of several members of the German Association of Manufacturers of Textile and

Leather Auxiliaries, Tanning and Detergent Raw Materials (TEGEWA). According to the report of the Federal Institute for Material Testing in Berlin, the result of this trial justified the international standardization of the Bundesmann test method. This decision was made in relation to ISO Standard 4920 which was of only limited suitability for the evaluation of water repellent properties. The wide distribution of Bundesmann testers was also taken into consideration. International standardization of the Bundesmann method was a particularly useful development since experience had shown that other procedures used up to that time had often led to certain variations or errors (according to Bürlefinger).

An automatic and maintenance-free watertight encapsulated reversing drive is used to control the test head of the Bundesmann tester which can accept up to 4 fabric test specimens (Fig. 2). Each specimen holder on the test head consists of a bevelled tensioning device, a rotating cross-member which rubs against the underside of the test specimen and a collecting cup with an outlet tap. The test specimens are mounted on the cups by means of the bevelled tensioning device. During exposure to simulated rain, the test head rotates and the cross-member executes a to and fro rubbing action on the underside of the test specimen. Uniform pressure of the cross-member is ensured by counter weights. Water penetrating through the test specimen during the test is collected in the cup beneath and can be measured by opening the outlet tap.

Water repellent (hydrophobic). Water drops falling on to a water repellent textile fabric should run off the surface without wetting it. (→ Water repellency test). A water repellent effect suitable for rainwear, dress fabrics, bathing costumes, hosiery, etc. must, of necessity, have good → Air permeability and → Water vapour transmission properties in order to transport perspiration away from the body (see Fig). A "permanent" water repellent finish is resistant to washing and/or dry cleaning, or resistant to washing at the boil. In practice, "hydrophobic" has the same meaning as "water repellent" (→ Water repellent finishing). The term "water repellent" does not apply to water repellent finishes impervious to air since these are more correctly described as → Waterproof.

Fig.: Water droplets being repelled on a water repellent fabric (by Sulzer Rüti).

Water repellent finishes, effect on air permeability The influence of deformation due to swelling on the air permeability of cotton fabrics through the application of water repellants by padding is much greater than the influence of the water repellant product itself. The presence of a water repellant reduces the amount of swelling so that the air permeability is somewhat better than would be the case if the fabric had been padded with pure water alone. In order to reduce the influence of this swelling but nevertheless still be able to conduct comparative tests on various water repellants of importance for the production of hydrophobic finishes on woven cotton fabrics, a low swelling finish was first applied to a textile material followed by the water repellent finish. With this procedure, the silicone products tested here were found to improve the air permeability (compared to the fabric with a low swelling finish alone) by a maximum of 2.6%, whilst paraffin emulsions containing metal salts reduced it by a maximum of 3.4%. Fat-modified synthetic resins also reduced the air permeability by a maximum of 3.5%. Fluorocarbon resins can either somewhat reduce or increase the air permeability depending on the particular commercial product used.

The air permeability of a woven fabric is only influenced to an insignificant extent by the water repellant agent, compared to the considerable reduction in air permeability which results from the padding process. The swelling and deformation associated with the first padding process in particular reduces the air permeability considerably. If this application-specific reduction in air permeability is too great for a particular end use, then a different method of application, e.g. by spraying with less water or by using a solvent system with a lower swelling action must be employed or, alternatively, the fabric construction itself should be modified at the outset to provide higher air permeability. A low swelling finish also has the effect of causing a markedly lower reduction in air permeability (according to Schindler).

Water-repellent finishing Undesirable substances which become deposited on the surface of a textile during use or cleaning represent foreign matter. Textile finishes capable of repelling foreign matter directly from the surface of a textile fabric include (Fig. 2):

1. soil release finishes (effective dry).
2. oil-repellent finishes (effective dry).
3. water-repellent finishes (effective wet).
4. anti-soil-redeposition in washing (effective wet).

A distinction has therefore to be made between those

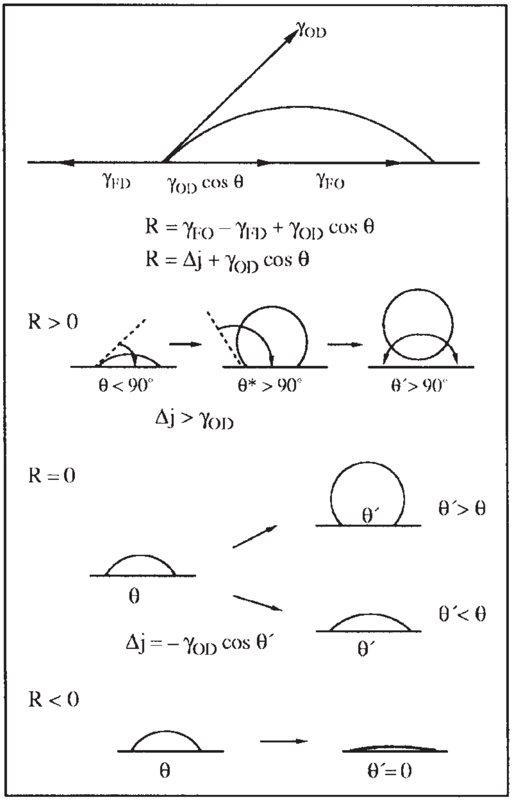


Fig. 1: Young's equation for quantitative representation of the wetting properties of fibre surfaces with liquids (oil or water).

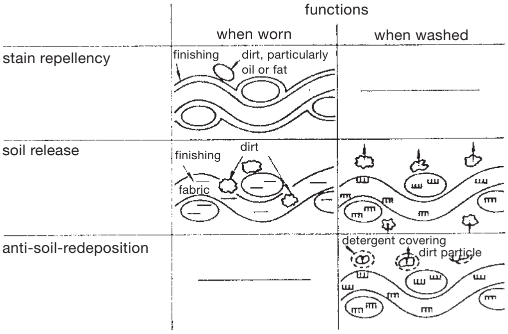


Fig. 2: The effect of anti-soil finishes.

	Oil repellency	Water repellency	Stain remov-ability	Soil release	Greying from washing
Oil-repellent water-repellent FC	good	good	good	bad	bad
Oil-repellent hydrophilic FC	good	average	good	very good	good
Silicon finishing	bad	very good	average	bad	bad
Soil release finishing	bad	none	bad	good	average

Tab.: Connection between oil-repellency, water-repellency and stain removability.

finishes that are effective at the solid/gaseous (fabric/air) interface in the dry state and those which are effective at the solid/liquid (fabric/liquor) interface in the wet state (e.g. during washing). In this connection, it is necessary to distinguish between the terms lipophilic/lipophobic; oleophilic/oleophobic and hydrophilic/hydrophobic (see Tab.). Products with intermediate properties between these extremes, the surfactants, also have a role to play in water repellent and oil repellent finishes as well as hydrophilic and soil release finishes. Anti-soil finishes are applied to reduce or prevent the soiling of textiles in use. Synthetic fibres are particularly prone to soiling and, for this reason, special fibres capable of repelling soil have been developed for the carpet sector in particular. This development has proceeeded through the following stages:

1st generation: normal polyamide fibres.

2nd generation: soil-hiding fibres.

3rd generation: antistatic fibres.

4th generation: antistatic and fluorocarbon-finished (oil-repellent) fibres.

5th generation: a) 4th generation + stain blocker; b) 4th generation + fluorocarbon + stain blocker; c) fibres with built-in flurocarbons. Stain blockers are polymers which are applied to fibres in order to facilitate the removal of fruit juice stains on carpets (contain ascorbic acid, pH 2.8, so that they are able to exhaust on to polyamide like "acid dyes").

The lower the surface tension of a liquid compared to that of the fibre, the better it is able to spread on the fibre surface. This is expressed by the wetting angle θ. If water is to occupy a 1 cm^2 greater surface area, then work of $7.2 \cdot 10^{-6}$ J/cm^2 is necessary (surface tension). Fluorocarbon compounds and organosilicates have the unique property of reducing the critical surface tension of textile fibres (Fig. 3). If the surface of a textile is wetted (soiled) by a liquid then the liquid must have a lower surface tension than the finish. Consequently, polymers with a high fluorocarbon content are used for oil and water repellent effects and organosilicates for dry soil repellency. Young's equation for surface wettability (Fig. 1) shows how the surface energy of the liquid γ_{OD}, the surface tension (surface work γ_{FO}) and the surface energy of the solid γ_{FD} stand in relation to one another. Spreading occurs if $R < 0$; whereas for repulsion it is necessary for $R > 0$.

The surface energy of a solid material can be considerably reduced by the introduction of fluorocarbon groups which makes the wettability of its surface repel

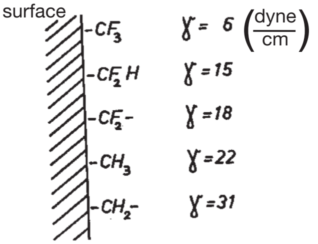


Fig. 3: Effect of fluoride compounds on critical surface tension (dyne/cm = 10^{-3} N/m).

liquids, having a greater surface energy. Conversely, the surface of a fibre can also be modified in such a way that it becomes very accessible to water (water spreads and the material is highly hydrophilic).

Depending on the particular end use of a textile fabric, it may be given either a fully water-impermeable finish (i.e. resistant to water pressure) or a water repellent finish only. In the latter case, the aim is to achieve a substantial water repellent effect together with permeability to air and water vapour. In principle, all these processes are based on the deposition of water repellent and water-insoluble substances on the fibre (Fig. 4). Complete impermeability to water may be achieved by coating. The type of weave and the quality of yarns used in a textile fabric have a considerable influence on the finish.

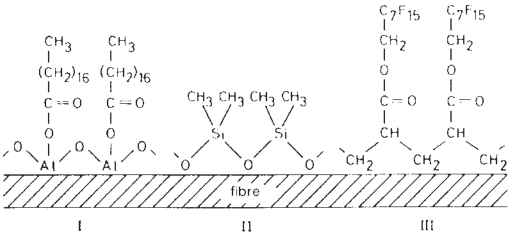


Fig. 4: Arrangement of the various water-repellent finishing auxiliaries on the fibre surface.
I = aluminium salt/paraffin emulsion; II = dimethylpolysiloxane; III = fluorocarbon polymer.

1. Waterproof (water pressure resistant) finishes: these are used for tentings, tarpaulins and other articles. In this case, the interstices of a woven fabric are filled in by the waterproofing agent and the pores closed with the result that air permeability is lost. Fabrics treated in this way, which must be capable of withstanding a water column pressure greater than 1000 mm before penetration with a few drops of water takes place, are no longer “breathable”. In most cases, the handle of fabrics treated in this way is also greatly affected (stiffening). All these finishes must bond firmly with the fabric and should not flake off or crack on bending.

2. Water-repellent or porous water-repellent finishes: these are used for outerwear articles. Such fabrics must have good permeability to air and water vapour after finishing and the products used must not irritate the skin. Suitable polymer products which are impermeable to water yet permeable to water vapour are available. Residues of surface active auxiliaries used in pretreatment can severely impair the water repellent effect in finishing. If possible, therefore, only those surfactants which can be readily washed out should be used in washing treatments. Silicone and fluorocarbon products react more sensitively to residues of anionic auxiliaries than aluminium/paraffin wax finishes, which react more to non-ionic auxiliaries. Three main methods are used for the production of water-repellent finishes:

a) deposition of water repellent agents on the fibre by purely mechanical means. The durability of the effects to washing varies.
b) chemical reaction between hydrophobic substances and the fibre. These effects are durable to washing.
c) formation of water-repellent films on the fibre. These effects are also durable to washing.

Method a) involves the application of salts: the sequence of operations begins by impregnating the textile in a soap solution into which paraffin or wax has also been emulsified. Drying and subsequent impregnation with aluminium formate or acetate solution is possible for the production of a water-repellent finish. However, the single-bath method with stable emulsions of paraffin, waxes and aluminium or zirconium salts is mainly used nowadays. Some of these products also contain glue. By substituting the aluminium salt with a zirconium salt, water repellent impregnations with relatively good durability to washing are obtained. The drying temperature for all these methods after impregnation should be as high as possible so that product migration to the surface of the material can take place.

Method b) which involves chemical reaction with the fibre gives even better durability to washing through esterification or etherification of the cellulose with water repellent auxiliaries of the following types:

- cationic fatty acid derivatives with affinity for the fibre,
- fatty acid derivatives containing metals,
- fat-modified synthetic resins.

The “Inflos” process, which was based on the application of fatty acid chlorides from organic solvents, may be mentioned as the first process of this kind. However, it was not developed commercially for economic reasons. These products only achieved practical significance, in fact, after it became possible to apply them as aqueous emulsions. A textile fabric is impregnated with an emulsion of one of these products on the padder, dried, then subjected to a heat treatment and, if necessary, afterwashed. Another process uses isopropenyl stearate with an acid catalyst. The reaction takes place in a few seconds in hot air at 180°C.

Method c) involves the application of polymers: film-forming products are used for synthetic fibres. Silicones and fluorocarbon derivatives form the basis of such products which are, of course, not only suitable for synthetic fibres but may also be applied to natural fibres. Polysiloxane products, together with fatty acid-modified aminoplasts or epoxy resins to increase their impermeability to water, are applied to cellulosic fibres with melamine precondensates or reactant resins. These water repellent finishes suffer from the disadvantage that the fastness of dyeings, e.g. the colour fastness to light and rubbing, is reduced. Moreover, the finished fabrics are prone to "chalking", i.e. when the fabric is stroked with the finger a lighter stripe remains on the surface. This problem may be remedied by post-calendering. Special products are available for solvent application. Silicones are mainly used (Fig. 5), especially if their elastomer characteristics are an important factor. A special field of application for a water-repellent finish is the application of fluorocarbon compounds to bullet-proof vests. The resistance of woven Twaron fabrics (a highly aromatic polyamide fibre) to penetration by bullets is increased by the application of such a finish since the exclusion of water as a lubricant allows bullets to be intercepted more effectively.

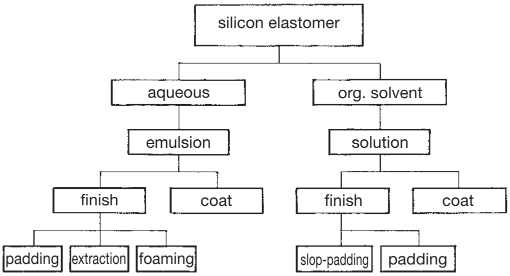


Fig. 5: Silicon elastomer application possibilities for water-repellent finishing.

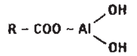
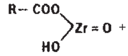
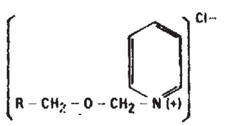
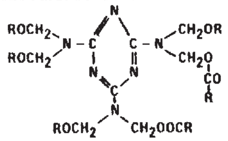
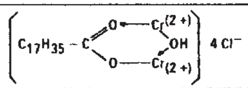
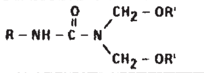
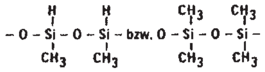
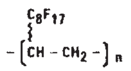
Evaluation (Fig. 6): a subjective assessment of water repellency is possible by means of the Spray Test AATCC 22-1952 (highest rating 100; for ratings 90–0 the increase in wettability is assessed by comparison against a rating chart). In the 3M Test for the subjective determination of oil repellency, the ratio of paraffin oil and n-heptane which allows oil to penetrate through a finished fabric is evaluated. The highest possible rating corresponds to a proportion of 0 parts paraffin oil (by volume) and a proportion of 100 parts heptane (by volume). For a rating of 0, pure paraffin oil penetrates through the fabric.

substituent	oil repellency	water repellency
CF_3-	0	50
C_2F_5-	60	70
C_3F_7-	90	70
C_5F_{11}-	100	70
C_7F_{15}-	120	70
C_9F_{19}-	130	80
$HCF_2(CF_2)_7$-	50	80
$Cl(CF_2CFCl)_3CF_2$-	0	80

1% coating of homopolymerized $\text{Rf-CH}_2\text{O}\overset{\overset{\text{O}}{\|}}{\text{C}}\text{-CH=CH}_2$

Fig. 6: Cotton finished with substituted polyacrylates: assessment scale.

Water-repellent finishing auxiliaries Water repellents (see Tab.) are used for → Water repellent textile finishes and consist, as a rule, of paraffin wax emulsions with aluminium or zirconium salts. For water repellent effects with a particularly high durability to washing, however, preparations containing quaternary organic compounds or urea derivatives, fatty acid mod-

name	diagrammatic formula
alluminium salt/paraffin emulsions	 $R-COO-Al(OH)_2$ + paraffin with or without protective colloid
zirconium salt/paraffin emulsions	 + paraffin
alkoxymethyl pyridinium chloride	
fatty acid modified synthetic resins (on the basis of hexamethylol melamine ethers)	
stearylchromyl chloride	
modified alkylurea	
polysiloxanes	
fluorocarbon compounds	

Tab.: Water-repellent finishing auxiliaries.

ified melamine resins, chromium complex salts as well as silicones are used. They are applied either as aqueous dispersions or from organic solvents. Impregnating agents are used for → Waterproof textile finishes. For this purpose, metallic soaps, based mainly on aluminium or zirconium salts are used in combination with fats, waxes, resins and inorganic fillers. In addition, pore-closing water-insoluble plastics and mixtures of plastics are used which may be applied as aqueous dispersions or from organic solvents.

Water requirements for dyeing and finishing As minimum requirements for dyeing and finishing, a suitable process water must be absolutely clear and transparent, colourless, neutral and as soft as possible. Specific requirements also include freedom from iron, manganese, lead, zinc, tin salts, and especially the absence of nitrates and nitrites as well as a low electrolyte (salt) content.

Water requirements for steam boilers Minimum requirements for boiler feed water include the absence of oil and suspended solids (foaming, spitting, corrosion) as well as the absence of atmospheric oxygen and free carbonic acid (corrosion) and a minimum alkalinity (mg/l caustic soda for water with a low salt content = sodium hydroxide 200–500, for feed water with no phosphate content = 400–2000, for feed water containing phosphates = 100–400). Further requirements include: the lowest possible salt content (test at 15–20°C, 1°Bé = 1000 g salt/m^3) especially salts which form precipitates in the boiler (water hardness salts), low carbonate content (10 mg/l), low content of sulphates and especially silicates, as well as the presence of an excess of hardness precipitating agents (in mg/l = sodium carbonate 50–100, NaOH 20–40, trisodium phosphate 26–120), with no final softening reaction in the boiler if possible.

Boiler feed water specifications differ according to steam pressure ratings as well as the use of continuous or forced circulation steam boilers. This provides the basis to make the most appropriate choice of make-up water treatment, condensate treatment and chemical conditioning from the many variants available. Feed water specifications differ, above all, depending on whether salt-free or salt-containing water is used and whether an alkaline or neutral procedure is applied. Combined processes may also be adopted without objection.

In the feed water specifications for forced circulation boilers, the graduation according to pressure ratings predominates. The type of conditioning required to achieve a pH between 11–12 at pressures up to 5.3 MPa or a pH between 9.5–10.5 at operating pressures > 5.3 MPa is open to choice. The guidelines also take into account whether salt-free or water containing salt is fed to the boiler. With salt-free water, volatile alkaline agents can be used exclusively with limited boiler water conductivity, or a neutral procedure (by adjusting the pH to 7–8 with NaOH) can be followed in addition to the combined application of solid and volatile alkaline agents. In all these guidelines, boiler water conductivity and silicic acid content are given in relation to the pressure ratings. Finally, the necessary steam quality is decided by the requirements placed on the feed water. If attention is paid to deposition problems in the boiler superheater, separate specifications for saturated steam and fresh steam are necessary.

Water Resources Law The Water Resources Law (Wasserhaushaltsgesetz – WHG) of 27.7.1957 which came into force in Germany from 1.3.1960 in accordance with the statutory provisions of Article 75, Clause 4 of the German Constitution controls, with the aid of appropriate amendments, the abstraction, exploitation and drawing of water as well as the cleaning and treatment of effluents within the Federal Republic, in addition to the water legislation of the individual German states. Extract: the use of a water course is subject to the permission or consent of the authorities. Water courses include surface waters, coastal waters and ground water.

I. Pollution control (§ 26):

1. Solid substances must not be introduced into water courses for the purpose of disposal. Substances in the form of sludges or slurries do not count as solid substances.
2. Substances may only be stored or deposited in a water course provided no pollution of the water or other detrimental change in its properties is to be expected. This also applies to pipelines for the transportation of liquids and gases.
3. Whosoever introduces substances into a water course causing harm to the water is obliged to pay compensation for the damage incurred.

II. Biodegradability of detergents (→ Biodegradation of surfactants):

1. § 1: anionic detergents in washing and cleaning agents must be at least 80% biodegradable.
2. § 2: the biodegradability must be determined in accordance with specified measuring procedures.

III. Detergents law (law on detergents and cleaning agents): this law governs the manufacture of → Detergents and their biodegradability (in force since 6.9.1961).

An appendix has been allocated in the WHG to all sectors of industry. Appendix 38 applies specifically to textile finishing. In the new draft of this appendix (1991) more stringent threshold limits have been imposed on textile manufacture resp. finishing. As before, chemical oxygen demand (COD) remains an important parameter to determine the pollution load of effluents due to the presence of oxidizable and mainly organic substances. The pollution load of the water may be estimated from the oxygen consumption of a strong oxidizing agent. The biological oxygen demand (BOD) on the other hand provides an indication of the oxygen consumption to be expected in a waste water treatment plant. The oxygen consumption is determined by inoculating the effluent under test with water that contains microorganisms. The relationship of COD to BOD is dealt with in more detail in Appendix 38.

The colour of effluents must not exceed certain specified intensities. For the determination of colour, a distinction is made between the yellow, red and blue regions of the spectrum and precisely defined wavelengths have been allocated in each case. The intensity is expressed in terms of the spectral absorption coefficient. The requirements placed on the pollution of segregated waste water streams are also given prominence (→ Segregated stream). Segregated streams are effluents from individual production units or individual finishing stages and arise from the following processes in particular:

- desizing,
- bleaching,
- dyeing,
- printing,
- finishing,
- coating or laminating,
- centralized cleaning of drums and containers.

The definition of segregated effluent streams in the textile industry is difficult. Although the further difficulty arises that processes for segregated stream disposal cannot yet be described as state-of-the-art, certain threshold limits have been stipulated, e.g. for hydrocarbons and chromium. Provided the concentrations fall below these limits, a segregated stream treatment is not required. Special regulations also apply to the handling of residual liquors. →: Waste water regulations; Legislation on environmental protection; Water-endangering substances.

Water retention → Moisture behaviour of fibres and yarns.

Water retention in organic solvents The water retention capacity of organic solvents, e.g. in dry cleaning with dry cleaning detergents. The water retention is the quantity of water remaining in the solvent (expressed as a percentage of the quantity used in each case) after 30 min at 20°C. In addition to time and temperature, it is also dependent on a) the type of dry cleaning detergent used; b) the concentration of dry cleaning detergent; c) the type of textile material; d) the water content of the solvent and e) the type of solvent. The textile fibre absorbs virtually no dry cleaning detergent in regions of high water retention; in regions of low water retention, a certain quantity of dry cleaning detergent goes on to the fibre together with the water. Thus, the undesired absorption of dry cleaning detergent by textile materials is dependent on water retention in the solvent.

Water retention of fibres → Moisture behaviour of fibres and yarns.

Water ring vacuum pump A → Liquid ring vacuum pump which uses water as the operating liquid (see Fig.).

Water rollers (starch rollers). In multicolour roller printing, a plain unengraved roller fed from a colour box containing thickened water, e.g. a thin starch paste (hence the alternative term "starch roller"), which is usually positioned in the machine between two engraved rollers printing contrasting colours. Its function is to remove surplus printing paste from the printed fabric in order to minimise contamination of a subsequent engraved printing roller by a colour paste carried over from the previous printing roller. Like the printing rollers, a water roller is also provided with doctor blades.

Water separator In dry cleaning machines, a water separator is a container which may be of variable construction, used for the physical separation of solvent from the cooling and condensed water. The solvent/water mixture carried over by the water has three sources:

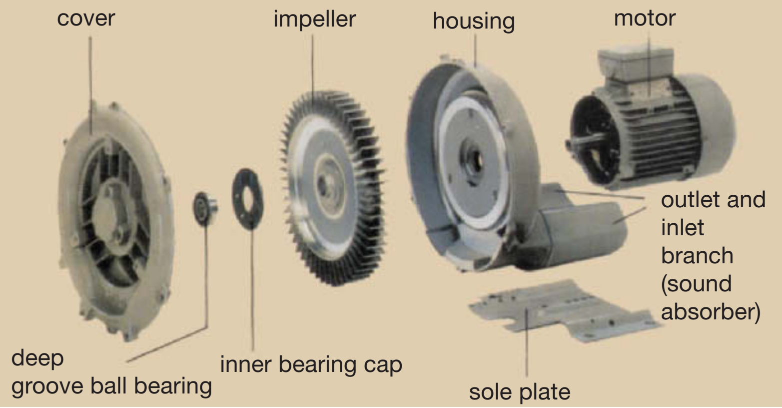


Fig.: Individual parts of an Elmo-G vacuum pump; the impeller rotates friction-free in the housing.

I. From distillation: under favourable circumstances the solvent/water mixture evaporates at the azeotropic boiling point, i.e. evaporation takes place simultaneously at 87.1°C and 1013 mbar = 81.4 (76.5)% tetrachloroethene + 15.9 (23.5)% water (figures in brackets = vol.%).

II. From the drying stage due to the action of blowing warm air through the goods whereby water + tetrachloroethene integrated into the absorbed moisture reaches the cooler as a water/tetrachloroethene mixture.

III. By regeneration of the activated carbon bed during solvent recovery whereby tetrachloroethene deposited on the activated carbon is stripped off with steam and, after condensation in the recooling system, accumulates in the water as a water/tetrachloroethene mixture.

In each case, the water/tetrachloroethene mixture must be cooled, usually in the recooling system, where water runs to the cooling mixture on the countercurrent principle. A complete separation should take place at the critical point.

Conditions for good water separation:

1. The solvent should be at as low a temperature as possible (up to 20°C). In conventional water separators, the temperature range lies between 20–30°C. Under these conditions, 1 kg water takes up 0.16–0.17 g tetrachloroethene. Conversely, the water content in 1 kg tetrachloroethene is 0.072–0.110 g (Tab.).

temperature [°C]	tetrachloroethene in water [mg/l]	water in tetrachloroethene [mg/kg]	water in tetrachloroethene [mg/l]
0	150	40	64
10	160	50	80
20	160	72	115
30	170	110	176
40	180	140	224
50	190	190	304
60	210	250	400
70	224	340	544

Tab.: Effect of temperature on the miscibility of water and tetrachloroethene.

2. The higher the water temperature, the longer it takes for the mixture to separate; the usual dwell time is approx. 10 min.
3. Contact surfaces between the already separated media should be kept as small as possible. Conical constructions, or those provided with a siphon, make it easier for the tetrachloroethene, distributed in the water as droplets, to sink to the bottom and encourage the less dense water to float above it.

Water softening The removal of "hardness" mainly due to calcium and magnesium ions → Water hardness salts. → Water softening processes.

Water softening agents The function of these products is to eliminate the harmful effects of → Water hardness salts and other metal salts by complex formation (use of appropriate sequestering agents). Suitable products are based on salts of polycarboxylic acids, polyphosphates or preparations containing these agents. Such water softening agents are used in all fields of textile dyeing and finishing.

Water softening auxiliaries These additives are only able to assist the water softening process. Such methods are used especially in (outmoded) treatments for water softening by small textile plants with a) soda ash: addition of 2 g per degree of hardness per 100 l, followed by bringing to the boil and skimming off the precipitate formed; b) acetic (or formic) acid: only used to overcome (temporary) carbonate hardness, e.g. by addition of acetic acid 8°Bé = 4.64 g for each 1°d per 100 l. Sulphuric and hydrochloric acids have also been recommended for this purpose (cheaper) but must be added carefully in portions (either alone or combination) where appropriate; c) → Water softening agents, capable of sequestering calcium and magnesium ions, offer a more favourable working pH as well as other advantages in textile wet finishing processes.

Water softening by hydrogen exchange A water softening process based on the principle of desalination by a hydrogen ion exchange process (→ Ion exchanger). With this method, e.g. hydrogen takes the place of a calcium hardness salt. If a neutral exchanger is then used downstream in order to remove the free acid formed at the same time, a softened water results which is free of carbonate hardness.

Water-softening by inactivating additions (hardness binding processes). These processes are based on the chemical inactivation of water hardness salts and other metals (in order to make them harmless) by means of inorganic or organic → Complexing agents (→ Water softening agents) by direct addition to the water.

For water softening purposes, a distinction is made between these products with a sequestering action, and those water softening agents which actually remove water hardness salts from the water.

Water softening processes For the removal of → Water hardness salts.

I. Cultonex process with milk of lime or lime water. In this process, the water hardness is brought down to 2–4°d by stoichiometric dosing.

II. → Lime-soda water softening process with high carbonate and non-carbonate hardness. This process brings the water hardness down to 1–2°d.

III. Soda regeneration process, used specifically for non-carbonate hardness (boiler feed water).

IV. → Trisodium phosphate water softening process: the addition of trisodium phosphate produces a floccular sludge. Water is softened to 0.1°d by this method.

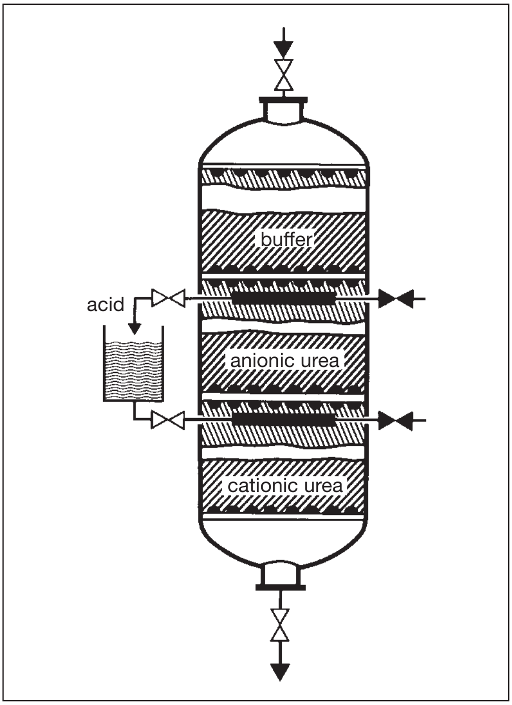


Fig.: Continuous water softener by means of ion-exchange.

V. Baryta process for water with a high non-carbonate hardness (sulphur oxide), residual hardness 1–2°d.

VI. → Ion-exchange processes for complete water softening (Fig.).

Water solubility limit Pure water is a poor conductor of electrical current. Conductivity is, of course, dependent on the degree of dissociation, i.e. on the formation of reactive ions. The addition of certain salts/acids/bases (electrolytes) brings about a considerable increase in conductivity due to electrolytic dissociation. Ionic reactions are some of the most important of all chemical processes (because of their speed). The presence of dissolved substances is of considerable importance in this regard. All solubility processes are temperature-dependent, however, and are also usually influenced by the presence of salts with like ions (e.g. the reverse displacement solubility of calcium chloride by calcium sulphate, or sodium chloride by magnesium chloride) to a greater extent than with salts having unlike ions (= increased solubility, e.g. sodium chloride by magnesium sulphate) and a heat of solution is generated (dependent on concentration). The freezing point, boiling point and vapour pressure of water change in the presence of dissolved salts and other substances (elevation of boiling point and depression of freezing point) so that evaporation leads to concentration and often results in a corresponding increase of activity as well.

Water sorption → Sorption.

Water spotting fastness (colour fastness to water spotting). The resistance of dyeings and prints to spotting with distilled, condensed or rain water. The test guidelines apply to all types of fibres. A few drops of distilled water are worked into the test specimen with a glass rod. Assessment a) after 2 min (wet); b) after drying in air. Results are assessed with the grey scale for change in colour.

Water spotting resistance Resistance of fabrics mainly composed of bright viscose filaments to water spotting which can otherwise cause localized changes in lustre or shade variations in unfinished material (i.e. without a water repellent finish). Such shade variations can be largely attributed to a change in the structure of the fabric surface due to localized swelling which changes the light reflection from the affected area. This has unfortunate consequences in practice since is often difficult or no longer possible to remedy the discoloration by subsequent ironing. Satisfactory resistance to water spotting can be achieved by applying a preventative combination finish, i.e. synthetic resin plus a water repellant. → Water spotting fastness.

Water sprinkling apparatus Pfersee (Bundesmann method). The Bundesmann rain simulation tester is used for the precise evaluation of water repellent impregnations on textiles and offers a high degree of reproducibility. The principle employed in this test method is based on subjecting test specimens to a simulated rain shower falling from a specified height over a specified time. As the test specimens circulate under the shower of water, special wipers consisting of rotating cross members with 4 arms inside the bezels of the cups rub the undersides of the specimens in order to reproduce mechanically the rubbing action which occurs in practice when, e.g. a raincoat is worn. The test is therefore designed to simulate exposure to practical conditions as closely as possible. The Bundesmann tester consists of a multi-nozzle drop producer (atomizing jets with drop forming rods), 4 cups which are covered by textile fabric specimens under slight tension (allows the simultaneous testing of 4 test specimens) and the necessary drive gear. A test exposure of 10 min duration corresponds to the quantity of rain falling as natural rain in 18 h or in a cloudburst in 1 h. The test determines a) the % water uptake of the fabric, b) the quantity of water passing through the fabric in ml during the specified exposure time and c) a visual comparison of the water repellent effect against photographic standards. Manuf.: Pfersee; Erhardt-Leimer.

Water storage reservoir for fire extinguishing In order to prevent environmental pollution due to the contamination of nearby water receiving bodies or water courses by water used for extinguishing chemical fires, it may be necessary to block off certain areas of an industrial plant, depending on the type of chemicals

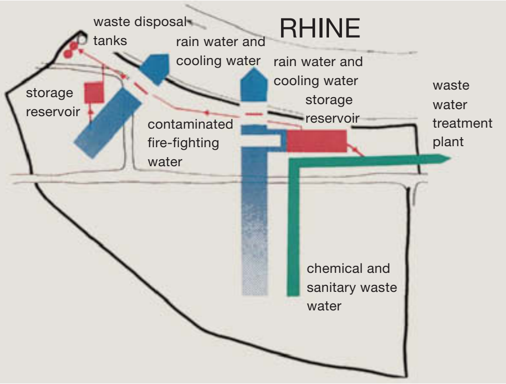


Fig.: Design of water storage reservoir from fire extinguishers in the Sandoz plant, Muttenz.

used in the production processes, and dispose of the contaminated firefighting water within these confined areas in dedicated storage reservoirs (see Fig.).

By means of such dams, contaminated firefighting water can be retained in the drainage system and diverted to a dedicated storage reservoir. Depending on the degree of pollution, it can be subsequently transported to a waste water treatment plant for cleaning or pumped into a disposal tank for intermediate storage.

Water tap test An imprecise test method for water repellent impregnations on (flat) textile fabrics. Procedure: the fabric to be tested is held under slight tension, tilted at an angle, and held approx. 50 cm beneath a water tap where it is subjected to a fine stream of water in one area for approx. 30 s. A good water repellent impregnation should be resistant to wetting under these conditions (wetted areas on dyed or printed goods appear darker).

Water treatment process A distinction is made between processes for the treatment of drinking water and processes for the treatment of industrial water. →: Waste water; Waste water treatment plants.

Water vapour Molecules close to the surface of water can escape from the liquid provided their kinetic energy is sufficient to overcome the forces of attraction. These molecules then pass into the gas phase above the liquid. During this process, the average kinetic energy of the remaining molecules is reduced and the liquid water gives up heat (latent heat of evaporation). This process of evaporation therefore causes cooling (→ Vapour pressure).

Heating causes the temperature of liquid water to increase at first and is accompanied by a slight increase in volume (Fig. 1: transition from state 1 to state 2). On reaching the boiling point evaporation begins. Energy supplied in the form of heat is only used to convert liquid water into the vapour state and the temperature remains constant (Fig. 1: transition from state 2 to state 3) whilst the specific volume is drastically increased. The mixture of boiling liquid and saturated steam is known as wet steam (→ Steam). Only after all the liquid water has evaporated does the temperature of the saturated steam rise to the temperature of superheated steam (Fig. 1: transition from state 4 to state 5).

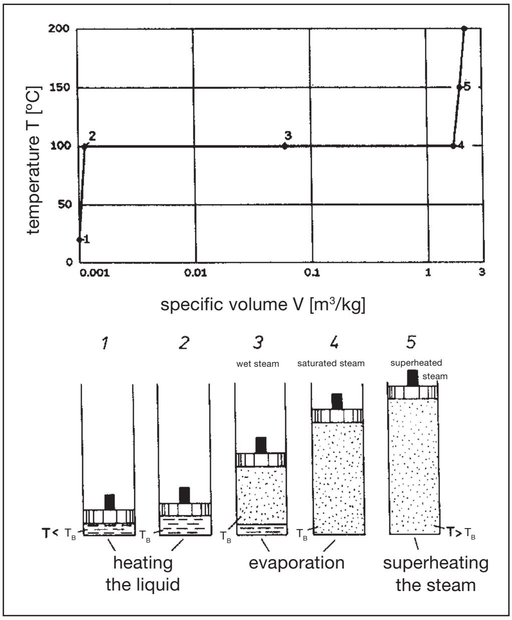


Fig. 1: Evaporation process at a constant pressure of p = 1 bar. T_S = boiling temperature.

The pressure exerted by the evaporated molecules, e.g. against the walls of a vessel, or against the atmospheric pressure, is called the vapour pressure. The energy required to evaporate one mol of a liquid at a specific temperature is called the molar heat of evaporation or evaporation enthalpy (for p = a constant). The relationship between the boiling pressure p_s and the boiling temperature T_s is unambiguous and is described by the vapour pressure curve. The energy required to evaporate 1 kg of liquid at constant pressure is called the evaporation enthalpy Δh_v or the heat of evaporation r. Like the boiling temperature, the evaporation enthalpy is pressure-dependent.

The saturated steam temperature T_s and evaporation enthalpy Δh_v are represented in Fig. 2 as a function of the saturated steam pressure p_s for water. As an example, saturated steam at a pressure of 10 bar has a saturated steam temperature of 179.88°C and an evaporation enthalpy of 2013.6 kJ/kg (→ Water as finishing medium).

Water vapour

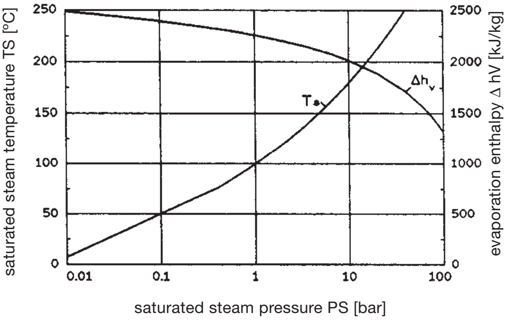


Fig. 2: Saturated steam temperature and evaporation enthalpy.

The opposite process to evaporation is called condensation. In this case, the steam gives up energy, especially the evaporation enthalpy. This principle finds application, e.g. in the indirect heating of a convection drier by means of a steam/air heat exchanger.

When steam condenses (becomes compressed) to the liquid phase, a numerically equal quantity of heat is released. This is called condensation enthalpy (for p = a constant). The higher the concentration of molecules in the gas phase, the more frequently they collide with each other, come into contact with the surface of the liquid phase, and are captured by it. In a state of equilibrium, as many molecules leave the liquid per unit time as condense again. The concentration of molecules in the gas phase (steam space) is constant. The gas pressure of the evaporating liquid is then called the saturation vapour pressure (i.e. the vapour pressure of a vapour in contact with its liquid form).

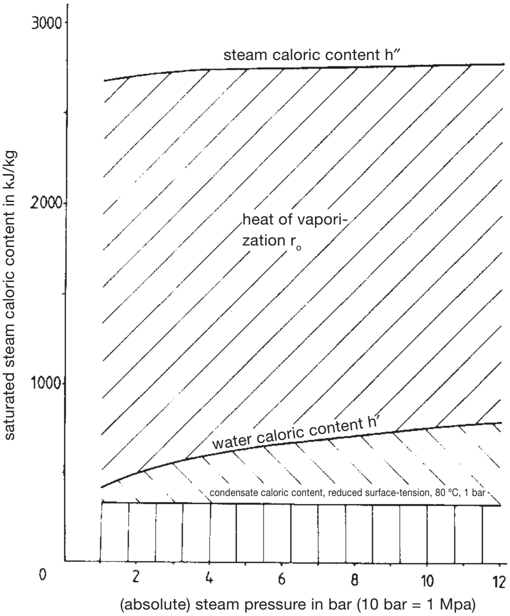


Fig. 3: Saturated steam caloric content, depending on steam pressure.

Water vapour is a true gas (Fig. 3). At low pressures and high temperatures, steam approximates the state of an ideal gas. The more superheated a gas, the more it behaves like an ideal gas. For an isothermal change of state in a closed system, which proceeds at the given temperature T then, according to the second law of thermodynamics, the increase in entropy S of the system is given by:

$$\Delta S = \frac{Q_{rev}}{T} \quad \text{(reversible isothermal processes)}$$

$$\Delta S = \frac{Q_{irr}}{T} \quad \text{(irreversible isothermal processes)}$$

In the above equations, T is the absolute temperature of the system and Q is the heat supplied to the system from its surroundings. If the initial and final states are known one considers, for example, a particular chemical reaction proceeding in accordance with a formula conversion at given values of temperature T and pressure p, then ΔS has a specific value irrespective of whether the reaction proceeds reversibly or irreversibly since S is a state function. The heat Q, on the other hand, is not a state function: it has different values depending on whether a process proceeds reversibly, or irreversibly. This is made clear by the index "rev" or "irr" for Q. For an isothermal process, ΔS can be positive as well as negative. The entropy in such a process can therefore decrease as well. For any processes in closed systems, the first law of thermodynamics requires that:

$$\Delta U = 0 \quad \text{(law of energy conservation)}$$
$$\Delta U = Q + W$$

where U is the internal energy, ΔU the increase in internal energy of the system, and W is the energy performed on the system. A negative value of Q or W means that heat is given up by the system to its surroundings or that work is performed by the system. If the process proceeds under isobaric conditions, i.e. at a constant pressure p, then the reversible volume work supplied to the system is represented by –pΔV, where ΔV signifies the increase in volume of the system. If the work performed on the system is designated W', then as long as it does not exist in the volume work, for an isobaric change of state, the enthalpy H (= U + pV) of a closed system is given by:

$$\Delta H = \Delta U + p\Delta V = Q + W' \quad \text{(isobaric processes)}$$

If the free enthalpy G (= H – TS) of the system is now introduced, then for an isothermal-isobaric change of state in closed systems it follows that:

$$\Delta G = \Delta H - T\Delta S = Q + W' - T\Delta S$$
$$\text{(isothermal-isobaric processes)}$$

By observing the relationship for ΔS, it also follows that:

$\Delta G = W'_{rev}$ (reversible isothermal-isobaric processes)
$\Delta G < W'_{irr}$ (irreversible isothermal-isobaric processes)

Since G (like U, H and S) is a state function (unlike Q, W and W'), the variable ΔG always has the same value for a given initial state and a given final state, irrespective of whether the change of state takes place reversibly or irreversibly. If, therefore, a certain change of state proceeds at a given temperature and given pressure in such a way that work W' can be performed by the system ($W' < 0$, $\Delta G < 0$), e.g. in the form of electrical work, then the work ($-W'_{rev}$) gained in a reversible performance of the process (performed by the system) must be greater than the work gained during an irreversible performance of the process. For this reason, the variable $-W'_{rev} = -\Delta G$ (T,p = a constant) is also called the "maximum effective work".

Steam is a real gas; the state of steam can therefore be described by the following measurable state variables:

- temperature T in K (0 °C = 273.15 K),
- pressure p in Pa or bar,
- volume V in m^3.

For these variables, the following relationship applies to ideal gases according to the kinetic gas theory:

$$p \cdot V = nRT$$

n = quantity of substance
R = the gas constant = 8.314 bar · l/K/mol

The first law of thermodynamics applies to the transition from state 1 to state 2 with the corresponding specific variables (Fig. 4):

$$q_{12} + w_{12} = u_2 - u_1$$

q_{12} = specific heat,
w_{12} = specific work.

The transition from state 1 to state 2 represents a pressure drop from pressure p_1 to pressure p_2 with an increase in volume from V_1 to V_2. The difference between the work components in both states corresponds to the difference in areas $F_1 - F_2$ in the p-V diagram (Fig. 4).

$$p_1 \cdot V_1 - p_2 \cdot V_2 = \underbrace{(p_1 - p_2) \cdot V_1}_{\equiv F_1} - \underbrace{(V_2 - V_1)\, p_2}_{\equiv F_2}$$

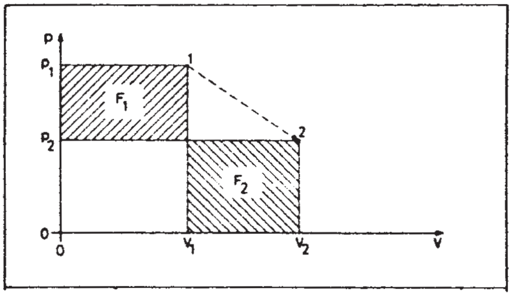


Fig. 4: Change of state in the p-V diagram.
p = pressure; F = area; V = volume.

Work is not a property of a system and is therefore not a state variable either. Work describes a process of exchange between a system with its surroundings. If we consider the volume work $A = -pdV$, then energy is given by the system by the volume. This means that energy flows from one system to another by work. In thermodynamics, the exchange of any non-thermal energy difference is understood as work.

Like work, heat is also not a state variable. Apart from work then, energy in the form of heat can also be exchanged between systems. Heat exchange does not inevitably involve the temperature. This is demonstrated by the example of water evaporating at a constant pressure. Although heat is supplied to the system (as evaporation enthalpy) the temperatures of the liquid water and the vapour remain constant. The heat is transferred between two systems with different temperatures. Heat is the energy which is exchanged without any work mechanism. The entropy always changes in this exchange. The specific heat capacity corresponds to the energy which must be supplied to, or given up by, a substance having a mass of 1 kg or a volume of 1 m^3 (standard cubic metre) in order to raise or lower its temperature by 1 K. In general, the specific heat capacity is dependent on temperature and pressure. In calculations, approximate values or averages between the initial and final temperatures are often chosen. A distinction must be made, especially in the case of gases, as to whether the change of temperature takes place at constant volume or constant pressure. In the first case, the substance (of mass m) is firmly enclosed (V = constant), and the heat supplied increases the internal energy U. The heat capacity is given the index v and is defined by partial differentiation thus

$$c_v = \frac{1}{m}\left(\frac{\partial U}{\partial \Theta}\right)_v$$

Θ = absolute temperature.

In the second case, however, the substance can expand at constant pressure (p = constant) and the energy increases the enthalpy H. The heat capacity is given the index p and is defined by

$$c_p = \frac{1}{m}\left(\frac{\partial H}{\partial \Theta}\right)_p$$

Since, in this case, displacement work is lost or, the molecules of the substance can move away from one another, the rise in temperature is less than in the first case so that, in principle

$$c_p > c_v$$

In order to raise or lower the temperature of a substance, the energy

$$Q = mc\,(\vartheta_2 - \vartheta_1)$$

ϑ = temperature of the substance before or after the supply or loss of energy,
m = mass of the substance,
c = specific heat capacity (c_p or c_v, valid in the temperature range ϑ_1 to ϑ_2).

must be supplied or given up. For an adiabatic system the applied heat, which is also known as sensible heat, causes an increase in temperature (with no heat transfer through the walls) and the following applies:

$$Q_{1,2} = m \cdot c_p \cdot \Delta T$$

If the boiling temperature is reached, the temperature of the liquid/vapour mixture does not change when further heat is supplied as long as liquid water is still present. The heat involved in the process of evaporation is also called latent heat. Water boils at 100°C at a total pressure of 1 bar and has a heat of evaporation Δhv of 2257.3 kJ/kg at this point. The sudden jump in the specific enthalpy of water which takes place on evaporation is shown in the table (definition: h_{aq} (ϑ = 0 °C) = 0):

ϑ [°C]	0	20	50	100 (liquid)	100 (gaseous)
h [kJ/kg]	0	83.6	209	418	2675

The sensible heat of water at 100°C is only just 16% of the latent heat of water vapour at 100°C. For the calculation of internal energy, the work W also contains the displacement work, which often cannot be made use of technically. Thus, the work performed by the substance flowing with and flowing against the surrounding pressure in the form of displacement work W_u is lost. The enthalpy of a substance

$$H = U + pV$$

U = internal energy,
p = pressure,
V = volume.

takes this displacement work into account according to definition. At the same time, therefore, the change in enthalpy

$$H_2 - H_1 = Q_{12} + W_t$$

Q_{12} = supplied heat,
W_t = supplied technical work (on the way from 1 to 2)

represents a different formulation of the 1st law of technical thermodynamics as applies to all heat engines and work machines. For the enthalpy state variable, definition of the null point is also open since, in general, it is only a change in enthalpy that is of interest. In practical applications, the specific enthalpy h = H/m is often used which is related to the mass m of the substance.

The h-x diagram is an equilibrium (phase) diagram for moist air with the parameters h, x and T. The reference mass is 1 kg of dry air and the total pressure $p = p_D = p_L$ (generally = 1 bar) remains constant. The absolute vapour content x of the air is entered on the abscissa and the specific enthalpy h_{1+x} on the ordinate (enthalpy of 1 kg of dry air and x kg of water vapour).

$$h_{1+x} = 1 \cdot h_L + x \cdot h_D$$

For the sake of simplicity, and without limiting its general validity, the enthalpy of dry air of 0°C and that of liquid water of 0°C are both equal to zero (standardized to the zero point on the Celsius scale). For not excessively high pressures, the following equation gives a good approximation in the unsaturated region ($\varphi < 1$):

$$h_{1+x} = C_{p,L} \cdot \vartheta + x\,(\Delta h_V + C_{p,D} \cdot \vartheta)$$

After inserting the substance values for air and water we obtain:

$$h_{1+x} = 1.006 \cdot \vartheta + x\,(2500 + 1.86 \cdot \vartheta)$$

If right-angled coordinates are chosen for the equilibrium (phase) diagram h_{1+x}, x, V, then the important region for unsaturated moist air is represented in an indistinct narrow region. Consequently, an oblique-angled coordinate system is constructed in such a way that the V = 0°C isotherms in the unsaturated region describe a horizontal course.

Steam is generated in textile dyeing and finishing mills in various types of boilers at high or low pressure to supply the plant's requirements. Before leaving the boiler, steam is often further superheated and then used for the generation of electrical energy in a turbine, where its pressure is reduced to a lower pressure rating before it is fed into the steam network. More or less superheat is given up by the steam in the pipelines, depending on their length to the point of consumption and depending on the quality of insulation. If steam is fed into the pipelines with a low degree of superheat, it soon reaches a state of saturation. Further heat loss results in the formation of condensate and the steam becomes wet. Depending on the length of the pipeline and its technical configuration, as well as the steam throughput, pressure losses arise which can be described by the formula

$$\Delta p = \xi \cdot \frac{\rho}{2} \cdot w^2 \; [\mathrm{N/m^2}]$$

ξ = loss correction value,
ρ = density [$\mathrm{kg/m^3}$],
w = flow rate [m/s].

The state of steam at various points of consumption can therefore vary considerably from the state of steam fed into the pipeline network. Because of the many unknown pressure and heat losses which occur in the pipelines and at various finishing machines, the behaviour of steam can be explained more clearly with the h-x diagram than other mathematical procedures such as, e.g. pressure loss calculations.

Changes in the state of steam flowing freely into the atmosphere from machines consuming steam or throttled down steam in decatizing are represented by straight horizontal lines in the h-s diagram, i.e. lines where the heat content of steam h = constant (Fig. 5). This is valid as long as no mixing with the surrounding air takes place. Thus, whilst the enthalpy remains constant when the steam pressure is reduced, the entropy increases since a non-reversible process is involved. All the information relating to the state of equilibrium can be obtained from the groups of curves for constant pressure (isobars), constant temperature (isotherms), constant specific volume (isochores) and constant steam content in the wet steam region. The isobars and isotherms coincide in the wet steam region, i.e. below the saturation isotherm. These are lines with the gradient dh/ds = T. Since open steam is given up by the steam supply network as dry saturated steam, these horizontal lines have their starting point A at the point where the respective high pressure steam curve intersects the saturation isotherm.

For a pressure reduction at the machine, the following cases are possible: (1) steam flows out into the free atmosphere. In this case, the curve starting from point A with h = constant, proceeds to point B which intersects the pressure curve p = 0 bar corresponding to the external air pressure. The superheat temperature up to the intersection point B can be read off the group of temperature curves in the superheated region. (2) The steam pressure is reduced by a reducing valve at the machine to a pressure of p = 2 bar and consumed by the machine at this pressure. In this case, the intersection B' with the p = 2 bar line is decisive. The superheat temperature at B' is higher than at B. (3) The steam pressure is reduced to a pressure of, e.g. p = 6 bar and a further reduction occurs in the machine. Since no heat is lost in this reduction, the intermediate reduction with

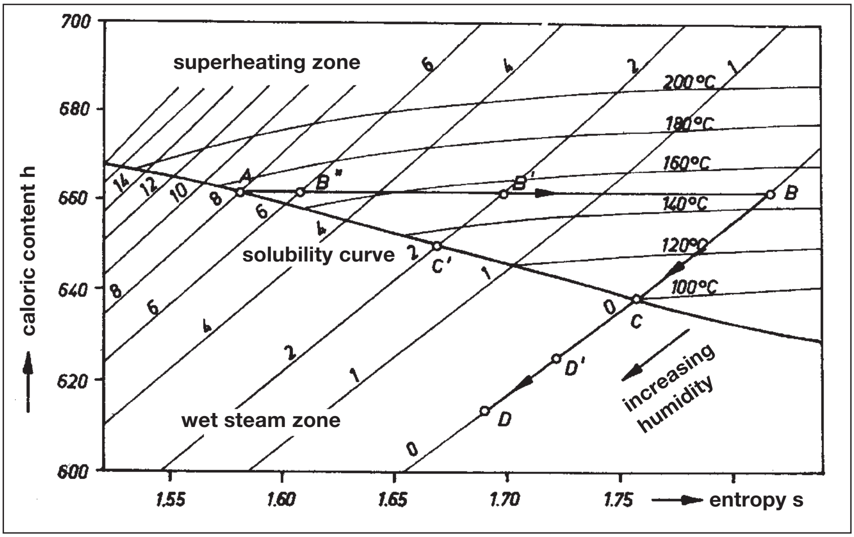


Fig. 5: Progression of the reduction of high pressure steam to low pressure steam and freely escaping steam at a pressure of 0 bar, shown in an h-s diagram. 0–14 = bar overpressure (on isobars).

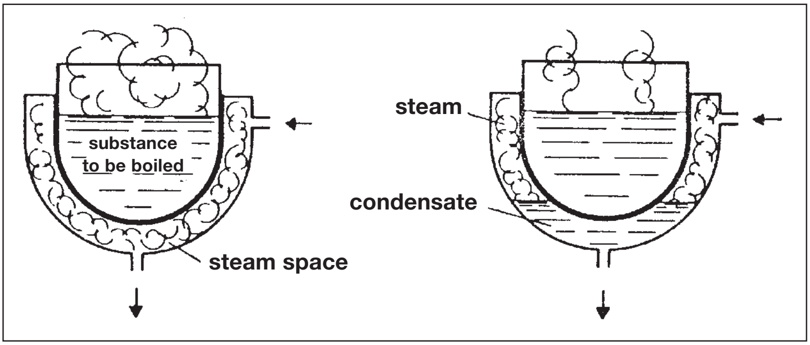


Fig. 6: Indirect heating of a finishing vessel with and without condensate formation.

intersection B' for the superheating has practically no significance. The line A–B'' continues to proceed to the point where it intersects with the pressure prevailing in the machine. From points B, B' and B'', the steam moves from the respective pressure curves to the saturation isotherm at points C, C' due to cooling losses in the machine, and from there it proceeds in the direction of point D in the wet steam region, depending on the degree of cooling, where partial condensation takes place.

During condensation, a condensate forms on the cooling surface as a film or as water droplets depending on the nature of the surface. Heat transmission coefficients of 1–10 kW/m^{2}K are achieved depending on the length of the condenser tubes, the temperature conditions (cooling surface/steam) and the characteristics of the surface, etc. Heat flows if a temperature gradient exists between a liquid or gas and an adjoining wall. In this heat transfer, the molecules of liquid or gas are in motion and transport heat by conduction and convection before giving up their energy through condensation (Fig. 6).

Water vapour pressure That component of atmospheric pressure exerted by the → Water vapour in the atmosphere (→ Water).

Water vapour transmission When applied to textiles, this property is described as "breathable" in the trade. The term "breathable" is, however, somewhat misleading since there is only a passive participation of the textile in its interactions with water in liquid or vapour form. In terms of clothing physiology, therefore, the term "breathable" means permeable to water vapour.

Because of its complicated chemical structure and morphology, one of the characteristics of wool is that the surface of the fibre is hydrophobic or water repellent but, at the same time, contains innumerable tiny pores that allow water vapour to penetrate into the hydrophilic or "moisture-friendly" interior of the fibre. This unusual combination of properties assists the natural cooling mechanism of the human body (evaporation of perspiration through the skin) by promoting the transport of perspiration away from the skin in the form of vapour but not in liquid form (Fig. 1). Wool fibres are very hydrophobic on their surface (repellent to liquid water) but are nevertheless capable of absorbing water vapour and have a high retention potential, i.e. the capacity to absorb, store and desorb moisture in the vapour phase in quantities up to 30% of their own weight without feeling wet.

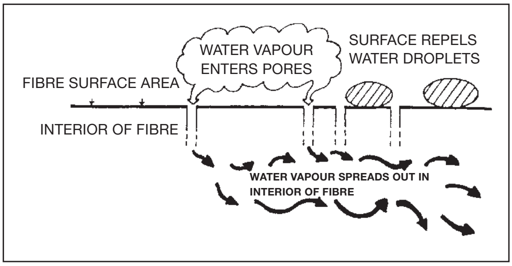


Fig. 1: Sorption properties of woollen fibres towards water vapour and water in liquid form based on the water vapour transmission of the hydrophobic scale layer.

Polyester microfibres are hydrophobic because of their chemical constitution which is based principally on hydrophobic monomers. Consequently, rainwater runs off the surface of a tightly woven fabric made from polyester microfibres whilst water vapour, in the form of perspiration separated from the body, diffuses through the fine pores of the woven fabric as shown in Fig. 2 (water vapour transmission). Tightly woven microfibre fabrics are particularly suitable for active sportswear since they also have a low permeability to air and are therefore able to protect the body against the wind.

Numerous methods to determine the permeability of textiles to water vapour are known. Some of these may differ significantly with regard to

- procedure,
- time required,
- range of application,

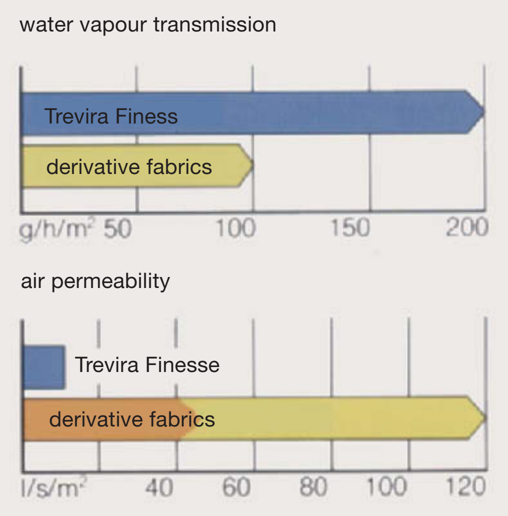


Fig. 2: Comparison of water vapour transmission and air permeability in microfibre fabrics (Trevira Finess, Hoechst) and derivative fabrics.

- reproducibility of results,
- inclusion of accompanying factors.

Depending on the choice of method, therefore, considerable variations in results can arise and, for this reason, the mechanisms and principles involved in a particular test method must be considered in some depth. Numerical ratings are only of value when the test method, as well as the test conditions, are known. As a rule, results obtained from different methods are not transferable. Standard methods, or in-house methods developed by testing institutes, manufacturers or users are usually employed. General requirements for textile testing such as statistically reliable sampling, number of test specimens and air conditioning should always be taken into consideration as far as possible. Only a few of the numerous test methods available can be described here.

For gravimetric methods, water vapour permeability is determined by the weight of water vapour diffusing through one square metre of a test fabric in 24 h under a specified humidity gradient at a particular temperature. The quantity of diffused water vapour is given by the increase in weight of the adsorption medium. Depending on the permeability of the sample, weighings are carried out at fixed intervals of time (e.g. < 24, 24, 48, 96 h). As soon as the increase in weight follows a linear progression, the water vapour permeability can be calculated by the following formula:

$$WDD = \frac{24}{t} \cdot \frac{\Delta m}{A} \cdot 10^4 \quad [g/m^2d]$$

t = time span between 2 weighings,
Δm = difference in weight between the last 2 weighings,
A = area of test specimen in cm^2.

In all these tests it is recommended to include a reference fabric with known values along with the particular fabric under test. This helps to put the results in the correct order and allows the test conditions to be compared. Since the construction of the test apparatus also has an influence on water vapour permeability, appropriate constants must likewise be established from comparative tests. The water permeability values obtained in these tests are not material constants but merely represent a selective description of the behaviour of a specific sample under standard climatic conditions. It is up to the tester to modify the test procedure as required but all test conditions must be recorded and typical sources of error avoided in order to achieve reproducible results. Problems mainly arise in:

- achieving constant climatic conditions,
- air circulation, i.e. in order to ensure that all test specimens are subjected to the same specified conditions,
- carrying out intermediate weighings without affecting the result through variations in the climatic conditions.

Simplified methods are less useful for the measurement of characteristic values than for making a quick comparison of different materials in order to determine trends and ranking order. Gravimetric methods are based on two fundamental principles, i.e.:

- the use of desiccants and diffusion of water vapour into the adsorption medium,
- the use of water-filled vessels and diffusion of water vapour into the external phase.

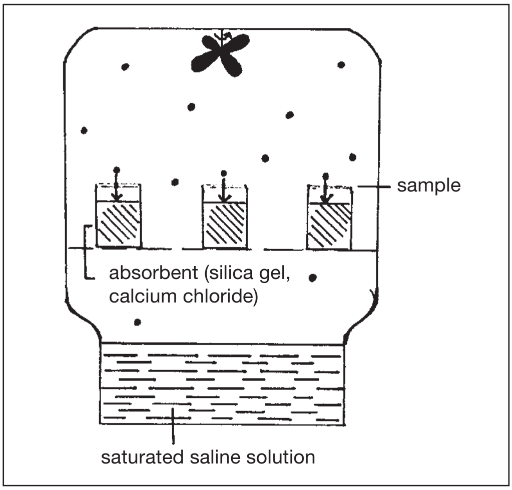


Fig. 3: Gravimetric process following DIN 53 122 (part 1).

Water vapour transmission

The simplest gravimetric method is known as the "beaker method"; a sample is stretched over a beaker filled with a desiccant and stored in a climatic test cabinet. As with other methods, the test is carried out under standard climatic conditions in which a uniform distribution of air humidity is assured by air circulation. The beaker method is carried out with 95% relative humidity at 20°C or 37°C. The in-house method of the Chemische Fabrik Pfersee is carried out in a similar manner but with a relative humidity of 65% and a temperature of 20°C in this case. A gravimetric test method is specified in DIN 53 122, part 1 (Fig. 3).

The adsorption surface, whose relative humidity at the beginning of the test should not exceed 1%, must be sealed by the sample so that moisture can only reach the inside through the sample area. The textile only comes into contact with atmospheric humidity, i.e. water vapour and not water. This method is mainly suitable for materials with a water vapour transmission above 0.5 g/m^2 which is determined by weighing the adsorption medium. As a rule, it takes 24 h to carry out this test. A similar test to DIN 53 122 for the determination of water vapour transmission is described in DIN 53 333 using a different apparatus. Numerous in-house methods are also based on the gravimetric principle using desiccants. Care must be taken to ensure that the desiccant does not become saturated during the test. Simplification of such methods has now reached the stage where a rapid test with silica gel can be carried out within 1 h. In this test (Fig. 4), which was developed by the British Textile Technology Group (formerly Shirley Institute), the results must be regarded with some criticism. A measuring beaker is filled with 10 g silica gel and closed with the sample. The sample is placed over a layer of nonwoven material soaked in distilled water in such a way that no water is present on the upper layer. A humidity of 100% is reached on the surface of the sample through the nonwoven material. The silica gel is carefully removed after 1 h and reweighed. As in other gravimetric methods, the water vapour transmission is calculated from the increase in mass. However, this method appears to be unsuitable for determining absolute values on different materials. On the one hand, a test duration of 1 h does not guarantee a linear increase in water vapour in every case and, on the other hand, it is questionable whether direct contact of the sample surface with the nonwoven layers does not favour the transport of water vapour through compact hydrophilic layers. Capillary action also conducts liquid water to the sample so that the diffusion is intensified for materials subject to swelling. This method clearly demonstrates how the choice of test conditions influences the evaluation of different materials. It is therefore easy to understand why water vapour transmission values are given in numerous publications which do not correlate with each other.

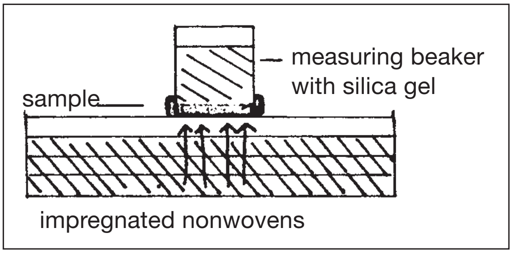


Fig. 4: Determining water vapour transmission in a standard operating environment (Shirley Institute).

Silica gel can not only be used as a desiccant, humidity conditions may also be defined by means of saturated salt solutions. A simplified method for determining the resistance to water vapour transmission has been introduced by the Institut Hohenstein e.V. This so-called "beaker method" is not universally applicable, however, since the thickness of the textile sample must not exceed 10 mm. With this method, the water vapour transmission of the sample is determined from the increase in mass of the measuring beaker. The measured value contains constants for the apparatus, e.g. the resistance values of Gore-tex membranes which must be included in the calculation. With such a method, it is obvious that no water vapour transmission higher than that of a Gore-tex membrane can be determined (Fig. 5).

In the following test methods, the direction of diffusion is reversed as an alternative to the use of desiccants, i.e. water diffuses through a textile sample from a container into an external climate. The simplest method (ASTM Method E 96) functions in a similar manner to the beaker method (Fig. 6). A sample and a reference are tested without covering. The water temperature can be selected in various steps. The main advantage of this method, i.e. its ability to test many samples at the same time with minimum effort, has predestined it for production control purposes. In this application, it is frequently used in conjunction with standards. The ASTM method is therefore used when it is only required to determine trends, but not precise values, with simple equipment. Such a test can also be extended by carrying out an external wetting (Fig. 7).

By using an experimental procedure with a simulated rain tester, the quantity of rain water absorbed by a sample is determined from the difference in weight compared to a test with an empty measuring beaker (Fig. 8).

The CGSB Control Dish Method represents a refinement of the ASTM Method since the external air space is also defined (Fig. 9). A uniform air flow over the sample is ensured by rotation of the container assembly. The transport of water vapour depends not only on the resistance of the material but also on the construction of the apparatus whereby the air spaces above

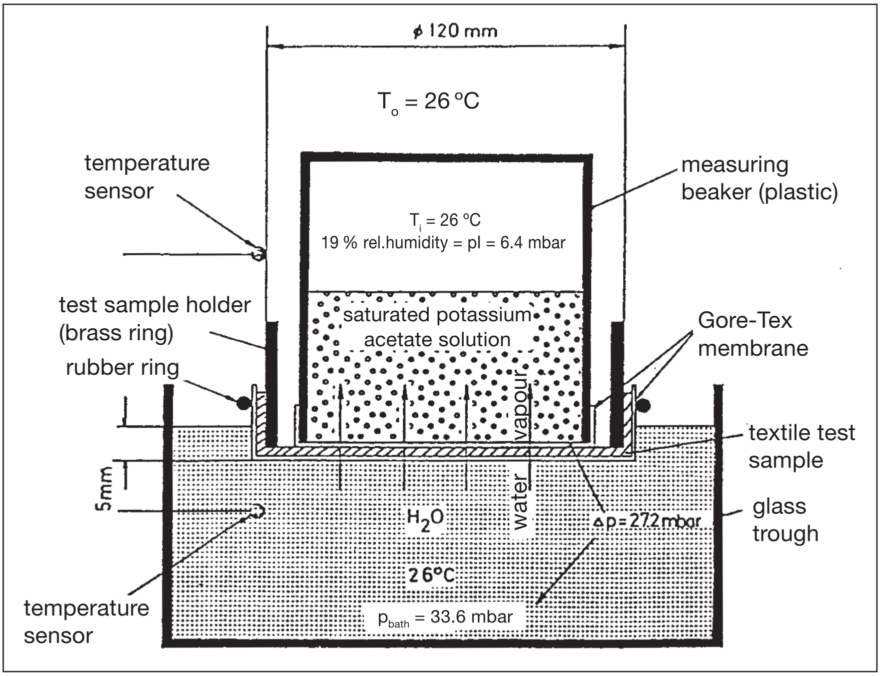


Fig. 5: Beaker method to determine water vapour transmission.

and beneath the sample offer different levels of resistance. The water vapour transmission of hydrophilic coatings is also influenced by the relative and absorbed humidity of the sample. The air spaces of different thickness represent the resistance of the apparatus which must first be determined for all samples. In the CGSB Method, a humidity of 84% is reached on the sample.

The ASTM method involves even higher values which makes the application of such methods difficult

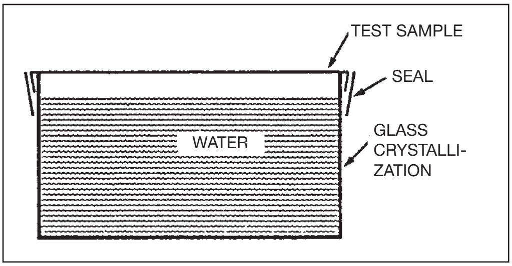


Fig. 6: ASTM Method E 96, method B, water temperature 23°C.

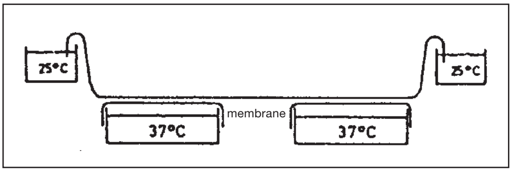


Fig. 7: Determination of water vapour transmission with external damping. Temperature: 25 ± 2°C, rel. air humidity: 50 ± 2%.

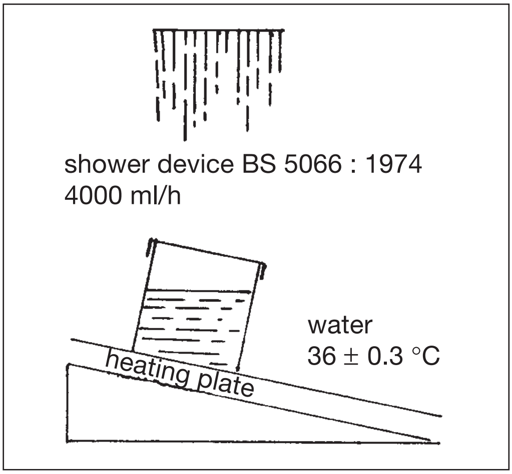


Fig. 8: Experimental arrangement using a shower device. Temperature: 21 ± 2°C, rel. air humidity: 65 ± 2%.

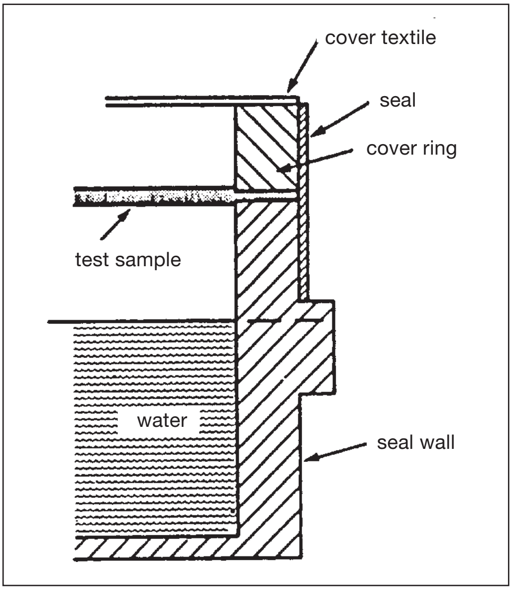


Fig. 9: CGSB (Canadian General Specification Board) Control Dish Method. Temperature: 20 ± 2 °C, rel. air humidity: 65 ± 2%.

or impossible for hydrophilic coatings. No accurate values can be determined since the diffusion varies with the relative humidity.

In the DND method (Fig. 10), the test specimen is placed between two Gore-tex films with the upper film forming the floor of a water reservoir whilst dried air is conducted along the underside of the lower film. With this test method no resistance from the air spaces exists but, as with the beaker method, it is obvious that water vapour permeability values higher than those of a Gore-tex membrane cannot be achieved. Moreover, the effects of the mass of water on the volume of the test specimen are not clear and the entire test apparatus must be weighed. The fact that no conditioned surrounding air is necessary and the samples are easily inserted and suitable for repeat tests are advantages of this method.

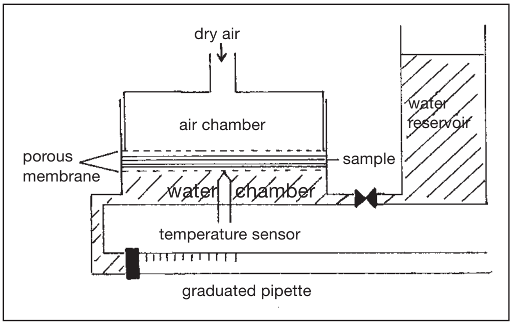


Fig. 11: Water vapour resistance meter.

In order to prevent any load on the sample by the water mass, a reverse principle has been developed (Fig. 11). In this case, the quantity of evaporated water can be determined with a graduated pipette and the water vapour permeability of the sample is calculated dependent on time.

The electrolytic method according to DIN 53 122 (part 2) is suitable for materials with a water vapour permeability lying between 0.01 and 5 g/m^2 and, by adaptation of the measuring area, even higher water vapour permeabilities can be measured. The water vapour permeability is determined with the aid of a Keidel electrolytic hygrometer (Fig. 12). In this electrolysis

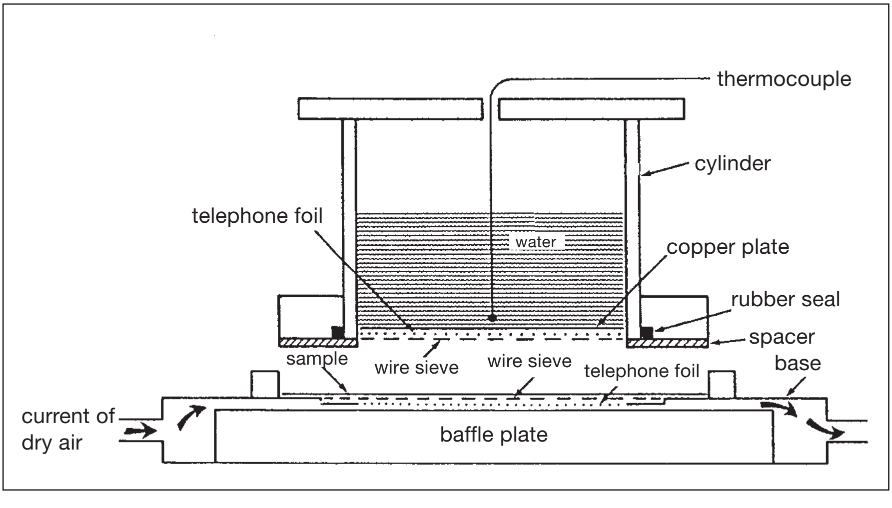


Fig. 10: DND method.

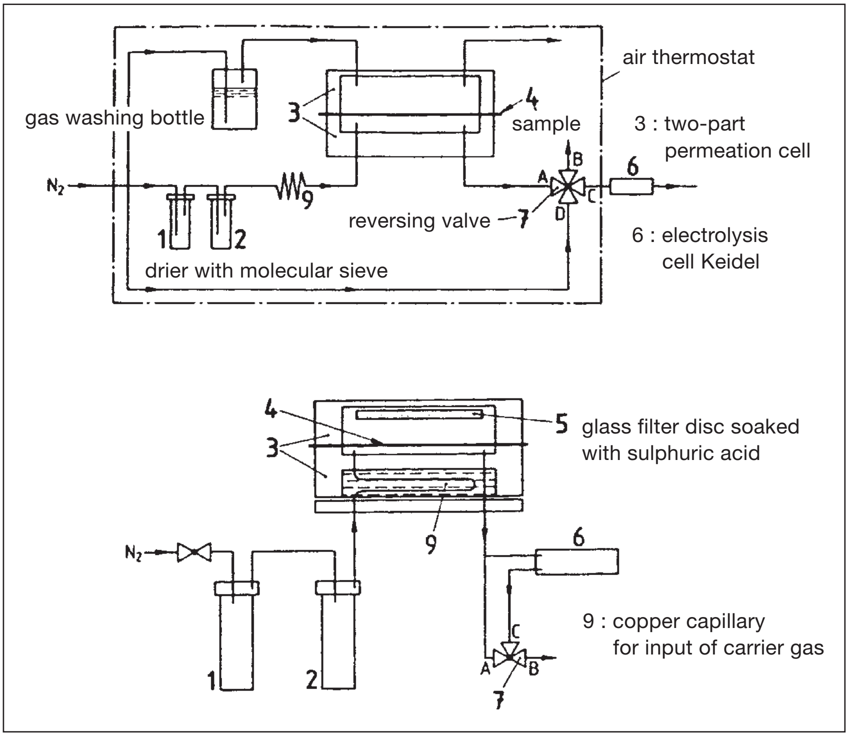


Fig. 12: Process of electrolysis.

cell, water vapour which has permeated through the test specimen is rinsed and electrolytically decomposed into hydrogen and oxygen. The quantity of water vapour per interval of time is calculated from the strength of the electrolytic current. The transport of water vapour is ensured by using a carrier gas (N_2). Measurements are carried out under standard climatic conditions where a constant air humidity can be established with a gas washing bottle (filled with a saturated aqueous salt solution) on the one hand, or a glass filter plate impregnated with sulphuric acid on the other.

The "R-Tube" method is also based on the measurement of humidity. Four moisture sensors are inserted between a dry and a saturated climate contained in a tube. The steadily increasing rise in humidity inside the tube is disturbed by a clamped test specimen, and the discontinuity of this interruption provides a measure of the water vapour resistance.

Water vapour permeability is also calculated by the measurement of humidity in the measuring system illustrated in Fig. 13. The Lyssy Vapor Permeation Tester is based on two compartments separated by the interposition of a test specimen. Compartments 2 contains a saturated atmosphere and the relative humidity in compartments 1 is measured continuously as a function of time at a specific temperature. The change in its humidity is a measure of the water vapour permeability of the test specimen. The short time required (10–20 min) and the continuous recording of measured values on a strip chart are advantages of this method. Threshold limits through which the state of humidity passes are used. The results are converted by reference to a fixed water vapour permeability value, e.g. a Gore-tex membrane.

The DSC (differential scanning calorimeter) method also calculates water vapour permeability as a function of time. In this case, a special type of vessel is divided by a test specimen and a constant temperature of

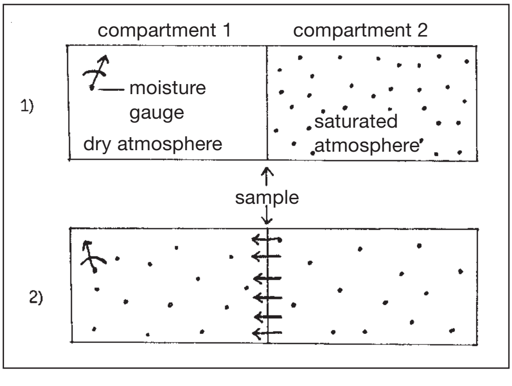


Fig. 13: Lyssy Vapor Permeation Tester.

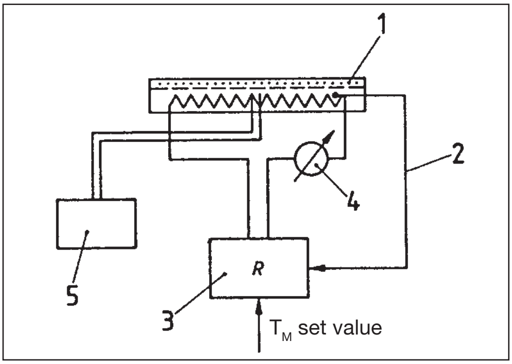


Fig. 14: Principle of the skin model.
1 = sample on heatable, porous measuring surface; 2, 3, 4 = circuit to regulate heating for the transport of water vapour; 5 = water dosage unit.

40 or 80°C is established on both sides of it. This temperature is sufficient to completely evaporate the water contained in one chamber. The moisture is rinsed out of the second chamber with dry nitrogen. The time required to produce a dry state in the original water chamber in a linear relationship to the weighed quantity of water is recorded.

With the aid of the thermoregulation model (skin model), the resistance to water vapour transmission (R_{et}) of a material is determined which allows a derivation of the water vapour permeability. The R_{et} value is a measure of the stationary water vapour transport capacity of a sample and is expressed in $m^2 \cdot mbar/W$. A simplified representation of the procedure specified in DIN 54 101 (part 1) is illustrated in Fig. 14 and is currently the best procedure for measuring absolute values. The surrounding temperature is adjusted to 35°C so that water vapour condensation is avoided under isothermal conditions. The relative humidity of the air then corresponds to 40%. The absorbed heat supplied to the measuring area in a stationary condition serves as a measure for the quantity of water evaporated. With the skin model, stationary conditions may be simulated, i.e. constant flows of heat and humidity or even non-stationary impulses by special modifications to the procedure. In a similar model, the dry and wet heat loss can be determined. The heat flow is dependent on processes of condensation, evaporation, adsorption and desorption (and therefore not only on the material but also on apparatus constants).

Conditions conforming to those encountered in practice are achieved by a modification of the skin model (DIN 54 101) which tests the water vapour permeability with simulated rain and condensation phenomena resulting from temperature differences. → Water repellency of textile fabrics (Bundesmann method).

Watt (Symbol W). The derived unit of power (mechanical, thermal and electrical) in the → SI system of Units named after James Watt (1736–1819). It is defined as the power when work of 1 J is done in 1 s or an equal heat transfer occurs in 1 s. In electrical applications, 1 W is the product of 1 ampere and 1 volt. Derived units of power, electrical energy and heat are all quotients obtained from a statutory unit of energy, work or quantity of heat, and a statutory unit of time.

$$1\ W = 1\ J/s$$
$$1\ W = 1\ Nm/s$$

In the SI system, the watt has now replaced the former unit of mechanical power, i.e. horse power (HP). Conversion: 1 HP = 745.70 W.

Wavy selvedge An undulating selvedge that does not lie flat. Causes: the use of different materials in fabric and selvedge, overturned selvedges due to creased edges, defective beaming, defective temple adjustment on the weaving machine, etc.

Wax A special group of low melting, thermoplastic organic mixtures generally opaque in appearance. Some are hydrocarbons, others are esters of fatty acids and alcohols. Soluble in most organic solvents, insoluble in water. Saponification of saponifiable waxes yields → Fatty acids and → Fatty alcohols. Classification:

I. Natural waxes: most of these are highly complicated chemical mixtures of esters of higher fatty acids with higher monovalent alcohols, besides free acids, free alcohols and hydrocarbons.

a) Mineral waxes, consist chiefly of higher hydrocarbons, e.g. fossil or earth waxes (ozocerite; montan; → Ceresin wax).
b) Vegetable waxes, e.g. → Japan wax or → Carnauba wax.
c) Animal waxes, e.g. →: Beeswax; Spermaceti; Wool fat (→ Lanolin).

II. → Synthetic waxes:

a) Ethylenic polymers and polyol ether esters.
b) Chlorinated naphthalenes.
c) Hydrocarbon types obtained by Fischer-Tropsch synthesis.

Chemical characteristics →: Iodine number; Acid value; Saponification number.

Wax crayons Coloured crayons for retouching purposes which contain a) colorants (inorganic or organic pigments as well as soluble ”aniline-based” dyes), b) binding agents (vegetable oils, waxes, resins or resin soaps) and c) filling agents (usually clay or chalk). Wax crayons of this composition are soft and have a high tinctorial strength suitable for retouching small localized light places after spotting treatments or to cover up any remaining stains. The colour fastness is naturally somewhat limited but may be improved under certain circumstances by subsequent steaming or hot ironing (using a slightly moist ironing cloth).

Waxing A treatment given to threads or yarns to facilitate production/improve stitch formation by making the threads/yarns smoother and more resistant to mechanical stress. During the rewinding process, the yarn is allowed to run against a block of paraffin wax (see Fig.).

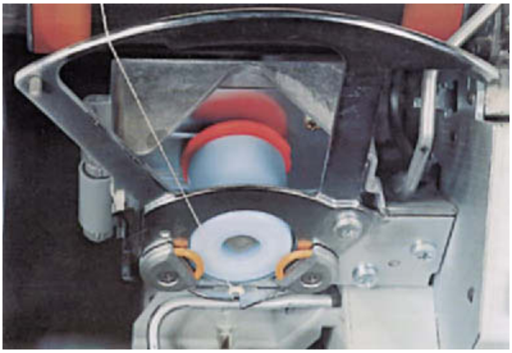


Fig.: Waxer on a Schlafhorst spooler.

Waxing with paraffin wax A → Waxing treatment with paraffin wax which is mainly given to machine knitting yarns. During the rewinding process, the yarn passes tangentially against a solid block of paraffin wax and the abraded wax is distributed unevenly on the yarn. Despite the well-known disadvantages associated with this method, e.g. the non-uniform application mainly on the surface of the yarn, it is still the most widely used procedure. The hairiness of yarns waxed with paraffin wax is more pronounced due to roughening in the machine. Additional monitoring of the wax applicator and its precise adjustment is necessary. During times of high material throughput, variations in the coefficient of friction of yarns waxed with paraffin wax are experienced again and again. These differences are often due to variations in the moisture content of yarn packages after a steaming process. → Wet paraffining.

Wax resist printing (→ Wax resists), batik-like prints with a wax resist suitable for the production of → Africa prints are typically obtained, e.g. by the route shown in the Fig.

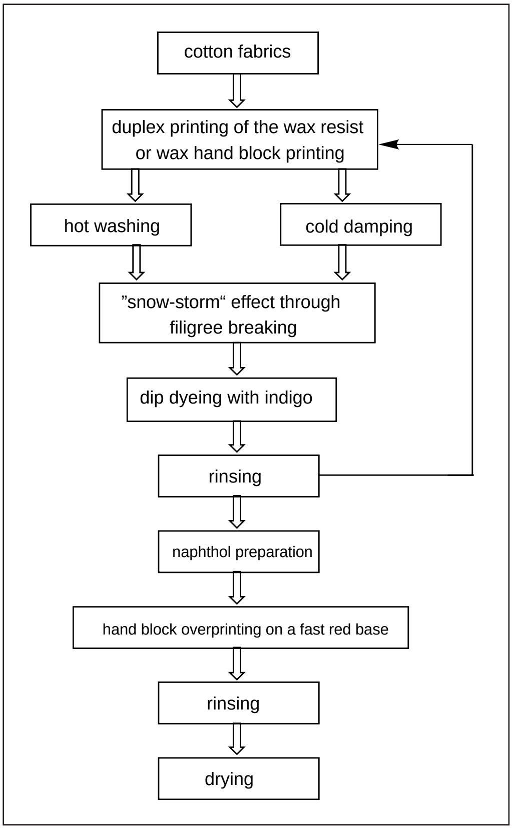


Fig.: Process technology for filigree wax-batique imitation combined with the "snow-storm" effect.

Wax resists (wax and resin resists) are employed as mechanical resists in resist printing (especially batik articles) for the production of pure untinted white effects that are almost impossible to achieve with reductive discharges. Wax resists consist mainly of natural resins (pine resin, colophony), beeswax, ceresin, stearin, spermaceti, tallow, etc. melted with turpentine oil or rectified petroleum. They are applied to bleached fabric by hand block printing or from heated rollers with deep engravings on a printing machine. To avoid sticking and smearing, the printed material is sprinkled with kaolin, diatomaceous earth or fuller's earth. The goods are then dried by hanging in air for 2–3 days, washed cold and subsequently dyed, usually with cationic or selected acid, direct and mordant dyes as well as indigo. The dyes used must not be soluble in benzine or solvents since, after cold dyeing, rinsing and drying, a passage through benzine must be given to remove the wax (only benzine produced from benzene and toluene is suitable, not petroleum spirit). After squeezing-off or centrifuging, the fabric is dried (steamed if necessary) and hung. Cationic dyes are dyed under neutral or weakly acidic (acetic acid) conditions in 2–4 h (and treated in cold tannin and tartar emetic baths if necessary). Acid dyes are dyed with 20% formic acid 90% based on the weight of dye for 30 min followed by another acid addition and dyeing for a further 30 min. For discharge batiks, dyed and batiked silk is allowed to lie in a cold bath containing 20–30 g sodium dithionite, removed after 30–45 min, 4–5 ml/l sulphuric acid 78.5% added, and the fabric treated for 15 min, after which it is rinsed and the cracked wax resists are dyed with another colour in a fresh bath (using acid or substantive dyes).

Wax-soluble dyes → Oil-and-fat soluble dyes.

Wear fastness properties In → Colour fastness testing, a distinction is made between those colour fastness properties that are of particular relevance to the end consumer, e.g. colour fastness to light, washing, chlorinated water, sea water, water spotting, perspiration, rubbing, dry cleaning, etc. i.e. properties which relate to the performance of a dyed or printed textile in use, and those which are only important in textile manufacturing processes, e.g. colour fastness to decatizing, stoving, sublimation, vulcanizing, etc.

Wearing comfort is concerned with aspects of protection and well-being afforded by a textile garment during wear. Wearing comfort is a complex and somewhat subjective term. To the extent that it can be measured in physical terms, wearing comfort is influenced by the fit of a garment, its design, weight, volume, behaviour towards water vapour and humidity, thermal retention, air permeability, stiffness, surface characteristics and its resistance to the build-up of electrostatic charges. Subjective components of wearing comfort include fashion style, colour and the image of the raw material and garment manufacturer. The term wearing comfort can be understood in terms of interactions between factors such as softness, thermal protection and moisture balance. The comfort factor includes clothing characteristics which have a direct influence on the temperature regulation of the human body (chiefly thermal insulation, evaporation and transport of perspiration and air permeability). Wearing comfort is regarded as a generic term which, in addition to the abovementioned factors, also includes other factors such as garment construction, contact between garment and body, influence of textile finishes and clothing physiological characteristics. Some distinguishing features of comfort include: perceptible comfort in wear, impulse-stimulated reactions of the autonomic brain and nervous system to control functions of the body's organs with effects on health and performance, comfort in the care of textiles in the sense of simplifying and reducing the amount of work required.

The primary objective of clothing physiology is regarded as the investigation of relationships between the mechanical body, its clothing and the ambient climate.

The second largest field of investigation in clothing physiology is concerned with the effects of certain specific variable parameters involved in the manufacture of a garment such as:

– type of fibre,
– fibre titre,
– fibre profile,
– type of yarn,
– woven or knitted fabric,
– fabric thickness,
– finish,
– cut of garment.

In addition, clothing physiology is also concerned with developing optimum clothing for specific end uses such as workwear and protective clothing, military service and battledress, sportswear, leisurewear, underwear, bed linen, etc.

The overall objective of clothing physiology is to improve the living standards of human beings by paying special attention to health, hygiene and comfort. Wearing comfort is the result of a balanced interaction between "body, climate and clothing" and is a combination of several components (see Fig.).

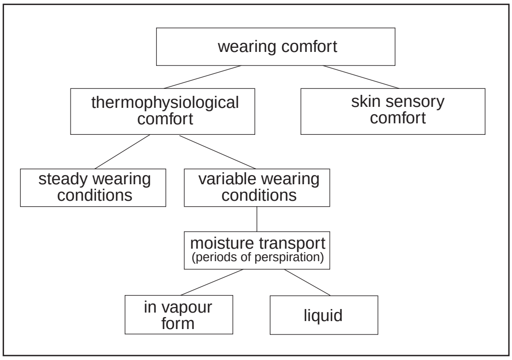


Fig.: Components of clothing wearing comfort.

Thermophysiological wearing comfort is achieved when the transport of heat and moisture from the body through the clothing is controlled in such a way that the so-called "energy balance" of the human body is in equilibrium and when the temperature and moisture levels in the "microclimate" of the garment are experienced as "comfortable" by the wearer.

The thermophysiological wearing comfort of a garment may be described in terms of numerous textile and clothing-specific ratings. A distinction is also made between stationary and non-stationary wearing conditions. Stationary wearing conditions are said to exist when the flow of heat and moisture from the body is constant over long periods of time under reasonable climatic and working conditions. Non-stationary wearing conditions thus occur if the body perspires due to impulse when the body is subjected to stress for a period of time or when a sudden change of temperature (hot/cold) occurs and perspiration leaves the body in the form of liquid or vapour.

Sensations experienced through the skin in contact with a garment arise from the stimulation of sensory receptors located beneath the skin and are concerned with tactile comfort. The sensations conveyed by the touch, thermal and pain receptors make the individual aware of the area and location affected, and the duration of the sensation. A variety of sensations arising from fabric contact may be experienced as a feeling of softness, smoothness, roughness, scratchiness, etc. Discomfiture arising from fabric cling due to a sweaty skin may be followed by a tacky sensation if there is a residue of perspiration. A very smooth fabric surface is more prone to clinging under these circumstances whilst a hairy surface reduces clinging since there is a reduction in the area of fabric contact with the skin. The hairs help to maintain a degree of separation between the fabric and the skin which facilitates drying and thus makes a positive contribution to wearing comfort. Finally, it is possible for a garment worn on the body to become electrostatically charged, which again causes fabric cling, and therefore has a negative impact on wearing comfort (according to Umbach).

Wear resistance → Textile serviceability.

Wear shine, removal of → Stain removal dry cleaning.

Wear, wear and tear When applied to textile materials, the term "wear and tear" refers to the gradual and unintentional wearing away of a textile surface due to specific mechanical effects such as friction (textile wear resistance → Abrasion resistance).

Weathering → Weathering fastness.

Weathering apparatus A testing device designed to carry out accelerated tests for → Weathering fastness, e.g. the → Weather-O-Meter.

Weathering fastness (colour fastness to weathering). Determination of the resistance of dyeings and prints on textiles of all kinds to the action of weathering. Accelerated weathering conditions can be achieved in the laboratory by exposing test specimens to conditions that involve changes in temperature, relative humidity and radiant energy, with or without a direct water spray (simulated rain) in an attempt to reproduce changes in the material similar to those observed after long-term, continuous, outdoor exposure. A suitable test apparatus uses filtered xenon arc radiation and an additional water spray. The test is carried out according to DIN 54 071 and the results are assessed with the blue scale.

Weather-O-Meter A laboratory testing device for determining the resistance of textile materials to weathering.

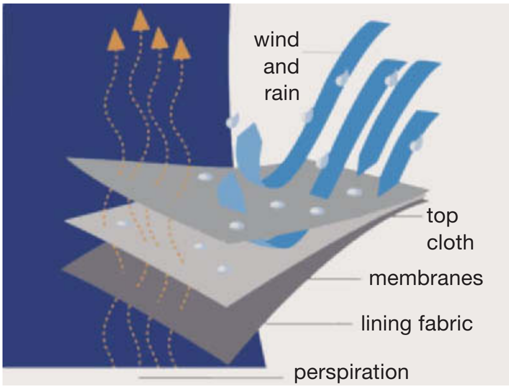


Fig. 1: Weatherproof leisurewear system (Proline).

Weatherproof leisurewear High-tech articles were formerly limited to special applications or specific target groups, e.g. the aeronautics and aerospace industries, the computer industry, military protective clothing, etc. In recent years, however, the worldwide consumer market has changed considerably and high-tech finishes, or the sports and leisurewear to which they have been applied, now represent the fastest growing segment of the clothing industry. Besides the originally predominant "protective" function of sports and leaisurewear, the term "comfort" also plays an important role nowadays and the combined effects of these relatively non-specific concepts is of interest in the protective function of so-called weather-resistant clothing (Fig. 1).

The effects of

- wind resistance,
- water repellency/waterproofing,
- water vapour transmission,

can be achieved with conventional finishes, film laminates (hydrophilic polyester), microfibres or "breathable" coatings.

Waterproofing is a parameter which depends on the effective stresses that an article of clothing will be subjected to in use. The following classification is helpful in this regard:

- resistance up to 1000 mm water column (100 mbar): perfectly adequate for normal weather-resistant clothing (70% of the market),
- resistant up to 1000–3000 mm water column (100–300 mbar): suitable for specific sportswear sectors, e.g. sailing, winter sports, etc. (20% of the market),
- resistance above 3000 mm water column (above 300 mbar): suitable for extreme sports, e.g. mountain climbing, hang gliding, etc. (10% of the market).

Wind resistance is automatically provided by garments whenever a combination of water vapour transmission and water repellency has been achieved. The chemical industry offers suitable systems for specific target groups:

- for resistance above 3000 mm water column (above 300 mbar), coagulated polyurethane (solvent/water),
- for resistance to 1000–3000 mm water column (100–300 mbar), hydrophilic polyurethane (solvent),
- for resistance up to 1000 mm water column (100

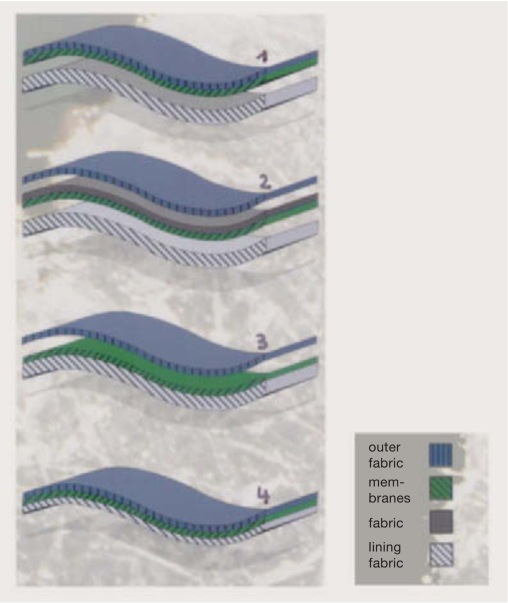


Fig. 2: Various types of weatherproof leisurewear (depending on profile of requirements) (according to Proline).
1 = most waterproof design; 2 = with membrane inserted between lining and outer fabric, requiring fewer seam sealing tapes and allowing shorter garment manufacturing times; 3 = waterproof version processible independently of outer fabric; 4 = windproof, elastic design which keeps out the cold and allows great freedom of movement.

mbar), microporous polyurethane foam (polyurethane with water).

The construction of some variants of weather-resistant clothing is explained in Fig. 2.

Materials made from synthetic fibres or their blends predominate for weather-protective articles and winter sportswear. So-called microporous membranes, e.g. Gore-tex, which confer water and wind resistant properties and good water vapour transmission, are frequently used for this purpose. In most cases, two methods are used to apply the membranes. Either the membrane is laminated to the outer fabric (outer fabric/membrane/lining) or it is applied in the form of an insert laminate (outer fabric/membrane/nonwoven/lining). The membranes are composed of polyester or polytetrafluoroethylene. In addition to the above-mentioned properties, these membranes are characterized by outstanding resistance to water pressure as measured by a high water column rating. As a rule, the outer fabric is either impregnated alone or combined with the membrane. The objective of this process is to achieve excellent water repellency.

Whilst impregnation was still carried out with silicone-based products until a few years ago, a → Fluorocarbon finishing is generally preferred today. Silicone impregnation suffers from the disadvantage that silicones have certain lipophilic properties (greasy, soiled edges) and also impair the laminating effect. These disadvantages are avoided with fluorocarbon finishes which are also characterized by significantly higher durability.

A soft handle continues to be a major requirement for these articles. Consequently, it is necessary to select special softeners capable of producing a good soft handle on the one hand, but which do not impair the waterproofing effect on the other.

In general, it has been assumed that silicone elastomers, which give the best handle effects, are not suitable in combination with fluorocarbon resins. This is only partly true, however, and it is certainly possible to achieve a good soft handle with selected siloxanes.

Weave Or fabric structure, i.e. the pattern of interlacing warp and weft yarns in a woven fabric which is responsible for its durability, design and external appearance. The main basic weaves include (see Fig.):

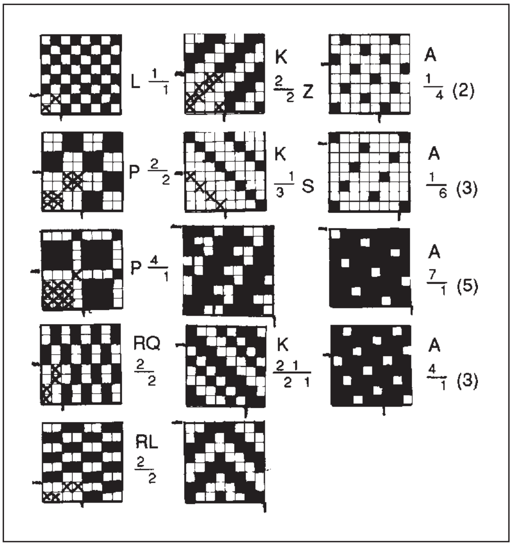


Fig.: Types of ground weave and some derivatives.
Left: plain weaves: basket weave, Panama, patterned Panama, warp ribs. Centre: twill weaves: twill of uniform line, weft twill, steep twill (gabardine), stitched twill, zigzag twill. Right: atlas weaves: two weft and two warp atlases.

a) Plain weave (tabby or taffeta weave). The simplest, shortest and most important of all weave interlacings in which alternating warp yarns are present on both sides of the fabric. The plain weave repeats on two ends and two picks, i.e. the first end passes over the first pick and under the second pick whilst the second end reverses this sequence. A plain weave is used for broadcloth, calico, muslin, print cloth, taffeta and sheeting.

b) Twill weave: a basic weave characterized by a diagonal rib or twill line on the face of the fabric which usually runs from lower left to upper right. Each end floats over or under at least two consecutive picks, and the points of intersection move one outward and one upward or downward on succeeding picks to produce the diagonal line. More prominent and less prominent twill effects are produced by having a predominance of warp yarns on the face side = warp twill, or a predominance of weft yarns on the face side = weft twill. A broken twill is formed when the diagonal lines run in alternating directions.

c) Satin weave: a basic weave in which the yarn crossover or interlacing points are spaced as evenly and widely as possible and in which the yarn crossover points lying between the visible crossover points are more or less covered by yarns lying on the surface (floats). As in the case of twill fabrics, both warp and weft satins are produced. A warp-faced satin contains many more ends than picks. A weft-faced satin is also called a sateen fabric. Satin weaves are produced with 3, 5, 8 and 11 shafts.

d) Derived weaves: all other weaves derived from a) to c) or combinations of these; e.g. basket (panama), repp and gauze or leno weaves are derived from the plain weave; herringbone, fancy and honeycomb weaves from the twill weave; double satin, crêpe and shadow repp from the satin weave.

Weaving The conversion of yarn into fabric by interlacing two independent yarn systems, i.e. the warp and the weft, on a weaving machine or loom. In a weaving machine, the warp yarns are passed from a warp beam (wound warp) to the fabric beam (wound fabric). During this process, each warp yarn is led through an eye on a heald attached to a harness. The harness lifts some of the warp yarns, e.g. the even-numbered warp yarns, and depresses the remainder to form a gap between them known as a “shed” through which the weft is inserted. This operation is known as shedding and the insertion of weft is called “picking”. The sley beats up the weft to the edge of the woven fabric (→: Woven

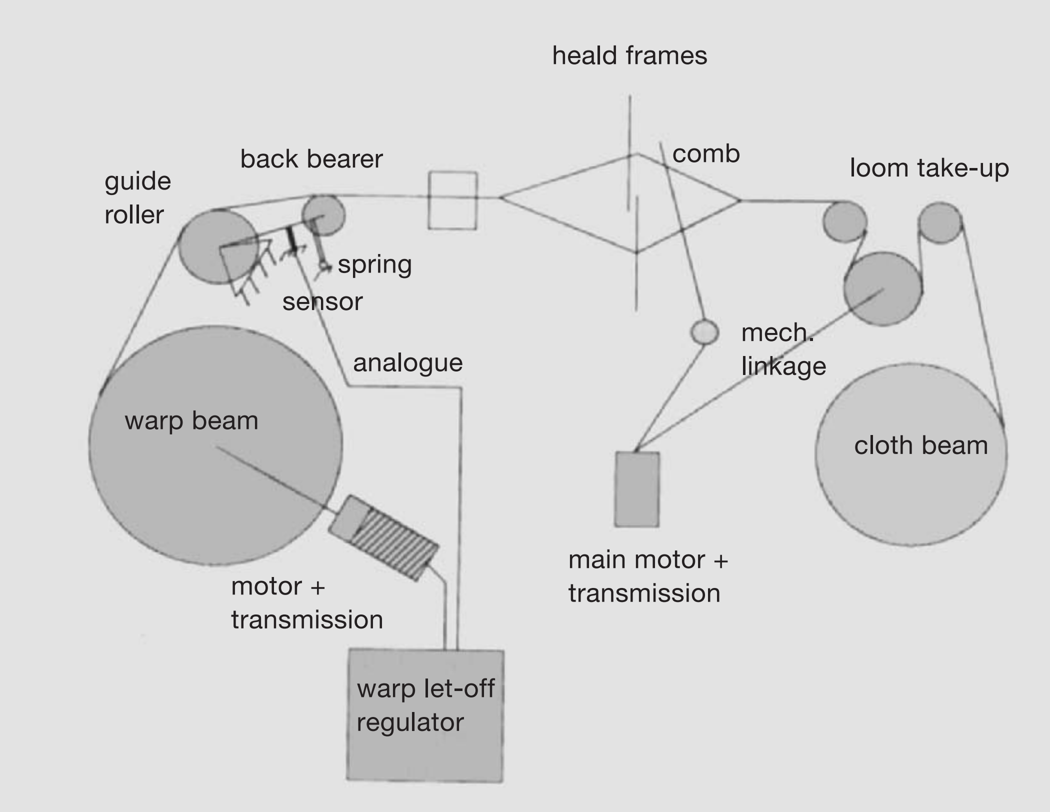


Fig. 1: Principle of a conventional loom drive with control system (Berger Lahr).

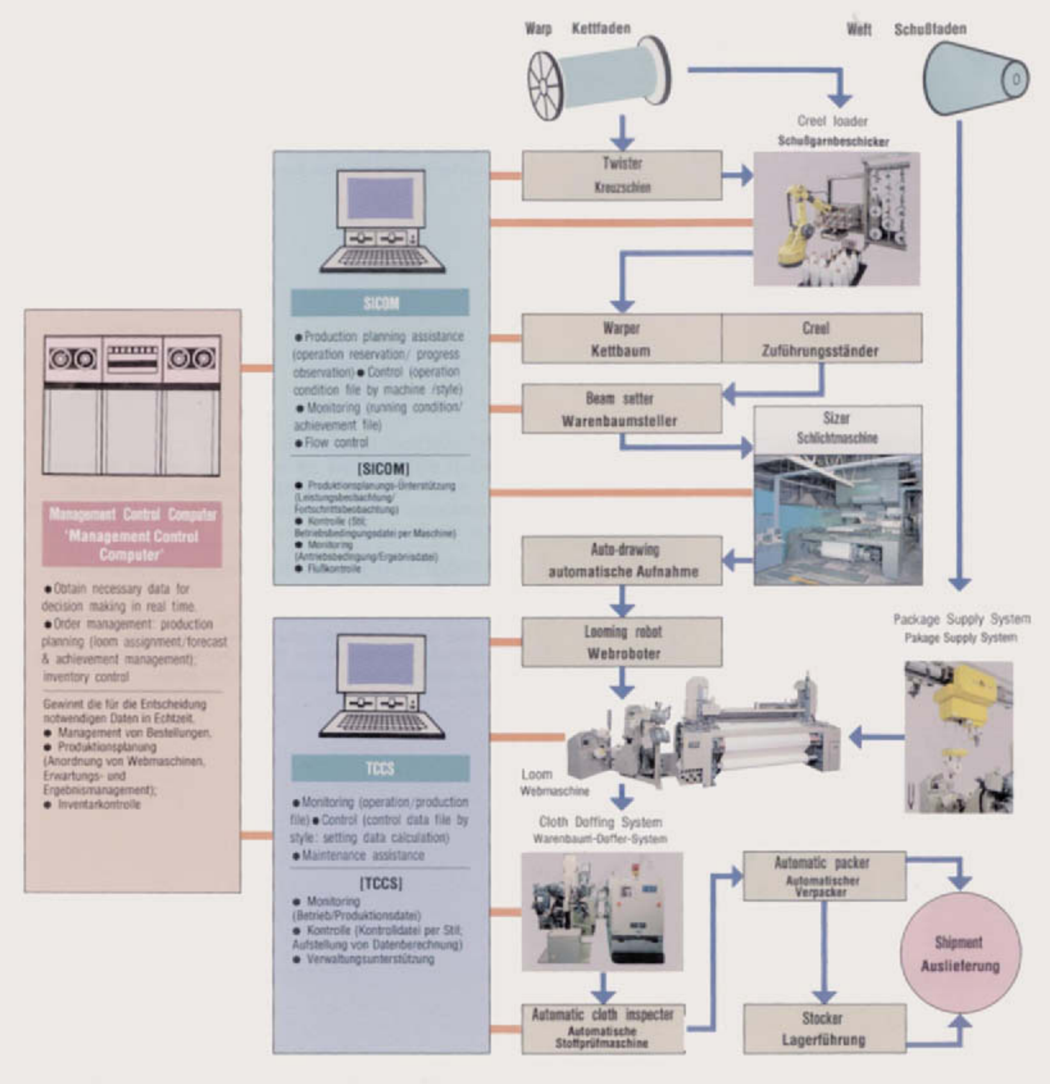


Fig. 2: CIM control of weaving preparation and weaving.

fabric; Weave). Weaving machines are classified according to the type of weft insertion system which at present includes shuttles, rapiers, projectiles, air jets and water jets (→ Weft insertion systems).

The principle of a weaving machine is illustrated in Fig. 1. The main drive is the central drive element and supplies all moving parts such as the head motion, reed, fabric take-up and winding. Selvedge trimming is also coupled to this drive, i.e. the movement of all working parts is synchronized through the main drive. The warp let-off motion is an exception here and is controlled by a dedicated electric drive which only unwinds sufficient quantity of yarn from the warp beam as required for weaving. The tension of the warp yarns is also kept sufficiently constant to ensure an optimum weaving result.

Centralized control of weaving machines through the application of CIM technology, whereby the various operations are organized by an internal network, represents a major technical advance in weaving (Fig. 2). The latest development in weaving technology (Figs. 3–6) is the linear shed weaving-machine (Sulzer).

Weaving performance development A tremendous increase in weaving performance has taken place

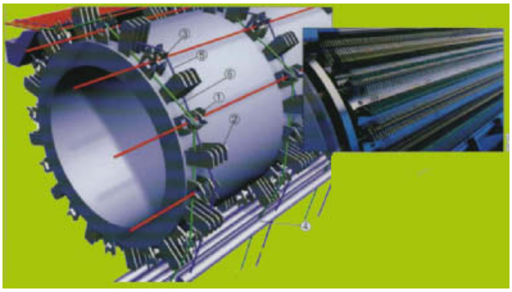


Fig. 3: The shed formation elements in the M8300 linear-shed weavingmachine. The guide bars position the warps so that they are raised above the shed holding elements, thus creating the upper shed, or kept in the lower shed position. ① = shed holding elements; ≠ = weaving reed; ③ = weft channel; ④ = guide bars; ∞ = upper shed; ± = lower shed.

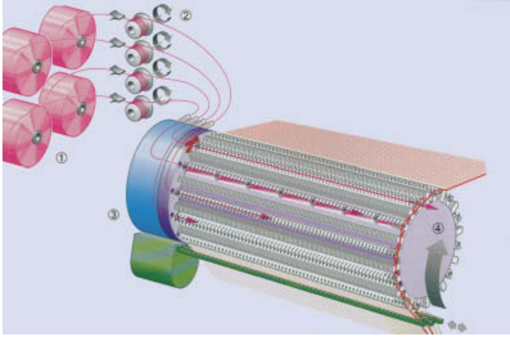


Fig. 4: The weft insertion elements.
① = take-off spools; ≠ = straightening rollers; ③ = weft processing; ④ = weaving rotor.

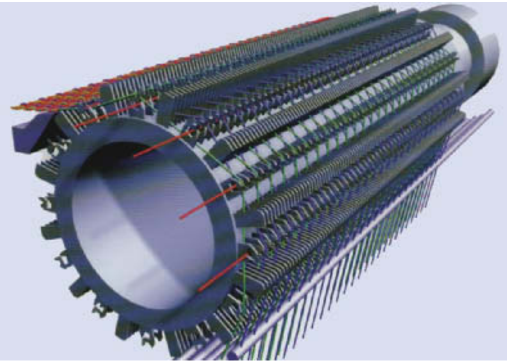


Fig. 5: The wefts are staggered on insertion and guided to the edge of the cloth by the rotor movement.

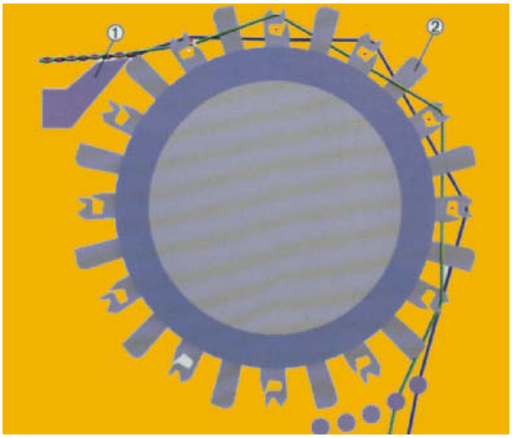


Fig. 6: The weft is attached to the edge of the cloth by the specially designed weaving reads.
① = fabric support; ≠ = weaving reed.

since 1965 when the production of woven fabrics began to switch over from shuttle weaving with pirns to automatic projectile weaving machines, (Fig. 1). A maximum performance of 6 m^2 fabric per hour per weaving machine was possible with shuttle weaving (for normal densities of worsted fabrics); in 1965, however, a weaver only needed about 1 working hour to weave 100 m of fabric at a (finished) width of 1.50 m on 10 automatic projectile weaving machines operated simultaneously by a single weaver (Fig. 2). In the meantime, automatic rapier and air jet weaving machines now operate at such high speeds that a performance of 25 m^2/h per machine is no longer an exception. Such outstanding performance in weaving has given rise to problems with the yarns used. If only two yarn breaks occur per 100 000 picks = machine stoppages, the weaving efficiency (Fig. 3) falls from 100% at approx. 200 rpm (e.g. old generation of automatic projectile weaving machines) through 95% at 500 rpm (e.g. rapier types) to 93% at 700 rpm (air jet weaving ma-

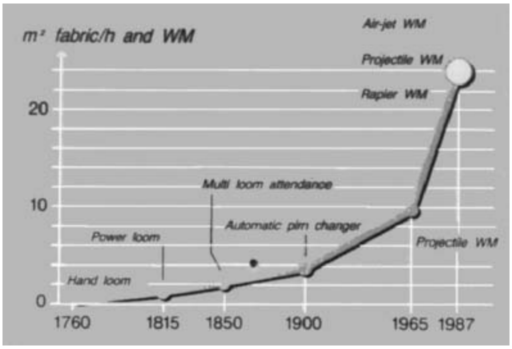


Fig. 1: Development of productivity in weaving.

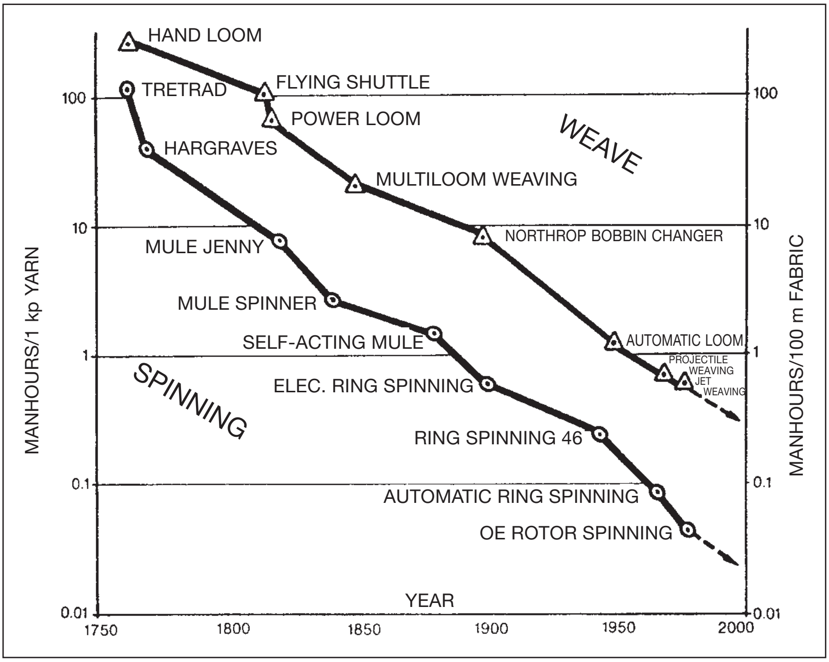


Fig. 2: Development of production in weaving and spinning (according to Krause).

chines). Since, however, yarns of lower strength (due to the use of unconventional yarns besides ring-spun yarns) are being used on an increasing scale by the yarn production sector, the number of yarn breaks per 100 000 picks has risen, e.g. to 10, so that weaving efficiency falls from 93% at 200 rpm through 87% at 500 rpm to 83% at 700 rpm. If the number of yarn breaks per 100 000 picks can be kept low (e.g. by using filament yarns), one weaver can operate a far greater number of machines (Fig. 4): e.g. with 2 yarn breaks/ 100 000 picks on projectile machines about 80 machines, on rapier types about 60 machines and on air jets about 40 machines. These figures fall drastically if the number of yarn breaks rises. Considerations such as these have led to a demand for high quality yarns in weaving in order to achieve optimum weaving performance (according to Weissenberger).

For the finisher of woven fabrics on the other hand, weaving performance involves different criteria. A woven fabric should be as uniform as possible for optimum dyeing and finishing.

One prerequisite for increased productivity, amongst others, is uniform preparation of the starting material to within close manufacturing tolerances. The (physical) uniformity of a textile fibre structure, on the surface of which the finishing-specific processes of

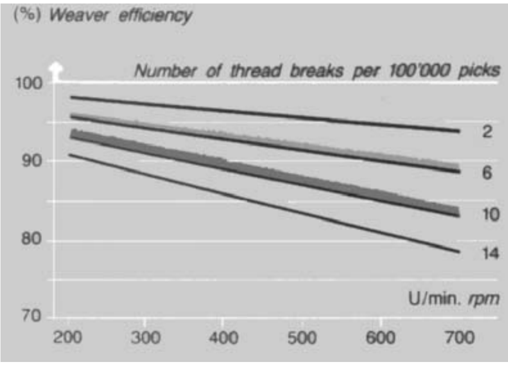


Fig. 3: Effect of rotational speed on weaver efficiency.

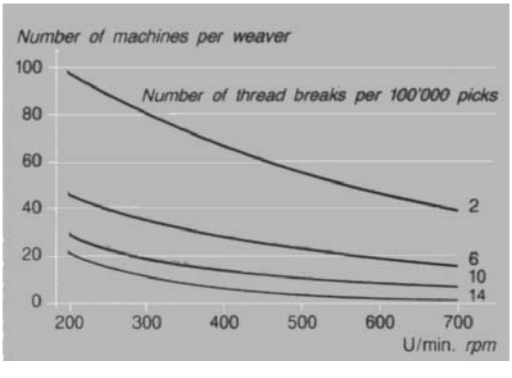


Fig. 4: Effect of rotational speed on weaver distribution.

(dye) mass, liquor and energy transfer take place, is of prime importance to the textile finisher. Experience has shown that uniformity of the fibre structure in a woven fabric is more “disturbed” by side/centre differences in the fabric, i.e. in the weft direction, than in the warp direction. The areas of a woven fabric close to the edges, which are often (relatively) more dense than the middle of the fabric, are generally dyed a lighter shade in continuous dyeing especially, i.e. the denser edges of a woven textile fabric are responsible for shading in dyeing which gives rise to customer complaints. This is the main reason why the textile dyer and finisher requires a highly uniform fibre structure across the width of a textile fabric in order to produce dyeings with a low incidence of customer complaints.

From the weaver’s standpoint, however, the uniformity of a woven fabric across its width is already assured by his production criteria. The percentagewise somewhat higher number of warp yarns in the area of the fabric edges is “contributed” by the modern weaving machine especially when its utilization is optimized by higher weft insertion performance and open fabric constructions. This situation often leads to frustrating discussions on customer complaints between the finisher and the weaver. The finisher cites his lighter dyed edges and the weaver his superficial and (to him) insignificantly higher number of warp yarns in the edge area of the fabric. But for continuous dyeing it is essential that the (weight) ratio of dye liquor to textile material is identical in all parts of the fabric in order to obtain a level dyeing with the same depth of shade throughout. This liquor (weight) ratio is “predetermined” by the fabric’s passage through the gap between the padder rollers where the thickness of the gap is constantly maintained throughout the dyeing run. In “conventional” dye padders, the thickness of the gap is identical even across the full width of the fabric. It therefore follows that a fabric which is identical in both the warp and weft directions will always be loaded with the same liquor (weight) ratio during its passage through the dye padder, i.e. these conditions ensure the production of a level continuous dyeing with the same depth of shade throughout. A somewhat higher number of warp yarns, or a higher fabric weight, in the areas near to the edges of a fabric occurs particularly in high-speed weaving machines with high weft insertion rates. From the weaver’s standpoint, these side/centre differences are insignificant. Even for the garment maker and the exhaust dyer who dyes his fabrics in beam dyeing machines or in rope form, such side/centre differences are insignificant. For continuous dyeing, however, such side/centre differences are extremely detrimental. This becomes clear if the liquor (weight) ratio in the gap between the padder rollers can be imagined. For the same gap thickness, the gap volume between the padder rollers is also the same. It therefore follows that the sum of textile material volume and liquor volume in the gap of the padder is always constant or, it will remain the same for a given padder setting even across the entire width of the fabric. Now, if the weight of the fabric in the edge areas is 2% greater than in the centre of the fabric, then the volume of textile material in the edge areas is also 2% greater and consequently the space available for dye liquor in the edge areas is inevitably reduced by 2%. From this it also follows that in this dyeing location near the fabric edges, the dyeing will always be lighter by double the percentage of the difference in fabric weight between the centre of the fabric and the edges. In this particular numerical example, therefore, a dyeing which is about 4% lighter in the edge areas must be reckoned with. A constant value relationship exists between the fabric weight and the sum of the numbers of warp and weft yarns. Consequently, a measurement tolerance of ± 5% for the fabric weight can be used directly to count the warp and weft yarns. If, for the sake of example, the number of warp or weft yarns is, say 30 yarns/cm, then the number of warp and weft yarns would therefore have to be “accurately” counted to ± 5% of 30, i.e. to ± 0.15 yarns/cm which, according to experience, is totally impractical or could only be carried out after an intolerable amount of time. From this example it can be concluded that the counting of warp and weft yarns as a means of detecting or determining uniformity variations capable of interfering with the dyeing process is unsuitable because it is too “inaccurate” (according to Kretschmer).

Webbing → Automobile safety belts.

Web bonding effect of binders Two different bonding mechanisms are involved here, the consequences of which have an opposing influence on each other under certain circumstances and can therefore have an effect on tensile strength.

1. Cohesive mechanism: this mechanism functions as a result of high binder cohesion which reaches its optimum effect when two fibres are fully included in a crossover point. For this type of bond, the approximate-

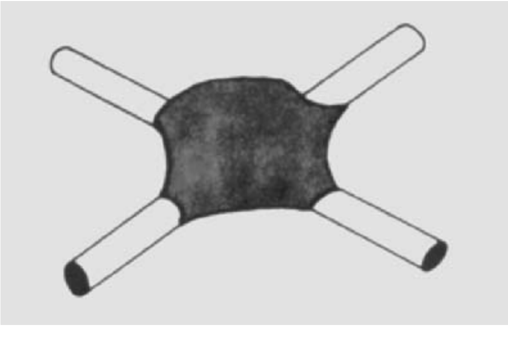


Fig. 1: Model of binder distribution with cohesive bonding.

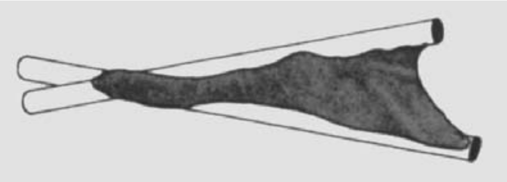


Fig. 2: Model of adhesive binder distribution.

ly spherical interlacing point is ideal for high tensile strength in a nonwoven material (Fig. 1).

2. Adhesive mechanism: this mechanism functions as a result of high binder adhesion forces and achieves its optimum effect usually between fibres or parts of fibres running approximately parallel to each other. For this type of bond, the bonding zone should be as extensive as possible to provide an ideal basis for high tensile strength (Fig. 2).

Various kinds of binder deposits on fibres, dependent on their form of application, are illustrated in Figs. 3 + 4.

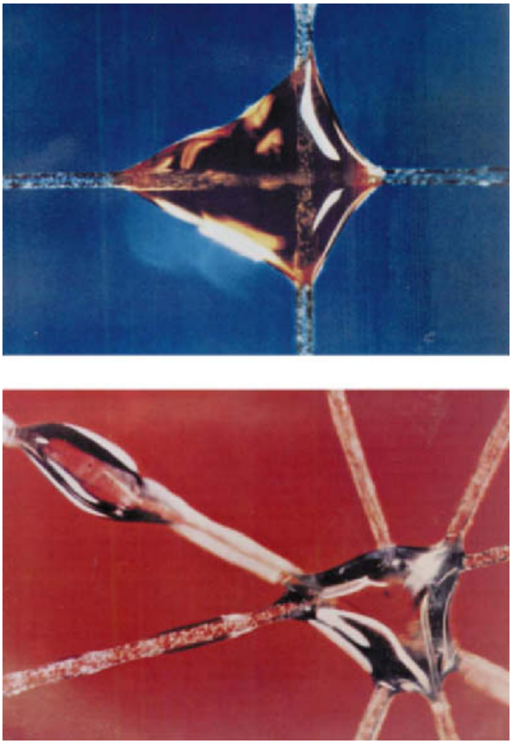


Fig. 3: Differences in binder cover depending on application: Bonding points from dipping (top) and foam application (bottom) (Bayer).

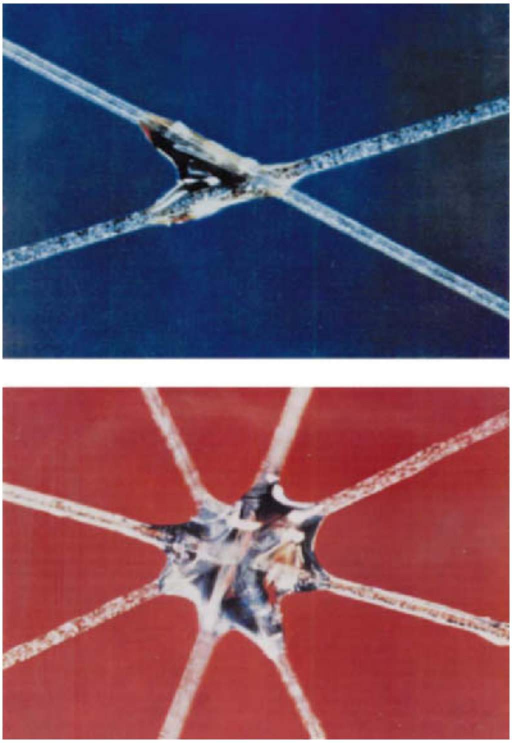


Fig. 4: Sail formation with foam application (top) in contrast to a spherical arrangement (bottom) with spray application (Bayer).

Web guiders, fabric guiders Mechanical (Fig. 1), pneumohydraulic (Fig. 2) or electronically controlled guiding systems are used in textile finishing processes to ensure an edge-straight and crease-free fabric run, especially on printing machines. In many electronic web guiding systems, a sensor detects the web position in relation to a reference value. This is usually the web edge, a printed line or a strong colour contrast on the web. The actual web position value is compared with a set value by the controller. The difference between these two values is sent from the controller as a signal to the system-actuating element which, in turn, adjusts the passage of the web by appropriate corrective action.

Standardized units detect the running fabric across its entire width to align the fabric precisely (Fig. 3). These devices are particularly suitable as centering systems when it is necessary to guide the fabric along the centre-line of a machine, e.g. washing ranges and coating plants. Higher production speeds can be achieved with sliding swivel rollers. Segmented roller guiders resistant to acids, lyes and liquor temperatures up to 104°C are used for many wet processing treatments.

The fabric guider type BF of IFS Systembau (Fig. 4)

Fig. 1: Mechanical web guiders, fabric guiders for dry (top) and wet (bottom) operation of pt Planotex.

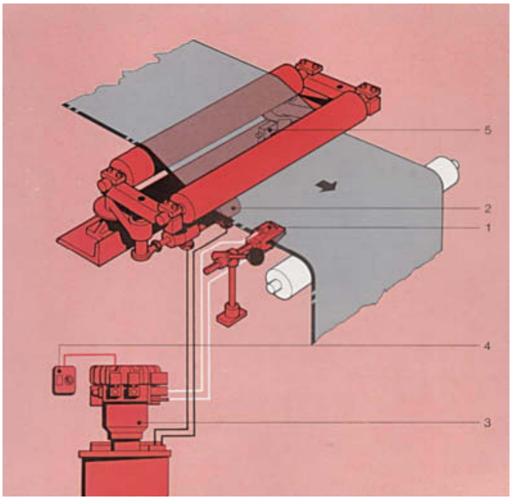


Fig. 2: Erhard & Leimer BS 4-VG 27 fabric guider with pneumohydraulic control according to guidance system.
1 = edge feeler; 2 = adjustable roller; 3 = control unit;
4 = control switch; 5 = centering device.

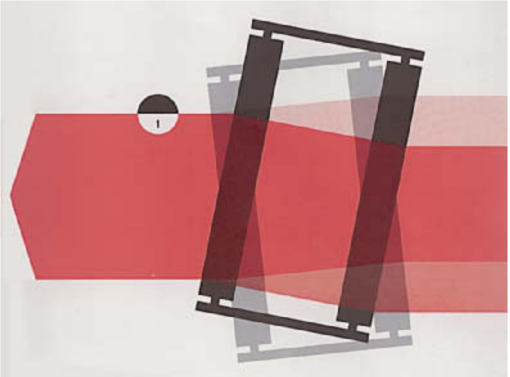


Fig. 3: Diagram showing the principle of the fabric guidance system.
1 = edge feeler.

ensures accurate crease-free single edge or centre-line guiding of textile fabrics even where wide deviations from the target position occur. A short-duration increase in the guiding forces by contact pressure with one of the two groups of brushes to the left or right of the expander roller brings about a rapid correction of the running web even when wide deviations are involved. Long lead paths for the fabric feed are therefore unnecessary. The driven expander roller simultaneously opens out the fabric and corrects curled selvedges if necessary. With wide-band scanning, there is no need for sensor tracking when variations in width arise. In addition to fabric guiding, this system can also carry out width measurements which makes it suitable for integration into production, planning and control systems.

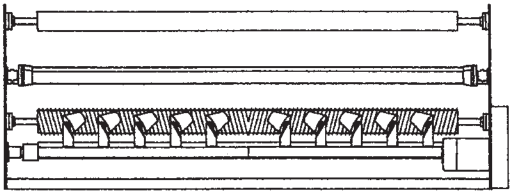


Fig. 4: BFE.1 fabric guidance system with a powered rotary stretcher, electromagnetic actuator and wide-band recognition.

The operating principle of a type BF fabric guider (Fig. 4) is as follows: the fabric first passes over an expander roller and the optoelectronic position-sensing system installed behind this roller emits a digital signal if any deviation in the centre or selvedge position of the fabric occurs. Correction of the fabric position is carried out by the specific application of fabric opening forces by means of controlled pressure brushes so that the fabric is immediately restored to its correct selvedge or centre position again. In all these systems, the contact pressure of the brushes is proportional to the deviation of the running fabric and acts in the opposite direction to the deviation either on the left or right side of the expander roller. This arrangement allows an extremely sensitive and gentle correction of the fabric position. Depending on the particular type of fabric guider, a second expander roller is finally brought into play in order to ensure a fully opened out fabric.

Web guiding systems → Expander.

Web slitting machines (fabric slitting machines), are used to slit running fabrics down the middle or in longitudinal strips of predetermined width. They are designed for installation on production machines.

Wedge-type template For the visual assessment of outlines, contours or sharpness of mark in textile printing. The length of the wedge still printed by a particular print paste is used as a measure (see Fig.). The printing quality of different thickeners or print paste recipes can be compared in this way. The length of the wedge from its lower thick end to its fine tip is divided up into 100%, 80%, 60%, 40% and 20%.

Fig.: Wedge-type template for the assessment of print contours.

Weft → Weft, filling.

Weft cracks Cracks present in individual and sometimes neighbouring weft yarns in woven crêpe fabrics produced from viscose or cupro yarns. Causes: embossing conditions too severe, or fibres weakened by oxidized linseed oil sizes.

Weft distortion is caused by external mechanical forces acting on a woven fabric (mechanical distortion) as well as internal latent tensions already contributed by the yarns themselves, or which have developed during the processes of manufacture (shrinkage distortion). Any force acting on a finished textile material, which has not been applied uniformly across its entire width, causes a displacement of the original right-angled configuration of the warp and weft (Fig. 1). Any non-uniformity in the path between the edges of a running fabric gives rise to a difference in tensile force and has the same consequences. It is therefore necessary to take care that as few partial forces as possible are applied to the textile material and that all the transport elements for processing a woven fabric (rollers, chains, etc.) are always in parallel alignment and equal in length. A distinction is made between:

- Skew distortion: a condition in which one side of the fabric is further advanced in relation to the other thereby causing a diagonal distortion of the weft yarns. Thus, although the warp and weft yarns may still be largely straight, they no longer lie at right angles to each other.

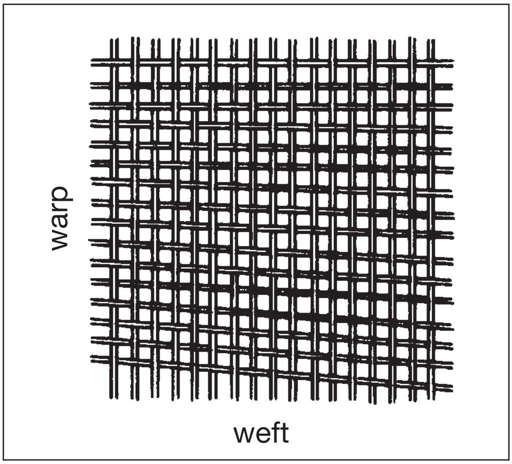


Fig. 1: Weft distortion.

- Bow distortion: a curvature in the path of the weft yarns, i.e. although the left and right ends of the weft yarns are at the same height they are displaced either forwards or backwards in the centre of the fabric in relation to the edges.
- Combined bow and skew distortion: the weft follows a curved path and the ends of the weft yarns are not at the same height.
- S-shaped distortion: the weft is wavy and lies in a series of small curves. It is largely dependent on the weave pattern.
- Irregular distortion: the weft yarns may follow any path across the width of a woven fabric. This type of distortion usually involves a combination of straight skew and various bow-shaped components.

The extent of the distortion is generally expressed in percentage overfeed, i.e. the overfeed of one area of weft yarns in front of another related to the fabric width (example: 160 cm fabric width, 16 cm overfeed: $[16 : 160] \cdot 100 = 10\%$ distortion). For measurement of the overfeed, the following definitions apply (according to international standards):

- The extent of a skew distortion is determined as the distance of one weft yarn from a point on the same selvedge touched by a line from another end of the weft yarn which lies at right angles to the normal position of the warp.
- The extent of a bow distortion is the distance between a line connecting both ends of a weft yarn and the point where the same weft yarn is furthest away.
- The extent of a double or multiple distortion is given as the narrow side of the smallest right angle which can be described around one weft yarn, the long sides of which run parallel to the distortion line between the ends of the weft yarn.

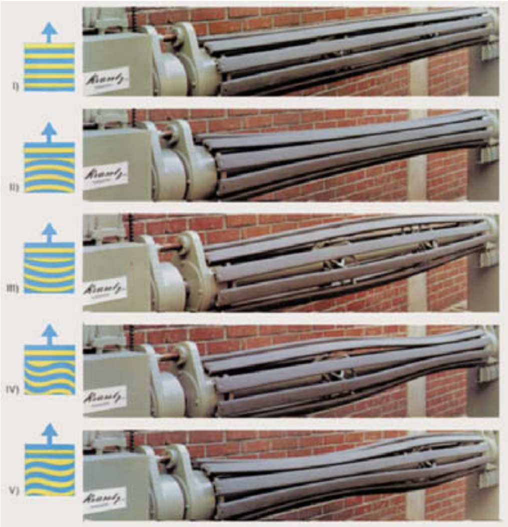


Fig. 2: Krantz fabric rectification roller with flexible laths.

In the main, two possibilities, which can be applied individually or in combination, are available to straighten distorted fabrics during finishing. The most popular solution involves the installation of a typical roller type straightening machine controlled by an automatic scanning and control system between a padder and a stenter drier.

The straightening principle is based on allowing the overfed part of a weft yarn to be held back by causing it to travel over an appropriately longer path distance so that, after this diversion, the lie of the weft yarn becomes synchronized once more (Fig. 2). Straight cylindrical rollers, which can be adjusted diagonally, are used for the correction of skew distortions. As far as the effect is concerned it should, however, be noted that the effective correction is always less than the theoretical diversion. The main reason for this is that the fabric is allowed to stretch to some extent so that only a part of the diversion applied to correct distortion is actually transferred to the fabric. The fabric tension prevailing at the time is particularly important in this regard.

The correction of bow distortion is carried out in the same manner when the axis of the bowed cylindrical rollers is rotated in such a way that, compared to the edges, the centre of the fabric is required to follow a longer or shorter path as required (Fig. 3). In this case also, the effective straightening action is always less than the theoretical diversion. The automatic scanning and control system controls the skew and bow rollers independently to such an extent in the direction of an excessive diversion until the actual position of the weft yarns is straight. This correction can function only as long as the theoretical straightening action can be kept sufficiently large. Certain limitations apply, especially with extensive bow distortions and narrow fabric widths in relation to the nominal width of the machine. The accuracy of this correction is not always sufficient in every case. On the one hand, a running web may contain relatively extensive irregular distortions so that

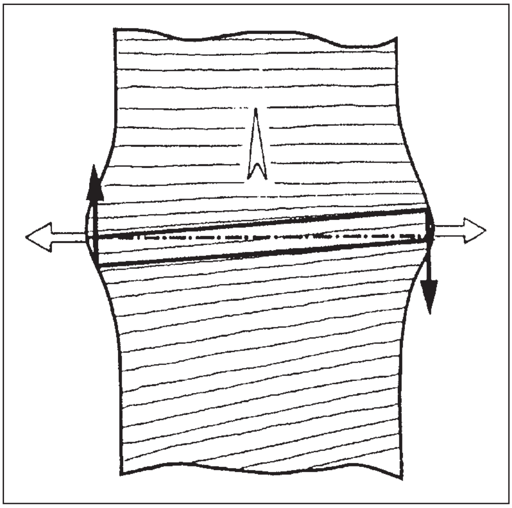


Fig. 3: Pin wheel system: when tensile forces (white arrows) appear, combatting forces (black arrows) guide the weft.

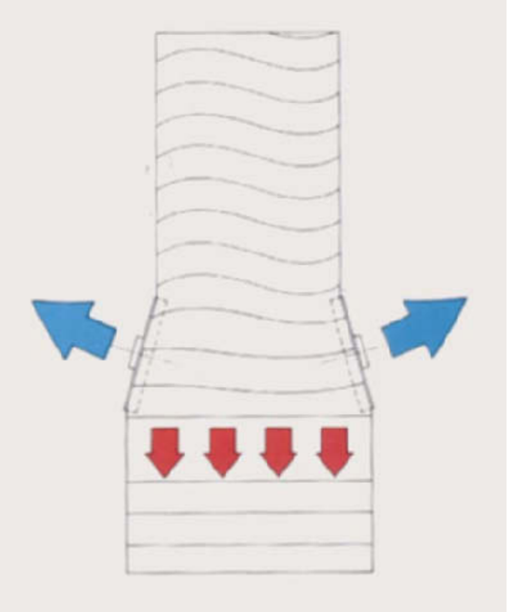


Fig. 4: Tschuiya (Japan) pin wheel principle, based on the Palmer Principle.

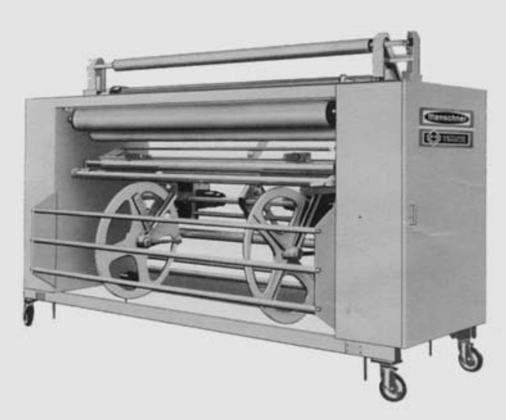


Fig. 5: "Correfix" weft straightener (Menschner).

complete straightening is no longer possible and, on the other hand, some fabrics may become distorted again during their passage through the stenter. In order to straighten residual skew distortions and residual bow distortions, or bow distortions formed in the stenter, a finely tuned straightening system is often applied after a normal straightening machine. In such a system, the correction of skew distortion is achieved by adjusting the running speed of the stenter chains and the bow distortion is corrected by adjusting the speed or the diameter of the delivery roller. Another possibility (now seldom used) is to allow bowed rollers, or rollers with changeable diameters, to "free-wheel" with the fabric.

The pin wheel straightener (Figs. 3–5) is based on the Palmer principle. Straightening is effected by means of two wheels with pins around their circumference to take up the fabric selvedge. These pin wheels are not driven, i.e. both are free running. In addition, the pin wheels are diagonally adjustable in relation to each other. During rotation of the pin wheels, this diagonal position stretches the distorted weft yarns and serves as a control element for the position of both pin wheels in their turning angle to each other. After a turn of 180° between pinning on and pinning off, the weft position is once again at right angles to the warp irrespective of the nature and extent of the distortion.

Weft, filling Threads or yarns running across the width of a → Woven fabric (→ Weaving) from selvedge to selvedge and at right angles to the warp. The weft binds the warp yarns (→ Warp) by interlacing with them to form a woven fabric structure and also serves as a filling material. Each weft yarn is called a pick.

Weft insertion A textile fabric with a system of alternating individually woven stripes and knitted wales. The latter take the form of weft threads which serve to bind the individually woven stripes together into a coherent textile fabric.

Weft insertion systems A distinction is made between the following weft insertion systems used on weaving machines (→ Weaving):

I. → Shuttles, as used in → Shuttle looms.

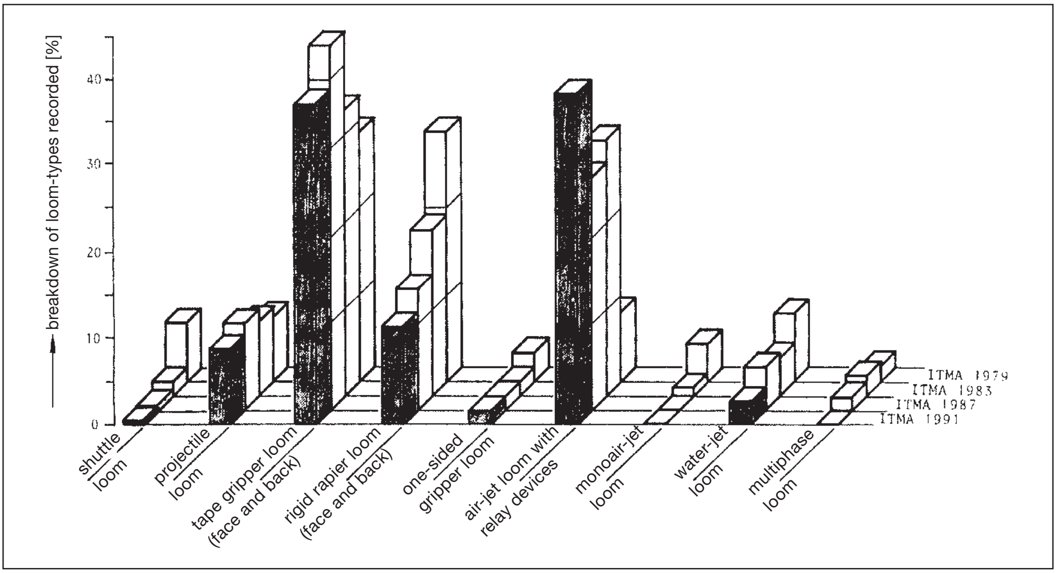


Fig. 1: Breakdown of the weft insertion procedures for weaving machines shown at the ITMA 1979–1991 (hand-operated pattern looms and circular looms were disregarded) (according to Kohlhaas).

II. Projectiles (gripper shuttles) used in projectile weaving machines: the weft yarn is gripped by jaws fitted in a projectile which is then propelled by non-positive action through the shed.

III. Rapiers used in → Rapier looms: the rapier takes the form of a rigid or telescopic rod, or a flexible steel tape with a clamp at the tip (the rapier) and carries pieces of weft yarn positively through the shed to the opposite side.

IV. Jets:

a) Air insertion: an intermittently directed jet of compressed air, with or without additional air jets, is used to transport the weft yarn through the shed. → Air jet weaving machines.

b) Water: an intermittently directed jet of water is used to transport the weft yarn through the shed.

If all the various weaving machines with their weft insertion systems exhibited at ITMA 1991 are taken as a fair reflection of market expectations (and this assumption cannot be fundamentally unsound), it should certainly be possible to discern particular trends for future development from the relative share of the different weft insertion systems exhibited and their development over the last four ITMA cycles. The relative percentage shares of different weft insertion systems for weaving machines exhibited at ITMA during the period 1979–1991 are presented in Fig. 1.

Shuttle weaving machines are now only to be found in a few niche markets. Thus, at ITMA 1991, only one wide weaving machine of this type having a reed width of 11.6 m (manufactured by Jürgens Maschinenbau) with a band-driven shuttle was exhibited. Because of its well-known drawbacks (high noise levels, high consumption of spare parts, low performance limits), weft insertion by shuttles only finds application nowadays for special materials where the above-mentioned limitations are balanced by the advantages which this particular insertion principle has to offer (e.g. extremely wide insertion widths), e.g. for weaving tyre cord lattice fabrics.

The share of projectile weaving machines (gripper shuttles) has remained about the same during the period under review from 1979–1991. The machine maker Sulzer resp. Sulzer-Rüti, is practically synonymous with this type of machine. Even at ITMA 1991 only the projectile weaving machines made by this company were to be seen. With a share of 8.6%, the projectile weaving machine has secured a relatively stable position for itself among the various weft insertion systems.

After air jet weaving machines, flexible rapier weaving machines with insertion from both sides represent the second largest group with a share of just over a third (36.9%). Although still represented at ITMA 1987 with a 42% share, this insertion system has a number of advantages especially with regard to high flexibility and favourable dimensions for wide reed widths. It is therefore not surprising that more than half the machine makers now offer machines of this type.

With a still significant share of more than 11%, rigid rapier weaving machines with insertion from both sides are well represented. However, the share of these machines has continually declined over the last four exhibition cycles due to their displacement by flexible rapier and air jet systems. This group includes all the weaving machines with double action weaving methods (for the production of velvet, velours and carpets with double weft systems) manufactured by machine makers such as Webmaschinenbau Chemnitz, N.V. Michel van de Wiele and Günne Webmaschinenfabrik. Another important representative of this weft insertion system is Dornier with its (positive) controlled weft yarn transfer. The insertion principle with just a single rapier acting from one side, and therefore without yarn transfer in the middle of the fabric, was only to be seen on a few of the machines exhibited. This type of weft insertion is, in principle, not suitable for high weft insertion performance because of the unavoidable empty stroke of the insertion element. Consequently, this system only finds application in special fields; machines of this type are used for the production of conveyor belts and flat carpets with very coarse weft yarns.

Weaving machines with air jet insertion and relay nozzles have the largest share at 38.5%. This weft insertion system has become more and more established because of the high productivity offered by this system

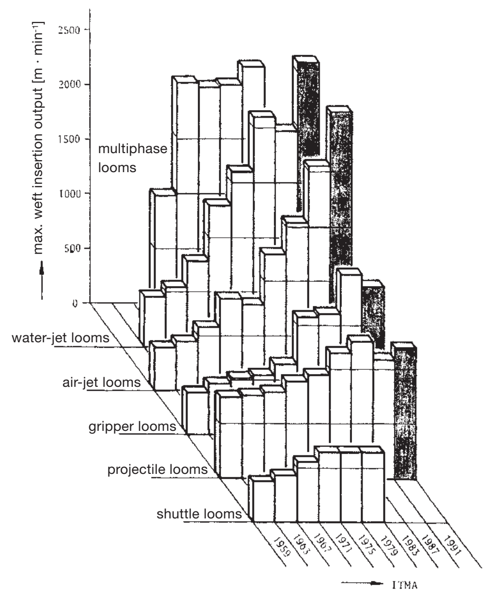


Fig. 2: Maximum weft insertion output of weaving machines at the ITMA settings (according to Kohlhaas).

and its market share shows a positive trend. The range of applications is continuously being extended; even difficult yarns can be used with high insertion efficiencies. An air jet weaving machine with a "demonstration speed" of 1500 rpm (Tsudakoma Corp.) as demonstrated at ITMA 1991 can achieve a weft insertion performance of 2550 m/min. This corresponds to an increased performance of at least 25% compared to ITMA 1987, a rate of increase which was not expected even when allowance is made for the fact that it only represents a "demonstration" performance. Air jet weaving machines with single jet insertion and confusor were no longer represented at ITMA 1991 nor at the one before that. This weft insertion system has two significant characteristics, i.e. a width limitation of approx. 2m and the limited warp density which if exceeded leads to warp stripiness. This principle has now been displaced by the development of other competitive weft insertion systems.

Water jet weaving machines have a share of less than 3%. This weft insertion system holds the record for the maximum achievable weft insertion performance as already demonstrated at the previous ITMA. An example from Tsudakoma Corp. can work with a weft insertion frequency of 1700 rpm which corresponds to a weft insertion performance of at least 2600 m/min at an insertion width of 153 cm. The rate of increase compared to the last ITMA (Fig. 2) was therefore more than 30%. This demonstration performance was, however, only achieved with specially selected weft yarns and fabric parameters and it was also necessary to mount the machine on a special foundation. The small and continually declining share of water jet systems clearly demonstrates that the field of application for this weft insertion system is also quite limited (according to Kohlhaas).

Weft-knitted fabrics → Knitted fabrics in which one or more thread systems run widthwise across the fabric forming all of the loops in each course. Weft-knitted fabrics are produced on flat and circular knitting machines. Typical weft-knit fabrics include double knit, fully fashioned, interlock, jersey, knitted fleece, knitted terry, rib knit, etc.

Weft slubs Consist mainly of short irregularities in the weft direction (easily visible when viewed against the light). Weft slubs are almost always caused by defective material (impurities), spinning defects (variations in yarn count or titre, differences in twist, irregular yarn, uneven yarn thickness), or defective dyeings (streaky dyeings).

Weft straightener, automatic All woven and knitted fabrics are subjected to a variety of stresses and dimensional changes during textile manufacture and finishing processes. These may take the form of distortions as well as displacements in the positions of the yarn which are unevenly distributed in a textile fabric and result in a new distorted state of equilibrium. As a rule, distortions in the weft yarns are involved here. The mechanics of weft straightening are based essentially on the fact that the distortions are produced during individual process stages through changes in length and tension and can therefore be corrected again. Thus, e.g. the overfed part of the weft is straightened by lengthening the path it has to travel relative to the remainder of the weft so that it is restrained. Monitoring of the running fabric with the human eye at high machine speeds is problematic and often impossible. Automatic controllers have therefore been introduced to overcome such problems. Detection of the weft position is accomplished in most cases by photoelectric means, whereby the reflection properties of the fabric surface dependent on the position of the weft and warp yarns, as well as the path of the individual yarn itself, are used as measurement criteria. The angle-dependent reflection of the surface is naturally dependent on the structure and pattern of the fabric whereas measurement of the position of individual yarns is largely free of such limitations, but is only possible as long as the yarns can be made visible in the projection. An angular-position-dependent output signal can be produced by projecting the weft yarns through two narrow slits behind each of which a photoelement is mounted. When the yarns pass under the slits with a certain amount of skew distortion, they produce a light/dark modulation on the photoelements which is all the greater the more parallel the weft is in relation to the slit.

For a normal weft configuration, the modulation of both elements is the same. After analysing the data from all the scanning heads, the system generates matching alternating current signals which can then be amplified, rectified, and subtracted from each other to obtain a position-dependent signal which can be used to display the weft position and control an associated straightening machine at maximum possible speed. From the magnitude and polarity of these signals, a microprocessor inside each scanner processes the initial distortion-related signals and determines the extent of its deviation from the norm. The higher the number of scanning heads, the better the signal communication and reliability of the display. If measures are taken to reduce the dead time of the control loop to negligible proportions by using straightening machines with a small fabric content and by keeping a short distance between the scanning heads and the straightening machine, any distortion which occurs can be corrected within a few metres.

The straightening unit illustrated in the Fig. detects the position of the yarns by optoelectronic means as a light/dark modulation with a photoelectric converter. This detection is contact-free and independent of the machine speed over wide limits. Two to eight scanning heads, with a motor drive to space them evenly across

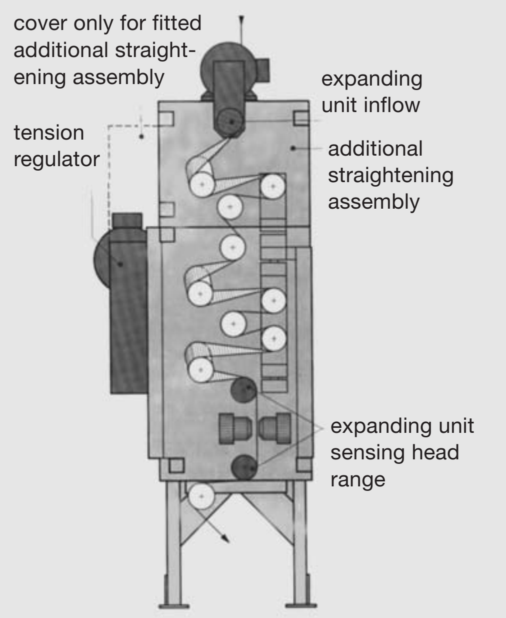


Fig.: Orthomat (Mahlo) straightening unit with additional facilities (cloth passage).

the fabric web, receive the modulated light from the fabric, convert the optical signal into an electrical signal and transmit this information via a transistor amplifier to dedicated display instruments. The number of scanning heads is determined by the width of the widest fabrics and the severity of the distortions. Provided the weft is uniformly skewed or bowed, fewer scanning heads will be required than if it were distorted into an irregular wavy configuration. As a rule, however, the more scanning heads there are, the more accurate the weft line analysis. By comparing the signals from several scanning heads, control commands are generated and adjustment of the bow and skew straightening machine is carried out simultaneously by two electronic controllers independently of each other and at maximum speed. Internal control loops adapt the Orthomat automatically to different fabrics. Transparency and contrast are balanced by changing the total sensitivity and lightness of the light source. The operator of the machine neither needs to preset a base setting nor readjust the system after a batch change. Colour, type of fibre, yarn count, surface effects, print design, pile and machine speed have no influence on the function of the unit. Only absolute impermeability to light and the total absence of any transverse structure impair the function of the Orthomat. The machine operator can view the state of the warp and, above all, the weft position in relation to it, from conveniently sited display units, e.g. at the entry to a drying stenter, but he does not need to do anything.

Weft straightening During textile processing, situations can arise when the weft in a particular fabric is no longer straight and at right angles to the warp (→ Weft distortion) and is either bow-shaped or diagonally skewed in relation to the warp. Weft straighteners (see Fig.) are used as a pretreatment to straighten the weft yarns in woven fabrics before printing, e.g. by running the goods through a levelling stenter or special weft straighteners installed at the entry to a drying machine. Even when, in engraved roller printing, horizontal stripes in a design have been engraved at a slight angle to the horizontal (“slashed”) in order to prevent the edge of the doctor blade digging into the engraved stripe on the printing roller, the weft yarns in the fabric must also be diagonally offset to the same extent before printing.

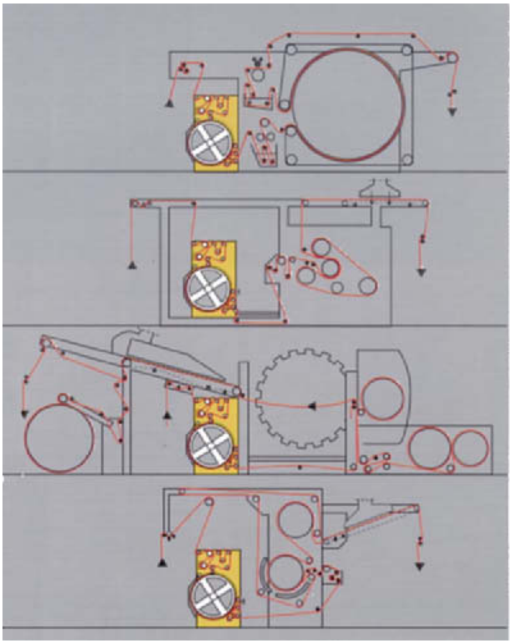


Fig.: Various possible applications of a weft straightener (Correfix).

Weft yarn A soft-twist wool weft yarn produced from hard worsted yarn or Cheviot yarn; not as lustrous as → Lustra fabrics.

Weibull functions in weathering Various models for the change in properties caused by weathering have been proposed, most of which use an exponential curve. The general form of the Weibull function (see Fig.) is

$$y = b_1 \exp\left[-\left(\frac{t+b_2}{b_3}\right)^{b_4}\right] + b_5$$

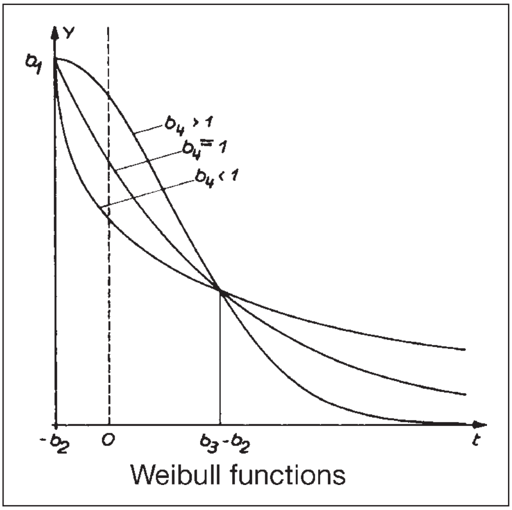


Fig.: Weibull functions.

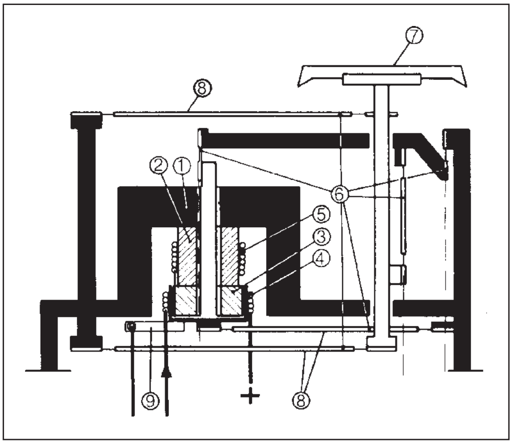


Fig. 2: Mettler electromagnetic force compensation. Schematic diagram of a weighing cell.
1 = magnet yoke and housing; 2 = permanent magnet; 3 = pole shoe; 4 = compensating coil; 5 = temperature compensation; 6 = flection bearings; 7 = weighing pan; 8 = link rods; 9 = position transmitter.

The five parameters describe the damage curve in general terms and can be interpreted physically as follows: b_1 is related to the maximum property to time $t = -b_2$ ($b_1 + b_5 = \text{max.}$); b_2 is the pre or post-ageing, i.e. if b_2 is positive, a certain amount of ageing or damage has already occurred at the beginning of the test corresponding to time b_2; b_3 signifies a kind of half-life period (time of $t = -b_2$ calculated until the property has decreased to 37%); b_4 describes the shape of the curve; $b_4 \leq 1$ quicker initial decrease, $b_4 > 1$ delayed decrease at the beginning; b_5 is an asymptotic value of the property (the value at $t = \infty$). Usually, b_5 is = 0, i.e. the tensile strength is = 0 for any further exposure.

Weighing machine Weighing machines are used for weighing textiles, dyes and chemicals to convert recipes into concrete quantities. Chemicals in solid or liquid form can be dispensed into a previously tared container placed on the platform of a weighing machine (i.e. weighing machine plus empty container set to zero). A suitable weighing machine can be integrated into dispensing systems to weigh out the various products in a colour kitchen or dye store (Fig. 1).

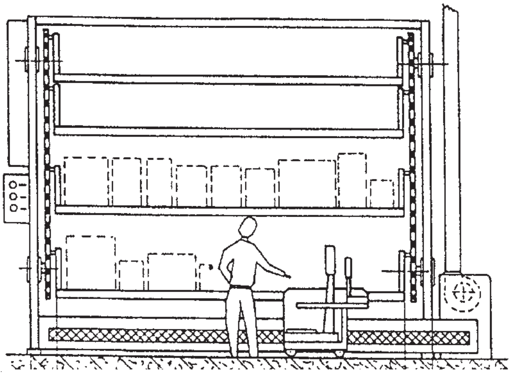


Fig. 1: Chemicals store (paternoster) with weighing up unit.

The weighing range of an industrial weighing machine is selected according to particular requirements. For rapid damping, weighing machines with electronic force compensation systems (Fig. 2) are used. The weighing data for a weighing machine can be transmitted via a computer interface (BCD output), keypad or floppy disk.

Weighing of dyes In order to implement recipes which are stated in % with respect to the weight of goods for exhaustion processes and in g/l for application methods, it is necessary to weigh dyes, etc., following any appropriate calculations. To avoid error wherever possible, the following methods are used:

– a key access card on each drum of dye; before weighing the dye the scales must be unlocked using the card.
– connecting the scales to the (electronic) dye measuring and recipe mixing system, which does not permit weighing of the next dye until the preceding one has been correctly weighed out.
– automatic weighing stations.

The third method offers the additional advantage that, in the case of dyes in powder form, there is no need for any person to come into contact with any dye dust.

In the case of the Color Service System (Figs. 1 and 2), powdered dyes are drawn off from the drums in which they are delivered into 90 litre dispensing con-

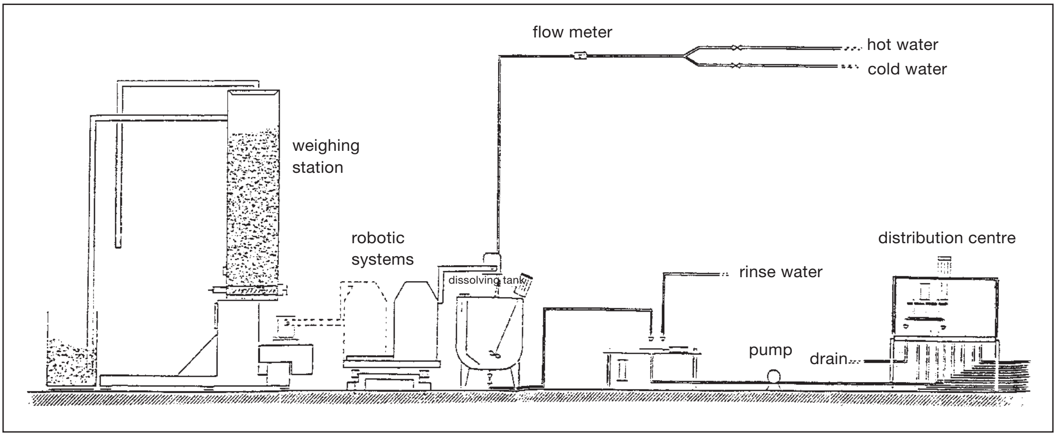


Fig. 1: Color-Service robotized (automatic) weighing station for powdered dyestuffs.

tainers. At the base of each of these containers is a helical screw conveyor which can deliver the dye powder, as required by the recipe, into drums which travel on a track along the row of dispensing containers. Each collecting drum rides along the track on a scale so that the dye can be weighed as it is dispensed from the helical conveyor. Once loaded with the correct amounts of the dyes required, the drum is transferred by robot to the dye dissolving tank in the dye kitchen.

Fig. 2: Robot for transferring weighed dye powder container from scales to dissolving container.

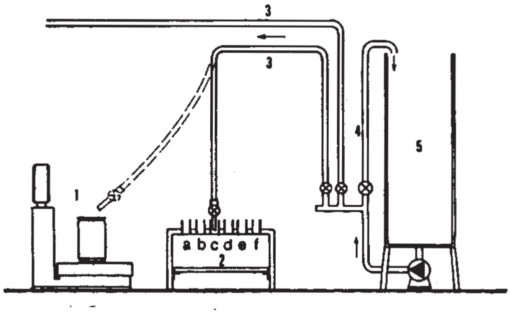


Fig. 3: Conveying thickeners or stock colour pastes to the weighing point (partial automation).
1 = scales; 2 a–f = mountings; 3 = feed pipes from silo to weighing point ; 4 = thickener circulation 5 = silo.

In order to minimize the problems associated with old or residual printing pastes in the print shop, it is important to weigh as accurately as possible only the quantity of dye paste which is absolutely needed. The relative quantities of dye must also match, of course, when weighing stock colour pastes. Under a semi automated system, thickeners and stock colour pastes can be pumped and piped to the weighing station (Fig. 3).

Weighing stations The monitoring of scales, meters and weights is an activity which constantly recurs in textile finishing. At various locations along the route of material flow, scales are used both continuously and non-continuously to weigh quantities. This provides important measured quantitative results for the production information system, while at the same time serving to guarantee consistent quality. Precision electronic and analytical scales have long become standard in the laboratory; of no lesser significance, however, is the increasing importance of exact weighing during production, particularly when the constant increase in raw material costs is considered. Nowadays production can make use of fully electronic industrial scales with a range of up to 6 t and which are accurate enough to permit the application of processes and recipes which have been tested in the laboratory.

The textile finishing material flow may be divided schematically into the entry of goods, warehouse or buffer store, finishing stages, finished product warehouse and despatching. Scales are needed to fulfil different tasks within these functional areas; in addition to use in the actual material flow, this also includes scales employed in analysis in development and quality assurance laboratories. This is by no means an exhaustive listing, serving only to indicate the variety of uses to which scales are put. However, it permits a demand profile to be derived for scales, which function as material sensors.

Simplified, the following features characterise the material flow scale:
- high precision with reproducible results,
- flexibility of use at different stages of the work,
- robust, i.e. suitable for an industrial environment,
- system compatible,
- data saving at all stages.

In dyeing, scale are a component within the entire weighing station (→ Weighing of dyes, see Fig. 1). Dye is drawn off from warehouse containers and weighed on travelling scales according to the recipe for the current batch. Robots equipped with manipulating arms remove the containers with the weighed out dye from the weighing station scales and transfer the dye to the dissolving tanks. The weighing container is rinsed in the dissolving tank and then returned to the scales by the robot. The dissolving tanks are equipped with:
- a circulation pump for dissolving the dye,
- sensors for minimum and maximum level,
- a temperature sensor for the dissolving temperature data,
- direct steam heating,
- litre meters for cold and hot water with a litre scale,
- series of automatic valves for the functions: fill, top up rinse, container rinse, sensor wash (these functions can be carried out using either hot or cold water and are monitored by the litre meter).

Dissolving time and temperature for each dye are specified by the weighing station computer: it determines the highest temperature and the longest time for dissolving as per the recipe and passes them as instructions to the dissolving station. The dye is only tipped into the dissolving tank once a prescribed quantity of liquor for dissolving has been added. The prescribed temperature is achieved by mixing hot and cold water. If the prescribed temperature cannot be achieved by water mixing, the mixture is additionally heated using direct steam. The specified dissolving time does not begin to run until required conditions for dissolving have been achieved. The circulation pump runs continuously while the weighing container is being emptied and during the dissolving time which follows, thoroughly mixing the dye with the liquor and ensuring that it is dissolved to the best effect. Once the dissolving time is over, the liquor circulation is stopped by a three-way valve which empties the dissolving tank. The dissolved dye flows via a distribution station either to mixing tanks at the dyeing machines or into a dye kitchen. Each mixing tank to which the dye is delivered has a separate inlet connection. A rotating arm moves to the correct position, docks and thus connects the dissolving tank with the mixing tank at the machine. A pump controls the flow of the dye from dissolving tank to distribution station. The work sequence then ends with a rinse programme which cleans the dissolving tank and the pipes connecting it to the mixing tank at the machine. A complete weighing and dissolving station supplied with 90 powder dyes performs as follows: on average every three hours, 39 recipes each containing 5 dyes can be weighed out, dissolved and delivered to the mixing tanks at the machines in the dyeing shop.

Weighting,

I. A formerly common practice of artificially increasing the weight of cotton goods by adding kaolin, magnesium sulphate, zinc sulphate, etc., the purpose being to give the illusion of better quality.

II. → Weighting of silk in order to compensate for weight lost during the removal of bast and to achieve particular qualities. Weighting is applied either to the yarn or to the piece. The weighting of pieces was standard practice in the 1930s but then the use was largely discontinued. In the case of tie silk, weighting is a finishing process applied to the yarn. The handle this achieves together with the heavier seeming fabric, contribute to the high value of yarn dyed tie silk. Both vegetable and mineral weighting are known; the former is scarcely represented any more, whereas the tin phosphate-silicate method has proved itself. More common, however, is polymer weighting on the basis of MAA (methylacrylic acid amide), whereby the reaction is triggered using ammonium persulphate. Not only can the loss of weight from the bast be recovered, but an acceptable handle can be achieved at up to 35% above raw material weight (also true for tie silk). Results were first achieved using a jigger, subsequently also a beam dyeing machine.

Weighting finishes Carried out in order to produce a fuller handle in both fabrics and knit goods. The process should no longer be applied for the purpose of falsifying better quality (→ Weighting). Instead of natural products (starch, dextrin and similar), plastics are now used to achieve a fuller handle (resins of polyvinyl, polyacryl, polemetacryl and urea). For effects which are wash fast at high temperatures, soluble ether celluloses are used which are deposited on the fibre using a salt bath.

Weighting of silk In earlier times, silk, in particular, being the most precious and costly of natural fibres, was traded by weight. As a consequence, the high weight loss during degumming often led silk dyers to restore this loss through a weighting process, or even to exceed the raw material weight. Following newly developed fabric constructions, silk is nowadays essentially only weighted to achieve improved sheen, handle, fall or fullness for specific final articles such as ties, edging and embroidery. As a rule, weighting is done before the yarn is dyed in rope form. Silk may be charged (weighted) with:

– metallic salts (tin phosphate-silicate weighting),
– vegetable extracts (tanning agents),
– synthetic resins (e.g. methacrylamide).

I. As yet no substitute has been found for the tin phosphate-silicate weighting process known for decades. This method of weighting nowadays plays only a minor role, but the principle may be explained briefly.

The process comprises various stages which may be repeated several times according to the degree of weighting desired. A "tin weighting" treatment (with tin and phosphate) achieves a weight increase of between 10 and 15%. a) The silk is first treated in a cold 28–32°Bé solution of tin(IV) chloride for 1 to 1.5 hours, spun and then rinsed cold. It is important that soft water is used since water containing calcium leads to precipitation and loss of sheen. b) After rinsing the silk is treated for 1 hour using a 5–9°Bé strong solution of disodium hydrogen phosphate (Na_2HPO_4) at 50–60°C. Depending on the degree of weighting desired, these latter two stages may be repeated 2 to 4 times. c) After the final treatment, the silk is immersed in a bath of 2–7°Bé concentrated silicate at 50–60°C, whereby the basic tin phosphate already formed is converted into wash fast tin-sodium silicate. The water glass treatment achieves in the silk an increase in volume and an essential improvement in sheen and handle as well as in dye uptake. These processes for weighting silk using tin salts, though widespread in earlier times, are seldom carried out nowadays on account of the disadvantages associated with mineral weighting (reduction in the life of the silk, particularly when subjected to mechanical stresses, and the great demands of the multi-stage process) which are greater than the advantages in weight gain and improved handle and fall.

II. Vegetable weighting using tanning agents is easy to carry out and the silk is not damaged in the process. However, large quantities are required to restore the original weight and the greatest increase obtainable is at best 10% above the original.

III. For several years the weighting of degummed silk has been carried out by means of graft polymerisation using monomeric methacrylamide, which leads to results in handle, sheen and fullness comparable to those under I. The polymerisation occurs in a thin aqueous solution of methacrylamide at temperatures below 100°C. It is usually done immediately following degumming, the yarn being in the form of rope or wound on packages, and in advance of dyeing on the dyeing machine. New investigations are concerned with the weighting of fabrics in order to achieve improved care characteristics. Such a weighting is wash resistant and persists after dyeing. Despite consistency in the process conditions great variation in the degree of weighting can arise. Other graft polymerisation processes using vinyl compounds have until now, only be applied to silk in the form of fibre or yarn. Their purpose is not so much to weight the silk as to improve the quality of the silk textile.

General disadvantages of the weighting process, in addition to the costly and cumbersome process, are ecological problems, possible damage to the fibres, poor affinity to dyes and poor wash fastness of the dyed goods. In consequence, silk is nowadays weighted only for use in specific final articles.

Weight per metre → Fabric weight.

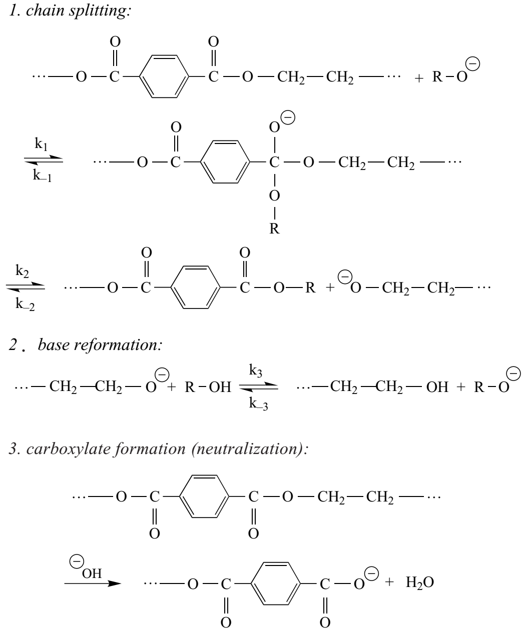
Weight per square metre → Fabric weight.

Weight-reducing (de-weighting). The term refers to a heterogeneous method of → Weight reduction involving alkali hydrolytic treatment of the sheath of polyester fibres. The required heat zone dwelling is carried out, for example, under the pad-roll system (Apolotex Elektron Reactor) or modified processes. Whereas previously only 2–3% of fabric weight was lost during alkaline weight reduction, a 20–30% degree of weight reduction is normal. This is dependent upon liquor concentration, temperature and exposure time. Hoechst process: a continuous process involving highly concentrated alkali in the padding liquor, if possible minimally applied, and then short (1 minute) HT steam treatment (approx. 120–150°C); a loss of tensile strength is noted. The Debaca process reduces the loss of tensile strength by impregnating twice with dilute sodium hydroxide solution as part of a pad steam process (second time in the steamer). → Alkali treatment of polyester.

Weight reduction of polyester fibres The weight reduction of polyester fibres in fabrics derives from patents held in the 1950s by ICI and Dupont and is therefore as old as the large-scale production of polyester fibre. The aim of weight reduction is to produce finer fibres in order to alter the handle and the visual properties of a fabric. This aim is documented by the fact that this finishing effect is also referred to as "silk finish". A lowering of breaking strength is sought as a secondary effect, which leads to a reduction in snag susceptibility as well as, for yarn fabrics, of pilling. In the case of Japanese Shingosen articles, microfibres (which themselves have the finest titres of 0.1 dtex) are alkalised using the pad-steam process to achieve a weight loss of 3–5%, thus obtaining extremely soft polyester articles.

The chemistry of weight reduction is based on the saponification of the polyester to glycol and terephthalate at the surface of the fibre with lyes, whereby the terephthalic acid formed neutralizes sodium hydroxide solution and so leads to a steady fall in the pH of the treatment bath (→ Alkali treatment of polyester).

As a general rule the process makes use of an aqueous sodium hydroxide solution in a more or less long liquor. The rate of weight reduction, of course, increases with liquor concentration and temperature. The



process temperatures lie in the range 9–130°C and treatment times, depending on liquor concentration and temperature, from 1–4 hours. The rate of weight reduction is strongly influenced by the state of the fibre material, such that whenever excess liquor is used in order to achieve a prescribed weight reduction (e.g. 10%), colour matching must be carried out specific to the material, bringing with it a series of associated difficulties not discussed further here. To overcome these difficulties it is necessary to use only sufficient sodium hydroxide solution as is required in stoichiometric terms to achieve the prescribed weight reduction (100% theoretical conversion, Fig. 2).

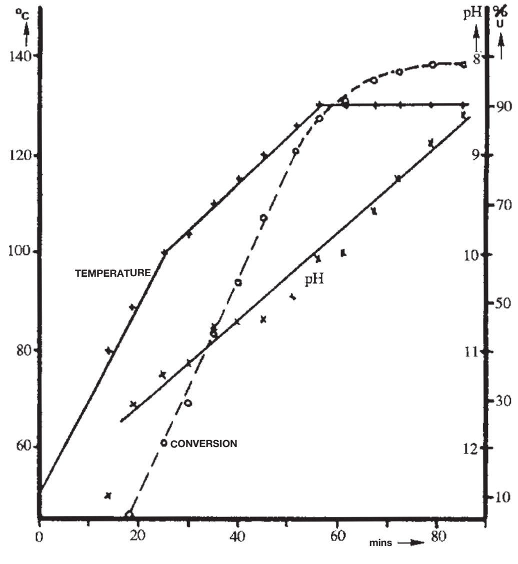


Fig. 1: Progress over time of a polyester fibre alkalization process in a beam dyeing machine; polymer weight reduction in %/min, liquor pH change in pH/min, heating up rate in °C/min.

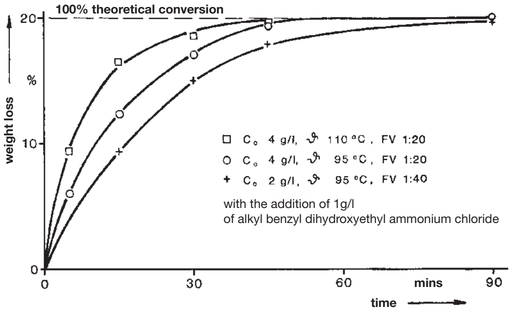


Fig. 2: Polyester polymer weight loss with caustic soda.

For long liquor processes, the low liquor concentration leads either to too long a dwelling time or requires the use of highly effective accelerators. However, these accelerators, as with all other known commercial accelerators, have the disadvantage that their use slightly yellows the goods, which is a disadvantage for white goods, pastel colours and prints on a white ground. Attempts to remove this yellow discolouration using oxidation and/or a reduction have so far failed. The use of higher temperatures in processes with long liquor and consequent relatively long dwelling times leads to a disproportionate loss of strength. When weight reduction is carried out at low temperature (95°C), as well as an excellent weight reduction of approx. 20%, an almost parallel progression can be observed of the maximum tensile force to the highest possible maximum tensile force, which should fall due to the increase in fineness corresponding to the weight reduction. This behaviour can be interpreted in terms of the orientation of the molecules being higher in the outer region of the fibre, thus making a greater contribution to overall fibre strength. At a higher weight reduction temperature (130°C), on the other hand, sodium hydroxide solution diffuses into the fibre core and there hydrolyses the molecules relevant to the strength.

Weight units → SI system of Units.

Weisz's Pore Model Used in the discussion of textile chemical processes, it has the advantage of clarity and offers the experimental textile chemist a mechanical interpretation of events at the molecular level.

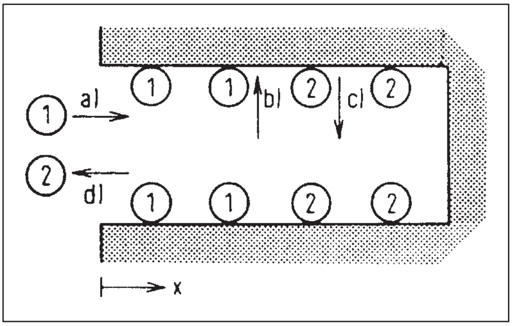


Fig.: Diagram of a textile substrate pore (Weisz's Pore Model).
1 + 2 = various sorptives, e.g. 1 = dye; 2 = retarder.

The Fig. shows a diagram of a pore in a substrate which is to be dyed.

If one assumes good circulation (a sufficiently rapid transportation of the material in the dye bath), the dye process can be paraphrased in general, in terms of the following processes:

a) diffusion of (1) in the substrate,
b) immobilization of (1) (e.g. through adsorption or chemical reaction),
c) mobilization of (2) (e.g. through desorption),
d) diffusion of (2) out of the substrate.

The → Diffusion of the two mobile substances, processes a + d, can be considered static movement processes in the sense of the first → Fick's law of diffusion.

Weld → Natural dyes.

Welding,

I. The uniting of metal parts by heating without the aid of any additional binding agent (in contrast to → Brazing). Autogenous welding is carried out with the aid of an oxy-hydrogen flame, a methane-oxygen flame or an oxy-acetylene flame; welding is also carried out electrically. Argon is used as a shielding gas when welding V4A steel in order to prevent later corrosion of the welding seam.

II. → Heat bonding of thermoplastics.

Welliné (Fr. = waved) A wave-shaped → Ratiné effect. It involves carded yarn ratiné material with a wave-like structure. The waves may be oriented longitudinally, transversely or diagonally. The basic material of the cloth is wool velour. In order to achieve a particularly fine effect, cashmere, mohair, camel hair or alpaca is used as upper weft.

Well water → Ground water.

Wesel triangle A so-called physiological triangle used for calculating and predicting the efficiency of any given item of clothing. It derives its name from the letters WSL, whereby these form the three corners or the triangle and allow for the expression of the relationship between the following three basic tests (W, S and L in German) for →: Heat retention; Perspiration transport measurement; Air permeability. If one enters the measured values on the sides of the wesel triangle, the result is the linear relationships between: heat retention and perspiration transport on the side WS, perspiration transport and air permeability on the side SL, heat retention and air permeability on the side WL. Joined together, the three points create the central ABC field as a measure of "comfort" (clothing physiological basic characteristic), while the triangles I, II and III in the corners W, S and L indicate by means of their form and size the significance of the individual factors heat retention (W), perspiration transport (S) and air permeability (L) (Fig.).

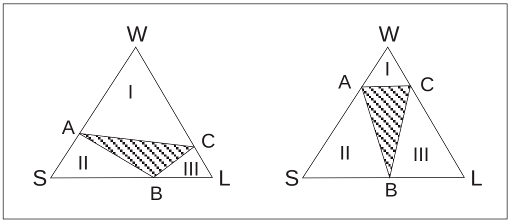


Fig.: Wesel triangle.

Wet aftercleaning treatment A post-treatment in the field of dry cleaning undertaken to remove water soluble residues. It can, depending on the goods and the residues concerned, be a total or partial wet treatment, but is not a form of washing. Wet aftercleaning must fulfil the fundamental requirement of maintaining, as far as possible, the form and finish of the goods. Any goods wet aftercleaned, according to regulations, must retain the character resulting from the dry cleaning process.

Wet brushing machine → Raising machines.

Wet bulb temperature When a wet textile is being dried the temperature in the drying medium at some distance from the fibre may be, for example, 140°C (t_{jet}). However, if the laminar boundary layer was penetrated in the immediate vicinity of the fibre in order to measure its temperature (Fig. 1), it would be found that, so long as surface water remains present, the temperature falls to that of the so-called wet bulb temperature of the fibre. Because this surface water is constantly renewed at the fibre surface due to capillary action during the first drying phase, mass transfer can take place in a way similar to that following the laws of evaporation from an open water surface. If it is imagined that the surface of the goods has a random dimension, then after an initial warming up phase the temperature of a damp textile over which air of low temperature flows will stabilise at a constant value. Through cooling, the

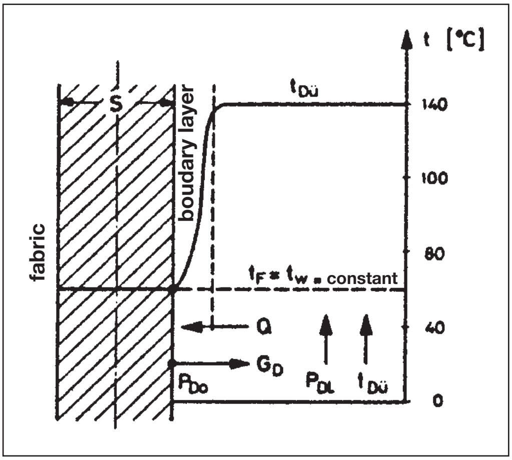


Fig. 1: Temperature curve at the surface of a fibre (in the 1st drying phase).

surrounding air will also tend towards this constant limiting value (thus the term wet bulb temperature).

For the first drying phase it is therefore true that the same temperature is obtained at the surface of damp goods as would be obtained at the open surface of the same liquid, that is to say in the case of drying by hot gas, the so-called surface temperature or adiabatic steady state temperature. According to Kröll, the surface temperature during the first drying phase depends upon the velocity and direction of the air flow in so far as does the relationship of the heat transfer coefficient and the mass transfer coefficient. For a water/air system the adiabatic steady state temperature of the fluid approximates to the wet bulb temperature.

In highly simplified form, the phenomenon of wet bulb temperature may be explained as follows. The temperature difference between the circulating air and the wet goods will tend to fall due to temperature equalisation: liquid and goods tend to acquire the temperature of the circulating air. However, as the water would attain its boiling point in the process, it takes up a large amount of energy for evaporation; this energy is extracted from the goods in the form of latent heat of vaporisation. These two tendencies, heating up to the same temperature as the circulating air versus cooling due to the extraction of latent heat, result in a balance characterised as the wet bulb temperature.

During drying, moisture can be transported to the surface of the goods from the interior in either liquid or vapour form. A migration is, however, only possible in the liquid phase. Once the first reversal point is reached the movement mechanism of the liquid phase at the surface of the goods is interrupted. The drying level, which marks the boundary between the liquid and gaseous phase, migrates into the interior of the goods. Presupposing that the total of small capillaries reaching the surface is significantly greater than the total of larger capillaries, then the small capillaries remain filled with liquid for as long as their capillary action exceeds the friction. As a consequence, liquid flows in the small capillaries during the first drying phase both from the interior of the goods and from the larger capillaries. During this phase the fine capillaries are continuously supplied with liquid from the interior of the goods, and the concentration of this liquid rises accordingly because the solvent evaporates at the open surface while the dispersed particles remain behind. The surface of the goods remains moist for as long as the suction of the capillaries is sufficient to draw enough moisture from the fabric interior as is lost by evaporation at the surface under atmospheric conditions. Once this is no longer the case, the rate of drying is reduced. The various points at which evaporation takes place, which together represent the “drying level”, migrate deeper and deeper into the interior of the goods. In non-hygroscopic materials, this drying level represents the boundary between capillary and gaseous moisture transportation. In the case of a hygroscopic material there is no true drying level in the form of a distinct boundary between dry and moist layers of material, but rather areas of differing moisture content within which a vapour pressure balance is maintained which depends on the particular local temperature and humidity. During the first drying phase, dissolved substances which become transported to the surface with the capillary water concentrate there if they cannot evaporate, and thereby give rise to the phenomenon of migration.

The first breakpoint in the drying curve occurs when the rate at which liquid is transported within the capillary system becomes less than the rate of evaporation. The liquid menisci in the capillaries, and thus also the drying level, retreat deeper into the capillaries towards the interior of the goods. The location of the break in the curve for any given liquid depends on the capillary properties and the temperature of the goods. From this point on the drying curve, the properties of the goods influence the drying process and the second drying phase begins. The transport of water within the textile material continues due to capillary action in the wet material up to the evaporation zone. From that point on the dampness must be transported by gaseous diffusion through the already dried layer to the surface, from where it is removed by the surrounding air. During the second drying phase the rate of drying becomes ever more dependent on thermal conductivity and gaseous diffusion across the dry layer. As a result the drying rate during the first phase can no longer be maintained. As the factors hindering moisture transport increase, ever decreasing quantities of water can be transported to the surface.

During the second drying phase (Fig. 2), both the

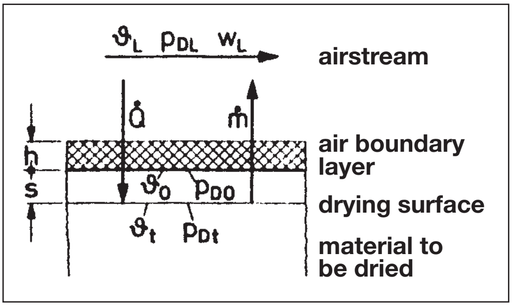


Fig. 2: Heat and material flow in the 2nd drying phase.

transport of heat energy and of mass must take place across increasing distances through the already dried layer of goods by, respectively, the mechanisms of thermal conductivity and diffusion. The heat transition coefficient k and the vapour permeability coefficient σ_D now come into effect.

heat flow: $$\dot{Q} = A \cdot k\,(\vartheta_L - \vartheta_t)$$

mass flow: $$\dot{m} = \frac{A \cdot \sigma_D}{R_D \cdot T}\,(p_{Dt} - p_{DL})$$

with $$k = \frac{1}{\frac{1}{\alpha} + \frac{s}{\lambda_S}}$$

and $$\sigma_D = \frac{1}{\frac{1}{\beta} + \frac{\mu_D \cdot s}{D}}$$

k = heat transfer coefficient (W/m^2K);
α = vapour permeability coefficient (m/s);
ϑ = temperature (°C);
p_{Dt} = vapour partial pressure at the drying level;
μ_D = diffusion resistance coefficient;
t = at the drying level;
L = in the air stream.

During this drying phase, roles are played by both the external diffusion conditions (β and the difference in partial pressure $p_{Dt} - p_{DL}$), which may be influenced both by the temperature and the velocity of the air, and by the diffusion properties μ_D and D of the goods. To the extent that the distance s separating the location of drying within the material from the surface increases, the influence of the heat transfer coefficient α and of the material transfer coefficient β, and thus of the air velocity w_L on the drying rate, decreases. Air velocity has barely any remaining influence on the final drying of thicker goods; the factors time and temperature play a decisive role instead of the difference in partial pressure.

In totally non-hygroscopic goods the final residue of humidity evaporates at saturated vapour pressure and at a drying rate which is greater than zero, the process occurring at the point of greatest distance from the ventilated surface of the goods. In the case of hygroscopic goods the drying rate sinks still further, i.e. a second break occurs in the drying curve and the third drying phase commences. In addition to the constraints in operation during the second drying phase relating to the diffusion of water vapour through the capillaries, moisture transport is now further constrained by diffusion within the fibre material. The drying rate progresses during the final phase towards zero accompanied by a final moisture content which is determined by the sorption properties of the goods together with the relative humidity of the drying air. Drying ceases to operate once the partial vapour pressure in both the goods and the surrounding air are equal. In other words, the final result achieved is in balance with the atmospheric humidity of the surrounding air at that time.

When the humidity within the goods reduces to the point that evaporation at the surface slows down, the temperature of the goods begins to rise. Goods emerging from the drying chamber have a temperature which lies somewhere between the wet bulb temperature and that of the dry air. The temperature profile of the goods is entered on a drying curve as a function of the treatment time t and the speed of the goods v. The length of the treatment chamber L is represented as a line defined by the product of v multiplied by t (Fig. 3).

In the full process cycle the time t_1, the speed of the goods v_1 and the treatment chamber length $L = v_1 \cdot t_1$ are realised. If the speed of the goods v is increased, then to maintain the condition $L = v \cdot t$ the time must be decreased. If, for example, the machine is run with a speed of goods v_2 then only the time t_2 may be taken for

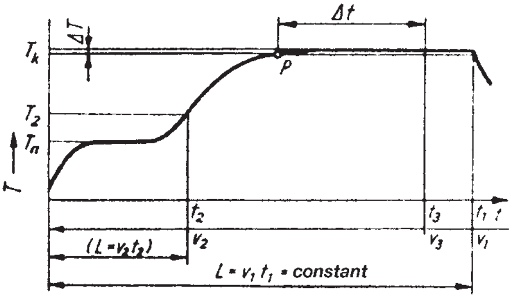


Fig. 3: Temperature of textile fabric T = f(t) in drying and heat setting in one operation.

the process and the resulting goods temperature T_2 characterises the machine purely as a drying machine. The profile of any drying curve does, of course, depend on the type of fibre, but also on the thickness and thus the permeability of the goods. The weight of the goods determines, via the quantity of water absorbed, the drying rate. Should goods be dried which contain not only water but also solutions (e.g. dilute sulphuric acid from carbonising), migration can result.

Wet crease resistance The property of a fabric whereby it does not acquire creases when squeezed in a wet state. Wet crease resistance includes an anti-creasing capacity, in other words the ability of the fabric to lose creases acquired during wear when immersed in water. (This is tested by squeezing the dry fabric in such a way as to cause creases, then laying the fabric in water; if the creases smooth away once wetted, this indicates good crease recovery.) It can be observed that a crease resistant fabric at the same time possesses an anti-creasing capacity, whereas a fabric with a high anti-creasing capacity but poor crease resistance acquires folds during washing. In other words, crease resistance determines whether no creases or only a few creases are present after washing.

Wet crease-resistant finishing A process in resin finishing for improving wet crease resistance. Processes particularly suited for this are those which enable the cross-linking of cellulose when in a swollen state (→ Wet cross-linking process).

Wet cross-linking process A resin finishing process for cross-linking cellulose in a swollen state by means of hydrolysis resistant resin finishing agents in the presence of strong acid, e.g. hydrochloric acid, or strong alkali, e.g. sodium hydroxide solution, at room temperature. Method of working: pad the finishing liquor, batch rotation, dwelling at room temperature, after-washing. Finishing effect: a very good wet crease recovery angle, unaltered dry creasing angle with associated slight loss of strength, in particular of abrasion resistance. When cross-linking in an acid medium, DMDHEU and tetramethylol acetylenediurea are preferred. The reaction time is 16–24 hours. Application is for tablecloths, furnishing fabrics and bedding; the preferred fibres are cotton and linen. Wet cross-linking in an alkaline medium is part of a multi-stage process, and has acquired no practical significance in isolation (in contrast to wet cross-linking in acid medium). The first stage is classical → Dry cross-linking. The second stage is alkaline wet cross-linking with, for example, epichlorhydrin, dichlorpropanol, n-methylolacrylamide, sulphonium compounds. → Ambivalent crosslinking.

Wet decatizing → Decatizing wool in hot water.

Optimum fixation is achieved during wet decatizing when the goods have become able to withstand the finishing processes which follow or when tensions or faults arising from preceding processes (e.g. the snowing of dyes) are removed in a controlled manner. However, the optimum conditions for the fixation of different textile fabrics are themselves different. The finishing process which is to follow also determines the extent of fixation. Thus goods which are to be dyed in rope form must first be treated at boiling or even higher temperatures, whereas an article which will only ever be washed at 40°C needs to be fixed to a lesser degree in order to avoid wash creases. Temperature, time and humidity, when suitably applied, provide for good fixation stability. If the temperature is raised the time must be shortened. The time can also be shortened through the addition of reducing agent at an unchanged or a higher temperature without prejudicing fixation stability. Time and temperature clearly interact together and can vary according to quality. The prerequisite for a regulated process cycle (i.e. one under the control of the finisher) is the optimum setting of the pH value of the goods. In the case of patterned goods, in pursuit of colour fastness at the necessary temperatures of 60–70°C, the pH is by preference adjusted towards acid. However, this means that the optimal conditions for fixation in water are no longer obtained. The nature of cooling which follows the boiling process is of significance for the sought fixation effect. The reduction of temperature at this stage strongly influences the partial removal of crosslinks. The degree of fixation depends during the cooling phase on the state of tension in the fabric; a relaxation of tension is a precondition for good dimensional stability during later processes.

Four different stages of work are carried out in the course of wet finishing, which are falsely generally referred to as boiling. According to the different fixation effects, one should distinguish between the following wet decatizing processes:

- burning,
- crabbing,
- smoothing,
- fixation.

1. Burning refers to the treatment of goods in boiling water followed by immediate total cooling in cold water. The goods may not be cooled on rollers because slight glazed moirés can form. The purpose is to fix the raw goods (increasing the textile stability). This generally tends to guarantee that no significant changes occur to the fabric surface or the body of the fabric as a consequence of subsequent washing. With this end in view a synthetic detergent is added to the liquor. This leads to rapid wetting of the goods and prevents any burning in of the dirt. The liquor is then brought to the boil in the tub and treated thus for 8–12 minutes without the application of pressure. The goods are then drawn off through cold water. To ensure identical treatment of both ends, the fabric may be drawn with numbered end first on the first occasion and with unnumbered end first on the second occasion. Light worsteds,

ladies goods and sometimes even heavy gabardine (for raincoats) are burned in order to retain a clearly defined thread on finishing.

2. Crabbing refers to a treatment of the goods at 40°C on the scouring machine. Crabbing results in the goods swelling and, like burning, precedes the washing process. The treatment serves to prevent breakages of the thread in the washing machine in principally, heavily woven worsteds and goods manufactured from heavily twisted ply-yarns. Again as with burning, a synthetic detergent is added to the crabbing liquor with this end in view. Once cooled, the goods are moved to the washing machine either after a short time or immediately.

3. Smoothing leads to an improvement of the goods in terms of both appearance and handle, becoming smoother, more even and shinier across the surface and both softer and more supple to the hand. The strength of glaze achieved is dependent on the pre-treatment of the goods, the temperature of the water, the duration of treatment, the pressure applied and the length of time for which the goods are cooled on the drum (fixation). In the case of goods which will only be washed, it is sufficient to remove the so-called unevenness by treatment on the scouring machine in water at 45°C. Piece dyed goods, on the other hand, must be treated in water at 50–60°C after dyeing because rope creases originating in the dye shop are difficult to remove. Depending on the type of article, the goods are treated for 5–12 minutes and then allowed to cool on rollers. An excessively long cooling of panama, fresco and gabardine, etc. on batching rollers leads to the formation of glazed moirés or reversed ridging (the cooling time should be at the most 2–3 hours).

4. Piece dyed goods are fixed before dyeing on the scouring machine in water at a temperature of at least 80°C. The fixation effect becomes more favourable the higher the temperature difference chosen between heating and cooling. Treatment above 80°C and, under some circumstances, with the addition of a reducing agent produces stronger fixation. After treatment on the scouring machine the goods are wound onto a roller and completely cooled by being left overnight. Reversing the rolling up during the scouring treatment improves identical effects at both ends.

On grounds of cost effectiveness, smoothing goods following rope and at times also open width washing, fixing rope dyed goods in advance of dyeing and smoothing such goods following dyeing are usually carried out on the Konticrab machine. It is clear, nonetheless, that the results obtained by such a continuous process are not as good as those using a crabbing jack. This is particularly true of articles which are particularly susceptible to rope creases, such as flannel. However, the higher productivity, better integration into the finishing sequence and the evenness of effects at the ends of material argue in favour of accepting the risk of possibly non-removed rope creases on the Konticrab and of only using the crabbing jack in exceptional circumstances. Fixation which differs at the two ends, which can arise easily on the crabbing jack, leads to uneven dyeing of piece dyed articles if the fault arises before dyeing. The end of the piece which was at the bottom of the beam in the crabbing jack (the "tail end") dyes darker in such a case. Differing effects at the two ends result in differences in glaze during smoothing following the dyeing; the end rolled inside the roll of goods has a higher glaze. For these reasons the crabbing jack is rarely used any more for fixation processes in the modern textile finishing plant.

Wet decatizing fastness → Potting fastness.

Wet development → Fixation of dyeings and prints carried out in an aqueous medium. Prints are with vat leuco ester, naphthol and reactive dyes in particular on cotton, linen and viscose.

Wet dwell (batch) process The fixation of compounds (e.g. resin finishes or reactive dyes or peroxide) by dwelling of the goods in a wet state.

Wet extensibility The phenomenon of moisture dependent increase in both width and length of polyamide goods. The polyamide fibre stretches by approx. 2–3% due to the take up of moisture; the effect is reversible.

Wet fastnesses A collective term generally used for the demand that during use dyeings and prints exhibit colour fastness to →: Water, Perspiration, Washing and Wet ironing, whereby more specialist demands also include fastness to →: Alkali fastness of dyeings and prints; Fastness to cross dyeing; Fastness to sea water as well as wet light fastness.

Wet finishing (wet processing). The term encompasses all wet treatment processes such as bleaching, dyeing, printing, impregnation, mercerising, carbonising, milling, etc. in contrast to → Dry finishing of fabrics.

Wet finishing of wool piece goods In the course of wet finishing wool, four varying processes are carried out which are generally described falsely as boiling. They should be distinguished as follows:

I. Burning. This is the treatment of goods in boiling water followed by immediate complete cooling in cold water. The goods may not be cooled on rollers because slight glazed moirés can form. The purpose is to fix the raw goods (increasing the stability of the textile) in order to preclude changes to the surface or the body of the fabric as a consequence of subsequent washing. A synthetic detergent is added to the liquor, as is a reducing agent under some circumstances (to fix the textile), in order to produce rapid wetting and to stabilise the form. The liquor is then brought to the boil in the tub and treated for 8–12 minutes without the application of pressure. The goods are then drawn off through cold water. To ensure identical treatment of both ends, the

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fabric may be treated for a second time, starting at the opposite end. Light worsteds and sometimes also heavy gabardine (for raincoats) are burned in order to retain a clearly defined thread on finishing.

II. Crabbing. This means the treatment of the goods at 40°C on the scouring machine, synthetic detergent also being added. Crabbing results in the goods swelling and also precedes the washing process. The treatment prevents breakages of the threads in the washing machine in, principally, heavily woven worsteds and goods manufactured from heavily twisted ply-yarns. Once cooled, the goods are plaited down on a batch roller either after a short time or immediately, and then moved to the washing machine.

III. Smoothing. This process leads to an improvement of both appearance and handle. The strength of glaze achieved is dependent on the pre-treatment of the goods, the temperature of the water, the duration of treatment, the applied pressure and the length of time during which the goods are cooled on the drum (fixation). In the case of goods which will only be washed, treatment on the scouring machine in water at 45°C is sufficient. Piece dyed goods, on the other hand, must be treated in water at 50–60°C after dyeing because rope creases originating in the dye shop are difficult to remove. Depending on the type of article, the goods are treated for 5–12 minutes and then allowed to cool partially or completely on rollers. An excessively long cooling of panama, fresco and gabardine, etc. on batching rollers leads to the formation of glazed moirés or reversed ridging (cooling time may last at the most 2–3 hours).

IV. Fixation. Piece dyed goods are fixed before dyeing on the scouring machine at a temperature of at least 80°C. Such a treatment can be seen as a substitute for wet decatizing (in some circumstances with the addition of a textile fixing agent). The fixation effect becomes more favourable the higher the temperature difference between heating and cooling. Treatment above 80°C produces stronger fixation. After treatment the goods are wound onto a roller and completely cooled by being left overnight. Reversing the rolling up during the scouring treatment improves identical effects at both ends. Because of cost effectiveness, smoothing goods following rope, and at times also open width washing, fixing rope dyed goods in advance of dyeing and smoothing such goods following dyeing are usually carried out continuously (see Fig.). It is clear, nonetheless, that the results obtained by such a continuous process are not as good as those using a crabbing jack. This is particularly true of articles which are susceptible to sharp rope creases, such as flannel. However, higher productivity, better integration into the finishing sequence and the evenness of effects at the ends of material argue in favour of continuous processing. Fixation which differs at the two ends, which can arise easily on the crabbing jack, leads to uneven dyeing of piece dyed articles if the fault arises before dyeing, since the “tail end” of the piece usually dyes darker in such cases. Differing effects at the two ends result in differences in glaze during smoothing following the dyeing; the end rolled inside the roll of goods has a higher glaze.

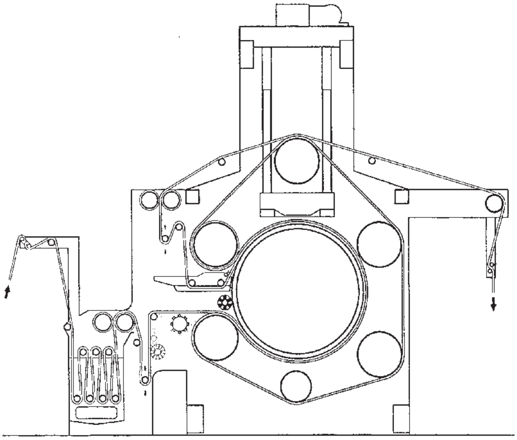

Fig: Continuous fixation machine “Multiset” for wet finishing of wool piece goods (Sperotto Rimar).

Wet fire extinguisher → Water fire extinguisher

Wet fixation process A special fixation process used for prints in which the dye is applied without or with only a proportion of the fixing chemicals, and in which fixation follows without intermediate steaming and in a bath containing no, or only a proportion of, the fixing chemicals. For example: for reactive dyes, a caustic shock process; for vat leuco ester dyes, a nitrite process.

Wet impregnation,

I. → Impregnation.

II. → Water-impermeable finishes.

Wet lamination Instead of using foil to stick together the separate layers (dry lamination), an adhesive is used which is applied to both sides of the middle layer (e.g. by spraying) of the lamination package before it enters the two-bowl padder (see Fig.). Once the adhesive has been heat hardened, the laminate is batched.

Wet modulus Describes the force in cN/dtex which is theoretically required in order to stretch a fibre in a wet state by 100%. The force measured is the force which is required to stretch the fibre in a wet state by 5%, and this figure is then multiplied by a factor of twenty. A high wet modulus serves as a criterion of dimensional stability. → Modal fibres.

Wet-on-dry finishing The application of finishing liquor to dry goods.

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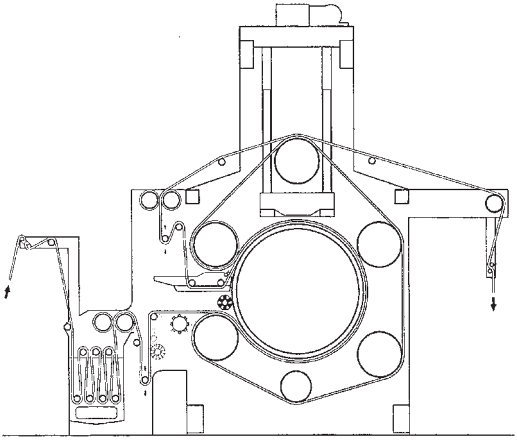

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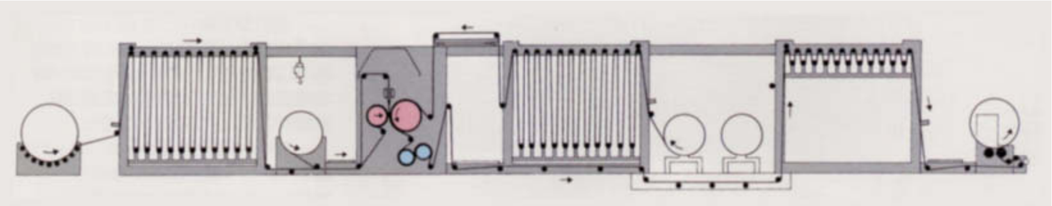


Fig.: Wet lamination plant (Stork).

Wet-on-wet dyeing process In the course of the application of different ingredients in the dyeing process (e.g. reactive dye and alkali, or etching base and naphthanilide) in continuous production each of a series of passes through the padder can involve application onto the wet goods emerging from the preceding pass. As a result, wet goods enter the liquor, which should ideally be additive (for example, 70% moisture content plus a newly acquired 20% moisture content totals 90% wet-on-wet moisture content). The advantages of this dyeing process are a saving in drying energy and a high rate of passage of steam, thus providing a significant cost reduction and making the process particularly suitable for dyeing voluminous textiles such as terry and cord fabrics (see Fig.).

Example: The dry, absorbent terry material (1) is prepared with hot naphthanilide solution on the first padder (2). The preparation cools during the ventilated stage (3). Developing with a diazo solution follows wet-on-wet on the second padder (4). A ventilated stage (5) guarantees complete disengagement. The dyeing is post-treated by passing through several rope washing machines (6) before the terry fabric is opened, de-watered and dried. Under this process it is also possible to work by batch rotating and dwelling the goods following preparation.

The winch dyeing machine / padder process is suited for dyeing tubular knitted goods. The tricot tube is prepared with a highly substantive naphthanilide using the exhaustion process on a jet (or a winch flow or winch dyeing machine). The pieces, stitched together and prepared, and with the tube having been expanded to a balloon by the injection of compressed air, are squeezed on a de-watering padder. Finally, the goods are developed on a second padder using the diazo solution and then laid in a box cart. To achieve complete disengagement the dyeing is allowed to dwell for 15–30 minutes, before being soaped and finished in the usual way on the winch dyeing machine.

Wet-on-wet impregnation The wet-on-wet technique for coating is greatly favoured in some areas of continuous finishing. The reasons for this are to be found in the undeniable advantages such as saving on drying energy and thus costs, as well as the dispensing with a drying pass, a reduction in textile handling requirements and an increase in drying capacity. A disadvantage is seen in the greater complexity arising from the higher demands placed on operating personnel qualifications and on the general level of knowledge concerning recipe and process know-how which must be brought into play. The problem of entrapped air (as in dry-on-wet impregnation = wetting) does not arise here, but instead there are other problems.

In wet-on-wet impregnation without pre-drying there are in theory two possible mechanisms for effecting a constant take-up of chemicals or dye: either a complete fluid exchange or else addition impregnation. In the first case the impregnation liquor is constantly diluted, and the desired concentration in the padding trough must be maintained by adding more strongly concentrated liquor. If wet goods pass through a colour trough, approx. 60% of the liquor will be exchanged. If, instead, a horizontal two-bowl padder is used, liquor exchange is reduced to approx. 10%. Suitable measuring equipment must be deployed in order to ensure an even uptake of chemicals. In the case of “addition impregnation” the goods are squeezed as powerfully as possible (requiring a high performance squeezer) and

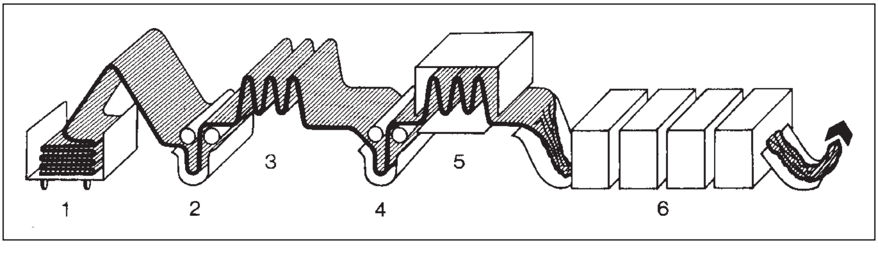


Fig.: Wet-on-wet dyeing process.

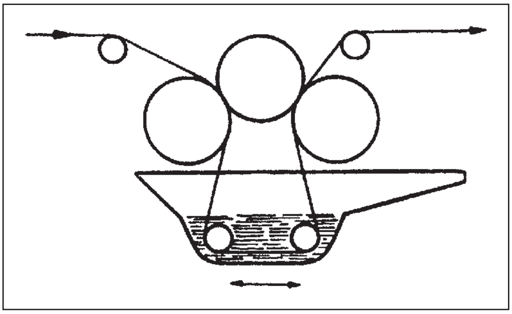


Fig. 1: Wet-on-wet impregnation according to the classical addition pick-up principle.

then impregnated on a padder with the shortest possible immersion path (only possible on a horizontal two-bowl padder) and with a higher level of fluid uptake (Fig. 1). Dilution of the liquor in this case need not be taken into account. In practice this process demands particularly exact monitoring. New principles in addition impregnation were established by the Flexnip process (Fig. 2).

Evac, in the USA, has constructed a vacuum based application technique. During the passage through a padder of a fabric composed of 55% polyester and 45% cotton, a liquor take-up of 55% is achieved. A subsequent pass across a suction slot device reduces the liquor application to 37% while the liquor thus removed is re-circulated back to the padder. Application control is exercised through using two beta radiation sources, one upstream and one downstream of the treatment (as in the Triatex principle in minimum application coating). If the system is used for the reactive dyeing of cotton the reactive dye shows 15–20% more reactivity because excessive water is removed and less hydrolysis therefore takes place. In this case the sequence of distinctive operations is as follows:

1. dye application in padder with 70% liquor application
2. reduction to 50% liquor application by suction
3. wet-on-wet chemical application in second padder (NaOH, salt)
4. reduction to 50% liquor application by suction
5. steaming.

The OK intermediate drying unit from Krantz is also suitable for wet-on-wet liquor application. The wet goods are flamed directly with Osthoff burners, drying the goods to the same extent as that encountered in a normal stenter and thus making a new product application (e.g. using chemical nip padding) possible.

The Küsters Flexnip is used to pre-treat cotton goods with salt solution on a padder. Now wet-on-wet, the goods then descend into a wedge-shaped slot which narrows at the bottom and is closed by two laterally laid horizontal flexible tubes. The interior of the wedge is lined with a hydrophobically treated coated fabric. The content of the wedge varies between 1.8 and 9.5 litres depending on the type of dyeing. Steel wedges are so adjusted with respect to the width of the goods that the two selvedges of the piece almost touch the two side wedges. When the fabric is drawn through the liquor, which is topped up from above via about 35 semi-circular formed feed pipes, it passes through the lips at the bottom of the wedge and in effect aquaplanes on the liquor drawn with it. The result is a constant and relatively high liquor application of 120%. The change of dye liquor is carried out in such a way that the minimum amount of fabric remains undyed.

Continuous pre-treatment processes are often carried out wet-on-wet. Since all intermediate drying is omitted, the cellulose fibres spend the entire pre-treatment phase in a partial or completely swollen state,

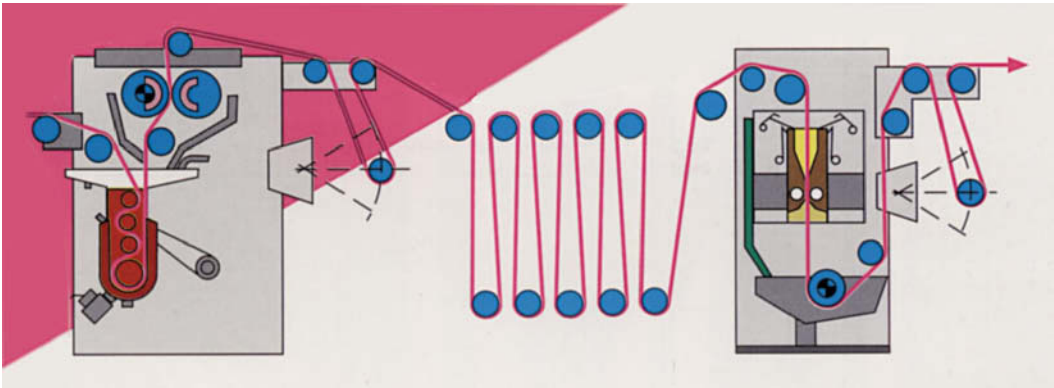


Fig. 2: Addition impregnation using Küsters Flexnip method: left, dry-on-wet Foulard impregnation; right, Flexnip wet-on-wet addition impregnation; e.g. equalized reactive dyeing using reactive dye application and subsequent alkali impregnation.

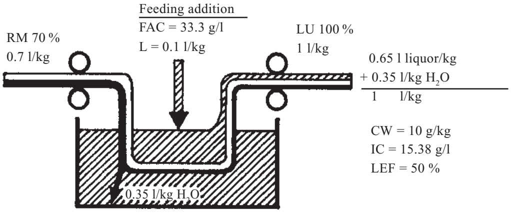


Fig. 3: Impregnating section in a continuous open-width pretreatment unit, wet-on-wet.
RM = residual moisture; FAC = feeding addition concentration; L = loss; LU = liquor up-take, CW = water content; IC = impregnating liquor concentration; LEF = liquor exchange factor.

which in turn has a positive influence on the final result. The processes which take place during wet-on-wet impregnation are relatively easily seen in open-width pre-treatment. Using the example of open-width impregnation in a roller vat, these are the factors which must be observed when calculating both impregnation recipe and the metering of top-up additions (Fig. 3).

The goods are largely de-watered by the entry squeezer in order to ensure the highest possible liquor application difference between entry and exit squeezer. The textile material is impregnated in the treatment liquor in the impregnation section and then evenly squeezed, whereby a liquor uptake of 90–100% is aimed for. The liquor uptake is determined not only by the difference but also by the liquor exchange. By liquor exchange is meant the mixing which takes place between the impregnation liquor and the water which is carried in by the goods themselves. False assumptions are often made regarding the exchange effect and its significance. The exchange effect depends not only on the length of time during which immersion occurs, but equally strongly on the structure of the fabric and the mechanical treatment to which the fabric is exposed in the impregnation section. The viscosity of the impregnation liquor also influences liquor exchange. Even while using a horizontal padder, in which the immersion path is only a few centimetres long, an exchange effect of 10–15% may be achieved; it is some 40–60% when using a simple V-trough, and approx. 70–90% in a roller vat. The exchange effect is distinctly smaller for a light fabric made from hard turned yarns, for example cotton voile, than for a normal cotton fabric. In consequence, such a light fabric contains less chemical in terms of grams per kilogram than does, for example, a cretonne article.

It is not the chemical concentration in the impregnation bath which is decisive for the scouring or bleaching effect, but rather the content of chemicals per kilogram of goods following the exit squeezer. It would therefore be ideal to determine the concentration of chemicals on the goods before the goods enter the reaction chamber. This is entirely possible for control purposes: the facility is stopped briefly, a fabric sample is taken and the chemical load of the goods is determined by titration. The assumption is made here that the chemical concentration on the goods downstream of the exit squeezer remains constant if the concentration in the impregnation section is kept constant. However, this is only true in practice if the liquor content before the exit squeezer and the liquor exchange do not vary at all.

The chemical concentration on the goods, which is decisive for the final effect, results in principle from the difference in liquor content between the entry and exit squeezers and from the exchange effect. Two further factors must also be mentioned which may influence the final effect. It is always assumed in practice that the chemicals used have no substantivity to the fibre, and that no chemical is consumed as a result of any chemical reaction in the liquor itself: however, each of these assumptions will at times be wrong. Account must also be taken of the fact that liquor contents are different from one fabric to another despite constant squeezer settings, which fact is of great importance when calculating the metering of chemical dosing by means of more highly concentrated addition. This causes major problems above all in commission finishing, whereby various fabrics are taken in for treatment. The liquor content at the entry squeezer together with the exchange effect are responsible for dilution of the impregnation liquor. This dilution must be compensated continuously by the addition of chemical in such a way as to ensure that the chemical concentration and the liquor level in the impregnation section remain as constant as is possible. A flawlessly working high performance squeezer, guaranteeing high liquor exchange and a sufficiently large difference in liquor contents, is important here. All these factors influencing the decisive chemical concentration in the fabric in grams per kilogram downstream of the exit squeezer may be listed as follows:

- liquor content,
- liquor exchange effect,
- immersion time in the impregnation liquor,
- mechanics within the impregnation liquor,
- fabric structure.

The above mentioned factors have an influence on the initial concentration in the impregnation section and on subsequent metering. If one takes account, on the one hand of all those factors which decide the chemical concentration on the goods in grams per kilogram, and on the other, of the problem of continuous monitoring, the relative value of all exact mathematical methods for computing the bath concentration and supplementary metering becomes clear.

The chemical concentration in the impregnation section can be kept constant in various ways. Best

Wet-on-wet impregnation

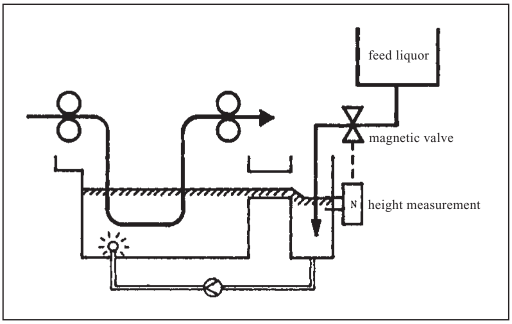


Fig. 4: Wet-on-wet impregnation of a component through level control.

known in practice is the metering of supplementary chemical from more concentrated additive tanks. Older rope and open width bleaching systems are usually equipped with only one tank from which all the chemicals (mixed at enhanced concentration) are added together to the impregnation bath. Such a tank is located in a raised position above the machinery, thus providing a positive head, and an intermediate feeding tank with level control may be included in order to ensure operation at constant pressure. The additional liquor is added to the impregnation section on the entry side, usually through a perforated distribution pipe or over an overflow trough extending across the entire width of the impregnation section. The addition rate is controlled by one of several different methods:

- a simple hand-operated valve
- a flow meter
- a metering pump (allowing the additive tank to be placed directly beside the machine)
- level control (Fig. 4).

Mixing of the additive with the impregnation solution is usually achieved thanks to the motion of the moving fabric itself. Bath circulation produces better results, and metered additives can be delivered into a separate mixing tank included in the liquor circulation system. A lint separator can also be built into such a circulation system. Single component metering often produces major problems with respect to liquor stability, since such highly concentrated baths impose the greatest demands on chemical stability. Newer facilities are therefore often equipped with several additive tanks, thus making possible two component or multiple component metering. For example:

1. Scouring: a) sodium hydroxide solution; b) surfactant, complexing agent or specific extraction agent.
2. Bleaching: a) hydrogen peroxide, organic stabilizers, surfactant; b) sodium hydroxide solution, water glass.

In order to compute the addition of supplements, the liquor contents FA_1 and FA_2 for the entry and exit squeezers are required. The measured or assumed liquor exchange effect must also be included. Calculating the supplement:

$$NF = \frac{(FA_1 - FA_2) + \frac{E}{100} \cdot FA_1}{FA_2}$$

NF = supplement factor
FA_1 = % liquor content at entry squeezer
FA_2 = % liquor content at exit squeezer
E = liquor exchange effect in %.

Liquor contents and liquor exchange effect differ from article to article. Since a specific supplementation cannot be mixed or adjusted to match liquor content in practice for every article, values are used in actual production which correspond to an average of all qualities of goods treated. For this reason a liquor exchange of 100% is often deliberately assumed in practice for an impregnation vat. Then, whether supplementation is controlled by means of a hand-operated valve, a flow meter or a metering pump, the quantity must be calculated which is to be added to the impregnation section per hour or per minute in order to maintain constant concentration. This depends on the one hand on the weight of goods per running metre and on the other hand on the machine speed. A simplification is presented by metering via a level controller, in other words via a float valve, since then both machine speed and running metre length can be discounted. The precondition remains, however, that neither the liquor contents nor the liquor exchange vary significantly. These simple metering systems prove effective so long as sufficiently experienced and reliable operators are available and also long lengths of the same article are pre-treated.

Demands on quality, and quite specifically on the uniformity of pre-treatment of large lengths of fabric, have risen enormously. Compared to J-box or pad-roll systems, the dwelling time in the reaction chambers of newer continuous open width pre-treatment systems are a mere 1–30 minutes, depending on the machine: short period steamer, U-box, conveyor or roller-bed steamer. Shorter reaction times require higher concentrations of chemicals in the impregnation section, in the supplementary additive tanks and on the goods. The baths are not only expensive, but also pose the risk of damage to fibres due to large upward jumps in concentration. The problem is particularly relevant since such expensive facilities are increasingly entrusted to less well trained auxiliary personnel. Through the use of solenoid valves for the addition of chemicals via level controllers, continuously variable metering pumps or a combination of the two, chemicals are added directly to the impregnation bath either undiluted or as concentrated stock solutions. This means that many of the well-known sources of error when working with concentrated supplementation baths no longer apply. In all three of the above systems metering is matched to the fabric weight of the article passing through the system, in other words in grams per kilogram dry weight of goods (Fig. 5). Calculation of the difference in liquor contents is no longer necessary. Metering is controlled by a pulsed timer (e.g. a signal device) which is usually mounted on the exit squeezer, so that the chemicals can be delivered at a rate matching the machine speed. The addition of chemicals rises with increasing machine speed and reduces with decreasing machine speed. If the machine stops, the addition of chemicals automatically stops, too. Water is added independently in order to maintain a constant liquor level.

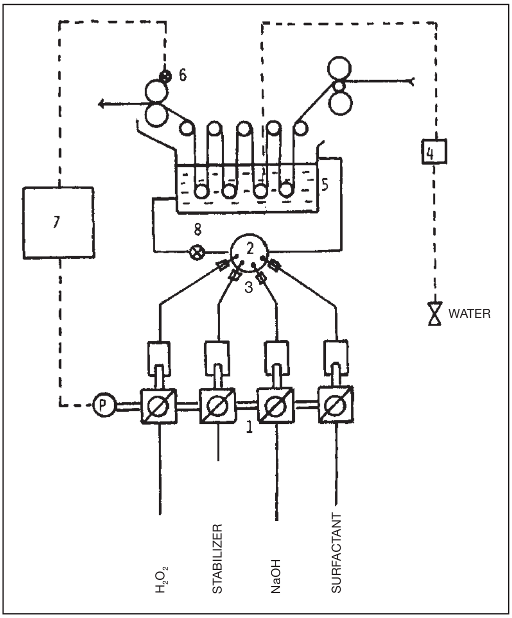


Fig. 5: Bran and Lübbe metering system for scouring and bleaching.
1 = metering pump; 2 = mixing tank; 3 = pressure holding valve; 4 = height regulator; 6 = trigger wheel; 7 = control box with potentiometer; 8 = circulating pump.

Chemicals are metered either pure or from concentrated stock solution. They should not be pumped directly into the impregnation section but instead into a mixing tank through which liquor from the impregnation section circulates constantly. Products are pumped individually into the mixing tank through separate pipes, which makes possible a manual control of the pump delivery settings. Depending on the total of pump heads available, the products can be metered either one at a time or else pre-mixed in any specific ratio, which latter method ensures reliable stability for such concentrated mixtures. In order to permit chemicals to be delivered to the impregnation section via pumps direct from the drums or containers in which they are delivered, they must be made available in low-viscosity trade form and must be easily miscible with water.

Among the various possible ways of metering chemicals in continuous wet-on-wet pre-treatment processes, doing so from more highly concentrated baths of supplement is the most widely used in practice. In such a procedure it is absolutely necessary to monitor the concentration in the impregnation bath continuously. This can be done either by titration or by making use of instrumentation and control technology. The actual values are measured and then compared with predefined target values, and should any deviation be discovered a suitable correction is initiated. Various kinds of instrumentation may be used for the monitoring of concentration, of which the following are examples:

- titration with special electrodes,
- conductivity measurement,
- redox potential measurement,
- thermometric measurement.

Continuous monitoring of the impregnation concentration is also to be recommended in the case of systems in which chemicals are metered in grams per kilogram of textile weight. Deviations are relatively small when working with the same goods over a long period of time, provided that the metering calculations and settings have been carried out exactly; however, should significantly different articles be processed, the liquor exchange changes and thus also the concentration in the impregnation bath (according to Mazenauer).

Wet-on-wet printing The overprinting of two print pastes where the first is not yet dry; a common process.

Wet opener (bleach cake opener, dye cake opener), used to separate the hard mass of fibres produced by squeezing.

Wet paraffining (paraffin lubrication, paraffining apparatus, paraffin wax treatment). A method of paraffining being industrially proved since the beginning of the 1970s and which, because of good results, was widely used as a preferred method for polyacrylonitrile, wool and polyacrylonitrile/viscose mixes (→ Waxing). Its decisive advantage is the uniformity of the coefficient of friction in a batch of yarn and its reproducibility in following batches. As a rule it is sufficient to test only a few packages for friction in order to obtain a result valid for the entire batch. Wet paraffined yarns with a coefficient of friction of less than 0.2 µ may (since the coefficient remains constant) be processed further without problems and, because of their usually uniform lubricant application, are suitable for further processing even at values greater than 0.2 µ. A restriction is that the results using cotton and cotton mixes, e.g. with polyester, are not equally satisfactory; despite good product applications, the coefficients of friction obtained using → Waxing with paraffin wax have not yet been achieved.

Application possibilities:

I. On the smoothing machine: especially for wool and synthetic fibre combed tops. Treatment in the final rinsing bath (antistatic additive in the penultimate rinsing bath) with 20–30 g/l of wet paraffining product and 5–10 g/l of a suitable softener (paying attention to tolerability, otherwise there is a blocking effect), generally at room temperature (if suitable wet paraffining product used) and optimum line speed. Take care with the quantity of product application and with choice of softener. Wet paraffining is recommended in the area of mixing (spray coating) or spinning preparation.

II. On the dyeing machine: results obtained are predominantly good. Wet paraffining application can be controlled to a wide degree, resulting in wet paraffining coatings which make subsequent waxing with paraffin wax in the spinning shop superfluous. Treatment carried out in either open or closed dyeing machines, most often of cross-wound packages (but all standard package types can be accommodated). Specifically: a long liquor of 1 : 18–40 is possible, set at pH 5–7 depending on desired process cycle, using 1.5–3% wet paraffining product in relation to weight of goods (appropriately diluted and added from the mixing or metering tank). Use a reversing liquor circulation with a 3–8 minute cycle, ideally commencing from outside. Control uptake temperature by raising temperature from 20–65°C. Process time is approx. 10–30 minutes, bath exhaustion approx. 70–90%. Possible fault: during the knitting of occasional batches of tricot yarn, colour rings and frequent periodic deviations in tension may occur; examination of the relevant yarn packages will reveal clear differences in the coefficient of friction between outer and inner layers of yarn, and these can be traced back to differing degrees of wet paraffining product coating (the so-called inner/outer effect) caused by poor process control. Origin of the fault: lack of or incorrect liquor circulation (due to incorrect bath conditions or pH), flocculation of the dispersed paraffin (due to high pressure and temperature). Sometimes inadequate lubrication in external dye package areas is also involved. Without exception, such packages have been dried in rapid driers or through driers where momentary overheating, with evaporation of some of the lubricant can arise. Conclusion: exercise optimum monitoring of the application process and in particular the drying process.

III. In a centrifuge by means of spraying onto the centrifuged material.

Wet processing A common term used in various senses, also as wet finishing:

I. Finishing using an aqueous solution (in contrast to → Dry finish employing organic solvent liquor).

II. Wet treatment processes in finishing technology such as wet decatizing, kier-boiling, bleaching, mercerising, carbonising, milling, dyeing, etc.

III. As a pre-treatment for all finishing processes which precede dyeing, in other words in addition to those under II. also, for example, singeing, thermofixation, raising, etc.

Wet sizing Conventional → Sizing in contrast to → Solvent sizing.

Wet spinning A spinning process used in the production of chemical fibres (especially viscose, cupro, polyvinyl alcohol) based on the principal of precipitation fibre formation or coagulation in an aqueous precipitation bath which takes place once the spinning solution has passed out of the spinning nozzle.

Wet steam → Steam containing water droplets, in contrast to → Dry steam.

Wet steamer (booster system tanner), particularly in the continuous dyeing or steaming of larger lengths of light toned material, especially for wet-on-wet processes in vat dyeing, or dye padding on an upstream padder. Reducing agent in the "booster" (the steamer subcomponent) is applied during the pass

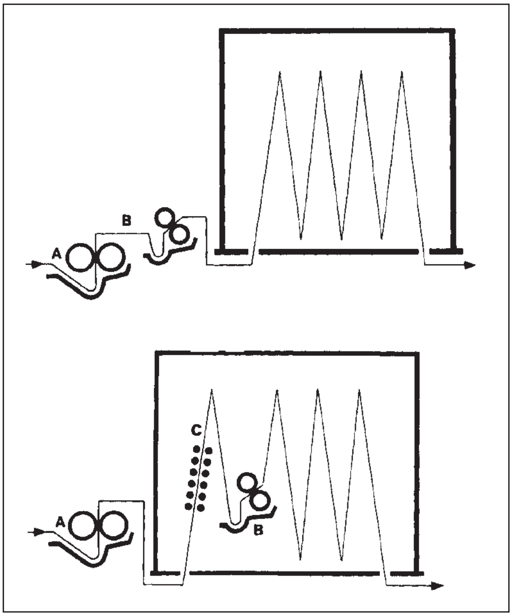


Fig.: Flow diagram showing the wet steam process with reactive dyes and sodium carbonate as the fixing alkali (two-bath process).
Variant 1: A = dye pad liquor; B = chemical pad liquor as wet-on-wet impregnation; Variant 2: A = dye pad liquor; B = chemical pad liquor ("booster"); C = infra-red zone.

through the steam (see Fig.). In this process, which is significantly cheaper than the usual pad steam facility, there is no high temperature flue required for intermediate drying. the best dye fixation is achieved using saturated steam or slightly superheated steam.

Wet strength Analogous to the way in which → Tensile strength in an air dry state is referred to as dry strength (Rt), wet strength (Rn) is determined in the wet state, as is usual in terms of relative wet strength as % of dry strength:

$$\frac{Rn}{Rt} \cdot 100\ (\%)$$

or as wet strength loss in %:

$$\frac{Rt - Rn}{Rt} \cdot 100\ (\%)$$

The material to be tested must be thoroughly wet (1 g wetting agent / litre distilled water, wetting time for cellulose and protein fibres 10 seconds, for acetate and synthetic fibres 2 minutes, for yarns, twists and fabrics 15 minutes). Recognition of relative wet strength more usually has a role with respect to man-made fibres, being as a rule higher than the dry value for cellulose natural fibres but 50–70% lower than the dry value for cellulose man-made fibres. This is determined by the spinning technology in manufacture and the associated extensive loosening of the amorphous regions, such that the inner fibre cohesion falls correspondingly due to swelling processes (sorption) under additional tensile load. On the other hand, a higher degree of crystallization, greater orientation and an increased proportion of longer chain lengths occurs in connection with higher wet strength, as can be seen in viscose high strength fibre at almost 90% and in synthetic fibres with wet strength values between 85–110%. From among the most important fibre materials, the synthetic fibres polyamide, polyester and propylene show high fibre strength, while acetate and triacetate show lower fibre strength. Among the natural fibres, flax, mulberry silk and cotton are the strongest, while wool is not so strong. The highest wet strength is shown by flax, polyester, polypropylene and polyamide, whereby only their relative order changes compared with their fibre strength; lower values are again shown by wool, acetate and triacetate. Only flax (at + 13%) and cotton (+ 5%) have a higher wet than dry strength. The other natural fibres and all man-made fibres have wet strength either the same as or lower than their dry strength. The wet strength falls significantly in comparison with the dry strength in the cases of viscose and cupro (– 40%), acetate and triacetate (– 35%) and wool (– 20%).

Wettability → Wetting agent test methods.

Wettability of differently pretreated fabrics This is dependent on residual fat content and tends to favour those goods which have been pretreated with solvent. For example, the sink test of a polyester-cotton fabric (wettability in seconds):

raw woven cloth	60 s
heat fixed woven cloth	60 s
heat fixed, water washed, bleached	50 s
de-sized, water washed, bleached	35 s
heat fixed, solvent cleaned, bleached	10 s
solvent cleaned, bleached	2 s

Wetting,

I. The tendency of a liquid to spread out across a surface. A → Wetting angle of zero corresponds to being fully spread out. The greater the wetting angle between solution and surface, the poorer the wetting. If we define wetting as a process whereby a solid/vapour interface is replaced by a solid/liquid interface, then wetting becomes the first phase in dispersion. The wetting of solid particles (e.g. pigments) can be considered as a computable combination of →: Adhesion; Immersion; Spreading capacity (see Fig.).

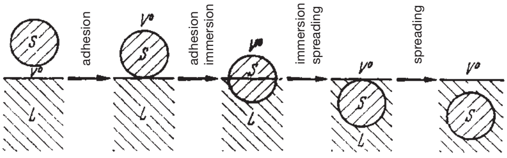


Fig.: Wetting steps (in diagram form): S = substrate; L = solution; V^0 = air.

II. The wetting of a solid body may be described in terms of the angle θ between it and a droplet of liquid, e.g. water, applied to its surface. The defined wetting tension j obtains along the liquid/gas/solid three phase profile as follows:

$$j = \gamma_{13} - \gamma_{23} = \gamma_{12} \cos \theta$$

γ_{13} = solid/air surface tension,
γ_{23} = solid/liquid surface tension,
γ_{12} = liquid/air surface tension,
θ = (static) wetting angle.

If a capillary tube of radius r is immersed into a liquid described by its viscosity η, its surface tension γ and its density ρ, the liquid will rise in the capillary tube as a function of time t. The amount of rise at time t (h_t) is calculated as a function of the variables r, η, γ, s and θ of the dynamic wetting angle.

A textile material may be seen as a large number of capillaries with differing → Wetting properties arranged in parallel and experiencing an exchange of liquid one with another. The individual capillaries are of differing radii, since it is of fundamental importance that account is taken of capillaries formed by fibres within the yarn and of capillaries formed by yarns within the fabric. The wetting process during padding may be considered as a short period wetting process, for which the term “short period” should be understood with respect to the achievement of balanced states. For a limiting case the Washburn relationship approximates (h = elevation) :

$$h_t^2 \approx \frac{\gamma_{12}}{2\eta} \cdot \cos\theta \cdot t \cdot r$$

In the above equation r describes the textile fabric in terms of the average radius of the capillary, $\frac{\gamma_{12}}{2\eta}$ is given by the wetting liquid, and cos θ characterises the fibre/liquid interchange. In practical circumstances the velocity of impinging liquid must also be allowed for. Wetting behaviour can also be influenced by the addition of a wetting agent.

Wetting agent When a textile enters an aqueous finishing liquor, the rapid wetting of the fibre bundles with water is hindered by both a hydrophobic fibre surface and by entrapped pockets of air. As mediators between mutually exclusive phases (liquid and gas, or solid and liquid), wetting agents are chemically constructed such that they possess both hydrophobic and hydrophilic structures within one and the same molecule. By the fact that it occupies evenly the surface which is to be wetted (which in itself is hydrophobic with respect to water) by permitting its hydrophobic parts to be adsorbed onto the surface while exposing its hydrophilic parts to the aqueous phase, the wetting agent reduces the surface tension of the fibre bundle compared with water. As a result the textile becomes wet. At the same time the trapped air escapes because the affinity of the water to the fibre surface (covered with molecules of wetting agent) is now greater than the affinity of the air to the interstitial spaces within the fibre bundle. The natural buoyancy of air bubbles in water assists the air to escape. In order that a wetting agent should diffuse with the wetting liquor face as it flows through the fibre bundle, thus accelerating the wetting process, the wetting agent should be constructed from surfactant molecules which are as spherical and as small as possible. This is achieved by branching of the hydrophobic tail, though this must not result in any reduction of the agents biodegradability. Wetting agents used in acidic or alkaline liquors must be either acid or alkali resistant, again without any reduction in biodegradability.

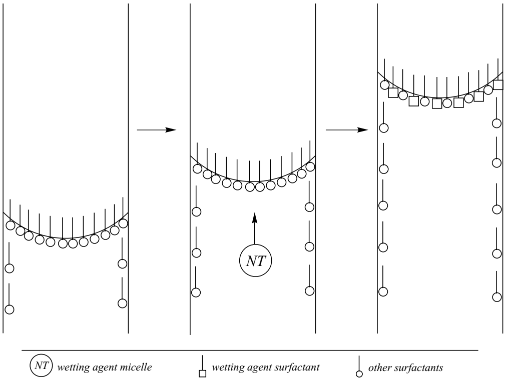


Fig. 1: “caterpillar track” model of the wetting of a capillary.

It is possible to reduce the stability of a micelle of wetting agent as it diffuses at the wetting face by adding a co-surfactant (e.g. tributyl citrate). The advance of the wetting face during the wetting of a strip of fabric may be imagined as in the “caterpillar track” model (Dussan, Davis 1974) (Fig. 1). The advance of the surfactant loaded wetting face slows because, as it rolls forward, surfactant molecules are left behind attached

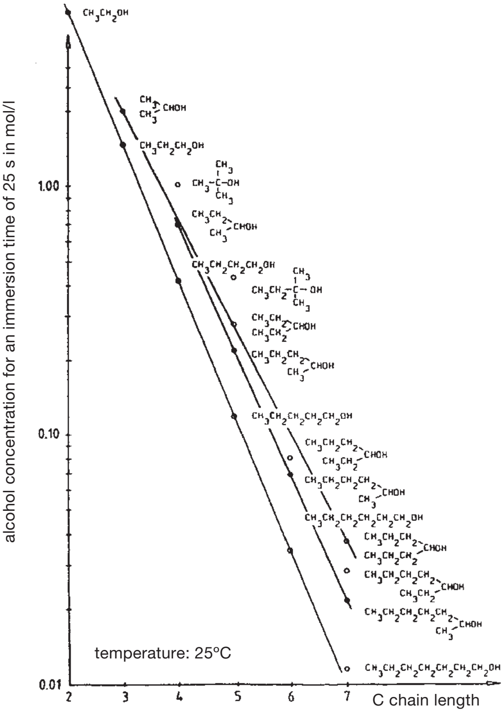


Fig. 2: Increase in the wetting agent effect depending on carbon chain length increase (according to Traber).

to adhesion points on, for example, the wall of the capillary. In this way the surfactant molecules are depleted at the wetting face unless more wetting agent is rapidly delivered by wetting agent micelles. A well-known example of this is provided by the isooctyl ester of succinic acid and the secondary alkyl sulphonate.

Homologous series of linear anionic surfactants show a maximum wetting effect for certain lengths of their hydrophobic tails. Traber shows that alcohols of increasing chain length and with increasing degrees of branching wet more effectively (Fig. 2). However, alkyl sulphates with longer hydrophobic tails are also more effective wetting agents (Fig. 3). Such a maximum is dependent upon external factors. With increasing temperature it migrates towards longer carbon chains if the salt content of the liquor is raised. Other rules apply to polyglycol ether surfactants with respect to length of the hydrophilic head. The purity of surfactants in general, and in particular the narrow distribution of isomers in polyglycol ether surfactants, has a favourable effect on wetting. The most satisfactory effectiveness is found at concentrations near that critical for micelle formation, and specifically for non-ionogenic polyglycol ether surfactants at temperatures lying closely below the cloud point.

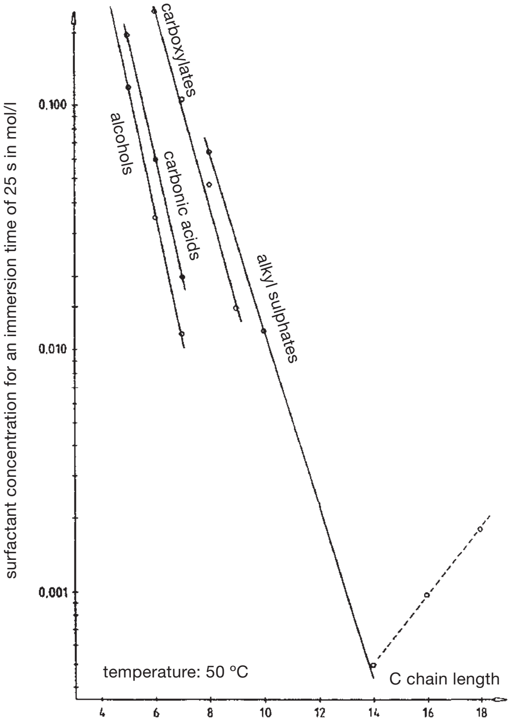


Fig. 3: Connection between wetting effect and alkyl chain length (according to Traber).

Wetting agent action The influence of surfactant substances on the wetting behaviour of cotton fabric is shown in Fig. 1:

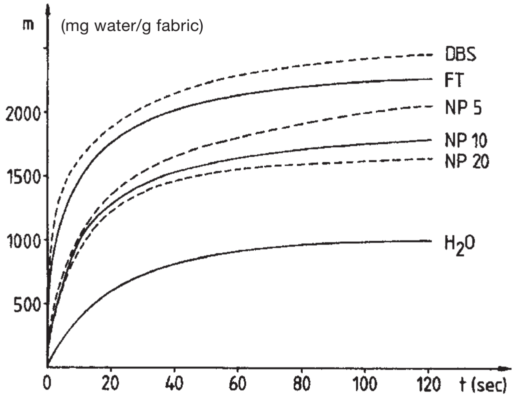


Fig. 1: Weight-time diagram of a cotton fabric upon wetting with various surfactants (see text).

It is clear that it is possible to differentiate between different surfactants. Water uptake with wetting by anionically active dodecylbenzene sulphonic acidic sodium (DBS) and fluorinated surfactant (FT) rises more rapidly than by non-ionogenic nonylphenolethoxylate (NP). In the case of the latter, on the other hand, those with a lower degree of ethoxylation favour wetting more strongly than those with a higher degree. As a result it is possible to use this method of measurement

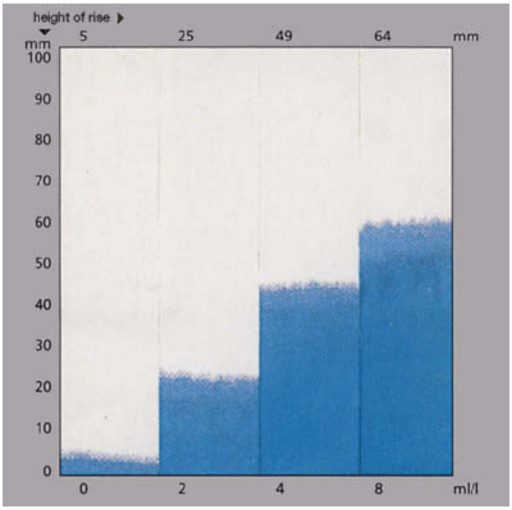


Fig. 2: Varying heights of rise in the horizontal absorbency test for cotton fabrics with various concentrations of wetting agent (Sandoz's Sandopan BFN liquid).

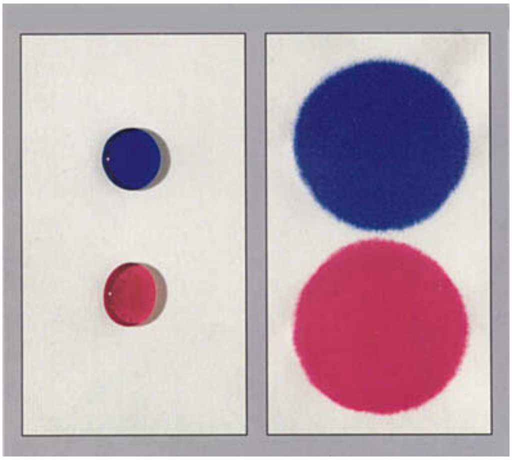


Fig. 3: Demonstration of the wetting of raw cotton with wetting agents (right) and without (left).

with a specified fabric to undertake a classification of wetting agents. Above all during the pretreatment of cotton, wetting agents have a strong influence on the effect, for example in bleaching, with respect to the absorbency of the goods. Thus, for example, certain wetting agents produce higher absorbency when applied in higher concentration (Fig. 2). Raw cotton can be wetted rapidly with red or blue dyed water when a wetting agent is used (Fig. 3).

Wetting agents for dyeing and dyeing oils These increase the wetting capacity of textiles to be dyed. As a rule, a dyeing oil gives the dyed goods an additional softening effect. Product basis: surface-active compounds or preparations based on, e.g. alkyl sulphates, alkyl sulphonates, fatty acid condensation products and sulphonated oils.

Wetting agent test methods,

I. Physical method using measurement of:

a) surface tension (simple to conduct), such as elevation method, bubble pressure method, annular separation method (DIN 53914/1968, → Surface tension).

b) → Wetting angle. Demanding and only of limited validity.

II. Measurements of the wetted textile surface:

a) droplet method: a drop is allowed to fall onto a stretched sample of fabric from a micro-burette, then the patch of liquid is measured.

b) elevation method: strips of fabric, weighted at the bottom, are dipped vertically into the wetting fluid and the height of the wet portion of fabric above the fluid surface is measured after a specified time.

III. Sink (immersion) method, simple and quick:

a) DIN 53 901 or the Draves-Clarkson test (AATCC standard test method 17).

b) hydrometer method: the increase in apparent specific gravity of the fibre is measured while the wetting liquor penetrates the fibre.

IV. Diverse: the wetting process itself is not measured, but rather the results of it, for example swelling, dimensional change, electrical conductance, etc.

(→ Wetting, measurement of).

Wetting angle The angle of contact between a drop of liquid resting in contact with an even surface, the drop of liquid being in a stable state and lens shaped, and the tangent to that surface; or, in a transmission sense, the relationship of a fibre to dirt (wetting angle 90° and often almost 180°). Hydrophilic materials display a wetting angle of 0–90°, and are capable of being wetted by water. Materials which tend to be water repellent display a wetting angle greater than 90° and are thus hydrophobic (e.g. paraffin, ceresin wax with a wetting angle of 105–110°). It is the main function of capillary active agents to reduce wetting angles approaching 90° and above, since pure water cannot attach itself to any fibre displaying such an angle. →: Surface tension; Wetting process.

Wetting angle measurement Measurement based on observation at short time intervals of the physical → Wetting angle between a drop of liquid and a textile substrate. It makes use of a measuring arrangement for determining wettability in which the physical wetting angle can be recorded repeatedly at short intervals of time.

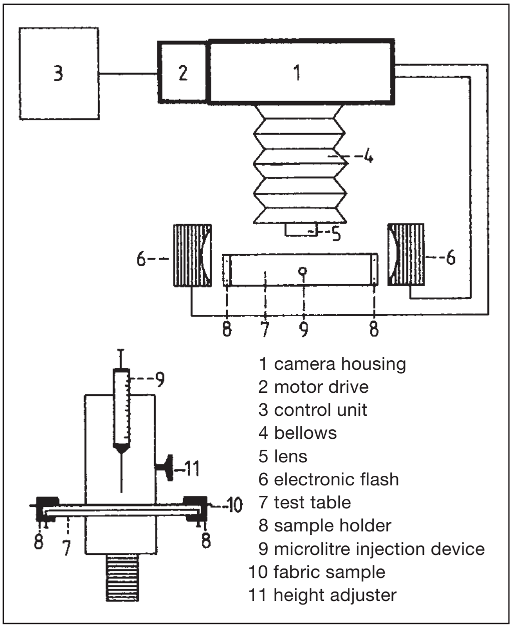


Fig. 1: Measuring apparatus for photographic wetting angle calculation. View of the measuring apparatus and front view of the test table.

The camera is fitted with a motorised drive and optical bellows (Fig. 1). Its magnifying object lens makes a magnification of x12 possible. The photograph sequence timing is governed by a control unit. The test table, on which the fabric to be wetted can be secured using two clamps, is illuminated by means of automatic flash units. A drop of the wetting fluid is applied using a micro-litre syringe, and the camera is started at the same time. From the prints of the resulting photographs the change of the wetting angle over time may be determined.

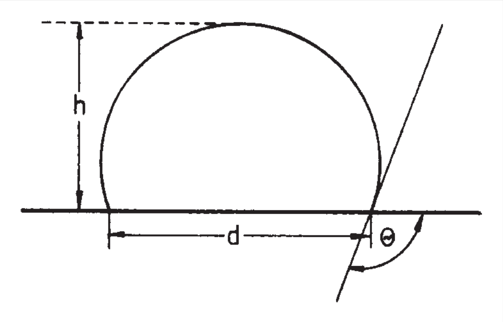


Fig. 2: Diagram of a drop on a solid surface for calculation of the wetting angle.

The wetting angle is calculated using the principle of the spherical segment method (Fig. 2) from the height of the droplet h and the line of contact between droplet and fabric, the droplet base d, according to the equation:

$$\Theta (t) = 2 \arctan \frac{2 h (t)}{d (t)}$$

As can be seen from Young's equation

$$j = \gamma_s - \gamma_{sl} = \gamma_l \cos \theta$$

the quantity which determines the → Wetting process is not the surface tension of the wetting liquid but rather its wetting tension $j = (\gamma_s - \gamma_{sl})$ with respect to a specific material. In order to achieve the greatest possible wetting effect, therefore, the wetting tension must be of the highest possible value. This in itself is achieved through a lowering of the surface tension at the solid/liquid interface (γ_{sl}). In other words, the wetting agent should not reduce the surface tension of the liquid (γ_l) but rather that of the solid / liquid interface (γ_{sl}). If a fabric is wetted with a solution of surfactant, the lowering of the surface tension at the solid/liquid interface (γ_{sl}) depends upon the adsorption of the wetting agent at the liquid/air interface and the solid/liquid interface. In the case of a fabric which has been treated with a wetting agent, surfactant molecules are already adsorbed onto the surface of its fibres (Fig. 3). This means that when wetting with water it is the solid (surfactant loaded)/liquid interface which is decisive in reducing surface tension.

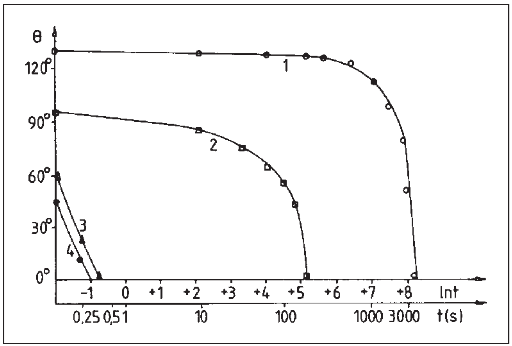


Fig. 3: Effect of wetting pretreatment and of a surface-active liquid on the time rate of change of the wetting angle.
1 = cotton/water; 2 = cotton/0.1%DBS; 3 = wetting pretreated cotton/water; 4 = wetting pretreated cotton/ 0.1%DBS.

Both a solution of surfactant and also water spread out spontaneously in contact with a cotton fabric which has been treated with a wetting agent (curves 3 and 4). The spreading time of water of 0.5 seconds (curve 3) indicates clearly that pretreatment with a wetting agent has a much grater effect on wetting speed as does the addition of a surfactant to the wetting liquid. Combining both methods (curve 4) has only a slight further effect on wetting speed.

Wetting angle progressive/retrogressive The angle of contact measured perpendicular to the surface of the liquid phase is progressive during immersion and retrogressive during withdrawal. Both wetting angles are different for a solid surface. The difference results from angle measurements made of the velocity of immersion and withdrawal; it can be made more precisely using test methods.

Wetting energy, free The work done (i.e. the energy lost) when a surface is isothermically and reversibly wetted without a simultaneous change in its free surface area can be observed in the loss of free energy (wetting energy) from the system and is expressed either in ergs or joules.

Wetting hysteresis The work required in order to immerse an element of a solid physical surface slowly and at constant velocity into a liquid phase differs from the comparable work required in order to withdraw the same element from the liquid phase. The difference between these two quantities, related to surface area, corresponds to a → Hysteresis which is known here as the wetting hysteresis. It is expressed in either ergs or joules and is numerically the same as the difference between the progressive and the retrogressive → Wetting tension.

Wetting, measurement of Surface energy, interface energy and the work done in adhesion have a central role to play in the concept of thermodynamic adhesion. For the release of the adhesive joint of two substances 1 and 2 it is true that:

$$W_A = \gamma_1 + \gamma_2 - \gamma_{1/2}$$

W_A = the thermodynamic work done in adhesion,
γ_1, γ_2 = the free surface energy of substances 1 and 2,
$\gamma_{1/2}$ = the interface tension.

If it is assumed that the intermolecular forces are mutually independent, then both the work done in adhesion and the surface energy may be divided into separate components:

$$W_A = W_A^d + W_A^{sb} + W_A^p + \dots$$

d = dispersion interaction,
sb = acid-base interaction,
p = polar interaction.

If applying the geometric means for the adhesive work done in cohesion for substances 1 and 2, it is true for the dispersion component that:

$$W_A^d = 2(\gamma_1 \gamma_2)^{1/2}$$

If the polar component is disregarded, then for the acid base interaction it is true that:

$$W_A^{sb} = \gamma_1 + \gamma_2 - \gamma_{1/2} - 2(\gamma_1 \gamma_2)^{1/2}$$

The dispersion and the acid-base components of the work done in adhesion may be determined for fibre bundles and for filling material by measuring the wetting angle. Measurement for fibre bundles is done using the elevation method (see Fig.). If laminar flow is present within the pore spaces and if the force due to gravity is disregarded, the following relationship between Δm and time t is true:

$$(\Delta m)^2 = F(c\,\rho^2 \gamma_L \cos\theta; 2\eta)\, t$$

c = the geometry/packing density,
ρ = the density of the measuring liquid,
η = the viscosity of the measuring liquid,
θ = the wetting angle,
γ_L = the surface tension of the measuring liquid.

With

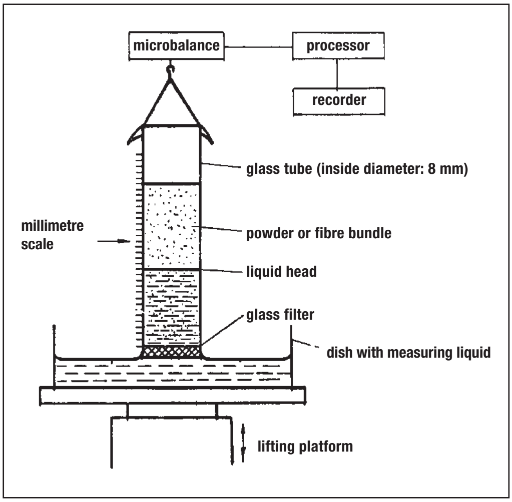


Fig.: Measuring apparatus for wetting measurement by determining wetting angle by capillary lift height (according to Jacobasch).

$$\gamma_L \cos\theta = \gamma_S - \gamma_{SL} \text{ and}$$

$$W_A = \gamma_S + \gamma_L - \gamma_{SL}$$

the work done by adhesion is

$$W_A = \gamma_L (1 + \cos\theta).$$

If non-polar wetting liquids are used only dispersion interchanges occur. As a result the dispersion component of surface energy becomes

$$\gamma_L^d (1 + \cos\theta) = 2(\gamma_S^d \gamma_L^d)^{1/2}.$$

If, on the other hand, test liquids are used which permit specific interchanges, then it is true that

$$W_A^{sb} = \gamma_L (1 + \cos\theta) - 2(\gamma_S^d \gamma_L^d)^{1/2}.$$

From this it is possible to determine both the work done in dispersion and in adhesion (according to Jacobasch).

Wetting power (wetting ability, wetting strength) The degree of capability for → Wetting based on the → Capillary activity of wetting agents. Wetting power is tested according to DIN 53 901 (see Fig.).

Wetting process Water remains as droplets on the surface of hydrophobic fabric. If the wetting of fibres is considered statistically and if one defines, for example, cotton as a solid matrix containing pores, then the total volume of the structure is given as $V = V_M + V_P$ (where V_M = the volume of the matrix, V_P = the volume of the pores). If this total volume is then occupied by a vol-

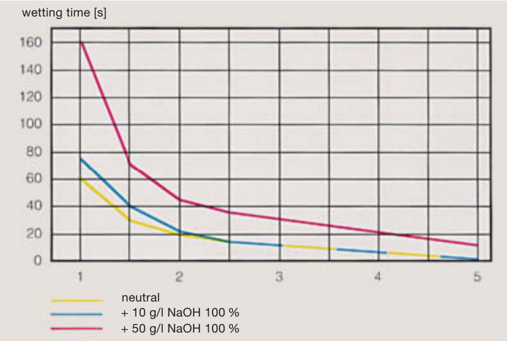


Fig.: Wetting agent (Kieralon CD, BASF) dependency of the content's wetting power (abscissa: g/l) tested according to DIN 53 901 in alkaline liquor.

ume of water V_W then, depending on the volume of water applied, the following two limiting conditions must be considered:

condition 1 between $V_W > V_P$ and $V_W = V_P$
and
condition 2 between $V_W = V_P$ and $V_W < V_P$

Condition 1 describes the state in which the fibre is adequately supplied with water, in other words a uniform flooding of the substrate with finishing liquor is guaranteed. This is the condition under which a traditional continuous product coating technique works, e.g. a padder. Condition 2 relates to an under-provision of the fibre with water, in other words all finishing processes are able to operate which do not require a uniform flooding of the substrate in order to achieve their desired finishes – processes such as softening, softeners, resin finishing and the like. In either case, however, a penetration of the liquor into the fibre mass is necessary.

In the textile area, the wetting process is characterised by the penetration of the liquor into the capillary system of the textile item with an accompanying expulsion of air from the interstitial spaces in the textile. The wetting process is nothing other than the replacement of a solid/gaseous interface with a developing solid/liquid interface. When a textile is being wetted, air bubbles within its capillaries escape (Fig. 1) if the contact angle θ_1 decreases on that side of the bubble on which the meniscus becomes larger due to the advancing movement of the bubble in this direction (Fig. 2), i.e. $\theta_1 > \theta_2$ if there is movement.

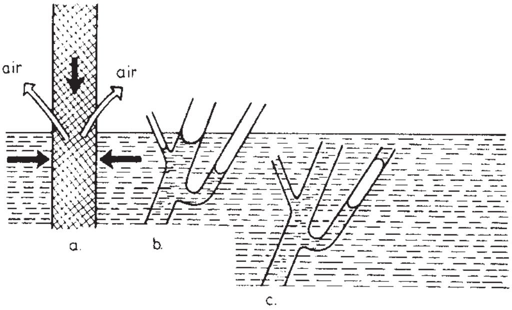


Fig. 1: Ventilation (air) on entry of a dry fabric (vertical arrow) into a liquid which penetrates into the fabric (penetration illustrated by horizontal arrows). In the fabric capillaries (b) the air softens or stays (bad wetting: c).

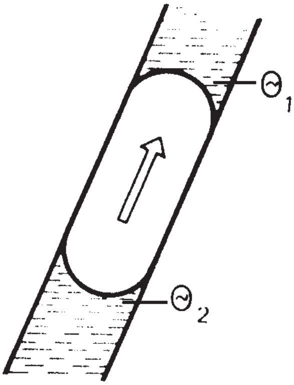


Fig. 2: Air bubble in a textil material capillary advancing on wetting.

If the length of such a capillary is taken as l and the rate of flow of a liquid in this capillary during wetting is taken as w (Fig. 3), then the difference in pressure between the two ends of the capillary is given by Poisseuille's equation and defines the direction (towards decreasing pressure) in which a liquid/air column of length x, measured between the upper and lower menisci, will move.

$$\frac{8\,\eta_l\,x}{r_m^2}\cdot w = \frac{2\,\gamma_{lv}\cdot\cos\theta}{r_m} + H\cdot\rho_l$$

η_l = viscosity of the solution,
ρ_l = density of the solution,
γ_{lv} = surface tension (air/solution),
r_m = capillary diameter.

The left side of the equation describes the influence of the viscosity of the solution. The right side describes the pressure differential arising from the capillary forces: its value becomes negative if the contact angle θ exceeds 90°, in which case wetting is avoided under certain circumstances.

A laminar flow develops as liquor travels through the capillary. When working with higher temperatures, which is done to reduce water viscosity, this laminar flow can result in large temperature differences (Fig. 4).

Wetting process

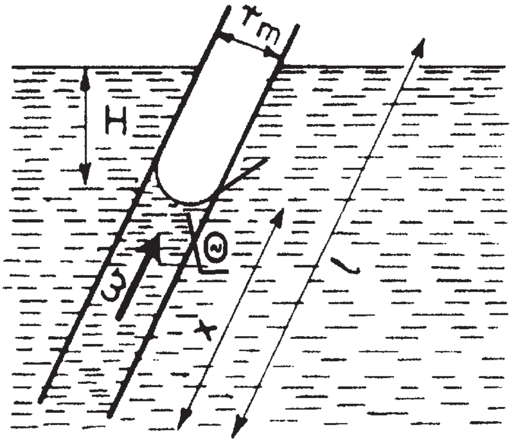


Fig. 3: Parameters which determine the pressures in a capillary upon wetting.
H = height of the remaining liquid columns (hydrostatic pressure); r_m = average diameter of the capillaries.

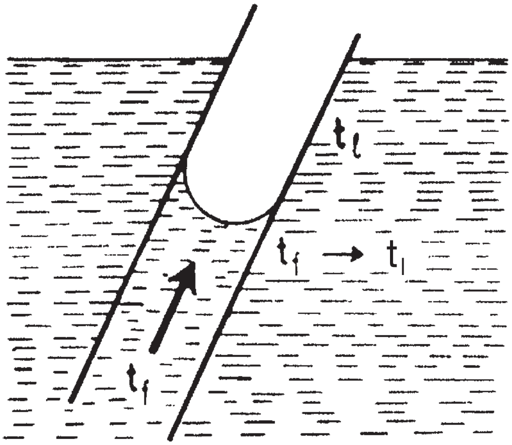


Fig. 4: Temperature differences when a solution at temperature t_l flows in a capillary (at temperature t_f).

When a fibre/solid body surface is wetted with a droplet of liquid (Fig. 5), the rules of Young's equation apply. The wetting tension j applies at the three phase liquid/gas/solid boundary:

$$j = \gamma_S - \gamma_{SL} = \gamma_L \cdot \cos\theta$$

γ_S = surface tension of solid,
γ_{SL} = surface tension between solid and liquid,
γ_L = surface tension of liquid,
θ = wetting angle.

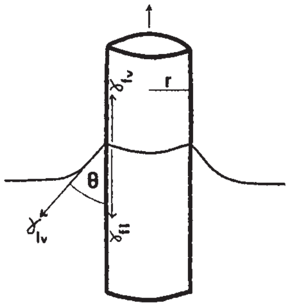


Fig. 5: Diagram of the wetting of solid backings.

The smaller the wetting angle the better the resultant wetting. In the case of immersion wetting, that is, the dipping of a solid body into a liquid, the solid body surface is replaced by the formation of a new solid/liquid phase boundary. The liquid surface remains unchanged, and the energy balance results from the wetting tension j.

$$j = \gamma_S - \gamma_{SL}$$

The same change in energy takes place when a liquid moves within a capillary. The higher the wetting tension the better the resultant wetting. The wetting of a textile material with water may be seen as the opposite of the rolling up mechanism which applies to an oil droplet on the surface of a textile during washing. If a wetting agent is added to an aqueous solution it becomes adsorbed onto the interface and gives rise to a reduction in the surface tension of the liquid γ_L and in the liquid/solid surface tension γ_{SL}, while the surface tension of the solid γ_S remains unchanged. This reduction in γ_L and γ_{SL} promotes wetting: cos θ thus becomes larger in Young's equation, and the wetting angle itself becomes smaller.

Since wetting tension is the determining characteristic in immersion wetting, which is the wetting process most often used in the textile industry, it must acquire values as high as possible, which in turn, are achieved by reducing γ_{SL}. A reduction in the surface tension of the liquid γ_L favours above all spreading out and the displacement of air trapped within the textile. The wetting process of a single fibre (Fig. 5) can be followed in theory by measurement of the wetting angle. However, there are two limitations on the application of the method of measuring wetting angle: it requires a smooth solid surface and it delivers only equilibrium values. In practice a fibre is a structure having a geometrically poorly defined surface; equilibrium values for wetting tension are indeed of interest here, but the dynamics of the wetting process is of far greater importance in textile finishing.

What is needed is a method of measurement from which those quantities influencing the wetting process may be derived. The method which has proved itself with respect to textiles is the so-called elevation method. Basically, this method consists in lowering the lower end of a vertically suspended fabric into the wetting fluid and then measuring the progress of the fluid drawn up by the textile against time. The process may be considered as that of the movement of the fluid within a capillary. Given the Washburn relationship

$$h_t^2 = \gamma_L \cdot \cos\theta \cdot r \cdot t$$

h_t = elevation
γ_L = surface tension (influence of the liquid)
θ = wetting angle (influence of the liquid/substrate interchange)
r = material constant (influence of the textile)
t = rise time

the viscosity η of the liquor (dependent on the temperature) may be entered, which is then given as

$$k = \frac{r \cdot \gamma_L \cdot \cos\theta}{2\eta}$$

While the quantities γ_L and η of the wetting fluid are measured independently, the material constant r only occurs together with the equally unknown quantity cos θ. The quantity r is determined as follows. The measurement is carried out using liquids which spread out on the relevant fibre material, i.e. which do not show a finite wetting angle. This means that $\cos\theta = 1$ and thus r may be determined. Once the value of r has been substituted in the equation, liquids can be measured on the material which form a wetting angle of between 0° and 90°. Cos θ may now be calculated and thus also (using Young's equation) the wetting tension.

The rate of wetting k rises in keeping with the speed at which the surface tension approaches the equilibrium value. At an advancing wetting face, the surface tension is a direct consequence of the adsorption of molecular dissolved surfactant on the newly formed surface and interface. The faster the diffusion (characterised by the diffusion coefficient of the surfactant) to and with the wetting face by constant interfacial activity, the greater the rate of wetting. This requirement is taken into account for the wetting agent involved (by means of a shape for the substance promoting wetting which approaches the spherical) by the fact that wetting agents, in contrast to other surfactants, are heavily branched and show a lesser tendency to form micelles.

Wetting promoters These are textile additives not possessing surface activity but which nevertheless make wetting possible without accompanying generation of foam. They are absorbed by fibres and then impart the wetting process. They are known as special "air removing" wetting agents, in particular phosphoric acid trialkyl ester. Since they are barely soluble in water they are applied as an emulsion or from the vapour phase. In the latter case a metered quantity is condensed onto the goods (cotton, wool) to enable uniform wetting of the goods when subsequently immersed in water. There are many organic compounds which are effective when so used, provided that they have a boiling point favourable to the condensation process.

Wetting properties This is the ability of a textile surface to be wetted. A fibre may be well wetted by water if there are chemical groups on its surface which can take up water, for example because of hydrogen bridges, dipolar forces or ionic forces. Groups such as $-COO^{\theta}$ and $-SO_3^{\theta}$ are strongly hydrophilic; OH, OR, NH_2 and C=O groups are weakly hydrophilic. As a rule hygroscopic fibres are at the same time hydrophilic; wool is an exception, having a hydrophobic surface. Wetting is of particular importance in finishing, especially in minimum application techniques as well as in → Clothing physiology (→ Rendering hydrophilic).

The wetting properties of a fibre derive from the effect of so-called surface tension, where on the one hand a pulling force affects water molecules (a sphere of wa-

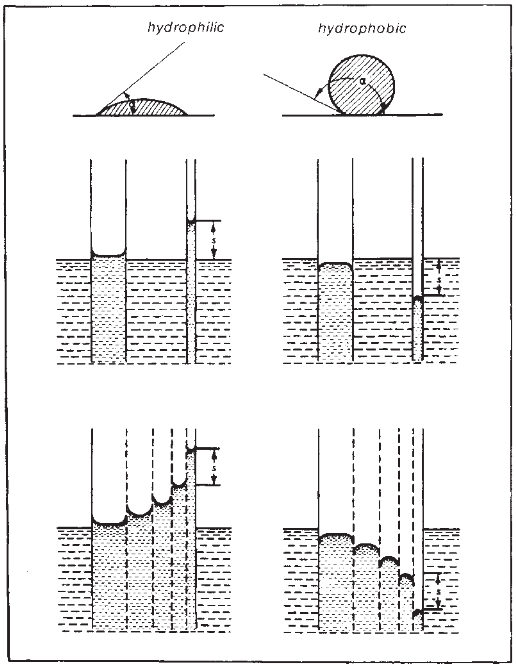


Fig.: Diagram of the effect of wetting properties on moisture transmission. Top: individual droplets on a level surface with the various wetting angles or contact angles. Middle: Separated individual capillaries made of varying material and with varying diameters. Bottom: system of capillaries connected with one another so that each capillary draws water from the neighbouring capillary.

ter) while on the other, a pressure force affects them (a mound of water). When this effect of surface forces is investigated in narrow tubes or capillaries, it is found that in the capillaries of easily wetted materials, there is a considerable suction – or capillary action – due to the tension.

In the first case (see Fig.) the capillary shows a tendency to encourage the water to rise within it, the more so the narrower the tube; conversely in the second case, the narrower the tube the greater the tendency to drive water out of it. In physical terms the pores of a fabric may be imagined as being an interconnected series of larger and smaller capillaries. These do indeed carry out capillary functions, as is seen in daily practice. However, a fabric contains no isolated single capillaries but rather a large number of both fine and large capillaries which are all connected one to another. A result of this is that each capillary draws liquid out of the next largest, leading to a significantly greater rise than would be encountered with an isolated tube. In the case of a hydrophobic surface, ie., poor wetting properties, a similar but opposite effect comes into play, in other words in the sense of the expulsion of water from a capillary. This means in practice that products made from easily wetted synthetic materials show a large capillary action or absorption power, whereas products made from hydrophobic materials, such as wool show a low capillary action or absorption power.

Wetting tension This is the force per unit length which is caused by free → Wetting energy in a liquid-solid system. It is numerically the same as the free wetting energy per unit area and is expressed in dyne/cm or N/m. Wetting tension corresponds to a progressive or retrogressive → Wetting angle. Measurement is done, for example, using a registered tensiometer. A flat piece of textile is immersed slowly into distilled water and the force acting on the sample is recorded using an induction recorder. This force F is the sum of the force exerted due to gravity, the buoyancy and the wetting force. The test apparatus is shown schematically in the Fig. Using the known surface tension of distilled water of 72 mN/m and the length of the steel plate of 36 mm, the wetting force measured gives directly the wetting tension j or the contact angle θ.

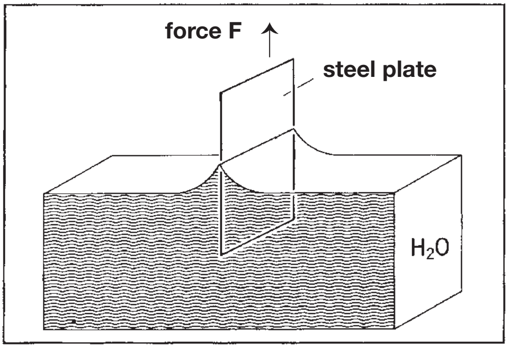


Fig. Diagram of test set-up for measuring wetting force (wetting tension) (according to Wilhelmy).

$$j = F/L = \gamma \cdot \cos\theta$$

An adequately clean steel surface is hydrophilic, which gives a contact angle of 0° and a wetting tension of 72 mN/m. Adsorption of a densely packed film of amphiphilic molecules turns the surface strongly hydrophobic, making the contact angle greater than 90° and the wetting tension less than 0 mN/m. If the surface concentration of amphiphilic molecules is increased further the adsorption film becomes two-layered; the surface then becomes hydrophilic once again and wetting tension increases once more.

Wet tow dyeing A collective term common for the → Gel dyeing of wet-spun and still not dried acrylic spinning tows.

Wet transfer printing A facility for the wet transfer printing process on acrylic, polyamide and wool and comprising an impregnation padder, transfer calender (of the felt calender type) and a J-wash box. Even light and extremely sensitive qualities are suitable for this wet transfer printing process.

Wet transfer printing process In contrast to a dry transfer printing process, the transfer of dye in the wet transfer printing process takes place by migration in the aqueous phase or in an organic phase, formed by wetting or other additives, at temperatures of 100–150°C. Wet post-treatment is usually necessary. → Transfer printing.

WF → Virgin wool, symbol according to the → EDP key system.

WG → Vicuna, → Textile fibre symbols, according to DIN 60 001 T4/08.91.

Wheat starch A columnar, crystalline or radioactive powder, forming a pure white homogeneous “flour” (greyer than potato starch). The handle is similar to maize starch. It is often adulterated using potato starch (detectable under magnifying glass or microscope). Its water content is 15–18%. Heating of a suspension results in: swelling at 50°C, agglutination begins at 65°C, agglutination ends at 67.5°C. The agglutinated starch is bluish-white and not as translucent as potato starch (nevertheless with more gluing and stiffening power, though less than rice or maize starch). Its response to chemicals is similar to that of potato starch. Its handle in finishing is harder and more granular than potato starch. It is used as a → Starch.

Wheelchair-resistant Characteristic of a textile floor covering which enables it to withstand the pressure and abrasion imposed by a wheelchair. It is tested according to DIN 54 324.

WHG (Ger.) abbrev. for: Wasserhaushaltsgesetz (→ Water Resources Law).

Whipcord The name immediately indicates an appearance of firmness. These materials appear in the form of worsted yarn warp and weft, worsted yarn warp and carded yarn weft, and occasionally carded yarn warp and weft. The warp yarns at the least are sharply twisted, usually the yarns are a mouliné twist. The binding may be of special gabardine binding; as a consequence these materials have a gabardine like appearance, in other words they have a more or less pronounced corded effect. Their finishing character is bare or clear threaded. These materials are used for riding breeches, sports jackets and trousers and especially for work wear.

Whirled pile finish The treatment of raw goods with special, usually round brushes for the manufacture of whirled plush fabrics (woven imitation furs).

Whitaker process →: Knit-deknit method; Space dyeing.

White A sensory perception; according to Ostwald, the sum of all → Chromatic colours and a body which reflects all visible colours. →: Colorimetric measures; Grey series; Ideal white.

White chate marks ("white abrasion"), rubbed areas on satin-like goods (especially on silk), and also frequently on poplin clothing in dry cleaning and laundry, caused by faulty mechanical influences. It also occurs as abrasion caused by normal wear on pockets, sleeves and the like, and as abraded crossover points (giving rise to an altered reflection of light, which causes separate portions of fibre to appear "white"). It can be reduced or, in favourable circumstances, removed by using → Spirit cleaner.

White content White in relation to → Standard white. As a measure of → Detergency power, white content is the difference in brightness before and after washing (usually measured using a 460 nm filter). It is defined by the whiteness calculated by measuring whiteness (→ Whiteness, degree of). The limit of the eye's sensitivity lies at an approximately 5–10% difference in white content.

White goods → Laundry goods.

White laundry goods White washing in the sense of → Wringable laundry and to a certain extent also body clothes.

White lead test paper Test paper soaked in white lead used as a quick test for hydrogen sulphide.

Whitener → Fluorescent brightening agents.

Whiteness, degree of A dimensionless number giving a measure of → White content and used as a scale for evaluating the effect of bleaching, for example, or the brightening of goods involved in dry cleaning or the colourlessness of lubricating oils and the like. The degree of whiteness is determined by various formulae for → Whiteness, measurement of.

Whiteness formulae Used in calculating the → Whiteness, degree of. Distinction is made between:

I. Whiteness formulae which are based directly on measured physical values, e.g. from Stephansen (not for samples treated with brightening agent): $W_{st} = 2 \cdot R_{46} - R_{62}$.

II. Whiteness formulae which are based on colour values, e.g. from Berger: $W_B = Y + 3.448 \cdot Z - 3.904 \cdot X$. These correspond better to the characteristics of the human eye.

A large number of whiteness formulae have been proposed since not only do differences in sensitivity between observers play a role in the evaluation of shades of white, but also the preferences for specific white nuances. In addition, "optimum" white is dependent on the product.

After years of investigation the CIE has decided to recommend the following whiteness formulae.

CIE whiteness formula for D65/10°:

$$W = Y + 800\,(0.3138 - x) + 1700\,(0.3310 - y)$$

Colour cast (tint):

$$T = 900\,(0.3138 - x) - 650\,(0.3310 - y)$$

- if T is positive the sample has a red cast
- if T is negative the sample has a green cast
- limits of application: $Y > 70$ and $T < \pm 3$.

The CIE confines the application of the formulae to whitenesses of more than 40. White tests with a colour shade wavelength of more than 466 nm are seen as "neutral". The tests are mainly not neutral white but compared with those colour shades reddish or greenish, also the shade (T, tint) as well as whiteness will also be given.

Whiteness index The opposite of → Saturation in → Chromatic colours and not to be confused with → Lightness even though a solid colour may appear brighter the more white it is, for example when it appears under above average illumination which causes an almost total white sensitivity as it approaches the level of being blinding.

Whiteness, measurement of White itself is also a colour which may be determined using colorimetric methods. White differs from the chromatic colours in that white products show a high degree of brightness combined with very low colour saturation. the chromaticity of white, in other words, is very weak. The evaluation of white samples is often fundamentally more difficult than that of chromatic dyeings, the reason lying in the fact that white is a concept of subjective quality subject to a great degree, to the influence of personal taste. A bluish white is preferred to a yellowish white provided that the two differ only in terms of their hue.

The practitioner is faced with the problem of how to evaluate data obtained as a result of spectral photometry measurements. Values can be calculated from standard colour values (or derivatives thereof) with the aid of various whiteness formulae. It is of importance here that each whiteness formula contains a different specific weighting for the three colour characteristics of hue, saturation and brightness: in other words, its evaluation is subjective. As a consequence, the practitioner is less interested in absolute whiteness than in pursuing, as with chromatic dyeings, differences between master samples.

Final checks in whiteness measurement show how brightening relates to the reference sample in terms of brightness, purity and hue. The use of the hue-chromaticity level of the CIELAB colour space has shown its value for the evaluation of samples treated with fluorescent brightening agent. The representation permits a clear localisation of the nuance of a fluorescent brightening agent. In particular, it also shows how the intrinsic colour of a product becomes visible following excessive metering. Chromaticity increases with high concentrations (greening, for example), which makes it feasible to compare products in terms of their price, quantity required and whiteness effect.

The options for an instrumental evaluation of white may be divided crudely into three areas. A purely physical method making use of spectral photometry allows the whiteness effect to be analysed and its various components to be compared qualitatively. It is then possible to distinguish between the contributions of the underlying white of the substrate, the fluorescent brightening agent and any shading dye which may be present. Valuable information is thus obtained for the reproduction of white master samples and for the investigation of faults or inquiries. A triple zone device cannot deliver this information; a spectral photometer is required. The second area entails relative whiteness evaluation, the third entails absolute whiteness evaluation. Absolute evaluation differs from relative evaluation by including an exact definition of the illumination; this means the excitation of the brightening agent corresponding to an average level of daylight, and reference of the degree of whiteness and the hue calculated against an existing scale of whiteness. This method alone offers reproducibility which is adequate to all practical needs and a capacity to compare results obtained using different instruments. An evaluation using the Ganz whiteness formula has the advantage of including a correction for UV.

Whiteness reduction The effect of fluorescent brightening agents in terms of an increase of the degree of whiteness and the brilliance of lighter colours is connected to the effect of fluorescence. All factors which contribute towards a reduction in fluorescence also lead to a reduction in the whiteness effect and are thus undesirable in the brightening process.

The phenomenon which appears as a reduction in fluorescence is often referred to in the literature as simply → Fluorescence quenching. Thus, fluorescence quenching becomes a collective term describing a series of negative final effects which are brought about by, for example, an excessive concentration or the addition of foreign substances (so-called quenchers) to solutions or to absorbing agents. This phenomenon can be observed both with fluorescent dyes and fluorescent brightening agents.

This reduction in brightening effect due to excess concentration is explained by the displacement of the absorbing part of the spectrum into the visible area of the spectrum. Were the concentration of brightening agent to be increased even further, one would have to expect an even deeper displacement of the absorption spectrum into the longer wavelength colours.

The reduction in the degree of whiteness due to the addition of foreign substances must first be ascribed to fluorescence quenching; only when coloured substances are involved, e.g. $FeCl_3$, should the absorption of the primary light and of the secondary light of fluorescence be considered the cause. The lesser reduction in whiteness due to excess concentration of fluorescent brightening agent rarely occurs in practice because the agent can be metered precisely. On the other hand, the influence of foreign substances is far less easy to avoid as these cannot always be controlled directly. It has been shown that traces of some metal ions (especially in solution) can cause fluorescence quenching even when present in the very lowest concentrations. This is particularly noticeable when ions of copper or iron are present in the treatment bath. Spectroscopic investigation has been able to demonstrate the association of fluorescent brightening agents with metal ions to form a complex which itself does not fluoresce.

Whiteness scale A comparative series of textiles treated with brightening agent and used for the evaluation of the intensity of fluorescent brightening agents. The fluorescent brightening agent is applied in increasing concentrations to a number of substrate samples. The differences in concentration are to be chosen such that any two consecutive samples show a clearly visible difference in brightening effect. An arbitrary differentiation by numbers then follows, for example, 200 points for the maximum effect achieved and 0 points for the untreated substrate, the scale being divided in steps of 20 points. The sample of fabric which is to be tested is then compared against samples from the scale and the brightening effect it shows is numerically determined. An experienced tester can (for a scale as described above) reliably judge differences as fine as 2.5 points, even when the fabric structure itself varies. A separate whiteness scale must be established for each type of fibre. When variations occur in the substrate or in hue, saturation or brightness a visual evaluation usually becomes more difficult and depends strongly on the individual tester. There is also often a desire to make visual grading match values achieved instrumentally. →: Textile whiteness scale; Ciba-Geigy white standard.

Whiteness value A number which characterises whiteness as a visual perception of white. Whiteness samples of differing appearance can receive the same whiteness value, for which reason the whiteness value can be calculated more precisely from measurements using the → Whiteness formulae.

White spots (polyacrylonitrile fibre rope). Whitish areas caused by uneven drying during manufacture; they have a loose structure and show reduced physical-mechanical properties between intact and defective fibres.

White toner → Fluorescent brightening agents.

White, visual assessment of The visual assessment of white is influenced by the colour of the surroundings and of the background (a light grey - i.e. neutral - plate, coloured ground or bleached and not brightened paper or cotton are best), by the angle of observation (45° to the observer is optimum), by changes of position of the samples and by personal factors. Sampling should be done in a cabin kept neutrally grey and under standard lighting. Method a): hold the samples one in each hand at an angle of 45°; exchange the samples several times from hand to hand. Method b): wind the samples around a glass or plastic sheet free of fluorescing or UV absorbing compounds and hold as in a; the samples overlap alternately. Method c): lay the samples next to each other flat on a white or light grey ground free of optical brightener and press flat using a glass sheet which does not absorb UV; change positions several times. → Whiteness scale.

Wicking-test A test of the absorbency of fabrics following pretreatment for dyeing or finishing. Strips for testing are suspended vertically with their lower ends in the test liquid, and the elevation with time is measured (the wick effect). The test is important in the assessment of fabrics in minimal application techniques.

Width stretching (stretching out). The lateral stretching of milled goods if the lateral contraction has become too great and the longitudinal contraction has not yet reached an acceptable maximum.

Wild silks In addition to the → Silk obtained from the mulberry silkworm, other silks obtained from various nocturnal moths found in both Asia and Africa are of interest in textile processing. The cocoons are as a rule larger than those of the mulberry silkworm and often not suitable for reeling. The chemical properties of these wild silks are very similar indeed to those of so-called true silk, but they are more resistant to both acid and alkali and are not as easy to bleach or dye (having a higher content of natural dye). The cement found in the silk threads, sericin, is difficult to remove. The morphology of wild silks is distinctly less regular than that of true silk (individual threads with flat or wedge sections, longitudinal grooves, twists in the cocoon thread). Because of these features the thread is thicker and less regular and the goods have a stiffer and more grainy feel with a broken glaze. Tensile strength and expansion coefficient are both lower than those of true silk. Those wild silks important in textile processing include →: Anaphe silk; Eri silk; Fagara silk; Muga silk; Tussah silk; Yama-mai silk.

Williams Unit A variant of a type of → Roller vat which has an extremely restricted liquor volume. Each assembly comprises four vertical stainless steel containers, each of a U-shaped form. While temporarily removing the sheet suspended in each U-unit, piece goods are introduced and guided between upper and lower rollers arranged across the bend in the U. The separation between the casings inside the U is only 0.5 cm, meaning that there is an extremely short liquor ratio. The liquor is heated by a steam jacket to temperatures of 90–95°C (or to temperatures above 100°C if high pressure steam or hot oil is used). The speed of goods varies between 50–150 m/min, producing strong turbulence in the liquor and promoting good dye penetration. A Williams unit holds 350 litres of liquor and approx. 10 metres of goods with a throughput time of 6–8 seconds. The liquor circulation and the movement of the goods are according to the counterflow principle. It can be combined freely for continuous machines (e.g. in a pad-steam process). Dye consumption, liquor exhaustion, dye penetration, evenness, savings on steam and so on are favourable.

Winch (reel, windle, winder). A device, mechanically powered or hand driven, of adjustable circumference used to wind on or off (batching, reeling) rope or yarn. According to DIN/ISO a winch is: a rotating guide or transporting structure, the circumference of which is composed of individual carrying elements. The winch may be an open or closed structure.

Winch beck (piece dyeing vat, piece vat). A device for the dyeing of piece goods, especially lighter and thinner materials, jersey knits, etc., not suitable for dyeing on a jigger. A carpet winch dyeing machine is used for carpets. The principle is as follows: The beck, or vat, has a narrow boiling chamber at the side which can also serve for the addition of dye and the like, and which is separated from the remaining liquor and the goods by means of a perforated dividing wall. Situated above the beck and nearest to the dividing wall is a guide roller, a rake with teeth for separating the individual ropes of goods, and then a rotating round or oval winch with an adjustable speed drive. In special cases a swing-mounted vertical squeezer roller is also located above the winch and can be engaged once dyeing is completed. Specially constructed fully enclosed superstructures are also known, complete with a transparent vapour hood (containing an vapour flap valve and a ventilation shaft for escaping vapour) and a sliding door for servicing. The piece goods, sewn together at their ends into endless parallel ropes, are transported by the winch through the dye bath, over the guide roller, through the rake, over the winch and back into the dye bath, and so on. The winch is set higher or lower, depending on the goods. In the age of the jet, soft or overflow machine, the winch beck is easily seen as backward; however, it remains valid in several areas of textile finishing. Its flexibility of use, simple construction, ease of operation and unlimited size, together with improved details such as circulation pumps, mean that it retains a place all over the world in the dyeing of carpets, furnishing fabrics and terry fabrics.

Winch dyeing machine history The winch beck is the oldest dyeing machine. Originally constructed as an open beck, or vat, with a directly heated heating wall (Fig. 1), it was equipped with a large circular or oval drive winch above its rear portion and a smaller guide winch in the vicinity of the heating wall. Even after the head space was enclosed to avoid steam and mist (Fig. 2), temperature distribution within the vat of liquor remained poor (Fig. 3). The need to dye at temperatures above boiling point forced the use of a boiler construction with pressurized operation and liquor circulation system (Fig. 4). A particular problem was the passage of goods through a continuously operating series of

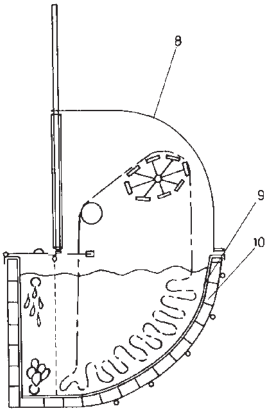


Fig. 2: Closed atmospheric winch dyeing machine.
8 = V4A hood;
9 = V4A sheet steel lining;
10 = wooden bottom.

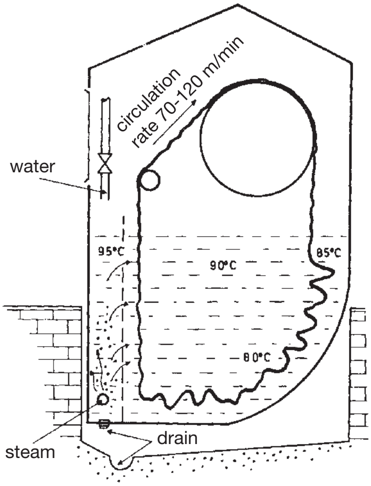


Fig. 3: Conventional winch dyeing machine (diagrammatic) with boil partition (left).

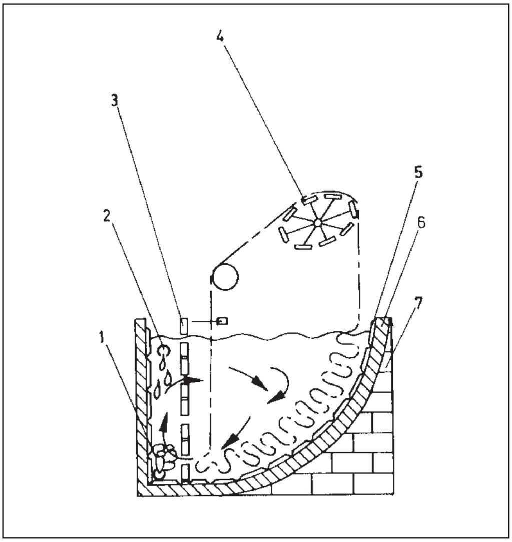


Fig. 1: Open atmospheric winch dyeing machine.
1 = perforated pipe; 2 = water feed; 3 = perforated, tiled partition; 4 = slatted wooden winch; 5 = tiled lining;
6 = cement bottom; 7 = brickwork.

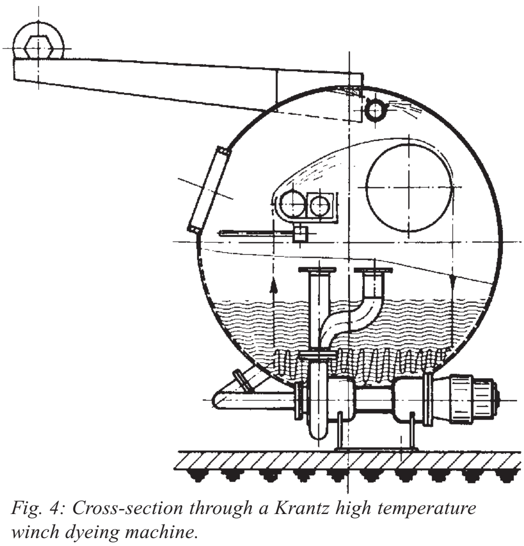


Fig. 4: Cross-section through a Krantz high temperature winch dyeing machine.

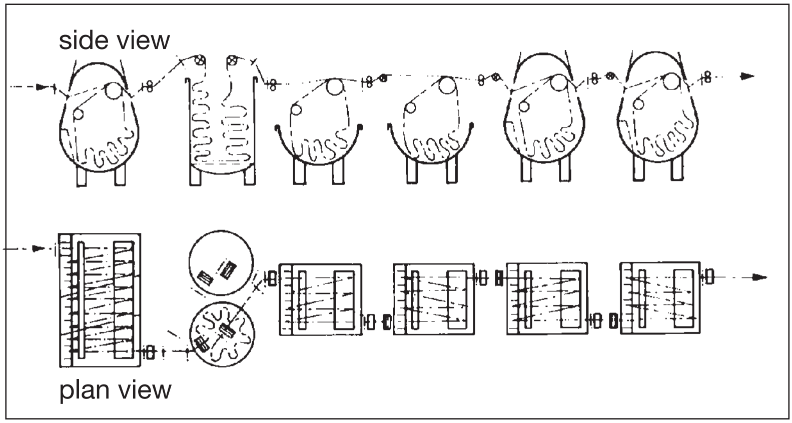


Fig. 5: Winch dyeing machine line with bleaching vat for pretreating and after-treating a tricot bleach.

vats in pressurized after-washing or in the pretreatment of circular knitted goods (Fig. 5).

More than any other, Brückner concentrated on improving the design and equipping of the winch vat. As a result the Haspelflow B (Fig. 6) for tubular goods was optimised in terms of its liquor exchange in that the dye liquor was drawn off from the trough through a pipe and circulated through a lint filter. The liquor was pumped over a bare tube heat exchanger, through a riser pipe and then flowed over an overflow weir onto the goods.

For the dyeing of tufted pile carpets, Brückner adapted the winch vat to an open width dyeing machine (Fig. 7), and then later transferred the knowledge gained to woven fabrics. These planar fabrics, however, are difficult to guide in open width, which was done by means of a special airflow system in the front ex-

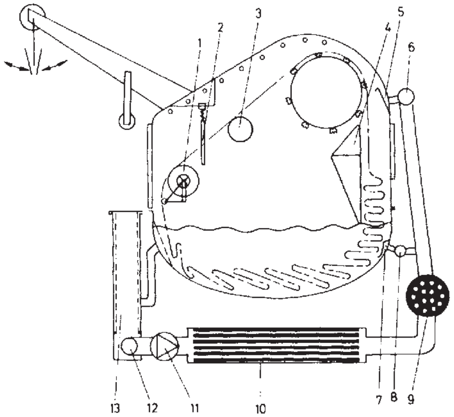


Fig. 7: Brückner open-width carpet winch dyeing machine. 1–4 = fabric guide elements; 5–13 = liquor circulation system.

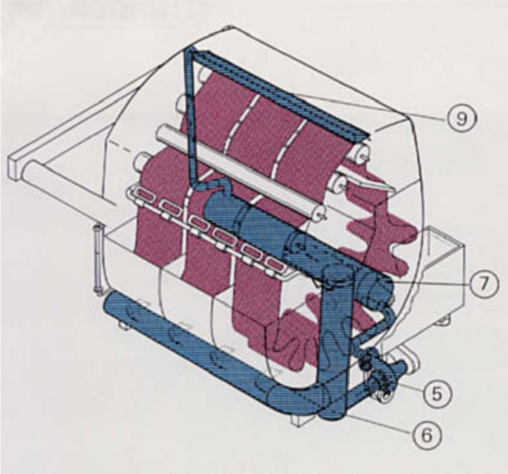


Fig. 6: Haspelflow B. 5 = liquor pump; 6 = filter; 7 = bare tube heat exchanger; 9 = overflow weir.

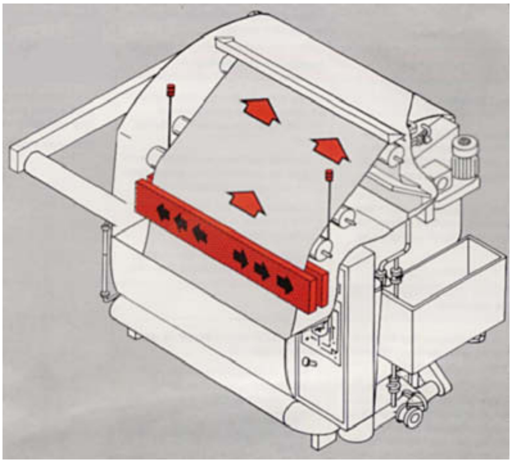


Fig. 8: Brückner open width fabric winch dyeing machine.

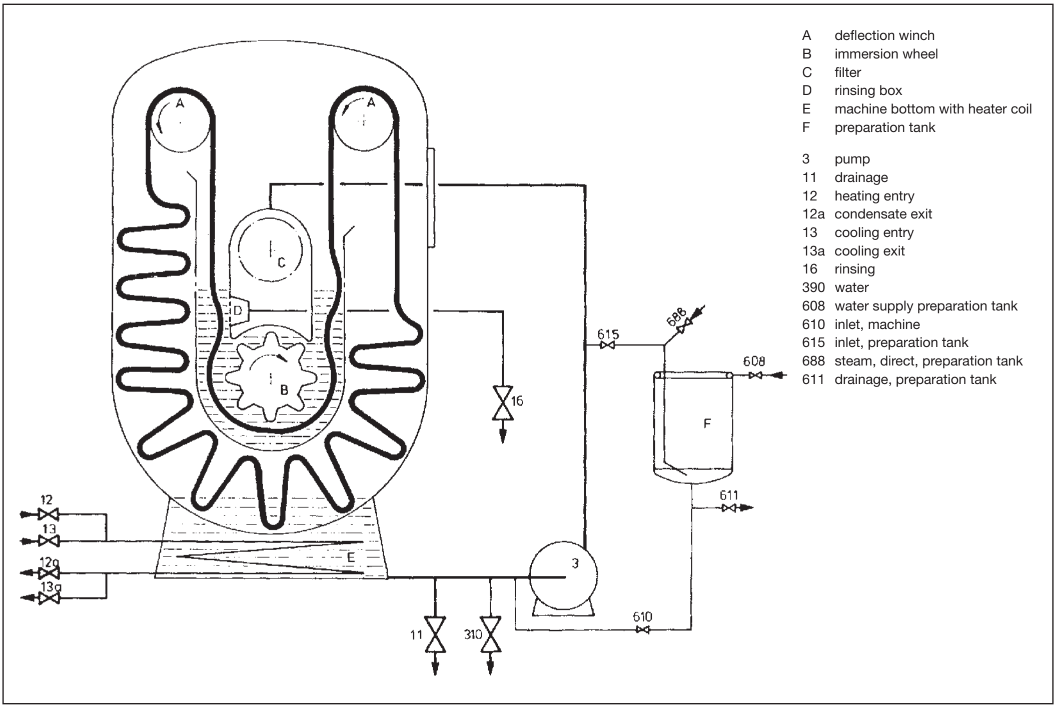


Fig. 9: Thies combined winch.

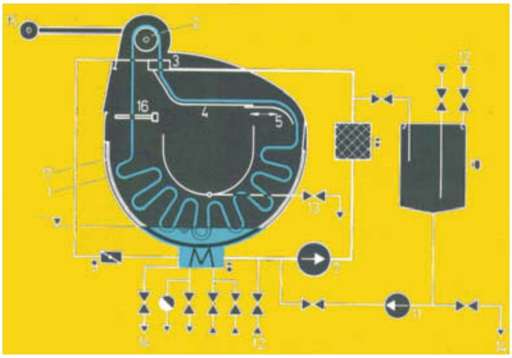


Fig. 10: Then winch dyeing machine.
1= fabric store; 2 = guide roller; 3 = flooding; 4 = transport length; 5 = plaiter; 6 = heating and cooling unit; 7 = liquor pump; 8 = filter; 9 = bypass; 10 = preparation tank; 11 = adding pump; 12 water feed; 13 = rinsing overflow; 14 = drain; 15 = unloading winch; 16 = fabric dividers; 17 = special slide bottom.

pander slot (Fig. 8). Béné also made use of air in order to inflate the tube in the winch beck, thus making it easier to lay (Fig. 11).

In the interest of better liquor exchange, Thies (in the combination beck, Fig. 9) and Then (Fig. 10) ap-

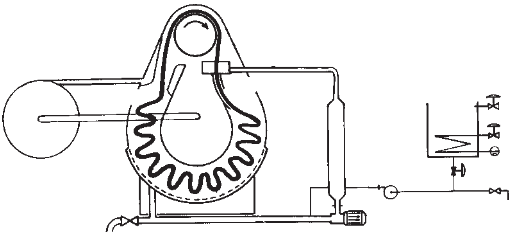


Fig. 11: Beneflow winch dyeing machine with air input.

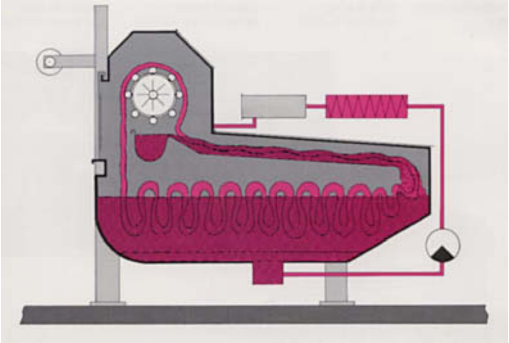


Fig. 12: Espa-Surfer (Krantz).

plied special methods which allowed for significantly shorter liquor ratios. Krantz produced the Espa-Surfer, a type of winch beck which was extended to the rear to incorporate a special transport track (Fig. 12).

Winch machines → Winch.

Winding,

I. The reeling or winding on of yarns (see Fig.) on → Yarn package winding machines. Usually the yarn is at the same time cleaned and thin or thick sections are removed using mechanical or electronic yarn cleaners.

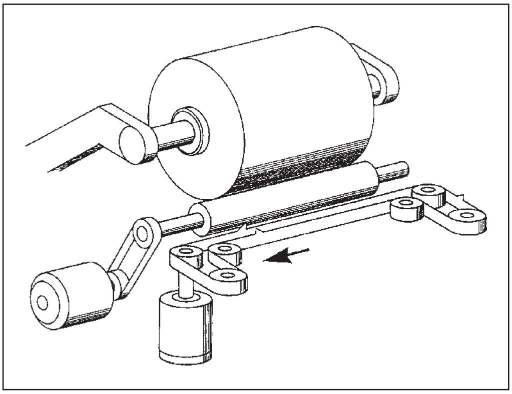


Fig.: Winding head with belt thread guides (Hacoba).

II. The looping of a thread around the core of a package. →: Package winding systems; Yarn packages, preparation.

Winding machine for card/emerizing rolls A machine for uniformly winding card strips or emery paper strips onto card or emerizing rollers (see Fig.).

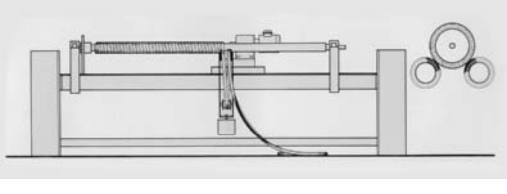


Fig.: Menschner's winding machine for card/emerizing rollers.

Winding spindle, batching-off shell A rotating cylindrical object with either an uninterrupted axial bore or with lugs fastened to each end which is used in the batching off of goods (DIN/ISO 5248).

Window In textile finishing this means the sample pattern at the end of a piece for the colour matching of dyed or printed samples, for example when dyeing on a jigger.

Window curtaining fabrics (curtain fabrics) → Net curtain fabrics and decorative materials made from wool, polyamide, polyester, cellulose, polyacrylonitrile, glass fibres and mixtures.

Wipes When used for special purposes, for example in dusting microchips, the wipe itself must not create dust, i.e. must not deposit fragments of fibre. The surface of the wipe must also be indestructible in terms of the fibre used. The wipe must not take any electrostatic charge, which means that no finishing agent may be used since its antistatic nature must be permanent.

Kanebo has achieved this by mixing ultra-microfibres (Fig. 1) as fine as 1–5 Ïm with carbon coated polyester fibres (Fig. 2) which on the one hand conduct away any electrostatic charge and on the other protect the surface from damage. The super-microfibres absorb dust reversibly.

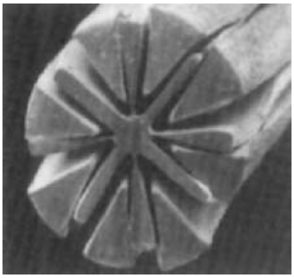


Fig. 1: Super-microfibres for wipes, made from 29% polyamide and 71% polyester.

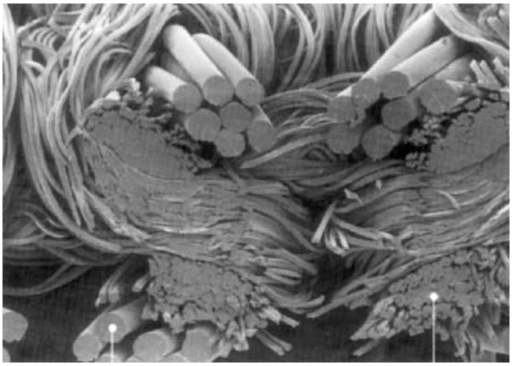


Fig. 2: Electron microscopic photograph of a cross-section through a Kanebo wipe.
Belima C = carbon vapour-blasted polyester yarn; Belima X = super-microfibres (see Fig. 1).

WIRA An English textile research institute; → Technical and professional organizations.

Wire card →: Raising; Raising elements.

Wire carpets Machine woven carpets with three warp thread systems (pile warp, filling warp and binding warp) and two or three weft thread systems. Steel pile wires are included during weaving such that the warp yarn is not merely laid around the weft yarn but at the same time formed by the presence of the metal wire into a loop. As soon as the pile is tied securely below the wires, these wires are pulled out and then re-included for the purpose of creating further loops. If the wires are equipped with knives they cut open the loops when withdrawn, resulting in a wire pile carpet (velour carpet). Examples are →: Bouclé carpets; Brussels carpet; Tapestry carpet; Tournay carpet.

Wire raising machine A roller raising machine, brush raising machine or universal wire raising machine fitted with metal wire cards in order to work as a raising tool. → Raising.

Wire sleeve A flexible dyeing sleeve made from stainless steel wire used as a package during the treatment of yarns which may shrink significantly.

WK → Camel hair, → Textile fibre symbols, according to DIN 60 001 T4/08.91.

WL → Llama hair, → Textile fibre symbols, according to DIN 60 001 T4/08.91.

WM → Mohair, → Textile fibre symbols, according to DIN 60 001 T4/08.91.

WN → Rabbit hair, → Textile fibre symbols, according to DIN 60 001 T4/08.91.

WO → Wool, → Textile fibre symbols, according to DIN 60 001 T4/08.91.

Wo → Wool, → Textile fibre symbols, according to DIN 60 001 until 1988, from 1991 → WO.

W/O Abbrev. for oleaginous. → Emulsions, i.e., water in oil system.

Woad A blue → Natural dyes (a vat dye) obtained from the leaves of the golden flowering woad plant (weld, dyer's weed) and squeezed into the form of a ball. Its working ingredient is → Indigo. Woad was superseded by indigo, which has 30 times the concentration of dye, at the beginning of the nineteenth century.

Woad vat The oldest type of vat, it contains a mixture of → Woad with bran and madder (as a fermentation agent). Processing is carried out using bran and lime. → Fermentation vat.

Wollsiegel-Verband e.V. Trademark association of the International Wool Secretariat (IWS) in Düsseldorf. It is responsible for issuing licences for the use of the international woolmark, monitoring the observance of contractual duties by contract partners, carrying out quality control checks and dealing with all questions concerning the laws on competition.

Wood dyes These are dyes used in the dyeing of various types of wood and are usually cationic dyes, acid dyes and metal complex dyes.

Wood pulp A product obtained through the extraction of cellulose from wood and which remains after encrusted substances (lignin) have been removed. It is composed principally of α–cellulose (approx. 89%), the remaining 11% being provided by the hemicellulose forms β–cellulose and γ–cellulose. Among other uses, wood pulp is exploited on a large scale in the manufacture of viscose fibre.

Wood spirit → Methanol.

Wood turpentines → Turpentine oils. Also found in this group is → Pine oil.

Woody fibre These are the fibres in deciduous trees which lend them their strength and also serve to transport air and water. They are 0.5–1.5 mm in length, are narrow and have thick walls. Their ends are pointed. An analogy is found in components of the central lamella in →: Bast fibres; Hard fibres.

Wool A textile fibre belonging to the group of → Natural protein fibres. Only the hair of sheep can be referred to as wool. The amount of wool which grows on 1 cm^2 of skin is about 10 000 hairs and a single sheep produces about 100 million hairs and about 20 km or 6 g (3 dtex) every day. The fur of all other animals used for production of fibres is referred to as hair. In general, there is no basic difference between wool and hair in terms of substance. Rather, the difference lies in the appearance and fine structure. Wools are curly, bulky and fairly fine. Hairs, on the other hand, are straight, smooth and predominantly coarser and longer. There are also the so-called fine → Animal hair fibres (Cashmere, etc.).

Breeding has made it possible to produce a type of hair with (depending on the breed of sheep) uniform properties. Basically, there are three different types:

- fluffy or woolly hair: fine, soft, curly, short mat and fleshy;
- long coarse hair: coarser, more brittle, straighter, longer, glossier and hollow;
- short bristly hair: coarse, hard, straight, stiff, short, smooth, glossy, white and rough.

The fluffy or woolly hair and the long, coarse hair are wools in every sense. Depending on the breed and breeding, they exist separately or even as a mixture in the animal's coat. The short bristly hair is not fully hair and in all breeds only occurs singly and at particular places on the body of the animal where the bones lie directly beneath the skin or where the animal has been injured. Old animals and animals where the breeding has been neglected have a larger amount of short bristly hair. Because of its internal structure, it dyes differently or not at all; the dye is not even retained well in the fibre lattice. Normally, this is undesirable and is separated out but occasionally it is very much desired as a fashion effect.

The climatic conditions in which the sheep live and the associated soil conditions (basis for nutrition) are decisive in the build-up of wool hairs. There is a difference between the following two main categories:

1. Mountain sheep: of all sheep, the merino breed is essentially the most important. Its natural home is Spain where the living conditions are those of a high altitude climate, hot during the day and cold at

night. The animal's coat is able to compensate for the large fluctuations in temperature. Merinos supply fluffy or woolly hair with lengths ranging from about 40–150 mm and finenesses from around 17–24 µm. The main representative of this breed is the Australian merino; the purest breed on the other hand is the Rambouillet.

2. Lowland sheep: these develop in damp, mild but rough oceanic climates. Their natural home is England and the islands of the North Sea. They are mainly represented by the English countryside breeds such as the Lincoln, Leicester and Cheviot sheep, chiefly producing long coarse hair with lengths ranging from 120–300 mm and, in the case of particularly long wools, lengths up to 550 mm. Finenesses range from 24–48 µm.

The so-called "Crossbreds" have been developed by crossing the English Lincoln breed with the fine-woolled merino. This mixed breed has proved itself to be particularly resilient in regard to climate and disease, etc. In spite of the increased shearing yield, it is possible to increase the coarseness of the wool of these crossbreds by back-breeding with merinos. These back-bred sheep are called "Comebacks".

Shearing takes place either twice a year (half-shear), once a year (full-shear) or three times in two years (three-quarter shear). Virgin wool is wool which has been shorn from the animal while it is alive. The coherent coat which is produced during sheep shearing is called the fleece. This is divided up into different wool qualities depending on the part of the sheep's body from which it has been shorn. The different areas of the fleece listed below are shown in Fig. 1

- range I: best quality;
- range II: good average wool;
- range III: somewhat coarse, frequently brittle and open, greasy, dirty and fleshy;
- range IV: coarse, short and knotted;
- sorting: short, permeated with bristles and frequently felted.

After shearing, the fleece is divided up (by tearing it apart) and sorted by a practised hand into the various wool qualities.

The fineness is defined as the diameter of the fibre in µm. This is classified into the following categories:

– fine merino wools	17–20 µm
– merino wools	20–24 µm
– fine crossbreds	24–28 µm
– medium crossbreds	28–37 µm
– coarse crossbreds	more than 37 µm

Because wool occurs in different fibre thicknesses and the finer wools are always shorter and the coarser wools always longer, in practice, the fibres are also classified according to their fineness (see range IV). The English classification (e.g. 66's) signifies the Number English (Ne) worsted yarn to which the wool could be spun. The German is arbitrary and uses the capital letters of the alphabet (e.g. AA/A).

merino wools:	80's	or AAA
	70's	or –
	64/70's	or AA
	64's	or A
	60's	or A/B
crossbred:	58/60's	or B
	56/58's	or B/C 1
	50/56's	or C 1
	50's	or C 2
	48/50's	or D 1
crossbred coarse:	48's	or D I/D 2
	46's	or D 2/E 1
	40/46's	or E 1/E 2
	36's	or F 1

The layer of scales which can be seen under an electron microscope is characteristic of the morphology of the

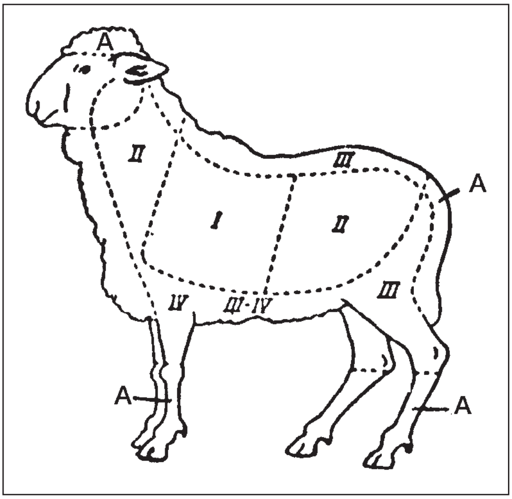


Fig. 1: Wool ranges (I–IV) and parts for sorting (A).

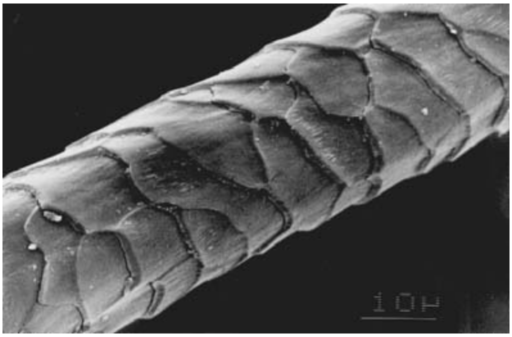


Fig. 2: SEM photograph of an untreated wool fibre (DWI).

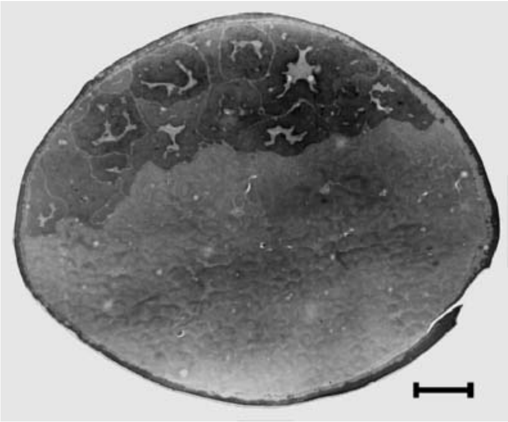


Fig. 3: Cross section of an untreated wool fibre (DWI).
Bar: 2 µm. Paracortex = dark staining of the transmission photograph using Ag-staining technique.

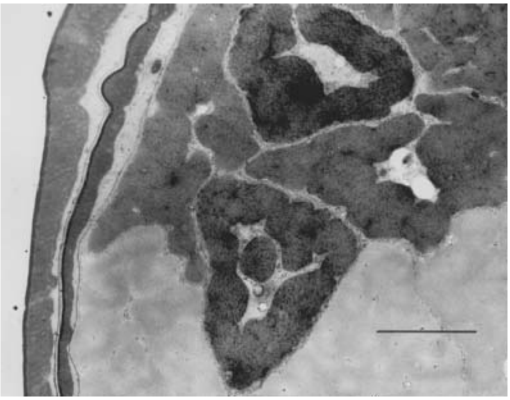
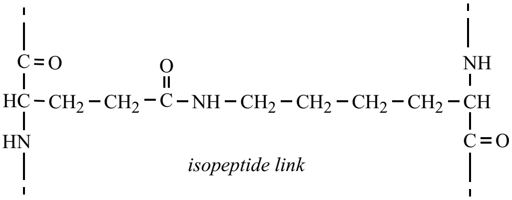


Fig. 4: Cross section of an untreated wool fibre with intact cuticle (DWI).
Bar: 1 µm. Light stained = orthocortex; dark stained = paracortex; even darker stained = mesocortex cells.

wool fibre (Fig. 2). The o-p-Cortex structure is made visible by skilfully producing fibre cross sections (Fig. 3). A stronger magnification of the cross section shows the different structure of the scale layer (Fig. 4); two scale layers can be recognized. From outside to inside, the components are as follows:

- extremely sulphur-rich A-layer (Ag contrasting),
- sulphur-rich exocuticle,
- endocuticle,
- cell-membrane complex (between the cuticle layers).

Wool chemistry In molecular fibre science, physical, chemical and technological properties are attributed to the primary structure of the linear macromolecules, their conformation (secondary structure) and the interactions between the certain parts of the macromolecules, the side-chain groups in particular (tertiary structure). The tertiary structure is effectively fixed by the intra- and interchenaric bonds (crosslinks). No other textile fibres – such as keratin hair which includes human hair – show so many different aspects in their crosslink chemistry as does wool, as it is made up of 18 different amino acid residues as monomers, of which approximately half act as a source of reactive side-chain groups. There is a difference between primary and secondary valence links but, in many cases, it is not possible to differentiate clearly between the two. A further distinction can be made between natural crosslinks produced in the wool by the biosynthesis and synthetic links, which do not appear until they are formed during the reactions which occur later. The insolubility of the cell membrane is explained by the presence of glycoproteins and isopeptide links.



$$\overset{\overset{|}{C=O}}{\underset{\underset{|}{HN}}{HC}}-CH_2-CH_2-\overset{O}{\overset{\|}{C}}-NH-CH_2-CH_2-CH_2-CH_2-\overset{\overset{|}{NH}}{\underset{\underset{|}{C=O}}{CH}}$$

Even the intermacrofibrillar material appears to be stabilized by the isopeptide links. The keratin of wool may be summarized as shown in Tab. 1. If hair or wool is left to swell in hot water, it is possible to stretch it by around 100%. On relaxation, it contracts again to approximately its original length. According to X-ray photographs, modified keratin occurs in two different forms: the α-keratin of the unstretched wool, where the

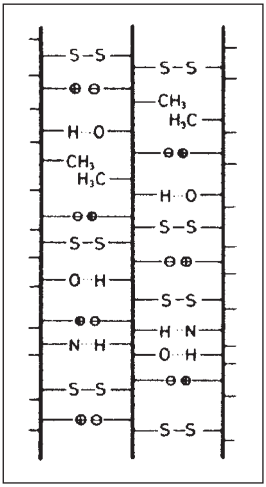


Fig. 1: Diagram of the chemical construction principle of wool showing its "ladder pattern" (by Zenko Stary). The main chains are linked to one another through disulphide (cystine) bonds, salt linkages, hydrogen bonds and also hydrophobic interactions.

polypeptide chains are folded together in a particular way and are therefore shortened, and the β-keratin, where the polypeptide chains occur as in silk. In 1928, Zenko Stary developed the ladder model to help understand the chemical structure of wool (Fig. 1).

In α-keratin, the polypeptide chain is wound in the shape of a spiral or screw (Fig. 2). The side chains are oriented towards the outside and each amino acid has an intramolecular hydrogen bond between it and the third neighbouring group in the direction of the helix, thus stabilizing the molecule.

chemical composition: 80% keratin proteins;
19% non-keratin proteins
1% internal lipids
molecular masses: 9000 to 60 000
intermolecular forces: cystine bonds, hydrogen bonds and salt linkages;
hydrophobic interactions
isoionic point: pH 4.9
moisture pick-up: 18%
crystal structure (30%): α-helix
fibre period: 0.51 nm
amorphous sections: non-helical segments in microfibrils; matrix in macrofibrils; non-keratin proteins
microfibrils: 7 to 11 nm
macrofibrils: 50 to 200 nm
pore volumes: 35%
biological composite structures: cortex, cuticle
glass temperature dry: + 174 °C
wet: - 5 °C
decomposition temperature: 250 °C

Tab. 1: Summary of wool properties.

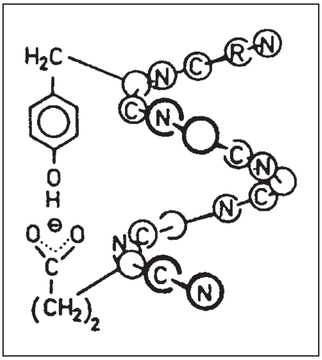


Fig. 2: Diagram of an intrahelical H-bond between a phenol hydroxyl group and a carboxylate anion of the wool keratin, representing α-keratin.

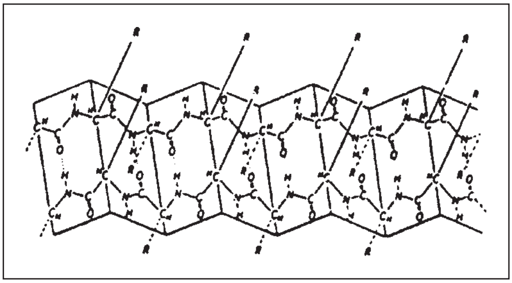


Fig. 3: Pleated sheet structure according to Pauling and Corey, based on inter-chain H-bonds between the antiparallel arranged polypeptide chains of silk, similar to the β-keratin in stretched wool hairs.

The helical structure of α-keratin, however, only occurs in wool fibre in its unstretched state. When the fibre is stretched, the α-keratin structure is converted to the “pleated sheet” structure of β-keratin (Fig. 3), while the intramolecular hydrogen bonds break and reform as intermolecular links between two different polypeptide chains. This process is reversible, i.e., α-helix is produced again as soon as the wool hair can relax (Fig. 4). This so-called α-β switchover is the reason for the elastic properties of wool.

Apart from keratin, wool also contains non-keratin proteins. Among these are molecular substances such as lipids. The non-keratin proteins, which are characterized by a lower cystine content in comparison to keratin proteins, are cell-core, cytoplasmic and cell-membrane proteins chiefly found in the cell-membrane complex, the intermacrofibrillar cement and the endocuticle. In spite of the fact that lipids are involved in only 1% of the total chemical structure of the wool, they are still important as they make up 35% of the cell-membrane complex. The chemical composition in terms of amino acid content is shown as a percentage in Tab. 2.

The terms “acid” and “basic” amino acids only refer to the chemical structure of the nondissociated and dissociated carboxyl groups –COOH of the aspartic acid and glutamic acids or nonprotonated groups in the lysine, histidine and arginine.

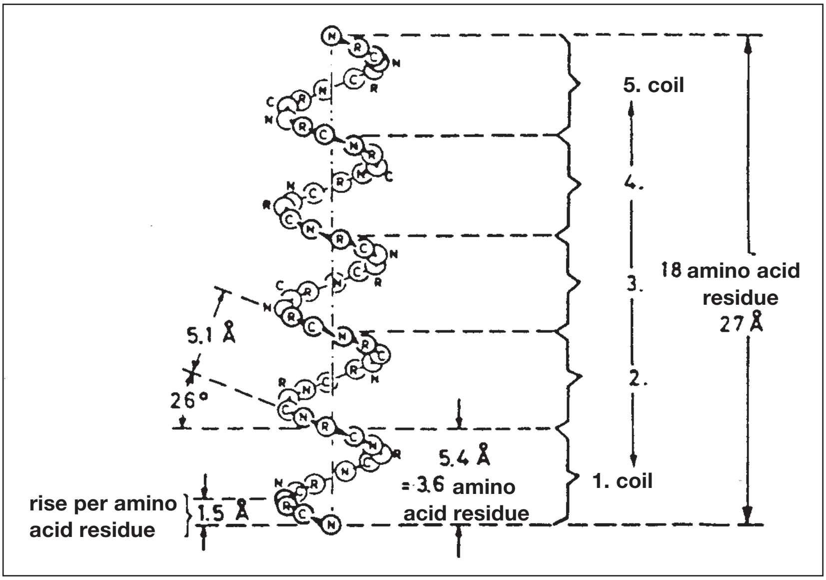
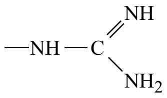


Fig. 4: Secondary structure of proteins: diagram of the α-helix according to Corey and Pauling.

$\sim NH_2$

$—N=$



$-NH-C(=NH)-NH_2$

Since both “acid” and “basic” groups exist simultaneously in amino acids, they react with each other to form “salt linkages” (Fig. 5). The “acid” amino acid in the salt linkage, glutamic acid, no longer exists in its acidic form but rather in its basic carboxylation form and the “basic” amino acid arginine in the salt linkage no longer exists in its basic form but in its protonated guanidinium form.

Proteins are termed polyampholytes because they contain many cationic and anionic groups at the same time. Proteins, therefore, are highly effective buffers which are able to chemically neutralize both acids and alkalis which have been added to the system, such as hydrochloric acid or sodium hydroxide.

The isoionic point is the point at which the same number of anions and cations exist in a molecule at the same time. From the outside, the molecule appears to

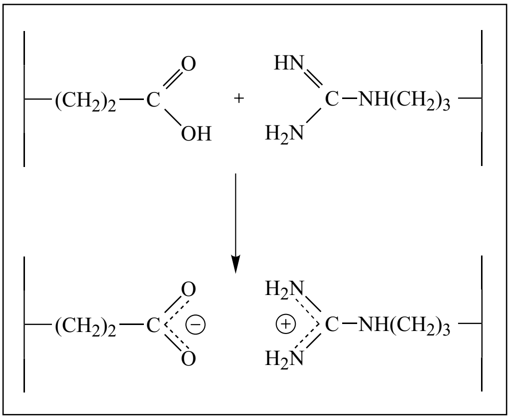


Fig. 5: Diagram of the formation of a “salt linkage” through reaction of the “acid” amino acid glutamic acid with the “base” amino acid arginine in a protein.

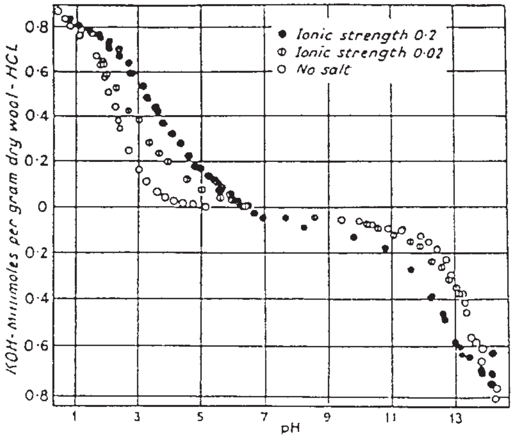
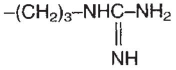
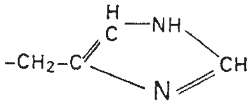
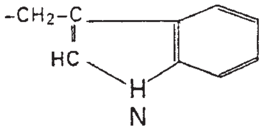
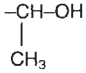
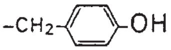
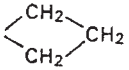
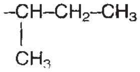
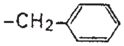


Fig. 6: Titration curve of wool (according to Steinhard and Harries).

group	name	side chain	concentration [µmol/g]
”acid“ amino acids and their ω-amides	aspartic acid	$-CH_2-COOH$	200
	glutamic acid	$-(CH_2)_2-COOH$	600
	asparagine	$-CH_2-CONH_2$	360
	glutamine	$-(CH_2)_2-CONH_2$	450
”base“ amino acids and tryptophan	arginine	 $-(CH_2)_3-NH\underset{\underset{NH}{\|}}{C}-NH_2$	600
	lysine	$-(CH_2)_4-NH_2$	250
	histidine		80
	tryptophan		40
amino acids with hydroxyl groups in the side chain	serine	$-CH_2-OH$	900
	threonine	 $-\underset{\underset{CH_3}{\|}}{CH}-OH$	570
	tyrosine		350
sulphorous amino acids	cysteine	$-CH_2-SH$	10
	thiocysteine	$-CH_2-S-SH$	5
	cysteic acid	$-CH_2-SO_3H$	10
	cystine	$-CH_2-S-S-CH_2-$	460
	lanthionine	$-CH_2-S-CH_2-$	5
	methionine	$-(CH_2)_2-S-CH_3$	50
without reactive groups in the side chain	glycine	$-H$	760
	alanine	$-CH_3$	470
	valine	$-CH(CH_3)_2$	490
	proline		520
	leucine	$-CH_2-CH(CH_3)_2$	680
	isoleucine	 $-\underset{\underset{CH_3}{\|}}{CH}-CH_2-CH_3$	270
	phenylalanine		260

Tab. 2: Amino acid composition of delicate Merino wool. The description “acid” and “base” amino acids relates only to the chemical structure of the non-dissociated carboxyl group –COOH in aspartic and glutamic acid or of the non-protonated groups.

be uncharged, a state which is determined by the ratio of acid and basic groups in the molecule. The acid and base bonding capacity can be established using titration curves (Fig. 6).

Instead of showing the isoionic point, the titration curve spreads across a broad pH range (isoelectric zone) within which neither the acid nor the base is in the bonded state. This is explained by the formation of the → Electrical double layer which hinders the penetration of hydrogen ions. By adding salt, this double layer is suppressed and the fibre is able to bond to larger amounts of acids or alkalis.

The isoelectric point of wool is at pH 4.9 (at 20°C) or pH 4.6 (at 90°C). Wool has its lowest reactivity at its isoelectric point. Consequently, it is in its most stable state because it is at the point where its salt-link formation capacity is at its maximum.

Although the surface of the wool has hydrophobic properties, it is a typical hygroscopic fibre which is capable of absorbing moisture from the air or, when wet, to release moisture to the air (desorption). The amount of bound water in relation to dry weight of the fibre can be as high as 33% (saturation humidity) and is dependent on the humidity of the air and the temperature, and on whether the equalization is taking place from the wet or dry state (→ Hysteresis). As water is absorbed, the fibre swells (increases in volume). At the isoelectric point, fibre swelling is at its minimum but increases as the pH increases or decreases. Swelling mainly takes place in the non-oriented, amorphous zones of the fibre and increases the fibre's susceptibility to attack from air, light and chemical agencies. The reason for this is that water is absorbed by the numerous hydrophilic groups in the wool molecule such as amino, carboxylic and hydroxyl groups. These hydrophilic groups while interacting with each other are partially exposed by the water and are surrounded by water molecules. At the same time, the hydrogen bonds between the neighbouring polypeptide chains are removed. The hydrophilic fibre stem is enveloped with the hydrophobic cuticle in the form of overlapping scales (coarser wools frequently have a pulp layer as well, know as the medulla). The top side of cuticle cells is called the exocuticle and the under side the endocuticle. The epicuticle, a thin skin with cells terminating on the outside, lies on top of the scales' cells (→ Wool structure).

During textile finishing, the wool passes through different finishing processes where it is treated with, amongst others, alkalis, acids, oxidation agents and reducing agents. Alkali is added, for example, in the soda-alkali raw-wool scouring step or during alkaline milling. Sulphuric acid is used to hydrolyse the vegetable impurities during the carbonizing stage. Under certain circumstances, reducing agents are used during chemical decatizing and oxidizing agents are used during oxidative bleaching and antifelting finishing. Behaviour in regard to these substances will be described briefly in the following.

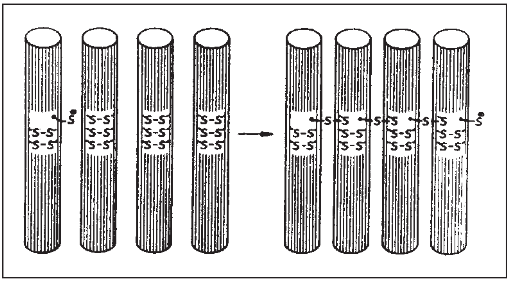
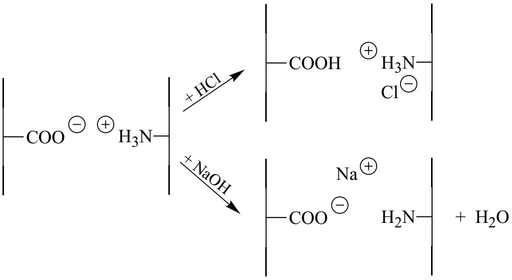
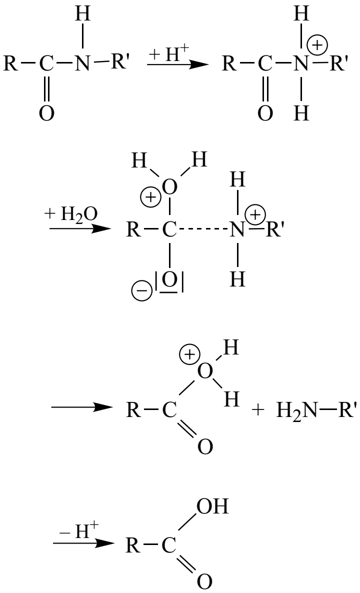


Fig. 7: Diagram of the self cross-linking of 4 protofibrils (gram-molecular weight approximately 40 000) in wool through chain disulphide exchange.

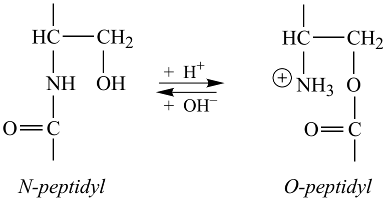
As proteins contain many cationic and anionic groups at the same time, they are proper buffers and are able to neutralize both acids and alkalis.



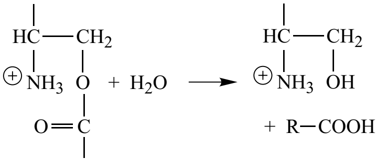
Among the characteristic properties of wool is its resistance to mineral acids. However, in the presence of water, peptides can be hydrolyzed by concentrated acids. This happens, for example, if carbonizing is not properly controlled:



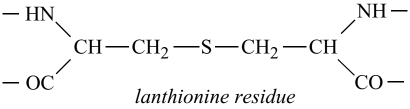
An N→O peptide shift is also possible:



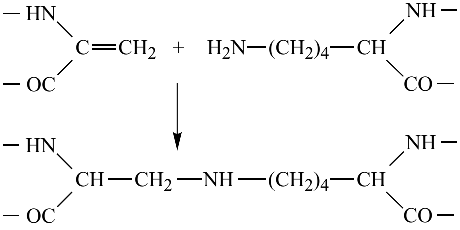
The peptide ester is in far greater danger of hydrolysing than the carbonamide group:



The effectiveness of an alkali in splitting the hydrogen bond, altering the amino acid chains and converting the peptide and disulphide links differs according to its concentration and temperature (Fig. 7). While concentrated alkalis dissolve wools by breaking the peptide links, during relatively mild treatment with alkali, the fibre structure remains intact. However, some of the cystine sulphur splits off in the form of hydrogen sulphide as the amount of cystine decreases. The sulphur that is left exists in another form:



Since this is a bond of low reactivity, the new crosslink, R–CH$_2$–S–CH$_2$–R’ is relatively resistant to alkalis. Additional crosslinking is obtained by the formation of lysinoalanine from an integral aminoacrylic acid and the free side chain of the lysine residue.



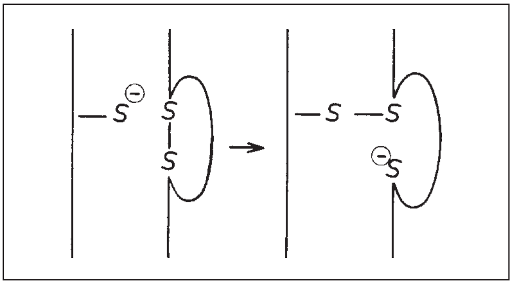
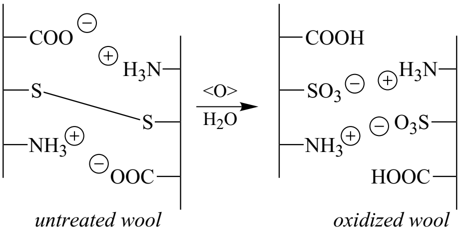


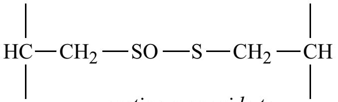
Fig. 8: Crosslinking of wool molecules with inter-chain disulphide bonds through disulphide exchange.

Burley considered the lack of any decrease in cystine content on careful treatment with alkali, but possible decrease in urea-bisulphite solubility, to be due to the formation of a new crosslink system (Fig. 8). During this reaction, an intrachenaric –S–S bond is attacked by a neighbouring SH group to form a new interchenaric cystine link.

The behaviour of wool towards oxidation agents is essentially determined by the disulphide links. Complete oxidation of the cystine groups not only means that the covalent bonds are broken but also the salt linkages:

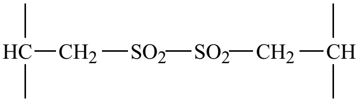


An increase in cysteic acid is characteristic of an oxidative change. During oxidative antifelt finishing and bleaching, the drastic oxidative decomposition of cystine links is highly undesirable due to the associated damage and loss in weight. For this reason, work must always be carried out under mild conditions where the oxidation of cystine can take place without the breaking of links:



$$HC{-}CH_2{-}SO{-}S{-}CH_2{-}CH$$

cystine monoxide to cystine tetroxide



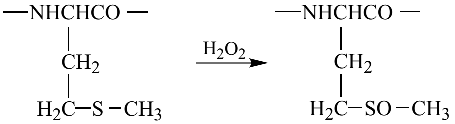
$$HC{-}CH_2{-}SO_2{-}SO_2{-}CH_2{-}CH$$

Other amino acids susceptible to oxidation are, e.g.:

cysteine

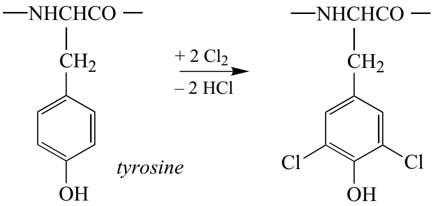
$$\textcircled{W}-SH + HS-\textcircled{W} \xrightarrow{-2\,H} \textcircled{W}-S-S-\textcircled{W}$$

methionine

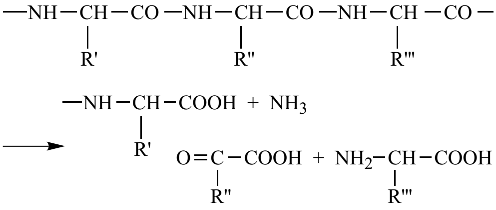


$$\begin{array}{c}\mathrm{-NHCHCO-}\\ |\\ \mathrm{CH_2}\\ |\\ \mathrm{H_2C-S-CH_3}\end{array} \xrightarrow{H_2O_2} \begin{array}{c}\mathrm{-NHCHCO-}\\ |\\ \mathrm{CH_2}\\ |\\ \mathrm{H_2C-SO-CH_3}\end{array}$$

Oxidizing agents can attack the molecule at several locations: the phenolic hydroxyl group can be oxidized and the reactive hydrogen atoms on the phenolic ring can be substituted. In the end, via an intermediate product, this can lead to a break in the peptide chain on the tyrosyl residue:



On the main chain, oxidative cleavage between the NH group and the R–CH residue may take place,



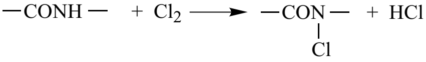
$$\mathrm{-NH-\underset{R'}{\underset{|}{CH}}-CO-NH-\underset{R''}{\underset{|}{CH}}-CO-NH-\underset{R'''}{\underset{|}{CH}}-CO-}$$

$$\longrightarrow \mathrm{-NH-\underset{R'}{\underset{|}{CH}}-COOH} + \mathrm{NH_3} \quad \mathrm{O=\underset{R''}{\underset{|}{C}}-COOH} + \mathrm{NH_2-\underset{R'''}{\underset{|}{CH}}-COOH}$$

which can then lead to the formation of chloramine

$$R-NH_2 + Cl_2 \longrightarrow R-NHCl + HCl$$

and chloramide.



$$\mathrm{-CONH-} + Cl_2 \longrightarrow \mathrm{-\underset{Cl}{\underset{|}{CON}}-} + HCl$$

During chlorination, the N-chlorine links are formed first and this is followed by oxidation of the disulphide bonds and cleavage of the tyrosyl links.

Unlike oxidation, the reducing agent will attack the cystine sulphur in preference. The reductive cleavage of cystine links is utilised in the fixation of the surface of woollen fabrics. During the first stage of chemical fixation, the disulphide links are broken. Various different reducing agents can be used for this purpose:

a) sulphitolysis (sodium hydrogen sulphite)

$$\textcircled{W}-S-S-\textcircled{W} \xrightarrow{NaHSO_3} \textcircled{W}-SH + \textcircled{W}-S-SO_3Na$$

b) hydrolysis (water, alkali and heat)

$$\textcircled{W}-S-S-\textcircled{W} \xrightarrow{H_2O} \textcircled{W}-SH + \textcircled{W}-S-OH$$

c) thiolysis (hydrogen sulphide)

$$\textcircled{W}-S-S-\textcircled{W} \xrightarrow{H_2S} \textcircled{W}-SH + \textcircled{W}-S-SH$$

d) mercaptolysis (thioglycolic acid: $HOOC–CH_2–SH$)

$$\textcircled{W}-S-S-\textcircled{W} \longrightarrow \textcircled{W}-SH + \textcircled{W}-S-S-CH_2-COOH$$

The thiol groups which are produced react with the neighbouring disulphide links during the second stage, in a so-called thiol-disulphideexchange, leading to a rearrangement of the sulphur links. During the last stage, the disulphide links are closed again by oxidation, thereby stabilizing the new fibre structure.

In 1955, Burley suggested a theory for the mechanism of wool fixation. According to this, the permanent fixation relies on the action mechanism of a thiol-catalysed disulphide exchange. The formation of thiol groups brought about by the cleavage of disulphide bonds follows the set up below:

$$R-S-S-R + NaHSO_3 \rightleftharpoons R-SH + NaSO_3-S-R$$

There is only a small number of thiol groups in wool fibre. Their number is increased by reaction with reducing agents or hot water, steam or alkali. In the case of stretched fibre, the thiol bond is formed in the vicinity of a disulphide bond. During this process, the disulphide bond is broken by the free thiol group, while a new thiol group and a new disulphide bond are formed. The new free thiol group also cleaves a disulphide link, while again a free thiol group and a new disulphide link are produced.

A schematic of the “zip-fastener” mechanism by which the thiol-catalysed disulphideexchange reactions promote and stabilize fixation is shown in Fig. 9.

Wool fibres are not only stabilized by covalent bonds but also, and more particularly, by hydrogen bonds. The function of fixing agents consists of cleaving enough disulphide links to weaken the stability of the wool fibres. This eases deformation.

Under the influence of moisture and high temperature or hydrogen-bond cleaving agents such as urea, fixation is brought about by re-orientation of the hydrogen bonds.

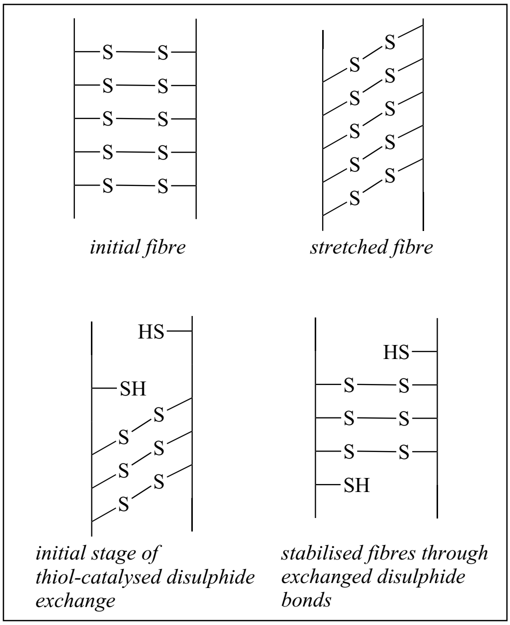


Fig. 9: The thiol-catalysed disulphide exchange mechanism.

With Kier decatizing, a process has been available for permanent fixation of woollen fabrics since the mid 1960's. The permanent fixation of stretched woollen fabric can be summarized as follows. The stretching process stresses the interactions which stabilise the keratin lattice. Hot water or steam splits the hydrogen bonds and salt linkages. This process has a loosening and weakening effect on the molecular structure. Reducing agents can penetrate to the covalent bonds more easily and faster and cleave them according to the thiol-catalysed, disulphideexchange mechanism. After the wool fibre has been deformed and the hot water or steam has been removed, new hydrogen bonds and salt linkages are formed which stabilise the newly imposed shape of the wool fibres.

In drawing up a list of fixation processes in order of their intensity, it is possible to say, with some reservation, that the effects of treatments using mild conditions – which merely consist of reorienting the hydrogen bonds and the effects of treatments using strong conditions (which also involves modification of the disulphide bonds) – increase in intensity in accordance with the following sequence:

- crease formation while the woollen article is being used,
- shrinkage on the London shrink unit,
- drying on the stretching machine,
- pressing,
- finish decatizing,
- press luster decatizing,
- kier decatizing,
- chemical fixation.

According to this, chemical fixation is the most intensive form of treatment as the moisture and sulphite-based reducing agent softens the sulphur-rich keratin matrix. The softened material can therefore be easily deformed under pressure. After deformation, the softening effects are easily removed by oxidation, in the simplest case, by hot air followed by drying, and the material is therefore fixed in the newly imposed shape.

Wool/cotton union, acidic single-bath dyeing The dyeing of wool/cotton unions using the single-bath method with union dyes or with wool dyes and direct dyes in acetic acid liquor, plus suitable levelling and retarding agents. Advantages: gentle treatment of wool, improved handle of fabric, tone-in-tone dyeings or two-colour effects achieved when the choice of dye is appropriate. Even condition largely retained in the case of wool/mohair plush.

Wool/cotton union/polyamide, dye range All union dyes are suitable. For plain dyeing, the addition of special retarding agents is beneficial for the avoidance of strong adsorption of mixed wool dyes on to polyamide. For bicolour dyeing, it is imperative.

Wool damage → Fibre damage (wool), tests for.

Wool dyeing The presence of acid and basic functional groups on the side chains of the fibre protein are a basic requirement for the dyeing of wool with anionic and cationic dyes (Fig. 1). The dyes which are suitable for colouring wool are classified in accordance with their chemical structure and behaviour as follows:

- acid dyes (world-wide, approx. 0.4 million t),
- metal-complex dyes (1 : 1 complex: world-wide, approx. 0.1 million t; 1 : 2 complex: approx. 0.4 million t),
- chrome dyes (world-wide, approx. 0.6 million t),
- reactive dyes (world-wide, approx. 0.1 million t, trend increasing).

Important factors for the even dyeing of wool are:

- affinity,
- dye uptake (substantivity),
- migration properties,
- degree of dispersion of the dye.

The exhaustion rate of dyes (Fig. 2) is mainly determined by their diffusion properties. Due to their high diffusion rates, dyes with small molecules have a fast exhaustion rate whereas those with large molecules have a relatively low exhaustion rate. The exhaustion rate is also dependent on the degree of affinity between the fibre and the dye.

As a general rule for the migration capacity of dyes, those with small molecules (levelling dyes), due to their lower bonding capacities arising from van-der-Waal forces and because of their high diffusion capacity, migrate relatively well and therefore compensate for the disadvantages of a high exhaustion rate. Dyes with

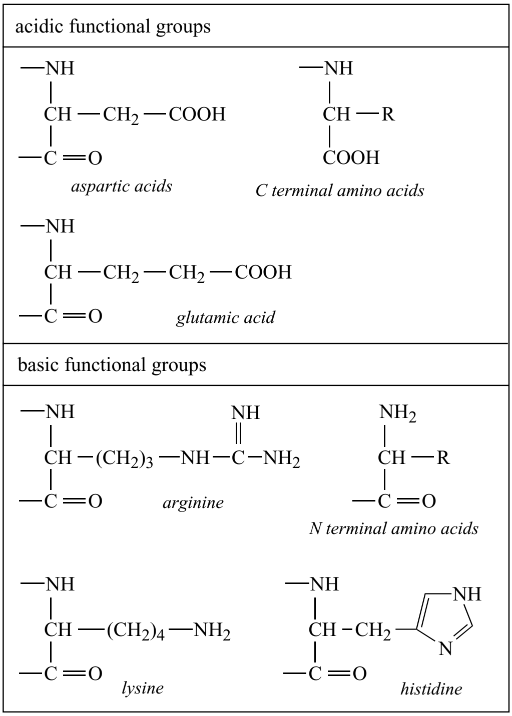
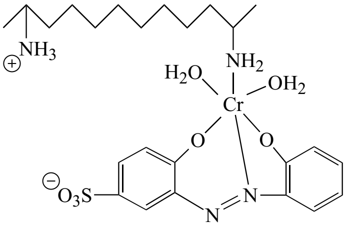


Fig. 1: Possible functional wool groups which can react with dyes.

large molecules (milling dyes and 2 : 1 metal complex dyes), on the other hand, hardly migrate at all or only migrate a little because of their high affinity and low diffusion capacity, and because of their relatively low rate of adsorption, can easily dye unevenly. The wet fastnesses of wool dyeings are directly related to the migration capacities of the dyes (Fig. 3).

The dye/fibre bond is determined by physical and chemical interactions which more or less result in the dye being immobilized. Apart from the hydrogen bonds, van-der-Waal forces and hydrophobic interactions, the most important bonding forces, are as follows (Fig. 4):

1. Ionic bonding: in the case of anionic dyes, the ionic bond is derived from the electrostatic attraction between the positively charged amino groups on the wool and the negatively charged dye ions. The ionic bond is relatively weak and can be removed by modifying the charge on the wool (by increasing the pH). Additional forces are therefore necessary to achieve an adequate fastness.
2. Coordinate bonding: for chrome dyes and 1 : 1 metal complex dyes, apart from the forces already mentioned, coordinate bonds are formed between the chrome atom of the dye complex and the amino and imino groups on the wool.



With 1 : 2 metal-complex dyes, this possibility does not exist because the coordination sites on the chrome atom are both taken up by the two associated dye molecules. Formation of the metal complex

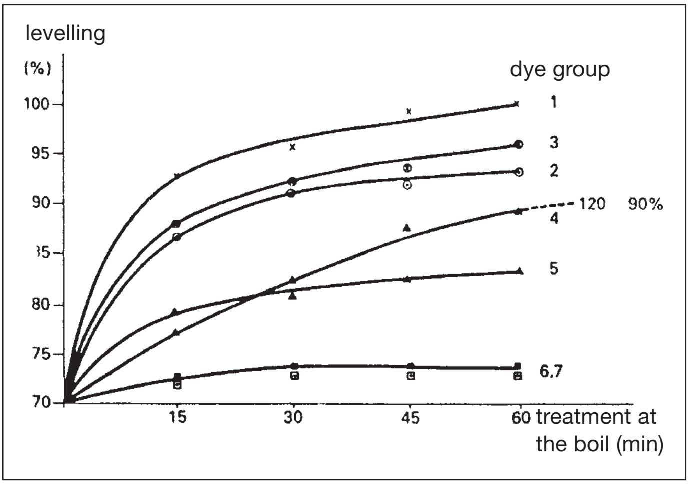


Fig. 2: Migration behaviour of wool dyes.
1 = strongly acidic levelling dye;
2 = slightly acidic levelling dye;
3 = acid dye; 4 = 1 : 1 metal-complex group; 5 = 1 : 2 metal-complex group;
6 = 1 : 2 metal-complex group with 1 sulphonic group; 7 = 1 : 21 : 2 metal-complex dyes with 2 sulphonic groups.

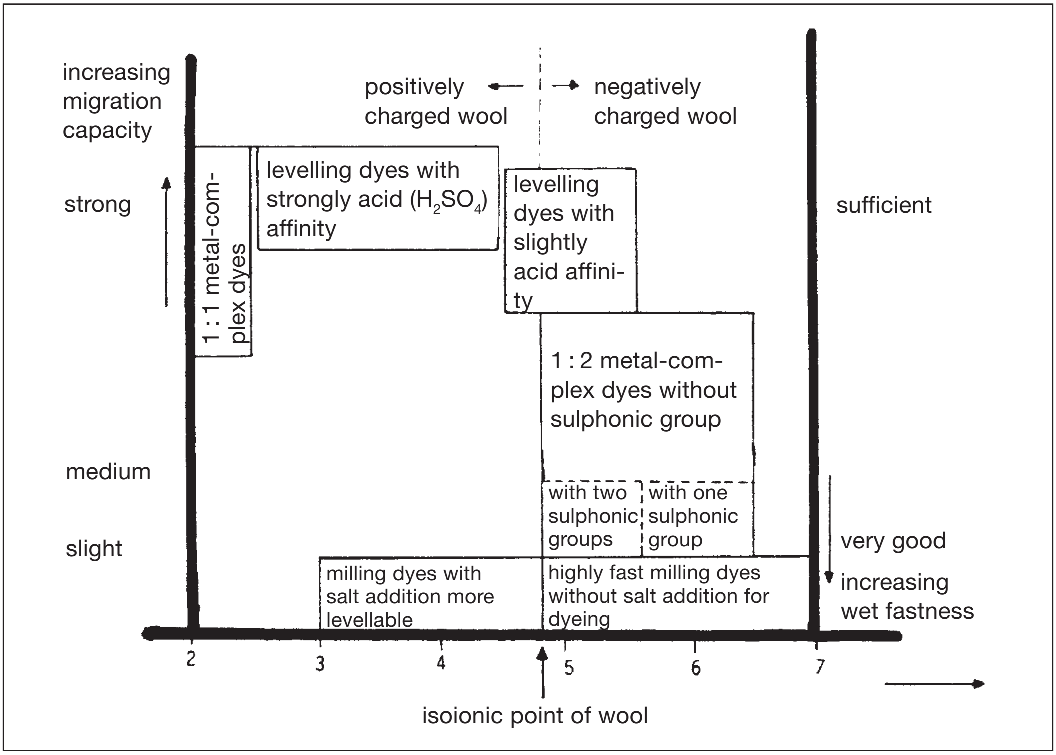


Fig. 3: Connection between migration capacity and wet fastnesses of dyes.

does not take place until it is rinsed with weak acid, the amino groups which are capable of reacting, only being formed in the acid range where they exist as ammonium ions.

3. Covalent bonding: reactive dyes can also form covalent bonds with the reactive groups on the wool. Under dyeing conditions, it is supposedly the thiol, amino and imino groups which become available as the reaction partner (Fig. 5).

Mechanism of the dyeing process: under strongly acid conditions, the carboxyl groups on the wool are protonated first. The acid anions rapidly diffuse into the fibre

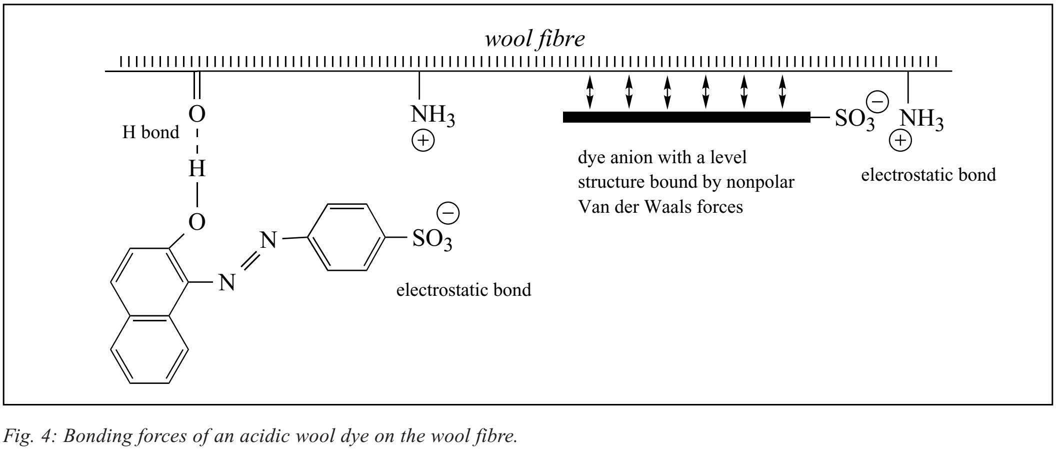


Fig. 4: Bonding forces of an acidic wool dye on the wool fibre.

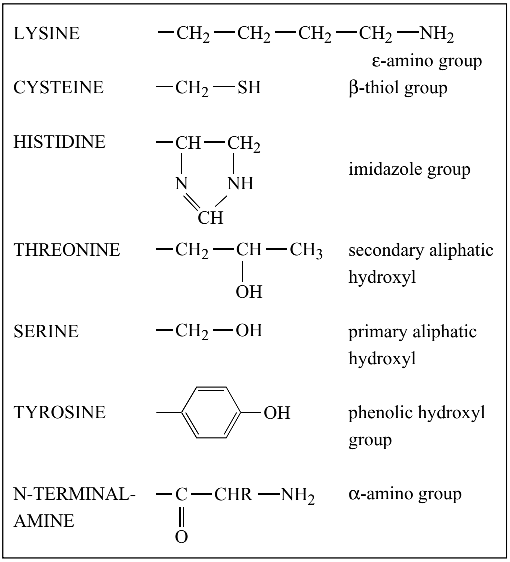


Fig. 5: Wool side chains which can react with reactive dyes.

to produce a state of electro-neutrality. Due to the affinity between the dye and fibre, the slowly diffusing dye anions replace the inorganic anions as the dyeing time increases, i.e. the dye is bonded to the fibre in an ion exchange reaction. These type of dyeing conditions are mainly to be found in the case of dyes with a lower affinity for wool, such as levelling acid dyes. The high concentration of cationic groups at pH 2 provides the necessary attraction for the dye anions. Under these conditions, the addition of salt, for example sodium sulphate, may have a levelling effect. Because of their superiority in numbers, the additional sulphate ions compete with the dye for the cationic ammonium groups on the wool. Fig. 6 shows the effect of using sodium chloride or hydrochloric acid against dyeing time.

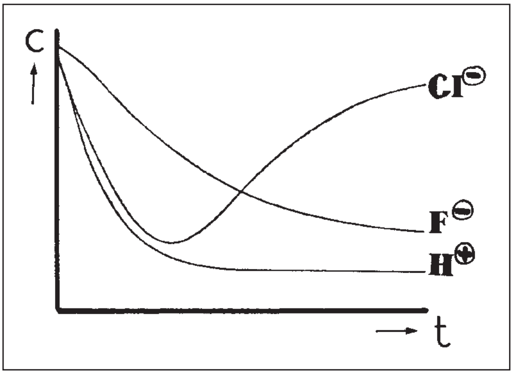


Fig. 6: Diagram of the variation with time of the concentration of dye, hydrogen and chloride ions in a wool-dyeing acid dye bath.
c = concentration; t = dyeing time.

For dyes with higher affinities, such as 1 : 2 metal complex dyes, the non-polar interactions between the dye and the fibre are sufficient for adsorption, so dyeing can be carried out under neutral conditions. The dye anions adsorb on to the fibre first and the sodium ions follow in order to ensure electro-neutrality. In this case, the sodium salt of the dye is bound. Adding sodium sulphate usually leads to the “salting out” of dye on to the fibre, i.e. instead of producing a retarding, levelling effect, adding sodium sulphate leads to a larger degree of exhaustion of the dyebath.

Levelling agents: as already mentioned, in strongly acid conditions, sodium sulphate takes on the role of a levelling agent. In the case of dyes with high affinity, to achieve even dyeings, it is appropriate to add levelling agents which

- temporarily reduce affinity,
- reduce the exhaustion rate,
- improve the migration capacity,
- equalize differences in affinity on the wool.

By means of their ionic character and affinity, levelling agents are classified into either fibre-affinity or dye-affinity auxiliaries. Non-ionic and amphoteric auxiliaries which have a high affinity for dyes are important for 1 : 2 metal-complex dyes.

Under the normal conditions of wool dyeing in the weak acid range, the driving force for bath exhaustion is the potential difference between the dyes with negatively charged SO_3 groups and the positively charged wool (Fig. 7).

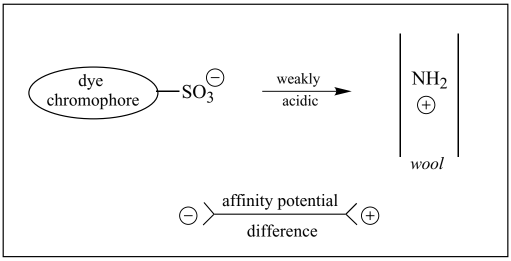


Fig. 7: Normal condition of an acidic wool dyeing without levelling agent using dyes containing SO_3 groups.

Dyeing in the presence of a levelling agent (Fig. 8) can result in a dye/auxiliary complex, the total negative potential of which produces increased dye affinity. This increases bath exhaustion, deepens dyeing, reduces the effluent produced and makes the dyeing process more economic.

Levelling is achieved by the complex, which has

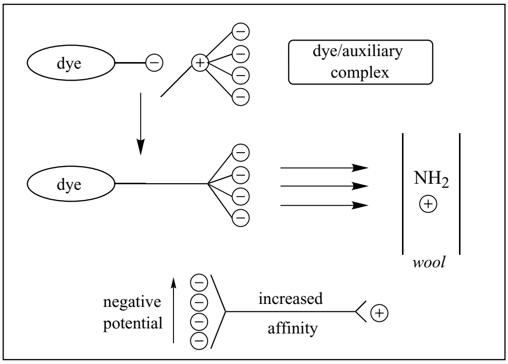


Fig. 8: Dyeing method using levelling agent and dyes containing SO_3 groups (according to Stockhausen).

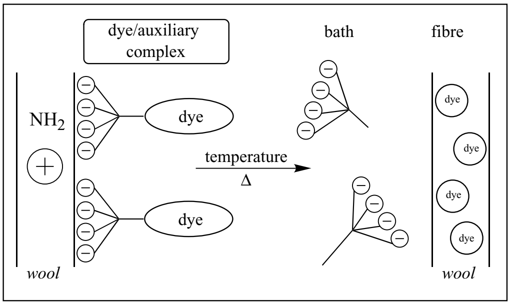


Fig. 9: Levelling mechanism at the boil with dyes containing SO_3 groups (according to Stockhausen).

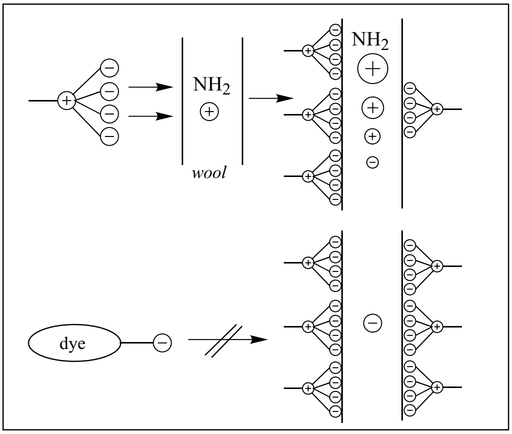


Fig. 10: How a levelling agent acts as a retarder through transpolation of the wool fibre charge (according to Stockhausen).

adsorbed on to the fibre at low temperature (Fig. 8), decomposing at the higher fixing/boiling temperature (Fig. 9), so that the dye can diffuse into the fibre while the levelling agent remains in the liquor.

If wool dyes are used which are free of SO_3 groups, then routes are possible for the dye/levelling agent/fibre interaction: the retarding properties of the auxiliary may dominate when it has a high affinity for the fibre and reverses or decreases the polarity of the charge on the fibre (Fig. 10).

Increasing the temperature gradually removes the fibre-affinity auxiliary and the fibre gradually recovers its positive charge; the dye fills up slowly (with levelling).

The dye affinity of the auxiliary is less important (Fig. 11). A surfactant micelle is produced which incorporates the dye. Due to its hydrophilic properties, this micelle is oriented towards the liquor (the micelle is very soluble) and has limited mobility in the bath due to its large volume.

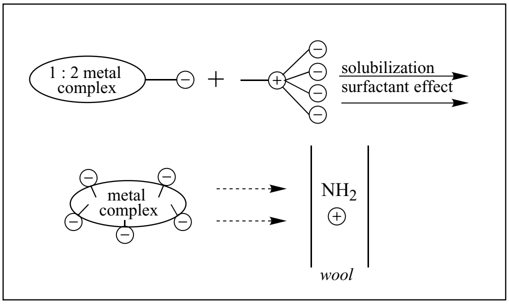


Fig. 11: Dye affinity of an auxiliary towards dyes not containing SO_3 groups (according to Stockhausen).

Damage to the fibre: during treatments involving boiling, wool is subject to changes to its chemical and mechanical properties. In addition to this, the pH difference at the isoelectric point of wool and the time factor at the boiling temperature are also important dyeing conditions. If the pH deviatiates slightly from the pH at the isoelectric point, reversible cleavage of the salt-linkages and hydrogen or hydroxide ion bonds will take place but may be reversed by rinsing under neutral conditions.

Irreversible damage is caused by highly concentrated acids or alkalis as well as by long treatment times at higher temperatures. When dyeing under strongly acid conditions, the peptide links experience hydrolytic attack which is characterised by decomposition of the fibre protein to their amino acids via simple peptides (→ Degradation). In preference, this takes place on the amino groups of aspartic acid and serine. As the wool degrades, protein fragments are released from the fibre in the form of wool gelatine. Due to its high swelling capacity, the wool gelatine comes from the non-ker-

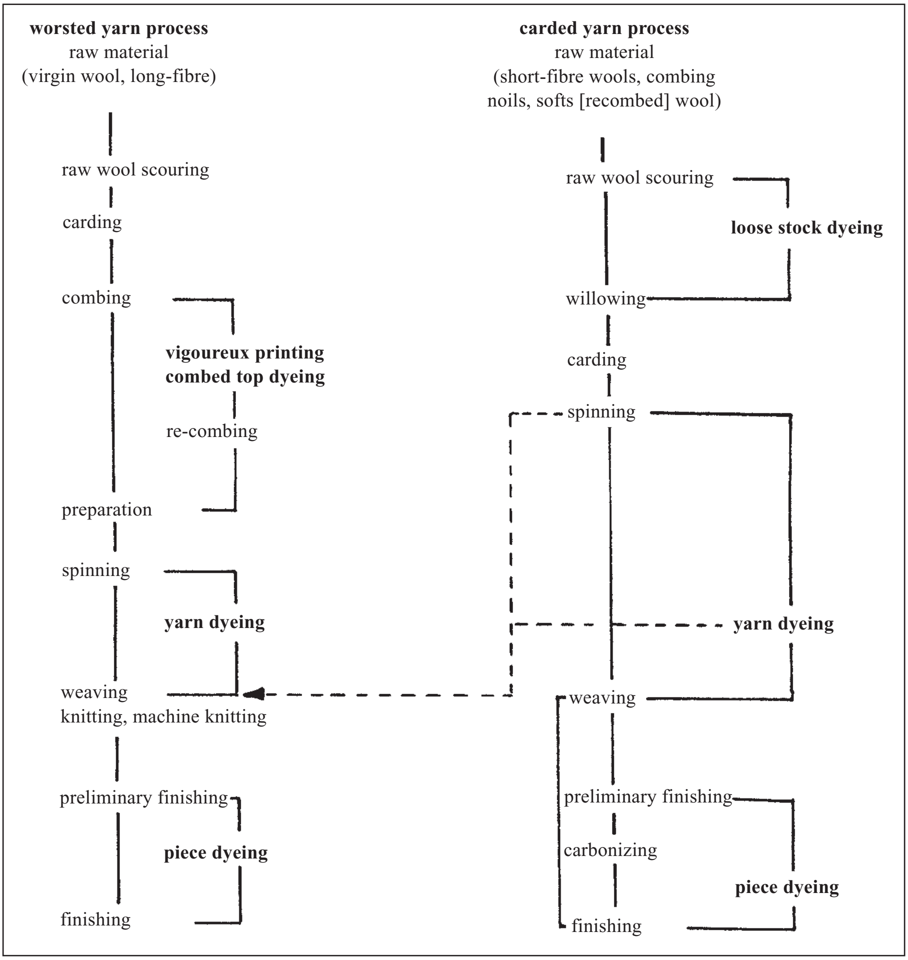


Fig. 12: Wool make-up forms for dyeing at various finishing stages.

atin proteins. In addition to this, the cell-membrane complex of the cortex is attacked in the strongly acid range and the endocuticle is probably attacked in alkali. Under alkaline conditions, almost all types of bond are attacked but especially those of cystine. Different decomposition and intermediate products are produced and new crosslinks, such as lanthionine, are formed at the same time.

Make-ups: wool appears in different make-ups depending on the finishing stage during which dyeing is to be carried out (Fig. 12). For reasons of economy, storage and delivery time, etc., an effort is made to finish the wool as near to the final article as possible. Thus, piece dyeing and the dyeing of ready-to-wear knitwear has become considerably more important. It is possible to dye the web or knitwear in wide or rope form. The deciding factors in this choice are the properties of the fabric, such as its tendency to crease and felt. The requirements for piece dyeing are as follows:

- surface evenness, especially if different wool qualities have been used,
- the possibility of correcting defective dyeings,
- maintenance of wool quality,
- fastness requirements both during manufacture and during use.

Dyeing method: by exploiting all the technical understanding in terms of dyeing and materials, the dyeing process should be controlled so as to produce reproducible, even and economic dyeings with as little damage to the wool as possible. The starting point is the method of controlled adsorption which is split into the process steps shown in Fig. 13.

1. Combination compatibility: in order to avoid variations in shade and unevenness, dyes should be selected which have similar exhaustion curves.
2. Final bath exhaustion: if this is high, it will result in good reproducibility, high dye yield and low effluent loadings. Bath exhaustion is limited by the de-

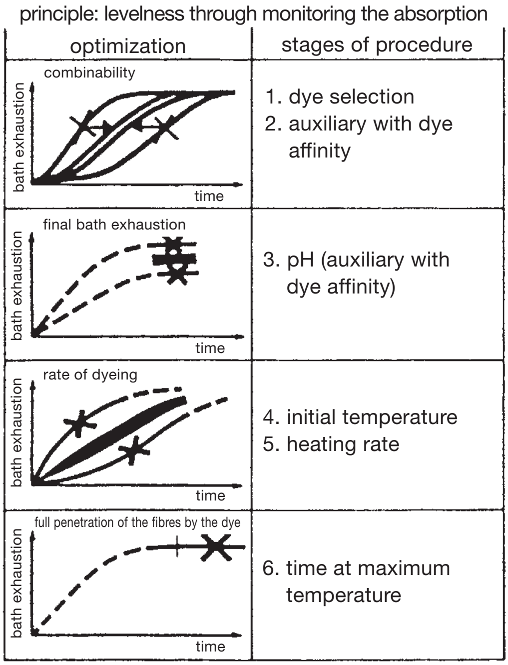


Fig. 13: Systematic wool dyeing process (by Bayer).

gree of evenness which is to be achieved. It is dependent on the operating conditions, type of dye, depth of dyeing and the affinity of the wool and should be controlled by the pH and the auxiliary.

3. Starting temperature: the starting temperature must be selected to achieve slow exhaustion (dead time) while avoiding an initial adsorption which is too fast and non-uniform. Also to be taken into account is that the wool is more accessible at higher temperatures and dye aggregation decreases.
4. Exhaustion rate: this should be selected so that the adsorption of 80% of the dye is controlled. The exhaustion range should be 50°C, as calculated from the starting temperature. Dye adsorption can also be controlled by metering the dye or the acid, in which case the difference between the start temperature and the dyeing temperature can be reduced and the exhaustion rate can be increased.
5. Penetration dyeing: the reduction in dyeing time at maximum temperature is limited by the penetration of dye into the fibre and a uniform scale structure.

Wool dyeing, afterchrome process When dyeing wool according to the afterchrome process, only those dyes can be considered which contain functional groups capable of forming ultra complexes. In most cases, these are hydroxyl groups which are situated in the ortho position in relation to the azo group on the aromatic ring (→ Wool dyes).

During the dying process, the dye first adsorbs on to the wool fibre like an acid dye. The fastness of the wool dyeing is significantly improved by fixing the acid dye with Cr^{3+} ions. When afterchroming using $K_2Cr_2O_7$, a redox reaction takes place with the wool. As the potassium dichromate is a strong oxidizing agent, it is capable of reacting with the amino acid, cystine (Fig. 1). Because of their anionic nature, sulphonic acid groups can either act as a source of surface charge or, in their role as charged functional groups, soften the scale structure by absorbing water into the outer regions of the wool fibre by osmosis.

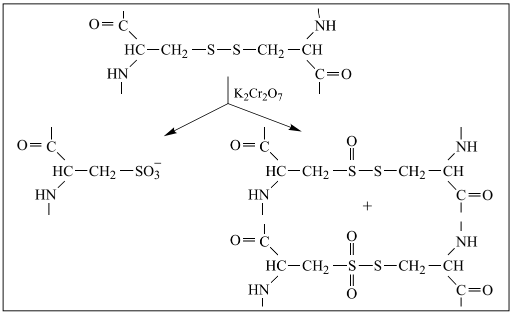


Fig. 1: Possible oxidation products of cystine on aftertreatment with potassium dichromate.

The Cr^{3+} ions produced are complexed by the dye ligands and the functional groups of the wool. Direct use of Cr^{3+} salts prevents complex formation with the dye molecules as the hydrolysed Cr^{3+} ion is relatively inert to substitution and adsorbs very poorly on to the wool.

When afterchrome dyeing, it must be ensured that exhaustion of the dye from the dye liquor is, if possible, complete, otherwise the dye remaining in the bath will afterchrome as well and then deposit onto the fibre surface. This will result in diminished rubbing fastness for the dyed goods.

During the afterchrome dyeing of wool, crosslinking is also possible between the protein chains due to the effect of potassium dichromate (for example, by complexing two dye ligands bonded to two different protein chains). As mentioned before, potassium dichromate is a strong oxidizing agent. This means that, in the case of amino acids which are sensitive to oxidation such as cystine, the redox reactions which take place can yield a large number of oxidation products.

Currently, afterchrome dyes cannot be replaced mainly because of the level of fastness. Apart from that, using afterchrome dyes is significantly cheaper than using reactive dyes. However, when using chrome dyes, a decrease in the effluent loading must be

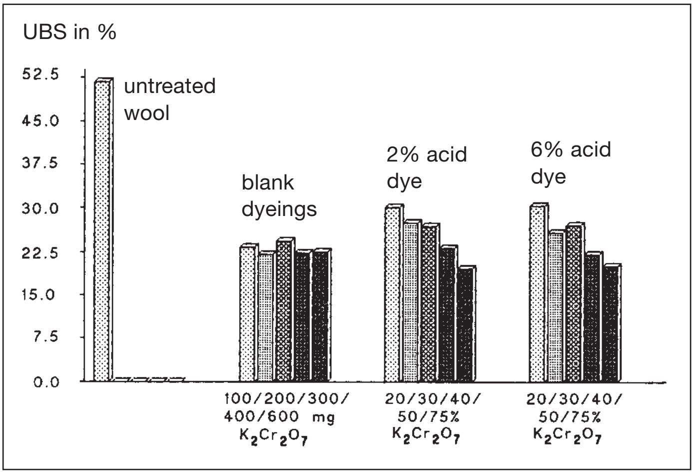


Fig. 2: Urea bisulphite solubility of wool combed tops after blank dyeing and dyeing with an afterchrome dye with the addition of various quantites of potassium dichromate (according to Höcker et al.).

achieved by using the smallest quantity of chrome salts (by observing the chrome factor).

The urea bisulphite solubility steadily decreases with increasing amounts of potassium chromate. This is indicative of the appearance of new crosslinking sites during afterchroming, as the acid dye which is used does not lead to any change in the bisulphate solubility in relation to the dye concentration (Fig. 2).

It can be presumed that, after the addition of potassium dichromate, redox reaction takes place between the wool and the dichromate anion, during which Cr^{3+} ions are formed, which are not yet solvated. In a competitive reaction, these chrome ions can form ligands both with water and dye molecules. Even a few functional groups on the wool, such as the ε-amino group of lysine, can provide donor ligands and form a complex with the chrome ion. It is certain that the dye molecules will predominantly react with the formation of Cr^{3+} ion complexes, as the formation of chelate complexes is thermodynamically more favourable than the formation of mono-dentate ligands such as water. The formation of 1:2 metal complex dyes on the wool results in new crosslinking sites when the two dye ligands are bonded to two different protein chains. These additional crosslinking sites may explain the decrease in keratin solubility found in solutions containing urea bisulphite.

In the case of the amino acids serine and threonine, which have a single aliphatic hydroxyl group on the amino acid side chain, using potassium dichromate may result in the oxidation of the OH group of the aldehyde or carboxyl group. The aldehyde group produced may react further during crosslinking, which may explain the reduced solubility seen in the urea bisulphate test. A possible reaction of the aldehyde group may take place with the free amino groups of the proteins (for example, with the ε-amino group of lysine) during the formation of a Schiff base (Fig. 3).

Very little is known about the possible reactions between potassium dichromate and wool during afterchroming, so further work is needed in order to clarify the position in regard to these reactions and their products (according to Virnich).

Wool dyeing at the isoelectric point Wool can be dyed particularly gently by using selected dyes (Fig. 1)

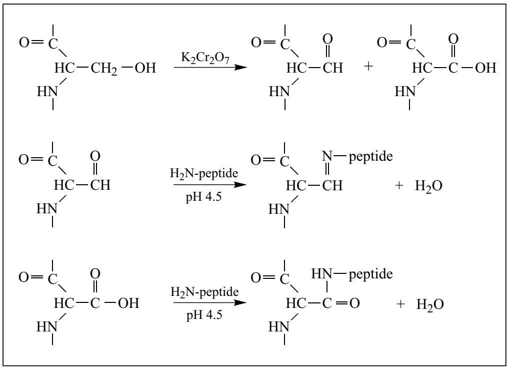


Fig. 3: Possible crosslinking between proteins through the influence of potassium dichromate.

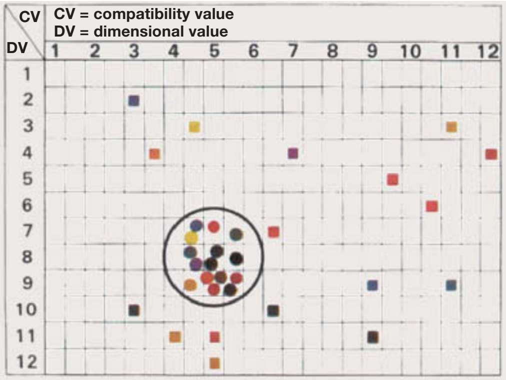


Fig. 1: Wool quality after treatment at different pH values (by Ciba Geigy).

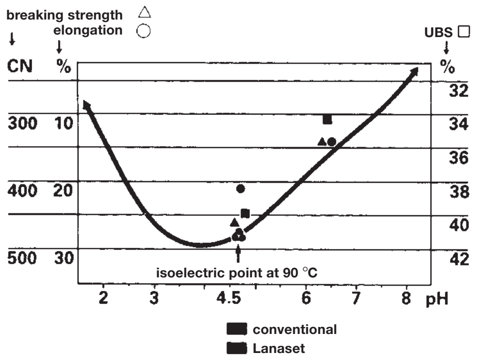


Fig. 2: Wool dye combination possibilities through selection (Ciba Geigy Lanaset dyes). CN = Centi Newtons; UBS = Urea bisulfite solubility.

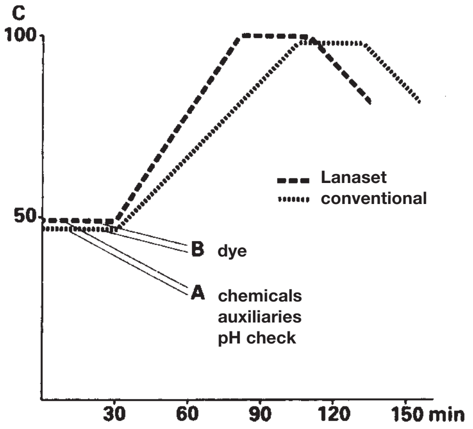


Fig. 3: Dyeing process using Lanaset dyes (Ciba Geigy).

which combine well in the vicinity of the isoelectric point, i.e. exhaust at the same rate, and suitable auxiliaries (Fig. 2). Fig. 3 shows the relevant dyeing trend in comparison with one for conventional dyeing methods at pH 6–7.

Wool dyeing, isothermal The amino groups of wool are positively charged in the acid range. This means that it is possible to dye wool using anionic acid dyes. The maximum adsorption of acid 1 : 2 metal-complex dyes in a neutral pH range, which is mild for wool fibre, can be achieved by using salts which increase the ionic strength of the solution. The titration curve mirrors the corresponding bonding capacities of acid and caustic with and without the addition of salt.

Of course, the reaction of wool with dyes in the acid range not only relies on an ion-exchange mechanism, there are other complex interactions which influence the dyeing process just as much. Although a titration curve for wool makes it possible to control the exhaustion of the dye from the bath in a manner which is common practice in industry (Fig. 1), i.e. via specified temperature/time trends, a dyeing method which is isothermal is just as conceivable, if the acid addition is regulated using a closed-loop control circuit and the course of the bath exhaustion consciously controlled. A process such as this presupposes the use of mechanical devices which, apart from recording changes in the conditions, colour, pH, conductivity and liquor throughput in

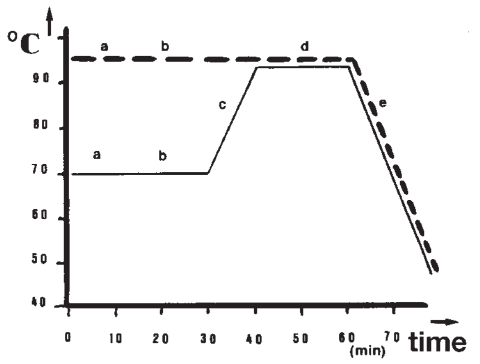


Fig. 1: The dyeing process with the isotherm (dotted line) and classical dyeing methods, using Isolan S dyes (Bayer), press thickness 540 g/l of the yarn packages. a = prewetting; b = acid addition; c = heating; d = setting; e = rinsing.

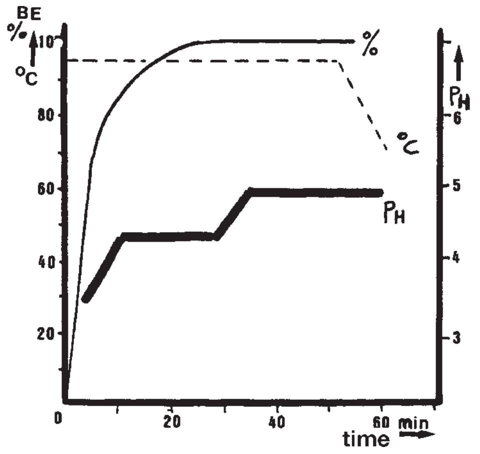


Fig. 2: Dyeing course under isothermic dyeing conditions according to the "all-in" process with single liquor flow direction, using Isolan S dyes (Bayer) with package dyeing whilst gradually adding acid.

the dyeing machine by means of suitable sensors, also contain efficient controllers (Fig. 2).

In the dyeing of polyamide fibres in carpet dyeing using the exhaustion method, the current technology is to control bath exhaustion at boiling point by metering the acid. Only the end groups and carbonamide groups react with acid in the case of polyamides, so the behaviour of the complex side-chain structure of wool in response to the metered acid is the reason for pH-controlled wool exhaustion dyeing having so far only been used in practice in batch processes. Mosimann has done the most detailed work on the pH control of wool dyeing where, as usual, the bath temperature was raised continually together with a decrease in pH produced by adding sulphuric acid. The technical advantage of pH-controlled wool dyeing is realized as follows: the negative effects of fluctuating process-water quality or the effects of the alkali or acid residues in the substrate from the initial stages cause the actual pH to deviate from the set-point pH. Timely correcting these deviations using measurement and control systems means that the dyeing result of the batch in question is not put at risk.

Wool dyeing (loose wool dyed articles) Unlike → Piece dyeing or → Yarn dyeing, this refers to articles which are dyed in the flock (carded yarn) or in the combed top (Worsted yarn). → Loose stock dyeing.

Wool dyeing under strongly acidic conditions Dyeing with 1 : 1 metal-complex dyes at pH 2 leads to significant damage to the wool fibre due to hydrolysis and extraction of parts of the cell membrane complex (Fig. 1).

When wool undergoes hydrolytic degradation at pH 2 and temperatures from 80–120°C, it is known that peptides hydrolyse, N-terminal acetyl groups split off and protein fragments leach out of the wool in the form of wool gelatine. This produces the following relationships: in all cases, the temperature dependence is quadratic and time dependence is linear. Cleavage of the acetyl groups follows a similar trend.

1912	BASF develops and patents the first 1 : 1 MCD, though without colouristic application
1915	The Gesellschaft für Chemische Industrie [Chemical Industry Society] in Basel First patent application for 1 : 1 MCD on wool
1919/20	from CIBA; first Neolan dyes on the market BASF; Palatin fast dyes are introduced
1924	Neoplan Blue 2G, the oldest Neolan dye which still forms part of the range
1950	Neoplan Blue 3R, the most modern Neolan dye
1954	BASF introduces Neopalatin dyes (1 : 1 metal-complex dyes with clear ligand) onto the market, taken off the market at the beginning of the sixties
1984	First patent application for modified 1 : 1 metal-complex dyes
1988	15th February, introduction of the Neoplan Plus system for wool, consisting of 7 Neoplan P dyes

Tab. 1: How 1 : 1 metal-complex dyes (1 : 1 MCD) for wool developed.

Until now, approx. 50% mono- and disulphonic acid levelling dyes and approx. 50% 1 : 1 metal complex dyes (under strongly acid dyeing conditions) have been used in piece dyeing. 1 : 2 metal complex dyes and re-

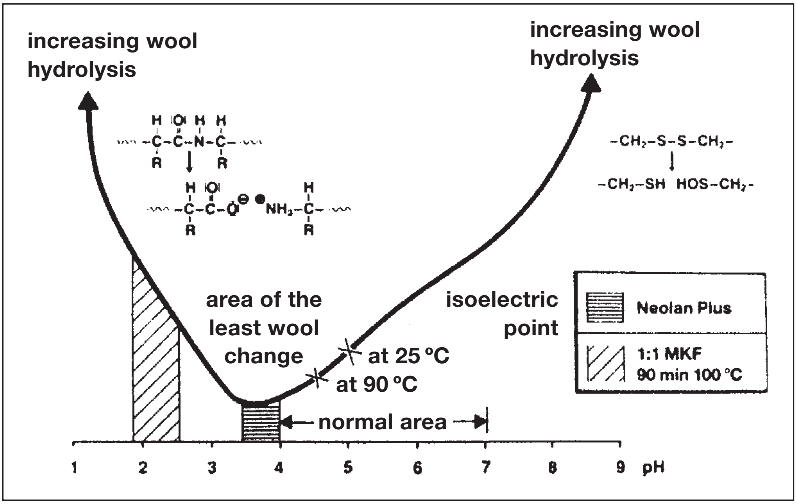


Fig. 1: Wool hydrolysis and the area of the least wool change depending on the pH of the dye bath at 100°C.

active dyes are relatively little used as they highlight deficiencies or defects in the pre-treatment of piece goods.

1 : 1 metal complex dyes have been used in the piece dyeing of wool for about 70 years (Tab. 1). To some extent, they have replaced acid dyes, particularly in the case of middle to dark shades.

Advantages:

- good levelling and penetration, even in the case of closely woven goods,
- dyeing of carbonised, non-acid-free goods,
- better wet fastnesses than acid dyes for middle to dark shades.

Disadvantages:

- strongly acid (sulphuric acid) dyeing conditions have a negative effect on fibre properties such as wear resistance and stretching,
- in the case of dark shades, residual sulphuric acid in the goods has to be buffered.

During the past 15 years, some progress in optimising the process has been made, such as dyeing with reduced amounts of sulphuric acid using special auxiliaries or replacing the sulphuric acid with sulphamic acid (1982). However, these can only be regarded as partial solutions.

Established criteria and boundary conditions have led to a dyeing system consisting of the three following extended components:

- a small gamut of 8 modified 1 : 1 metal complex dyes (yellow to black);
- a special auxiliary,
- pH 3.5–4 for all colour depths and make-ups, adjusted using formic acid.

Modified 1 : 1 metal complex dyes, an example of which is the oldest representative, Neolan Blue 2G, commercially available since 1924, demonstrate the possibilities of a ligand exchange at the trivalent chrome atom with a coordination number of 6 (Fig. 2).

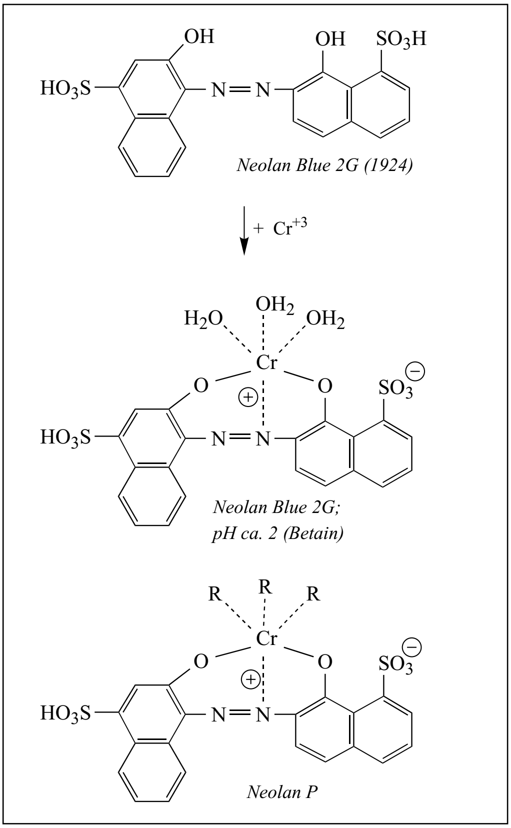


Fig. 2: New modified 1 : 1 metal-complex dyes.

Modified 1 : 1 metal complex dyes contain fluorosilicate. The modification is produced when the dye is dissolved in almost boiling water (minimum final temperature 80°C) in relatively concentrated form. 1 : 1 metal complex dyes such as these can used for the gentle dyeing of fibres at pH 3.5–4 in the presence of special levellers (with formic acid).

Typical chemical data for wool which has been dyed conventionally at pH 2 using 1 : 1 metal complex dyes

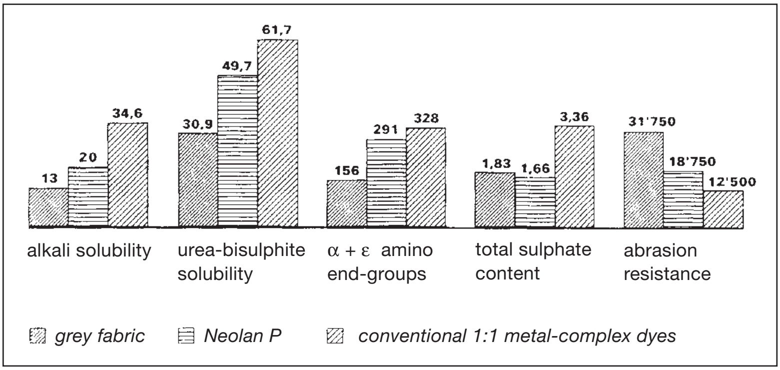


Fig. 3: Chemical and physical tests of carbonised carded yarn wovens (by Ciba Geigy).

article/care level		water	washing	sweat
hand knitting yarn				
care level 1	(no antifelting finish)	3–4/3–4/3–4	——	——
care level 2	(non-felt, non-shrink)	——	3/3–4/–	——
care level 3	(machine wash, gentle cycle 30 °C)	——	3/3–4/–	——
care level 4	(superwash, machine wash, 40 °C)	——	3–4/4/3–4	3–4/4/3–4
care level 1	(as above)	3/3/3	——	——
care level 2		——	3/3–4/–	——
care level 3		——	3/3–4/–	——
care level 4		——	3–4/4/3–4	3–4/4/3–4

Tab. 2: IWS minimum requirements for woolmark products.

and at pH 3.5–4 using modified 1 : 1 metal complex dyes is shown in Fig. 3.

The relationship between different easy care steps and wet fastnesses required for them has been clearly established (Tab. 2). While good wash fastness is sufficient for care step 1, care steps 2–3, i.e. felt-free finished qualities, require a wash fastness of 30°C ; for care step 4 (superwash standard) specific regulations such as perspiration fastness and wash fastness with perborate apply, the difficulty being that chlorine or resin finished accompanying material must also be used at the same time.

Felt-free finishing wool also introduces colour problems and even problems in terms of evenness and fastness. A chlorination treatment, such as that used for the type of finishing considered here, recognizably increases the adsorption rate of dyes and reduces their wet fastness. Although using dyes with good migration properties produces a result with a high level of uniformity, problems arise with reproducibility or wet fastness. If, on the other hand, wet-fast dyes with lower migration capacities are used, the reproducibility and wet-fastness problems are avoided but difficulties arise with uniformity, especially when dyeing high-twist hand-knit yarns and knitwear. The cause of these difficulties lies in the chemical nature of wool dyes as these are characterized either by high wet fastness or good levelling properties.

The diagram in Fig. 4 shows the relationship between the dyeing properties of the most important group of wool dyes and their wet fastness. The sulphuric-acid adsorbing dyes, which have outstanding migration properties but correspondingly low wet fastness, are at the top left of the diagram (the equilibrium tends towards the dyebath). The neutral-adsorbing 2 : 1 metal complex dyes, which tend to migrate less and have correspondingly high wet fastnesses, are on the bottom right of the diagram. Dyes are now being

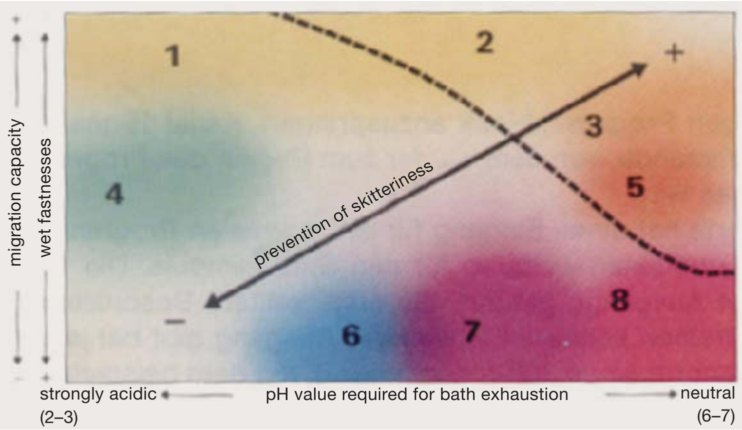


Fig. 4: The behaviour of acidic and metal-complex dyes on wool (by Sandoz).
Dye classes: 1 = dyes with sulphuric acid affinity; 2 = dyes with formic acid affinity; 3 = dyes with acetic acid affinity; 4 = 1 : 1 metal-complex dyes; 5 = acid dyes; 6 = disulphonated 1 : 2 metal-complex dyes;
7 = monosulphated 1 : 2 metal-complex dyes; 8 = neutral dyeing acid dyes.

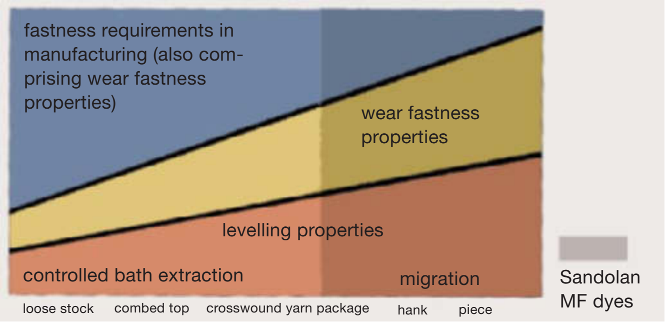


Fig. 5: The dependency of wear fastness properties and fastness requirements in manufacturing (not including light fastness) on affinitative and migrational behaviour (by Sandoz).

sought which can satisfy higher requirements in regard to wet fastness but still have good migration properties. Based on a classification of acid dyes according to migration and adsorption behaviours, a dyeing diagram can be prepared which exactly complies with these requirements, characterized by Zone 5 in Fig. 4. On shrinkproof finished wool, they actually make it possible to achieve the required wet strengths for care level 3 (machine washable to 30°C, gentle action wash). In many cases, for wool which has been antifelt finished according to an additive process it is possible to achieve the level of fastness required for care level 4 (machine washable to 40°C).

Due to the good levelling properties and high degree of reproducibility of these dyes and their high level of compatibility when used in combination, they are making headway particularly when used in the women's outerwear and men's and boys' outerwear sector for yarn and piece dyeing, i.e. for articles which are dyed in the final stage of production, where manufacturing fastness is no longer crucial but only wear-fastness properties (Fig. 5).

Wool dyeing with reactive dyes In principle, reactive dyes are acid dyes with several sulphonic acid groups and a reactive group which is capable of reacting with the functional groups of protein while forming a covalent bond. Reactive dyes are characterized by their particularly high fastness when the unreacted residues of the dye have been removed by an alkaline post treatment.

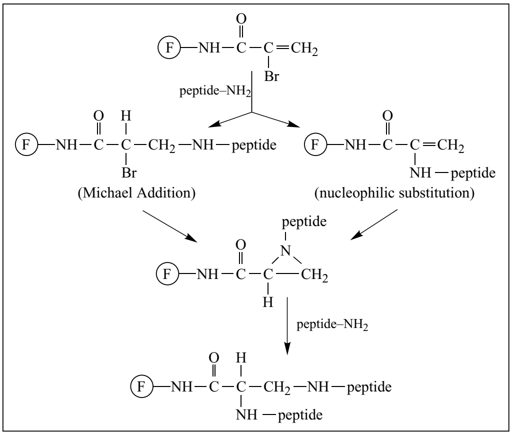


Fig. 1: Possible reactions between a bromoacrylamide dye and the lysine amino acid side chain.

The possible reactions can be described using the bromoacrylamide dyes as an example (Fig. 1). Different protein chains can be crosslinked via the intermediate product which contains the aziridine ring. Difluoropyrimidine dyes can also react forming crosslinks at the reactive groups by double substitution of the fluorine atoms.

Fig. 2 shows the possible bonding sites for reactive dyes on wool (in comparison to cotton).

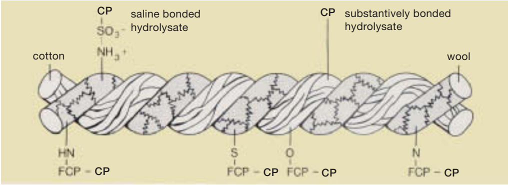


Fig. 2: Possible bonds of Levafix EA dyes;
FCP = 2.4-difluoro-5-chloropyrimidine (by Bayer).
CP = chromophore part.

When dyeing wool unions, after dyeing, the non-reactive hydrosylate is found on both fibre components apart from the reactive bonded dye. The bond on cotton is substantive whereas that on wool, like that of an acid dye, is formed via the sulphonic acid group of the chromophore. This part, which increases with increasing depth of colour, must be removed by the post treatment stage in order to achieve the required level of fastness.

A boiling post-wash treatment, such as that generally prescribed for articles made of pure cotton, harbours the risk of serious damage to the wool if used after the alkaline dyeing process.

Crosslinking wool with bifunctional reactive dyes results in a decrease in solubility of the urea bisulphite (Fig. 3).

Wool dyes Acid, 1 : 1 metal-complex, 1 : 2 metal-

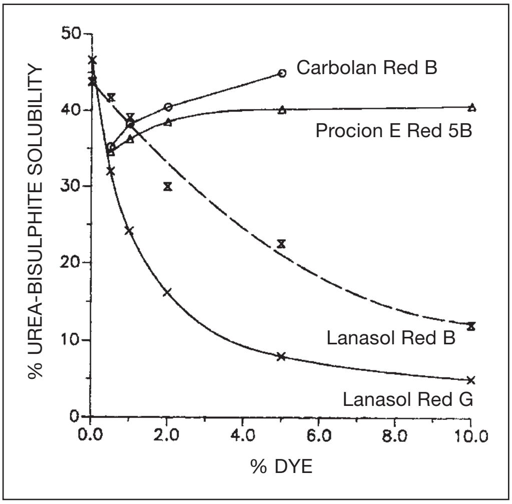


Fig. 3: Urea bisulphite solubility as a function of the dye concentration for the dyes Lanasol Red B and Lanasol Red G (Ciba Geigy), Procion Red E-5B (ICI) and Carbolan Red B after dyeings at a pH of 4.4 (by Virnich).

complex, chrome and reactive dyes are all used for dyeing wool. Mono- and disulphonic acid levelling dyes and 1 : 1 metal-complex are mainly used in wool piece dyeing. 1 : 2 metal-complex and reactive dyes are used to a lesser degree as they highlight insufficiencies or defects in the pretreatments of piece goods.

I. Metal-complex dyes: metal complexes involve the bonding of a metal ion via ligands, i.e. with a particle (ion or molecule), containing one or more free electron pairs. Bi- and polyfunctional ligands can occupy two or more coordination sites on the metal ion to form ring-shaped complexes called chelates.

1. 1 : 1 metal-complex dyes are chrome complex salts in which case the dye molecule contains a chrome atom. These dyes bond to the basic groups on the wool via salt-type and complex-type bonds. The advantages of these dyes are good wet fastness, high migration capacity and very good light fastness. The pH of the dyebath is around 2.5.
2. In the case of 1 : 2 metal-complex dyes without sulphonic acid groups, a single metal ion is linked to two dye molecules. They contain, for example, $-SO_2CH_3$ or $-SO_2NH_2$ groups as water soluble functions, as anions would cause adsorption to be too rapid and non-uniform. Because of their high affinity, these dyes are used at pH 4–5 with a levelling agent.
3. 1 : 2 metal-complex dyes with a single sulphonic acid group were developed especially with the dyeing of polyamide/wool mixtures in mind. Because of their high affinity, they adsorb rapidly and highlight differences existing in the fibres. Dyeing is carried out at pH 4.5–5.
4. 1 : 2 metal-complex dyes with two sulphonic acid groups are used for dyeing loose stock and combed top, as non-uniformities produced during spinning can be smoothed out. Unlike the metal-complex dyes not containing sulphonic acid groups, these can be used to produce brilliant shades. The light and wet fastness of these dyes are good. The dyebath should be weakly acidic with a pH of around 5–6.

II. Acid dyes: these belong to a larger group of anionic dyes of relatively low molecular weight containing one to three sulphonic acid groups. In the acid dyebath, some of the wool's own carboxylic acid groups are neutralized and adsorb a counter ion to maintain electro-neutrality.

$$\textcircled{W}-\mathrm{COO}^{\ominus}\,{}^{\oplus}\mathrm{H_3N}-\textcircled{W} \xrightarrow[\mathrm{HSO_4^-}]{\mathrm{H^+}}$$

$$\textcircled{W}-\mathrm{COOH} + \mathrm{HSO_4^{\ominus}}\,{}^{\oplus}\mathrm{H_3N}-\textcircled{W}$$

The actual dyeing process consists of an ion exchange between the counter ion and the dye anion because the affinity of the dye anion for the substrate is greater than that of the acid residue – the greater the affinity the dye has, the weaker the acid conditions needed to cause the dye to adsorb.

Fibre/dye bond:

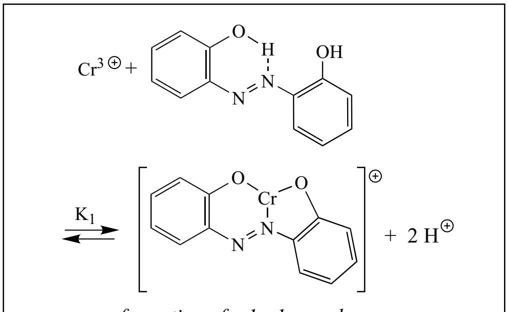
$$\textcircled{W}-\mathrm{NH_3}^{\oplus}\,{}^{\ominus}\mathrm{O_3S}-\textcircled{F}$$

Acid dyes are classified in regard to their adsorption behaviour as follows:

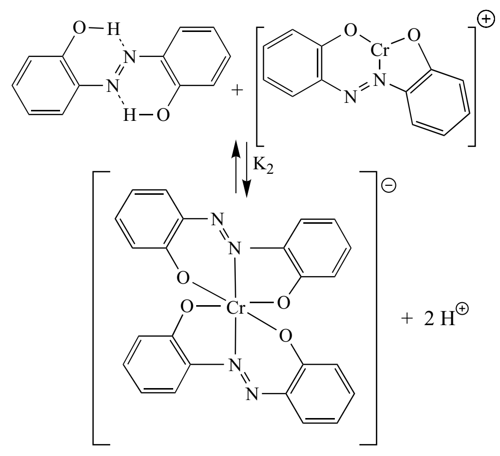
1. Strong-acid adsorbing levelling dyes have a low affinity for fibre and must therefore be applied under strong acid conditions. They are characterized by high migration capacity but rather moderate wet strength.
2. Weak-acid adsorbing levelling dyes are used at pH 4.5–5.5 because of their greater affinity caused by their larger molecular structure.
3. Due to their large molecular weight, milling dyes have distinctly lower migration capacities. The dye is bonded to the fibre via salt-type bonds, van-der-Waal forces and hydrogen bonds. For this reason, their wet fastness is so good that they are capable of withstanding mild milling.

III. Because of certain reactive groups, reactive dyes are in a position to form covalent bonds with wool. In this case, the functional groups on the wool taking part are the amino, hydroxyl and thiol groups. This type of bond produces excellent wet fastness. Another advantage of this class of dye is brilliance of the shades produced.

IV. Afterchrome dyes are characterized by their having the best fastness which is only matched by vat or reactive dyes. The dye adsorbs on to the fibre like an acid dye from acid liquor (pH 3.5–4). After the bath has become exhausted, a dye/chrome complex forms on the fibre due to treatment with chrome salts (Fig.).



formation of a 1 : 1 complex



formation of a 1 : 2 complex

Fig.: Formation of chromium complexes (any excess charges of the complexes are counter-balanced by integrated counter-ions).

This treatment also improves light fastness as well as reducing the solubility of the dye by adding more coordinate bonds to the functional groups on the wool.

Wool fast dyes,

I. Frequently-used term for individual dyes.

II. Range of light, water, milling, and sea water acid dye ranges.

Wool fat (lanolin). Before further processing, raw wool must be freed from wool fat, sweat, dirt and, if possible, smaller pieces of vegetable matter. Contamination varies according to the origin of the raw wool which contains

15–72%	wool hair,
12–47%	wool fat and sweat, of which 2–4% consists of water-soluble calcium salts,
3–24%	vegetable matter (burrs and straw, etc.) and dirt (faeces, sand and loam, etc.),
2–24%	moisture.

Wool fat, a secretion of the sebaceous glands, is a greasy, often sticky, yellow to brown paste. It consists of a mixture of fatty acids, waxy esters and hydrocarbons of approximately the following composition: 50–55% fatty acid esters, 40–45% unsaponafiables and 1–2% free fatty acids. Wool fat is not actually a fat but more a wax which protects the wool hair from external effects.

Sweat and wool fat are the main components which are removed during the scouring process (→ Raw wool scouring). Scouring must be carried out so as to cause as little harm to the wool fibre as possible, both from the chemical and the mechanical (felting) point of view. In large raw-wool laundries, it must also be possible to recover the lanolin – a component of wool fat of great value to the cosmetic industry.

Wool fat extraction The effluent from a raw-wool scouring line (Fig. 1) is largely contaminated by wool fat (lanolin) in addition to other contaminants. It is worthwhile recovering the lanolin from the primary scouring baths and using it in cosmetic creams or hygienic fat emulsions.

After separating the wash water and rinsing water in wool scouring, the waste water treatment essentially consists of the following steps:

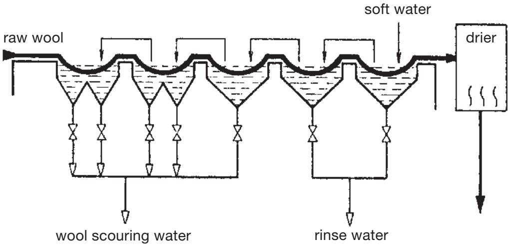


Fig. 1: BWK (Bremen Wool-Combing Works) process wool scouring machine.

1. Sedimentation and partial degreasing of the wool washings while recycling the partially degreased washing water (Fig. 2).
2. Evaporation and combustion of the organically highly contaminated wool washings while
   - recycling the evaporator condensate,
   - recovering the energy in the form of steam and electrical power,
   - purifying the flue-gas.

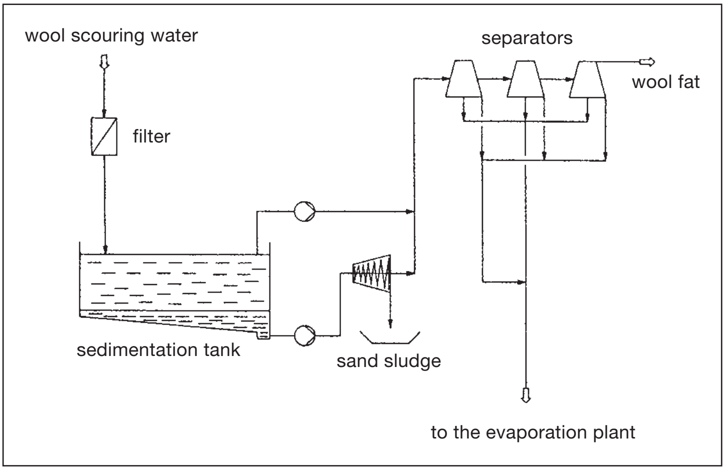


Fig. 2: Sedimentation tank and wool fat extraction.

3. Biological purification of all process waters in an effluent treatment plant.

The dwell time for wool washings in the sedimentation tank is around 30 h. and the sedimented sand sludge is thickened further to 70% dry solids in a centrifuge. About 40% of the wool fat is removed from the pre-purified wool washings by a series of three separators connected in series before it is pumped into the evaporation and combustion plant. Some of the degreased wool washings are returned to the wool-washing process.

Wool felt → Felting propensity of wool.

Wool fibre evenness Term used for the property of wool hair of having evenly distributed thickness and crimp along its entire length: → Abnormal fibre (wool).

Wool grease, suint Component of → Raw wool (greasy wool). Sum of all wool contaminants which can be removed by scouring (liquid excretions from the skin, wool-grease, salts, sand, dirt and faecal matter, etc.).

Woollen cloth General term for woollen fabrics (made from carded yarn or worsted yarn, as well as worsted-yarn warp and carded-yarn weft) to some extent also in twill or satin weave (twill or satin cloth). Surface produced by roughening, milling, shearing, brushing, steaming and pressing. Used for women's outerwear and men's and boys' outerwear.

Wool man-made fibre → Keratose.

Woolmark International wool mark introduced in 1964 by the International Wool Secretariat (IWS) and lodged in more that 100 countries all over the world for legal protection. Guarantees pure → Virgin wool and other quality characteristics. Only valid if the label is firmly sewn in and provided with a code number.

Wool, nonfelting The anti-felting effects achieved by the traditional wool chlorinating process using chlorotriazine-type products have so far not been achieved by any alternative method or product. However, components of wool or substances which accompany wool (such as lubricants) and which are either soluble right from the start or become soluble after conversion, form absorbable organic chlorinated compounds with chlorotriazines at a concentration which will restrict their future use in Germany to a limited degree. In the meantime, their substitution with AOX-free products has become possible for batch → Antifelting finish without any significant loss in quality. It is only in the case of continuous combed-top finishing and print pretreatment that there is a need for further development.

Peroxysulphate compounds (such as caroat) are freely soluble salts which are not only free of halogens but also free of a few other problems produced by chlorine.

Advantages and disadvantages of caroat in comparison to chlorine:

- no AOX,
- no yellowing,
- improved levelling properties,
- almost no smell,

but:

- antifelting properties not so effective,
- paler print.

Fig. 1 shows how yellowing increases with increased chlorination strength (Basolan DC) whereas, under treatment with caroat (+ sulphite, Basolan 2448) this at least stays constant or even decreases. This is not only of benefit to white or white/coloured goods but also to plain dyed goods because yellowing often causes a

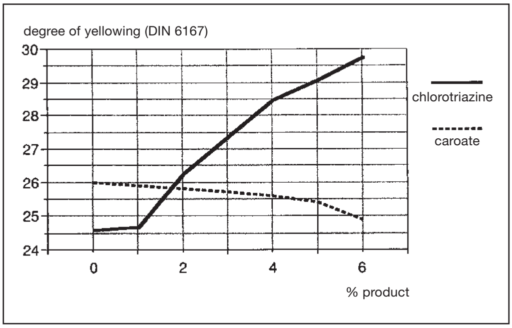


Fig. 1: Effect of antifelting products (BASF) on the degree of yellowing of wool.

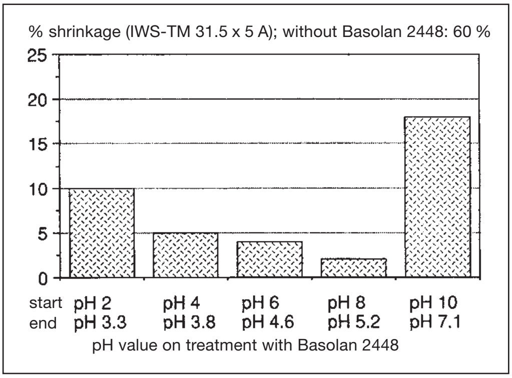


Fig. 2: Effect of the application quantity of Basolan 2448 (BASF) on the felting shrinkage of knitted piece goods (coloured knitgoods, aftertreatment with 4% Basolan MW, BASF.)

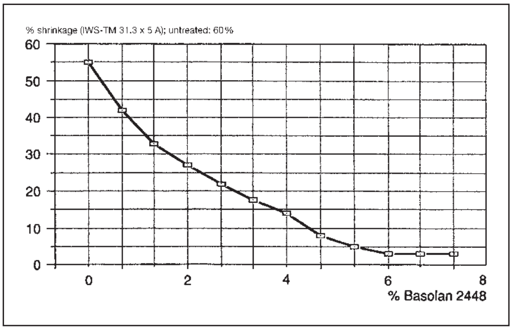


Fig. 3: Effect of pH in a bath with Basolan 2448 (BASF) on felting shrinkage (coloured knitgoods, 5% Basolan 2448, 4% Basolan MW, BASF).

shift in the colour shade. By using caroat treatment instead of chlorination, it is even more possible to carry out the treatment after dyeing. Only now and again are there woollen goods which felt so much that chlorination has to be used. For these cases, a combination of chlorine and peroxide is indicated which is at least low in AOX.

Treatment with caroat not only avoids yellowing, but also attacks dye less frequently than treatment with chlorine. Among the many wool dyes which have been tested so far for their suitability for this form of oxidative/reductive aftertreatment, only four have proved to be unsuitable because of a shift in colour and a further four were found to be of limited suitability.

The following dyes are unsuitable for aftertreatment using caroat/sulphite:

- C.I. Acid Red 42,
- C.I. Acid Yellow 221,
- C.I. Acid Blue 72,
- C.I. Acid Blue 333.

The following dyes are of limited suitability:

- C.I. Acid Green 104,
- C.I. Reactive Blue 2,
- C.I. Reactive Blue 177,
- C.I. Reactive Blue 69.

Basically, all fibre mixtures with wool can be finished according to the caroat method. From the point of view of colour, mixtures with cellulose fibres require special attention as it is known that cellulose dyeings are sensitive to oxidation or reduction. But it is also true that the effect on colour shade is less than it is for chlorine. The potential deterioration in wet fastness of wool dyeings is of the same order as that for chlorine. This happens during treatment both before and after dyeing. This deterioration may amount to more than a single point and may require aftertreatment.

As shown in Fig. 2, the amount of peroxysulphate used has a considerable effect on shrink resistance during washing but this is so only up to 6% wool by weight.

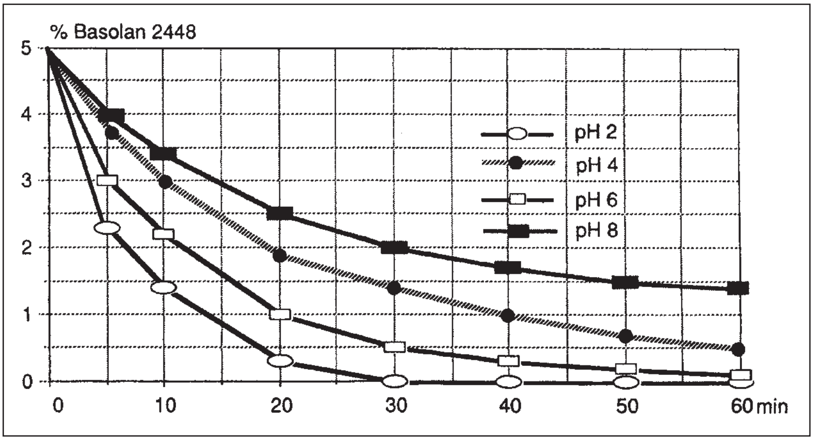


Fig. 4: Effect of pH in a bath with Basolan 2448 (BASF) on the reaction speed (coloured knitgoods, 1 : 20, 25 °C).

(Fig. 4) applies to the effects of pH in the peroxymonosulphate bath. This does not have as much relevance to antifelting as chlorination. Under certain circumstances, the addition of formic acid to a bath which is already acid reacting is recommended. This produces a pH of around 3. According to Fig. 3, the addition is not necessary as 5% caroat produces a pH of around 4 on dyed wool, which is adequate.

Wool origins, analysis As well as the different genetic and climatic conditions in the various countries of origin (provenances), the quality of wool is also affected by the different feeding and breeding conditions.

The sheep breeds and climate zones of wool export countries are distributed on a percentage basis as follows (r/y = rainfall per year):

I. Australia: predominantly merino sheep (approx. 77%). Climate: a) pastoral zone: 25 cm r/y; b) wheat/sheep zone: 25–65 cm r/y; c) high rainfall zone: 50–100 cm r/y.

II. New Zealand: South Island: mainly merino/Lincoln crossbreds (Corriedale) or merino/border Leicester crossbreds. Climate: very rainy and damp. North Island: 80% Romney Marsh and Southdown. Climate: more rainy than South Island but milder.

III. South Africa: 85–90% merino sheep. Remainder: caracul, coarse wool, fat-tailed sheep, native, dorper, Dohne merino, dormer and Persian fat-tailed sheep. Climate: a) Karoo: 12.5–75 cm r/y, b) Lesotho: 50–80 cm r/y; c) highland areas: 100 cm r/y, very cold during winter; d) Natal (400 m over N.N.): 30–60 cm r/y.

IV. Argentina: 33% Lincoln, 32% merino, 18% Romney Marsh and 7% Corriedale. Special: Chubut Province (southern zone): 100% merinos. Climate: a) southern zone: dry, exposed to strong winds, 5–25 cm r/y; b) central zone: flat savannah, grassland, approx. 25 cm r/y; c) northern zone: flat land, much rain.

V. Uruguay: 22% Corriedale; 11% merino, 11% Romney Marsh, 2% Lincoln. Remainder: others. Climate: warm, up to 150 cm r/y, northern and central area dry, with occasional periods of drought.

Vl. Brazil: 20% merinos, 15% Romney Marsh, 10% Corriedale. Climate: northern tropical, southern subtropical, windward side of mountains rainy, lee side and valleys dry.

VII. South Chile: 50% Criolla, 20% Hampshire Down, 20% Romney Marsh and 10% others. Climate: strong fluctuations in climate, dry hot tropical climate in the north and oceanic cold in the south.

VIII. Germany: 43% German merinos, German merino mutton, marsh, heath and mountain sheep (Goggel, Zackel, Bergamo). Climate: European transition climate, rain all times of the year, decreasing further west and more in the summer, fluctuations in temperature stronger towards the east.

IX. Hungary: 71% Hungarian merinos, 19% crossbreds, 7% Tsigai and 3% Zackel.

While the quality of wool in the classical wool-producing countries, Australia, South Africa and New Zealand is constantly monitored and a high standard is consistently maintained through strict selection among the herds, in many other countries, such as the South American states both the examination and selection of sheep according to particular wool properties is completely absent.

Objective qualitative assessment of the wool is mainly carried out with the help of a table drawn up by Henning which gives the characteristics of wool-fibre in the fibre bundle or as individual fibres.

Classification of fibre properties according to Henning:

I. Properties of the individual fibre:
  1. vectorial properties:
     a) geometric characteristics:
        – average fineness,
        – fineness variation coefficient,
        – shape of cross-section,
        – average fibre length,
        – fibre-length variation coefficient,
        – proportion of short fibre,
        – number of crimping arches,
        – depth of crimp;
     b) tensile strength properties:
        – crimp contraction – degree of crimp,
        – crimp-straightening tension,
        – crimp resistance,
        – modulus of elasticity,
        – stress-strain relationship,
        – plasticity;
     c) strength properties under stress reversal:
        – durability;
     d) bending properties:
        – bending modulus,
        – bending strength,
        – bending endurance,
        – crease recovery;
     e) colour:
        – white content,
        – number of pigmented hairs,
        – bristle content,
     f) lustre;
     g) coefficient of friction.
  2. properties of fibre substance (scalar):
     a) chemical composition;
     b) solubilities;
     c) hygroscopicity;
     d) admixtures, extracts, pH, acid content.

II. Properties of fibre in the bundle:
  1. fibre bulge:
     a) compressive stress;
     b) compressibility;
     c) softness;
     d) bulge elasticity.
  2. felting properties.

3. presence of contaminants and proportion of burrs.

While the physical (vectorial) characteristics, fineness, fibre length, crimp, lustre, colour, bending strength, bulge elasticity and tensile strength have already been used by wool traders for assessing the quality of wool, scalar properties such as solubilities, chemical composition of fibre, hygroscopicity and admixture were not introduced into quality assessment until the last few decades. As the factors, genetics, climate, solid condition, nourishment and breeding fluctuate more or less from country to country, the question also arises whether wools of different origin should be characterized according to their wool quality as well. An additional factor affecting the assessment of South American wools is that these wools predominantly reach the world market in an already scoured and combed state.

Of particular interest to the textile industry is the question of provincial deviations in wool quality. In this case, knowledge of the characteristics of a certain batch of wool which are relevant to practice (and gained at the earliest possible moment) could enable problems which may arise during the processing stage to be assessed as the wool is being purchased, so that the different wool qualities could then be used for applications which are more appropriate.

During the last 30 years, a large number of analytical methods have been developed which enable a wool to be characterized down to its molecular structure. Many of these methods are used in wool research. Thus, with the aid of screen electron microscopy it is now possible, for example, to photograph and document surface modifications of the wool which, until now, have mainly been identified using staining tests which are more or less specific. Another possible application for screen electron microscopy is the measurement of scales in the cuticle (shape, height and expansion), and this can be used to explain properties such as the lustre and felting behaviour of the wool.

The quantitative measurement of fluorescence intensity, using fluorescence microscopy is used, among other things, to investigate the problem of wool yellowing and its causes. Scanning photometer microscopy makes it possible to monitor and quantify the diffusion processes. This is of particular importance during dyeing where it can be used to discover the possible causes of differences in the resulting shades of otherwise identically treated wools.

Until now, thermoanalysis (such as differential scanning calorimetry measurements) have mainly been carried out in order to determine how the thermal behaviour of wool changes in response to the effect of different chemicals.

Other methods such as atomic absorption spectroscopy, amino acid analysis and gel electrophoresis can be used to work out the composition of wool fibre in terms of its amino acids, trace elements and proteins (according to Kleiker).

Wool or silk poplin Poplin-type wool or silk material.

Wool printing To achieve the optimum print results, proper pretreatment is important for all classes of dye to the same extent. To this end, the following procedural steps are necessary (Fig. 1):

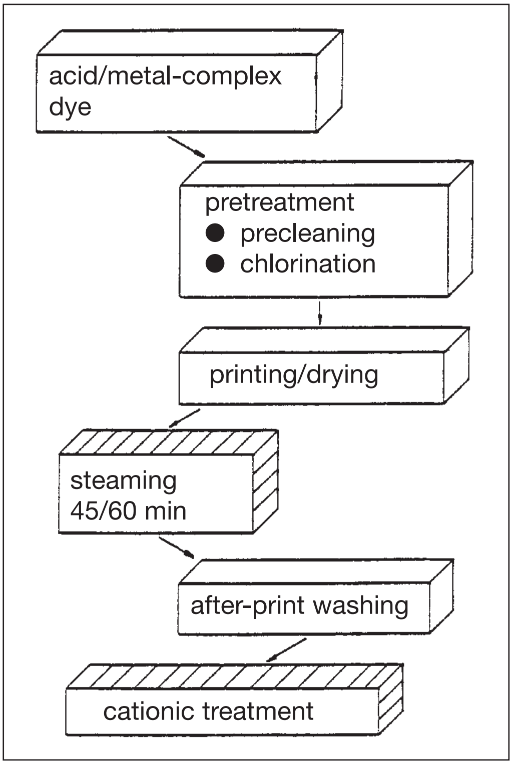


Fig. 1: Process of operation for direct printing on wool.

1. Cleaning the fibre material:
   - singeing,
   - shearing,
   - prewashing.
2. Stabilizing and pre-fixing the goods:
   - crabbing,
   - annealing.
3. Increasing the dye affinity:
   - chlorination,
   - bleaching,
   - optical brightening.

Of these, the most important process step is the chlorination process which must be carried out with great care (or may even be omitted as shown in Fig. 2). Chlorination yields the following benefits:

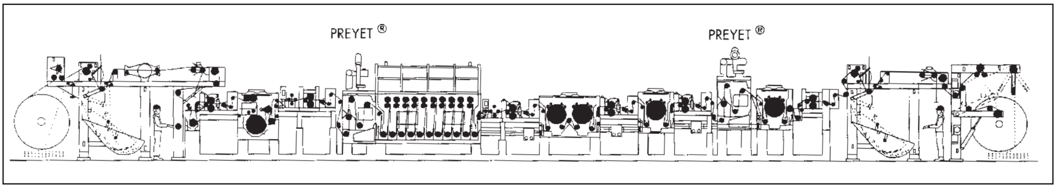


Fig. 2: Kleinewefers KTM Preyet (Azeta version) for shrinking, short bleaching and wool fixation (crabbing).

- increased dye affinity: colour build and brilliance,
- improved printing properties: evenness,
- improved dimensional stability: prevention of felting and shrinkage.

However, chlorination will have to be replaced by other printing pretreatments which do not produce effluents loaded with AOX.

In the following, the technical differences encountered in using vinylsulphone dyes in comparison with acid and metal-complex dyes will be examined as vinylsulphone dyes, unlike chlorotriazine reactive dyes, do not contaminate the effluent from the print washings with AOX.

The two classes of dye differ only in their fixing times and, in the case of acid and metal-complex dyes, an additional cationic posttreatment.

Although the total cost of wool printing is made very expensive by this elaborate pretreatment, the main contribution to the costs is still the actual printing process: pre-treatment 15%, design preparation and screen making 15%, coloration, formulation and paste preparation 20%, machine preparation and drying 30%, fixing, washing and drying 10% and finishing 10%.

Standard printing pastes have the composition shown in Fig. 3.

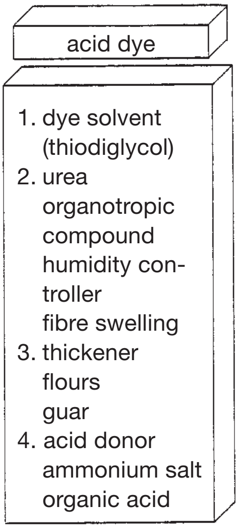


Fig. 3: Print paste composition.

When dissolving acid and metal-complex dyes, it is frequently necessary to add so-called dye solvents such as thiodiglycol, because a few of the dyes are only slowly soluble. It is also necessary to use hot water for dissolving. Dissolving often takes place at the inlet pipe. In this case, vinylsulphone dyes offer the advantage of requiring neither special dyestuff solvents nor hot water as they are already soluble as powder-granule or fluid brands. Vinylsulphone dyes can also be added by means of the sprinkling method. Here, the dye is worked into a prepared thickener containing all the necessary auxiliaries, such as chemicals, using a high speed stirrer. This eases work in the dye kitchen.

Urea, a hydrotropic agent, is used both with acid and metal-complex dyes as well as vinylsulphone dyes as a solubilizer in the printing paste. It also promotes water absorption and assists as a fibre-swelling agent during steaming. Acid resistant thickeners are used in the case of acid and metal-complex dyes. These are usually in the form of flour or guar derivatives. In the case of vinylsulphone dyes, alginate thickeners can also be used as the addition of acid to the printing pastes ceases.

The acid and metal-complex dyes are fixed in acid media, where either the acid donor, for example, ammonium sulphate or organic acids, such as citric acid, are added to the printing paste. Vinylsulphone dyes are fixed using sodium acetate as the alkali donor. High durabilities are achieved for the printing pastes when sodium acetate is used. Sodium-m-nitrobenzenesulphate is added to protect reactive dyes from reducing effects. Saturated steam is required for fixing both acid and metal-complex dyes as well as vinylsulphone dyes. Prints should not be over dried before steaming. Alternatively, they can be moistened again with sprays before entering the steamer.

Regarding the necessary fixing times, vinylsulphone dyes have advantages in comparison to acid and metal-complex dyes. Vinylsulphone dyes can be fixed within 10–20 min depending on the quality of saturated steam, whereas acid dyes and metal-complex dyes have to be steamed for 45–60 min. Using vinylsulphone dyes, it is possible to use continuous steaming which produces further advantages:

- reduction in steam consumption,
- higher utilisation efficiency of the continuous steamer,

- savings in time when preparing pattern remnants/collections,
- lower costs as a result of machine stoppages when preparing machine remnants, etc.

As a rule, a temperature of 40°C is not exceeded during after-print washing in the case of acid and metal-complex dyes, as there is a danger of strongly ionic-bonded dyes becoming detached, which can lead both to undesirable areas of lighter shades and an increased risk of contamination of the ground by the detached dye. In the case of vinylsulphone dyes, the temperature is raised to 70–80°C after the initial cold and warm rinse in order to remove the small proportion of non-reactively fixed vinylsulphone dye from the fibre and ensure that fastness is high. Acid and metal-complex dyes require special auxiliaries to protect the white ground from being stained by the colours bleeding on to it during the initial rinse.

In most cases, the process is followed by cationic aftertreatment to improve fastness. This also has the advantage of improving the fastness to water and perspiration by an average of one grade. The disadvantages which must be taken into account are that cation active aftertreatment auxiliaries can reduce light fastness by about one grade, particularly in the case of pale shades. The cationic fibre surface shows a high affinity for detached dyes which are present in the wash liquor (mordant effect). Cationic aftertreatment is not a permanent finish either because the complex becomes less stable with each wash. When cationic aftertreatment is carried out in the presence of a softener, the products must be matched to ensure they are compatible. Vinylsulphone dyes require only 1–2 g/l conc. ammonia solution to deactivate any reactive dye which has not been fixed, protect the white ground from contamination and achieve the required level of fastness.

The ionic bond of an acid dye can be regarded as relatively weak and can be removed by raising the pH. Other specific bonds are possible through

- dipole forces,
- hydrogen bonds,
- van-der-Waal forces.

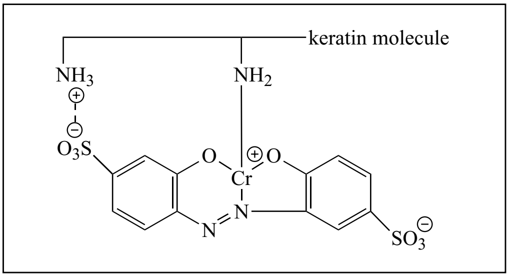


Fig. 4: Dye/fibre bonding with 1 : 1 chromium-complex dyes.

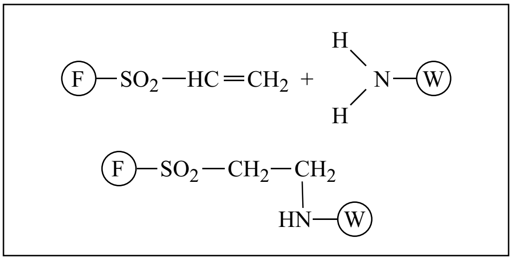
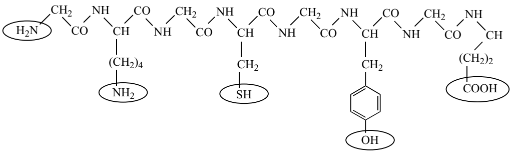


Fig. 5: Covalent bonding of vinylsulphone dyes with wool.

In the case of 1 : 1 metal-complex dyes, there is an additional coordinate bond between the chrome atom of the dye complex and, for example, the amino group on the wool in addition to the bonds already mentioned (Fig. 4). The bonding forces are therefore somewhat higher than those of acid dyes.

Vinylsulphone dyes, on the other hand, form genuine covalent bonds with the wool fibres. Fig. 5 shows the reaction of the amino groups of the wool with the reactive groups of the vinylsulphone dye.

Other classes of wool which react with vinylsulphone dyes are indicated in the diagram below:



Higher colour yields are obtained for vinylsulphone dyes due to their higher reactivity with wool.

Wool protection against insect attack During storage, woollen textiles can be at risk from different species of insect. These are mainly the larvae of carpet beetles and moths but also occasionally include fur beetles. Agents for permanent finishing or for treatment with limited duration of effect are available for the protection of woollen textiles against these pests. A significant contribution to the protection of wool flocks, yarns and textiles can be made by practising good storage hygiene. Periodic cleaning of the storage facilities prevents the long-term accumulation of deposits of wool, which has not been given sufficient protection in corners, under stands and pallets and which enable whole generations of pests to develop. When storing in old buildings, it must be ensured that wool deposits cannot find their way between the floors and in cavity walls. Even insulation material of vegetable origin, which can serve as nourishment for textile pests, must be removed. → Moth proofing.

I. Permanent protection: heavy woollen textiles such as carpets, woollen blankets and uniform materials as well as pullovers, socks and gloves made from coarse yarns can be protected for many years against insects by using proper industrial finishes. A prerequisite for this is that a suitable finishing aid is used and that its concentration is adjusted to the carpet beetle which is the most commonly occurring textile pest in Europe. If the textile has been properly treated, aftertreatment with insecticides will not be necessary.

II. Temporary protection: this may be advisable for textiles where the storage period is foreseeable, for light textiles or those which have already undergone permanent finishing and have to be stored after occasional wear and cleaning. Light fabrics and thin yarns cannot be protected with an oral poison or feeding deterrent as they may be damaged with a single bite. These require a treatment using a fast-acting, insect-specific poison which also has a permanent effect.

At the right concentration, products based on phosphoric acid esters can provide protection for six months. The disadvantage of these substances is, for purely preventative use, the relatively high vapour pressure of the active substance, which means that they can concentrate in confined spaces. Substances such as pyrethroids are also suitable for this application. They can be used both for permanent finishing and for aqueous and organic sprays. They act as neurotoxic contact insecticides, they are not toxic to humans and adsorb well on to the fibre. The disadvantages of pyrethroids are their high toxicity to fish and their wide use. Natural and synthetic pyrethroids are used all over the world for the protection of plants, forests and in storage and material protection as well as being used against household pests, ectoparasites and hygiene pests. Resistance must be expected in the long term, therefore, especially in the case of carpet beetles.

Apart from this, a long-term and high level of protection of textiles is possible using aqueous sprays based on growth regulators. From the ecological point of view, products such as these may limit the use of solvents as well as pyrethroids which are toxic to fish. However, the use of aqueous products means in practice that the treated textiles must be dried well before stacking in order to avoid damage to the wool due to residual moisture and fungi. For the control of existing insect infestations, growth regulators must be mixed with respiratory, contact or oral insecticides in order to achieve rapid cessation of damage before the next larvae hatch.

In order to use insecticide more sparingly, insect infestation in loosely stored textile lots can be controlled using short-term shock freezing. A temperature of – 26°C for 2 h will result in the death of clothes moths, fur beetles and carpet beetles at all their stages of development. A temperature of – 20°C for 74 h, however, is not sufficient to kill beetle larvae (according to Graf and Lanz).

Wool scour → Washing wool fabric.

Wool scouring →: Raw wool scouring; Washing wool fabrics.

Wool scouring effluent In addition to recoverable wool grease (or more precisely, wool wax) wool-scouring effluent contains so many harmful substances that a typical COD would be 40 000 mg O_2/l. The equivalent BOD is around 6000 mg O_2/l. The high proportion of non-biological substances mainly comes from wool wax. But apart from wool wax there are also pesticides (0.2 mg/l) and a certain number of compounds containing halogens (sources of AOX) which account for some of the high loadings of pollutant in wool-scouring effluent. This kind of effluent can be treated in different ways, as shown in Tab.

pretreatment of wool scouring water	*final treatment of the overall waste water*
- wool fat extraction (acid cleavage)	none
- sedimentation - wool fat extraction through separators	aerobic biology
- sedimentation - wool fat extraction through separators - evaporation plant and furnace	aerobic biology

Tab.: Raw wool scouring waste water treatment possibilities.

Wool scouring machines →: Leviathan; Smoothing machine.

Wool scouring range Loose wool can be washed very gently (i.e. without felting or alkaline damage) in accordance with the water-extraction through-flow

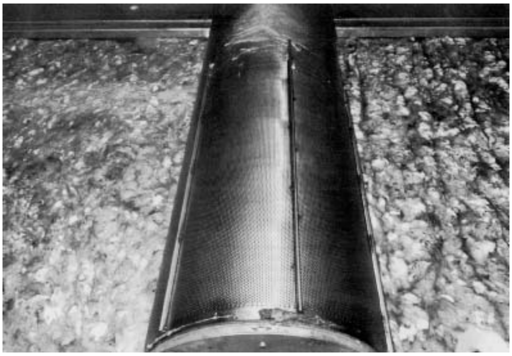


Fig.: Fleißner's suction-drum rawwool washing unit.

principle using 4–5 sieve-drum washing machines in a row. The wool floats through the plant as a well spread-out fleece (Fig.).

Wool setting Strived for in wool finishing and wool yarn finishing. Water, both as a liquid and in the form of steam, can affect the structure of interactions between the protein chains in the morphological system of the fibres. Hydrogen bonds, salt-type linkages, hydrophobic interactions and disulphide links can be re-oriented according to conditions. This is used to convert the wool fibres in the matrix of the textile goods, for example, either in the yarn or the fabric. At the same time, under certain circumstances, the hygralic expansion of the fibre is also affected which, for example, if increased, can lead to problems in regard to being able to shape the fabric in ready-to-wear clothing. It is difficult for the finisher to assess the degree of fixing of a woollen fabric: he wants to guarantee

- good shrinkage values during ironing,
- a low tendency to bagginess,
- good handle and optimum lustre,
- satisfactory wear properties.

It is important to define the slight differences in the degree of fixing.

The following distinctions are made:

- Permanent fixing: resistant to 30 min treatment at 70°C (elsewhere 1 h boiling),
- Cohesive fixing: not resistant to water (30 min, 20°C) but stable in air at room temperature,
- Temporary fixing: not resistant to hot water or steam but very resistant to cold water.

If the term “glass transition temperature (Tg)” is used for wool, then cohesive fixing is defined as the re-orientation of hydrogen bonds above the glass transition temperature, which remains stable as long as any subsequent treatment is carried out below the glass transition temperature. Each heat treatment using hot air is followed by cohesive fixing. Relaxation shrinkage occurs if tensions (creases and over-stretching) are fixed by cooling during cohesive fixing. These relax, for example, as soon as the fabric is steamed while the fabric is not under tension. Apart from the drier, cohesive fixing is also achieved using a rotary cloth-press, a plate press or a calender, so pressed fabrics must be fixed in their pressed state before the effect is lost again through water or steam.

The method of cooling after finish decatizing can have a significant effect on the extent of cohesive fixing. The temperature while batching off or unreeling has a profound effect on fixing: if the goods in the package are cooled by suction, cohesive fixing takes place in the fabric while in the sandwich state (formed from back grey and wool fabric). If the fibres are still above the glass transition temperature “in steam” as the fabric leaves the decatizing process, the fabric tends to take up the relaxed state of the fibres. Alternatively, the fabric can be run out “in steam”, shock-cooled via the suction roller. Relaxation and “freezing” take place simultaneously while the fabric is run out in the most relaxed state possible so that some of the cohesive fixing produced by shock cooling is retained. In general, to summarize, cohesive fixing mainly depends on the water content of the fabric, as this significantly affects the glass transition temperature (Fig. 1).

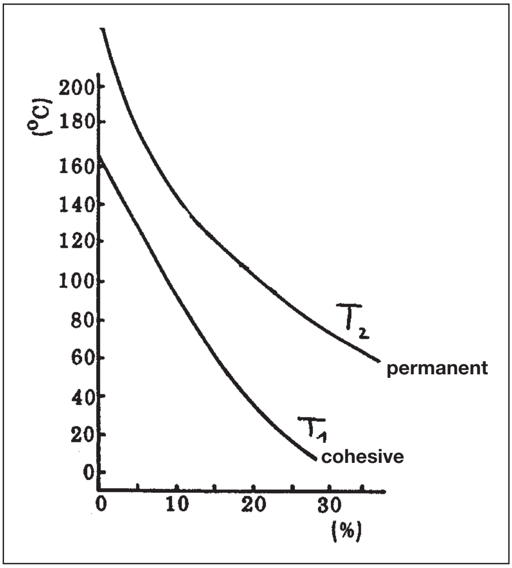


Fig. 1: First order (T_1) and second order (T_2) glass transition temperature depending on the wool fabric moisture content (by CSIRO).

According to this, the glass transition temperature of wet wool is below room temperature, which is why the shape of air-dried fibre is cohesively fixed. Every form of cohesive fixing found in the raw fabric, such as the fixing of mechanical tensions which have been introduced into the fibre during spinning and weaving, becomes relaxed during washing. More extensive than this wash-relaxation is the relaxation and permanent fixing of fibres in textile goods during classical crabbing (a treatment using boiling water) because the fibre-to-fibre friction is more effectively removed during this process, so that the fibre can be “accommodated” in a position which is free of tension. This type of relaxation reduces the bending and shear stiffness of the fabric, which is why the elasticity of the weave increases. The shear and bending hysteresis is reduced by the permanent fixing process to below the value of fabrics which have not been fixed. Piece dyeing, kier decatizing and chemical fixing produce this effect to the same extent as crabbing. The resulting reduction in yarn interactions, on the other hand, allows the effect of hygralic expansion with increasing water content in the fibres (swelling), which is why the corresponding fabrics bulge (particularly at the seams and at front-fixed places) or straighten out or do not maintain the shaped-up form.

The swelling of fibres caused by the absorption of moisture from the air increases their diameter and the radius of bend of the fibres in the fibre matrix, such as the yarn. This causes bent fibres to straighten and the fabric to become longer. In the case of fabrics which have not been fixed, i.e. non-relaxed fabrics, this swelling force is exceeded by the fibre-to-fibre frictional forces in the yarn and the swollen yarns produce longer looping routes for crossing yarns (either the warp or the weft), which is why the fabric is forced to shrink (through hygralic expansion). The dimensional changes in the moisture angle of fixed or unfixed fabrics, i.e. their hygralic expansion, is always a result of the state of equilibrium between the yarn de-crimping (elongation) and the shrinkage due to swelling (shortening) (Fig. 2). Permanent fixing therefore increases the effect of hygralic expansion, which is why kier decatizing does not necessarily lead to the stability of a surface dimension during the ironing test. Thus, the ironing test actually stipulates a difference between shrinkage due to relaxation (during steaming) and shrinkage which is measured initially as a result of hygralic expansion due to storage under climatic conditions.

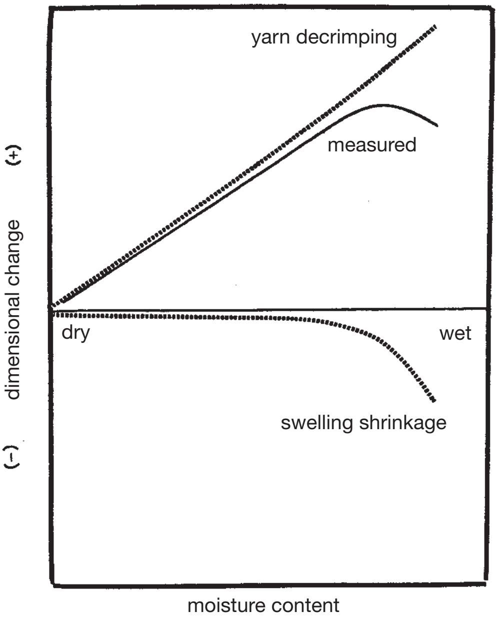


Fig. 2: Dimensional change mechanism of wool fabrics with moisture changes following hygralic expansion.

Permanent fixing of wool requires that the hydrogen bonds, such as those which are formed during cohesive fixing, are re-oriented and that the disulphide links undergo reductive cleavage and oxidative reorganization. High temperatures and humidity as well as the use of reducing media promote permanent fixing, as more thiol groups are formed which force the reorganization of covalent sulphur links through thiol-catalysed disulphide exchange.

The temperature required for permanent fixing, i.e. the inclusion of disulphide links, is much higher than the corresponding glass transition temperature at the same humidity (Fig. 1), which suggests that other factors also take part. The "conversion temperature" required to achieve permanent fixing depends both on the moisture content and the pH.

Permanent fixing in the kier decatizing process can be envisaged as shown in Fig. 3.

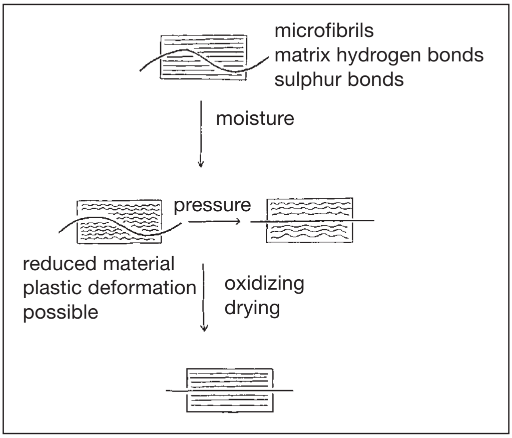


Fig. 3: Diagram showing the sequence and mechanism of flat setting (according to Wortmann).

Moisture and reducing agents soften the sulphur-rich matrix keratins. Material softened in this way can be deformed under pressure. After deformation, the softening effect is removed by oxidation (in the simplest case, by the air), heat and drying and the material is fixed in its new shape. During the fixing process, the tension or compression experienced by the fibre at the time of treatment has a significant effect on the extent of fixing. Speakman has already demonstrated the effect of super-contraction with subsequent detachment of fibres during steaming.

The stress/strain curve of a wool fibre may be divided up into the following sections:

- the area representing Hook's Law behaviour with high stress absorption,

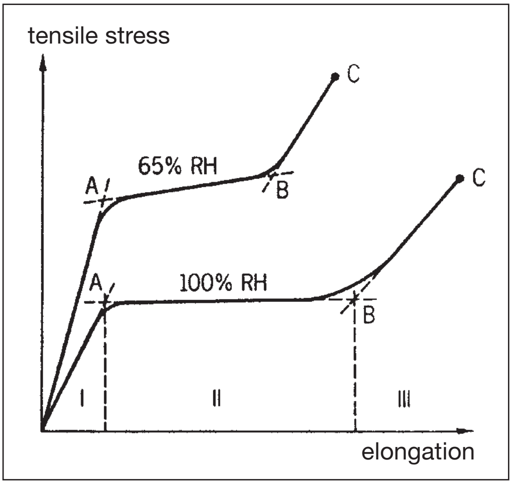


Fig. 4: Stress/elongation curves of hairs at varying humidities (RH).
I = Hookean zone; II = plasticity zone; III = postplasticity zone; A = Hookean limit; B = flex point; C = tear point.

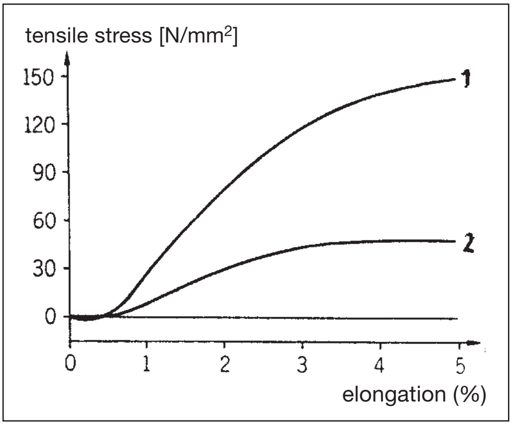


Fig. 5: Hookean zones of stress/elongation curves for determination of the elasticity modules.

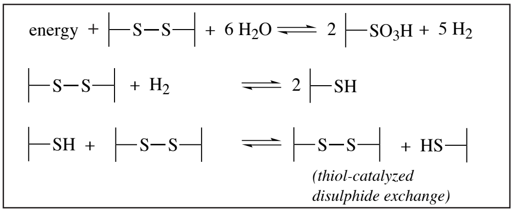
- the area representing yield with a significant amount of strain,
- the area representing renewed stiffening to fracture at high stretch.

Before the fracture point is reached, the denaturing of keratin (α-keratin converts to β-keratin) is reversible. As moisture increases, this S-shaped curve is shifted downwards parallel to the stress axis, while the two inflections remain approximately the same in relation to the strain axis (Figs. 4 and 5).

As the fibre dries out, its stiffness increases. An increase in temperature reduces the modulus of elasticity (seen as an increase in the Hook's Law area of the curve), i.e. there is a decrease in the tensile strength of the fibre, especially above the glass-transition temperature (Tg). Until the fibre stretches by approx. 2%, both the hydrogen and the disulphide bonds absorb the stress without breaking. The hydrogen bonds do not break until higher extensions are reached below the glass transition temperature and the transition from α-keratin to β-keratin begins. This "hydrolysis" of the hydrogen bonds requires less energy in the presence of more water – the "enemy of hydrogen bonds" (Fig. 5). Up to this point, all the processes which have been described are reversible, as it is only the reorganization of hydrogen bonds which is involved at the most. If the process takes place above the glass-transition temperature (e.g. when Tg = 65°C) then the disulphide links are rearranged and the stretch is irreversible.

If during kier decatizing in the presence of cotton back grey, its surface structure (molleton or satin) and its batching tension are of crucial importance for the decatizing/fixing result, then it is mainly the effect on the stress/strain curve of the fibre which makes the presence of the back grey indispensable (unlike the rubber blanket back greys in the case of continuous decatizing).

The question also arises as to how kier decatizing produces such good fixing effects at around 130°C. Under certain circumstances, in its capacity as a reducing medium, steam may react with wool in the following manner:



$$\text{energy} + \vdash S-S \dashv + 6\,H_2O \rightleftharpoons 2 \vdash SO_3H + 5\,H_2$$

$$\vdash S-S \dashv + H_2 \rightleftharpoons 2 \vdash SH$$

$$\vdash SH + \vdash S-S \dashv \rightleftharpoons \vdash S-S \dashv + HS \dashv$$

(thiol-catalyzed disulphide exchange)

So far however, cysteic acid has not been found in kier decatized wool. In addition, in the absence of a redox counterpart such as wool, steam will only split into a reducing species (and oxygen) in accordance with the equation below at too high temperatures for wool:

$$296\ \text{kJ/mole} + H_2O \rightleftharpoons H_2 + {}^{1}/_{2}\,O_2$$

Wool structure Because → Wool is an animal hair, it represents the keratin fibres of many different types of sheep. The term keratin is not definite. It is used to describe the proteins of wool and hairs which, in the untreated state, are immune from attack by proteolytic enzymes. It mainly occurs in the macrofibrils in the cortex and the exocuticle. Proteins which are not

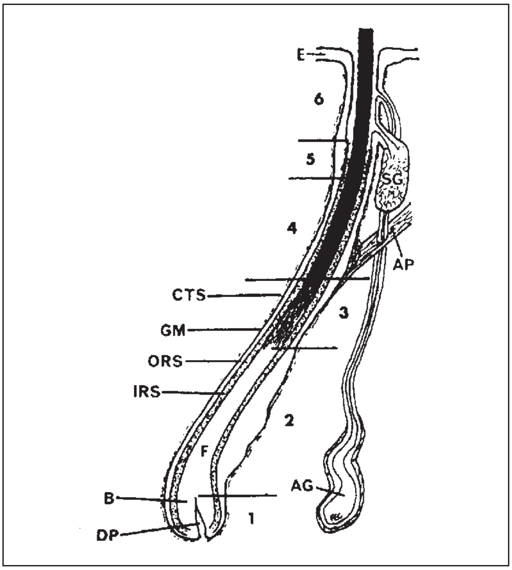


Fig. 1: Diagram of a wool follicle.
DP = papilla made from corium (dermis), B = bulb, F = wool fibre, IRS = inner root sheath, ORS = outer root sheath, GM = glassy membrane, CTS = connective tissue stratum, E = epidermis, AG = sweat gland, AP = hair erector muscle, SG = sebaceous gland; 1–6 wool fibre formation zones: 1 = bulb, 2 = keratin-forming zone, 3 = the hardening processes (keratinisation) cease, 4 = inner root sheath is decomposed, 5 = inner root sheath and cells from the outer root sheath are expelled, 6 = wool fibre canal.

keratins are those of the marrow (medullary) cells, the inner root-sheath of the hair (coleorhiza), the endocuticle, the intermacrofibrillar material and the residues of the cell nucleus. These are decomposed by proteolytic enzymes and solubilized.

Like other animal hair and human hair, wool fibres are formed by follicles (Fig. 1). These are introversions of the epidermis of the skin upon which are based the papillae made up of mesodermal cells. The malpighian layer is responsible for the development of the wool hair. The hair papille are formed in the sack-like pits in the skin, so-called hair shafts, from which grow the wool hairs. The duct to the sebaceous gland, which supplies the hair with grease, leads out to the top layer (the epidermis). The sweat gland opens out at the exit to the hair shaft. In the event of danger, a hair-follicle muscle hermetically seals the exit to the hair shaft. The hair grows in phases and, as it leaves the malpighian layer, it is almost formed.

Follicles are dynamic organisms in which different processes take place at the same time. These are: division, differentiation and upward movement of the cells which form the fibre (trichocytes), as well as biosynthesis of the monomeric amino acids for the wool proteins (Fig. 2) as gene products and finally self ordering of the monomers for the supermolecular structures and their “keratinization” (cornification) through the formation of disulphide crosslinks. As well as this, cells from the root sheath are broken down.

The different stages of development of the growing

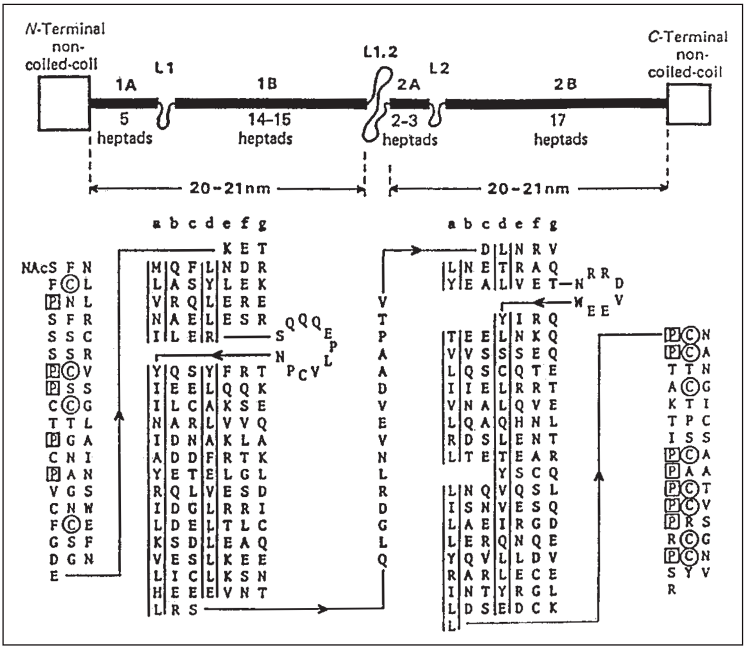


Fig. 2: Primary structure, i.e. amino acid sequence in wool protein 8 c-l according to Dowling.

wool fibre (Fig. 3) in the follicle can be divided up into six zones (Fig. 1). Even in the upper part of zone 1, around 8–12 nm fine → Intermediate filaments (microfibrils) (Fig. 4) and trichohyalin granules form. The filaments come together as macrofibrils between zones 1 and 2. Matrix proteins rich in sulphur are deposited in the macrofibrils of the paracortex cells. Amorphous protein aggregates (approx. 30 μm diameter) are formed in the cuticle cells of the wool in zone 2. A filament-matrix structure can be found in the orthocortex cells (Fig. 5). At the end of zone 2, the cuticle cells are

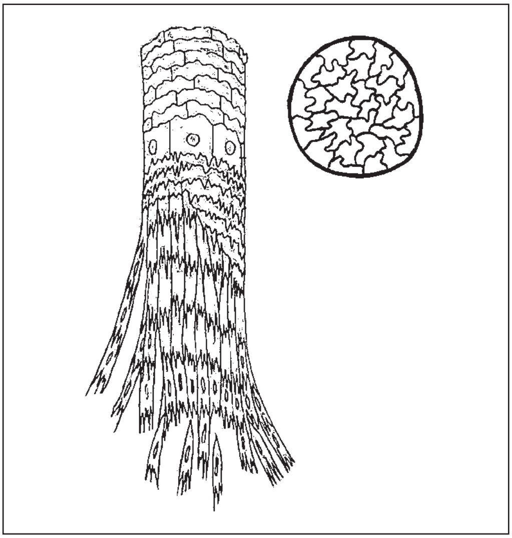


Fig. 3: Incorporation of cuticle and cortex cells prior to keratinisation with fringe formation through the effect of shear strength in the orientation "flow direction" (according to Kassenbeck).

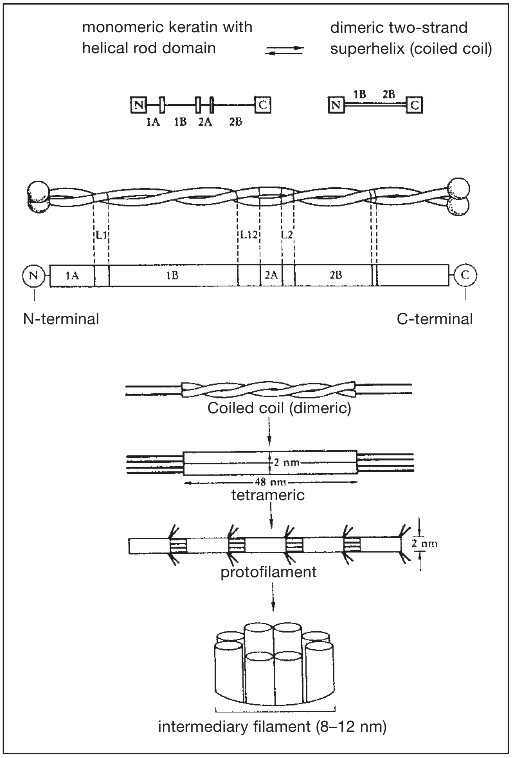


Fig. 4: Keratin polymers form intermediate filaments on the base of the hair follicle.

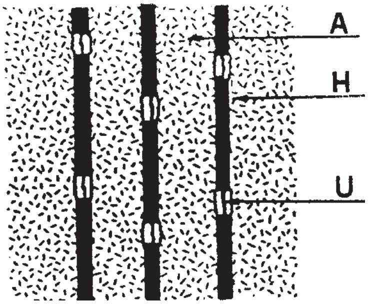


Fig. 5: Filament-matrix structure with amorphous matrix (A), helically-structured microfibrils (H) and less-ordered areas (U).

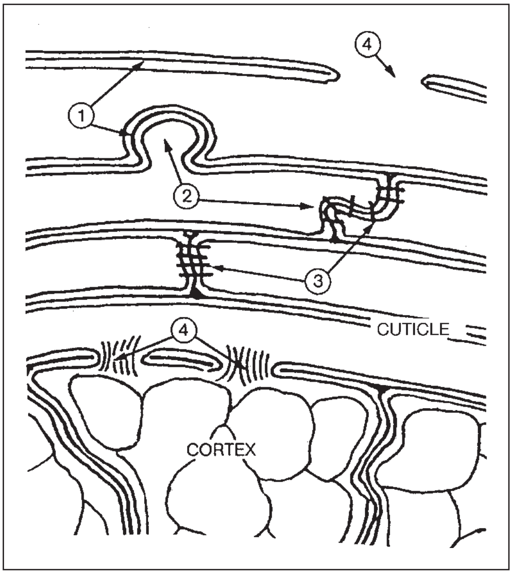


Fig. 6: Interconnection system between the keratinous cells of the hair (according to Kassenbeck).
1 = central strip (holding plate or cementing substance to be more precise); 2 = button-type, mechanical bracings;
3 = lining bonds strengthened by "rivets"; 4 = weld seam-type intercellular bonds.

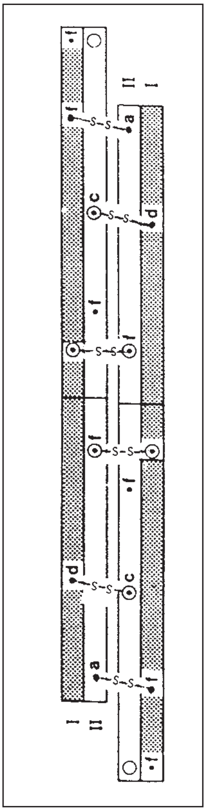


Fig. 7: Positions of probable disulphide bridges after keratinisation in zone 2 of a type I/II heterodimer in a keratin-intermediate filament (according to Fraser).

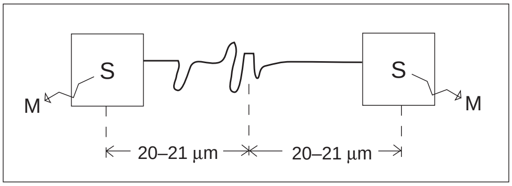


Fig. 8: Keratin molecule with low-sulphur polymer chains (2 x 20 nm), containing unordered loops, between 2 high-sulphur terminal blocks (S) which form disulphide bridges to the matrix (M).

already hardened (Fig. 6) while final keratinisation of the whole fibre does not begin until zone 3 (Fig. 7).

Observing an individual polymer chain of the keratin of the intermediate filaments (Fig. 8), it will be found to be poor in sulphur in two 20 µm long sections lying between two terminal blocks which are rich in sulphur. These filaments are bonded to the matrix via disulphide links from the sulphur-rich terminal blocks.

Reliable identification of wool and fine animal hair is becoming increasingly important from an economic point of view. At the same time, the distinction between yak and cashmere, alpaca and mohair, for example, or wools of different provenance is of particular interest, as financial losses due to undeclared blends continue to increase. The height of the scale edge can be used as a distinguishing criterion (wool approx. 1 µm and cashmere approx. 0.5 µm) (Fig. 9). As a characteristic "database" for each individual, the DNA is basically predestined for the unambiguous identification of the species. However, DNA analysis has so far been used in the analysis of wools with caution, as the isolation and unambiguous identification of genetic material in the hairs has been made more difficult by processes such as bleaching.

High molecular DNA (1.4 x 10^7 Dalton, approx. 20 000 base pairs) can be recovered from the hair shafts, so statements about the origin of unknown wool samples can be made (Fig. 10). DNA are mainly to be found in the highly crosslinked exocuticle (Fig. 11), but not in the cell residues of the p-cortex.

At higher humidities, the wool fibre is able to absorb up to 33% of its own weight in water (Fig. 12). In comparison to the hydrophilic fibre stem, which readily absorbs steam, the surface of wool is extremely hydrophobic to water in its liquid state. It is the "epicuticle" which is considered responsible for these hydrophobic properties. At high water adsorption, water is incorporated via hydrogen bonds among others. The high humidity perception limit of 13% can be explained by the immobilization of water. These factors are very important for the physiology of the clothing.

The morphology of the wool can be broken down stepwise into a two-component structure (Tab.). The

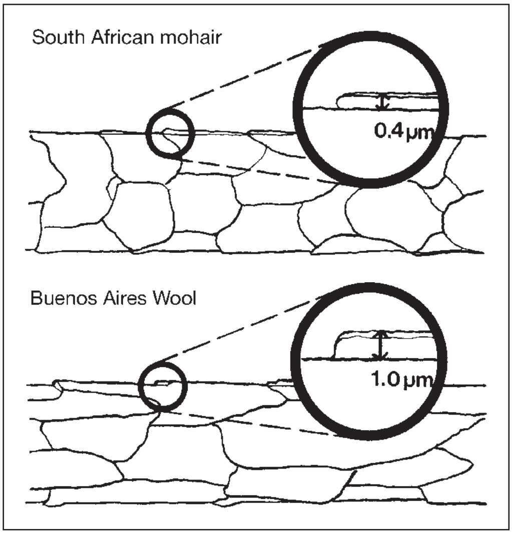


Fig. 9: Height of scale edges of mohair (top) and wool (bottom).

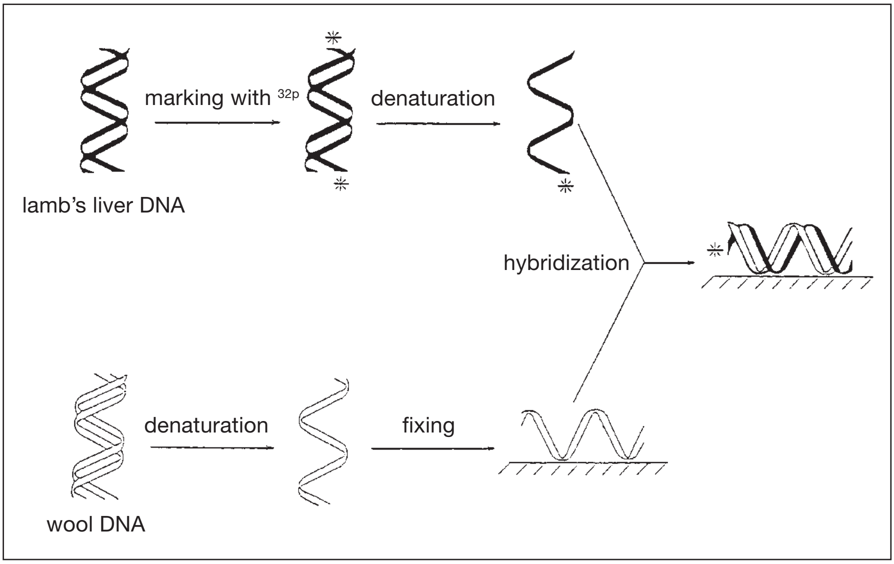


Fig. 10: The dot-blot hybridization principle as shown by lamb's liver DNA in comparison with wool DNA.

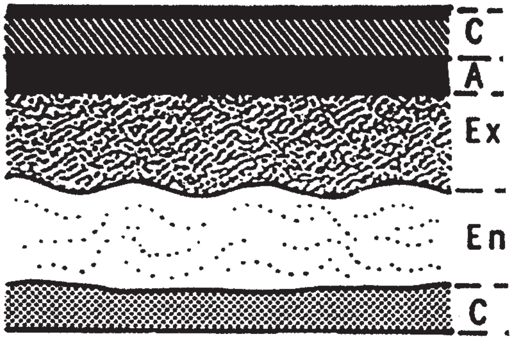


Fig. 11: Scales as the verification point of DNA (in exocuticle).
C = cell membrane; A = A-layer; Ex = exocuticle; En = endocuticle.

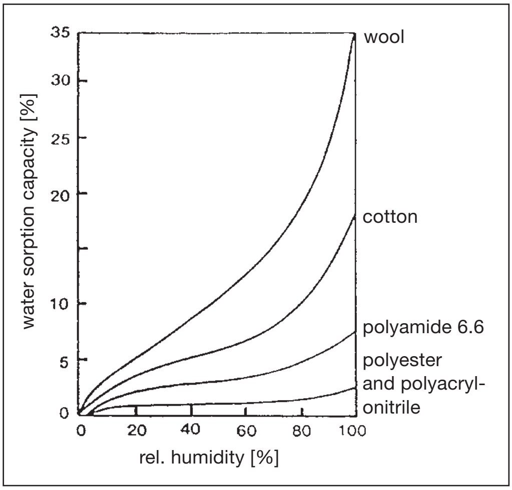


Fig. 12: Water sorption isotherms of various textile fibres.

Tab: Morphology of wool as a combination of two-component structures.

Composite	Type *	1st components	2nd components
wool fibre	r/c	cuticle	cortex
cortex	f/m	cortex cells	cell mebrane complex
cortex cell	f/m	macrofibrils	intermacrofibrillar cement
macrofibril	f/m	microfibrils	matrix

* r/c = ring/core structure, f/m = filament/matrix structure

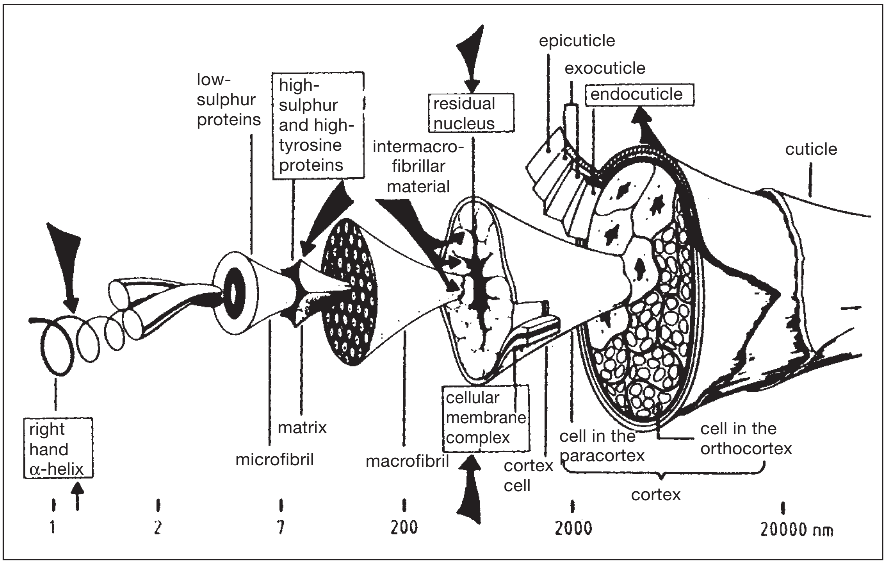


Fig. 13: Hierarchy of a fine Merino wool fibre (CSIRO Melbourne). Arrows indicate the weak points of the biological structure and peptide chains.

outer sheath of the wool fibre consists of flattened out, scale-shaped cuticle cells which are made up of extremely thin (only 2–10 µm thick) epicuticle, exocuticle (rich in disulphide crosslinks – exocuticle A = 35% cystine; exocuticle B = 15% cystine) and the softer endocuticle (3% cystine). The intercellular cement contains only 1% cystine.

The principle of the composite structure is described as follows (Fig. 13):

Component 1: the α-helix exists in the crystalline phase in the subfilaments which form continuous filaments in the direction of the fibre.

Component 2: the matrix containing all the remaining non-crystalline material, i.e. both the interfilament material visible under the electron microscope and the part of the keratin intermediate filament without a helical structure.

The elastic properties of the composite material are determined by the different crystalline or amorphous ratios of its components.

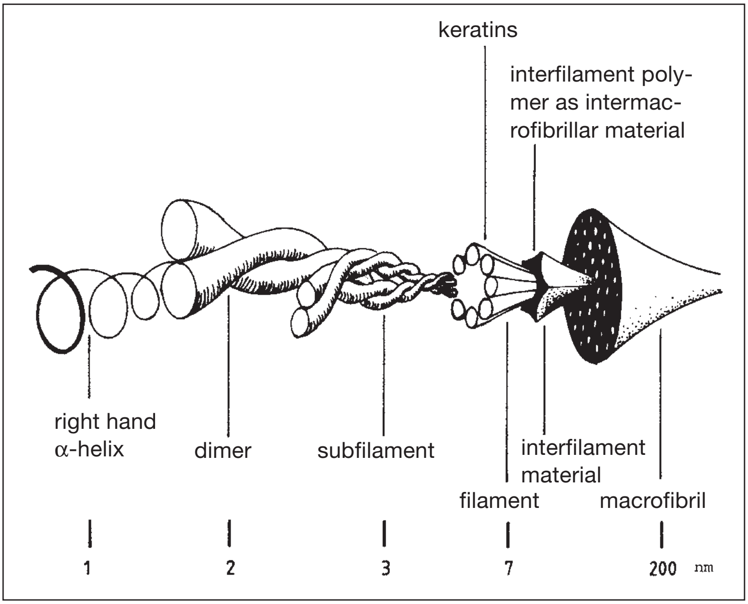


Fig. 14: Fine structure of a macrofibril in wool or human hair, modified representation (magnification of Fig. 13) following the Fraser wool model (according to Zahn).

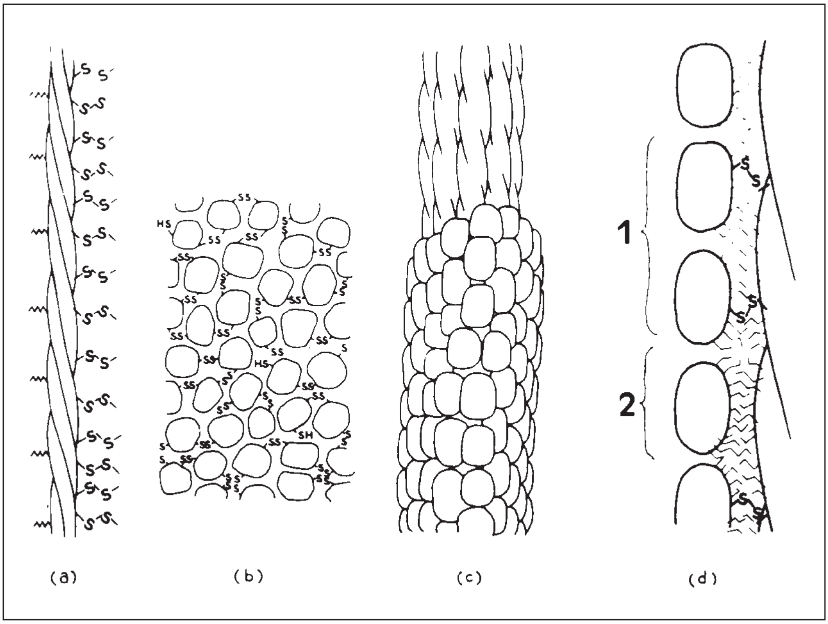


Fig. 15: Diagram of possible structures in wool cortex cells. 1 = stretched in the postyield area; 2 = stretched in the yield area; a = protofibril with acid-labile (wavy line) crosslinkages and disulphide bonds; b = matrix with intermolecular disulphide bonds; c = single microfibril, surrounded by "matrix" molecules; d = microfibrils and matrix molecules exert mutual reaction on their side chains including disulphide bridges (according to Crewther).

A wool fibre which is free of marrow is an example of the complex structure (Fig. 14) which reflects the structural principle of all biological and many synthetic materials, made up of components with different properties united to form a material which is optimally suited to its purpose. As chemical constituents, the α-keratins are insoluble, hard substances with high elastic moduli. They are present in the macrofibrils in the form of two components – the microfibrils and the matrix. The matrix consists of proteins rich in tyrosine and sulphur, while the main component of the microfibrils is represented by proteins poor in sulphur. The mechanical-elastic behaviour of the composite is demonstrated by a two-phase model (Fig. 15), according to which, the different morphological components are assembled into two phases:

1. the α-helices aggregate in the microfibrils as continuous, elastic filaments,
2. the matrix which is composed of all the remaining non-crystalline viscoelastic material, including the intermacrofibrillar cement, cell-membrane complex and cuticle.

Because wool not only predominantly consists of helical crystalline microfibrils but also an amorphous region, it is possible to associate it with a glass-transition temperature (Fig. 16). The glass-transition temperature of wool depends on the amount of water absorbed.

Knowledge of the glass-transition temperature T_G of wool as a function of its water content is of vital importance for understanding its viscoelastic fibre properties (Fig. 17), especially under fluctuating moisture and

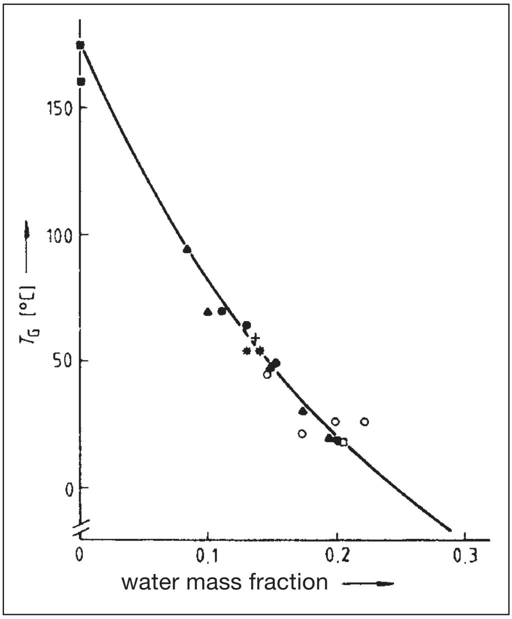


Fig. 16: Wool glass temperature dependency on the water weight share of the fibre.
The T_G values as a function of the water content were determined by Wortmann from documented data via the temperature dependency of the following physical properties:
● recovery of torsional setting; ■ torsion properties;
❐ recovery of elongation setting; ▲ dielectric properties;
✳ crease recovery of fabrics; ○ adiabatic calorimetry;
+ force at 4% stretch (Zahn, Altenhofen, Wortmann, 1983).

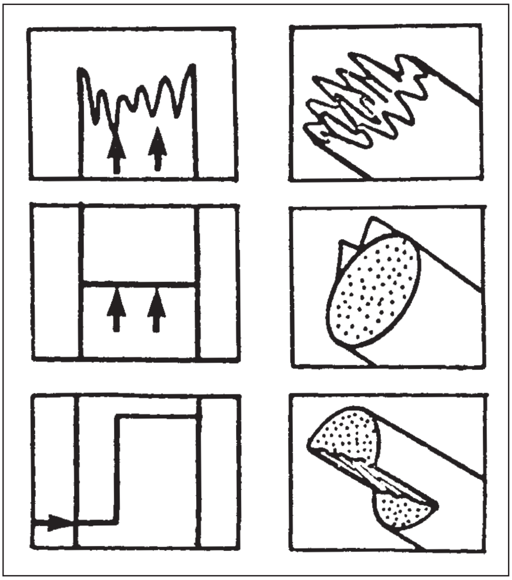


Fig. 17: The most significant fracture surfaces for Cape Mohair and wool when torn in liquid nitrogen (top), in air (middle) and in hot water at 60ºC (bottom).

Fig. 18: Diagram, drawn from electron microphotographs, of reconstructed microfibrils from low-sulphur wool proteins in thiol form (Thomas, Conrads and Phan 1985).

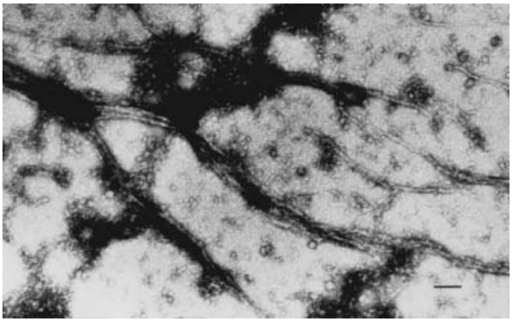


Fig. 19: Wool intermediate filaments as an in vitro reconstruction (according to Thomas and Phan). Bar = 100 nm.

temperature conditions such as those encountered during the processing and wearing of woollen fabrics, as well as being important for understanding the ageing and temperature processes in woollen fabrics – not to mention creasing at high moistures and temperatures and ironing and decatizing.

Although microfibrils were discovered early using electron microscopy (Zahn 1941), it has not been possible until now to reconstruct microfibrils from the proteins (which are poor in sulphur) from which they are made (Figs. 18 +19). This is now possible as the methods used in cell biology to form intermediate filaments from the dissolved intermediate proteins have been

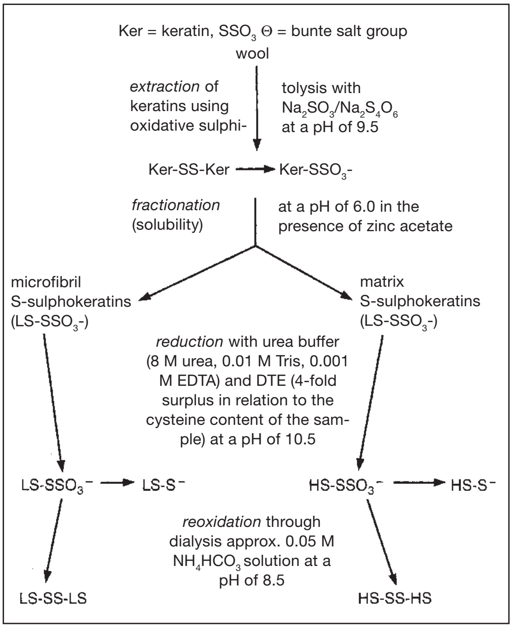


Fig. 20: Diagram of steps for the isolation of the low sulphur (LS) and high sulphur (HS) wool proteins in disulphide form (according to Hüskens).

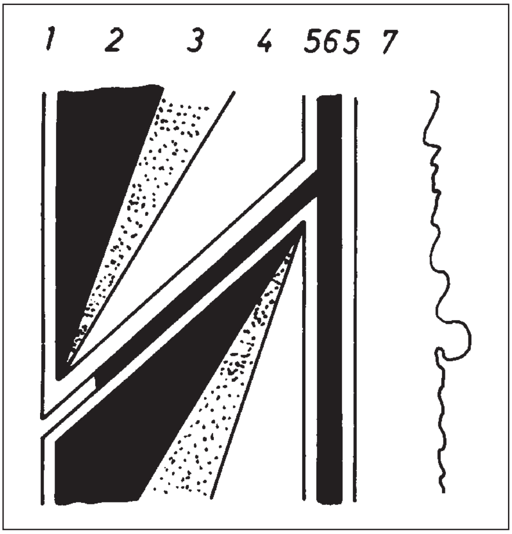


Fig. 21: Surface coating of a wool fibre in the scale over-lap zone (according to Lehnen).
1 = epicuticle; 2 = exocuticle; 3 = mesocuticle; 4 = endocuticle; 5 = cell membranes; 6 = intercellular cement; 7 = cortex.

adopted and new methods have been found to remove wool proteins gently from the fibre without irreversible attachment at the cystein sulphur atom (Fig. 20).

If the cuticle is mechanically removed by shaking the fibres with corundum grinding powder in a water/propanol mixture, then it is possible to separate the microfibrils and the matrix by reductive extraction and by converting the dissolved cortex proteins into the bunte salt (sodium alkylthiosulphate). If the S-sulphonate protective group is then split again by thiodisulphide exchange, unprotected microfibrils and matrix proteins are obtained and these can be re-oxidized selectively.

The histological and chemical composition of wool has a decisive effect on the behaviour of the textile fibre during the numerous finishing stages in wool processing.

The cell-membrane complex (Fig. 21) stretches throughout the whole fibre as the so-called “interpenetrating polymer network”. The exact mechanism of the formation of the cell-membrane complex during keratinisation is still not explained. The development of the cell-membrane complex can be illustrated as shown in the scheme in Fig. 22. A distinction can be made between the soft, easily swellable “intercellular cement” composed of proteins with few crosslinks, a lipid component and a chemically resistant protein membrane which surrounds each cuticle and cortex cell. The epicuticle is part of this membrane. Then an intracellular layer can be identified which can be recognized most clearly in the scheme according to the fibre (Fig. 22).

The lipid components of the cell-membrane complex of wool are made up of free fatty acids (Fig. 23), free sterols and polar lipids such as cholesterol sulphate and sphingolipids. Unlike the cortex cell, cuticle cells

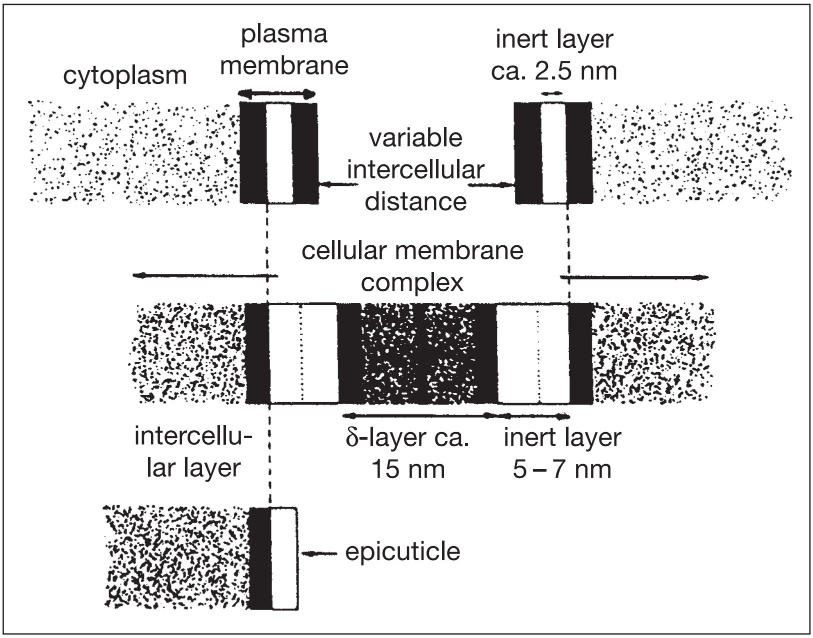


Fig. 22: Cellular membrane complex in the scale layer (according to Fraser).

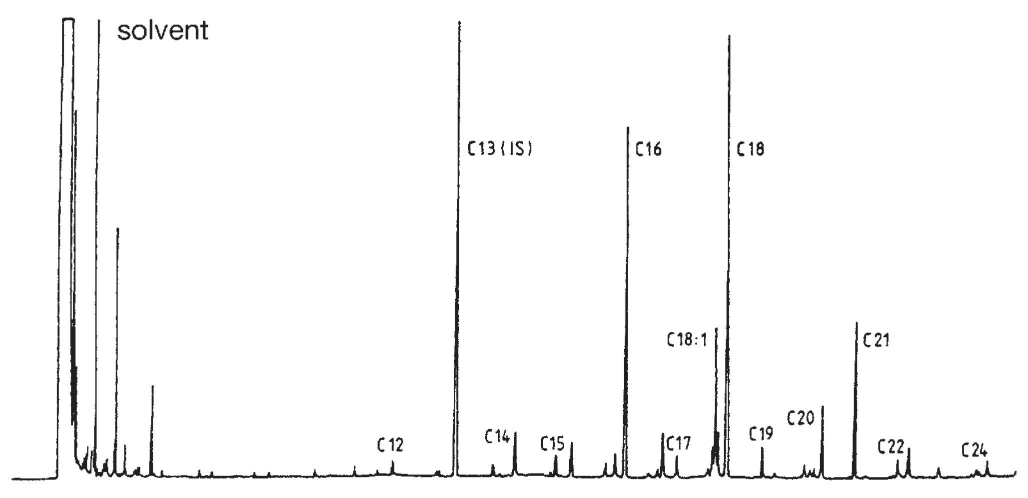


Fig. 23: Separation of the fatty acids of wool cell membrane lipids using capillary chromatography: fatty acids are found in the chain length zone of 12–24 C-atoms (C12–C24; C21 = 18 methyleicosanoic acid; C13 = tridecanoic acid methyl ester as an internal standard; LM = solvent) (according to Körner and K. Rouette).

contain a fatty acid with 21 carbon atoms. This acid, unlike the free fatty acids, stearic, oleic or palmitic acid, can be extracted from the intact fibre to only a small degree. The existence of a covalent bond between the C_{21} acid and the proteins of the fibre surface has already been postulated; it is suspected that this bond could be in the form of an ester link to a serine residue. The C_{21} acid is released in the fibre by papain/dithioerythritol and treatment with alkali. It is then found in the free fatty acid.

The wool fibre is regarded as a composite made up of cuticle and cortex cells and is held together by the cell-membrane complex. The stability of the wool fibre is determined not only by the cortex cells from which it is formed but also and to a much greater extent by the forces acting between the cells. As in a chain, the stability of the composite structure is determined by its weakest component. The cell-membrane complex represents just such a weak link, as it is the only continuous phase of the wool fibre and possesses only a small amount of mechanical and chemical stability.

Because the structure is made up of the cortex and the cuticle, the wool fibre can be regarded as a core/mantle-type bi-component fibre. The effects of this type of structure are reflected in the properties of the wool.

An argument for the significance of the cell-membrane complex is supported by the fracture morphology of wool and mohair fibres which have been stretched in liquid nitrogen, air and warm water at 60°C (Fig. 17). Fractures which have occurred in liquid nitrogen have irregular profiles such as those seen in composite materials which have a statistical distribution of similar weak sites (statistical failure). Fracture routes which follow the morphology of the material have not been found. When the fracture has occurred in air, the site has a granular texture at right angles to the fibre axis. These are typical of a fracture in composite materials which have pronounced interfaces between the components of the material. Deviation from the primary fracture route is seen at the projecting piece of cuticle. This indicates that adhesion between the cuticle and the cortex is relatively weak.

The fracture surfaces resulting from fibre breaks in water at 60°C look quite different. In this case, an extensive longitudinal crack appears resembling a fracture in simple composite materials, which is the result of weak interfaces between the “matrix” and the components which carry the bulk of the load. In fact, the longitudinal route of the crack runs predominantly along the length of the cell membranes and border lines of the macrofibrils. It is the non-keratin areas of the fibre which are weakened in preference, due to the combined effect of heat and water.

Macrofibrils consist of microfibrils. These fibre-axial oriented cylinders, with diameters of around 7 nm, are embedded in the matrix. The structural element of the microfibrils, effectively acting mechanically as a filament, is the proportion of α-crystalline helixes, which are regarded as the smallest building blocks of the fibre (diameter approx. 1 nm). Approx. 50% of the microfibrils, which can be reproduced using an electron microscope, consist of helical domains forming the continuous crystalline filaments due to their ar-

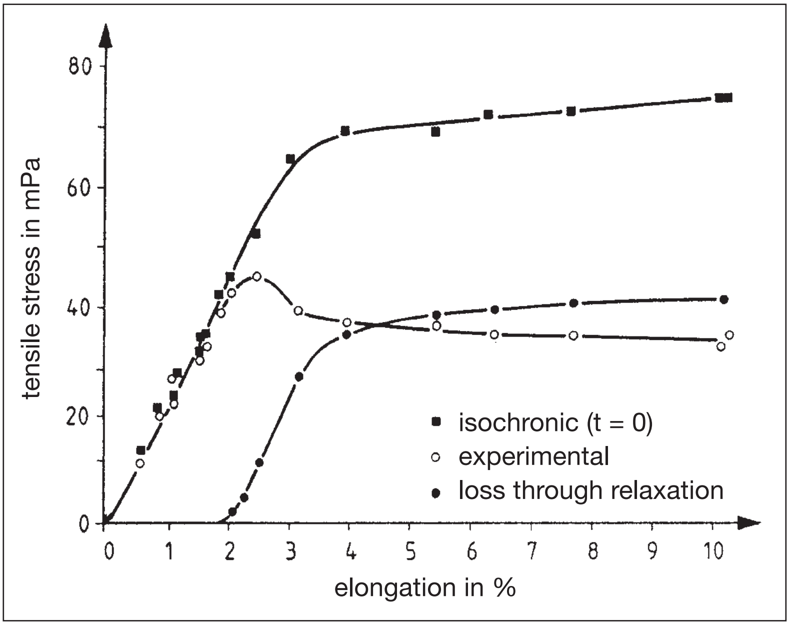


Fig. 24: Elastic and viscoelastic portion of the stress/elongation diagram of the matrix phase of a wool fibre under normal climactic conditions (60% rel. humidity, 20°C). The curves and viscosity values are calculated through analysis of the non-linear viscoelastic relaxation behaviour using the two phase model as a basis (according to Wortmann).

rangement into increasingly complex, rope-like superlattices (dimers and tetramers). Although the helices only make up approx. 30% of the total structure of wool, they represent the whole fibre in regard to its deformation in the linear elastic range of extensions up to about 2%. This is of more importance in wool processing than greater elongations (Fig. 24) (contributed by Zahn, Wortmann, Thomas and team).

Wool sulphur determination → Benedict-Denis reagent.

Wool testing → Fibre damage (wool), tests for.

Wool union Term used for mixtures of wool and cotton and mixtures of animal hairs and natural or regenerated cellulose fibres in general (wool, mohair and other animal hairs mixed with cotton, viscose and cupro fibres). The mixing ratios of the two types of fibre can vary considerably. The term wool union is used almost exclusively in dyeing technology.

Wool union/acetate dyes Commercial range of neutral-dyeing mixtures of acetate dispersion and wool-union dyes, for dyeing acetate-containing wool-union fibre mixtures the same shade.

Work Physics: product of force and distance: SI unit = joule.

Work allocation In textile finishing, when certain work is done outside rather than by the companies own staff (as an order = commission finishing) the systems used must be compatible with the company's own machinery and/or computer system.

Working life → Forming time of glues and coating compounds, etc. Term originating from wood gluing (formerly the melting of glutine-based glue in pots in a hot water bath).

Working platform In dyehouses, the working platform separates the section used for the charging of the dyeing machine from section giving access to the drive and energy supply "under floor". On the working platform, the operators operate the service equipment such as the crane for charging and emptying the dyeing machine. Under the working platform, the service personnel carry out repairs and overhaul the dyeing machine.

Working position After receiving the appropriate command, machine tools adopt the work position in or-

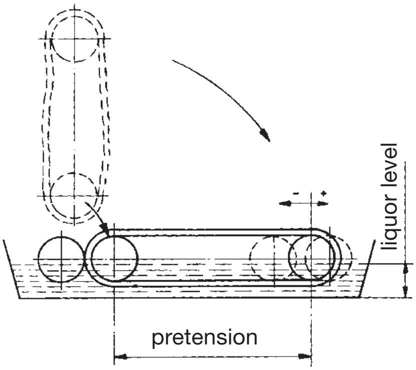


Fig.: Tension rollers swinging down into the operating position or preliminary tension position in a hank yarn mercerizing line.

der to carry out the textile finishing step for which they have been designed. Otherwise, they remain in the rest position (see Fig.).

Working pressure In a pipe, for example, the permitted working pressure (operating pressure) is the maximum pressure (N/mm^2) under which a pipe, which has been designed for a certain → Nominal pressure, must be operated, subject to the operating temperature and material used. If the starting material used is that intended according to the dimensional standard, then at 20°C, the permitted working pressure equals the nominal pressure. The highest permitted working pressure is the steam pressure laid down in the permit in bar in the steam chamber of a steam generator before entering the superheater or, in the case of once through boilers, the pressure at the end of the superheater.

Working voltage The electrical voltage of plant components operating locally between two conductors.

Workplace illumination → Illumination of factory work areas.

Works laboratory An important control centre in the textile finishing works. Purpose: to monitor the dyes and auxiliaries used and carry out quality control of the raw goods and finished goods, to develop and perfect methods/processes and supply information to the purchasing and sales departments as well as the production and design departments (→ Laboratory). On the other hand, the cost of works having their own research laboratory are so high that even for the major textile groups, they do not pay off, except when they concentrate on very specific restricted areas.

Workwear Clothing worn for work, the wearer himself being responsible for its general condition, as opposed to → Industrial protective clothing. The rules are different in Germany for personnel working in hospitals and shopping centres, etc. (representation workwear). In this case, for reasons of safety at the workplace (particularly for personnel working near moving or rotating parts) the following rules apply: workwear must always be in perfect condition including footwear (non-slip soles).

Worm-like grooving (worms). Faults which appear in crêpe fabrics like irregular breaks, folds or ribs. Examples of causes are: unsuitable preparation, tension, twisting, uneven introduction of the crêpe material into the crêping bath (folds = crêpe breaks). Avoided by crêping the previously embossed raw material against paper using a suitable pattern at approx. 80°C. This can produce a better evening-out effect.

Worn Denim Look Fashion trend for casual wear, particularly for → Jeans made from denim fabric such as blue warp (grey weft). Gives the impression of previously worn garments which must not only be produced by the "washout" effect (indigo-colour with the typical appearance of frequent washing = washed jeans) but also may be produced by use in wearing ("controlled" abrasion effect). This can also be achieved by gently treating with enzymes.

Worsted fabric Fabrics made from (single or twist) worsted spun yarns in the warp and the weft. In most cases, relatively fine thread, light to medium weight, smooth and napless cloth qualities. Anything from pure virgin wool, viscose or man-made fibres, including mixtures, can be used. The fabrics can be wool, yarn or piece-dyed. A particular characteristic is the smoothness of thread achieved by worsted-spun yarns and napless finish. In comparison to carded materials, because of fine and smooth yarns, the appearance of the weave is more elegant and neat. In spite of the relatively low weight of the cloth, worsted fabrics are hard wearing. This is particularly true in the case of high-quality merino virgin wool qualities; crossbred virgin wool qualities, on the other hand, are more crease resistant but less abrasion resistant.

Worsted spinning High quality threads prepared from staple fibre. The origin of the textile fibre can be natural or synthetic. In the main, wools and wool mixtures are spun with polyester, polyacrylonitrile or other man-made fibres. The fibres are single or twisted during weaving or knitting to produce the fabrics. The cloth and knitwear is most widely used in ladies' and men's outer clothing.

The most important process steps in the production of worsted yarn can be listed as follows:

1. Bale breaking: loosening up pressed wool.
2. Opening, willowing: opening the wool flocks.
3. Mixing: production of a large homogeneous mass of fibres by intensive mixing.
4. Scouring: removal of impurities.
5. Drying: reduction of wool moisture.
6. Lubricant: adjustment of friction parameters relevant to the process.
7. Carding: parallelizing and fine opening; production of a fibre ribbon (card sliver).
8. Drawing: similar treatment to the card slivers or combed tops by twisting and drawing; reduction in weight of the fibre bundles; sliver formation.
9. Combing: separating out short fibres (combing noils), non-fibre inclusions and knops.
10. Drawing: as 8 above.
11. Possible combed-top dyeing (such as vigoureux printing).
12. Mixing: uniform mixing of individual fibre or colour components.
13. Drawing: reduction or sliver thickness; production of a rove.
14. Fine spinning: spinning the yarn on combed-top spinning machines.

Steps 1–6 are part of the general preparations for spinning. The actual combed-top spinning starts at step 7. The fibre material is subjected to high stress due to friction between the fibre and metal predominantly during combing and this reduces the average length of staple (hauteur). In order to control this, it is necessary to apply a suitable lubricant before combing. To produce large coloured batches and yarn effects in particular (colour blends), the wool or man-made combed-top, which are supplied in the undyed state, are dyed before the actual spinning process. After dyeing, the combed-tops show comparable properties to wool after raw-wool scouring. The slivers are rough, stumpy and brittle; so that they can be processed further, they are now softened (modification of the static and dynamic friction behaviour, softening, antistatic finishing). Depending on requirements, different methods are available for softening, which can be carried out in the dyehouse. In practice, the following methods are mainly used:

- backwashing treatment,
- final brightening in the dyeing machine.

The purpose of backwashing treatment is to wash the combed-tops emerging from the dyeing process in a continuous process. Unfixed dye residues and dye auxiliaries are removed during this process. Highly curled wool is straightened out at the same time and the wool becomes more “sized”. This property is beneficial for the draught process and, to some extent, for the nature of the yarn. The backwashing process involves a series of 4–5 washing and rinsing baths connected in sequence, followed by a sieve-drum drier. Some of the auxiliary required for spinning is applied in the final rinsing bath. Softening is carried out according to the forced-application method. The application is controlled via the quantity of liquor dragged in by the combed-top (squeezing effect). The ionicity of the lubricant in this form of application is insignificant.

In order to reduce the high costs of the backwashing process, the worsted yarn industry is occupied with the development of alternative methods of applying lubricant to the combed-top. Basically, it is possible to carry out post-treatment processes according to forced-application processes or exhaustion processes. In the forced application case, the auxiliaries are diluted and sprayed on to the combed-top, for example, according to the pressure drier or the centrifuge method. In the exhaustion case, after thorough rinsing in fresh liquor in the dyeing machine, products are used which are oppositely charged to that of the substrate. This property gives the products an affinity for the fibre. Here, either genuine or pseudocationic lubricants are preferably used.

When lubricating polyesters in the dyeing machine, suitable steps must be taken to reduce the oligomers. During the rinsing stage in the dyeing machine, the combed-tops which are present in the form of yarn packages act as filters and make the removal of oligomers more difficult. Oligomers which may still be in the combed-top, have a tendency to deposit on the stretch-pressure cylinders of the gill boxes which follow and cause frequent coiling and non-uniform slivers. On the backwashing machines where the combed-tops are washed continuously in ribbon form, this problem does not appear so often.

In order to achieve the optimum spinning results, it is necessary to re-lubricate both the undyed and the dyed and softened combed-tops during the spinning of worsted yarn. This fine tuning satisfies different requirements in regard to adhesion and friction, electrostatics and moisture management. Particularly in the case of mixtures of wool and man-made fibres, there are significant differences in the friction properties of the individual fibres in relation to each other. The Fig. shows the places where lubrication or softening can be applied. To ensure that the lubricant is well distributed on the substrate, lubrication must take place as far in advance of the comber or ring-spinning frame as possible. Spraying is carried out on the stretching passages two or four times, depending on the operational requirements. Lubrication normally takes place on the delivery side to avoid coiling on the stretching machine rollers. The lubricant is always applied by aqueous dilutions, mainly to improve the distribution of the products and to even out the distribution of moisture in the fibre.

The combed-tops of the wool-combing plant are put together as a spinning batch, taking into account the properties the yarn will have later on and the efficient

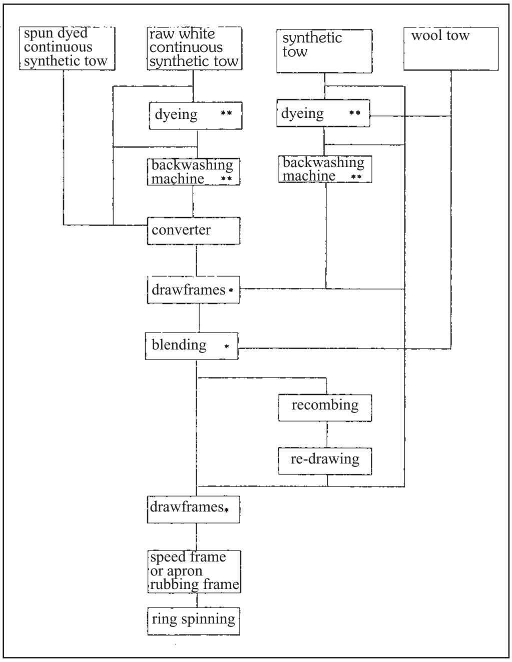


Fig.: Points at which lubricant (*) or spin finish (**) can be applied in worsted yarn spinning/dyeing.

use of raw materials. The mixing process, which is purely mechanical, is accomplished by repeated bringing together and combined drawing. There are three different methods:
a) the French or continuous system,
b) the English or Bradford system,
c) the German system, which is a combination of a & b.
The main differences between the systems is the way the different types of twist are introduced into the rove. While the French system involves introducing a false twist, in the case of the other systems the rove is given a genuine twist. The fineness of the spun yarn depends on the fineness of the rove and the draw.

The machine most widely used for spinning worsted yarn is the ring-spinning frame. The rove which is produced in rove spinning is initially pre-stretched in the ring-spinning frame using a high performance stretching mechanism. The yarn is then given a twist which is produced by an eye-shaped traveller running on a ring. This rotates around a fast-running, vertically aligned spindle with a winding bobbin and is rotated by the pull of the thread coming from the bobbin. The speed of the spindle depends on the fineness being attempted for the yarn (partially contributed by Bekker).

Worsted yarn Yarn produced in → Worsted spinning where the short fibres (combing noils) are removed by the combing process. This produces a smooth even yarn.

Wound (yarn) package → Package.

Woven carpets Carpets which are woven by machine or on hand looms (→ Machine-woven carpets).

Woven fabric Textile fabric formed by threads crossing each other at right angles consisting of at least two thread systems (warp and weft). → Weave.

WP → Alpaca, → Textile fibre symbols, according to DIN 60 001 T4/08.91.

Wrap fibre The so-called covering fibres of rotor-spun yarns which, among other things, improve the abrasion resistance during practical use. Research has shown that the total number of wrap fibres is smaller for a larger rotor and that coarser and longer fibres form approximately four times as many wrap fibres as finer and shorter fibres.

Wringable laundry Washing classification term according to the finishing work, i.e. → Laundry which can be put through a mangle, such as bed linen, table linen, hand towels, with possible sub-classifications into large and small pieces.

Wrinkle Recovery Tester American instrument for determining the → Crease recovery angle. Consists of a solid disc with graduations from 0–180° and rotatable, transparent measurement disc with vertical setting mark. The longer leg of the broken test strip is fastened in the centre of the instrument, while the freely movable short leg can stand upright. After appropriate adjustment of the rotatable front disc, the current crease recovery angle can be read directly off the solid disk. Manuf.: Monsanto.

WRONZ Wool Research Organization of New Zealand Inc., New Zealand. Textile research organization. → Technical and professional organizations. Scope of activities: wool research (→ WRONZ wool scouring process), information service, commercial test projects, annual report and report series.

WRONZ wool scouring process Process used to achieve slight destabilization of wool-fat emulsions:

1. Small wash trough with $^1/_3$ of the usual bath capacity, vigorous bath circulation and mechanical movement of wool. The system includes the removal of flocks and solid particles, fat recovery and utilization of waste heat.
2. Breaking the emulsion using N-pentanol.

WS → Cashmere, → Textile fibre symbols, according to DIN 60 001 T4/08.91.

W type, man-made fibres from wool type.

WU → Guanaco, → Textile fibre symbols, according to DIN 60 001 T4/08.91.

WV → Virgin wool, → Textile fibre symbols, according to DIN 60 001 T4/08.91.

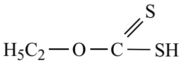
WY → Yak, → Textile fibre symbols, according to DIN 60 001 T4/08.91.

X

Xanthane Natural polysaccharide consisting of a chain of glucose units with complexed mannose and glucuronic acid units. It is used as a thickening agent.

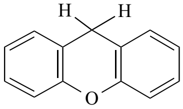
Xanthangumme This is the name given to the bacterium “xanthomonas campestris”, which causes xanthane gum to build up from (mono, di and oligo) polysaccharide units on a sugar solution as a result of microbiological synthesis. Xanthane gum has a polyanionic function and is used primarily as a thickening agent in carpet printing and space dyeing.

Xanthate A salt of xanthogenic acid. It is produced as a result of the effect of carbon disulphide on sodium alcoholate. → Cellulose xanthate.



$$H_5C_2{-}O{-}\overset{\overset{\textstyle S}{\|}}{C}{-}SH$$

Xanthene dyes An alternative term for → Phthaleins, as these are mostly derived from xanthene. They are derivatives of triphenyl methane carboxylic acid or triphenyl carbinol carboxylic acid, in particular phenolphthalein, fluorescein, eosine and rhodamine.



Xantho-protein reaction The yellowing of proteins containing the amino acids tyrosine or tryptophan after a short period of boiling in 10% nitric acid (→ Nitric acid solubility test). During this process, nitro groups enter the benzene ring in the amino acids, causing yellow “nitro dyes” (xanthoproteins) to be produced. Since non-protein fibres remain undyed, the xanthoprotein reaction can be used to test for fibres of animal origin. These are dyed more or less strongly yellow; so too are the protein inclusions in the lumen of non-protein fibres.

Xantho-, xanth- (Gk.: xanthos), yellow.

Xe Element symbol for xenon (54).

Xenon arc lamp →: Light fastness testing; Xenotest Light Fastness Tester.

Xenon high pressure lamp (UV lamp), the spectral ray density distribution largely corresponds with that of an overcast sky, with a high proportion of UV radiation. The colour bleaching effect is greater than the effect on a light exposure gauge. → Xenotest Light Fastness Tester.

Xenotest Light Fastness Tester Instrument for → Light fastness testing. The basis of these instruments, which can vary in size, is 1 or 3 vertically arranged xenon emitters surrounded by variable optic filter systems that allow the spectral distribution to be varied from “unlight through a window” (light fastness) to “sunlight in the open air” (weather fastness). A high correlation to sunlight can be achieved. This means that the light fastness results achieved correspond closely with those that occur naturally. The advantage is that the high level of radiation means that the test duration is shorter (ratio approx. 1 : 9 for the central European climate) (Tab.).

type	Xenon emitter output in kW*	number of test sample carriers	test sample area in cm^2**	size of the illuminated area per test sample carrier (mm)
150 S	1.3	10	900	100 x 45
450	4.5	22	3600	180 x 45
1200	13.5 (3 x 4.5)	(***)	approx. 20 000	(***)

Tab.: Xenotest devices.
** due to decreasing radiation intensity, the suggestion is for 1500 h worth of working hours, resulting in a drop of less than 10%; ** test sample area in the reverse run (front and back filled with test samples); *** larger test samples can also be illuminated.*

The sample holders have spring clamps to hold the samples affixed to opaque cardboard with the masking screen. During the test, the sample holders rotate approx. 5 times a minute around the emitter, which means that the required radiation mix is guaranteed even when the filter system is changed (IR filter, UV filter, poss. window glass). The lower UV limit behind the UV filters is approx. 310–320 nm. The IR filters ensure a high level of absorption between 700–1000 nm, so that the test temperature does not rise too high. The sample holders turn during rotation once per rotation by 180°

(simulation of day and night, sample cooling), but they can be operated directly without rotation. All instruments have a cooling system that is installed separately, which should be set at a constant low temperature. Additionally, all the instruments have devices (ultrasound water atomizers) so that the test environment can be set at a constant humidity (up to max. 95% relative humidity). There are also devices that generate precipitation onto the samples, so that weather fastness can be tested with an artificial xenon arc lamp (xenotest W).

The company Heraeus has developed a portable device for rapid illumination sun testing to test the behaviour of material under the influence of light. The test is quick, however it does not comply with DIN. There is an increased UV ratio, which means that any sample size up to a max. 500 cm^2 can be tested within a short time, and since the testing and acquisition costs are low, even smaller companies can afford to carry out light fastness testing. The sample being tested is in a test chamber, in which there is a parabolic reflector to ensure even distribution of radiation over the entire surface of the sample. The emitter (1.1 kW) has a radiation strength of 765 W/m^2 (at max. level of UV filtering for 1 < 800 nm) and can be cooled down by approx. 10°C using an additional sample table with a cooling facility. Various different filters (UV filters or special window glass) ensure that radiation is adjusted the same as natural sunlight (D_{65}). An overflow system for cyclic wetting is also available (according to Wehlow).

Xerogels Gels that have lost their liquid as a result of vaporization, extraction by suction, etc., and are below their glass temperature state. They are not gels in the true sense (→ Lyogel). Since they have the spatial structure of a polymer and are filled with air, they can be classified as (hard) foams. The best known xerogel is silica gel. The swelling of a xerogel occurs in the same way as the dissolution of a non-crosslinked polymer. The diffusion process is controlled by the common diffusion coefficient of the network and the swelling liquid; this can for instance be determined in a purely mechanical way by the penetration speed of the swelling agent. However in contrast to the dissolution of a non-crosslinked polymer, the swelling of a crosslinked polymer does not progress to the point of complete dissolution, because elastic restoring forces are present as a result of crosslinking (according to Elias).

XPS X-ray photoelectron spectroscopy; → Spectroscopy.

X-ray fluorescence Principle: any element that is subjected to electron or X-ray radiation with sufficient energy emits X-rays at around 0.1 nm. The fluorescence lines so generated can be identified and measured using an X-ray spectrometer, which means that qualitative and quantitative analysis of the elements present in the sample is possible. The lower the atomic number of the element, the lower is the energy in the fluorescence radiation, which makes analysis more difficult. X-ray spectrometer: high performance X-ray tubes irradiate the sample at close range (e.g. fabric), and the fluorescence radiation is broken down by suitable crystals. The fluorescence radiation is collected in a scintillation or gas flowmeter, and the individual impulses are summarized using a specially designed meter. The device can be used for quantitative and qualitative dye analysis on textile substrates on the basis of the so-called tracers that are present in the dye but not at all or only in small quantities on the fabric. The most important tracers are as follows, with the fluorescence line Kα shown in nm:

sulphur	0.536
chlorine	0.472
cobalt	0.179
nickel	0.166
copper	0.154
bromine	0.104

The results are relative values. They can be converted to absolute values by means of calibration, where the content is defined by analysis or preparation. Low quantities of tracers are almost always present in fabrics. This causes residual fluorescence in the fabric, which has a negative influence on analysis. The resulting blank value for sulphur (on cotton) = approx. the same as for 0.1% dyeing, for cobalt (on cotton) = approx. the same as for 0.03% dyeing. For this reason results can be inaccurate at a low dye concentration. If the fabric is pretreated, the blank values can be reduced, e.g. by boiling in distilled water. Advantages: the test can be carried out easily, and it is possible to obtain evidence regarding the evenness of penetration dyeing in the fabric.

X-ray fluorescence spectroscopy This refers to the possibility of inducing an element to emit characteristic X-rays as a result of being subjected to radiation.

X-ray photoelectron spectroscopy (XPS). The basis of this is an X-ray tube with a monochromatic illuminator; the monochromatic X-rays strike the sample and produce photoelectrons that originate from the inner shell of the elements within the sample (hydrogen and helium are not detected as they only have an external electron shell). The kinetic energy (Fig. 1) of the photoelectrons leaving the atoms can be defined, firstly by the (known) energy of the X-rays hitting the sample, and secondly by the bonding energy of the photoelectrons which is specific to each element, and also by means of the elements chemical environment in its chemical compound. The second principal component of this equipment is the analyser, which discriminates against the photoelectrons according to their kinetic energy. The result is an outline spectrum, which shows the different elements in the surface, and the peak values can be used for quantification.

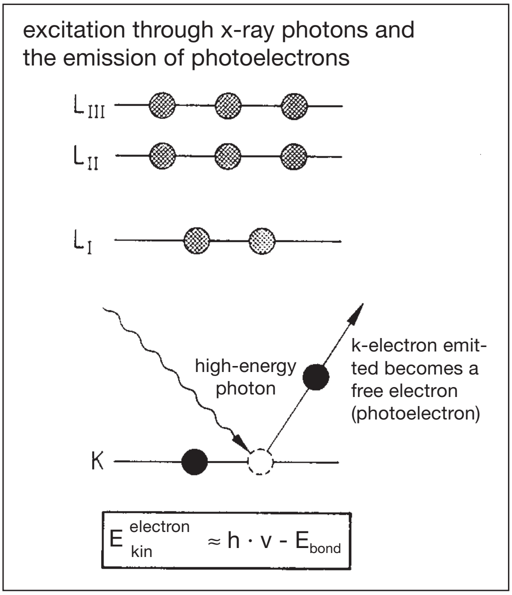


Fig. 1: Principle of X-ray photoelectron spectroscopy (XPS).

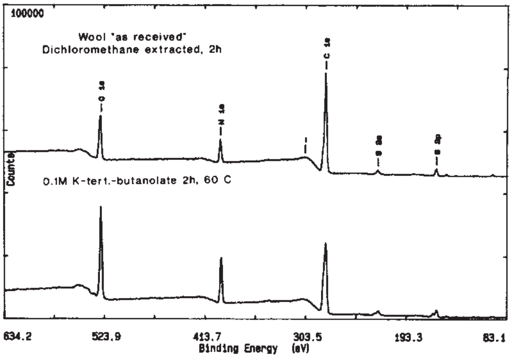


Fig. 2: XPS, general spectrum of wool. Top: untreated, dichloromethane extracted wool, bottom: wool treated with potassium tert.-butanolate (according to Höcker et al.).

The upper spectrum in Fig. 2 is of untreated wool fibre that has been extracted with dichloromethane, and the lower one is of wool fibre after treatment with potassium tert. butylate. With this treatment, a fatty acid bonded to the surface, that causes the wool fibre to be hydrophobic, is split off. This can be seen clearly by the fact that the carbon peak drops off.

The high resolution of the peak (Fig. 3) also shows that it is actually the aliphatic carbon level that has declined relatively during treatment.

In the case of treatment with alkali, the disulphide bridges have obviously partially oxidised. This effect becomes even more apparent if the wool tested has been exposed to the weather or UV radiation. In this situation the carbon curve changes only slightly, on the other hand the surface oxygen content increases significantly. The high-resolution spectrum (Fig. 4) shows that the bands of carbon remain relatively unchanged, while a clear SO_2 sulphur band occurs next to the disulphide band. Bonding forces can be assigned by means of model substances (according to Höcker).

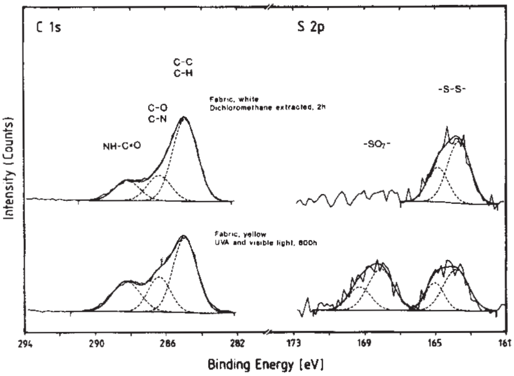


Fig. 3: XPS of wool, high resolution of carbon and sulphur lines (according to Höcker et al.).

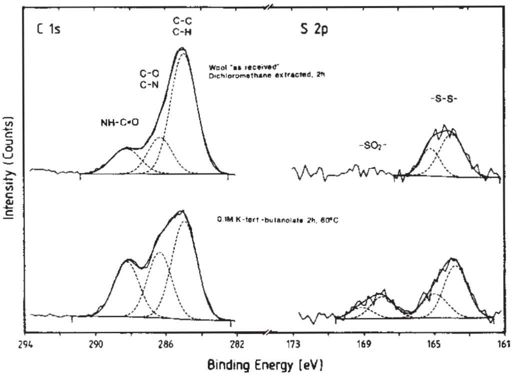


Fig. 4: XPS of wool, before and after weathering/UV radiation, high resolution of carbon and sulphur lines (according to Höcker et al.).

X-rays X-rays consist of a bundle of rays (travelling at a speed of 300 000 km/s) produced on the same principle as cathode rays (and reflected by the anode opposite the cathode) that can penetrate substances and enable their structure to be detected. They are stopped to a greater or lesser degree by solid substances (e.g. metals), broken down into a clearly defined line spectrum by crystals. The wavelength or oscillation count for each atom is characteristic (in direct ratio to the atomic charge and number).

Xylene (dimethyl benzene). $C_6H_4(CH_3)_2$, density 0.856; flashpoint –115°C; boiling point 136–140°C. Colourless liquid with a characteristic odour. Has highly refractive properties, flammable (the flame produces a high level of soot). Not particularly soluble in water, easily soluble in alcohol, ether, benzene, benzine, etc. In quantity it is the most significant component of pure benzene. Properties/application: → Benzine; Benzene.

XYZ Colour measurement system → : Colorimetric measures; Colorimetry; Chromaticity diagram.

Y

Y Element symbol for Yttrium (39).

Yak Hairs that are categorized as fibres of animal origin (see Fig.) from the Tibetan yak; these are the long hairs on the belly and tail.

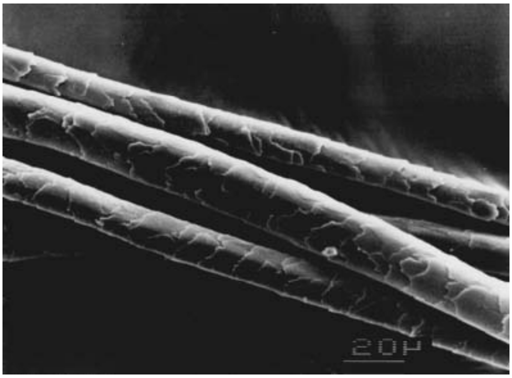


Fig.: Yak hairs (SEM photograph).

Yama-mai silk → Wild silks originating from the Japanese tussah spider, which is extremely similar to real silk in lustre and fineness. It is regular, and is white, yellowish or greenish in colour.

Yard (yd), English unit of length:

1 yd = 0.9144 m; 1 m = 1.0940 yd.

Yarn → Thread consisting of individual fibres produced by spinning and twisted to a greater or lesser degree.

There are different types depending on use: crochet, sewing, knitting yarns. Double or multiple yarns are known as → Ply-yarn.

Yarn bulking and steaming unit For the dyeing, printing and bulking of individual threads. Up to 8 threads are drawn off the take-off spool individually, continuously treated and then rewound again.

Yarn bundling press Packaging device for yarns in batch form that are pressed and threaded up into a → Bundle pack.

Yarn carriers This can mean:

I. Perforated inserts on which the yarn is wound.

II. Spindles or perforated tubes onto which the yarn packages are put so that the liquor can flow through them.

III. Moveable material carriers that can be inserted into the dyeing machine, with a hollow base into which the spindles or dyeing tubes can be inserted.

I. Yarn carriers in the form of inserts can be conical or cylindrical in form, and made of plastic or metal. The profile of requirements for contemporary plastic yarn carriers is essentially defined by steps towards rationalisation and improved quality for the user. These include good start-up properties (Fig. 1) with optimum spool construction, for further processing the guaranteed thread reserve for compression dyeing, and the guarantee that all the yarn will be used up with no wastage. The development strategy to achieve these requirements is agreed in co-operation with users, manufacturers of textile machines and producers of inserts. The results of calculations, for instance the profile of the insert, are put into the tool production process (Fig. 2). The choice of plastic is particularly important. The use of optimum plastic types suitable for specific pur-

Fig. 1: Axially pressable dyeing tubes on the Autoconer 238 (Schlafhorst) ready for yarn winding.

Yarn carriers

Fig. 2: The design and material-compatible conversion of technical textile requirements in a plastics injection moulding tool is effected by the tube manufacturer, also with the aid of specially designed electronic data processing systems.

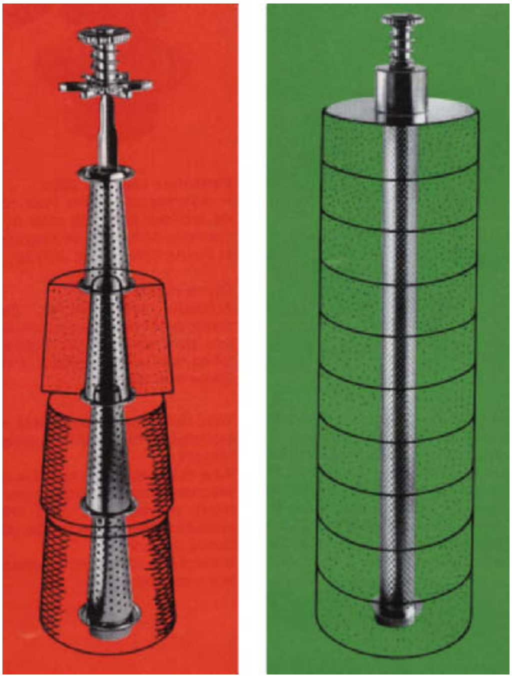


Fig. 3: Geitner steel yarn carrier tubes.

poses has an influence on the mechanical properties, e.g. the properties of the press, or the stability of the dye tubes in the dyeing column.

II. Yarn carriers in the form of spindles or dyeing tubes (Fig. 3): when conical yarn packages are put onto spindles using robots (Fig. 5), spacers and a seal are necessary to ensure that the resulting dye column is properly sealed. In compression technology using axi-

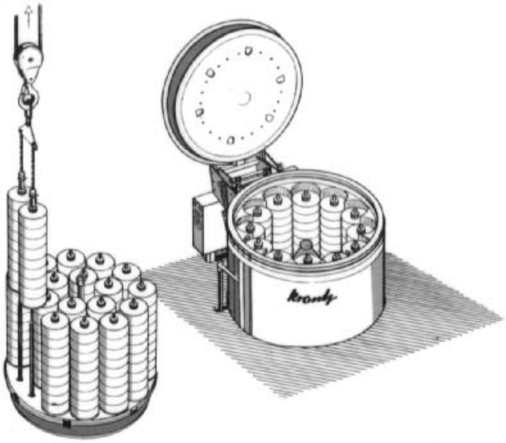


Fig. 4: Unloading a yarn carrier.

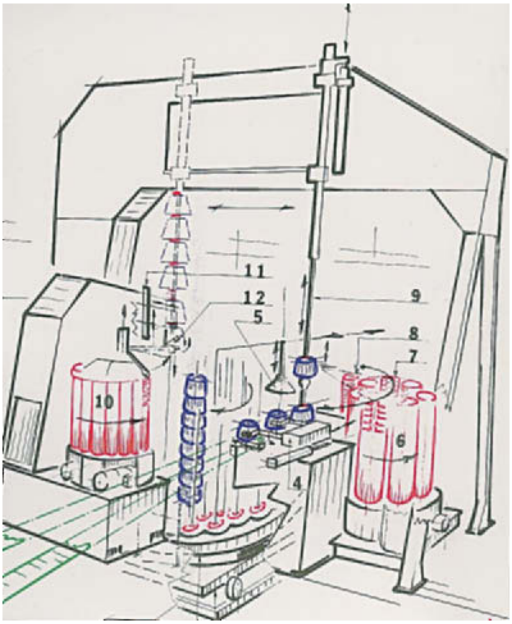


Fig. 5: Loading a Barriquand robot vertical yarn package carrier.
4 = operating panel; 5 = cone presser; 6 = yarn carrier (already loaded); 7 = ready loaded package column; 8 = carrier loading position; 9 = central robot arm; 10 = yarn package supply; 11 = supply package accommodation spindle; 12 = column with supply packages.

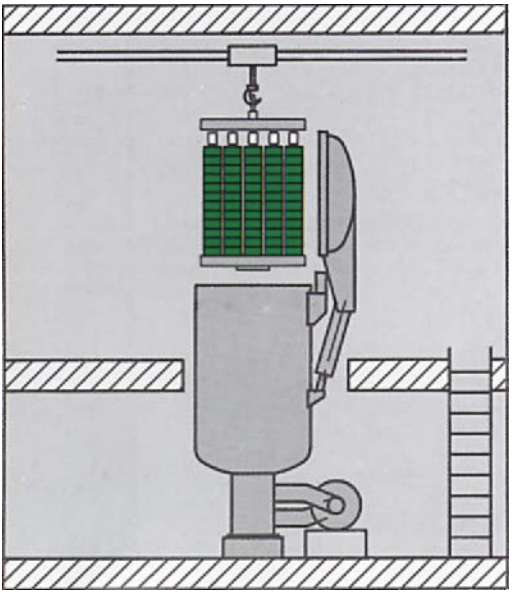


Fig. 6: Crane loading a vertical yarn dyeing machine with yarn carriers.

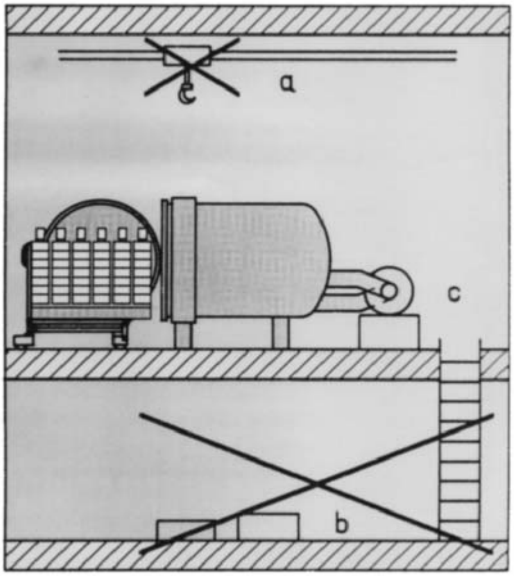


Fig. 7: Yarn carrier for horizontal dyeing machines.

al-flexible cylindrical tubes, dyeing tubes form the core of the dyeing column.

III. Yarn carriers used as dye tubes for yarn dyeing autoclaves are charged with yarn packages outside the machine. If the compression column technique is used, the individual columns are removed from the material carrier with a crane, where they are centred by spindles. The dyed pressure columns are centrifuged while still wet and HF dried (Fig. 4).

Dyeing machines for yarn packages are available as standing machines, which can be loaded or unloaded from above with a crane. In this type of machine the yarn carrier is round and has a cone in its hollow base that fits onto a matching cone in the base of the dyeing vat (Fig. 6).

Right-angled yarn carriers are used if horizontal machines have to be loaded automatically in certain circumstances (Fig. 7). In this case, the seal is situated in the head side in the hollow base to connect the material carrier to the liquor circulation.

Yarn composites Flexible, porous fabrics (→ Bonded fabrics) made from threads or thread layers and bonded by sewing, glueing, plasticizing, fibre bonding, or combinations of these techniques.

Yarn counts → Linear density of fibres and yarns.

Yarn dryer, air stream This type of dryer is used for drying yarn packages (on perforated inserts) in columns on spindles or perforated tubes as a discontinuous process. If yarn packages with a large quantity of wound yarn are used in the compression column dyeing process, the yarn packages have a high level of flow resistance, and for this reason they are dried using a high frequency dryer after continuous centrifugal drying.

These are the different types of flow dryer:

I. Rapid dryers, which suck in air from outside through a fan, which is then heated, blown through the yarn packages in the drying tank, and discharged externally in the form of exhaust without a heat recovery process. As a result the state of the drying air before it enters the material carrier is dependent on the humidity, temperature, air pressure and purity of the external air that is sucked in.

II. Air circulation dryers, where as soon as a certain level of humidity in the circulating air is reached (caused by flowing through the yarn packages), some of the air is discharged as exhaust and replaced with fresh air.

III. Pressure dryers, which operate as a completely sealed system, where the circulating air is heated on entry in the wet package columns, and then the moisture is removed in a condenser as the air leaves the package columns (cold water indirect heat exchanger in the form of a cooler or spray condenser, in which the moist warm air is cooled by cold water vapour by means of direct heat exchange).

The principles of flow drying are based on the property of water to absorb water in a gaseous state up to saturation point. The heat content per kg of moist air can be raised by an increase in temperature, density and humidity ratio, which is utilized in this drying technology. In flow drying, the effectiveness of these parameters as well as the air throughput volume or flow quantity is de-

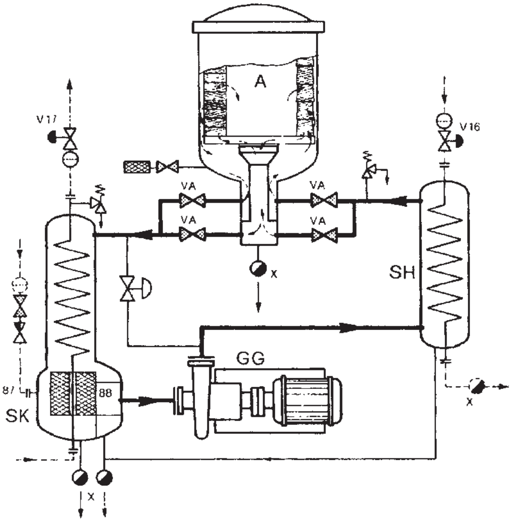


Fig. 1: Scholl THD 6 pressure dryer.
A = autoclave; GG = fan unit; SH = air heater;
SK = cooler; VA = check valve; V 16, V17 = regulating valves; X = steam trap; 87 = compressed air feed;
88 = water separator.

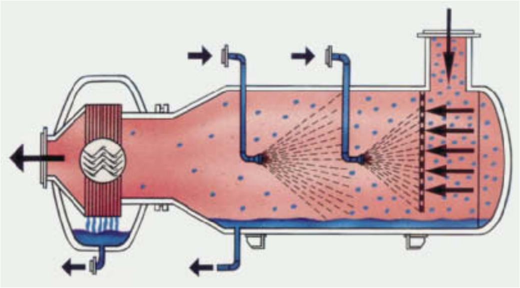


Fig. 2: Indirect (Thies) heat exchanger for condensation of damp air.

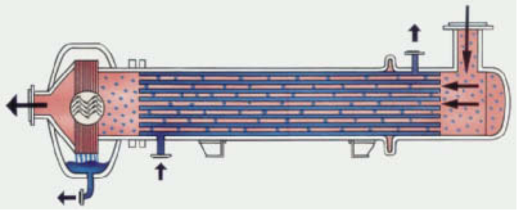


Fig. 3: Direct (Thies) heat exchanger which sprays cold water into the warm stream of damp air.

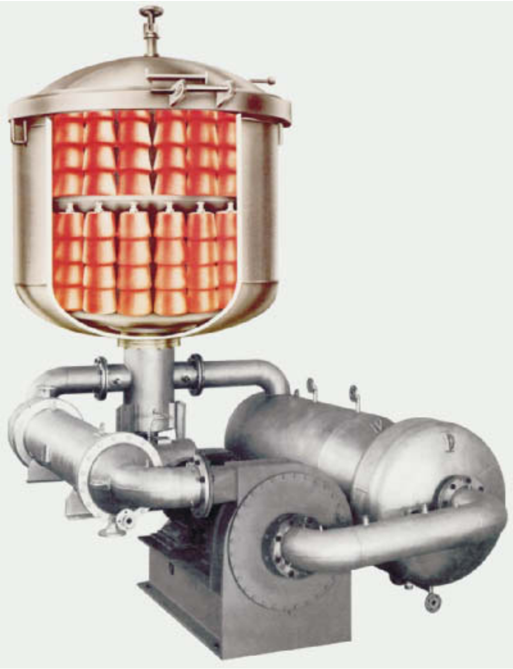


Fig. 4: Thies pressure dryer.

pendent on the textile. The air throughput volume is orientated to the level of flow resistance through a yarn package, and it is dependent on the type and size of package, the fibre and yarn parameters, the package density representing weight/volume, the parameters of the drying air, such as pressure, temperature and humidity ratio, as well as the ratio of humidity in the yarn package and its temperature. If the air throughput volume for each individual drying section is known, an approximate prediction of the drying process can be calculated.

Modern pressure dryers are supplied with computerized controllers. The user is guided by an interactive program and requires neither knowledge of programming nor parallel coding lists. Pressure dryers designed in this way are made for instance by Scholl (Fig. 1) as well as Thies (Figs. 2–4) and Then.

Yarn dyed Dyed in yarn make-up, e.g. in hank form (→ Dyeing of yarn in hank form), as a yarn package, or spool, and in continuous form.

Yarn dyeing In the past it was standard practice to dye only conical yarn packages (Fig. 5), warp beams (Fig. 4), and yarn in hank form (Fig. 1). The dye tub can take up to 40% more weight if yarn packages on axial-flexible dye tubes are used (Fig. 6), because over 25% increase in yarn density can be achieved by compressing the dye columns. With modern yarn package winding machines it is no longer necessary to break (round off) the edges of the package if cylindrical yarn packages are used. For production reasons it is practical for the packages to be as large as possible, but at certain dimensions even the most powerful pumps are not able to force the liquor through the yarn layer. If the yarn pack-

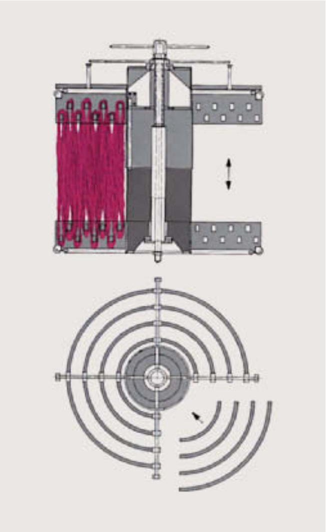


Fig. 1: Hank yarn material carrier (Krantz).

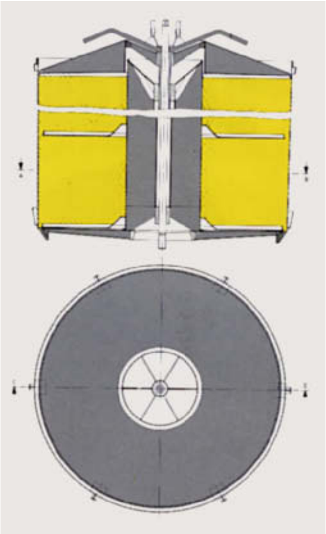


Fig. 2: Loose material carrier (Krantz).

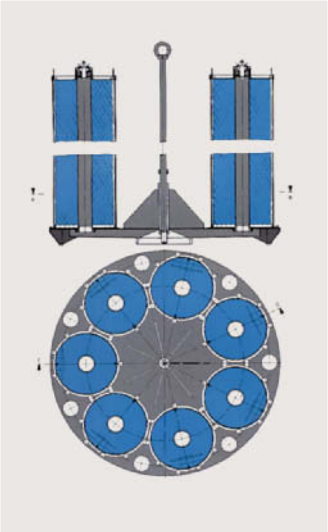


Fig. 3: Tops carrier (Krantz).

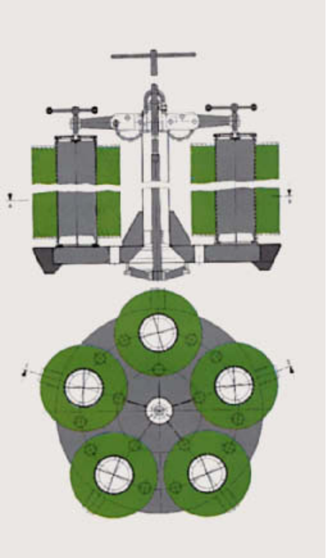


Fig. 4: Warp beam carrier (Krantz).

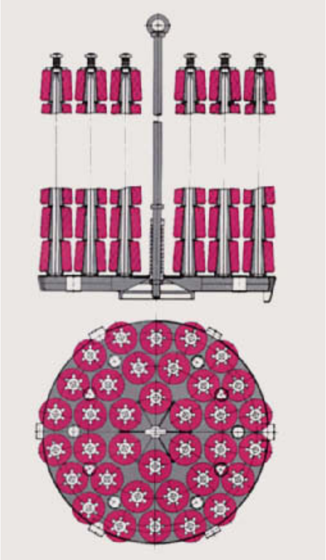


Fig. 5: Cross-wound yarn package carrier (Krantz).

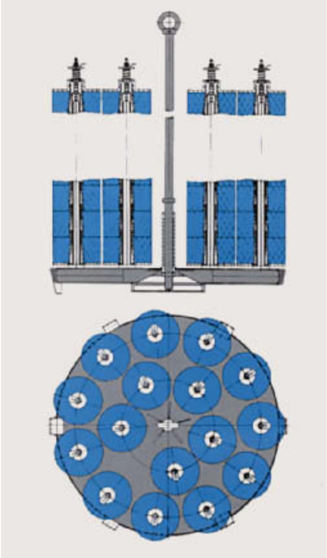


Fig. 6: Pressure package carrier (Krantz).

ages have been wound on strong dye tubes, they are put onto spindles (deflecting bars), or if they are wound on flexible spring sleeves, onto tubes. The spindles and tubes (Fig. 7) are located on a hollow plate (the carriers are connected to the liquor entry area via a conical link). With stiff inserts, several packages are stacked above one another with spacers for sealing; with flexible dye tubes, the packages seal themselves. This is also the case with insert-free systems, where the inserts used for winding are removed before dyeing. If the production volume is sufficient, it may be worth acquiring a robot-type automatic device for loading and unloading the material carrier (Fig. 11). To utilize the dyeing machine to an optimum, enough yarn carriers must be

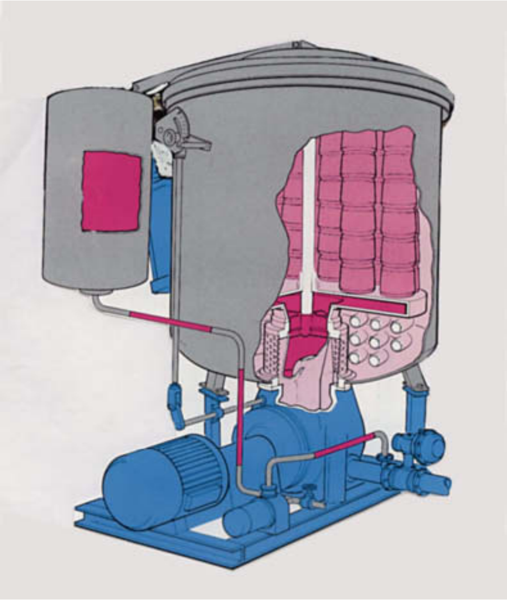


Fig. 7: Longclose yarn dyeing machine (the material carrier's hollow floor is highlighted in the cross-sectional cut-out).

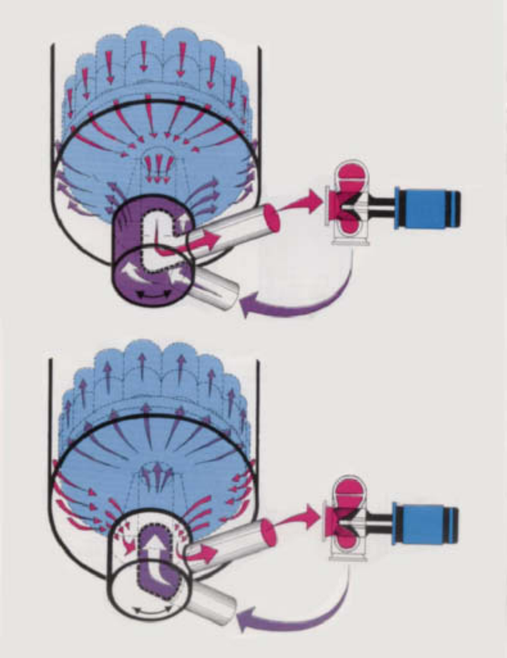


Fig. 8: Automatic liquor change unit in cross-wound yarn package dyeing with the Krantz Alterator (below: inside to outside; top: outside to inside).

available to ensure that there are no waiting periods. There are special yarn carriers for yarn in forms other than packages (Figs. 2 + 3). The yarn carrier loaded with the packages enters the calorifier in the circulation system, where it is placed on the liquor supply aperture. Most calorifiers can be sealed, and can sometimes be used at pressures of up to 4 bar.

The dye liquor is pumped under pressure from inside to outside or vice versa (Fig. 8) through the hollow base and the packages. Usually the liquor direction is alternated at certain intervals. Modern circulation systems are constructed in such a way that the liquor ratio can be kept as short as possible, and the liquor throughput, i.e. l liquor/min and kg of textile, is high. Throughput should be adjusted to suit the dye uptake speed. For dyes with efficient levelling, this figure will be about 15 l/min/kg. With modern machinery, these parameters can be exceeded by a long way (up to 50 l/min/kg). High-speed dyeing machines circulate the entire liquor about 6–10 times per min. This means that the liquor can be heated and cooled quickly.

Liquor throughput:	l liquor per kg textile per minute
Circulation rate:	number of circulations per min for the entire liquor

However there are limits to the circulation rate, and if these limits are exceeded, the yarn wind starts to become deformed. There are gauges in the system itself to measure flow and differential pressure, but they do not necessarily provide information regarding the liquor

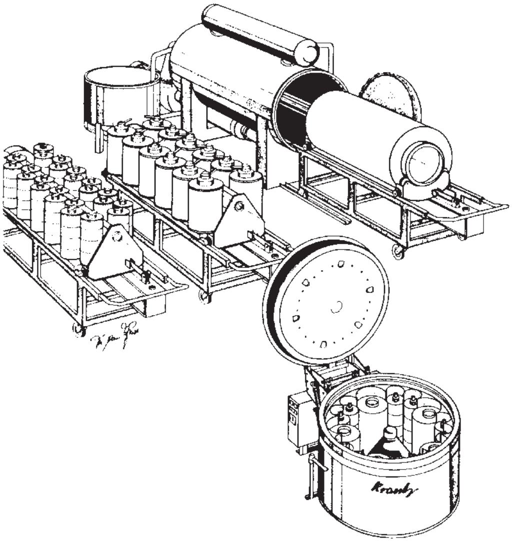


Fig. 9: Krantz horizontal dyeing machine for yarn (and piece dyeing).

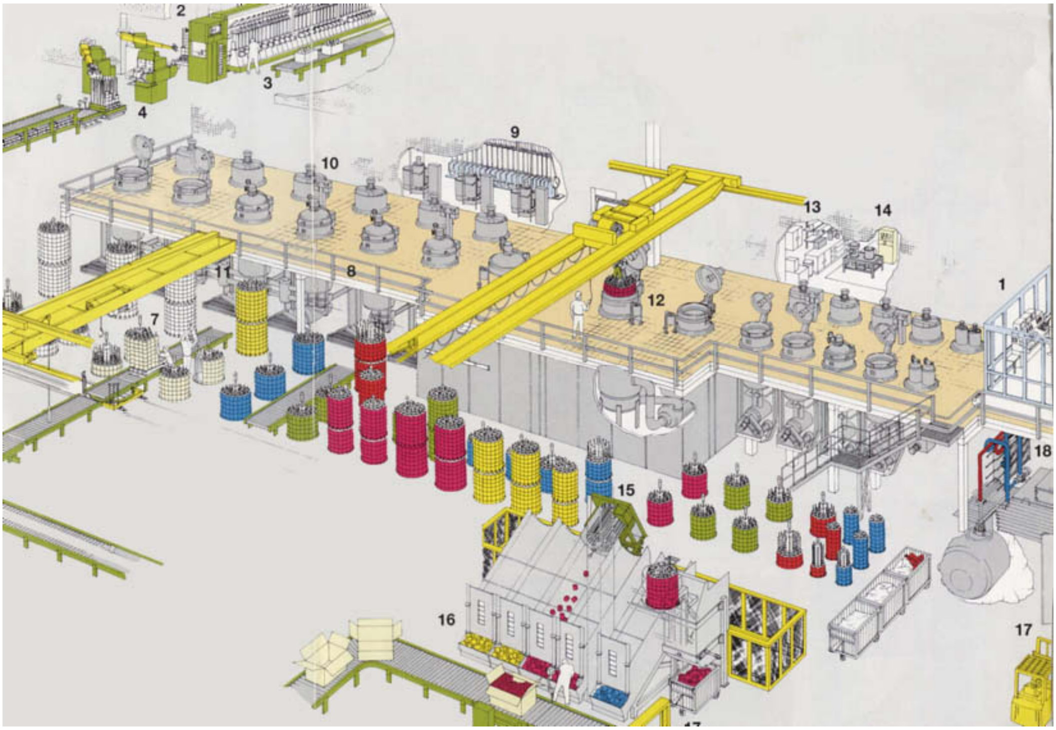


Fig. 10: Jasper yarn dyehouse.

circulation within the yarn packages. Hoechst has designed a machine for measuring the differential pressure for individual packages. The liquor direction through the yarn package is alternated at pre-defined intervals. The usual values are alternately 2 min internal/external and 3 min internal/external. In individual processes, circulation can also take place from inside to outside. The quantity of liquor circulated in the period up to the point of direction change is the crucial factor. If the direction alternation is too rapid, it causes the cores of the packages to be too light in colour. In the case of machines that have centrifugal pumps fitted, the liquor alternation is carried out by means of a 4-way device, which nowadays operates automatically but used to be manual (Fig. 8). If axial pumps are used, the device is redundant, because the direction change can be activated by pole reversal in the motor. The Serracant JM dyeing machine has an original variant, with a piston pump situated inside the dye container, which pumps the liquor backwards and forwards through the yarn.

With new equipment, liquor heating and cooling takes place outside the dye container with heat exchangers, which guarantees evenness of temperature throughout the whole liquor. It is important to de-aerate the yarn before starting dyeing in standard processes, because the air within the fibre hinders liquor access. De-aeration agents make the removal of air from the fibre easier. Another way is the technique recommended by Obermaier of vacuum dyeing by creating a vacuum in the machine. Examples of this type of system are: Burlvac (Thies), Rapid Reversal (Gaston County), Flashflow (Mortensen). With the correct inserts, these circulation machines can be used for dyeing yarn packages, warp beams, hanks and soft packages (Figs. 1–6). Almost all machines have a vertical dye container, but there are some with a horizontal cylinder (Fig. 9). In the Pozzi system, the dye tube turns on its own axis during dyeing. The trend towards saving energy and water has led to machines being redesigned in the past years. Shortening the piping system and fitting a pump in the base of the calorifier resulted in a significant shortening of the liquor ratio. This type of machine is supplied by Brückner, Krantz, Then, Thies, Scholl, for example. A further stage was the allocation of a separate dye container for each spindle, thereby eliminating wasted space. Examples of this type are: Turborapid (MTM Obermaier), CS and Favorit (Frauchiger), Steam jector (Mortensen). Machines where only the liquor is in the sump and the actual yarn to be dyed is outside it, constitute the final stage of liquor shortening. In this situation, the only liquor direction possible is inside/outside. Sump dyeing is possible in most machines with alter-

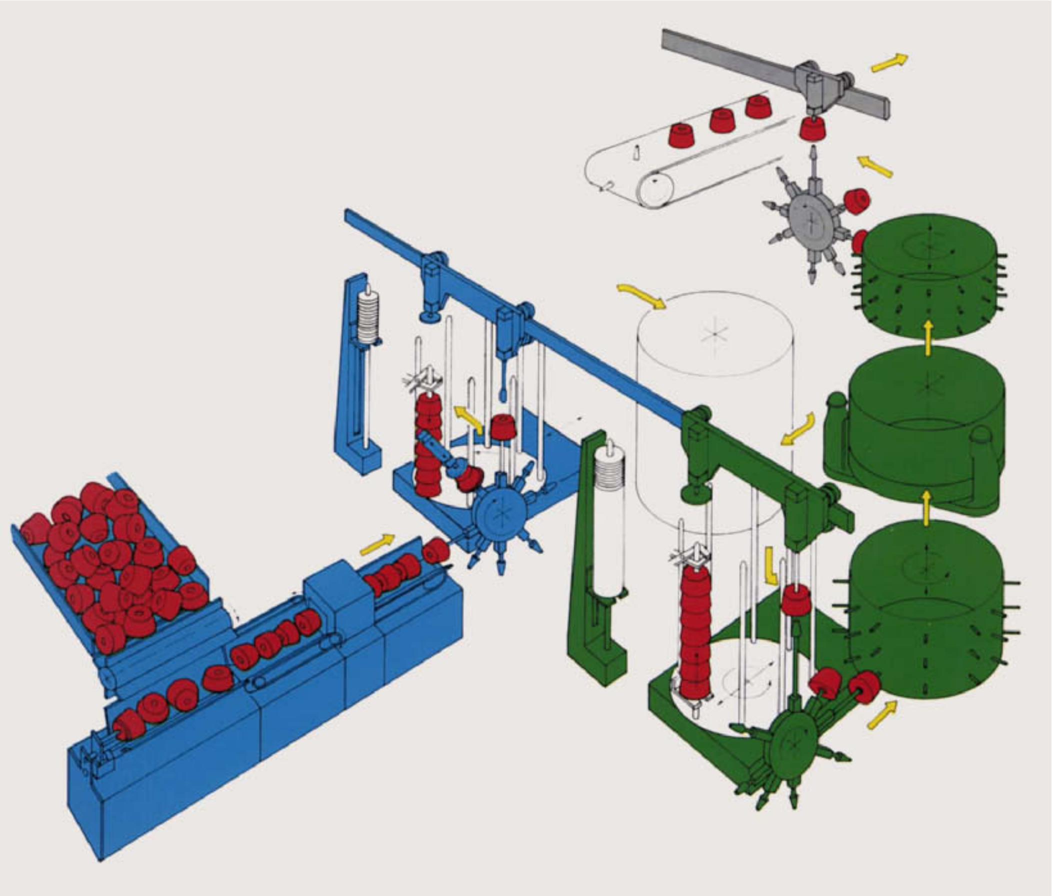
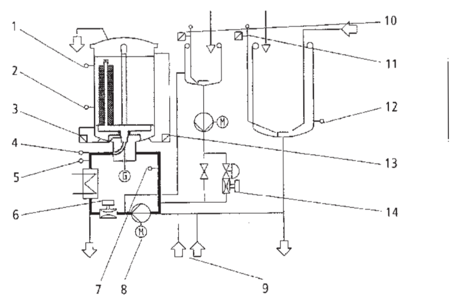


Fig. 11: Officine Minetti, automatic yarn package carrier loading.

nating liquor circulation if the liquor direction is restricted to inside/outside. Jasper takes a different approach, with the option of compressing the yarn package columns in the machine when it is closed. Open circulation machines are becoming less common in dyeing. With these machines there is the constant hazard of vapour bubbles forming in the pump suction pipes (cavitation), which reduces circulation.

For this reason, sealed HT machines are preferable, even when dyeing at temperatures above boiling point is not required. HT machines are manufactured in all sizes. Different individual machines can also be linked together to dye large batches under uniform conditions (Fig. 10). Colour matching in non-pressure machines is carried out by batching off the yarn from one or preferably several packages. In HT machines this is done using a lock. In some machines, bypass devices have been fitted, in which a sample package is dyed. Dyeing uniform shades on a continuous thread, i.e. from package to package, is mainly of importance for the manufacture of sewing thread. Immaculate winding is a crucial factor for successful warp beam dyeing. The diameter of the winding cylinder (standpipe) must be set to suit the warp length, because the layer thickness of the yarn winding must not exceed a maximum thickness. Standpipes are available with diameters from 100 to 500 mm. The perforation holes usually have a diameter of 5 mm, but 20 mm holes are also in existence. The usual winding thickness is 380–420 g/dm^3, for dyes with good levelling properties up to 520 g/dm^3. Liquor flow direction inside/outside approx. 16 l/kg/min. Excess pressure when the pump is started or when the flow direction is alternated can be prevented by using pumps with a gentle start or bypass devices. Uneven yarn dyeing is caused by non-uniform package winding or uneven arrangement of different sized packages.

Yarn dyeing automation: In comparison with other production processes the degree of automation in yarn finishing is relatively high (Fig. 11), with the result that the innovations and further developments presented



Fibre material	cotton	cotton	polyester	polyacrylic	wool	polyamide
Dyestuff class	cold-reactive	vat	disperse	cationic	acid	acid
Main parameters	salt/alcali	hydrosulphite	temperature	temperature	acid	acid

Fig. 12: Measuring systems on dyeing machines (drawing: Then).
1 = vessel pressure; 2 = temperature; 3 = differential pressure; 4 = pH value; 5 = temperature; 6 = liquor throughflow; 7 = conductivity; 8 = frequency control; 9 = water counter; 10 = level measurement addition tank; 11 = level measurement secondary tank; 12 = temperature; 13 = level measurement; 14 = dispensing of chemicals/ products.

concern the refinement or improvement of the measuring and control technology as well as computer-assisted systems for organisational planning, control and monitoring of the production flow. There are many reasons for the application of automation systems in production and in administration. One important aim is to increase productivity by lowering production costs, and also to improve flexibility. Besides this, the rising quality demands also play an important role. The question is, however, what degree of automation will best meet the individual requirements of the mill in question. Often the ideal solution is to find a compromise that is, of necessity, orientated towards the objectives and the conditions prevailing in each individual company.

Measuring and control technology (Fig. 12) is instrumental towards automation of the production flow. Flow rate measuring and control instruments, controlled circulation pumps, level measuring equipment for optimum filling of the dye vessel, as well as differential pressure measuring and control equipment is state-of-the-art with most machine manufacturers. In most cases, measuring and controlling the pH value, redox potential and salt concentration is carried out manually or semi-automatically.

A further important area of automation is dominated by production planning and control systems (Fig. 13) (PPS). The control of the machines, transport systems, robots but also the control of machines and plant hierarchies is effected via efficient microprocessors. Stored programme control systems (SPC) are used as an interface between the industrial PC and the dyeing machines, and are today state-of-the-art with virtually all manufacturers. Most companies opt for central control of the process sequence via SPC. In this respect, Then (D) have taken a different route. With their new control concept "TLON", the control functions of the entire dyeing range are no longer effected centrally via SPC, but are divided into several small, parallel sub-functions. Production planning and control (PPS) has an important task within CIM (computer integrated manufacturing). Some machine builders have, therefore, already gone one step further. The resulting demands on a CIM concept include efficient software systems which can effectively deal with the quantity and quality of requisite information, the administrative expenditure and a relatively high degree of automation.

The term CIM usually conjures up a picture of a fully automated, computer-controlled mill. There are in the meantime systems on the market which offer a wide range of functions and, with their further developments, meet CIM requirements. In this sector development is right at the beginning. CIM subsystems and units, e.g. PPS, CAD, CAP systems and automatic handling and transport equipment are already available. These include the components of information technology (operating systems, communication and development systems). The CIM subsystems have already achieved a high level of sophistication and enjoy widespread use, with a whole range of connection and integration potential. Other systems fulfil the basic PPS

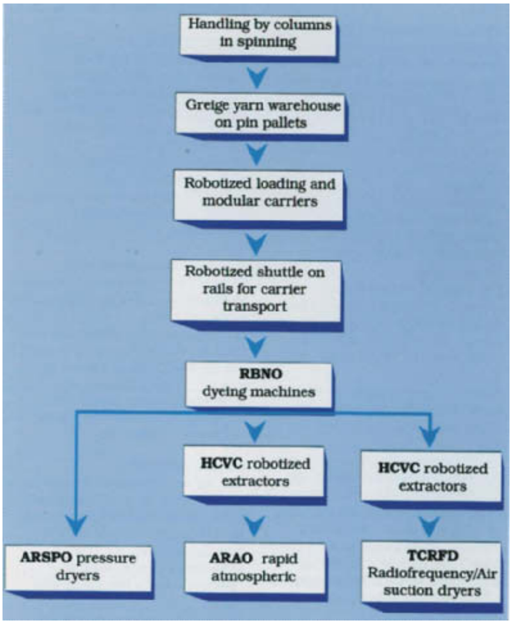


Fig. 13: Production planning and control system in a yarn dyehouse.

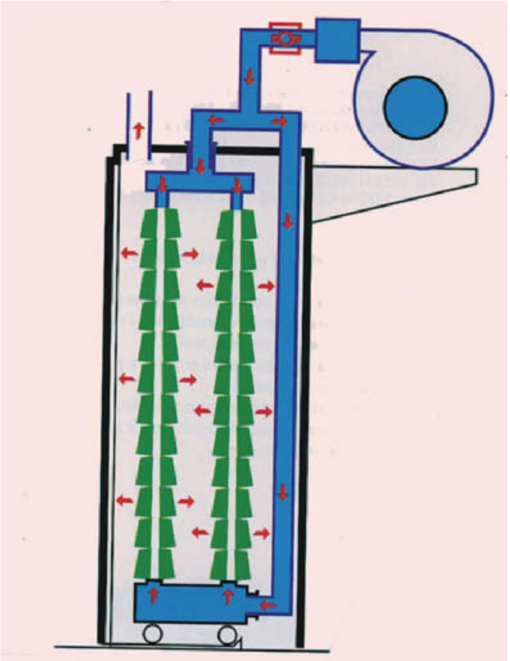


Fig. 14: Cone dryer (Loup).

functions at a high level, exhibiting optimum flexibility where modification is concerned.

The concept of modular carriers (by Bellini) operates with modular interchangeable carriers. Dyeing machine and drying systems may contain one, two or three carriers in series. The base module is exchanged therefore between machines of different sizes. The interchangeability of carriers means an outstanding operating flexibility for just-in-time operation, as it enables a dyehouse to dye all kinds of materials, for instance in the worsted industry to dye both yarn packages (Fig. 14) and tops or bumps, or in the upholstery industry to dye packages of medium diameter for cotton and viscose yarns and very large diameter for textured polyester yarns by fully exchangeable carriers.

Yarn dyeing automation → Yarn dyeing.

Yarn dyeing machines →: Rope dyeing machines; Spray dyeing machine.

Yarn finish Cotton or linen sewing thread is soaked in starch and wax or paraffin, dried, stretched (lustred) and brushed to give it a smooth surface. → Glossing; Lustring.

Yarn hairiness Yarn → Hairiness.

Yarn handling Yarn finishing usually involves complicated handling because of the small individual components (packages or hanks), and for this reason process automation is ideal for yarn finishing. Robots are used to load and unload centrifuges, made by Robotel (Bobex), Pozzi (Mov-ex), Dettin (Berta 24), Frauchiger (Transroc) or Calvanin (Carousel) and Obem (centrifuging horizontal yarn package columns in the hydro-extractor IC 5/A). Even and rational compression of the yarn is a decisive factor for the usual dyeing machine compression techniques, i.e. the loose yarn should be compressed in such a way that densities of

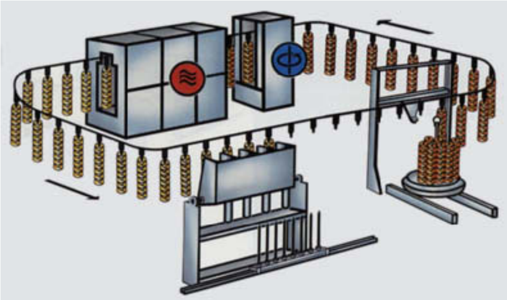


Fig. 1: Suspended yarn package column (with dyeing tubes) transport through the Thies centrifuge hydroextractor and high frequency dryer.

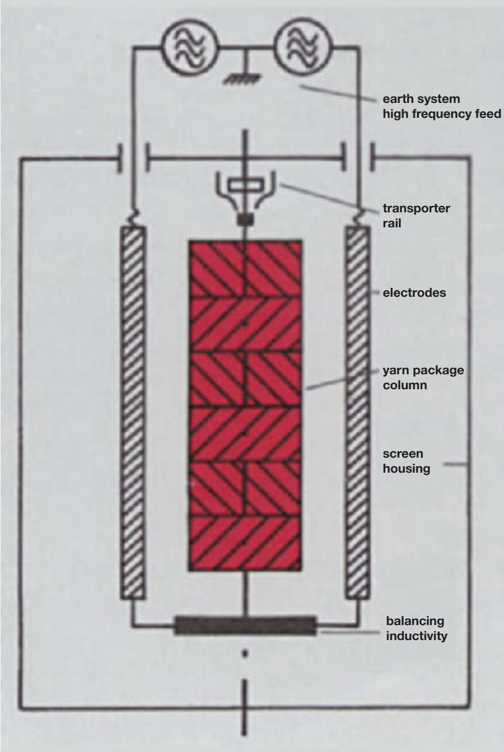


Fig. 2: Diagrammatic view of the suspension transport system for yarn package columns in the Thies high frequency dryer.

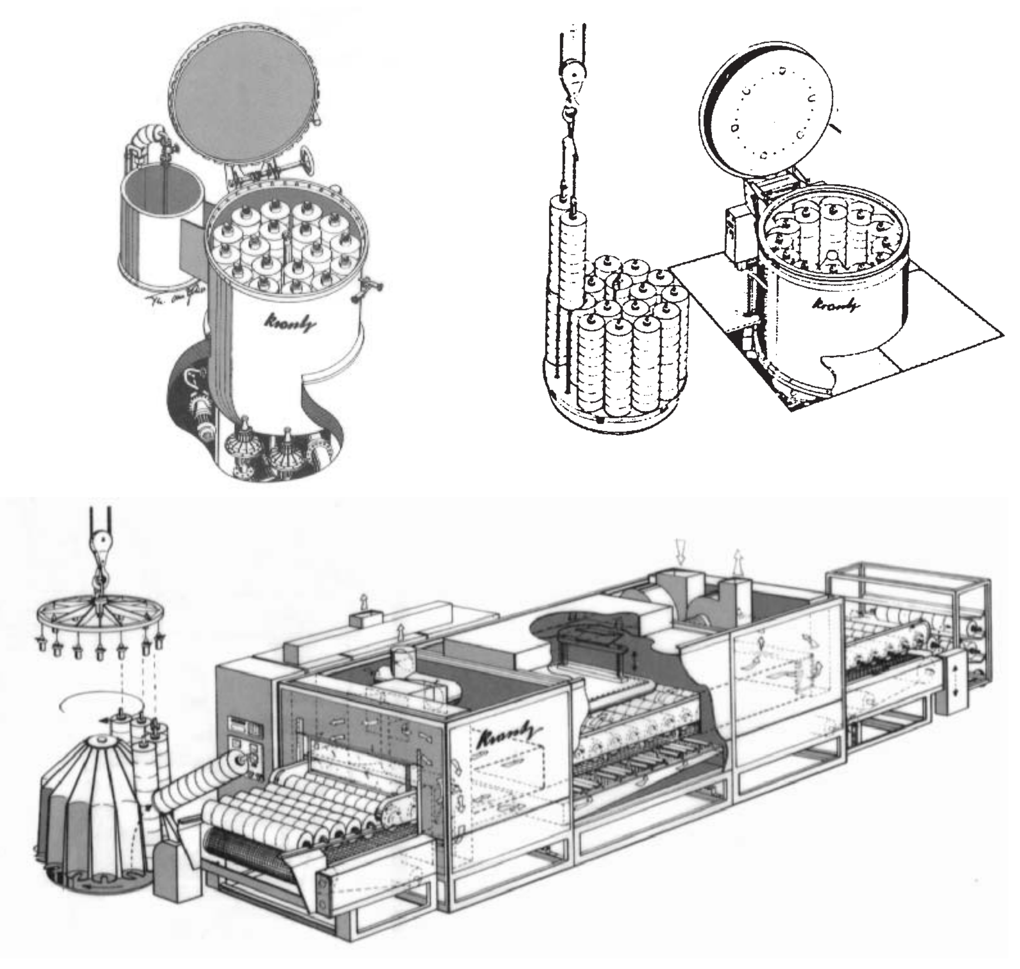


Fig. 3: Operational sequence and yarn column transport in Krantz hydroextraction and high frequency drying, with yarn columns upright round the centrifuge periphery, and yarn columns laid on their sides in the high frequency dryer.

400 kg/m^3 can be achieved. The Jasper TOP (transport without personnel) system offers an elegant method of compressing package columns, which is almost an upside-down dyeing vat. The dyeing vat is cylindrical and open at the bottom, and is lifted using hydraulics for loading and unloading the system, so that the yarn carrier, which is located on the fixed lower part, can be removed. After the lower part has been reloaded with the new yarn carrier, which contains cylindrical packages with axial-flexible dye tubes that have not yet been compressed, the package columns are pressed onto the yarn carrier when the upper part of the vat is shut. After the yarn packages have been dyed, they should be spun (pre-dried) and dried (Fig. 3). When columns with compressed packages on axial-flexible cylindrical dye tubes are used, the principle of leaving the dye tubes in the columns for as long as possible applies. The Krantz system packs the columns into a centrifuge and spins off most of the water from a dye batch. Then robots put the columns onto the conveyor belt of a high-frequency dryer. The dry dye columns are then put onto transport trolleys to take them to the next section.

Thies takes a different approach, in which the package columns coming out of the dyeing machine on the dye tube are hung up to be transported through a spin-dryer (Fig. 1). They are dried there by revolving each column on its longitudinal axis at high speed. Next the transport system (Fig. 2) takes the hanging columns through the high-frequency dryer.

There are also continuous yarn finishing processes. In this way, cotton yarn can be mercerized with liquid ammonia using the Prograde process. Raising knitting yarn on yarn raising machines is another typical example of a continuous treatment process.

Yarn humidifying agent These are used for humidifying yarns, to set the required humidity level and maintain it during the course of subsequent textile finishing processes, as well as to cause an increase in strength or shape retention. Stabilized wetting agent solutions with added preservatives, bactericides or anti-fungal products are usually used.

Yarn length calculations If the yarn count of a batch remainder is known, the available yarn length L can be calculated using the following formula (weight G in kg):

Tex system: $$L = G \cdot \frac{10\,000}{\text{dtex}} \text{ km}$$

Denier system: $$L = G \cdot \frac{9\,000}{\text{den}} \text{ km}$$

Metric system: $$L = (G \cdot \text{Nm}) \text{ km}$$

For warp beam yarns, this length should be divided by the number of threads.

Yarn liquoring machine (straining machine, starching machine). This is used for sizing and dyeing (e.g. vat pad process for strongly twisted yarns, naphthol dyeing), for preparing, unwinding, rinsing, soaping, etc. of yarn hanks. It consists of a trough on each side (short liquor heated/cooled), a rubber compression roller, a collar roller, and a metal skeleton roller that can be adjusted by a lever for taking up 1 kg of hank yarn, which is stretched, divided, immersed/printed, lifted again, de-tensioned and removed when ready. Time setting is possible for all of these. Newer models are also available with a trough carousel.

Yarn lubrication Additional yarn scrooping (additional lubrication) in two-for-one twist yarns. Increasing processing speeds and a growing proportion of synthetic fibre repeatedly leads to processing problems in yarn manufacturing and processing. These problems can be seen in the form of a negative influence on strength, a significant tendency to generate dust and increased yarn roughness. Problems like this are caused in particular by insufficient lubrication of fibres or threads at the point of contact with fibre/yarn guiding devices of all types. In addition to this, synthetic fibres have a greater level of sensitivity to abrasion compared with natural fibres when subjected to friction under standard high-speed conditions (25 m/s). Yarn lubrication is intended to prevent this type of fibre damage. It can either be done as offline yarn lubrication: manual or mechanical soaking (spraying the yarn packages or brushing the lubricant onto the abutting face of the yarn packages before the twisting process) or inline yarn lubrication: automatic addition of lubricant to the thread as it passes through the twisting machine. Inline yarn lubrication has numerous advantages, and for this reason it is constantly becoming more significant. There are different types of lubricant and lubrication systems. The minimum application quantity is dependent on the lubricant and yarn type. For delicate yarn types (yarns that contain low-pill polyester) the application quantity needs to be higher than for non-delicate yarn types.

Yarn make-up For the purpose of further processing or packaging. Make-up forms: →: Bobbins; Pirn; Warp beam; Cop; Package; Yarn package; Winding; Skeins; Hank; Bundle pack.

Yarn mercerizing → Mercerizing plays an important part in the pre-treatment of yarn. Yarns are mercerized continuously in hank form (Fig. 1) or as a continuous run of yarn. For yarns in hank form the following method is still in use in some cases: yarn is soaked in caustic soda solution 25–50°Bé (at 10–20°C), it is squeezed off and tensioned to the original length. Washing takes place under tension. This type of finishing is wrongly known as tension-free mercerizing. Lye treatment of the tensioned yarns is more important. Here there are two types of mercerizing – raw yarn

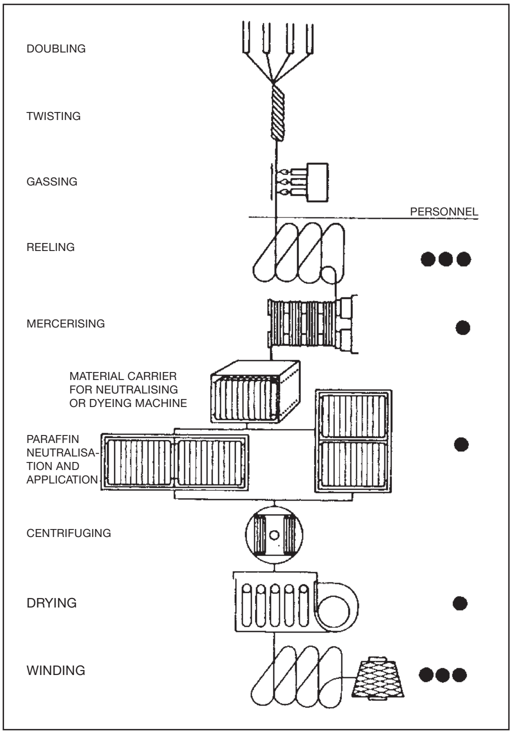


Fig. 1: Yarn finishing for knitwear fabrics before knitting.

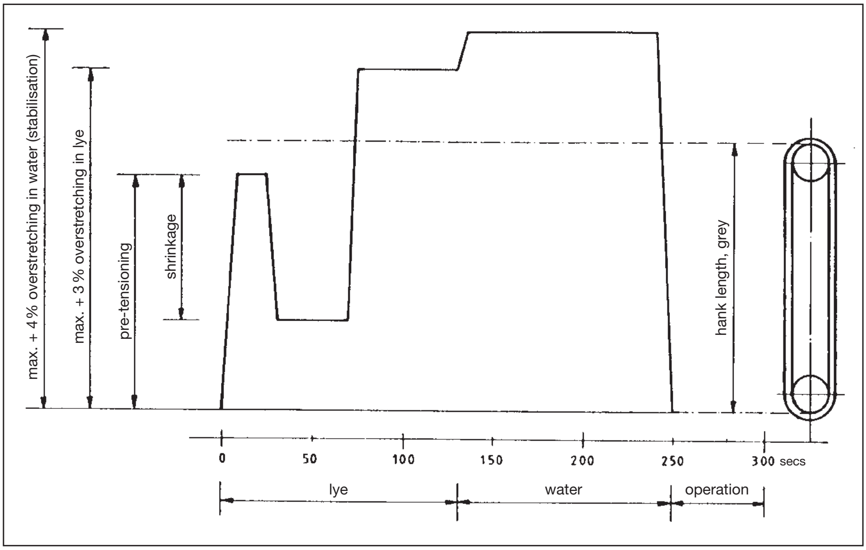


Fig. 2: Hank length change during yarn mercerizing and stabilization.

mercerizing (dry mercerizing) and boiled yarn mercerizing (wet mercerizing). With the first type, a wetting agent, often known as a “mercerizing booster”, has to be added to the lye, to achieve even penetration of the dry yarn.

One disadvantage of dry mercerizing is that the lye becomes soiled quickly. In wet mercerizing, the yarn has been boiled and spun but is still damp when it enters the lye. The same effect is achieved in both processes. The principal component of a yarn mercerizing machine is the pair of rollers used as a yarn carrier, each with one fixed rotating roller and one tensioning roller, which can be positioned at the required interval from the fixed roller by means of a weighted lever or hydraulic pressure, so that the yarn can be tensioned (Fig. 2) and shrinking can be prevented. There is a third roller positioned against the fixed roller, which acts as a squeezing roller to squeeze off most of the lye (Fig. 3). Smaller machines have 1 or 2 pairs of rollers like this; larger ones have 6–8 pairs arranged around a common axis. On modern machines, such as the Neutromercer (Kleinewefers-Jaeggli), the cotton yarn is not only rinsed, but also treated with acid at the end. The Jaeggli-Meccanotessile hank yarn mercerizing machine is charged with the yarn hanks via two metal sheets, which pull it up onto the two treatment rollers that are each situated on one side. During charging the roller pairs are arranged vertically, and they move back to a horizontal position for treatment, where mercerizing takes place under tension. The roller pairs fold into a vertical position again to remove the hanks, where the metal sheets come into action for removal in the same way as for charging. It is quite clear that with this machine, automation offers protection from potentially hazardous handling of caustic soda solution; the staff are only required to operate the charging/removal sheets.

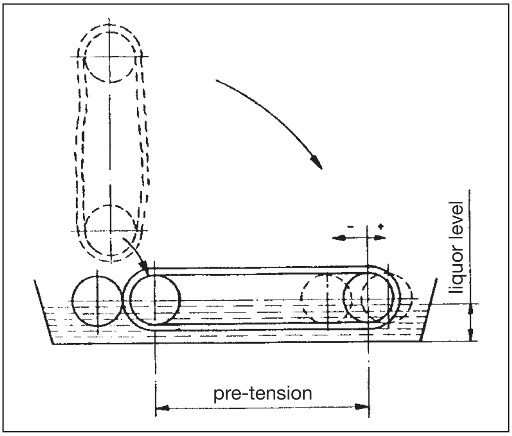


Fig. 3: Swinging the tensioning rollers into the operating position or the pre-tension position during yarn mercerizing.

The tension ratio of the yarn during mercerizing is important; the tension has an influence on the orientation of the cellulose crystallites or their size. As the tension increases, the strength increases up to a maximum point, and the elongation reduces. The lustre and handle of the mercerized yarn is further improved after drying by beating the hanks hard by hand on the wringing post or mechanically using a stretching machine. Cotton yarns are primarily mercerized for use in the knitgoods industry.

It is expensive to unwind yarn from cones into

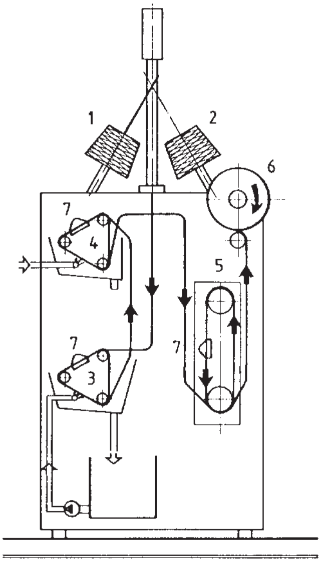


Fig. 4: MM-CO model yarn mercerizing machine (Kleinewefers-Jaeggli).
1 = working yarn package; 2 = supply yarn package for continuous yarn package changing; 3 = mercerizing zone with lye circulation; 4 = washing and neutralizing zone (circulation); 5 = dryer; 6 = winding unit; 7 = comb for yarn guiding in the axial direction.

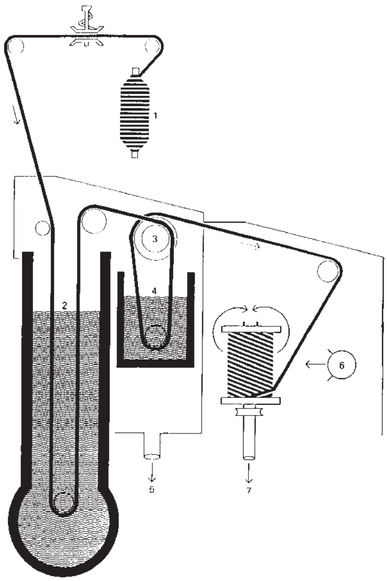


Fig. 5: Processing principle of the treatment of cotton yarns with liquid ammonia in accordance with the L & P Coats Ltd Prograde process.
1 = yarn package; 2 = liquid ammonia (–33 °C); 3 = stretching roller; 4 = hot water (95 °C); 5 = ammonia recovery; 6 = hot air; 7 = exhaust air.

hanks and back onto cones after mercerizing. Cost savings can be achieved by using large hanks (800 g instead of 300–400 g), which can be manufactured on special winch machines. Some systems also mercerize a continuous thread (Fig. 4). A large number of parallel threads run through machines in a similar way to the mercerization of woven fabrics (warp-free system). In the Prograde process, individual threads are treated with liquid ammonia (Fig. 5).

Yarn number systems → Linear density of fibres and yarns.

Yarn package,

I. Piece make-up: piece goods wound onto a yarn package carrier (→ Batching roller).

II. Yarn make-up: → Package where the support (spindle or insert) is removed when the process is finished, a yarn spool or winding structure without an insert.

Other winding forms for commercial purposes are clews or skeins (for crochet, knitting and embroidery yarns), reels (for sewing silk) and other winding structure for wide-wound yarns (DIN/ISO 5248).

Yarn packages in dyeing When dyeing yarn on packages, the type and quality of winding, but also the package and insert system, have a particular influence on the quality of dyeing. Conical yarn inserts continue to be used widely even though they have some disadvantages in comparison with modern cylindrical insert systems:

- uneven package flow,
- insert/spacer leaking,
- low batch weight,
- unfavourable liquor ratio,
- high personnel costs for loading and unloading the carrier,
- unsuitable environment for using robots for loading and unloading.

The reason behind the uneven flow in conical yarn packages is to do with the varying radii of the insert between the tip and base of the cone. On one hand the radial liquor flow reduces as the internal diameter becomes smaller, and on the other hand the conical form causes

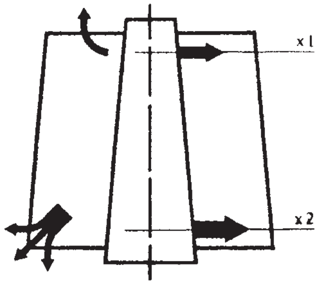


Fig. 1: Liquor flow through conical yarn packages.

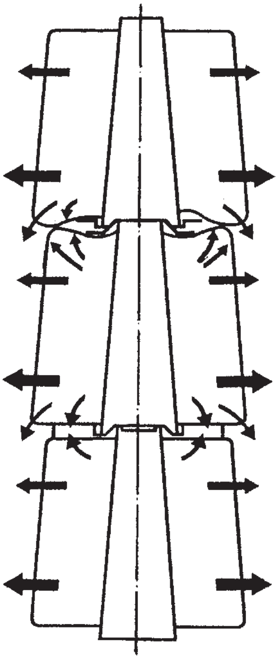


Fig. 2: Liquor flow in a cone column, with (top) and without star spacers.

differences in the winding density, because the winding speed and thread tension at the base of the cone are greater due to the larger circumference than at the tip of the cone (Fig. 1).

As a result, the dye and chemical supply for the fibres is uneven, which can lead to problems with evenness, particularly at the edges. A further problem, if conical dye tubes are used, is liquor wastage. One way in which liquor is wasted is as a result of axial flow within the yarn package, where the liquor leaks out through the abutting surfaces of the package and is lost. It is also caused by leakages at the spacers and column seals (Fig. 2). Liquor wastage can total over 50%.

Further disadvantages of dyeing conical yarn packages are handling and the strain on the system. First, all the packages have to be chamfered to reduce the hazard of liquor loss at the edges. When loading and unloading a dyeing machine, each dyeing column must be constructed and dismantled with packages and spacers. This takes time and is awkward. Conical yarn packages cannot be compressed. This situation, in combination with the relatively low weights of the packages, reduces the optimum utilization capacity of the machine, as well as the financial viability.

A conical yarn package (Fig. 3) is defined by:

- radii,
- overall volume,
- winding density.

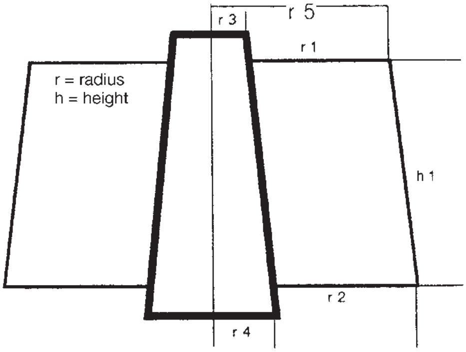


Fig. 3: Build-up of a conical yarn package.

Calculation of package radius:
$(r_1 + r_2) : 2 + (r_3 + r_4) : 2 = \text{radius } r_5$

Calculation of volume:
$r_5^2 \cdot \pi \cdot hl = V_{total}$ (total volume of yarn with insert)

$[(r_3 + r_4) : 2]^2 \cdot \pi \cdot hl = V_{insert}$ (volume of inserts).

$V_{total} - V_{inserts} = V_{yarn}$ (net yarn volume).

Calculation of density:
Weight of package with insert – insert = net yarn weight.

Weight (net in kg) : volume (net in cm^3) = density g/cm^3.

Conical yarn packages have so-called “dead zones”, where liquor shortages can occur as a result of the package shape (Fig. 4). In order to achieve a more even supply of liquor at the peripheral areas of the package, and therefore reduce or eliminate the hazard of uneven dyeing, packages of this type need to be chamfered (Fig. 5).

Because cylindrical dye tubes are symmetrical in shape, a more even distribution of winding density can

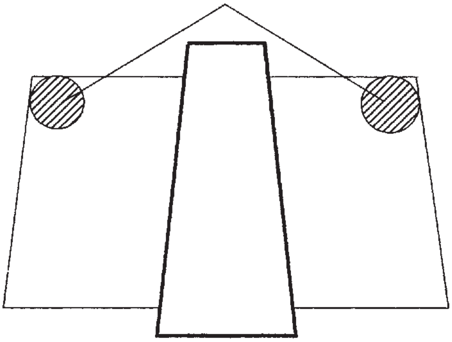


Fig. 4: “Dead zones“ in a cone.

Yarn packages in dyeing

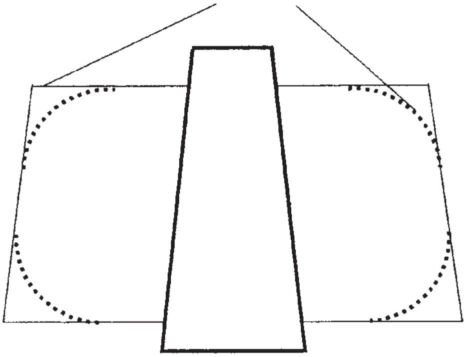


Fig. 5: Conical yarn package before and after chamfering.

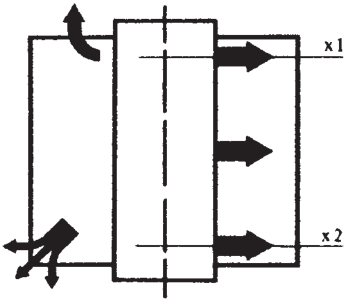


Fig. 6: Pressure distribution in a cylindrical yarn package.

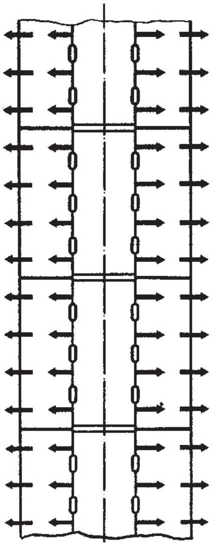
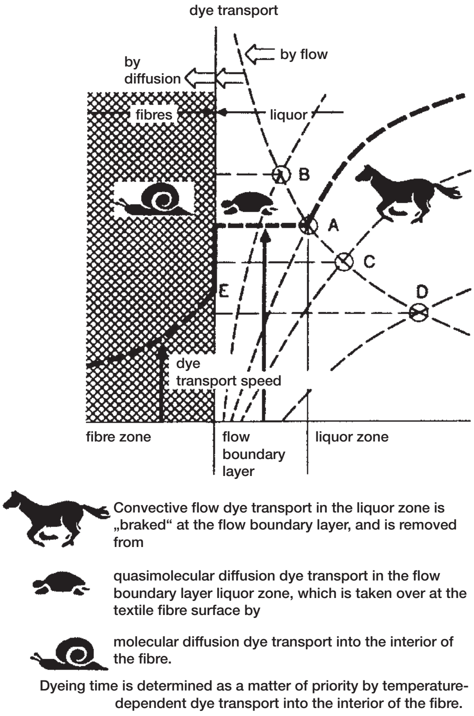


Fig. 7: Compressed dyeing columns made up of cylindrical yarn packages.



Convective flow dye transport in the liquor zone is „braked“ at the flow boundary layer, and is removed from

quasimolecular diffusion dye transport in the flow boundary layer liquor zone, which is taken over at the textile fibre surface by

molecular diffusion dye transport into the interior of the fibre.

Dyeing time is determined as a matter of priority by temperature-dependent dye transport into the interior of the fibre.

Fig. 8: Dyeing kinetics in yarn dyeing after Kretschmer (didactically reduced).

be achieved when winding onto packages, and for this reason better liquor flow can be achieved than when using conical dye tubes (Fig. 6).

Telescopic cylindrical inserts provide the opportunity to compress this type of package on the dyeing column. Several advantages are associated with this:

- no liquor wastage through the abutting surfaces of the package or leakage between packages,
- higher batch weights, more favourable liquor ratios,
- overall better utilization of the machine,
- the use of modern handling systems is possible.

A compressed column of cylindrical yarn packages is theoretically a homogeneous structure, which behaves in the same way as a warp beam for the purpose of dyeing. The flow resistance is theoretically almost the same at all points, and the flow direction is almost exclusively radial (Fig. 7).

Dyeing kinetics: a package constitutes a large fibre surface area that has to be supplied with dye evenly from the aqueous liquor. For this reason, transport of the dye flowing through a yarn package is of great significance for even dyeing. The quality-related context of dye transport is explained in Fig. 8.

In the “galloping horse” area, the dye is transported through the liquor to overflow and at high speed. As a result of the friction at the fibre surface, this speed is reduced greatly until it drops to a much lower velocity, which is quasim… molecular diffusion dye transport in the liquor area denoted by the tortoise. The thickness of this flow boundary film is dependent on the speed of the liquor flowing through the fibre and the speed of the diffusion substance flow. The greater the liquor flow and the diffusion substance flow, the thinner the flow boundary film, which ultimately results in a more rapid dye transport. In the “snail” fibre area, the dye is transported with molecular diffusion substance flow. This speed is significantly lower than in the previous zones, and can not be influenced by the flow velocity. For this reason the dyeing time is primarily dependent on the speed of the molecular diffusion substance flow, which increases disproportionately in line with temperature, because the kinematic viscosity of the liquor becomes lower. Even dyeing of the fibre can only occur if the quantity of dye being transported through the flow boundary film is exactly the same size as the quantity that diffuses into the fibre.

When yarn packages are being dyed there are great differences in liquor supply in some areas of the package. The areas near to the dye tube are subjected to abundant liquor flow and dye, however, often only a fraction of this quantity of liquor is available to the edge areas. Fig. 9 shows an example of synthetic fibre dyeing under idealized conditions, the external and internal dye distribution with respect to the fibre as well as the liquor.

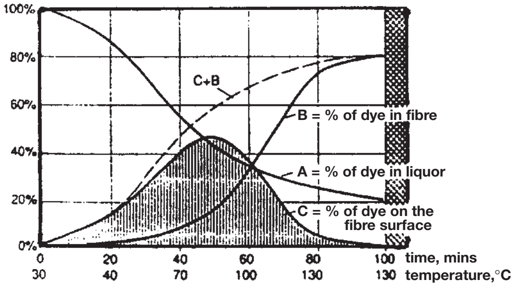


Fig. 9: Dye distribution in fibre and liquor.

The curves A and B represent the dye uptake properties. The A curve relates to the time/temperature-related reduction in dye concentration, curve B relates to the simultaneous dye absorption by the fibre. Curve C reflects the extent of dye absorption at the fibre surface. In principle this curve is not useable, because the parameters represented are not practical or possible to record in the experiment. Surplus liquor is absolutely necessary to ensure even dyeing with even shade depth where flow of a yarn package occurs convectively. It also serves as a buffer by compensating or alleviating the unevenness between the flow-dependent and temperature-dependent transport of dye, with the aim of achieving even dyeing of the yarn package.

Modern winding machines are mostly automated, so that yarn packages with the same dimensions and weight can be manufactured. However, even with optimum adaptation to the substrate it is not possible to avoid differences in winding density. In practice, differences in winding densities of 5–8% are considered quite normal if the conditions relevant for yarn processing are fulfilled, such as good running properties, guaranteed thread reserve, and minimal loss equality in yarn length. In yarn dyeing, up to 10% differences in winding density within a batch have to be taken into account with the same yarn substrate, fineness and package shape. However, in practice it can not be assumed that the radial winding density in yarn packages is evenly distributed. In the area near the dye tube the density is often 30–50% higher than in the outer layers, because the tensile forces in the yarn during winding cause radial compression. Compression is necessary because the shape retention properties of the yarn package are higher than the friction coupling actuated by adherence in the yarn at the crossing points, of which a standard yarn package has approx. 10–20 million. If the liquor flows through the yarn package, it breaks up the friction coupling at the yarn crossing points, causing the layers of yarn near to the insert to be sealed even more efficiently. The auxiliaries necessary for dyeing can increase this effect further because of their consistency, which has anti-friction properties. A further reason can be found in the shear forces generated by the liquor flow on the fibre surface. These cause additional radial pressure in the zone nearest the insert and therefore pressure forces and sealing, which occur particularly when the liquor direction changes. The differences in winding density resulting from these causes can not be prevented or noticeably reduced with today’s state of yarn package technology, as long as the current type of yarn package system is dyed.

Since radial differences in winding density in yarn packages cannot be eliminated, it poses the question as to how such differences will affect the dyeing properties and final result. To establish this, the relationship between liquor throughput, differential pressure and shear stress in a yarn package that is subject to radial flow needs to be investigated. The liquor throughput volume of a dyeing machine is usually measured in the supply pipe to the dyeing vat, showing the quantity of liquor in litres. Differential pressure is caused when the yarn packages create resistance to the liquor, which is being supplied by a pump, and the resistance causes build-up pressure between the pump and the yarn being dyed. With differential pressure, the pressure behind and in front of the yarn is measured and indicated. The resistance of the yarn winder is caused by the so-called shear stress, which is generated by the friction from the liquor flowing past the fibre surface. The differential pressure displayed on the manometer is therefore a measurement of the (liquid) friction in the package loading and therefore for the shear stress, which is a significant factor in the transport of dye to the package surface.

Kretschmer carried out extensive tests on the mathematical connection between radial winding density, differential pressure and shear stress, and he came to the conclusion that yarn dyeing batches with varying winding densities or heights at the same differential pressure have different levels of liquor flow. Fig. 10 elucidates this statement. The numeric values relate to cylindrical cotton packages, however the general conclusions can also be applied to other substrates and package types. Fig. 10 shows how great the liquor flow difference is when dyeing takes place at the same differential pressure with varying densities (top and middle of package) and volumes (top and bottom). However, the shear stress τ_U is a more important factor for even dyeing, because in principle this parameter reflects the conditions of dye transport. The values recorded were practically identical.

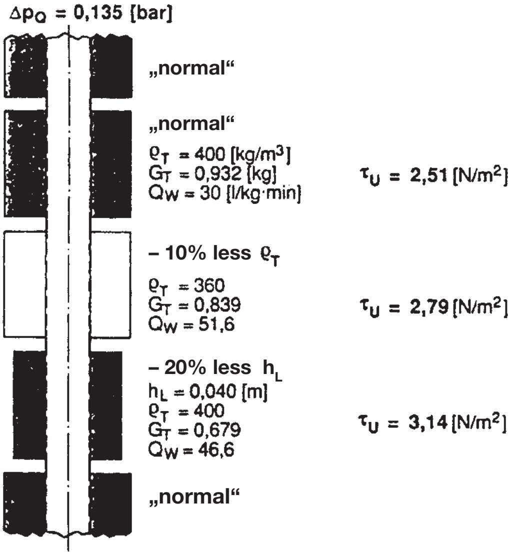


Fig. 10: Effects of different winding densities and winding heights.
Δp_Q = differential pressure in bar; ρ_T = density in kg/m^3; G_T = weight in kg; Q_W = liquor quantity flowing through in l/kg/min; τ_U = dye transport conditions in N/m^2 (shear stress); h_L = winding height in m.

Further experiments were carried out in the different winding zones to provide more information regarding the relationships between winding density, differential pressure and shear stress in yarn package dyeing. The experiments prove the theoretical assumptions that the winding density increases in the area adjacent to the dye tube. The differential pressure and therefore the shear stress in the inner layers are of more significance in yarn dyeing. Only 16.5% of the package weight causes 62% of the differential pressure and 75% of the shear forces. In the area near to the dye tube, it can be said that there is an “over-supply” of dye in relation to the shear forces. In the zones away from the dye tube in a package, shear stress and differential pressure are low, so that an “under-supply” of dye would occur if dye transport to the fibre surface were slower than the diffusion dye transport into the fibre. This type of effect is accentuated in practice by inconvenient package shapes (e.g. conical dye tubes) and the associated liquor wastage via the abutting surfaces, spacers and column seals.

Air flow measurements are used to record the increase in winding density of a yarn package as a result of pretreatment, compression and dyeing. To do this, a package is measured before and after pretreatment or dyeing. Essential conditions for this are that the packages are of equal weight, or identical in their dry state, as well as constant differential pressure and the same amount of air in the measuring gauge. Flow resistance measurements on yarn packages are carried out using a modified textile meter usually used for woven fabrics, designed by Kretschmer. The measured values are shown in 0.1 s. The suction aperture of the textile meter is uncovered when the fabric tensioning device is uninstalled. A conical rubber ring creates an airtight link

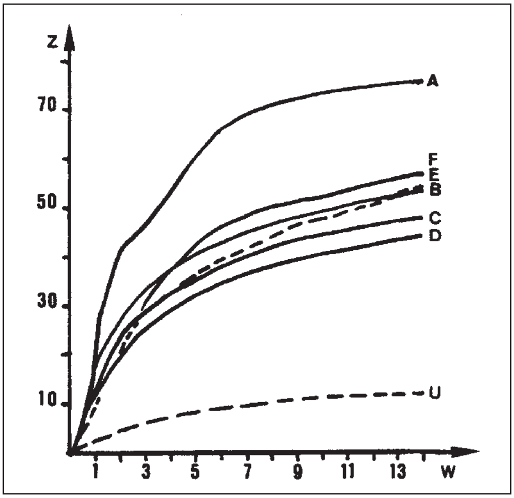


Fig. 11: Flow through profile (ordinate Z = time in s in order to suck 1 l of air through a yarn package; abscissa W = winding zone) of 6 compressed yarn packages (see Fig. 12) from a compression column (A–F) as compared with an uncompressed yarn package (U).

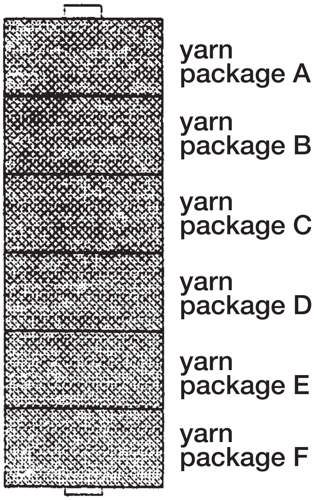


Fig. 12: Structure of a compression column (see Fig. 11).

between the base of the package insert and the suction aperture; the top of the insert is sealed with a standard rubber stopper. All points of connection must be greased before assembly to ensure the maximum possible seal quality. The textile meter is designed to compare the measured values with each other, e.g. to identify flow differences within a package batch before or after dyeing. However air flow measurement does not provide any conclusive evidence relating to the flow properties of water through the yarn packages, since its physical properties are different.

It has been established (Fig. 11) that neither the differences in winding density within the package column or within the individual yarn packages are balanced; the compression process can only even out variations in density at the edges and abutting surfaces of the package. The density of the other zones in the package, e.g. the winding zones adjacent to the insert, is increased by means of axial compression, but not balanced. It is noticeable that the first and last package in the column (Fig. 12, packages A and F) have the highest winding density for all types of insert system. The packages in the middle were subjected to a lesser degree of pressure; as a result they have lower winding densities. This can be explained by the fact that the package column is subjected to the highest pressure from the package compression device from above and beneath. The pressure drops towards the middle of the column. However if the package level of the middle packages is considered (packages B to E) after the compression or fixing process, it can be seen in almost all cases that it is lower compared with the top or bottom package.

Yarn packages, preparation The processing of yarn cops into yarn packages. The essential purpose of a yarn package winding machine is to ensure that the yarn package is calibrated from the point of view of density, shape and weight, as well as to the machines and processes for the subsequent finishing phases, so that production is guaranteed. Perforated → Dye tubes are used as a yarn carrier, usually made of plastic, either disposable or re-usable, and either conical or cylindrical in shape (Fig. 2: on axialy flexible inserts). There are two different winding methods, random winding and precision winding (Fig. 1).

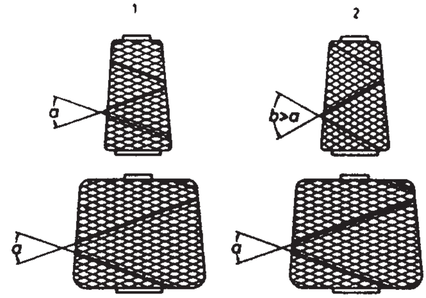


Fig. 1: Yarn package winding systems: 1 = random winding; 2 = precision winding.

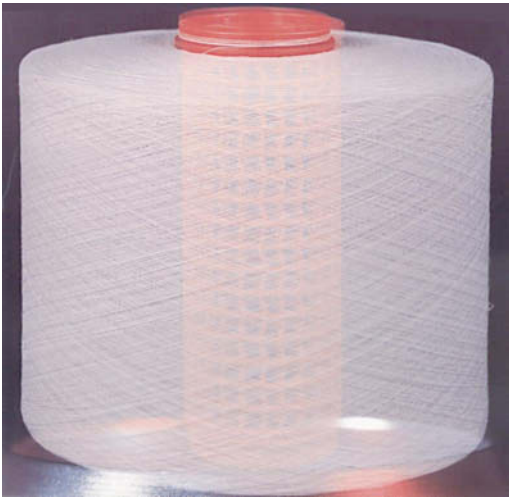


Fig. 2: Cylindrical yarn package with axially flexible dyeing tube.

1. In random winding, the thread cross-over angle is almost identical in all zones of the package. Thread guiding in this type of winding is done by a grooved drum, which also drives the package. In random winding, the package density can essentially only be influenced by the tracking force exerted by the package on the grooved drum and the thread tension. It is

not possible to control these settings automatically during the winding process. For this reason it is also not possible to achieve an even winding density on the whole package. The yarn turning points must not be exactly on top of each other to ensure that the edges are softer. For this reason most winding machines have a device for edge displacement, which displaces the yarn turning points by means of an oscillating axial movement of the packages.

2. In precision winding, the yarn is controlled by a thread guider. When yarn is wound onto a dye tube, the cross-over angle of the yarn reduces as the diameter of the package increases, and the winding density in the area adjacent to the dye tube is lower for instance than is the case with random winding, and for this reason provides ideal liquor throughflow conditions during dyeing. Furthermore, the overall package density can be increased using this winding technique, which means that a higher yarn weight per package is possible, thereby improving the economic viability of the dyeing machine.

The most up-to-date systems that use the precision winding method, e.g. the Schweiter Digicone system and the Schlafhorst Digipac system, use a thread guide that can be controlled. This technique enables a package to be manufactured that has identical yarn cross-over angles, even winding density and optimized dyeing qualities. In spinning, the objective is always to reduce the manufacturing costs of yarn. One option is to increase the performance of the ring spinning machine. However there are limits to this because of the necessity to comply with regulations. Another possibility is to introduce automation into the production process. An example of that is a combination system consisting of a ring spinning machine and an automatic winder.

This combi system has several significant advantages:

- faster yarn throughput without the danger of confusion or the necessity of manual transport,
- interim storage, containers and trolleys for cops are not necessary; there is a reduced requirement for dye tubes,
- personnel costs and spatial requirements per kg of yarn produced are lowered,
- the use of long ring spinning machines with automatic stripping provides ideal conditions for processing small cop formats that were previously uneconomical.

Since most of the machines in current use are not suitable for the ring spinning machine/winding machine combination, the combination system is primarily reserved for new investments. If this system is used, there are several consequences that should be taken into account:

- the climate for spinning and winding can not be adjusted separately for the two process phases in combination;
- the cops need to be wound without any down time and without steaming;
- since there is no interim storage for the cops, the yarn must be available from the ring spinning machine;
- as the dye tubes are running continuously, i.e. they circulate at short intervals, they need to be of good quality;
- the building needs to have enough available space for the long machine combination.

Yarn package winding machines Automatic yarn package winding takes on an important function in the textile production process. A package must be properly wound in order to be suitable for productivity in subsequent stages, whether for twisting, warping, weaving or knitting. “Quality packages” reduce the frequency of out-time and avoid errors.

A modern package winding machine for manufacturing yarn packages is described as follows, using the Schlafhorst Autoconer 238 as an example. There is a splicer at each winding point. The periods of time required for the breaking and splicing during splicing are set by input into the central control system (M.I.C.). Automatic splicing means that the thread ends can be severed cleanly and a good overlap in the splicing zone can be achieved, which means that the splice connections are slim and almost level with the yarn, which contributes towards increased yarn strength. The splice connections on each package are controlled by an electronic cleaning unit, located in the thread path above the splicer. There is also an option of stopping the yarn package with a switch to carry out a manual check.

A separately controlled waxing device ensures even wax application independent of the height and weight of the paraffin roller. If the waxing device is situated above the cleaning unit, it is not possible for paraffin to be deposited in the measuring field of the cleaning unit.

At the start of the winding point (see Fig.), a frequency controlled motor ensures that the thread guiding drum starts smoothly and is gentle on the yarn, and does not slip through under the yarn package, whether the package diameter is small or large or whether a high or low winding speed is used. This avoids the occurrence of randomly wound layers.

Electronic ribboning prevention is adjusted to suit the yarn package conditions in each case, i.e. it is automatically adjusted to the diameter of each package. The required intensity can be programmed into the controller centrally from the winding points and machine. Ribboning prevention is generated by periodically switching the motor at each winding point on and off. The standard version of this winding machine also incorporates edge displacement to avoid hard edges. The motor changes its direction of rotation in order to pick up the upper thread with a suction jet, and rotates the thread guide drum and yarn package backwards at varying

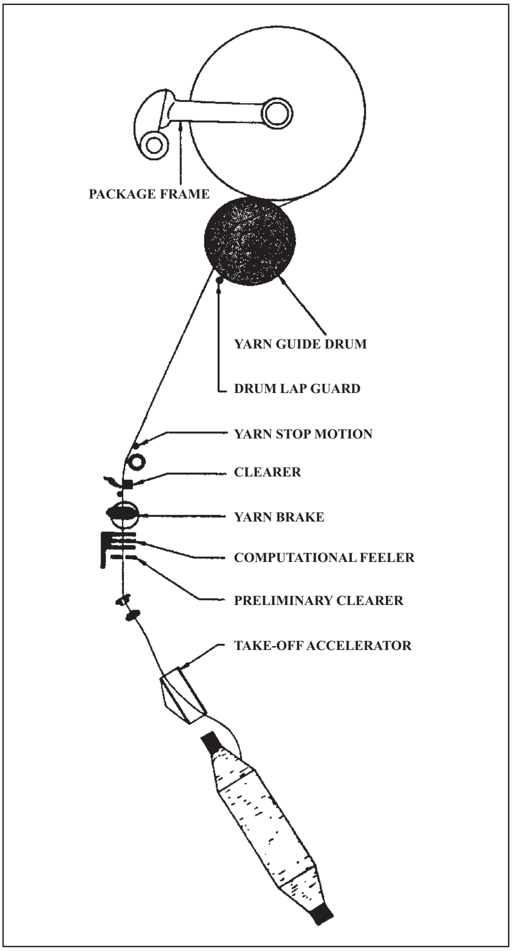


Fig.: Winding position (Schlafhorst).

speeds depending on the diameter of the yarn package. The thread end on the yarn package is presented at least twice during the search process while the suction jet is travelling backwards, which reduces malfunctions.

Another variant is the Autoconer-Dicopac, a fully automatic yarn package winding machine operating on the stage precision winding process. Dicopac is a joint development by the companies Schweiter and Schlafhorst based on the Schweiter Digicone. In this system, as with random winding, the yarn package is powered by means of friction around its circumference. The winding ratio is changed by layer rather than continuously as is the case with random winding, by controlling the movement of the thread guide. This ensures that each yarn layer is wound on the principle of precision winding. Winding is controlled by a microprocessor. The crossing angle changes only within narrow limits within each layer. It stays consistent across the whole package structure independent of the package diameter.

The Dicopac machine combines the advantages of random winding with those of precision winding. These are

- almost constant cross-over angle,
- constant, high winding density,
- even tensile thread strength,
- stable yarn package,
- no ribboning zones,
- precise thread laying,
- almost equal thread length per double hub.

These advantages result in

- high draw-off speeds,
- low level of thread breakages,
- good dyeing properties.

(according to Thomas).

Yarn polishing machine (yarn lustring or glossing machine) → Lustring.

Yarn preparations,

I. Making a preparation (demonstration object).

II. In the textile industry, preparation or → Spin finishes means substances or compounds that are intended to make subsequent fibre processing easier, e.g. scrooping, textile lubricants and spray oils. Fibres and yarns are treated with spin finishes to reduce friction resistance during the subsequent spinning, winding and twisting processes. The proportion of the product that adheres to the fibre or yarn surface is significant for subsequent processing. The proportion that diffuses into the fibre is no longer available in the form of a lubricant. When preparations are applied to a thread in continuous motion via dispensers, the level of application varies. These variations occurring all along the thread, which are frequently periodic, are superimposed by the free migration of the preparation in the package. As a result, the preparation is distributed non-homogeneously in an insular way. The way in which the distribution of the preparation could be changed is dependent on a range of parameters (chemical structure of the preparation, viscosity, wetting properties, package capillary system, etc.) (see Fig.).

Pre-oiling is a thread preparation for a low level of oil application. It is used when winding dyed yarns from the dye package to prevent dye deposits on the thread brake or other thread deflection points. Oligomer deposits are also bonded as a result of pre-oiling. When the thread balloon is touched with a porous sinter ceramic element situated between the feed spool and the thread insulation, the yarn takes up a small quantity of oil. The fixed sinter ceramic element is supplied with oil per machine or per field. Dry waxing is used primarily for spun knitting yarn, and occasionally also for weaving yarns. A yarn that has been waxed to the ideal friction coefficient of 0.13–0.15 μ guarantees trouble-free subsequent processing in knitting and weaving. As

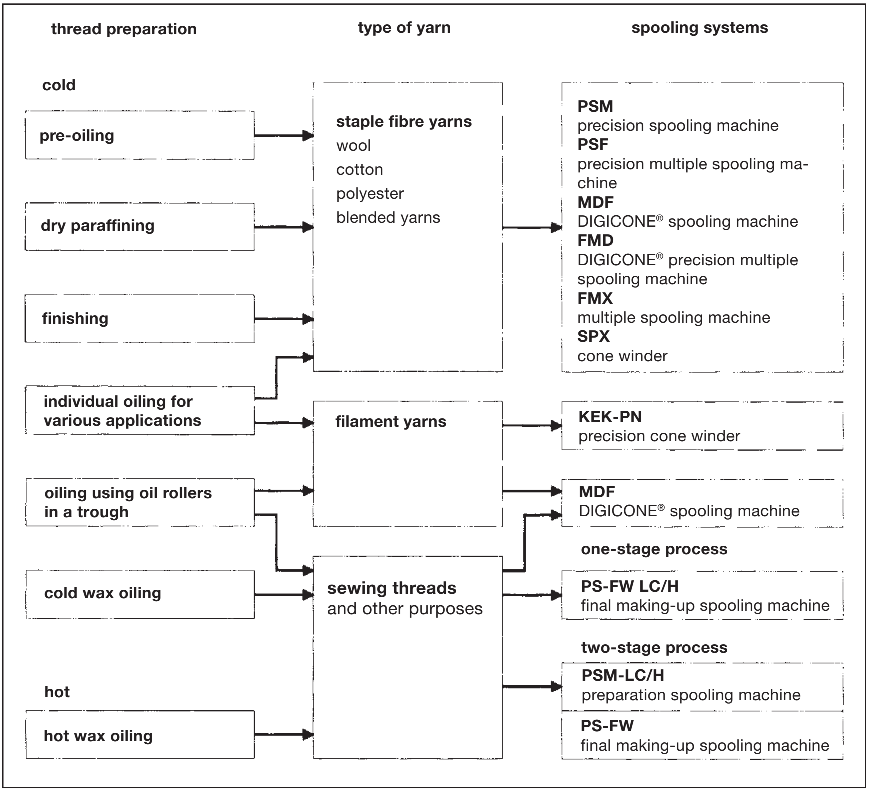


Fig.: Outline of the possibilities of thread preparation with regard to the various types of yarn and spooling systems (Schärer Schweiter Mettler).

well as improving the lubrication properties, dry waxing also results in a slight reduction in fly. Waxing rolls with different levels of hardness (melting point and penetration), as well as wax application that can be set to the optimum friction coefficient, mean that thread preparation can be adapted ideally for subsequent processing. The waxing device operates individually per spindle, and is normally located in the thread triangle between the thread insulation and the automatic batching spool.

For scrooping, yarn preparations with a low level of oil application are used (max. 1%) when winding staple fibre yarns onto flat bobbins. Scrooping using a powered oil application roller improves running properties in the twisting process and reduces fly. Furthermore soiling of the two-for-one spindle is reduced. The oil application roller is usually situated in the thread triangle between the insulation and the automatic batching spool, and is supplied with oil per machine or field.

Individual oiling for different purposes is a universal thread preparation with a powered oil roller for staple fibre yarns and filaments. There are various subsequent processes that require oiled yarn, e.g. twisting to prevent fly. If oiling is carried out individually, the required level of oil application can be controlled per spindle for each application area. The oil roller is driven per spindle and can be controlled individually with infinite variability via an interactive electronic control panel. Depending on machine type or field, the oil supply is from four spindles at a time.

To give filament yarns better running properties for further processing, they are oiled on different yarn winding machines by a powered oil roller (kiss roll), which is immersed in the preparation. The preparation liquid is in a trough that spans four spindles. In order to meter the precise quantity required for oil application, the revolution count of the oil roller can be varied infinitely. The trough is positioned between the feeder rollers and the thread insulation, with a moisture application roller per winding point. The reason for oiling sewing yarn is to achieve optimum lubrication properties to reduce the needle temperature and to reduce fibre crocking on the eye of the needle in industrial sewing machines.

For technical reasons, a variety of spin finishes are applied to the fibre during the course of wool processing. In the combing section, for instance, oils with variable ingredients are used before teasing and combing the scoured wool. Spin finishes are then applied again for worsted spinning. The composition of the residual fat on the surface of the wool, the lubricating oils applied and also any reaction products produced during processing are of great interest when trying to establish causes of quality faults during manufacture. When the residual fat is being extracted from the wool surface using organic solvents, the extract contains a complex mixture of spin finishes, native wool wax and internal lipids. Natural wool wax consists mainly of fatty alcohol and stearin esters with long chains. The rest consists of free and oxidized stearins, free alcohols, free fatty acids and hydrocarbons.

Yarn printing Yarn printing is done to cause certain fuzzy coloured patterns after weaving, knitting or tufting. For this technique, yarns are printed either in hank form (single shade/pearl printing, or multi-colour/ombré printing), or in warp form (→ Warp printing) or in knitted form (→ Space dyeing).

Yarn printing machine Parallel winched hanks are printed under tension with relief print rollers (→ Hank yarn printing machine).

Yarn raising A yarn raising machine is suitable for raising yarns for hand and machine knitting in the range Nm 20 and coarser. The raising process is carried out by raising rollers on individual threads (Fig. 1). The raising intensity can be altered by changing the speed and contact of the raising rollers, as well as by the selection of covering for the raising rollers. Raising rollers are available with pins, wires or brushes. The rollers are interchangeable with each other. The yarn is wound onto conical inserts using the random winding method. The thread being wound is displaced by a thread guide, providing ideal winding conditions.

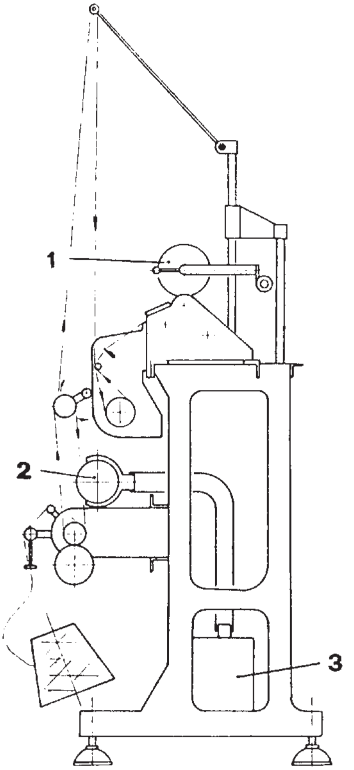


Fig. 1: Tangential raising roller contact with straight-running yarn .
1 = cone winding unit; 2 = raising unit; 3 = extraction.

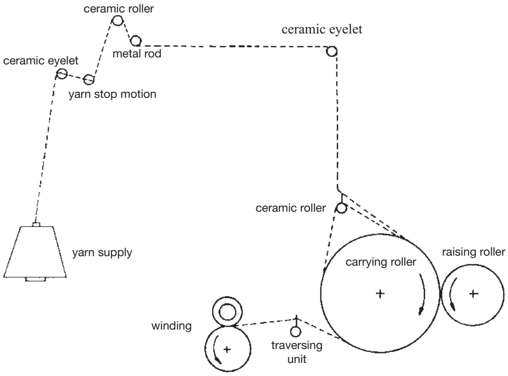


Fig. 2: Tangential raising roller contact with the yarn, which is running round a drum.

The yarn can loop one or several times around a central cylinder, against which the raising roller rotates rapidly at defined intervals (Fig. 2).

Yarn singeing machine → Gassing machines.

Yarn spray-dyeing machine → Spray-dyeing machine.

Yarn steamer → Batch steamers.

Yarn steaming Various forces arise in the yarn as a result of spinning and winding. These cause a certain instability in the yarn. In a free state, the yarn has the tendency to untwist or to form loops and snarls. To enable wool to be fixed, a minimum temperature of 90°C is required; synthetic fibres on the other hand require fixation temperatures of 110–140°C. It is only possible to overcome the problem posed by these differences in fixation temperatures for wool blend yarns due to the fact that wool is able to withstand higher fixation temperatures at a low pH without yellowing. Increasingly large packages are being produced on spinning and twisting frames. Crosswound yarn packages which are processed as weft yarn therefore need to be fixed well. Vapour penetration of wound yarn packages, type of steam, temperature accuracy and reproducibility of programmes have all become more significant in yarn steaming. Yarn fixation is generally carried out in pressure steam chambers with vacuum and excess pressure ranges. The steam is supplied either directly from the

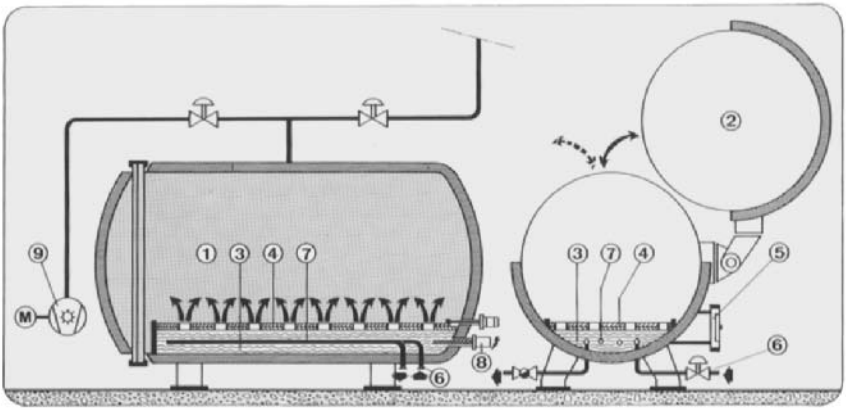


Fig. 1: Xorella yarn steamer (batch type) with water bath.
1 = steaming chamber; 2 = lid; 3 = water bath; 4 = water bath cover; 5 = level control; 6 = steam, hot water or heating oil; 7 = heater coil; 8 = electric heating; 9 = vacuum pump.

steam network or indirectly via an integrated water bath (Fig. 1).

The machines have automatic program control and charging the machines for either a one-way or continuous operation is also an automatic process (Fig. 2). The yarn make-up depends on the effect to be achieved. Textured yarns are fixed to achieve a high bulk with minimum tension. The treatment time depends primarily on the penetration of the yarn package. As the package size increases and the winding becomes denser and harder, the treatment time needs to be extended. The steam penetrates the yarn package at a variable rate from the surface inwards. If the yarn carriers are perforated or deformed, it can also penetrate from the side of the yarn carrier. An intermediate vacuum in the first third of the treatment time facilitates even penetration. An insufficiently long treatment time and varying package density result in widely varying properties along the fibre, which become very noticeable on further treatment.

Yarn twist → Twist of spun yarns.

Yb Chemical element for ytterbium (70).

Yeasts (saccharomycetes). Microbes which produce a mould film on the surface of liquids, causing the fermenting process. Occur as harmless → Saprophytes (→ Moulds), potentially pathogenic. Also present in perspiration.

Yellowing during wear This is caused by insufficient light-fastness, perspiration and urine, combined with the effects of dry cleaning and laundering due to auxiliary residues, including optical brightening agents which have been removed, insufficiently fixed, or have altered fastness properties, and are generally more visible after finishing treatments (ironing, pressing, mangling). For measuring techniques: the grey/whiteness measurement using whiteness measuring devices is not sufficient as deposits, which tend to be yellow to brown, play a significant part in the altered fabric appearance as "yellowing". It is true that grey with a blue cast appears more pleasing, "whiter" (optical brightening agent) to the eye than grey with a yellow cast with the same degree of greying. To be able to measure both greying and yellowing of a strip of test fabric, this is graded on a blue-grey-yellow scale: it is neutral grey if

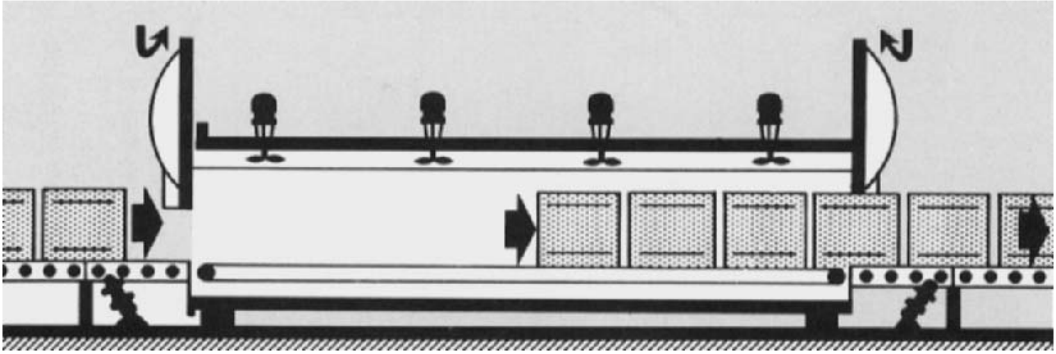


Fig. 2: Hemmer continuous yarn steamer for boxes of cops.

it reflects light of different wavelengths to an equal degree; i.e. it has a constant degree of whiteness when various filters are placed in front of it. The assessment scale is two-dimensional, reflecting breadth and depth. The “degree of yellowing” should be broad (a negative “degree of yellowing” would have a blue cast) and the “degree of greying” deep. Both values are measured by exchanging the filters. Green filter (G) = degree of whiteness; green filter minus blue filter (B) = “degree of yellowing”. Negative differential values (with blue cast) only tend to occur with optical brightening agents. It is the degree of yellowing, rather than the degree of greying in itself, which is crucial in assessing the final fabric appearance. Occurs in particular with woollen or silk goods. Optical brightening agents do not prevent yellowing, but tend to intensify the effect.

Yellowing of wool Environmental influences on fibrous materials include:

- solar radiation, artificial light sources etc. (→ Light exposure damage),
- temperature,
- oxygen,
- water (sorption water, water vapour, etc.),
- various harmful pollutants e.g. pollutant gases (ozone, nitrogen, sulphur oxide etc.), solvents.

These factors may occur in a wide range of combinations and at varying intensities and exert different effects on wool. The physical values of radiation and temperature represent key functions for the photochemical changes to the wool fibre (Tab. 1). By thermal exposure of wool, the extremely damaged scale structure of the fibres can be clearly identified. Wool samples tested were exposed for three cycles in accordance with DIN 75 202; this resulted in a loss of breaking strength of approx. 70%. Tab. 1 shows the distribution of the energy radiation of the sun and its effect on wool. Tab. 2 shows the surface temperatures measured.

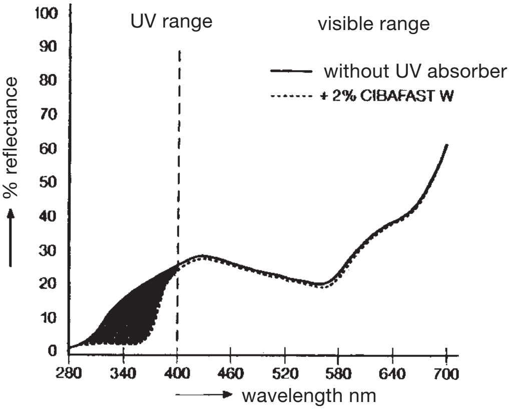


Fig. 1: Reflectance spectra of two identical wool dyeings with and without Cibafast W (Ciba Geigy).

When wool is exposed to radiation from the sun (or similar light sources in the spectrum), two apparently opposite processes can be observed: wavelengths of between approx. 280–400 nm result in yellowing and fibre degradation, whereby the short-wave, higher-energy portion of 280–330 nm (blocked by window glass) has a significantly more damaging effect than the range of approx. 330–400 nm (Fig. 1). The range of approx. 400–460 nm has a photo-bleaching effect, on the other hand. When wet wool is exposed to radiation, photo-bleaching and photo-yellowing is accelerated. With finished wool, there is not only a change to the absorption of solar radiation in the visible range – depending on the dyestuff, optical brightener etc., the same occurs in the UV and IR range. Heat alone tends primarily to have a yellowing effect on wool; fibre degradation is low.

In practice, wool tends to be dyed, and its absorption spectrum for radiation is therefore altered to a

wavelength [nm]	intensity of irradiation [W/m^2]		proportion [%]		range	effect on wool
< 280	0		0		ultra-violet	
280– 320	5	68	0,5	6,1		**photochemical effect**
320– 360	27		2,4			• yellowing fibre degradation
360– 400	36		3,2			
400– 480	129	493	11,5	44,0	visible	(400-450 nm range has a photobleaching effect)
480– 560	136		12,1			
560– 640	121		10,9			
640– 720	107		9,5			
720– 800	87	559	7,8	49,9	infra-red	• acceleration of photochemical processes
800–1000	156		13,9			
1000–1400	173		15,5			
1400–3000	143		12,7			**thermal effect**

Tab. 1: Strength of vertical incidence global radiation and its effect on wool (radiation varies according to location, time, weather and thickness and composition of the atmosphere etc.).

flat woven wool fabric (dyeings with metal complex dyes)	undyed	bright yellow (1/20 RT)	yellow (1/1 RT)	bright bordeaux (1/20 RT)	bordeaux (1/1 RT)	navy	beige (0.1 % dye)	dark brown (3.3 % dye)
surface temperature	38.8°C	40.2°C	49.2°C	41.7°C	51.9°C	58.5°C	44°C	51.5°C

Tab. 2: Surface temperature of variously dyed flat woven fabrics measured in the open air in sunshine (non-contact measurement, double layers, outside temperature 34.5°C). RT = standard depth.

greater or lesser extent. Tab. 2 gives temperatures which have been measured on woollen fabrics which have been dyed with various metal-complex dyes. These differences in temperature are caused by the altered radiation absorption of the fabrics in particular in the visible, longer wavelength range and near-infrared. Heat accelerates the photochemical degradation processes of wool. This fact should be noted e.g. when using these fibres in cars.

The mechanisms and chromophores arising in connection to photochemical yellowing and fibre degradation are largely unknown. The amino acid analyses of

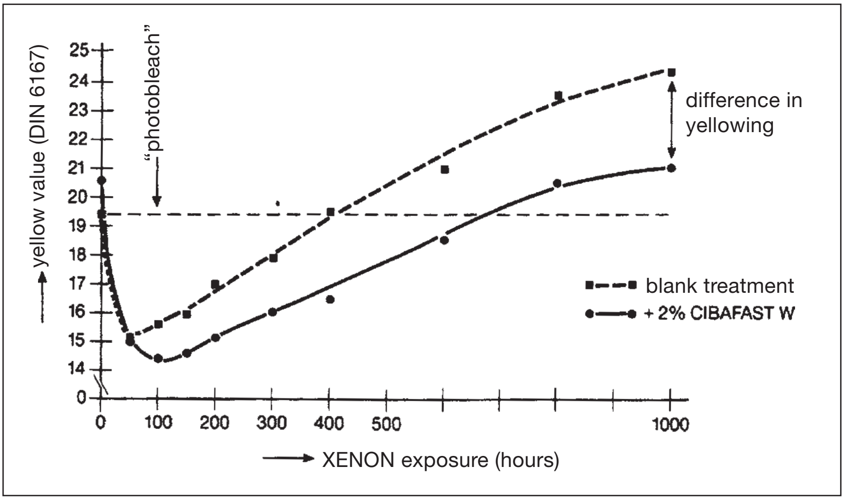


Fig. 2: Change in the basic white of wool on exposure in accordance with SN-ISO 105-B02 (xenon) which contained no Cibafast W (Ciba Geigy) or contained 2%. The yellow values were calculated in accordance with DIN 6167 [woven serge fabric blank treated by the Lanaset process (Ciba Geigy)].

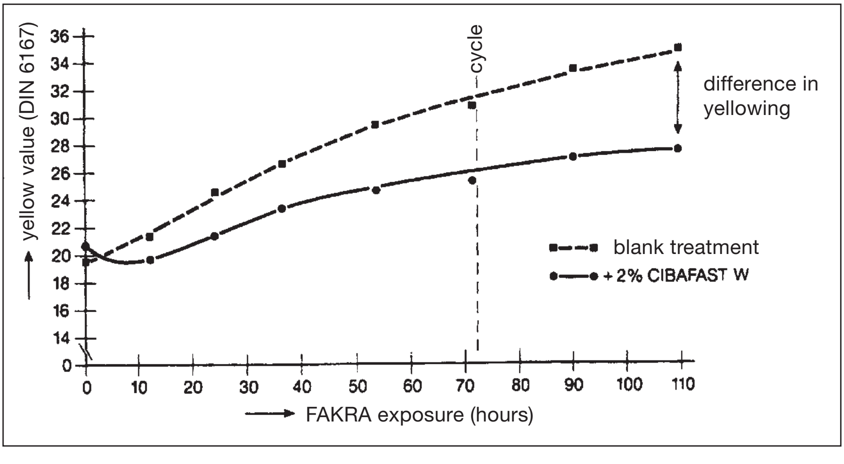
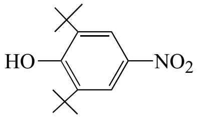


Fig. 3: Change in basic white of wool on hot exposure in accordance with DIN 75 202 (FAKRA) which contained no Cibafast W (Ciba Geigy) or contained 2%. The yellow values were calculated in accordance with DIN 6167 [woven serge fabric blank treated by the Lanaset process (Ciba Geigy)].

carefully irradiated wools demonstrate characteristic changes in the cases of the amino acids tryptophane, tyrosine, histidine, cystine and methionine. Stronger irradiation causes almost all amino acids to deteriorate. Numerous mechanisms are known in relation to photochemical yellowing: on the one hand, reactions of the amino acids altered on radiation, and on the other the occurrence of ketone compounds, double bonds or reactions in non-protein areas.

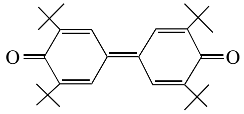
The aim of protecting wool against the negative effects of light, in particular against yellowing, i.e. improving the light-fastness of wool and its dyes in the UV-range (Fig. 2) has been achieved by means of a UV-absorber of the o-hydroxy-phenyl-benzotriazole type (Fig. 3) (according to Reimert).

Yellowing on storage In the wide majority of cases of white goods yellowing on storage, three yellow components were found. These yellow components occurred individually, but also in varying blending ratios. These yellow components have been identified as one nitrophenol derivative and two quinone compounds.



compound I
2.6-di-tert.butyl-4-nitrophenol

This yellow body forms easily due to the effect of nitrogen oxides on the sterically hindered phenol 2,6 di-tert.butyl-4-nitrophenol. The formation of compound I is also possible if there is a substituent in p-position, however.



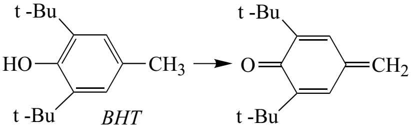
compound II
3.3‘.5.5‘-tetra-tert.butyl-4.4‘-diphenoquione

Compound II is formed on oxidation of compound I with potassium hexacyanoferrat in a caustic alkaline solution and also under mild reaction conditions. This formation of II from I explains the fact that when testing incidences of yellowing, compounds I and II are repeatedly found side by side.

Identifying the yellowing products also led to insight into the reaction mechanism of yellowing on storage. According to this, yellowing which occurs when ultra-white or pastel-coloured textiles are stored is due to reaction products in the storage atmosphere in the majority of cases (nitration and/or oxidation) with sterically hindered phenols. This reaction mechanism is not only limited to sterically hindered phenols – it naturally also applies to other phenols. Seen from a purely theoretical point of view, other phenols could therefore possibly cause the formation of yellowing components on textiles.

Oxidation of sterically hindered or other phenols is known and has been investigated in depth. Sterically hindered phenols are widespread as anti-oxidants and anti-agers and may therefore cause a yellow cast on textiles through packaging materials such as foils or rubber threads which come into contact with textiles.

One phenol compound often used as an anti-oxidant for polyethylene foil is sterically hindered 2,6-di-tert.butyl-4-methylphenol, generally known as “butylated hydroxytoluene” or “BHT”.



While it would appear sensible to regard BHT as an intermediate product in the formation of stilbene quinone due to its low stability, it is extremely surprising that it has been possible to isolate this compound from garments which have yellowed on storage.

To clarify why only the polyester sewing thread yellowed on storage, rather than a made-up garment, it has been assumed that the sewability improver on the sewing thread is much more likely to be capable of absorbing and retaining volatile phenol compounds than the base fabric which had no final finishing. The phenol compounds therefore yellow due to the effect of nitrogen oxide in the atmosphere.

Rinsed yarns and polyester fabrics finished with neither oils nor softeners absorbed little nitrophenol in the test, whereas yarns with slipping properties absorbed sufficient nitrophenol to become clearly yellow. This is an exact reproduction of what happens when phenol yellowing occurs on storage.

Various measures to reduce the risk of phenol yellowing to a minimum include:

- Finishing the textiles in an acid medium with a non-volatile acid such as citric acid, as the presence of alkalis constitutes an additional factor to convert BHT to stilbene quinone.
- Using top quality phenol-free cardboard boxes or recyclable synthetic packaging.
- Minimising the nitrogen oxide content in the storage rooms.
- Ensuring that any packaging materials coming into direct contact with the textiles do not contain any volatile phenol anti-oxidants and that no nitrogen oxides and phenol compounds could affect them.

– Wherever possible, working with finishing agents which have minimal affinity for volatile phenol compounds.

Yellow prussiate of potash → Potassium hexacyanoferrat (II).

Yellow weed Mordant dye. → Natural dyes.

Yield Yield, pure substance content, output, efficiency rate. Raw sheep's wool yield = pure wool content after removal of wool grease, suint and contaminants. Spinning yield = fibre yield from spinning.

Y-machine Drum washing machine with a → Y partition.

Young's equation When a fibre surface is wetted with a liquid droplet, Young's equation applies:

$$\gamma_S - \gamma_{SL} = \gamma_L \cdot \cos\theta$$

γ_S = surface tension of the solid (fibre),
γ_{SL} = surface tension between the solid and liquid,
γ_L = surface tension of the liquid,
θ = wetting angle.

Where the liquid is water and a surfactant is dissolved in this, γ_L and γ_{SL} are reduced by the adsorption of the surfactant, while γ_S remains unaffected. It can be inferred from the equation that the wetting angle is consequently reduced. This can result in $\theta = 0$ and the liquid may therefore spread spontaneously across the surface. →: Surface-active compounds; Wetting.

Young's modulus This is used to characterise the elasticity of fibres. Gradient of the tangents on the stress-strain curve through its origin (approx. elasticity modulus).

If the stress-strain curve of a glass fibre is observed compared to other fibres (see Fig.), the linear gradient of the measuring curve can be identified until the point at which the fibre breaks. The fibre has a high initial modulus, which accounts for the stiffness of components manufactured from this, but has virtually no permanent elongation.

Y partition Type of → Drum partitions in the form of a three-section inner drum with three chambers in the drum cross-section in garment dyeing machines.

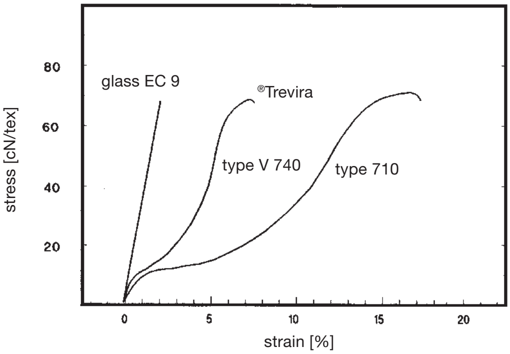


Fig.: Stress-strain diagrams.

Yucca fibres Similar to → Sisal, a leaf bast fibre which is obtained from the 25–60 cm long leaves of the yucca plant (yucca filamentosa L.) e.g. from the native family Liliaceae of southern North America. They are harvested twice a year. Fibres are developed either chemically (lime preparation) or by boiling under pressure, which releases lignin from the yucca fibre to a large extent. Short elementary fibres (approx. 1.3–1.5 mm), breaking length 40–67 cN/tex. Use: for twine, agricultural twine, also for carpet fabrics, tarpaulins, etc.

Yuzen printing (Ju-Sen printing). Artisanal printing process practiced in Japan. A forerunner to modern screen printing. Named after its inventor, the artist Yuzensai Miyasaki (1654–1736). Papery sheets are produced from the bast of the mulberry tree by pasting together several layers, these are stiffened, then made watertight with oil. The screens are manufactured from these by cutting out the motives. Print paste is applied in various ways e.g. hair brush, besom, doctor blade and spray nozzles on paper funnels. This method is used to produce high-quality prints on kimono materials. Depending on the process technique used, direct print or resist effects are obtained.

Z

Zahn Wellens Test For determining the eliminability (also called “apparent biological degradability”) of refractory contamination in waste water, in accordance with DIN 38 412 L 25. The test is carried out to enable forecasts to be made on eliminability in practical waste water treatment plants. The usual test periods of 14 and 28 days appear to be too long on account of the numerous possible adaptation phenomena. In view of the waste water management framework regulation, which mentions the test as the sole degradation test, a test period of 7 days is suggested.

There is a range of possibilities for forecasting the degradation/elimination behaviour of compounds in waste water treatment plants for the laboratory scale. The usual waste water simulation tests (e.g. coupled unit test) have proved themselves with surfactants among other detergent content substances, but they work in a concentration range of 10–20 mg/l of DOC at a high experimental cost and with long familiarisation and adaptation times which can have a considerable effect on the result.

The static Zahn Wellens Test works in a substrate concentration range which is realistic for substances in textile waste water. There are however different regulations and standards or variants for practical implementation (e.g. the EMPA test), so that uniform conduct of the tests and evaluation of the results is not always guaranteed, especially as the test regulations, particularly the OECD guideline, often allow wide latitude in test conditions (e.g. seeding density and test concentrations).

The Zahn Wellens testing process can be used on water-soluble, non-volatile organic substances and on waste water containing such substances. The basic principle of the process is using activated sludge from a waste water treatment plant and a mineral nutritive substance solution together with the test substance over a longish period (up to 28 days) at 22 ± 3 °C. Elimination can be controlled by determining the dissolved COD or DOC value. Two parallel formulations are tested with the test substance. Biocoenosis behaviour must be monitored with the reference substance, to which end diethylene glycol is suitable, since degradation of this substance also requires 5–7 days, and runs parallel to the tests. Under certain circumstances, testing the blank test without sludge is dispensed with if the samples to be tested contain no significant quantities of volatile substances. The test formulation is made with 21 volumes and a content of 1 g of dry substance over 7 days, the COD being determined after 3, 6, 24, 48, 72 and 168 hours.

Eliminability is currently determined from

$$D_t = \left(1 - \frac{C_t - C_{Kt}}{C_a}\right) f \ [\%]$$

D_t = eliminability of the test substance and the waste water at time t [%],

C_t = DOC and COD value of the test formulation at time t [mg/l],

D_{Kt} = DOC and COD value of the control sludge formulation at time t [mg/l],

C_a = DOC and COD value of the test substance at the start of the test [mg/l],

f = conversion factor, f = 100.

Zanella Smooth, highly lustrous, Atlas construction lining fabric (cotton and also cotton warp + worsted yarn weft = wool/cotton union-Zanella),

Zardozi Old Indian gold embroidery (silk yarn wrapped with metal foil) on heavyweight fabrics.

Zarts solution Dyestuff mixture for differentiating between cupro (violet/blue colouration) and viscose fibres (= pink/red colouration) in fibre blends. Reliable method of differentiation.

Zaza-printing method Yarn sheet printing process (similar to the vigoureux printing process), in which yarn sheets run between a relief and a felt roller which is supplied with printing paste from the printing paste trough via a rubber roller, printing paste being transferred to the yarn material in raised places of the relief through felt roller contact pressure. Five shades can be produced with one ground colour and four pairs of rollers.

ZE → Zein fibre, DIN 60 001 symbol up to 1988.

Zefir → Zephyr.

Zein Vegetable protein from maize (botanical = zea). Used for producing adhesives, plastics and fibres.

Zein fibre Man-made protein fibres from the zein contained in maize meal. Spun by the wet spinning process (precipitating bath: dilute sulphuric acid, acetic acid and zinc sulphate). Dry strength 11 cN/tex at 40% elongation. Used in a blend with cellulosic and other fibres (increases elasticity, improves crease resistance) for warp and weft knitted fabrics and woven pile fabrics.

Zeolites Inorganic silicate ion exchangers and therefore cation exchangers (→ Ion exchanger) which are also suitable for neutral exchange. Natural zeolites: crystallised, water-containing alumina silicates of differing composition, frequently so-called greensands. Artificial zeolites: melting of alumina silicates with sodium carbonate or sodium aluminium silica gel precipitates (Permutit type). In zeolites of the sodium aluminium silicate type ($NaO_2 \cdot Al_2O_3 \cdot 3\,SiO_2 \cdot 5\,H_2O$), the H_2O is not chemically bonded but distributed over hollow spaces between SiO_4 tetrahedrons which give it off continuously on heating, and re-absorb it to moist air. Natural zeolites are water resistant up to 35°C, while artificial zeolites can only be charged with cold water. Achievable residual hardness 0.1–0.05°d. Filter wear with natural zeolites is approx. 4–5% per year.

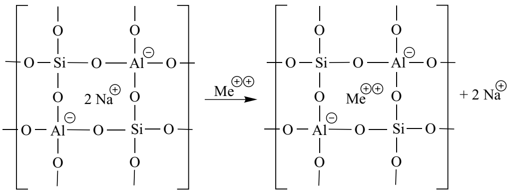


Fig. 1: Ion exchange through zeolite A.

Synthetic crystalline zeolite type A (Fig. 1) is represented by the following formula:

$$Na_{96}[(CAlO_2)_{96} \cdot (SiO_2)_{96}] \cdot 216\,H_2O$$

The ratio SiO_2/Al_2O_3 is about 2 : 1, a relatively large number of exchangeable cations being present. The spatial network structure of zeolite A is characterised by a large hollow space with openings (0.4 nm diameter). This structure develops in a complicated reaction: first of all aluminosilicate by reorientation of the primary components AlO_4 and SiO_4, resulting in secondary aggregations in the form of so-called sodalite grid units

$$- Na_8[Cl_2(AlSiO_4)_6] -$$

with small hollow spaces which then combine to form zeolite type A (Fig. 2).

Zeolites used as detergent components are of such a small particle size (a few ∝m) that they can precipitate neither during the washing process nor during discharge of the used washing liquor.

From Japan comes a processing variant for antibacterial finishing which utilises the properties of zeolites. These are inorganic compounds which are capable of working as ion exchangers and of storing molecules. The processes can be selectively carried out depending on the structure of the zeolite. By storing silver ions in specific zeolites and subsequent spinning into polymers, it is possible to achieve a very low concentration of silver ions on the fibre surface. Since silver ions diffuse slowly out of the fibre interiors on to the surface, an antibacterial finish is produced over a lengthy period.

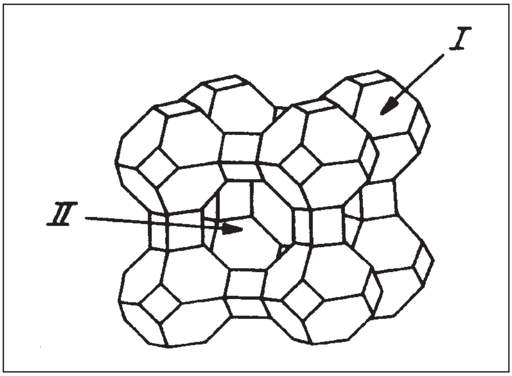


Fig. 2: Sodalite unit with small cavity (I); large cavity with aperture (II); diameter 0.4 nm.

Zephyr,

I. Thick, soft twisted (mostly multifold) worsted yarn (fine Merino wool) for warp and weft knitting and embroidery purposes.

II. Dense, fine thread (cotton, silk, union silk) plain weave fabric (fine varieties) cambric. Designation in accordance with fibre type and use (cotton zephyr, blouse zephyr, shirting zephyr and dress zephyr).

Zeta potential (ζ potential) → Electrokinetic interfacial potential. Where solids are in contact with aqueous electrolyte solutions, there is, at the phase boundary, a different distribution of electrically charged particles from that in the interior of the solid and liquid phases. A concentration of charged particles at the phase boundary is possible for polymers through the dissociation of relevant molecule groups at the phase boundary and a variously high degree of adsorption of anions and cations at the interface. The charged particles found on the solid surface interact with the ions in the electrolyte solution, forming an electrochemical double layer (Fig. 1).

For describing the potential difference at the phase boundary of the solid polymer/electrolyte solution, the Stern double layer model is generally used as a basis. After that, ions are firmly adsorbed at the interface. The charge of these ions, and also through dissociation of relevant molecule groups found at the interface, is compensated by counterions, which are found fixed opposite the ions at the interface, and also through counteri-

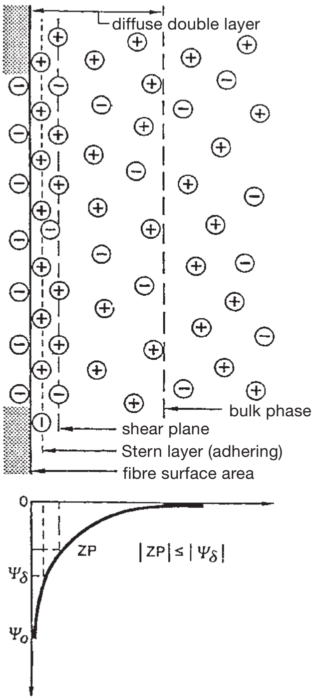


Fig. 1: Model of the electrochemical double layer.

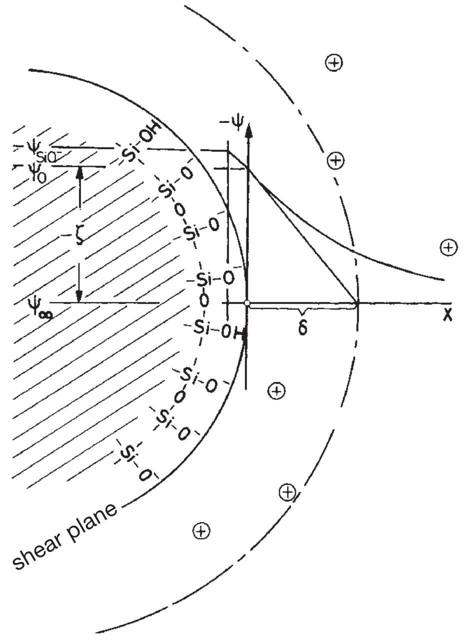


Fig. 2: Potential run and charge distribution on the surface of a SiO_2 particle.

ons which are found at a greater distance from the interface due to thermal agitation. The electrochemical double layer is divided by Stern into a “rigid” and a “diffuse” part. The interaction between polymers dissolved or dispersed in aqueous solutions etc. is affected by the electrical charge conditions on the polymer surface, by the potential difference in the double layer, and by the charge density at the interface and at the boundary rigid/diffuse double layer. This applies particularly to dispersed solids, dyes and textile auxiliary agents.

SiO_2 particles dispersed in water can be used for quantitative interpretation (Fig. 2). These particles have silanol groups on the surface which can dissociate in polar solvents, the negative charge remaining on the surface. Since there is electroneutrality outside, the charge of the solid and particle surfaces (in this case the negative charge of the SiO_2 groups) has to be compensated by a positive charge of identical amount, e.g. by the dissociated protons. The shear plane separates the part of the charge fixed on the surface from the movable part of the charge, i.e. the part freely movable in the double layer.

The abscissa x in Fig. 2 has its origin on the particle surface (phase boundary), and points from it vertically into the interior of the solution. The ordinate ψ is the tangent to the particle surface at the intersection of the abscissa x with the surface. The electrical potential ψ falls from the value $\psi_{SiO_2^-}$ at the particle surface to a value of ψ_0 at the shear plane. From that point, it decreases exponentially to the interior of the solution, reaching a value of ψ_∞ at infinity, as the charged particles have a Boltzmann distribution in the diffuse layer, which is connected to the shear plane. Resulting from this is the electrophoretic mobility B, caused by an external electrical field. The mobility B of the particles is defined as the quotient of the velocity of migration v of the particles and the external field strength E:

$$B = \frac{v}{E}.$$

The electrokinetic behaviour of the SiO_2 particles is characterised by the electrokinetic potential ζ (zeta potential), which should be equal to the potential difference between an imaginary shear plane and the interior of the liquid phase. It should therefore be equated with potential difference $(\psi_0 - \psi_\infty)$. The potential $\psi_{SiO_2^-}$ of the potential-determining groups at the surface is not generally identical with the potential ψ_0 of the shear plane. If the thickness of the diffuse charge layer is great compared with the layer of the potential-determining ions, this additional potential difference $(\psi_{SiO_2^-} - \psi_0)$ can be ignored. The connection between mobility

B and zeta potential is obtained by the following relationship:

$$\zeta = B \cdot \frac{\eta}{\varepsilon \cdot \varepsilon_0}$$

This relationship applies in general only when the quotient of viscosity η and dielectric constant ε is constant within the diffuse charge layer. Since the rational system of units is used for the calculation, the dielectric displacement constant ε_0 has to be taken into account.

By zeta potential measurement, the potential distribution in the diffuse double layer can be determined relative to the valency and concentration of the electrolyte. Most of the electrokinetic trials on fibre materials have been conducted in accordance with the streaming potential method principle. Electrokinetic measuring methods are characterised by the fact that, when an electric field is applied to solids dispersed in electrolyte solutions, the dispersed solid particles (electrophoresis) or the electrolyte solution (electro-osmosis) move, or that, with the relative motion of solution and dispersed phase, an electric field occurs (streaming potential or sedimentation potential). It is an accepted fact that, when an electric field is applied, the charged particles of the rigid part of the electrochemical double layer remain on the solid, endowing it with a surplus charge, which is responsible for electrophoretic migration, and that the ions of the diffuse double layer migrate in the electric field, bringing about the electro-osmotic liquid motion.

Errors of measurement particularly concern inexact determination of the pore geometry of the diaphragm, failure to take account of the flow resistance in the measuring capillaries in electro-osmotic measurement, and inexact measurement of the electrical values. By excluding these sources of error, the zeta potentials determined on fibres in electrolytic solutions are independent of packing density and the voltage applied or the pressure difference. The measurement and evaluation method to be employed is primarily oriented to the type of fibre and the measured solution. For synthetic fibres in neutral diluted electrolytic solutions, the most reliable values are obtained by the streaming flow method with the use of Ag/AgCl electrodes. In an alkaline medium, preference is to be given, under otherwise identical conditions, to the streaming potential method using precious metal electrodes. On the other hand, electro-osmosis offers advantages for swelling fibres (cellulose, wool, asbestos).

fibre	water absorption at 100 % rel. humidity [%]	Zeta potential [mV] ζ_0	ζ_∞
viscose filament	45.0	16.60	3.20
cotton	22.0	54.00	30.20
mercerised cotton	33.0	74.00	24.40
silk fibroin	28.0	59.90	23.46
2.5-acetate			
(50 % CH_3COOH)	14.0	71.00	50.10
(53 % CH_3COOH)	13.7	49.20	37.50
triacetate			
(59 % CH_3COOH)	9.0	47.80	40.20
(62,5 % CH_3COOH)	1.5	108.10	100.06
polyacrylonitrile	2.0	43.00	37.70
polyester			
A	0.5	81.62	74.20
B	1.7	58.20	64.20
polyvinylchloride	1.4	48.00	51.40
glass fibre	0.5	41.10	35.19

Tab.: Zeta potential and water absorption according to Kanamaru.

According to Kanamaru, the zeta potential of any fibre is reduced by its water absorbency, the kinetics of this reduction being expressed by the relationship:

$$-\ln \frac{\zeta - \zeta_\infty}{\zeta_0 - \zeta_\infty} = k \cdot t$$

ζ_∞ is the value of the zeta potential to which the ζ-t-curve approaches asymptotically; ζ_0 is the value determined immediately after introducing the dry fibre test specimen into the measuring solution; k is a constant. It has been additionally established by Kanamaru that the value of ($\zeta_0 - \zeta_\infty$) of water uptake at 100% relative humidity is proportional, i.e. the potential reduction is proportional to the water uptake (Tab.). The constant k is dependent on the fibre structure, and is therefore smaller below the freezing temperature (T_G) of a fibre than above it. The cause of zeta potential reduction due to water uptake is seen by Kanamaru in a change in the dielectric constants of the fibre materials.

Typical measuring cells (Figs. 3 + 4) for zeta potential determination consist of two silver/silver chloride electrodes with ceramic frit and an ion meter with an input resistance of 10^{13} Ω. Adsorption phenomena on the silver chloride surface are prevented by the presence of potassium chloride bridges. The zeta potential is calculated from the streaming potential in terms of the Smoluchowski equation:

$$\zeta\,[\mathrm{mV}] = \frac{6.75 \cdot 10^7 \cdot 4\,\pi\,\eta \cdot E \cdot X}{\varepsilon \cdot \Delta p}$$

Δp = pressure difference (measured in front of and behind the test specimen),
E = streaming potential.

This zeta potential is not however regarded as an absolute value, but merely as a comparison parameter for the different test specimens, because the conditions

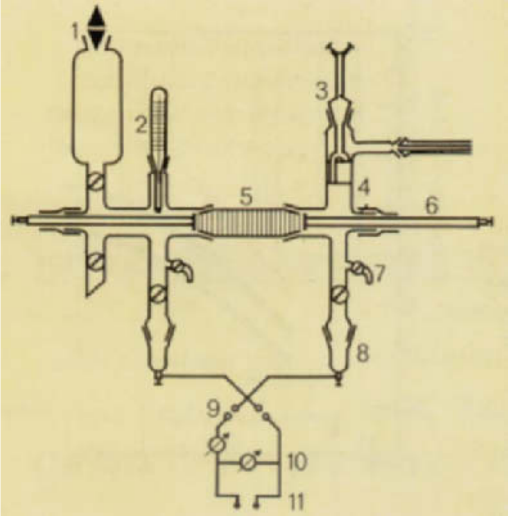


Fig. 3: Measuring cell for determining the zeta potential of fibres (according to Stackelberg).
1 = pressure gauge; 2 = air pressure; 3 = thermometer; 4 = diaphragm; 5 = measuring capillary; 6 = conductivity vessel; 7 = movable electrode; 8 = rinsing tap; 9 = platinum electrode; 10 = commutating switch; 11 = circuit breaker.

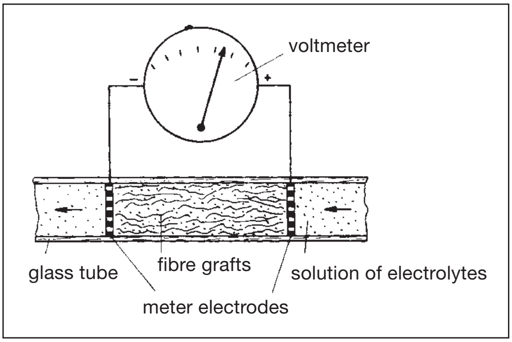


Fig. 4: Measuring arrangement for detecting the unsteady flow potential.

for the validity of the Smoluchowski equation are not complied with:

- the test specimen is only approximately capillary shaped,
- its surface is not in equilibrium with the solution,
- wetting, hydration and desorption phenomena may predominate,
- other parameters, such as the viscosity at the fibre surface, may vary from that of the water.

In a study of the zeta potential of wool fibres, Capablanca and Watt demonstrated that wool is positively charged below the isoelectric point, and negatively above it (Fig. 5).

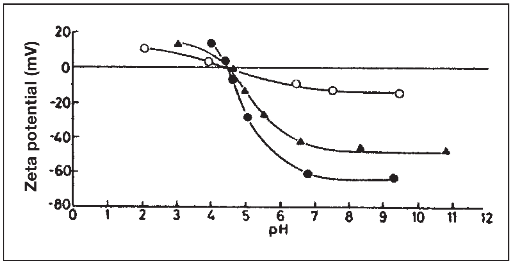


Fig. 5: Dependency of the zeta potential of wool on the pH of the flowing liquor.

The importance of the streaming potential for textile finishing processes is uncertain. It seems reasonable to assume that the electrochemical double layer on the surface of fibres affects the exhaustion behaviour of ionic dyes, since the adsorption of dye anions is made more difficult by negative zeta potential, and is made easier by positively charged dye anions. The zeta potential of fibre materials also changes during the adsorption of dye ions on the fibre surface by nature, while, at the end of the dyeing process, it again reaches the value of the undyed fibre, because all the dye ions are diffused into the interior of the fibre. According to Jacobasch however, zeta potential measurements are not very meaningful as regards the dyeing process, since the dye molecules are bonded less by electrostatic than by van der Waal forces (direct dyes). In addition, the speed-determining step in the dyeing process of cotton is not dye adsorption but diffusion in the fibre. On the other hand, the dye uptake of variously heat set polyester fibres correlates with their max. zeta potential in potassium chloride solutions.

Exhaust processes are selected for finishing with cationic softeners because the negative zeta potential of the fibres to be finished possibly produces affinity between softener and fibre. This kind of affinity is not observed for anionic auxiliary agents (except for wool), and they are applied in the coating process for that reason. Nevertheless, there are no study results which unambiguously cover this electrochemical double layer effect. In washing processes, the addition of anionic surfactants increases the electrokinetic potential of the fibres, to the surface of which the surfactants are adsorbed via their hydrophobic residue. Because the negative zeta potential of pigment dirt in water is also increased by anionic surfactants, the washing effect in such systems can be attributed to the reinforced electrostatic repulsion of fibre and dirt. This also explains the wash inactivity of cationic surfactants at lower application concentrations.

Zibeline Imitation sable fur. The fine, silvery and mainly lustrous hair tips are characteristic of the animal fur, and are imitated in zibeline by wool blended with fine mohair (also by short bristly hair perhaps). These materials mostly have a lengthwise raised finish zigzag meander conformation in accordance with the model. Used for womenswear, costumes and overcoats.

Zickzack-Mäander-Konformation (Zigzag meander conformation). With non-ionic surfactants, a structural change takes place with average chain lengths between 9 and 12 ethoxy units from the zigzag to the meander form in flowing transition under contraction (Fig. 1). In addition, telescoping or denticulation of long, meander form chain lengths into the zigzag form of the shorter chain lengths due to radiographically determined interplanar spacing has been calculated for chain length distributions over a range of approx. 10–15 ethoxy units (Fig. 2).

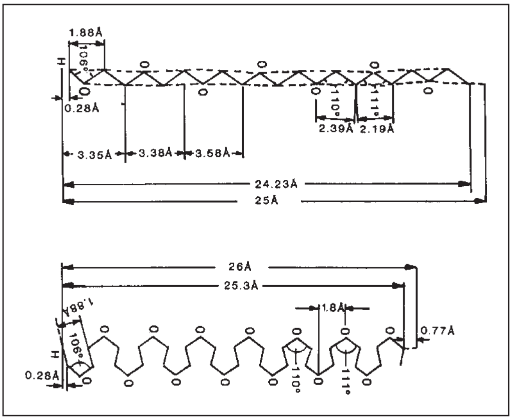


Fig. 1: Conformation of a single zigzag meander polyethylene oxide chain (according to Rösch). 1Å = 0.1 nm.

Due to the aryl group volume ratio, interdenticulation of the pure meander polyethylene oxide chains is held to be possible in the case of alkyl aryl-containing ethoxylated surfactants. In contrast, in comparison with pure polyethylene oxide chains, transition to the meander form in the case of ethoxylated fatty alcohols by the fatty alcohol residues suspended at one end of the ethylene oxide chain is blocked.

Zinc (Zn). Atomic weight 65.4. Bluish white metal, fast to atmospheric influences, fairly brittle, extensible, can be drawn and rolled at 100–150°C, brittle again above 200°C. Melting point 420–430°C. Easily soluble in diluted acids (hydrogen production), lyes and ammonia. Non-metallic compound: divalent; gives colourless salts with colourless acid anion. Water-soluble as zinc sulphate, zinc chloride; insoluble as zinc sulphide, zinc carbonate, zinc phosphate and zinc oxyphosphate. Precipitations mostly soluble in diluted acids (exception: zinc sulphide). Zinc oxyhydrate soluble in excess caustic lye or ammonia; forms salts with acids and concentrated bases = zincates. Use: as metal, → Zinc dust (for dithionites and discharge agents in printing), non-metallic compounds for paints, and in textile printing. Salts as mordants and/or white resists (zinc acetate, zinc chloride, zinc carbonate).

Zincates → Zinc.

Zinc carbonate $ZnCO_3$. Molecular weight 125.4. Use: in textile printing (mordants, white resists, discharge agents in printing, the latter for weighted silks).

Zinc chloride $ZnCl_2$. Molecular weight 136.2. White salt, extremely hygroscopic, easily soluble in water. Easily splits off hydrochloric acid when heated. Use: in textile printing (for white resists on bromine indigo etc), (rarely) antiseptic for sizes and chemical finishes etc.

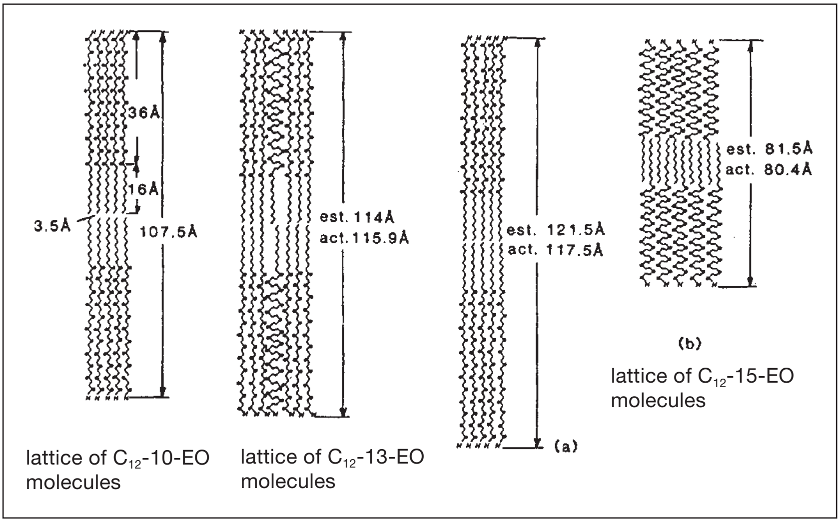


Fig. 2: Conformation of many zigzag meander polyethylene oxide chains (according to Rösch). 1Å = 0.1 nm.

Zinc chloride/formic acid solution Used in fibre identification. 100 ml of zinc chloride solution, density 1.566 (produced by dissolving 100 g of moisture-free $ZnCl_2$ in 100 ml of water, and setting the density to 1.566) are mixed with 6 ml of 98–100% formic acid. Use:

I. Solution cold: differentiating between 2.5 acetate and triacetate (2.5 acetate = dissolved, triacetate = merely slightly swollen). Polyamide 3, polyamide 6 and polyamide 6.6 produce Koch's → contraction reaction at room temperature. Vinylal fibres reveal the same reaction as with zinc chloride-iodine solution but faster and with no staining. Polyacrylonitrile is insoluble.

II. Solution at 70°C (10 min) dissolves silk, slowly dissolves regenerated cellulose, does not dissolve wool, regenerated protein fibres, cotton and bast fibres.

Zinc chloride-iodine solution Dissolve 66 g anhydrous zinc chloride and 6 g potassium iodide in 34 ml water. Next add iodine until the solution is saturated. The solution should be stored in a dark bottle as it is light-sensitive. Reactions with fibres:

a) Cellulosic fibres: blue colouring, regenerated cellulose shows a deeper blue colouring than natural cellulose; woody cellulose = yellow; material which has been well broken down = blue. X- and v- transverse splits in bast fibres are heavily dyed. Natural celluloses swell, cottons show a similar reaction to that in cuprammonium.
b) Animal fibres are not dyed.
c) Acetate: dissolution with yellow colouring and no swelling.
d) Polyacrylonitrile: dissolution with poss. swelling. Insoluble types also exist. No yellow colouring.
e) Polyamide, polyurea fibres: yellow colouring and → Koch's contraction reaction without dissolution.
f) Polyester, polyvinyl chloride: no yellow colouring or dissolution.
g) Polyvinyl alcohol: initially greyish-blue, then the fibre core becomes a strong blue and is distorted into a zigzag formation. Eventually becomes straight again and generally yellow in colour.

Zinc chloride solubility test This is a solution of zinc chloride (54°Bé) or 100 g molten zinc chloride + 85 ml water + 4 g zinc oxide at 100°C dissolved in approx. 15 min. Only dissolves pure silk (not tussah-silk) and acetate (gelatinous type is dissolved) in fibre blends.

Zinc chlor-iodide solution Compound consisting of iodine, potassium iodide and zinc chloride. Use: to test for acetate, cupro and viscose in fibre blends. The following colourings occur: yellow = acetate; brown = cupro; green = viscose; other fibres do not change colour.

Zinc dust Grey powder, finely divided metallic → Zinc (some zinc oxide). Strong reducing agent. Use: for producing indigo vats, and for discharges in textile printing.

Zinc dust discharges Only rarely used → Reductive discharges; → Discharge printing.

Zinc formaldehyde sulphoxylate → Sulphoxylates.

Zinc-lime-vat Used in indigo dyeing, mainly for ordinary cotton yarn, lighter-weight piece goods and paste resist printing (→ Vat dyes in resist printing). Disadvantages as compared with indigo sodium dithionite vat: not salt-free, higher reduction losses. Produces a somewhat redder shade. Dye vat: 1000 l contain 400 g of zinc dust (flushed with water) + 2 kg of dissolved lime (mixed to a paste), left to stand overnight, indigo addition as necessary. In the case of yellow vat dye, begin with dyeing.

Zinc oxide (zinc white). ZnO. Molecular weight 81; density 5.78. Loose white powder, practically insoluble in water, soluble in acids (salt formation); temporarily yellowing when heated (slightly luminescent in the cooled state). Use: much used pigment for viscose delustring (fixated with fatty sulphonates; dyed with cationic or direct dyes for coloured delustring); for sodium dithionite resists; resist for aniline black in printing; for producing damask effects in printing; for neutralising naphthol-diazo- solution; production of cements, drying agents etc.

Zinc soaps Formation like → Lime soap by water hardness salts.

Zinc sulphate (white vitriol) $ZnSO_4 \cdot 7\,H_2O$. Molecular weight 288. Colourless crystals; weakly acid. Use: alkali binders in naphthol dyeing, for printing mordants, as an antiseptic for sizes and chemical finishes (out of date).

Zinc sulphoxylates → Sulphoxylates.

Zinc vitriol → Zinc sulphate.

Zinc white → Zinc oxide.

Zip-fastener finishing The material used for zip fastener fabrics (such as polyamide) and the incorporated teeth of the zip fasteners make it possible to colour the yard goods batched on the beam. The textile components of the zip fasteners – the velcro tapes (hook and loop) – must be subjected to nip padding on the reverse to make sure they do not fray. Diluted polyester polyurethane, mixed with the crosslinking agent polyaziridine, is padded on. A subsequent fixing treatment crosslinks the polyester system effectively without impairing its elasticity (according to Stahl).

Zirchrome process Combined mineral dyeing and chemical finishing process for woven cotton fabrics. Principle: formation of chromium and zirconium oxide complexes using Cr-chloride, Zr-ammonium carbonate and ammonium oxalate. Result: greenish khaki shades; the fabrics are simultaneously protected against bacterial attack.

Zirconia element → Zirconium sensor.

Zirconium (Zr). Atomic weight 91.22; density 6.52; melting point 1860°C. Metallic element. Pure,

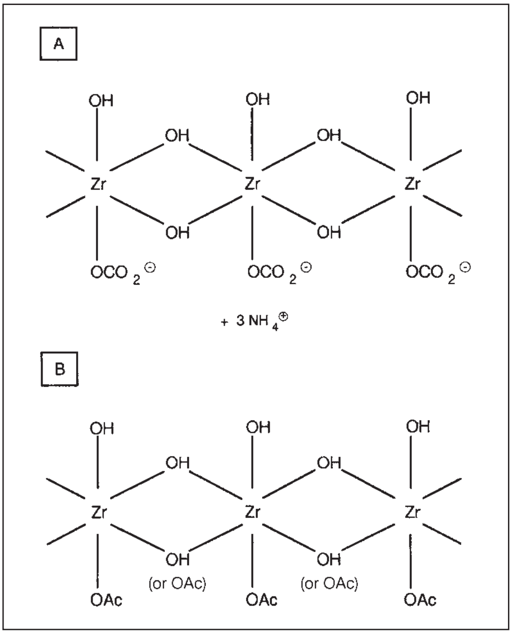


Fig.: Ammonium zirconium carbonate (A) and zirconium acetate (B) structures, according to McAlpine.

massive zirconium (hardness 7–8) is melted until it is pliable and steel-bright (processable into rolled sheet and wire), as a fine powder, black. Massive zirconium is resistant to water and hydrochloric, nitric and phosphoric acid and lyes, for example. Rapidly soluble in hydrofluoric acid at room temperature, hot concentrated sulphuric acid and nitrohydrochloric acid. Is attacked by molten caustic lyes, chlorine and suchlike substances. Zirconium compounds (Fig.) are generally tetravalent (2, 3), preferentially colourless and non-toxic. Zirconium alloys can attain unusual degrees of hardness. Use: crucibles and fire-resistant equipment (ZrO_2); alloy components; for textile water repellent agents (zirconium chloride, basic zirconium formiate, zirconium acetate etc); dye and pigment binders for printing pastes; for leather tanning (Zr sulphate) etc.

Zirconium salt/paraffin emulsions → Water impermeability testing.

Zirconium sensor For measuring the oxygen content in the air. If this changes owing to water vapour or any other gas in the air, the zirconia element (Fig.) indicates the change in relation to the air. The heated sensor has two electrodes, one of which is exposed to the process air, the other to the air in the room. Depending on the process air moisture and polluting (e.g. chemical finishes) vapour content, the sensor sends a specific voltage signal. This signal is processed in the measuring amplifier for further processing by the evaluating electronics, which calculates from the measuring amplifier signals with the aid of a microcomputer the sum of process air moisture (water vapour) and polluting vapour content. The unit of measurement is g/kg (grammes of water + equivalent polluting vapour content/kilogram of dry air).

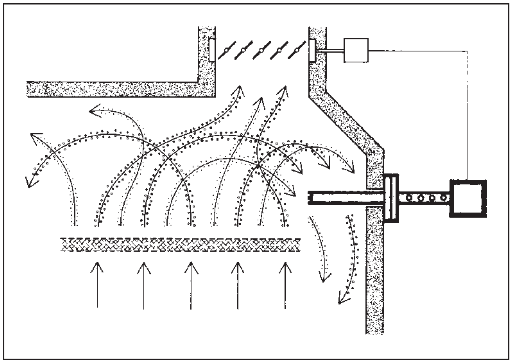


Fig.: Measuring device based on zirconium sensor for determining the oxygen content of a gas (Pleva).

Zirpro process → Flame retardant finishing of wool by applying titanium/zirconium salt. Application is basically possible in any wool processing stage, i.e. as loose stock, tops, yarn (hank or yarn package), piece goods (woven or knitted fabric), carpets, and can be effected by the following processes:

1. exhaust process.
2. pad/dwell/rinse/dry process.
3. pad/steam/rinse/dry process.
4. dip/squeeze/dwell/dry process.
5. solvent process.

Zirpro finishing is predominantly effective in the solid stage through the increased formation of insulating carbon.

Advantages:

- small quantity of applied chemicals,
- low chemical cost,
- handle is not impaired,
- colour fastness and physical properties are not impaired,
- simple application,
- finish is resistant to washing and dry-cleaning,
- Zirpro-finished wool fabrics meet smoke development standards,
- possibility of combination with other processes.

Disadvantages:

- Zirpro/titanium treatment causes slight yellowing.

Zn Element symbol for zinc (30).

Z-Polyethylene Gravure printed polyethylene after its inventor Ziegler.

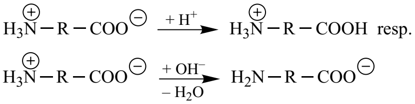
Zr Element symbol for zirconium (40).

ZTDI Textile documentation and information centre; → Technical and professional organizations.

Z twist Spun yarn twist.

ZW Abbreviation of the no longer admissible concept → Rayon staple fibre.

Zwitterions Term borrowed from colloquial speech for compounds which have in the same molecule a positively charged group (ammonium and sulphonium ions, more rarely carbenium or phosphonium ions), and also a negatively charged group, and can therefore be understood as intramolecular salts. The negative charge is mostly localised on oxygen atoms by the giving off of a proton of carboxyl or sulpho-groups, phosphoric acid esters, acidic phenolic or enolic hydroxyl groups. Zwitterions behave like ampholytes, which appear as uncharged towards the outside at a characteristic pH – the isoelectric point – and do not therefore migrate in the electrical field, and act as buffers with the addition of acids and bases:



$$H_3\overset{\oplus}{N}-R-COO^{\ominus} \xrightarrow{+\,H^+} H_3\overset{\oplus}{N}-R-COOH \text{ resp.}$$

$$H_3\overset{\oplus}{N}-R-COO^{\ominus} \xrightarrow[-\,H_2O]{+\,OH^-} H_2N-R-COO^{\ominus}$$